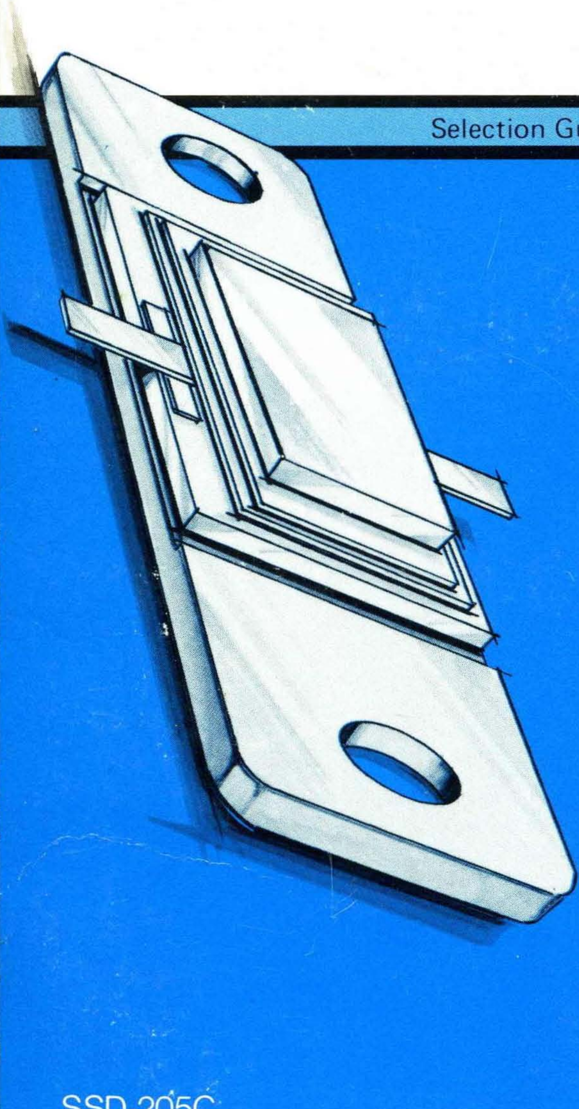
RCA

RF/Microwave Devices

Selection Guide / Data / Application Notes



SSD-205C
1975 DATABOOK Series

RCA Solid State

RCA RF/Microwave Devices
SSD-205C
1975

A New Approach To Data Service . . .

1975 RCA Solid State DATABOOKS

Seven textbook-size volumes covering all current commercial RCA solid-state devices (through January 1, 1975)

Announcement Newsletter: "What's New in Solid State" Availabe FREE to all DATABOOK users.

"Bingo-type Response-Card Service" included with Newsletter Available FREE to all DATABOOK users.

Update Mailing Service available by subscription.

Indexed Binder available for Update Filing.

NOTE: See pages 3 and 4 for additional information on this total data service. To qualify for Newsletter mailing, use the form on page 4 (unless you received your DATABOOK directly from RCA). You must qualify annually since a new mailing list is started for each edition of the DATABOOKS.

RCA

RF/Microwave Devices

This DATABOOK contains complete data and related application notes on rf and microwave power devices presently available from RCA Solid State Division as standard products. For ease of type selection, power-frequency curves and application charts are given on pages 9-16. Data sheets are then included in type number sequence, followed by dimensional outlines for all types, application notes in numerical order, and finally a comprehensive subject index.

To simplify data reference, data sheets are arranged as much as possible in numerical-alphabetical-numerical sequence of type numbers. Because some data sheets include more than one type number, however, some types may be out of sequence. If you don't find the type you're looking for where you expect it to be, please consult the Index to Devices on pages 7 and 8.

Trade Mark(s) Registered ®
Marca(s) Registrada(s)

Printed in USA/11-74

RCA Solid State | Box 3200 | Somerville, N.J., U.S.A. 08876
RCA Limited | Sunbury-on-Thames | Middlesex TW16 7HW, England
RCA s.a. | 4400 Herstal | Liege, Belgium

RCA Solid State Total Data Service System

The RCA Solid State DATABOOKS are supplemented throughout the year by a comprehensive data service system that keeps you aware of all new device announcements and lets you obtain as much or as little product information as you need – when you need it.

New solid-state devices and related publications announced during the year are described in a newsletter entitled "What's New in Solid State". If you obtained your DATABOOK(s) directly from RCA, your name is already on the mailing list for this newsletter. If you obtained your book(s) from a source other than RCA and wish to receive the newsletter, please fill out the form on page 4, detach it, and mail it to RCA.

Each newsletter issue contains a "bingo"-type fast-response form for your use in requesting information on new devices of interest to you. If you wish to receive all new product information published throughout the year, without having to use the newsletter response form, you may subscribe to a mailing service which will bring you all new data sheets and application notes in a package every other month. You can also obtain a binder for easy filing of all your supplementary material. Provisions for obtaining information on the update mailing service and the binder are included in the order form on page 4.

Because we are interested in your reaction to this approach to data service, we invite you to add your comments to the form when you return it, or to send your remarks to one of the addresses listed at the top of the form. We solicit your constructive criticism to help us improve our service to you.

Order Form for "What's New in Solid State" and for further information on Update Mailings and Binders

Please fill out just one copy of this form, and mail it to:

(a) from U.S.A. and Canada:

RCA Solid State Division
Box 3200
Somerville, N. J., U.S.A. 08876

(b) from Latin America and Far East:

RCA Solid State
International Sales
Somerville, N. J., U.S.A. 08876

(c) from United Kingdom, Europe, Middle East, and Africa:

RCA Limited
Sunbury-on-Thames
Middlesex TW16 7HW, England

or

RCA s.a.
4400 Herstal
Liege, Belgium

☐ Please add my name to the mailing list for "What's New in Solid State"

☐ Please send me details on obtaining update mailings for my DATABOOKS and a binder for filing of supplementary material.

Name ☐☐☐☐☐☐☐☐☐☐☐☐☐☐ (Last) ☐☐☐ (Initials)

Company ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Address ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ (Number) (Street, RFD, P.O. Box)

Home ☐
Business ☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐ (City) ☐☐☐☐☐☐☐☐ (State or Prov.)

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ (Country) ☐☐☐☐☐ (Zip or Pstl. Zone)

Function: (Check One)

A ☐ Executive/Administration
B ☐ Purchasing/Procurement
C ☐ Research/Development
D ☐ Design Engineer
E ☐ Application/Components Engineer
F ☐ Production/Manufacturing
G ☐ Documentation/Library
H ☐ Reliability/QA
I ☐ Education/Training
J ☐ Program/Project Management
K ☐ Marketing

Activity: (Check One)

A ☐ Broadcast
B ☐ Communication
C ☐ Instrumentation/Control
D ☐ Computer/Data Processing
E ☐ Computer, Peripheral
F ☐ Automotive
G ☐ Industrial
H ☐ Medical
I ☐ Research
J ☐ Transportation
K ☐ Consumer, Electronic
L ☐ Consumer, Appliance
M ☐ Space
N ☐ Ordnance
O ☐ Avionics
P ☐ Electronic Warfare

Product Interest: (Indicate order of interest if more than one is marked)

A ☐ Linear IC's
B ☐ Digital IC's, COS/MOS
C ☐ Digital IC's, Bipolar
D ☐ Thyristors/Rectifiers
E ☐ Liquid Crystals
F ☐ Semiconductor Diodes
G ☐ RF Power Semiconductors
H ☐ MOSFETS
I ☐ Power Transistors
J ☐ Power Hybrid Circuits

Table of Contents

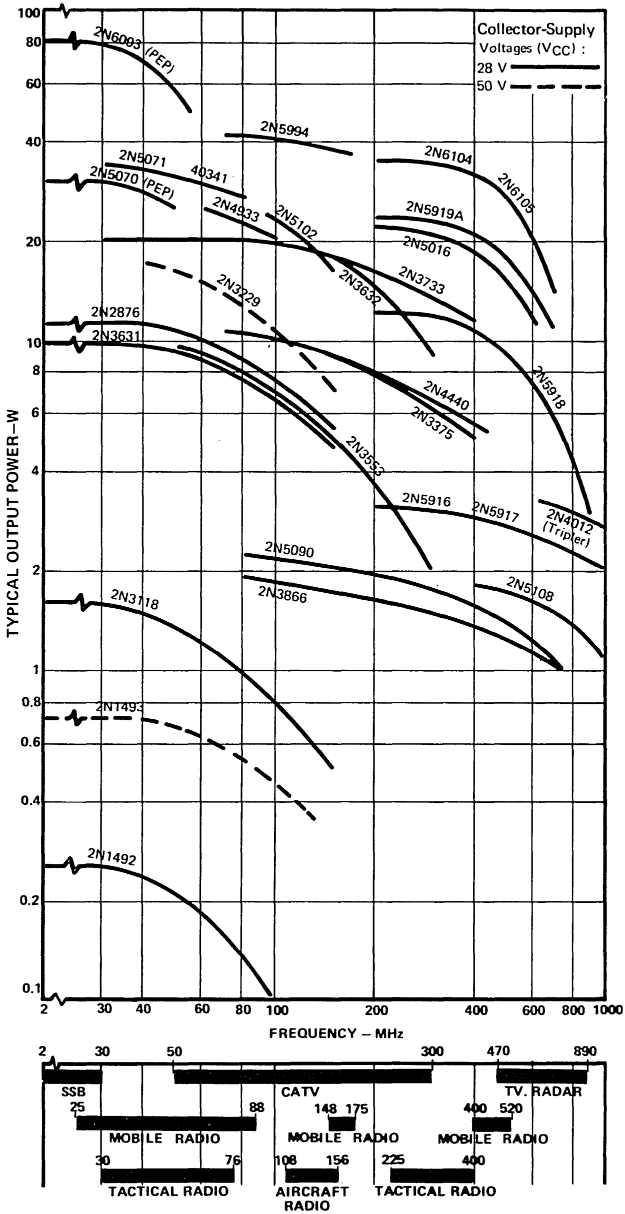
Application Notes

Index to RF Power Devices

Type No.	Page	Output Power (W) or Noise Figure (dB) or Power Gain (dB)	Frequency (MHz)	Supply Voltage (V)	File No.
2N918	18	NF = 6	60	6-15(V_{CE})	83
2N1491	22	0.01	70	20	10
2N1492	22	0.1	70	30	10
2N1493	22	0.5	70	50	10
2N2631	26	7.5	50	28	32
2N2857	30	NF = 4.5	450	6-15(V_{CE})	61
2N2876	26	10	50	28	32
2N3118	34	1	50	28	42
2N3119	38	1	50	28	44
2N3229	42	15	50	50	50
2N3262	45		High-speed switching		56
2N3375	49	3	400	28	386
2N3478	56	NF = 4.5	200	6-15(V_{CE})	77
2N3553	49	2.5	175	28	386
2N3600	18	NF = 4.5	200	6-15 (V_{CE})	83
2N3632	49	13.5	175	28	386
2N3733	59	10	400	28	72
2N3839	63	NF = 3.9	450	6-15(V_{CE})	229
2N3866	67	1	400	28	80
2N4012	71	2.5	1000 (tripler)	28	90
2N4427	75	1	175	12	228
2N4440	80	5	400	28	217
2N4932	84	12	88	13.5	249
2N4933	84	20	88	24	249
2N5016	88	15	400	28	255
2N5070	92	25(PEP)	30	28	268
2N5071	96	24	76	24	269
2N5090	100	1.2	400	28	270
2N5102	104	15	136	24	279
2N5109	108	NF = 3	200	15	281
2N5179	114	NF = 4.5	200	6(V_{CE})	288
2N5180	119	NF = 2.5	200	8(V_{CE})	289
2N5189	123		High-speed switching		296
2N5262	127		High-speed switching		313
2N5470	132	1	2000	28	350
2N5913	137	2	470	12	423
2N5914	142	2	470	12	424
2N5915	142	6	470	12	424
2N5916	148	2	400	28	425
2N5917	148	2	400	28	425
2N5918	153	10	400	28	448
2N5919A	157	16	400	28	505
2N5920	162	2	2000	28	440
2N5921	168	5	2000	28	427
2N5995	175	7	175	12.5	454
2N6093	179	75(PEP)	30	28	484
2N6104	184	30	400	28	504
2N6105	184	30	400	28	504
2N6265	190	2	2000	28	543
2N6266	195	5	2000	28	544
2N6267	200	10	2000	28	545
2N6268	206	2	2300	22	546
2N6269	206	6.5	2300	22	546
2N6389	216	NF = 6	890	10	617
2N6390	220	3	2000	28	626
2N6391	223	5	2000	28	627
2N6392	227	10	2000	28	628
2N6393	227	10	2000	28	628
40080	231	0.1	27	12	301
40081	231	0.4	27	12	301
40082	231	3	27	12	301
40280	234	1	175	13.5	68
40281	234	4	175	13.5	68
40282	234	12	175	13.5	68
40290	237	2	135	12.5	70
40291	237	2	135	12.5	70
40292	237	6	135	12.5	70
40340	241	25	50	13.5	74
40341	241	30	50	24	74
40446	231	3	27	12	301
40581	231	3.5	27	12	301
40582	231	3.5	27	12	301
40608	244	NF = 3	200	15	356
40637A	248	0.1	175	12	655
40665	49	13.5	175	28	386
40666	49	3	400	28	386
40836	251	0.5	2000	21	497
40837	251	1.5	2000	28	497
40893	256	15	470	12.5	514
40894	260	G_{PE} = 15	200	12	548
40895	260	G_{PE} = 15	200	12	548
40896	260	G_{PE} = 15	200	12	548
40897	260	G_{PE} = 18	200	12	548
40898	265	2	2300	22	538
40899	265	6	2300	22	538
40909	272	2	2000	25	547
40915	276	NF = 2.5	450	10	574
40934	280	2	470	12.5	550
40936	283	20(PEP)	30	28	551
40940	287	5	400	28	553
40941	291	1	400	28	554
40953	295	1.75	156	12.5	579
40954	295	10	156	12.5	579
40955	295	25	156	12.5	579
40964	299	0.4	470	12	581
40965	299	0.5	470	12	581
40967	302	2	470	12.5	596
40968	302	6	470	12.5	596
40970	305	30	470	12.5	656
40971	305	45	470	12.5	656
40972	310	1.75	175	12.5	597
40973	310	10	175	12.5	597
40974	310	25	175	12.5	597
40975	313	0.05	118	12.5	606
40976	313	0.5	118	12.5	606
40977	313	6	118	12.5	606

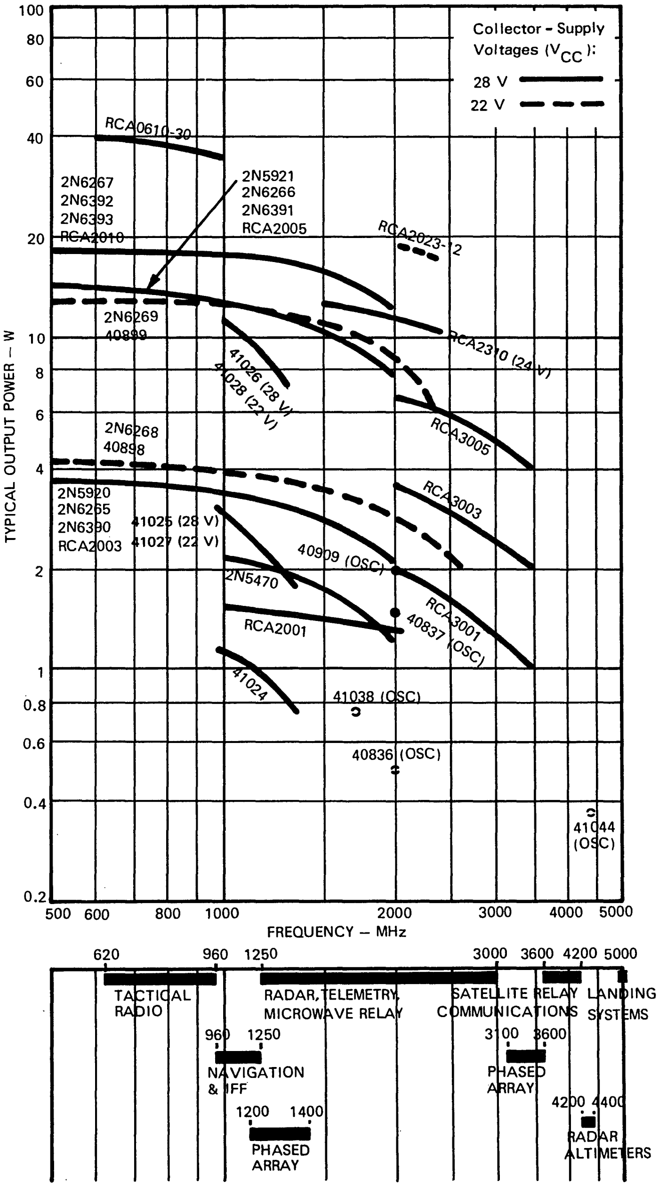
Type No.	Page	Output Power (W) or Noise Figure (dB) or Power Gain (dB)	Frequency (MHz)	Supply Voltage (V)	File No.
41008	317	0.5	470	9	616
41008A	317	0.5	470	9	616
41009	317	2	470	9	616
41009A	317	2	470	9	616
41010	317	5	470	9	616
41024	322	1	1000	28	658
41025	325	3	1000	28	641
41026	325	10	1000	28	641
41027	331	3	1000	22	640
41028	331	10	1000	22	640
41038	337	0.75	1680	20	679
41039	340	NF = 3.2	200	15(V_{CE})	764
41044	354	0.4	4360	20	783
RCA0610-30	348	30	1000	28	790
RCA2001	353	1	2000	28	759
RCA2003	220	2.5	2000	28	626
RCA2005	223	5	2000	28	627
RCA2010	227	10	2000	28	628
RCA2023-12	357	12.5	2300	22	801
RCA2310	360	10	2300	24	765
RCA3001	363	1	3000	28	657
RCA3003	363	2.5	3000	28	657
RCA3005	363	4.5	3000	28	657

RF Power Transistors for Operation at 28 V or 50 V



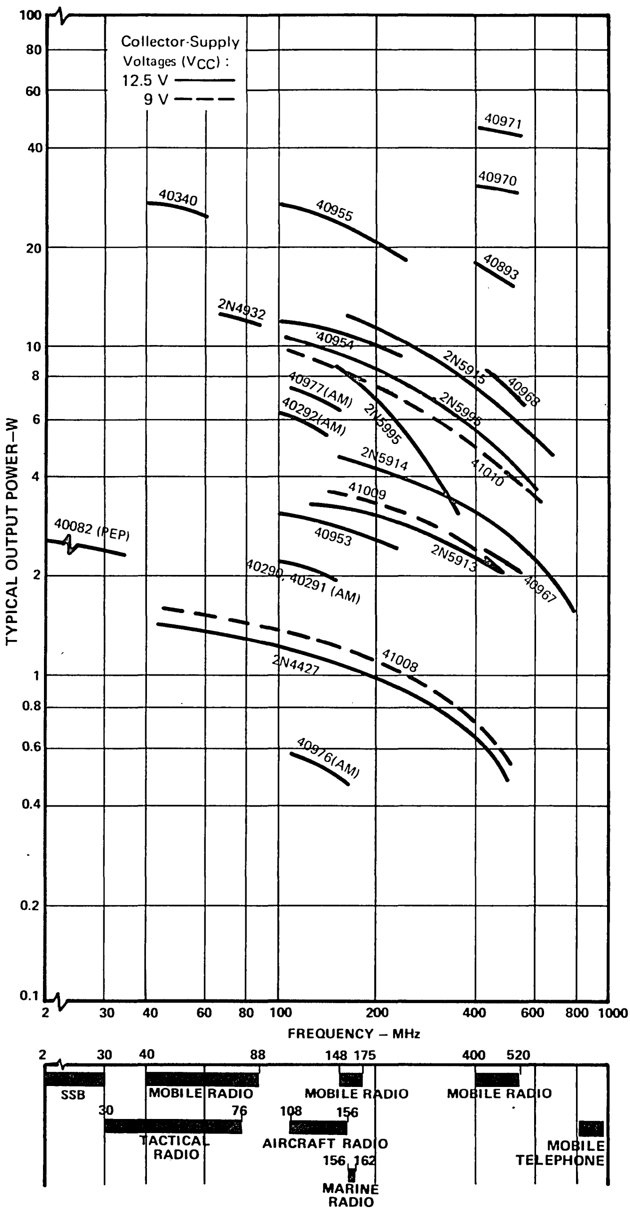
92CM-24934

RF Power Transistors for Operation at 22 V or 28 V



92CM-24935

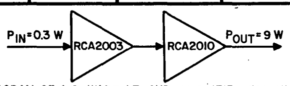
RF Power Transistors for Operation at 9 V or 12.5 V



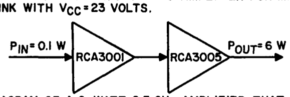
92CM-24936

Types For Microwave Applications

Type	Operating Frequency (GHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Collector Efficiency (%)	Package Type
Lead						
41024	1	1	28	5	35	TO-39
41038	1.68	0.75	20	(OSC)	20	TO-46
Stripline						
41027	1	3	22	6	50	HF-41
41025	1	3	28	7	50	HF-41
41028	1	10	22	5.5	50	HF-41
41026	1	10	28	6	50	HF-41
2N6265	2	2	28	8.2	33	HF-28
2N6266	2	5	28	7	33	HF-28
2N6267	2	10	28	7	35	HF-28
2N6268	2.3	2	22	7	33	HF-28
2N6269	2.3	6.5	22	5	32	HF-28
2N6390	2	3	28	8	30	HF-46
2N6391	2	5	28	7	30	HF-46
2N6392	2	10	28	5	33	HF-46
2N6393	2	10	28	7	35	HF-46
RCA2001	2	1	28	7	30	HF-46
RCA2003	2	2.5	28	7	30	HF-46
RCA2005	2	5	28	7	30	HF-46
RCA2010	2	10	28	5	33	HF-46
RCA2310	2.3	10	24	8.2	30	HF-46
RCA3001	3	1	28	7	30	HF-46
RCA3003	3	2.5	28	5	30	HF-46
RCA3005	3	4.5	28	5	30	HF-46
41044	4.36	0.4	20	(OSC)	15	HF-56
Coaxial						
40836	2	0.5	21	(OSC)	20	TO-215AA
2N5470	2	1	28	5	30	TO-215AA
40837	2	1.25	28	(OSC)	20	TO-215AA
2N5920	2	2	28	10	40	TO-215AA
40909	2	2	25	(OSC)	20	TO-201AA
2N5921	2	5	28	7	40	TO-201AA
40898	2.3	2	22	7	35	TO-215AA
40899	2.3	6	22	6	35	TO-201AA
GIGAMATCH Broadband Transistors with Internal Matching						
RCA0610-30	0.6–1.0	30	28	8	55	HF-55
RCA2023-12	2.0–2.3	12.5	22	7	40	HF-50

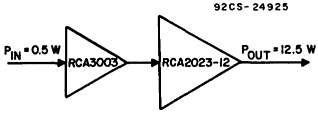


BLOCK DIAGRAM OF A 9-WATT 1.7-GHZ AMPLIFIER FOR MICROWAVE RELAY LINK WITH V_{CC}=23 VOLTS.



BLOCK DIAGRAM OF A 6-WATT 2.3-GHz AMPLIFIER THAT OPERATES FROM A 22-VOLT SUPPLY.

92CS-24925

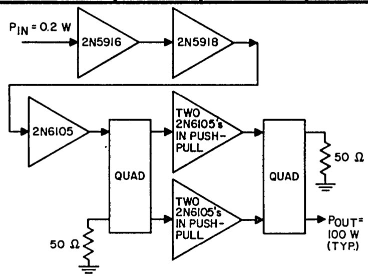


BLOCK DIAGRAM OF A 12.5-WATT 2.0-2.3 GHz AMPLIFIER.

92CS-24927

Types For UHF Military Applications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
2N3866	400	1	28	10	TO-39
40941	400	1	28	10	HF-31
2N5916	400	2	28	10	TO-216AA
2N5917	400	2	28	10	HF-31
40940	400	5	28	5.2	TO-216AA
2N5918	400	10	28	8	TO-216AA
2N5919A	400	16	28	6	TO-216AA
2N6104	400	30	28	5	HF-32
2N6105	400	30	28	5	TO-216AA

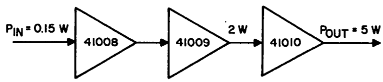


BLOCK DIAGRAM OF A 100-WATT 225-400 MHz AMPLIFIER.

92CS-24929

Types For UHF Mobile-Radio Applications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
41008	470	0.5	9	5.2	HF-47
41008A	470	0.5	9	5.2	HF-41
41009	470	2	9	6	HF-47
41009A	470	2	9	6	HF-41
41010	470	5	9	4	HF-41
40964	470	0.4	12	6	TO-39
40965	470	0.5	12	7	TO-39
2N5914	470	2	12.5	7	TO-216AA
40934	470	2	12.5	7	HF-31
40967	470	2	12.5	7	HF-44
40968	470	6	12.5	4.8	HF-44
2N5915	470	6	12.5	4.8	TO-216AA
40893	470	15	12.5	5.2	HF-36
40970▲	470	30	12.5	5	HF-40
40971▲	470	45	12.5	4.8	HF-40



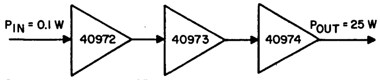
BLOCK DIAGRAM OF 9-V, 5-W, 440-470 MHz AMPLIFIER FOR HAND-HELD MOBILE EQUIPMENT.

92CS-24931

▲ Internal input matching

Types For VHF Mobile-Radio Applications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
2N4427	175	1	12	10	TO-39
40280	175	1	13.5	9	TO-39
2N5913	175	1.75	12.5	12.4	TO-39
40972	175	1.75	12.5	12.4	TO-39
40281	175	4	13.5	6	TO-60
2N5995	175	7	12.5	9.7	TO-216AA
40973	175	10	12.5	7.6	HF-44
40282	175	12	13.5	4.8	TO-60
40974	175	25	12.5	4.5	HF-44

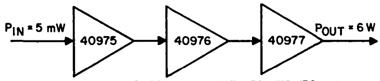


BLOCK DIAGRAM OF A 25-WATT AMPLIFIER FOR 148-175 MHz MOBILE APPLICATION.

92CS-24932

Types For Aircraft-Radio Applications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
40975	118–136	0.05	12.5	10	TO-39
40976	118–136	0.5	12.5	10	TO-39
40977	118–136	6	12.5	10.8	HF-44
2N5994	118–136	15	12.5	7	TO-216AA
40290	118–136	2	12.5	6	TO-39
40291	118–136	2	12.5	6	TO-60
40292	118–136	6	12.5	4.8	TO-60
2N5102	118–136	15	24	4	TO-60



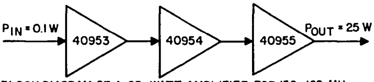
BLOCK DIAGRAM OF A 6-WATT AMPLIFIER FOR 118-136 MHz AIRCRAFT-RADIO APPLICATION.

92CS-24930

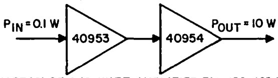
*New product - coming soon

Types For Marine-Radio Applications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
40953	156	1.75	12.5	12.4	TO-39
40954	156	10	12.5	7.6	HF-44
40955	156	25	12.5	4.5	HF-44



BLOCK DIAGRAM OF A 25-WATT AMPLIFIER FOR 156-162 MHz MARINE APPLICATION.

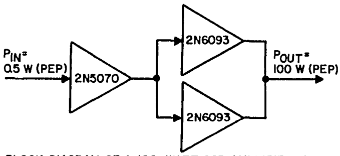


BLOCK DIAGRAM OF A 10-WATT AMPLIFIER FOR 156-162 MHz MARINE APPLICATION.

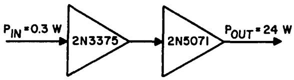
92CS-24933

Types For Single-Sideband Applications and For Military Communications

Type	Operating Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Min. Power Gain (dB)	Package Type
40082	30	2.5(PEP)	12.5	10	TO-39
2N5992	30	15(PEP)	12.5	10	TO-216AA
40936	30	20(PEP)	28	13	TO-60
2N5070	30	25(PEP)	28	13	TO-60
2N6093	30	75(PEP)	28	13	TO-217AA
2N5071	76	24	24	9	TO-60



BLOCK DIAGRAM OF A 100-WATT SSB AMPLIFIER FOR 2-30 MHz OPERATION.



BLOCK DIAGRAM OF A 24-WATT AMPLIFIER FOR 30-76 MHz OPERATION.

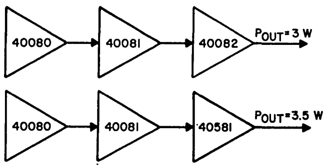
92CS-24928

Types For CATV/MATV and Small-Signal Low-Noise Applications

Type	Operating Frequency (MHz)	Noise Figure (dB)	Collector-to-Emitter Voltage (V)	Min. Power Gain (dB)	Package Type
2N918	60	6	6	13	TO-72
2N3478	200	4.5	6–15	11.5	TO-72
2N5179	200	4.5	6	15	TO-72
40894	200	3	12	15	TO-72
40895	200	–	12	15	TO-72
40896	200	–	12	15	TO-72
2N3600	200	4.5	15	17	TO-72
40897	200	–	12	18	TO-72
40915	450	2.5	10	14	TO-72
2N2857	450	4.5	6	12.5	TO-72
2N3839	450	3.9	6	12.5	TO-72
2N5109	200	3	15	11	TO-39
40608	200	3	15	11	TO-39
2N6389	890	6	10	15	TO-72
41039	200	3.2	15	8	TO-39

Types For CB-Radio Applications

Type	Frequency (MHz)	Min. Output Power (W)	Collector-Supply Voltage (V)	Package Type
40080	27	0.1	12	TO-5
40081	27	0.4	12	TO-5
40082†	27	3.0	12	TO-39
40581†	27	3.5	12	TO-39



BLOCK DIAGRAMS OF 3-WATT AND 3.5-WATT OSCILLATOR/ AMPLIFIER CHAIN FOR CB-RADIO APPLICATIONS.

92CS-24926

†Available with flange

Technical Data

RCA

Solid State
Division

RF Power Transistors

2N918
2N3600

RCA-2N918 and RCA-2N3600 are double-diffused epitaxial planar transistors of the silicon n-p-n type. They are extremely useful in low-noise-amplifier, oscillator, and converter applications at VHF frequencies.

These devices utilize a hermetically sealed four-lead JEDEC TO-72 package. All active elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead in applications requiring minimum feedback capacitance, shielding of the device, or both.

MAXIMUM RATINGS, Absolute-Maximum Values:

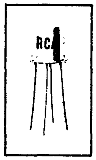
	2N918	2N3600		
COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	30	30	max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	15	15	max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	3	3	max.	V
COLLECTOR CURRENT, I_C	50	*	max.	mA
TRANSISTOR DISSIPATION, P_T:				
For operation with heat sink:				
At case temperatures** up to 25°C	300	300	max.	mW
At case temperatures** above 25°C	Derate at 1.71 mW/°C			
For operation at ambient temperatures:				
At ambient temperatures up to 25°C	200	200	max.	mW
At ambient temperatures above 25°C	Derate at 1.14 mW/°C			
TEMPERATURE RANGE:				
Storage and Operating (Junction)	-65 to +200			°C
LEAD TEMPERATURE (During Soldering):				
At distances ≥ 1/16 inch from seating surface for 60 seconds max.	300	300	max.	°C

* Limited by transistor dissipation.

** Measured at center of seating surface.

SILICON N-P-N EPITAXIAL PLANAR TRANSISTORS

For VHF Applications In Military, Communications, and Industrial Equipment



JEDEC TO-72

FEATURES

- high gain-bandwidth product
- hermetically sealed four-lead package
- low leakage current
- high 200-MHz power gain

2N3600

- low noise figure
  NF = 4.5 dB max. at 200 MHz
- low collector-to-base time constant
  $r_b'C_c$ = 15 ps max.
- high power gain as neutralized amplifier
  G_{pe} = 17 dB min. at 200 MHz

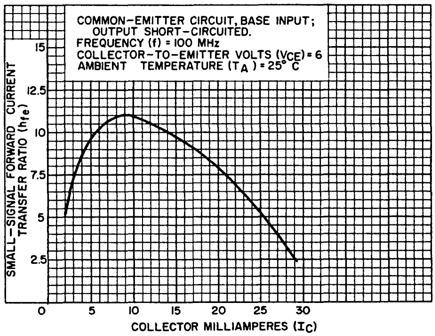


Fig.1 - Small-signal beta characteristic for types 2N918 and 2N3600.

10-66

ELECTRICAL CHARACTERISTICS

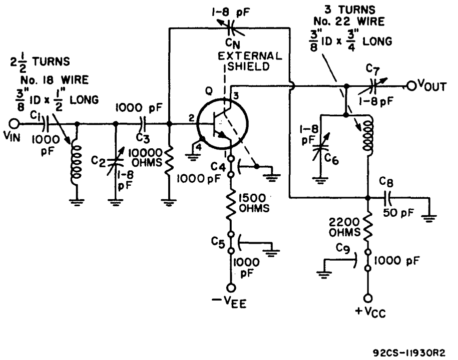
Characteristics	Symbols	TEST CONDITIONS: Ambient Temperature T_A (°C)	Frequency f (MHz)	DC Collector-to-Base Voltage V_{CB} (V)	DC Collector-to-Emitter Voltage V_{CE} (V)	DC Emitter Current I_E (mA)	DC Collector Current I_C (mA)	DC Base Current I_B (mA)	LIMITS: Type 2N918 Min.	Type 2N918 Typ.	Type 2N918 Max.	Type 2N3600 Min.	Type 2N3600 Typ.	Type 2N3600 Max.	Units
Collector-Cutoff Current	I_{CBO}	25 150		15 15		0 0			- -	- -	0.01 1	- -	- -	0.01 1	μA μA
Collector-to-Base Breakdown Voltage	BV_{CBO}	25				0	0.001		30	-	-	30	-	-	V
Collector-to-Emitter Sustaining Voltage	$BV_{CEO}(sus)$	25					3	0	15	-	-	15	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}	25				0.01	0		3	-	-	3	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$	25					10	1	-	-	0.4	-	-	0.4	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$	25					10	1	-	-	1	-	-	1	V
Static Forward Current-Transfer Ratio	h_{FE}	25			1		3		20	-	-	20	-	150	
Small-Signal Forward Current-Transfer Ratio[a]	h_{fe}	25	100 100 1 kHz		10 6 6		4 5 2		6 - -	- - -	- - -	- 8.5 40	- - -	- 15 200	
Common-Base Output Capacitance[b]	C_{ob}	25	0.1 to 1	10 0		0 0			- -	- -	1.7 3	- -	- -	- -	pF pF
Collector-to-Base Feedback Capacitance[b]	C_{cb}	25	0.1 to 1	10		0			-	-	-	-	-	1	pF
Common-Base Input Capacitance[c] ($V_{EB}=0.5V$)	C_{ib}	25	0.1 to 1				0		-	-	2	-	1.4	-	pF
Collector-to-Base Time Constant[a]	$r_b'C_c$	25	40 31.9	6 6			2 5		- -	15 -	- -	- 4	- -	- 15	ps ps
Small-Signal Power Gain in Neutralized Common-Emitter Amplifier Circuit[a] (See Fig.2 & Fig.3)	G_{pe}	25	200		12 6		6 5		15 -	21 -	- -	- 17	- -	- 24	dB dB
Small-Signal Power Gain in Unneutralized Common-Emitter Amplifier Circuit[a] (See Fig.4)	G_{pe}	25	200		10		5		-	13	-	-	-	-	dB
Power Output in Common-Emitter Oscillator Circuit[c] (See Fig.5)	P_o	25	≥ 500	10		12			30	-	-	20	-	-	mW
Nose Figure[a] (See Fig.2)	NF	25	200		6		1.5		-	-	-	-	-	4.5	dB
Noise Figure[a,d]	NF	25	60		6		1		-	-	6	-	-	3	dB

[a] Lead No.4 (case) grounded.

[b] Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

[c] Lead No.4 (case) floating.

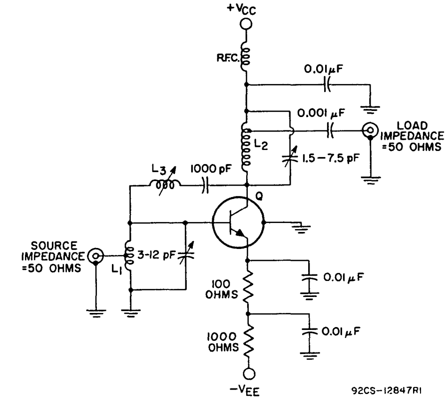
[d] Generator Resistance (R_g) = 400 ohms.



NOTE: (Neutralization Procedure): (a) Connect a 50-Ω rf voltmeter to the output of a 200-MHz signal generator (R_g = 50 Ω), and adjust the generator output to 5 mV. (b) Connect the generator to the input and the rf voltmeter to the output of the amplifier, as shown above. (c) Apply V_{EE} and V_{CC}, and adjust the generator output to provide an amplifier output of 5 mV. (d) Tune C_2, C_6, and C_7 for maximum amplifier output, readjusting the generator output, as required, to maintain an output of 5 mV from the amplifier. (e) Interchange the connections to the signal generator and the rf voltmeter. (f) With sufficient signal applied to the output terminals of the amplifier, adjust C_N for a minimum indication at the amplifier input. (g) Repeat steps (a), (b), (c), and (d) to determine if retuning is necessary.

Q = Type 2N3600

Fig.2 - Neutralized amplifier circuit used to measure power gain and noise figure at 200 MHz for type 2N3600.



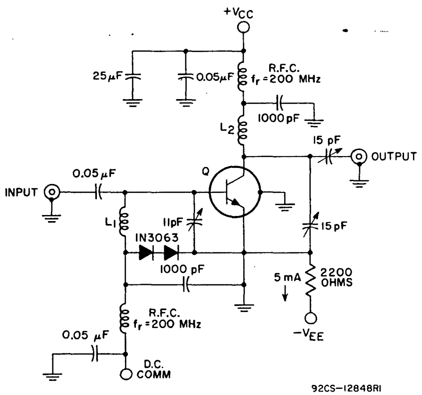
L_1 - 3.5 turns No.16 tinned copper wire; 5/16" dia.; 7/16" long; turns ratio ≃ 4:2

L_2 - 8 turns No.16 tinned copper wire; 1/8" dia.; 7/8" long; turns ratio ≃ 8:1

L_3 - MILLER #4303 (0.4 - 0.65 µH) or equivalent

Q = Type 2N918

Fig.3 - Neutralized amplifier circuit used to measure power gain at 200 MHz for type 2N918.

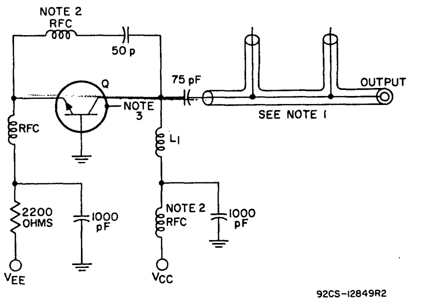


L_1 - 1 loop #12 AWG wire; I_D = 13/16"

L_2 - 1/2 loop #12 AWG wire; I_D = 1-3/16"

Q = 2N918

Fig.4 - Circuit used to measure 200-MHz unneutralized power gain for type 2N918.



Note 1 - Coaxial-Line output network consisting of:
- 2 General Radio Type 874 TEE or equivalent
- 1 General Radio Type 874-D20 Adjustable Stub or equivalent
- 1 General Radio Type 874-LA Adjustable Line or equivalent
- 1 General Radio Type 874-WN3 Short-circuit termination or equivalent

Note 2 - RFC = 0.2 µH Ohmite #2-460 or equivalent

Note 3 - Lead Number 4 (case) floating

L_1 - 2 turns #16AWG wire, 3/8 inch OD, 1-1/4 inch long

Q = 2N918 or 2N3600

Fig.5 - Circuit used to measure 500-MHz oscillator power output for types 2N918 and 2N3600.

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF COLLECTOR CURRENT (I_C) FOR RCA TYPES 2N918 AND 2N3600

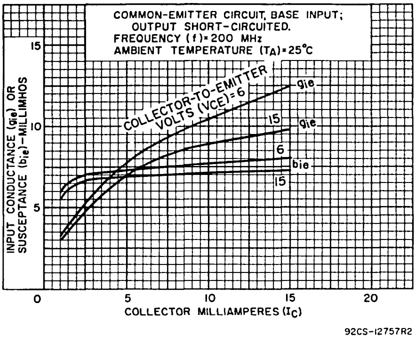


Fig.6 - Input admittance (y_{ie}).

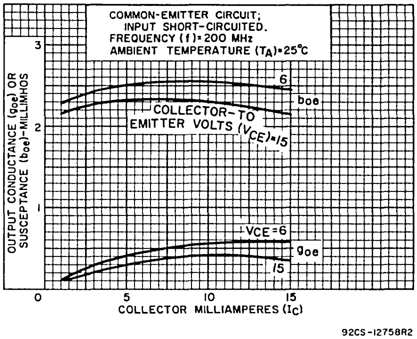


Fig.7 - Output admittance (y_{oe}).

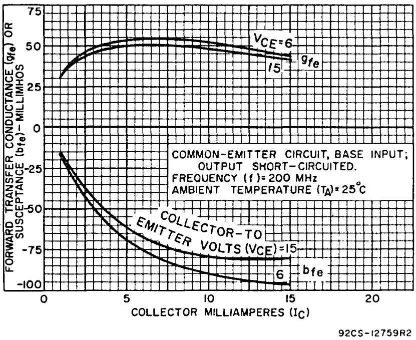


Fig.8 - Forward transadmittance (y_{fe}).

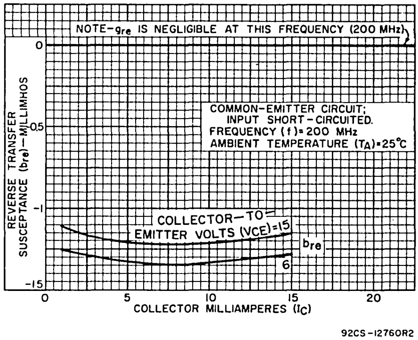


Fig.9 - Reverse transadmittance (y_{re}).

TERMINAL CONNECTIONS

LEAD 1 - EMITTER

LEAD 2 - BASE

LEAD 3 - COLLECTOR

LEAD 4 - CONNECTED TO CASE

RCA

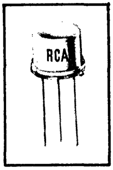
Solid State Division

RF Power Transistors

2N1491
2N1492
2N1493

RCA-2N1491, 2N1492, and 2N1493 are triple-diffused transistors of the silicon n-p-n type. These transistors are intended for a wide variety of applications in industrial and military electronic equipment. They are particularly useful in large-signal power-amplifier, video-amplifier, and oscillator circuits operating in the HF and VHF regions over wide ranges of ambient temperature.

VHF Amplifier & Oscillator Service



JEDEC TO-39

RATINGS

Maximum Ratings, *Absolute-Maximum Values:*

		2N1491	2N1492	2N1493		
COLLECTOR-TO-BASE VOLTAGE . . .	V_{CBO}	30	60	100	max.	V
COLLECTOR-TO-EMITTER VOLTAGE:						
With emitter-to-base reverse biased. .	V_{CEV}	30	60	100	max.	V
EMITTER-TO-BASE VOLTAGE.	V_{EBO}	1	2	4.5	max.	V
COLLECTOR CURRENT	I_C	500	500	500	max.	mA
EMITTER CURRENT		500	500	500	max.	mA
TRANSISTOR DISSIPATION, See *Fig.3:*	P_T					
Operation in free air:						
Ambient temperature = 25° C . . .		0.5	0.5	0.5	max.	W
Ambient temperature = 100° C. . .		0.25	0.25	0.25	max.	W
Operation with heat sink:						
Case temperature = 25° C		3	3	3	max.	W
Case temperature = 100° C.		1.5	1.5	1.5	max.	W
AMBIENT TEMPERATURE RANGE:						
Operating and storage			−65 to +175			°C

- High V_{CB} Ratings – up to 100 V
- High Transistor -Dissipation Ratings – up to 3 watts
- High Typical f_T at I_C = 25 mA – up to 380 MHz
- High Typical Power Gain at 70 MHz – up to 12 db at 500-mW output
- JEDEC TO-39 Package

ELECTRICAL CHARACTERISTICS, *Ambient Temperature = 25° C*

Characteristics	Symbol	TEST CONDITIONS: DC Collector Voltage (volts) V_{CB}	DC Collector Voltage (volts) V_{CE}	DC Collector Current (mA)	DC Emitter Current (mA)	LIMITS: Type 2N1491 Min.	Type 2N1491 Max.	Type 2N1492 Min.	Type 2N1492 Max.	Type 2N1493 Min.	Type 2N1493 Max.	Units
Collector Breakdown Voltage	BV_{CBO}			0.1	0	30		60		100		volts
Collector Cutoff Current	I_{CBO}	12			0		10		10		10	μA
Emitter Cutoff Current	I_{EBO}		V_{EB} 0.5	0			100		100		100	μA
Collector-to-Base and Stem Capacitance	–	30			0		5		5		5	pF
Small-Signal Current Transfer Ratio: at 1 KHz	h_{fe}		20	15		15	200	15	200	15	200	
Power Gain at 70 MHz Power Output (mW) See *Fig.11*												
= 10	PG	20			−15	13						dB
= 100		30			−15			13				dB
= 500		50			−25					10		dB
Thermal Resistance Junction-to-case	R_T						50		50		50	°C/W

5-66

PERFORMANCE CHARACTERISTICS

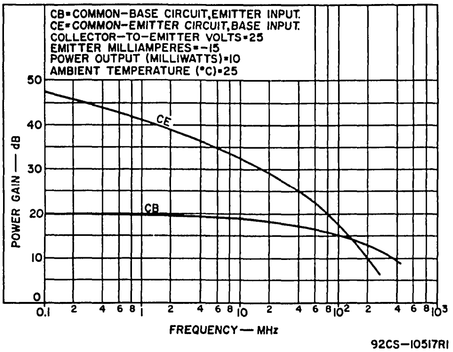


Fig. 1

DISSIPATION DERATING GRAPH

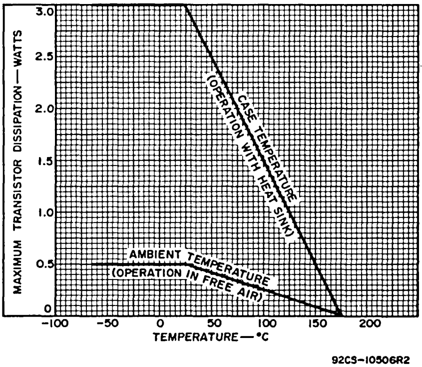


Fig. 3

TYPICAL COLLECTOR CHARACTERISTICS

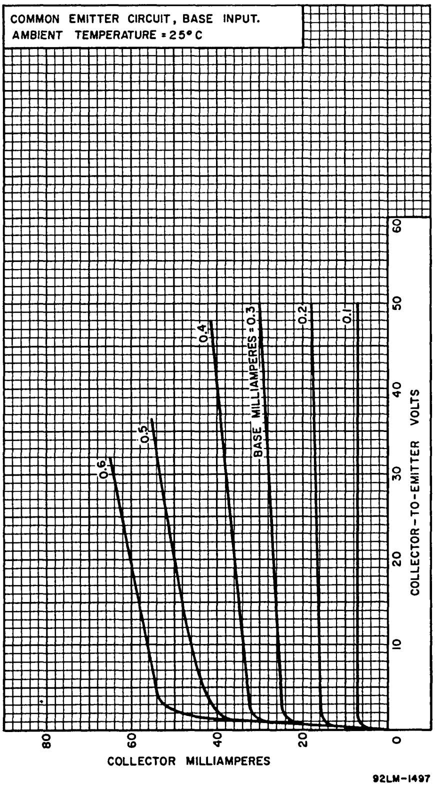


Fig. 2

TYPICAL CHARACTERISTICS

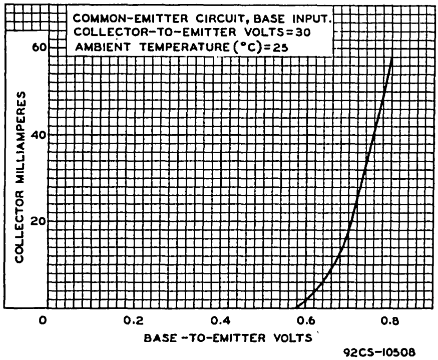


Fig. 4

TYPICAL DC BETA CHARACTERISTICS

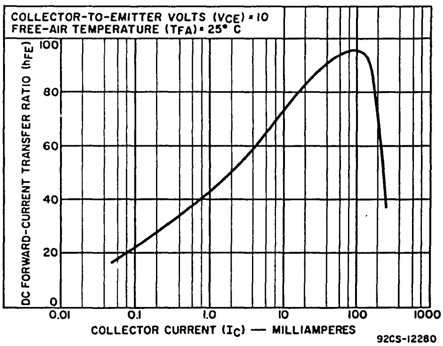
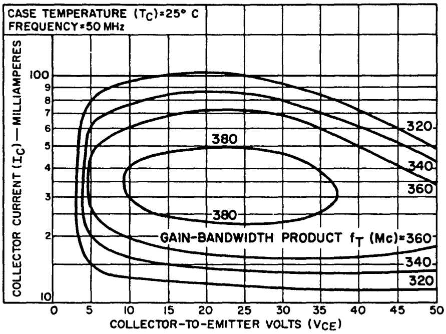


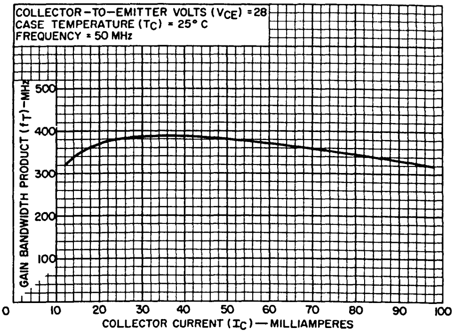
Fig. 5

TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTICS



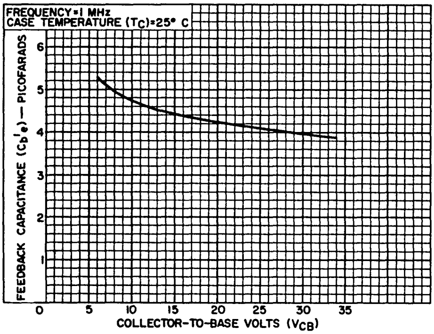
92CS-12286

Fig. 6



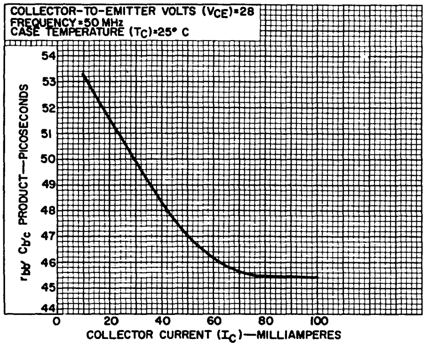
92CS–12287

Fig. 7



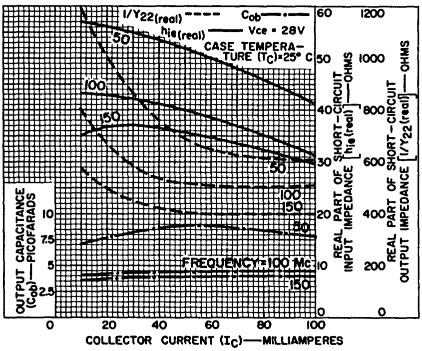
92CS-12283R1

Fig. 8



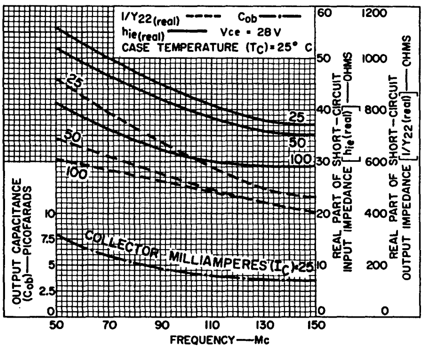
92CS-12284

Fig. 9



92CS-12289R1

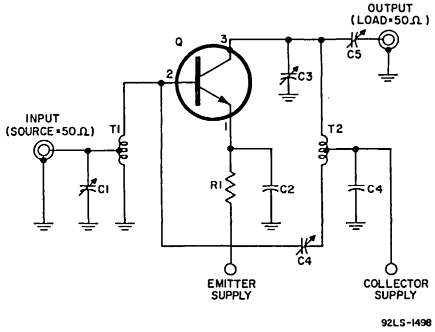
Fig. 10



92CS-12288R1

Fig. 11

POWER GAIN TEST CIRCUIT



C_1: 3-20 pF variable
C_2, C_6: 0.01 μF
C_3: 3-20 pF variable
C_4: 7-100 pF variable
C_5: 3-20 pF variable
Q: All Types
T_1: 8 turns No.24 wire tapped at 1 turn
T_2: 8 turns No.24 wire tapped at 2.5 turns

Fig. 12

TERMINAL CONNECTIONS

Lead No. 1 – Emitter
Lead No.2 – Base
Case, Lead No.3 – Collector

RCA

Solid State Division

RF Power Transistors

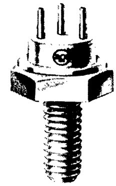
2N2631
2N2876

For Large-Signal, High-Power, VHF Applications in Military and Industrial Communications Equipment

RCA-2N2876 and 2N2631 are triple-diffused planar transistors of the silicon n-p-n type. These devices are intended for applications in AM, FM, and CW service at frequencies up to 150 Mc.

The 2N2876 utilizes a stud-mounted TO-60 package which is electrically isolated from all the electrodes and is designed to provide excellent performance at very high frequencies. The 2N2631 TO-39 package is identical to the JEDEC TO-5 package except for shorter leads (0.5 inch).

JEDEC TO-39



JEDEC TO-60

RF SERVICE

Maximum Ratings, *Absolute-Maximum Values:*

	2N2876	2N2631		
COLLECTOR-TO-BASE VOLTAGE, V_{CBO} . . .	80	80	max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open, V_{CEO} .	60	60	max.	volts
With V_{BE} = -1.5 volts, V_{CEV} . . .	80	80	max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO} . . .	4	4	max.	volts
COLLECTOR CURRENT, I_C .	2.5	1.5	max.	amp
TRANSISTOR DISSIPATION, P_T:				
At case temperatures up to 25°C	17.5	8.75	max.	watts
At case temperatures above 25°C	Derate linearly 100mw/°C	Derate linearly 50 mw/°C		
TEMPERATURE RANGE:				
Storage.	-65to+200	-65to+200		°C
Operating (Junction)	-65to+200	-65to+200		°C
LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/32" from ceramic wafer for 10 sec. max. .	230	-	max.	°C
At distances ≥ 1/32" from seating surface for 10 sec. max. .	-	230	max.	°C

- High Power Output, Unneutralized (P_{OUT}):
  - 10 w min. at 50 Mc, 3 w min. at 150 Mc — 2N2876
  - 7.5 w min. at 50 Mc, 3 w min. at 150 Mc — 2N2631
- High Voltage Ratings:
  - V_{CBO} = 80 volts max.
  - V_{CEO} = 60 volts max.
- 100 per cent tested to assure freedom from second breakdown in class A operation at maximum ratings

RCA-2N2876 Features:

- Low Thermal Resistance (θ_{J-C})—
  high-thermal-conductivity ceramic insulation between collector and mounting stud
- Isolated Stud Package:
  all three electrodes electrically isolated from case —for design flexibility
  heavy copper mounting stud—for effective contact with heat sink
  pin terminals arranged on a .200" pin-circle diameter —fit commercially available sockets

5-66

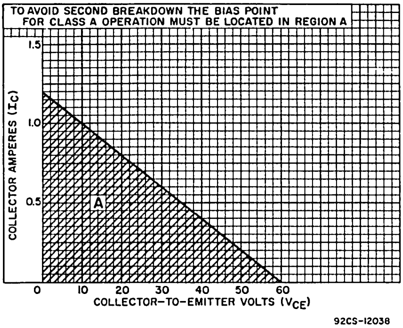


Fig. 1 - Region of Safe Operation (Without second breakdown) in Class A Service for Type 2N2876.

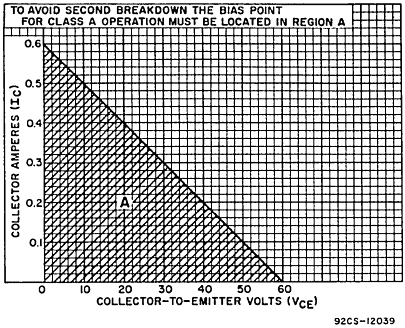


Fig. 2 - Region of Safe Operation (Without second breakdown) in Class A Service for Type 2N2631.

ELECTRICAL CHARACTERISTICS

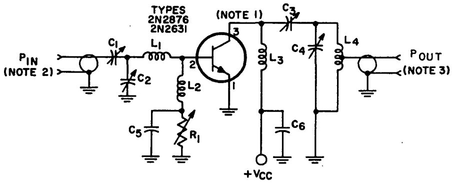
Case Temperature = 25° C Unless Otherwise Specified

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Base Volts V_{BE}	DC Current (Milliamperes) I_E	I_B	I_C	LIMITS 2N2876 Min.	2N2876 Max.	2N2631 Min.	2N2631 Max.	Units
Collector-Cutoff Current	I_{CBO}	30			0			-	0.1	-	0.1	μa
Collector-to-Base Breakdown Voltage	BV_{CBO}				0		0.5	80	-	80	-	volts
Collector-to-Emitter Breakdown Voltage (Sustaining)	$BV_{CEO}(sus)$					0	500*	60	-	60	-	volts
Collector-to-Emitter Breakdown Voltage	BV_{CEV}			-1.5			0.1	80	-	80	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	4	-	4	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					300	1.5 amp	-	-	-	1	volt
						500	2.5 amp	-	1	-	-	volt
Feedback Capacitance (Measured at 140 Kc)	$C_{b'c}$	30			0			-	20	-	20	pf
RF Power Output, Unneutralized (see *Fig.3*):	P_{out}											
Measured at 50 Mc			28				500	10[a]	-	-	-	watts
50 Mc			28				375	-	-	7.5[b]	-	watts
150 Mc			28				275	3[b]	-	3[b]	-	watts
Gain-Bandwidth Product	f_T		28				250	200 (typ.)		200 (typ.)		Mc
Base Spreading Resistance (Measured at 400 Mc)	$r_{bb'}$		28				250	6.0 (typ.)		6.0 (typ.)		ohms
Collector-to-Case Capacitance	C_c							-	6	-	-	pf

* Pulsed. Pulse duration ∠ 5 μsec; duty factor ∠ 1%.

[a] For P_{IN} = 2 watts.

[b] For P_{IN} = 1 watt.



92CS-12040

NOTE 1: COLLECTOR GROUNDED TO CASE IN TYPE 2N2631; SEE *TERMINAL DIAGRAM.*

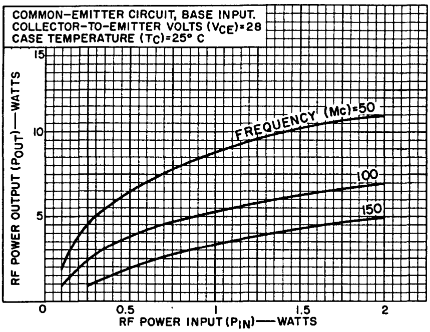
NOTE 2: GENERATOR IMPEDANCE = 50 OHMS.

NOTE 3: LOAD IMPEDANCE = 50 OHMS.

	For 50-Mc Operation		For 150-Mc Operation
C_1 C_2 C_3 C_4	8-60 pf	C_1 C_2 C_3 C_4	4-40 pf
C_5 C_6	0.005 μf	C_5 C_6	0.005 μf
L_1	8 turns No. 16 wire, 3/8" ID x 9/16" long	L_1	1 turn No. 16 wire, 1/4" ID x 3/16" long
L_2	Ferrite choke, Z = 750 (±20%) ohms	L_2	Ferrite choke, Z = 750 (±20%) ohms
L_3	10 μh	L_3	1.5 μh
L_4	7 turns No. 14 wire, 1/2" ID x 7/8" long; tap 2 turns from ground end	L_4	3 turns No. 14 wire, 3/8" ID x 3/4" long; tap 1-1/2 turns from ground end
R_1	5000 ohms	R_1	50 ohms

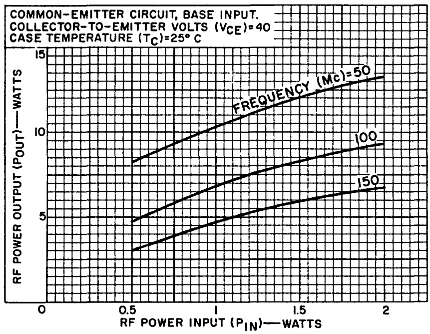
Fig. 3 - Circuit of Unneutralized Amplifier Used to Measure Power Output of Types 2N2876 and 2N2631.

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 2N2876



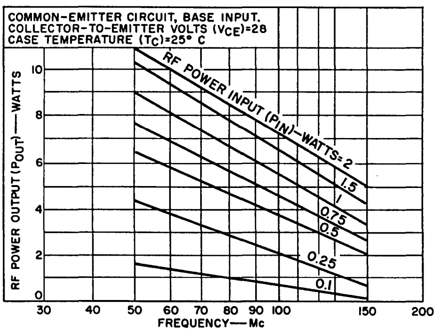
92CS-12062

Fig. 4

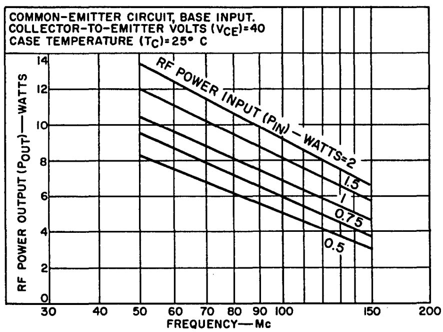


92CS-12064

Fig. 6



92CS-12061



92CS-12060

TYPICAL OPERATION CHARACTERISTICS FOR TYPE 2N2631

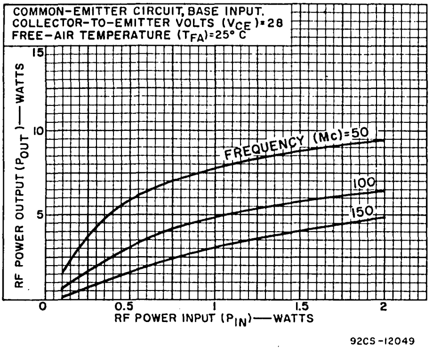


Fig. 8

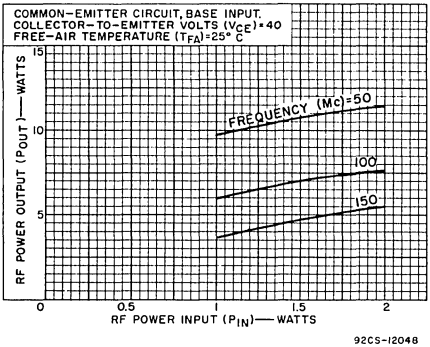


Fig. 10

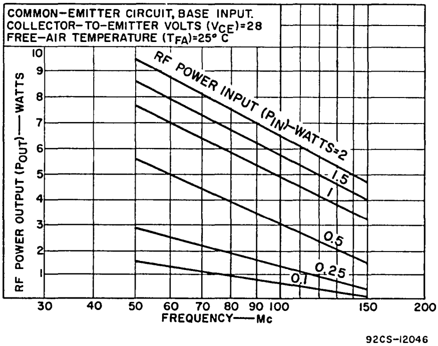


Fig. 9

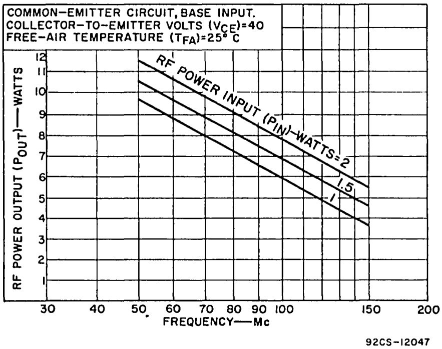
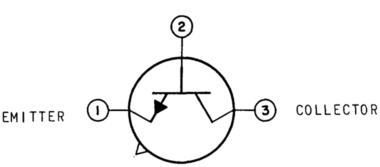


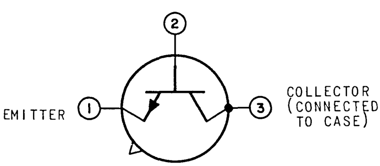
Fig. 11

TERMINAL DIAGRAMS
(Bottom View)

2N2876



2N2631

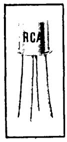


RCA
Solid State
Division

RF Power Transistors

2N2857

SILICON N-P-N EPITAXIAL PLANAR TRANSISTOR



JEDEC
TO-72

For UHF Applications in Industrial and Military Equipment

RCA-2N2857 is a double-diffused epitaxial planar transistor of the silicon n-p-n type. It is extremely useful in low-noise-amplifier, oscillator, and converter applications at frequencies up to 500 MHz in the common-emitter configuration, and up to 1200 MHz in the common-base configuration.

The 2N2857 utilizes a hermetically sealed four-lead JEDEC TO-72 package. All active elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead in applications requiring shielding of the device.

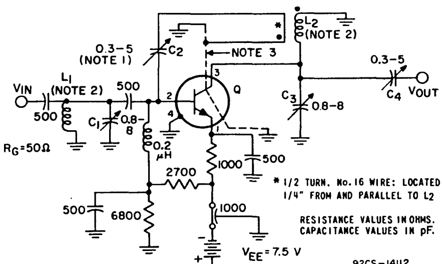
Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	30 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	15 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	2.5 max.	V
COLLECTOR CURRENT, I_C	40 max.	mA
TRANSISTOR DISSIPATION, P_T:		
At case temperatures* up to 25° C.	300 max.	mW
At case temperatures* above 25° C.	Derate at 1.72	mW/°C
At ambient temperatures up to 25°C	200 max.	mW
At ambient temperatures above 25° C.	Derate at 1.14	mW/°C
TEMPERATURE RANGE:		
Storage and Operating (Junction)	-65 to +200	°C
LEAD TEMPERATURE (During soldering):		
At distances ≥ 1/32 inch from seating surface for 10 seconds max	265 max.	°C

* Measured at center of seating surface.

FEATURES

- high gain-bandwidth product— f_T = 1000 MHz min.
- high converter (450-to-30 MHz) gain— G_c = 15 dB typ. for circuit bandwidth of approximately 2 MHz
- high power gain as neutralized amplifier— G_{pe} = 12.5 dB min. at 450 MHz for circuit bandwidth of 20 MHz
- high power output as uhf oscillator— P_o = 30 mW min., 40 mW typ. at 500 MHz; 20 mW typ., at 1 GHz
- low device noise figure— NF = 4.5 dB max. as 450 MHz amplifier; 7.5 dB typ. as 450-to-30 MHz converter
- low collector-to-base time constant— $r_b'C_c$ = 7 ps typ.
- low collector-to-base feedback capacitance— C_{cb} = 0.6 pF typ.



Q = 2N2857

NOTE 1: (NEUTRALIZATION PROCEDURE): (A) CONNECT A 450-MHz SIGNAL GENERATOR (WITH R_G = 50 Ω) TO THE INPUT TERMINALS OF THE AMPLIFIER. (B) CONNECT A 50-Ω RF VOLTMETER ACROSS THE OUTPUT TERMINALS OF THE AMPLIFIER. (C) APPLY V_{EE}, AND WITH THE SIGNAL GENERATOR ADJUSTED FOR 5 mV OUTPUT FROM THE AMPLIFIER, TUNE C1, C3, AND C4 FOR MAXIMUM OUTPUT. (D) INTERCHANGE THE CONNECTIONS TO THE SIGNAL GENERATOR AND THE RF-VOLTMETER. (E) WITH SUFFICIENT SIGNAL APPLIED TO THE OUTPUT TERMINALS OF THE AMPLIFIER, ADJUST C2 FOR A MINIMUM INDICATION AT THE INPUT. (F) REPEAT STEPS (A), (B), AND (C) TO DETERMINE IF RETUNING IS NECESSARY.

NOTE 2: L1 & L2 — SILVER-PLATED BRASS ROD, 1-1/2" LONG x 1/4" DIA. INSTALL AT LEAST 1/2" FROM NEAREST VERTICAL CHASSIS SURFACE.

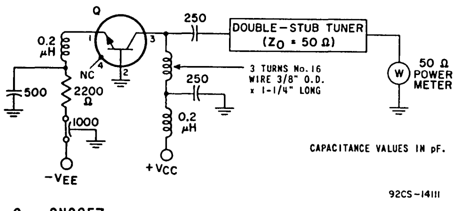
NOTE 3: EXTERNAL INTERLEAD SHIELD TO ISOLATE THE COLLECTOR LEAD FROM THE EMITTER AND BASE LEADS.

Fig. 1 - Neutralized amplifier circuit used to measure 450 MHz power gain and noise figure for type 2N2857.

ELECTRICAL CHARACTERISTICS, *At an Ambient Temperature, T_A = 25° C, Unless Otherwise Specified*

Characteristic	Symbol	Frequency f	TEST CONDITIONS: DC Collector-to-Base Voltage V_{CB}	DC Collector-to-Emitter Voltage V_{CE}	DC Emitter-to-Base Voltage V_{EB}	DC Emitter Current I_E	DC Base Current I_B	DC Collector Current I_C	LIMITS Type 2N2857 Min.	Typ.	Max.	Units
		MHz	V	V	V	mA	mA	mA				
Collector-Cutoff Current	I_{CBO}	T_A = 25°C T_A = 150°C	15 15			0 0			-	-	10 1.0	nA µA
Collector-to-Base Breakdown Voltage	BV_{CBO}					0		0.001	30	-	-	V
Collector-to-Emitter Breakdown Voltage	BV_{CEO}						0	3	15	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					-0.01		0	2.5	-	-	V
Static Forward-Current Transfer Ratio	h_{FE}			1				3	30	-	150	
Small-Signal Forward-Current Transfer Ratio	h_{fe}	0.001[c] 100[c]		6 6				2 5	50 10	- -	220 19	
Collector-to-Base Feedback Capacitance	C_{cb}	0.1 to 1[b]	10			0			-	0.6	1.0	pF
Input Capacitance	C_{ib}	0.1 to 1[a]			0.5			0	-	1.4	-	pF
Collector-to-Base Time Constant	$r_b'C_c$	31.9[c]	6			-2			4	7	15	ps
Small-Signal, Common-Emitter Power Gain in Neutralized Amplifier Circuit (See Fig. 1)	G_{pe}	450[c]		6				1.5	12.5	-	19	dB
Power Output as Oscillator (See Fig. 2)	P_o	≥ 500[a]	10			-12			30	-	-	mW
UHF Device Noise Figure	NF	450[c, d, f]		6				1.5	-	3.8	4.5	dB
UHF Measured Noise Figure	NF	450[c, d]		6				1.5	-	-	5.0	dB
VHF Device Noise Figure	NF	60[b, d]		6				1	-	2.2	-	dB

[a] Fourth lead (case) not connected
[b] Three-terminal measurement: Lead No. 1 (Emitter) and lead No. 4 (Case) connected to guard terminal.
[c] Fourth lead (case) grounded.
[d] Generator resistance, R_g = 50 ohms.
[e] Generator resistance, R_g = 400 ohms.
[f] Device noise figure is approximately 0.5 dB lower than the measured noise figure. The difference is due to the insertion loss at the input of the test circuit (0.25 dB) and the contribution of the following stages in the test set-up (0.25 dB).



Q = 2N2857

Fig. 2 - Oscillator circuit used to measure 500-MHz power output for type 2N2857.

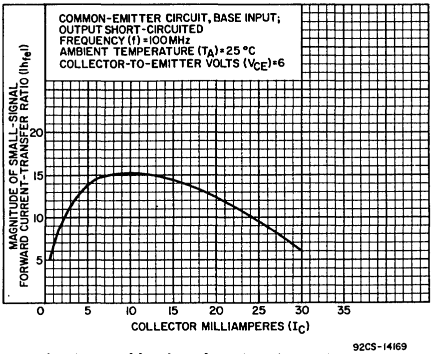


Fig.3 - Small-signal beta characteristic for type 2N2857.

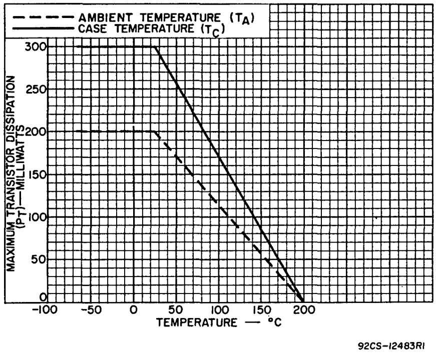


Fig.4 - Rating chart for type 2N2857.

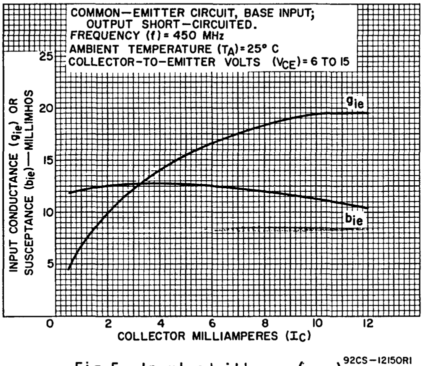


Fig.5 - Input admittance (y_{ie}).

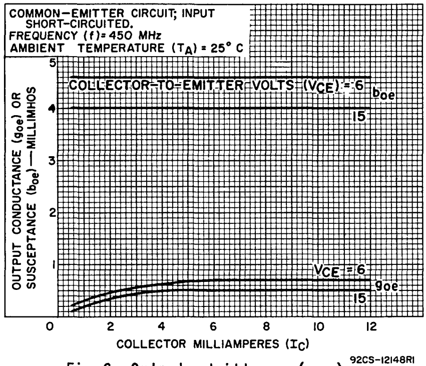


Fig.6 - Output admittance (y_{oe}).

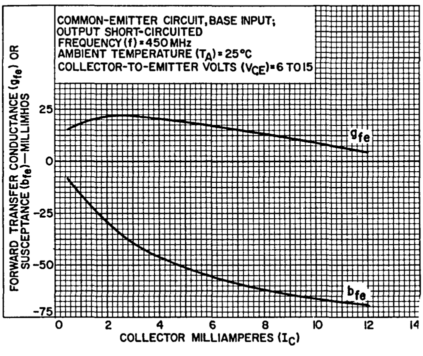


Fig.7 - Forward transadmittance (y_{fe}).

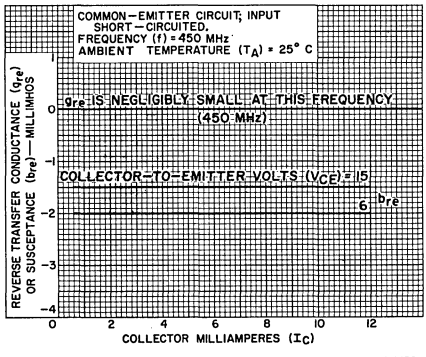


Fig.8 - Reverse transadmittance (y_{re}).

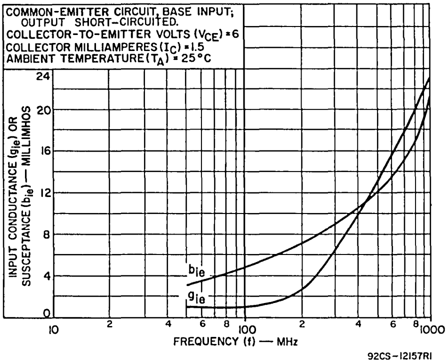


Fig.9 - Input admittance (y_{ie}).

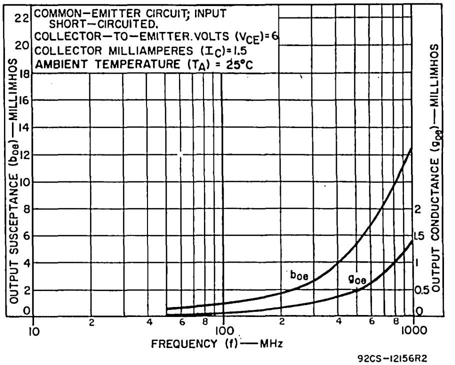


Fig. 10 - Output admittance (y_{oe}).

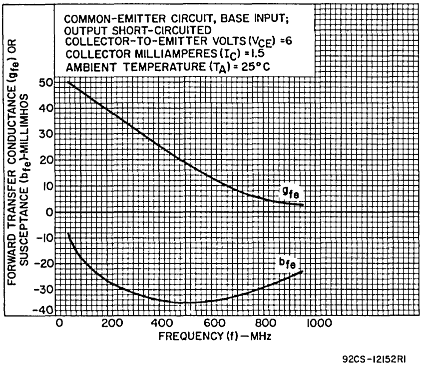


Fig. 11 - Forward transadmittance (y_{fe}).

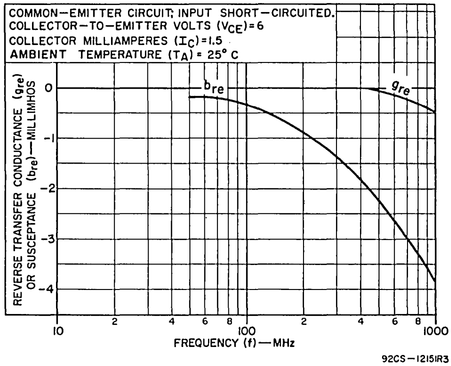
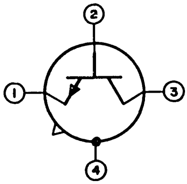


Fig. 12 - Reverse transadmittance (y_{re}).

TERMINAL DIAGRAM
Bottom View



LEAD 1 - EMITTER
LEAD 2 - BASE
LEAD 3 - COLLECTOR
LEAD 4 - CONNECTED TO CASE

RCA

Solid State Division

RF Power Transistors

2N3118

RCA-2N3118 is a triple-diffused planar transistor of the silicon n-p-n type intended for use in RF amplifiers in military and industrial HF and VHF communication equipment. It is designed especially for large-signal Class-C and small-signal Class-A service.

Maximum Ratings, *Absolute-Maximum Values:*

Collector-to-Emitter Voltage:
- Reverse bias (V_{CEX})
  - For V_{BE} = −1.5 volts .... 85 max. volts
  - With base open (V_{CEO}) .... 60 max. volts

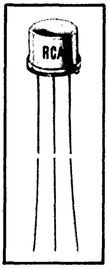
Emitter-to-Base Voltage (V_{EBO}) .... 4 max. volts

Collector Current (I_C) .... 0.5 max. ampere

Transistor Dissipation (P_T):
- At case temperatures up to 25°C .... 4 max. watts
- At free-air temperatures up to 25°C .... 1 max. watt
- At temperatures above 25°C .... See Fig. 1

Temperature Range:
- Storage .... −65 to +200 °C
- Operating (Junction) .... −65 to +200 °C

For Large-Signal VHF Class-C and Small-Signal VHF Class-A Amplifier Service



JEDEC TO-5

- High power dissipation — 4 watts at case temperature of 25° C
- High output power — Class-C service; 28-volt operation: 1 watt minimum at 50 Mc; 0.4 watt minimum at 150 Mc
- High collector-to-emitter voltage ratings — V_{CEX} = 85 volts; V_{CEO} = 60 volts
- High gain-bandwidth product — 380 Mc typical
- High power gain — Class-A service, neutralized: 25 db at 50 Mc, 200 mw output

ELECTRICAL CHARACTERISTICS

Characteristics	Symbols	TEST CONDITIONS: Case Temperature (T_C) °C	Frequency Mc	DC Collector-to-Base Voltage (volts) V_{CB}	DC Collector-to-Emitter Voltage (volts) V_{CE}	DC Emitter-to-Base Voltage (volts) V_{EB}	DC Collector Current (ma) I_C	DC Emitter Current (ma) I_E	DC Base Current (ma) I_B	LIMITS Min.	LIMITS Max.	Units
Collector-Cutoff Current	I_{CBO}	25(T_{FA})▲ 150(T_{FA})▲		30 30				0 0			0.1 100	µa µa
Emitter-to-Base Breakdown Voltage	BV_{EBO}	25					0	0.1		4		volts
Collector-to-Emitter Breakdown Voltage (Sustaining)	BV_{CEO}(sus)	25					10 pulsed□		0	60		volts
Reverse Collector-to-Emitter Breakdown Voltage	BV_{CEX}	25				1.5	0.1			85		volts
Feedback Capacitance	$C_{b'c}$	25	1	28			0				6	pf
$r_{bb'}$ $C_{b'c}$ Product	$r_{bb'}C_{b'c}$	25	50		28		25				60	psec
DC Forward-Current Transfer Ratio□	h_{FE}	25			28		25			50	275	
Small-Signal Forward-Current Transfer Ratio	h_{fe}	25	50		28		25			5		
Real Part of Short-Circuit Input Impedance	h_{ie}(real)	25	50		28		25			25	75	ohms
Real Part of Short-Circuit Output Impedance	$1/Y_{22}$(real)	25	50		28		25			500	1000	ohms
Output Power Class-C Service P_{in} = 0.1 watt (with heat sink)	P_{OUT}	25 25	50* 150●		28 28					1.0 0.4		watt watt
Power Gain Class-A Service P_{out} = 0.2 watt (with heat sink)	PG	25	50★		28		25			18		db

▲ T_{FA} = free-air temperature □ Pulse duration, 300 µsec; duty factor, less than 1.8% * See *Fig.5* ● See *Fig.3* ★ See *Fig.13*

RATING CHART

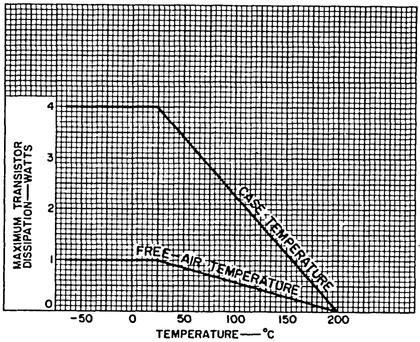


Fig.1

TYPICAL LARGE-SIGNAL OPERATION, CLASS-C SERVICE, 150 MC

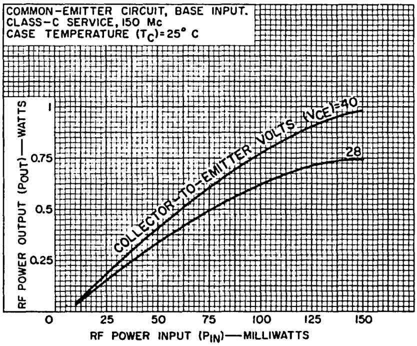
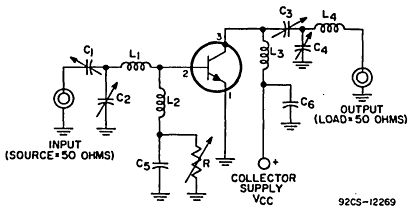


Fig.2



C_1,C_2: 1.5–20 pf
C_3: 4–40 pf
C_4: 7–100 pf
C_5: 1800 pf
C_6: 0.01 µf
R: 100 ohms, variable

L_1: 0.1 µh, 4 turns, No.18 wire, 1/4" ID, closely wound
L_2: 750-ohm ferrite choke
L_3: 0.075 µh, 4 turns, No.16 wire, 1/4" ID x 3/8" long
L_4: 0.055 µh, 3 turns, No.16 wire, 1/4" ID x 1/4" long

Fig.3

TYPICAL LARGE-SIGNAL OPERATION, CLASS-C SERVICE, 50 MC

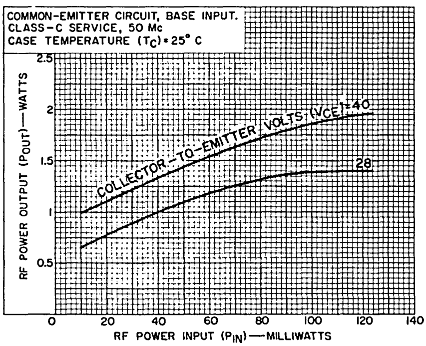
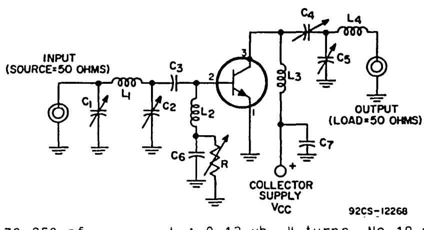


Fig.4 92CS-12272



C_1: 70–350 pf
C_2,C_4,C_5: 7–100 pf
C_3: 0.01 µf
C_6: 0.002 µf
C_7: 0.02 µf

R: 1000 ohms, variable

L_1: 0.13 µh, 4 turns, No.18 wire, 1/4" ID, closely wound
L_2: 2.4 µh, choke, Miller Part No.4606
L_3: 0.6 µh, 10 turns, No.18 wire, 3/8" ID, closely wound
L_4: 0.6 µh, 10 turns, No.18 wire, 3/8" ID, closely wound

Fig.5

TYPICAL SMALL-SIGNAL OPERATION CHARACTERISTICS

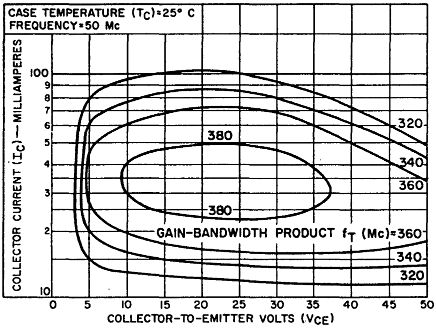


Fig.6

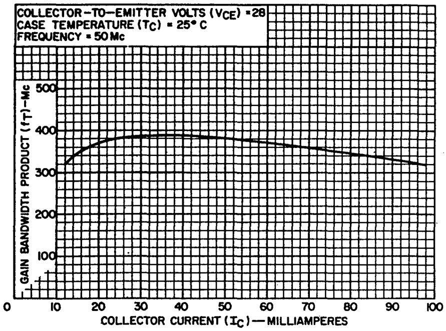


Fig.7

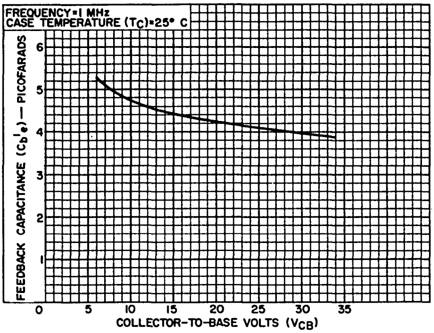


Fig.8

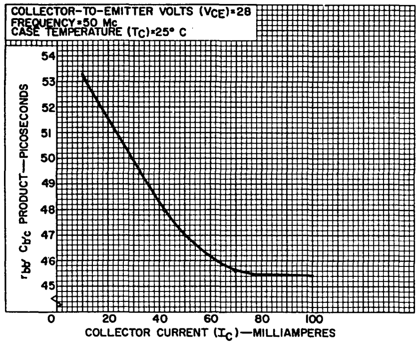


Fig.9

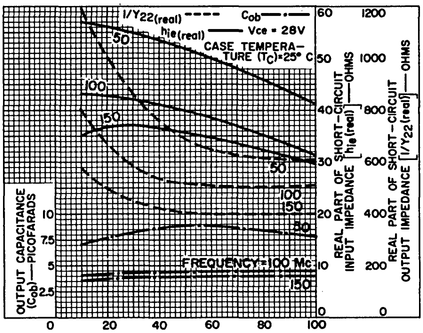


Fig.10

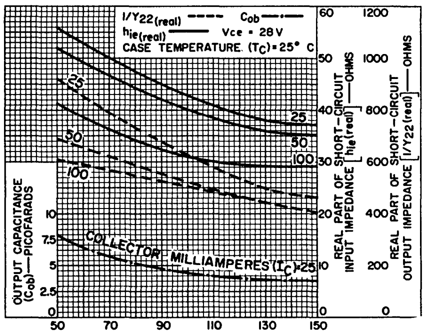


Fig.11

TYPICAL CLASS-A-SERVICE-OPERATION, 50 MC, NEUTRALIZED

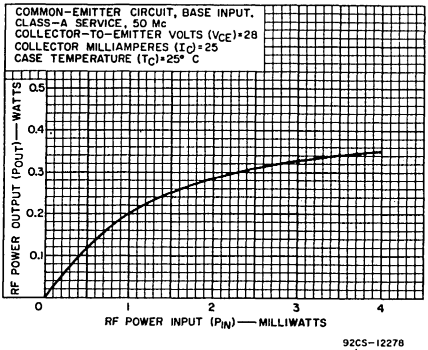
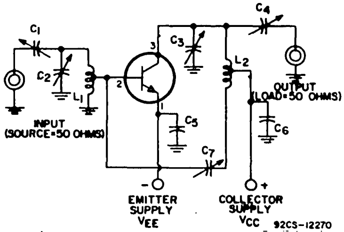


Fig.12



C_1: 7–100 pf
C_2: 8–60 pf
C_3: 14–150 pf
C_4: 6–80 pf
C_5,C_6: 0.005 μf
C_7: 0.9–7 pf

L_1: 0.12 μh, 3 turns, No.16 wire, 7/16" ID x 1/4" long, tap at 1 turn from ground
L_2: 0.23 μh, 5 turns, No.16 wire, 7/16" ID x 1/2" long, tap at 3 turns from collector terminal

Fig.13

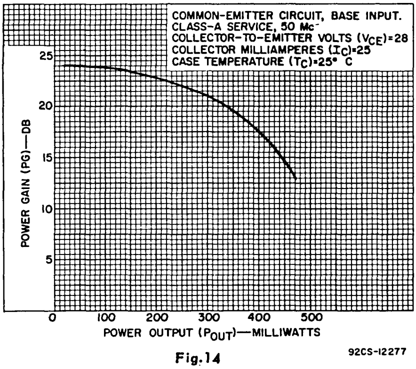


Fig.14

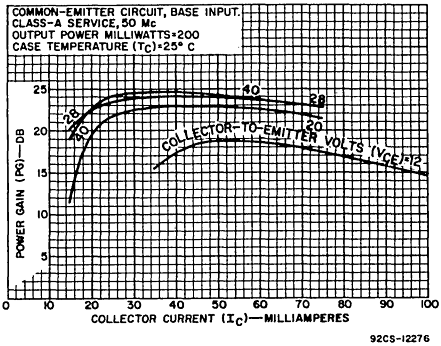
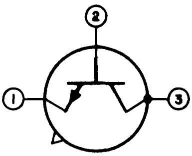


Fig.15

TERMINAL DIAGRAM

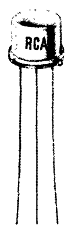
LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE



RCA
Solid State
Division

RF Power Transistors

2N3119



JEDEC TO-5

H-1380

High-Power Silicon N-P-N Planar Transistor

For Switching and Pulse-Amplifier Applications

Features:

- **High voltage ratings:**
  V_{CEX} = 100 V, V_{CEO} = 80 V
- **Fast rise time:**
  10 ns with 50-V pulse, 1-KΩ load
- **High power dissipation:**
  4 W at T_C = 25° C

RCA-2N3119 is a triple-diffused planar transistor of the silicon n-p-n type intended for high-voltage high-frequency pulse amplifiers and high-voltage saturated switches in military and industrial equipment.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	100	V
COLLECTOR-TO-EMITTER VOLTAGE:			
* With base open	V_{CEO}	80	V
With base-emitter junction reverse-biased (V_{BE} = −1.5 V)	V_{CEX}	100	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*COLLECTOR CURRENT:	I_C		
Continuous		0.5	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25° C		4	W
At free-air temperatures up to 25° C		1	W
At temperatures above 25° C		See Fig. 1	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
*LEAD TEMPERATURE (During soldering):			
At 1/16 in. ± 1/32 in. (1.59 mm ± 0.8 mm) from seating plane for 10 s max.		255	°C

*In accordance with JEDEC registration data format

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C unless otherwise specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTS V_{CB}	DC COLLECTOR VOLTS V_{CE}	DC EMITTER VOLTS V_{BE}	DC CURRENT (MILLIAMPERES) I_E	DC CURRENT (MILLIAMPERES) I_B	DC CURRENT (MILLIAMPERES) I_C	LIMITS MIN.	LIMITS MAX.	UNITS
* Collector-Cutoff Current At T_{FA} = 25° C = 150° C	I_{CBO}	60 60			0 0			– –	50 50	nA μA
* Reverse Collector Current	I_{CEV}		60	−1.5				–	0.2	μA
* Emitter-Cutoff Current (At T_{FA} = 25° C)	I_{EBO}			−3			0	–	100	nA
* Base Current	I_B		60	−1.5				–	0.2	μA
* Collector-to-Emitter Breakdown Voltage (Sustaining)	$BV_{CEO}(sus)$					0	10•	80	–	V
* Reverse Collector-to-Emitter Breakdown Voltage	BV_{CEX}			−1.5			0.10	100	–	V
* Collector-to-Base Breakdown Voltage	BV_{CBO}				0		0.10	100	–	V
* Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.10		0	4	–	V
* DC Forward-Current Transfer Ratio	h_{FE}		10 10• 10•				10 100 250	40 50 20	– 200 –	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					10	100	–	0.5	V
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					10	100	–	1.1	V
* Base-to-Emitter Voltage (Pulsed)	V_{BE}		10•				100	–	1.1	V
Feedback Capacitance (At 1 Mc)	$C_{b'c}$	28					0	–	6	pF
* Common-Base Output Capacitance (at 1 mC)	C_{ob}	28					0	–	6	pF
* Gain-Bandwidth Product (At 50 Mc)	f_T		28				25	250	–	Mc
* Pulse-Amplifier Delay + Rise Time (See Figs. 9 & 10)	$t_d + t_r$		V_{CC} = 80				10	–	20	ns
Sat. Switch Turn-On Time (delay time + rise time) (See Figs. 7 & 8)	t_{on}		V_{CC} = 28			I_{B_1} = 10	100	–	40	ns
Sat. Switch Turn-Off Time (storage time + fall time) (See Figs. 7 & 8)	t_{off}		V_{CC} = 28			I_{B_2} = −10	100	–	700	ns
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$							–	44	°C/W

*In accordance with JEDEC registration data format
•Pulsed; pulse duration = 300 μsec; duty factor = 1.8%

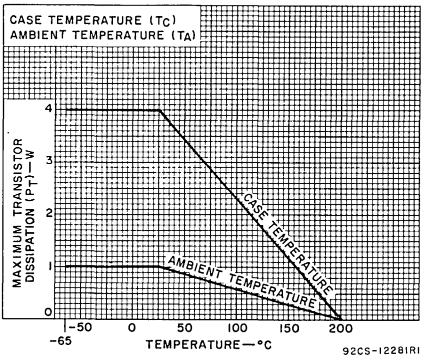


Fig. 1—Rating chart

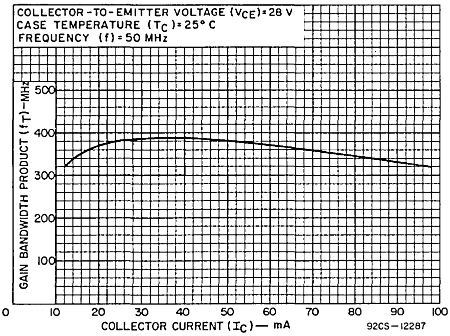


Fig. 2—Typical gain-bandwidth product characteristic

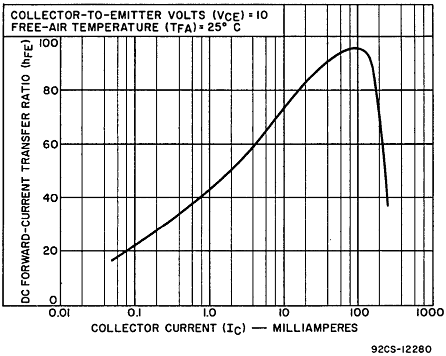


Fig. 3—Typical dc beta characteristic

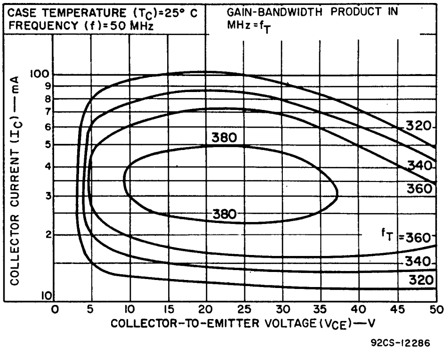


Fig. 4—Typical variation of f_T with collector current and collector-to-emitter voltage

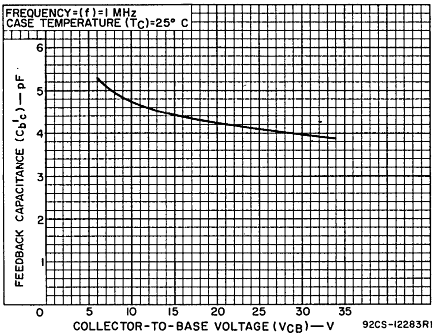


Fig.5—Typical variation of feedback capacitance vs. collector-to-base voltage

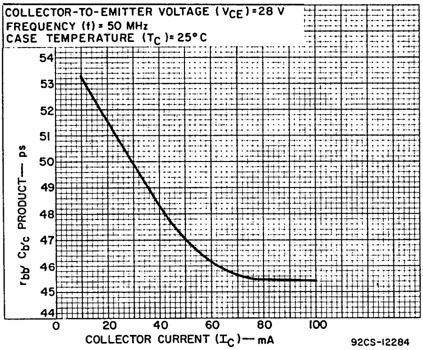
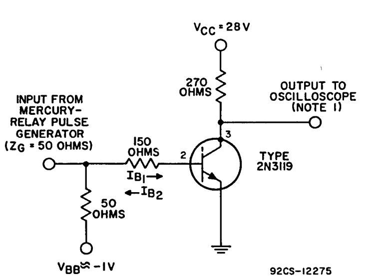


Fig. 6—Typical $r_{bb'} C_{b'c}$ product vs. collector current

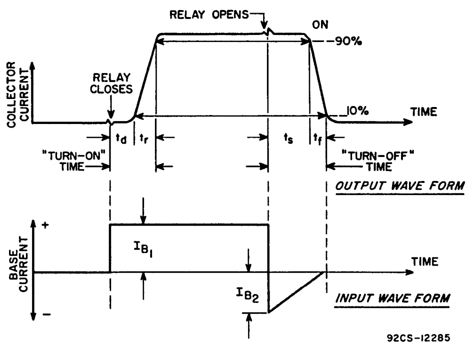


INPUT PULSE:

t_r < 3 nsec
t_f < 10 nsec
REP. RATE = 120 CPS
PULSE WIDTH = 300 μsec

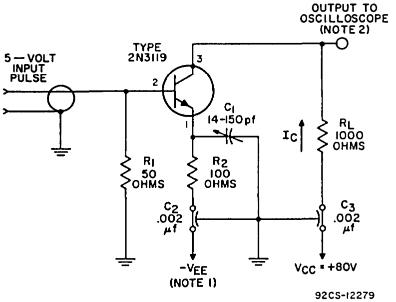
NOTE 1: WITH C_{IN} <1 pf SHUNTED BY 5,000 OHMS; t_r = 1 nsec.

Fig. 7—Circuit used to measure t_{on} and t_{off} for 2N3119 operating as a saturated switch



I_{B_1}	=	10 ma	t_{on}	=	40 nsec
I_{B_2}	=	−10 ma	t_{off}	=	700 nsec
I_C	=	100 ma			

Fig. 8—Waveforms for saturated switch circuit shown in Fig. 7



NOTE 1: V_{EE} ADJUSTED FOR I_C = 10 ma WITH NO INPUT.
NOTE 2: WITH C_{IN} < 1 pf SHUNTED BY 100,000 OHMS; t_r = 1 nsec.

Fig. 9—Pulse-amplifier test circuit

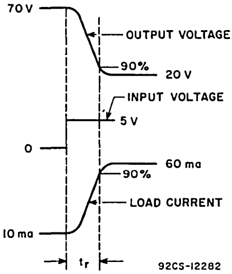


Fig. 10—Waveforms for pulse-amplifier test circuit shown in Fig. 9

TERMINAL CONNECTIONS

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

RCA
Solid State Division

RF Power Transistors

2N3229

RCA-2N3229 is a triple-diffused planar transistor of the silicon n-p-n type. This device is intended for applications in AM, FM, and CW service at frequencies up to 150 Mc.

The 2N3229 utilizes a new stud-mounted package which is electrically isolated from all the electrodes and is designed to provide excellent performance at very high frequencies.

RF SERVICE

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	105 max.	volts
COLLECTOR-TO-EMITTER VOLTAGE:		
With base open, V_{CEO}	60 max.	volts
With V_{BE} = -1.5 volts, V_{CEV}	105 max.	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	4 max.	volts
COLLECTOR CURRENT, I_C	2.5 max.	amperes
TRANSISTOR DISSIPATION, P_T:		
At case temperatures up to 25° C.	17.5 max.	watts
At case temperatures above 25° C.	Derate linearly	100 mw/°C
TEMPERATURE RANGE:		
Storage	-65 to 200	°C
Operating (Junction)	-65 to 200	°C
LEAD TEMPERATURE (During soldering):		
At distances ≥ 1/32" from ceramic wafer for 10 sec. max.	230 max.	°C

REGION OF SAFE OPERATION (WITHOUT SECOND BREAKDOWN) IN CLASS-A SERVICE FOR TYPE 2N3229

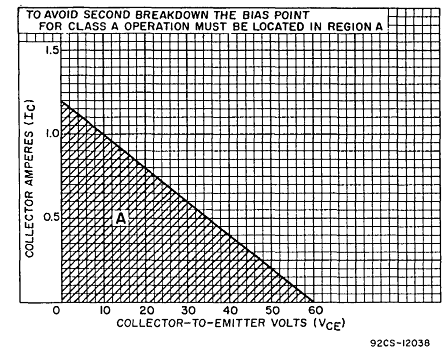
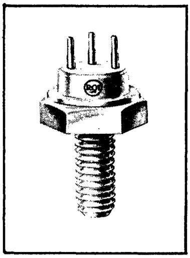


Fig.1

For Large-Signal, High-Power, VHF Applications in Military and Industrial Communications Equipment



JEDEC TO-60

- High Power Output, Unneutralized (P_{OUT}):
  15 w min. at 50 Mc
  5 w min. at 150 Mc
- High Voltage Ratings:
  V_{CBO} = 105 volts max.
  V_{CEV} = 105 volts max.
  V_{CEO} = 60 volts max.
- 100 per cent tested to assure freedom from second breakdown in class-A operation at maximum ratings
- Low Thermal Resistance (θ_{J-C})—
  high thermal-conductivity ceramic insulation between collector and mounting stud
- Isolated Stud Package:
  all three electrodes electrically isolated from case—for design flexibility

  heavy copper mounting stud—for effective contact with heat sink

  pin terminals arranged on a .200" pin-circle diameter—fit commercially available sockets

5-66

ELECTRICAL CHARACTERISTICS

Case Temperature = 25° C Unless Otherwise Specified

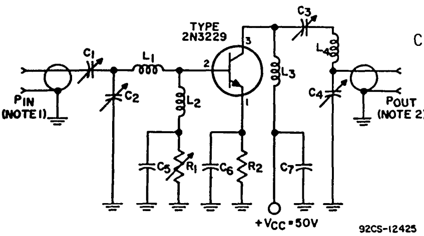
Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Base Volts V_{BE}	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	DC Current (Milliamperes) I_C	LIMITS Min.	LIMITS Max.	Units
Collector-Cutoff Current	I_{CBO}	30			0			-	0.1	μa
Collector-to-Base Breakdown Voltage	BV_{CBO}				0		0.5	105	-	volts
Collector-to-Emitter Breakdown Voltage (Sustaining)	$BV_{CEO}(sus)$					0	500*	60	-	volts
Collector-to-Emitter Breakdown Voltage	BV_{CEV}			-1.5			0.1	105	-	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	4	-	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					500	2.5 amp	-	1	volt
Feedback Capacitance (Measured at 140 Kc)	$C_{b'c}$	30			0			-	20	pf
RF Power Output, Unneutralized (See *Fig.* 2.): Measured at 50 Mc	P_{out}		50				550	15[a]	-	watts
150 Mc			50				250	5[b]	-	watts
Gain-Bandwidth Product	f_T		28				250	200(typ.)		Mc
Base-Spreading Resistance (Measured at 400 Mc)	$r_{bb'}$		28				250	6.0(typ.)		ohms
Collector-to-Case Capacitance	C_c							-	6	pf

* Pulsed. Pulse duration ≤ 5 μsec; duty factor ≤ 1%.

[a] For P_{IN} = 2 watts

[b] For P_{IN} = 1 watt

CIRCUIT OF UNNEUTRALIZED AMPLIFIER USED TO MEASURE POWER OUTPUT OF TYPE 2N3229



NOTE 1: GENERATOR IMPEDANCE = 50 OHMS.

NOTE 2: LOAD IMPEDANCE = 50 OHMS.

For 50-Mc Operation

- C_1: 4–40 pf
- C_2, C_4: 7–100 pf
- C_3: 1.5–20 pf
- C_5, C_6, C_7: 0.005 μf
- L_1: 5-1/2 turns No.18 wire, 1/4" ID, closely-wound
- L_2: Ferrite choke, Z = 750(±20%) ohms
- L_3: 6 turns No.18 wire, 3/8" ID, wire spacing = 1 wire dia. (slug-tuned)
- L_4: 8 turns No.18 wire, 3/8" ID, closely-wound (slug-tuned)
- R_1: 1,000 ohms
- R_2: 3.9 ohms (non-inductive)

For 150-Mc Operation

- C_1, C_2: 4–40 pf
- C_3, C_4: 1.5–20 pf
- C_5, C_7: 0.005 μf
- L_1: 1-1/2 turns No.16 wire, 1/4" ID, wire spacing = 1 wire dia.
- L_2: Ferrite choke, Z = 750(±20%) ohms
- L_3: 2.4 μh
- L_4: 6 turns No.16 wire, 3/8" ID, closely-wound
- R_1: 100 ohms
- R_2: = 0 (Emitter connected to ground)

Fig.2

TYPICAL-OPERATION CHARACTERISTICS FOR TYPE 2N3229

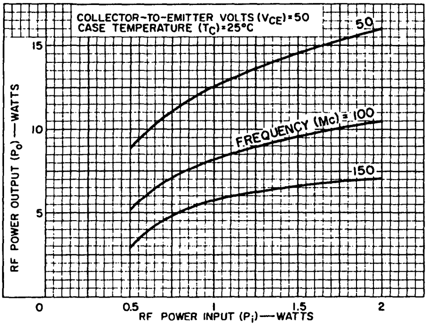


Fig.3

TYPICAL-OPERATION CHARACTERISTICS FOR TYPE 2N3229

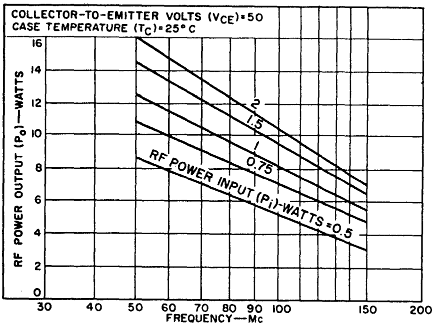
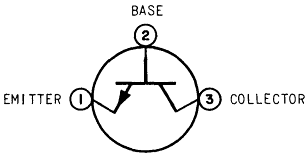


Fig.4

TERMINAL DIAGRAM



RCA

Solid State
Division

RF Power Transistors

2N3262

RCA-2N3262 is a triple-diffused planar transistor of the silicon n-p-n type intended for high-voltage, high-frequency pulse amplifiers and high-voltage saturated switches in military and industrial equipment. The high-current switching capability of the 2N3262 makes it especially suitable for memory-core driver applications.

The 2N3262 utilizes the JEDEC TO-39 package which is identical to the JEDEC TO-5 package except its leads have a minimum length of 0.5".

For High-Voltage, High-Speed Switching and Pulse-Amplifier Applications

JEDEC TO-39

- High Voltage Ratings —
- Fast Rise Time at High Collector Currents— 20 nsec rise time (max.) at 1 ampere
- High Power Dissipation —
- Low Collector to Emitter Saturation Voltage at High Collector Currents— 0.6 volts (max.) at 1 ampere

Maximum Ratings, *Absolute-Maximum Values:*

Collector-to-Base Voltage, V_{CBO}	100 max.	volts
Collector-to-Emitter Voltage		
Reverse bias, V_{CEX}		
For V_{EB} = 1.5 volts	100 max.	volts
With base open (sustaining voltage), $V_{CEO}(sus)$	80 max.	volts
Emitter-to-Base Voltage, V_{EBO}	4 max.	volts
Collector Current, I_C	1.5 max.	amperes
Transistor Dissipation, P_T:		
At case temperatures up to 25° C	8.75 max.	watts
At case temperatures above 25° C	Derate linearly (50 mw/°C) to 175° C	
At free-air temperatures up to 25° C	1 max.	watt
At free-air temperatures above 25° C	Derate linearly (5.71 mw/°C) to 175° C	
Temperature Range:		
Storage	-65 to +200	°C
Operating (Junction)	-65 to +200	°C
Lead Temperature:		
1/16" ± 1/32" from seating surface for 10 sec. max.	230	°C

Electrical Characteristics, *Case Temperature = 25° C Unless Otherwise Specified*

Characteristic	Symbol	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Emitter Volts V_{EB}	DC Current (Milliamperes) I_E	I_B	I_C	LIMITS Min.	Max.	Units
Collector-Cutoff Current at T_{FA} = 25° C	I_{CBO}	30			0				0.1	µa
Emitter-Cutoff Current	I_{EBO}			3			0		100	µa
Collector-to-Emitter Sustaining Voltage with External Base-to-Emitter Resistance (R_{BE}) = 10 ohms	$V_{CER}(sus)$						500*	90		volts
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$					0	500*	80		volts
Reverse Collector-to-Emitter Breakdown Voltage	BV_{CEX}			1.5			0.25	100		volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	4		volts
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					100	1000		1.4	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					100	1000		0.6	volts
DC Forward Current Transfer Ratio	h_{FE}		4				500	40		
Input Capacitance (at 1 Mc)	C_{ib}			3			0		300	pf
Feedback Capacitance (at 1 Mc)	$C_{b'c}$	28					0		20	pf
Pulse-Amplifier Rise Time (See Figs. 13 & 14)	t_r		V_{cc}=80				25		20	nsec
Sat. Switch Turn-On Time— Delay Time + Rise Time (See Figs. 8 & 10)	t_{on}		28		$I_{B1}=I_{B2}$ =100		1000		40	nsec
Sat. Switch Turn-Off Time— Storage + Fall Time (See Figs. 8 & 10)	t_{off}		28		$I_{B1}=I_{B2}$ = 100				750	nsec
Forward Current Transfer Ratio (at 50 Mc)	h_{fe}		28				100	3		

* Pulsed; pulse duration = 15 µsec; duty factor = 0.15%.

TYPICAL TRANSFER CHARACTERISTICS

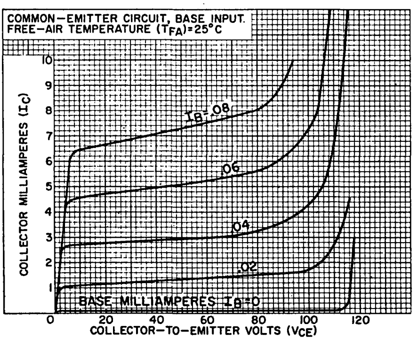


Fig.1

TYPICAL OPERATION CHARACTERISTICS

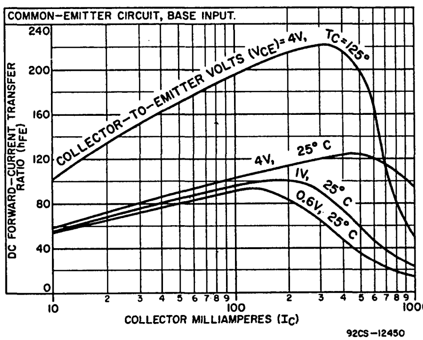
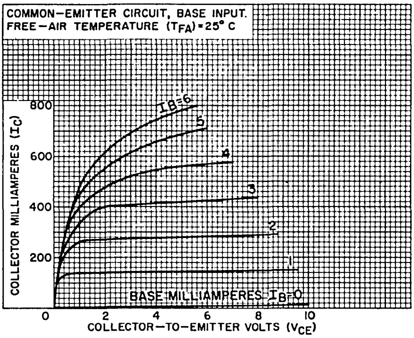


Fig. 2

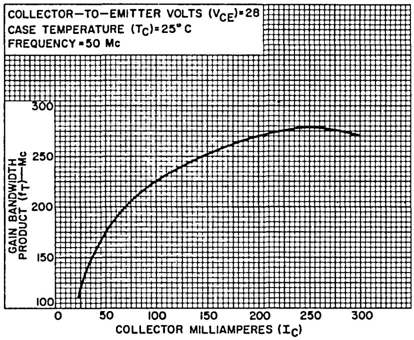
TYPICAL TRANSFER CHARACTERISTICS



92CS-12456

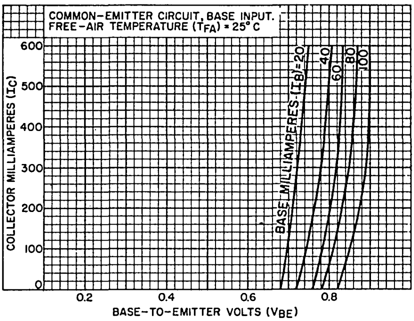
Fig. 3

TYPICAL OPERATION CHARACTERISTICS



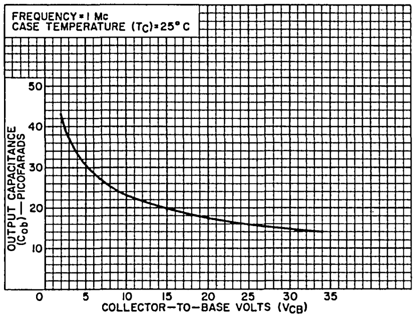
92CS-12457

Fig.4



92CS-12449

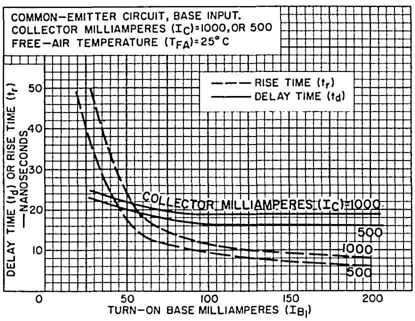
Fig.5



92CS-12453

Fig.6

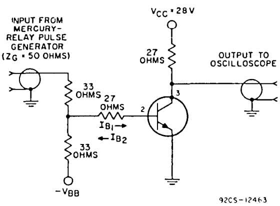
TYPICAL SATURATED-SWITCHING CHARACTERISTICS AND TEST CIRCUIT



92CS-12458

Fig.7

CIRCUIT USED TO MEASURE t_{on} AND t_{off} FOR OPERATION AS A SATURATED SWITCH

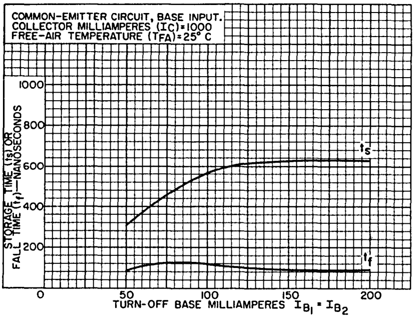


INPUT PULSE:

t_r < 3 nsec	REP. RATE = 120 CPS
t_f < 10 nsec	PULSE WIDTH = 300 μsec

Fig. 8

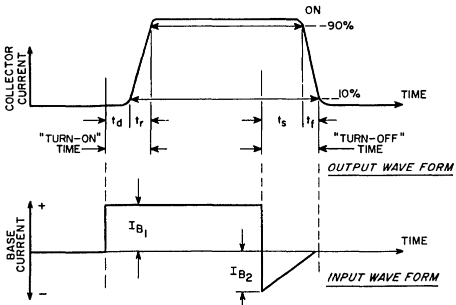
TYPICAL SATURATED-SWITCHING CHARACTERISTICS AND TEST CIRCUIT



92CS-12459

Fig.9

WAVE FORMS FOR SATURATED SWITCH CIRCUIT



92CS-12460

I_{B1} = 100 ma	t_{on} = 40 nsec
I_{B2} = -100 ma	t_{off} = 750 nsec
I_C = 1 amp	

Fig.10

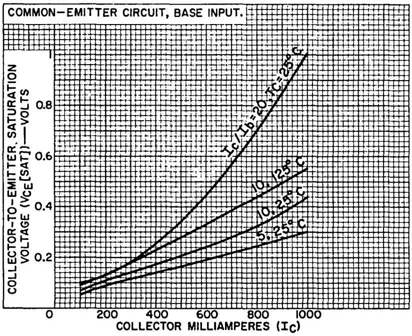


Fig.11

92CS-12461

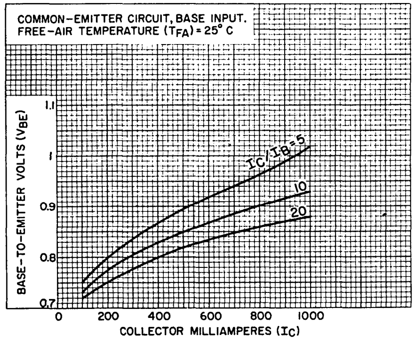
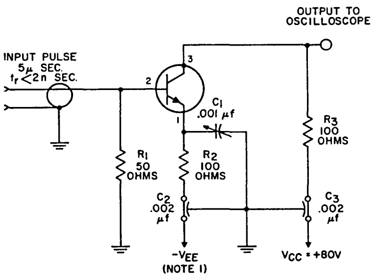


Fig.12

92CS-12451

PULSE-AMPLIFIER TEST CIRCUIT

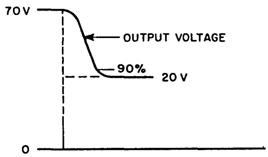


92CS-12464

NOTE 1: V_{EE} ADJUSTED FOR I_E = 35 ma WITH NO INPUT.

Fig.13

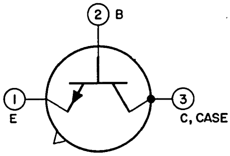
WAVE FORM FOR PULSE-AMPLIFIER TEST CIRCUIT



92CS-12462

Fig.14

TERMINAL DIAGRAM



LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

RCA
Solid State
Division

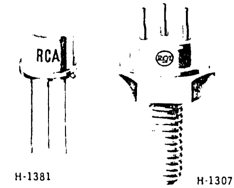
RF Power Transistors
2N3375 2N3553 2N3632 40665 40666

RCA 2N3632, 2N3553, 2N3375, 40665 and 40666 are epitaxial silicon n-p-n transistors of the "overlay" emitter electrode construction. They are intended for use in class A, B, and C amplifiers, frequency multipliers and oscillators. The 2N3375, 2N3553, and 40666 are especially intended for VHF-UHF applications while the 2N3632 and 40665 are designed for use in VHF circuits.

All the pins of the 2N3632 and 2N3375 are electrically isolated from the case. In the 40665 and 40666 (variants of types 2N3632 and 2N3375, respectively), the emitter is connected internally to the case.

SILICON N-P-N OVERLAY TRANSISTORS

For VHF-UHF Applications



2N3553	2N3632 2N3375 40666 40665
JEDEC TO-39	JEDEC TO-60

- **High Power Output, Class-C Amplifier:**

TYPE	400 MHz	260 MHz	175 MHz	100 MHz
2N3632 40665		10 W Typ.	13.5 W Min.	
2N3553		2.5 W Typ.	2.5 W Min.	
2N3375 40666	3 W Min.			7.5 W Min.

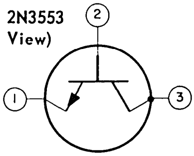
- **High Power Output, Oscillator:**
  2.5W (Typ.) at 500 MHz, (2N3375)
  1.5W (Typ.) at 500 MHz, (2N3553)
- **High Voltage Ratings**
- **Internally Grounded Emitter Types (40665 and 40666) available.**

Maximum Ratings, *Absolute-Maximum Values:*

		2N3553	2N3375 40666	2N3632 40665	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	65	65	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With base open	V_{CEO}	40	40	40	V
With V_{BE} = −1.5V	V_{CEV}	65	65	65	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	4	4	V
COLLECTOR CURRENT:					
Peak		1.0	1.5	3.0	A
Continuous	I_C	0.33	0.5	1.0	A
TRANSISTOR DISSIPATION	P_T				
At case temperatures up to 25° C		7.0	11.6	23	W
At case temperature above 25° C. Derate linearly to 0 watts at 200° C					
TEMPERATURE RANGE:					
Storage & Operating (Junction)			-65 to 200		°C
LEAD TEMPERATURE (During soldering): At distances ≥ 1/32 in. (.793 mm) from insulating wafer (TO-60 package) or from seating plane (TO-39 package) for 10 s max			230		°C

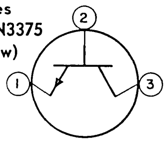
TERMINAL DIAGRAMS

For Type 2N3553 (Bottom View)



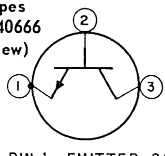
LEAD 1 - EMITTER
LEAD 2 - BASE
LEAD 3 - COLLECTOR, CASE

For Types 2N3632 & 2N3375 (Top View)



PIN 1 - EMITTER
PIN 2 - BASE
PIN 3 - COLLECTOR
STUD - NO CONNECTION

For Types 40665 & 40666 (Top View)



PIN 1 - EMITTER, CASE
PIN 2 - BASE
PIN 3 - COLLECTOR
STUD - EMITTER

ELECTRICAL CHARACTERISTICS: *At Case Temperature (T_C) = 25°C*

Characteristic	Symbol	TEST CONDITIONS						LIMITS						Units
		DC Collector Volts		DC Base Volts	DC Current (Milliamperes)			40665 2N3632		2N3553		40666 2N3375		
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	Min.	Max.	Min.	Max.	Min.	Max.	
Collector-Cutoff Current	I_{CEO}		30			0		-	0.25	-	0.1	-	0.1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0 0 0		0.1 0.3 0.5	- - 65	- - -	- 65 -	- - -	65 - -	- - -	V
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$					0	0 to 200[a]	40[b]	-	40[b]	-	40[b]	-	V
	$V_{(BR)CEV}$			−1.5			0 to 200[a]	65[b]		65[b]		65[b]	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.1 0.25		0 0	- 4	- -	4 -	- -	4 -	- -	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					100 50	500 250	- -	1 -	- -	- 1	- -	1 -	V
Collector-to-Base Capacitance Measured at 1 MHz	C_{obo}	30			0		-	-	20	-	10	-	10	pF
RF Power Output Amplifier, Unneutralized At 100 MHz (See Fig. 24) 175 MHz (See Fig. 22 & 27) 260 MHz (See Fig.21, 23, & 28) 400 MHz (See Fig. 25)	P_{OE}		28 28 28 28					- 13.5[e] 10[f] (typ.) -	- - -	- 2.5[g] - -	- - - -	7.5[c] - - 3[d]	- - - -	W
Gain-Bandwidth Product	f_T		28 28				100 150	- 400 (typ.)	- 	500 (typ.) -		- 500 (typ.)	- 	MHz
Base-Spreading Resistance Measured at 100 MHz 200 MHz 400 MHz	$r_{bb'}$		28 28 28				100 250 250	- 6.5 (typ.) -	- -	12.0 (typ.) - -	 - -	- - 10.0 (typ.)	- - 	ohms

[a]Pulsed through an inductor (25 mH); duty factor = 50%.

[b]Measured at a current where the breakdown voltage is a minimum.

[c]For P_{IE} = 1.0 W; minimum efficiency = 65%.

[d]For P_{IE} = 1.0 W; minimum efficiency = 40%.

[e] For P_{IE} = 3.5 W; minimum efficiency = 70%.

[f] For P_{IE} = 3.0 W; typical efficiency = 60%.

[g]For P_{IE} = 1/4 W; minimum efficiency = 50%.

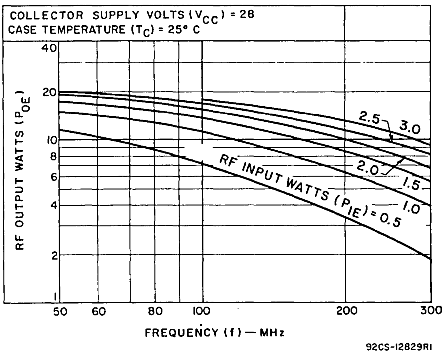


Fig.1 - Power output vs frequency for 2N3632 & 40665

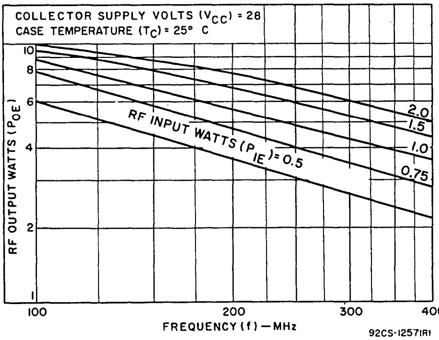


Fig.2 - Power output vs frequency for 2N3375 & 40666

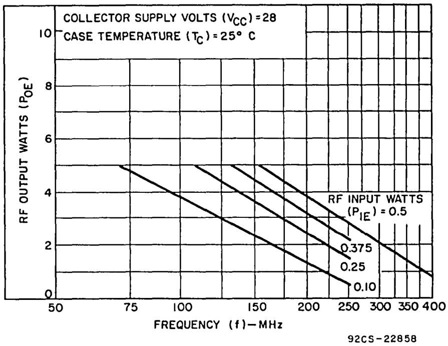


Fig.3 - Power output vs frequency for type 2N3553

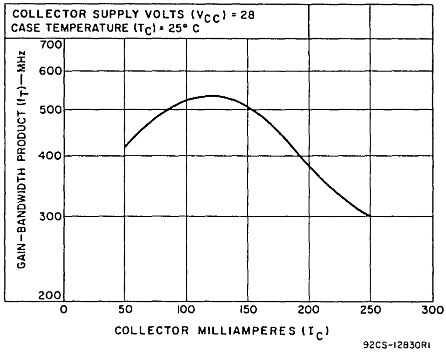


Fig.4 - Gain-bandwidth product vs collector current for types 2N3632 & 40665

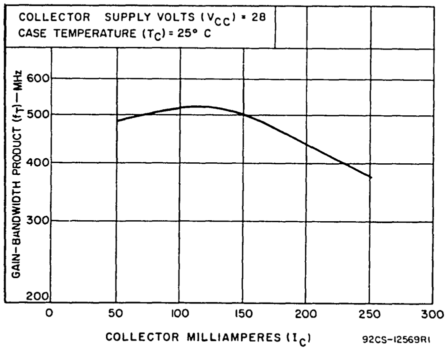


Fig.5 - Gain-bandwidth product vs collector current for types 2N3375 & 40666

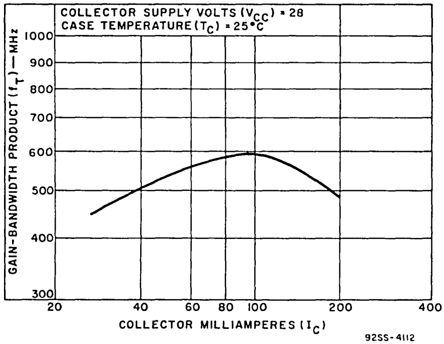


Fig.6 - Gain-bandwidth product vs collector current for 2N3553

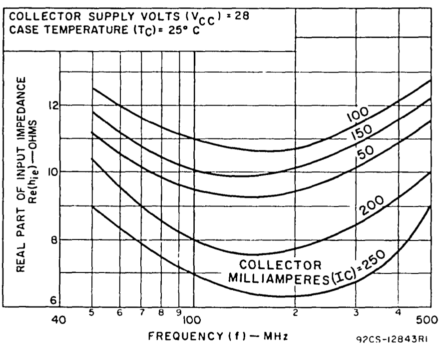


Fig.7 - Series input resistance vs frequency for type 2N3632

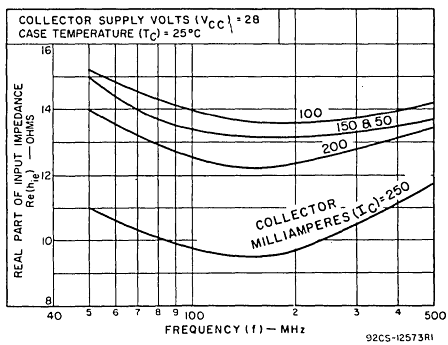


Fig.8 - Series input resistance vs frequency for type 2N3375

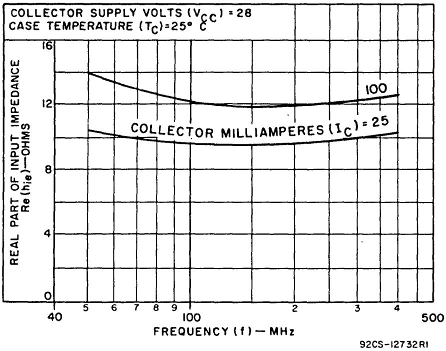


Fig.9 - Series input resistance vs frequency for 2N3553

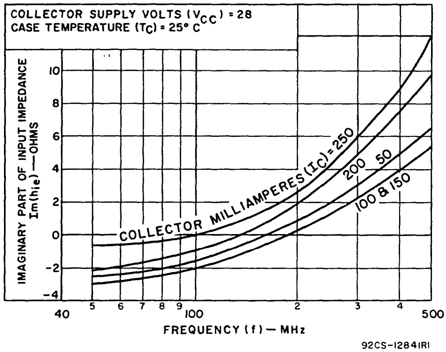


Fig.10 - Series input reactance vs frequency for 2N3632

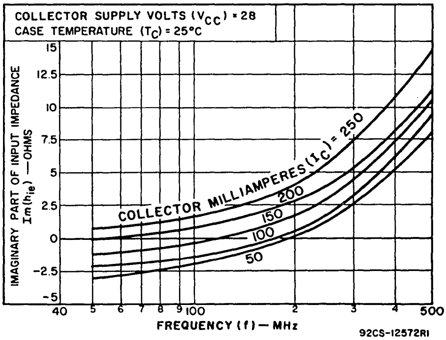


Fig.11 - Series input reactance vs frequency for 2N3375

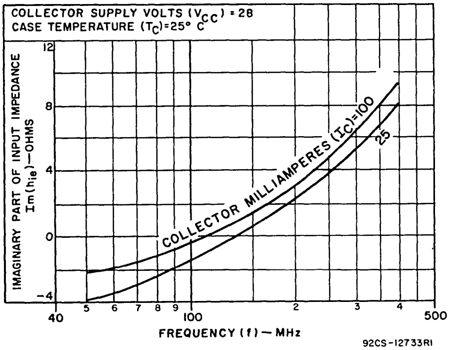


Fig.12 - Series input reactance vs frequency for 2N3553

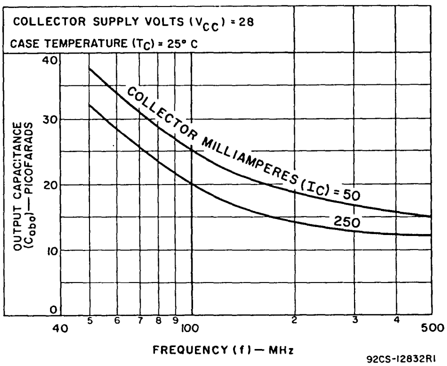


Fig.13 - Parallel output capacitance vs frequency for 2N3632

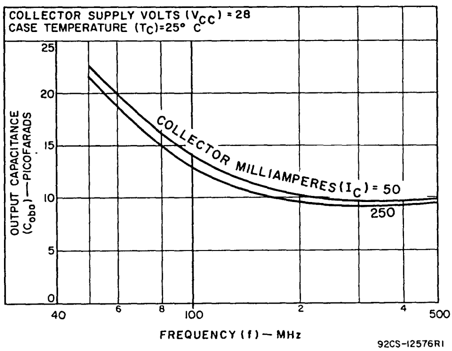


Fig.14 - Parallel output capacitance vs frequency for 2N3375

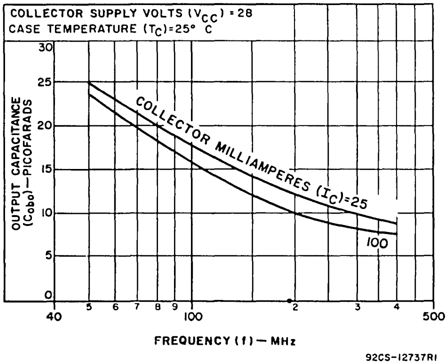


Fig.15 - Parallel output capacitance vs frequency for 2N3553

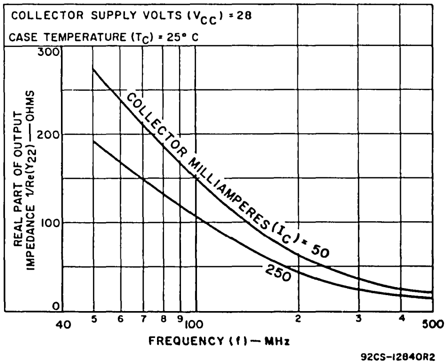


Fig.16 - Parallel output resistance vs frequency for 2N3632

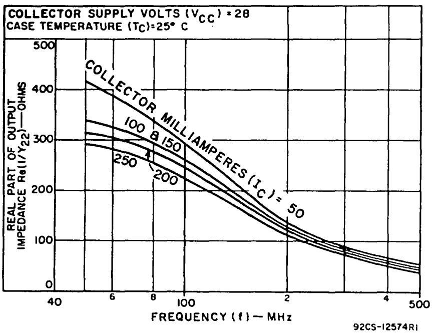


Fig.17 - Parallel output resistance vs frequency for 2N3375

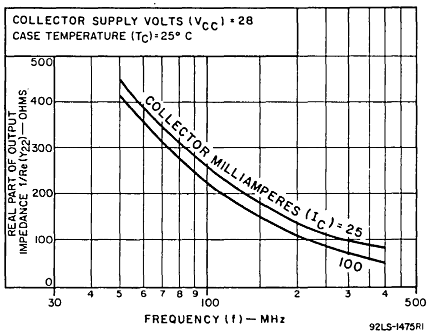


Fig.18 - Parallel output resistance vs frequency for 2N3553

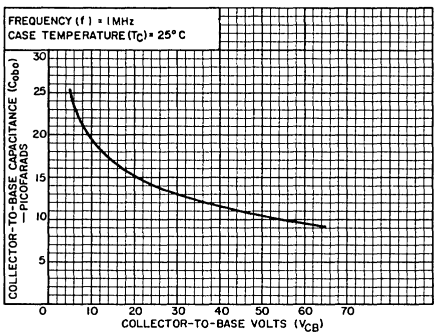


Fig.19 - Collector-to-base capacitance vs collector-to-base voltage for types 2N3632 & 40665

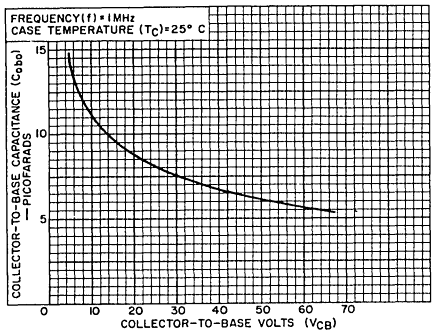
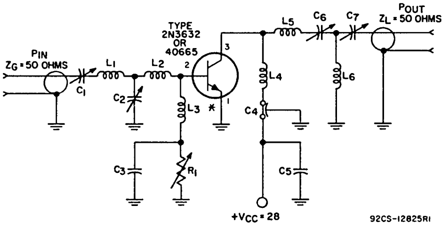
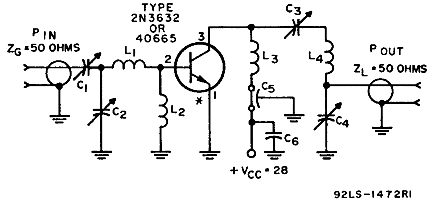


Fig.20 - Collector-to-base capacitance vs collector-to-base voltage for 2N3553



* Emitter in type 40665 is connected internally to case.



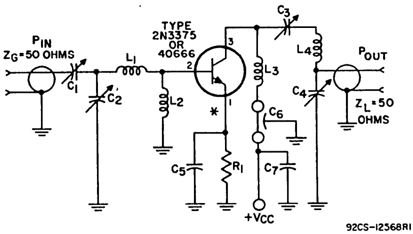
* Emitter in type 40665 is connected internally to case.

C_1: 3-35 pF
C_2, C_7: 8-60 pF
C_3, C_5: 0.005 μF, disc ceramic
C_4: 1000 pF
C_6: 1.5-20 pF
L_1: 3 turns No. 18 wire, 1/4 in. ID, 1/4 in. long
L_2: 3/16 in. wide copper strip, 3/8 in. long
L_3: Ferrite choke, Z = 450 ohms
L_4: RF choke, 0.47 μH
L_5: 3-1/2 turns No. 16 wire, 1/4 in. ID, 7/16 in. long
L_6: 1 turn No. 16 wire, 1/4 in. ID, 3/8 in. long
R_1: 50 ohms

Fig.21 - 260 MHz amplifier test circuit for measurement of power output for 2N3632 & 40665

C_1, C_2, C_3, C_4: 7-100 pF
C_5: 1000 pF
C_6: 0.01 μF, disc ceramic
L_1: 1.5 turns No. 16 wire, 3/16 in. ID, 5/16 in. long
L_2: Ferrite choke, Z = 450 ohms
L_3: 1 turn No. 16 wire, 1/4 in. ID, 3/8 in. long
L_4: 2 turns No. 16 wire, 1/4 in. ID, 1/4 in. long

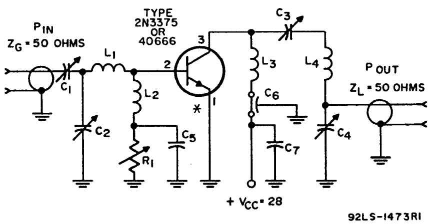
Fig.22 - 175 MHz amplifier test circuit for measurement of power output for 2N3632 & 40665



* Emitter in type 40666 is connected internally to case.

C_5 and R_1: are not used for 40666 test
C_1: 2.25 pF
C_2, C_3, C_4: 4-40 pF
C_5: 50 pF, disc ceramic
C_6: 1500 pF
C_7: 0.005 μF, disc ceramic
L_1: 1 turn No. 16 wire, 1/4 in. ID, 1/8 in. long
L_2: Ferrite choke, Z = 450 (+20%) ohms
L_3: 0.47-μH choke
L_4: 2 turns No. 16 wire, 3/8 in. ID, 7/16 in. long
R_1: 1.35 ohms, non-inductive

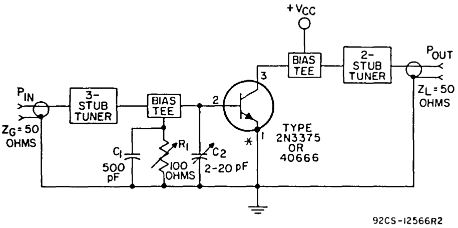
Fig.23 - 260 MHz amplifier test circuit for measurement of power output for 2N3375 & 40666



* Emitter in type 40666 is connected internally to case.

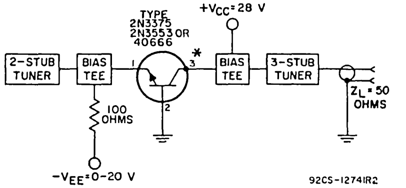
C_1, C_2, C_3, C_4: 7-100 pF
C_5: 0.005 μF, disc ceramic
C_6: 1000 pF
C_7: 0.01 μF, disc ceramic
L_1: 2 turns No. 16 wire, 3/8 in. ID, 3/4 in. long
L_2, L_3: 1.5 μH choke
L_4: 7 turns No. 16 wire, 3/8 in. ID, 1 in. long
R_1: 1000 ohms

Fig.24 - 100 MHz amplifier test circuit for measurement of power output for 2N3375 & 40666



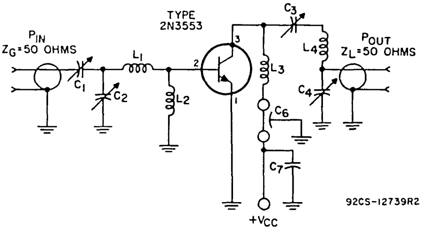
∗ Emitter in type 40666 is connected internally to case.

Fig.25 - 400 MHz amplifier test circuit for measurement of power output for 2N3375 & 40666



∗ Collector in type 2N3553 is internally connected to the case.

Fig.26 - 500 MHz oscillator circuit for measurement of power output for 2N3553 & 2N3375



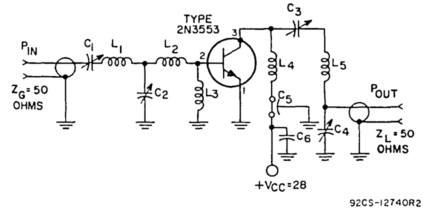
For 50-MHz Operation:

- C_1, C_2: 24-200 pF
- C_3: 32-250 pF
- C_4: 7-100 pF
- C_5: 1800 pF, disc ceramic
- C_6: 2000 pF
- C_7: 0.01 μF, disc ceramic
- L_1: 5 turns No. 16 wire, 1/4 in. ID, 1/2 in. long
- L_2: Ferrite choke, Z = 450 ohms
- L_3: 7-μH choke
- L_4: 6 turns No. 20 wire on 3/8 in. coil form (slug-tuned), 1-1/8 in. long
- R_1: 1.35 ohms, non-inductive

For 175 MHz Operation:

- C_1: 2-25 pF
- C_2: 4-40 pF
- C_3: 1.5-20 pF
- C_4: 1.5-20 pF
- C_5: 100 pF, disc ceramic
- C_6: 2000 pF
- C_7: 0.01 μF, disc ceramic
- L_1: 1-1/2 turns No. 16 wire, 5/16 in. ID, 1/2 in. long
- L_2: Ferrite choke, Z = 750 ohms
- L_3: 4 turns No. 16 wire, 5/16 in. ID, 1 in. long
- L_4: 7 turns No. 16 wire, 5/16 in. ID, 1-1/8 in. long
- R_1: 1.35 ohms, non-inductive

Fig.27 - Amplifier circuit for measurement of power output for 2N3553 at 50 and 175 MHz



- C_1, C_4: 1.5-20 pF
- C_2, C_3: 3-35 pF
- C_5: 1,000 pF
- C_6: 0.005 μF, disc ceramic
- L_1: 4 turns No. 16 wire, 3/8 in. ID, 3/8 in. long
- L_2: 3/16 in. wide copper strip, 7/16 in. long
- L_3: Ferrite choke, Z = 450 ohms
- L_4: 1/2 turn 3/16 in. wide copper strip, 1/4 in. ID
- L_5: 2 turns 3/16 in. wide copper strip, 1/4 in. ID, 1/2 in. long

Fig.28 - 260 MHz amplifier circuit for measurement of power output for 2N3553

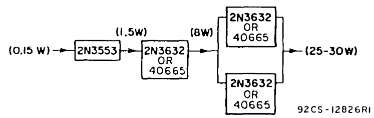


Fig.29 - Typical 175 MHz amplifier chain for P_{OE} of 25 to 30 watts

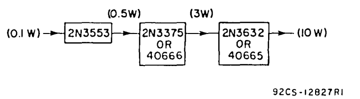


Fig.30 - Typical 260 MHz amplifier chain for P_{OE} of 10 watts

RCA
Solid State
Division

RF Power Transistors

2N3478

JEDEC TO-72 H-1299

SILICON N-P-N EPITAXIAL PLANAR TRANSISTOR

For VHF/UHF Applications
in Industrial and Commercial Equipment

Features:

- high gain-bandwidth product – f_T = 900MHz typ.
- low noise figure
  NF = 5dB typ. at 470MHz
  4.5dB max. at 200MHz
  2.5dB typ. at 60MHz
- high unneutralized power gain G_{pe} = 11.5dB min. at 200MHz
- hermetically sealed four-lead package
- all active elements insulated from case
- low collector-to-base feedback capacitance, C_{cb} 0.7 pF max.

RCA-2N3478 is an epitaxial planar transistor of the silicon n-p-n type with characteristics which make it extremely useful as a general purpose rf amplifier at frequencies up to 470MHz. These characteristics include an exceptionally low noise figure at high frequencies, low leakage current, and a high gain-bandwidth product.

The 2N3478 utilizes a hermetically sealed four-lead package in which active elements of the transistor are insulated from the case. The case may be grounded by means of a fourth lead in applications requiring minimum feedback capacitance, shielding of the device, or both.

Maximum Ratings, *Absolute-Maximum Values:*

Collector-to-Base Voltage, V_{CBO}	30 max.	V
Collector-to-Emitter Voltage, V_{CEO}	15 max.	V
Emitter-to-Base Voltage, V_{EBO}	2 max.	V
Collector Current, I_C	limited by dissipation	
Transistor Dissipation, PT:		
at ambient temperatures up to 25° C	200 max.	mW
at ambient temperatures above 25° C	See *Fig. 1*	
Temperature Range:		
Storage and Operating (Junction)	-65 to 200	°C
Lead Temperature (During Soldering):		
At distances not closer than 1/32" to seating surface for 10 seconds max.	265 max.	°C

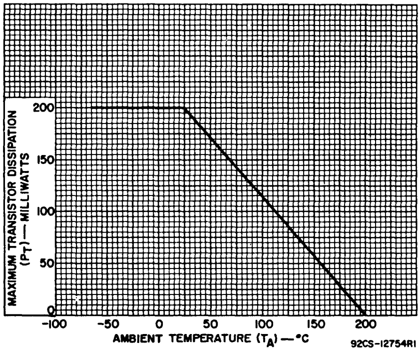


Fig. 1 - Rating chart for type 2N3478

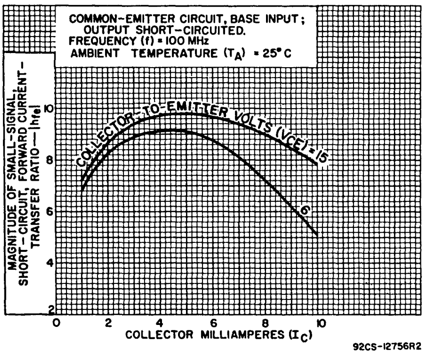


Fig. 2 - Typical small-signal beta characteristics for type 2N3478

9-74

ELECTRICAL CHARACTERISTICS, *At an Ambient Temperature (T_A) of 25° C*

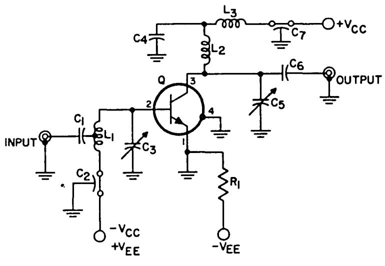
Characteristics	Symbols	TEST CONDITIONS: Frequency f (MHz)	DC Collector-to-Base Voltage V_{CB} (V)	DC Collector-to-Emitter Voltage V_{CE} (V)	DC Emitter Current I_E (mA)	DC Collector Current I_C (mA)	LIMITS Type 2N3478: Min.	Typ.	Max.	Units
Collector-Cutoff Current	I_{CBO}		1		0		–	–	0.02	μA
Collector-to-Base Breakdown Voltage	BV_{CBO}				0	0.001	30	–	–	V
Collector-to-Emitter Breakdown Voltage	BV_{CEO}					0.001	15	–	–	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}				-0.001	0	2	–	–	V
Static Forward-Current Transfer Ratio	h_{FE}			8		2	25	–	150	
Magnitude of Small-Signal Forward-Current Transfer Ratio	h_{fe}[a]	100		8		2	7.5	9	16	
Collector-to-Base Feedback Capacitance	C_{cb}[b]	1	10		0		–	–	1	pF
Small-Signal, Common-Emitter Power Gain in Unneutralized Amplifier Circuit (See *Fig. 3*)	G_{pe}[a]	200		8		2	11.5	–	17	dB
Small-Signal, Common-Emitter Power Gain in Neutralized Amplifier Circuit	G_{pe}[a, c]	470		6		1.5	–	12	–	dB
UHF Noise Figure	NF[a, c]	470		6		1.5	–	5	–	dB
VHF Noise Figure (See *Fig. 3*)	NF[a]	200		8		2	–		4.5	dB
	NF[a, d]	60		8		1	–	2.5	–	dB

[a] Fourth lead (case) grounded.

[b] C_{cb} is a three terminal measurement of the collector-to-base capacitance with the emitter and case connected to the guard terminal.

[c] Source Resistance, R_s = 50 ohms.

[d] Source Resistance, R_s = 400 ohms.



C_1, C_4 = 510 pF
C_2, C_7 = 2300 pF
C_3, C_5 = 2-25 pF
C_6 = 10 pF
R_1 = 2000 ohms
Q = 2N3478
L_1 = ½ Turn #14 Formvar● center tapped
Length$_1$, ℓ_1 = 2 inches
L_2 = ½ Turn #14 Formvar●
Length$_2$, ℓ_2 = 1 ½ inches
L_3 = 1 μH RF choke
Source (Generator) Resistance R_g = 50 ohms
Load Resistance R_L = 50 ohms
● Trademark, Shawindian Products Corporation.

Fig. 3 - 200 MHz power gain and noise figure test circuit for type 2N3478

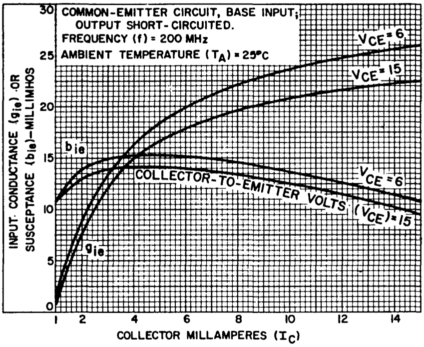


Fig. 4 - Input admittance (y_{ie})

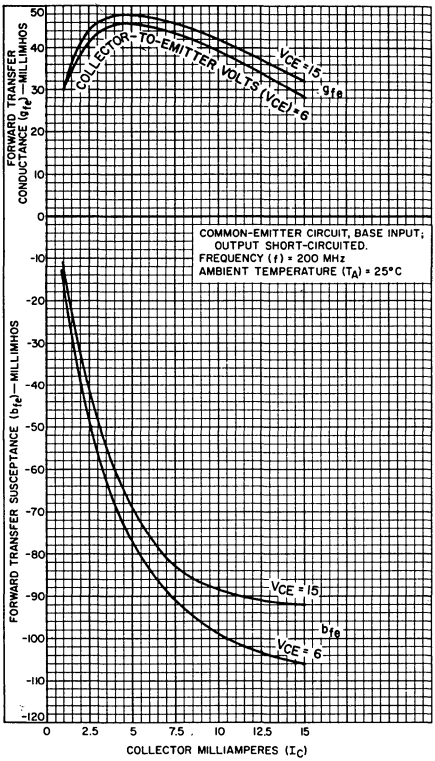


Fig. 6 - Forward transadmittance (y_{fe})

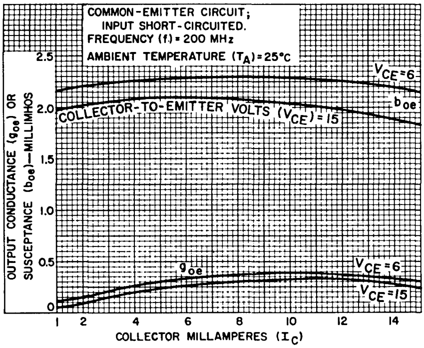


Fig. 5 - Output admittance (y_{oe})

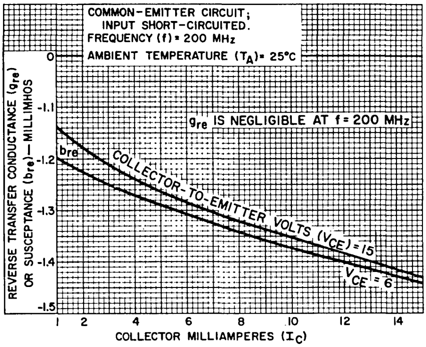


Fig. 7 - Reverse transadmittance (y_{re})

TERMINAL CONNECTIONS

Lead 1 — Emitter
Lead 2 — Base
Lead 3 — Collector
Lead 4 — Connected to Case

Solid State Division

RF Power Transistors

2N3733

JEDEC TO-60

10-W, 400-Mc Silicon N-P-N Overlay Transistor

For Large-Signal, High-Power VHF/UHF Applications

Features:

- High power output, unneutralized Class C amplifier:
  - at 400 Mc 10 W min.
  - at 260 Mc 14.5 W typ.
- High voltage ratings:
  - V_{CBO} = 65 V max.
  - V_{CEV} = 65 V max.
  - V_{CEO} = 40 V max.
- 100 per cent tested to assure freedom from second breakdown for operation in Class A applications
- Low thermal resistance

RCA-2N3733 is an epitaxial silicon n-p-n planar transistor intended for class A, B, and C amplifier, frequency-multiplier, or oscillator operation. The 2N3733 was developed for vhf/uhf applications.

The transistor employs the overlay concept in emitter-electrode design -- an emitter electrode consisting of many microscopic areas connected by a diffused-grid structure and an overlay of metal applied on the silicon wafer by means of a photo-etching technique. This arrangement provides the very high emitter-periphery-to-emitter-area ratio required for high efficiency at high frequencies.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction reverse-biased (V_{BE} = -1.5 V)	V_{CEV}	65	V
*With base open	V_{CEO}	40	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*COLLECTOR CURRENT:			
Continuous	I_C	1	A
Peak		3	A
*CONTINUOUS BASE CURRENT	I_B	1	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		23	W
At case temperatures above 25°C		Derate linearly to 0 watts at 200°C	
*TEMPERATURE RANGE:			
Storage and operating (junction)		-65 to 200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ⩾ 1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

*In accordance with JEDEC registration data

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc			CURRENT mA dc			LIMITS		UNITS
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector Cutoff Current: With base open	I_{CEO}		30			0		-	0.25	mA
With base-emitter junction reverse-biased	I_{CEV}		65	-1.5				-	5	mA
At T_C = 200°C			30	-1.5				-	10	mA
With emitter open	I_{CBO}	65						-	0.5	mA
* Emitter Cutoff Current	I_{EBO}			-4				-	0.25	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0		0.5	65	-	V
Collector-to-Emitter Breakdown Voltage: With base-emitter junction reverse-biased	$V_{(BR)CEV}$			-1.5			0 to 200•	65**	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.25		0	4	-	V
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$					0	200	40	-	V
With external base-to-emitter resistance (R_{BE}) = 100 Ω	$V_{CER}(sus)$						200	40	-	V
* DC Forward Current Transfer Ratio	h_{FE}		5 5				1 0.25	5 10	- 150	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					200	1000	-	1	V
* Base-Emitter Voltage	V_{BE}		5				1000	-	1.5	V
Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 100 Mc)	$\|h_{fe}\|$		28 28				250 250	2.5* 4.0 (typ.)	-	
* Collector-to-Base Capacitance (f = 0.1 to 1 Mc)	C_{ob}	28					250	-	25	pF
* Available Amplifier Signal Input Power P_o = 10 W, Z_G = 50 Ω, f = 400 Mc	P_i							-	4	W
* Collector Circuit Efficiency P_o = 10 W, Z_G = 50 Ω, f = 400 Mc	η_C							45	-	%
Base-Spreading Resistance Measured at 200 Mc	r_{bb}		28				250	6.5 (typ.)		Ω
Collector-to-Case Capacitance	C_s							-	6	pF
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$							-	7.5	°C/W

•Pulsed through an inductor (25 mH); duty factor = 50%

**Measured at a current where the breakdown voltage is a minimum

*In accordance with JEDEC registration data

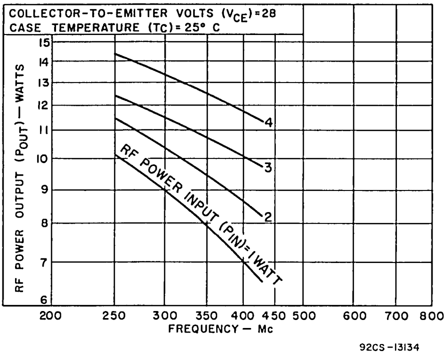


Fig. 1—Power output vs. frequency.

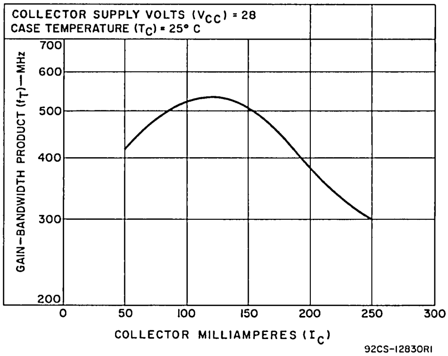


Fig. 2—Gain-bandwidth product vs. collector current.

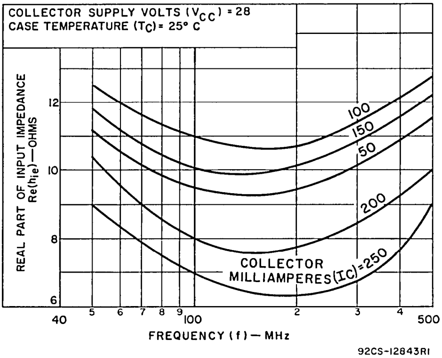


Fig. 3—Series input resistance vs. frequency.

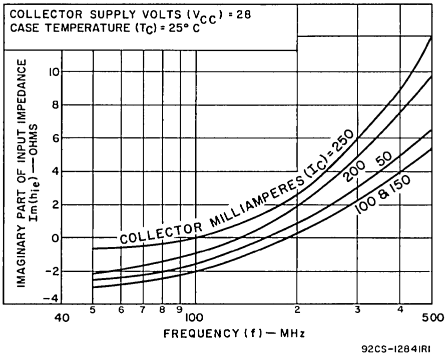


Fig. 4—Series input reactance vs. frequency.

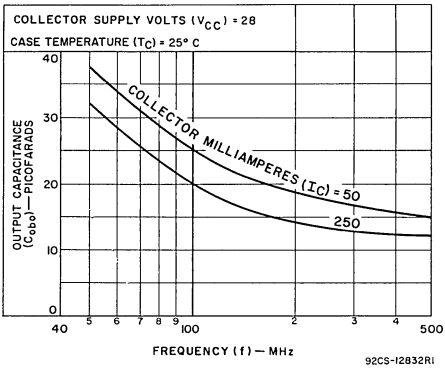


Fig. 5—Output capacitance vs. frequency.

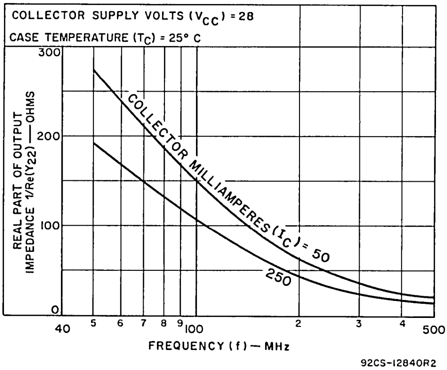


Fig. 6—Output resistance vs. frequency.

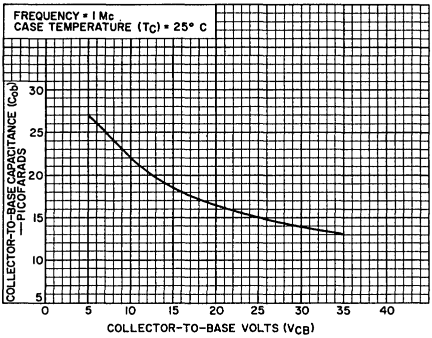


Fig. 7—Variation of collector-to-base capacitance.

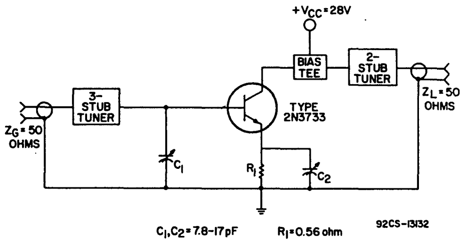
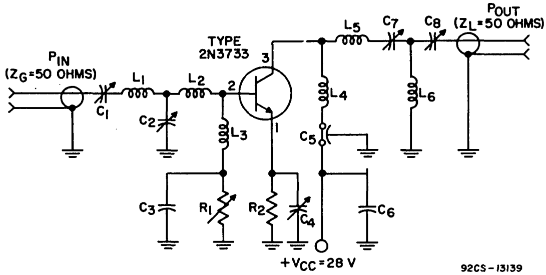


Fig. 8—RF amplifier circuit for power output test at 400 Mc.



C_1: 3-35 pF
C_2,C_4,C_8: 8-60 pF
C_3,C_6: 0.005 μF, disc ceramic
C_5: 1,000 pF
C_6: 1.5 - 20 pF
L_1: 3 turns No. 18 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
L_2: 3/16 in. (4.76 mm) wide copper strip, 3/8 in. (9.52 mm) long
L_3: Ferrite choke, Z = 450 ohms
L_4: RF choke, 0.47 μH
L_5: 3-1/2 turns No. 16 wire, 1/4 in. (6.35 mm) ID, 7/16 in. (11.11 mm) long
L_6: 1 turn No. 16 wire, 1/4 in. (6.35 mm) ID, 3/8 in. (9.52 mm) long
R_1: 50 ohms
R_2: 0.56 ohm

Fig. 9—RF amplifier circuit for power output test at 260 Mc.

TERMINAL CONNECTIONS

Pin No. 1 – Emitter
Pin No. 2 – Base
Pin No. 3 – Collector

RCA

Solid State
Division

RF Power Transistors

2N3839

RCA-2N3839* is a double-diffused epitaxial planar transistor of the silicon n-p-n type. It is extremely useful in low-noise-amplifier, oscillator, and converter applications at frequencies up to 500 MHz in the common-emitter configuration, and up to 1200 MHz, in the common-base configuration.

The 2N3839 is mechanically and electrically like the 2N2857, but has a substantially lower noise figure.

The 2N3839 utilizes a hermetically sealed four-lead JEDEC TO-72 package. All active elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead in applications requiring shielding of the device.

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	30 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	15 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	2.5 max.	V
COLLECTOR CURRENT, I_C	40 max.	mA
TRANSISTOR DISSIPATION, P_T:		
For operation with heat sink:		
At case temperatures** up to 25°C	300 max.	mW
At case temperatures** above 25°C	Derate at 1.72	mW/°C
For operation at ambient temperatures:		
At ambient temperatures up to 25°C	200 max.	mW
At ambient temperatures above 25°C	Derate at 1.14	mW/°C
TEMPERATURE RANGE:		
Storage and Operating (Junction)	-65 to +200	°C
LEAD TEMPERATURE (During Soldering):		
At distances ≥ 1/32 inch from seating surface for 10 seconds max.	265 max.	°C

* Formerly Dev. No. TA-2363

** Measured at center of seating surface.

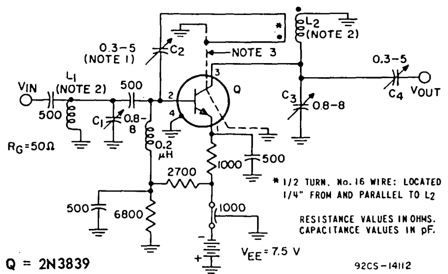
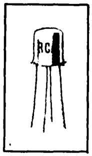


Fig.1 - Neutralized amplifier circuit used to measure 450-MHz power gain and noise figure for type 2N3839.

SILICON N-P-N EPITAXIAL PLANAR TRANSISTOR



JEDEC TO-72

For Low-Noise UHF Applications in Industrial and Military Equipment

FEATURES

- very low device noise figure — NF = 3.4 dB max. as 450-MHz amplifier
- high gain-bandwidth product — f_T = 1000 MHz min.
- high converter (450-to-30 MHz) gain — G_c = 15 dB typ. for circuit bandwidth of approximately 2 MHz
- high power gain as neutralized amplifier — G_{pe} = 12.5 dB min. at 450 MHz for circuit bandwidth of 20 MHz
- high power output as UHF oscillator — P_o = 30 mW min., 40 mW typ. at 500 MHz = 20 mW typ. at 1 GHz
- low collector-to-base time constant — $r_b' C_c$ = 7 ps typ.
- low collector-to-base feedback capacitance — C_{cb} = 0.6 pF typ.

NOTE 1: (NEUTRALIZATION PROCEDURE): (A) CONNECT A 450-MHz SIGNAL GENERATOR (WITH R_g = 50 OHMS) TO THE INPUT TERMINALS OF THE AMPLIFIER. (B) CONNECT A 50-OHM RF VOLTMETER ACROSS THE OUTPUT TERMINALS OF THE AMPLIFIER. (C) APPLY V_{EE}, AND WITH THE SIGNAL GENERATOR ADJUSTED FOR 5 mV OUTPUT FROM THE AMPLIFIER, TUNE C_1, C_3, AND C_4 FOR MAXIMUM OUTPUT. (D) INTERCHANGE THE CONNECTIONS TO THE SIGNAL GENERATOR AND THE RF VOLTMETER. (E) WITH SUFFICIENT SIGNAL APPLIED TO THE OUTPUT TERMINALS OF THE AMPLIFIER, ADJUST C_2 FOR A MINIMUM INDICATION AT THE INPUT. (F) REPEAT STEPS (A), (B), AND (C) TO DETERMINE IF RETUNING IS NECESSARY.

NOTE 2: L_1 & L_2—SILVER-PLATED BRASS ROD, 1-1/2" LONG x 1/4" DIA. INSTALL AT LEAST 1/2" FROM NEAREST VERTICAL CHASSIS SURFACE.

NOTE 3: EXTERNAL INTERLEAD SHIELD TO ISOLATE THE COLLECTOR LEAD FROM THE EMITTER AND BASE LEADS.

ELECTRICAL CHARACTERISTICS, *At an Ambient Temperature, T_A, of 25°C, Unless Otherwise Specified*

CHARACTERISTICS	SYMBOL	TEST CONDITIONS: FREQUENCY f (MHz)	DC COLLECTOR-TO-BASE VOLTAGE V_{CB} (V)	DC COLLECTOR-TO-EMITTER VOLTAGE V_{CE} (V)	DC EMITTER-TO-BASE VOLTAGE V_{EB} (V)	DC EMITTER CURRENT I_E (mA)	DC BASE CURRENT I_B (mA)	DC COLLECTOR CURRENT I_C (mA)	LIMITS TYPE 2N3839 Min.	Typ.	Max.	UNITS
Collector-Cutoff Current T_A = 25°C	I_{CBO}		15			0			-	-	10	nA
T_A = 150°C			15			0			-	-	1.0	μA
Collector-to-Base Breakdown Voltage	BV_{CBO}					0		0.001	30	-	-	V
Collector-to-Emitter Breakdown Voltage	BV_{CEO}						0	3	15	-	-	V
Emitter-to-Base Breakdown Voltage	BV_{EBO}					0.01		0	2.5	-	-	V
Static Forward Current-Transfer Ratio	h_{FE}			1				3	30	-	150	
Small-Signal Forward Current-Transfer Ratio	h_{fe}	0.001[c]		6				2	50	-	220	
		100[c]		6				5	10	-	20	
Collector-to-Base Feedback Capacitance	C_{cb}	0.1 to 1.0[b]	10			0			-	0.6	1.0	pF
Input Capacitance	C_{ib}	0.1 to 1.0			0.5			0	-	1.4	-	pF
Collector-to-Base Time Constant	$r_{b'}C_c$	31.9[c]	6			-2			1	7	15	ps
Small-Signal, Common-Emitter Power Gain in Neutralized Amplifier Circuit (See *Fig.1*)	G_{pe}	450[c]		6				1.5	12.5	-	19	dB
Power Output as Oscillator (See *Fig 2*)	P_o	≥500[a]	10			-12			30	-	-	mW
UHF Measured Noise Figure (See *Fig.1*)	NF	450[c,d]		6				1.5	-	-	3.9	dB
UHF Device Noise Figure	NF	450[c,d,f]		6				1.5	-	-	3.4	dB
VHF Measured Noise Figure	NF	60[c,e]		6				1	-	2	-	dB

[a] Lead No.4 (case) not connected.

[b] 3-terminal measurement with emitter and case connected to guard terminal.

[c] Lead No.4 (case) grounded.

[d] Generator resistance, R_g = 50 ohms.

[e] Generator resistance, R_g = 400 ohms.

[f] Device noise figure is approximately 0.5 dB lower than the measured noise figure. The difference is due to the insertion loss at the input of the test circuit (0.25 dB) and the contribution of the following stages in the test setup (0.25 dB).

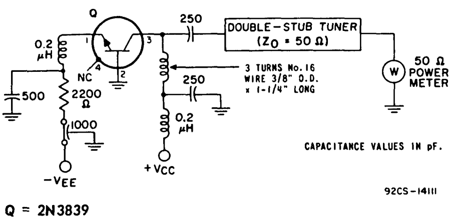
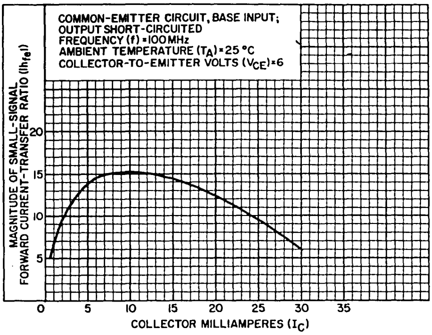
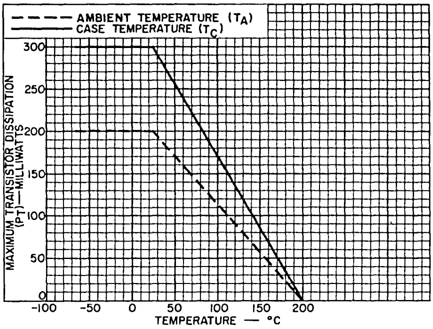


Fig.2 - Oscillator circuit used to measure 500-MHz power output for type 2N3839.



92CS-14169

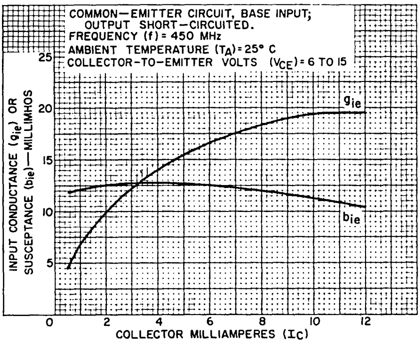
Fig.3 - Small-Signal Beta Characteristic for Type 2N3839.



92CS-12483R1

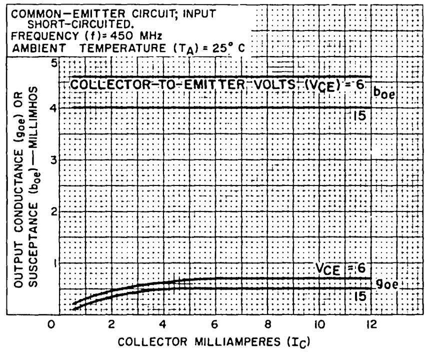
Fig.4 - Rating Chart for Type 2N3839.

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF COLLECTOR CURRENT (I_C)



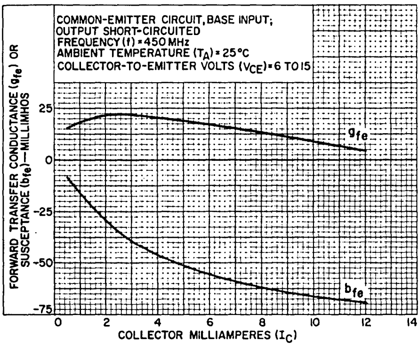
92CS-12150R1

Fig.5 - Input Admittance (y_{ie}).



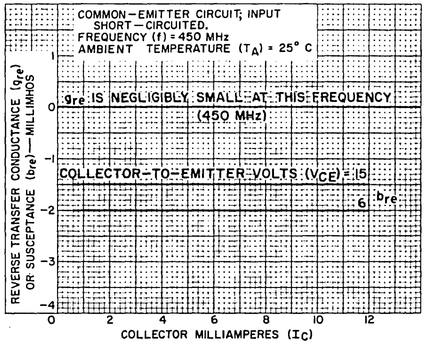
92CS-12148R1

Fig.6 - Output Admittance (y_{oe}).



92CS-12149R1

Fig.7 - Forward Transadmittance (y_{fe}).



92CS-12154R2

Fig.8 - Reverse Transadmittance (y_{re}).

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF FREQUENCY (f)

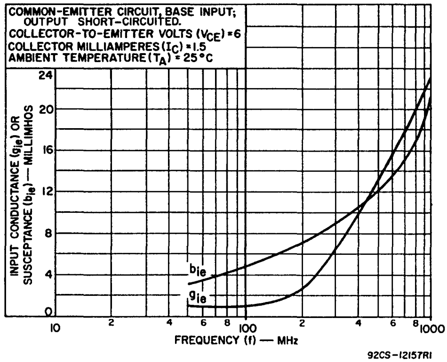


Fig.9 - Input Admittance (y_{ie}).

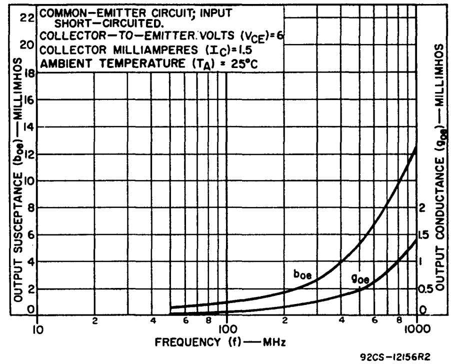


Fig.10 - Output Admittance

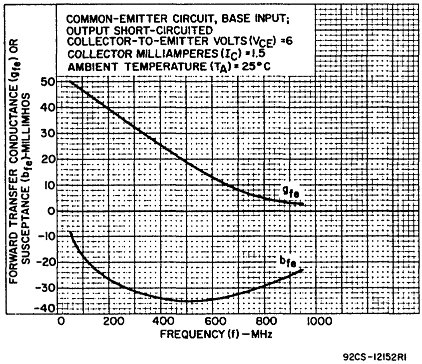


Fig.11 - Forward Transadmittance (y_{fe}).

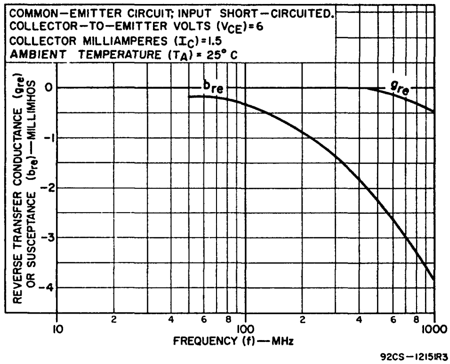


Fig.12 - Reverse Transadmittance (y_{re}).

TERMINAL CONNECTIONS

LEAD 1 - EMITTER
LEAD 2 - BASE
LEAD 3 - COLLECTOR
LEAD 4 - CONNECTED TO CASE

RCA
Solid State
Division

RF Power Transistors

2N3866

Silicon N-P-N Overlay Transistor

High-Gain Driver for VHF/UHF Applications
in Military and Industrial Communications Equipment

JEDEC TO-39 H-1381

Features

- **High Power Gain, Unneutralized Class C Amplifier**
  1 W output at 400 MHz (10 dB gain)
  1 W output at 250 MHz (15 dB gain)
  1 W output at 175 MHz (17 dB gain)
  1 W output at 100 MHz (20 dB gain)
- **Low Output Capacitance**
  C_{obo} = 3 pF max.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 10Ω	V_{CER}	55	V
* With base open	V_{CEO}	30	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	0.4	A
* CONTINUOUS BASE CURRENT	I_B	0.4	A
* TRANSISTOR DISSIPATION	P_T		
At case temperature up to 25°C		5	W
At case temperatures above 25°C		See Fig. 4	
* TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
* LEAD TEMPERATURE			
At distances ≥ 1/16 in. (1.58 mm) from seating plane for 10 s max.		230	°C

* In accordance with JEDEC registration data format JS-6 RDF-3.

RCA-2N3866 is an epitaxial silicon n-p-n planar transistor employing an advanced version of the RCA-developed "overlay" emitter-electrode design. This electrode consists of many isolated emitter sites connected together through the use of a diffused-grid structure and a metal overlay which is deposited on a silicon oxide insulating layer by means of a photo-etching technique. This overlay design provides a very high emitter periphery-to-emitter area ratio resulting in low output capacitance, high rf current handling capability, and substantially higher power gain.

The 2N3866 is intended for class-A, -B, or -C amplifier, frequency-multiplier, or oscillator circuits: it may be used in output, driver, or pre-driver stages in vhf and uhf equipment.

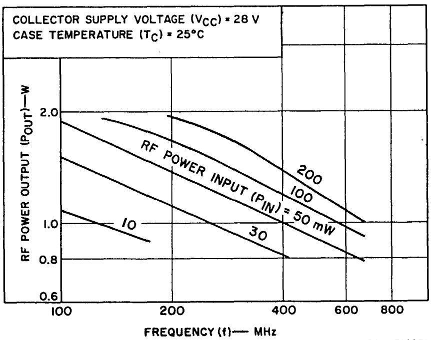
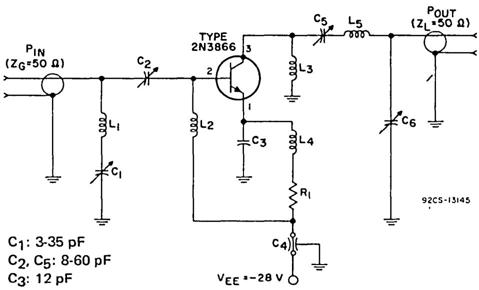


Fig. 1 - Power output vs. frequency



C_1: 3-35 pF
C_2, C_5: 8-60 pF
C_3: 12 pF
C_4: 1,000 pF, feedthrough
C_6: 0.9-7 pF
L_1: 2 turns No. 18 wire, 1/4" ID, 1/8" long
L_2: Ferrite rf choke, 1 turn, Z = 450Ω
L_3, L_4: RF choke, 0.1 μH
L_5: 2-1/2 turns, No. 18 wire, 1/4" ID, 3/16" long
R_1: 5.6Ω, 1 W

Fig. 2 - RF amplifier circuit for power output test (400-MHz operation)

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage (V) V_{CE}	DC Voltage (V) V_{EB}	DC Current (mA) I_E	DC Current (mA) I_B	DC Current (mA) I_C	LIMITS Min.	LIMITS Max.	UNITS
* Collector-Cutoff Current: Base-emitter junction reverse biased	I_{CEX}	55	1.5				–	0.1	mA
T_C = 200°C		30	1.5				–	5	mA
Base open	I_{CEO}	28			0		–	20	µA
* Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	55	–	V
* Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	5	30	–	V
With base connected to emitter through 10-ohm resistor	$V_{(BR)CER}$		0			5	55	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
* Emitter-Cutoff Current	I_{EBO}		3.5				–	0.1	mA
* Collector-to-Emitter Saturation Voltage	$V_{CE(sat)}$				20	100	–	1.0	V
* DC Forward-Current Transfer Ratio	h_{FE}	5 5				360 50	5 10	– 200	
Thermal Resistance: (Junction-to-Case)	$\theta_{J\text{-}C}$						–	35	°C/W

DYNAMIC

TEST & CONDITIONS	SYMBOL	FREQUENCY MHz	LIMITS MINIMUM	LIMITS MAXIMUM	UNITS
Power Output (V_{CC} = 28 V): P_{IE} = 0.1 W	P_{OE}	400	1.0	–	W
Large-Signal Common-Emitter Power Gain (V_{CC} = 28 V): P_{IE} = 0.1 W	G_{PE}	400	10	–	dB
* Collector Efficiency (V_{CC} = 28 V): P_{IE} = 0.1 W, P_{OE} = 1 W, Source Impedance = 50Ω	η_C	400	45	–	%
* Magnitude of Common-Emitter, Small Signal, Short-Circuit Forward-Current Transfer Ratio I_C = 50 mA, V_{CE} = 15 V	$\lvert h_{fe} \rvert$	200	2.5	–	
* Available Amplifier Signal Input Power, P_{OE} = 1 W, Source Impedance = 50Ω (See Fig. 2)	P_i	400	–	0.1	W
* Common-Base Output Capacitance (V_{CB} = 28 V)	C_{obo}	1	–	3	pF

* In accordance with JEDEC registration data format JS-6 RDF-3

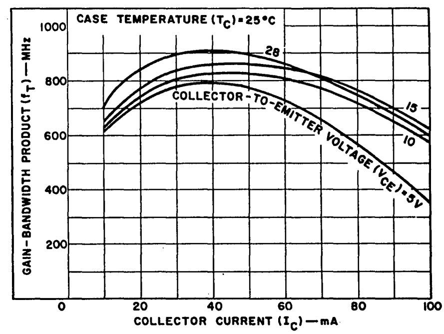


Fig. 3 - Gain-bandwidth product vs. collector current

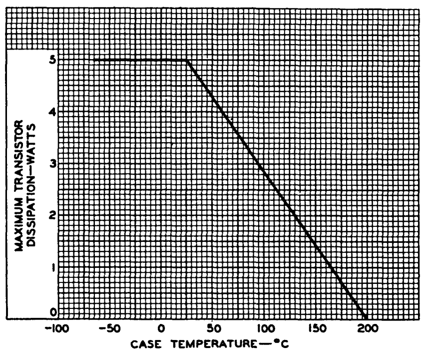


Fig. 4 - Dissipation derating curve

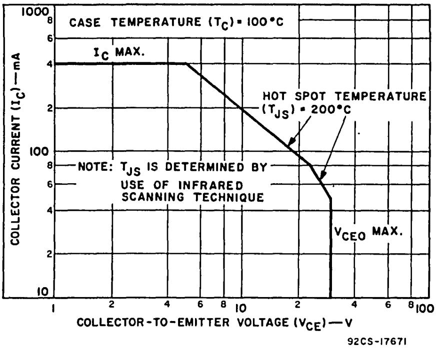


Fig. 5 - Safe area for dc operation

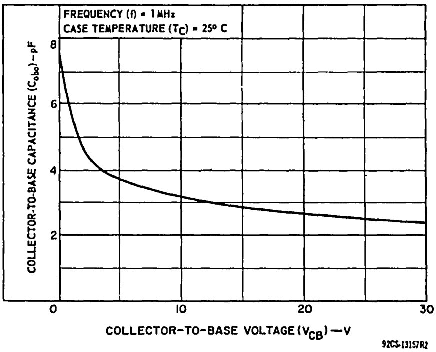


Fig. 6 - Variation of collector-to-base capacitance

DESIGN DATA

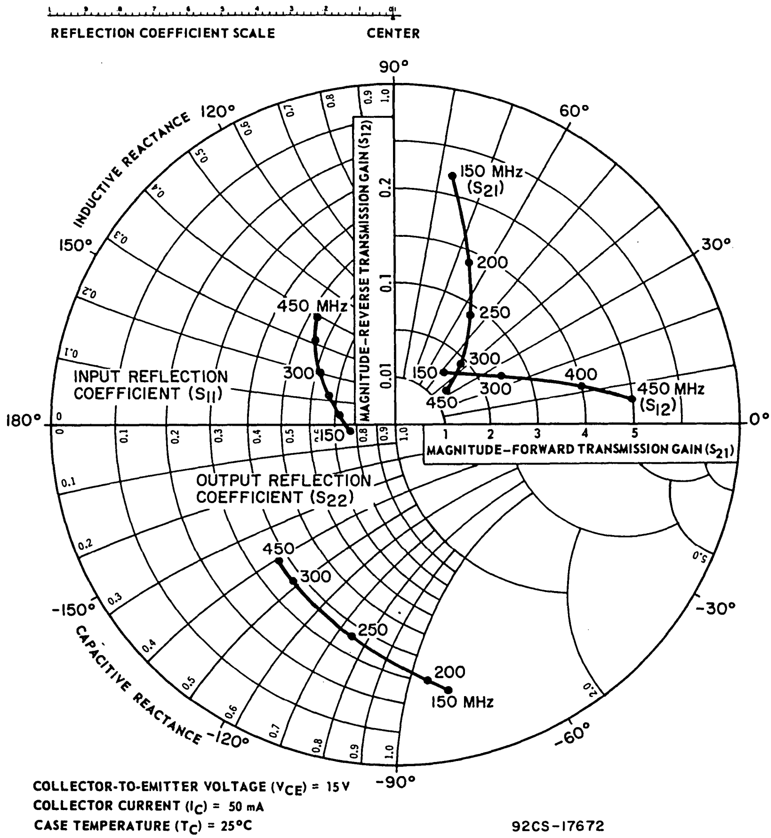


Fig. 7 - Typical S parameters vs. frequency

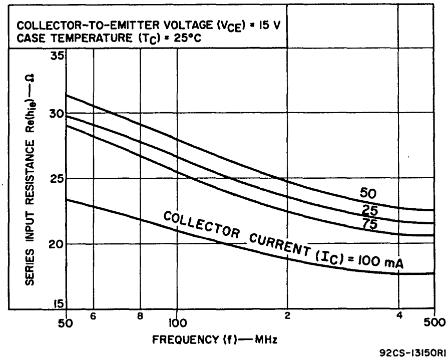


Fig. 8 - Typical series input resistance vs. frequency

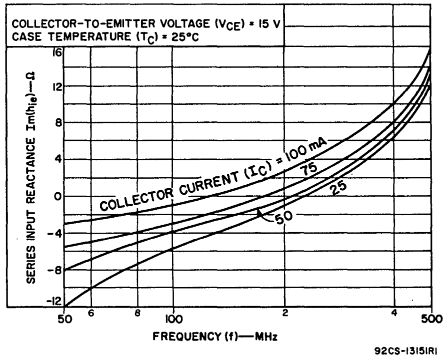


Fig. 9 - Typical series input reactance vs. frequency

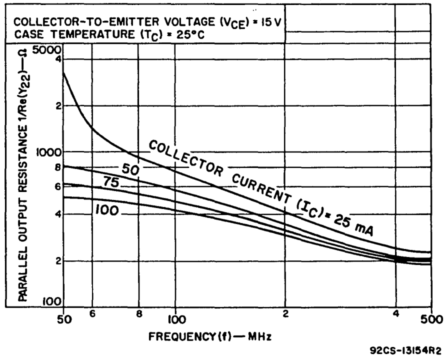


Fig. 10 - Typical parallel output resistance vs. frequency

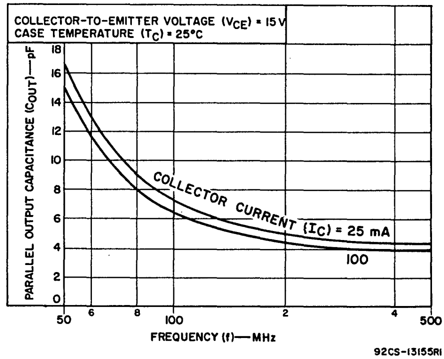


Fig. 11 - Typical parallel output capacitance vs. frequency

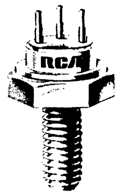
TERMINAL CONNECTIONS

Lead 1 — Emitter
Lead 2 — Base
Lead 3 — Collector, Case

RCA
Solid State
Division

RF Power Transistors

2N4012



JEDEC TO-60 H-1307

High-Power Silicon N-P-N Overlay Transistor

For Applications as a Frequency Multiplier Into the UHF or L-Band Range

Features

- **2.5 W output with 4 dB conversion gain (min.) as tripler to 1 GHz**
- **3 W output with 4.8 dB conversion gain (typ.) as doubler to 800 MHz**
- **High voltage ratings**
- **Freedom from second breakdown**

RCA-2N4012 is an epitaxial silicon n-p-n planar transistor of the "overlay" emitter electrode construction. It is especially designed to provide high power as a frequency multiplier into the uhf, or L-band, frequency range for military and industrial communications equipment.

Frequency multiplication – with power amplification – is possible with the overlay structure because the variable collector-to-base capacitance becomes the nonlinear element of a harmonic generator. The collector-to-base capacitance acts like a variable-capacitance diode, or varactor, in parallel with the amplifier section of the transistor.

In the overlay structure, there are a number of individual emitter sites which are all connected in parallel and used in conjunction with a single base and collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, and frequency capability.

The 2N4012 pellet is mounted in a JEDEC TO-60 package electrically isolating all three electrodes from the case for design flexibility and features low lead inductance and thermal resistance. The heavy copper mounting stud provides effective contact with a heat sink.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	40	V
With V_{BE} = −1.5 volts	V_{CEV}	65	V
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
COLLECTOR CURRENT	I_C	1.5	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		11.6	W
At case temperatures above 25°C		See Fig. 12	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

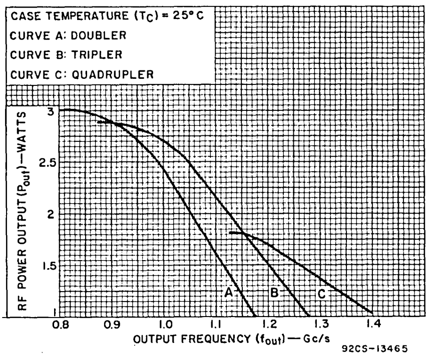


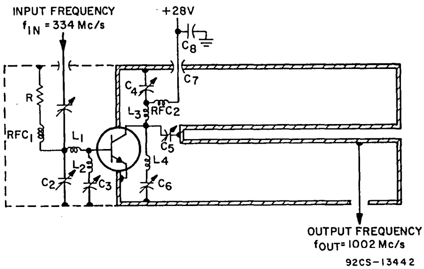
Fig. 1—Output power vs. output frequency

ELECTRICAL CHARACTERISTICS, Case Temperature = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Base Volts V_{BE}	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	DC Current (Milliamperes) I_C	LIMITS Min.	LIMITS Max.	UNITS
Collector-Cutoff Current	I_{CEO}		30			0		–	0.1	mA
Collector-to-Base Breakdown Voltage	BV_{CBO}				0		0.1	65	–	volts
Collector-to-Emitter Breakdown Voltage	BV_{CEO}					0	0 to 200[a]	40[b]	–	volts
	BV_{CEV}			-1.5			0 to 200[a]	65[b]	–	volts
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	4	–	volts
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					100	500	–	1	volt
Collector-to-Base Capacitance (See Fig. 4)	C_{ob}	30			0			–	10	pF
RF Power Output Tripler At 1002 Mc/s (See Fig. 2) Doubler At 800 Mc/s (See Fig. 3)	P_{OUT}		28 28					2.5[c] 3.0[d] (typ.)		watts

a Pulsed through an inductor (25 mH); duty factor = 50%.
b Measured at a current where the breakdown voltage is a minimum.
c For P_{IN} = 1.0 W; at 334 Mc/s; minimum collector efficiency = 25%.
d For P_{IN} = 1.0 W; at 400 Mc/s; typical collector efficiency = 35%.
e Cutoff frequency is determined from Q measurement at 210 Mc/s. The cutoff frequency of the collector-to-base junction of the transistor, f_c = Q x 210 Mc/s.

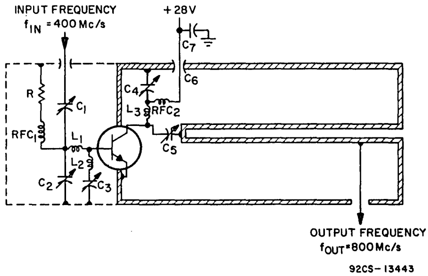
TRIPLER CIRCUIT FOR POWER OUTPUT TEST



C_1 = 0.9 – 7 pF
C_2 = 1 – 10 pF
C_3, C_4, C_5, C_6 = 0.8 – 10 pF
C_7 = 1000 pF
C_8 = 0.2 μF
RFC_1 = 0.22 μH
RFC_2 = 0.33 ohms, W.W. Resistor
L_1 = 2 turns, 3/8" diameter, No. 16 wire
L_2 = 1/16" width copper strip, 3/8" long
L_3 = 2 turns, 3/8" diameter, No. 18 wire
L_4 = 1-1/2 turns, 3/8" diameter, 1/16 copper strip
R = 2.7 ohms
Output Cavity = 1-1/4" x 1-1/4" x 2-1/4"
Center Conductor = 1/4" OD tube
Output direct couple = 1/2" from shorted end

Fig. 2

DOUBLE CIRCUIT FOR POWER OUTPUT TEST



C_1 = 0.9 – 7 pF
C_2 = 1 – 10 pF
C_3, C_4, C_5 = 0.8 – 10 pF
C_6 = 1000 pF
C_7 = 0.2 μF
RFC_1 = 0.22 μH
RFC_2 = 0.33 ohms, W.W. Resistor
R = 2.7 ohms
L_1 = 1 turn, 3/8" diameter, No. 16 wire
L_2 = 1/16" width copper strip, 3/8" long
L_3 = 2 turns, 3/8" diameter, No. 18 wire
Output Cavity = 1-1/4" x 1-1/4" x 2-1/4"
Center Conductor = 1/4" OD tube
Output direct couple = 1/2" from shorted end

Fig. 3

COLLECTOR-TO-BASE CAPACITANCE vs. COLLECTOR-TO-BASE VOLTAGE

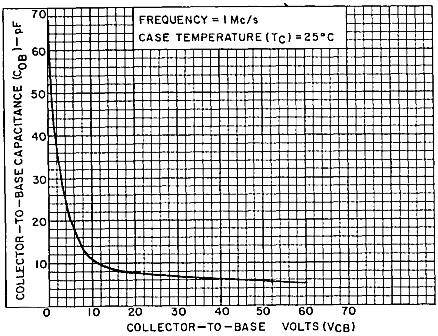


Fig. 4 92CS-13441

POWER OUTPUT vs. POWER INPUT

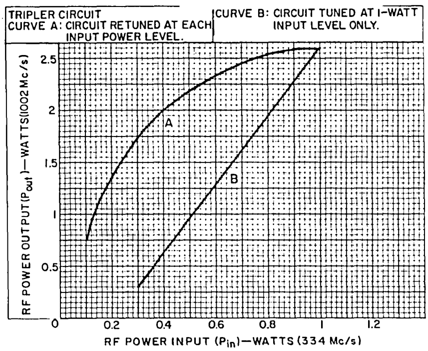


Fig. 5 92CS-13444

POWER OUTPUT vs. COLLECTOR SUPPLY VOLTAGE

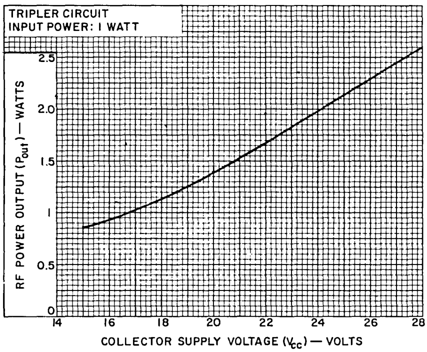


Fig. 6 92CS-13445

GAIN-BANDWIDTH PRODUCT vs. COLLECTOR CURRENT

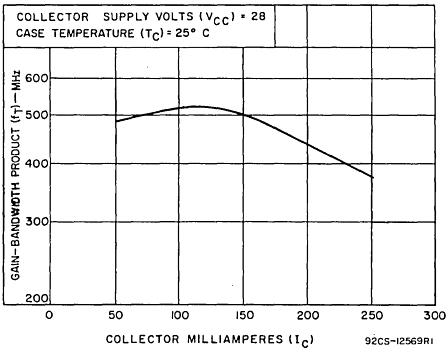


Fig. 7 92CS-12569R1

SERIES INPUT RESISTANCE vs. FREQUENCY

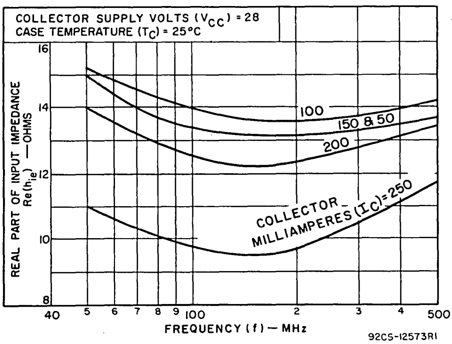


Fig. 8 92CS-12573R1

SERIES INPUT REACTANCE vs. FREQUENCY

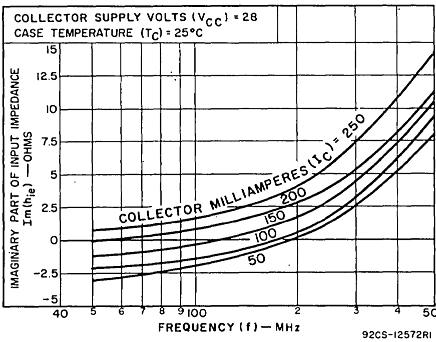


Fig. 9 92CS-12572R1

PARALLEL OUTPUT CAPACITANCE vs. FREQUENCY

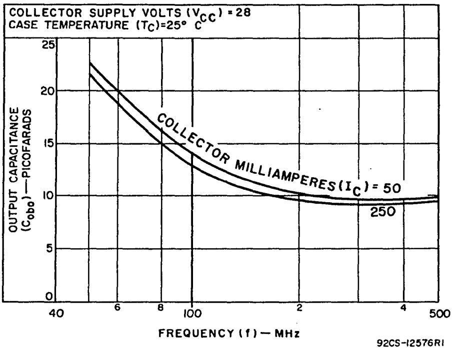


Fig. 10

PARALLEL OUTPUT RESISTANCE vs. FREQUENCY

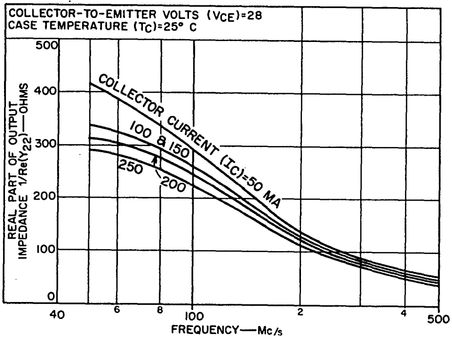


Fig. 11

DISSIPATION DERATING CURVE

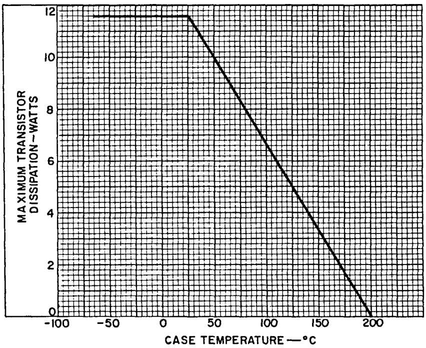


Fig. 12

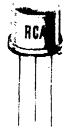
TERMINAL CONNECTIONS

Pin No. 1 – Emitter
Pin No. 2 – Base
Pin No. 3 – Collector

RCA
Solid State
Division

RF Power Transistors

2N4427



JEDEC TO-39

H-1381

Silicon N-P-N Overlay Transistor

High-Gain Driver for VHF-UHF

Features:

- 1 W output with 10 dB gain (min.) at 175 MHz
  V_{CC} = 12 V
- 0.4 W output with 5 dB gain (typ.) at 470 MHz
  V_{CC} = 12 V

RCA-2N4427 is an epitaxial silicon n-p-n planar transistor of the "overlay" emitter electrode construction. It is intended for class A, B, or C amplifier, frequency-multiplier, or oscillator circuits; it may be used in output, driver, or pre-driver stages in vhf and uhf equipment.

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a single base and collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, and frequency capability.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	V
* COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	20	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	2	V
* CONTINUOUS COLLECTOR CURRENT	I_C	0.4	A
* CONTINUOUS BASE CURRENT	I_B	0.4	A
* TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 100°C		2	W
At case temperatures above 100°C		*See Fig. 14*	
* TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
* LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

* In accordance with JEDEC registration data format JS-6 RDF-3.

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C.

Characteristic	Symbol	TEST CONDITIONS: DC Voltage (V) V_{BE}	V_{EB}	V_{CB}	V_{CE}	DC Current (mA) I_E	I_B	I_C	Limits Min.	Max.	Units
* Collector-Cutoff Current: With base open	I_{CEO}				12		0		–	0.02	mA
With base-emitter junction reverse-biased	I_{CEV}	−1.5			40				–	0.1	mA
T_C = 150°C	I_{CEV}	−1.5			12				–	5	mA
* Emitter-Cutoff Current	I_{EBO}		2						–	0.1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$					0		0.1	40	–	V
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$						0	5	20	–	V
With external base-to-emitter resistance (R_{BE}) = 10Ω	$V_{CER}(sus)$							5	40	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					0.1		0	2	–	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$						20	100	–	0.5	V
* DC Forward Current Transfer Ratio	h_{FE}				5 5			360 100	5 10	– 200	
* Magnitude of Common-Emitter Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 200 MHz)	$\|h_{fe}\|$				15			50	2.5	–	
* Collector-to-Base Capacitance (f = 1 MHz)	C_{ob}			12		0			–	4	pF
RF Power Output Class C Amplifier, Unneutralized (f = 175 MHz, P_{IE} = 0.1 W, $\eta_C \geq$ 50%) See Fig. 2	P_{OE}			12 (V_{CC})					1	–	W
* Available Amplifier Signal Input Power (f = 175 MHz, P_{OE} = 1 W, Z_{IN} = 50 Ω) See Fig. 2	P_i			12 (V_{CC})					–	0.1	W
* Collector Efficiency (f = 175 MHz, P_{OE} = 1 W, Z_{IN} = 50 Ω) See Fig. 2	η_C			12 (V_{CC})					50	–	%
Thermal Resistance Junction-to-Case	$R_{\theta JC}$								–	50	°C/W

* In accordance with JEDEC registration data format JS–6 RDF–3.

175 MHz OPERATION

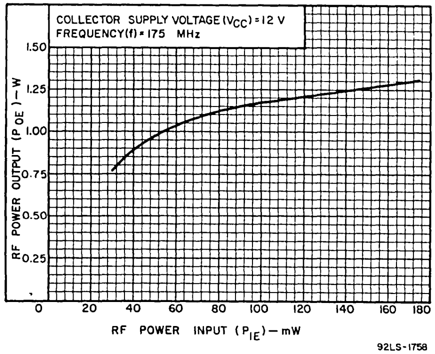
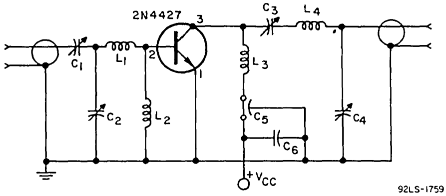


Fig.1 — Power output vs. power input.



C_1, C_2, C_3, & C_4: 3-15 pF trimmer, ARCO 403 or equivalent
C_5: 1,000 pF feedthrough
C_6: 0.01 μF disc.
L_1: 2 turns No.16 wire, 3/16 in. (4.76 mm) ID, 1/4 in. (6.35 mm) long
L_2: Ferrite choke, Z = 450 Ω
L_3: 2 turns No.16 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
L_4: 4 turns No.16 wire, 3/8-in. (9.52 mm) ID, 3/8 in. (9.52 mm) long

Fig.2—175-MHz rf amplifier circuit for power-output test.

470 MHz OPERATION

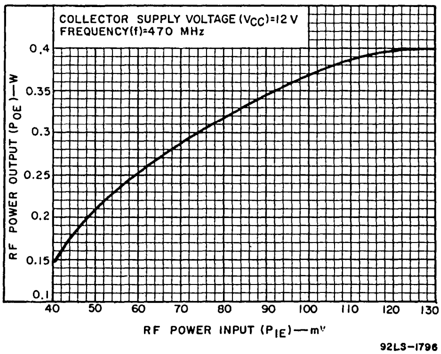
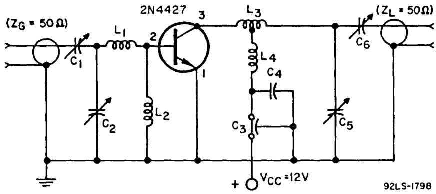


Fig.3— Power output vs. power input.



C_1, C_2, C_5, & C_6: 0.9–7 pF trimmer, ARCO 400, or equivalent
C_3: 1000 pF feedthrough
C_4: 0.02 μF disc.
L_1: 1 turn No.20 wire, 3/16 in. (4.76 mm) ID, Space wire diameter
L_2: 0.47 μH Nytronics Corp., or equivalent
L_3: 2 turns No.18 wire, 1/4 in. (6.35 mm) ID, Space wire diameter C.T.
L_4: 2 turns No.20 wire, 3/16 in. (4.76 mm) ID, Space wire diameter

Fig.4— 470-MHz rf amplifier circuit.

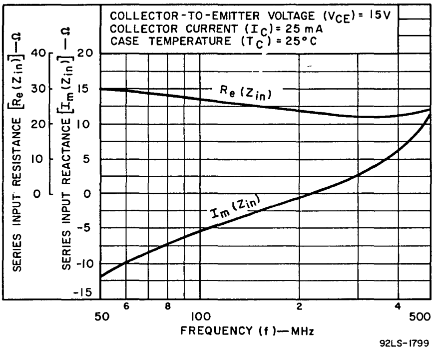


Fig.5—Series input impedance vs. frequency.

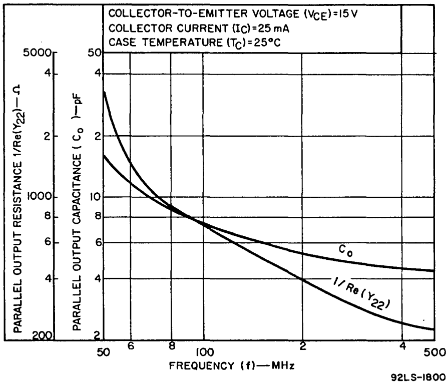


Fig.6—Parallel output resistance & capacitance vs. frequency.

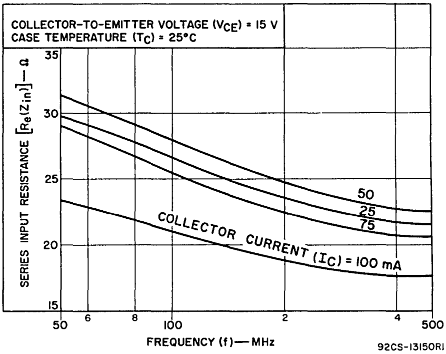


Fig.7—Series input resistance vs. frequency.

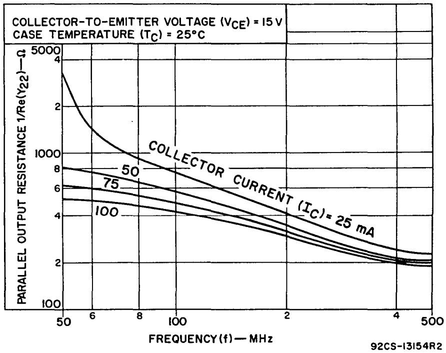


Fig.8—Parallel output resistance vs. frequency.

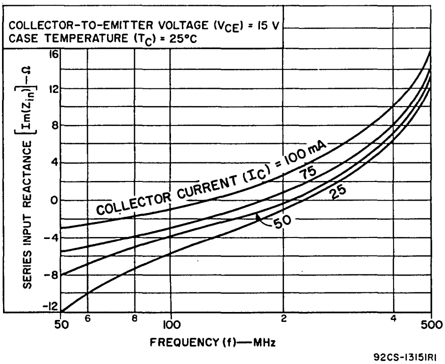


Fig.9—Series input reactance vs. frequency.

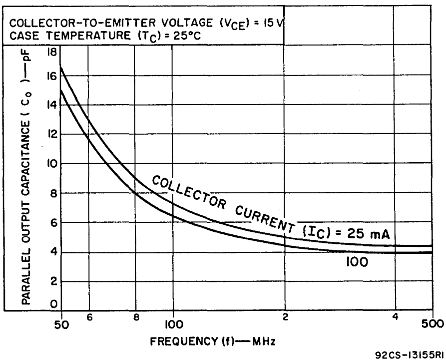


Fig.10—Parallel output capacitance vs. frequency.

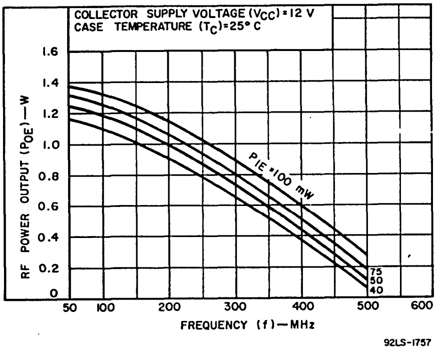


Fig.11—Power output vs. frequency.

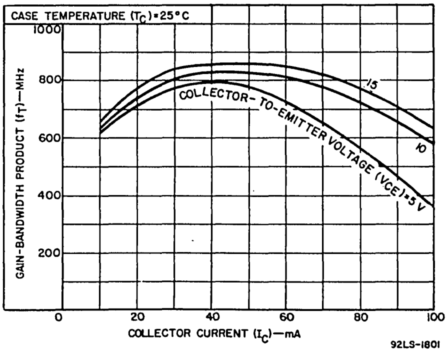


Fig.12—Gain-bandwidth product vs. collector current.

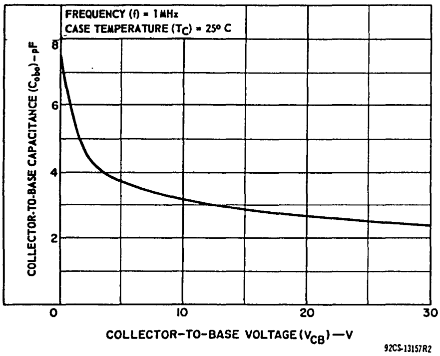


Fig.13—Variation of collector-to-base capacitance.

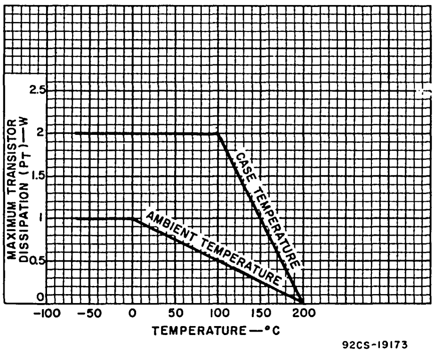


Fig.14—Dissipation derating curve.

TERMINAL CONNECTIONS

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

RCA
Solid State
Division

RF Power Transistors

2N4440

JEDEC TO-60 H-1307

Silicon N-P-N Overlay Transistor

For Class A, B, or C VHF/UHF
Military and Industrial Communications Equipment

Features:

- **5 W output min. at 400 MHz**
- **6.5 W output typ. at 225 MHz**

RCA-2N4440● is an epitaxial silicon n-p-n planar transistor of the overlay emitter-electrode construction. It is intended for Class A▲, B, and C rf amplifier, multiplier, or oscillator operation for military and industrial communications service (175 to 400 MHz).

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a common collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, frequency capability, and linearity.

●Formerly RCA Dev. No. TA2875.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
*COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction reverse-biased (V_{BE}) = -1.5 V	V_{CEV}	65	V
* With base open	V_{CEO}	40	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*CONTINUOUS COLLECTOR CURRENT	I_C	1.5	A
*CONTINUOUS BASE CURRENT	I_B	0.2	A
*TRANSISTOR DISSIPATION▲:	P_T		
At case temperatures up to 25°C		11.6	W
At case temperatures above 25°C		See Fig. 2	
*TEMPERATURE RANGE:			
Storage and operating (junction)		-65 to 200	°C
LEAD TEMPERATURE (During soldering):			
At distances ⩾ 1/32 in. (0.8 mm) from insulating wafer for 10 s max		230	°C

*In accordance with JEDEC registration data

▲Secondary breakdown considerations limit maximum dc operating conditions. . .contact your RCA Representative for specific data.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS						LIMITS		UNITS
		VOLTAGE V dc			CURRENT mA dc					
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector Cutoff Current: With base open	I_{CEO}		30			0		-	0.1	mA
With base-emitter junction reverse-biased	I_{CEV}		65	-1.5				-	1	mA
At T_C = 200°C	I_{CEV}		30	-1.5				-	5	mA
* Emitter Cutoff Current	I_{EBO}			-4				-	0.1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0		0.1	65	-	V
Collector-to-Emitter Breakdown Voltage: With base-emitter junction reverse-biased	$V_{(BR)CEV}$			-1.5			0 to 200●	65**	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.1		0	4	-	V
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$					0	200●	40	-	V
With external base-to-emitter resistance (R_{BE}) = 100Ω	$V_{CER}(sus)$						200●	40	-	V
* DC Forward Current Transfer Ratio	h_{FE}		5 5				1350 125	3 10	- 200	
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					50	250	-	1	V
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 100 MHz)	$\|h_{fe}\|$		28				125	4	-	
* Collector-to-Base Capacitance (f = 1 MHz)	C_{ob}	28					125	-	12	pF
* Available Amplifier Signal Input Power (P_o = 5 W, Z_G = 50Ω, f = 400 MHz)	P_i							-	1.7	W
* Collector Circuit Efficiency (P_o = 5 W, Z_G = 50Ω, f = 400 MHz)	η_C							45	-	%
Collector-to-Case Capacitance	C_s							-	6	pF
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$							-	15	°C/W

●Pulsed through an inductor (25 mH); duty factor=50%

**Measured at a current where the breakdown voltage is a minimum

*In accordance with JEDEC registration data.

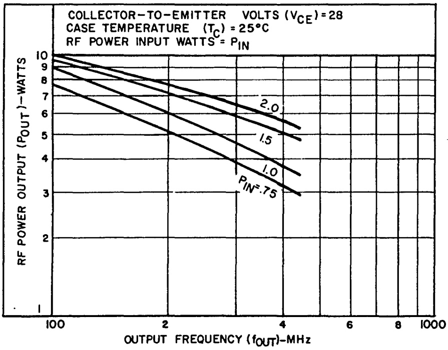


Fig. 1—Typical power output vs. frequency

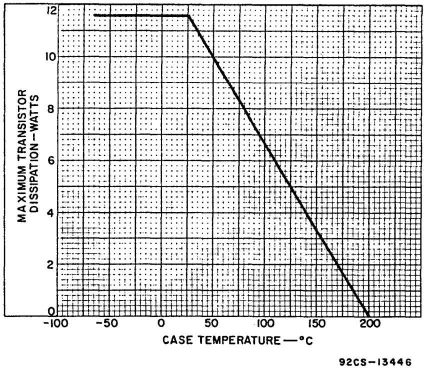


Fig. 2—Dissipation derating chart

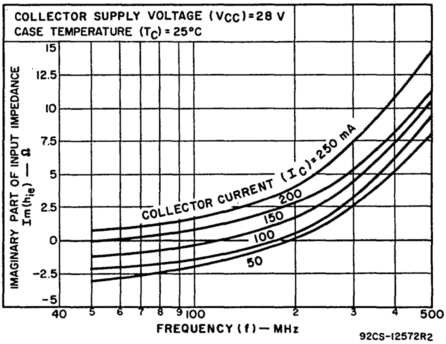


Fig. 3—Typical series input reactance vs. frequency

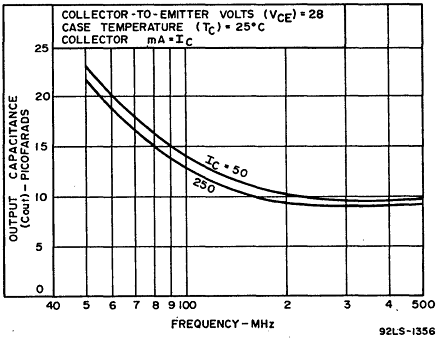


Fig. 4—Typical output capacitance vs. frequency

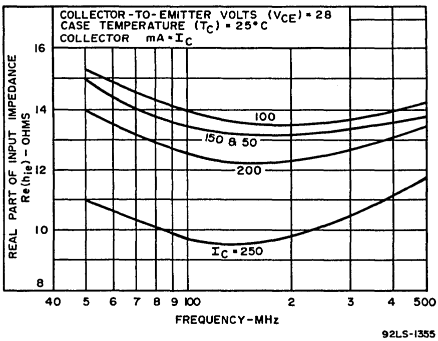


Fig. 5—Typical series input resistance vs. frequency

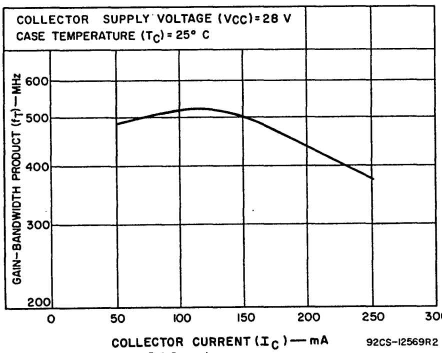


Fig. 6—Typical gain-bandwidth product vs. collector current

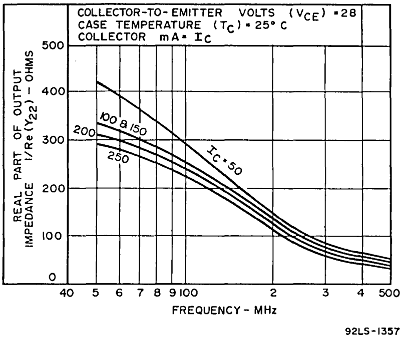


Fig. 7—Typical output resistance vs. frequency

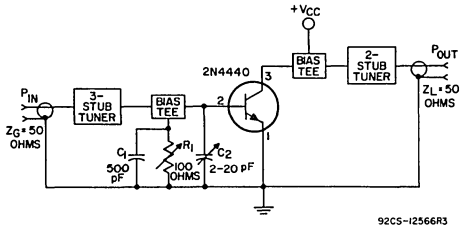
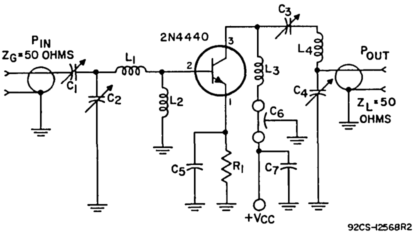


Fig. 8—RF amplifier circuit for power output test at 400 MHz



C_1: 2-25 pF
C_2, C_3, C_4: 4-40 pF
C_5: 50 pF, disc ceramic
C_6: 1500 pF
C_7: 0.005 μF, disc ceramic
L_1: 1 turn No. 16 wire, 1/4 in. (6.35 mm) ID, 1/8 in. (3.17 mm) long
L_2: Ferrite choke, Z = 450 (±20%) ohms
L_3: 0.47-μH choke
L_4: 2 turns No. 16 wire, 3/8 in. (9.52 mm) ID, 7/16 in. (11.11 mm) long
R_1: 1.35 ohms, non-inductive

Fig. 9—RF amplifier circuit for power output test at 225 MHz

TERMINAL CONNECTIONS

Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

RCA

Solid State Division

RF Power Transistors

2N4932
2N4933

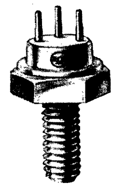
RCA-2N4932* and RCA-2N4933▲ are epitaxial silicon n-p-n planar transistors of the "overlay" emitter electrode construction. They are especially intended to provide high power as class C rf amplifiers for International VHF Mobile and Portable Communications service (66 to 88 MHz). The 2N4932 is designed to operate from a 13.5-volt power supply; the 2N4933, from a 24-volt power supply.

The transistors feature protection against load mismatch.

In the overlay structure, there are a number of individual emitter sites which are all connected in parallel and used in conjunction with a common collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, frequency capability, and linearity.

* Formerly RCA Dev. No.TA2828

▲ Formerly RCA Dev. No.TA2792



JEDEC TO-60

For International VHF Mobile and Portable Communication, 66 to 88 MHz

Operation From a Power Supply of –
13.5 volts (2N4932)
24 volts (2N4933)

Power Output (Min.) at 88 MHz
12 watts (2N4932)
20 watts (2N4933)

Load Protection

High Voltage Ratings

RATINGS

Maximum Ratings, ***Absolute-Maximum Values:***

		2N4932	2N4933	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	70	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open	V_{CEO}	25	35	V
With V_{BE} = −1.5V	V_{CEV}	50	70	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4.0		V
COLLECTOR CURRENT:				
Peak		10		A
Continuous	I_C	3.3		A
RF INPUT POWER	P_{in}			
At 88 MHz		3.5		W
Below 88 MHz		See *Fig.7*		
TRANSISTOR DISSIPATION	P_T			
At case temperatures up to 25° C		70		W
At case temperatures above 25° C		See *Fig.1*		
TEMPERATURE RANGE:				
Storage & Operating (Junction)		−65 to 200		°C
LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/32 in. from insulating wafer for 10 s max.		230		°C

DISSIPATION DERATING CURVE

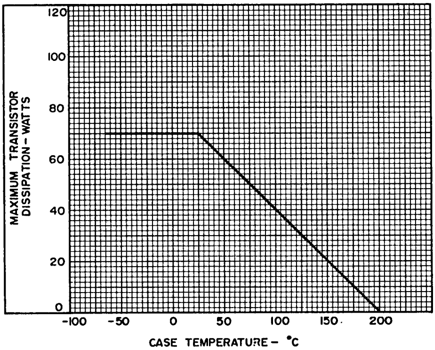


Fig.1

ELECTRICAL CHARACTERISTICS FOR 2N4932
Case Temperature = 25° C

Characteristic	Symbol	TEST CONDITIONS						Limits		Units
		DC Collector Volts		DC Base Volts	DC Current (Milliamperes)					
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	Min.	Max.	
Collector-Cutoff Current	I_{CEO}		15			0			1.0	mA
	I_{CBO}	40			0				10	mA
Collector-to-Emitter Breakdown Voltage	$V_{CEV}(sus)$			−1.5			200[a]	50		V
	$V_{CEO}(sus)$					0	200[a]	25		V
Emitter-to-Base Breakdown Voltage	BV_{EBO}				10		0	4		V
Collector-to-Base Capacitance	C_{ob}	15			0				120	pF
RF Power Output (See *Fig.2*)	P_{out}							12[c]		W

ELECTRICAL CHARACTERISTICS FOR 2N4933
Case Temperature = 25° C

Characteristic	Symbol	TEST CONDITIONS						Limits		Units
		DC Collector Volts		DC Base Volts	DC Current (Milliamperes)					
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	Min.	Max.	
Collector-Cutoff Current	I_{CEO}		30			0			1.0	mA
	I_{CBO}	50			0				10	mA
Collector-to-Emitter Breakdown Voltage	$V_{CEV}(sus)$			−1.5			200[a]	70		V
	$V_{CEO}(sus)$					0	200[a]	35		V
Emitter-to-Base Breakdown Voltage	BV_{EBO}				10		0	4		V
Collector-to-Base Capacitance	C_{ob}	30			0				85	pF
RF Power Output (See *Fig.3*)	P_{out}							20[b]		W

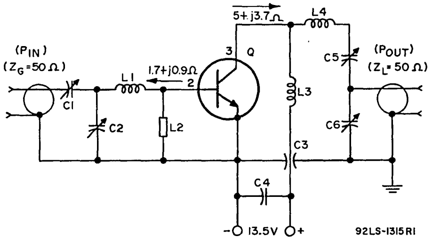
[a]Pulsed through an inductor (25mH), duty factor = 50%

[b]For P_{in} = 3.5 W, at 88 MHz; V_{cc} = 24V, minimum efficiency = 70%

[c]For P_{in} = 3.5 W, at 88 MHz; V_{cc} = 13.5V, minimum efficiency = 70%

RF AMPLIFIER CIRCUIT FOR POWER OUTPUT TEST
(66 to 88 MHz Operation)

2N4932



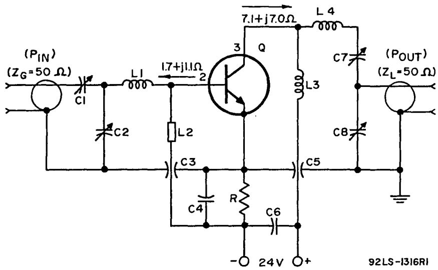
C_1 = 7-100 pF
C_2 = 14-150 pF
C_3 = 1000 pF
C_4 = .05 µF
C_5 = 70-350 pF
C_6 = 32-250 pF

L_1 = 1 turn, No.16 wire, 1/4" ID, 1/8" long
L_2 = Ferrite Choke, Z = 450 Ω, Ferroxcube #VK200 01-3B*
L_3 = 2 turns, No.16 wire, 1/4" ID, 3/8" long
L_4 = 2 turns, No.10 wire, 1/2" ID, 1/2" long
Q = 2N4932

* Ferroxcube Corp. of America Saugerties, N.Y.

Fig. 2

2N4933



C_1 = 7-100 pF
C_2 = 14-150 pF
C_3, C_5 = 1000 pF
C_4, C_6 = .05 µF
C_7 = 70-350 pF
C_8 = 32-250 pF
R = 0.33 Ω

L_1 = 1 turn, No.16 wire, 1/4" ID, 1/8" long
L_2 = Ferrite Choke, Z = 450 Ω, Ferroxcube #VK200 01-3B*
L_3 = 3.5 turns, No.16 wire, 1/4" ID, 1/2" long
L_4 = 3 turns, No.10 wire, 1/2" ID, 3/4" long
Q = 2N4933

*Ferroxcube Corp. of America Saugerties, N.Y.

Fig. 3

TYPICAL POWER OUTPUT vs POWER INPUT

2N4932

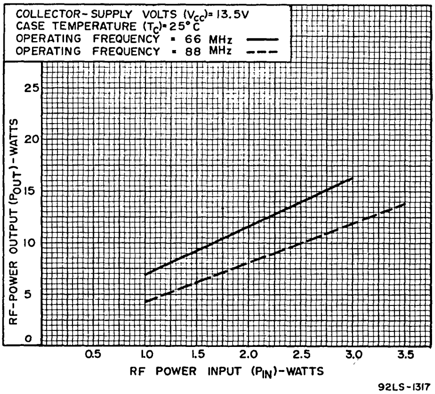


Fig. 4

2N4933

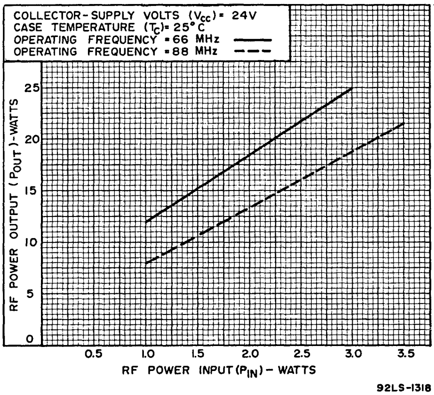


Fig. 5

SPECIAL PERFORMANCE DATA

The transistor can withstand any mismatch in load, which can be demonstrated in the following test:

1. The test is performed using the arrangement in *Fig.6*.
2. The tuning stub is varied through a half wavelength, which effectively varies the load from an open circuit to a short circuit.
3. Operating conditions: V_{CC} = 13.5V (2N4932), 24V (2N4933); RF input power = 3W @ 66 MHz.
4. Transistor Dissipation Rating must not be exceeded. During the above test, the transistor will not be damaged or degraded.

BLOCK DIAGRAM FOR MISMATCH TEST

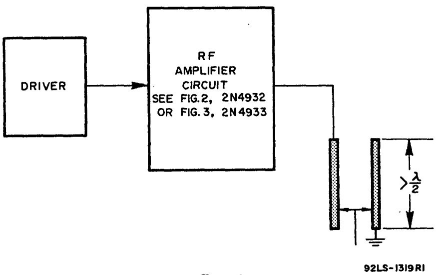


Fig. 6

INPUT DERATING CURVE

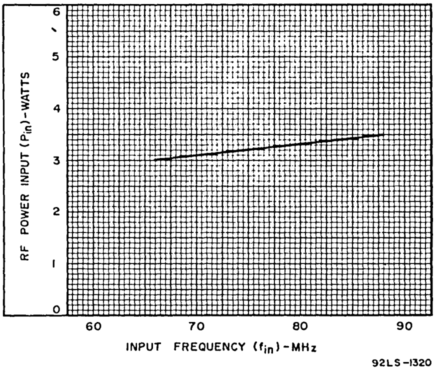


Fig. 7

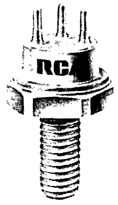
TERMINAL CONNECTIONS

Case, Mounting Stud, Pin No.1 - Emitter
Pin No.2 - Base
Pin No.3 - Collector

RCA
Solid State
Division

RF Power Transistors

2N5016



JEDEC TO-60 H-1307

High-Power Silicon N-P-N Overlay Transistor

For VHF/UHF Communications Equipment

Features:

- For class B or C vhf/uhf military and industrial communications
- 15 W output (min.) at 400 MHz
- 23 W output (typ.) at 225 MHz
- Emitter grounded to case

RCA 2N5016* is an epitaxial silicon n-p-n planar transistor of the "overlay" emitter-electrode construction. It is intended for large-signal, high-power, class B and C rf amplifiers for military and industrial communications service (200 to 700 MHz).

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a common collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, frequency capability, and linearity.

* Formerly RCA Dev. Type TA2675.

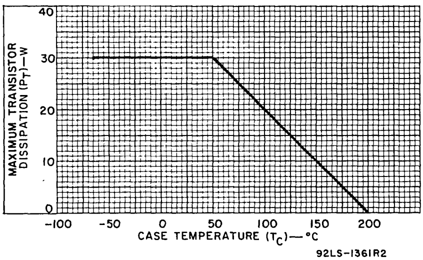


Fig. 1—Dissipation derating curve.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction reverse-biased, V_{BE} = −1.5 V	V_{CEV}	65	V
With external base-to-emitter resistance, R_{BE} = 30 Ω	V_{CER}	40	V
* With base open	V_{CEO}	30	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*CONTINUOUS COLLECTOR CURRENT	I_C	4.5	A
*CONTINUOUS BASE CURRENT	I_B	1.5	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 50°C		30	W
At case temperatures above 50°C		See Fig. 1	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ≥1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

*In accordance with JEDEC registration data.

 9-71

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE – V: V_{CB}	V_{CE}	V_{BE}	DC CURRENT mA: I_E	I_B	I_C	LIMITS: MIN.	MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}		30			0		–	10	mA
* With base-emitter junction reverse-biased	I_{CEV}		60	-1.5				–	10	mA
* T_C = 150°C	I_{CEV}		30	-1.5				–	10	mA
* Emitter Cutoff Current V_{BE} = 4 V	I_{EBO}							–	5	mA
Collector-to-Emitter Sustaining Voltage: * With base open	$V_{CEO}(sus)$					0	200[a]	30	–	V
* With external base-to-emitter resistance (R_{BE}) = 30 Ω	$V_{CER}(sus)$					0	200[a]	40	–	V
With base-emitter junction reverse-biased	$V_{CEV}(sus)$			-1.5			200[a]	65	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				5		0	4	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					400	2000	–	1	V
* DC Forward Current Transfer Ratio	h_{FE}		4 4				4500 500	3 10	– 200	
Thermal Resistance: Junction-to-Case	$R_{\theta J\text{-}C}$							–	5	°C/W

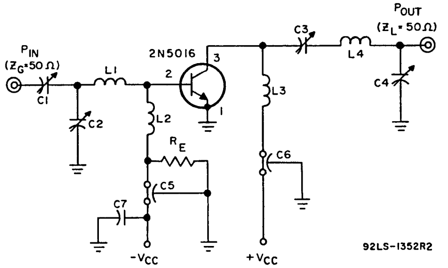
DYNAMIC

CHARACTERISTIC	SYMBOL	V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	UNITS
* Available Amplifier Signal Input Power (P_{OE} = 15 W, Z_{IN} = 50 Ω, V_{CC} = 28 V, f = 400 MHz) See Fig. 3	P_i							–	5	W
* Collector Efficiency (P_{IE} = 5 W, P_{OE} = 15 W, Z_L = 50 Ω, f = 400 MHz) See Fig. 3	η_C							50	–	%
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 400 MHz)	$\|h_{fe}\|$		15				500	1.25	–	
* Collector-to-Base Capacitance (f = 1 MHz)	C_{ob}	30			0			–	25	pF

TYPICAL APPLICATION INFORMATION

CHARACTERISTIC	SYMBOL	V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	UNITS
RF Power Output Amplifier, Unneutralized At 225 MHz (See Fig.2)	P_{OE}		28					23[b] (typ.)		W
400 MHz (See Fig.3)	P_{OE}		28					15[c]	–	W
Dynamic Input Impedance at 400 MHz (See Fig.3)	Z_{IN}		28					2.5 + j5 (typ.)[c]		Ω

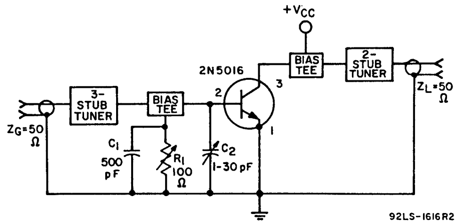
[a]Pulsed through an inductor (25 mH); duty factor = 50%.
[b]For P_{IE} = 5.0 W; minimum efficiency = 60%.
[c]For P_{IE} = 5.0 W; minimum efficiency = 50%.
*In accordance with JEDEC registration data.



C1: 4-40 pF trimmer, ARCO 422*
C2: 7-100 pF trimmer, ARCO 423*
C3: 3-35 pF trimmer, ARCO 403*
C4: 8-60 pF trimmer, ARCO 404*
C5,C6: 1500 pF feedthrough
C7: 0.01 μF disc, ceramic
RE: 0.68 Ω wire-wound 1W
L1: 1.5 turns No. 16 wire 1/4 in. (6.35 mm) ID, 3/16 in. (4.76 mm) long
L2: Ferrite choke, Z = 750 Ω
L3: 1.5 turns No. 16 wire, 1/4 in. (6.35 mm) ID
L4: 4.5 turns No. 16 wire, 1/4 in. (6.35 mm) ID, 3 in. (76.20 mm) long

* Or equivalent.

Fig.2--RF amplifier circuit for power output test at 225 MHz.



Note 1: For optimum performance, C2 in Fig. 3 should be mounted between emitter and base with minimum lead lengths.

Note 2: The emitter resistor, RE, in Fig. 2 provides self bias and is recommended for imnroved stability and collector efficiency.

Fig.3—RF amplifier circuit for power output test at 400 MHz.

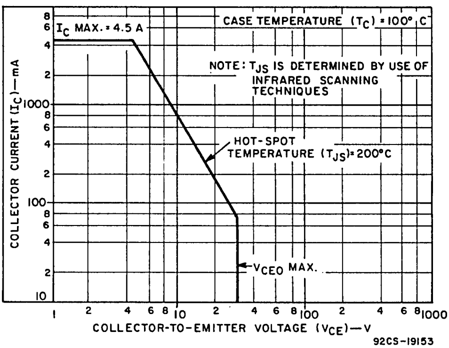
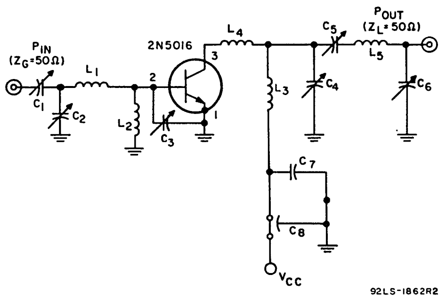


Fig.4—Safe area for dc operation.



C1: 0.1-10 pF piston capacitor
C2,C3,C4,C5,C6: 1.0-30 pF piston capacitor (Note 2)
C7: 0.01 μF disc ceramic
C8: 1000 pF feedthrough
L1: 1/4 in. (6.35 mm) OD copper tubing; 1-1/4 in. (31.75 mm) long (Note 1)
L2: 0.12 μH choke
L3: 0.27 Ω wire-wound
L4: 1/8 x 1/32 x 5/8 in. (3.17 x 0.79 x 15.87 mm) long copper strap
L5: 1/4 in. (6.35 mm) OD copper tubing, 2-1/4 in. (57.15 mm) long (Note 1)

Note 1: L1 and L5 are mounted coaxially within a 1-5/8 x 1-5/8 x 6 in. (41.27 x 41.27 x 152.40 mm) box.

Note 2: For optimum performance, C3 should be mounted between emitter and base with minimum lead lengths.

Fig.5— Typical 400-MHz rf amplifier circuit,

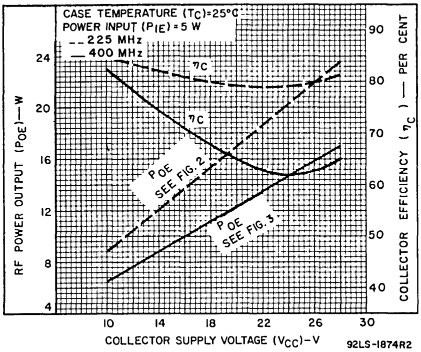


Fig.6—Typical power output and collector efficiency vs. collector supply voltage.

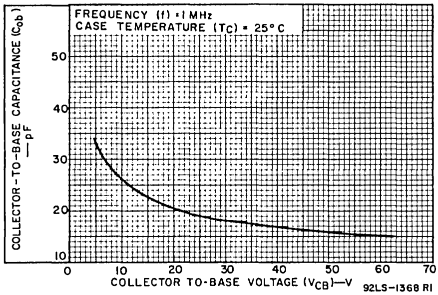


Fig.7—Typical variation of collector-to-base capacitance.

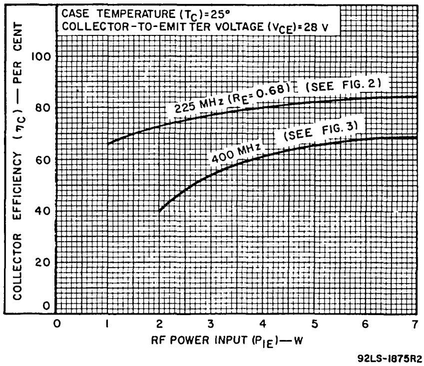


Fig.8—Collector efficiency vs. power input.

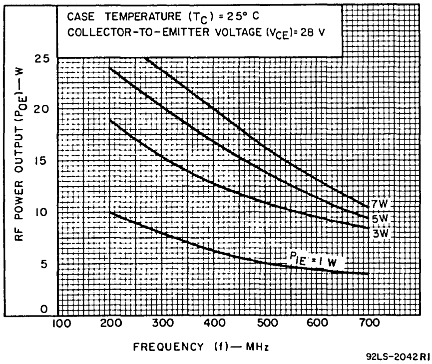


Fig.9—Typical power output vs. frequency.

TERMINAL CONNECTIONS

Case, Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

RCA
Solid State
Division

RF Power Transistors

2N5070

Silicon N-P-N Overlay Transistor

JEDEC TO-60 H-1307

For High-Frequency Single-Sideband Communications Equipment

Features:

- Suitable for class A or class B amplifiers
- 25 W PEP output min. at 30 MHz with
  gain: 13 dB
  η: 40% min.,
  IMD: 30 dB max.
- Low thermal resistance

RCA–2N5070● is an epitaxial silicon n-p-n planar transistor of the overlay emitter-electrode construction. It is especially designed for linear applications to provide high power in class A or class B service. This device is intended for 2-to-30-MHz single-sideband power amplifiers operating from a 28-volt power supply.

The inherent high-frequency capability of the overlay structure together with individually ballasted emitter sites makes it possible to forward-bias the device into the active region without incurring thermal instability.

The emitter pin is common to the case to minimize lead inductance.

●Formerly RCA Dev. No. TA2793.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

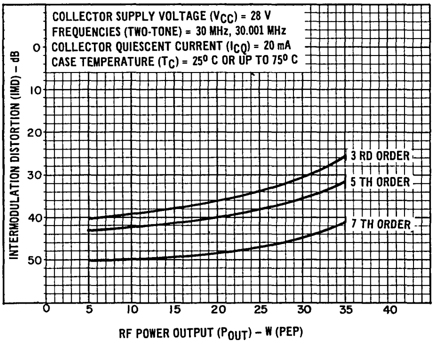
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction reverse-biased (V_{BE}) = -1.5 V	V_{CEV}	65	V
With external base-to-emitter resistance (R_{BE}) = 5Ω	V_{CER}	40	V
* With base open	V_{CEO}	30	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*COLLECTOR CURRENT:	I_C		
Continuous		3.3	A
Peak		10	A
*CONTINUOUS BASE CURRENT	I_B	1	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		70	W
At case temperatures above 25°C		See Fig. 2	
*TEMPERATURE RANGE:			
Storage and operating (junction)		-65 to 200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ⩾ 1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

*In accordance with JEDEC registration data

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25° C unless otherwise specified*

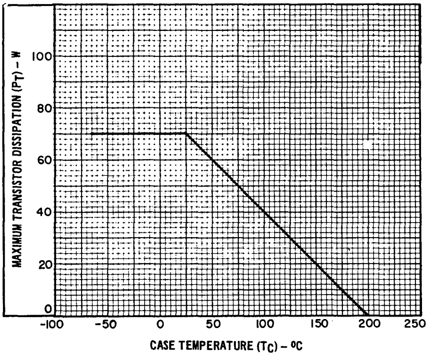
CHARACTERISTIC	SYMBOL	TEST CONDITIONS						LIMITS		UNITS
		VOLTAGE V dc			CURRENT mA dc					
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector Cutoff Current: With base-emitter junction reverse-biased	I_{CEV}		60	-1.5				–	10	mA
At T_C = 150° C	I_{CEV}		60	-1.5				–	10	mA
With emitter open	I_{CBO}		60		0			–	10	mA
With base open	I_{CEO}		30			0		–	5	mA
* Emitter Cutoff Current	I_{EBO}			4				–	10	mA
Collector-to-Emitter Sustaining Voltage: With base-emitter junction reverse-biased	$V_{CEV}(sus)$			-1.5			200[a]	65	–	V
* With base open	$V_{CEO}(sus)$					0	200[a]	30	–	V
* With external base-to-emitter resistance (R_{BE}) = 5Ω	$V_{CER}(sus)$						200[a]	40	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				10			4	–	V
* DC Forward Current Transfer Ratio	h_{FE}		5 5				3000 1000	10 20	100 –	
* Magnitude of Common-Emitter Small-Signal Short-Circuit Forward Current Transfer Ratio (f = 50 MHz)	$\|h_{fe}\|$		15				1000	2	–	
* Output Capacitance (f = 1 MHz)	C_{ob}	30			0			–	85	pF
* Available Amplifier Signal Input Power (See Fig. 8) Z_G = 50Ω, P_o = 25 W(PEP) f_1 = 30 MHz, f_2 = 30.001 MHz	P_i							–	1.25 PEP	W
* Intermodulation Distortion Z_G = 50Ω, P_o = 25 W(PEP) f_1 = 30 MHz, f_2 = 30.001 MHz	IMD							–	30	dB
* Collector Efficiency Z_G = 50Ω, P_o = 25 W(PEP) f_1 = 30 MHz, f_2 = 30.001 MHz	η_C							40	–	%
Thermal Resistance Junction-to-Case	$R_{\theta JC}$							–	2.5	°C/W

*In accordance with JEDEC registration data format
[a]Pulsed through a 25-mH inductor; duty factor = 50%



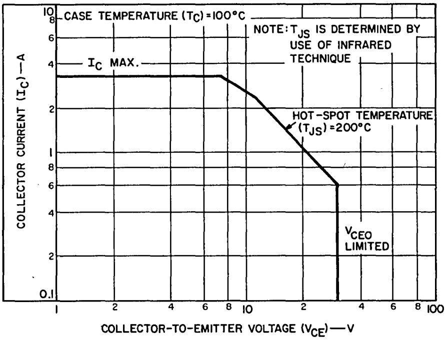
92LS-1877R1

Fig. 1—Typical intermodulation distortion vs. rf power output.



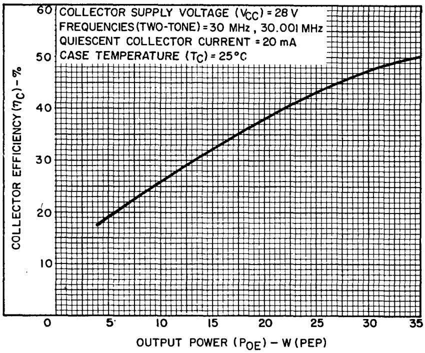
92LS-1882R2

Fig. 2—Dissipation derating chart.



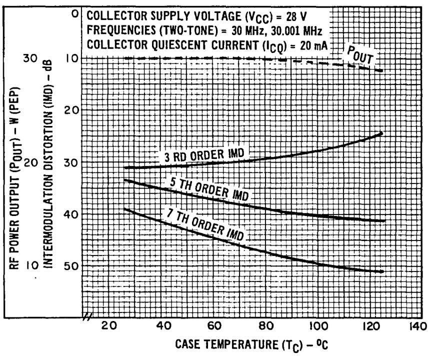
92CS-19139

Fig. 3—Safe operation with dc forward bias.



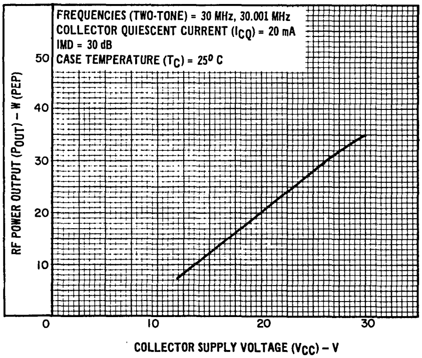
92LS-1880R2

Fig. 4—Typical collector efficiency vs. rf power output.



92LS-1881R1

Fig. 5—Typical rf power output and intermodulation distortion vs. case temperature.



92LS-1883R2

Fig. 6—Typical rf power output vs. collector supply voltage.

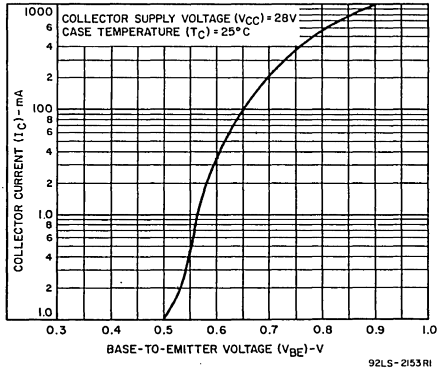
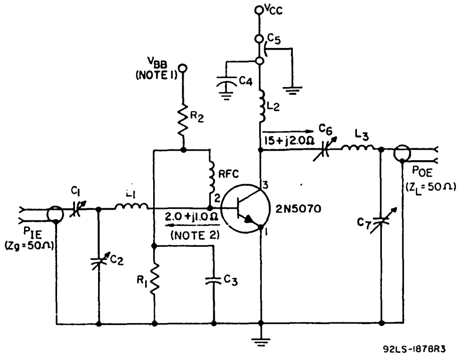


Fig. 7—Typical transfer characteristics.



L_1: 3T No. 12 wire, 1/4 in. (6.35 mm) ID, 1/2 in. (12.7 mm) long
L_2: 6T No. 14 wire, 3/8 in. (9.52 mm) ID, 3/4 in. (19.05 mm) long
L_3: 5T No. 10 wire, 3/4 in. (19.05 mm) ID, 3/4 in. (19.05 mm) long

C_1: 140-680 pF, Arco 468 or equivalent
C_2: 170-780 pF, Arco 469 or equivalent
C_3: 0.05 μF, ceramic
C_4: 0.1 μF, ceramic
C_5: 1000 pF feedthrough
C_6: 24-200 pF, Arco 425 or equivalent
C_7: 32-250 pF, Arco 426 or equivalent

R_1: 1Ω, 5 W
R_2: 50Ω, 25 W
RFC: 350 Ferrite choke, Ferroxcube #VK200 01-03B or equivalent

Note 1: Adjust V_{BB} for a collector quiescent current of 20 mA with no rf input signal.

Note 2: Impedance measurements are made at transistor socket pins.

Single-Sideband Suppressed-Carrier Service

Peak envelope conditions for a signal having a minimum peak-to-average power ratio of 2.

Test Operation

In test circuit shown, with "Two-Tone" Modulation, at $T_C = 30^\circ$ C, and at 30 MHz.

Collector Supply Voltage	28 V
Collector Bias Current	20 mA
RF Power Output:	
Average	12.5 min. W
Peak Envelope	25 min. W
Intermodulation Distortion[a]	30 max. dB
Collector Efficiency	40 min. %

[a]Referenced to either of the two tones and without the use of feedback to enhance linearity.

Fig. 8—Linear rf amplifier circuit for power output test at 30 MHz.

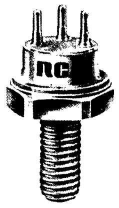
TERMINAL CONNECTIONS

Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

RCA
Solid State
Division

RF Power Transistors

2N5071



JEDEC TO-60 H-1307

24-W (CW), 76-MHz Emitter-Ballasted Overlay Transistor

Silicon N-P-N Device for 24-Volt Applications in VHF Communications Equipment

Features:

- **For class B or class C amplifiers**
- **For 24-V FM (30 to 76 MHz) communications**
- **24 W output at 76 MHz with 9 dB gain (Min.)**
- **Low thermal resistance**

RCA type 2N5071[a] is an epitaxial silicon n-p-n planar transistor featuring overlay emitter electrode construction. This device utilizes many separate emitter elements and has individual ballast resistance in each of the emitter sites for stabilization. It is especially designed as a high-power, class B and C rf amplifier for FM communications with a 24-volt power supply. It is useful for both narrowband and wideband applications in the 30- to 76-MHz frequency range.

The transistor can be operated under a wide range of mismatched load conditions. All units are tested for a load mismatch having a VSWR of 3:1 which is varied through all phases. The test is performed at 30 MHz and 30 watts output.

[a]Formerly RCA Dev. No. TA2827.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
*COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}	30	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*COLLECTOR CURRENT:			
Continuous	I_C	3.3	A
Peak		10	A
*CONTINUOUS BASE CURRENT	I_B	1	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		70	W
At case temperatures above 25°C		See Fig. 5	
*TEMPERATURE RANGE:			
Storage and operating (junction)		−65 to 200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from insulating wafer for 10 s max.		230	°C

*In accordance with JEDEC registration data

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C.

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage-V		DC Base Voltage-V	DC Current mA			LIMITS		UNITS
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector-Cutoff Current:	I_{CEV}		60	−1.5				–	10	mA
At T_C = 150°C			60	−1.5				–	10	
With base open	I_{CEO}		30			0		–	5	
With emitter open	I_{CBO}	60						–	10	
* Emitter-Cutoff Current	I_{EBO}			4				–	10	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0		200[a]	65	–	V
* Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0		200[a]	30	–	V
* Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$					0	200[a]	30	–	V
With external base-to-emitter resistance (R_{BE}) = 5 Ω	$V_{CER}(sus)$						200[a]	40	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					10	0	4	–	V
* DC Forward Current Transfer Ratio	h_{FE}		5				3 A	10	100	
			5				1 A	20	–	
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$							–	2.5	°C/W

[a]Pulsed through a 25-mH inductor; duty factor = 50%; repetition rate ≥ 60 Hz.

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC})—V	Input Power (P_{IE})—W	Frequency (f) - MHz	LIMITS: MIN.	MAX.	UNITS
Power Output	P_{OE}	24	3	76	24	–	W
Power Gain	G_{PE}	24	3	76	9	–	dB
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio	$\|h_{fe}\|$	V_{CE} = 15 V, I_C = 1 A		50	2	–	
* Available Amplifier Signal Input Power	P_i	Source impedance (Zg) = 50	P_{OE} = 24 W	76	–	3	W
* Collector Efficiency	η_C	24	3	76	60	–	%
Load Mismatch	LM	24	1.2	30	GO/NO GO VSWR = 3:1		
* Collector-to-Base Capacitance	C_{obo}	V_{CB} = 30 V	–	1	–	85	pF

* In accordance with JEDEC registration data

PERFORMANCE DATA

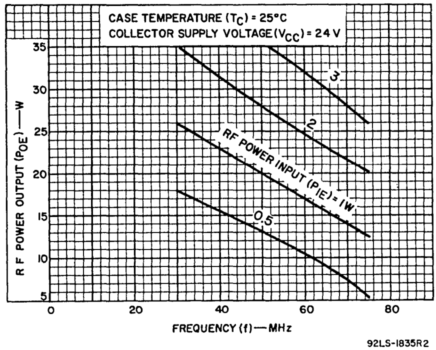


Fig.1—Typical output power vs. frequency.

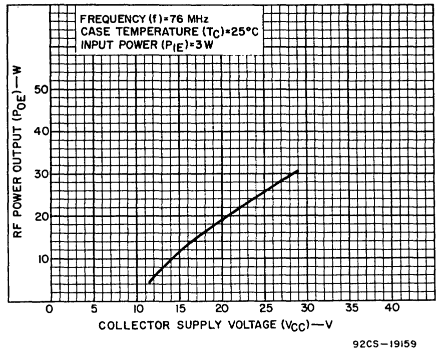


Fig.2—Typical output power vs. collector supply voltage.

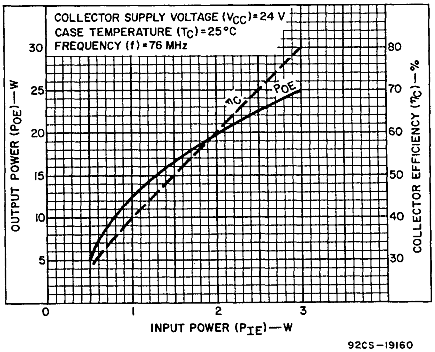


Fig.3—Typical output power or collector efficiency vs. input power at 76 MHz.

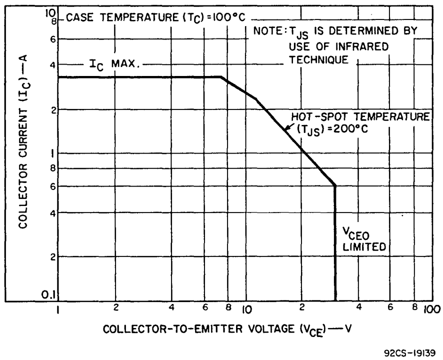


Fig.4—Safe area for dc operation.

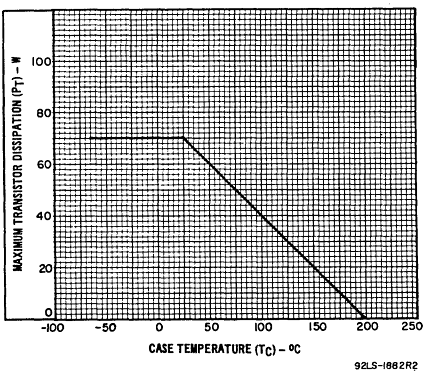


Fig.5—RF Dissipation derating curve.

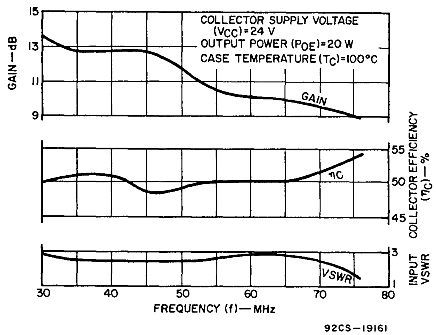


Fig.6—Typical broadband performance of 2N5071.

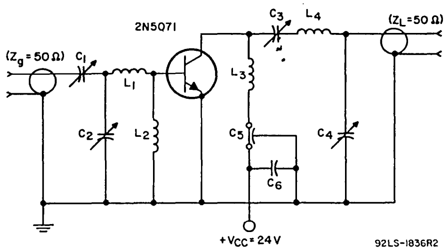


Fig.7—Narrowband rf amplifier circuit for power output test (76-MHz operation).

C_1, C_2: 55-300 pF trimmer capacitor, ARCO 427, or equivalent
C_3, C_4: 32-250 pF trimmer capacitor, ARCO 426, or equivalent
C_5: 1000 pF feedthrough
C_6: 0.1 μF (50V) electrolytic
L_1: 1 turn, No.16 wire, 5/16 in. (7.93 mm) ID
L_2:1 Ferroxcube No.VK200 01-3B, or equivalent
L_3, L_4: 3 turns, No. 10 wire, 5/16 in. (7.93 mm) ID, 1/2 in. (12.7 mm) long

Note: Impedance measurements are made at transistor socket pins.

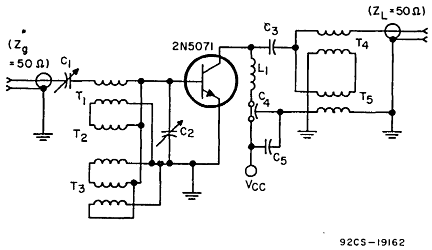


Fig.8—Wideband rf amplifier circuit (30-to-76 MHz).

C_1, C_2: 55-300 pF trimmer capacitor, ARCO 427, or equivalent
C_3, C_5: 0.47 μF ceramic
C_4: 1000 pF feedthrough
L_1: Ferroxcube No.VK200 01-3B, or equivalent
T_1, T_2, T_3: 6 twisted pairs (10 turns/in.) of No. 28 wire connected in parallel. 3 1/2 turns on Indiana General CF-108-Q2 ferrite core, or equivalent.
T_4, T_5: 2 lengths of RE-196A/U cable connected in parallel. 7 turns on Indiana General CF-111-Q1 ferrite core, or equivalent.

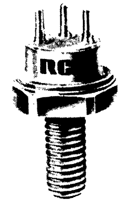
TERMINAL CONNECTIONS

Mounting Stud, Case, Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

RCA Solid State Division

RF Power Transistors

2N5090



JEDEC TO-60 H-1307

High-Power Silicon N-P-N Overlay Transistor

High-Gain Type for Class A, B, or C Operation in VHF/UHF Circuits

Features:

- **Maximum safe-area-of-operation curve**
- **1.2 W (min.) output at 400 MHz (7.8 dB gain)**
- **1.6 W (typ.) output at 175 MHz (12 dB gain)**
- **Hermetic stud-type package**
- **All electrodes isolated from stud**

RCA-2N5090● is an epitaxial silicon n-p-n planar transistor employing the RCA-developed "overlay" emitter-electrode design. It is intended for rf amplifier, frequency-multiplier, and oscillator service in vhf and uhf communications equipment.

The overlay structure contains many isolated emitter sites connected in parallel by means of a diffused grid structure and a deposited metal overlay. The overlay design provides a very high emitter-periphery-to-emitter-area ratio and results in low output capacitance, high rf-current-handling capability, and high power gain.

●Formerly RCA Dev. No.TA7146.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With external base-to-emitter resistance, R_{BE} = 10Ω	V_{CER}	55	V
* With base open	V_{CEO}	30	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	0.4	A
*CONTINUOUS BASE CURRENT	I_B	0.4	A
*TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 100°C		4	W
At case temperatures above 100°C		Derate linearly at 0.04 W/°C	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/16 in. (1.58 mm) from insulating wafer for 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3.

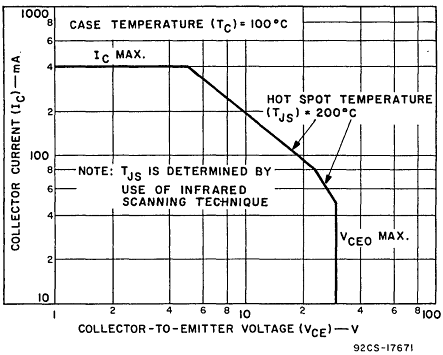


Fig. 1—Safe area for dc operation.

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage-V	DC Base Voltage-V	DC Current mA			LIMITS		UNITS
			V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
*	Collector-Cutoff Current: With base open	I_{CEO}	28			0		–	0.02	mA
	With base-emitter junction reverse-biased	I_{CEV}	55	−1.5				–	0.1	mA
	With base-emitter junction reverse-biased & T_C = 200°C	I_{CEV}	30	−1.5				–	5	mA
*	Emitter-Cutoff Current	I_{EBO}		3.5				–	0.1	mA
	Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	55	–	V
*	Collector-to-Emitter Sustaining Voltage: With base-open	$V_{CEO}(sus)$				0	5	30	–	V
	With external base-to-emitter resistance (R_{BE}) = 10Ω	$V_{CER}(sus)$					5	55[a]	–	V
	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
*	Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				20	100	–	1.0	V
*	DC Forward-Current Transfer Ratio	h_{FE}	5 5				360 50	5 10	– 200	
	Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						–	25	°C/W

[a]Pulsed through a 25-mH inductor; duty factor = 0.05%.

DYNAMIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage V	Output Power (P_{OE}) W	Input Power (P_{IE}) W	Collector Current (I_C) mA	Frequency (f) MHz	LIMITS MIN.	MAX.	UNITS
	Power Output (Class C amplifier, unneutralized) (See Fig. 2)	P_{OE}	V_{CC} = 28		0.2		400	1.2	–	W
	Gain-Bandwidth Product	f_T	V_{CE} = 15			50		500	–	MHz
*	Magnitude of Common Emitter, Small-Signal, Short-Circuit Forward-Current Transfer Ratio	$\|h_{fe}\|$	V_{CE} = 15			50		2.5	–	
*	Available Amplifier Signal Input Power	P_i		1.2			400	–	0.2	W
*	Collector Efficiency	η_C		1.2				45	–	%
*	Collector-to-Base Capacitance	C_{obo}	V_{CB} = 30				1	–	3.5	pF

*In accordance with JEDEC registration data format JS-6 RDF-3.

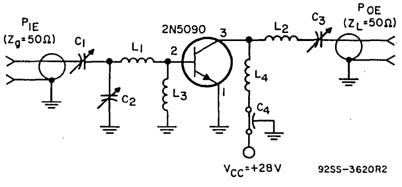


Fig.2–400-MHz rf amplifier for output power test.

C_1: 0.9-7 pF, ARCO 400, or equivalent
C_2, C_3: 1.5-20 pF, ARCO 402, or equivalent
C_4: 1,000 pF, feedthrough type
L_1: 2 turns No.18 wire, ¼ in. (6.35 mm) ID, 1/8 in. (3.17 mm) long
L_2: 3 turns No.16 wire, ¼ in. (6.35 mm) ID, 3/8 in. (9.52 mm) long
L_3: 0.1 μH, RFC
L_4: 2 turns No.18 wire, 1/8 in. (3.17 mm) ID, 1/8 in. (3.17 mm) long

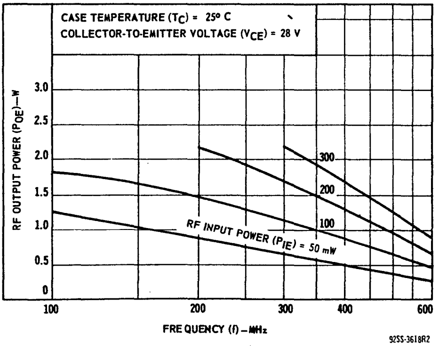


Fig.3—Typical output power vs. frequency.

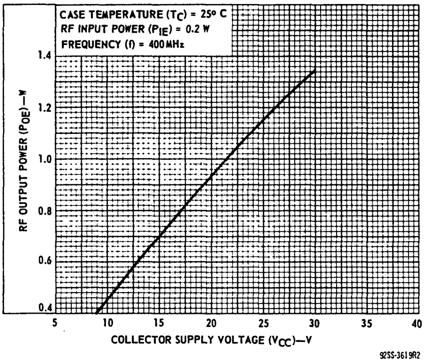


Fig.4—Typical output power vs. collector supply voltage.

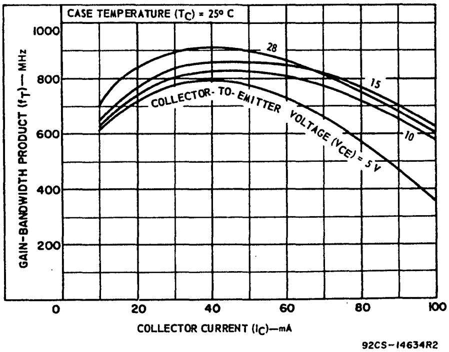


Fig.5—Typical gain-bandwidth product vs. collector current.

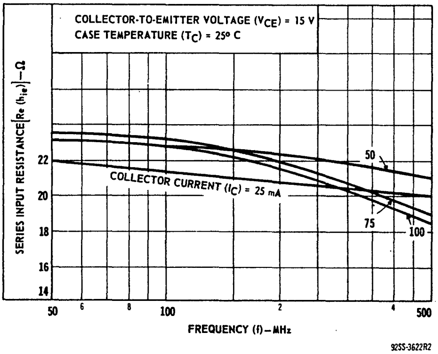


Fig.6—Typical series input resistance vs. frequency.

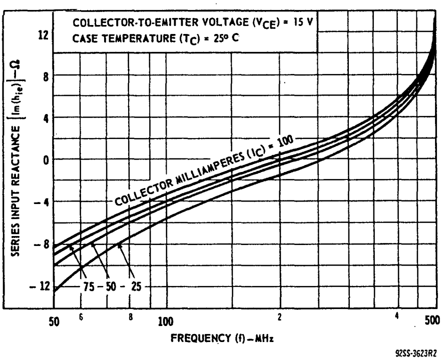


Fig.7—Typical series input reactance vs. frequency.

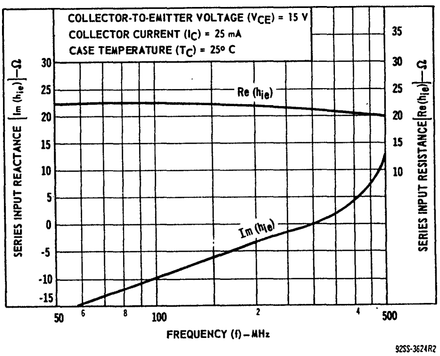


Fig.8—Typical series input resistance and reactance vs. frequency.

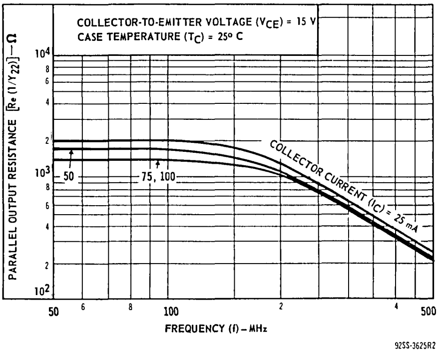


Fig.9—Typical parallel output resistance vs. frequency.

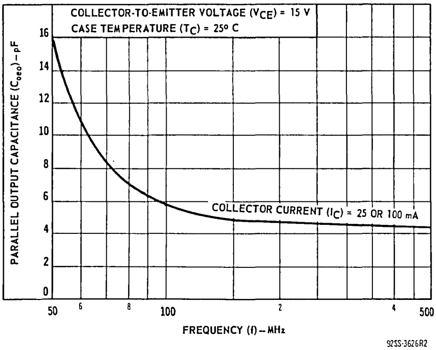


Fig.10—Typical parallel output capacitance vs. frequency.

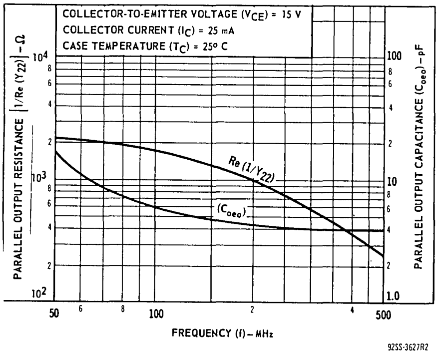


Fig.11—Typical parallel output resistance and capacitance vs. frequency.

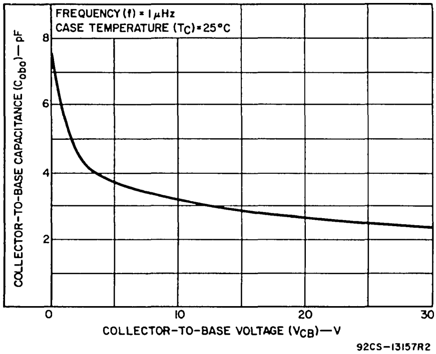


Fig.12—Typical variation of collector-to-base capacitance. with collector-to-base voltage.

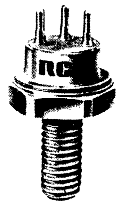
TERMINAL CONNECTIONS

Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector
Case—Isolated

RCA
Solid State
Division

RF Power Transistors

2N5102



JEDEC TO-60 H 1307

High-Power Silicon N-P-N Overlay Transistor

For Class C, AM Operation in VHF Circuits

Features:

- **15 W output min. at 136 MHz**
- **For 24 V aircraft communication**
- **Load mismatch protection**
- **High voltage ratings**
- **Emitter grounded to case**

TERMINAL CONNECTIONS
Case, Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

RCA-2N5102• is an epitaxial silicon n-p-n planar transistor of the overlay emitter-electrode construction. It is especially designed with integral ballast resistors in each emitter site to provide high power as a class C rf amplifier for vhf aircraft communications service (108 to 150 MHz) with amplitude modulation and 24-volt power supply.

The transistor features complete protection against any load mismatch. Each unit is tested at 118 MHz with full modulation and no current limiting for all load-mismatch conditions from short-circuit to open-circuit.

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a common collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain efficiency, frequency capability, and linearity.

•Formerly RCA Dev. No. TA2791

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	90	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction reverse-biased, $V_{BE} = -1.5$ V	V_{CEV}	100	V
*With external base-to-emitter resistance, $R_{BE} = 5\ \Omega$	V_{CER}	50	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*CONTINUOUS COLLECTOR CURRENT	I_C	3.3	A
PEAK COLLECTOR CURRENT		10	A
*CONTINUOUS BASE CURRENT	I_B	1	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		70	W
At case temperatures above 25°C		See Fig. 6	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ⩾ 1/32 in. (0.8 mm) from insulating wafer for 10 s max		230	°C

*In accordance with JEDEC registration data.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C unless otherwise specified*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS						LIMITS		UNITS
		VOLTAGE V dc			CURRENT mA dc					
		V_{CB}	V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector Cutoff Current: With base-emitter junction reverse biased	I_{CEV}		83	−1.5				–	20	mA
* At T_C = 150°C	I_{CEV}		30	−1.5				–	10	mA
With external base-to-emitter resistance (R_{BE}) = 5 Ω	I_{CER}		50					–	10	mA
* Emitter Cutoff Current	I_{EBO}			−4				–	10	mA
* Collector-to-Emitter Sustaining Voltage: With base-emitter junction reverse biased	$V_{CEV}(sus)$			−1.5			600[a]	100	–	V
With external base-to-emitter resistance (R_{BE}) = 5 Ω	$V_{CER}(sus)$						200[a]	50	–	V
With base open	$V_{CEO}(sus)$					0	200[a]	35	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				10		0	4	–	V
* DC Forward Current Transfer Ratio	h_{FE}		4 4				3 A 0.5 A	10 10	– 100	
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit Forward Current Transfer Ratio (f = 150 MHz)	$\|h_{fe}\|$		24				500	1	–	
* Output Capacitance (f = 1 MHz)	C_{ob}	30			0			–	85	pF
* Available Amplifier Signal Input Power[b] (P_o = 15 W, Z_G = 50 Ω, f = 136 MHz)	P_i							–	6	W
* Collector Circuit Efficiency (P_{IE} = 6 W, Z_G = 50 Ω, f = 136 MHz)	η_C							70	–	%
Modulation[c] (f = 118 MHz)	M		24 (V_{CC})					80	–	%
Load Mismatch[d] (f = 118 MHz)	LM		24 (V_{CC})				1100	Will not be damaged		
Dynamic Input Impedance (See Fig. 10) (P_{IE} = 6 W, f = 150 MHz)	Z_{IN}		24 (V_{CC})					1.7 + j 2.6 (typ)		Ω
Thermal Resistance (Junction to Case)	$R_{\theta JC}$							–	2.5	°C/W

*In accordance with JEDEC registration data.

[a]Pulsed through a 9-mH inductor; duty factor = 50%.

[b]Unmodulated carrier.

[c]See Figs. 9 & 10. Carrier Power, P_{CAR}, = 15 W;

$$V_{CC} \text{ modulation} = 100\%;\ M = \sqrt{\frac{2(P_{AM} - P_{CAR})}{P_{CAR}}} \times 100\%.$$

[d]Under conditions of *footnote* **c**, the transistor is subjected to all conditions of load mismatch from short-circuit to open-circuit.

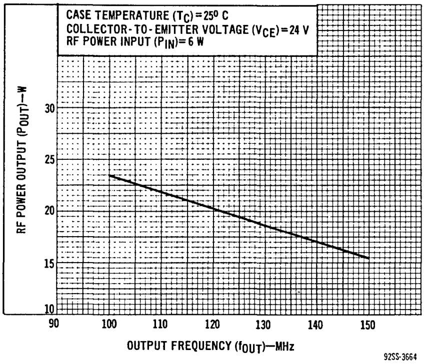


Fig. 1—Typical power output vs. frequency.

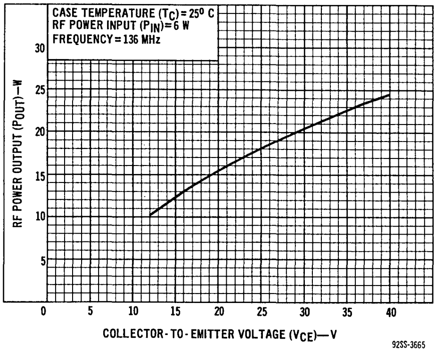


Fig. 2—Typical rf power output vs. collector-to-emitter voltage.

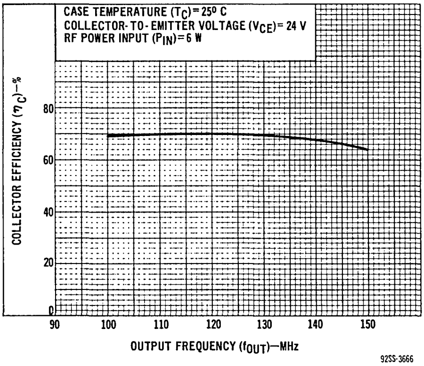


Fig. 4—Typical power output vs. power input.

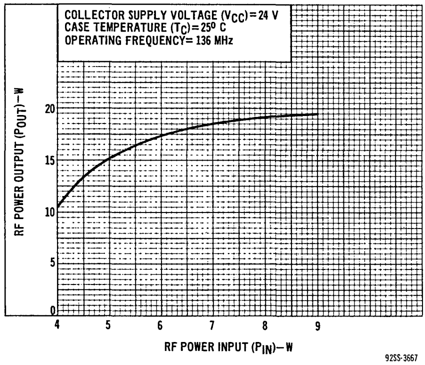


Fig. 3—Typical collector efficiency vs. frequency.

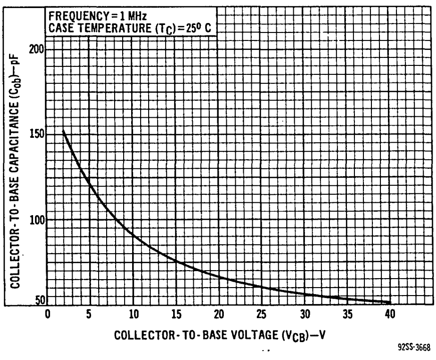


Fig. 5—Typical variation of collector-to-base capacitance.

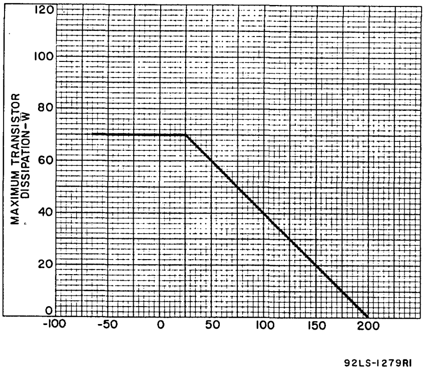
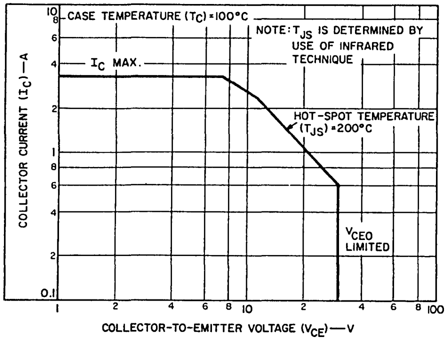
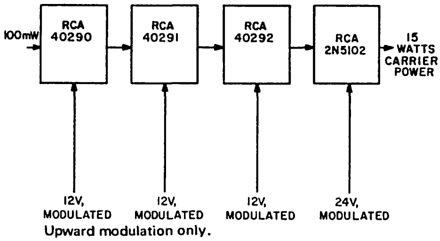


Fig. 6—Dissipation derating curve.



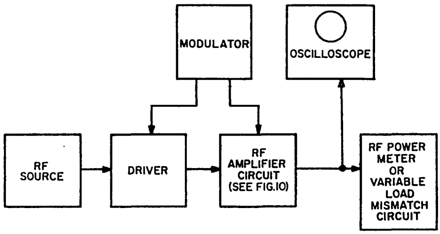
92CS-19139

Fig. 7—Safe operation area with dc forward bias.



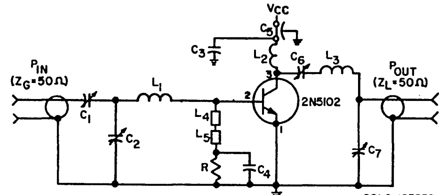
92LS-1277R2

Fig. 8—Block diagram of a typical narrowband aircraft radio transmitter chain.



92LS-1276R2

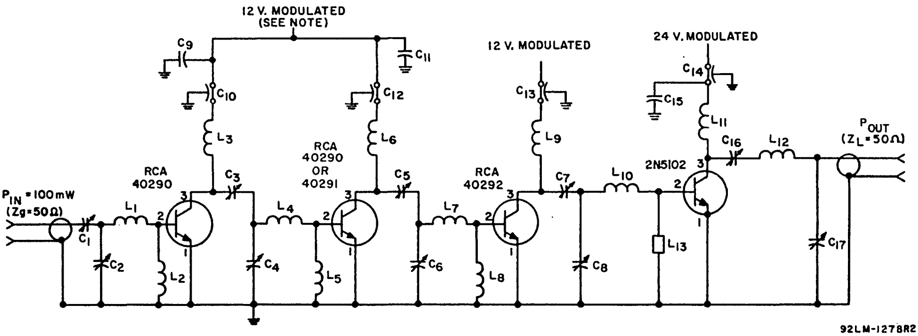
Fig. 9—Block diagram for modulation test.



92LS-1275R2

C_1, C_6:	3-35 pF
C_2, C_7:	7-100 pF
C_3:	0.1 µF
C_4:	0.05 µF
C_5:	1,000 pF
R:	1 Ω wire wound
L_1:	3 1/4 turns, 1/8 in. (3.17 mm) dia. No. 14 wire
L_2:	2 turns, 3/8 in. (9.52 mm) dia. No. 14 wire
L_3:	4 turns, 3/8 in. (9.52 mm) dia. No. 14 wire
L_4, L_5:	350 Ω Ferrite choke, Ferroxcube # VK200 01-3B

Fig., 10—RF amplifier circuit for power output test.



92LM-1278R2

C_1, C_3, C_5, C_7, C_{16}:	3-35 pF
C_2, C_4, C_6, C_8, C_{17}:	8-60 pF
C_9, C_{11}, C_{13}:	0.03 µF
C_{10}, C_{12}, C_{14}:	1,000 pF
C_{15}:	0.1 µF
L_1, L_9:	3 turns, 1/4 in. (6.35 mm) dia., No. 16 wire
L_2, L_5:	Ferrite choke, Z = 450 ohms, Ferroxcube # VK200 01-4B
L_3:	RF choke, 1.5 µH
L_4, L_7:	4 turns, 1/4 in. (6.35 mm) dia., No. 16 wire
L_6:	RF choke, 1.0 µH
L_8:	wire-wound resistor, R = 2.4 ohms
L_{10}:	3 turns, 1/8 in. (3.17 mm) dia., No. 14 wire
L_{11}:	2 turns, 1/2 in. (12.7 mm) dia., No. 16 wire
L_{12}:	4 turns, 1/2 in. (12.7 mm) dia., No. 16 wire
L_{13}:	350 Ω ferrite choke, Ferroxcube # VK200 01-3B

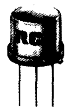
Note: Upward modulation only.

Fig. 11 — Circuit diagram of a typical narrowband aircraft radio transmitter chain.

RCA Solid State Division

RF Power Transistors

2N5109



JEDEC TO-39

H 1381

Silicon N-P-N Overlay Transistor

High Gain for Line Amplifiers in CATV and MATV Equipment

Features:

- **High gain-bandwidth product**
- **Large dynamic range**
- **Low distortion**
- **Low noise**

RCA-2N5109* is an epitaxial silicon n-p-n planar transistor employing "overlay" emitter electrode construction. It is especially designed to provide large dynamic range, low distortion, and low noise as a wideband amplifier into the vhf range.

A high gain-bandwidth product over a wide range of collector current makes the 2N5109 ideally suited for such applications as CATV and MATV line amplifiers and low-noise linear amplifiers.

*Formerly RCA Dev. No. TA2800.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	V
COLLECTOR-TO-EMITTER VOLTAGE:			
* With base open	V_{CEO}	20	V
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	40	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	3	V
* CONTINUOUS COLLECTOR CURRENT	I_C	0.4	A
* CONTINUOUS BASE CURRENT	I_B	0.4	A
* TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		2.5	W
At case temperature above 75°C		See Fig. 10	
* TEMPERATURE RANGE:			
Storage and operating (Junction)		-65 to +200	°C
* LEAD TEMPERATURE (During Soldering):			
At distances ≥ 1/32 in. (0.8 mm) from the seating plane for 10 s max		230	°C

* In accordance with JEDEC registration data

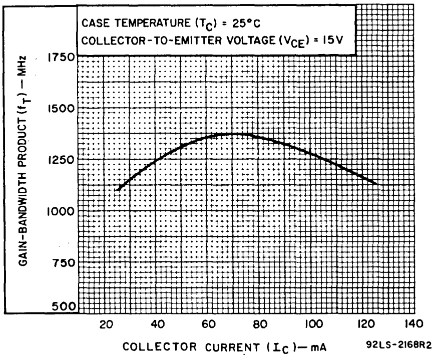


Fig. 1—Gain-bandwidth vs. collector current for type 2N5109.

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C Unless Otherwise Specified

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE – V: V_{CB}	V_{BE}	V_{CE}	DC CURRENT (mA): I_E	I_C	LIMITS: MIN.	MAX.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}			15			–	20	μA
* With base-emitter junction reverse-biased	I_{CEV}		-1.5	35			–	5	mA
* T_C = 150°C			-1.5	15			–	5	mA
* Emitter-Cutoff Current	I_{EBO}		−3				–	0.1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0	0.1	40	–	V
* Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)^a$					5	40	–	V
With base open	$V_{CEO}(sus)$					5	20	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.1	0	3	–	V
Collector-to-Emitter Saturation Voltage (I_B = 10 mA)	$V_{CE}(sat)$					100	–	0.5	V
* Collector-to-Base Capacitance (f = 1 MHz)	C_{cb}	15			0		–	3.5	pF
* DC Forward-Current Transfer Ratio	h_{FE}			15 5		50 360	40 5	120 –	
Small-Signal Common-Emitter Forward Current Transfer Ratio (f = 200 MHz)	h_{fe}			15 15 15		25 50 100	4.8 6 4.8	– – –	
* Magnitude of Common-Emitter Small-Signal Forward Current Transfer Ratio (f = 200 MHz)	$\|h_{fe}\|$			15		50	6	–	
* Available Amplifier Signal Input Power (See Fig. 9) (P_{out} = 1.26 mW, Source Impedance = 50 Ω, f = 200MHz)	P_i	15 (V_{CC})				50	–	0.1	mW
* Voltage Gain, Wideband, 50 to 216 MHz (See Fig. 8.)	G_{VE}			15		50	11		dB
Cross Modulation @ 54 dBmV[b] Output (See Fig. 14.)	CM			15		50	−57 (typ.)		dB
Power Gain, Narrowband (f = 200 MHz, P_{IN} = −10 dBm)	G_{PE}			15		10	11		dB
Noise Figure (f = 200 MHz) (See Fig. 9.)	NF			15		10	3 (typ.)		dB
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						–	50	°C/W

[a]Pulsed through a 25 mH inductor; duty factor = 50%

[b] O dBmV = 1 millivolt.

* In accordance with JEDEC registration data

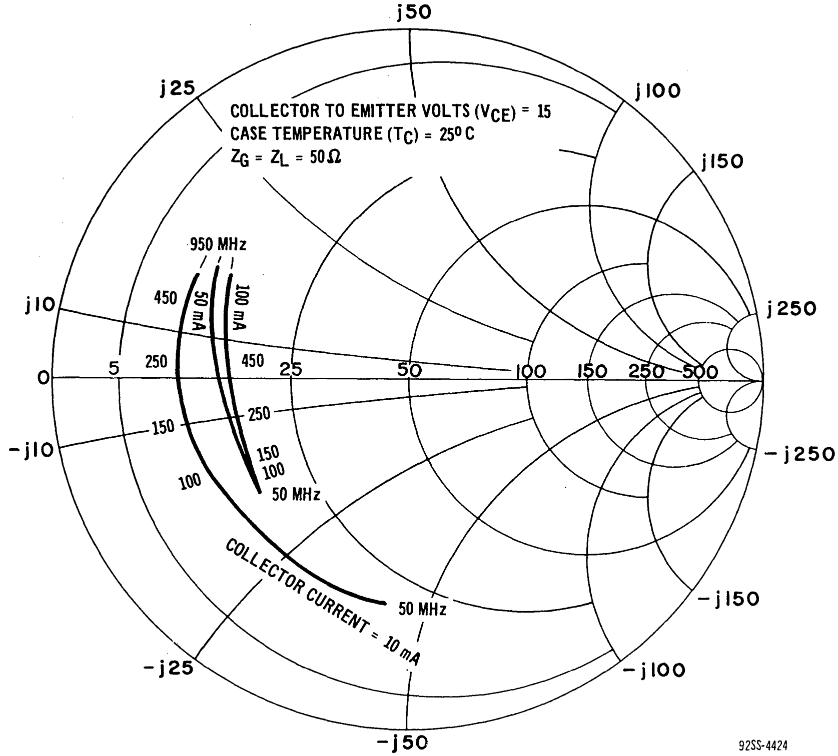


Fig.2—Input reflection coefficient (S_{11e}) vs. frequency for type 2N5109.

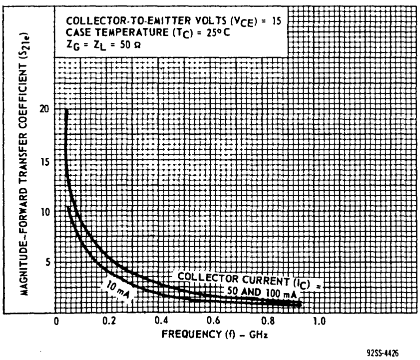


Fig.3—Magnitude of common-emitter forward transfer coefficient (S_{21e}) vs. frequency for type 2N5109.

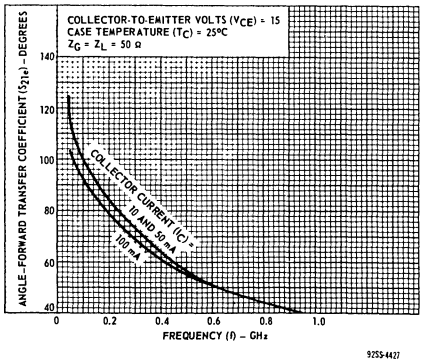


Fig.4—Angle of common-emitter forward transfer coefficient (S_{21e}) vs. frequency for type 2N5109.

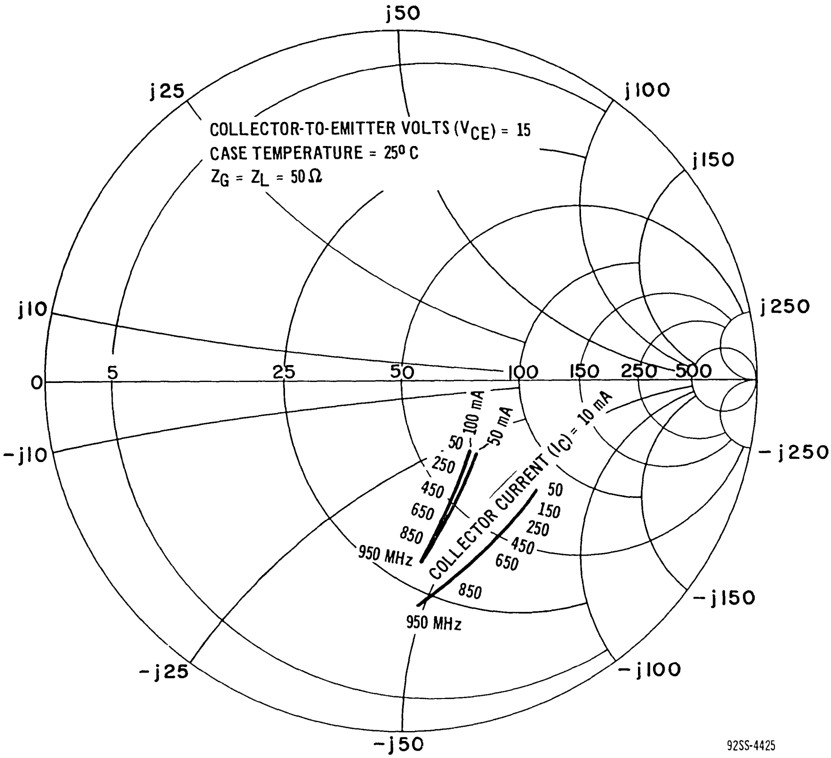


Fig.5—Output reflection coefficient (S_{22e}) vs. frequency for type 2N5109.

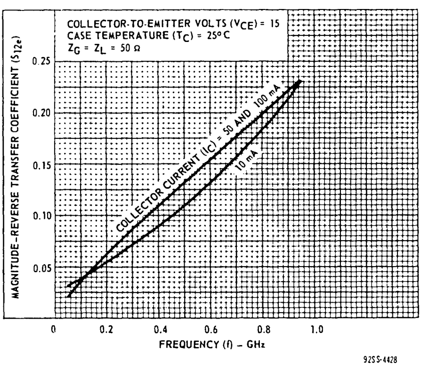


Fig.6—Magnitude of common-emitter, reverse transfer coefficient (S_{12e}) for type 2N5109.

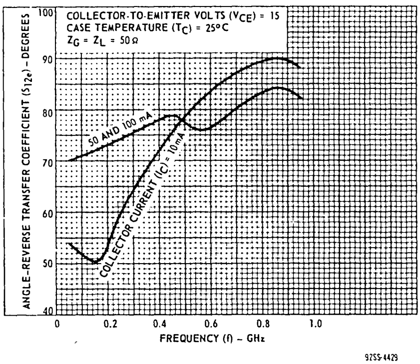
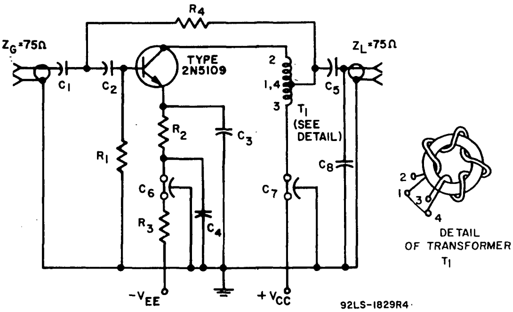
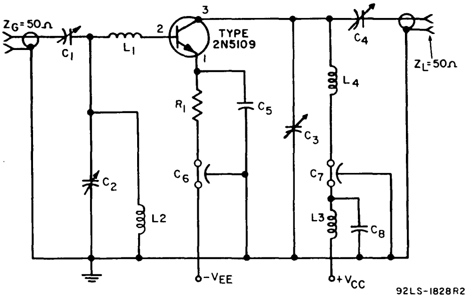


Fig.7—Angle of common-emitter reverse transfer coefficient (S_{12e}) vs. frequency for type 2N5109.



C_1, C_2, C_3, C_5: 0.002 μF
C_4: 0.03 μF
C_6, C_7: 1500 pF
C_8: 18 pF
R_1: 4.7 kΩ, ¼ W
R_2: 6.8 Ω, ½ W
R_3: 330 Ω, 1 W
R_4: 200 Ω, ¼ W
T_1: 4 turns No. 30 wire bifilar wound on "Indiana General" core No. CF-102-Q1, or equivalent.

Fig.8—RF amplifier for voltage-gain testing of type 2N5109.



C_1, C_2, C_3: 1.0–30 pF, mica trimmer, ARCO or equivalent
C_4: 1.0–20 pF disc ceramic
C_5: 10,000 pF disc ceramic
C_6, C_7: 1,000 pF disc ceramic
C_8: 0.01 μF disc ceramic
L_1: 4-1/2 turns, No. 22 wire, 3/16 in. (4.76 mm) I.D.
L_4: 3-1/2 turns, No. 22 wire, 3/16 in. (4.76 mm) I.D.
L_2, L_3: 0.82 μH RFC
R_1: 240 Ω, 2 W, carbon

Fig.9—200-MHz amplifier for power-gain and noise-figure testing of type 2N5109.

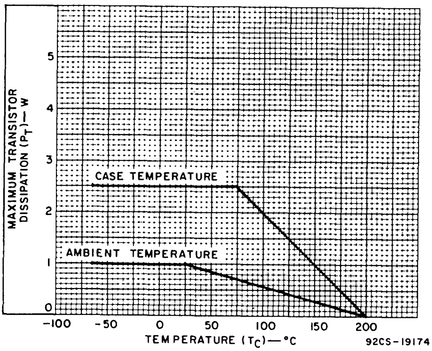


Fig.10—Dissipation derating curve for type 2N5109.

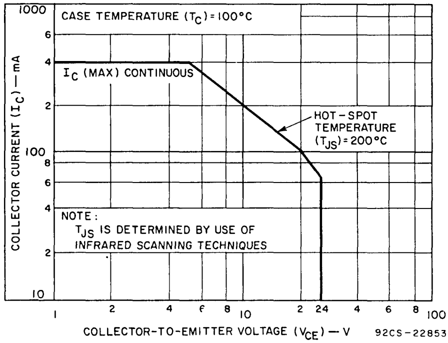


Fig. 11-Maximum operating area for type 2N5109.

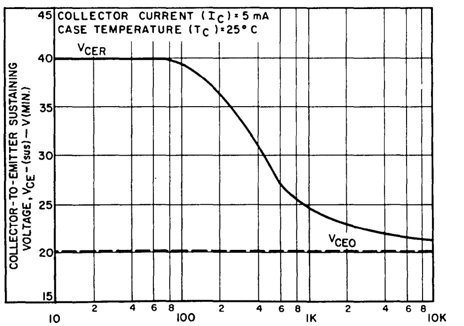


Fig. 12—Sustaining voltage vs. base-to-emitter resistance for type 2N5109.

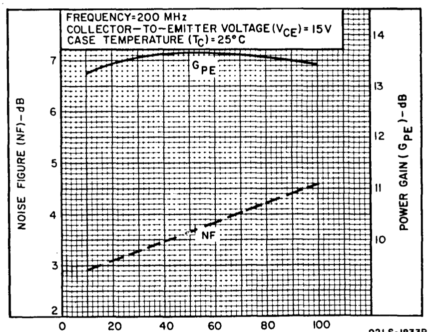
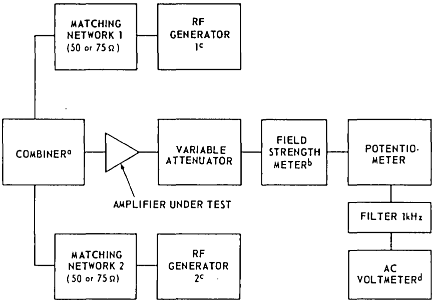


Fig. 13—Power gain and noise figure vs. collector current for type 2N5109.



a Provides 20 db isolation between generators
b 50—220 MHz with detector output
c Hewlett—Packard HP 608 D or equivalent
d Ballantine 861 or equivalent

Fig. 14—Test set-up for measuring cross modulation in type 2N5109.

CROSS-MODULATION TEST PROCEDURE:

1. Set up equipment as shown in Fig. 14.
2. Set generator 1 to 150 MHz modulated 30% by 1,000 Hertz, and tune field strength meter to 150 MHz.
3. Adjust output level of generator 1 to give rated output from the amplifier under test.
4. Adjust potentiometer and AC voltmeter for a convenient level. This level then corresponds to 100% cross modulation.
5. Remove modulation. Readjust output level of generator 1 if necessary, to obtain the AC voltmeter "100% level". Do not readjust generator 1 during the following steps.
6. Set generator 2 to 210 MHz modulated 30% by 1,000 Hertz and tune field strength meter to 210 MHz.
7. Adjust output level of generator 2 to give rated output of the amplifier; i.e., the AC voltmeter indicates the " 100% level".
8. Tune field strength meter to 150 MHz CW and read the AC voltmeter (a change of the AC voltmeter scale may be necessary).
9. Calculate percentage of cross modulation by comparing the reading of step 8 to the "100% level".

TERMINAL CONNECTIONS

Lead No.1 — Emitter
Lead No.2 — Base
Lead No.3 — Collector
Case — Collector

RCA
Solid State Division

RF Power Transistors

2N5179

RCA-2N5179* is a double-diffused epitaxial planar transistor of the silicon n-p-n type. It is extremely useful in low-noise tuned-amplifier and converter applications at UHF frequencies, and as an oscillator up to 500 MHz.

The 2N5179 utilizes a hermetically sealed four-lead JEDEC TO-72 package. All active elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead in applications requiring minimum feedback capacitance, shielding of the device, or both.

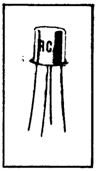
* Formerly Dev. No. TA7319.

Maximum Ratings, Absolute-Maximum Values:

COLLECTOR-TO-BASE VOLTAGE, V_{CBO}	20 max.	V
COLLECTOR-TO-EMITTER VOLTAGE, V_{CEO}	12 max.	V
EMITTER-TO-BASE VOLTAGE, V_{EBO}	2.5 max.	V
COLLECTOR CURRENT, I_C	50 max.	mA
TRANSISTOR DISSIPATION, P_T:		
For operation with heat sink:		
At case temperatures** up to 25°C	300 max.	mW
At case temperatures** above 25°C	Derate at 1.71mW/°C	
For operation at ambient temperatures:		
At ambient temperatures up to 25°C	200 max.	mW
At ambient temperatures above 25°C	Derate at 1.14mW/°C	
TEMPERATURE RANGE:		
Storage and Operating (Junction)	−65 to +200	°C
LEAD TEMPERATURE (During Soldering):		
At distances ≥ 1/32" from seating surface for 10 seconds max.	265 max.	°C

** Measured at center of seating surface.

SILICON N-P-N EPITAXIAL PLANAR TRANSISTOR



JEDEC TO-72

For UHF Applications in Military, Communications, and Industrial Equipment

- high gain-bandwidth product — 1000MHz min.
- hermetically sealed TO-72 four-lead metal package
- low leakage current
- high power gain as neutralized amplifier — G_{pe} = 15dB min. at 200MHz
- high power output as UHF oscillator — 20mW typ. at 500MHz
- low noise figure — NF = 4.5dB max. at 200MHz
- low collector-to-base time constant — $r_b'C_c$ = 14ps max.
- high reliability — production lots of RCA-2N5179 are subjected to and meet the minimum mechanical, environmental, and life-test requirements of the basic MILITARY specification MIL-S-19500. See page 5 for a description of the Group A and Group B Tests.

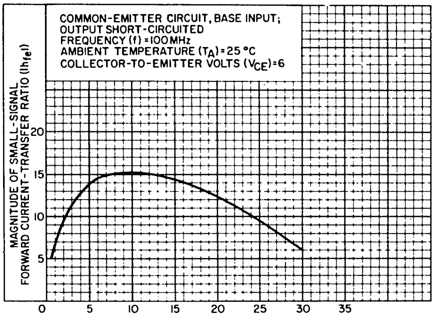


Fig. 1 – Small-Signal Beta Characteristic for Type 2N5179

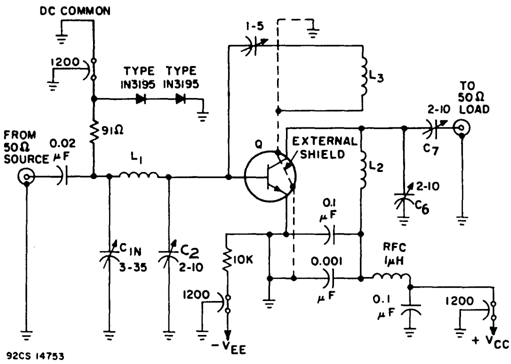
ELECTRICAL CHARACTERISTICS, *At Ambient Temperature (T_A) = 25°C Unless Otherwise Specified*

Characteristics	Symbols	TEST CONDITIONS						LIMITS			Units
		Frequency f	DC Collector-to-Base Voltage V_{CB}	DC Collector-to-Emitter Voltage V_{CE}	DC Emitter Current I_E	DC Collector Current I_C	DC Base Current I_B	Type 2N5179			
		MHz	V	V	mA	mA	mA	Min.	Typ.	Max.	
Collector-Cutoff Current	I_{CBO}		15		0			-	-	0.02	µA
At T_A = 150°C			15		0			-	-	1	µA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0	0.001		20	-	-	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$					3	0	12	-	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				−0.01	0		2.5	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$					10	1	-	-	0.4	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$					10	1	-	-	1	V
Static Forward Current-Transfer Ratio	h_{FE}			1		3		25	70	250	
Magnitude of Small-Signal Forward Current-Transfer Ratio[a]	$\|h_{fe}\|$	100		6		5		9	14	20	
		1 kHz		6		2		25	90	300	
Collector-to-Base Feedback Capacitance[b]	C_{cb}	0.1 to 1	10		0			-	0.7	1	pF
Common-Base Input Capacitance[c] (V_{EB}= 0.5V)	C_{ib}	0.1 to 1				0		-	-	2	pF
Collector-to-Base Time Constant[a]	$r_b'C_c$	31.9	6			2		3	7	14	ps
Small-Signal Power Gain in Neutralized Common-Emitter Amplifier Circuit[a] (See Fig. 2)	G_{pe}	200		12		5		15	21	-	dB
Power Output in Common-Emitter Oscilator Circuit[c] (See Fig. 3)	P_o	>500	10		-12			20	-	-	mW
Noise Figure[a]	NF	200		6		1.5		-	3	4.5	dB

[a] Lead No.4(case) grounded; R_g = 125Ω

[b] Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

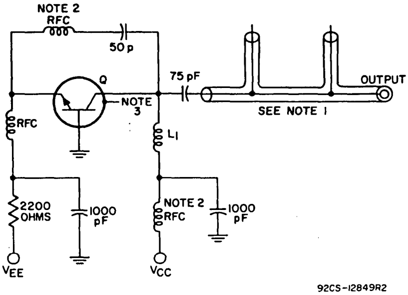
[c] Lead No. 4 (case) floating.



NOTE: (Neutralization Procedure): (a) Connect a 50-Ω rf voltmeter to the output of a 200-MHz signal generator (R_g = 50Ω), and adjust the generator output to 5mV. (b) Connect the generator to the input and the rf voltmeter to the output of the amplifier, as shown above. (c) Apply V_{EE} and V_{CC}, and adjust the generator output to provide an amplifier output of 5mV. (d) Tune C_2, C_6, and C_7 for maximum amplifier output, readjusting the generator output, as required, to maintain an output of 5mV from the amplifier. (e) Interchange the connections to the signal generator and the rf voltmeter. (f) With sufficient signal applied to the output terminals of the amplifier, adjust C_N for a minimum indication at the amplifier input. (g) Repeat steps (a), (b), (c), and (d) to determine if retuning is necessary.

Q = Type 2N5179

Fig. 2 – Neutralized Amplifier Circuit Used to Measure Power Gain and Noise Figure at 200MHz for Type 2N5179



Note 1 — Coaxial-Line output network consisting of:

- 2 General Radio Type 874 TEE or equivalent
- 1 General Radio Type 874-D20 Adjustable Stub or equivalent
- 1 General Radio Type 874-LA Adjustable Line or equivalent
- 1 General Radio Type 874-WN3 Short-circuit termination or equivalent

Note 2 — RFC = 0.2μH Ohmite #2-460 or equivalent

Note 3 — Lead Number 4 (case) floating

L_1 — 2 turns #16AWG wire, 3/8 inch OD, 1¼ inch long

Q = 2N5179

Fig. 3 – Circuit Used to Measure 500MHz Oscillator Power Output for Type 2N5179

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF COLLECTOR CURRENT (I_C) FOR RCA TYPE 2N5179

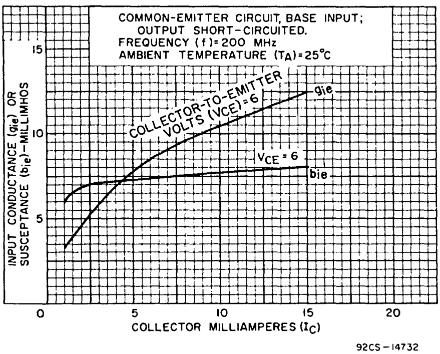


Fig. 4 – Input Admittance (y_{ie})

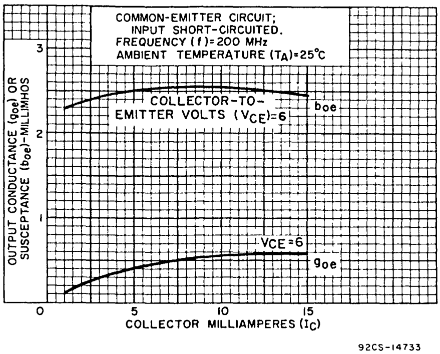


Fig. 5 – Output Admittance (y_{oe})

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF COLLECTOR CURRENT (I_C) FOR RCA TYPE 2N5179

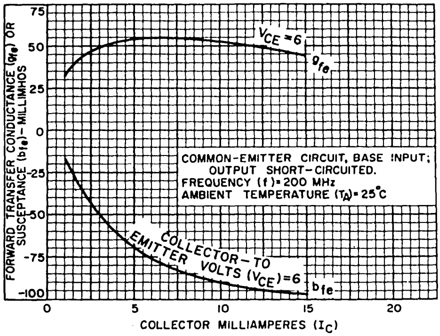


Fig. 6 – Forward Transadmittance (y_{fe})

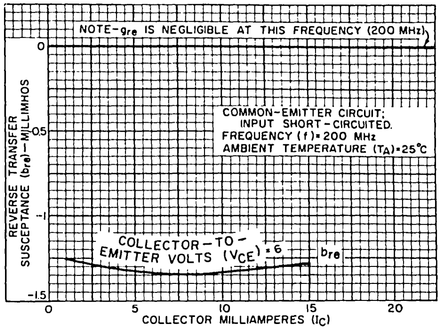


Fig. 7 – Reverse Transadmittance (y_{re})

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF FREQUENCY (f) FOR RCA TYPE 2N5179

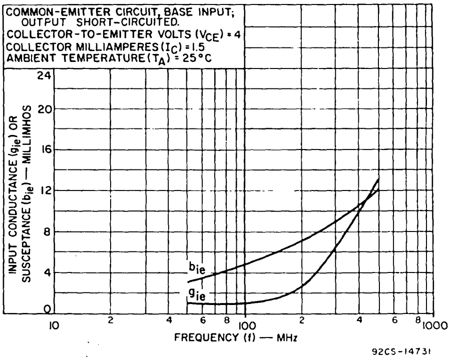


Fig. 8 – Input Admittance (y_{ie})

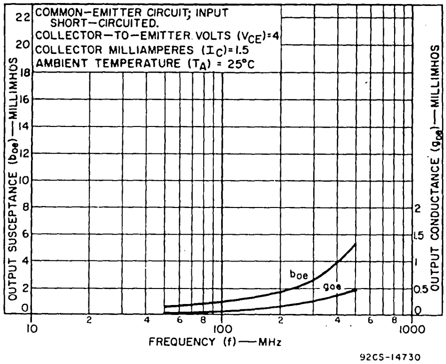


Fig. 9 – Output Admittance (y_{oe})

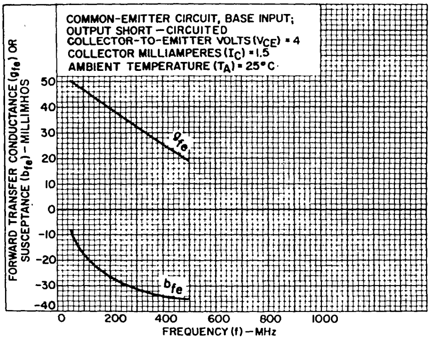


Fig. 10 – Forward Transadmittance (y_{fe})

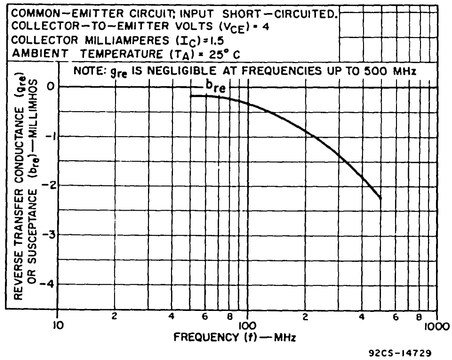
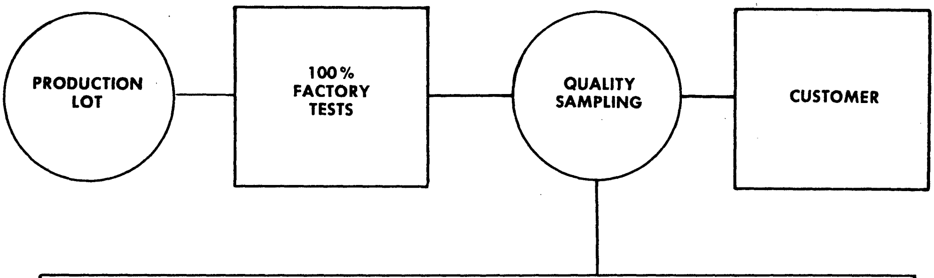


Fig. 11 – Reverse Transadmittance (y_{re})

GROUP A AND GROUP B QUALITY SAMPLING TESTS



ITEM	TEST DESCRIPTION	LTPD
GROUP A TESTS		
Subgroup 1.	Visual and Mechanical Examination	5%
Subgroup 2.	Electrical	10%
GROUP B TESTS		
Subgroup 1.	Physical Dimensions	20%
Subgroup 2.	Solderability, Temperature Cycling, Thermal Shock, Moisture Resistance	20%
Subgroup 3.	Shock, Vibration Fatigue, Vibration Variable Frequency, Constant Acceleration	20%
Subgroup 4.	Terminal Strength	20%
Subgroup 5.	Salt Atmosphere	20%
Subgroup 6.	High-Temperature Life, Non-Operating (T_A = 200°C)	λ = 10%
Subgroup 7.	Steady-State-Operation Life (P_D = 300mW, T_A = 25°C)	λ = 10%

TERMINAL CONNECTIONS

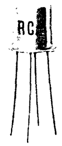
LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR
LEAD 4 – CONNECTED TO CASE

RCA

Solid State
Division

RF Power Transistors

2N5180



JEDEC TO-72 H-1299

Silicon N-P-N Epitaxial Planar Transistor

For VHF Applications in
Industrial and Commercial Equipment

Features:

- High gain-bandwidth product
- Low noise figure
- High unneutralized power gain
- Hermetically sealed four-lead metal package
- All active elements insulated from case
- Low collector-to-base feedback

RCA-2N5180* is an epitaxial planar transistor of the silicon n-p-n type with characteristics which make it extremely useful as a general-purpose RF amplifier at vhf frequencies. These characteristics include an exceptionally low noise figure at high frequencies, low leakage current, and a high gain-bandwidth product.

The 2N5180 utilizes a hermetically sealed four-lead metal package in which all active elements of the transistor are insulated from the case. The case may be grounded by means of a fourth lead in applications requiring minimum feedback capacitance, shielding of the device, or both.

* Formerly Dev. No. TA7303.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	30	V
*COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}	15	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	2	V
*CONTINUOUS COLLECTOR CURRENT	I_C	limited by dissipation	
*TRANSISTOR DISSIPATION:	P_T		
At ambient temperatures up to 25°C		180	mW
At ambient temperatures above 25°C		See Fig.2	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 175	°C
*LEAD TEMPERATURE (During Soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		265	°C

* In accordance with JEDEC registration data format JS-9 RDF-1.

ELECTRICAL CHARACTERISTICS, at T_A = 25°C

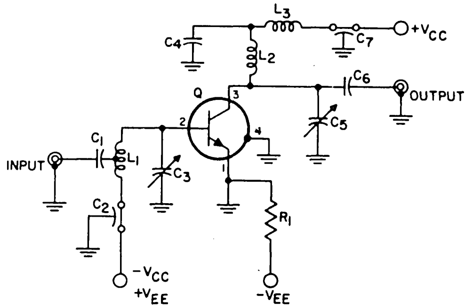
	Characteristics	Symbols	Frequency f	DC Collector-to-Base Voltage V_{CB}	DC Collector-to-Emitter Voltage V_{CE}	DC Emitter Current I_E	DC Collector Current I_C	LIMITS Type 2N5180 Min.	Typ.	Max.	Units
			MHz	V	V	mA	mA	Min.	Typ.	Max.	
*	Collector-Cutoff Current	I_{CBO}		8		0		-	-	0.5	μA
*	Collector-to-Base Breakdown Voltage	BV_{CBO}				0	0.001	30	-	-	V
*	Collector-to-Emitter Breakdown Voltage	BV_{CEO}					0.001	15	-	-	V
*	Emitter-to-Base Breakdown Voltage	BV_{EBO}				-0.001	0	2	-	-	V
*	Static Forward-Current Transfer Ratio	h_{FE}			8		2	20	-	200	
*	Magnitude of Small-Signal Forward-Current Transfer Ratio	$\|h_{fe}\|$[a]	100		8		2	6.5	9	17	
*	Collector-to-Base Feedback Capacitance	C_{cb}[b]	0.1 to 1	8		0		-	-	1	pF
*	Small-Signal, Common-Emitter Power Gain in Unneutralized Amplifier Circuit (See Fig. 1)	G_{PE}[a]	200		10		2	12	-	19	dB
	VHF Noise Figure (See Fig. 1)	NF[a] NF[a,c]	200 60		8 8		2 1	- -	- 2.5	4.5	dB dB
*	Collector-Base Time Constant	$r_{b'}C_c$	31.9	8		-2		2	–	16	ps
*	Real Part of Common-Emitter Small-Signal Short-Circuit Input Impedance	$R_e(h_{ie})$	200		10		2	60	–	240	Ω
*	Bandwidth	BW	200		10		2	650	–	1700	MHz

[a]Fourth lead (case) grounded.

[b]C_{cb} is a three terminal measurement of the collector-to-base capacitance with the emitter and case connected to the guard terminal.

[c]Source Resistance, R_s=400 ohms.

* In accordance with JEDEC registration data format JS-9 RDF-1.

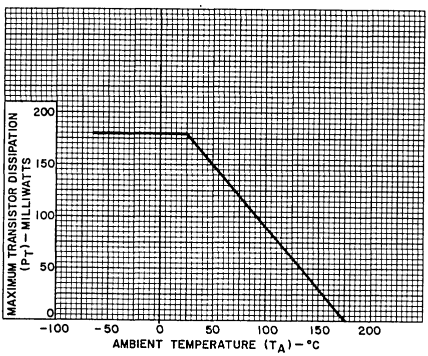


92CS-12753

C_1, C_4 = 510pF
C_2, C_7 = 2300pF
C_3, C_5 = 2-25pF
C_6 = 10pF
R_1 = 2000 ohms
Q = 2N5180
L_1 = ½ Turn #14 Formvar● center tapped; length = 2 inches

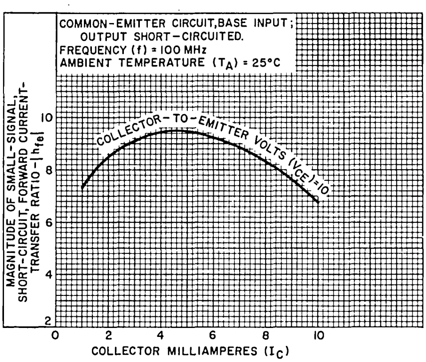
L_2 = ½ Turn #14 Formvar●; length = 1½ inches
L_3 = 1μH RF choke
Source (Generator) Resistance R_S = 50 ohms
Load Resistance R_L = 50 ohms
● Trademark, Shawinidan Products Corporation.

Fig.1 — 200 MHz power gain and noise figure test circuit for type 2N5180



92CS 14777

Fig.2 — Rating chart for type 2N5180



92CS-14785

Fig.3 — Typical small-signal beta characteristics for type 2N5180

TYPICAL y PARAMETER CHARACTERISTICS

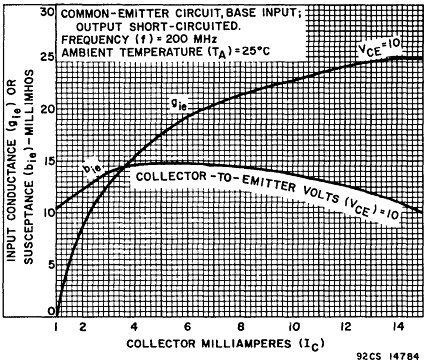


Fig.4 – Input admittance (y_{ie}) vs collector current (I_C)

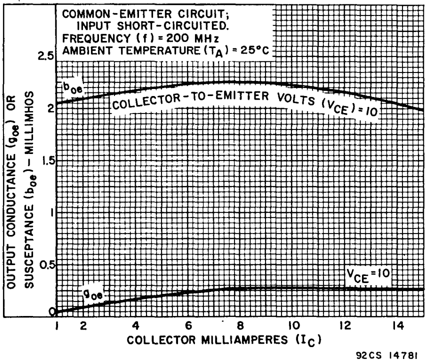


Fig.5 – Output admittance (y_{oe}) vs collector current (I_C)

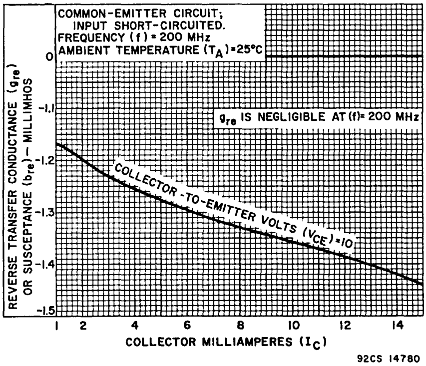


Fig.6 – Reverse transadmittance (y_{re}) vs collector current (I_C)

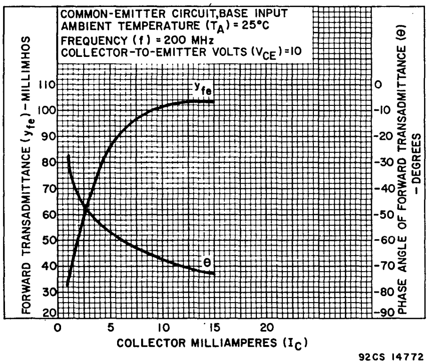


Fig.7 – Forward transadmittance (y_{ie}, $\angle\theta$) vs collector current (I_C)

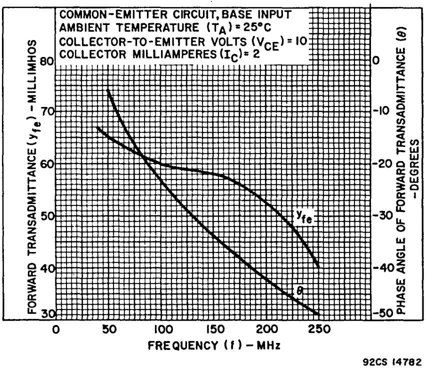


Fig.8 – Forward transadmittance (y_{ie}, $\angle\theta$) vs. frequency (f)

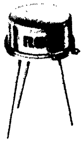
TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector
Lead 4 – Connected to case

RCA
Solid State
Division

RF Power Transistors

2N5189



Low-profile TO-39

H-1546

High-Voltage Silicon N-P-N Switching Transistor

For Core-Driver and Line-Driver Service in Data-Processing Equipment and Other Critical Industrial and Military Applications

Features:

- **Excellent power handling capability**
- **High switching speeds at high currents**
- **High breakdown-voltage capabilities**
- **High reliability**

TERMINAL CONNECTIONS

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

RCA-2N5189● is a double-diffused epitaxial planar transistor of the silicon n-p-n type featuring high breakdown voltages, low saturation voltages, and high switching speeds over a wide range of collector current.

It is especially useful in switching applications of high-performance computers and in other critical industrial applications where high-voltage and high-current-handling capabilities and short "turn-off" and "turn-on" times are important design features. These features also make the 2N5189 particularly useful in class C circuits for mobile and portable equipment.

The 2N5189 is hermetically sealed in a metal package like the JEDEC TO-39 but with a reduced height (0.180 in. max., 0.160 in. min.) and 0.5 in. min. leads.

●Formerly RCA Dev. No. TA7322.

MAXIMUM RATINGS, *Absolute Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	V
COLLECTOR-TO-EMITTER VOLTAGE:			
* With base shorted to emitter	V_{CES}	55	V
With base open	V_{CEO}	35	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	2	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		5	W
At case temperatures above 25°C, derate linearly		28.5	mW/°C
* At ambient temperatures up to 25°C		0.8	W
* At ambient temperatures above 25°C, derate linearly		4.57	mW/°C
*TEMPERATURE RANGE:			
Storage and operating (Junction)		–65 to +200	°C
*LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		265	°C

* In accordance with JEDEC registration data format JS-8/RDF-7.

ELECTRICAL CHARACTERISTICS, *At Ambient Temperature (T_A) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS VOLTAGE V dc V_{CB}	TEST CONDITIONS VOLTAGE V dc V_{CE}	TEST CONDITIONS CURRENT A dc I_C	TEST CONDITIONS CURRENT A dc I_B	LIMITS 2N5189 MIN.	LIMITS 2N5189 MAX.	UNITS
*Collector Cutoff Current: With emitter open	I_{CBO}	60				–	100	μA
With emitter-base junction shorted	I_{CES}		55			–	100	μA
*Emitter Cutoff Current (V_{EB}=5V)	I_{EBO}			0		–	10	μA
*Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$			0.01		35	–	V
*Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			1[a]	0.1	–	1	V
*Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$			1[a]	0.1	–	1.5	V
*DC Forward Current Transfer Ratio	h_{FE}		1 1 1	0.1[a] 0.5[a] 1[b]		30 35 15	– – –	
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 100 MHz)	h_{fe}		10	0.05		2.5	–	
Common-Base, Open-Circuit Output Capacitance (f = 1 MHz)	C_{ob}	10				–	15	pF
*Switching Time (I_{B1}=0.1 A):				I_C	I_{B2}			
Turn-on ($t_d + t_r$)	t_{ON}			1	–	–	40	ns
Turn-off ($t_s + t_f$)	t_{OFF}			1	−0.1	–	70	ns

*In accordance with JEDEC registration data format JS-8/RDF-7.

[a]Pulsed: Pulse duration = 300 μs; duty factor ≤ 2%.

[b]Pulsed: Pulse duration ≤ 400 μs; duty factor ≤ 0.03.

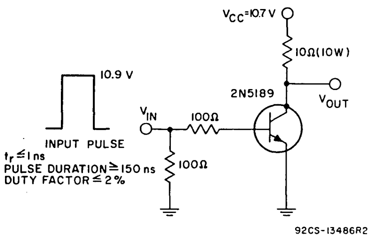


Fig. 1—Circuit used to measure turn-on time.

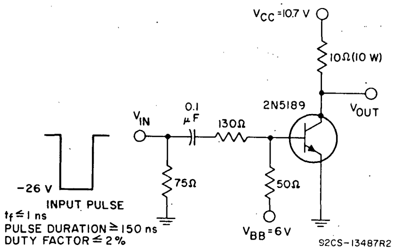


Fig. 2—Circuit used to measure turn-off time.

TYPICAL CHARACTERISTICS

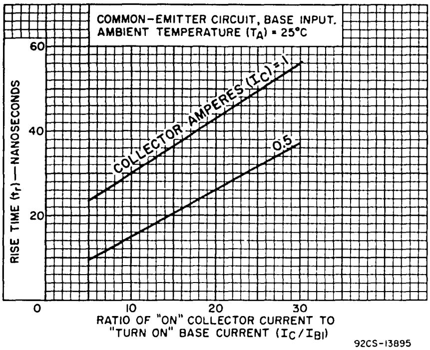


Fig. 3 – Rise Time vs I_C/I_{B1}

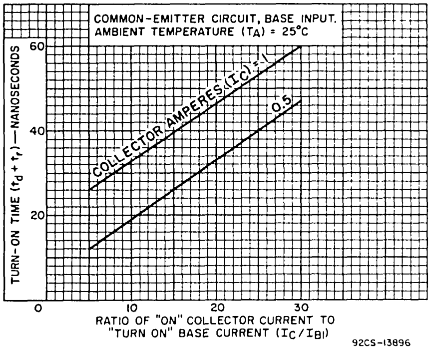


Fig. 4 – Turn-On Time vs I_C/I_{B1}

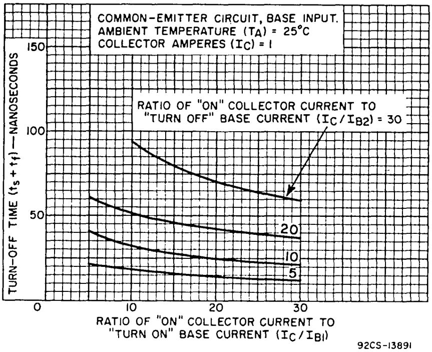


Fig. 5 – Turn-Off Time vs I_C/I_{B1}

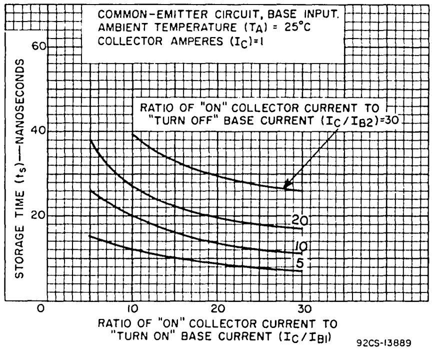


Fig. 6 – Storage Time vs I_C/I_{B1}

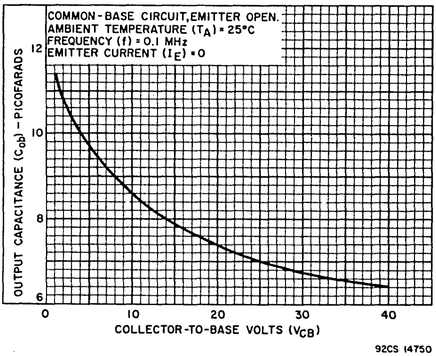


Fig. 7 – Output Capacitance vs Collector-to-Base Voltage

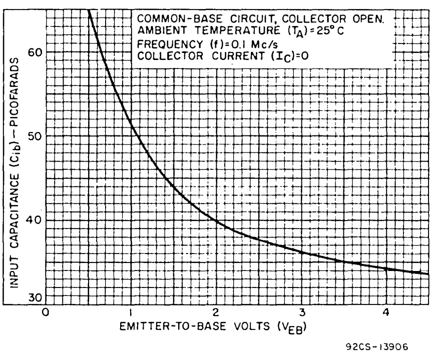


Fig. 8 – Input Capacitance vs Emitter-to-Base Voltage

TYPICAL CHARACTERISTICS

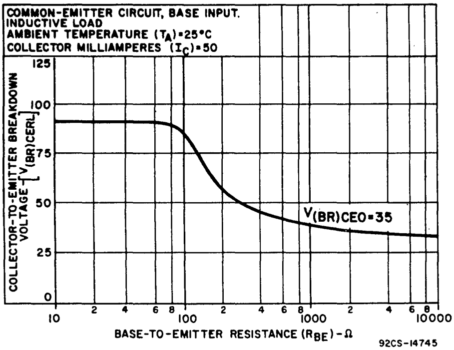


Fig. 9 – Collector-Cutoff Current vs Ambient Temperature

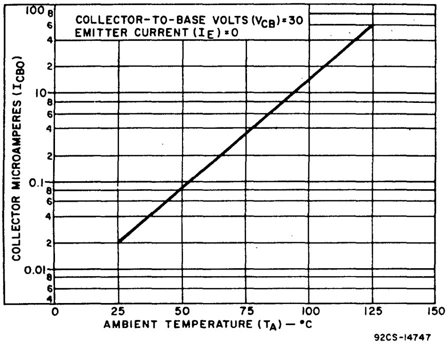


Fig. 10 – Collector-to-Emitter Breakdown Voltage vs Base-to-Emitter Resistance

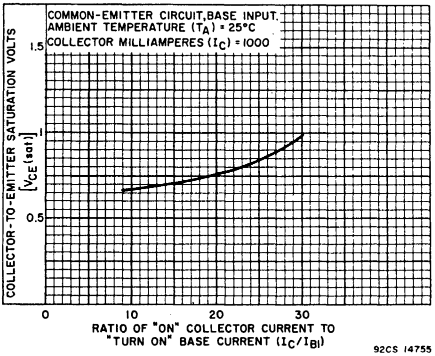


Fig. 11 – Collector-to-Emitter Saturation Voltage vs I_C/I_{B1}

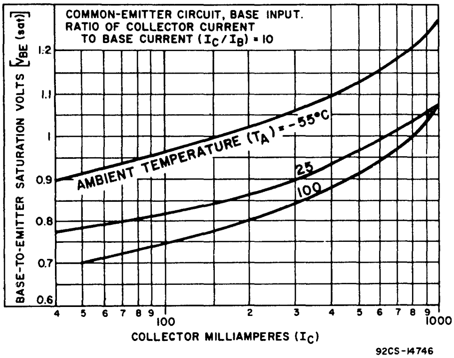


Fig. 12 – Base-to-Emitter Saturation Voltage vs I_C

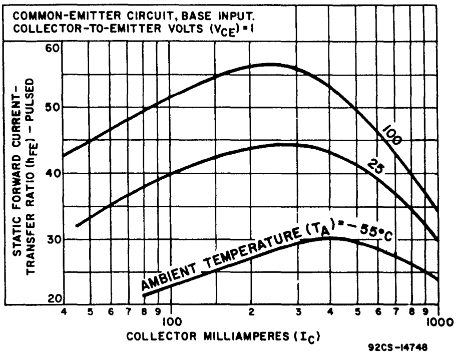


Fig. 13 – Static Forward Current-Transfer Ratio (Pulsed) vs I_C

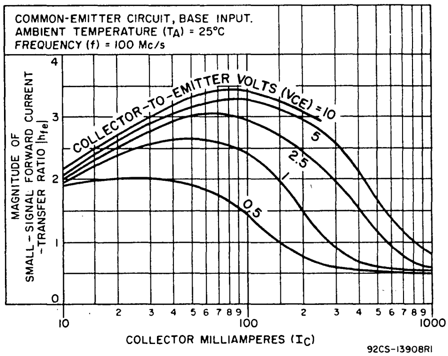
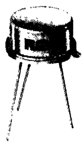


Fig. 14 – Small-Signal Forward Current-Transfei Ratio vs I_C

RCA
Solid State
Division

Power Transistors

2N5262



"Low-Profile TO-39"

H-1546

Silicon N-P-N High-Speed Switching Transistor

For Memory-Driver Service in Data-Processing Equipment and Other Critical Industrial Applications

Features:

- Fast switching at 1A:
  t_{on} = 30 ns max.
  t_{off} = 60 ns max.
- High voltage ratings
- High power dissipation ratings
- High dc beta at 1A – 25 min.
- Low saturation voltage at 1 A:
  0.5 V typ.
- Maximum-area-of-operation curves for dc and pulse operation
- Hermetic "low-profile TO-39" package
- Meets MIL-S-19500 specifications

RCA-2N5262● is a silicon n-p-n, epitaxial planar transistor with characteristics which make it exceptionally desirable for high-speed, high-voltage, high-current switching applications. In addition, the 2N5262 features very short turn-on and turn-off times and low saturation voltages. It is also controlled for freedom from second breakdown under both forward-bias and reverse-bias conditions, when operated within specified maximum ratings.

The 2N5262 meets the requirements of the basic military specification MIL-S-19500, and is hermetically sealed in a metal "low-profile JEDEC TO-39" package.

RCA-2N5262 is primarily intended for use as a driver for "2-1/2D" coincident-current and word-organized magnetic-memory systems, and in the other critical industrial applications requiring switching of large currents through inductive loads.

● Formerly RCA Dev. No. TA7238.

Maximum Ratings, *Absolute-Maximum Values*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	75	V
* COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	50	V
With emitter-base shorted	V_{CES}	60	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	5	V
COLLECTOR CURRENT:			
* Continuous		2	A
Instantaneous (See Fig.4)		3	A
* TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		4	W
At case temperatures above 25°C		Derate linearly 22.8 mW/°C	
At ambient temperatures up to 25°C		0.8	W
At ambient temperatures above 25°C		Derate linearly 4.57 mW/°C	
* TEMPERATURE RANGE:			
Storage and operating (Junction)		−65 to 200	°C
* LEAD TEMPERATURE (During soldering):			
At distance ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max		265	°C

* In accordance with JEDEC registration data format JS-8/RDF-7.

ELECTRICAL CHARACTERISTICS, *At Ambient Temperature (T_A) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc V_{CE}	V_{CB}	CURRENT A dc I_C	I_E	I_B	LIMITS 2N5262 MIN.	MAX.	UNITS
* Collector Cutoff Current: With emitter-to-base junction shorted	I_{CES}	60					–	10	μA
With emitter open	I_{CBO}		75				–	100	μA
* Emitter-to-Base Cutoff Current (V_{EB} = 5V)	I_{EBO}						–	100	μA
* Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$			0.01			50	–	V
* Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			1[a]		0.1	–	0.8	V
* Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$			1[a]		0.1	–	1.4	V
* DC Forward Current Transfer Ratio	h_{FE}	1 1 1		0.1[a] 0.5[a] 1[b]			35 40 25	– – –	
Common-Emitter, Small-Signal, Short-Circuit, Forward Current Transfer Ratio (f = 100 MHz)	h_{fe}	10		0.05			2.5	–	
Common-Base, Open-Circuit Output Capacitance (f = 1 MHz)	C_{ob}		10		0		–	15	pF
* Switching Time:				I_C	I_{B1}	I_{B2}			
Turn-on ($t_d + t_r$)	t_{ON}			1	0.1	–	–	30	ns
Turn-off ($t_s + t_f$)	t_{OFF}			1	0.1	–0.1	–	60	ns

* In accordance with JEDEC registration data format JS-8/RDF-7.

[a] Pulsed: Pulse duration = 300 μs; duty factor ≤ 2%.

[b] Pulsed: Pulse duration ≤ 400 μs, duty factor ≤ 0.03.

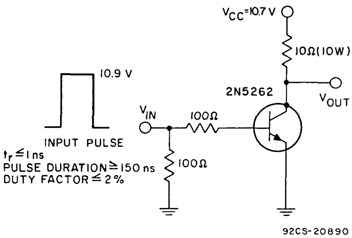


Fig.1–Circuit used to measure turn-on time.

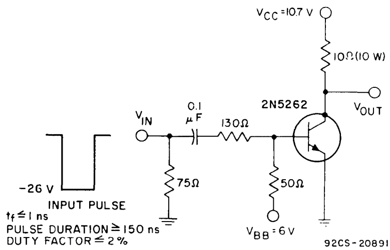


Fig.2–Circuit used to measure turn-off time.

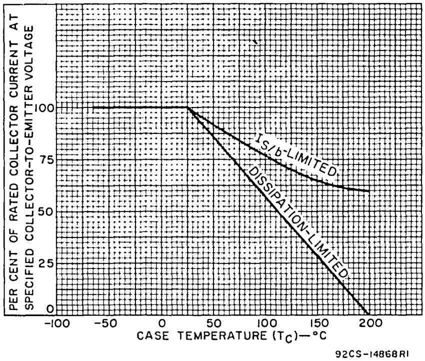


Fig.3—Derating curves.

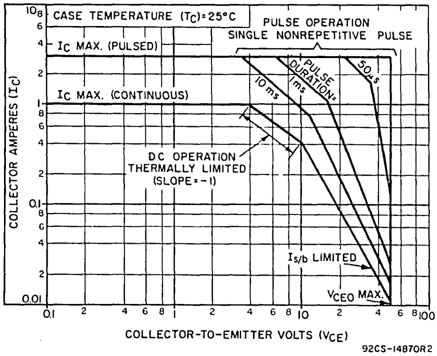


Fig.4—Safe area of operation.

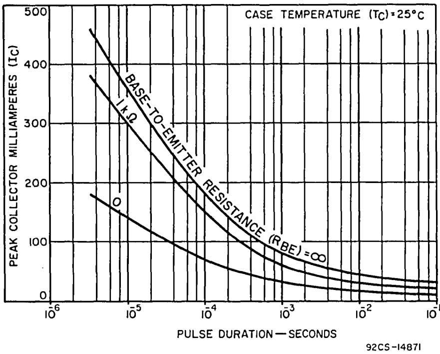


Fig.5—Typical second-breakdown characteristics.

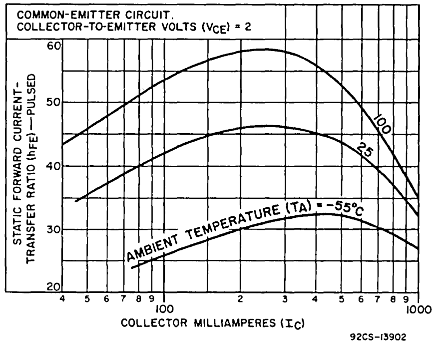


Fig.6—Typical dc beta characteristics.

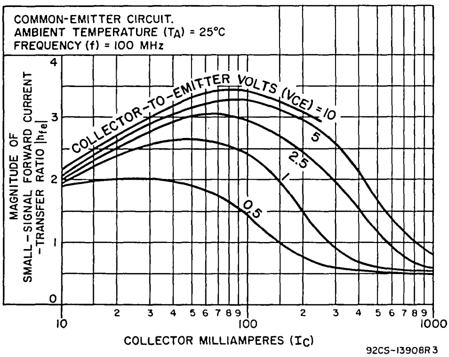


Fig.7—Typical small-signal beta characteristics.

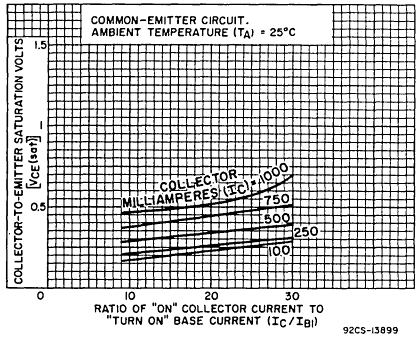
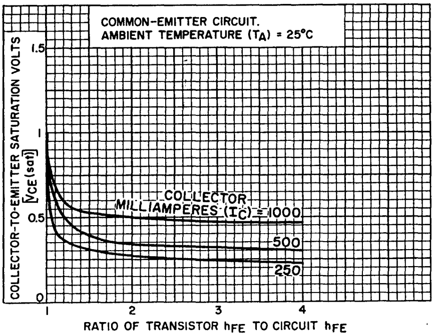
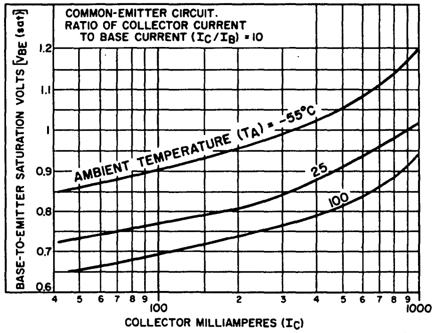


Fig.8—Typical saturation-voltage characteristics.



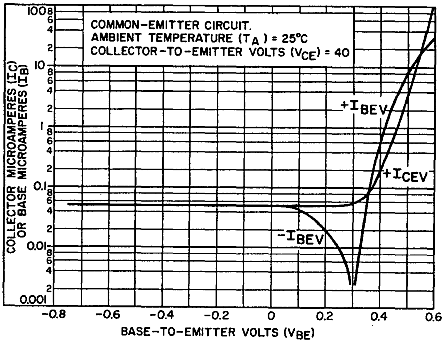
92CS-13900

Fig.9—Typical characteristics of saturation voltage vs. ratio of transistor beta to circuit beta.



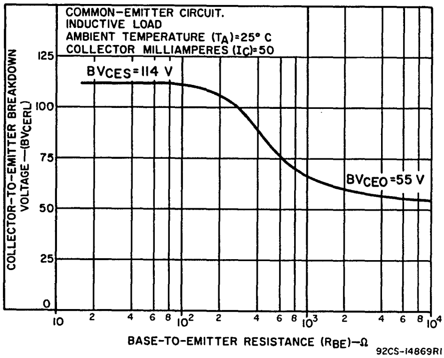
92CS-13901R1

Fig.10—Typical base-to-emitter saturation voltage vs. collector current.



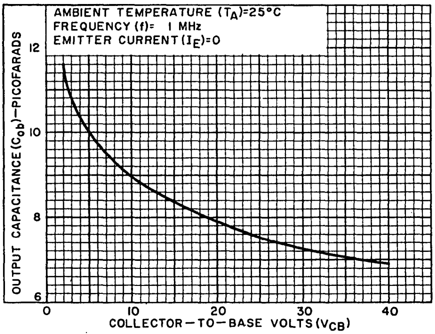
92CS-13898R1

Fig.11—Typical transfer characteristics.



92CS-14869R1

Fig.12—Typical collector-to-emitter breakdown voltage vs. resistance.



92CS-14867R1

Fig.13—Typical output capacitance vs. collector-to-base voltage.

TERMINAL CONNECTIONS

LEAD 1 — EMITTER
LEAD 2 — BASE
LEAD 3 — COLLECTOR, CASE

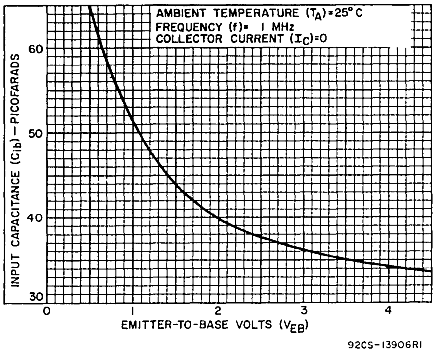


Fig.14—Typical input capacitance vs. emitter-to-base voltage.

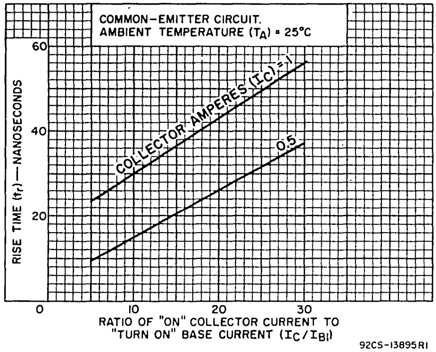


Fig.15—Typical rise-time characteristics.

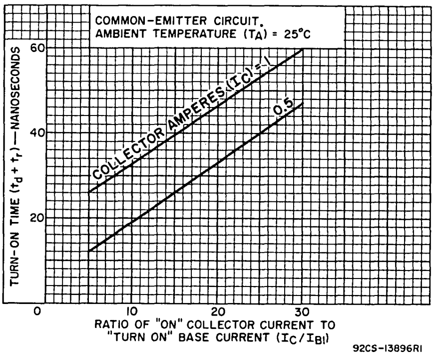


Fig.16—Typical turn-on time characteristics.

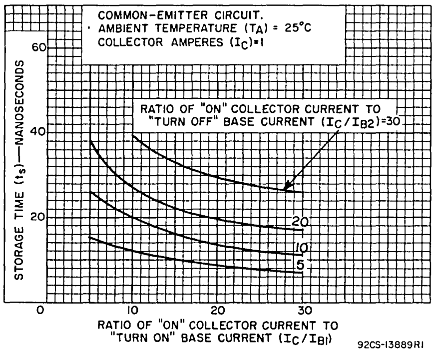


Fig.17—Typical storage time characteristics.

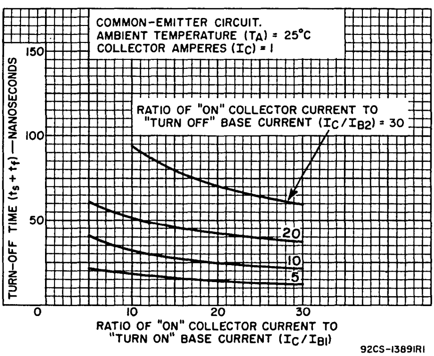


Fig.18—Typical turn-off time characteristics.

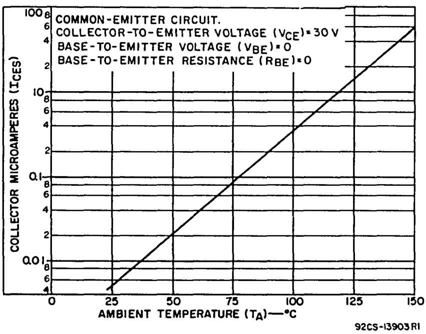


Fig.19—Typical collector cutoff current as a function of temperature.

RCA
Solid State Division

RF Power Transistors

2N5470

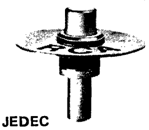
RCA-2N5470* is an epitaxial silicon n-p-n planar transistor employing the overlay emitter-electrode construction. It is intended for solid-state microwave radiosonde, communications, and S-band telemetry equipment.

The ceramic-metal coaxial package of the 2N5470 features low parasitic capacitances and inductances which provide for stable operation in the common-base amplifier configuration. This transistor can be used in both large and small-signal applications in coaxial, stripline, and lumped-constant circuits.

For application information on the 2N5470, see RCA Application Note AN3764, "Microwave Amplifiers and Oscillators Using the New RCA 2N5470 Power Transistor," by G. Hodowanec, O.P. Hart, and H.C. Lee.

*Formerly RCA Dev. Type No. TA7003

SILICON N-P-N "overlay" TRANSISTOR



JEDEC
TO-215AA package H-1598

For UHF/Microwave Power Amplifiers, Microwave Fundamental-Frequency Oscillators, and Frequency Multipliers

FEATURES

- **1-W output with 5-dB gain (min.) at 2GHz**
- **2-W output with 10-dB gain (typ.) at 1 GHz**
- **Ceramic-metal hermetic package with low inductance and low parasitic capacitances**

Maximum Ratings, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
EMITTER-TO-BASE VOLTAGE........	V_{EBO}	3.5	V
PEAK COLLECTOR CURRENT........		0.4	A
CONTINUOUS COLLECTOR CURRENT ..	I_C	0.2	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25 °C		3.5	W
At case temperatures above 25 °C	See Fig. 2.		
TEMPERATURE RANGE:			
Storage and operating (junction)......		−65 to +200	°C

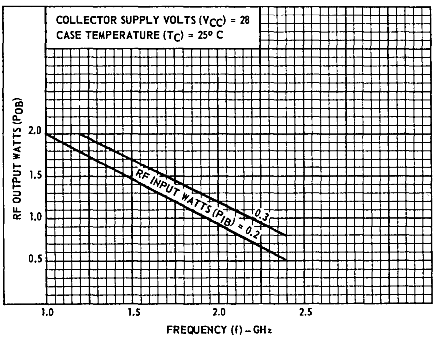


Fig. 1 - Typical Output Power vs. Frequency for Common-Base Power Amplifier

ELECTRICAL CHARACTERISTICS *At Case Temperature (T_C) = 25 °C*

CHARACTERISTICS	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	V_{CE}	DC Current (mA) I_E	I_B	I_C	LIMITS Min.	Max.	UNITS
Collector-Cutoff Current	I_{CES}		50		0		–	1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	50	–	V
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$					5	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	–	1.0	V
Collector-to-Base Capacitance (Measured at 1 MHz)	C_{cb}	30		0			–	3.0	pF
RF Power Output (Common-Base Amplifier): At 2 GHz[a] (See Fig. 5.)	P_{OB}	28					1.0	–	W
At 1 GHz[b] (See Fig. 12.)		28					2.0 (typ.)		W
RF Power Output (Common-Base Oscillator): At 2 GHz (See Fig. 15.)	P_{OB}	24				80	0.3 (typ.)		W

[a]For P_{IB} = 0.316 W; minimum efficiency = 30%
[b]For P_{IB} = 0.20 W; typical efficiency = 50%

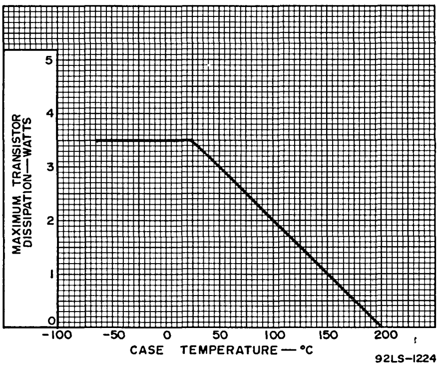


Fig. 2 - Dissipation Derating Curve

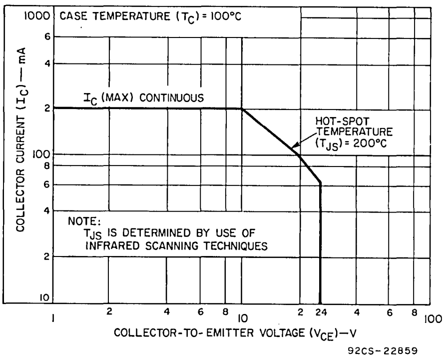


Fig. 3 - Maximum Operating Area for Forward-Bias Operation

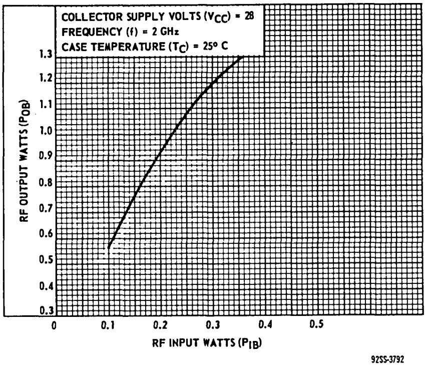


Fig. 4 - Typical Output Power vs. Input Power for 2-GHz Common-Base Power Amplifier

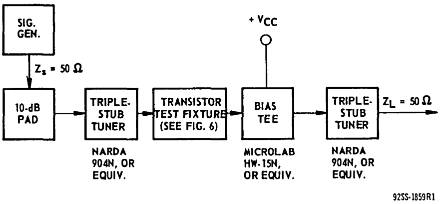
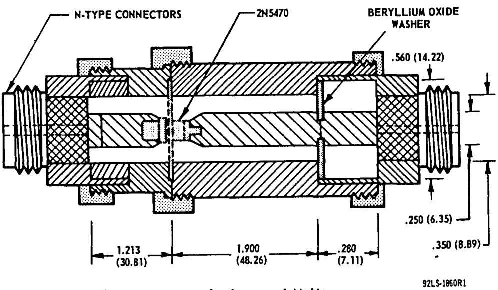


Fig. 5 - Block Diagram of Test Set-up for Measurement of Output Power from 2-GHz Common-Base Amplifier



Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 6 - Suggested Test Fixture for Test Set-Up Shown in Fig. 5.

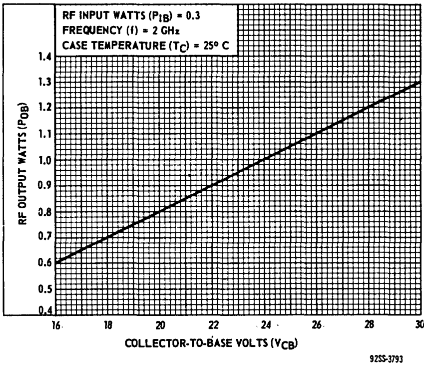


Fig. 7 - Typical Output Power vs. Collector-to-Base Voltage for 2-GHz Common-Base Power Amplifier

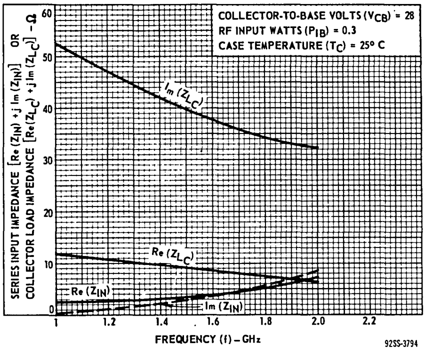


Fig. 8 - Typical Series Input Impedance and Collector Load Impedance vs. Frequency for Common-Base Power Amplifier

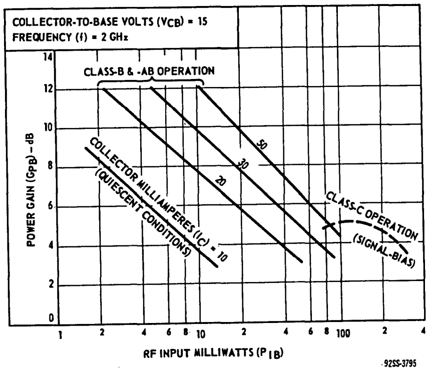
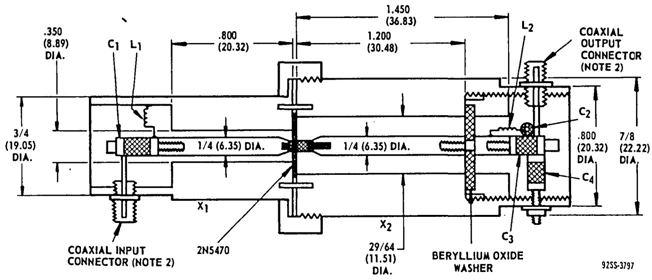


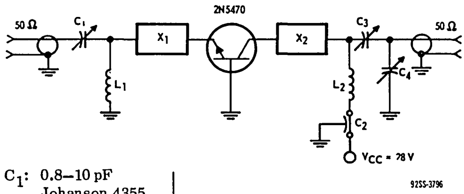
Fig. 9 - Typical Power Gain vs. Input Power for 2-GHz Common-Base Power Amplifier



Note 1: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Note 2: Conhex 50-045-0000, Sealectro Corp., or equivalent.

Fig. 10 - Constructional Details of 2-GHz Power Amplifier Shown in Fig. 11.



C_1: 0.8–10 pF Johanson 4355, or equivalent

C_2: 1,000 pF, feed-through, Allen-Bradley FB2B, or equivalent

C_3: 0.3–3.5 pF Johanson 4701, or equivalent

C_4: 0.35–3.5 pF Johanson 4702, or equivalent

L_1, L_2: RF choke, 3 turns No. 30 wire, 1/16 in. (1.57) ID 3/16 in. (4.75) long

X_1, X_2: Coaxial lines; see Fig. 11 for details.

Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 11 - Typical Circuit for 2-GHz, Coaxial-Line Power Amplifier Shown in Fig. 10.

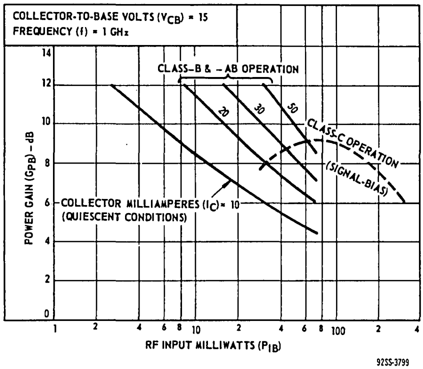
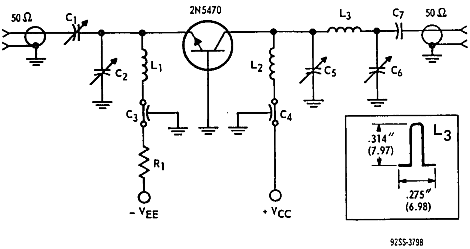


Fig. 12 - Typical Power Gain vs. Input Power for 1-GHz Power Amplifier



Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

C_1, C_5, C_6: 1–14 pF, air-dielectric, Johanson 3901, or equivalent

C_2: 0.35–3.5 pF, air-dielectric, Johanson 4701, or equivalent

C_3, C_4: 1000 pF, feed-through, Allen-Bradley FA5C, or equivalent

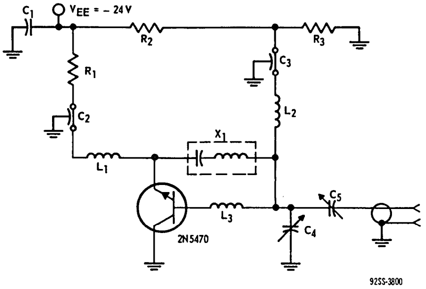
C_7: 1000 pF, ceramic, leadless

L_1, L_2: RF choke, 0.1 μH, Nytronics Deci-Ductor

L_3: 0.01-in. (.254) thick, 0.157 in. (3.98) wide copper strip shaped as shown in inset drawing

R_1: 100 Ω, ½ W

Fig. 13 - Typical Circuit for 1-GHz Power Amplifier



C_1: 0.01 μF disc ceramic

C_2, C_3: 100 pF, feed-through, Allen-Bradley FA5C, or equivalent

C_4, C_5: 0.35–3.5 pF, Johanson 4701, or equivalent

L_1, L_2: RF choke, 4 turns, No. 33 wire, 0.062 in. (1.57) ID, 3/16 in. (4.75) long

L_3: 3/64 in. (1.17) length of No. 22 wire

X_1: 0.82 pF, "gimmick", Quality Components type 10% QC, or equivalent

R_1: 5–10 Ω, 1/2 W

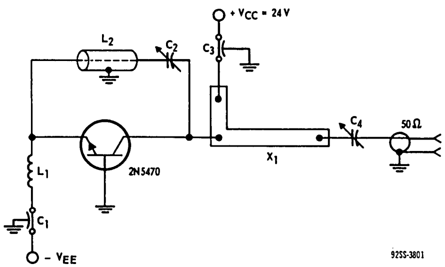
R_2: 51 Ω, 1/2 W

R_3: 1200 Ω, 1/2 W

Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 14 - Typical Circuit for 2-GHz Grounded-Collector Power Oscillator

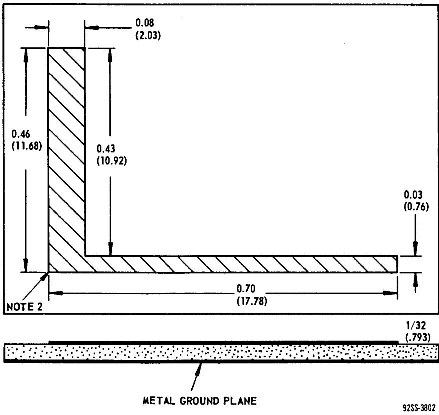


C_1, C_3: 100 pF, feed-through, Allen-Bradley FA5C, or equivalent	L_1: RF choke, 5 turns No. 33 wire, 1/16 in. (1.57) ID, 3/16 in. (4.76) long
C_2, C_4: 0.35–3.5 pF, Johanson 4702, or equivalent	L_2: 50-Ω miniature coaxial line 1.5 in. (38.1) long
	X_1: Microstripline circuit; see Fig. 16 for details.

Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Fig. 15 - Typical Circuit for 2-GHz Grounded-Base Power Oscillator



Dimensions in Inches and Millimeters

Note 1: Dimensions in parentheses are are in millimeters and are derived from the basic inch dimensions as indicated.

Note 2: Produced by removing portion of upper layer of double-clad, Teflon board, Budd Co. Polychem Div. Grade 108T, 1 oz, 1/32 in. (.793) thick, (ε = 2.6), or equivalent.

Fig. 16 - Detail Drawing of Microstripline, X_1 Specified in Fig. 15.

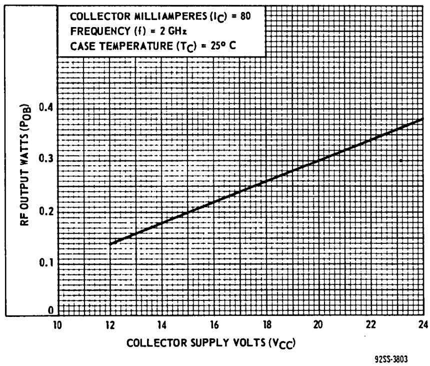


Fig. 17 - Typical Output Power vs. Collector Supply Voltage for 2-GHz Grounded-Base Power Oscillator

TERMINAL CONNECTIONS

No. 1 — Emitter
No. 2 — Base
No. 3 — Collector

RCA
Solid State
Division

RF Power Transistors

2N5913

JEDEC TO-39 H-1381

Silicon N-P-N Overlay Transistor

12.5-Volt, High-Gain Type for Class-C Amplifiers in VHF/UHF Communications Equipment

Features:

- **High Power Gain, High Power Output . . .**
  At 12.5 V:
  - 2-W (typ.) output at 470 MHz (7-dB gain)
  - 2-W (typ.) output at 250 MHz (9-dB gain)
  - 2-W (typ.) output at 175 MHz (13-dB gain)

  At 8 V:
  - 1.5-W (typ.) output at 470 MHz (4.8-dB gain)
  - 1.5-W (typ.) output at 250 MHz (7.0-dB gain)
  - 1.5-W (typ.) output at 175 MHz (10-dB gain)

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

* COLLECTOR-TO-BASE VOLTAGE.	V_{CBO}	36	V
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:			
With base shorted to emitter	$V_{(BR)CES}$	36	V
* With base open	$V_{(BR)CEO}$	14	V
* EMITTER-TO-BASE VOLTAGE . . .	V_{EBO}	3.5	V
* CONTINUOUS COLLECTOR CURRENT	I_C	0.33	A
* TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C. .		3.5	W
At case temperatures above 75°C .		Derate at 0.0028 W/°C	
* TEMPERATURE RANGE:			
Storage & Operating (Junction) . .		-65 to +200	°C
* LEAD TEMPERATURE:			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max. .		230	°C

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

RCA Type 2N5913▲ is an epitaxial silicon n-p-n planar transistor featuring "overlay" emitter electrode construction. It is intended for VHF/UHF mobile, portable, and VHF marine transmitters, as well as UHF CB, sonobuoy, beacon, and other applications where intermediate power output is required at low supply voltage.

▲ Formerly RCA Developmental Type TA7477.

TERMINAL CONNECTIONS

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

ELECTRICAL CHARACTERISTICS *Case Temperature (T_C) = 25°C Unless Otherwise Specified*

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage (V) V_{CE}	TEST CONDITIONS: DC Voltage (V) V_{EB}	TEST CONDITIONS: DC Current (mA) I_E	TEST CONDITIONS: DC Current (mA) I_B	TEST CONDITIONS: DC Current (mA) I_C	LIMITS Min.	LIMITS Max.	UNITS
*	Collector-Cutoff Current									
	Base Connected to Emitter	I_{CES}	12.5			0			1.0^b	mA
	Base Open	I_{CEO}	10			0			0.3	mA
*	Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.5	36	–	V
*	Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	25^a	14	–	V
	With base connected to emitter	$V_{(BR)CES}$		0			25^a	36	–	V
*	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	V
	Thermal Resistance: (Junction-to-Case)	$\theta_{J\text{-}C}$						–	35.7	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

[b] T_C = 100°C.

DYNAMIC

	TEST & CONDITIONS	SYMBOL	FREQUENCY MHz	LIMITS MINIMUM	LIMITS TYPICAL	UNITS
	Power Output (V_{CC} = 12.5 V): P_{IE} = 0.1 W	P_{OE}	175	1.75		W
*	Large-Signal Common-Emitter Power Gain (V_{CC} = 12.5 V): P_{IE} = 0.1 W	G_{PE}	175	12.4		dB
*	Collector Efficiency (V_{CC} = 12.5 V): P_{IE} = 0.1 W	η_C	175	50		%
*	Common-Base Output Capicatance V_{CB} = 12 V	C_{obo}	1	15 (max.)		pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

PERFORMANCE DATA

TYPICAL AMPLIFIER PERFORMANCE (V_{CE} = 12.5 V)

FREQUENCY (f)-MHz	INPUT POWER (P_{IE})-W	OUTPUT POWER (P_{OE})-W	COLLECTOR EFFICIENCY η_C	CIRCUIT
175	0.1	2	60	Fig.6
250	0.25	2	65	Fig.6
470	0.4	2	65	Fig.7
156 (Marine Transmitter)	.005	2	–	Fig.8

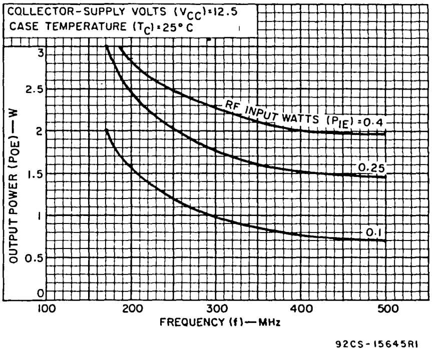


Fig.1 - Typical power output vs. frequency.

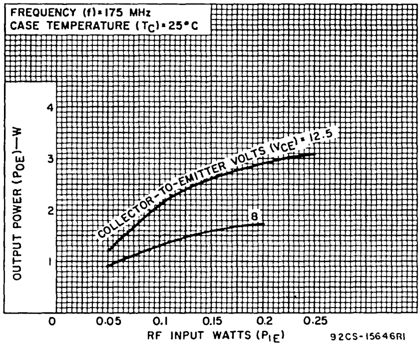


Fig. 2 - Typical power output vs. power input at 175 MHz for circuit shown in Fig.5.

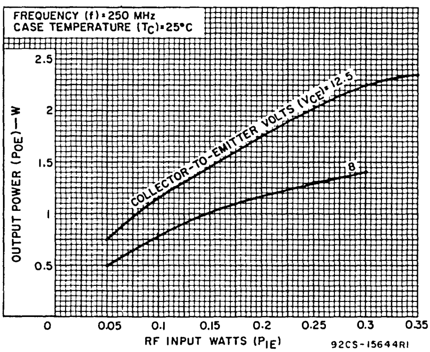


Fig. 3 - Typical power output vs. power input at 250 MHz for circuit shown in Fig.5.

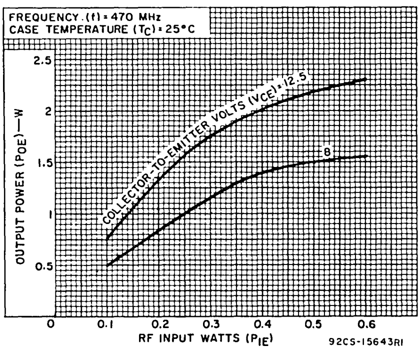
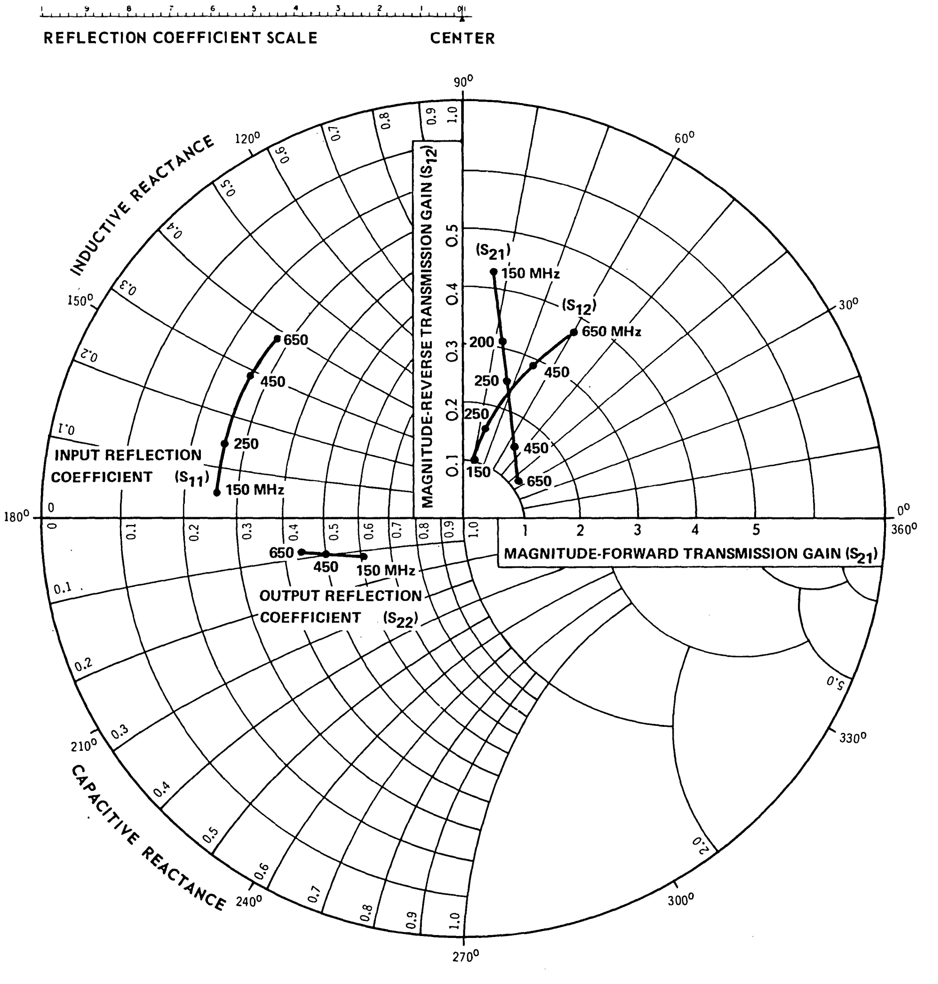


Fig. 4 - Typical power output vs. power input at 470 MHz for circuit shown in Fig.7.

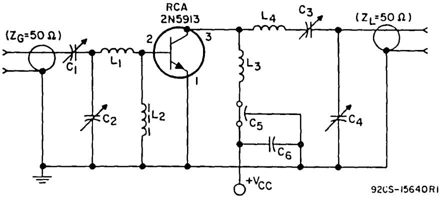
DESIGN DATA



Collector-to-Emitter Voltage (V_{CE}) = 12.5 V
Collector-Current (I_C) = 100 mA
Case Temperature (T_C) = 25°C

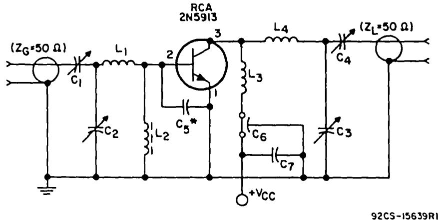
Fig. 5 - Typical S parameters vs. frequency.

APPLICATION DATA



C_1, C_2, C_3, & C_4: 7-35 pF, ARCO 403, or equivalent
C_5: 1,000 pF, feed-through
C_6: 0.005 μF, disc ceramic
L_1: 2 turns No.16 wire, 3/16 in. ID, 1/4 in. long
L_2: Z = 450 ohms; Ferroxcube VK200-09/3B, or equivalent
L_3: 2 turns No.14 wire, 1/4 in. ID, 5/16 in. long
L_4: 3 turns No.14 wire, 3/8 in. ID, 3/8 in. long

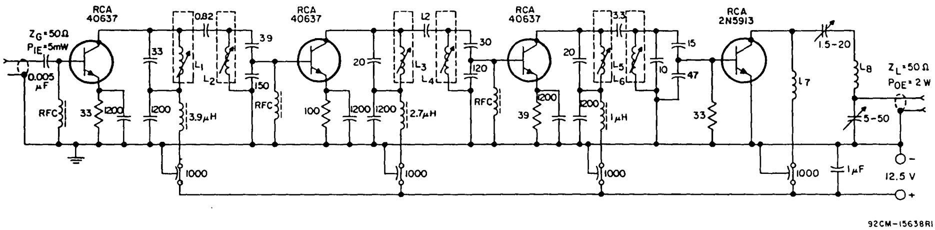
Fig. 6 - 175/250-MHz amplifier test circuit for measurement of power output.



C_1, C_2, C_3: 0.9-7 pF, ARCO 400, or equivalent
C_4: 7-35 pF, ARCO 903, or equivalent
C_5: 22 pF, ± 5% silver mica
C_6: 470 pF, feed-through
C_7: 0.1 μF, disc ceramic
L_1, L_3, L_4: 1 turn No.18 wire 1/4 in. ID, 1/8 in. long
L_2: 0.39 μH, Nytronics Deci-Ductor, or equivalent

* Mount C_5 as close as possible to base and emitter pins.

Fig. 7 - 470-MHz amplifier test circuit for measurement of power output.



L_1 - L_2: 10-1/2 turns, close-wound, #22 enameled wire
L_3 - L_4: 4-1/2 turns, close-wound, #22 enameled wire
L_5 - L_6: 1-1/2 turns, 1/4 in. length, #20 bare wire

All coils on slug-tuned forms 15/64-in. O.D. Corbonyl* S.F. 10-32 threaded slug or equivalent, with 1/2-in. x 1/2-in. x 1-in. shield cans.

L_7: 2 turns, 3/16-in. length, 3/16-in. dia., #20 bare wire
L_8: 2-1/2 turns, 1/4-in. length, #20 bare wire
RFC: 4 turns, #30 enameled wire on Ferroxcube† ferrite bead #56-590-65/48, or equivalent

All capacitor values are in picofarads unless otherwise specified.
All resistances are in ohms and are 1/4-watt types.

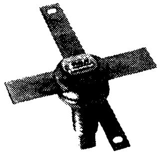
* Arnold Magnetics Corp., Los Angeles, Cal.
† Ferroxcube Corp. of America, Saugerties, N.Y.

Fig. 8 - Typical circuit for a frequency-multiplier chain (f_{IN} = 13 MHz, f_{OUT} = 156 MHz) for 156-MHz marine-radio transmitter.

RCA
Solid State
Division

RF Power Transistors

2N5914 2N5915



TO-216AA package

H-1675

High-Power Silicon N-P-N Overlay Transistors

12.5-Volt, High-Power Types For Class-C Amplifiers in VHF/UHF Communications Equipment

Features:

- Low inductance radial leads — particularly useful for strip-line circuits
- Hermetically sealed ceramic-metal package
- Electrically isolated mounting stud
- 6 watts minimum output from 2N5915 amplifier at 470 MHz
- 7-dB gain from 2N5914 driver at 470 MHz

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

		2N5914	2N5915	
• COLLECTOR-TO-BASE BREAKDOWN VOLTAGE	$V_{(BR)CBO}$	36	36	V
• COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:				
With base connected to emitter	$V_{(BR)CES}$	36	36	V
With base open	$V_{(BR)CEO}$	14	14	V
• EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
• COLLECTOR CURRENT:				
Continuous	I_C	0.5	1.5	A
• TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 75°C		5.7	10.7	W
At case temperatures above 75°C		See Fig. 7		
• TEMPERATURE RANGE:				
Storage & Operating (Junction)		−65 to +200°C		
• CASE TEMPERATURE (During soldering):				
For 10 s max.		230		°C

• In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

RCA 2N5914[a] and 2N5915[b] are epitaxial silicon n-p-n planar transistors featuring overlay emitter electrode construction.

2N5914 and 2N5915 feature an hermetic, ceramic-metal package having leads isolated from the mounting stud. These rugged, low-inductance, radial-lead types are designed for strip-line, as well as lumped-constant circuits.

[a]Formerly RCA Dev. Type TA7408.

[b]Formerly RCA Dev. Type TA7409.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C

Static

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTS V_{CE}	DC BASE VOLTS V_{BE}	DC CURRENT mA I_E	I_B	I_C	LIMITS 2N5914 MIN.	2N5914 MAX.	2N5915 MIN.	2N5915 MAX.	UNITS
●	Collector-Cutoff Current	I_{CEO}	10			0		–	0.3	–	1.0	mA
●	Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.5	36	–	–	–	V
							1.0	–	–	36	–	
●	Collector-to-Emitter Breakdown voltage: With base open	$V_{(BR)CEO}$			0		25[a]	14	–	–	–	V
							75[a]	–	–	14	–	
	With base connected to emitter	$V_{(BR)CES}$		0			25[a]	36	–	–	–	
							75[a]	–	–	36	–	
●	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	–	–	V
					1.0		0	–	–	3.5	–	

[a] Pulsed through a 25-mH inductor; duty factor = 50%

Dynamic

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC}) – Volts	Input Power (P_{IE}) – Watts	Frequency (f) – MHz	LIMITS 2N5914 MIN.	2N5914 TYP.	2N5915 MIN.	2N5915 TYP.	UNITS
●	Power Output	P_{OE}	12.5	0.4	470	2.0		–		W
				2.0		–		6		
●	Power Gain	G_{PE}	12.5	0.4	470	7		–		dB
				2.0		–		4.8		
●	Collector Efficiency	η_C	12.5	0.4	470	65		–		%
				2.0		–		65		
	Load Mismatch (Fig. 14)	LM	12.5	2N5914 0.4 2N5915 2	470	GO/NO GO				
●	Collector-to-Base Capacitance	C_{obo}	12 I_C = 0		1	–	15 (max.)	–	30 (max.)	pF
	Gain-Bandwidth Product	f_T	12, I_C = 200 mA				900	–		MHz
			12, I_C = 300 mA			–			800	

● In accordance with JEDEC registration data fromat JS-6 RDF-3/JS-9 RDF-7

PERFORMANCE DATA

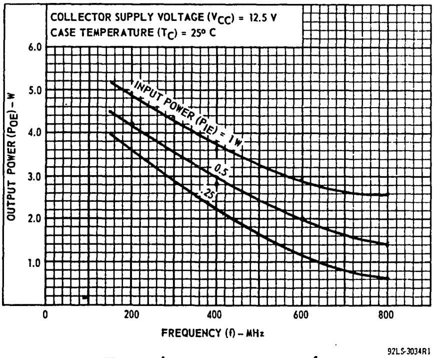


Fig. 1 - Typical output power vs. frequency for 2N5914

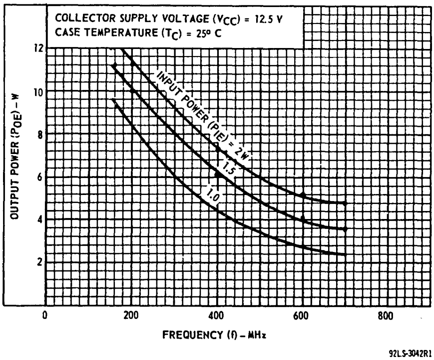


Fig. 2 - Typical output power vs. frequency for 2N5915

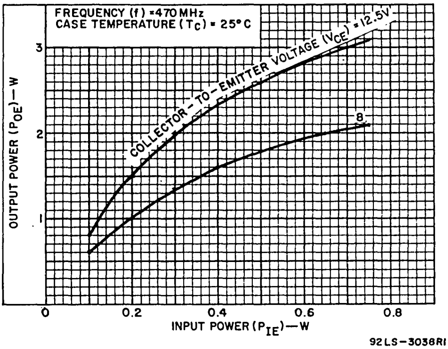


Fig. 3 - Typical output power vs. input power at 470 MHz for 2N5914 in circuit shown in Fig. 8

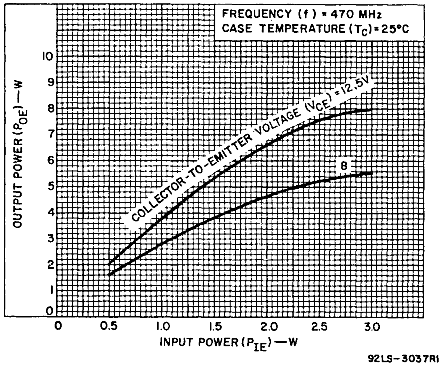


Fig. 4 - Typical output power vs. input power at 470 MHz for 2N5915 in circuit shown in Fig. 8

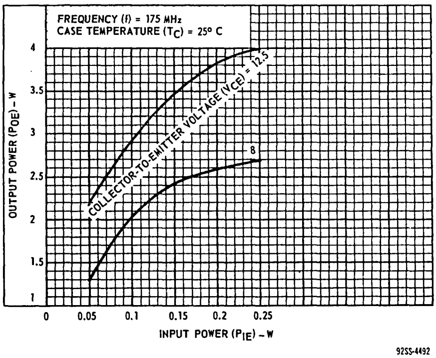


Fig. 5 - Typical output power vs. input power at 175 MHz for 2N5914 (Fig. 15)

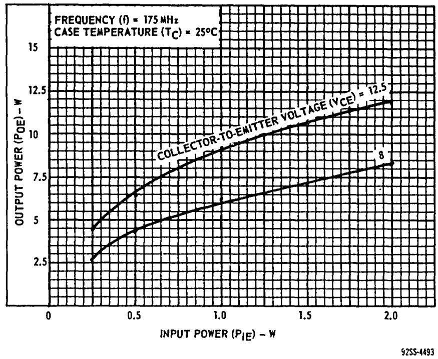


Fig. 6 - Typical output power vs. input power at 175 MHz for 2N5915 (Fig. 15)

DESIGN DATA

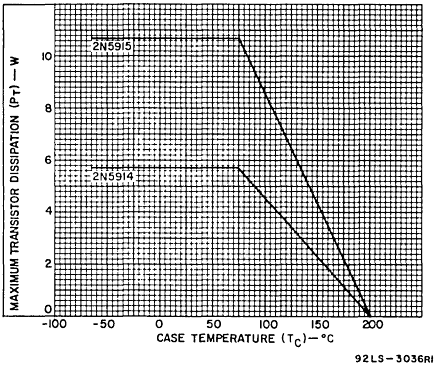


Fig. 7 - Dissipation derating for 2N5914 and 2N5915

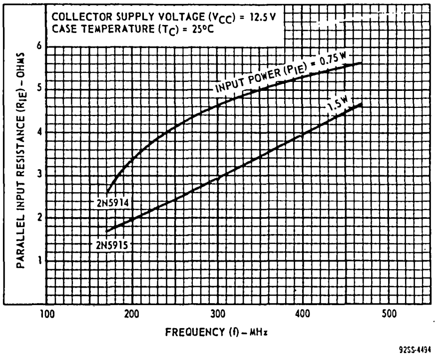


Fig. 8 - Large signal equivalent parallel input resistance vs. frequency for 2N5914 and 2N5915

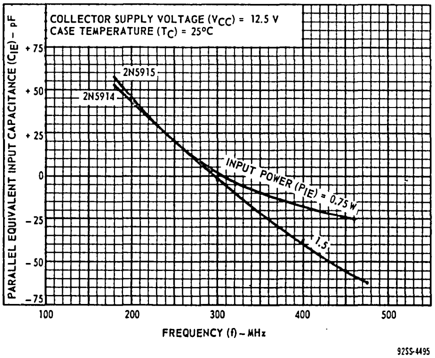


Fig. 9 - Large signal parallel equivalent input capacitance vs. frequency for 2N5914 and 2N5915

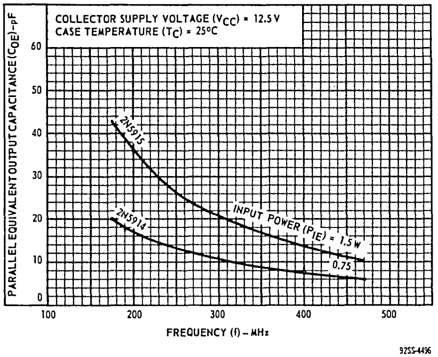


Fig. 10 - Large signal equivalent parallel output capacitance vs. frequency for 2N5914 and 2N5915

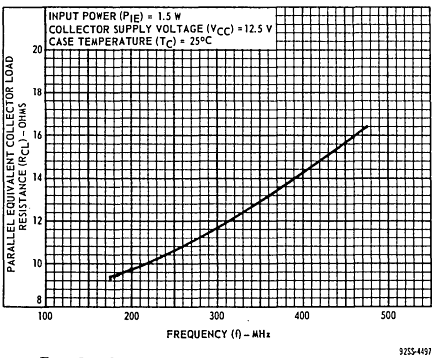


Fig. 11 - Large signal parallel load resistance vs. frequency for 2N5915

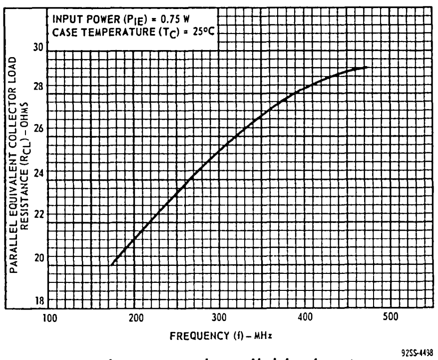
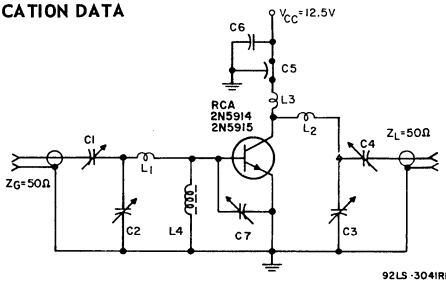


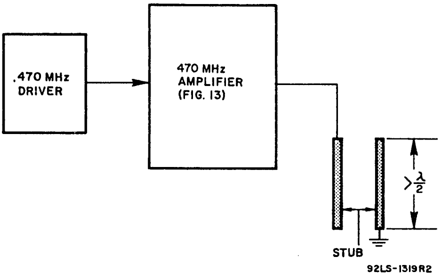
Fig. 12 - Large signal parallel load resistance vs. frequency for 2N5914

APPLICATION DATA



C_1, C_2, C_3 - 0.9-7.0 pF, ARCO # 400, or equivalent
C_4 - 1.5-20 pF, ARCO # 402, or equivalent
C_5 - 1000 pF (feed-through)
C_6 - 0.1 μF (ceramic)
C_7 - 2-18 pF, Amperex HT10MA/218, or equivalent connect between the base and emitter with the shortest possible leads.
L_1, L_2 - 1 turn # 16 wire, 3/16 in. I.D., 1/8 in. long
L_3 - 1 turn # 20 wire, 3/16 in. I.D., 1/8 in. long
L_4 - Ferrite choke, 450Ω impedance, Ferroxcube VK-200-09-3B, or equivalent

Fig. 13. 470 MHz amplifier used for measuring power output and power gain in 2N5914 and 2N5915

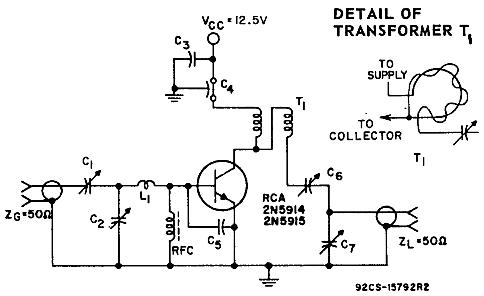


SPECIAL PERFORMANCE DATA

The transistor can withstand any mismatch in load, which can be demonstrated in the following test:

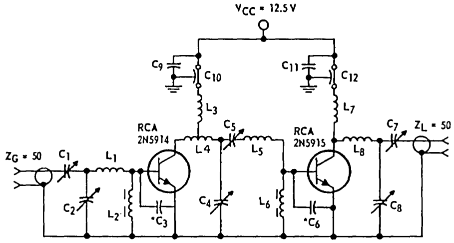
1. The test is performed using the arrangement shown.
2. The tuning stub is varied through a half wavelength, which effectively varies the load from an open circuit to a short circuit.
3. Operating conditions; V_{CC} = 12.5
   RF input power = 0.4 W for 2N5914, 2.0 W for 2N5915
4. Transistor Dissipation Rating must not be exceeded. During the above test, the transistor will not be damaged or degraded.

Fig. 14 - Test set-up for testing load mismatch capability of 2N5914 and 2N5915



L_1 - 1/2 turn # 14 wire, 1/4-in. I.D.
RFC - Z = 450Ω, Ferroxcube VK-200-09/3B, or equivalent
C_1 - 7-100 pF, Arco 423, or equivalent
C_2 - 4-40 pF, Arco 422, or equivalent
C_3 - 0.1 μF ceramic
C_4 - 0.001 μF feedthrough
C_5 - 62 pF silver mica
C_6 - 14-150 pF, Arco 424, or equivalent
C_7 - 24-200 pF, Arco 425, or equivalent
T_1 - Twisted pair of # 20 enameled wire; 14 turns/in. Formed in a loop 3/8 in. diameter, cross connected (End of one winding connected to beginning of other)

Fig. 15 - 175-MHz amplifier for measuring power output and power gain in 2N5914 and 2N5915



$C_1, C_2, C_4, C_5, C_7, C_8$	0.9 – 7.0 pF		
C_3, C_6	18 pF	L_4	1 TURN NO. 18 WIRE 1/4 IN. I.D., 1/8 IN. LONG TAP AT 1/4 TURN FROM COLLECTOR
C_9, C_{11}	0.1 μF	L_5	1 TURN NO. 20 WIRE 1/8 IN. I.D., 1/8 IN LONG
C_{10}, C_{12}	.001 μF	L_8	1 TURN NO. 18 WIRE 1/4 IN. I.D. 1/8 IN. LONG
L_1	1 TURN NO. 16 WIRE 3/16 IN. I.D. 1/8 IN LONG		
L_2, L_6	FERRITE CHOKE Z = 450Ω FERROX CUBE VK-200-09-3B OR EQUIV.		
L_3, L_7	1 TURN NO. 20 WIRE 3/16 IN. I.D. 1/8 LONG		

*CONNECT C_3 AND C_6 BETWEEN THE BASE AND EMITTER

92SM-4499

Fig. 16 - Typical 470 MHz amplifier with 0.4 W input and 6.0 W output

TERMINAL CONNECTIONS

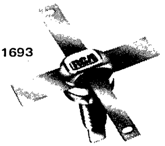
Terminal No. 1, 3 – Emitter
Terminal No. 2 – Base
Terminal Nol 4 – Collector

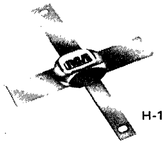
RCA Solid State Division

RF Power Transistors

2N5916 2N5917

2N5916
TO-216AA
package H-1693





2N5917
RCA HF-31
package

H-1676

High-Gain Silicon N-P-N Overlay Transistors

For VHF/UHF Communications Equipment

Features:

- Radial leads for microstripline circuits
- 2 watts (min.) output at 400 MHz (10-dB gain)
- 2 watts (typ.) output at 1 GHz (5-dB gain)
- Low-inductance, ceramic-metal hermetic packages
- All electrodes isolated from stud
- 100 mW (typ.) broadband 50/450-MHz (10-dB gain)

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		2N5916 2N5917	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	V
*COLLECTOR-TO-EMITTER VOLTAGE With base open	V_{CEO}	24	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	0.2	A
*TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 100°C		4	W
At case temperatures above 100°C		Derate linearly at 0.04 W/°C	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		–65 to +200	°C
* CASE TEMPERATURE (During soldering):			
For 10 s max		230	°C

*In accordance with JEDEC registration data format JS-6, RDF-3/JS-9 RDF-7

RCA 2N5916 and 2N5917▲ are epitaxial silicon n-p-n planar transistors featuring "overlay" emitter electrode construction. They are intended for large-signal and small-signal high-gain rf amplifiers and driver applications for VHF/UHF communications equipment.

Type 2N5916 features a new hermetic, ceramic-metal package having terminals isolated from the mounting stud. These rugged, low-inductance, radial leads are designed for microstripline as well as lumped-constant circuits. 2N5917 is a 2N5916 without the mounting stud.

▲Formerly RCA Dev. Type Nos. TA7411 and TA7852, respectively.

"**WARNING:** RCA types 2N5916 and 2N5917 should be handled with care. The ceramic portion of these transistors contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the transistors because the dust resulting from such action may be hazardous if inhaled."

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25 °C

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS DC Collector Voltage V_{CE}	DC Base Voltage V_{BE}	DC Current mA I_E	I_B	I_C	LIMITS MIN.	MAX.	UNITS
*	Collector-to-Emitter Cutoff Current: Base-emitter junction shorted	I_{CES}	30[b]	0				–	1	mA
*	Collector-to-Emitter Breakdown Voltage:	$V_{(BR)CES}$		0			5[a]	55	–	V
	With base open	$V_{(BR)CEO}$					5[a]	24	–	V
*	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
	Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	–	0.5	V
	Thermal Resistance: (Junction-to-Case)	$\theta_{J\text{-}C}$						–	25	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%
[b] Case temperature = 100°C

DYNAMIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS DC Collector Supply (V_{CC}) – V	Output Power (P_{OE}) – W	Input Power (P_{IE}) – W	Frequency (f) – MHz	LIMITS MIN.	MAX.	UNITS
*	Power Output (See Fig. 10)	P_{OE}	28		0.2	400	2.0	–	W
*	Power Gain	G_{PE}	28	2		400	10	–	dB
*	Collector Efficiency	η_C	28		0.2	400	50	–	%
*	Collector–Base Capacitance	C_{cb}	30(V_{CB})			1	–	4.5	pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

TERMINAL CONNECTIONS
Terminals 1,3 – Emitter
Terminal 2 – Base
Terminal 4 – Collector

PERFORMANCE DATA

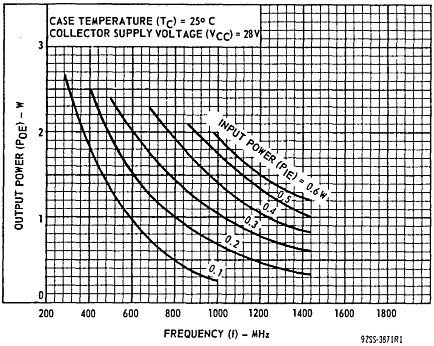


Fig. 1 - Typical power output vs. frequency (for both types).

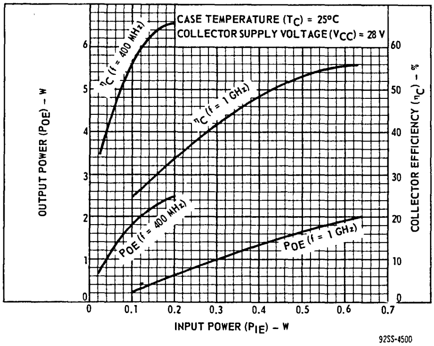


Fig. 2 - Typical power output and collector efficiency vs. power input (for both types).

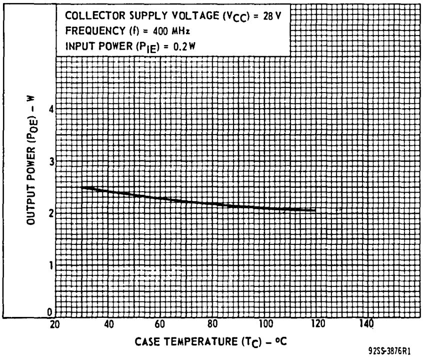


Fig. 3 - Typical power output vs. case temperature (for both types).

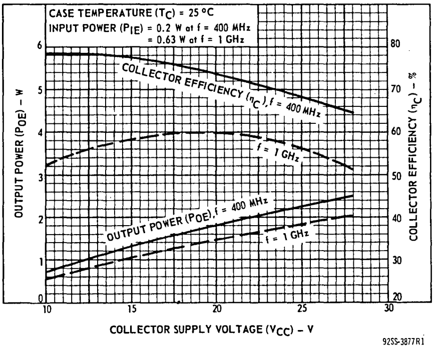


Fig. 4 - Typical power output or collector efficiency vs. collector supply voltage (for both types).

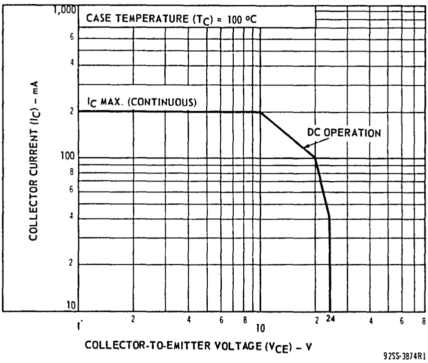


Fig. 5 - Safe operating area, for dc operation (for both types).

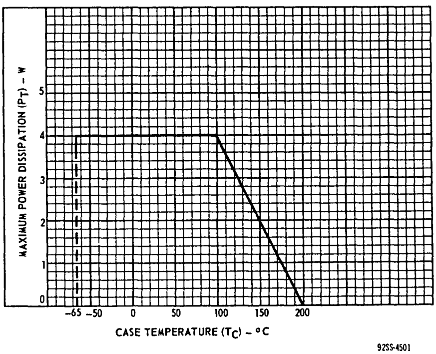


Fig. 6 - Derating curve (for both types).

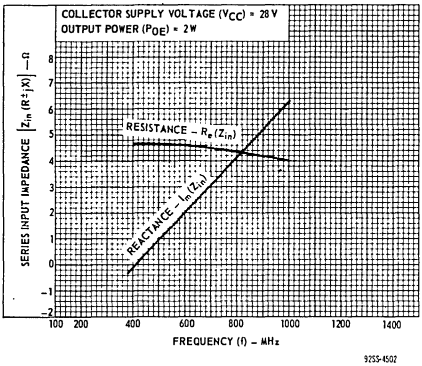


Fig. 7 - Typical large-signal series input impedance vs. frequency (for both types).

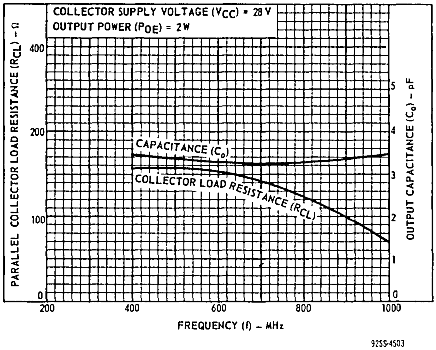


Fig. 8 - Typical large-signal, parallel collector load and parallel output capacitance vs. frequency (for both types).

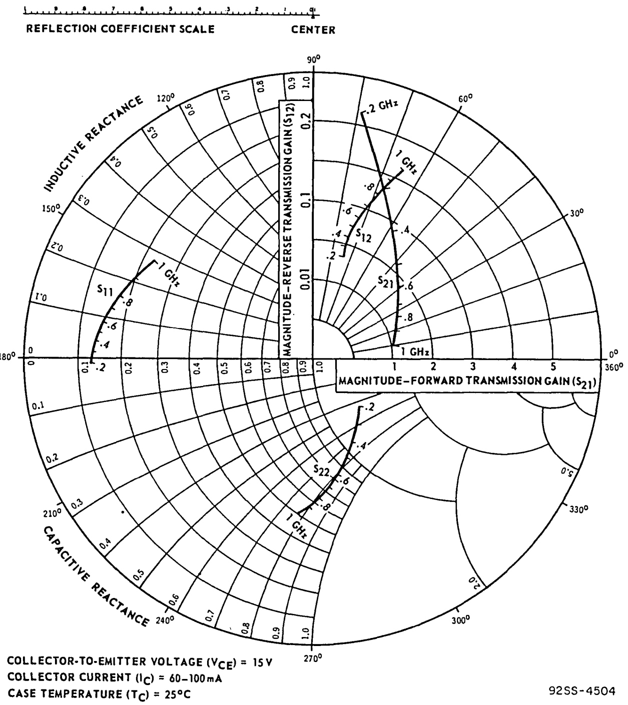
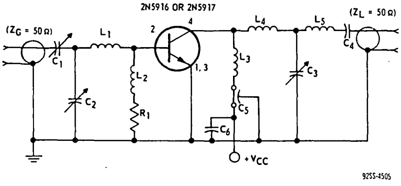


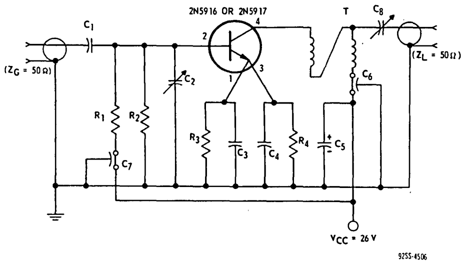
Fig. 9 - Typical S parameters vs. frequency (for both types).



C_1, C_3 – 0.9–7 pF, ARCO 400*
C_2 – 1.5–20 pF, ARCO 402*
C_4 – 0.0015 μF, disc ceramic
C_5 – 1,000 pF, feedthrough type, Allen-Bradley FA5C*
C_6 – 1 μF, electrolytic
L_1, L_5 – 1 turn ▲
L_2 – RFC, .1 μH
L_3 – 3 turns ▲
L_4 – 2 turns ▲
R_1 – 10 Ω, carbon

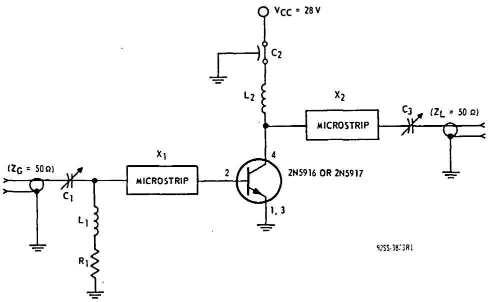
* Or equivalent
▲All coils 5/32 in. (3.96 mm) I.D. #18 wire, 12 turns per inch

Fig. 10 - 400-MHz amplifier test circuit for measurement of power output.



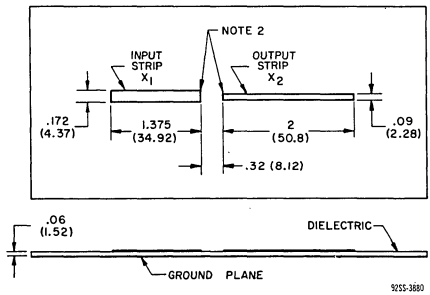
C_1 – 0.0015 μF, disc ceramic
C_2, C_8 – 2–18 pF, Amperex H.T. 10mA/218, or equivalent
C_3, C_4 – 680 pF, chip cap., Allen-Bradley B166811, or equivalent
C_5 – 1 μF, electrolytic
C_6, C_7 – 1,000 pF, feedthrough type
R_1 – 2 kΩ, ½ W, carbon
R_2 – 500Ω, ½ W, carbon
R_3, R_4 – 250Ω, ½ W, carbon
T – Twisted pair of #22 wire, 10 twists, 1 in. long

Fig. 11 - 50/450 – MHz 10-dB broadband amplifier using type 2N5916 or 2N5917.



C_1, C_3: 0.35-3.5 pF, Johanson 4701, or equivalent
C_2: 470 pF, feed-through type, Allen Bradley FA5C, or equivalent
L_1: 3 turns No. 22 wire 5/32 in. (3.96 mm) ID, 3/8 in. (9.52 mm) long
L_2: 1½ turns No. 22 wire 5/32 in. (3.96 mm) ID, 3/8 in. (9.52 mm) long
R_1: 10-Ω, 1/4-W carbon
X_1, X_2: Microstrip details given in Fig. 13

Fig. 12 - 1 – GHz amplifier using type 2N5916 or 2N5917.



Note 1: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Note 2: Produced by removing upper layer of double-clad, Teflon board, Budd Co. Polychem Div. Grade 108T, 1 oz. 1/16 in. (1.52 mm) thick, (ϵ = 2.6), or equivalent.

Fig. 13 - Typical microstrip layout for 1-GHz power amplifier circuit shown in Fig. 12.

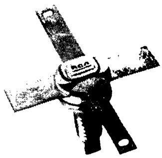
RCA
Solid State
Division

RF Power Transistors

2N5918

10-W, 400-MHz High-Gain Silicon N-P-N Emitter-Ballasted Overlay Transistor

For VHF/UHF Communications Equipment



TO-216AA package

H-1675

Features:

- 10 W output at 400 MHz (8 dB min. gain)
- Emitter-ballasting resistors
- Broadband performance (225–400 MHz)
- Low-inductance, ceramic-metal hermetic package
- All electrodes isolated from stud
- Radial leads for stripline circuits

MAXIMUM RATINGS, *Absolute-Maximum Values.*

* COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	30	V
* COLLECTOR-TO-BASE VOLTAGE . .	V_{CBO}	60	V
* EMITTER-TO-BASE VOLTAGE . . .	V_{EBO}	4	V
* CONTINUOUS COLLECTOR CURRENT	I_C	0.75	A
* TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 75°C . . .		10	W
At case temperatures above 75°C . . .		Derate linearly at 0.08 W/°C	
* TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
* CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

RCA type 2N5918* is an epitaxial silicon n-p-n planar transistor employing "overlay" emitter-electrode construction. This device features emitter-ballasting resistors which improve ruggedness and overdrive capability, and a hermetic ceramic-metal package with terminals isolated from the mounting stud. The terminals are rugged, low-inductance, radial leads suitable for microstrip as well as lumped-constant circuits.

The 2N5918 is intended for use in large-signal, high-power, broadband and narrow-band amplifiers in vhf/uhf communications equipment.

* Formerly RCA Dev. Type No. TA7367.

TERMINAL CONNECTIONS

Terminals 1, 3 - Emitter
Terminal 2 - Base
Terminal 4 - Collector

WARNING: RCA Type 2N5918 should be handled with care. The ceramic portion of this transistor contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the transistor because of dust resulting from such action may be hazardous if inhaled.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS		UNITS
		DC Collector Voltage	DC Base Voltage	DC Current mA					
		V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector-to-Emitter Cutoff Current: Base-emitter junction shorted	I_{CES}	30	0				–	5	mA
* Collector-to-Emitter Breakdown Voltage:	$V_{(BR)CES}$		0			100[a]	60	–	V
With base open	$V_{(BR)CEO}$					100[a]	30	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			1		0	4	–	V
Thermal Resistance: (Junction-t o-Case)	$\theta_{J\text{-}C}$						–	12.5	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		DC Collector Supply (V_{CC})–V	Output Power (P_{OE})–W	Input Power (P_{IE})–W	Frequency (f)–MHz	MIN.	MAX.	
* Power Output (See Fig. 10)	P_{OE}	28		1.59	400	10	–	W
* Power Gain	G_{PE}	28	10		400	8	–	dB
* Collector Efficiency	η_C	28	10		400	60	–	%
* Collector-to-Base Output Capacitance	C_{obo}	30(V_{CB})			1	–	13	pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

PERFORMANCE DATA

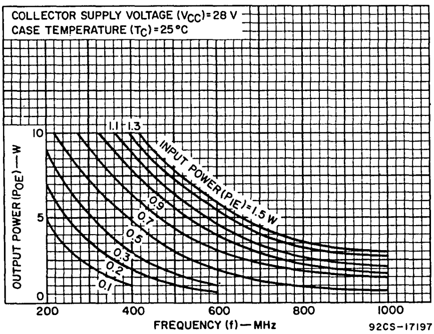


Fig. 1 - Typical output power vs. frequency.

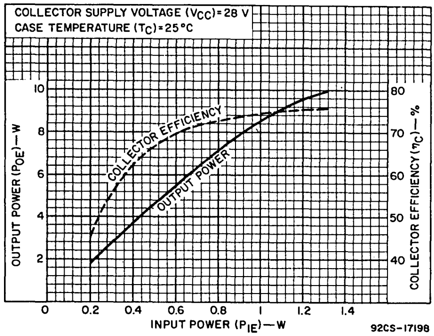


Fig. 2 - Typical output power or collector efficiency vs. input power at 400 MHz.

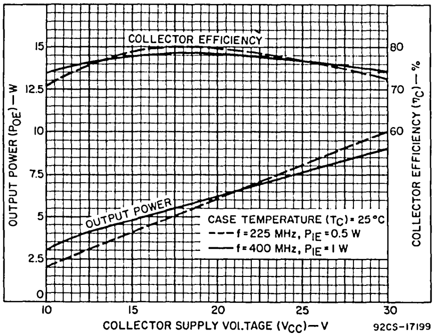


Fig. 3 - Typical output power or collector efficiency vs. collector supply voltage.

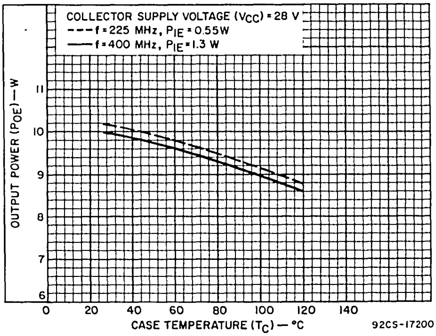


Fig. 4 - Typical output power vs. case temperature.

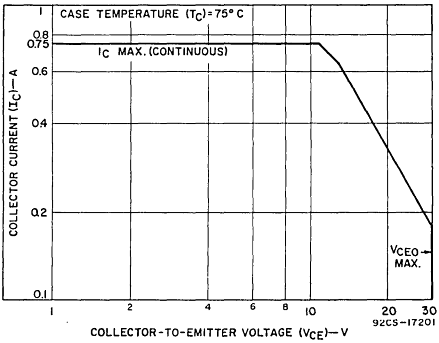


Fig. 5 - Maximum operating area for dc operation.

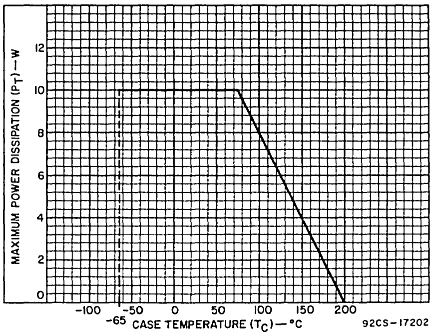


Fig. 6 - Dissipation derating curve for rf class-C operation.

DESIGN DATA

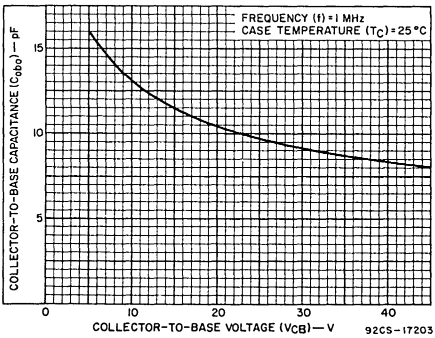


Fig. 7 - Typical variation of collector-to-base capacitance.

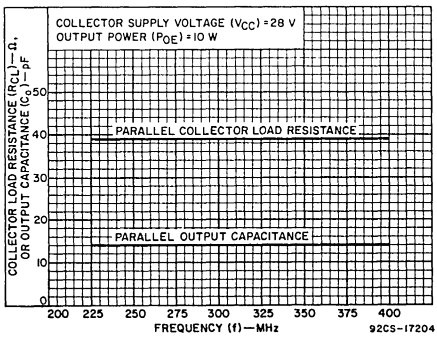


Fig. 8 - Typical large-signal parallel collector load and parallel output capacitance vs. frequency.

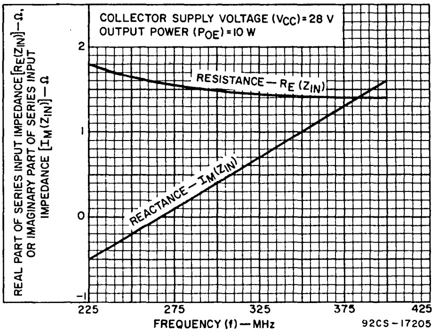
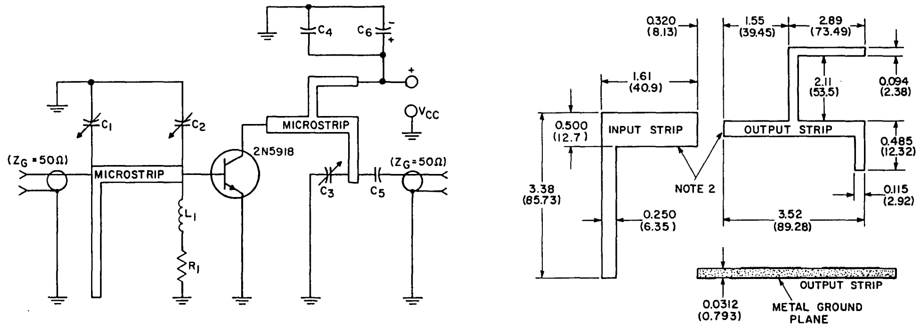


Fig. 9 - Typical large-signal series input impedance $[R_e(Z_{in}) + j\ I_m(Z_{in})]$ vs. frequency.



C_1, C_2, C_3: 12-18pF, AMPEREX HT10MA/218, OR EQUIVALENT
C_4, C_5: 1000pF, ATC-100, OR EQUIVALENT
C_6: 1.0μF, ELECTROLYTIC
L_1: 0.12μH RF CHOKE
R_1: 5.1Ω, 1/2 W CARBON

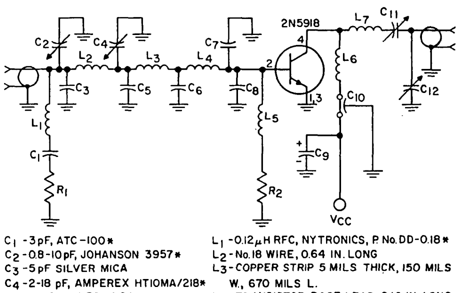
DIMENSIONS IN INCHES AND MILLIMETERS

NOTE 1: DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS AND ARE DERIVED FROM THE BASIC INCH DIMENSIONS AS INDICATED

NOTE 2: PRODUCED BY REMOVING UPPER LAYER OF DOUBLE-CLAD TEFLON BOARD, 1/32 IN. THICK, (ϵ = 2.6).

92CM-17206

Fig. 10 - 400-MHz amplifier test circuit for measurement of power output.



C_1 - 3pF, ATC-100*
C_2 - 0.8-10pF, JOHANSON 3957*
C_3 - 5pF SILVER MICA
C_4 - 2-18 pF, AMPEREX HT10MA/218*
C_5 - 24pF, SILVER MICA
C_6 - 51pF, ATC-100*
C_7 - 47pF, ATC-100*
C_8 - 68pF, ATC-100*
C_9 - 1μF, ELECTROLYTIC
C_{10} - 1000 pF, FEEDTHROUGH TYPE, ALLEN-BRADLEY FA5C*
C_{12} - 1.5-20 pF, ARCO 402*
C_{11} - 0.9-7 pF, ARCO 400*

L_1 - 0.12μH RFC, NYTRONICS, P. No. DD-0.18*
L_2 - No.18 WIRE, 0.64 IN. LONG
L_3 - COPPER STRIP 5 MILS THICK, 150 MILS W., 670 MILS L.
L_4 - TRANSISTOR BASE LEAD, 0.16 IN. LONG
L_5 - 0.1μH RFC, NYTRONICS, P. No. DD-0.10*
L_6 - No.18 WIRE, 1.08 IN. LONG
L_7 - 2 TURNS, 5/32 IN. I.D. No.18 WIRE, 12 TURNS PER IN.
R_1 - 100Ω, 1/2 W, CARBON
R_2 - 5.1Ω, 1/4 W, CARBON

* OR EQUIVALENT

92CS-17207

Fig. 11 - 225/400-MHz broadband amplifier using 2N5918.

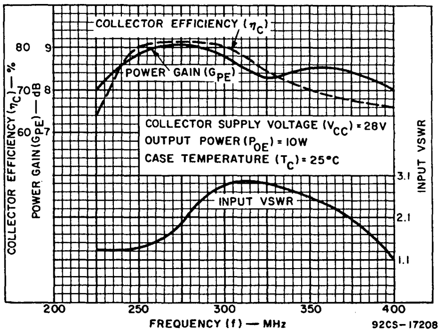
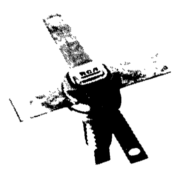


Fig. 12 - Typical broadband performance of the 225/400-MHz amplifier circuit shown in Fig. 11.

RCA
Solid State
Division

RF Power Transistors

2N5919A



JEDEC TO-216AA
H-1693

16-W, 400-MHz, Silicon N-P-N Emitter-Ballasted Overlay Transistor

Improved Version of 2N5919 Features Overdrive Capability of 20-W Output

Features:

- 6-dB gain (min.) at 400 MHz with 16 watts (min.) output
- Integral emitter-ballasting resistors
- Broadband performance (225-400 MHz)
- Low-inductance, ceramic-metal, hermetic package
- Radial leads for microstripline circuits
- All electrodes isolated from the stud

RCA Type 2N5919A● is an epitaxial silicon n-p-n planar transistor with "overlay" emitter-electrode construction.

The 2N5919A is unilaterally interchangeable with the 2N5919. Both types employ a construction which features many separate emitter elements; however, for stabilization, the 2N5919A has integral emitter ballast resistance.

●Formerly RCA Dev. No.TA7532.

The 2N5919A features the same hermetic, ceramic-metal package with rugged, low-inductance radial leads for microstripline as well as lumped-constant circuits.

This transistor is intended for use in large-signal, high-power, broadband and narrowband amplifiers in vhf/uhf equipment.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	30	V
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
*CONTINUOUS COLLECTOR CURRENT	I_C	4.5	A
*TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 75°C		25	W
At case temperatures above 75°C		Derate at 0.2	W/°C
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
*CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/ JS-9 RDF-7.

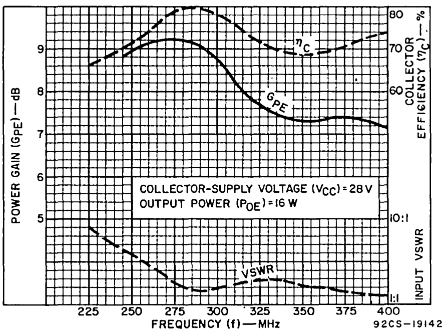


Fig.1—Typical performance of the 225-400-MHz broadband amplifier circuit shown in Fig.12.

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage-V V_{CE}	DC Base Voltage-V V_{BE}	DC Current mA I_E	I_B	I_C	LIMITS MIN.	MAX.	UNITS
* Collector-to-Emitter Cutoff Current: With base connected to emitter	I_{CES}	30	0				–	10	mA
* Collector-to-Emitter Breakdown Voltage: With base connected to emitter	$V_{(BR)CES}$		0			200[a]	65	–	V
With base open	$V_{(BR)CEO}$					200[a]	30	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			5		0	4	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$							5.0	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC})-V	Input Power (P_{IE})-W	Output Power (P_{OE})-W	Frequency (f)–MHz	LIMITS MIN.	MAX.	UNITS
Output Power (See Fig. 11)	P_{OE}	28	4.0		400	16	–	W
* Overdrive Objective Test	P_{OE}	28	7.0		400	20		W
* Power Gain	G_{PE}	28		16	400	6	–	dB
* Collector Efficiency	η_C	28	4.0		400	65	–	%
* Collector-to-Base Output Capacitance	C_{obo}	30 (V_{CB})			1	–	22	pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

TERMINAL CONNECTIONS

Terminals 1, 3 - Emitter
Terminal 2 - Base
Terminal 4 - Collector

WARNING: The ceramic heat-sink portion of this device contains beryllium oxide. Do not crush, grind, or abrade this portion because the dust resulting from such action may be hazardous if inhaled, Disposal should be by burial.

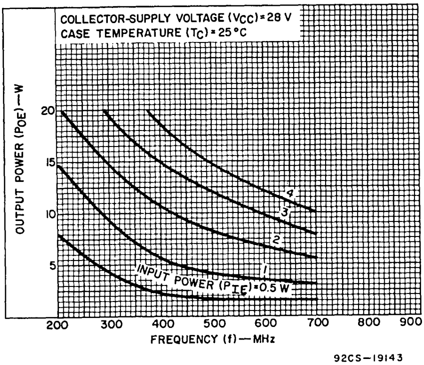


Fig.2—Typical output power vs. frequency.

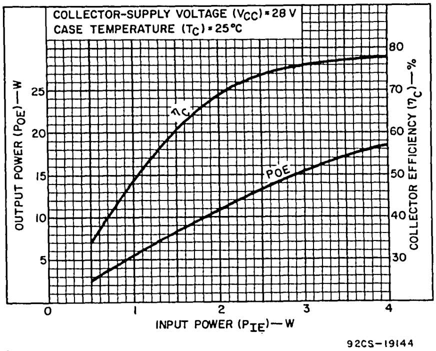


Fig.3—Typical output power and collector efficiency vs. input power.

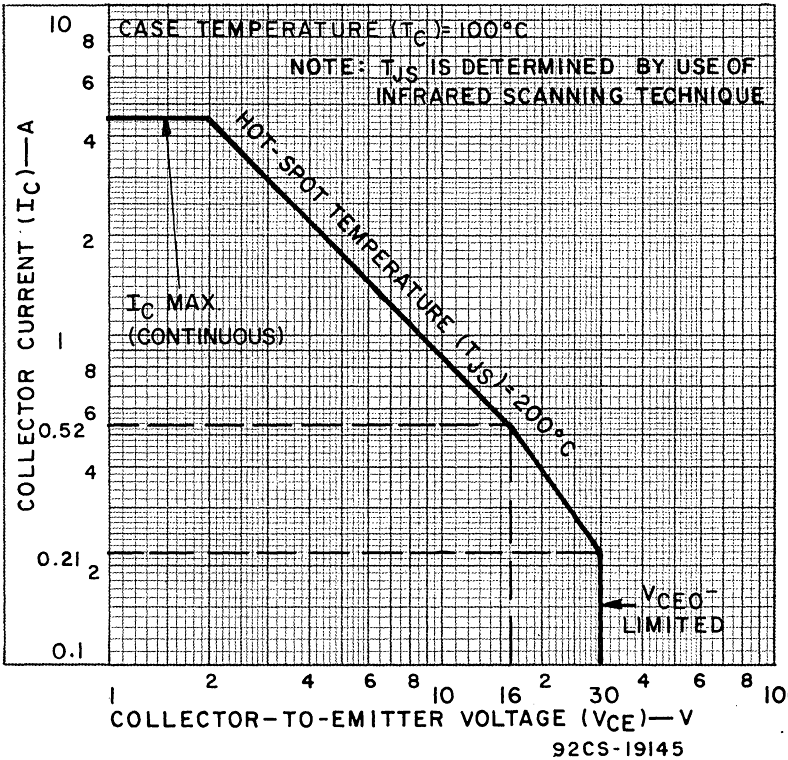


Fig.4—Maximum dc operating area for type 2N5919A.

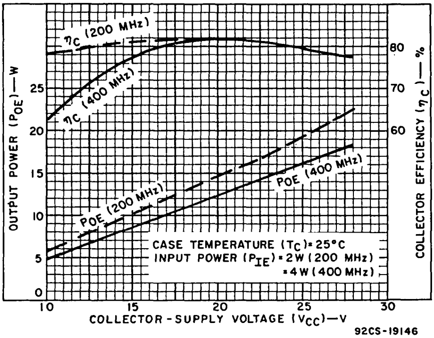


Fig.5—Typical output power and collector efficiency vs. collector-supply voltage.

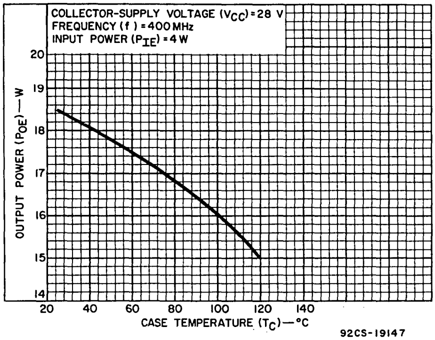


Fig.6—Typical output power vs. case temperature.

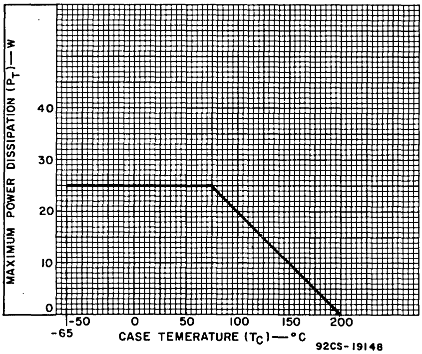


Fig.7—Dissipation-derating curve for class C operation.

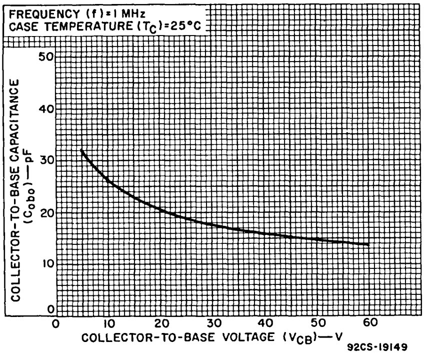


Fig.8—Typical variation of collector-to-base capacitance with collector-to-base voltage.

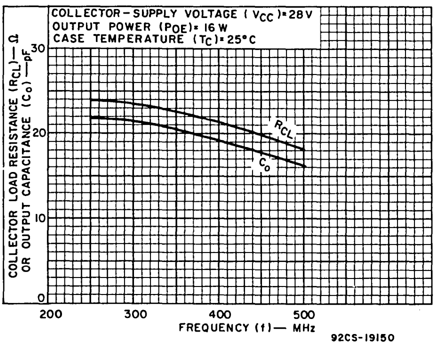


Fig.9—Typical large-signal parallel collector load resistance and parallel output capacitance vs. frequency.

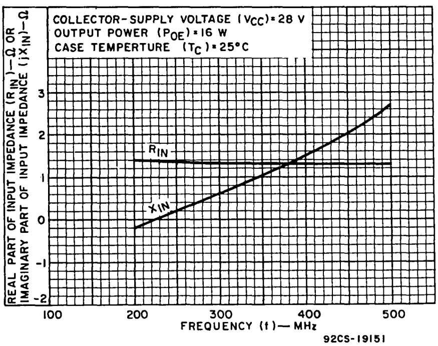
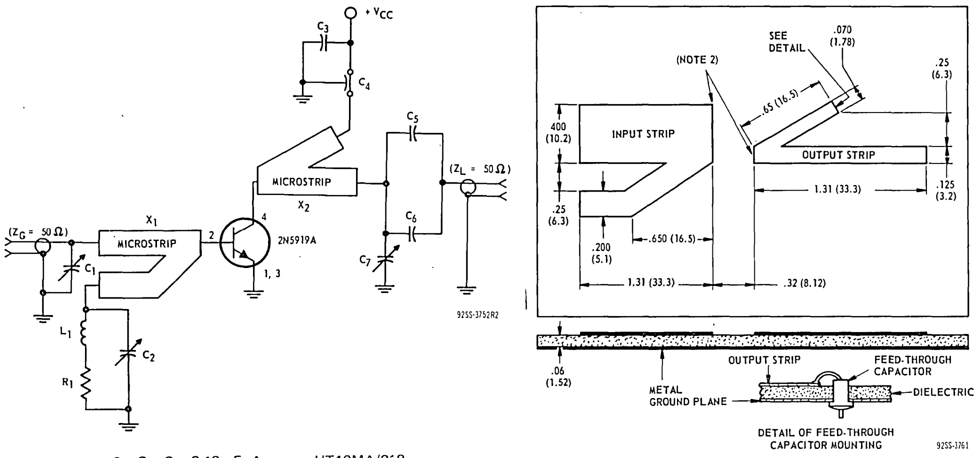


Fig.10—Typical large-signal series input impedance vs. frequency.



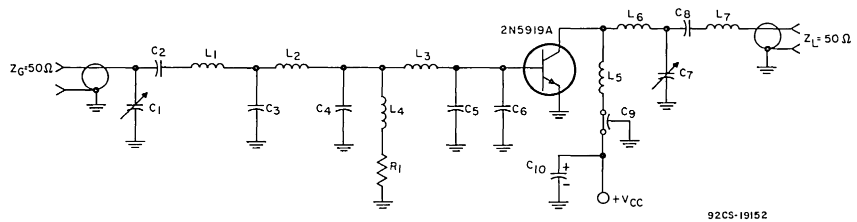
C_1, C_2, C_7: 2-18 pF, Amperex HT10MA/218, or equivalent
C_3: 0.03 μF, disc type
C_4: 470 pF, feed-through type, Allen-Bradley FA5C, or equivalent
C_5, C_6: 0.005 μF, disc type
L_1: 0.22 μH, rf choke
R_1: 5.1 Ω, 1/2 W carbon

Dimensions in Inches and Millimeters

Note 1: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Note 2: Produced by removing upper layer of double-clad, Teflon board, Budd Co. Polychem Div. Grade 108T, 1 oz, 1/16 in. thick, (ϵ = 2.6), or equivalent.

Fig. 11—400-MHz narrowband amplifier test circuit for measurement of power output.



C_1 - 0.8-10 pF, piston type, Johanson° 3957*
C_2 - 18 pF, silver mica
C_3 - 33 pF, chip type, Allen-Bradley° B16*
C_4 - 47 pF, chip type, Allen-Bradley B16*
C_5, C_6 - 62 pF, chip type, American Technical Ceramics° ATC-100*
C_7 - 0.8-20 pF, piston type, Johanson 4802*
C_8 - 15 pF, silver mica
C_9 - 1000 pF, feedthrough, Allen-Bradley FA5C*
C_{10} - 1 μF, electrolytic

L_1, L_5, L_7 - Two turns**
L_2 - 1/2-in. (12.7 mm) length of No.20 wire

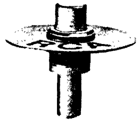
L_3 - Inductance of 5/32-in. (3.97 mm) long base lead of 2N5919A
L_4 - 0.1 μH, r-f choke, Nytronics°*
L_6 - 1-1/2 turns**
R_1 - 5.1 Ω, ½-W carbon
* or equivalent
°Johanson Mfg. Corp., Boonton, N. J. 07005
Allen-Bradley Co., Milwaukee, Wisc.
American Technical Ceramics
Huntington Station N.Y. 11746
Nytronics Inc., Berkeley Heights, N.J.
** No.20 wire, 14 turns/inch, 5/32 in. (3.97 mm) ID, 5/32 in. (3.97 mm) leads.

Fig. 12—225 to 400-MHz broadband amplifier circuit.

RCA
Solid State
Division

RF Power Transistors

2N5920



JEDEC TO-215AA

H-1598

2-W,2-GHz,Emitter-Ballasted Silicon N-P-N Overlay Transistor

For UHF/Microwave Power Amplifiers, Microwave Fundamental-Frequency Oscillators and Frequency-Multipliers

Features:

- **2-W output with 10-dB gain (min.) at 2 GHz**
- **3-W output with 12-dB gain (typ.) at 1 GHz**
- **Ceramic-metal hermetic package with low inductance and low parasitic capacitances**
- **Stable common-base operation**
- **For coaxial, microstripline, & lumped-constant circuit applications**
- **Integral emitter-ballasting resistors**

RCA 2N5920● is an epitaxial silicon n-p-n planar transistor featuring the overlay multiple-emitter-site construction. It is intended for solid-state equipment for microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance measuring equipment and collision avoidance systems.

Integral emitter-ballast resistance is employed for improved ruggedness and increased overdrive capability.

The ceramic-metal coaxial package of the 2N5920 features low parasitic capacitances and inductances which provide for stable operation in the common-base amplifier configuration. Ideal as a driver for the 2N5921, this transistor can also be used in large signal applications in coaxial, stripline and lumped-constant circuits.

● Formerly RCA Dev. Type No. TA7487.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
* COLLECTOR-TO-EMITTER VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 10 Ω, sustaining	$V_{CER}(sus)$	50	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
* DC COLLECTOR CURRENT (CONTINUOUS)	I_C	0.25	A
* TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		3.5	W
At case temperatures above 75°C, derate linearly		0.028	W/°C
For point of measurement of temperature (on collector terminal), see dimensional outline.			
* TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to +200	°C
* CASE TEMPERATURE (During Soldering):			
For 10 s max.		230	°C

* In accordance with JEDEC registration data format (JS-6-RDF-3/JS-9-RDF-7).

11-73

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C, unless otherwise specified.*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE (V) V_{CE}	V_{BE}	DC CURRENT (mA) I_E	I_B	I_C	LIMITS MIN.	MAX.	UNITS
• Collector-Cutoff Current	I_{CES}	45	0				–	2	mA
At T_C = 100°C	I_{CES}	50	0				–	3	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	50	-	V
• Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$					5[a]	50	-	V
• Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	-	1	V
Thermal Resistance: (Junction-to-collector terminal)	$R_{\theta JCT}$	10				100	-	30	°C/W

[a] Pulsed test, 50% duty factor.

DYNAMIC

CHARACTERISTIC	SYMBOL	POWER INPUT P_{IB} (W)	POWER OUTPUT P_{OB} (W)	SUPPLY VOLTAGE V_{CC} (V)	FREQUENCY (f) GHz	LIMITS MIN.	MAX.	UNITS
Power Output (See Fig. 5)	P_{OB}	0.2		28	2	2		W
• Power Gain	G_{PB}	0.2	2.0	28	2	10		dB
• Collector Efficiency	η_C	0.2	2.0	28	2	40		%
• Collector-to-Base Capacitance	C_{obo}			30(V_{CB})	1 MHz		3	pF

PERFORMANCE DATA

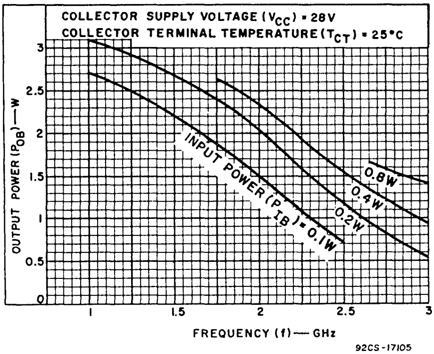


Fig. 1 - Typical output power vs. frequency for common-base amplifier.

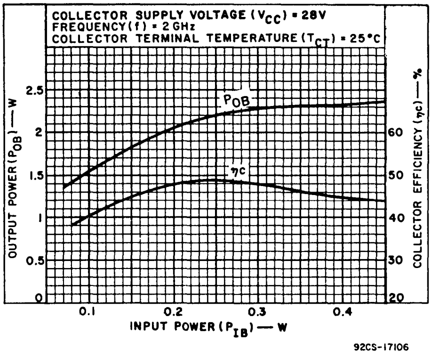


Fig. 2 - Typical output power and collector efficiency vs. input power for 2-GHz common-base power amplifier (Fig. 10)

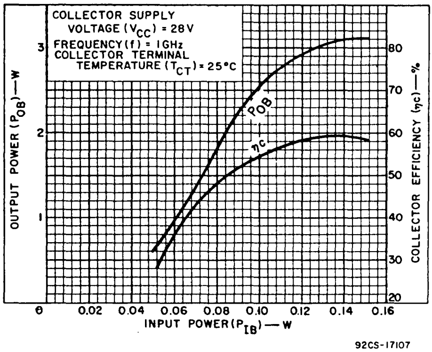


Fig. 3 - Typical output power and collector efficiency vs. input power for 1-GHz common-base power amplifier.

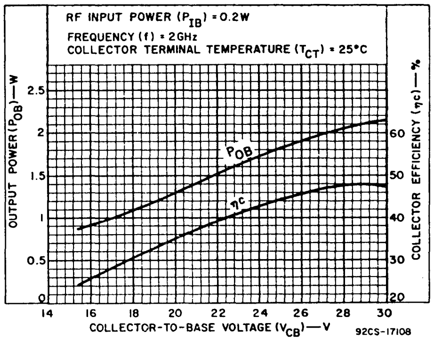


Fig. 4 - Typical output power and collector efficiency vs. collector-to-base voltage in a 2-GHz common-base amplifier.

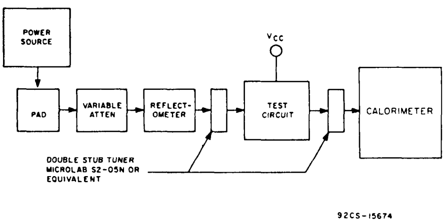


Fig. 5 - Block diagram of test set-up for measurement of output power from 1.0- or 2-GHz common-base amplifier.

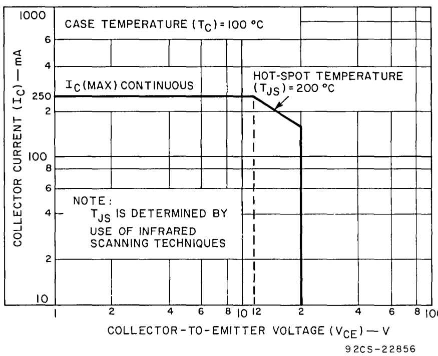


Fig. 6 - Maximum operating area for forward-bias operation.

DESIGN DATA

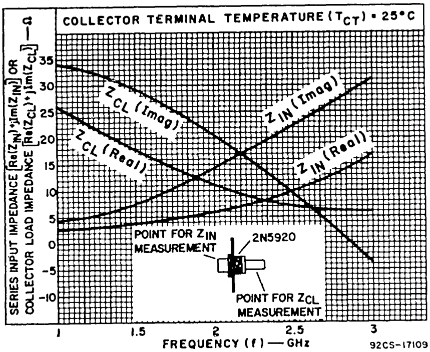


Fig. 7 - Typical large-signal series input impedance or large-signal collector load impedance vs. frequency.

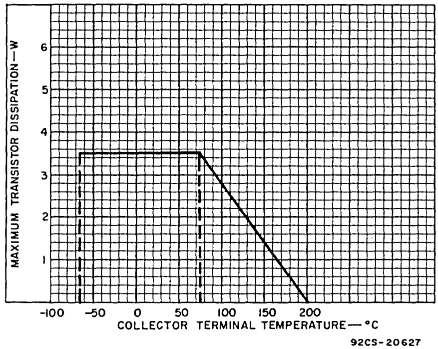


Fig. 8 - Temperature derating of power dissipation of the 2N5920.

APPLICATION DATA

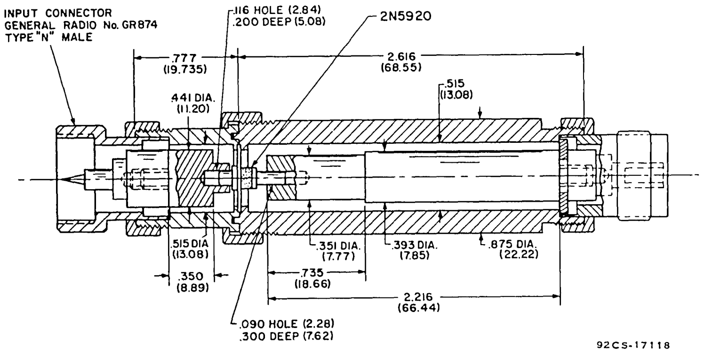
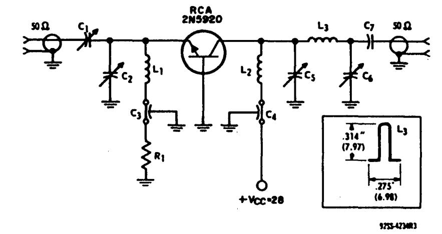


Fig. 9 - Constructional details of 2 GHz power amplifier.

SOLDERING INSTRUCTIONS

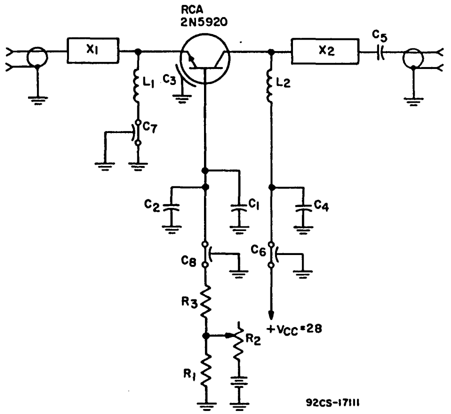
When soldering the 2N5920 into a microstripline or lumped-constant circuit, the collector and emitter terminals of the device must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

APPLICATION DATA (cont'd)



C_1, C_5, C_6:	1-14 pF, air-dielectric, Johanson 3901, or equivalent
C_2:	0.35-3.5 pF, air-dielectric, Johanson 4701, or equivalent
C_3, C_4:	1000 pF, feed-through, Allen-Bradley FA5C, or equivalent
C_7:	1000 pF, ceramic, leadless
L_1, L_2:	RF choke, 0.1μH, Nytronics Deci-Ductor
L_3:	0.01-in. (.254) thick, 0.157 in. (3.98) wide copper strip shaped as shown in inset drawing
R_1:	1Ω, ½ W

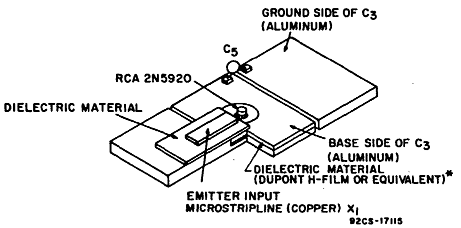
Fig. 10 - Typical circuit for 1-GHz power amplifier.



C_1, C_2, C_4:	0.005 uf
C_3:	This capacitance results from the mounting (See Fig. 12)
C_5:	.001 uf ATC
C_6, C_7, C_8:	.001 μf feedthrough capacitor
R_1:	75 Ω
R_2:	0-750 Ω potentiometer
R_3:	220 Ω
L_1 & L_2:	RF 6 turns No. 28-wire 0,062 in. (1.57) I. D., 3/16 in. (4.75) long
X_1:	UNIFORM MICROSTRIPLINE 0.107 in. (27. 9mm) wide 0.475 in. (120. 8mm) long 0.005 in. (0.13mm) thick copper
X_2:	UNIFORM MICROSTRIPLINE 0.065 in. (1.65mm) wide 1.150 in. (29.21mm) long 0.005 in. (0.13mm) thick copper

* Allen - Bradley
■ American Technical Ceramics, Huntington Station, N.Y. 11746

Fig. 11 - Typical forward-biased 2-GHz common-base amplifier using the 2N5920.



*2 MILS THICK

Fig. 12 - Construction details of low inductance base-bypass capacitor C_3 shown in Fig. 11.

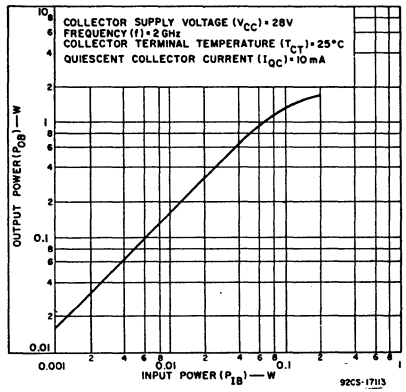


Fig. 13—Typical output power vs. input power of 2N5920 in a forward-biased 2-GHz amplifier (see Fig. 11).

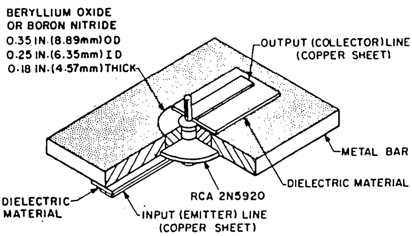
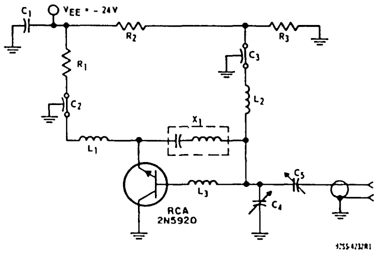


Fig. 14 - Suggested mounting arrangement of the 2N5920 in a microstripline circuit.



C_1:	0.01 μF, disc ceramic
C_2, C_3:	100 pF, feed-through Allen-Bradley FA5C, or equivalent
C_4, C_5:	0.35 – 3.5 pF, Johanson 4701, or equivalent
L_1, L_2:	RF choke, 4 turns, No. 33 wire, 0.062 in.(1.57) ID, 3/16 in.(4.75) long
L_3:	3/64 in(1.17) length of No. 22 wire
X_1:	0.82 pF, "gimmick", Quality Components type 10% QC, or equivalent
R_1:	5 – 10 Ω, 1/2 W
R_2:	51 Ω, 1/2 W
R_3:	1200 Ω, 1/2 W

Fig. 15 - Typical circuit for 2-GHz grounded-collector power oscillator.

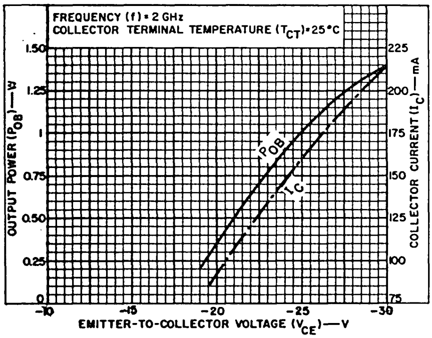


Fig. 16—Typical output power vs. supply voltage and current for 2-GHz grounded-collector oscillator (see Fig. 15).

TERMINAL CONNECTIONS

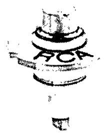
Terminal No. 1 – Emitter
Terminal No. 2 – Base
Terminal No. 3 – Collector

RCA

Solid State
Division

RF Power Transistors

2N5921



JEDEC TO-201AA H-1629

5-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For UHF/Microwave Power Amplifiers, Microwave Fundamental-Frequency Oscillators and Frequency Multipliers

Features:

- 5-W output with 5.5-dB gain (typ.) at 2.3 GHz
- 5-W output with 7-dB gain (min.) at 2 GHz
- 10-W output with 11-dB gain (typ.) at 1.2 GHz
- Integral emitter-ballasting resistors
- Ceramic-metal hermetic package with low inductance and low parasitic capacitances
- Beryllium oxide ceramic for low thermal-resistance path between collector stud & base flange
- Stable common-base operation
- For coaxial, microstripline, & lumped-constant circuit applications

RCA 2N5921● is an epitaxial silicon n-p-n planar transistor featuring the overlay multiple-emitter-site construction. It is intended for solid-state equipment for microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance measuring equipment and collision avoidance systems. Integral emitter-ballast resistance is employed for improved ruggedness and increased overdrive capability.

The ceramic-metal coaxial package of the 2N5921 features low parasitic capacitances and inductances which provide for stable operation in the common-base amplifier configuration. This transistor can be used in large signal applications in coaxial, stripline, and lumped-constant circuits. The 2N5921 can withstand load mismatch conditions at 2 GHz up to VSWR of 10:1 (all phases) in the common-base circuit shown in Fig. 9.

● Formerly RCA Dev. Type No. TA7205.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
* COLLECTOR-TO-EMITTER VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
* DC COLLECTOR CURRENT (CONTINUOUS)	I_C	0.7	A
TRANSISTOR DISSIPATION:	P_T		
* At case temperatures up to 25°C		14.5	W
* At case temperatures above 25°C, derate linearly		0.083	W/°C
* TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to + 200	°C
* CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

* In accordance with JEDEC registration data format (JS-6-RDF-3/JS-9RDF-7).

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C , unless otherwise specified.*

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector or Base Voltage (V) V_{CE}	V_{BE}	DC Current (mA) I_E	I_B	I_C	LIMITS Min.	Max.	UNITS
*	Collector-Cutoff Current	I_{CES}	45	0				–	2	mA
		I_{CES} (T_C = 100°C)	45	0				–	5	
	Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	50	–	V
*	Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$					10	50	–	V
*	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
	Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				20	100	–	1	V
	Thermal Resistance: (Junction-to-Flange)	$R_{\theta JF}$						–	12	°C/W

DYNAMIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Frequency (f) – GHz	DC Collector Supply Voltage (V_{CC}) – V	LIMITS Min.	Max.	UNITS
	Output Power P_{IB} = 1 W (See Fig. 9)	P_{OB}	2	28	5	–	W
*	Power Gain P_{OB} = 5 W	G_{PB}	2	28	7	–	dB
*	Collector Efficiency P_{OB} = 5 W	η_C	2	28	40	–	%
*	Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	8.5	pF

*In accordance with JEDEC registration data format (JS-6-RDF-3/JS-9-RDF-7).

TYPICAL APPLICATION INFORMATION

CIRCUIT & FREQUENCY	See Fig.	DC Collector Supply Voltage (V_{CC}) – V	Input Power (P_{IB}) – W	Output Power (P_{OB}) – W
Coaxial-Line				
2-GHz Amplifier	9	28	1	6
1.2-GHz Amplifier		28	0.75	10
Microstripline				
2-GHz Amplifier	11	28	1	5
Lumped-Constant				
1.4-GHz Amplifier	15	28	1	6.8
1-GHz Amplifier	14	28	1	10.6
Microstripline				
1.2-1.4 GHz Tunable Oscillator	16	28	–	4

PERFORMANCE DATA

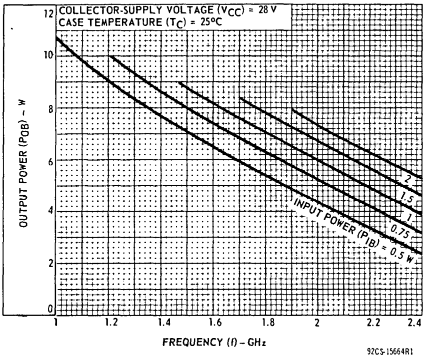


Fig. 1 - Typical output power vs. frequency.

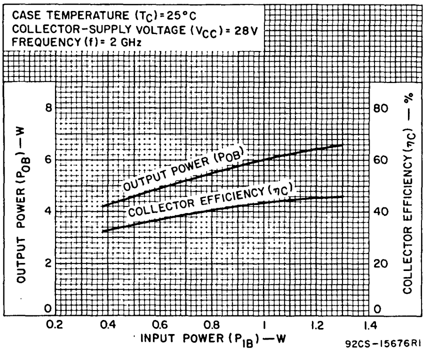


Fig. 2 - Typical power output or collector efficiency vs. power input at 2 GHz for circuit shown in Fig. 9.

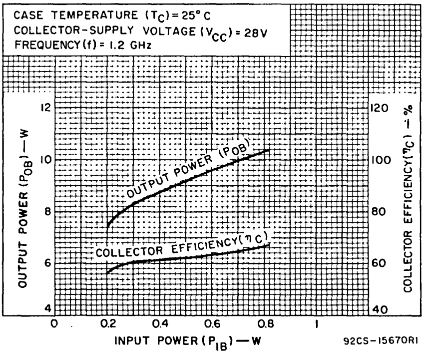


Fig. 3 - Typical power output or collector efficiency vs. power input at 1.2 GHz for circuit shown in Fig. 9.

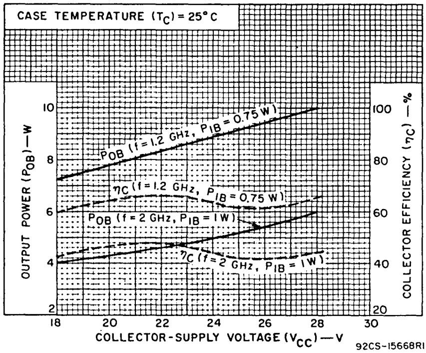


Fig. 4 - Typical power output or collector efficiency vs. collector supply voltage.

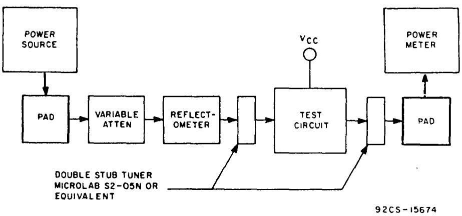


Fig. 5 - Block diagram of test set-up for measurement of output power from 1.2 - or 2-GHz common-base amplifier.

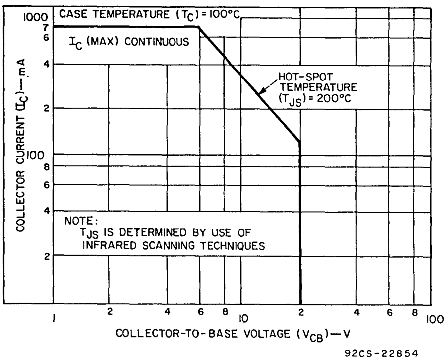


Fig. 6 - Safe operating area for dc operation.

DESIGN DATA

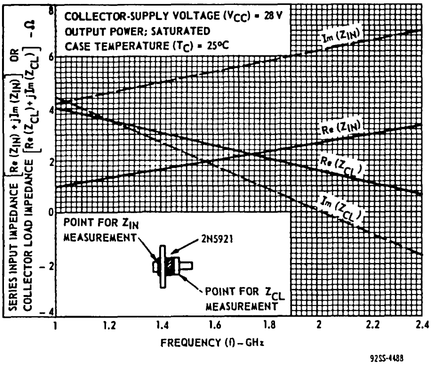


Fig. 7 - Typical large-signal series input impedance or large-signal collector load impedance vs. frequency.

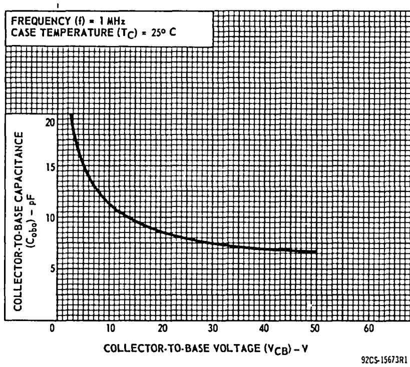
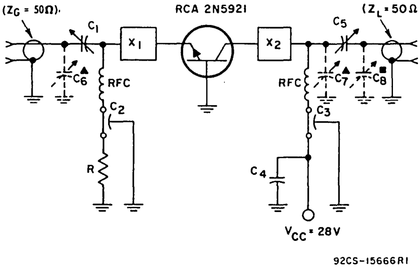


Fig. 8 - Typical collector-to-base capacitance vs. collector-to-base voltage.

APPLICATION INFORMATION



▲ Use only in the 2-GHz coaxial-line power amplifier circuit.
■ Use only in the 1.2-GHz coaxial-line test circuit.

* Johanson Mfg. Corp., Boonton, N.J. 07005

CIRCUIT	C_1 pF	C_2 pF	C_3 pF	C_4 μF	C_5 pF	C_6 pF	C_7 pF	C_8 pF	R Ω
1.2 GHz (Test Circuit)	1-10	1000	1000	0.01	1-10	-	-	0.3-3.5	0.75
2 GHz (Test Circuit)	1-10	470	470	0.01	1-10	-	-	-	0.43
2 GHz (Amplifier)	1-10	470	470	0.01	0.3-3.5	0.3-3.5	0.3-3.5	-	0.43

C_1 & C_5, 1-10pF Range: Johanson 4581, or equivalent*

C_5, C_6, C_7 & C_8, 0.3-3.5pF Range: Johanson 4700, or equivalent*

RFC: For 2-GHz Circuits: 3 turns No.32 wire 1/16 in. (1.59 mm) ID, 3/16 in. (4.76 mm) long.
For 1.2-GHz Circuit: 6 turns No.32 wire 1/16 in. (1.59 mm) ID, 3/16 in. (4.76 mm) long.

X_1, X_2: Coaxial-line circuits, see Fig. 10.

Fig. 9 - 1.2/2 GHz coaxial-line amplifier circuits.

TERMINAL CONNECTIONS

Terminal No. 1 – Emitter
Terminal No. 2 – Base
Terminal No. 3 – Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

APPLICATION INFORMATION (Cont'd)

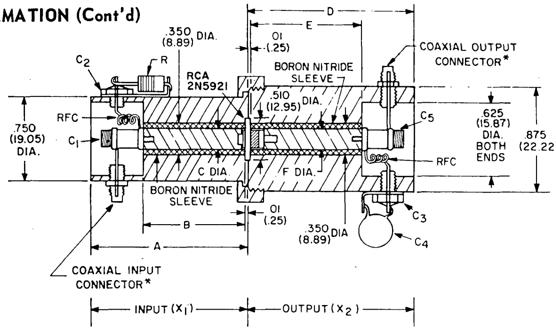


TABLE 1 - Dimensions of coaxial lines X_1 & X_2 for 2 GHz amplifier & 1.2 & 2-GHz test circuit

CIRCUIT	DIMENSIONS							
	INPUT (X_1)				OUTPUT (X_2)			
	A	B	C	Center Conductor	A	E	F	Center Conductor
1.2 GHz (Test Circuit)	1.385 (35.18)	.875 (22.22)	.282 (7.16)	.825 (20.95)	1.778 (45.16)	1.268 (32.21)	.213 (5.41)	1.05 (26.67)
2 GHz (Test Circuit)	.940 (23.88)	.430 (10.92)	.266 (6.76)	.380 (9.65)	1.04 (26.42)	.530 (13.46)	.266 (6.76)	.370 (9.39)
2 GHz (Amplifier)	.860 (21.84)	.350 (8.89)	.265 (6.73)	.300 (7.62)	1.06 (26.92)	.550 (13.97)	.270 (6.86)	.385 (9.78)

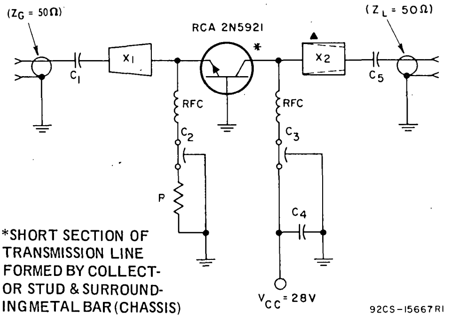
Dimensions in Inches and Millimeters

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

MATERIAL: Center conductor – copper
Outer conductor for input & output – brass

* Conhex 50-045-0000 Sealectro Corp., or equiv.

Fig. 10 - Constructional details of 1.2/2 GHz coaxial-line test circuits.



*SHORT SECTION OF TRANSMISSION LINE FORMED BY COLLECTOR STUD & SURROUNDING METAL BAR (CHASSIS) . . . See Fig. 12.

▲WITH SOME DEVICES, LOAD END OF X_2 MAY REQUIRE A SLIGHT TAPER TO INCREASE Z_0 FOR OPTIMUM MATCH CONDITION.

C_1,C_5: 300 pF disc ceramic
C_2,C_3: 470 pF, feed through, Allen-Bradley FA5C, or equivalent
C_4: 0.01 μF, disc ceramic
R: 0.43 Ω
RFC: No.32 wire, 0.4 in. (1.02 mm) long
X_1: TAPERED MICROSTRIPLINE –
0.15 in. (3.81 mm) wide, input end
0.30 in. (7.62 mm) wide, output end
0.525 in. (13.33 mm) long
0.005 in. (0.13 mm) thick, copper
X_2: UNIFORM MICROSTRIPLINE –
0.25 in. (6.35 mm) wide
0.36 in. (9.14 mm) long
0.005 in. (0.13 mm) thick, copper
DIELECTRIC MATERIAL: 0.5 in. (12.7 mm) wide
0.75 in. (19.05 mm) long
0.005 in. (0.13 mm) thick
DuPont H-Film, or equiv.
NOTE: See Fig. 12 for suggested mounting arrangement of 2N5921.

Fig. 11 - Typical circuit for 2-GHz grounded-base microstripline power amplifier.

APPLICATION INFORMATION (Cont'd)

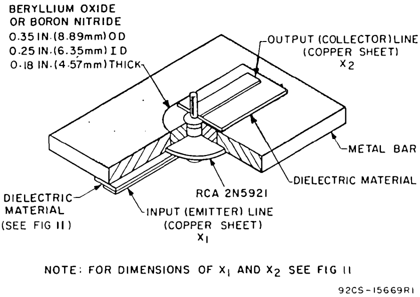


Fig. 12 - Suggested mounting arrangement of the 2N5921 in a microstripline circuit.

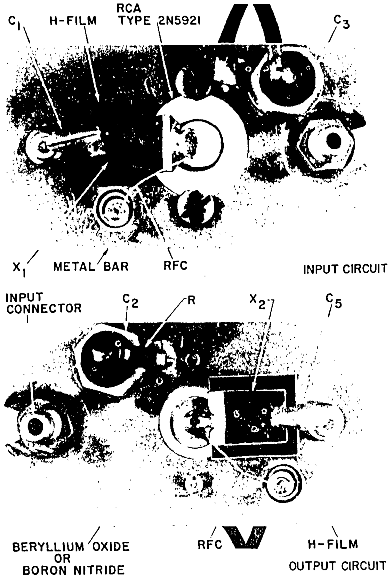
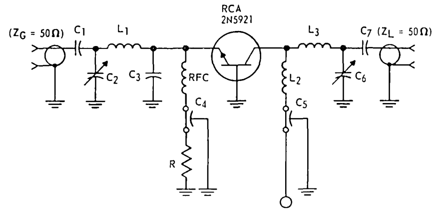


Fig. 13 - Suggested mounting arrangement of components for 2-GHz microstripline circuit shown in Fig. 11.

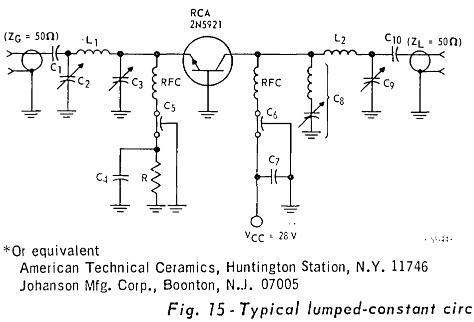


Bandwidth = 100MHz (1 dB)

C_1, C_7: 510 pF, ATC-200*
C_2, C_6: 1-10 pF, Johanson 2954*
C_3: 10 pF, ATC-100*
C_4, C_5: 470 pF, feed-through type, Allen-Bradley FA5C
L_1: 3.7 nH
L_2: 0.8 nH
L_3: 2.3 nH
R: 0.47 Ω
RFC: 5 turns, No. 28 wire, 0.05 in. (1.27 mm) I.D., 0.4 in. (10.16 mm) long.

*Or equivalent
American Technical Ceramics, Huntington Station, N.Y. 11746
Johanson Mfg. Corp., Boonton, N.J. 07005

Fig. 14 - Typical lumped-constant circuit for 1-GHz power amplifier.



C_1, C_{10}: 510 pF, ATC-100*
C_2, C_9: 0.3-35 pF, Johanson 4700*
C_3: Single, parallel-plate variable capacitor approx. 19 pF
C_4, C_7: 0.01 mF, disc ceramic
C_5, C_6: 470 pF, feed-through type, Allen-Bradley FA5C
C_8: 1-10 pF, Johanson 2954* (series resonant in this frequency range and used as a variable inductor)
L_1: 3.4 nH
L_2: 2.5 nH
R: 0.47 Ω
RFC: 5 turns, No. 28 wire, 0.05 in. (1.27 mm) I.D., 0.4 in. (10.16 mm) long.

*Or equivalent
American Technical Ceramics, Huntington Station, N.Y. 11746
Johanson Mfg. Corp., Boonton, N.J. 07005

Fig. 15 - Typical lumped-constant circuit for 1.4 GHz power amplifier.

APPLICATION INFORMATION (Cont'd)

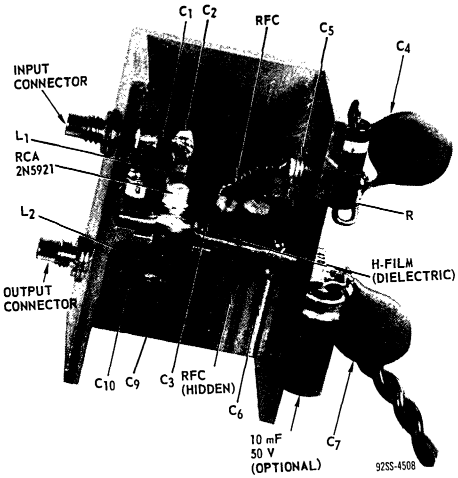
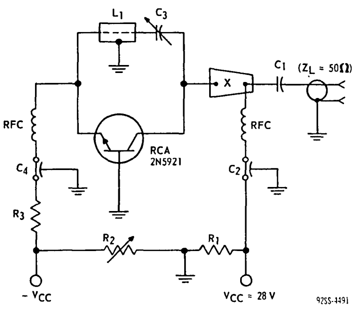


Fig. 16 - Suggested mounting arrangement of components for 1.4-GHz lumped-constant power amplifier circuit shown in Fig. 15.



*Johanson Mfg. Corp., Boonton, N.J. 07005

C_1: 300 pF, disc ceramic
C_2, C_4: 470 pF, feed-through type, Allen-Bradley FA5C, or equivalent
C_3: 0.3-3.5 pF, Johanson 4702, or equivalent*
L_1: 1.3 in. (33.02 mm) length of 50 Ω coaxial line
R_1: 1200 Ω
R_2: 0-250 Ω
R_3: 5 Ω
RFC: 3 turns, No. 29 wire, 0.06 in. (1.59 mm) I.D., 0.18 in. (4.77 mm) long.
X: TAPERED MICROSTRIPLINE –
0.1 in. (2.54 mm) wide, input end
0.24 in. (6.09 mm) wide, output end
0.475 in. (12.06 mm) long
0.005 in. (0.13 mm) thick, copper
DIELECTRIC MATERIAL: Same as that for Fig. 11
(See Fig. 12 for mounting of output section)

Fig. 17 - Typical circuit for tunable 1.2 - 1.4 GHz, 4-W microstripline power oscillator.

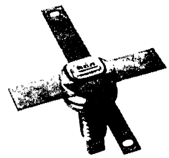
SOLDERING INSTRUCTIONS

When soldering the 2N5921 into a microstripline or lumped-constant circuit, the collector and emitter terminals of the device must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

RCA
Solid State
Division

RF Power Transistors

2N5995



TO-216AA

H-1693

7-W, (CW) 175-MHz Silicon N-P-N Overlay Transistor

For 12.5-Volt Applications in VHF Communications Equipment

Features:

- **Low-inductance radial leads**
- **Hermetically sealed ceramic-metal package**
- **Electrically isolated mounting stud**
- **7 watt (min.) output at 175 MHz**
- **9.7 dB (min.) gain at 175 MHz**
- **Infinite load mismatch tested at 175 MHz**

RCA type 2N5995[a] is an epitaxial silicon n-p-n planar transistor featuring overlay emitter-electrode construction. This type features a hermetic ceramic-metal package having leads isolated from the mounting stud. This rugged, low-inductance, radial-lead type is designed for stripline as well as lumped-constant circuits.

This transistor is completely tested for load-mismatch capability at 175 MHz with an infinity-to-one VSWR through all phases under rated power.

[a]Formerly RCA Dev. Type TA7922

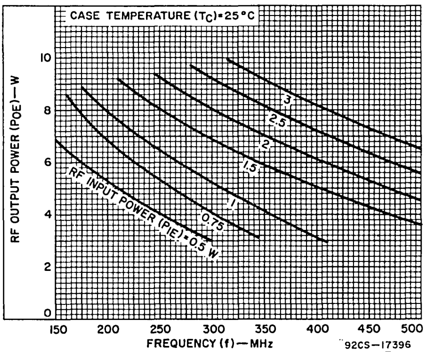


Fig. 1 — Typical rf output power vs. frequency.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	V
*COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:			
With base connected to emitter	$V_{(BR)CES}$	36	V
With base open	$V_{(BR)CEO}$	14	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
*COLLECTOR CURRENT:			
Continuous	I_C	1.5	A
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		10.7	W
At case temperatures above 75°C		See Fig. 9	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
*CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

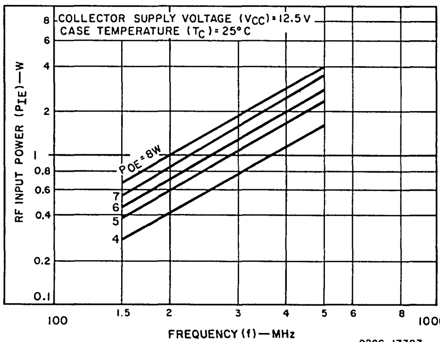


Fig. 2 — Typical rf input power vs. frequency.

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS		UNITS
			DC Collector Voltage-V	DC Base Voltage-V	DC Current mA					
			V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
*	Collector-Cutoff Current With base open	I_{CEO}	10			0		–	2.5	mA
	With base connected to emitter	I_{CES}	12.5	0				–	5[b]	mA
*	Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	36	–	V
*	Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$			0		75[a]	14	–	V
	With base connected to emitter	$V_{(BR)CES}$		0			75[a]	36	–	V
*	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			2		0	3.5	–	V
	Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$						–	11.7	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50% [b] T_C = 100°C

DYNAMIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS			LIMITS		UNITS
			DC Collector Supply (V_{CC}) -Volts	Input Power (P_{IE}) -Watts	Frequency (f) -MHz	MIN.	MAX.	
*	Power Output	P_{OE}	12.5	0.75	175	7	–	W
*	Power Gain	G_{PE}	12.5	0.75	175	9.7	–	dB
*	Collector Efficiency	η_C	12.5	0.75	175	65	–	%
	Load Mismatch (Fig. 11)	LM	12.5	0.75	175	GO/NO GO		
*	Collector-to-Base Capacitance	C_{ob}	12	–	1	–	80	pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7

TERMINAL CONNECTIONS

Terminals 1, 3 – Emitter
Terminal 2 – Base
Terminal 4 – Collector

WARNING: RCA Type **2N5995** should be handled with care. The ceramic portion of this transistor contains BERYLLIUM OXIDE as a major ingredient. Do not crush, grind, or abrade these portions of the transistor because the dust resulting from such action may be hazardous if inhaled.

PERFORMANCE DATA

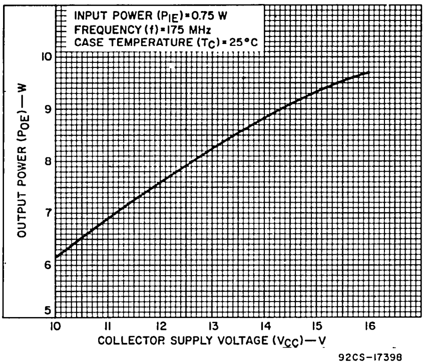


Fig. 3 — Typical output power vs. supply voltage (amplifier tuned at V_{CC} = 12.5 V).

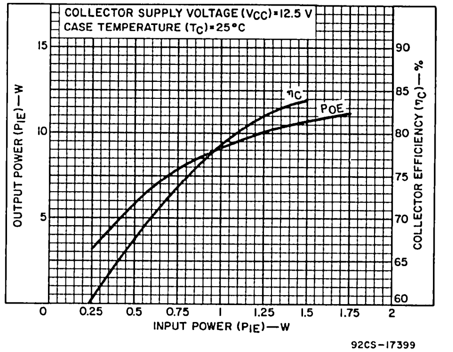


Fig. 4 — Typical output power and collector efficiency vs. input power at 175 MHz.

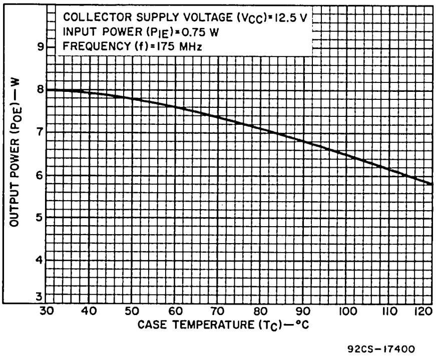


Fig. 5 — Typical output power vs. case temperature.

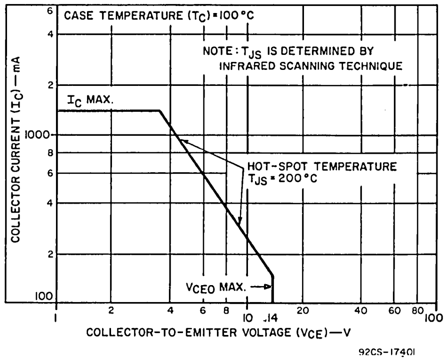


Fig. 6 — Safe area for dc operation.

DESIGN DATA

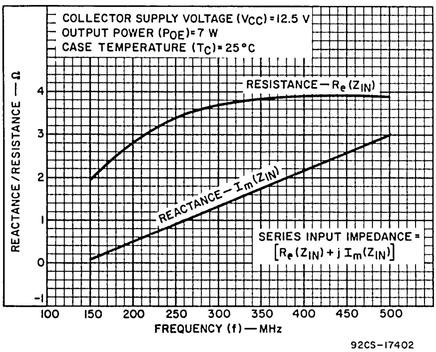


Fig. 7 — Typical large-signal series input impedance vs. frequency.

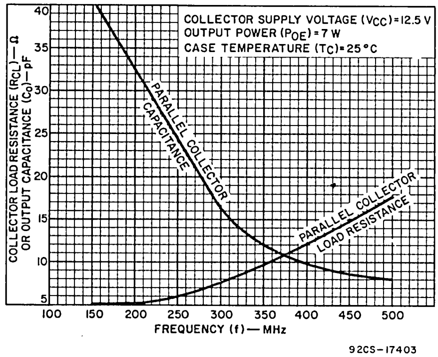


Fig. 8 — Typical large-signal parallel collector load resistance and parallel output capacitance vs. frequency.

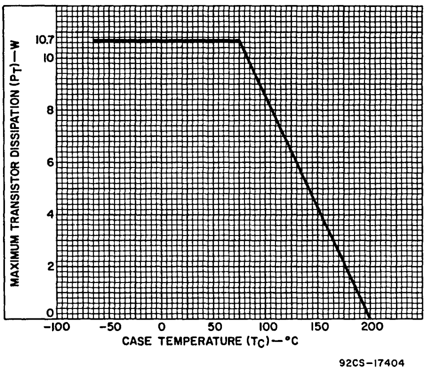
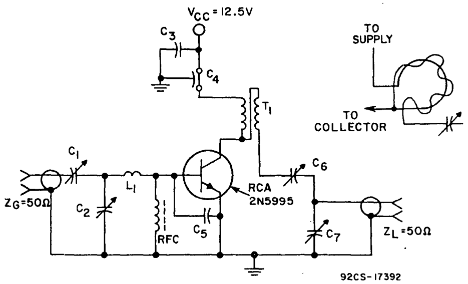


Fig. 9 — Dissipation derating.

APPLICATION DATA



L_1 - 1/2 turn No. 14 wire, 1/4-in. I.D.
RFC - Z = 450 Ω, Ferroxcube VK-200-09/3B or equivalent
C_1 - 7-100pF, Arco 423 or equivalent
C_2 - 4-40 pF, Arco 422 or equivalent
C_3 - 0.1 μF ceramic
C_4 - 0.001 μF feedthrough
C_5 - 62 pF silver mica
C_6 - 14-150pF, Arco 424 or equivalent
C_7 -24-200 pF, Arco 425 or equivalent
T_1 - Twisted pair of No. 20 enameled wire; 14 turns/in.
Formed in a loop 3/8 in. diameter, cross connected
(End of one winding connected to beginning of other)

Fig. 10 — 175-MHz amplifier for measuring power output and power gain.

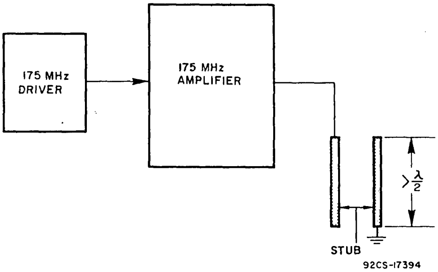
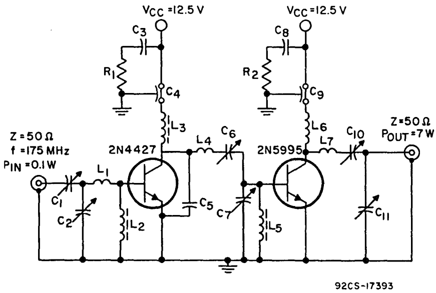


Fig. 11 — Test setup for testing load mismatch capability.



C_1, C_2, C_6:	8-60 pF, ARCO 404 or equivalent
C_3, C_8:	0.02 μF disc ceramic
C_4, C_9:	0.001 μF feedthrough
C_5:	15 pF silver mica
C_7:	14-150 pF, ARCO 424 or equivalent
C_{10}, C_{11}:	24-200 pF, ARCO 425 or equivalent
L_1:	2 Turns No. 18 wire, 1/4-in. I.D., 1/16-in. long
L_2, L_5:	RFC, Z = 450 Ω, Ferroxcube No. VK-200-09/3B or equivalent
L_3:	1 μH, Nytronics Deci-Ductor or equivalent
L_4:	2 Turns No. 18 wire, 1/4-in. I.D., 3/16-in. long
L_6:	3 Turns No. 16 wire, 1/4-in. I.D., 3/8-in. long
L_7:	1 Turn No. 16 wire, 1/4-in. I.D., 3/16-in. long
R_1, R_2:	12 Ω, 1/2 W

Fig. 12 — 175-MHz two-stage amplifier using 2N5995

SPECIAL PERFORMANCE DATA

The infinite VSWR load-mismatch capability of the transistor can be demonstrated in the following test:

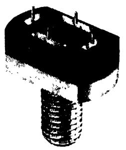
1. The test setup is shown in Fig. 11.
2. The tuning stub is varied through a half wavelength, which effectively varies the load from an open circuit to a short circuit.
3. Operating conditions are as follows: V_{CC} = 12.5 V, RF input power = 0.75 W.

Care should be taken not to exceed the maximum junction temperature by providing sufficient heatsinking during the above test to prevent device damage or degradation.

RCA
Solid State
Division

RF Power Transistors

2N6093



L-377

TO-217AA package

75-W (PEP) Emitter-Ballasted Overlay Transistor with Temperature-Sensing Diode

Silicon N-P-N Device for High-Gain Linear Amplifiers in HF Single-Sideband Equipment

Features:

- For 2- to- 30-MHz Single-Sideband Communications
- 75 Watts PEP Output (min.) at 30 MHz
  - with Gain: 13 dB (min.)
  - η: 40% (min.)
  - IMD: 30 dB (max.)
- 3:1 VSWR tested at rated power
- Low Thermal Resistance
- Isolated Pin-Pad Electrodes

RCA-2N6093* is an epitaxial silicon n-p-n planar transistor of the "overlay" emitter-electrode construction. This device utilizes many separate emitter elements and has individual ballast resistance in each of these emitter sites for stabilization. Linearity and greater protection from second breakdown are achieved by equalizing the current sharing between the emitter sites.

The 2N6093 is especially designed for linear applications to provide high power in class A or class B rf amplifier service.

The device is intended for 2- to- 30-MHz single-sideband power amplifiers operating from a 28-volt power supply.

Forward-bias control with temperature change is obtained by use of the built-in temperature-sensing diode.

Type 2N6093 features a molded silicone-plastic case with low-inductance, isolated electrodes. The case provides circuit flexibility for wiring to lumped-constant, strip-line, and printed-board circuits.

* Formerly RCA Type No.40675.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE:			
Base connected to emitter	V_{CES}	70	V
* With base open	V_{CEO}	35	V
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	70	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
*COLLECTOR CURRENT:	I_C		
CONTINUOUS		10	A
PEAK		30	A
DIODE CURRENT (DC, Max.)	I_F	100	mA
*TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		83.3	W
At case temperatures above 75°C		*See Fig. 9*	
*TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
*CASE TEMPERATURE			
(During soldering):			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *Case Temperature = 25° C*
STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage-V V_{CE}	DC Base Voltage-V V_{BE}	DC Current mA I_E	I_C	I_D	LIMITS Min.	Max.	UNITS
* Collector-to-Emitter Breakdown Voltage: With base connected to emitter	$V_{(BR)CES}$		0		200[a]		70	–	V
With base open	$V_{(BR)CEO}$				200[a]		35	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			20	0		3.5	–	V
* Collector-to-Emitter Cutoff Current: Base-emitter junction shorted, T_C = 55°C (Diode Voltage = 0)	I_{CES}	60	0				–	30	mA
* Compensating Diode Forward Voltage Drop	V_F				0	10	–	0.8	V
* DC Forward-Current Transfer Ratio	h_{FE}	6			5A		20	–	
Thermal Resistance Junction-to-case	$\theta_{J\text{-}C}$						–	1.5	°C/W

[a]Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC (Operating in a 30 MHz single-sideband amplifier)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage-V V_{CB}	V_{CC}	Power Output W(PEP) P_{OE}	Frequency MHz f	DC Collector Bias Current-mA I_C	LIMITS Min.	Max.	UNITS
RF Power Input* (See Fig. 12): Average	P_{IE}		28	37.5	30	20	–	1.88	W
Peak envelope (PEP)	P_{IE}		28	75	30	20	–	3.75	W
* Power Gain	G_{PE}		28	75	30	20	13		dB
* Collector Efficiency	η_C		28	75	30	20	40	–	%
* Magnitude of Common-Emitter, Small-Signal, Short-Circuit, Forward-Current Transfer Ratio	$\lvert h_{fe} \rvert$		28 (V_{CE})		50	1A	2	–	
Intermodulation Distortion	IMD		28	75	30	20	–	–30	dB
* Collector-to-Base Capacitance	C_{obo}	30			1		–	250	pF

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

PERFORMANCE DATA

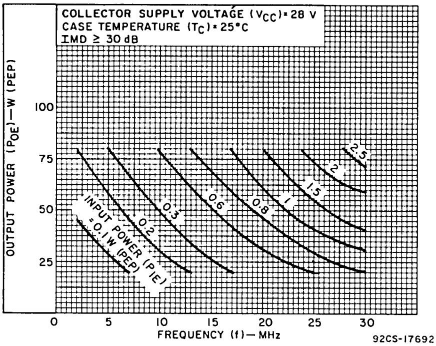


Fig. 1—Typical output power vs. frequency.

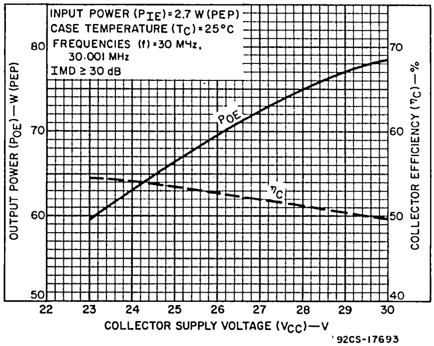


Fig. 2—Typical output power or collector efficiency vs. collector supply voltage.

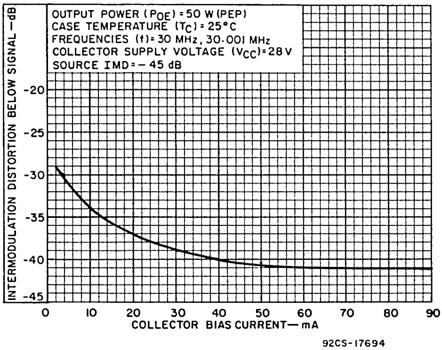


Fig. 3—Typical IMD vs. collector bias current.

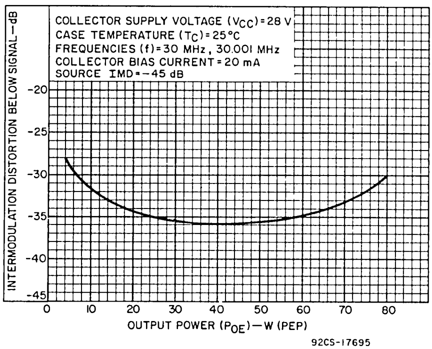


Fig. 4—Typical IMD vs. output power (PEP).

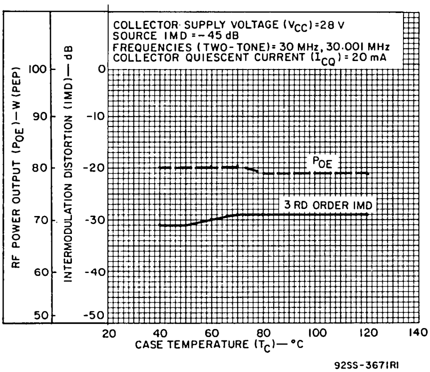


Fig. 5—Typical RF power output and intermodulation distortion vs. case temperature.

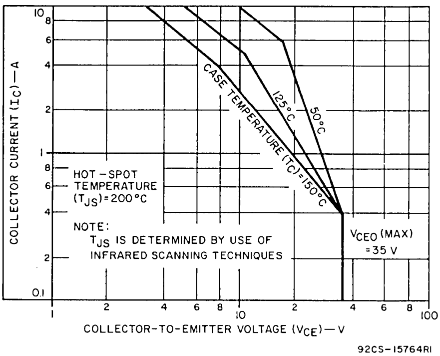


Fig. 6—Safe area for dc operation.

DESIGN DATA

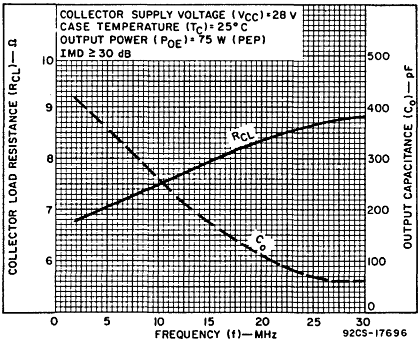


Fig. 7—Typical large-signal parallel collector load resistance and parallel output capacitance vs. frequency.

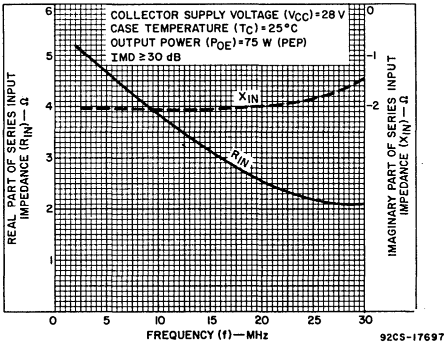


Fig. 8—Typical large-signal series input impedance (R_{in} + j X_{in}) vs. frequency.

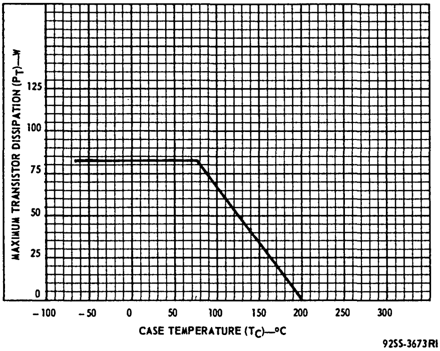


Fig. 9—RF dissipation derating.

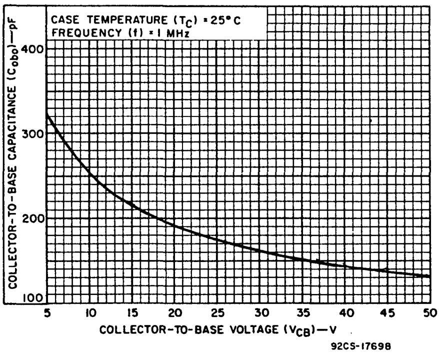


Fig. 10—Typical variation of collector-to-base capacitance vs. collector-to-base voltage.

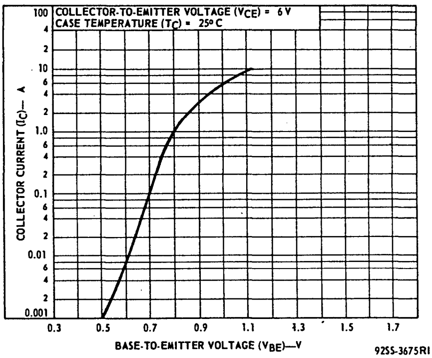
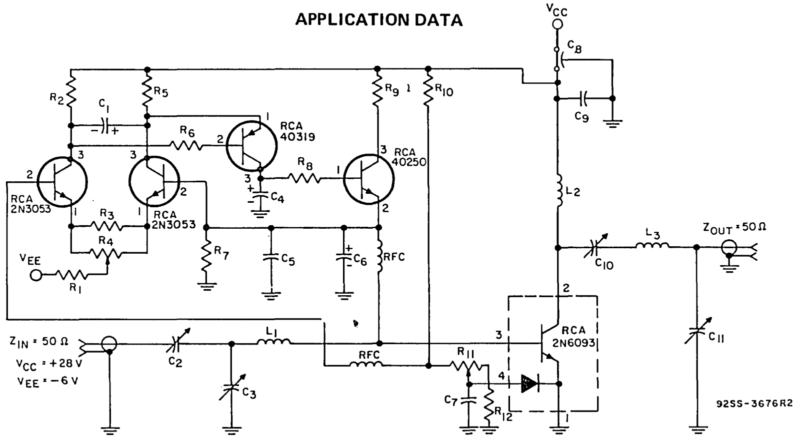


Fig. 11—Typical transfer characteristic.

APPLICATION DATA



C1, C4: 1 μF, 3 V, electrolytic
C2: 32-250 pF
C3: 55-300 pF
C5, C7: 0.0027 μF
C6: 100 μF, 3 V, electrolytic
C8: 1000 pF feedthrough
C9: 0.3 μF, 50 V
C10: 170-780 pF
C11: 80-480 pF

L1: 3 turns No.14 wire, ¼ in. I.D. ½ in. long
L2: 3 turns No.10 wire, ½ in. I.D. 3/8 in. long
L3: 3½ turns No.10 wire, 5/8 in. I.D. ½ in. long

R1, R8: 510 Ω
R2, R5: 2 kΩ
R3: 33 Ω
R4: 100 Ω
R6: 200 Ω
R7: 39 Ω
R9: 50 Ω
R10: 24 kΩ
R11: 100 Ω
R12: 1.5 kΩ

RFC: Ferroxcube No.VK200-01-3B, or equivalent
All resistors ½ watt

Fig. 12—30-MHz linear rf amplifier with temperature compensation.

TERMINAL CONNECTIONS

Pin. No.1—Emitter & Diode Cathode
Pin. No.2—Collector
Pin. No.3—Base
Pin. No.4—Diode Anode

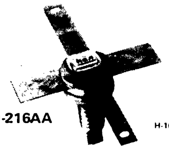
WARNING: The body of this device contains beryllium oxide. Do not crush, grind, or abrade that portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State
Division

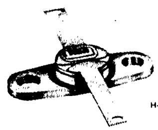
RF Power Transistors

2N6104
2N6105



2N6105
JEDEC TO-216AA

H-1675



2N6104
RCA HF-32

H-1688

30-W 400-MHz Broadband Emitter-Ballasted Silicon N-P-N Overlay Transistors

Features:

- 5-dB gain (min.) at 400 MHz with 30 watts (min.) output
- Emitter-ballasting resistors
- Broadband performance (225-400 MHz)
- Low-inductance ceramic-metal hermetic package
- Radial leads for microstripline circuits
- All electrodes isolated from the stud (2N6105)
- Flange is emitter lead (2N6104)

RCA types 2N6104 and 2N6105● are expitaxial silicon n-p-n planar transistors with overlay multiple-emitter-site construction and emitter-ballasting resistors. These transistors are intended for use in large-signal high-power cw and pulsed amplifiers in vhf/uhf communications equipment. The ceramic-metal hermetic packages have low parasitic inductances, and are ideally suited for use in microstripline and lumped-constant broadband and narrow-band amplifiers.

● Formerly RCA Dev. Nos. TA7707 and TA7706, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	30	V
* COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
* EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
* CONTINUOUS COLLECTOR CURRENT	I_C	4.5	A
* TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 75° C		36	W
At case temperatures above 75° C		Derate linearly at 0.288	W/°C
* TEMPERATURE RANGE:			
Storage & Operating (Junction)		– 65 to +200	°C
* CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

* In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

8-72

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified*

STATIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage V		DC Current mA		LIMITS		UNITS
			V_{CE}	V_{BE}	I_E	I_C	MIN.	MAX.	
*	Collector-to-Emitter Cutoff Current: Base connected to emitter, T_C=55°C	I_{CES}	30	0			–	10	mA
*	Collector-to-Emitter Breakdown Voltage: With base connected to emitter	$V_{(BR)CES}$		0		200[a]	65	–	V
	With base open	$V_{(BR)CEO}$				200[a]	30	–	V
*	Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			5	0	4	–	V
	Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						3.5	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

	CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC})-V	Input Power (P_{IE})-W	Output Power (P_{OE})-W	Frequency (f)–MHz	LIMITS Min.	Max.	UNITS
	Output Power (See Fig. 10)	P_{OE}	28	9.5		400	30	–	W
	Overdrive Test (See Fig. 10)	P_{OEO}	28	12.0		400	34	—	W
*	Power Gain	G_{PE}	28		30	400	5	–	dB
*	Collector Efficiency	η_C	28	9.5		400	65	-	%
*	Collector-to-Base Output Capacitance	C_{obo}	30 (V_{CB})			1	–	35	pF

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

TYPICAL APPLICATION INFORMATION

CIRCUIT	COLLECTOR SUPPLY VOLTAGE (V_{CC})–V	OUTPUT POWER (P_{OE})–W	INPUT POWER (P_{IE})–W	COLLECTOR EFFICIENCY (η_C) – %	FIG. NO.
225-400 MHz (2N6105)▲ Broadband Amplifier	28 20	30 20	5 – 7.5 5 – 7	69 – 77 70 – 82	13 13
400 MHz (2N6104-5) Narrow-Band Amplifier	28	34	9.5	78	10
225-400 MHz (2N6105)▲ Push-Pull Amplifier	28	60	11.5 – 18	72 – 84	16

▲ Similar performance can be obtained with the 2N6104.

RCA Application Notes

AN-4421 "16– and 25–Watt Broadband Power Amplifiers Using RCA–2N5918, 2N5919, and TA7706 UHF/Microwave Power Transistors."

AN-6010 "Characteristics and Broadband (225-to-400-MHz) Applications of the RCA-2N6104 and 2N6105 UHF Power Transistors."

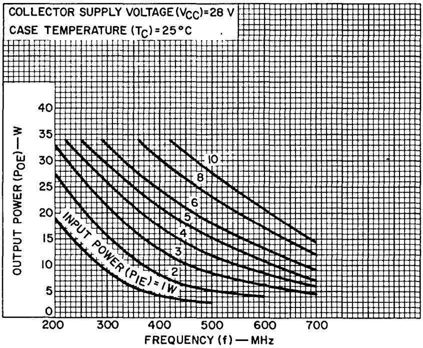


Fig. 1—Typical output power vs. frequency for both types.

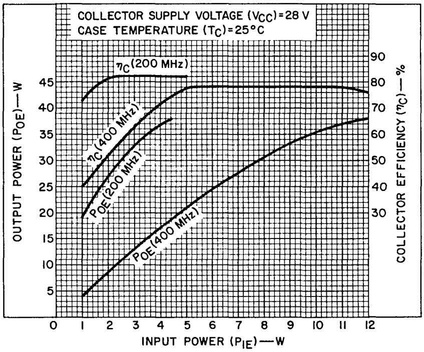


Fig. 2—Typical output power and collector efficiency vs. input power for both types.

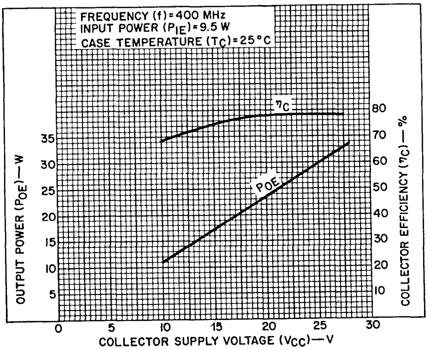


Fig. 3—Typical output power and collector efficiency vs. collector supply voltage for both types.

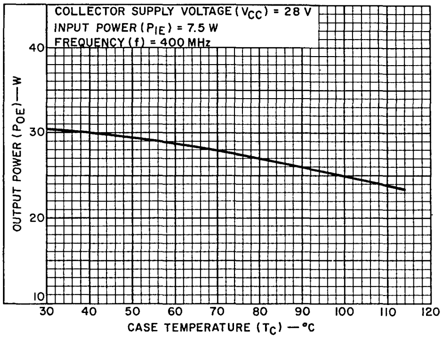


Fig. 4—Typical output power vs. case temperature for both types.

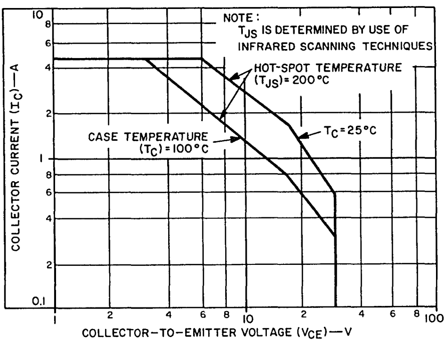


Fig. 5—Safe area for dc operation for both types.

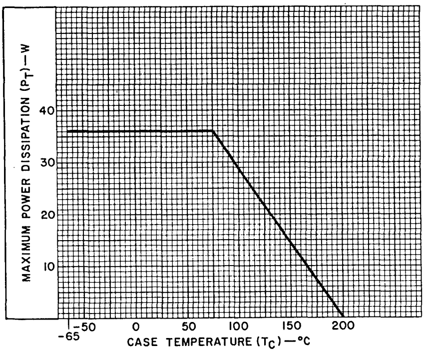


Fig. 6—Dissipation derating for class C operation for both types.

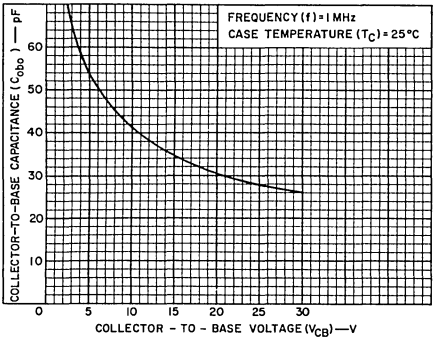


Fig. 7—Typical variation of collector-to-base capacitance vs. collector-to-base voltage for both types.

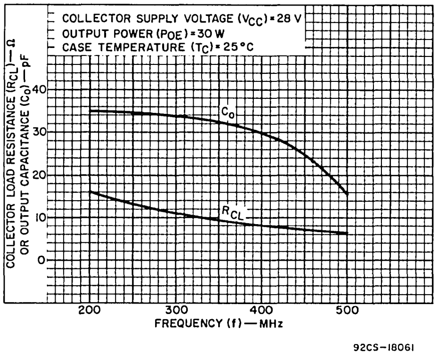


Fig. 8—Typical large-signal parallel collector load resistance and parallel output capacitance vs. frequency for both types.

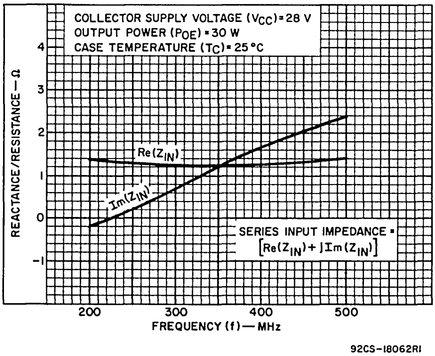
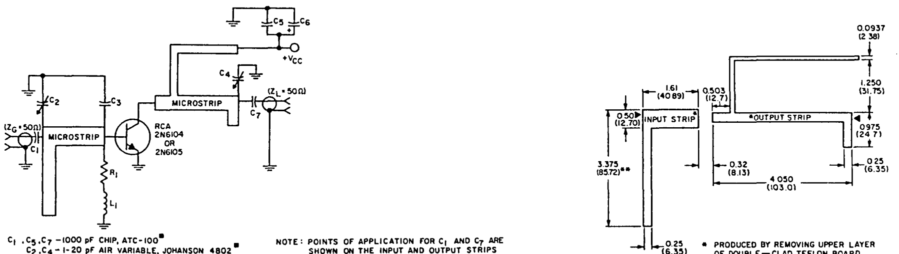


Fig. 9—Typical large-signal series input impedance vs. frequency for both types.



C_1, C_5, C_7 – 1000 pF CHIP, ATC-100■
C_2, C_4 – 1-20 pF AIR VARIABLE, JOHANSON 4802■
C_3 – 15 pF SILVER MICA
C_6 – 1 μF ELECTROLYTIC
L_1 – 0.1 μH RF CHOKE
R_1 – 5.1 Ω 1/2 W

■– OR EQUIVALENT

NOTE: POINTS OF APPLICATION FOR C_1 AND C_7 ARE SHOWN ON THE INPUT AND OUTPUT STRIPS IN THE DRAWING AT RIGHT (▶)

JOHANSON MANUFACTURING CORP. BOONTON, N.J. 07005
AMERICAN TECHNICAL CERAMICS HUNTINGTON STATION, N.Y. 11746

* PRODUCED BY REMOVING UPPER LAYER OF DOUBLE—CLAD TEFLON BOARD, 1 OZ., 1/32 IN. THICK, (ε = 2.6), OR EQUIVALENT

** DIMENSIONS IN PARENTHESES ARE MILLIMETERS.

92CS-19156R1

Fig. 10—400-MHz amplifier test circuit for measurement of output power for both types.

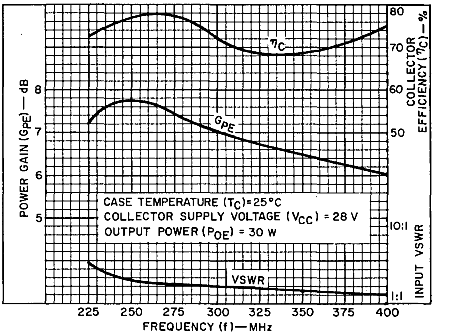


Fig. 11—Typical performance of a 225-400-MHz amplifier using RCA 2N6105 in circuit of Fig. 13, at $V_{CC} \approx 28$ V.

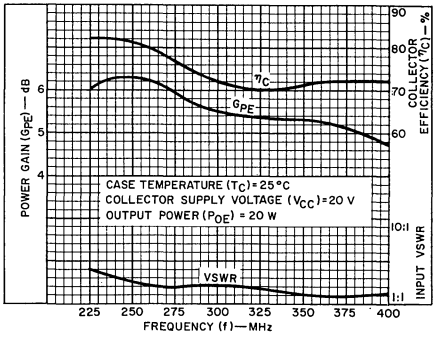
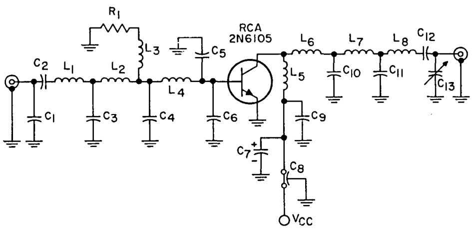


Fig. 12—Typical performance of a 225-400-MHz amplifier using RCA 2N6105 in circuit of Fig. 13, at V_{CC} = 20 V.



C_1: 8.2 pF chip, Allen-Bradley•
C_2: 18 pF silver mica
C_3: 33 pF chip, Allen-Bradley•
C_4: 47 pF chip, Allen-Bradley•
C_5: 68 pF chip, ATC-100•
C_6: 62 pF chip, ATC-100•
C_7: 1 μF electrolytic
C_8: 1000 pF feedthrough
C_9, C_{12}: 1000 pF chip, Allen-Bradley•
C_{10}: 22 pF chip, Allen-Bradley•
C_{11}: 6.9 pF chip, Allen-Bradley•
C_{13}: 0.8-10 pF variable air, Johanson No.3957•
L_1: 2 turns, 5/32 in. (3.968 mm) I.D. coil
L_2: 17/32 in. (13.49 mm) long wire
L_3: RFC, 0.1 μH, Nytronics•
L_4: 5/32 in. (3.968 mm) long transistor base lead
L_5, L_7: 13/16 in. (20.638 mm) long wire
L_6: 9/16 in. (14.287 mm) long wire
L_8: 7/8 in. (22.225 mm) long wire
R_1: 5.0 Ω, 1/4 W
All wire is No.20 AWG

•Or equivalent.

Fig. 13—225-400-MHz amplifier using RCA 2N6105.

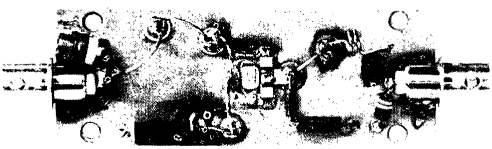


Fig. 14—Photograph of 225-400-MHz amplifier.

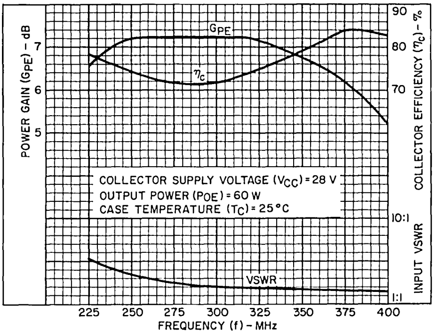
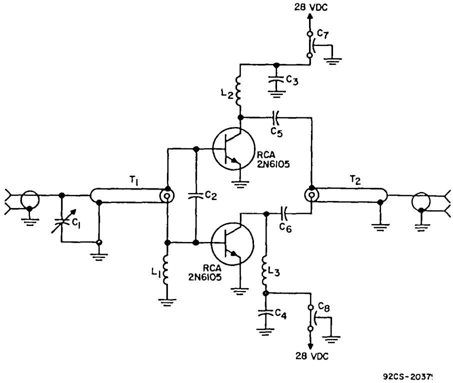


Fig.15—Typical performance of a 225-400-MHz push-pull amplifier using two RCA 2N6105's in circuit of Fig.16.



C_1	= 2 – 18 pF, Amperex HT10MA/218•
C_2	= 56-pF chip, ATC-100•
C_3, C_4, C_5, C_6	= 1000-pF chip, Allen-Bradley type•
C_7, C_8	= 1000 pF, feedthrough
L_1	= 0.18 μH RFC, Nytronics type•
L_2, L_3	= No. 20 wire, 0.75 in.(19.05 mm)long
T_1	= coaxial line, Z_0 = 25Ω, 3.75 in. (95.25 mm) long
T_2	= coaxial line, Z_0 = 25Ω, 4.50 in. (114.30 mm) long

•or equivalent

Fig. 16—225-to-400-MHz push-pull amplifier using two RCA 2N6105's.

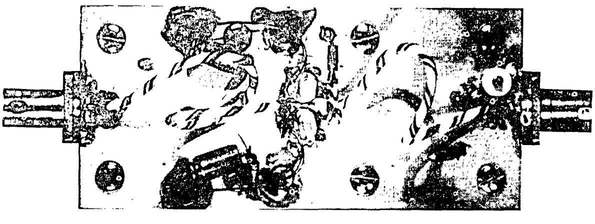


Fig. 17—Photograph of 225-400-MHz push-pull amplifier

TERMINAL CONNECTIONS

2N6104:

Flange (Terminals 1,3) — Emitter
Terminal 2 — Base
Terminal 4 — Collector

2N6105:

Terminals 1,3 — Emitter
Terminal 2 — Base
Terminal 4 — Collector

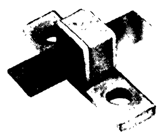
WARNING: The ceramic heat-sink portions of these devices contain beryllium oxide. Do not crush, grid or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State
Division

RF Power Transistors

2N6265



RCA HF-28 PACKAGE H-1712

2-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For UHF/Microwave Power Amplifiers,
Microwave Fundamental-Frequency
Oscillators and Frequency Multipliers

Features:

- **VSWR capability of ∞:1 at 2 GHz**
- **2-W output with 8.2-dB gain (min.) at 2 GHz**
- **3-W output with 12-dB gain (typ.) at 1 GHz**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For microstripline and lumped-constant circuit applications**

RCA – 2N6265● is an epitaxial silicon n-p-n planar transistor featuring the overlay multiple-emitter-site construction. It is intended for solid-state equipment for microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance measuring equipment, transponder, and collision avoidance systems.

The ceramic-metal stripline package of the 2N6265 features low parasitic capacitances and inductances which provide for stable operation in the common-base amplifier configuration. Ideal as a driver for the 2N6266 or 2N6267, this transistor can also be used in large-signal applications in microstripline, stripline, and lumped-constant circuits.

●Formerly RCA Dev. No. TA7993.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

***COLLECTOR-TO-BASE VOLTAGE**	V_{CBO}	50	V
***COLLECTOR-TO-EMITTER VOLTAGE:**			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
***EMITTER-TO-BASE VOLTAGE**	V_{EBO}	3.5	V
***CONTINUOUS COLLECTOR CURRENT**	I_C	0.275	A
***TRANSISTOR DISSIPATION:**	P_T		
At case temperature up to 75°C		6.25	W
At case temperature above 75°C		Derate linearly at 0.05 W/°C	
***TEMPERATURE RANGE:**			
Storage and operating (Junction)		-65 to +200	°C
***CASE TEMPERATURE** (during soldering)			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C* unless otherwise specified

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE (V) V_{CE}	V_{BE}	DC CURRENT (mA) I_E	I_B	I_C	LIMITS MIN.	MAX.	UNITS
* Collector-Cutoff Current	I_{CES}	45	0				–	2	mA
At T_C = 55°C	I_{CES}	40	0				–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	50	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
* Collector-to-Emitter Breakdown Voltage external base-to-emitter resistance R_{BE}=10Ω	$V_{(BR)CER}$					10	50	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	–	1	V
Thermal Resistance: (Junction-to-Flange)	$R_{\theta JF}$						–	20	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	POWER INPUT P_{IB}(W)	POWER OUTPUT P_{OB}(W)	SUPPLY VOLTAGE V_{CC}(V)	FREQUENCY (f) GHz	LIMITS MIN.	MAX.	UNITS
Power Output (See Figs. 5 & 12)	P_{OB}	0.3		28	2	2	–	W
* Power Gain	G_{PB}	0.3	2.0	28	2	8.2	–	dB
* Collector Efficiency	η_C	0.3	2.0	28	2	33	–	%
* Collector-to-Base Capacitance	C_{obo}			30(V_{CB})	1 MHz	–	5	pF

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

TYPICAL APPLICATION INFORMATION

CIRCUIT AND FREQUENCY	DC COLLECTOR SUPPLY VOLTAGE (V_{CC})–V	INPUT POWER (P_{IB})–W	OUTPUT POWER (P_{OB})–W
Microstripline 2-GHz Amplifier (Fig. 12)	28	0.30	2.1
Lumped Constant 1-GHz Amplifier (Fig. 10)	28	0.15	3.2

PERFORMANCE DATA

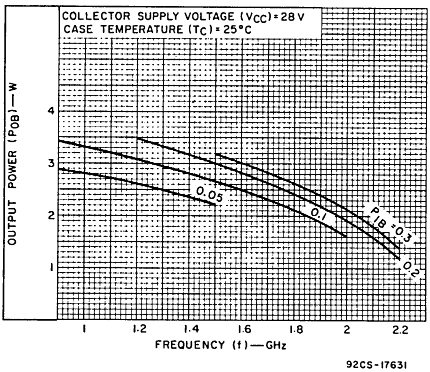


Fig. 1—Typical output power vs. frequency for common-base amplifier in the test set-up of Fig. 5.

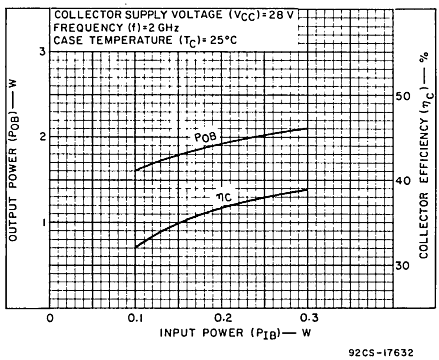


Fig. 2—Typical 2-GHz output power and collector efficiency vs. input power in the test set-up of Fig. 5.

PERFORMANCE DATA (cont'd)

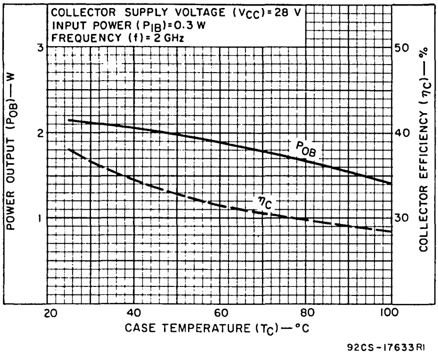


Fig. 3—Typical output power and collector efficiency at 2-GHz vs. case temperature in the test set-up of Fig. 5.

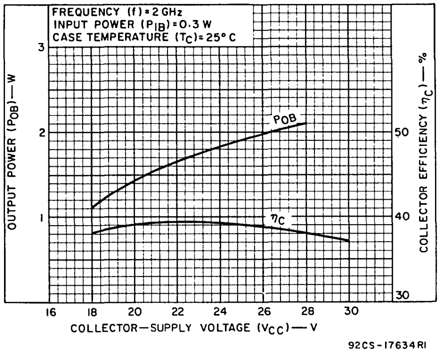


Fig. 4—Typical 2-GHz output power and collector efficiency vs. supply voltage in the test set-up of Fig. 5.

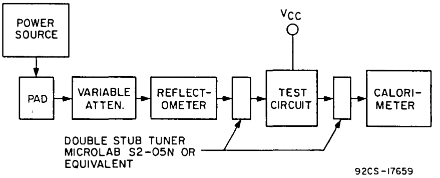


Fig. 5—Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier.

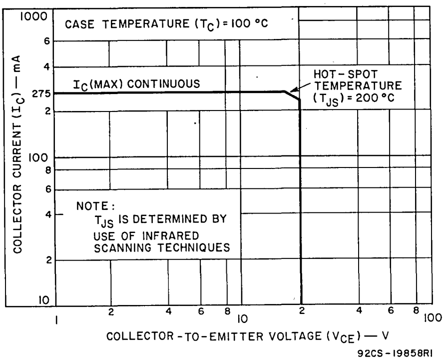


Fig. 6—Maximum operating area for forward-bias operation.

TERMINAL CONNECTIONS

Terminal 1 — Emitter
Terminals 2 & 4 — Base
Terminal 3 — Collector

SOLDERING INSTRUCTIONS

When soldering the 2N6265 into a microstripline or lumped-constant circuit, the collector and emitter terminals of the device must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

DESIGN DATA

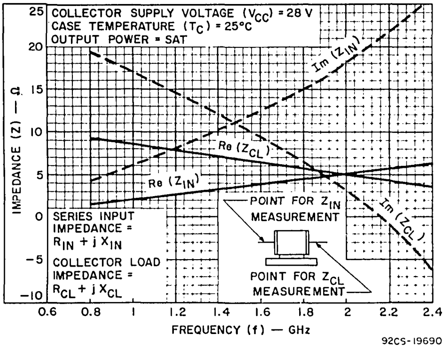


Fig. 7—Typical large-signal series input impedance and large-signal collector load impedance vs. frequency.

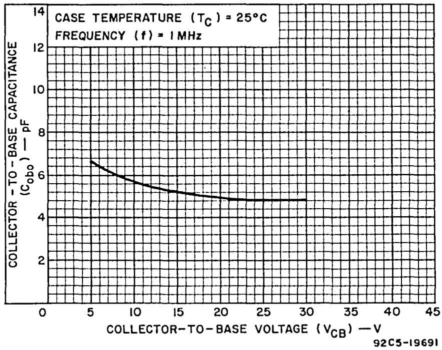
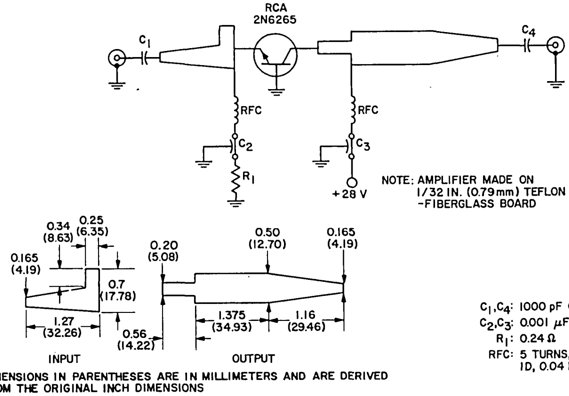


Fig. 8—Typical collector-to-base capacitance vs. collector-to-base voltage.

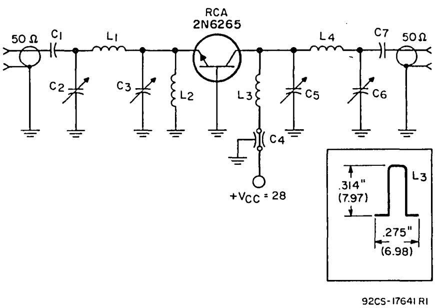


C_1, C_4: 1000 pF CERAMIC, ATC-100, OR EQUIVALENT
C_2, C_3: 0.001 μF FEEDTHROUGH
R_1: 0.24 Ω
RFC: 5 TURNS, NO. 28 WIRE, 0.05 IN. (1.27 mm) ID, 0.04 IN. (1.02mm) LONG

92CS-19692

Fig. 9—Typical 1-GHz microstripline power amplifier.

APPLICATION DATA

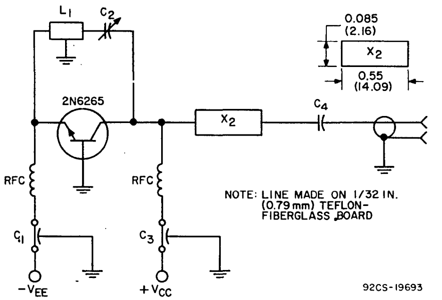


C_1, C_7: 1000 pF, ceramic, leadless
C_2, C_6: 0.35-3.5 pF, air-dielectric, Johanson 4701, or equivalent
C_3, C_5: 1-10 pF, air-dielectric, Johanson 2957, or equivalent
C_4: 1000 pF, feedthrough, Allen-Bradley FA5C, or equivalent
L_1, L_4: 0.01 in. (0.254)* thick, 0.157 in. (3.98)* wide copper strip shaped as shown in inset drawing
L_2, L_3: RF choke, 0.1μH, Nytronics Deci-Ductor, or equivalent

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

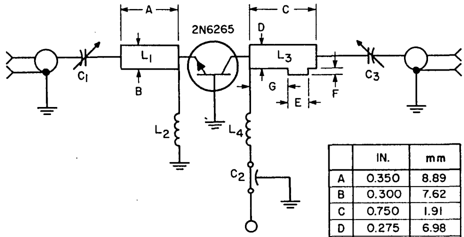
Fig. 10—Typical lumped-element circuit for 1-GHz power amplifier.

APPLICATION DATA (cont'd)



C_1,C_3: FILTERCON, ALLEN-BRADLEY SMFB-A1, OR EQUIVALENT
C_2: 0.3–3.5 pF, JOHANSON 4700, OR EQUIVALENT
C_4: 300 pF, ATC-100, OR EQUIVALENT
L_1: 1.0 IN. (25.4 mm) SECTION MINIATURE 50 CABLE
RFC: 3 TURNS, NO. 32 WIRE 0.0625 IN. (1.58 mm) ID, 0.187 IN. (4.76 mm) LONG.

Fig. 11—Typical 1.7-GHz oscillator circuit.



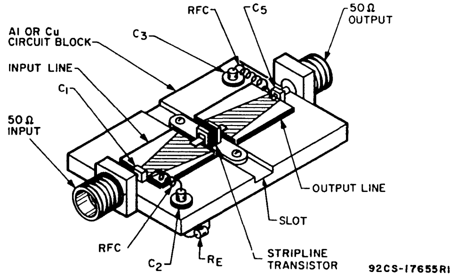
	IN.	mm
A	0.350	8.89
B	0.300	7.62
C	0.750	1.91
D	0.275	6.98
E	0.180	4.57
F	0.100	2.54
G	0.400	10.16

C_1,C_3: 0.35–3.5 pF, AIR-DIELECTRIC, JOHANSON 4701, OR EQUIVALENT
C_2: 1000 pF, FEEDTHROUGH, ALLEN BRADLEY FA5C, OR EQUIVALENT
L_1,L_3: MICROSTRIPLINE, 2 OZ. COPPER-CLAD 1/32 IN. (0.8)* TEFLON-FIBERGLASS
L_2,L_4: RF CHOKE, 4 TURNS NO. 28 WIRE, 0.062 IN. (1.57)* ID, 3/16 IN. (4.75)* LONG

92CS-19694

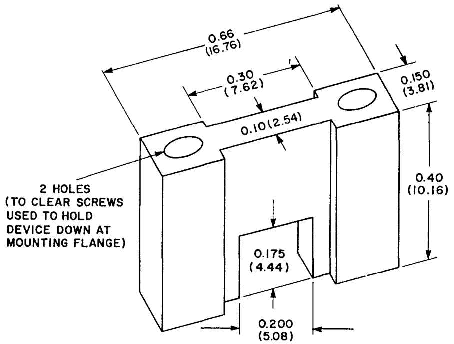
*NOTE: DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS AND ARE DERIVED FROM THE ORIGINAL INCH DIMENSIONS SHOWN.

Fig. 12—Typical circuit for 2-GHz microstripline amplifier.



C_1, C_5: DC-blocking capacitors
C_2, C_3: Feedthrough or filter capacitors

(a) Typical circuit



Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

(b) Circuit shield (Place over device and screw down to circuit board).

NOTE: The circuit shield (b) can be made as a part of a ridge in the circuit board (a) instead of the slot shown, and the device can be mounted upside down in a slot in this ridge for equivalent circuit isolation. For operation in the 2-2.4 GHz range, it is recommended that the circuit be completely shielded to prevent losses due to circuit radiation at these frequencies.

Fig. 13—Typical circuit construction.

RCA

Solid State
Division

RF Power Transistors

2N6266

RCA HF-28 package

H-1712

5-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For UHF/Microwave Power Amplifiers,
Microwave Fundamental-Frequency
Oscillators and Frequency Multipliers

Features:

- **Emitter-ballasting resistors**
- **VSWR capability of ∞ :1 at 2 GHz**
- **5 W output with 7 dB gain (min.) at 2 GHz**
- **13.5 W output with 11 dB gain (typ.) at 1 GHz**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **Stable common-base operation**
- **For microstripline, stripline, and lumped-constant circuit applications**

TERMINAL CONNECTIONS

Terminal 1 - Emitter
Terminals 2 & 4 - Base
Terminal 3 - Collector

RCA — 2N6266* is an epitaxial silicon n-p-n planar transistor featuring the overlay multiple-emitter-site construction and emitter-ballasting resistors. It is intended for solid-state equipment for microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance-measuring equipment, transponder, and collision-avoidance systems. The device can be used in large-signal cw or pulsed applications over the range of 0.5 GHz to 2.4 GHz in stripline, microstripline, or lumped-constant circuits.

The ceramic-metal stripline package of the 2N6266 features low parasitic capacitances and inductances which provide for stable operation in the common-base configuration. The use of emitter-ballasting resistors and the low-thermal-resistance package provide ruggedness and reliability.

*Formerly RCA Dev. No. TA7994.

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

* **COLLECTOR-TO-BASE VOLTAGE**	V_{CBO}	50	V
* **COLLECTOR-TO-EMITTER VOLTAGE:**			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
* **EMITTER-TO-BASE VOLTAGE**	V_{EBO}	3.5	V
* **CONTINUOUS COLLECTOR CURRENT**	I_C	1	A
* **TRANSISTOR DISSIPATION:**	P_T		
At case temperature up to 75°C		14.8	W
At case temperature above 75°C		Derate linearly at 0.118 W/°C	
* **TEMPERATURE RANGE:**			
Storage and operating (Junction)		-65 to +200	°C
* **CASE TEMPERATURE** (during soldering)			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C, unless otherwise specified*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector or Base Voltage (V)		TEST CONDITIONS: DC Current (mA)			LIMITS		UNITS
		V_{CE}	V_{BE}	I_E	I_B	I_C	Min.	Max.	
* Collector-Cutoff Current	I_{CES}	45	0				–	2	mA
At T_C = 55°C	I_{CES}	40	0				–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	50	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
* Collector-to-Emitter Breakdown Voltage With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$					10	50	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				20	100	–	1	V
Thermal Resistance: (Junction-to-Flange)	$R_{\theta JF}$						–	8.5	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Frequency (f) – GHz	TEST CONDITIONS: DC Collector Supply Voltage (V_{CC}) – V	LIMITS: Min.	LIMITS: Max.	UNITS
Output Power; P_{IB} = 1 W (See Figs. 7 & 11)	P_{OB}	2	28	5	–	W
* Power Gain, P_{OB} = 5 W	G_{PB}	2	28	7	–	dB
* Collector Efficiency, P_{OB} = 5 W	η_C	2	28	33	–	%
* Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	10	pF

*In accordance with JEDEC registration data format (JS-6 RDF-3/JS-9 RDF-7)

TYPICAL APPLICATION INFORMATION

CIRCUIT & FREQUENCY	See Fig.	DC Collector Supply Voltage (V_{CC}) – V	Input Power (P_{IB}) – W	Output Power (P_{OB}) – W
Microstripline 1–GHz Amplifier	10	28	1	13.5
Microstripline 2–GHz Amplifier	11	28	1	6
Microstripline (Broadband) 1.2–1.4-GHz Amplifier — Pulsed Power: Pulse Duration = 1.3 ms, Duty Factor = 30%	12	28	1	12
Microstripline 1.7–1.8-GHz Tunable Oscillator	13	28	–	3

PERFORMANCE DATA

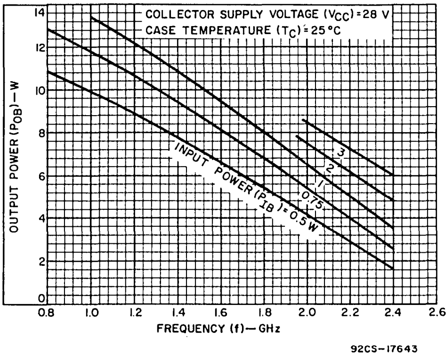


Fig. 1—Typical output power vs. frequency in test set-up of Fig. 7.

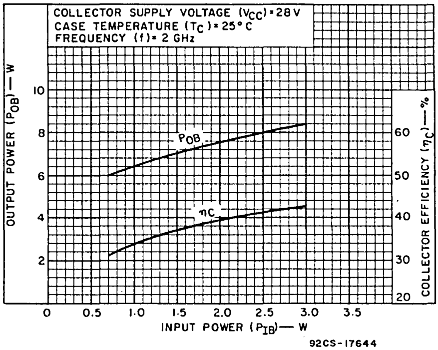


Fig. 2—Typical output power or collector efficiency vs. input power at 2 GHz in test set-up of Fig. 7.

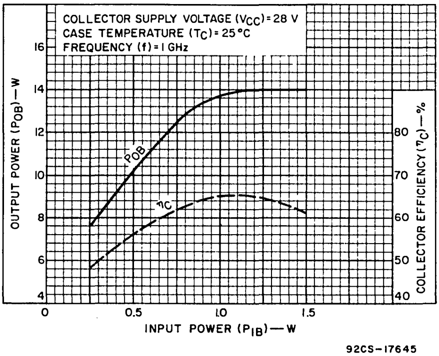


Fig. 3—Typical output power or collector efficiency vs. input power at 1 GHz in test set-up of Fig. 7.

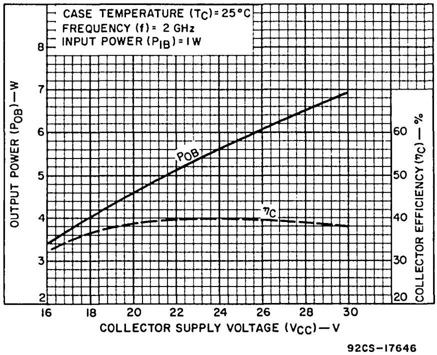


Fig. 4—Typical output power or collector efficiency vs. collector supply voltage at 2 GHz in test set-up of Fig. 7.

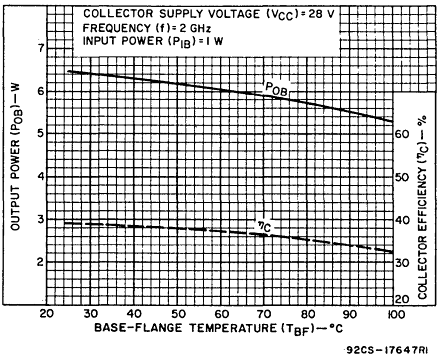


Fig. 5—Typical output power vs. case temperature at 2 GHz.

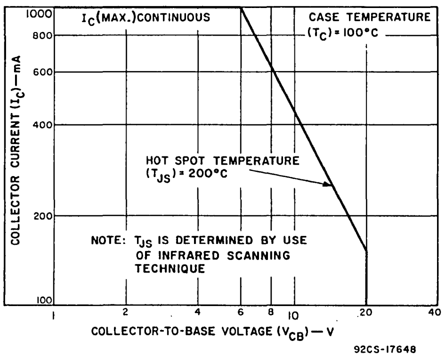


Fig. 6—Maximum operating area for forward-bias operation.

PERFORMANCE DATA (Cont'd)

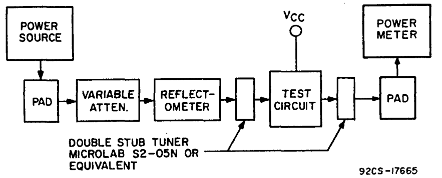


Fig. 7—Block diagram of test set-up for measurement of rf performance from 1- or 2-GHz common-base amplifier.

SOLDERING INSTRUCTIONS

When the 2N6266 is soldered into a microstripline or lumped-constant circuit, the collector and emitter terminals of the device must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

DESIGN DATA

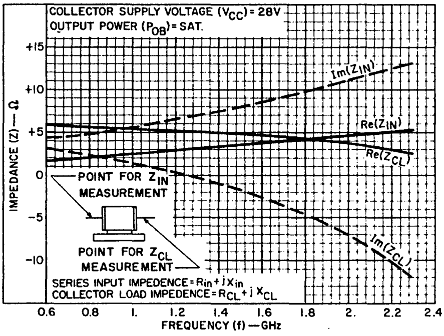


Fig. 8—Typical large-signal series input impedance or large-scale collector load impedance vs. frequency.

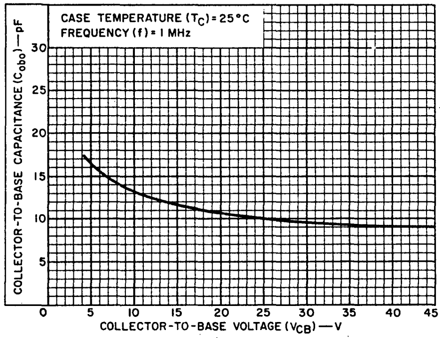
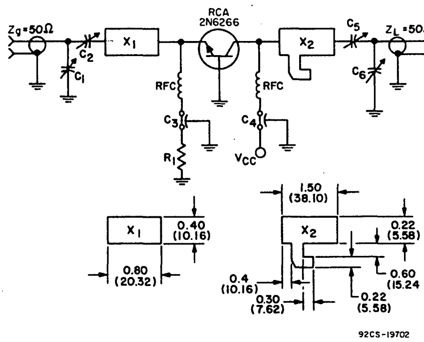


Fig. 9—Typical collector-to-base capacitance vs. collector-to-base voltage.

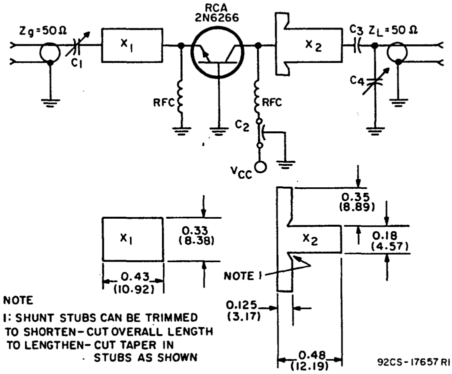


C_1, C_2, C_5, C_6: 0.8–10 pF, Johanson 5202, or equivalent
C_3, C_4: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: No. 32 wire, 3 turns, 0.0625 in. (1.58 mm) ID, 0.187 in. (4.76 mm) long
R_1: 1 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

•Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

Fig. 10—Typical 1-GHz microstripline power amplifier circuit.

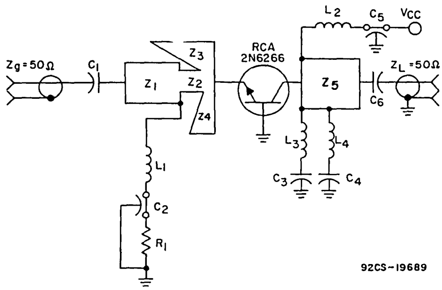


C_1, C_3, C_4: 0.3–3.5 pF, Johanson 4700, or equivalent
C_2: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: No. 32 wire, 0.4 in. (10.16 mm) long

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

•Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

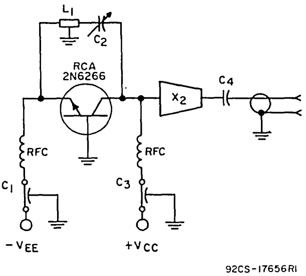
Fig. 11—Typical 2-GHz microstripline power amplifier circuit.

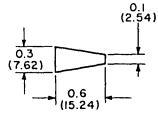


C_1, C_3, C_4, C_6: 1000 pF ceramic, ATC-100, or equivalent
C_2, C_5: 1000 pF feedthrough
L_1, L_2: RFC, 5 turns No. 32 wire, 0.0625 in. (1.58 mm) ID, 0.25 in. (6.35 mm) long
L_3: 0.005 in. (0.127 mm) lead length (C_3 lead)
L_4: 0.250 in. (6.35 mm) lead length (C_4 lead)
R_1: 0.47 Ω
Z_1: 0.34 in. x 0.525 in. (8.63 mm x 13.34 mm)
Z_2: 0.215 in. x 0.235 in. (5.46 mm x 5.97 mm)
Z_3: 0.075 in. x 0.4 in. x 0.77 in. (1.91 mm x 10.16 mm x 19.56 mm)
Z_4: 0.075 in. x 0.575 in. x 0.435 in. (1.91 mm x 14.61 mm x 11.05 mm)
Z_5: 1.12 in. (28.45 mm) x 0.59 in. (14.98 mm)

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

Fig. 12—Typical 1.2–1.4-GHz broadband amplifier circuit.



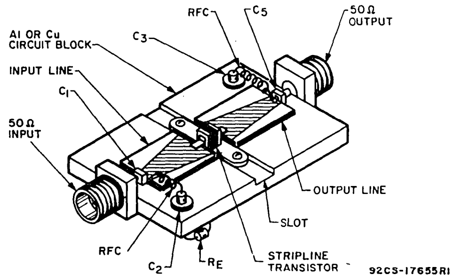


C_1, C_3: Filtercon, Allen-Bradley SMFB-A1, or equivalent
C_2: 0.3–3.5 pF, Johanson 4700, or equivalent
C_4: 300 pF, ATC—100 or equivalent
L_1: 1.0 in. (25.4 mm) length section miniature 50 Ω cable, or microstrip equivalent
RFC: 3 turns, No. 32 wire, 0.0625 in. (1.59 mm) ID, 0.187 in. (4.76 mm) long
X_2: 0.013 in. (0.33 mm) thick Teflon-Kapton double-clad circuit board (Grade PE-1243 as supplied by Budd Polychem Division, Newark, Delaware), or equivalent.
Line X_2 is exponentially tapered

NOTE: Oscillator is single screw tunable 1.6 GHz to 1.8 GHz

•Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

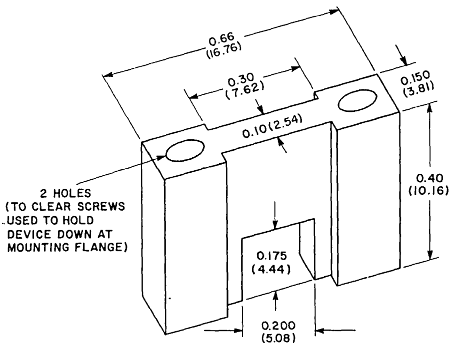
Fig. 13—Typical 1.7-GHz oscillator circuit.



C_1, C_5: DC-blocking capacitors
C_2, C_3: Feedthrough or filter capacitors

(a) Typical circuit

NOTE: The circuit shield (b) can be made as a part of a ridge in the circuit board (a) instead of the slot shown, and the device can be mounted upside down in a slot in this ridge for equivalent circuit isolation. For operation in the 2-2.4-GHz range, it is recommended that the circuit be completely shielded to prevent losses due to circuit radiation at these frequencies.



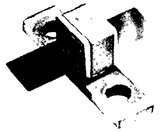
(b) Circuit shield (Place over device and screw down to circuit board).

Fig. 14—Typical circuit construction.

RCA
Solid State
Division

RF Power Transistors

2N6267



RCA HF-28 PACKAGE

H-1712

10-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For UHF/Microwave Power Amplifiers, Microwave Fundamental-Frequency Oscillators, and Frequency Multipliers

Features

- **Emitter-ballasting resistors**
- **10 W output with 7 dB gain (min.) at 2 GHz (28 V)**
- **8 W output with 6 dB gain (typ.) at 2.3 GHz (28 V)**
- **VSWR capability of 10:1 at 2 GHz**
- **Ceramic metal hermetic stripline package with low inductance and low parasitic capacitances**
- **Stable common-base operation**
- **For microstripline, stripline, and lumped-constant circuit applications**

RCA – 2N6267● is an epitaxial silicon n-p-n planar transistor featuring the overlay multiple-emitter-site construction and emitter-ballasting resistors. It is intended for solid-state equipment for microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance-measuring equipment, transponder, and collision-avoidance systems. The device can be used in large-signal cw or pulsed applications over the range of 0.5 GHz to 2.4 GHz in stripline, microstripline, or lumped-constant circuits.

The ceramic-metal stripline package of the 2N6267 features low parasitic capacitances and inductances which afford stable operation in the common-base configuration. The use of emitter-ballasting resistors and the low-thermal-resistance package provide increased ruggedness and reliability.

●Formerly RCA Dev. No. TA7995

MAXIMUM RATINGS, *Absolute-Maximum Values:*

***COLLECTOR-TO-BASE VOLTAGE**	V_{CBO}	50	V
***COLLECTOR-TO-EMITTER VOLTAGE:**			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
***EMITTER-TO-BASE VOLTAGE**	V_{EBO}	3.5	V
***CONTINUOUS COLLECTOR CURRENT**	I_C	1.5	A
***TRANSISTOR DISSIPATION:**	P_T		
At case temperature up to 75°C		21	W
At case temperature above 75°C		Derate linearly at 0.168 W/°C	
***TEMPERATURE RANGE:**			
Storage and operating (Junction)		-65 to +200	°C
***CASE TEMPERATURE** (during soldering)			
For 10 s max.		230	°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C* unless otherwise specified

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE (V)		TEST CONDITIONS: DC CURRENT (mA)			LIMITS		UNITS
		V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
* Collector-Cutoff Current	I_{CES}	45	0				–	2	mA
At T_C = 55°C		40	0				–	2	
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	50	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
* Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$					10	50	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				20	100	–	1	V
Thermal Resistance: (Junction-to-Flange)	$R_{\theta JF}$						–	6	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: FREQUENCY (f) – GHz	TEST CONDITIONS: DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	LIMITS: MIN.	LIMITS: MAX.	UNITS
Output Power, P_{IB} = 2 W	P_{OB}	2	28	10	–	W
* Power Gain, P_{OB} = 10 W	G_{PB}	2	28	7	–	dB
* Collector Efficiency, P_{OB} = 10 W	η_C	2	28	35	–	%
* Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	13	pF

*In accordance with JEDEC registration data format (JS-6 RDF-3/JS-9 RDF-7)

TYPICAL APPLICATION INFORMATION

CIRCUIT & FREQUENCY	SEE FIG.	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	INPUT POWER (P_{IB}) – W	OUTPUT POWER (P_{OB}) – W
Microstripline: 1–GHz Amplifier	14	28	1.5	14
Microstripline: 2–GHz Amplifier	13	28	2	12
Microstripline: 2.3–GHz Amplifier	16	28	2	8
Microstripline: 1.3–GHz Amplifier; Pulsed Power: Pulse Duration = 1.3 ms, Duty Factor = 30%	15	28	2	18
Microstripline: 1.6-1.8–GHz Tunable Oscillator	17	20	–	4

PERFORMANCE DATA

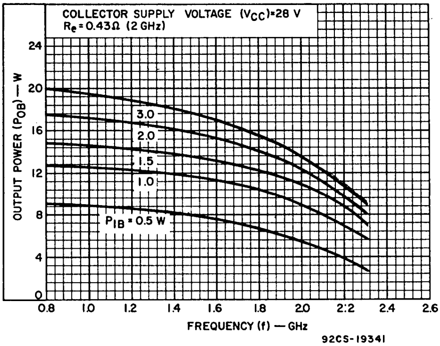


Fig.1– Typical output power vs. frequency in the test set-up of Fig. 8.

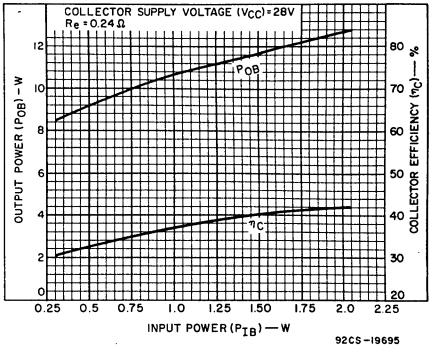


Fig.2–Typical output power and collector effeciency vs. input power at 2 GHz in the test set-up of Fig.8.

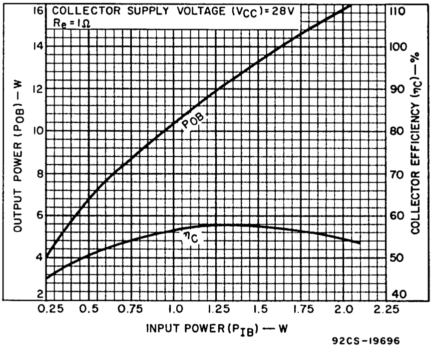


Fig.3–Typical output power and collector efficiency vs. input power at 1 GHz in the test set-up of Fig.8.

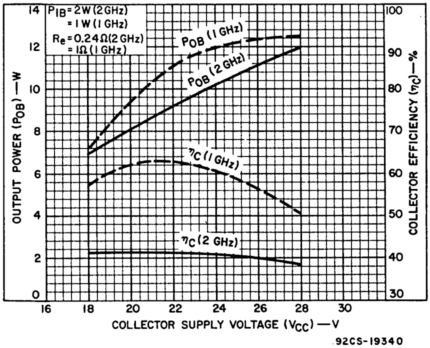


Fig.4–Typical output power and collector efficiency vs. collector supply voltage.

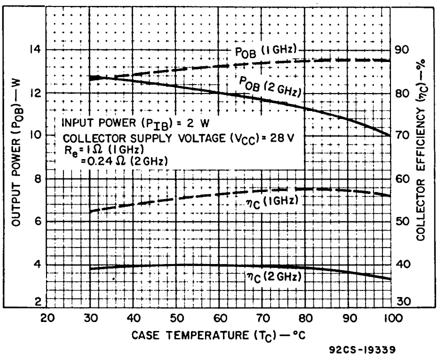


Fig.5–Typical output power vs. case temperature.

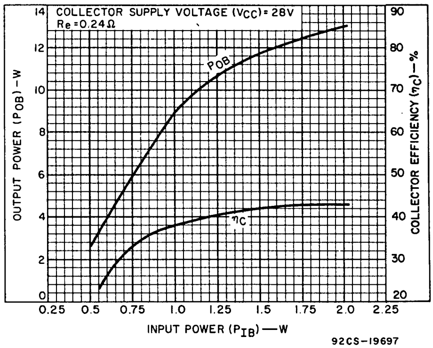


Fig.6–Typical output power and collector efficiency at 2 GHz in circuit of Fig.13.

PERFORMANCE DATA (CONT'D)

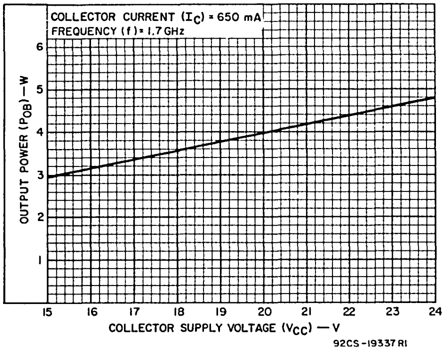


Fig.7—Typical output power in oscillator circuit shown in Fig.17.

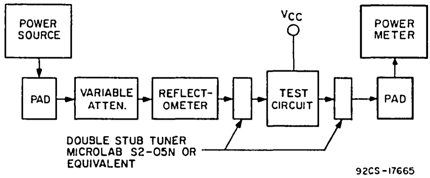


Fig.8—Block diagram of test set-up for measurement of rf performance from 1- or 2-GHz common-base amplifier.

DESIGN DATA

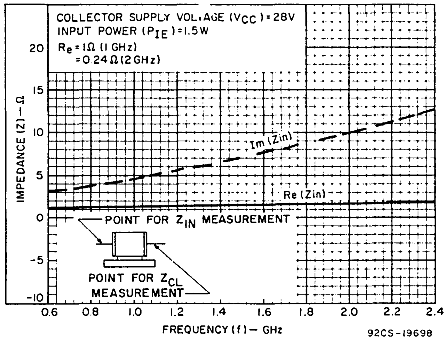


Fig.9—Typical large-signal series input impedance vs. frequency.

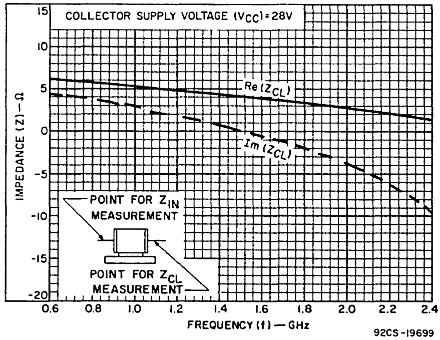


Fig.10—Typical large-signal collector load impedance vs. frequency.

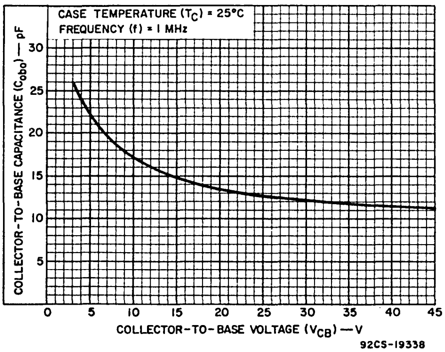


Fig.11—Typical collector-to-base capacitance vs. collector-to-base voltage.

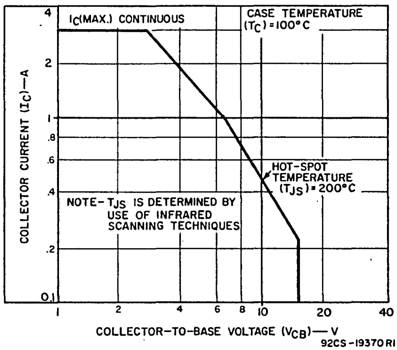
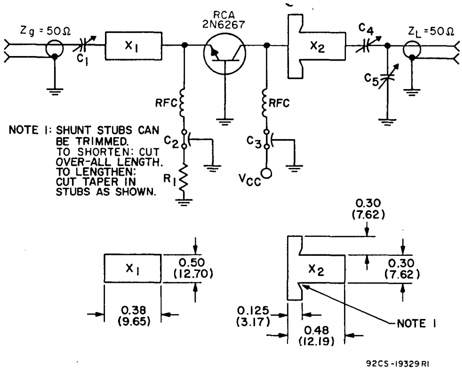


Fig.12—Maximum operating area for forward-bias operation.

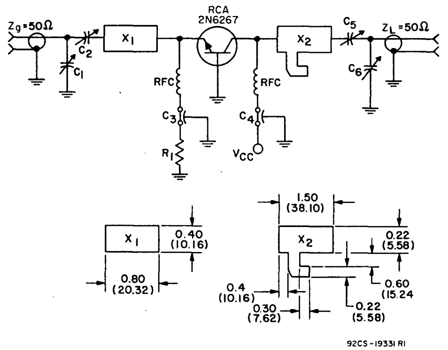
APPLICATION DATA



C_1, C_4, C_5: 0.3–3.5 pF, Johanson 4700, or equivalent
C_2, C_3: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: No. 32, wire, 0.4 in. (10.16 mm) long
R_1: 0.24 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

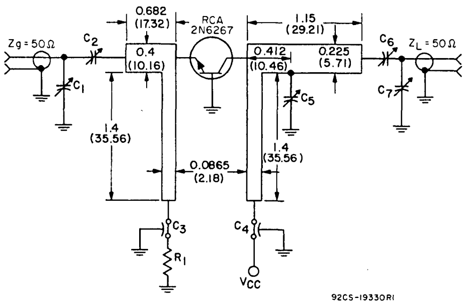
Fig. 13—Typical 2-GHz power amplifier circuit.



C_1, C_2, C_5, C_6: 0.8–10 pF, Johanson 5202, or equivalent
C_3, C_4: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: No. 32 wire, 3 turns, 0.0625 in. (1.58 mm) ID x 0.187 in. (4.76 mm) long
R_1: 1 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

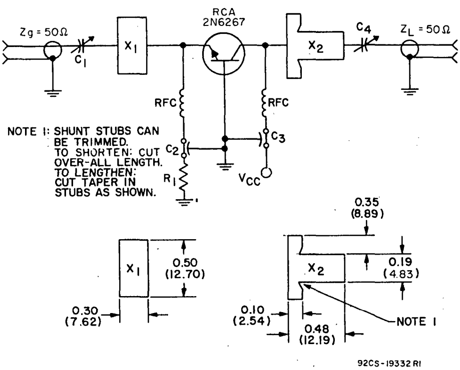
Fig. 14—Typical 1-GHz power amplifier circuit.



C_1, C_2, C_6: 1-10 pF JFD Electronics, MVM010, or equivalent
C_5, C_7: 0.3-3.5 pF, JFD Electronics, MVM003, or equivalent
C_3, C_4: 1000 pF feedthrough, Allen-Bradley FA5C, or equivalent
R_1: 0.75 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

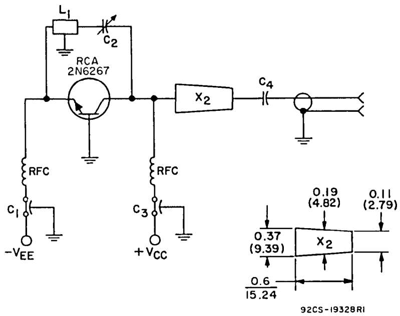
Fig. 15—Typical 1.3-GHz power amplifier circuit.



C_1, C_4: 0.3–3.5 pF, Johanson 4700, or equivalent
C_2, C_3: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: No. 32 wire, 0.4 in. (10.16 mm) long
R_1: 0.24 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

Fig. 16—Typical 2.3-GHz amplifier circuit.



C_1, C_3: Filtercon, Allen-Bradley SMFB-A1, or equivalent
C_2: 0.3–3.5 pF, Johanson 4700, or equivalent
C_4: 300 pF, ATC–100 or equivalent
L_1: 1.0 in (25.4 mm) length section miniature 50 Ω cable, or microstrip equivalent
RFC: 3 turns, No. 32 wire, 0.0625 in. ID, (1.59 mm) ID, 0.187 in. (4.76 mm) long
X_2: 0.013 in. (0.33 mm)–thick Teflon-Kapton double-clad circuit board (Grade PE-1243 as supplied by Budd Polychem Division, Newark, Delaware), or equivalent.
Line X_2 is exponentially tapered

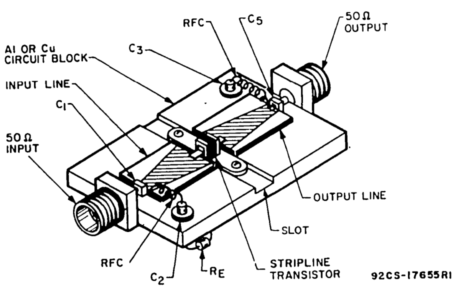
Dimensions in parentheses are in millimeters and are derived from the original inch dimensions as shown.
NOTE: Oscillator is single screw tunable 1.6 GHz to 1.8 GHz

Fig. 17–Typical 1.7-GHz oscillator circuit.

TERMINAL CONNECTIONS

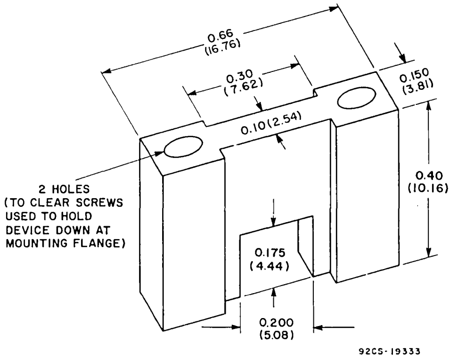
Terminal 1 – Emitter
Terminals 2 & 4 – Base
Terminal 3 – Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.



C_1, C_5: DC-blocking capacitors
C_2, C_3: Feedthrough or filter capacitors

(a) Typical circuit



Dimensions in parentheses are in millimeters and are derived from the original inch dimensions as shown.

(b) Circuit shield (Place over device and screw down to circuit board).

NOTE: The circuit shield (b) can be made as a part of a ridge in the circuit board (a) instead of the slot shown, and the device can be mounted upside down in a slot in this ridge for equivalent circuit isolation. For operation in the 2-2.4 GHz range, it is recommended that the circuit be completely shielded to prevent losses due to circuit radiation at these frequencies.

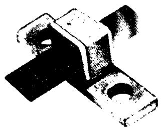
Fig. 18–Typical circuit construction.

RCA

Solid State
Division

RF Power Transistors

2N6268 2N6269



RCA HF-28 package

H-1712

6.5- and 2-W, 2.3-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in Microwave Power Amplifiers
Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- **Designed for 20- to 24-V equipment**
- **Emitter-ballasting resistors**
- **VSWR capability of 10:1 at 2.3 GHz**
- **2-W output with 7 dB gain (min.) at 2.3 GHz (22V) - 2N6268**
- **6.5-W output with 5 dB gain (min.) at 2.3 GHz - 2N6269**
- **Stable common-base operation**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuit applications**

RCA-2N6268 and 2N6269• are epitaxial silicon n-p-n planar transistors featuring the overlay multiple-emitter-site construction. They are designed especially for equipment using 20- to 24-V collector supplies in microwave communications, S-band telemetry, microwave relay link, phased-array radar, distance-measuring equipment, transponder, and collision-avoidance systems.

The ceramic-metal stripline package of these devices features low parasitic capacitances and inductances, which affords stable operation in the common-base configuration.

Ideal as a driver for the 2N6269, type 2N6268 can also be used in large-signal applications. The use of emitter-ballasting resistors and the low-thermal-resistance package make the 2N6269 especially suitable for large-signal, cw, or pulsed applications over the range of 0.5 GHz to 2.4 GHz in stripline, microstripline, and lumped-constant circuits.

•Formerly RCA Dev. Nos. TA8407 and TA7995A, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		2N6268	2N6269	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	45	45	V
*COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	45	45	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	0.350	1.5	A
*TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 75°C		6.25	21	W
At case temperature above 75°C ... Derate linearly at		0.05	0.168	W/°C
*TEMPERATURE RANGE: Storage and operating (Junction)		−65 to +200		°C
*CASE TEMPERATURE (during soldering) For 10 s max.		230		°C

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified.*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR OR BASE VOLTAGE (V) V_{CE}	V_{BE}	DC CURRENT (mA) I_E	I_B	I_C	LIMITS: 2N6268 MIN.	2N6268 MAX.	2N6269 MIN.	2N6269 MAX.	UNITS
* Collector-Cutoff Current	I_{CES}	40	0				–	2	–	2	mA
At T_C = 55°C	I_{CES}	30 35	0 0				– –	1 –	– –	– 2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	45	–	45	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	3.5	–	V
* Collector-to-Emitter Breakdown Voltage With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$					10	45	–	45	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10 20	100 100	– –	1 –	– –	– 1	V
Thermal Resistance (Junction-to-Flange)	$R_{\theta JF}$						–	20	–	6	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: FREQUENCY (f) – GHz	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	LIMITS: 2N6268 MIN.	2N6268 MAX.	2N6269 MIN.	2N6269 MAX.	UNITS
Output Power, P_{IB} = 0.4 W = 2 W	P_{OB}	2.3 2.3	22 22	2 –	– –	– 6.5	– –	W
* Power Gain, P_{OB} = 2 W = 6.5 W	G_{PB}	2.3 2.3	22 22	7 –	– –	– 5	– –	dB
* Collector Efficiency, P_{OB} = 2 W = 6.5 W	η_C	2.3 2.3	22 22	33 –	– –	– 32	– –	%
* Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	5.5	–	13	pF

*In accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

TYPICAL APPLICATION INFORMATION

CIRCUIT & FREQUENCY	SEE FIG.	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	INPUT POWER (P_{IB}) – W	OUTPUT POWER (P_{OB}) – W
Microstripline: 2.3-GHz Amplifier	28	22	2	7
Microstripline: 2-GHz Amplifier	25	22	2	9
Microstripline: 1.3-GHz Amplifier	27	22	1	11
Microstripline: 2-GHz Amplifier	23	22	0.3	2.1
Microstripline: 1.6–1.8-GHz Tunable Oscillator	29	20	–	3
Lumped Constant: 1-GHz Amplifier	22	22	0.15	3.2

PERFORMANCE DATA

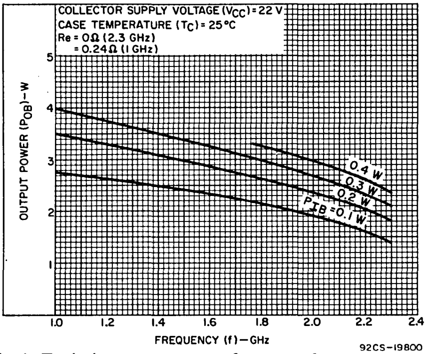


Fig. 1—Typical output power vs. frequency for common-base amplifier in test set-up of Fig. 14 for type 2N6268.

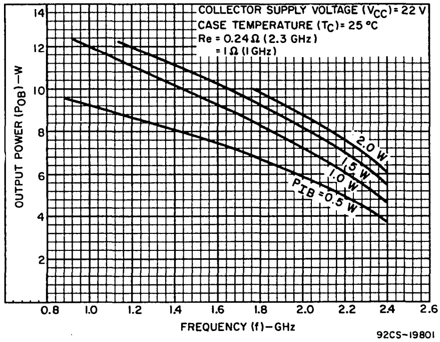


Fig. 2—Typical output power vs. frequency for common-base amplifier in test set-up of Fig. 15 for type 2N6269.

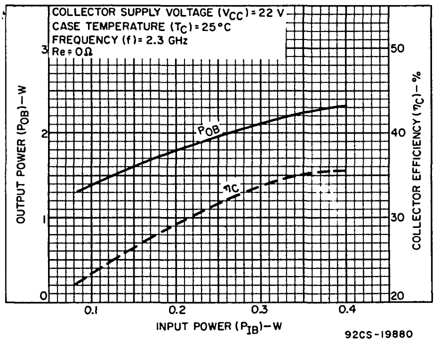


Fig. 3—Typical 2.3-GHz output power and collector efficiency vs. input power in test set-up of Fig. 14 for type 2N6268.

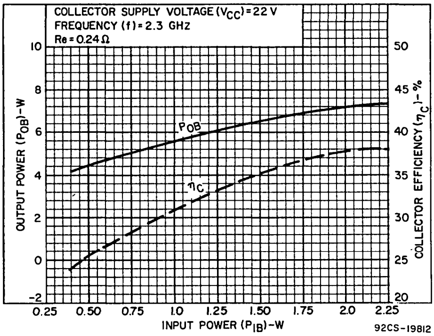


Fig. 4—Typical 2.3-GHz output power and collector efficiency vs. input power in test set-up of Fig. 15 for type 2N6269.

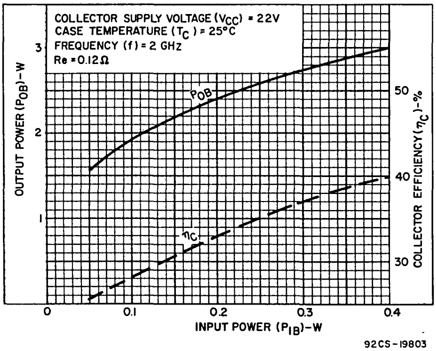


Fig. 5—Typical 2-GHz output power and collector efficiency vs. input power in test set-up of Fig. 14 for type 2N6268.

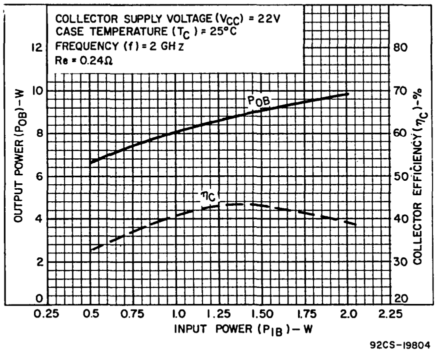


Fig. 6—Typical 2-GHz output power and collector efficiency vs. input power in test set-up of Fig. 15 for type 2N6269.

PERFORMANCE DATA

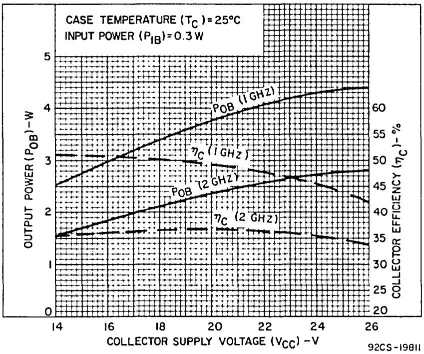


Fig. 7—Typical 1- and 2-GHz output power and collector efficiency vs. supply voltage for type 2N6268.

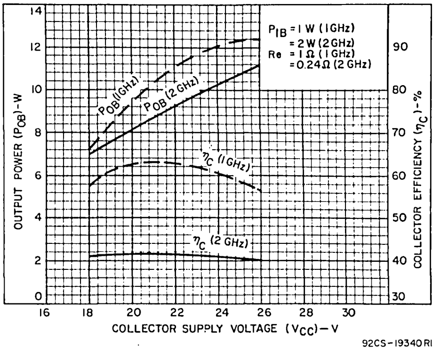


Fig. 8—Typical 1- and 2-GHz output power and collector efficiency vs. supply voltage for type 2N6269.

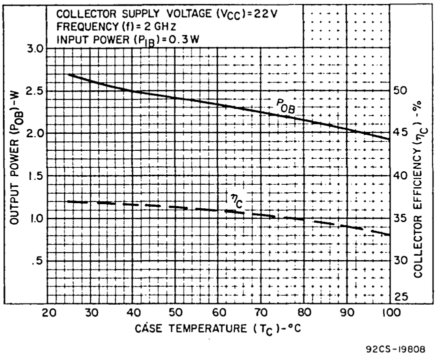


Fig. 9—Typical output power and collector efficiency vs. case temperature for type 2N6268 at 2 GHz.

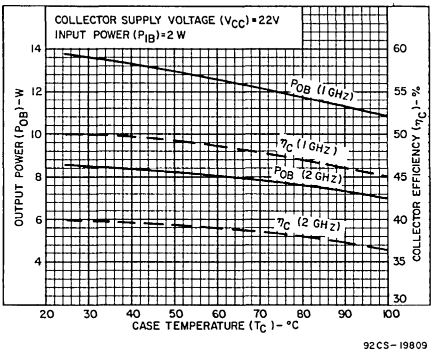


Fig. 10—Typical output power and collector efficiency vs. case temperature for type 2N6269 at 2 GHz.

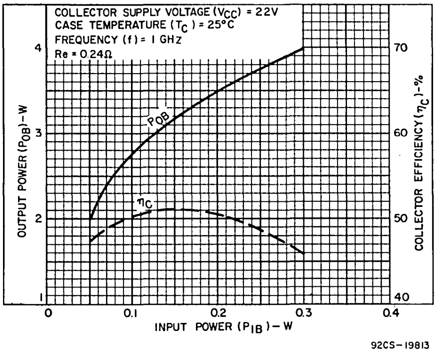


Fig. 11—Typical 1-GHz output power and collector efficiency vs. input power in test set-up of Fig. 14 for type 2N6268.

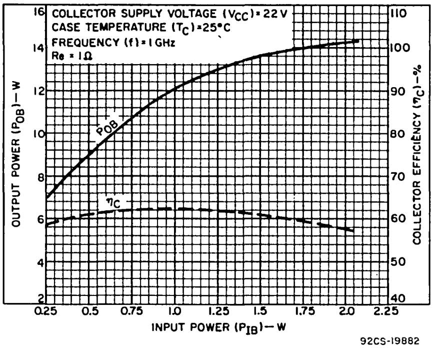


Fig. 12—Typical 1-GHz output power and collector efficiency vs. input power in test set-up of Fig. 15 for type 2N6269.

PERFORMANCE DATA

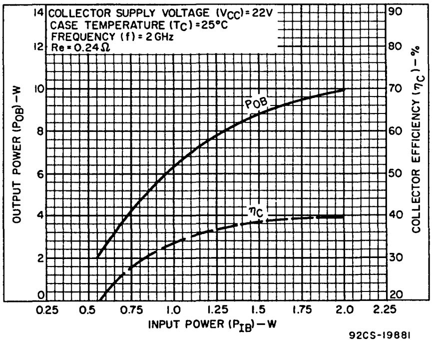


Fig. 13—Typical 2-GHz output power and collector efficiency for type 2N6269 in the circuit of Fig. 25.

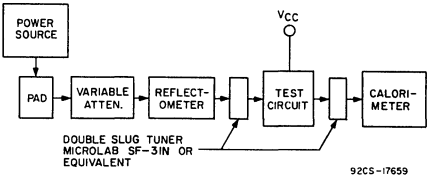


Fig. 14—Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier for type 2N6268.

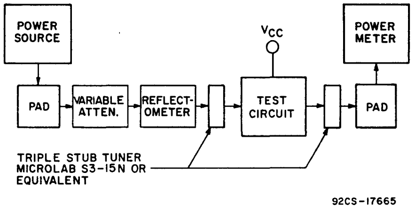


Fig. 15—Block diagram of test set-up for measurement of rf performance from 1- or 2-GHz common-base amplifier for type 2N6269.

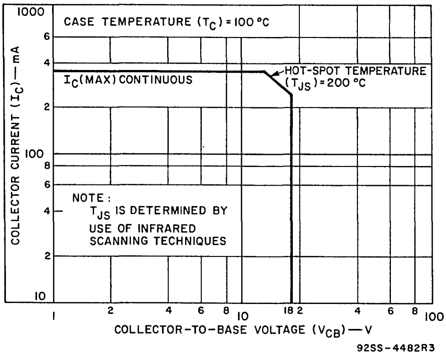


Fig. 16—Maximum operating area for forward-bias operation of type 2N6268.

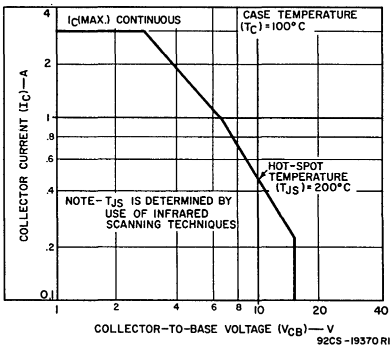


Fig. 17—Maximum operating area for forward-bias operation of type 2N6269.

DESIGN DATA

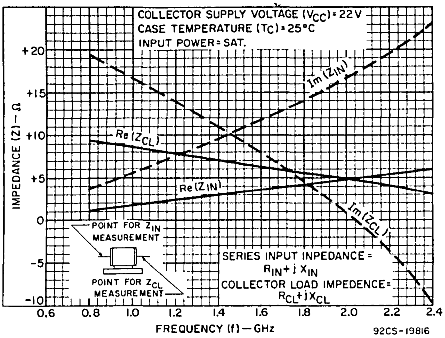


Fig. 18—Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for type 2N6268.

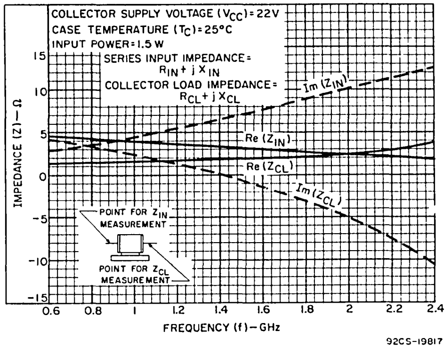


Fig. 19—Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for type 2N6269.

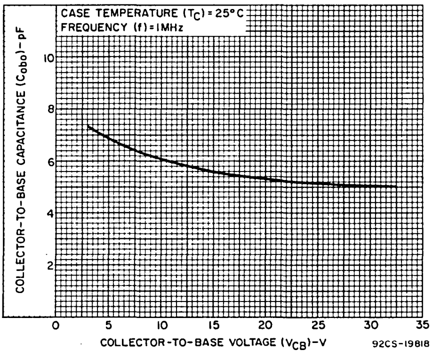


Fig. 20—Typical collector-to-base capacitance vs. collector-to-base voltage for type 2N6268.

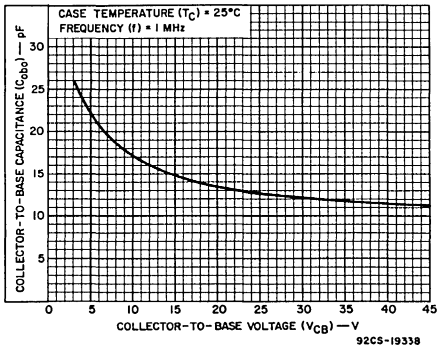


Fig. 21—Typical collector-to-base capacitance vs. collector-to-base voltage for type 2N6269.

SOLDERING INSTRUCTIONS

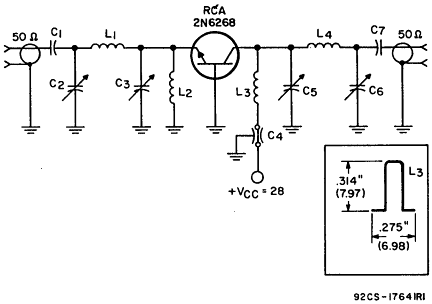
When the 2N6268 or 2N6269 are soldered into a micro-stripline or lumped-costant circuit, the collector and emitter terminals of the devices must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230 °C for a maximum of 10 seconds during tinning and subsequent soldering operations.

TERMINAL CONNECTIONS

Terminal 1 — Emitter
Terminals 2 & 4 — Base
Terminal 3 — Collector

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

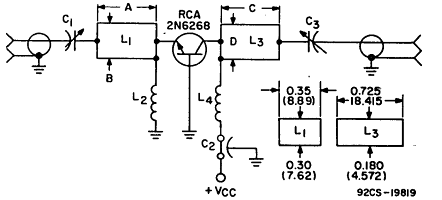
2N6268 APPLICATION DATA



C_1, C_7: 1000 pF, ceramic, leadless
C_2, C_6: 0.35-3.5 pF, air-dielectric, Johanson 4701•
C_3, C_5: 1-10 pF, air-dielectric, Johanson 2957 •
C_4: 1000 pF, feedthrough, Allen-Bradley FA5C•
L_1, L_4: 0.01 in. (0.254)* thick, 0.157 in. (3.98)* wide copper strip shaped as shown in inset drawing
L_2, L_3: RF choke, 0.1μH, Nytronics Deci-Ductor•

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
•or equivalent

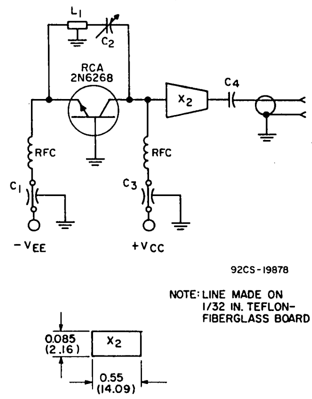
Fig. 22—Typical lumped-element circuit for 1-GHz power amplifier.



C_1 C_3: 0.35-3.5 pF, air-dielectric, Johanson 4701•
C_2: 1000 pF, feedthrough, Allen-Bradley FA5C•
L_1, L_3: Microstripline, 2 oz. copper-clad 1/32 in (0.8)* Teflon-fiberglass
L_2, L_4: RF choke, 4 turns, No. 28 wire, 0.062 in. (1.57)* ID, 0.187 in. (4.75)* long

*Note: Dimension in parentheses are in millimeters and are derived from the original inch dimensions shown.
•or equivalent

Fig. 23—Typical circuit for 2-GHz microstripline amplifier.

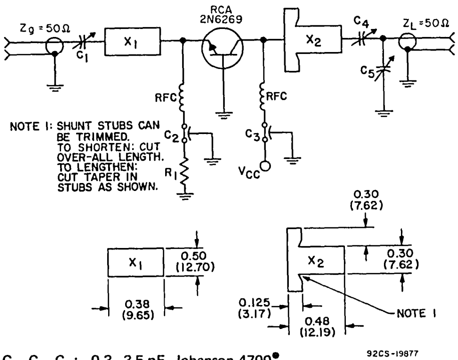


C_1, C_3: Filtercon, Allen-Bradley SMFB-A1•
C_2: 0.3-3.5 pF, Johanson 4700•
C_4: 300 pF, ATC 100•
L_1: 1.0 in. (25.4)* section miniature 50 cable
RFC: 3 turns, No. 32 wire, 0.062 in (1.57)* ID, 0.187 in (4.75)* long

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
•or equivalent

Fig. 24—Typical 1.7-GHz oscillator circuit.

2N6269 APPLICATION DATA

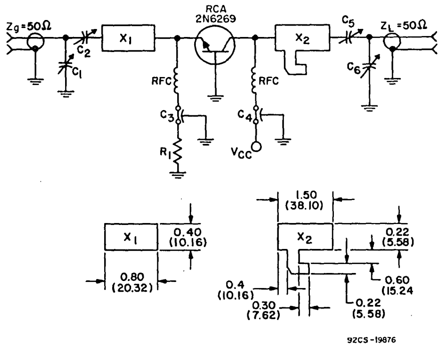


C_1, C_4, C_5: 0.3–3.5 pF, Johanson 4700●
C_2, C_3: Filtercon, Allen-Bradley SMFB-A1●
RFC: No. 32, wire, 0.4 in. (10.2)* long
R_1: 0.24 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
●or equivalent

Fig. 25—Typical 2-GHz power amplifier circuit.

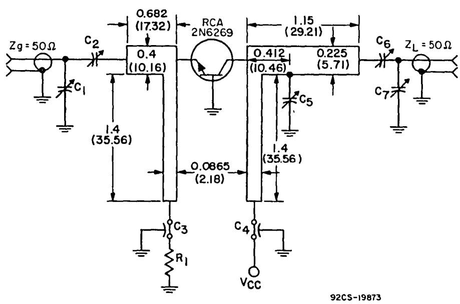


C_1, C_2, C_5, C_6: 0.8–10 pF, Johanson 5202●
C_3, C_4: Filtercon, Allen-Bradley SMFB-A1●
RFC: No. 32 wire, 3 turns 0.062 in. (1.58)* ID x 0.187 in. (4.76)* long
R_1: 1Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
●or equivalent

Fig. 26—Typical 1-GHz power amplifier circuit.



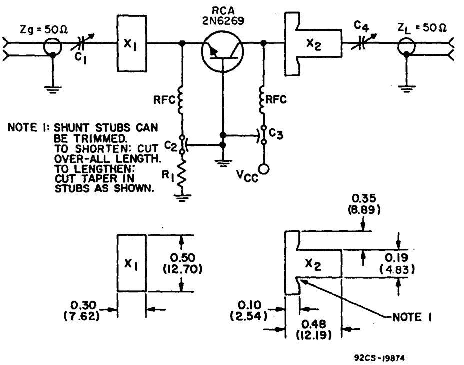
C_1, C_2, C_6: 1–10 pF JFD Electronics, MVM010●
C_5, C_7: 0.3–3.5 pF, JFD Electronics, MVM003●
C_3, C_4: 1000 pF feedthrough, Allen-Bradley FA5C●
R_1: 0.75 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
●or equivalent

Fig. 27—Typical 1.3-GHz power amplifier circuit.

2N6269 APPLICATION DATA

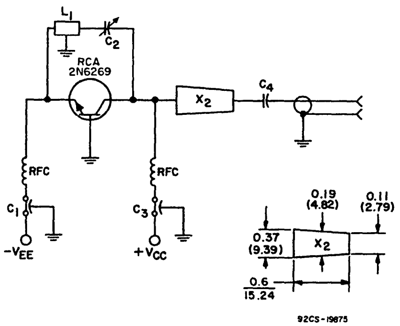


C_1, C_4: 0.3–3.5 pF, Johanson 4700●
C_2, C_3: Filtercon, Allen-Bradley SMFB-A1●
RFC: No. 32 wire, 0.4 in. (10.2)* long
R_1: 0.24 Ω

Dielectric material: 1/32 in. (0.79 mm) thick Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
●or equivalent

Fig. 28—Typical 2.3-GHz amplifier circuit.



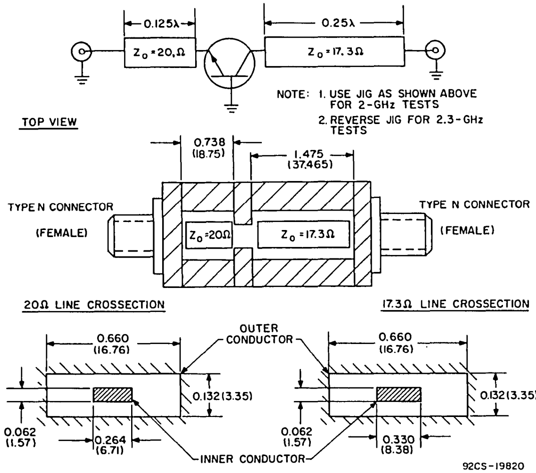
C_1, C_3: Filtercon, Allen-Bradley SMFB-A1●
C_2: 0.3–3.5 pF, Johanson 4700●
C_4: 300 pF, ATC–100●
L_1: 1.0 in (25.4)* section miniature 50 Ω cable, or microstrip equivalent
RFC: 3 turns, No. 32 wire, 0.062 in (1.57)* ID, 0.187 in. (4.75)* long
X_2: 13-mil thick Teflon-Kapton double-clad circuit board (Grade PE-1243 as supplied by Budd Polychem Division, Newark, Delaware), or equivalent.

Line X_2 is exponentially tapered
Oscillator is single screw tunable 1.6 GHz to 1.8 GHz

*Note: Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.
●or equivalent

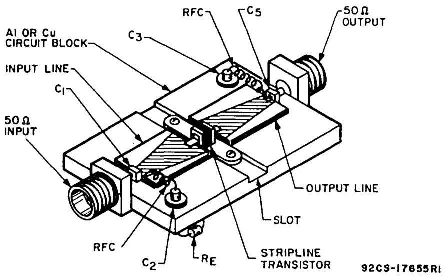
Fig. 29—Typical 1.7-GHz oscillator circuit.

2N6268 & 2N6269 APPLICATION DATA



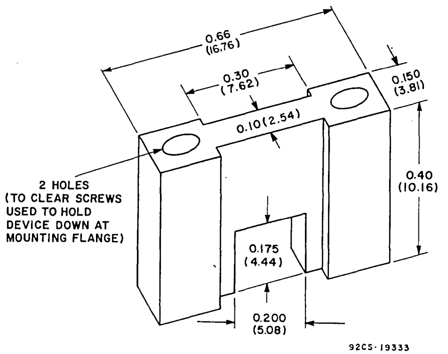
Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

Fig. 30–Typical circuit for 2- or 2.3-GHz stripline test jig for measurement of performance from 2- or 2.3-GHz common-base amplifier for 2N6268.



C_1, C_5: DC-blocking capacitors
C_2, C_3: Feedthrough or filter capacitors

(a) Typical circuit



Dimensions in parentheses are in millimeters and are derived from the original inch dimensions shown.

(b) Circuit shield (Place over device and screw down to circuit board).

NOTE: The circuit shield (b) can be made as a part of a ridge in the circuit board (a) instead of the slot shown, and the device can be mounted upside down in a slot in this ridge for equivalent circuit isolation. For operation in the 2-2.4 GHz range, it is recommended that the circuit be completely shielded to prevent losses due to circuit radiation at these frequencies.

Fig. 31–Typical circuit construction using 2N6268 or 2N6269.

RCA
Solid State
Division

RF Transistors

2N6389

JEDEC TO-72 H-1299

UHF/MATV Low-Noise Silicon N-P-N Transistor

For High-Gain Small-Signal Applications in UHF TV RF Amplifiers and UHF MATV Amplifiers

Features:

- **Low noise figure:**
  NF = 3 dB (typ.) at 450 MHz, 1.5 mA
  = 4 dB (typ.) at 890 MHz, 1.5 mA
  = 6 dB (typ.) at 890 MHz, 10 mA
- **High gain (tuned, unneutralized):**
  G_{PE} = 15 dB (min.) at 890 MHz
- **High gain-bandwidth product**
- **Large dynamic range**
- **Low distortion**
- **Low collector-base capacitance**

RCA 2N6389● is an epitaxial silicon n-p-n planar transistor intended for low-power, small-signal applications where both low noise and high gain are desirable. It utilizes a hermetically sealed four-lead JEDEC TO-72 package. All of the elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead.

●Formerly RCA No. 40989.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	20	V
*COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}	12	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	2.5	V
*COLLECTOR CURRENT (Continuous)	I_C	40	mA
*TRANSISTOR DISSIPATION:	P_T		
At ambient temperatures up to 25°C		200	mW
At ambient temperatures above 25°C		Derate linearly at 1.14 mW/°C	
*TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to +200° C	
*LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/16 in. (1.59 mm) from seating plane for 60 s max.		300° C	

*In accordance with JEDEC registration data format JS-9 RDF-1.

9-74

ELECTRICAL CHARACTERISTICS, *At Ambient Temperature (T_A) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS		UNITS
		VOLTAGE V dc		CURRENT mA dc					
		V_{CB}	V_{CE}	I_E	I_B	I_C	MIN.	MAX.	

STATIC

CHARACTERISTIC	SYMBOL	V_{CB}	V_{CE}	I_E	I_B	I_C	MIN.	MAX.	UNITS
* Collector Cutoff Current	I_{CBO}	15		0			–	20	nA
* Emitter Cutoff Current	I_{EBO}	(V_{EB}) 1				0	–	1	µA
* Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.001	20	–	V
* Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$				0	3	12	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.01		0	2.5	–	V
* DC Forward Current Transfer Ratio	h_{FE}		1			3	25	250	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	880	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	V_{CB}	V_{CE}	I_E	I_B	I_C	MIN.	MAX.	UNITS
Device Noise Figure: f = 890 MHz = 890 MHz = 450 MHz	NF	 10 10 10				 1.5 10 1.5	 – – –	 4(typ.) 6(typ.) 3(typ.)	dB
Small-Signal Common-Base Power Gain (f = 890 MHz)	G_{PB}	10				10	15	–	dB
* Small-Signal, Short Circuit Forward Current Transfer Ratio (f = 1 kHz)	h_{fe}		1			3	25	250	
* Magnitude of Small-Signal Short Circuit Forward Current Transfer Ratio (f = 200 MHz)	$\|h_{fe}\|$		10			1.5	5	15	
* Collector-to-Base Time Constant (f = 31.9 MHz)	$r_b'C_c$	10		1.5			1	15	ps
* Collector-to-Base Capacitance (f = 1 MHz)	C_{cb}	10		0			0.4	0.55	pF

* In accordance with JEDEC registration data format JS-9 RDF-1.

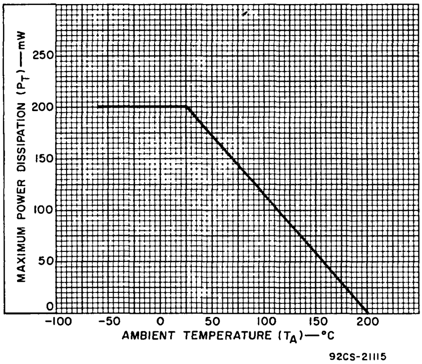


Fig. 1 — Power dissipation vs. ambient temperature.

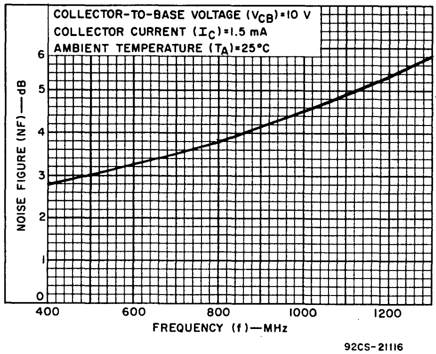


Fig. 2 — Typical common-base noise figure vs. frequency.

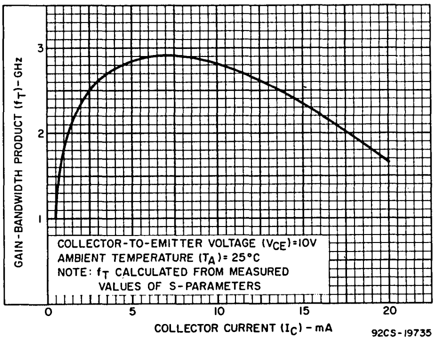
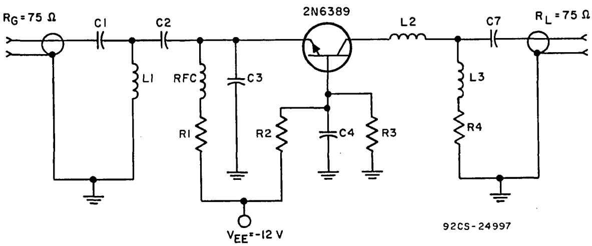


Fig. 3 — Gain-bandwidth product vs. collector current.

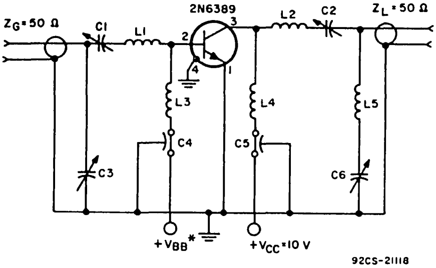


C_1,C_7: 3.3 pF disc ceramic
C_2: 2.7 pF disc ceramic
C_3: 1 pF disc ceramic
C_4: 25 pF, ATC-100 or equivalent

L_1,L_2: 2 turns, No. 18 wire, 0.125 in. (3.175 mm) ID
RFC: 8 turns No. 28 wire, 0.062 in. (1.57 mm) ID

R_1: 270 Ω
R_2: 2.2 kΩ
R_3: 4.7 kΩ
R_4: 4.7 Ω

Fig. 4—890-MHz common-base test circuit for gain and noise figure.



C_1: 1.0–30 pF
C_2,C_3: 1.0–20 pF
C_4,C_5: 0.04 μF
C_6: 1–10 pF

L_1: 2 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.10 in. (2.54 mm) long
L_2: 3 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.15 in. (3.81 mm) long
L_3,L_4: 0.22-μH rf choke
L_5: 3 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.15 in. (3.81 mm) long

R_1: 200Ω, 1/4 W

* $V_{(BB)}$ adjusted for I_C = 1.5 mA

Fig. 5—Circuit diagram of 450-MHz amplifier used for measurement of noise figure.

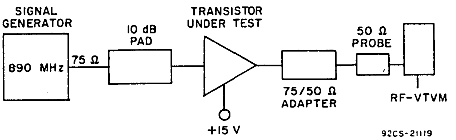


Fig. 6—Block diagram of test setup for measurement of gain.

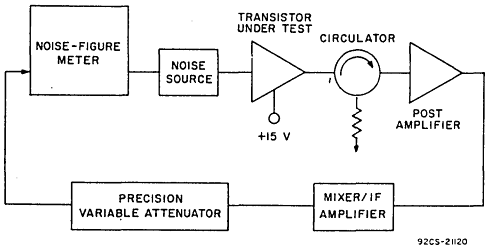


Fig. 7—Block diagram of noise-figure test set.

TERMINAL CONNECTIONS

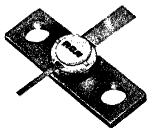
Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector
Lead 4 – Connected to case

RCA

Solid State
Division

RF Power Transistors

RCA2003 2N6390



RCA HF-46
(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

2.5- and 3-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- **2.5-W output with 7-dB gain (min.) at 2 GHz, 28 V (RCA2003)**
- **3-W output with 8-dB gain (min.) at 2 GHz, 28 V (2N6390)**
- **Load-VSWR capability of ∞:1 at 2 GHz**
- **Emitter-ballasting resistors**
- **Stable common-base operation**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuits**

RCA2003 and 2N6390● are emitter-ballasted epitaxial silicon n-p-n planar transistors that use overlay multiple-emitter-site construction. They are designed especially for use in microwave communications, L- and S-band telemetry, microwave relay links, phased-array radar, distance-measuring equipment, transponders, and collision avoidance systems.

The ceramic-metal stripline package of these devices has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

These transistors are especially suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

● Formerly RCA Dev. Nos. TA8748 and TA8747, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA2003	2N6390	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	V
*COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	50	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	1	1	A
*TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 75°C		8.34	8.34	W
At case temperature above 75°C . . . . Derate linearly at		0.067	0.067	W/°C
*TEMPERATURE RANGE: Storage and operating (Junction)		−65 to +200		°C
*LEAD TEMPERATURE (During soldering): At distances ≥ 0.02 in. (0.5 mm) from seating plane for 10 s max.		230		°C

* 2N6390 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C, unless otherwise specified:*

STATIC CHARACTERISTIC	SYMBOL	TEST CONDITIONS Voltage V dc V_{CE}	V_{CB}	Current mA dc I_E	I_C	LIMITS RCA2003 MIN.	MAX.	2N6390 MIN.	MAX.	UNITS
Collector Cutoff Current: With emitter open	I_{CBO}		28	0		–	0.5	–	–	mA
* With emitter connected to base	I_{CES}	45				–	–	–	2	mA
* At T_C = 55°C	I_{CES}	40				–	–	–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0 0	1 2	50 –	– –	– 50	– –	V
* Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				5	50	–	50	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			1	0	3.5	–	3.5	–	V
* Forward Current Transfer Ratio	h_{FE}	10			50	20	120	20	120	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	15	–	15	°C/W

DYNAMIC CHARACTERISTIC	SYMBOL	TEST CONDITIONS VOLTAGE V dc V_{CC}	FREQUENCY GHz f	POWER W P_{IB}	P_{OB}	LIMITS RCA2003 MIN.	MAX.	2N6390 MIN.	MAX.	UNITS
Output Power	P_{OB}	28 28	2 2	0.5 0.475		2.5 –	– –	– 3	– –	W
* Large-Signal Common-Base Power Gain	G_{PB}	28 28	2 2		2.5 3	7 –	– –	– 8	– –	dB
* Collector Efficiency	η_C	28 28	2 2		2.5 3	30 –	– –	– 30	– –	%
* Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	5	–	5	pF

* 2N6390 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

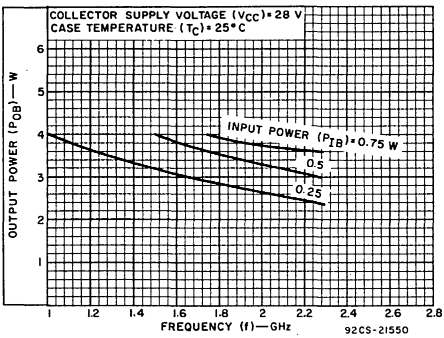


Fig.1 – Typical output power vs. frequency for both types.

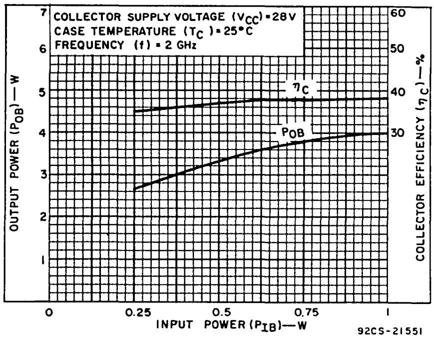


Fig.2 – Typical output power and collector efficiency vs. input power at 2 GHz for both types.

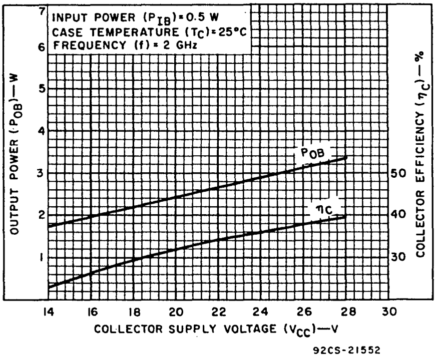


Fig.3 – Typical output power and collector efficiency vs. supply voltage for both types.

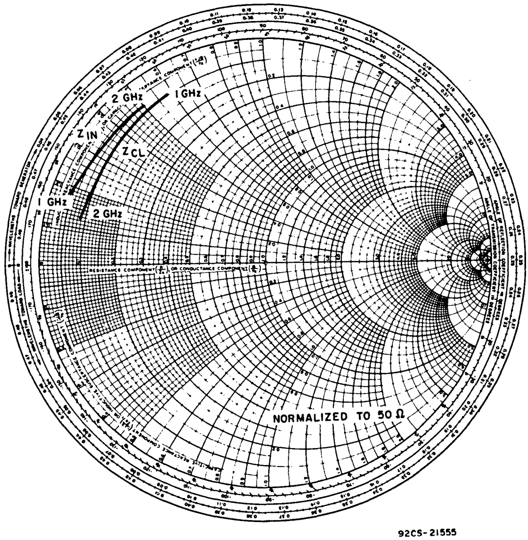
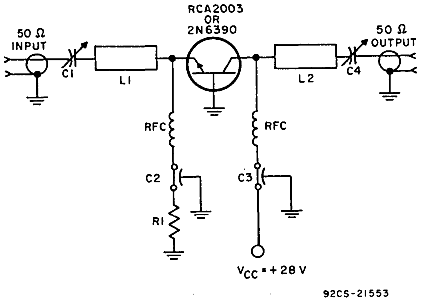


Fig.4 – Input and output impedances for both types.



C1, C4: 0.35–3.5 pF, Johanson 4702 or equivalent
C2, C3: 470 pF feedthrough, Allen-Bradley FB28 or equivalent
L1: Microstripline, 0.031 in. (0.79 mm) Teflon—Fiberglas, 0.18 in. (0.45 mm) wide, 0.350 in. (0.889 mm) long, $\epsilon = 2.6$
L2: Microstripline, 0.031 in. (0.79 mm) Teflon-Fiberglas, 0.18 in. (0.45 mm) wide, 0.66 in. (16.76 mm) long, $\epsilon = 2.6$
RFC: 3 turns No. 32 wire, 0.0625 in. (1.58 mm) ID, 0.25 in. (6.35 mm) long
R1: 0.12 Ω

Fig.5 – 2-GHz test circuit for both types.

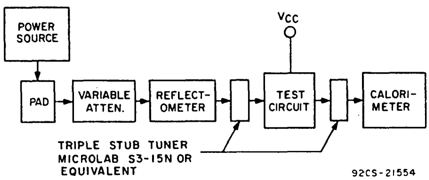


Fig.6 – Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier.

TERMINAL CONNECTIONS

Terminal 1 – Emitter
Terminals 2 & 4 – Base
Terminal 3 – Collector

WARNING: The ceramic body of these devices contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

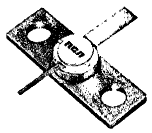
RCA
Solid State
Division

RF Power Transistors

RCA2005 2N6391

5-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers



RCA HF-46
(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

Features:

- **5-W output with 7-dB gain (min.) at 2 GHz, 28 V for both types**
- **Load-VSWR capability of ∞:1 at 2 GHz**
- **Emitter-ballasting resistors**
- **Stable common-base operation**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuits**

RCA2005 and 2N6391● are emitter-ballasted epitaxial silicon n-p-n planar transistors that use overlay multiple-emitter-site construction. They are designed especially for use in microwave communications, L- and S-band telemetry, microwave relay links, phased-array radar, distance-measuring equipment, transponders, and collision avoidance systems.

The ceramic-metal stripline package of these devices has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

These transistors are especially suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

● Formerly RCA Dev. Nos. TA8750 and TA8749, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA2005	2N6391	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	V
*COLLECTOR-TO-EMITTER VOLTAGE:				
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	50	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	2.5	2.5	A
*TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 75°C		16.7	16.7	W
At case temperature above 75°C . . . . Derate linearly at		0.133	0.133	W/°C
*TEMPERATURE RANGE:				
Storage and operating (Junction)		−65 to +200		°C
*LEAD TEMPERATURE (During soldering):				
At distances ≥ 0.02 in. (0.5 mm) from seating plane for 10 s max.		230		°C

* 2N6391 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C, unless otherwise specified:*

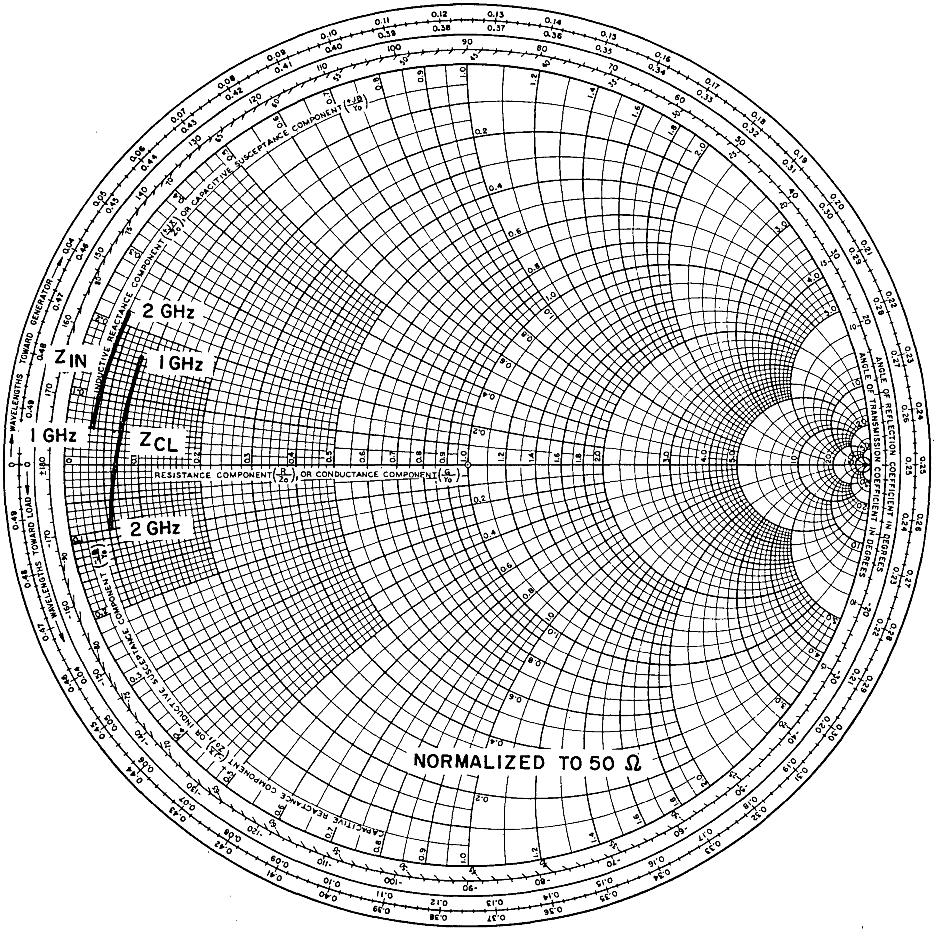
STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS				UNITS
		Voltage V dc		Current mA dc		RCA2005		2N6391		
		V_{CE}	V_{CB}	I_E	I_C	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: With emitter open	I_{CBO}		28	0		–	0.5	–	–	mA
* With emitter connected to base	I_{CES}	45				–	–	–	3	mA
* At T_C = 55°C	I_{CES}	40				–	–	–	3	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0 0	1 5	50 –	– –	– 50	– –	V
* Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				5	50	–	50	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			1	0	3.5	–	3.5	–	V
* Forward Current Transfer Ratio	h_{FE}	10			200	20	120	20	120	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	7.5	–	7.5	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS				UNITS
		VOLTAGE V dc	FREQUENCY GHz	POWER W		RCA2005		2N6391		
		V_{CC}	f	P_{IB}	P_{OB}	MIN.	MAX.	MIN.	MAX.	
Output Power	P_{OB}	28	2	1		5	–	5	–	W
* Large-Signal Common-Base Power Gain	G_{PB}	28	2		5	7	–	7	–	dB
* Collector Efficiency	η_C	28	2		5	30	–	30	–	%
* Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	9	–	9	pF

* 2N6391 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.



92CS-21565

Fig. 1 – Input and output impedances for both types.

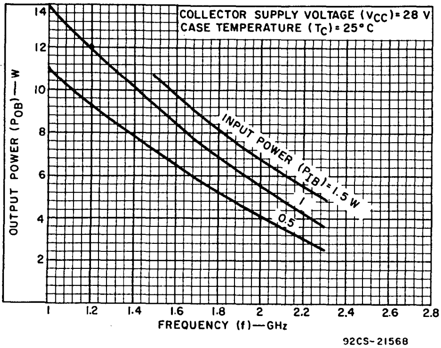


Fig. 2 — Typical output powers vs. frequency for both types.

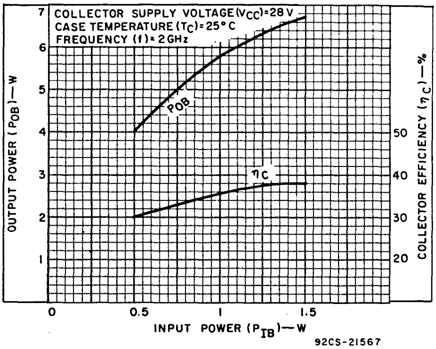


Fig. 3 — Typical output power and collector efficiency vs. input power at 2 GHz for both types.

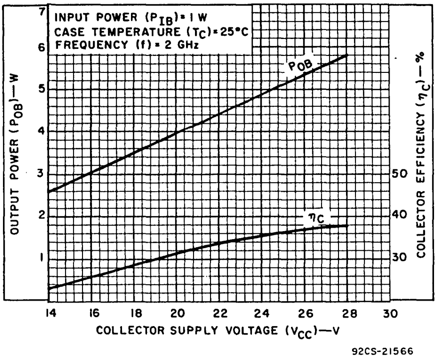
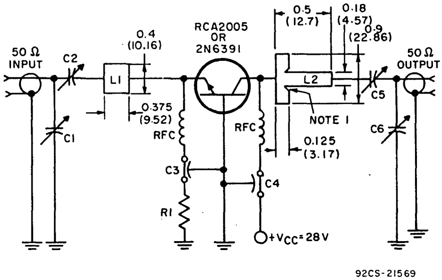


Fig. 4 — Typical output power and collector efficiency vs. supply voltage for both types.



C1, C2, C5, C6: 0.3-3.5 pF, Johanson 4700 or equivalent
C3, C4: Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 3 turns No. 30 wire 0.0625 in. (1.58 mm) dia., 0.25 in. (6.35 mm) long
R1: 0.24 Ω, 1 W, wirewound
Dielectric Material: 0.031 in. (0.79 mm) thick Teflon-Fiberglas double-clad circuit board (ϵ = 2.6)

Note 1: Shunt stubs can be trimmed
To shorten, cut overall length
To lengthen, cut taper in stubs

Fig.5 — 2-GHz test circuit for both types.

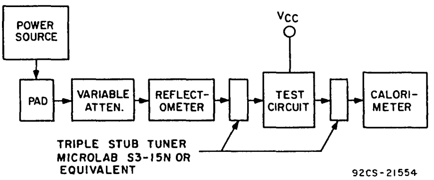


Fig.6 — Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier.

TERMINAL CONNECTIONS

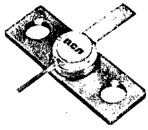
Terminal 1 — Emitter
Terminals 2 & 4 — Base
Terminal 3 — Collector

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

Solid State
Division

RF Power Transistors

RCA2010 2N6392 2N6393



RCA HF-46

(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

10-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- **10-W output with 7-dB gain (min.) at 2 GHz, 28 V (2N6393)**
- **10-W output with 5-dB gain (min.) at 2 GHz, 28 V (RCA2010, 2N6392)**
- **Load-VSWR capability of 10:1 at 2 GHz**
- **Emitter-ballasting resistors**
- **Stable common-base operation**

RCA2010, 2N6392, and 2N6393● are emitter-ballasted epitaxial silicon n-p-n planar transistors that use overlay multiple-emitter-site construction. They are designed especially for use in microwave communications, L- and S-band telemetry, microwave relay links, phased-array radar, distance-measuring equipment, transponders, and collision avoidance systems.

The ceramic-metal stripline package of these devices has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuits**

These transistors are especially suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

●Formerly RCA Dev. Nos. TA8752, TA8751, and TA8746, respectively.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA2010	2N6392	2N6393	
*COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	45	V
*COLLECTOR-TO-EMITTER VOLTAGE:					
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	50	45	V
*EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
*CONTINUOUS COLLECTOR CURRENT	I_C	3.5	3.5	3.5	A
*TRANSISTOR DISSIPATION:	P_T				
At case temperature up to 75°C		21	21	21	W
At case temperature above 75°C — Derate linearly at		0.167	0.167	0.167	W/°C
*TEMPERATURE RANGE:					
Storage and operating (Junction)			−65 to +200		°C
*LEAD TEMPERATURE (During soldering):					
At distances ≥ 0.02 in. (0.5 mm) from seating plane for 10 s max.			230		°C

*2N6392, 2N6393 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C, unless otherwise specified:*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Voltage -V dc		Current mA dc		LIMITS: RCA2010		2N6392		2N6393		UNITS
		V_{CE}	V_{CB}	I_E	I_C	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: With emitter open	I_{CBO}		28			–	0.5	–	–	–	–	mA
* With emitter connected to base	I_{CES}	45 40				– –	– –	– –	3 –	– –	– 3	mA
* At T_C = 55°C	I_{CES}	40 35				– –	– –	– –	3 –	– –	– 3	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	50	–	50	–	45	–	V
* Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				5	50	–	50	–	45	–	V
* Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			1	0	3.5	–	3.5	–	3.5	–	V
* Forward Current Transfer Ratio	h_{FE}	10			500[a]	20	120	20	120	20	120	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	6	–	6	–	6	°C/W

[a] Pulse test: pulse duration = 80 μs

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc	FREQUENCY GHz	POWER W		LIMITS: RCA2010		2N6392		2N6393		UNITS
		V_{CC}	f	P_{IB}	P_{OB}	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Output Power	P_{OB}	28 28	2 2	2 3		– 10	– –	– 10	– –	10 –	– –	W
* Large-Signal Common-Base Power Gain	G_{PB}	28	2		10	5	–	5	–	7	–	dB
* Collector Efficiency	η_C	28	2		10	33	–	33	–	35	–	%
* Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	10	–	11	–	11	pF

*2N6392, 2N6393 in accordance with JEDEC registration data format JS-6 RDF-3/JS-9 RDF-7.

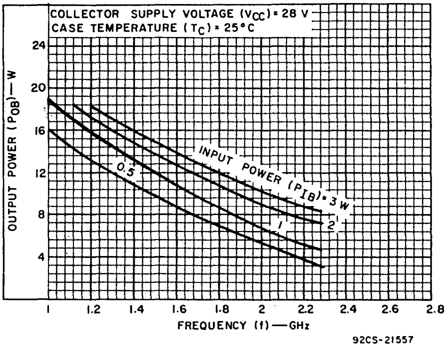


Fig.1 – Typical output power vs. frequency for RCA2010 and 2N6392.

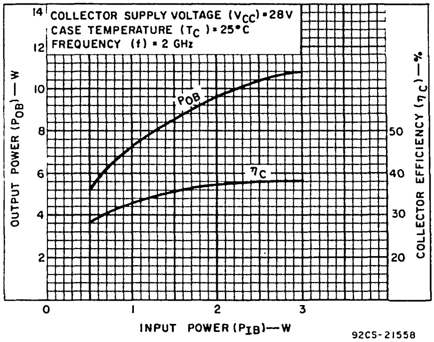


Fig.2 – Typical output power and collector efficiency vs. input power at 2 GHz for RCA2010 and 2N6392.

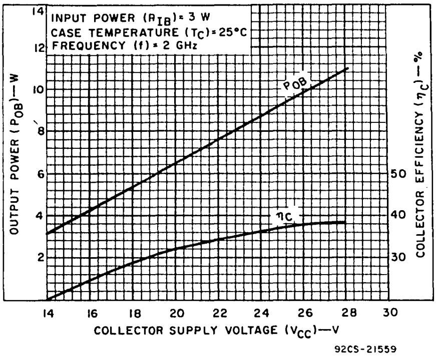


Fig.3 – Typical output power and collector efficiency vs. supply voltage for RCA2010 and 2N6392.

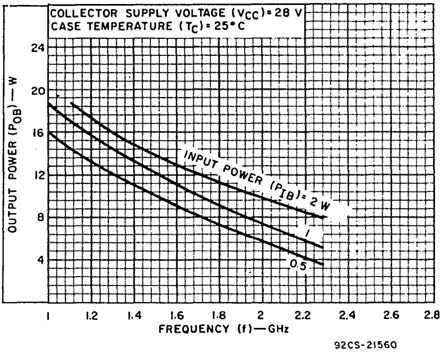


Fig.4 – Typical output power vs. frequency for 2N6393.

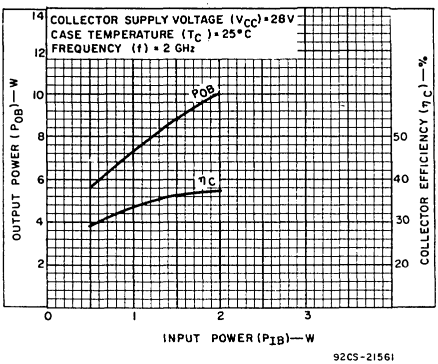


Fig.5 – Typical output power and collector efficiency vs. input power at 2 GHz for 2N6393.

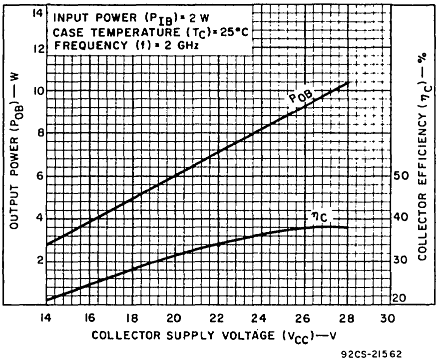
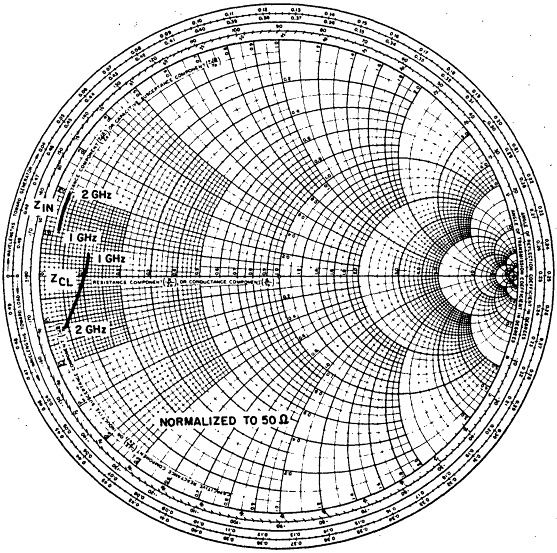
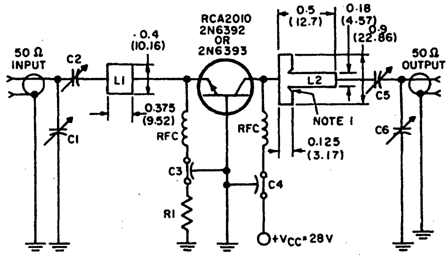


Fig.6 – Typical output power and collector efficiency vs. supply voltage for 2N6393.



92CS-21563

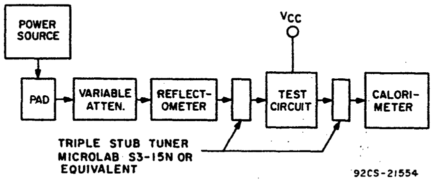
Fig.7 — Input and output impedances for all types.



92CS-21564

C1, C2, C5, C6: 0.3-3.5 pF, Johansen 4700, or equivalent
C3, C4: Filtercon, Allen-Bradley SMFB-A1, or equivalent
RFC: 3 turns No. 30 wire 0.0625 in. (1.58 mm) dia., 0.25 in. (6.35 mm) long
R1: 0.24 Ω, 1 W, wirewound
Dielectric Material: 0.031 in. (0.79 mm) thick Teflon-Fiberglas double-clad circuit board (ϵ = 2.6)
Note 1: Shunt stubs can be trimmed
To shorten, cut overall length
To lengthen, cut taper in stubs

Fig. 8 — 2-GHz test circuit for all types.



92CS-21554

Fig. 9— Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier.

TERMINAL CONNECTIONS

Terminal 1 — Emitter
Terminals 2 & 4 — Base
Terminal 3 — Collector

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State
Division

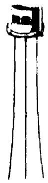
RF Power Transistors

40080 40082 40581
40081 40446 40582

40082
40581

JEDEC TO-39 H-1381

40582
40446
TO-39 with flange H-1375



40080
40081

JEDEC TO-5 H-1380

Silicon N-P-N Planar Transistors

For Class C Operation in
27-MHz "CB" Circuits

- **OSCILLATOR:** 40080 (TO-5)
- **DRIVER:** 40081 (TO-5)
- **OUTPUT:** 40082, 40581 (TO-39)
  40446, 40582 (TO-39 + Flange)

RCA-40080, 40081, 40082, 40446, 40581, and 40582 are triple-diffused, silicon planar n-p-n transistors, specifically designed for application in a 5-watt-output, 27-MHz citizens-band transmitter. Type 40581 is a higher-power version of the 40082 and is intended to provide an output power of 3.5 W in this application. Type 40582 is a higher-power version of the 40446. These types have factory-attached diamond-shaped mounting flanges.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40080	40081	40082 40581	40446 40582	
COLLECTOR-TO-EMITTER VOLTAGE:						
With V_{BE} = −0.5 volts	V_{CEV}	–	60	60	60	V
With base open	V_{CEO}	30	–	–	–	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	–	2.0	2.5	2.5	V
PEAK COLLECTOR CURRENT		0.25	0.25	1.5	1.5	A
TRANSISTOR DISSIPATION:	P_T					
At case temperatures up to 25°C		–	2.0	5.0	10	W
At free-air temperatures up to 25°C		0.5	–	–	–	W
At case temperatures above 25°C		← See Fig. 2 →				
TEMPERATURE RANGE:						
Storage & Operating (Junction)		← −65 to 200 →				°C
LEAD TEMPERATURE (During soldering):						
At distances ⩾ 1/32 in. (0.8 mm) from insulating wafer for 10s max		← 230 →				°C

ELECTRICAL CHARACTERISTICS, *Case Temperature (T_C) = 25°C*

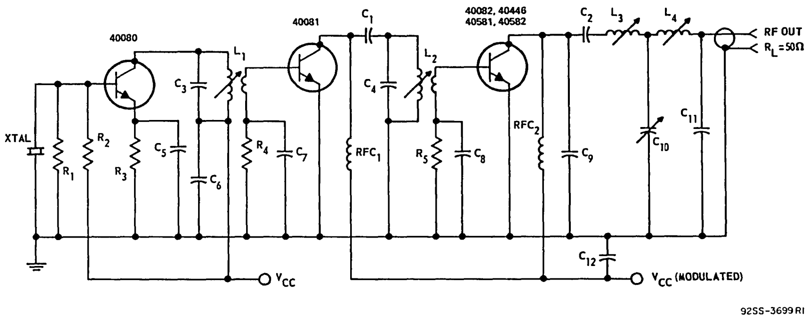
CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE V: V_{CB}	V_{CE}	V_{CC}	DC EMITTER OR BASE VOLTAGE V: V_{BE}	DC CURRENT mA: I_C	I_E	I_B	LIMITS: 40080 MIN.	40080 MAX.	40081 MIN.	40081 MAX.	40581 40582 40082 40446 MIN.	40581 40582 40082 40446 MAX.	UNITS
Collector-to-Emitter Voltage:	V_{CEO}					10		0	30	–	–	–	–	–	V
	V_{CEV}				-0.5 -0.5	100μA 500μA			–	–	60	–	60	–	V
Emitter-to-Base Voltage:	V_{EBO}					0 0	500μA 500μA		–	–	2.0	–	2.5	–	V
Collector-Cutoff Current	I_{CBO}	15 15 15					0 0 0		–	10	–	10	–	10	μA
Collector-to Base Capacitance: (Measured at 1 MHz)	C_{ob}		30 30 30							6		6		20	pF
RF Power Output: Oscillator (f = 27 MHz)	P_{OUT}			12		32			100		–	–	–	–	mW
Driver (f = 27 MHz, P_{IN} = 75 mW)	P_{OUT}			12		85			–	–	400		–	–	mW
Output Amplifier (f = 27 MHz, P_{IN} = 350 mW)	P_{OUT}			12		415							3.0 (min.) [40082, 40446]		W
				12		415							3.5 (min.) [40581, 40582]		W
Junction-to-Case Thermal Resistance:	$R_{\theta JC}$								350[a] (max.)		87.5 (max.)		17.5 (max.) [40446, 40582]		°C/W
													35 (max.) [40082, 40581]		°C/W

[a]Junction-to-Ambient Thermal Resistance, $R_{\theta JA}$

TYPICAL C.B. TRANSMITTER PERFORMANCE (V_{CC} = 13.8 V)

STAGE	RCA TYPE	NO MODULATION: I_C mA	NO MODULATION: RF P_{OUT} W	100% MODULATION: I_C mA	100% MODULATION: RF P_{OUT} W
Oscillator	40080	15	–	15	–
Driver	40081	55	–	50	–
Output	40082, 40581 40446, or 40582	330	3.5[a]	330	4.8 (typ.)

[a]Adjusted for maximum legal power output.



C_1: 47 pF
C_2: 100 pF
C_3: 30 pF
C_4: 51 pF
C_5: 75 pF
C_6, C_{12}: 0.01 μF
C_7: 0.001 μF
C_8: 0.002 μF
C_9: 24 pF
C_{10}: 90-400 pF, ARCO No. 429 or equiv.
C_{11}: 220 pF

L_1: Primary 14 turns, Secondary 3 turns No. 22 wire ¼ in. (6.35 mm) CTC coil form with "green dot" core 0.75–1.2 μH, Q = 100
L_2: Primary 14 turns, Secondary 2-¾ turns No. 22 wire ¼ in. (6.35 mm) CTC coil form with "green dot" core 0.75–1.2 μH, Q = 100
L_3: 11 turns No. 22 wire ¼ in. (6.35 mm) CTC coil form with "green dot" core 0.5–0.9 μH, Q = 120
L_4: 7 turns No. 22 wire ¼ in. (6.35 mm) CTC coil form with "green dot" core 0.21–0.34 μH, Q = 140
RFC_1, RFC_2: 15 μH, Miller No. 4624 or equiv.

R_1: 510 Ω
R_2: 5,100 Ω
R_3: 51 Ω
R_4: 120 Ω
R_5: 47 Ω
V_{CC}: 11 to 15 V
XTAL: 27 MHz

Fig. 1—Typical 27-MHz amplifier chain.

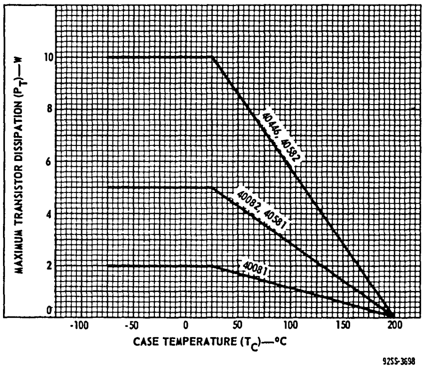


Fig. 2—Dissipation derating curve.

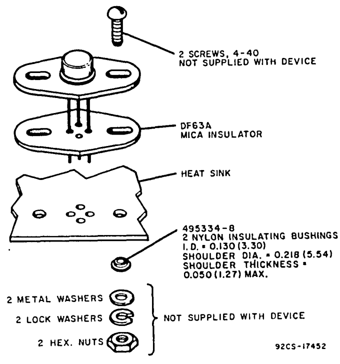


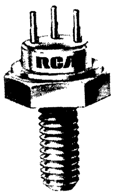
Fig. 3—Suggested mounting hardware for JEDEC TO-5 with mounting flange.

TERMINAL CONNECTIONS

Lead 1 - Emitter
Lead 2 - Base
Case, Lead 3 - Collector

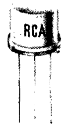
RCA
Solid State
Division

RF Power Transistors
40280
40281
40282



40281, 40282
JEDEC TO-60

H-1307



40280
JEDEC TO-39

H-1381

1,4,&12-W, 175-MHz Overlay Transistors

Silicon N-P-N Devices for High-Power VHF Amplifier Service

Features

- **Suitable for low-voltage supplies (13.5 V)**
- **High output power at 175 MHz, unneutralized class C amplifier**
- **High efficiency at 175 MHz**
- **Low input impedance**

RCA-40280, 40281, and 40282 are epitaxial silicon n-p-n planar transistors of the "overlay" emitter electrode construction. They are intended especially for high-power output, vhf class-C-amplifier service in low-voltage-supply applications.

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjuction with a single base and collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, and frequency capability.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40280	40281	40282	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	36	36	V
COLLECTOR-TO-EMITTER VOLTAGE:					
With base open	V_{CEO}	18	18	18	V
With V_{BE} = −1.5V	V_{CEV}	36	36	36	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	4	4	V
COLLECTOR CURRENT	I_C	0.5	1	2	A
TRANSISTOR DISSIPATION	P_T				
At case temperatures up to 25°C		7.0	11.6	23.2	W
At case temperatures above 25°C		Derate linearly to 0 watts at 200°C			
TEMPERATURE RANGE:					
Storage & Operating (Junction)		−65 to 200			°C
LEAD TEMPERATURE (During soldering):					
At distances ≥1/32 in. (0.8 mm) from insulating wafer (TO-60) package or from seating plane (TO-39 package) for 10 s max.		230			°C

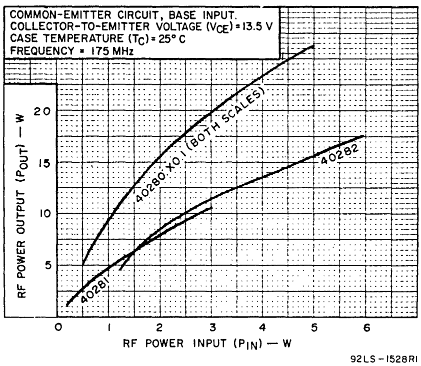
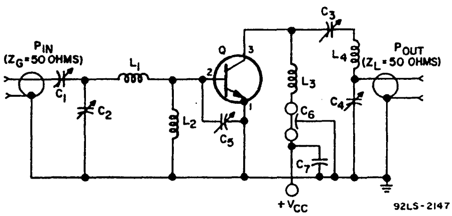


Fig. 1—Typical rf power output vs. rf power input at 175 MHz.

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

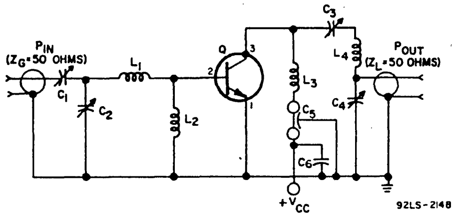
CHARACTERISTICS	SYMBOL	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Base Volts V_{BE}	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	DC Current (Milliamperes) I_C	LIMITS: Type 40280 Min.	Type 40280 Max.	Type 40281 Min.	Type 40281 Max.	Type 40282 Min.	Type 40282 Max.	UNITS
Collector Cutoff Current	I_{CEO}		15			0		–	100	–	100	–	250	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$				0 0		0.25 0.50	36 –	– –	36 –	– –	– 36	– –	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				0.10 0.25		0 0	4 –	– –	4 –	– –	– 4	– –	V
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEV}$			-1.5			200[a]	36	–	36	–	36	–	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$					0	200[a]	18	–	18	–	18	–	V
Real Part of Common-Emitter High-Frequency Input Impedance (f = 175 MHz)	$h_{ie}(real)$		13.5 13.5 13.5				100 400 800	10 (typ.) – –	 – –	– 7 (typ.) –	– –	– – 5 (typ.)	– – 	Ω
RF Power Output: As class C amplifier unneutralized (f = 175 MHz) See *Figs. 2 & 3*	P_{OUT}		13.5					1[b]	–	4[c]	–	12[d]	–	W
Gain-Bandwidth Product	f_T		13.5 13.5 13.5				100 400 800	550 (typ.) – –	 – –	– 400(typ.) –	– –	– – 350 (typ.)	– – 	MHz
Collector-to-Base Capacitance (f = 1 MHz)	C_{ob}	13.5			0			–	15	–	22	–	45	pF
Collector-to-Case Capacitance	C_s							–	–	–	5	–	5	pF
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$							–	25	–	15	–	7.5	°C/W

[a]Pulsed through an inductor (25 mH); duty factor = 50%.
[b]For P_{IN} = 0.125 w; minimum efficiency = 60%.
[c]For P_{IN} = 1.0W; minimum efficiency = 70%.
[d]For P_{IN} = 4.0W; minimum efficiency = 80%.



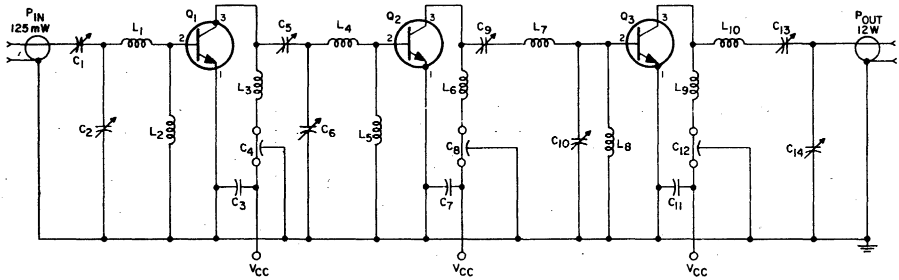
C_1, C_2, C_3, & C_4: 7-100 pF
C_5: 8-60 pF
C_6: 1,000 pF
C_7: 0.01 μF
L_1: 3 turns No.16 wire, 3/16 in. (4.76 mm) ID, 5/16 in. (7.93 mm) long
L_2: Ferrite Choke, Z = 450 ohms
L_3: 1 turn No.16 wire 1/4 in. (6.35 mm) ID, 3/8 in. (9.52 mm) long
L_4: 2 turns No.16 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
Q: 40281, 40282

Fig.2–RF amplifier circuit for power-output test at 175 MHz for types 40281 and 40282.

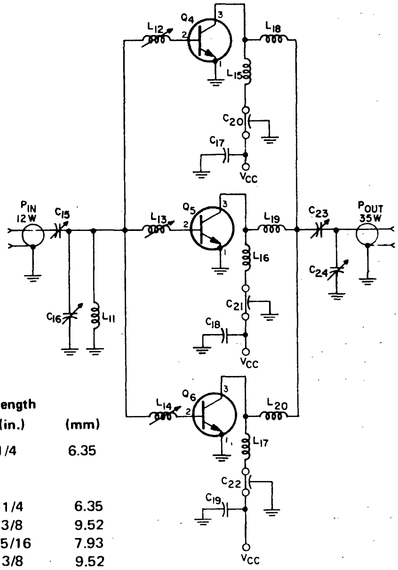


C_1, C_2, C_3, & C_4: 3-30 pF
C_5: 1,000 pF
C_6: 0.01 μF
L_1: 2 turns No.16 wire, 3/16 in. (4.76 mm) ID, 1/4 in. (6.35 mm) long
L_2: Ferrite choke, Z = 450 ohms
L_3: 2 turns No.16 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
L_4: 4 turns No.16 wire, 3/8 in. (9.52 mm) ID, 3/8 in. (9.52 mm) long
Q: 40280

Fig.3–RF amplifier circuit for power-output test at 175 MHz for type 40280.



92LM-2149



92LM-2150

Capacitors

C_1: 3-35 pF
C_2, C_6, C_{10}, C_{24}: 8-60 pF
C_3, C_7, C_{11}: 0.01 μF
C_4, C_8, C_{12}: 1500 pF
C_9, C_{10}, C_{13}, C_{14}, C_{23}: 7-100 pF
C_{15}: 1.5-20 pF
C_{17}, C_{18}, C_{19}: 0.2 pF
C_{20}, C_{21}, C_{22}: 1500 pF

Transistors

Q_1: 40280
Q_2: 40281
Q_3–Q_6: 40282

Inductors	Turns	Wire Size	ID (in.)	ID (mm)	Length (in.)	Length (mm)
L_1	2	16	3/16	4.76	1/4	6.35
L_2, L_5, L_8: ferrite choke, Z = 450 Ω						
L_3, L_6, L_{11}: 1 μH choke						
L_4, L_7	3	16	3/16	4.76	1/4	6.35
L_9	1-1/2	16	1/4	6.35	3/8	9.52
L_{10}	2	16	1/4	6.35	5/16	7.93
L_{12}, L_{13}, L_{14} (adjustable core)	3-1/2	16	1/4	6.35	3/8	9.52
L_{15}, L_{16}, L_{17}	2	18	1/8	3.17	1/8	3.17
L_{18}, L_{19}, L_{20}	2	18	1/4	6.35	1/4	6.35

Note: Driver and final supply voltages, V_{CC} = 13.5 V.

Fig.4—Typical 175-MHz amplifier.

TERMINAL CONNECTIONS FOR ALL TYPES

Pin or Lead No. 1 – Emitter (40280)
Emitter, Case (40281, 40282)
Pin or Lead No. 2 – Base
Pin or Lead No. 3 – Collector (40281, 40282)
Collector, Case (40280)

RCA

Solid State
Division

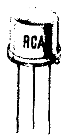
RF Power Transistors

40290
40291
40292

RCA-40290, 40291, and 40292 are epitaxial planar transistors of the silicon n-p-n type. They employ an "overlay" emitter electrode design and are intended for low-voltage, high-power output, amplitude modulated, VHF Class-C amplifier service.

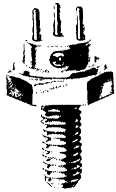
The voltage ratings for these transistors include RF voltage breakdown characteristics necessary to assure safe transistor operation with high RF voltages on the collector; a condition normally encountered in amplitude-modulated Class-C amplifiers.

For Low Supply Voltage, High Power Output, Amplitude Modulated, VHF Class-C Amplifier Service in Aircraft, Military, and Industrial Communications Equipment



40290

JEDEC TO-39



40291,40292

JEDEC TO-60

RF SERVICE

Maximum Ratings, *Absolute-Maximum Values:*

	40290	40291	40292	
COLLECTOR-TO-EMITTER VOLTAGE:				
With V_{BE} = -1.5 volts,				
V_{CEX}	50	50	50	volts
V_{CEV}(RF)	90	90	90	volts
EMITTER-TO-BASE VOLTAGE, V_{EBO}	4	4	4	volts
COLLECTOR CURRENT, I_C	0.5	0.5	1.25	amperes
TRANSISTOR DISSIPATION, P_T:				
At case temperatures up to 25° C.	7.0	11.6	23.2	watts
At case temperatures above 25° C.	Derate linearly to 0 watts at 200° C			
TEMPERATURE RANGE:				
Storage		-65 to 200°C		
Operating (Junction)		-65 to 200°C		
PIN OR LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/32 from insulating wafer (TO-60 package) or from seating plane (TO-39 package) for 10 seconds maximum			230	°C

FEATURES

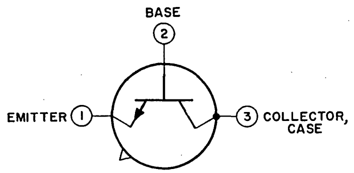
- High carrier output power as 135 Mc Class-C amplifier with 12.5 volt collector supply voltage
  - 40290 — 2 watts (min.) at P_{IN} = 0.5 watt
  - 40291 — 2 watts (min.) at P_{IN} = 0.5 watt
  - 40292 — 6 watts (min.) at P_{IN} = 2.0 watts
- 100% testing of all transistors performed to assure excellent upward modulation characteristics
- High collector efficiency at 135 Mc
- All electrodes isolated from case (40291 and 40292)

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Volts V_{CB}	DC Collector Volts V_{CE}	DC Base Volts V_{BE}	DC Current (Milliamperes) I_E	DC Current (Milliamperes) I_B	DC Current (Milliamperes) I_C	LIMITS: Type 40290 Min.	Type 40290 Max.	Type 40291 Min.	Type 40291 Max.	Type 40292 Min.	Type 40292 Max.	UNITS
Collector Cutoff Current	I_{CEO}		15			0		–	100	–	100	–	250	μa
Emitter-to-Base Breakdown Voltage	BV_{EBO}				0.1		0	4.0	–	4.0	–	–	–	Volts
					0.25		0	–	–	–	–	4.0	–	Volts
Collector-to-Emitter Breakdown Voltage	BV_{CEX}			−1.5			200[a]	50	–	50	–	50	–	Volts
Real Part of Common-Emitter Input Impedance (At f = 135 Mc)	$hie_{(real)}$		12.5				100	12(Typ.)		12(Typ.)		–	–	ohms
			12.5				400	–	–	–	–	6.5(Typ.)		ohms
RF Carrier Power Output: As Class-C Amplifier, (At f = 135 Mc)	P_{OUT}		12.5					2.0[c]	–	2.0[c]	–	6.0[d]	–	watts
Gain-Bandwidth Product	f_T		12.5				100	500(Typ.)		500(Typ.)		–	–	Mc
			12.5				400	–	–	–	–	300(Typ.)		Mc
Collector-to-Base Capacitance (At f = 1 Mc)	C_{ob}	12.5			0			–	17	–	17	–	30	pf
Collector-to-Case Capacitance	C_s							–	–	–	6.0	–	6.0	pf
Thermal Resistance (Junction-to-Case)	$\theta_{J\text{-}C}$							–	25	–	15	–	7.5	°C/W

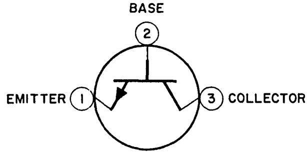
[a] Pulsed through an inductor (25 mh); R_{BE} = 39 ohms; duty factor = 50%.
[b] At frequencies of 100 Mc or higher.
[c] For P_{IN} = 0.5 w; minimum efficiency = 70%.
[d] For P_{IN} = 2.0 w; minimum efficiency = 70%.

TERMINAL DIAGRAM FOR TYPE 40290



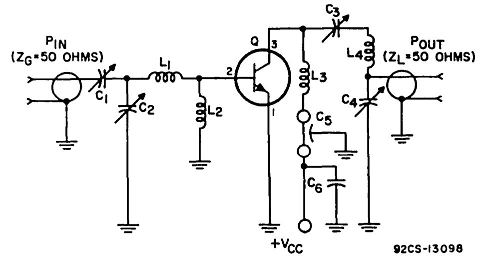
(Bottom View)

TERMINAL DIAGRAM FOR TYPES 40291 & 40292



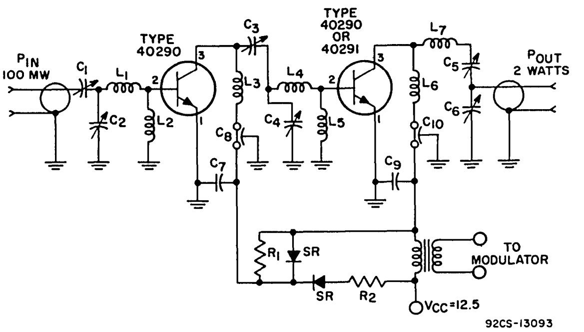
(Bottom View)

RF AMPLIFIER CIRCUIT FOR POWER-OUTPUT TEST
(135-Mc Operation)



Q = 40290, 40291	Q = 40292
C_1, C_3 = 3–35 pf	C_1, C_3 = 3–35 pf
C_2, C_4 = 8–60 pf	C_2, C_4 = 8–60 pf
C_5 = 1000 pf	C_5 = 1000 pf
C_6 = 0.02 μf	C_6 = 0.02 μf
L_1 = 3 turns No.16 wire, 5/16" ID, 5/16" long	L_1 = 3 turns No.16 wire, 5/16" ID, 5/16" long
L_2 = Ferrite choke, Z = 450 ohms	L_2 = wire wound resistor, R = 2.4 ohms
L_3 = 3 turns No.18 wire, 1/4" ID, 5/16" long	L_3 = 1 turn No.16 wire, 5/16" ID, 1/8" long
L_4 = 5 turns No.16 wire, 7/16" ID, 5/8" long	L_4 = 4 turns No.16 wire, 7/16" ID, 3/8" long

AMPLITUDE-MODULATED AMPLIFIER
135-Mc Operation, Carrier Power = 2 watts minimum, Bandwidth = 5%



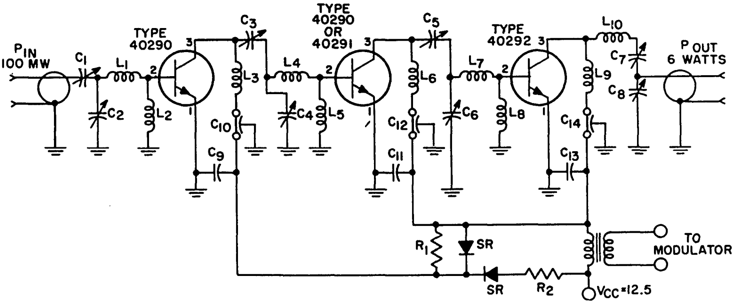
C_1, C_3, C_5 = 3–35 pf
C_2, C_4, C_6 = 8–60 pf
C_7, C_9 = 0.03 μf
C_8, C_{10} = 1000 pf
L_1 = 3 turns No.16 wire, 1/4" ID, 1/4" long
L_2, L_5 = Ferrite choke, Z = 450 ohms

L_3 = RF choke, 1.5 μh
L_4 = 4 turns No.16 wire, 1/4" ID, 3/8" long
L_6 = 3 turns No.18 wire, 3/16" ID, 3/8" long
L_7 = 5 turns No.16 wire, 3/8" ID, 1/2" long

R_1 = 220 ohms
R_2 = 180 ohms
SR = 1N2858

AMPLITUDE-MODULATED AMPLIFIER

135-Mc Operation, Carrier Power = 6 watts minimum, Bandwidth = 5%

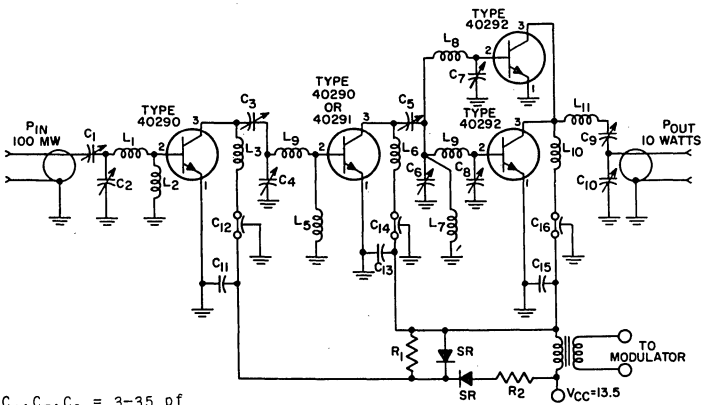


92CS-13094

- C_1, C_3, C_5, C_7 = 3-35 pf
- C_2, C_4, C_6, C_8 = 8-60 pf
- C_9, C_{11}, C_{13} = 0.03 μf
- C_{10}, C_{12}, C_{14} = 1000 pf
- L_1, L_9 = 3 turns No.16 wire, 1/4" ID, 1/4" long
- L_2, L_5 = Ferrite choke, Z = 450 ohms
- L_3 = RF choke, 1.5 μh
- L_4, L_7 = 4 turns No.16 wire, 1/4" ID, 3/8" long
- L_6 = RF choke, 1.0 μh
- L_8 = wire wound resistor, R = 2.4 ohms
- L_{10} = 5 turns No.16 wire, 3/8" ID, 1/2" long
- R_1 = 220 ohms
- R_2 = 180 ohms
- SR = 1N2858

AMPLITUDE-MODULATED AMPLIFIER

135-Mc Operation, Carrier Power = 10 watts minimum, Bandwidth = 5%

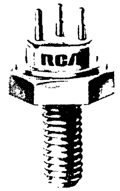


92CS-13095

- C_1, C_3, C_5, C_9 = 3-35 pf
- C_2, C_4, C_6, C_{10} = 8-60 pf
- C_7, C_8 = 1.5-20 pf
- C_{11}, C_{13}, C_{15} = 0.03 μf
- C_{12}, C_{14}, C_{16} = 1000 pf
- L_1 = 3 turns No.16 wire, 1/4" ID, 1/4" long
- L_2, L_5 = Ferrite choke, Z = 450 ohms
- L_3 = RF choke, 1.5 μh
- L_4 = 4 turns No.16 wire, 1/4" ID, 3/8" long
- L_6, L_7 = RF choke, 1.0 μh
- L_8, L_9 = 3 turns No.16 wire, 1/4" ID, 3/8" long
- L_{10} = 1 turn No.16 wire, 5/16" ID, 1/8" long
- L_{11} = 4 turns No.16 wire, 3/8" ID, 1/2" long
- R_1 = 33 ohms
- R_2 = 36 ohms
- SR = 1N2858

RCA
Solid State
Division

RF Power Transistors
40340
40341



JEDEC TO-60

H-1307

High-Power 50-MHz Emitter-Ballasted Silicon N-P-N Overlay Transistors

For 13.5-V and 24-V Applications in Mobile Communications Equipment

Features

- **Emitter ballasting resistors**
- **13.5 V—25 W min. power output, 7 dB min. gain (40340)**
- **24 V—30 W min. power output, 10 dB min. gain (40341)**
- **Emitter connected to case**
- **Infinite load mismatch tested at 50 MHz**

RCA-40340 and 40341 are epitaxial silicon n-p-n planar transistors of the "overlay" emitter electrode construction. They are intended especially for high-power-output, class-C amplifier service at frequencies up to 100 MHz.

In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a single base and collector region. When compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, and frequency capability.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40340	40341	
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open	V_{CEO}	25	35	V
With base-emitter junction reverse-biased (V_{BE}) = −1.5 volts	V_{CEV}	60	70	V
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	60	70	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4.0	4.0	V
PEAK COLLECTOR CURRENT		10	10	A
CONTINUOUS COLLECTOR CURRENT	I_C	3.3	3.3	A
TRANSISTOR DISSIPATION	P_T			
At case temperatures up to 25°C		70	70	W
TEMPERATURE (Operating junction)	T_J	200	200	°C

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V) V_{CB}	DC Collector Voltage (V) V_{CE}	DC Base Voltage (V) V_{BE}	DC Current (mA) I_E	DC Current (mA) I_C	LIMITS 40340 Min.	40340 Max.	40341 Min.	40341 Max.	UNITS
Collector-Cutoff Current: With base open	I_{CEO}		30				–	–	–	1.0	mA
			15				–	1.0	–	–	mA
With emitter open	I_{CBO}	50					–	–	–	10	mA
		40					–	10	–	–	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$					200[a]	25	–	35	–	V
With base-emitter junction reverse biased, and external base-to-emitter resistance (R_{BE}) = 20 Ω	$V_{(BR)CEV}$			−1.5		200[a]	60	–	70	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				10		4	–	4	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						2.5		2.5		°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

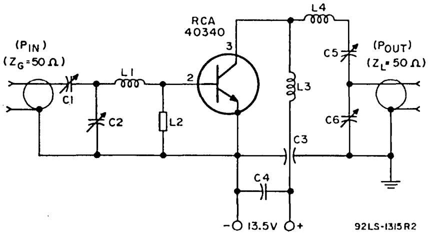
CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC})–V	Input Power (P_{IE})–W	Frequency (f) - MHz	LIMITS 40340 Min.	40340 Max.	40341 Min.	40341 Max.	UNITS
Power Output	P_{OE}	▲ 13.5	5	50	25	–	–	–	W
		‡ 24	3	50	–	–	30	–	W
Power Gain	G_{PE}	▲ 13.5	5	50	7	–	–	–	dB
		‡ 24	3	50	–	–	10	–	dB
Collector Efficiency	η_C	▲ 13.5	5	50	60	–	–	–	%
		‡ 24	3	50	–	–	60	–	%
Load Mismatch	LM	▲ 13.5	5	50	GO/NO GO				
		‡ 24	3	50					
Collector-to-Base Capacitance	C_{obo}	V_{CB} = 30		1	–	–	–	85	pF
		V_{CB} = 15		1	–	120	–	–	pF

▲ In circuit shown in Fig.1.

‡ In circuit shown in Fig.2.

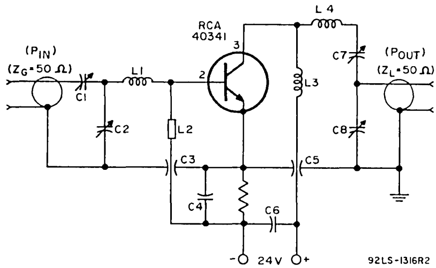
TERMINAL CONNECTIONS

Pin No.1 — Emitter
Pin No.2 — Base
Pin No.3 — Collector
Case, Mounting Stud — Emitter



C_1: 14-150 pF	L_1: 1 turn, No.16 wire, 5/16 in. (7.93 mm) ID, 1/8 in. (3.17 mm) long
C_2: 90-400 pF	L_2: Ferrite Choke, Z = 450 Ω
C_3: 1000 pF	L_3: 10 turns, No.20 enamel wire, close wound, 1/4 in. (6.35 mm) ID
C_4: 0.02 μF	L_4: 3 turns, No.10 wire, 3/4 in. (19.05 mm) ID, 3/4 in. (19.05 mm) long
C_5: 32-250 pF	
C_6: 32-250 pF	

Fig.1—RF amplifier circuit for 40340 power-output test (50-MHz operation).



C_1: 14-150 pF	L_1: 2 turns, No.16 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
C_2: 110-580 pF	L_2: Ferrite Choke, Z = 450 Ω
C_3, C_5: 1000 pF	L_3: 10 turns, No.20 enamel wire, close wound, 1/4 in. (6.35 mm) ID
C_4: 0.0018 μF	L_4: 3 turns, No.10 wire, 3/4 in. (19.05 mm) ID, 3/4 in. (19.05 mm) long
C_6: 0.2 μF	R_1: 0.33 ohms
C_7: 140-680 pF	
C_8: 32-250 pF	

Fig.2—RF amplifier circuit for 40341 power-output test (50-MHz operation).

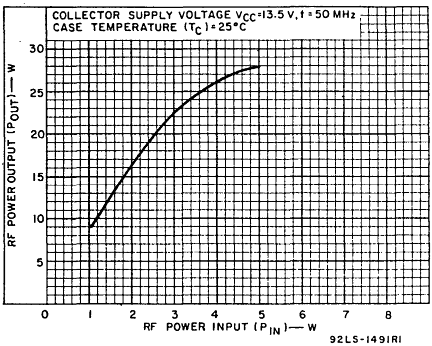


Fig.3—Typical performance of type 40340 in the common-emitter amplifier shown in Fig.1.

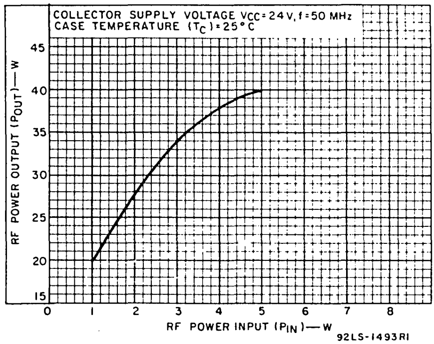


Fig.4—Typical performance of type 40341 in the common-emitter amplifier shown in Fig.2.

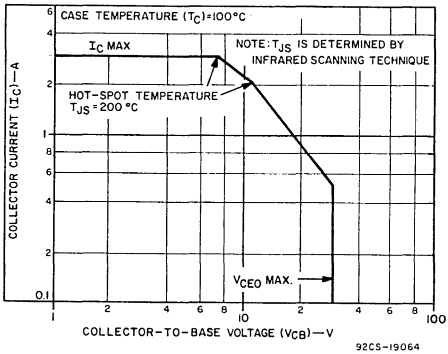


Fig.5—Safe area for dc operation.

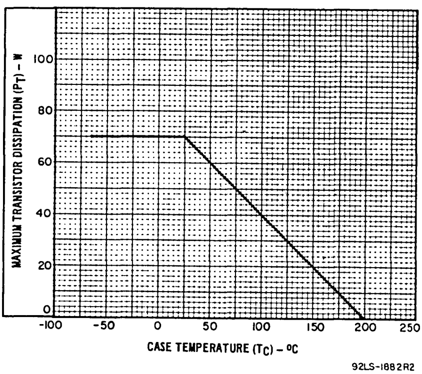


Fig.6—Dissipation derating curve.

RCA
Solid State
Division

RF Power Transistors

40608

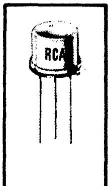
RCA-40608 is an epitaxial silicon n-p-n planar transistor. It is especially designed for operation as a Class A, wide-band power amplifier in VHF circuits.

The features of high gain-bandwidth product and low cross-modulation make the 40608 especially suited for use in CATV and MATV systems.

*Formerly RCA Dev. Type No. TA2761

SILICON N-P-N "overlay" TRANSISTOR

For Class A Wide-Band CATV and MATV Applicatiations



JEDEC TO-39

Features:

- High Gain-Bandwidth Product
- Low Cross-Modulation

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	V
COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance, (R_{BE}) = 100Ω	V_{CER}	40	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	2	V
COLLECTOR CURRENT	I_C	0.4	A
TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 25°C		3.5	W
At case temperatures above 25°C		See *Fig. 1.*	
TEMPERATURE RANGE: Storage & Operating (Junction)		-65 to +200	°C
LEAD TEMPERATURE (During soldering): At distances ≥ 1/32 in. (0.79 mm) from seating plane for 10 s max.		230	°C

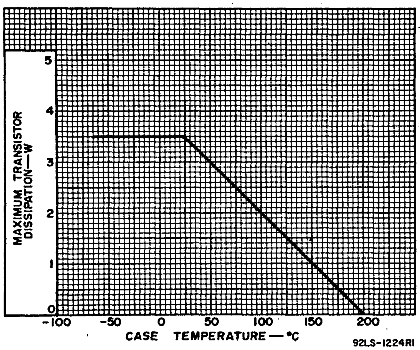
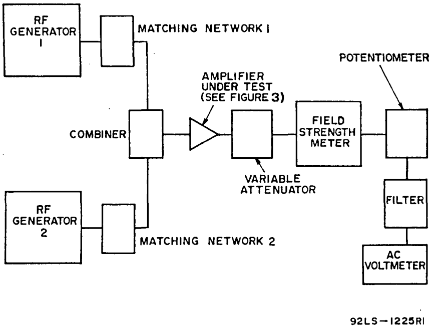


Fig. 1 - Dissipation Derating Curve

ELECTRICAL CHARACTERISTICS, *Case Temperature* = 25° C

Characteristic	Symbol	Test Conditions: DC Collector Volts		DC Current (mA)			Limits		Units
		V_{CB}	V_{CE}	I_E	I_B	I_C	Min.	Max.	
Collector-Cutoff Current	I_{CEO}		20		0			100	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	40		V
Collector-to-Emitter Voltage (Sustaining)	$V_{CER}(sus)$					50[a]	40		V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	2		V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	50		1.0	V
Collector-to-Base Capacitance (Measured at 1MHz)	C_{ob}	30		0				3.0	pF
Gain-Bandwidth Product	f_T		15			50	700		MHz
DC Forward-Current Transfer Ratio	h_{FE}		15			50	35	120	
Voltage Gain (See Fig. 2.)	VG		15			50	11		dB
Cross Modulation @46 dBmV (See Fig. 3.)	CM		15			50	−57 (Typ.)		dB

[a] Pulsed through an inductor (20 mH); duty factor = 50%; R_{BE} = 100 Ω.

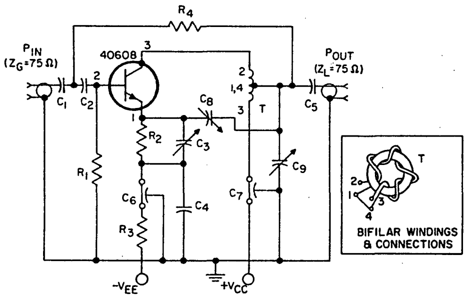


Generator No. 1 & No. 2	Hewlett-Packard, HP608D, or equivalent
Matching Network No. 1 & No. 2:	50 to 75 Ω
Combiner:	20 dB isolation between generators
Variable Attenuator:	As required
Field Strength Meter, with Detector Output:	50-220 MHz
Potentiometer:	100 kΩ
Filter:	1000 Hz
AC Voltmeter:	Ballantine 861, or equivalent

Fig. 2 - Block Diagram for Cross-Modulation Test Set-Up

OPERATING INSTRUCTIONS FOR CROSS-MODULATION TEST

1. Set up equipment as shown in Fig. 2.
2. Set generator No. 1 to 150 MHz modulated 30% by 1000 Hz, and tune field strength meter to 150 MHz.
3. Adjust output of generator No. 1 to give rated output of the amplifier.
4. Adjust potentiometer to calibrate voltmeter for a convenient level. This level then corresponds to 100% cross modulation.
5. Remove modulation.
6. Set generator No. 2 to 210 MHz modulated 30% by 1000 Hz and tune field strength meter to 210 MHz.
7. Adjust output of generator No. 2 to give rated output of the amplifier. (If the amplifier has a flat response then the output of the two signal generators will be equal.)
8. Tune field strength meter to 150 MHz CW and read voltmeter.
9. Turn voltmeter to proper scale for reading. Calculate percentage of cross modulation based upon 100% level set in step 4.



C_1, C_2, C_5: 0.002 μF
C_3: 7-100 pF, ARCO 423, or equivalent
C_4: .03 μF
C_6, C_7: 1,500 pF
C_8, C_9: 8-60 pF, ARCO 404, or equivalent
R_1: 390 Ω, ½ W
R_2: 6.8 Ω, ½ W
R_3: 330 Ω, 1 W
R_4: 270 Ω, ½ W
T: 4 turns No. 30 wire, bifilar wound; toroidal core: 3/8 in. OD, 3/16 in. ID, 1/8 in. thick, IGC* type Q-1, or equivalent.

*Indiana General Corp., Electronics/Ferrites Div., Keasbey, N.J.

Fig. 3 - RF Amplifier Circuit for Voltage Gain Test

TYPICAL ADMITTANCE CHARACTERISTICS
(Common-Emitter Circuit)

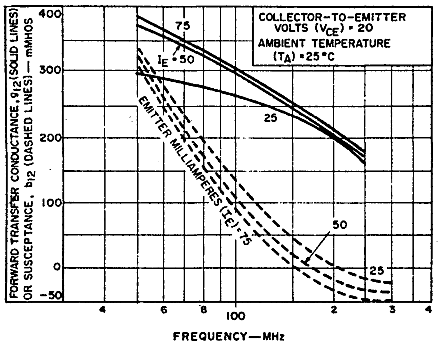


Fig. 4 - Forward Transfer Admittance

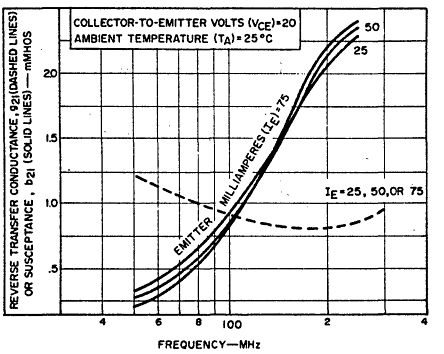


Fig. 5 - Reverse Transfer Admittance

TYPICAL ADMITTANCE CHARACTERISTICS

(Common-Emitter Circuit)

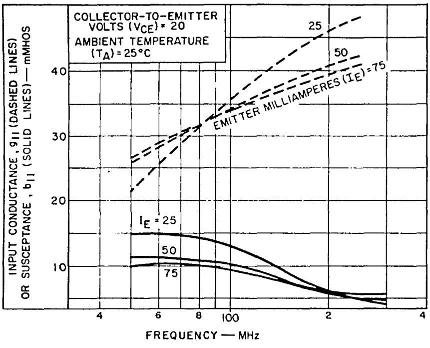


Fig. 6 - Input Admittance

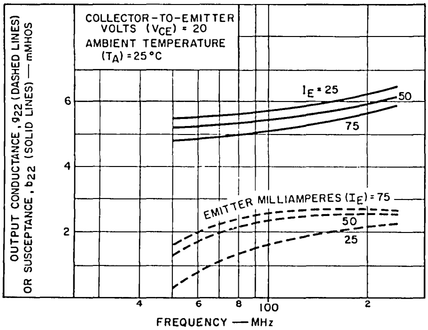


Fig. 7 - Output Admittance

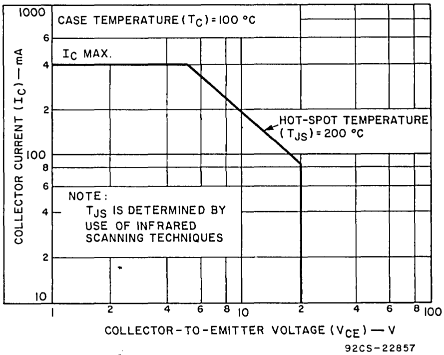
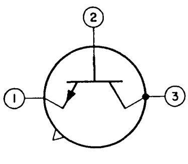


Fig. 8 - Safe Area for DC Operation

TERMINAL DIAGRAM



Lead 1 - Emitter
Lead 2 - Base
Lead 3 - Collector, Case

RCA
Solid State
Division

RF Power Transistors

40637A

TO-18

H-1311

Silicon N-P-N
Epitaxial Planar Transistor

For Frequency-Multiplier Service in
Mobile, Marine, and Sonobuoy VHF Transmitters

Features:

- **High transistor dissipation rating (P_T) = 2 W max.**
- **Low output capacitance (C_{ob}) = 4 pF max.**
- **Hermetically sealed JEDEC TO-18 package**

RCA-40637A is a silicon n-p-n epitaxial planar transistor intended for frequency multiplier service to 175 MHz. The 40637A is particularly suitable for low-level frequency-multiplier stages in vhf transmitters.

A multiplier chain of three RCA-40637A's can deliver 100 mW at 156 MHz, from a 5-mW, 13-MHz input with a 12-V supply. The RCA-40637A utilizes a JEDEC TO-18 hermetic package.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE:			
With base-emitter junction short-circuited	V_{CES}	36	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.2	A
TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 25°C		2	W
At case temperature above 25°C		See Fig.3	
At ambient temperature up to 25°C		0.75	W
At ambient temperature above 25°C		See Fig.3	
TEMPERATURE RANGE:			
Storage and Operating (Junction)		–65 to 200	°C
LEAD TEMPERATURE (During Soldering):			
At distances ⩾ 1/16 in. (1.58 mm) from seating plane for 10 s max.		265	°C

8-73

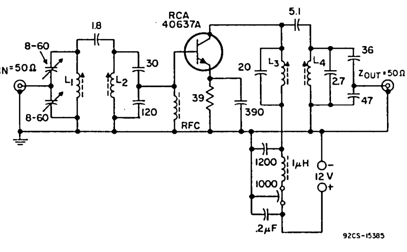
ELECTRICAL CHARACTERISTICS, *at Ambient Temperature (T_A) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		Voltage V dc		Current mA dc				
		V_{CE}	V_{BE}	I_E	I_C	MIN.	MAX.	
Collector Cutoff Current: With base-emitter junction short-circuited	I_{CES}	12	0	–	–	–	0.5	mA
Collector-to-Emitter Breakdown Voltage: With base-emitter junction short-circuited	$V_{(BR)CES}$	–	0	–	5	36	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$	–	–	–0.1	0	3.5	–	V
Thermal Resistance: Junction-to-case	$R_{\theta JC}$	–	–	–	–	–	87.5	°C/W
Junction-to-ambient	$R_{\theta JA}$	–	–	–	–	–	233	°C/W

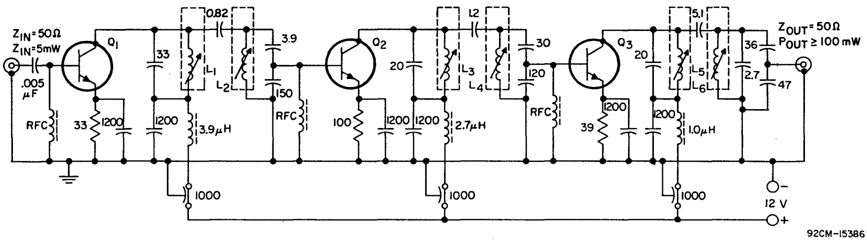
DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		VOLTAGE Vdc	FREQ. MHz	POWER mW				
		V_{CC}	f	P_{IE}	P_{OE}	MIN.	MAX.	
Output Power as a Frequency Doubler (See Fig. 1)	P_{OE}	12	78(f_{IN}) 156(f_{OUT})	37	–	100	–	mW
Efficiency as a Frequency Doubler (See Fig. 1)	η	12	78(f_{IN}) 156(f_{OUT})	–	100	18	–	%
Collector-to-Base Capacitance	C_{ob}	12 (V_{CB})	0.1 to 1	–	–	–	4	pF



L_1, L_2: 4-½ turns, No.22 enameled wire, close-wound
L_3, L_4: 4-½ turns, No.20 bare wire, 0.25 in. (6.35 mm) long
All coils wound on slug-tuned form, 0.234 in. (5.95 mm) O.D., with 0.5 in. (12.7 mm) x 0.5 in. (12.7 mm) x 1 in. (25 mm) shield cans Carbonyl* S.F. 10-32 threaded slug, or equivalent
RFC: 4 turns, No.30 enameled wire on ferrite bead, Ferroxcube† No.56-590-65/48, or equivalent
All capacitor values are in picofarads unless otherwise specified
All resistor values are in ohms and rated at ¼ watt unless otherwise specified
*Arnold Magnetics Corp., Los Angeles, CA. 90016
†Ferroxcube Corp. of America, Saugerties, N. Y. 12477

Fig.1 – Typical doubler (78-156 MHz) circuit.



L_1, L_2: 10-½ turns, No.22 enameled wire, close-wound
L_3, L_4: 4-½ turns, No.22 enameled wire, close-wound
L_5, L_6: 1-½ turns, No.20 bare wire 0.25 in. (6.35 mm) long
All coils wound on slug-tuned form▲ 0.234 in. (5.95 mm) O.D., with 0.5 in. (12.7 mm) x 0.5 in. (12.7 mm) x 1 in. (25 mm) shield cans▲ Carbonyl* S.F. 10-32 threaded slug, or equivalent
Q_1, Q_2, Q_3: RCA40637A
▲TRW/UTC Transformer Co. N.Y., N.Y. 10013

RFC: 4-turns No.30 enameled wire on ferrite bead Ferroxcube† No.56-590-65/48, or equivalent
All capacitor values are in picofarads unless otherwise specified
All resistor values are in ohms and rated at ¼ watt unless otherwise specified

*Arnold Magnetics Corp., Los Angeles, CA. 90016
†Ferroxcube Corp. of America, Saugerties, N. Y. 12477

Fig.2 – Typical frequency-multiplier chain, f_{IN} = 13 MHz, f_{OUT} = 156 MHz.

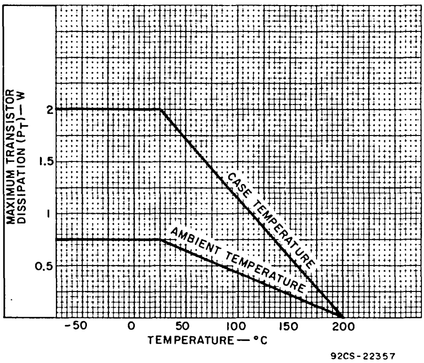


Fig.3 – Dissipation derating curves.

TERMINAL CONNECTIONS

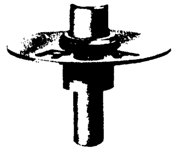
Lead 1 – Emitter
Lead 2 – Base
Case, Lead 3 – Collector

Solid State
Division

RF Power Transistors
40836
40837

High-Frequency Overlay Power Transistors

For Oscillators And Amplifiers In UHF/Microwave Equipment



JEDEC TO-215AA H-1598

Features

- 0.5 W (min.) oscillator output at 2.0 GHz (40836)
- 1.25 W (min.) oscillator output at 2.0 GHz (40837)
- Ceramic-metal hermetic coaxial package with low inductances and low parasitic capacitances
- Emitter connected to flange (for increased internal feedback) for higher efficiency at S-band frequencies in Colpitts oscillator circuits
- For coaxial, stripline, and lumped-constant circuits

RCA-40836 and 40837* are epitaxial silicon n-p-n planar transistors employing the "overlay" emitter-electrode construction. These devices feature a low-loss, ceramic-metal, coaxial package and are intended primarily for power oscillator applications in the L- and S-band frequency ranges.

If the safe-area-of-operation conditions are not exceeded, they may be used in class A amplifiers.

*Formerly RCA-Dev. types TA7403 and TA7679, respectively.

Applications

- L- and S-band power oscillators
- Common-emitter Class A amplifier

TERMINAL CONNECTIONS

Terminal No. 1 – Base
Terminal No. 2 – Emitter
Terminal No. 3 – Collector

MAXIMUM RATINGS, *Absolute-Maximum Values:*		40836	40837	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	50	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
DC COLLECTOR CURRENT (CONTINUOUS)	I_C	0.2	0.275	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 75°C		2.5	4.15	W
At case temperatures above 75°C		See Fig. 5	See Fig. 6	
For point of measurement of temperature (on collector terminal), see dimensional outline.				
TEMPERATURE RANGE:				
Storage and Operating (Junction)		← –65 to + 200 →		°C

11-73

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C*

Static

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V) V_{CE}	DC CURRENT (mA) I_E	I_B	I_C	LIMITS 40836 MIN.	40836 MAX.	40837 MIN.	40837 MAX.	UNITS
Collector-Cutoff Current	I_{CES}	45		0		–	1	–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0 0		0.1 1	50 –	– –	– 50	– –	V
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$				5	50	–	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.1		0	3.5	–	3.5	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			10 20	100 200	– –	1 –	– –	– 1	V
Thermal Resistance: (Junction-to-Collector Terminal)	$R_{\theta JCT}$					–	50	–	30	°C/W

Dynamic

CHARACTERISTIC	SYMBOL	POWER OUTPUT (P_{OB})–W	SUPPLY VOLTAGE (V_{CC})–V	FREQUENCY GHz	LIMITS 40836 MIN.	40836 TYP.	40837 MIN.	40837 TYP.	UNITS
Common-Collector Oscillator Output Power	P_{OB}		21 28	2 2	0.5 –	0.65 –	– 1.25	– 1.35	W
Oscillator Circuit Efficiency (See Fig. 11)	η_o	0.5 1.25	21 28	2 2	20 –	– –	– 20	– –	%
Collector-to-Base Capacitance	C_{obo}		30(V_{CB})	1 MHz	3.0 (Max.)		3.0 (Max.)		pF

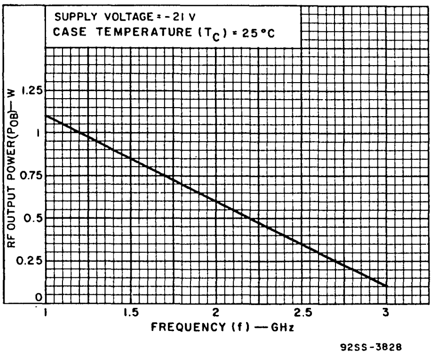


Fig.1—Typical power output vs. frequency for grounded collector power oscillator for 40836.

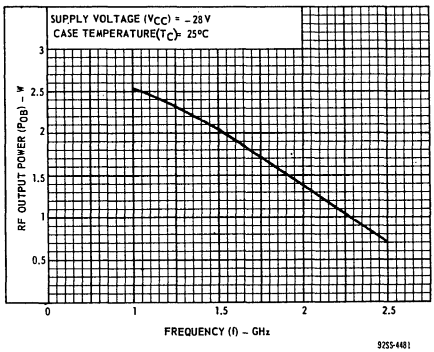


Fig.2—Typical power output vs. frequency for grounded collector power oscillator for 40837.

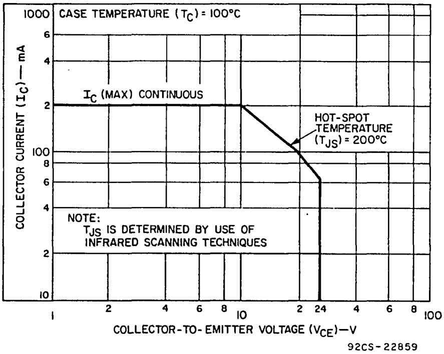


Fig.3—Maximum operating area for forward-bias operation for type 40836.

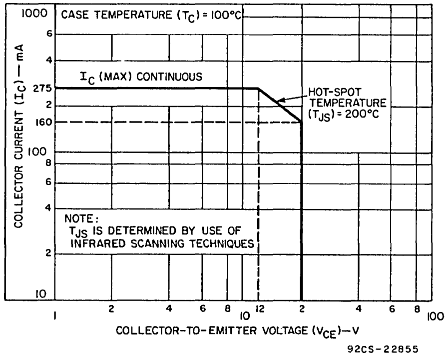


Fig.4—Maximum operating area for forward-bias operation for type 40837.

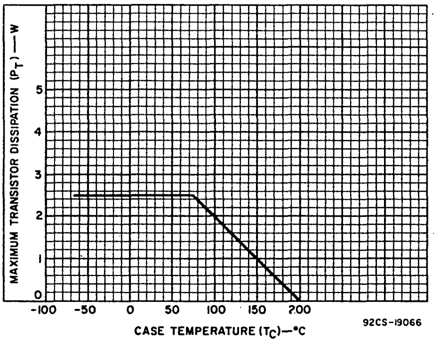


Fig.5—Dissipation derating curve for type 40836.

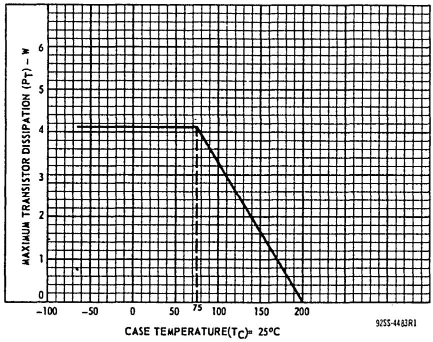


Fig.6—Dissipation derating curve for type 40837.

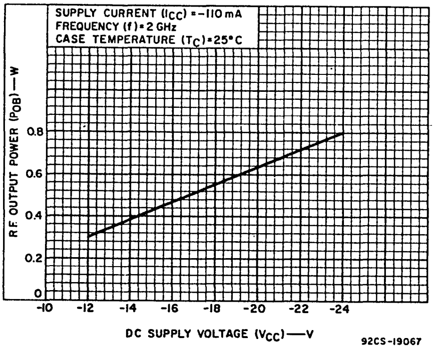


Fig.7—Typicaloutput power vs. supply voltage for the 2-GHz, grounded-collector oscillator (Fig.11) for type 40836.

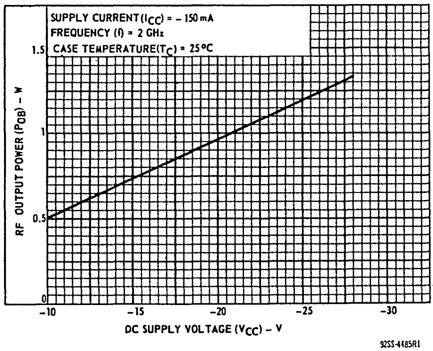


Fig.8—Typical output power vs. supply voltage for the 2-GHz, grounded-collector oscillator (Fig. 11) for type 40837.

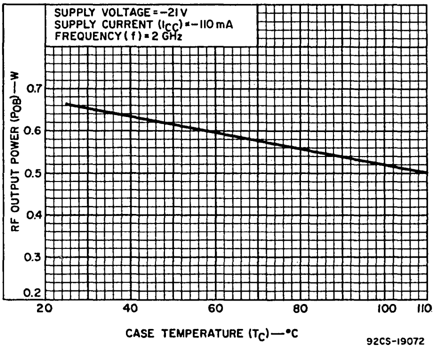


Fig.9—Typical output power vs. collector-terminal temperature for 40836 (circuit shown in Fig.11).

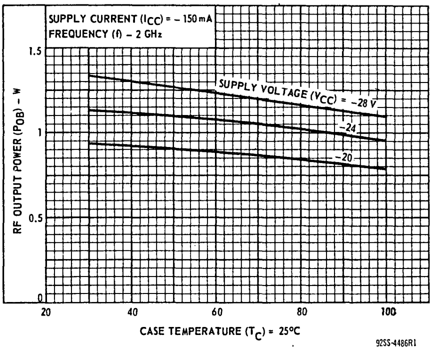
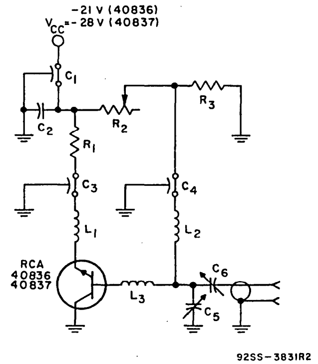


Fig.10—Typical output power vs. collector-terminal temperature for 40837 (circuit shown in Fig. 11).

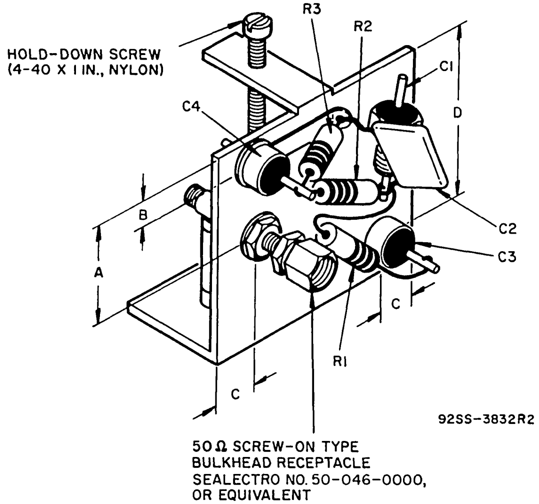
APPLICATION DATA

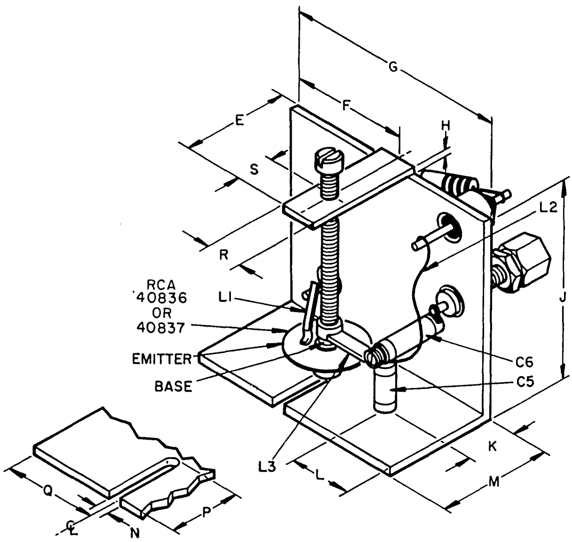


C_1, C_3, C_4:	470 pF, feedthrough Allen-Bradley FA4C, or equivalent
C_2:	0.2μ F, disc ceramic
C_5, C_6:	0.35 to 3.5 pF, Johanson 4702, or equivalent
L_1, L_2:	RF choke, 0.5 in. (12.70 mm) length of No. 32 wire
L_3:	Copper strip: 0.005 in (0.127)mm) thick 0.18 in. (0.457 mm) wide 0.3 in (0.76 mm) long
R_1:	10 Ω, ½ W
R_2:	0 to 500 Ω, 2 W
R_3:	1200 Ω, ½ W

NOTES:
1. The circuit shown above is tunable over the range of 1.8 GHz to 2.1 GHz.
2. For operation below 1.8 GHz, increase emitter-base capacitance and the value of L_3.
3. For operation between 2.1 GHz and 2.3 GHz, increase the collectc - base capacitance and decrease the value of L_3.

Fig.11—Typical 2-GHz, grounded-collector power oscillator.





SYMBOL	INCHES	MILLIMETERS
A	0.53	1.35
B	0.16	0.41
C	0.25	0.63
D	0.75	1.90
E	0.75	19.05
F	0.625	15.87
G	1.25	28.57
H	0.062	1.57
J	1.0	25.4
K	0.375	9.52
L	0.281	7.14
M	0.75	19.05
N	0.93	2.36
P	0.421	10.69
Q	0.625	15.87
R	0.25	6.63
S	0.375	9.52
T	0.75	19.05

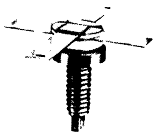
NOTE:
MATERIAL: 1/16 (1.52) THICK COPPER

Fig.12–Constructional details of 2-GHz power oscillator shown in Fig.11.

RCA
Solid State
Division

RF Power Transistors

40893



RCA HF-36
Package H-1761

15-W, 470-MHz Emitter-Ballasted Overlay Transistor

Silicon N-P-N Type for Class C Amplifiers in 12.5-V Mobile Communications Equipment

Features:

- 5.2-dB gain (min.) at 470 MHz, P_{OE} = 15 W (min.)
- VSWR tested – ∞ :1, P_{IE} = 4.5 W
- For operation in the 406–512-MHz band
- Integral emitter-ballasting resistors
- Hermetically-sealed, ceramic-metal, stud package
- Low-inductance radial leads for stripline circuits
- All leads isolated from mounting stud

RCA-40893* is an epitaxial silicon n-p-n planar transistor with "overlay" emitter-electrode construction.
Integral emitter-ballast resistance is employed for improved ruggedness and increased overdrive capability.

* Formerly RCA Dev. No. TA7686

The 40893 features a hermetic, ceramic-metal package with rugged, low-inductance radial leads for stripline or lumped-constant circuits.
This transistor is intended for use in high-power, broadband, mobile uhf amplifiers operating from a 12.5-volt supply.

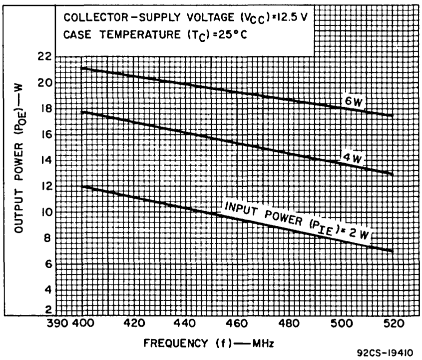


Fig. 1–Typical output power vs. frequency.

MAXIMUM RATINGS, Absolute-Maximum Values:

COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	14	V
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4.0	V
CONTINUOUS COLLECTOR CURRENT	I_C	3.0	A
TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 120°C		20	W
At case temperatures above 120°C		Derate at 0.25	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25ºC*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage—V V_{CE}	DC Base Voltage—V V_{EB}	DC Current—mA I_E	I_C	LIMITS Min.	Max.	UNITS
Collector-Cutoff Current	I_{CES}	12.5	0			–	10	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	20	36	–	V
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$		0		200	14	–	V
With base connected to emitter	$V_{(BR)CES}$				200	36	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			5		4.0	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						4.0	ºC/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Supply Voltage (V_{CC})—V	Input Power (P_{IE}) - W	Frequency (f) - MHz	LIMITS Min.	Typ.	UNITS
Power Output	P_{OE}	12.5	4.5	470	15	–	W
Power Gain	G_{PE}	12.5	4.5	470	5.2	–	dB
Collector Efficiency	η_C	12.5	4.5	470	60	–	%
Load Mismatch (See Fig. 10)	LM	12.5	4.5	470	Go/No Go		
Collector-to-Base Capacitance	C_{obo}	12(V_{CB})		1	60 (max.)		pF

TYPICAL APPLICATION INFORMATION

CIRCUIT	OUTPUT POWER (P_{OE})—W	INPUT POWER (P_{IE})—W	Collector Efficiency (η_C)—%	Figure No.
406-MHz Amplifier	18.0	4.5	68	4*
512-MHz Amplifier	14.5	4.5	65	4*
450—470-MHz Amplifier	15.0	4.5	60—72	4 ●

* Amplifier tuned to indicated frequency.
● Amplifier tuned at 470 MHz for maximum gain and minimum input reflection.

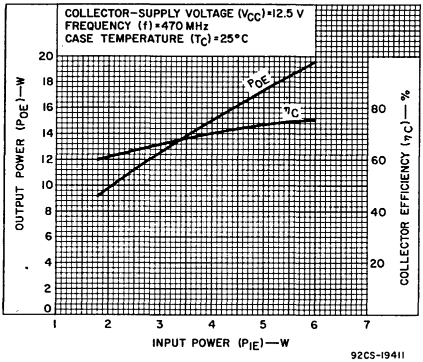


Fig. 2–Typical output power and collector efficiency vs. input power.

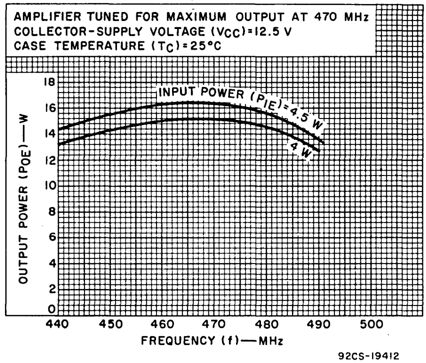
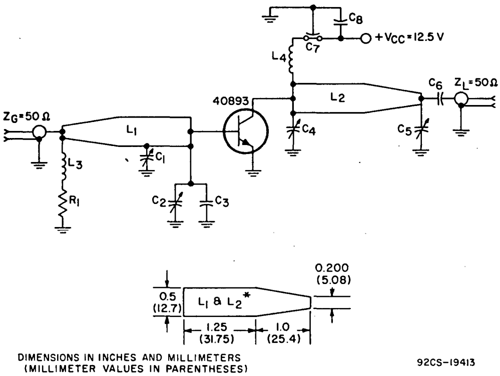


Fig. 3–Typical performance of the 450–470-MHz amplifier shown shown in Fig. 4



C_1, C_2, C_4, C_5 – 2–18 pF, Amperex HT10MA/218 ■
C_3 – 30 pF, American Technical Ceramics ATC-100 ■
C_6 – 0.01 μF, disc ceramic
C_7 – 1000 pF, feedthrough Allen-Bradley FA5C ■
C_8 – 1000 pF, ATC-100 ■
R_1 – 0.47 Ω, 1 W
L_3 – 0.22 μH, rf choke
L_4 – 10 turns No. 22 wire, 0.12" ID

■ Or equivalent

Allen-Bradley Co., Milwaukee, Wisc.
American Technical Ceramics
Huntington Station, N.Y.

* Produced by etching upper layer of double-clad teflon board: 1/16 in. thick, ε = 2.6

Fig. 4–Amplifier test circuit for measurement of output power, gain, efficiency, and load mismatch.

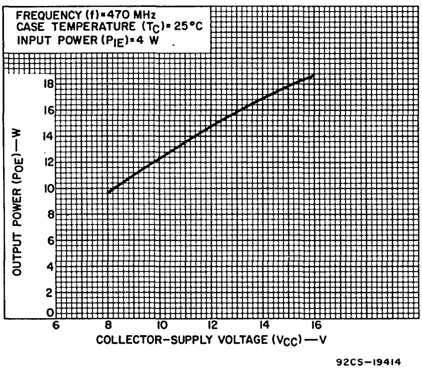


Fig. 5–Typical output power vs. collector-supply voltage.

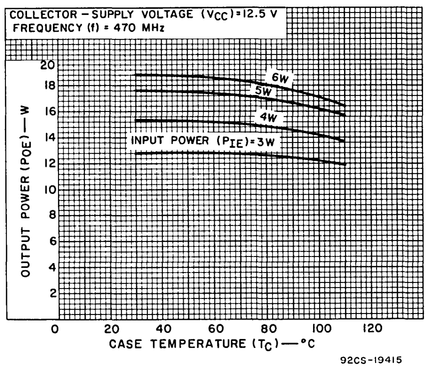


Fig. 6–Typical output power vs. case temperature.

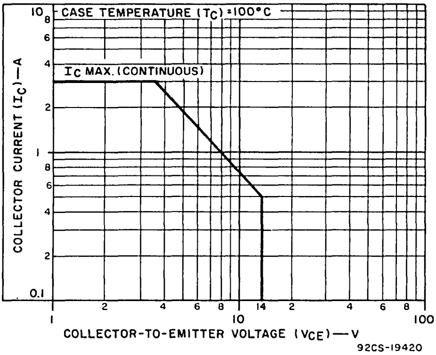


Fig. 7—Maximum dc operating area for type 40893.

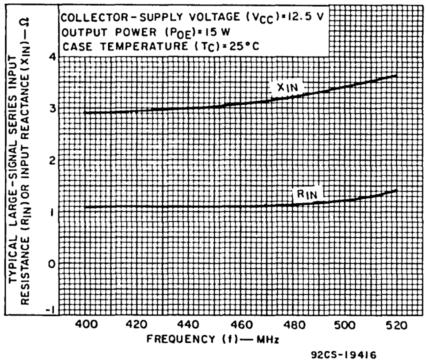


Fig. 8—Typical large-signal series input impedance vs. frequency.

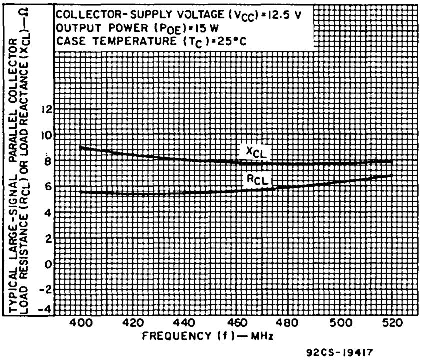


Fig. 9—Typical large-signal parallel collector load impedance vs. frequency.

TERMINAL CONNECTIONS

Terminal No. 1, 3 — Emitter
Terminal No. 2 — Base
Terminal No. 4 — Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

SPECIAL PERFORMANCE DATA

The transistor must withstand any load mismatch provided by the following test conditions:

1. The test is performed using the arrangement shown.
2. The tuning stub is varied through a half wavelength, which effectively varies the load from an open circuit to a short circuit.
3. Operating conditions: V_{CC} = 12.5 V, rf input power = 4.5 W.
4. Transistor dissipation rating must not be exceeded during the above test so that the transistor will not be damaged or degraded.

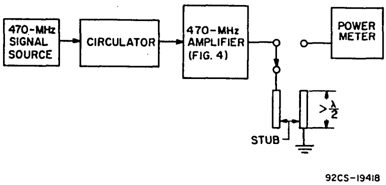
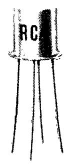


Fig. 10—Test set-up for testing load-mismatch capability.

RCA Solid State Division

RF Power Transistors

40894 40896
40895 40897



JEDEC TO-72 H-1299

High - Frequency Silicon N-P-N Transistors

For TV-Tuner, FM and AM/FM "Front-End", and IF Amplifier, Oscillator, and Converter Service

Features:

- **High gain-bandwidth products:**
  f_T = 1200 MHz typ. for tuner types
  = 800 MHz typ. for if-amplifier types
- **Very low collector-to-base feedback capacitance:**
  C_{cb} = 0.7 pF typ. for 40894, 40895
- **Low noise figure:**
  3 dB typ. at 200 MHz for rf amplifier type
- **High power gain as neutralized amplifier:**
  G_{PE} = 15 dB min. at 200 MHz (40894)
- **High power output as uhf oscillator:**
  P_{OE} = 20 mW typ. at 500 MHz (40896)
- **Low noise figure:**
  NF = 4.5 dB max. at 200 MHz (40894)
- **Low collector-to-base time constant:**
  $r_b'C_c$ = 14 ps max.

RCA-40894, 40895, 40896, and 40897 are high-frequency n-p-n silicon devices characterized especially for rf, mixer, oscillator, and if stages of vhf, SSB, and FM receivers.

These devices utilize a hermetically sealed four-lead JEDEC TO-72 package. All active elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead in applications requiring minimum feedback capacitance, shielding of the device, or both.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}	12	V
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	20	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	2.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	50	mA
TRANSISTOR DISSIPATION	P_T		
With heat sink, at case temperatures up to 25°C		300	mW
With heat sink, at case temperatures above 25°C		Derate linearly 1.71	mW/°C
At ambient temperatures up to 25°C		200	mW
At ambient temperatures above 25°C		Derate linearly 1.14	mW/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200	°C
CASE TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating surface for 10 seconds max.		265	°C

12-71

ELECTRICAL CHARACTERISTICS at Ambient Temperature (T_A) = 25°C unless otherwise specified

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS: FREQUENCY MHz	TEST CONDITIONS: DC COLLECTOR OR EMITTER VOLTAGE V			TEST CONDITIONS: DC CURRENT mA			LIMITS: TYPE 40894 RF AMPLIFIER			LIMITS: TYPE 40895 MIXER			UNITS
			V_{CB}	V_{CE}	V_{EB}	I_E	I_C	I_B	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector-Cutoff Current	I_{CBO}		15			0			-	-	0.02	-	-	0.02	μA
T_A = 150°C	I_{CBO}		15			0			-	-	1	-	-	1	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$					0	0.001		20	-	-	20	-	-	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$						3	0	15	-	-	15	-	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					0.01	0		2.5	-	-	2.5	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$						10	1	-	-	0.4	-	-	0.4	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$						10	1	-	-	1	-	-	1	V
Static Forward Current-Transfer Ratio	h_{FE}			6			1		50	80	250	40	70	250	
Magnitude of Common-Emitter, Small-Signal Short-Circuit, Forward Current Transfer Ratio[a]	$\|h_{fe}\|$	100 1 kHz		6 6			5 2		9 25	14 90	20 300	9 25	14 90	20 300	
Collector-to-Base Feedback Capacitance[b]	C_{cb}	0.1 to 1	10			0			-	0.7	1	-	0.7	1	pF
Common-Base Input Capacitance[c]	C_{ib}	0.1 to 1			0.5		0		-	-	2	-	-	2	pF
Collector-to-Base Time Constant[a]	$r_b'C_c$	31.9	6				2		3	7	14	3	7	14	ps
Small-Signal Power Gain in Neutralized Common-Emitter Amplifier Circuit[a] (see Fig. 6)	G_{PE}	10.7 200		12 12			5 5		- 15	- 21	- -	- 15	- 21	- -	dB
Noise Figure[a]	NF	200		6			1.5		-	3	4.5	-	-	-	dB

[a]Lead No. 4 (case) grounded; R_g = 125Ω

[b]Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

[c]Lead No. 4 (case) floating.

ELECTRICAL CHARACTERISTICS at Ambient Temperature (T_A) = 25°C unless otherwise specified

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS: FREQUENCY MHz	DC COLLECTOR OR EMITTER VOLTAGE V: V_{CB}	V_{CE}	V_{EB}	DC CURRENT mA: I_E	I_C	I_B	LIMITS: TYPE 40896 OSCILLATOR: Min.	Typ.	Max.	TYPE 40897 IF AMPLIFIER: Min.	Typ.	Max.	UNITS
Collector-Cutoff Current	I_{CBO}		15			0			-	-	0.02	-	-	0.02	µA
T_A = 150°C	I_{CBO}		15			0			-	-	1	-	-	1	µA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$					0	0.001		20	-	-	20	-	-	V
Collector-to-Emitter Sustaining Voltage	$V_{CEO}(sus)$						3	0	15	-	-	15	-	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$					0.01	0		2.5	-	-	2.5	-	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$						10	1	-	-	0.4	-	-	0.4	V
Base-to-Emitter Saturation Voltage	$V_{BE}(sat)$						10	1	-	-	1	-	-	1	V
Static Forward Current-Transfer Ratio	h_{FE}			6			1		27	50	250	70	120	250	
Magnitude of Common-Emitter, Small-Signal Short-Circuit, Forward Current Transfer Ratio[a]	$\|h_{fe}\|$	100 1 kHz		6 6			5 2		9 25	14 90	20 300	9 25	14 90	20 300	
Collector-to-Base Feedback Capacitance[b]	C_{cb}	0.1 to 1	10			0			-	0.7	1	-	0.7	1	pF
Common-Base Input Capacitance[c]	C_{ib}	0.1 to 1			0.5		0		-	-	2	-	-	2	pF
Collector-to-Base Time Constant[a]	$r_b'C_c$	31.9	6				2		3	7	14	3	7	14	ps
Small-Signal Power Gain in Neutralized Common-Emitter Amplifier Circuit[a] (see Fig. 6)	G_{PE}	10.7 200		12 12			5 5		– 15	– 21	- -	18 –	25 –	- -	dB
Noise Figure[a]	NF	200		6			1.5		-	-	-	-	-	-	dB

[a]Lead No. 4 (case) grounded; Rg = 125Ω

[b]Three-terminal measurement of the collector-to-base capacitance with the case and emitter leads connected to the guard terminal.

[c]Lead No. 4 (case) floating.

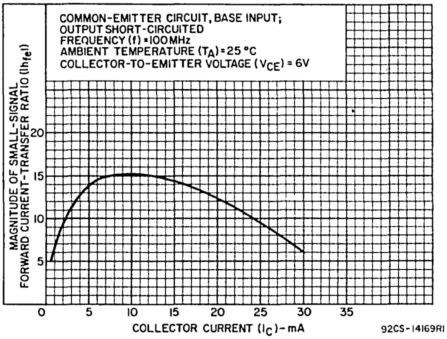


Fig. 1–Small-signal beta characteristic for all types

TWO-PORT ADMITTANCE (y) PARAMETERS AS FUNCTIONS OF FREQUENCY (f) FOR ALL TYPES

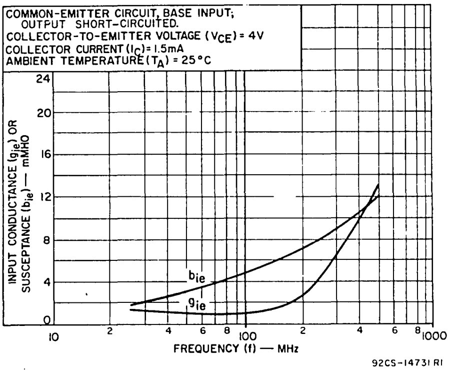


Fig. 2–Input admittance (y_{ie})

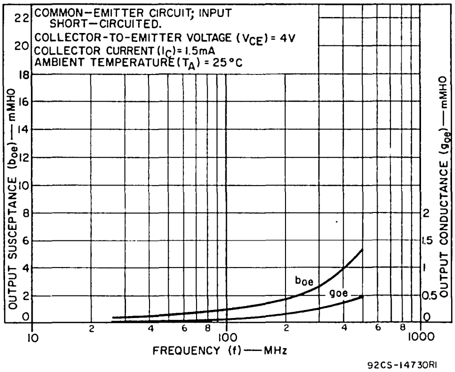


Fig. 3–Output admittance (y_{oe})

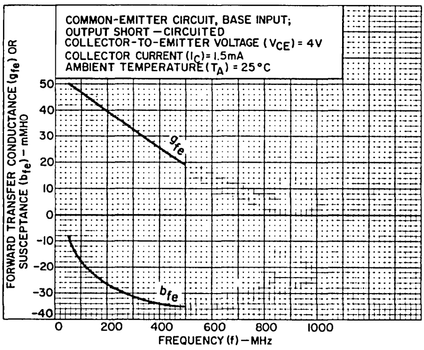


Fig. 4–Forward transadmittance (y_{fe}).

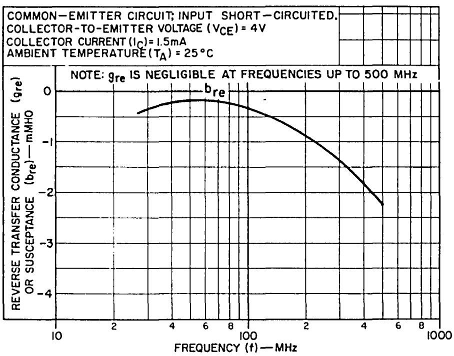
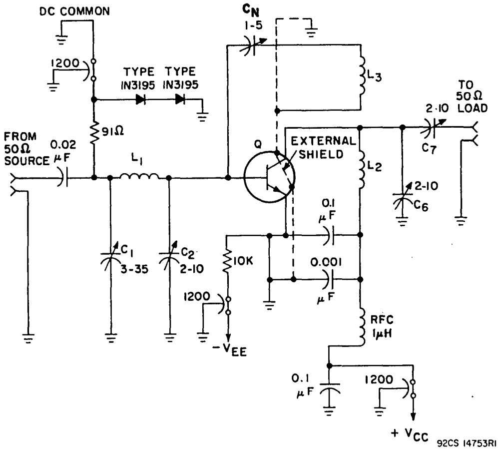


Fig. 5–Reverse transadmittance (y_{re})



NOTE: (Neutralization Procedure): (a) Connect a 50-Ω rf voltmeter to the output of a 200-MHz signal generator (R_g = 50Ω), and adjust the generator output to 5 mV. (b) Connect the generator to the input and the rf voltmeter to the output of the amplifier, as shown above. (c) Apply V_{EE} and V_{CC}, and adjust the generator output to provide an amplifier output of 5 mV. (d) Tune C2, C6, and C7 for maximum amplifier output, readjusting the generator output as required to maintain an output of 5 mV from the amplifier. (e) Interchange the connections to the signal generator and the rf voltmeter. (f) With sufficient signal applied to the output terminals of the amplifier, adjust C_N for a minimum indication at the amplifier input. (g) Repeat steps (a), (b), (c), and (d) to determine if retuning is necessary.

Q = Type 40894, 40895, 40896, or 40897

L_1: 1-3/4 turns No. 18 wire 0.5 in. (12.7 mm) long, 0.5 in. (12.7 mm) ID

L_2: 2 turns No. 16 wire, 0.5 in. (12.7 mm) long, 0.5 in. (12.7 mm) ID

L_3: 2 turns No. 18 wire, 0.25 in. (6.35 mm) long, 0.5 in. (12.7 mm) ID. Position approximately 1/4 in. (6.35 mm) from L_2.

All capacitances in pF unless otherwise specified.

Fig. 6–Neutralized amplifier circuit used to measure power gain and noise figure at 200 MHz for all types

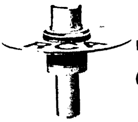
TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector
Lead 4 – Connected to case

Solid State
Division

RF Power Transistors

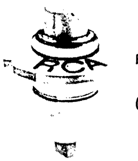
40898
40899



RCA-40898

(JEDEC TO-215AA Package)

H-1598



RCA-40899

(JEDEC TO-201AA Package)

H-1629

6- and 2-W, 2.3-GHz Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- Designed for 20- to 24-V equipment
- Emitter-ballasting resistors
- 6-W output with 6-dB gain (min.) at 2.3 GHz, 22 V – 40899
- 2-W output with 7-dB gain (min.) at 2.3 GHz, 22 V – 40898
- Stable common-base operation
- Ceramic-metal hermetic packages with low inductances and low parasitic capacitances
- For coaxial, microstripline, and lumped-constant circuit applications

The RCA-40898 and 40899* are epitaxial silicon n-p-n planar transistors with overlay multiple-emitter-site construction, designed especially for 20- to 24-volt operation. They are intended for solid-state equipment in microwave communications, S-band telemetry, microwave relay links, phased-array radar, distance-measuring equipment, and collision-avoidance systems in the frequency range from 0.5 to 2.4 GHz.

*Formerly RCA Dev. Nos. TA8439 and TA8440.

The ceramic-metal packages of the 40898 and 40899 have low parasitic capacitances and inductances for stable operation in the common-base amplifier configuration. The use of emitter-ballasting resistors provides ruggedness and reliability.

These transistors can be used in large-signal applications in coaxial, stripline, and lumped-constant circuits. The 40898 is a good driver for a 40899 output stage.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40898	40899	
COLLECTOR-TO-BASE VOLTAGE:	V_{CBO}	45	45	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	45	45	V
EMITTER-TO-BASE VOLTAGE:	V_{EBO}	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT:	I_C	0.35	1.5	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 75°C		4.15	14.8	W
At case temperatures above 75°C, derate linearly		0.033	0.118	W/°C
TEMPERATURE RANGE:				
Storage & Operating (Junction)		–65 to +200		°C
CASE TEMPERATURE (During soldering):				
For 10 s max (See Soldering Instructions on page 7.)		230		°C

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC VOLTAGE V	TEST CONDITIONS: DC CURRENT mA			LIMITS: 40898		LIMITS: 40899		UNITS
		V_{CE}	I_E	I_B	I_C	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current	I_{CES}	40				–	2	–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0		5	45	–	45	–	V
Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				10	45	–	45	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.1		0	3.5	–	3.5	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			10 20	100 100	– –	1 –	– –	– 1	V
Thermal Resistance: (Junction-to-Collector-Terminal)	$R_{\theta JCT}$						30	–	8.5	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: INPUT POWER (P_{IB})-W	OUTPUT POWER (P_{OB})-W	SUPPLY VOLTAGE (V_{CC})-V	FREQUENCY (f)-GHz	LIMITS: 40898		LIMITS: 40899		UNITS
						MIN.	MAX.	MIN.	MAX.	
Output Power (See Fig. 17)	P_{OB}	0.4 1.5		22 22	2.3 2.3	2.0 –	– –	– 6.0	– –	W
Power Gain	G_{PB}	0.4 1.5	2 6	22 22	2.3 2.3	7.0 –	– –	– 6.0	– –	dB
Collector Efficiency	η_C	0.4 1.5	2 6	22 22	2.3 2.3	35 –	– –	– 35	– –	%
Collector-to-Base Capacitance	C_{obo}			30 (V_{CB})	1 MHz	–	4	–	11.5	pF

TYPICAL APPLICATION INFORMATION

CIRCUIT & FREQUENCY	SEE FIG.	SUPPLY VOLTAGE (V_{CC})-V	40898: INPUT POWER (P_{IB})-W	40898: OUTPUT POWER (P_{OB})-W	40899: INPUT POWER (P_{IB})-W	40899: OUTPUT POWER (P_{OB})-W
Coaxial-Line 2.3-GHz Amplifier	17 21	22 22	0.4 –	2.1 –	– 1.5	– 6.5
Coaxial-Line 1.2-GHz Amplifier	21	22	–	–	1	13.5
Lumped-Constant 1-GHz Amplifier	19	22	0.21	3.8	–	–
Lumped-Constant 2-GHz Oscillator	18	22		0.75	–	–

PERFORMANCE DATA

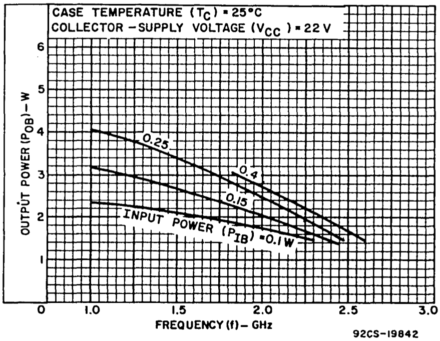


Fig. 1—Typical output power vs. frequency for type 40898 measured in the test set-up of Fig. 17.

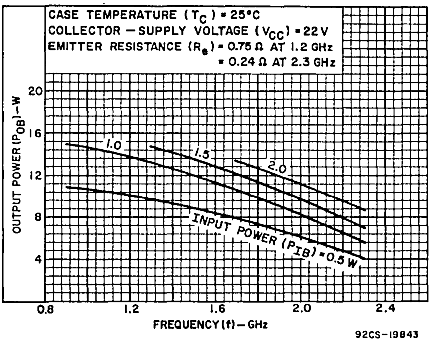


Fig. 2—Typical output power vs. frequency for type 40899, measured in the test set-up of Fig. 17.

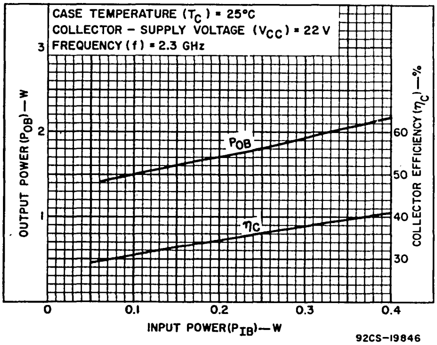


Fig. 3—Typical output power and collector efficiency vs. input power at 2.3 GHz for type 40898.

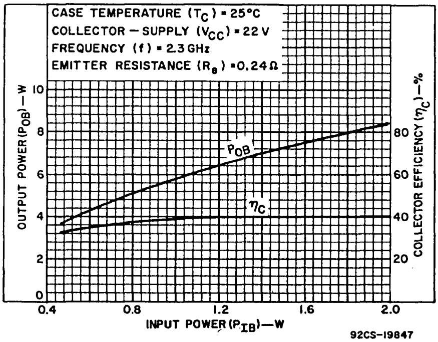


Fig. 4—Typical output power and collector efficiency vs. input power at 2.3 GHz for type 40899.

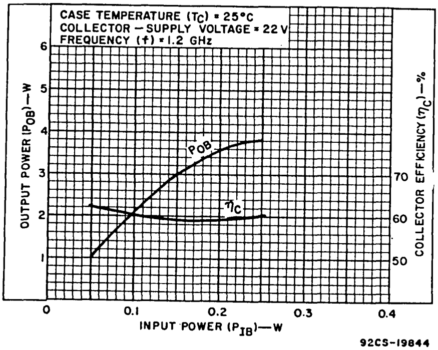


Fig. 5—Typical output power and collector efficiency vs. input power at 1.2 GHz, for type 40898 in common-base coaxial-line amplifier circuit.

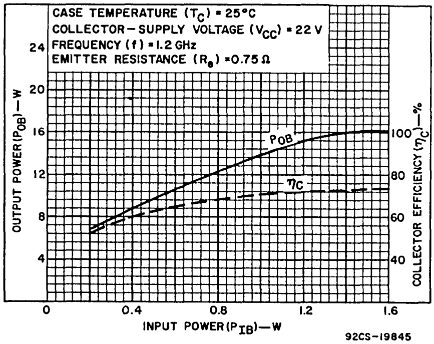


Fig. 6—Typical output power and collector efficiency vs. input power at 1.2 GHz for type 40899.

PERFORMANCE DATA (cont'd.)

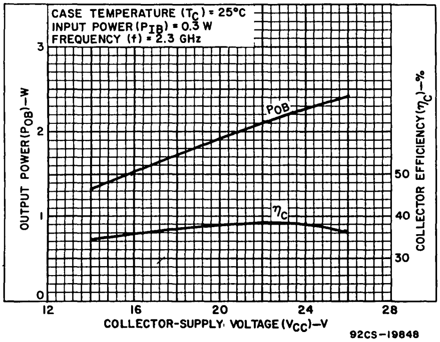


Fig. 7—Typical output power and collector efficiency vs. collector-supply voltage at 2.3 GHz for type 40898.

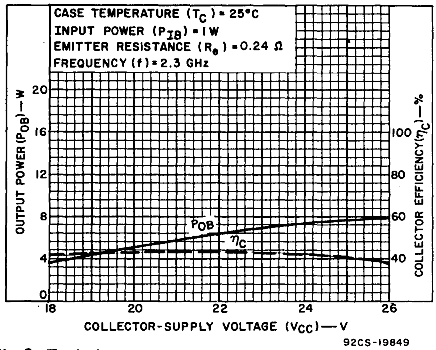


Fig. 8—Typical output power and collector efficiency vs. collector supply voltage at 2.3 GHz for type 40899.

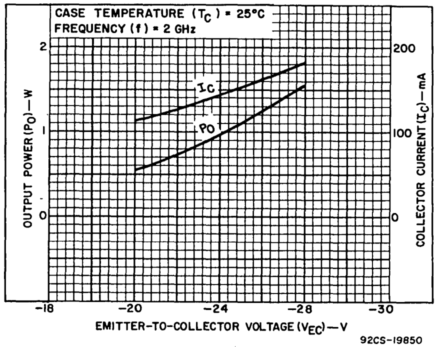


Fig. 9—Typical output power and collector current vs. emitter-to-collector voltage, for type 40898 in 2-GHz grounded-collector oscillator circuit shown in Fig. 18.

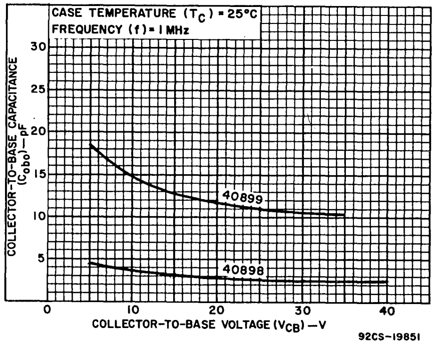


Fig. 10—Typical collector-to-base capacitance vs. collector-to-base voltage for types 40898 and 40899.

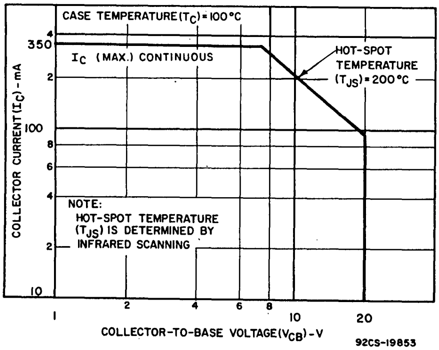


Fig. 11—Safe area for dc operation of type 40898.

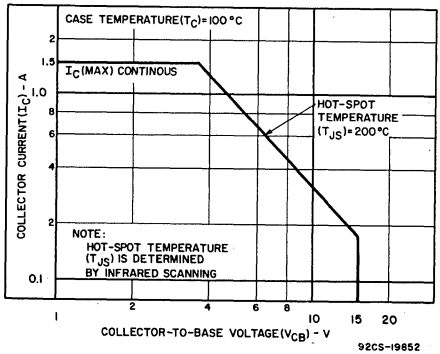


Fig. 12—Safe area for dc operation of type 40899.

DESIGN DATA

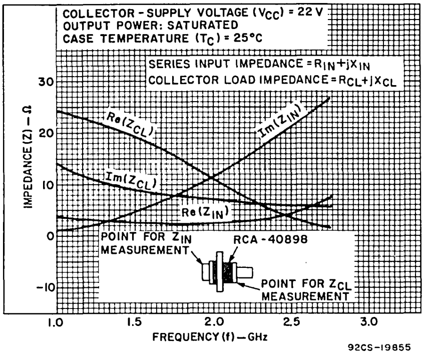


Fig. 13—Typical large-signal input impedance and large-signal collector load impedance vs. frequency for type 40898.

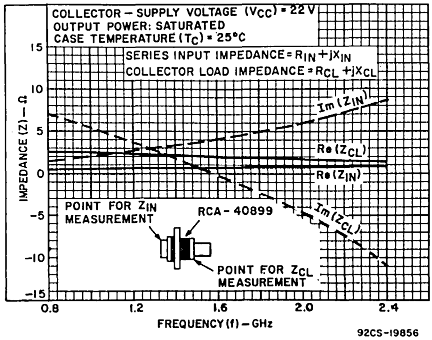


Fig. 14—Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for type 40899.

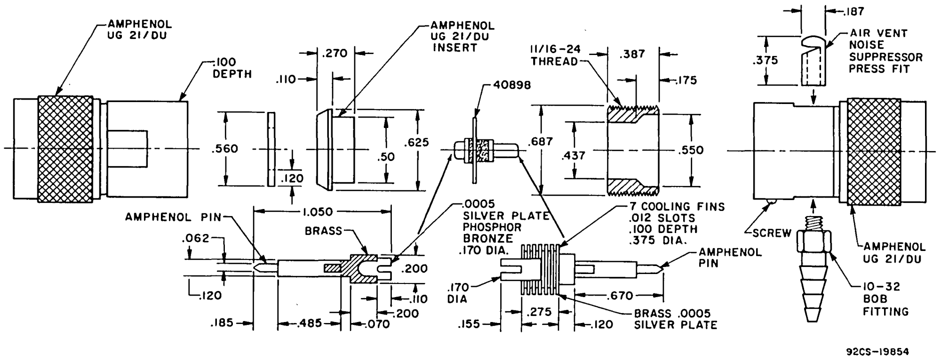
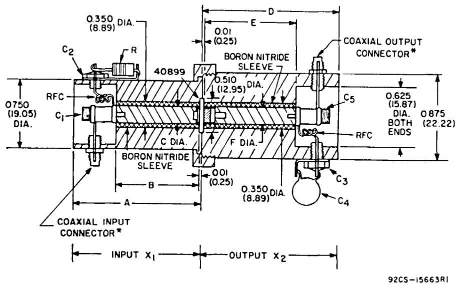


Fig. 15—Type 40898 in coaxial-line test fixture for 1.2- and 2.3-GHz amplifiers.



CIRCUIT	DIMENSIONS							
	INPUT (X_1)				OUTPUT (X_2)			
	A	B	C	Center Conductor	D	E	F	Center Conductor
1.2-GHz Amplifier	1.385 (35.18)	0.875 (22.22)	0.282 (7.16)	0.825 (20.95)	1.778 (45.16)	1.268 (32.21)	0.213 (5.41)	1.05 (26.67)
2.3-GHz Amplifier	0.772 (19.61)	0.262 (6.65)	0.265 (6.73)	0.212 (5.39)	0.922 (23.49)	0.412 (10.42)	0.270 (6.88)	0.245 (6.22)

DIMENSIONS IN INCHES AND MILLIMETERS

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

MATERIAL: Center conductor—copper
Outer conductor for input & output—brass

*Conhex 50-045-0000 (Sealectro Corp.), or equivalent.

Fig. 16— Type 40899 in coaxial-line test fixture for 1.2- and 2.3-GHz amplifiers. See Fig. 21 for component values.

APPLICATION INFORMATION

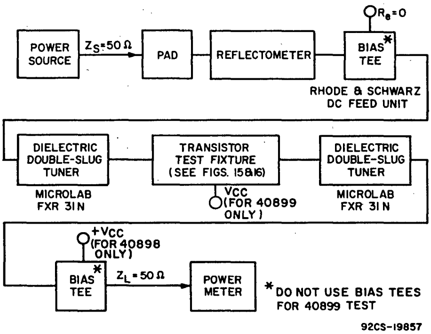
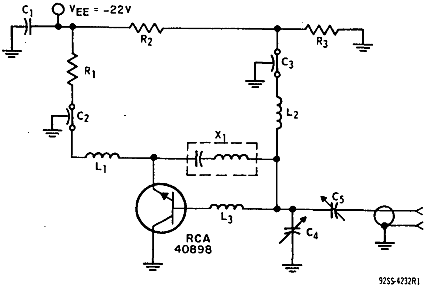
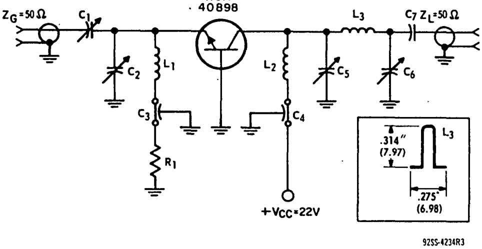


Fig. 17—Block diagram of test set-up used for measurement of output power from 1.2- and 2.3-GHz common-base amplifiers.



C_1: 0.01 μF, disc ceramic
C_2,C_3: 100 pF, feed-through, Allen-Bradley FA5C, or equivalent
C_4,C_5: 0.35 – 3.5 pF, Johanson 4701, or equivalent
L_1, L_2: RF choke, 4 turns, No. 33 wire, 0.062 in. (1.57 mm) ID, 3/16 in. (4.75 mm) long
L_3: 3/64-in. (1.17 mm) length of No. 22 wire
X_1: 0.82 pF, "gimmick", Quality Components type 10% QC, or equivalent
R_1: 5 – 10 Ω, 1/2 W
R_2: 51 Ω, 1/2 W
R_3: 1200 Ω, 1/2 W

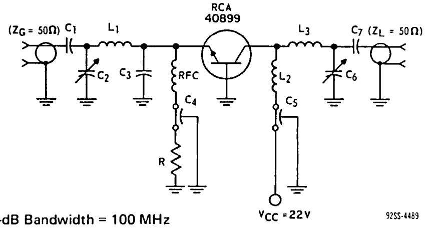
Fig. 18—Typical circuit for 2-GHz grounded-collector power oscillator using type 40898.



C_1,C_5,C_6: 1-14 pF, air-dielectric, Johanson 3901, or equivalent
C_2: 0.35–3.5 pF, air-dielectric, Johanson 4701, or equivalent
C_3,C_4: 1000 pF, feed-through, Allen-Bradley FA5C, or equivalent
C_7: 1000 pF, ceramic, leadless
L_1,L_2: RF choke, 0.1 μH, Nytronics Deci-Ductor
L_3: 0.01-in. (0.254 mm) thick, 0.157-in. (3.98 mm) wide copper strip shaped as shown in inset drawing
R_1: 1 Ω, 1/2 W

Fig. 19—Typical circuit for 1-GHz power amplifier using type 40898.

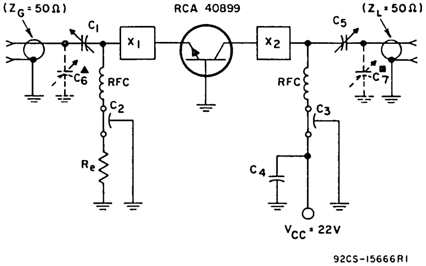
APPLICATION INFORMATION (cont'd)



1-dB Bandwidth = 100 MHz

C_1,C_7:	510 pF, ATC-200 or equivalent
C_2,C_6:	1-10 pF, Johanson 2954 or equivalent
C_3:	10 pF, ATC-100 or equivalent
C_4,C_5:	470 pF, feed-through type, Allen-Bradley FA5C
L_1:	3.7 nH
L_2:	0.8 nH
L_3:	2.3 nH
R:	0.47 Ω
RFC:	5 turns, No. 28 wire, 0.05 in. (1.27 mm) ID, 0.4-in. (10.16 mm) long

Fig. 20—Typical lumped-constant circuit for 1-GHz power amplifier using type 40899.



CIRCUIT	C_1 pF	C_2 pF	C_3 pF	C_4 μF	C_5 pF	C_6 pF	C_7 pF	R_e Ω
1.2-GHz Amplifier	1-10	1000	1000	0.01	1-10	–	0.3-3.5	0.75
2.3-GHz Amplifier	1-10	470	470	0.01	0.3-3.5	0.3-3.5	–	0.24

▲ Use only in the 2.3-GHz coaxial-line power amplifier circuit.
■ Use only in the 1.2-GHz coaxial-line power amplifier circuit.

C_1 & C_5:	1-10 pF	Johanson 4581 or equivalent
C_5, C_6 & C_7:	0.3-3.5 pF	Johanson 4700 or equivalent
RFC:	For 2.3-GHz circuit, 3 turns No. 32 wire 1/16 in. (1.59 mm) ID, 3/16 in. (4.76 mm) long. For 1.2-GHz circuit, 6 turns No. 32 wire 1/16 in. (1.59 mm) ID, 3/16 in. (4.76 mm) long.	
X_1, X_2:	Coaxial-line circuits; see Fig. 16.	

Fig. 21—Coaxial-line amplifier circuits using type 40899 for operation at 1.2- and 2.3-GHz.

SOLDERING INSTRUCTIONS

When the 40898 or 40899 is to be soldered into a microstrip-line or lumped-constant circuit, the terminals of the device must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

TERMINAL CONNECTIONS

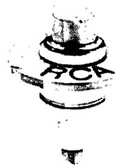
Terminal No. 1—Emitter
Terminal No. 2—Base
Terminal No. 3—Collector

WARNING: The ceramic body of the RCA-40899 contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA
Solid State
Division

RF Power Transistors

40909



H-1629

JEDEC TO-201AA PACKAGE

2-W, 2-GHz Emitter-Ballasted Silicon N-P-N Overlay Transistor

For Microwave Fundamental-Frequency Oscillators

Features:

- **Emitter-ballasting resistors**
- **2-W (min.) output at 2 GHz**
- **4-W (typ.) output at 1 GHz**
- **Emitter connected to flange (for increased internal feedback) for higher efficiency at S-band frequencies in Colpitts oscillator circuits**
- **Beryllium-oxide ceramic for low thermal resistance between collector stud and emitter flange**
- **For coaxial, stripline, and lumped-constant circuit applications**

RCA-40909▲ is an epitaxial silicon n-p-n transistor with overlay multiple-emitter-site construction. It is designed for use in power oscillators at microwave frequencies. The ceramic-metal coaxial package of the 40909 has low parasitic capacitances and inductances, and lends itself to mounting in coaxial, stripline, or lumped-constant circuits. Intended applications for this transistor include microwave communications, relay links, distance-measuring equipment, and collision-avoidance systems.

▲Formerly RCA Dev. No. TA7943

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
CONTINUOUS DC COLLECTOR CURRENT	I_C	0.7	A
TRANSISTOR DISSIPATION	P_T		
At case temperature up to 75°C		10.4	W
At case temperatures above 75°C derate linearly		0.083	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
CASE TEMPERATURE (During soldering): For 10 s max. (See Soldering Instructions on page 4.)		230	°C

11-73

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C unless otherwise specified.

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Voltage (V)	TEST CONDITIONS: DC Current (mA)			LIMITS		UNITS
		V_{CE}	I_E	I_B	I_C	Min.	Max.	
Collector-Cutoff Current	I_{CES}	45				-	2	mA
	I_{CES} (T_C = 100°C)	45				-	5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0		5	50	-	V
Collector-to-Emitter Breakdown Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				10	50	-	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.1		0	3.5	-	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$			20	100	-	1	V
Thermal Resistance: (Junction to Collector-Stud)	$R_{\theta JCT}$					-	8.5	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Frequency (f) – GHz	TEST CONDITIONS: DC Emitter Supply Voltage (V_{EE}) – V	LIMITS: Min.	LIMITS: Max.	UNITS
Oscillator Output Power (See Fig. 6)	P_O	2	25	2.0	-	W
Oscillator Circuit Efficiency	η	2	25	20	-	%

TYPICAL APPLICATION INFORMATION

Application	Collector Current (I_C) – mA	DC Emitter Supply Voltage (V_{EE}) – V	Output Power (P_O) – W
2-GHz Oscillator	400	25	2.5
1-GHz Oscillator	400	25	4.0

PERFORMANCE DATA

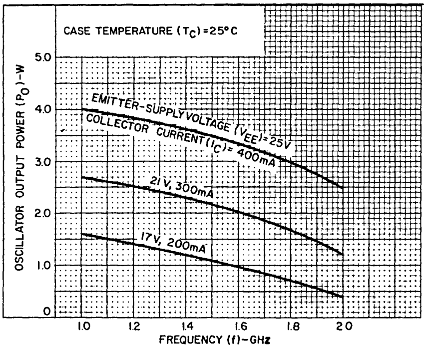


Fig. 1–Typical oscillator output power vs. frequency for the test set-up of Fig. 5.

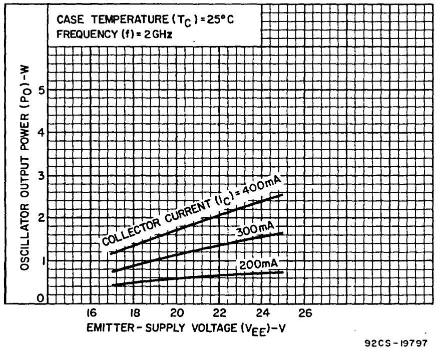


Fig. 2–Typical 2-GHz oscillator output power vs. emitter-supply voltage.

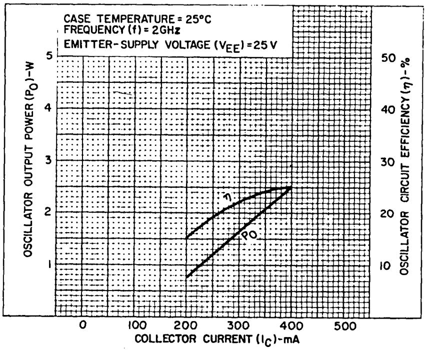


Fig. 3–Typical oscillator output power and circuit efficiency vs. collector current.

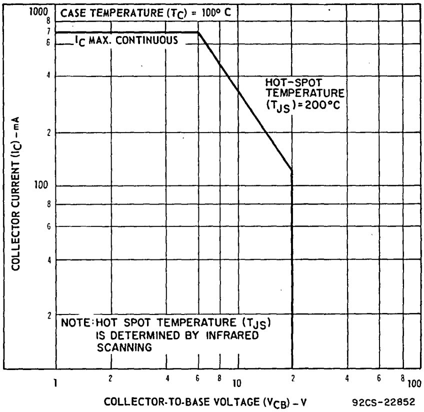


Fig. 4–Safe operating area for dc operation.

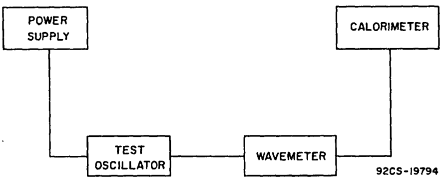


Fig. 5–Block diagram of test set-up for measurement of oscillator output power.

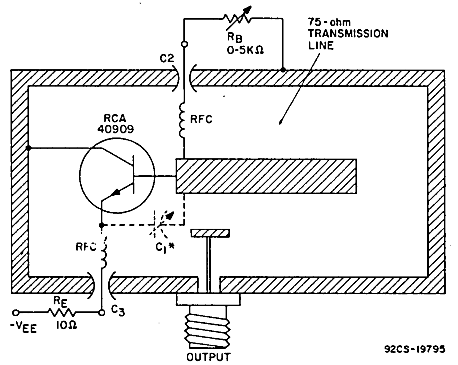
SOLDERING INSTRUCTIONS

When the RCA-40909 is soldered into a circuit, the terminals must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

TERMINAL CONNECTIONS

Terminal No. 1 – Base
Terminal No. 2 – Emitter
Terminal No. 3 – Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.



*C_1: Adjustable feedback capacitor for frequencies below 1.4 GHz, 0.3-3.5 pF, Johanson 4700 (Johanson Mfg. Corp., Boonton, N.J. 07005) or equivalent.

RFC: 5 turns No. 28 wire, 0.05 in. (1.27 mm) I.D., 0.4 in. (10.16 mm) long.

Fig. 6—Schematic diagram of basic oscillator circuit.

UNIVERSAL BREADBOARD OSCILLATOR CIRCUIT FOR OPTIMIZING MECHANICAL DIMENSIONS

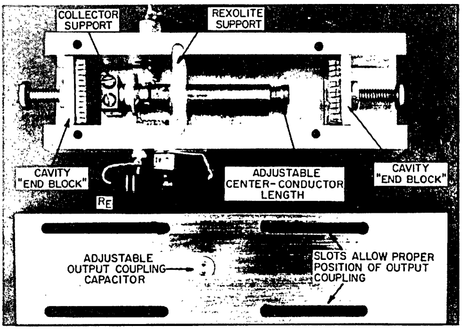


Fig. 7—Top view of test oscillator with cover removed.

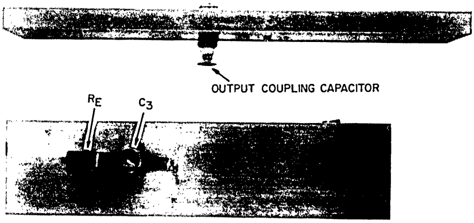
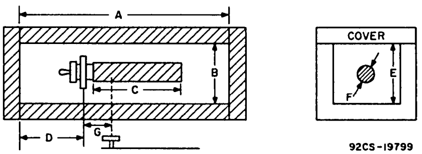


Fig. 8—Side view of test oscillator with cover removed.



Oscillation Frequency	A	B	C	D	E	F	G
1 GHz	3.10 (78.74)	0.775 (19.69)	2.30 (58.42)	0.600 (15.24)	0.775 (19.69)	0.250 (6.35)	1.20 (30.48)
2 GHz	2.00 (50.80)	0.775 (19.69)	0.975 (24.77)	0.160 (4.06)	0.775 (19.69)	0.250 (6.35)	0.600 (15.24)

Dimensions in parentheses are in millimeters, derived from the basic inch dimensions shown.

Fig. 9—Drawing (inside view) of oscillator, showing dimensions.

RCA
Solid State Division

RF Transistors

40915

JEDEC TO-72 H-1299

0.2-to-1.4-GHz Low-Noise Silicon N-P-N Transistor

For High-Gain Small-Signal Applications

Features:

- **Low noise figure:**
  NF = 2.5 dB (max.) with 11 dB gain at 450 MHz
  = 3.0 dB (typ.) at 890 MHz
  = 4.5 dB (typ.) at 1.3 GHz
- **High gain (tuned, unneutralized):**
  G_{PE} = 14 dB (min.) at 450 MHz
  = 6.5 dB (typ.) at 1.3 GHz
- **High gain-bandwidth product**
- **Large dynamic range**
- **Low distortion**

RCA-40915* is an epitaxial silicon n-p-n planar transistor intended for low-power, small-signal applications where both low noise and high gain are desirable. It utilizes a hermetically sealed four-lead JEDEC TO-72 package. All of the elements of the transistor are insulated from the case, which may be grounded by means of the fourth lead.

*Formerly RCA Dev. No. TA8104.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

Collector-to-Base Voltage	V_{CBO}	35	V
Collector-to-Emitter Voltage	V_{CEO}	15	V
Emitter-to-Base Voltage	V_{EBO}	3.5	V
Collector Current (Continuous)	I_C	40	mA
Transistor Dissipation:	P_T		
At ambient temperatures up to 25°C		200	mW
At ambient temperatures above 25°C		Derate linearly at 1.14 mW/°C	
Temperature Range:			
Storage and Operating (Junction)		−65 to +200	°C

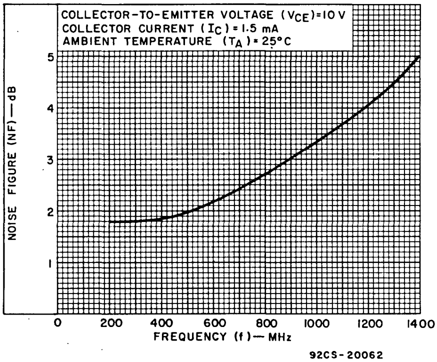


Fig. 1—Typical noise figure vs. frequency.

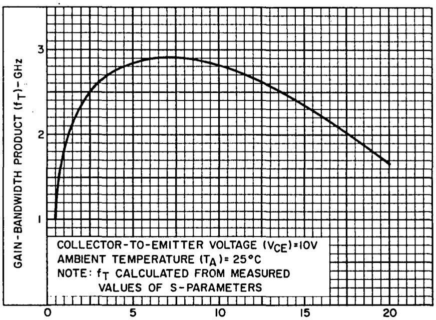


Fig.2—Gain-bandwidth product vs. collector current.

ELECTRICAL CHARACTERISTICS at Ambient Temperature (T_A) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V)		TEST CONDITIONS: DC CURRENT (mA)			LIMITS		UNITS
		V_{CB}	V_{CE}	I_E	I_B	I_C	MIN.	MAX.	
STATIC									
Collector Cutoff Current	I_{CBO}	10		0			–	20	nA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.01	35	–	V
Collector-to-Emitter Breakdown Voltage	$V_{(BR)CEO}$				0	0.1	15	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.01		0	3.5	–	V
DC Forward-Current Transfer Ratio	h_{FE}		10			3	20	–	–
Thermal Resistance: (Junction-to-Ambient)	$R_{\theta JA}$						–	880	°C/W
DYNAMIC									
Device Noise Figure (f = 450 MHz)	NF		10			1.5	–	2.5	dB
Small-Signal Common-Emitter Power Gain (f = 450 MHz) Unneutralized Amplifier At minimum noise figure	G_{PE}		10			1.5	13	–	dB
Collector-to-Base Output Capacitance (f = 1 MHz)	C_{obo}	10		0			–	1.0	pF

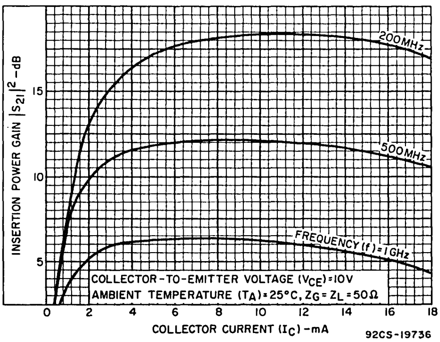


Fig.3—Typical insertion power gain vs. collector current.

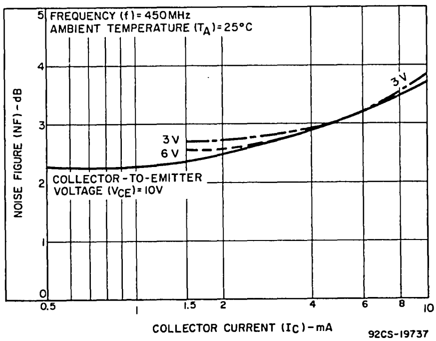


Fig.4—Typical noise figure vs. collector current.

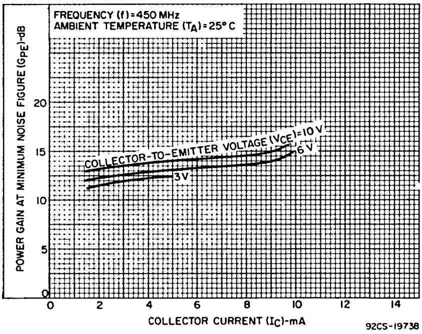


Fig.5—Typical power gain (at minimum noise figure) vs. collector current.

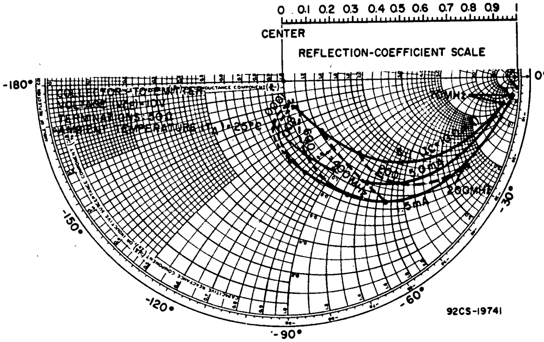


Fig. 8—Typical input reflection coefficient.

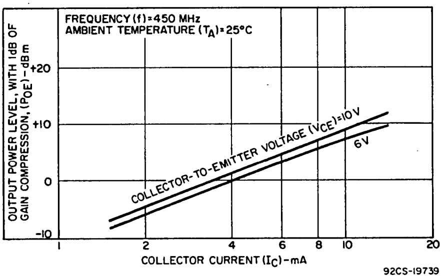
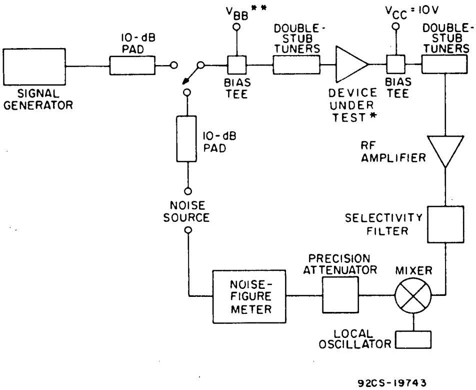


Fig.6—Typical output power level (with 1 dB of gain compression) vs. collector current.



* In General Radio type 1607-P44 transistor mount, or equivalent.

** V_{BB} adjusted for I_C = 1.5 mA.

Fig.9—Block diagram of test setup for measurement of power gain and noise figure.

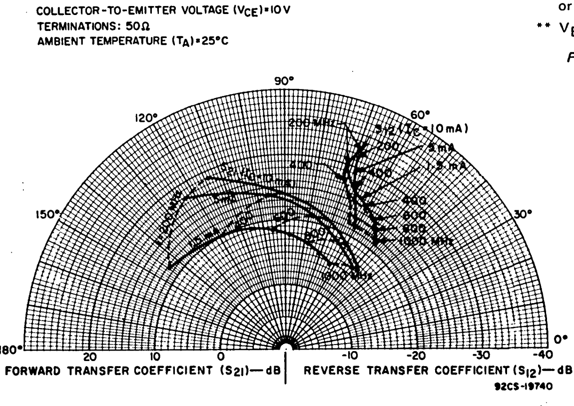


Fig.7—Typical forward and reverse transfer coefficients.

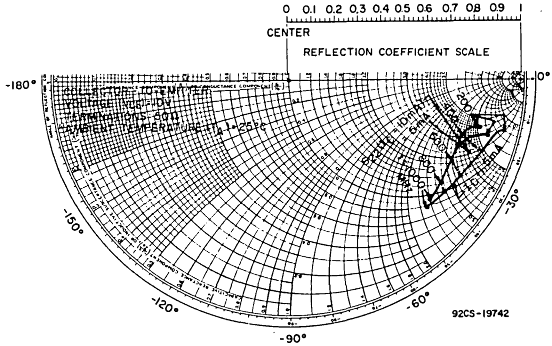
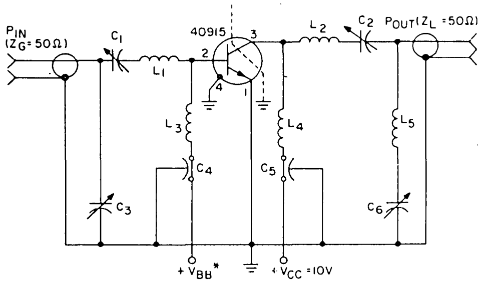


Fig. 10—Typical output reflection coefficient.



C_1: 1.0- 30 pF
C_2,C_3: 1.0-20 pF
C_4,C_5: 0.04 μF
C_6: 1-10 pF

L_1: 2 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.10 in. (2.54 mm) long
L_2: 3 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.15 in. (3.81 mm) long
L_3,L_4: 0.22-μH rf choke
L_5: 3 turns No. 18 wire, 3/16 in. (0.188 mm) ID, 0.15 in. (3.81 mm) long

* V_{BB} adjusted for I_C = 1.5 mA

Fig. 11—Circuit diagram of 450-MHz amplifier (unneutralized) used for measurement of power gain and noise figure.

TERMINAL CONNECTIONS

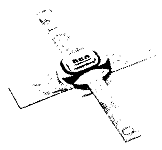
Lead 1 — Emitter
Lead 2 — Base
Lead 3 — Collector
Lead 4 — Case

Solid State
Division

RF Power Transistors

40934

High-Power Silicon N-P-N VHF/UHF Transistor



RCA HF-31 Package
("Studless TO-216 AA")

H-1676

12.5-Volt Type For Class C Amplifier Applications

Features:

- Low-inductance radial leads – particularly useful for stripline circuits
- Hermetically sealed ceramic-metal package
- Electrically isolated mounting surface
- 2-watt minimum output at 470 MHz
- 7-dB gain at 470 MHz

RCA-40934* is an epitaxial silicon n-p-n planar transistor that features overlay emitter-electrode construction and a hermetic ceramic-metal package with leads isolated from the mounting surface. This rugged, low-inductance, radial-lead device is designed for stripline as well as lumped-constant circuits.

*Formerly RCA Dev. No. TA7941.

Type 40934 is electrically identical to the RCA-2N5914, but employs a "studless TO-216AA" package.

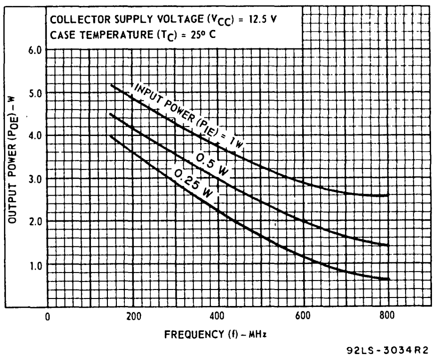


Fig. 1—Typical output power vs. frequency.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE BREAKDOWN VOLTAGE	$V_{(BR)CBO}$	36	V
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:			
With base connected to emitter	$V_{(BR)CES}$	36	V
With base open	$V_{(BR)CEO}$	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
COLLECTOR CURRENT:	I_C		
Continuous		0.5	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		5.7	W
At case temperatures above 75°C, derate linearly at		0.0456	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to +200°C	
CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V) V_{CE}	DC BASE VOLTAGE (V) V_{BE}	DC CURRENT (mA) I_E	I_B	I_C	LIMITS MIN.	MAX.	UNITS
Collector-Cutoff Current	I_{CEO}	10			0		–	0.3	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.5	36	–	V
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	25[a]	14	–	V
With base connected to emitter	$V_{(BR)CES}$		0			25[a]	36	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	V

[a]Pulsed through a 25-mH inductor; duty factor = 50%

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Collector Supply (V_{CC})–V	Input Power (P_{IE})–W	Frequency (f)–MHz	LIMITS MIN.	TYP.	UNITS
Power Output	P_{OE}	12.5	0.4	470	2.0		W
Power Gain	G_{PE}	12.5	0.4	470	7		dB
Collector Efficiency	η_C	12.5	0.4	470	65		%
Load Mismatch (Fig. 8)	LM	12.5	0.4	470	Open circuit through short circuit		–
Collector-to-Base Capacitance	C_{obo}	12 $I_C = 0$		1	–	15 (max.)	pF
Gain-Bandwidth Product	f_T	12 I_C = 200 mA			–	900	MHz

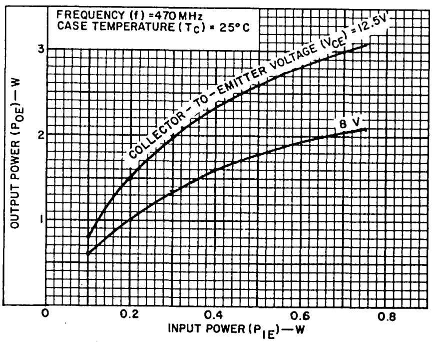


Fig. 2—Typical output power vs. input power at 470 MHz for 40934 in circuit shown in Fig. 7.

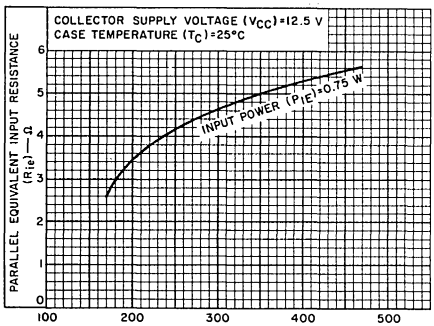


Fig. 3—Large-signal parallel equivalent input resistance vs. frequency.

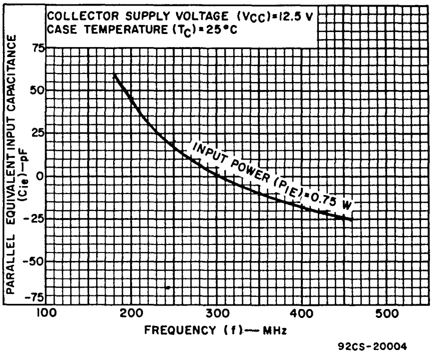


Fig. 4—Large-signal parallel equivalent input capacitance vs. frequency.

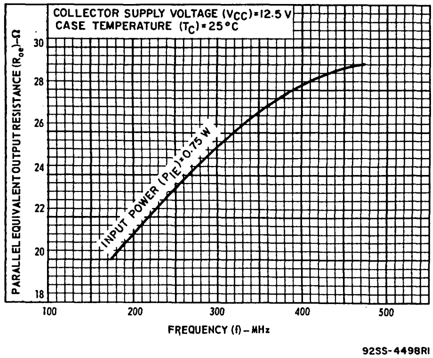


Fig. 5—Large-signal parallel equivalent output resistance vs. frequency.

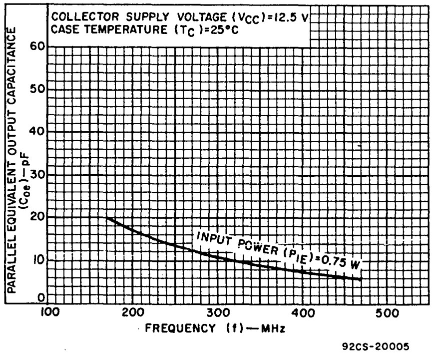
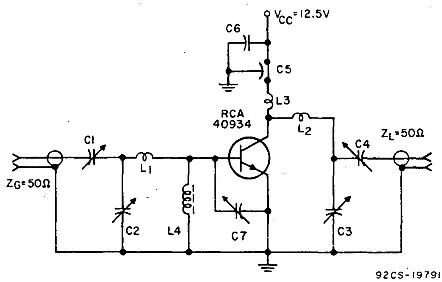
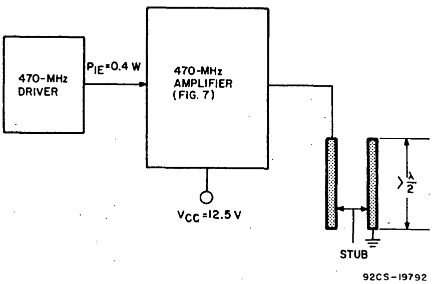


Fig. 6—Large-signal parallel equivalent output capacitance vs. frequency.



C_1, C_2, C_3: 0.9–7.0 pF, ARCO 400 or equivalent
C_4: 1.5–2.0 pF, ARCO 402 or equivalent
C_5: 1000 pF, feedthrough
C_6: 0.1 μF, ceramic
C_7: 2–18 pF, Amperex HT10MA/218 or equivalent, connected between the base and emitter with the shortest possible leads.
L_1, L_2: 1 turn No.16 wire, 3/16 in. (4.78 mm) I.D., 1/8 in. (3.18 mm) long
L_3: 1 turn No.20 wire, 3/16 in.(4.78 mm) I.D., 1/8 in. (3.18 mm) long
L_4: Ferrite choke, 450Ω impedance; Ferroxcube VK-200-09-3B or equivalent

Fig. 7—470-MHz amplifier test circuit for measurement of output power, gain, and load-mismatch capability.



The transistor must withstand any mismatch in load; the load can be varied from open circuit to short circuit by adjustment of the tuning stub through a half wavelength. (The dissipation rating of the transistor should not be exceeded during the test.)

Fig. 8—Test set-up for checking load-mismatch capability of 40934.

TERMINAL CONNECTIONS

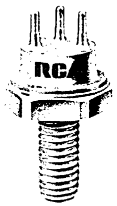
Terminal No. 1, 3 – Emitter
Terminal No. 2 – Base
Terminal No. 4 – Collector

WARNING: The ceramic heat-sink portion of this device contains berylium oxide. Do not crush, grind, or abrade this portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA
Solid State
Division

RF Power Transistors

40936



JEDEC TO-60

H-1307

20-W(PEP) Emitter-Ballasted Overlay Transistor

For 2- to-30-MHz Single-Sideband Linear Amplifier Applications

Features:

- **For class A or class B amplifier service**
- **Integral emitter-ballasting resistors**
- **20 W(PEP) output (min.) at 30 MHz with:**
  gain = 13 dB (min.); collector efficiency = 40% (min.);
  intermodulation distortion = -30 dB (max.)
- **Low-Thermal-Resistance Package**

RCA – 40936* is an epitaxial silicon n-p-n planar transistor with overlay emitter-electrode construction. It is designed especially for use in linear amplifiers to provide high power in class A or class B service. This device is intended for 2-to-30-MHz single-sideband power amplifiers operating from 28-volt power supplies.

The inherent high-frequency capability of the overlay structure, together with individually ballasted emitter sites, makes it possible to forward-bias the device into the active region without incurring thermal instability.

*Formerly RCA Dev. No. TA8236.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE:			
With V_{BE} = -1.5 V	V_{CEV}	65	V
With external base-to-emitter resistance R_{BE} = 5 Ω	V_{CER}	40	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
COLLECTOR CURRENT:			
Peak		10	A
Continuous	I_C	3.3	A
TRANSISTOR DISSIPATION	P_T		
At case temperatures up to 75°C		50	W
At case temperatures above 75°C	Derate linearly at 0.4 W/°C.		
TEMPERATURE RANGE:			
Storage & Operating (Junction)	-65 to	200	°C
LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.787 mm) from insulating wafer for 10 s max		230	°C

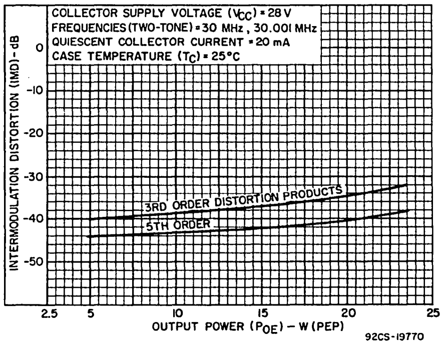


Fig. 1—Typical intermodulation distortion vs. output power.

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C

STATIC

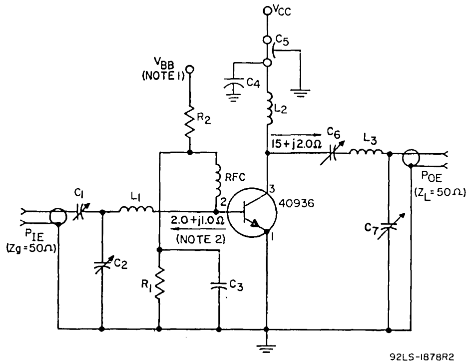
CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR VOLTAGE (V) V_{CB}	V_{CE}	DC BASE VOLTAGE (V) V_{BE}	DC CURRENT (mA) I_E	I_C	LIMITS MIN.	MAX.	UNITS
Collector-to-Emitter Sustaining Voltage: With base-emitter junction reverse biased	V_{CEV}(sus)			−1.5		200[a]	65	–	V
With external base-to-emitter resistance (R_{BE})=5Ω	V_{CER}(sus)					200[a]	40	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$				20		4	–	V
Collector-to-Emitter Cutoff Current	I_{CEO}		30				–	5.0	mA
Collector-to-Base Cutoff Current	I_{CBO}	60					–	10	mA
Collector-to-Base Capacitance (f = 1 MHz)	C_{obo}	30					–	85	pF
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						–	2.5	°C/W

[a]Pulsed through an inductor (25 mH); duty factor = 50%.

DYNAMIC (30-MHz Single-Sideband Amplifier)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR SUPPLY VOLTAGE (V) V_{CC}	OUTPUT POWER W(PEP) P_{OE}	FREQUENCY (MHz) f	DC CURRENT (mA) I_C	LIMITS MIN.	MAX.	UNITS
RF Input Power: Average	P_{IE}	28	10	30	20	–	0.5	W
Peak envelope (PEP)	P_{IE}	28	20	30	20	–	1.0	W
Power Gain	G_{PE}	28	20	30	20	13	–	dB
Collector Efficiency	η_C	28	20	30	20	40	–	%
Intermodulation Distortion*	IMD	28	20	30	20	–	-30	dB

*Referenced to either of the two tones, and without the use of feedback to enhance linearity.



L1: 3 turns No. 12 wire, 1/4 in. (6.35 mm) I.D., 1/2 in. (12.7 mm) long
L2: 6 turns No. 14 wire, 3/8 in. (9.53 mm) I.D., 3/4 in. (19.05 mm) long
L3: 5 turns No. 10 wire, 3/4 in. (19.05 mm) I.D., 3/4 in. (19.05 mm) long
C1: 140–680 pF, Arco 468, or equivalent
C2: 170–780 pF, Arco 469, or equivalent
C3: 0.05 pF, ceramic
C4: 0.1 μF, ceramic
C5: 1000 pF, feedthrough
C6: 24–200 pF, Arco 425, or equivalent
C7: 32–250 pF, Arco 426, or equivalent
R1: 20Ω, 1 W
R2: 300Ω, 5 W
RFC: 350Ω, Ferrite choke, Ferroxcube* No. 01-03B, or equivalent

*Ferroxcube Corp. of America, Saugerties, N.Y.

NOTES:

1. V_{BB} adjusted for a quiescent collector current of 20 mA.
2. Impedances measured at socket terminals.

Fig. 2—30-MHz linear amplifier test circuit used for measurement of dynamic characteristics.

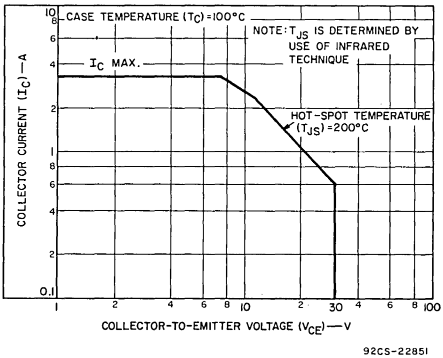


Fig. 3—Maximum operating area for forward-bias operation.

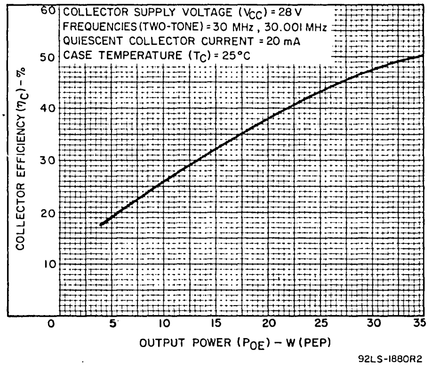


Fig. 4—Typical collector efficiency vs. output power.

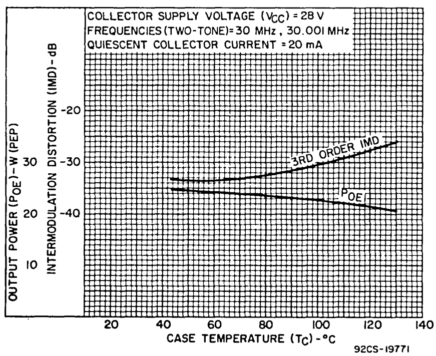


Fig. 5—Typical output power and intermodulation distortion vs. case temperature.

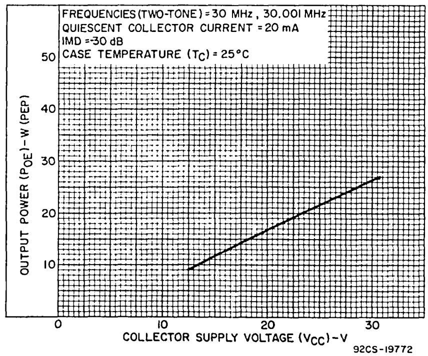


Fig. 6—Typical output power vs. collector supply voltage.

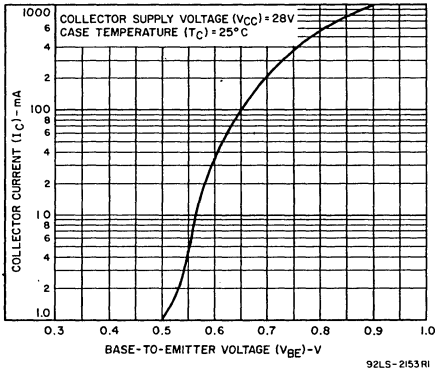


Fig. 7—Typical transfer characteristic.

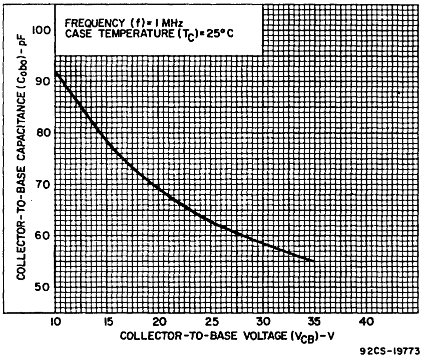


Fig. 8—Variation of output capacitance with collector-to-base voltage.

TERMINAL CONNECTIONS

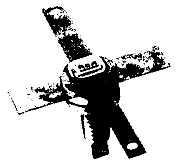
Case, Mounting Stud, Pin No. 1 — Emitter
Pin No. 2 — Base
Pin No. 3 — Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA
Solid State
Division

RF Power Transistors

40940



JEDEC TO-216AA H-1693

5-W, 400-MHz Silicon N-P-N Overlay Transistor

For VHF/UHF High-Power Amplifiers

Features:

- 5 W output at 400 MHz with 5.2 dB power gain
- 7.5 W output at 100 MHz with 8.7 dB power gain
- Low-inductance, ceramic-metal, hermetic package
- All electrodes isolated from the stud

RCA type 40940* is an epitaxial silicon n-p-n planar transistor with "overlay" emitter-electrode construction. In the overlay structure, a number of individual emitter sites are connected in parallel and used in conjunction with a single base and collector region. This arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter or collector areas for lower input and output capacitances. The overlay structure thus offers greater power output, gain, efficiency, and frequency capability.

*Formerly RCA Dev. No. TA7982.

TERMINAL CONNECTIONS

Terminals 1, 3 — Emitter
Terminal 2 — Base
Terminal 4 — Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	40	V
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	65	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	V
COLLECTOR CURRENT:	I_C		
Continuous		1.5	A
Peak		0.5	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		8.33	W
At case temperatures above 75°C, derate linearly at		0.067	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
CASE TEMPERATURE (During Soldering):			
For 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS		UNITS
		DC COLLECTOR VOLTAGE-V	DC BASE VOLTAGE-V	DC CURRENT mA					
		V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
Collector-to-Emitter Cutoff Current: With base open	I_{CEO}	30			0		–	0.1	mA
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				100	500	–	1	V
Collector-to-Emitter Breakdown Voltage: With base connected to emitter	$V_{(BR)CES}$		0			200[a]	65	–	V
With base open	$V_{(BR)CEO}$				0	200[a]	40	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	4	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	15	°C/W

[a]Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		DC COLLECTOR SUPPLY (V_{CC})-V	INPUT POWER (P_{IE})-W	OUTPUT POWER (P_{OE})-W	FREQUENCY (f)–MHz	MIN.	MAX.	
Output Power (See Fig. 11)	P_{OE}	28	1.5		400	5	–	W
(See Fig. 9)		28	1		100	7.5		
Power Gain	G_{PE}	28		5	400	5.2	–	dB
Collector Efficiency	η_C	28			400	50	–	%
Collector-to-Base Capacitance	C_{obo}	30 (V_{CB})			1	–	11	pF

TYPICAL APPLICATION INFORMATION

CIRCUIT	COLLECTOR SUPPLY VOLTAGE (V_{CC})-V	OUTPUT POWER (P_{OE})-W	INPUT POWER (P_{IE})-W	COLLECTOR EFFICIENCY (η_C)-%
400-MHz Narrowband Amplifier (See Fig. 10)	28	5	1.5	60
100-MHz Narrowband Amplifier (See Fig. 9)	28	7.5	1	70

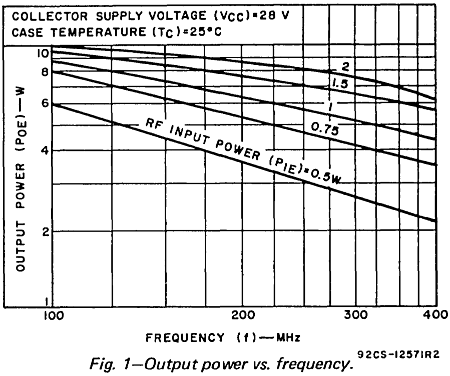


Fig. 1—Output power vs. frequency.

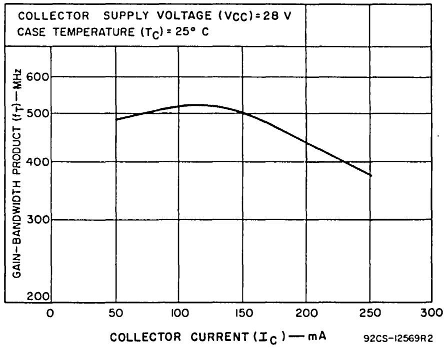


Fig. 2—Gain-bandwidth product vs. collector current.

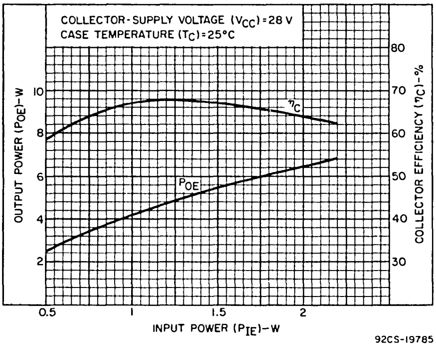


Fig. 3—Typical output power and collector efficiency vs. input power.

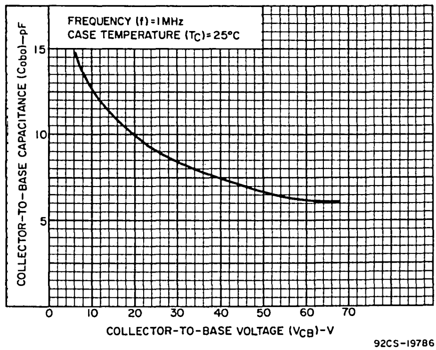


Fig. 4—Collector-to-base capacitance vs. collector-to-base voltage.

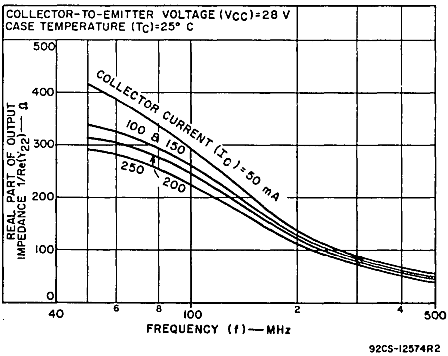


Fig. 5—Parallel output resistance vs. frequency.

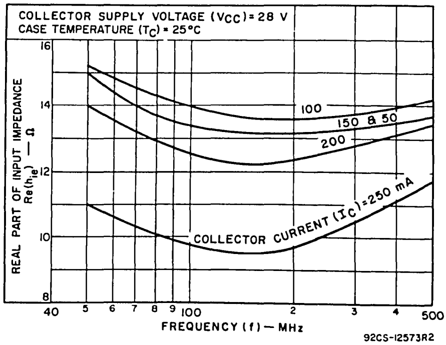


Fig. 6—Series input resistance vs. frequency.

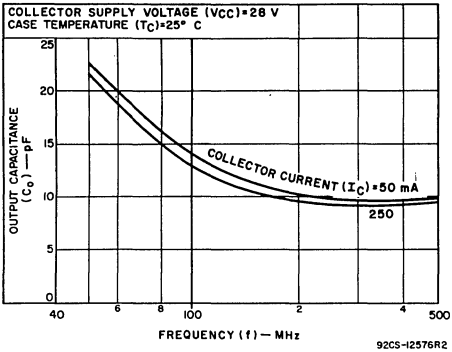


Fig. 7—Parallel output capacitance vs. frequency.

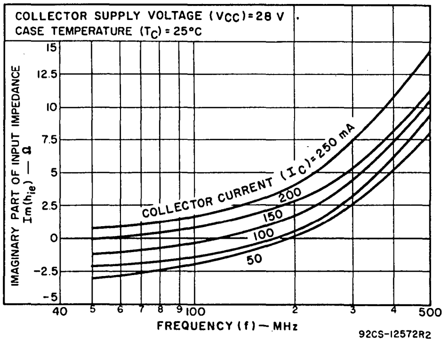
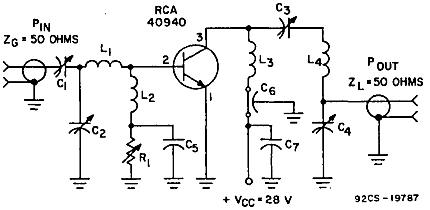
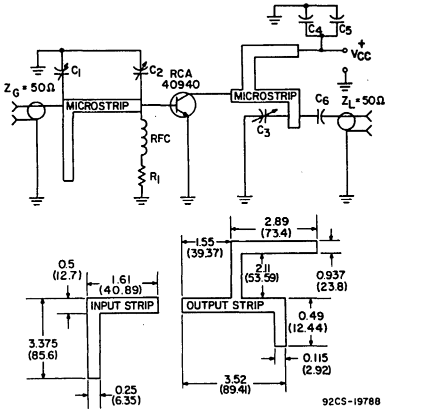


Fig. 8—Series input reactance vs. frequency.



C_1, C_2, C_3, C_4: 7-100 pF
C_5: 0.005 μF disc ceramic
C_6: 1000 pF
C_7: 0.01 μF disc ceramic
L_1: 2 turns No. 16 wire, 0.375 in. (9.5 mm) ID, 0.75 in. (19.05 mm) long
L_2, L_3: 1.5 μH
L_4: 7 turns No. 16 wire, 0.375 in. (9.5 mm) ID, 1 in. (25.4 mm) long
R_1: 1000 Ω

Fig. 9—100-MHz amplifier test circuit for measurement of power output.



C_1, C_2, C_3: 2-18 pF, Amperex HT10MA/218, or equivalent
C_4, C_5: 1 μF electrolytic
C_6: 1000 pF, ATC-100, or equivalent
R_1: 5.1 Ω, ½ W carbon
RFC: 0.12 μH

NOTES:

1. Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.
2. Produced by removing upper layer of double-clad, Teflon board, Budd Co. Polychem Div. Grade 108T, 1 oz, 1/32 in. (0.79 mm) thick, (ϵ = 2.6), or equivalent.

Fig. 10—400-MHz amplifier test circuit for measurement of power output.

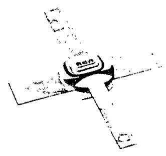
RCA
Solid State
Division

RF Power Transistors

40941

Silicon N-P-N Overlay Transistor

High-Gain Driver for VHF/UHF Applications
in Military and Industrial Communications Equipment



RCA HF-31 H-1676

Features:

- **High power gain, unneutralized class C amplifier:**
  1 W output at 400 MHz (10 dB gain)
  1 W output at 250 MHz (15 dB gain)
  1 W output at 175 MHz (17 dB gain)
  1 W output at 100 MHz (20 dB gain)
- **Low output capacitance**
  C_{obo} = 4 pF max.

RCA–40941* is an expitaxial silicon n-p-n planar transistor employing an advanced version of the RCA-developed "overlay" emitter-electrode design. This electrode consists of many isolated emitter sites connected together through the use of a diffused-grid structure and a metal overlay which is deposited on a silicon oxide insulating layer by means of a photo-etching technique. This overlay design provides a very high emitter periphery-to-emitter area ratio resulting in low output capacitance, high rf current handling capability, and substantially higher power gain.

The 40941 is intended for class-A, -B, or -C amplifier, frequency-multiplier, or oscillator circuits: it may be used in output, driver, or pre-driver stages in vhf and uhf equipment.

*Formerly RCA Dev. No. TA7680.

MAXIMUM RATINGS, *Absolute Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	30	V
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	55	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
COLLECTOR CURRENT:	I_C		
Continuous		0.4	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		5	W
At case temperatures above 75°C, derate linearly at		0.04	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to +200	°C
CASE TEMPERATURE (During soldering):			
For 10 s max		230	°C

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C unless otherwise specified.

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage (V) V_{CE}	DC Voltage (V) V_{EB}	DC Current (mA) I_E	DC Current (mA) I_B	DC Current (mA) I_C	LIMITS Min.	LIMITS Max.	UNITS
Collector-Cutoff Current: With base-emitter junction reverse-biased	I_{CEX}	55	1.5				–	0.1	mA
At T_C = 200°C		30	1.5				–	0.1	mA
With base open	I_{CEO}	28			0		–	20	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	55	–	V
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	5	30	–	V
With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$		0			5	55	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
Emitter-Cutoff Current	I_{EBO}		3.5				–	0.1	mA
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				20	100	–	1.0	V
DC Forward-Current Transfer Ratio	h_{FE}	5				360	5	–	
		5				50	10	200	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	22	°C/W

DYNAMIC

TEST & CONDITIONS	SYMBOL	FREQUENCY MHZ	LIMITS MINIMUM	LIMITS MAXIMUM	UNITS
Power Output (V_{CC} = 28 V): P_{IE} = 0.1 W (See Fig. 2)	P_{OE}	400	1.0	–	W
Large-Signal Common-Emitter Power Gain (V_{CC} = 28 V): P_{IE} = 0.1 W	G_{PE}	400	10	–	dB
Collector Efficiency (V_{CC} = 28 V): P_{IE} = 0.1 W, P_{OE} = 1 W, Source Impedance = 50 Ω	η_C	400	45	–	%
Magnitude of Common-Emitter, Small Signal, Short-Circuit Forward-Current Transfer Ratio I_C = 50 mA, V_{CE} = 15 V	h_{fe}	200	2.5	–	
Common-Base Output Capacitance (V_{CB} = 28 V)	C_{obo}	1	–	4	pF

PERFORMANCE DATA

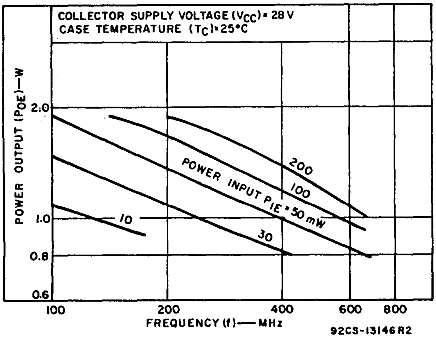
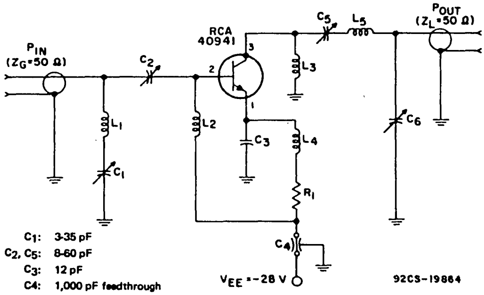


Fig. 1—Power output vs. frequency.



C1: 3-35 pF
C2, C5: 8-60 pF
C3: 12 pF
C4: 1,000 pF feedthrough
C6: 0.9-7 pF
L1: 2 turns No. 18 wire, 0.25 in. (6.35 mm) ID, 0.125 in. (3.17 mm) long
L2: Ferrite rf choke, 1 turn, Z = 450 Ω
L3, L4: RF choke, 0.1 μH
L5: 2-1/2 turns, No. 18 wire, 0.25 in. (6.35 mm) ID, 0.187 in. (4.76 mm) long
R1: 5.6 Ω, 1 W

Fig. 2—RF amplifier circuit for power output test (400-MHz operation).

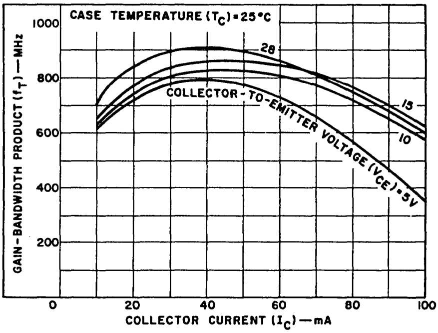


Fig. 3—Gain-bandwidth product vs. collector current.

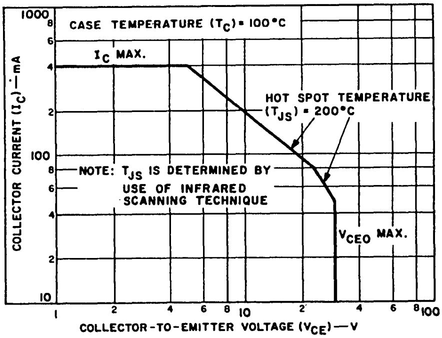


Fig. 4—Safe area for dc operation.

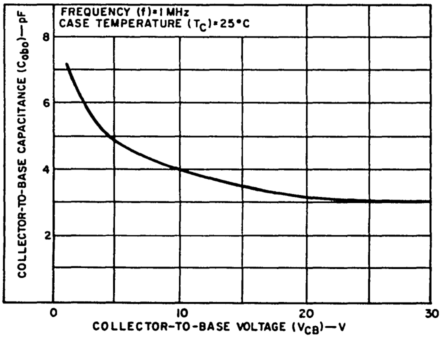


Fig. 5—Variation of collector-to-base capacitance.

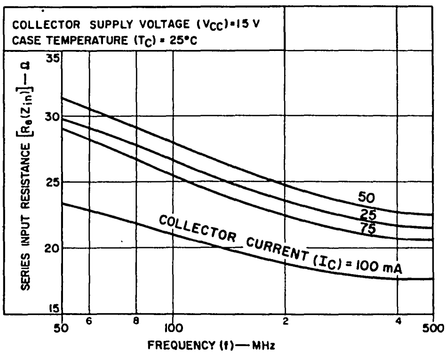


Fig. 6—Typical series input resistance vs. frequency.

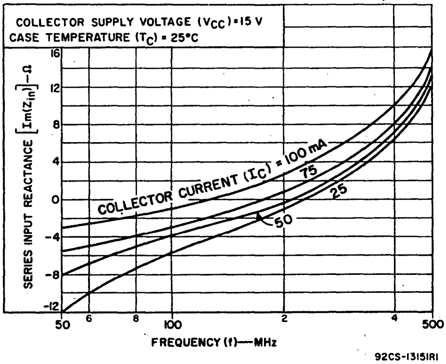


Fig. 7—Typical series input reactance vs. frequency.

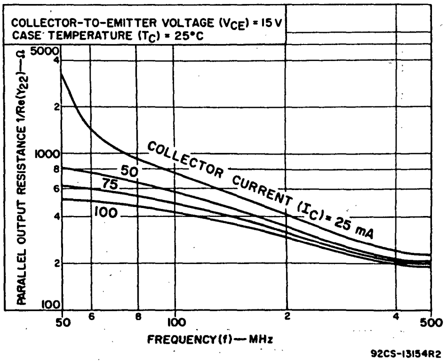


Fig. 8—Typical parallel output resistance vs. frequency.

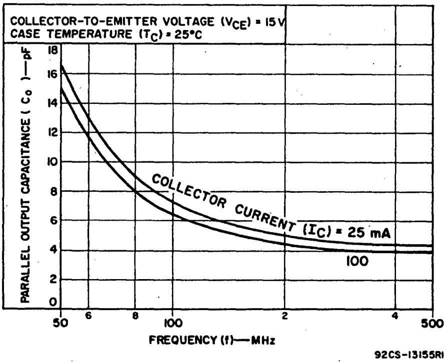


Fig. 9—Typical parallel output capacitance vs. frequency.

TERMINAL CONNECTIONS

Terminals 1, 3—Emitter
Terminal 2 —Base
Terminal 4 —Collector

WARNING: The ceramic body of this device contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA
Solid State
Division

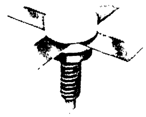
RF Power Transistors

40953 40954 40955

40953

JEDEC TO-39

H-1381



40954
40955

RCA HF-44

H-1779

1.75-, 10-, and 25-W, 156-MHz Silicon N-P-N Overlay Transistors

For High-Power VHF Amplifiers

Features

- Designed for vhf marine transmitters
- 25 W (min.) output at 156 MHz (12.5-V supply)
- Infinite VSWR load-tested at constant input power, f = 156 MHz, V_{CC} = 15.5 V (40955)

RCA-40953, 40954, and 40955* are epitaxial silicon n-p-n planar transistors of the overlay emitter electrode construction. They are intended for high-power-output, vhf, class-C amplifier service in low-voltage-supply applications.

These devices are especially intended for use in vhf marine transmitters operating from a 12.5-volt supply. The 40954 and 40955 are emitter-ballasted, and all 40955 units are tested at constant input power (f = 156 MHz, V_{CC} = 15.5 V, infinite load VSWR).

* Types 40954 and 40955 are the former RCA Dev. Nos. TA8559 and TA8561, respectively.

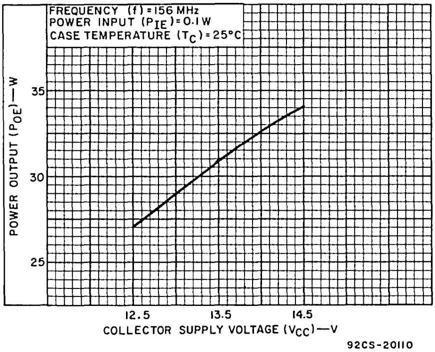


Fig. 1—Power output vs. supply voltage for amplifier shown in Fig. 6.

MAXIMUM RATINGS, *Absolute Maximum Values:*

		40953	40954	40955	
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:					
With base shorted to emitter	$V_{(BR)CES}$	36	36	36	V
With base open	$V_{(BR)CEO}$	14	14	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.33	4.5	5	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 75°C		3.5	25	35.7	W
At case temperatures above 75°C, derate linearly		0.028	0.2	0.286	W/°C
TEMPERATURE RANGE:					
Storage and operating (Junction)			–65 to +200		°C
LEAD TEMPERATURE (During soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.			230		°C

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage V		DC Current mA			LIMITS: 40953		40954		40955		UNITS
		V_{CE}	V_{EB}	I_E	I_B	I_C	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector-Cutoff Current: Base connected to emitter	I_{CES}	12.5			0		–	1	–	10	–	10	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	25[a]	14	–	–	–	–	–	V
					0	200	–	–	14	–	14	–	V
With base connected to emitter	$V_{(BR)CES}$		0			25[a]	36	–	–	–	–	–	V
						200	–	–	36	–	36	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	–	–	–	–	V
				5		0	–	–	3.5	–	3.5	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	35.7	–	5	–	3.5	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

TEST & CONDITIONS	SYMBOL	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	FREQUENCY (f)-MHz	LIMITS: 40953 MIN.	40953 MAX.	40954 MIN.	40954 MAX.	40955 MIN.	40955 MAX.	UNITS
Power Output: P_{IE} = 0.1 W (40953) 1.75 W (40954) 9 W (40955)	P_{OE}	12.5	156	1.75	–	10	–	25	–	W
Large-Signal Common-Emitter Power Gain: P_{OE}=1.75 W (40953) 10 W (40954) 25 W (40955)	G_{PE}	12.5	156	12.4	–	7.6	–	4.5	–	dB
Collector Efficiency: P_{OE} = 1.75 W (40953) 10 W (40954) 25 W (40955)	η_C	12.5	156	50	–	60	–	60	–	%
Collector-to-Base Output Capacitance	C_{obo}	12.5 (V_{CB})	1	–	15	–	30	–	80	pF

Type 40953

TERMINAL CONNECTIONS

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

Types 40954 and 40955

TERMINAL CONNECTIONS

LEADS 1 & 3 – EMITTER
LEAD 2 – BASE
LEAD 4 – COLLECTOR

WARNING: The body of types 40954 and 40955 contains beryllium oxide. Do not crush, grind, or abrade that portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

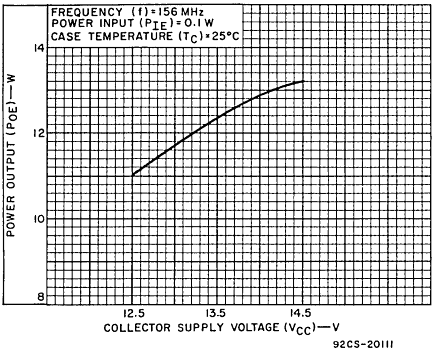


Fig.2–Power output vs. supply voltage for amplifier shown in Fig. 7.

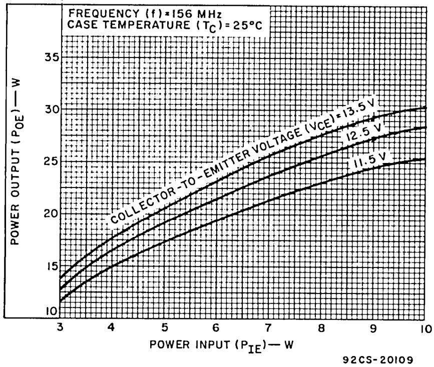


Fig.3–Typical power output vs. power input at 156 MHz for type 40955 in circuit shown in Fig. 9.

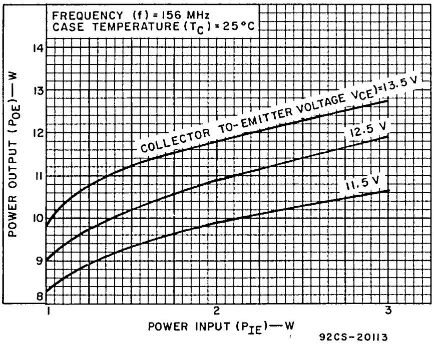


Fig.4–Typical power output vs. power input at 156 MHz for type 40954 in circuit shown in Fig. 9.

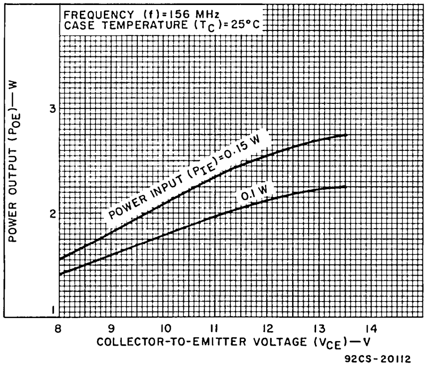
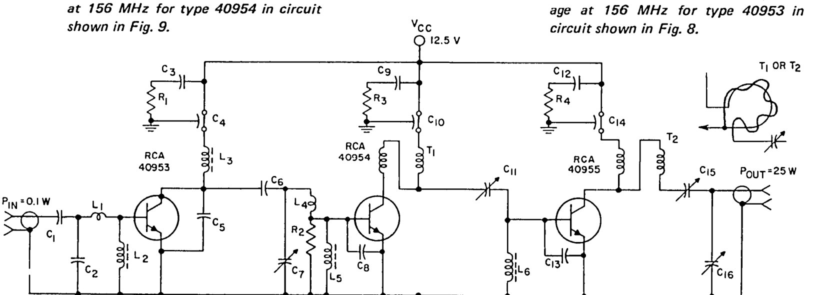
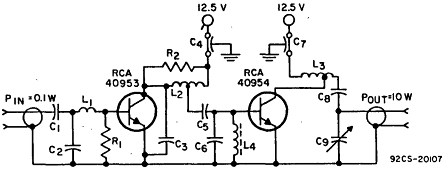


Fig.5–Typical power output vs. supply voltage at 156 MHz for type 40953 in circuit shown in Fig. 8.



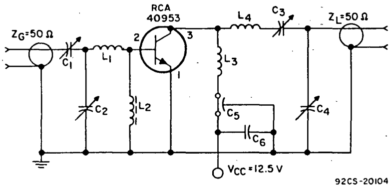
$C_{1,2}$: 18 pF silver mica
$C_{3,9,12}$: 0.02 μF disc ceramic
$C_{4,10,14}$: 0.001 μF feedthrough
C_5: 10 pF silver mica
C_6: 100 pF silver mica
$C_{7,15,16}$: 14–150 pF, ARCO 424, or equivalent
$C_{8,13}$: 120 pF silver mica
C_{11}: 7–100 pF, ARCO 423, or equivalent
$R_{1,3,4}$: 12Ω, 1/4 W
R_2: 20Ω, 1/4 W
L_1: 2 turns No. 20 enameled wire 3/16 in. (4.76 mm) ID, 1/8 in. (3.175 mm) long
L_2: 1 turn No. 28 enameled wire on Ferroxcube bead #56 590/4B
L_3: 0.39 μH, Nytronics Deci-Ductor, or equivalent
L_4: 1 turn No. 20 enameled wire 1/8 in. (3.175 mm) ID, 1/16 in. (1.58 mm) long
$L_{5,6}$: Z = 450Ω, Ferroxcube VK-200-09/3B, or equivalent
$T_{1,2}$: Twisted pair of No. 20 enameled wire 14 turns/in. Formed in a loop 3/8 in. (9.52 mm) diameter, cross connected (End of one winding connected to beginning of other)

Fig.6–156-MHz, 25-W amplifier for marine equipment



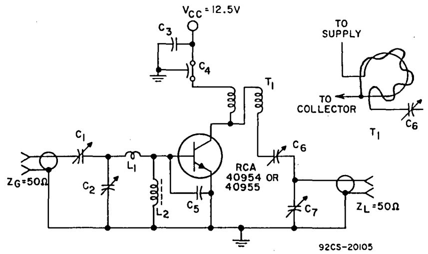
$C_{1,\ 2}$: 18 pF silver mica
C_3: 5 pF
$C_{4,\ 7}$: 0.001 μF feedthrough
C_5: 50 pF silver mica
C_6: 82 pF silver mica
C_8: 0.002 μF ceramic
C_9: 15–115 pF, ARCO 406, or equivalent
R_1: 39Ω, 1/4 W
R_2: 360Ω, 1/4 W
L_1: 2 turns No. 20 enameled wire 3/16 in. (4.76 mm) ID, 1/8 in. (3.175 mm) long
L_2: 4 turns No. 18 bare tinned wire 5/32 in. (3.96 mm) ID, 5/16 in. (7.93 mm) long; tap 3-1/2 turns from collector
L_3: 8 turns No. 18 bare tinned wire 5/32 in. (3.96 mm) ID, 9/16 in. (14.28 mm) long; tap 1 turn from C_8
L_4: RFC, Z = 450Ω, Ferroxcube VK-200-09/3B, or equivalent

Fig.7—156-MHz, 10-W amplifier for marine equipment.



$C_{1,\ 2,\ 3,\ 4}$: 7–35 pF, ARCO 403, or equivalent
C_5: 1,000 pF feedthrough
C_6: 0.005 μF disc ceramic
L_1: 2 turns No. 16 wire, 3/16 in. (4.76 mm) ID, 1/4 in. (6.35 mm) long
L_2: Z = 450 Ω Ferrocube VK-200-09/3B, or equivalent
L_3: 2 turns No. 14 wire, 1/4 in. (6.35 mm) ID, 5/16 in. (7.93 mm)
L_4: 3 turns No. 14 wire, 3/8 in. (9.52 mm) ID, 3/8 in. (9.52 mm) long

Fig.8—156-MHz amplifier test circuit for measurement of power output of 40953.



C_1: 7–100 pF, ARCO 423, or equivalent
C_2: 4–40 pF, ARCO 422, or equivalent
C_3: 0.1 μF ceramic
C_4: 0.001 μF feedthrough
C_5: 150 pF, ATC-100-B-150, or equivalent
C_6: 14–150 pF, ARCO 424, or equivalent
C_7: 24–200 pF, ARCO 425, or equivalent
L_1: 1/2 turn No. 14 wire, 1/4 in. (6.35 mm) ID
L_2: RFC, Z = 450Ω, Ferroxcube VK-200-09/3B, or equivalent
T_1: Twisted pair of No. 20 enameled wire; 14 turns/in. Formed in a loop 3/8 in. (9.52 mm) diameter, cross connected (End of one winding connected to beginning of other)

Fig.9—156-MHz amplifier test circuit for measurement of power output of 40954 and 40955.

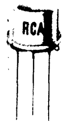
RCA

Solid State
Division

RF Power Transistors

40964
40965

Silicon N-P-N Overlay Transistors



JEDEC TO-39

High-Gain Devices for Class C VHF/UHF Multiplier and Amplifier Service

Features:

- **High power gain:**
  6 dB (min.) up to f = 470 MHz (40964 tripler)
  7 dB (min.) at f = 470 MHz (40965 amplifier)

RCA types 40964 and 40965● are epitaxial silicon n-p-n planar transistors featuring the overlay emitter-electrode construction. They are intended for vhf/uhf mobile and portable transmitters where intermediate power output is required at low supply voltage.

Type 40964 is especially useful as a frequency tripler into the 450-to-470-MHz band. The 40965 is intended for amplifier service in this band.

● Formerly RCA Dev. Nos. TA7514 and TA7588, respectively.

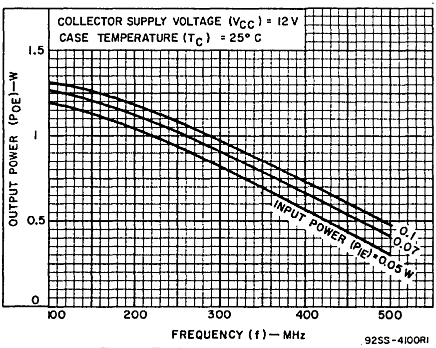


Fig. 1— Typical power output vs. frequency for 40965.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 33Ω	V_{CER}(sus)	36	V
With base open	V_{CEO}(sus)	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	2	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.2	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		3.5	W
At case temperatures above 25°C		See Fig. 6	
TEMPERATURE RANGE:			
Storage & Operating (Junction)		-65 to 200	°C
LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max		230	°C

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS Voltage V dc V_{CE}	Current mA dc I_E	I_B	I_C	LIMITS 40964 40965 Min.	Max.	UNITS
Collector-Cutoff Current	I_{CEO}	10		0		–	0.1	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0			36	–	V
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$			0	5[a]	14	–	V
With external base-to-emitter resistance (R_{BE}) = 33Ω	$V_{CER}(sus)$				5[a]	36	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.1		0	2	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	50	°C/W

[a]Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS Collector Supply (V_{CC}) - V dc	Input Power (P_{IE}) - W	Frequency (f) - MHz	LIMITS 40964 Min.	40964 Typ.	40965 Min.	40965 Typ.	UNITS
Power Output	P_{OE}	12	0.1	156.7-470	0.4	0.44	–	–	W
				470	–	–	0.5	0.55	
		8	0.1	156.7-470	–	0.33	–	–	
				470	–	–	–	0.33	
Power Gain	G_{PE}	12	0.1	156.7-470	6	6.4	–	–	dB
				470	–	–	7	7.4	
		8	0.1	156.7-470	–	5.2	–	–	
				470	–	–	–	5.2	
Collector Efficiency	η_C	12	0.1	156.7-470	25	–	–	–	%
				470	–	–	40	–	
		8	0.1	156.7-470	–	25	–	–	
				470	–	–	–	40	
Collector-to-Base Capacitance	C_{obo}	V_{CB} = 12 V I_C = 0	–	1	–	5 (max.)	–	5 (max.)	pF
Gain-Bandwidth Product	f_T	V_{CE} = 12 V I_C = 50 mA	–	–	–	700	–	700	MHz

TERMINAL CONNECTIONS

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

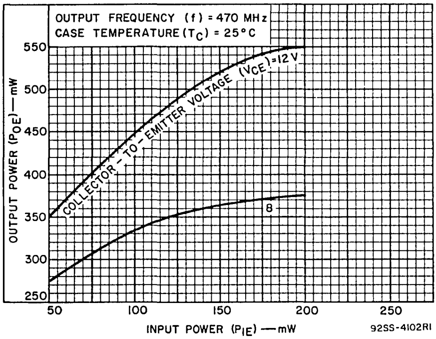


Fig. 2— Typical power output vs. power input for 40964 in the tripler circuit shown in Fig. 4.

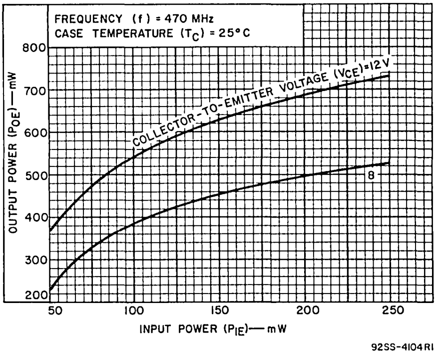
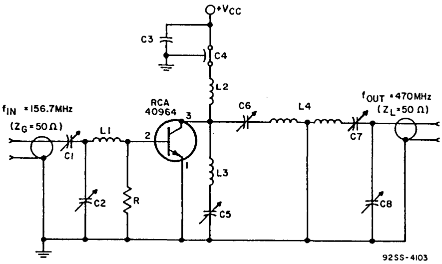
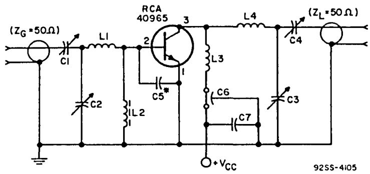


Fig. 3— Typical power output vs. power input for 40965 in the amplifier circuit shown in Fig. 5.



C1, C2: 8-60 pF, ARCO 404, or equivalent
C3: 0.01 μF, disc ceramic
C4: 1000 pF, feedthrough
C5: 1.5-20 pF
C6: 0.9-7 pF, ARCO 400, or equivalent
C7, C8: 1.5-20 pF, ARCO 402, or equivalent
L1, L2: 2 turns No. 18 wire, 1/4 in. (6.35 mm) ID, 1/4 in. (6.35 mm) long
L3: 3 turns No. 18 wire, 1/4 in. (6.35 mm) ID, 5/16 in. (7.93 mm) long
L4: 2 coils (1-1/4 turns No. 22 enamel wire, 1/4 in. (6.35 mm) ID, close-wound) wound in opposite directions, with 1/8 in. (3.17 mm) space between each section
R: 33 Ω, 1/4 W, carbon

Fig. 4— Tripler circuit (156.7 to 470 MHz) for measurement of power output for type 40964.



C1, C2, C3: 0.9-7 pF, ARCO 400, or equivalent
C4: 7-35 pF, ARCO 403, or equivalent
C5: 22 pF ±5%, silver mica
C6: 470 pF, feedthrough
C7: 0.1 μF, disc ceramic
L1: 1-1/2 turn No. 18 wire, 1/4 in. (6.35 mm) ID, 1/8 in. (3.17 mm) long
L2: 0.39 μH, Nytronics Deciductor, or equivalent
L3: 1 turn No. 18 wire, 7/32 in. (5.55 mm) ID, 1/8 in. (3.17 mm) long
L4: 1 turn No. 18 wire, 1/4 in. (6.35 mm) ID, 1/8 in. (3.17 mm) long

*Mounted as close as possible to base and emitter leads.

Fig. 5— 470-MHz amplifier test circuit for measurement of power output for type 40965.

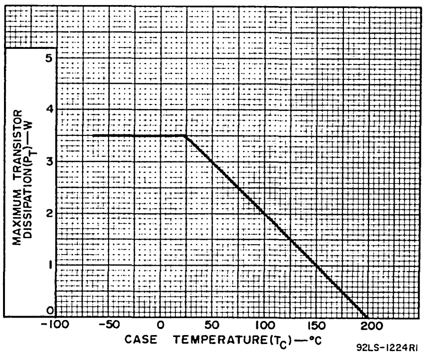
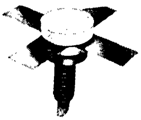


Fig. 6— Derating curve for both types.

Solid State
Division

RF Power Transistors

40967
40968



RCA HF-44 PACKAGE

H-1779

2-W and 6-W 470-MHz Silicon N-P-N Overlay Transistors

For UHF Amplifier Service

Features:

- **All devices tested at infinite VSWR with rated power input and V_{CC} = 15.5 V**
- **Devices capable of rated power output at elevated heat-sink temperatures**

RCA-40967 and 40968● are epitaxial silicon n-p-n planar transistors with overlay emitter-electrode construction. They are intended especially for uhf class C amplifier service in low-voltage-supply mobile applications.

●Formerly RCA Dev. Nos. TA8562 and TA8563, respectively.

TERMINAL CONNECTIONS

Leads 1 & 3 – EMITTER
Lead 2 – BASE
Lead 4 – COLLECTOR

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

MAXIMUM RATINGS, *Absolute Maximum Values*

		40967	40968	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	36	V
COLLECTOR-TO-EMITTER VOLTAGE:				
With base open	V_{CEO}	14	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.5	1.5	A
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 75°C		5.7	10.7	W
TEMPERATURE RANGE:				
Storage and operating (Junction)		← –65 to +200 →		°C
LEAD TEMPERATURE (During soldering):				
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		← 200 →		°C

8-72

ELECTRICAL CHARACTERISTICS, at Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage (V) V_{CE}	DC Voltage (V) V_{EB}	DC Current (mA) I_E	DC Current (mA) I_B	DC Current (mA) I_C	LIMITS 40967 MIN.	40967 MAX.	40968 MIN.	40968 MAX.	UNITS
Collector-Cutoff Current: Base connected to emitter	I_{CES}	12.5	0				–	1	–	5	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	25	14	–	–	–	V
					0	75[a]	–	–	14	–	V
With base connected to emitter	$V_{(BR)CES}$		0			25	36	–	–	–	V
			0			75[a]	–	–	36	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	–	–	V
				1		0	–	–	3.5	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	22	–	11.7	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%

DYNAMIC

TEST CONDITIONS	SYMBOL	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	FREQUENCY (f) – MHz	LIMITS 40967 MIN.	40967 MAX.	40968 MIN.	40968 MAX.	UNITS
Power Output: P_{IE} = 0.4 W (40967) 2 W (40968)	P_{OE}	12.5	470	2	–	6	–	W
Collector Efficiency: P_{OE} = 2 W (40967) 6 W (40968)	η_C	12.5	470	60	–	60	–	%
Collector-to-Base Output Capacitance	C_{obo}	12.5(V_{CB})	1	–	15	–	30	pF

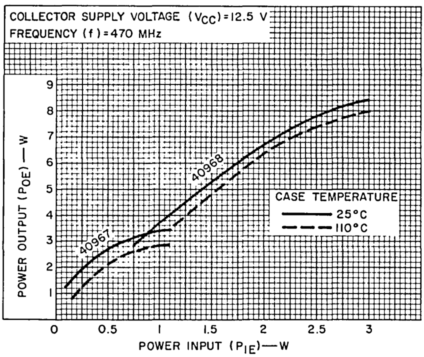


Fig.1—Typical power output vs. power input at 470 MHz for both types.

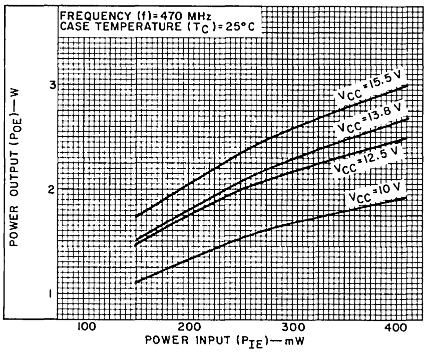


Fig.2—Typical power output vs. power input for 40967.

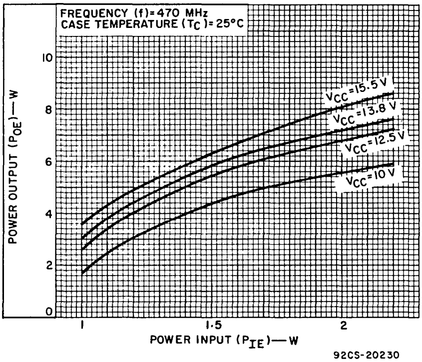
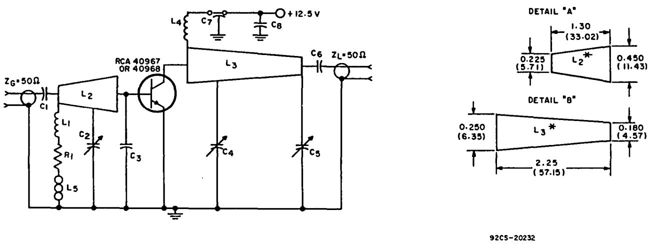


Fig.3—Typical power output vs. power input for 40968.



NOTES: C3 placement as close to base lead as possible.
C2 tapped 0.6 in. (15.24 mm) from base.
C4 tapped 0.70 in. (17.78 mm) from collector.

*Produced by etching upper layer of double copper-clad Teflon-fiber board, 0.0625 in. (1.58 mm) thick (ϵ = 2.6).

C1,3: 15 pF, American Technical Ceramics, ATC-100•
C2,4,5: 2-18 pF, Amperex HT 10KA/218•
C6: 300 pF, ATC-100•
C7: 1000 pF, feedthrough
C8: 0.01 μF ceramic disc
L1: 0.22 μH RFC

L2: See Detail "A"
L3: See Detail "B"
L4: 10 turns No. 18 wire, 0.125 in. (3.17 mm) ID
L5: Ferroxcube bead No. 56-590-65/46• over resistor lead
R1: 0.47 Ω, 1 W

Dimensions in parentheses are in millimeters and are derived from the original inch dimensions.

•Or equivalent

Fig.4—470-MHz test amplifier for 40967 and 40968.

RCA

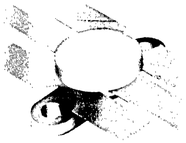
Solid State
Division

RF Power Transistors

40970
40971

30-W and 45-W, 12.5-V, UHF Mobile, Silicon N-P-N Overlay Transistors

With Internally Mounted Input-Matching Networks



RCA HF-40 H-1781

Features:

- **Internally mounted input "T" matching networks using MOS base-to-emitter capacitors**
- **Low input Q and increased input resistance for optimum broadband performance**
- **Withstand infinite load-mismatch at rated input power with V_{CC} = 15.5 V**
- **Emitter-ballasting and low thermal resistance ($R_{\theta JC}$) for added reliability**

Types 40970 and 40971* are epitaxial silicon n-p-n planar transistors with overlay multiple-emitter-site construction and emitter-ballasting resistors for improved ruggedness and increased overdrive capability.

The 40970 and 40971 incorporate internally mounted base-to-emitter MOS capacitors in an individual "T" matching network for each base cell, thus providing high input resistance and low input Q for broadband performance capability.

These transistors are intended for use in high-power broadband mobile uhf amplifiers operating from a 12.5-volt supply.

* Formerly RCA Dev. Nos. TA8172 and TA8493.

TERMINAL CONNECTIONS

Terminals No. 1 & 3 – Emitter

Terminal No. 2 – Base

Terminal No. 4 – Collector

WARNING: **The ceramic heat-sink portion of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.**

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		40970	40971	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	36	V
COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}	16	16	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	4	4	V
TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 120°C		53.5	80	W
At case temperature above 120°C, derate at		0.67	1	W/°C
TEMPERATURE RANGE:				
Storage and Operating (Junction)		–65 to +200		°C
CASE TEMPERATURE (during soldering)				
For 10 s max.		230		°C

ELECTRICAL CHARACTERISTICS *at Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc		TEST CONDITIONS: CURRENT mA dc		LIMITS: 40970		LIMITS: 40971		UNITS
		V_{CE}	V_{EB}	I_E	I_C	MIN.	MAX.	MIN.	MAX.	
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				200	16	–	16	–	V
With base connected to emitter	$V_{(BR)CES}$		0		200	36	–	36	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			5 10	0 0	4 –	– –	– 4	– –	V
Collector Cutoff Current	I_{CES}	12.5	0			–	5	–	10	mA
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	1.5	–	1	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: SUPPLY VOLTAGE (V_{CC})–V	TEST CONDITIONS: INPUT POWER (P_{IE}) - W	TEST CONDITIONS: FREQUENCY (f) - MHz	LIMITS: 40970 MIN.	LIMITS: 40970 MAX.	LIMITS: 40971 MIN.	LIMITS: 40971 MAX.	UNITS
Output Power	P_{OE}	12.5	10 15	470 470	30 –	– –	– 45	– –	W
Power Gain	G_{PE}	12.5	10 15	470 470	4.7 –	– –	– 4.7	– –	dB
Collector Efficiency	η_C	12.5	10 15	470 470	60 –	– –	– 55	– –	%
Collector-to-Base Capacitance	C_{obo}	12.5 (V_{CB})	–	1	–	110	–	220	pF
Load Mismatch (See Fig. 17)	LM	15.5	10 15	470 470	GO/NO GO –		– GO/NO GO		

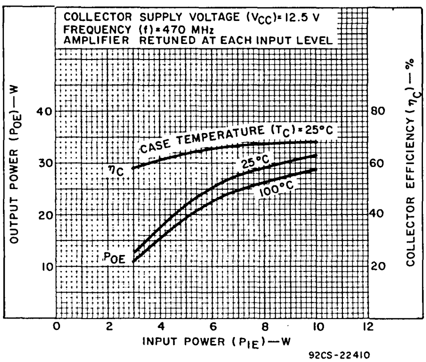


Fig. 1 – Typical output power and collector efficiency vs. input power for 40970 in test circuit of Fig. 13.

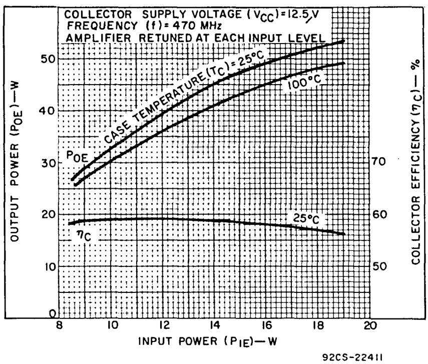


Fig. 2 – Typical output power and collector efficiency vs. input power for 40971 in test circuit of Fig. 13.

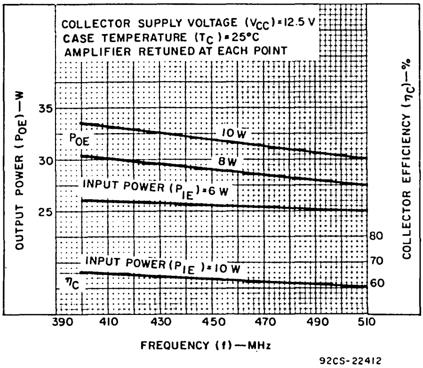


Fig. 3 — Typical output power and collector efficiency vs. frequency for 40970 in test circuit of Fig. 13.

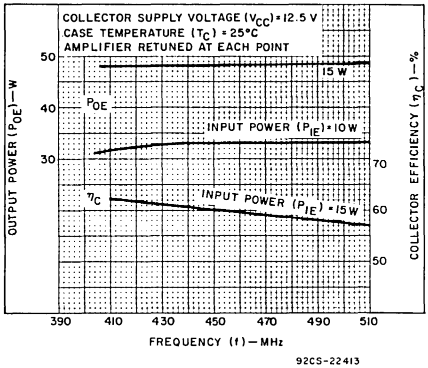


Fig. 4 — Typical output power and collector efficiency vs. frequency for 40971 in test circuit of Fig. 13.

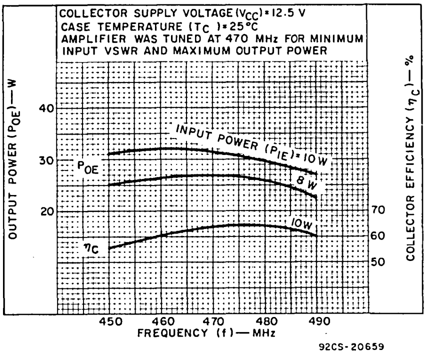


Fig. 5 — Typical broadband output power and collector efficiency vs. frequency for 40970 in amplifier circuit of Fig. 15.

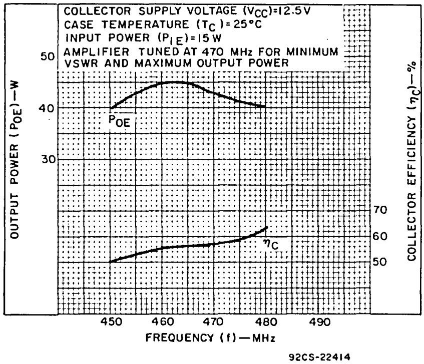


Fig. 6 — Typical broadband output power and collector efficiency vs. frequency for 40971 in amplifier circuit of Fig. 15.

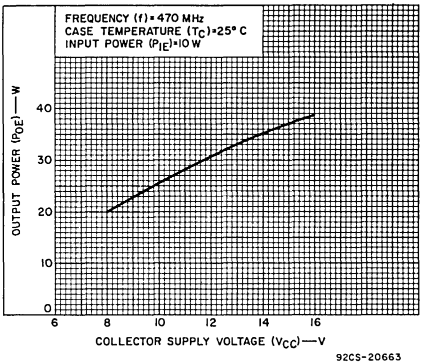


Fig. 7 — Typical output power vs. collector supply voltage for 40970.

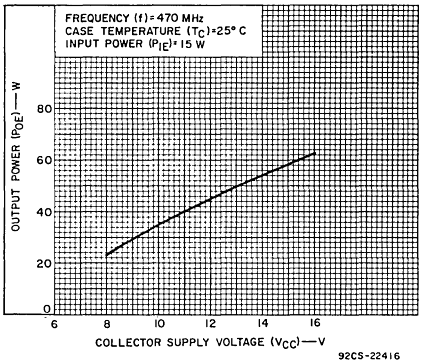


Fig. 8 — Typical output power vs. collector supply voltage for 40971.

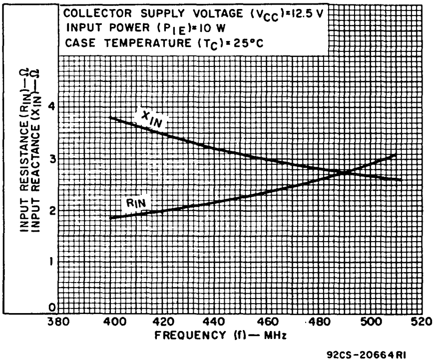


Fig. 9 — Typical large-signal series input impedance vs. frequency for 40970.

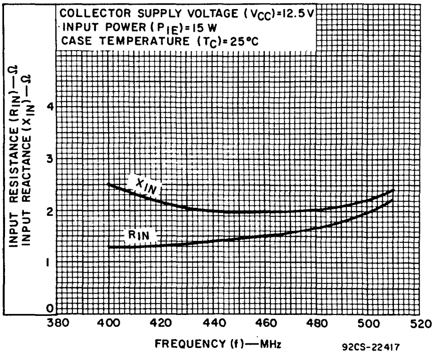


Fig. 10 — Typical large-signal series input impedance vs. frequency for 40971.

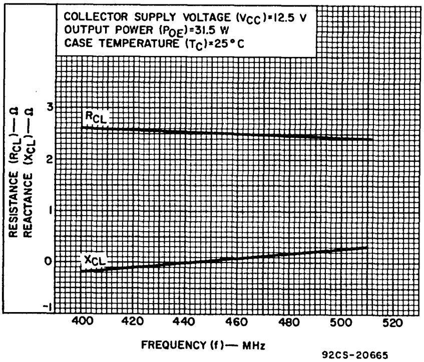


Fig. 11 — Typical collector load resistance and collector load reactance vs. frequency for 40970.

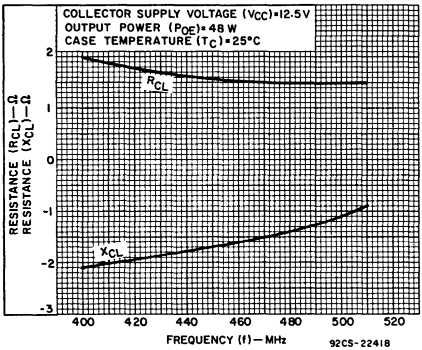
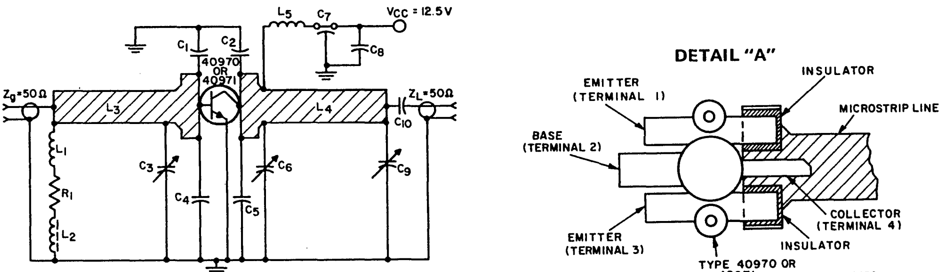


Fig. 12 — Typical collector load resistance and collector load reactance vs. frequency for 40971.



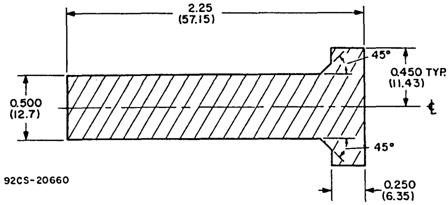
NOTE: A 0.002-in. (0.05-mm) insulator must be used under each emitter terminal to prevent grounding of the microstrip lines (see Detail "A").

C1, C4: 10 pF, disc, Allen-Bradley•
C2: 22 pF, disc, Allen-Bradley•
C3, C6, C9: 0.8–10 pF, Johanson•
C5, C10: 8.2 pF, disc, Allen-Bradley•
C7: 1000 pF, feedthrough
C8: 0.01 μF, disc, ceramic

L1: 0.22 μH RFC
L2: Ferroxube Bead No. 56-590-65/48•
L3, L4: See detail of construction (Fig. 14)
L5: 10 turns, No.20 wire, 0.187 in. (4.75 mm) ID
R1: 0.47 Ω, 1 W

•Or equivalent
Allen-Bradley Co., Milwaukee, Wisc.
Amperex, Hicksville, N.Y.
Ferroxcube Corp. of America, Saugerties, N. Y.
Johanson Mfg. Corp., Boonton, N.J.

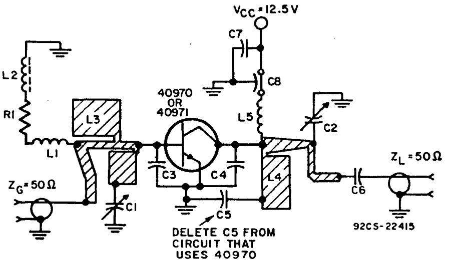
Fig. 13 — Amplifier test circuit for measurement of output power, gain, efficiency, and load mismatch, for 40970 and 40971.



NOTE 1: Produced by etching upper layer of double copper-clad Teflon glass epoxy board: 1/16 in. (1.58 mm) thick, $\epsilon = 2.6$.

NOTE 2: Dimensions in parentheses are in millimeters.

Fig. 14 – Construction details for L_3 and L_4 in amplifier test circuit of Fig. 13.

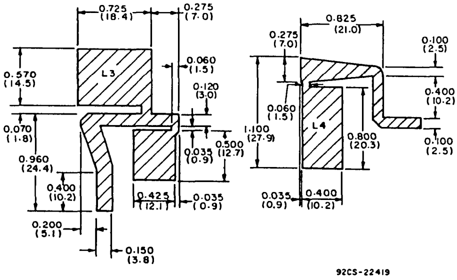


NOTE: Capacitors C3 and C4 are placed directly under base and collector terminals to ground

C1, C2: 2–18 pF, Amperex No. HT10MA/218•
C3: 47 pF, disc, Allen-Bradley•
C4: 47 pF, disc, Allen-Bradley•
C5: 6.8 pF, disc, Allen-Bradley• (omit from circuit that uses 40970)
C6: 1000 pF, disc, Allen-Bradley•
C7: 1 μF, electrolytic
C8: 1000 pF, feedthrough
L1: 0.22 μH RFC
L2: Ferroxcube Bead No. 56-590-65/48•
L3, L4: See detail of construction (Fig. 16)
L5: 15 turns, No.18 wire, 0.187 in. (4.75 mm) ID
R1: 0.47 Ω, 1W

•Or equivalent
Allen-Bradley Co., Milwaukee, Wisc.
Amperex, Hicksville, N.Y.
Ferroxcube Corp. of America, Saugerties, N. Y.

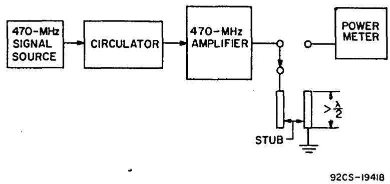
Fig. 15 – 450-470-MHz broadband amplifier circuit for 30 watts (using 40970) or 45 watts (using 40971).



NOTE 1: Produced by etching upper layer of double copper-clad Teflon glass epoxy board: 1/16 in. (1.58 mm) thick, $\epsilon = 2.6$.

NOTE 2: Dimensions in parentheses are in millimeters.

Fig. 16 – Construction details for L_3 and L_4 in 450-470-MHz broadband amplifier circuit of Fig. 15.



The transistor must withstand any load mismatch provided by the following test conditions:

1. The test is performed using the arrangement shown.
2. The tuning stub is varied through a half-wavelength, which effectively varies the load from an open circuit to a short circuit.
3. Operating conditions: V_{CC} = 15.5 V; rf input power = 10 W for 40970, = 15 W for 40971.
4. Transistor dissipation rating must not be exceeded during the above test so that the transistor will not be damaged or degraded.

Fig. 17 – Arrangement for testing load-mismatch capability of 40970 and 40971.

RCA
Solid State
Division

RF Power Transistors

40972 40973 40974

40972
JEDEC TO-39

H-1381

40973
40974
RCA HF-44

H-1779

1.75-, 10-, and 25-W, 175-MHz Silicon N-P-N Overlay Transistors

For High-Power VHF Amplifiers

Features:

- **Designed for vhf mobile transmitters**
- **25 W (min.) output at 175 MHz (V_{CC} = 12.5 V)**
- **Infinite VSWR load-tested at constant input power, f = 175 MHz, V_{CC} = 15.5 V (40974)**

RCA-40972, 40973, and 40974 are epitaxial silicon n-p-n planar transistors of the overlay emitter-electrode construction. They are intended for high-power-output vhf class C amplifier service in low-voltage-supply applications.

These devices are especially intended for use in vhf mobile transmitters operating from a 12.5-volt supply. The 40973 and 40974 are emitter-ballasted, and all 40974 units are tested at constant input power (f = 175 MHz, V_{CC} = 15.5 V, infinite load VSWR).

MAXIMUM RATINGS, *Absolute Maximum Values:*

		40972	40973	40974	
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:					
With base shorted to emitter	$V_{(BR)CES}$	36	36	36	V
With base open	$V_{(BR)CEO}$	14	14	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.33	4.5	5	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 75°C		3.5	25	35.7	W
At case temperatures above 75°C, derate linearly		0.028	0.2	0.286	W/°C
TEMPERATURE RANGE:					
Storage and operating (Junction)			–65 to +200		°C
LEAD TEMPERATURE (During soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.			230		°C

8-72

ELECTRICAL CHARACTERISTICS, At Case Temperature (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS						UNITS
		Voltage V dc		Current mA dc			40972		40973		40974		
		V_{CE}	V_{EB}	I_E	I_B	I_C	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: Base connected to emitter	I_{CES}	12.5	0		0		–	1	–	10	–	10	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	25[a]	14	–	–	–	–	–	V
					0	200	–	–	14	–	14	–	
With base connected to emitter	$V_{(BR)CES}$		0			25[a]	36	–	–	–	–	–	
						200	–	–	36	–	36	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	–	–	–	–	V
				5		0	–	–	3.5	–	3.5	–	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	35.7	–	5	–	3.5	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

TEST & CONDITIONS	SYMBOL	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	FREQUENCY (f)-MHz	LIMITS						UNITS
				40972		40973		40974		
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Output Power: P_{IE} = 0.1 W (40972) 1.75 W (40973) 9 W (40974)	P_{OE}	12.5	175	1.75	–	10	–	25	–	W
Large-Signal Common-Emitter Power Gain: P_{OE} = 1.75 W (40972) 10 W (40973) 25 W (40974)	G_{PE}	12.5	175	12.4	–	7.6	–	4.5	–	dB
Collector Efficiency: P_{OE} = 1.75 W (40972) 10 W (40973) 25 W (40974)	η_C	12.5	175	50	–	60	–	60	–	%
Collector-to-Base Output Capacitance	C_{obo}	12.5 (V_{CB})	1	–	15	–	30	–	80	pF

TERMINAL CONNECTIONS FOR 40972

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

TERMINAL CONNECTIONS FOR 40973 AND 40974

LEADS 1 & 3 – EMITTER
LEAD 2 – BASE
LEAD 4 – COLLECTOR

WARNING: The bodies of types 40973 and 40974 contain beryllium oxide. Do not crush, grind, or abrade that portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

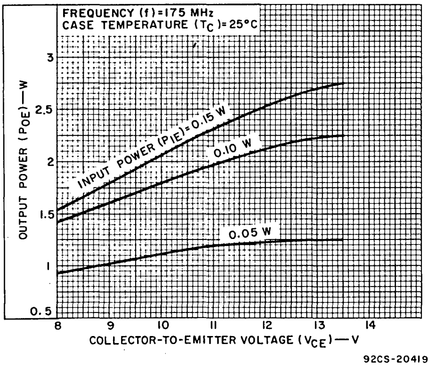


Fig. 1—Typical output power vs. supply voltage for RCA-40972 in the circuit of Fig. 4.

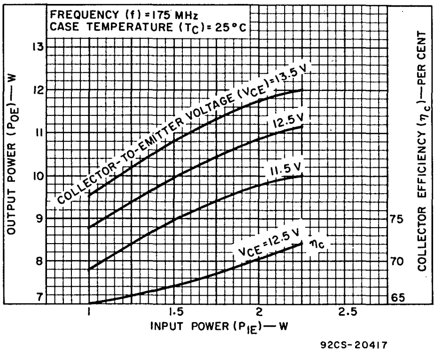


Fig.2—Typical output power and collector efficiency vs. input power for RCA-40973 in the circuit of Fig. 5.

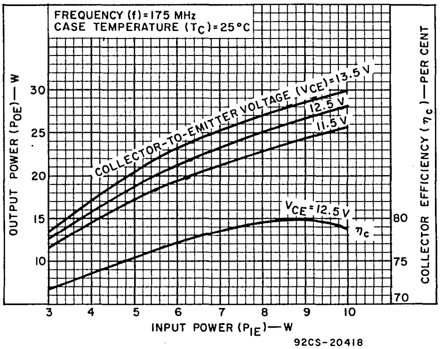
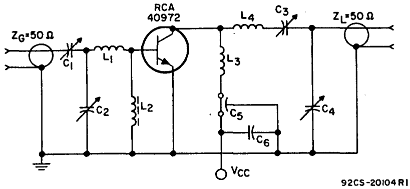
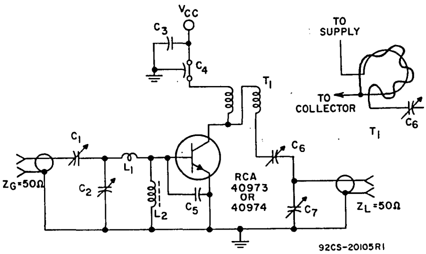


Fig.3—Typical output power and collector efficiency vs. input power for RCA-40974 in the circuit of Fig. 5.



$C_{1, 2, 3, 4}$: 7–35 pF, ARCO 403, or equivalent
C_5: 1,000 pF feedthrough
C_6: 0.005 μF disc ceramic
L_1: 2 turns No. 16 wire, 3/16 in. (4.76 mm) ID, 1/4 in. (6.35 mm) long
L_2: Z = 450 Ω Ferrocube VK-200-09/3B, or equivalent
L_3: 2 turns No. 14 wire, 1/4 in. (6.35 mm) ID, 5/16 in. (7.93 mm)
L_4: 3 turns No. 14 wire, 3/8 in. (9.52 mm) ID, 3/8 in. (9.52 mm) long

Fig.4—175-MHz amplifier test circuit for measurement of output power from RCA-40972.



C_1: 7–100 pF, ARCO 423, or equivalent
C_2: 4–40 pF, ARCO 422, or equivalent
C_3: 0.1 μF ceramic
C_4: 0.001 μF feedthrough
C_5: 150 pF, ATC-100-B-150, or equivalent
C_6: 14–150 pF, ARCO 424, or equivalent
C_7: 24–200 pF, ARCO 425, or equivalent

L_1: 1/2 turn No. 14 wire, 1/4 in. (6.35 mm) ID
L_2: RFC, Z = 450Ω, Ferroxcube VK-200-09/3B, or equivalent

T_1: Twisted pair of No. 20 enameled wire; 14 turns/in. Formed in a loop 3/8 in. (9.52 mm) diameter, cross connected (End of one winding connected to beginning of other)

Fig.5—175-MHz amplifier test circuit for measurement of output power and collector efficiency of RCA-40973 and 40974.

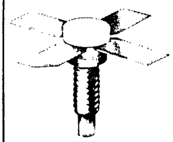
RCA
Solid State
Division

RF Power Transistors

40975 40976 40977

40975
40976
JEDEC TO-39

H-1381



40977
RCA HF-44

H-1779

0.05-, 0.5-, and 6-W, 118-136-MHz Silicon N-P-N Overlay Transistors

For High-Power VHF Amplifiers

Features:

- Designed for vhf aircraft transmitters
- 6 W (min.) output at 118 MHz (12.5-V supply)
- Infinite VSWR load-tested at constant input power, f = 118 MHz, V_{CC} = 25 V (40977)

RCA-40975, 40976, and 40977 are epitaxial silicon n-p-n planar transistors of the overlay emitter electrode construction. They are intended for high-power-output, vhf, class C amplifier service in low-voltage-supply applications.

These devices are especially intended foı use in vhf AM transmitters operating from a 12.5-volt supply. The 40977 is emitter-ballasted, and all 40977 units are tested at constant input power (f = 118 MHz, V_{CC} = 25 V, infinite load VSWR).

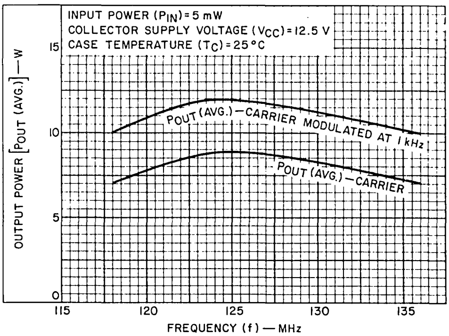


Fig.1 — Typical performance characteristics of the amplifier shown in Fig.2.

MAXIMUM RATINGS, *Absolute Maximum Values:*

		40975	40976	40977	
COLLECTOR-TO-EMITTER BREAKDOWN VOLTAGE:					
With base shorted to emitter	$V_{(BR)CES}$	55	60	60	V
With base open	$V_{(BR)CEO}$	30	30	30	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.4	0.5	5	A
TRANSISTOR DISSIPATION:	P_T				
At case temperatures up to 75°C		3.5	5	25	W
At case temperatures above 75°C, derate linearly		0.028	0.04	0.2	W/°C
TEMPERATURE RANGE:					
Storage and operating (Junction)			−65 to +200		°C
LEAD TEMPERATURE (During soldering):					
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.			230		°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

STATIC

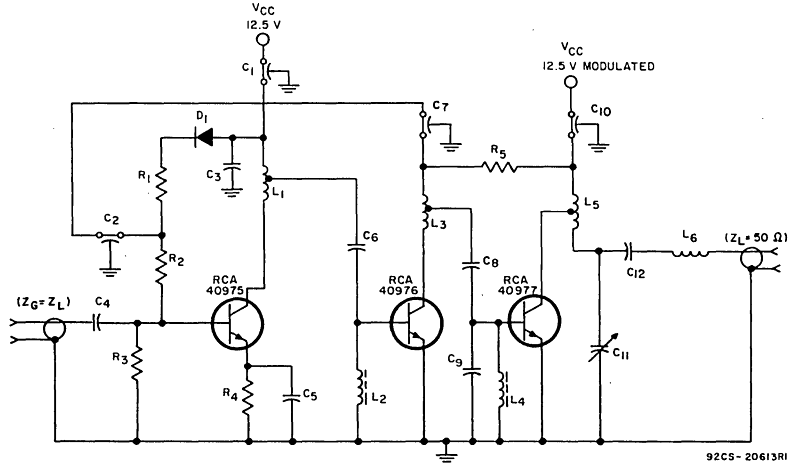
CHARACTERISTIC	SYMBOL	TEST CONDITIONS					LIMITS						UNITS
		DC Voltage V		DC Current mA			40975		40976		40977		
		V_{CE}	V_{EB}	I_E	I_B	I_C	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: Base connected to emitter	I_{CES}	12.5	0				–	0.1	–	1	–	10	mA
Collector-to-Emitter Breakdown Voltage: With base open	$V_{(BR)CEO}$				0	5	30	–	30	–	–	–	V
					0	200[a]	–	–	–	–	30	–	
With base connected to emitter	$V_{(BR)CES}$		0			5	55	–	60	–	–	–	
			0			200[a]	–	–	–	–	60	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	3.5	–	–	–	V
				5		0	–	–	–	–	3.5	–	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	35.7	–	25	–	5	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%.

DYNAMIC

TEST & CONDITIONS	SYMBOL	DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	FREQUENCY (f) – MHz	LIMITS						UNITS
				40975		40976		40977		
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Power Output: P_{IE} = 0.005 W (40975)	P_{OE}	12.5	118	0.05	–	–	–	–	–	W
0.05 W (40976)		12.5		–	–	0.5	–	–	–	
0.5 W (40977)		12.5		–	–	–	–	6	–	
1.2 W (40977)		25		–	–	–	–	22[b]	–	
Large-Signal Common-Emitter Power Gain: P_{OE} = 0.05 W (40975), 0.5 W (40976), 6 W (40977)	G_{PE}	12.5	118	10	–	10	–	10.8	–	dB
Collector Current: P_{OE} = 0.05 W (40975), 0.5 W (40976), 6 W (40977)	I_C	12.5	118	–	60	–	140	–	950	mA
Collector Efficiency: P_{OE} = 6 W (40977)	η_C	25	118	–	–	–	–	55	–	%
Collector-to-Base Output Capacitance	C_{obo}	12.5 (V_{CB})	1	–	4	–	15	–	30	pF

[b] Pulsed Input: Rep. rate = 1 kHz
Envelope shape = Square wave
Duty factor = 50%

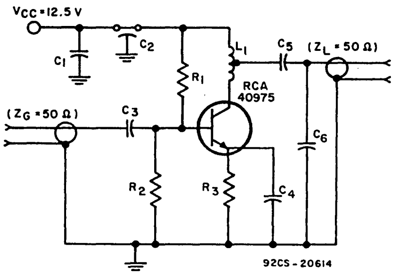


C_1, C_2, C_7, C_{10}: 1,000 pF feedthrough
C_3: 0.02 μF disc ceramic
C_4: 250 pF silver mica
C_5: 300 pF disc ceramic
C_6: 50 pF silver mica
C_8: 68 pF silver mica
C_9: 120 pF silver mica
C_{11}: 8–60 pF, ARCO 405, or equivalent
C_{12}: 62 pF silver mica

D_1: 1N5397, or equivalent
L_1: 8 turns No.20 wire, 5/32 in. ID, 5/8 in. long; tap 3-1/2 turns from V_{CC} side
L_2: 1 turn through Ferroxcube ferrite bead No.56-690-65/48, or equivalent
L_3: 8-1/2 turns No.20 wire, 5/32 in. ID, 5/8 in. long; tap 1-1/2 turns from V_{CC} side

L_4: Z = 450 Ω, Ferroxcube No. VK200-09/3B, or equivalent
L_5: 10 turns No. 20 wire, 5/32 in. ID, 11/16 in. long; tap 3 turns from output side
L_6: 3 turns No.20 wire, 3/32 in. ID, 3/16 in. long
R_1: 22 Ω, 1/2 W, carbon
R_2: 1.5 KΩ, 1/2 W carbon
R_3: 470 Ω, 1/2 W carbon
R_4: 47 Ω, 1/2 W carbon
R_5: 15 Ω, 1/2 W carbon

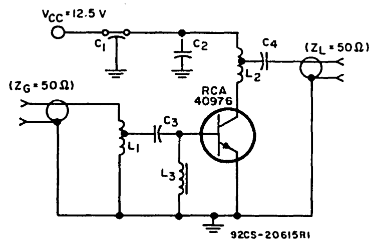
Fig.2 — 118-to-136-MHz 6-W AM amplifier for aircraft equipment.



C_1: 0.2 μF disc ceramic
C_2: 470 pF feedthrough
C_3: 250 pF silver mica
C_4: 300 pF disc ceramic
C_5: 50 pF silver mica
C_6: 39 pF silver mica

L_1: 8 turns No.20 wire, 3/16 in. ID, 5/8 in. long CT
R_1: 1.5 kΩ, 1/2 W carbon
R_2: 470 Ω, 1/2 W carbon
R_3: 47 Ω, 1/2 W carbon

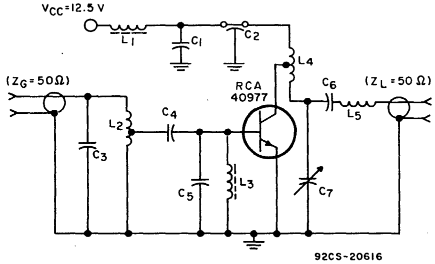
Fig.3 — 118-MHz amplifier test circuit for 40975.



C_1: 1,000 pF feedthrough
C_2: 0.05 μF disc ceramic
C_3: 50 pF silver mica
C_4: 68 pF silver mica

L_1: 8 turns No.20 wire, 3/16 in. ID, 5/8 in. long; tap 3 turns from ground
L_2: 7 turns No.20 wire, 3/16 in. ID, 5/8 in. long; tap 3-3/4 turns from collector
L_3: 1 turn ferrite choke, Ferroxcube Corp. ferrite bead No. 56-590-65/48, or equivalent

Fig.4 — 118-MHz amplifier test circuit for 40976.



C_1: 0.05 μF disc ceramic
C_2: 1,000 pF feedthrough
C_3: 7.5 pF disc ceramic
C_4: 68 pF molded mica
C_5: 120 pF silver mica
C_6: 62pF silver mica
C_7: 8–60 pF ARCO 405, or equivalent
L_1: Z = 750 Ω, Ferroxcube VK200-10/3B, or equivalent
L_2: 7 turns No.20 wire, 3/16 in. ID, 5/8 in. long; tap 1-1/2 turns from ground side
L_3: Z = 450 Ω, Ferroxcube VK200-09/3B, or equivalent
L_4: Nine 3/4-turns No.20 wire, 3/16 in. ID, 13/16 in. long; tap 3 turns from output side
L_5: 3 turns No.20 wire, 3/16 in. ID, 3/8 in. long

Fig.5 – 118-MHz amplifier test circuit for 40977.

TERMINAL CONNECTIONS FOR 40975 and 40976

LEAD 1 – EMITTER
LEAD 2 – BASE
LEAD 3 – COLLECTOR, CASE

TERMINAL CONNECTIONS FOR 40977

LEADS 1 & 3 – EMITTER
LEAD 2 – BASE
LEAD 4 – COLLECTOR

WARNING: The body of type 40977 contains beryllium oxide. Do not crush, grind, or abrade that portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State Division

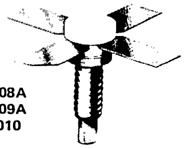
RF Power Transistors

41008 41009 41010
41008A 41009A

41008
41009

HF-47

H-1789



41008A
41009A
41010

HF-41

H-1788

0.5-W, 2-W, and 5-W, 470-MHz, 9-V Silicon N-P-N Overlay Transistors

For Low-Voltage Handheld UHF Broadband Amplifier Service

Features:

- **Infinite VSWR capability with rated power input and V_{CC} = 9 V**
- **Devices capable of rated power output at elevated heat-sink temperatures**

Types 41008, 41008A, 41009, 41009A, and 41010 are epitaxial silicon n-p-n planar transistors with overlay emitter-electrode construction.
They are especially intended for handheld broadband uhf class C amplifier service in low-voltage-supply applications.

WARNING: The bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade that portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		41008 41008A	41009 41009A	41010	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	36	36	36	V
COLLECTOR-TO-EMITTER VOLTAGE: With base open	V_{CEO}	14	14	14	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
TEMPERATURE RANGE: Storage and operating (Junction)		←	−65 to +200	→	°C
LEAD TEMPERATURE (During soldering): At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		←	200	→	°C

TERMINAL CONNECTIONS FOR 41008 and 41009

TERMINALS 1 & 3 – EMITTER
TERMINAL 2 – BASE
TERMINAL 4 – COLLECTOR

TERMINAL CONNECTIONS FOR 41008A, 41009A and 41010

TERMINALS 1 & 3 – EMITTER
TERMINAL 2 – BASE
TERMINAL 4 – COLLECTOR

ELECTRICAL CHARACTERISTICS, *At Case Temperature* (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc		CURRENT mA dc			LIMITS: 41008 41008A		41009 41009A		41010		UNITS
		V_{CE}	V_{EB}	I_E	I_B	I_C	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current: Base connected to emitter	I_{CES}	9	0				–	0.5	–	1	–	5	mA
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$				0	5[a]	14	–	–	–	–	–	V
					0	25[a]	–	–	14	–	–	–	
					0	75[a]	–	–	–	–	14	–	
With base connected to emitter	$V_{CES}(sus)$		0			5[a]	36	–	–	–	–	–	
			0			25[a]	–	–	36	–	–	–	
			0			75[a]	–	–	–	–	36	–	
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.5		0	3.5	–	–	–	–	–	V
				1		0	–	–	3.5	–	–	–	
				5		0	–	–	–	–	3.5	–	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	50	–	15	–	10	°C/W

[a] Pulsed through a 25-mH inductor; duty factor = 50%

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC COLLECTOR SUPPLY VOLTAGE (V_{CC}) – V	FREQUENCY (f) – MHz	LIMITS: 41008,A		41009,A		41010		UNITS
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Power Output: P_{IE} = 0.15 W (41008, A) 0.5 W (41009, A) 2 W (41010)	P_{OE}	9	470	0.5	–	2	–	5	–	W
Collector Efficiency: P_{OE} = 0.5 W (41008, A) 2 W (41009, A) 5 W (41010)	η_C	9	470	60	–	60	–	60	–	%
Collector-to-Base Output Capacitance	C_{obo}	9 (V_{CB})	1	–	4	–	6	–	25	pF

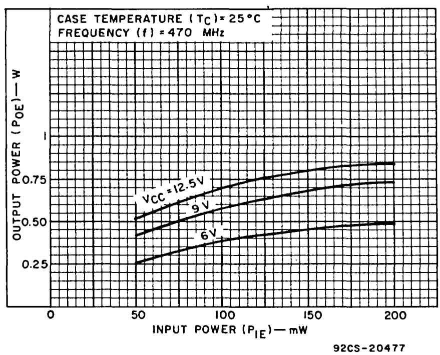


Fig.1 – Typical power output vs. power input at 470 MHz for 41008 and 41008A in the circuit of Fig.9.

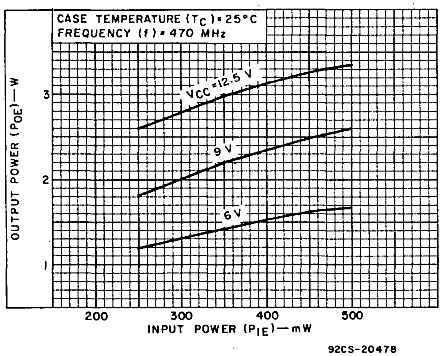


Fig.2 – Typical power output vs. power input at 470 MHz for 41009 and 41009A in the circuit of Fig.9.

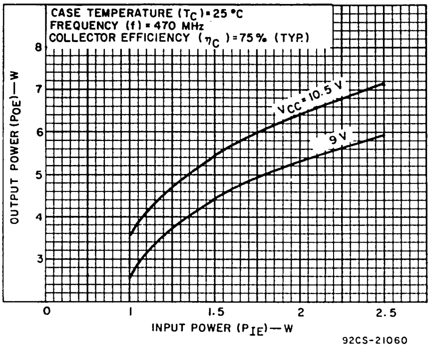


Fig.3 – Typical power output vs. power input at 470 MHz for 41010 in the circuit of Fig.9.

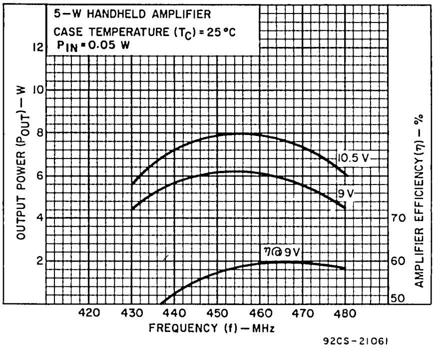


Fig.4 – Typical power output vs. frequency for amplifier chain using 41008 or 41008A, 41009 or 41009A, and 41010 with supply voltages of 9 and 10.5 volts, measured in the circuit of Fig.6.

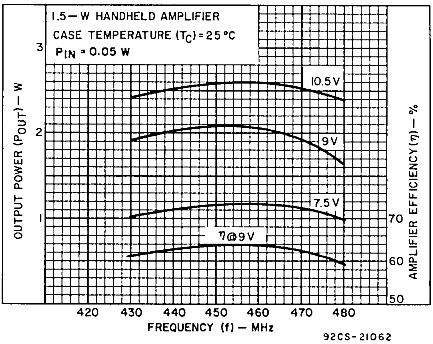
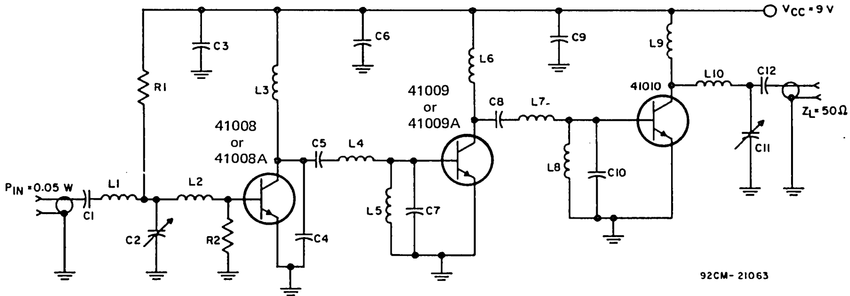


Fig.5 – Typical power output vs. frequency for amplifier chain using 41008 or 41008A and 41009 or 41009A with supply voltages of 7.5, 9, and 10.5 volts, measured in the circuit of Fig.7.



Z_{IN} = (4 + j 5.5) Ω Z_{IN} = (4.2 + j 5.5) Ω Z_{IN} = (2.3 + j 5.0) Ω

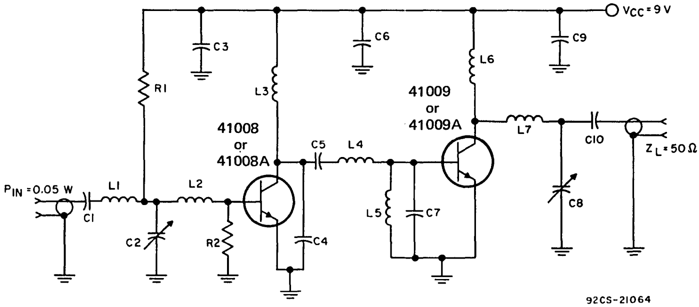
Z_{CL} = (20 + j 52.5) Ω Z_{CL} = (16 + j 7.5) Ω Z_{CL} = (9 + j 6.5) Ω

C_1: 10 pF disc ceramic
C_2, C_{11}: 2-18 pF Amperex HT10KA/218, or equivalent
C_3, C_9: 0.01 μF ceramic
C_4: 2 pF disc ceramic
C_5: 470 pF disc ceramic
C_6: 0.1 μF ceramic
C_7, C_{10}, C_{12}: 33 pF disc ceramic
C_8: 10 pF disc ceramic

R_1: 1.2 kΩ, 1/4 W carbon
R_2: 68 Ω, 1/4 W carbon
L_1: Single loop No. 20 wire 0.375 in. (9.52 mm) long, 0.0625 in. (1.58 mm) ID
L_2: Single loop No. 20 wire 0.25 in. (6.35 mm) long
L_3, L_5, L_8: 0.22 μH Nytronics Deci-Ductor, or equivalent

L_4, L_{10}: Single loop No. 20 wire 0.0625 in. (1.58 mm) long, 0.187 in. (4.76 mm) ID
L_6, L_9: 5 turns No. 20 wire 0.375 in. (9.52 mm) long, 0.125 in. (3.17 mm) ID
L_7: Single loop No. 20 wire 0.75 in (19.05 mm) long, 0.185 in. (4.70 mm) ID

Fig. 6–5-W, 9-volt amplifier with impedance data.



$Z_{IN} = (4 + j\,5.5)\ \Omega$	$Z_{IN} = (4.2 + j\,5.5)\ \Omega$
$Z_{CL} = (20 + j\,52.5)\ \Omega$	$Z_{CL} = (16 + j\,7.5)\ \Omega$

C_1: 1C pF disc ceramic
C_2, C_8: 2-18 pF Amperex HT10KA/218, or equivalent
C_3, C_9: 0.01 μF ceramic
C_4: 2 pF disc ceramic
C_5: 470 pF disc ceramic
C_6: 0.1 μF ceramic
C_7, C_{10}: 33 pF disc ceramic
R_1: 1.2 kΩ, 1/4 W carbon
R_2: 68 Ω, 1/4 W carbon
L_1: Single loop No. 20 wire 0.375 in. (9.52 mm) long, 0.0625 in. (1.58 mm) ID
L_2: Single loop No. 20 wire 0.25 in. (6.35 mm) long
L_3, L_5: 0.22 μH Nytronics Deci-Ductor, or equivalent
L_4: Single loop No. 20 wire 0.0625 in. (1.58 mm) long, 0.187 in. (4.76 mm) ID
L_6: 5 turns No. 20 wire 0.375 in. (9.52 mm) long, 0.125 in. (3.17 mm) ID
L_7: Single loop No. 20 wire 0.75 in. (19.05 mm) long, 0.185 in. (4.70 mm) ID

Fig. 7—1.5-W, 9-volt amplifier with impedance data.

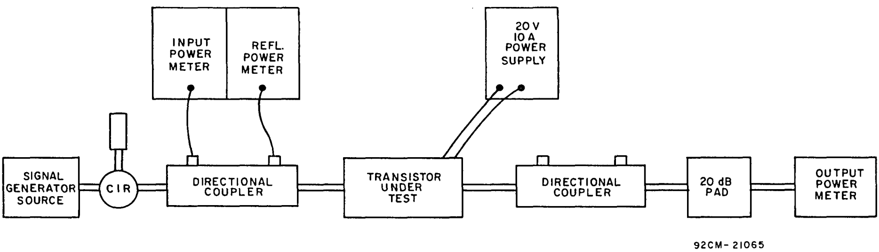
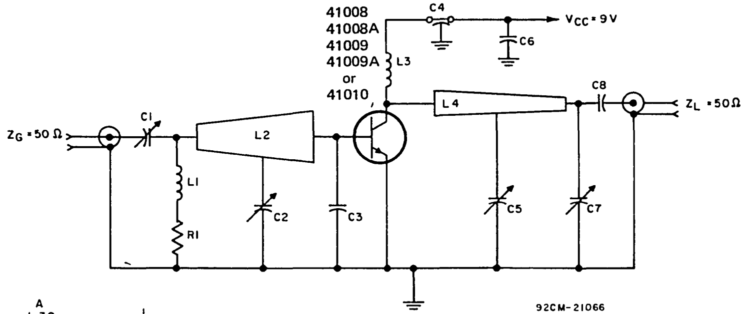
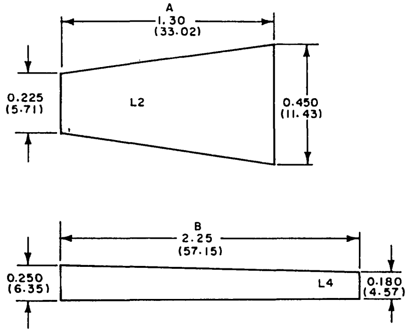


Fig.8 — 470-MHz power output test set-up for all types.





C_1, C_2, C_5, C_7: 2-18 pF Amperex HT10KA/218*
C_3: 15 pF American Technical Ceramics, ATC-100*
C_4: 1000 pF feedthrough
C_6: 0.01 μF disc ceramic
C_8: 300 pF American Technical Ceramics, ATC-100*
L_1: 0.22 μH choke
L_2: See A
L_3: 10 turns No. 18 wire 0.125 in. (3.17 mm) ID, 1 in. (25.4 mm) long
L_4: See B
R_1: 0.47 Ω, 1 W

Notes: C_3 placement as close to base lead as possible.
C_2 tapped 0.60 in. (15.24 mm) from base.
C_5 tapped 0.70 in. (17.78 mm) from collector.

*Or equivalent

Note 1: Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated.

Note 2: Produced by removing upper layer of double-clad, Teflon board, Budd Co. Polychem Div. Grade 108T 1 oz. 0.0625 in. (1.52 mm) thick, (ε = 2.6), or equivalent.

Fig. 9—470-MHz amplifier test circuit for measurement of power output for all types.

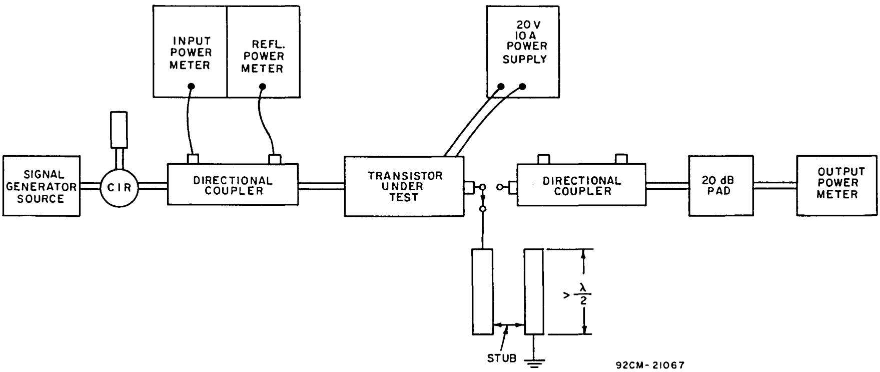
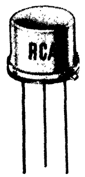


Fig. 10—Load-mismatch-capability test set-up for all types.

RCA
Solid State
Division

RF Power Transistors

41024



JEDEC TO-39 H-1381

1-W, 1-GHz Silicon N-P-N Overlay Transistor

High-Gain Device for Class B- or C-Operation in UHF Circuits

Features:

- **1-watt output min. at 1 GHz (5 dB gain)**
- **For sonde applications**
  0.3-watt output typ. at 1.68 GHz (V_{CC} = 20 V)

RCA-41024 is an epitaxial silicon n-p-n planar transistor of the overlay-emitter-electrode construction. It is intended as a high-power amplifier, fundamental-frequency oscillator and frequency multiplier. It may be used in final, driver, and predriver amplifier stages in uhf equipment and as a fundamental-frequency oscillator at 1.68 GHz.

In the overlay structure, a number of individual emitter sites connected in parallel are used in conjunction with a common collector region. Compared with other structures, this arrangement provides a substantial increase in emitter periphery for higher current or power, and a corresponding decrease in emitter and collector areas for lower input and output capacitances. The overlay structure thus provides greater power output, gain, efficiency, frequency capability, and linearity.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	55	V
COLLECTOR-TO-EMITTER SUSTAINING VOLTAGE:			
With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	55	V
With base open	V_{CEO}	24	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.4	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 25°C		3.5	W
At case temperatures above 25°C		See Fig. 1	
TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to 200	°C
LEAD TEMPERATURE (During soldering):			
At distances ≥ 1/32 in. (0.8 mm) from seating plane for 10 s max.		230	°C

TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, Case

8-73

ELECTRICAL CHARACTERISTICS, Case Temperature (T_C) = 25°C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Voltage V dc V_{CB}	Voltage V dc V_{CE}	Current mA dc I_E	Current mA dc I_B	Current mA dc I_C	LIMITS Min.	LIMITS Max.	UNITS
Collector Cutoff Current: With base open	I_{CEO}		15		0		–	20	μA
With base connected to emitter	I_{CES}		50				–	1	μA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		0.1	55	–	V
Collector-to-Emitter Sustaining Voltage: With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{CER}(sus)$					5	55	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	–	0.5	V
Collector-to-Base Capacitance (Measured at 1 MHz)	C_{ob}	30		0			–	3.0	pF
Magnitude of Common-Emitter Small-Signal Short-Circuit Forward-Current Transfer Ratio (Measured at 200 MHz)	$\|h_{fe}\|$		15			50	6.0	–	
RF Power Output Common Emitter Amplifier at 1 GHz (See Figs. 2 and 5)	P_{OUT}		28				1[a]	–	W

[a]For P_{IN} = 0.316 W, minimum efficiency = 35%.

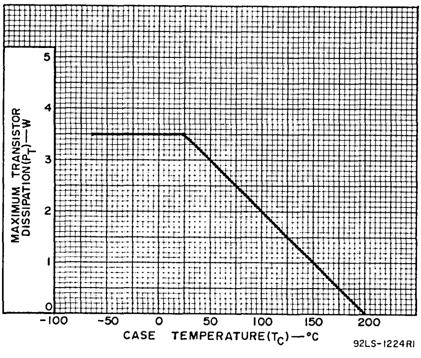


Fig. 1— Derating curve.

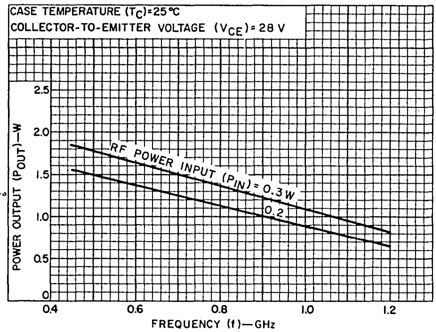


Fig. 2— Typical power output vs. frequency.

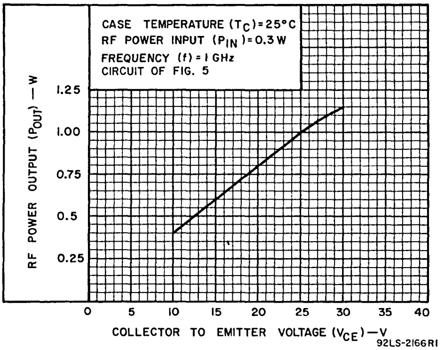


Fig. 3– Typical rf power output vs. collector-to-emitter voltage.

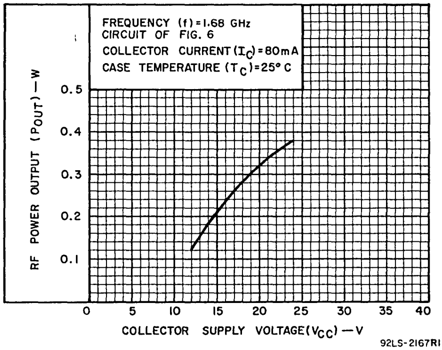
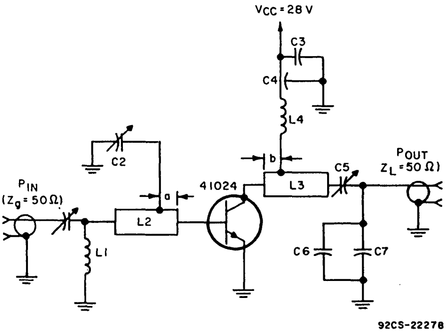


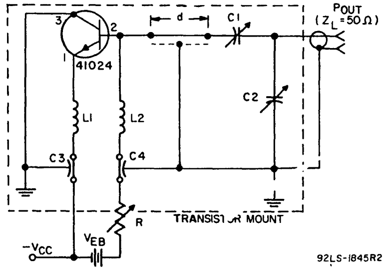
Fig. 4– Typical oscillator power output vs. collector supply voltage.



C1, C5, C7: 1–10 pF air-dielectric, Johanson●
C2: 0.6–6 pF
C3: 0.1 μF, 50 V disc
C4: 470 pF Feedthrough
C6: 10 pF, ATC●
L1: 0.1 μH RFC, Deciductor●
L2, L3: 0.16 in. (4.06 mm) wide, 1 in. (25.4 mm) long on 0.0625 in. (1.59 mm) thick Teflon-Fiberglas board (ϵ = 2.6)
L4: 1 turn, 0.125 in. (3.17 mm) ID, No. 26 wire
a: 0.300 in. (7.62 mm)
b: 0.25 in. (6.35 mm)

● Or equivalent

Fig. 5– RF amplifier circuit for power-output test at 1 GHz.



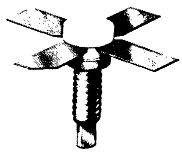
C1, C2: 0.35–3.5 pF
C3, C4: 500 pF feedthrough
d: 0.75 in. (19.1 mm) output line, center conductor width = 0.16 in. (4.06 mm)
L1, L2: RF choke – 5 turns, No. 28 wire, 0.125 in (3.17 mm) dia. x 0.5 in. (12.7 mm) long
R: 0–50 ohms
Transistor Mount: 0.0625 in. (1.59 mm)

Fig. 6– RF fundamental-frequency oscillator circuit for 1.68-GHz operation.

RCA Solid State Division

RF Power Transistors

41025 41026



HF-41 package

H-1788

3-W and 10-W 1-GHz Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in UHF/Microwave Common-Emitter Power Amplifiers, Oscillators, and Frequency Multipliers

Features:

- **Designed for supply voltages of 25 to 30 V**
- **Emitter-ballasting resistors**
- **3-W output with 7-dB gain (min.) at 1 GHz, 28 V (41025)**
- **10-W output with 6-dB gain (min.) at 1 GHz, 28 V (41026)**
- **Ceramic-metal stripline package with low inductances and low parasitic capacitances**
- **Suitable for stripline and microstripline circuits**

RCA-41025 and 41026* are epitaxial silicon n-p-n planar transistors with overlay multiple-emitter-site construction. They are designed especially for equipment using 25- to 30-V collector supplies in uhf and microwave communications, L-band microwave relay links, distance-measuring equipment, transponders, and collision-avoidance systems.

The ceramic-metal stripline packages of these devices have low parasitic capacitances and inductances that permit stable operation in the common-emitter configuration.

Ideal as a driver for the 41026, the 41025 can also be used in large-signal applications. The use of emitter-ballasting resistors and the low-thermal-resistance package make the 41026 especially suitable for large-signal cw or pulsed applications at frequencies from 0.7 GHz to 1.3 GHz in stripline and microstripline circuits.

* Formerly RCA Dev. Nos. TA8647 and TA8648.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		41025	41026	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	V
COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	50	50	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.35	1.5	A
TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 75°C		7.15	21	W
At case temperature above 75°C . . . Derate linearly at		0.057	0.168	W/°C
TEMPERATURE RANGE:				
Storage and operating (Junction)		−65 to +200		°C
CASE TEMPERATURE (during soldering) For 10 s max.		230		°C

5-73

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified.*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS				UNITS
		VOLTAGE V dc		CURRENT mA dc		41025		41026		
		V_{CE}	V_{BE}	I_E	I_C	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current	I_{CES}	45	0			–	2	–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	50	–	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1	0	3.5	–	3.5	–	V
Collector-to-Emitter Breakdown Voltage With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				10	50	–	50	–	V
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$					–	17.5	–	6	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		LIMITS				UNITS
		FREQUENCY GHz	SUPPLY VOLTAGE (V_{CC})-V dc	41025		41026		
				MIN.	MAX.	MIN.	MAX.	
Output Power, P_{IE} = 0.6 W	P_{OE}	1	28	3	–	–	–	W
= 2.5 W		1	28	–	–	10	–	
Power Gain, P_{OE} = 3 W	G_{PE}	1	28	7	–	–	–	dB
= 10 W		1	28	–	–	6	–	
Collector Efficiency, P_{OE} = 3 W	η_C	1	28	50	–	–	–	%
= 10 W		1	28	–	–	50	–	
Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	5	–	12	pF

TYPICAL APPLICATION INFORMATION

CIRCUIT	SEE FIG.	SUPPLY VOLTAGE (V_{CC}) –V dc	INPUT POWER (P_{IE})–W	OUTPUT POWER (P_{OE})–W
Microstripline 1-GHz Amplifier (41025)	10	28	0.6	3.3
Microstripline 1-GHz Amplifier (41026)	11	28	2.5	11.0
Microstripline 1.0-to-1.2-GHz Oscillator (41025)	12	28	–	3.2

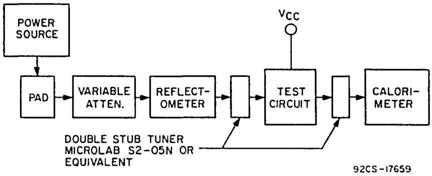


Fig.1 – Block diagram of test arrangement for measuring transistor performance.

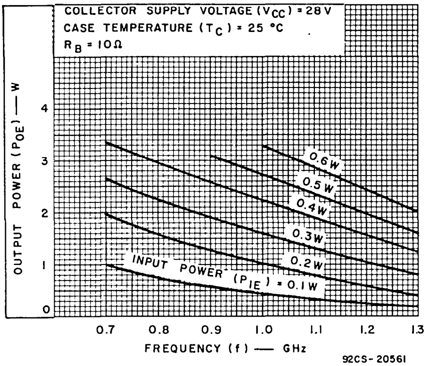


Fig.2 – Typical output power vs frequency for 41025 common-emitter amplifier in test arrangement of Fig.1.

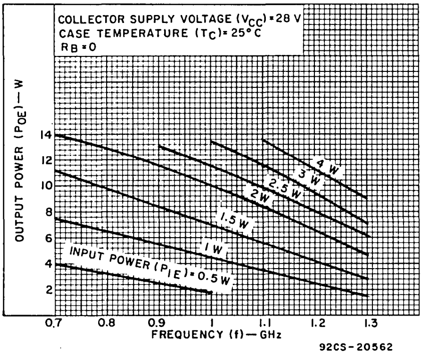


Fig.3 – Typical output power vs frequency for 41026 common-emitter amplifier in test arrangement of Fig.1.

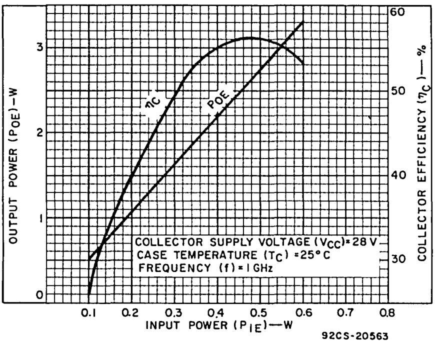


Fig.4 – Typical 1-GHz output power and collector efficiency vs. input power for 41025 in test arrangement of Fig.1.

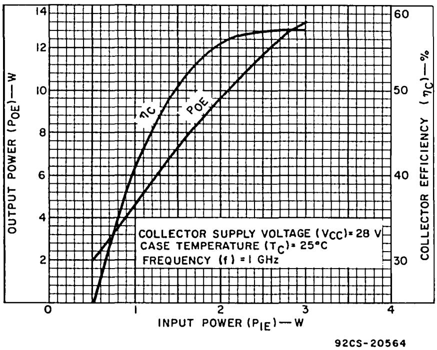


Fig.5 – Typical 1-GHz output power and collector efficiency vs. input power for 41026 in test arrangement of Fig.1.

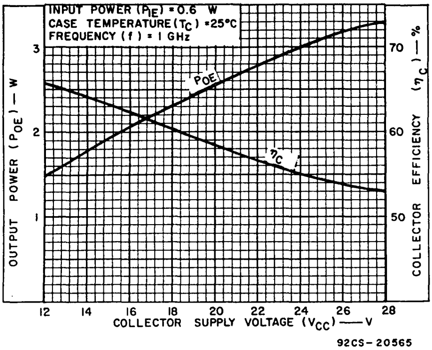


Fig.6 — Typical 1-GHz output power and collector efficiency vs. supply voltage for 41025 in test arrangement of Fig.1.

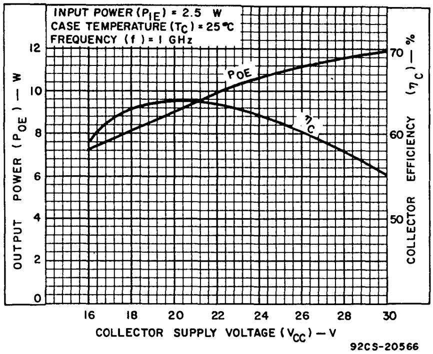


Fig.7 — Typical 1-GHz output power and collector efficiency vs. supply voltage for 41026 in test arrangement of Fig.1.

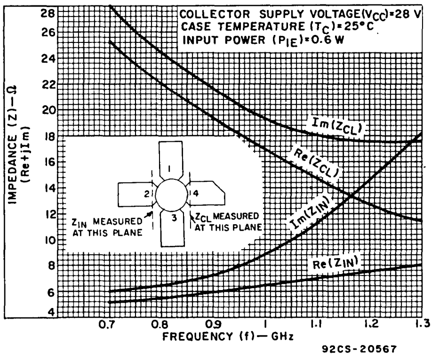


Fig.8 — Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for 41025.

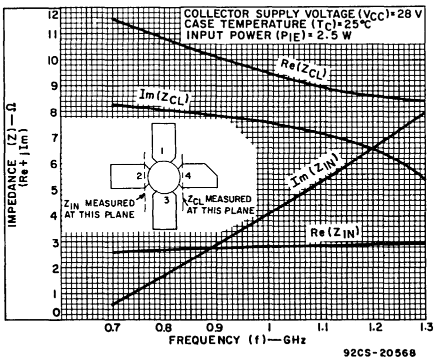
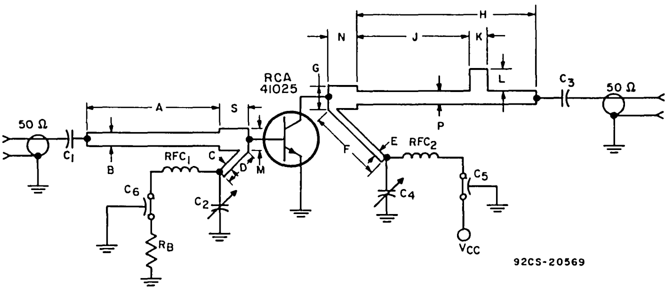


Fig.9 — Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for 41026.



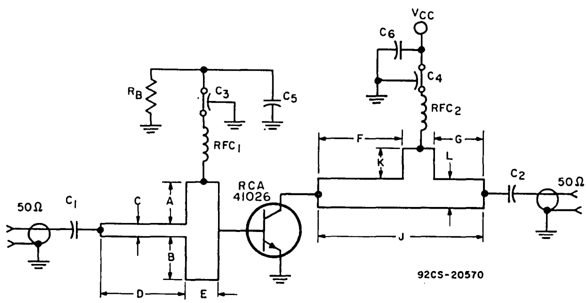
MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	1.900	48.26
B	0.086	2.18
C	0.086	2.18
D	0.470	11.94
E	0.086	2.18
F	1.10	27.94
G	0.300	7.62
H	2.82	71.63
J	1.97	50.04
K	0.275	6.99
L	0.300	7.62
M	0.300	7.62
N	0.400	10.16
P	0.170	4.32
S	0.400	10.16

C_1, C_3 = 30 pF, ATC 100●
C_2, C_4 = 1–10 pF, JOHANSON 2957●
C_5, C_6 = 1000 pF, ALLEN-BRADLEY FA5C●
RFC_1, RFC_2 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia., 0.300 in. (7.62 mm) long
R_B = 10 Ω

● Or equivalent

Fig.10–Microstripline circuit for 1-GHz power amplifier using 41025.



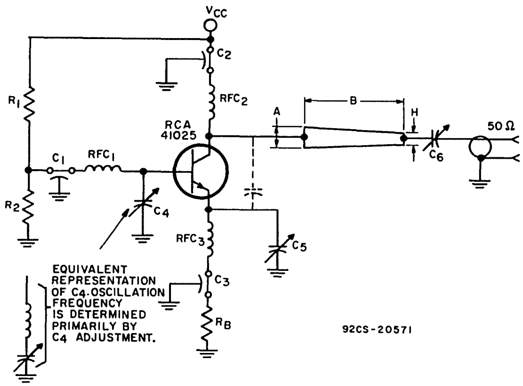
MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	0.885	22.48
B	0.885	22.48
C	0.080	2.03
D	1.725	43.82
E	0.545	13.84
F	1.125	28.58
G	0.870	22.10
J	2.320	58.93
K	0.290	7.37
L	0.270	6.86

C_1, C_2 = 330 pF, ATC 100●
C_3, C_4 = 1000 pF, ALLEN-BRADLEY FA5C●
C_5, C_6 = 1 μF, 50-V, electrolytic
R_B = 0 to 30 Ω
RFC_1, RFC_2 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia., 0.300 in. (7.62 mm) long

● Or equivalent

Fig.11–Microstripline circuit for 1-GHz power amplifier using 41026.



MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	0.300	7.62
B	1.500	38.10
H	0.150	3.81

C_1, C_2, C_3 = 470 pF feedthrough, ALLEN-BRADLEY FAC5●
C_4 = 1–20 pF, JOHANSON 4802●
C_5 = 0.3 – 3.5 pF, JOHANSON 4701●
C_6 = 1–10 pF, JOHANSON 4581●
R_1 = 2.2 kΩ
R_2 = 180 Ω
R_B = 10 Ω

RFC_1, RFC_2, RFC_3 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia., 0.300 in. (7.62 mm) long

● Or equivalent

Fig. 12—Microstripline circuit for 1.0- to 1.2-GHz oscillator using 41025.

SOLDERING INSTRUCTIONS

When these devices are to be soldered into microstripline circuits, the transistor terminals must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

TERMINAL CONNECTIONS

TERMINALS 1 & 3 – EMITTER
TERMINAL 2 – BASE
TERMINAL 4 – COLLECTOR

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

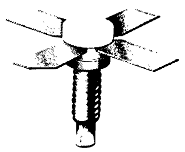
RCA Solid State Division

RF Power Transistors

41027 41028

3-W and 10-W 1-GHz Emitter-Ballasted Silicon N-P-N Overlay Transistors

For Use in UHF/Microwave Common-Emitter Power Amplifiers, Oscillators, and Frequency Multipliers



HF-41 Package

H-1788

Features:

- Designed for supply voltages of 20 to 25 V
- Emitter-ballasting resistors
- Load VSWR capability of 3:1 at 1 GHz
- 3-W output with 6-dB gain (min.) at 1 GHz, 22 V (41027)
- 10-W output with 5.5-dB gain (min.) at 1 GHz, 22 V (41028)
- Ceramic-metal stripline package with low inductances and low parasitic capacitances
- Suitable for stripline and microstripline circuits

RCA-41027 and 41028* are epitaxial silicon n-p-n planar transistors with overlay multiple-emitter-site construction. They are designed especially for equipment using 20- to 25-V collector supplies in uhf and microwave communications, L-band microwave relay links, distance-measuring equipment, transponders, and collision-avoidance systems.

The ceramic-metal stripline packages of these devices have low parasitic capacitances and inductances that permit stable operation in the common-emitter configuration.

Ideal as a driver for the 41028, the 41027 can also be used in large-signal applications. The use of emitter-ballasting resistors and the low-thermal-resistance package make the 41028 especially suitable for large-signal cw or pulsed applications at frequencies from 0.7 GHz to 1.3 GHz in stripline and microstripline circuits.

* Formerly RCA Dev. Nos. TA8649 and TA8650.

MAXIMUM RATINGS, *Absolute-Maximum Values:*		41027	41028	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	45	45	V
COLLECTOR-TO-EMITTER VOLTAGE: With external base-to-emitter resistance (R_{BE}) = 10 Ω	V_{CER}	45	45	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.35	1.5	A
TRANSISTOR DISSIPATION:	P_T			
At case temperature up to 75°C		7.15	21	W
At case temperature above 75°C	Derate linearly at	0.057	0.168	W/°C
TEMPERATURE RANGE:				
Storage and operating (Junction)		−65 to +200		°C
CASE TEMPERATURE (during soldering) For 10 s max.		230		°C

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C unless otherwise specified.*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS				UNITS
		VOLTAGE V dc		CURRENT mA dc		41027		41028		
		V_{CE}	V_{BE}	I_E	I_C	MIN.	MAX.	MIN.	MAX.	
Collector Cutoff Current	I_{CES}	40	0			–	2	–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	45	–	45	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1	0	3.5	–	3.5	–	V
Collector-to-Emitter Breakdown Voltage With external base-to-emitter resistance (R_{BE}) = 10 Ω	$V_{(BR)CER}$				10	45	–	45	–	V
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$					–	17.5	–	6	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		LIMITS				UNITS
		FREQUENCY GHz	SUPPLY VOLTAGE (V_{CC})-V dc	41027		41028		
				MIN.	MAX.	MIN.	MAX.	
Output Power, P_{IE} = 0.75 W	P_{OE}	1	22	3	–	–	–	W
= 2.8 W		1	22	–	–	10	–	
Power Gain, P_{OE} = 3 W	G_{PE}	1	22	6	–	–	–	dB
= 10 W		1	22	–	–	5.5	–	
Collector Efficiency, P_{OE} = 3 W	η_C	1	22	50	–	–	–	%
= 10 W		1	22	–	–	50	–	
Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz	–	–	5	–	12	pF

TYPICAL APPLICATION INFORMATION

CIRCUIT	SEE FIG.	SUPPLY VOLTAGE (V_{CC}) –V dc	INPUT POWER (P_{IE})–W	OUTPUT POWER (P_{OE})–W
Microstripline 1-GHz Amplifier (41027)	10	22	0.75	3.3
Microstripline 1-GHz Amplifier (41028)	11	22	2.8	11.0
Microstripline 1.0- to 1.2-GHz Oscillator (41027)	12	22	–	2

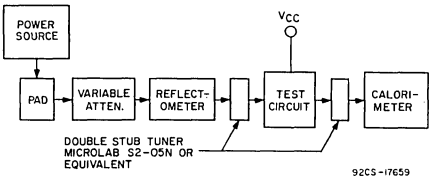


Fig.1 – Block diagram of test arrangement for measuring transistor performance.

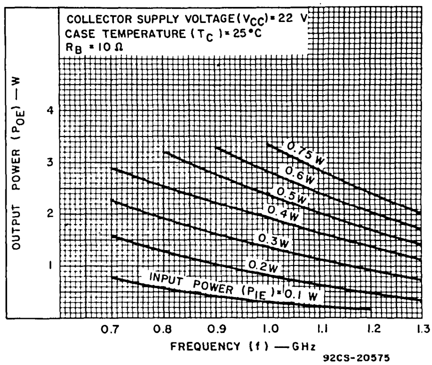


Fig.2 – Typical output power vs. frequency for 41027 common-emitter amplifier in test arrangement of Fig.1.

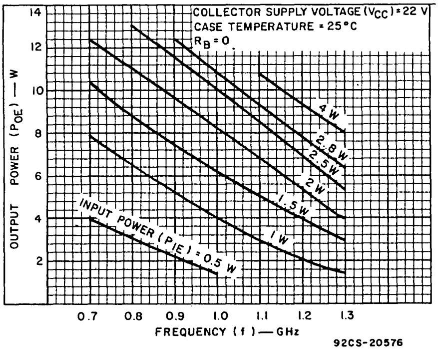


Fig.3 – Typical output power vs. frequency for 41028 common-emitter amplifier in test arrangement of Fig.1.

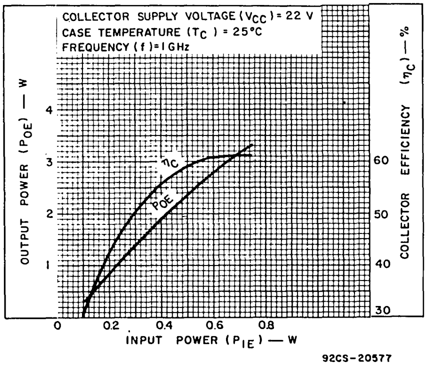


Fig.4 – Typical 1-GHz output power and collector efficiency vs. input power for 41027 in test arrangement of Fig.1.

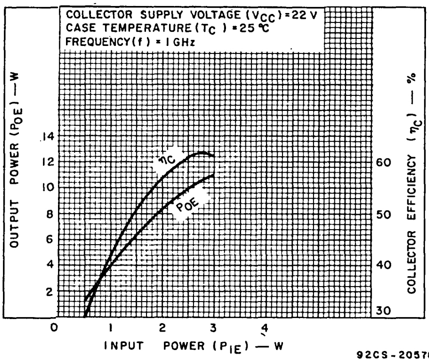


Fig.5 – Typical 1-GHz output power and collector efficiency vs. supply voltage for 41027 in test arrangement of Fig.1.

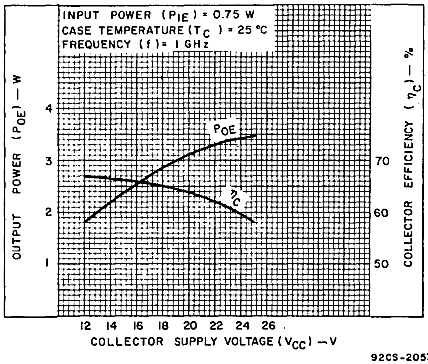


Fig.6 – Typical 1-GHz output power and collector efficiency vs. supply voltage for 41027 in test arrangement of Fig.1.

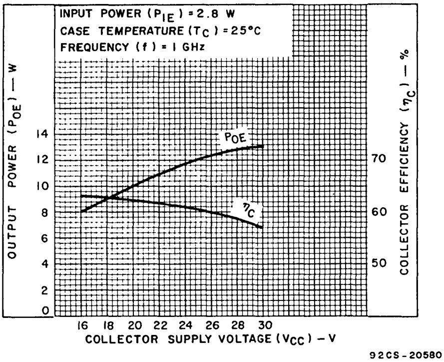


Fig.7 — Typical 1-GHz output power and collector efficiency vs. supply voltage for 41028 in test arrangement of Fig.1.

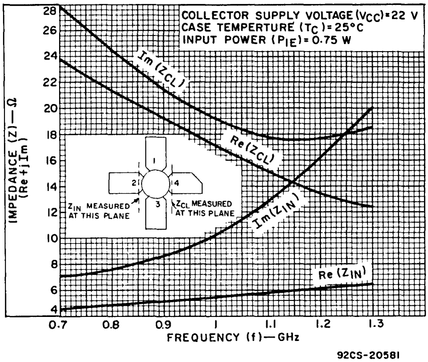


Fig.8 — Typical large-signal series input impedance and large-signal collector load impedance vs. frequency of 41027.

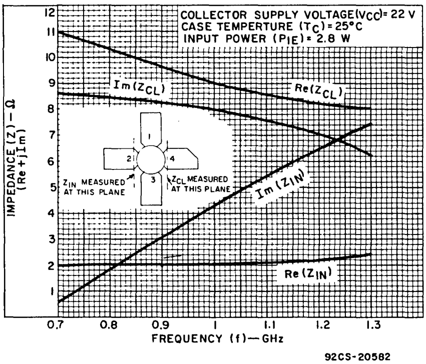
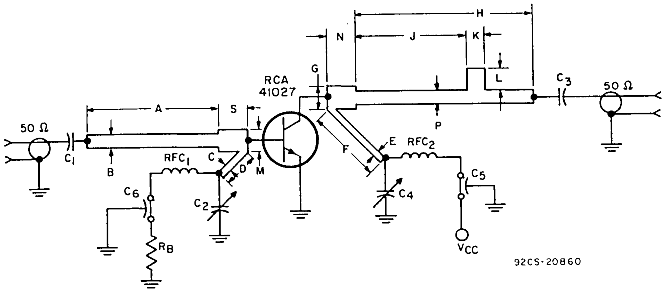


Fig.9 — Typical large-signal series input impedance and large-signal collector load impedance vs. frequency for 41028.



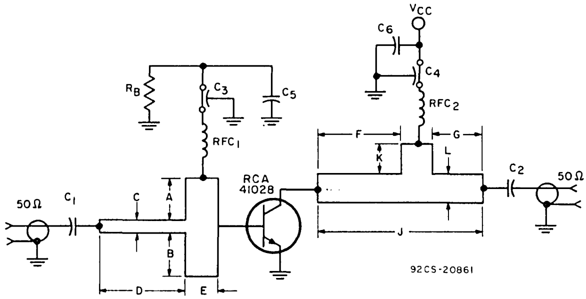
MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	1.900	48.26
B	0.086	2.18
C	0.086	2.18
D	0.470	11.94
E	0.086	2.18
F	1.10	27.94
G	0.300	7.62
H	2.82	71.63
J	1.97	50.04
K	0.275	6.99
L	0.300	7.62
M	0.300	7.62
N	0.400	10.16
P	0.170	4.32
S	0.400	10.16

C_1, C_3 = 30 pF, ATC 100●
C_2, C_4 = 1–10 pF, JOHANSON 2957●
C_5, C_6 = 1000 pF, ALLEN-BRADLEY FA5C●
RFC_1, RFC_2 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia., 0.300 in. (7.62 mm) long
R_B = 10 Ω

● Or equivalent

Fig. 10—Microstripline circuit for 1-GHz power amplifier using 41027.



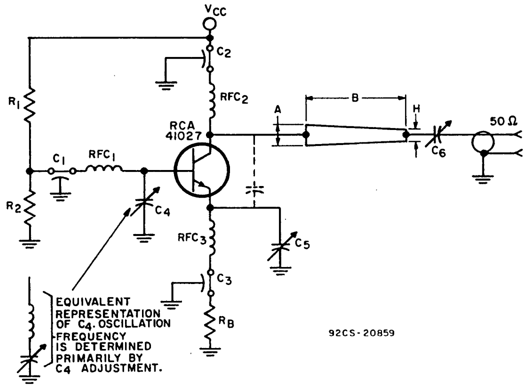
MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	0.885	22.48
B	0.885	22.48
C	0.080	2.03
D	1.725	43.82
E	0.545	13.84
F	1.125	28.58
G	0.870	22.10
J	2.320	58.93
K	0.290	7.37
L	0.270	6.86

C_1, C_2 = 330 pF, ATC 100●
C_3, C_4 = 1000 pF, ALLEN-BRADLEY FA5C●
C_5, C_6 = 1 μF, 50-V, electrolytic
R_B = 0 to 30 Ω
RFC_1, RFC_2 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia., 0.300 in. (7.62 mm) long

● Or equivalent

Fig. 11—Microstripline circuit for 1-GHz power amplifier using 41028.



MICROSTRIP MATERIAL:
1/32-INCH TEFLON FIBERGLASS

DIMENSION	INCHES	MILLIMETERS
A	0.300	7.62
B	1.500	38.10
H	0.150	3.81

C_1, C_2, C_3 = 470 pF feedthrough, ALLEN-BRADLEY FAC5●
C_4 = 1–20 pF, JOHANSON 4802●
C_5 = 0.3 – 3.5 pF, JOHANSON 4701●
C_6 = 1–10 pF, JOHANSON 4581●
R_1 = 2.2 kΩ
R_2 = 180 Ω
R_B = 10 Ω
RFC_1, RFC_2, RFC_3 = No. 32 wire, 5 turns 0.062 in. (1.57 mm) dia.,0.300 in. (7.62 mm) long

●Or equivalent

Fig. 12—Microstripline circuit for 1.0- to 1.2-GHz oscillator using 41027.

SOLDERING INSTRUCTIONS

When these devices are to be soldered into microstripline circuits, the transistor terminals must be pretinned in the region where soldering is to take place. The device should be held in a high-thermal-resistance support for this tinning operation. A 60/40 resin-core solder and a low-wattage (47 watts) soldering iron are suggested for the pretinning operation. The case temperature should not exceed 230°C for a maximum of 10 seconds during tinning and subsequent soldering operations.

TERMINAL CONNECTIONS

TERMINALS 1 & 3 – EMITTER
TERMINAL 2 – BASE
TERMINAL 4 – COLLECTOR

WARNING: The ceramic bodies of these devices contain beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA
Solid State Division

RF Power Transistors

41038

TO-46

H-1208

750-mW, 1.68-GHz Oscillator Transistor

Features:

- **Emitter-ballasting resistors**
- **750-mW oscillator power at 1.68 GHz (20 V)**
- **Collector connected to case**
- **For coaxial, stripline, and lumped-element circuits**

TERMINAL CONNECTIONS

Lead No. 1 – Emitter
Lead No. 2 – Base
Lead No. 3 – Collector, Case

Type 41038* is an epitaxial silicon n-p-n planar transistor with overlay multiple-emitter-site construction and emitter-ballasting resistors. Intended applications for this transistor include microwave communications, relay links, distance-measuring equipment, collision-avoidance systems, and low-cost radiosonde service.

* Formerly Dev. No. TA8340.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}		45	V
COLLECTOR-TO-EMITTER VOLTAGE	V_{CEO}		21	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}		3.5	V
TRANSISTOR DISSIPATION:	P_T			
At case temperatures up to 100°C			3.1	W
At case temperatures above 100°C		Derate at	0.031	W/°C
TEMPERATURE RANGE:				
Storage and Operating (Junction)			–65 to 200	°C

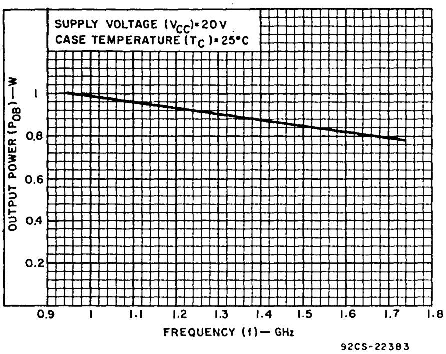


Fig.1 – Typical output power vs. frequency for 41038 oscillator in test arrangement of Fig. 5.

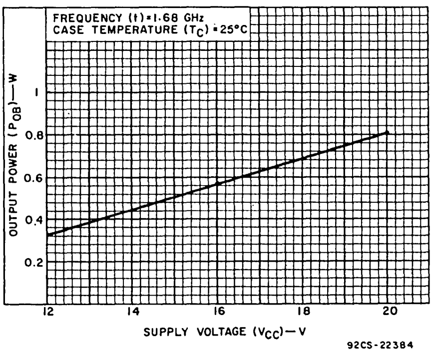


Fig.2 – Typical output power vs. supply voltage for 41038 oscillator in test arrangement of Fig. 5.

ELECTRICAL CHARACTERISTICS *at Case Temperature* (T_C) = 25°C

Static CHARACTERISTIC	SYMBOL	TEST CONDITIONS VOLTAGE V dc		CURRENT mA dc			LIMITS		UNITS
		V_{CE}	V_{BE}	I_E	I_B	I_C	MIN.	MAX.	
Collector Cutoff Current	I_{CES}	40	0		0		–	2	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		5	45	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$						–	32	°C/W

Dynamic CHARACTERISTIC	SYMBOL	POWER OUTPUT (P_{OB})–W	SUPPLY VOLTAGE (V_{CC})–V	FREQUENCY GHz	LIMITS MIN.	MAX.	UNITS
Common-Collector Oscillator Output Power	P_{OB}		20	1.68	0.75	–	W
Oscillator Circuit Efficiency	η_O	0.75	20	1.68	20	–	%
Collector-to-Base Capacitance	C_{obo}		30(V_{CB})	1 MHz	–	4	pF

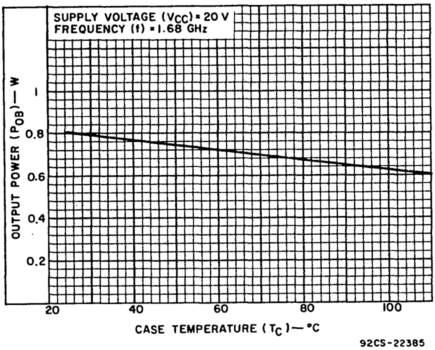


Fig.3 – Typical output power vs. case temperature for 41038 oscillator in test arrangement of Fig. 5.

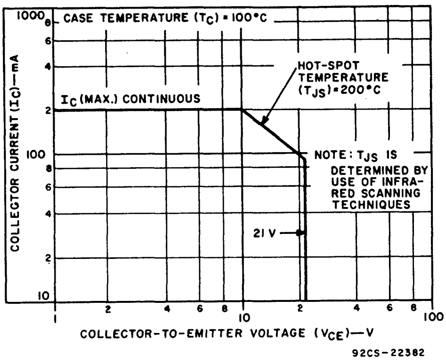


Fig.4 – Maximum operating area for forward-biased operation.

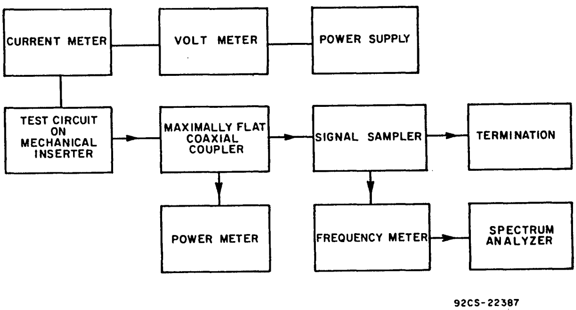
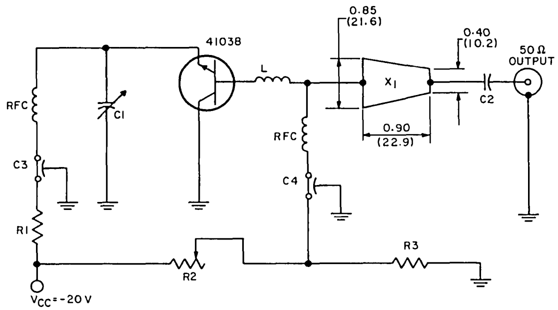


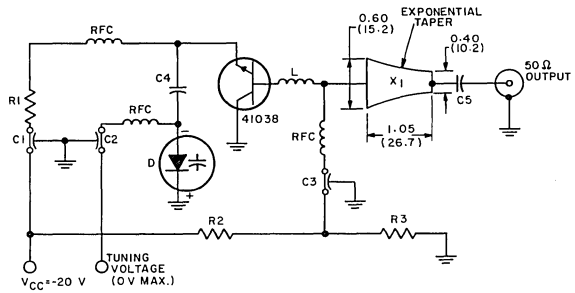
Fig.5 – Test arrangement for measurement of output power from 41038 oscillator.



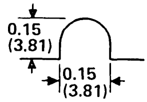
C1: 0.3 - 3.5 pF air piston capacitor, Johanson 4700 or equivalent
C2: 5 pF chip capacitor, ATC-100 or equivalent
C3, C4: 1000 pF feedthrough capacitor, Allen-Bradley FA5C or equivalent
RFC: choke, 0.12 μH, Nytronics or equivalent
L: 0.150-in. (3.8 mm) transistor lead length
R1: 0.82 Ω, 2 watt
R2: 0 - 500 Ω, 2 watts
R3: 2.2 kΩ, 1 watt
X1: Produced by removing upper copper layer from 1/32-in. (0.79-mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6).

92CM-22388

Fig.6 – L-band oscillator circuit using 41038.



C1, C2, C3: 1000 pF feedthrough, Filtercon SMFB-A1 or equivalent
C4: 2.2 pF, two 1-pF ATC-100 or equivalent in parallel
C5: 0.3 - 3.5 pF, Johanson 4700 or equivalent
R1: 10 Ω, 1/2 watt, carbon
R2: 0 – 500 Ω, 2 watts
R3: 2.2 kΩ, 1/2 watt, carbon
D: variable-capacitance diode, 7 - 15 pF across tuning voltage range
L: loop of transistor base lead



X1: produced by removing upper copper layer from 1/32-in. (0.79 mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6).

92CM-22389

Fig.7 – 950-MHz voltage-controlled oscillator.

RCA

Solid State Division

RF Transistors

41039

JEDEC TO-39

H-1381

Silicon N-P-N Overlay Transistor

For VHF Broadband Amplifiers in CATV and MATV Equipment

Features:

- **Low Device Noise Figure:**
  200-MHz narrow-band (30 mA) = 3 dB max.
  60-MHz narrow-band (30 mA) = 2 dB typ.
  50-250-MHz broadband = 6.5 dB typ.
- **High Gain:**
  G_{PE} (200 MHz, 30 mA) = 15 dB min.
  G_{VE} (50-250 MHz, broadband) = 10 dB typ.
  f_T (30 mA) = 1.8 GHz min.
- **Low Distortion:**
  Cross-modulation (40 dBmV, 17 V, 60 mA) = −67 dB typ.
  IMD (40 dBmV, 17 V, 60 mA) = −75 dB typ.
- **Collector-to-Base Time Constant:**
  (f = 31.9 MHz) = 7 ps typ.

RCA-41039* is an epitaxial silicon n-p-n planar transistor employing overlay emitter-electrode construction. It is intended for small-signal applications where both large dynamic range and high gain are needed.

* Formerly RCA Dev. No. TA8865.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	V
COLLECTOR-TO-EMITTER VOLTAGE:			
With base open	V_{CEO}	25	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	0.25	A
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 75°C		2.5	W
At case temperatures above 75°C ... Derate linearly at		0.02	W/°C
TEMPERATURE RANGE:			
Storage & Operating (Junction)		−65 to 200	°C
LEAD TEMPERATURE (During soldering):			
At distances ⩾ 1/32 in. (0.8 mm) from seating plane for 10 s max.		230	°C

TERMINAL CONNECTIONS

Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, Case

ELECTRICAL CHARACTERISTICS, *At Case Temperature* (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage V: V_{CB}	V_{CE}	DC Current mA: I_E	I_B	I_C	LIMITS: Min.	Max.	UNITS
Collector-Cutoff Current	I_{CBO}	18			0		–	100	µA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0		1	40	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1		0	3.5	–	V
Collector-to-Emitter Sustaining Voltage: With base open	$V_{CEO}(sus)$				0	20	25	–	V
Collector-to-Emitter Saturation Voltage	$V_{CE}(sat)$				10	100	–	0.25	V
DC Forward-Current Transfer Ratio	h_{FE}		15			50	60	350	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$						–	50	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: DC Voltage V: V_{CB}	V_{CE}	DC Current mA: I_E	I_B	I_C	LIMITS: Min.	Max.	UNITS
Small-Signal, Common-Emitter Power Gain (f = 200 MHz)	G_{PE}		15			30	15	–	dB
Noise Figure (Measured) (f = 200 MHz) See Fig. 3	NF		15			30	–	3.2[a]	dB
Wideband Voltage Gain (f = 50-250 MHz) See Fig. 4	G_{VE}		17			60	9.5	–	dB
12-Channel Cross Modulation Distortion (f = 50-250 MHz; output level = 40 dBmV) See Fig. 4	CMD		17			60	–62	–	dB
Gain-Bandwidth Product (f = 200 MHz)	f_T		15 15			30 60	1.8 2	– –	GHz
Collector-to-Base Capacitance (f = 1 MHz)	C_{obo}	30					–	2.5	pF

[a] Because of insertion loss of input test circuit, device noise figure is approximately 0.2 dB less than measured.

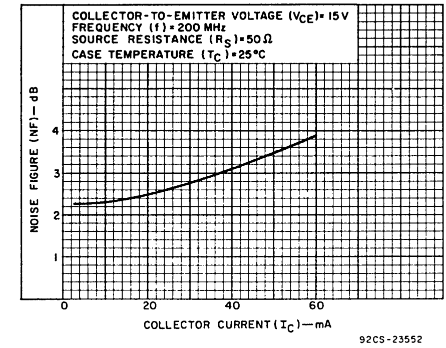


Fig. 1 — Typical measured narrow-band noise figure vs. collector current.

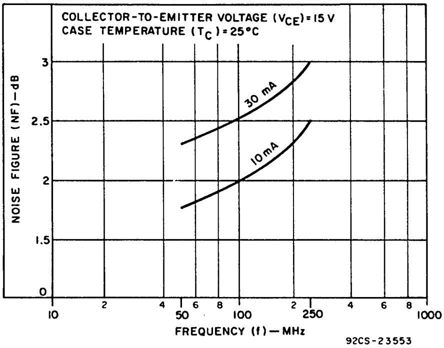


Fig. 2 — Typical measured narrow-band noise figure vs. frequency.

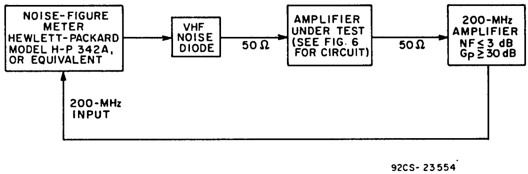


Fig. 3 — Noise-figure test setup.

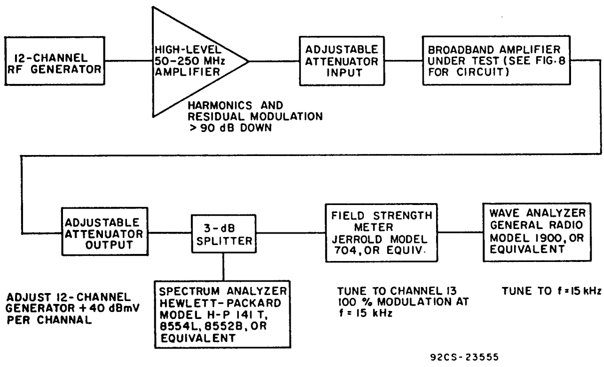


Fig. 4 — Cross-modulation-distortion setup.

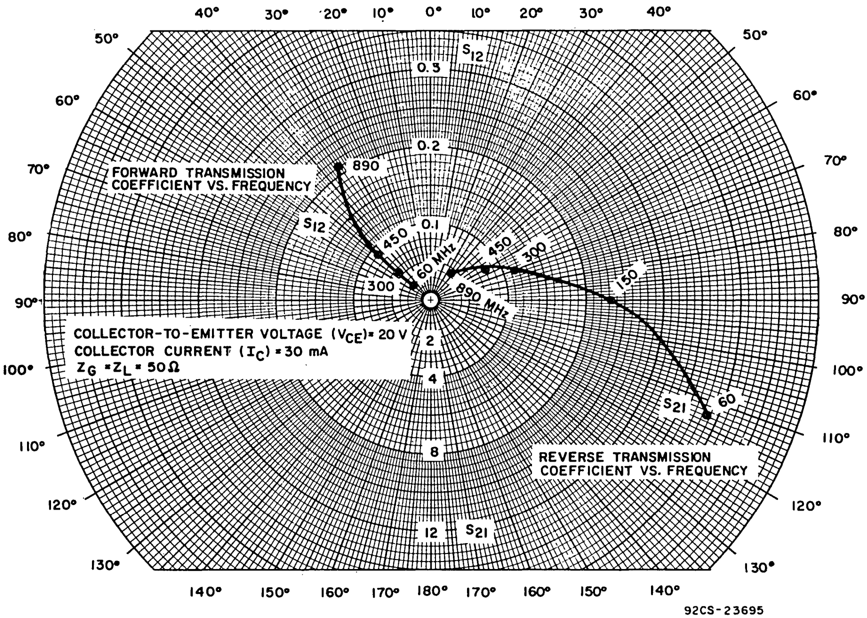
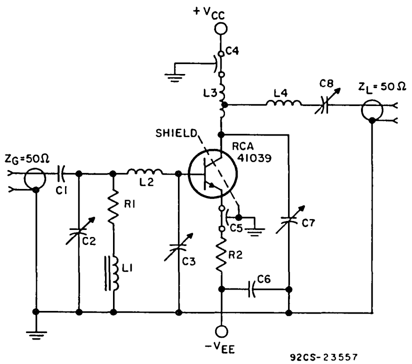


Fig. 5 – Typical transmission coefficients.



C1: 10 pF, disc ceramic
C2: 2.3-14.2 pF, E. F. Johnson 160-170*
C3: 3-35 pF, ARCO 404*
C4, C5: 1000 pF, feedthrough
C6: 1000 pF, disc ceramic
C7, C8: 0.9-7 pF, ARCO 400*
L1: RF choke, Ferroxcube #VK200-19/4B*
L2: 2 turns No. 12 wire, 0.25 in. (6.35 mm) ID, 0.25 in. (6.35 mm) long
L3: 3 turns No. 14 wire, 0.25 in. (6.35 mm) ID, 0.45 in. (11.43 mm) long, tapped at 1-1/2 turns
L4: 5-1/2 turns No. 14 wire, 0.25 in. (6.35 mm) ID, 0.5 in. (12.7 mm) long
R1: 220 Ω, 1/2 W, carbon
R2: 200 Ω, 1 W, carbon

* Or equivalent

Fig. 6 – 200-MHz narrow-band amplifier.

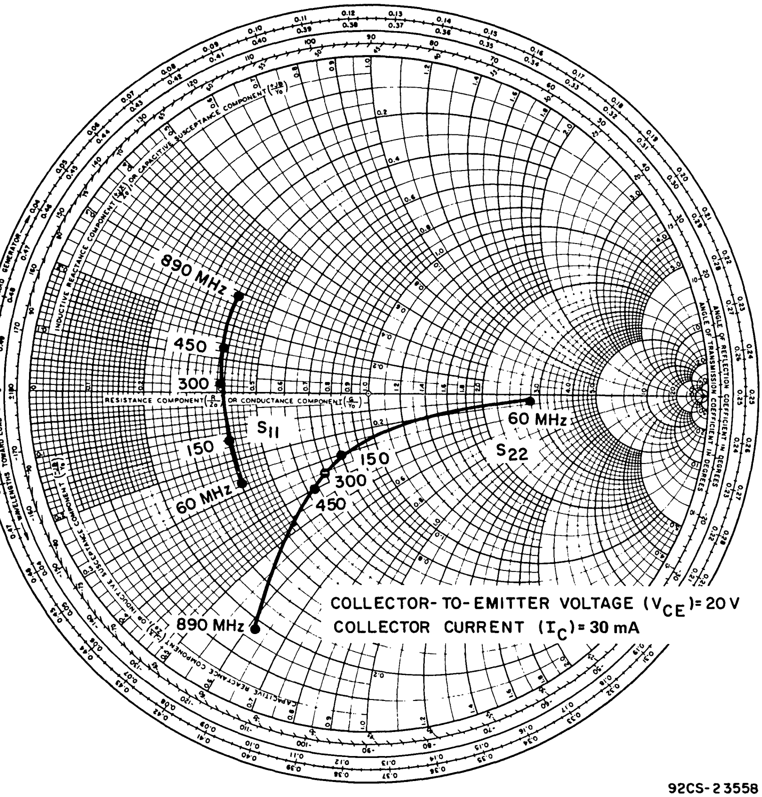
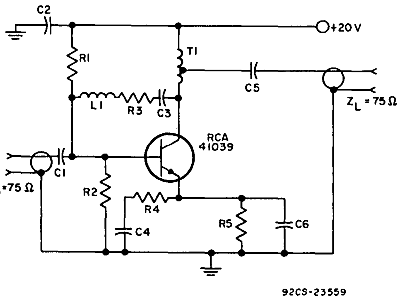


Fig. 7 – Typical reflection coefficients.



C1,3,4,5: 0.001 μF, disc ceramic
C2: 0.2 μF, disc ceramic
C6: 18 pF, disc ceramic
L1: 0.22 μH
R1: 3.6 kΩ, 1/2 W, carbon
R2: 910 Ω, 1/2 W, carbon
R3: 560 Ω, 1/4 W, carbon
R4: 39 Ω, 1/4 W, carbon
R5: 50 Ω, 1/2 W, carbon
T1: Core, Indiana General CF101, or equivalent; 6 turns primary, 2 turns secondary

Fig. 8 – 50-250 MHz broadband amplifier.

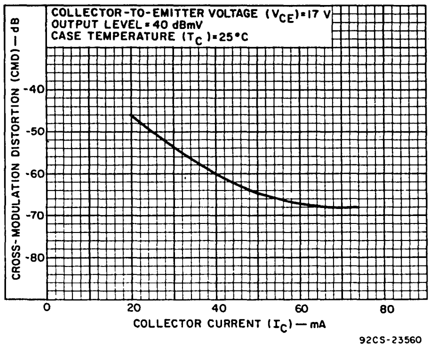
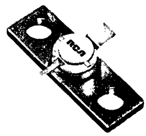


Fig. 9 – Typical 12-channel cross modulation of 50-250 MHz broadband amplifier.

Solid State
Division

RF Power Transistors

41044



RCA HF-56 Package
(can also be supplied without flange upon request.) H-1823R1

0.4-W, 4.36-GHz Oscillator Transistor

Features:

- 0.35-W (min.), 0.40-W (typ.) output at 4.36 GHz
- 0.65-W (typ.) output at 3.2 GHz
- Multicell structure for low thermal resistance
- Emitter-ballasting resistors
- Collector connected to flange
- For stripline and lumped-constant circuits

The RCA-41044* is an epitaxial n-p-n planar transistor with overlay emitter-electrode construction. It employs integral silicon emitter-ballasting resistors for ruggedness. This transistor operates at 20 volts, and is intended for common-collector operation as a fundamental-frequency oscillator at frequencies up to 4.5 GHz.

* Formerly RCA Dev. No. TA8955.

TERMINAL CONNECTIONS

Terminal 1 — Base
Terminals 2 and 4 — Collector
Terminal 3 — Emitter

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	40	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
TRANSISTOR DISSIPATION:	P_T		
At case temperatures up to 100°C		5	W
At case temperatures above 100°C derate linearly		0.05	W/°C
TEMPERATURE RANGE:			
Storage and Operating (Junction)		−65 to +200	°C
CASE TEMPERATURE (During soldering):			
For 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS, *At Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS DC Voltage (V)	DC Current (mA)		LIMITS		UNITS
		V_{CB}	I_E	I_C	Min.	Max.	
Collector Cutoff Current	I_{CBO}	20	0		–	0.5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0	5	40	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.1	0	3.5	–	V
Thermal Resistance (Junction-to-Collector Flange)	$R_{\theta JC}$				–	20	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS Frequency (f) – GHz	Supply Voltage (V_{CC}) – V	LIMITS Min.	Max.	UNITS
Oscillator Output Power	P_O	4.36	–20	0.35	–	W
Oscillator Circuit Efficiency	η	4.36	–20	15	–	%
Collector-to-Base Capacitance V_{CB} = 30 V	C_{obo}	1 MHz		–	4	pF

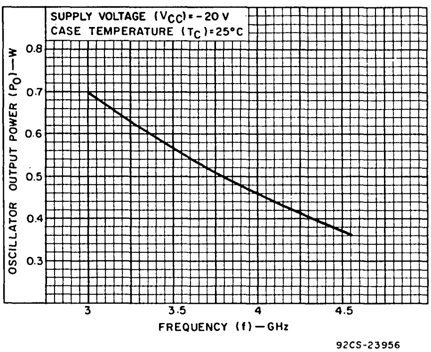


Fig. 1 – Typical oscillator output power vs. frequency.

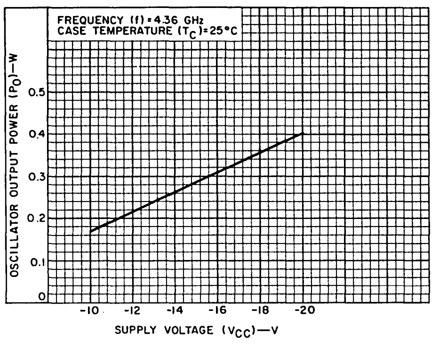
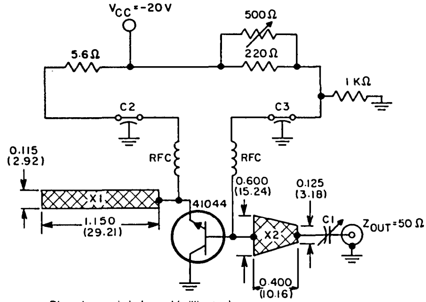


Fig. 2 – Typical 4.36-GHz oscillator output power vs. supply voltage.



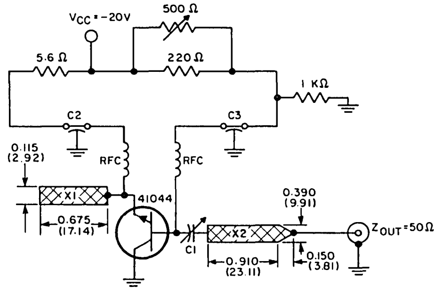
Dimensions are in inches and (millimeters).

C1: 0.6-4.5 pF, Johanson 7271 or equivalent
C2, C3: Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 0.63 in. (16.0 mm) of #32 wire (lay flat on circuit)

Dielectric material: 1/32-in. (0.79 mm) Teflon-fiberglass double-clad circuit board (ε = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

92CS-23958

Fig. 3 – Schematic diagram of 3.2-GHz oscillator circuit.



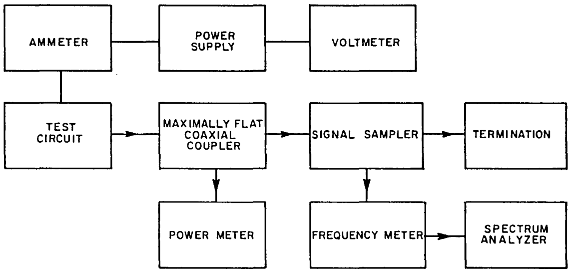
Dimensions are in inches and (millimeters).

C1: 0.4-2.5 pF, Johanson 7281 or equivalent
C2, C3: Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 0.50 in. (12.7 mm) of #32 wire (lay flat on circuit)

Dielectric material: 1/32-in. (0.79 mm) Teflon-fiberglass double-clad circuit board (ε = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

92CS-23959

Fig. 4 – Schematic diagram of 4.36-GHz oscillator circuit.



92CS-22387R1

Fig. 5 – Test arrangement for measurement of output power from 41044 oscillator.

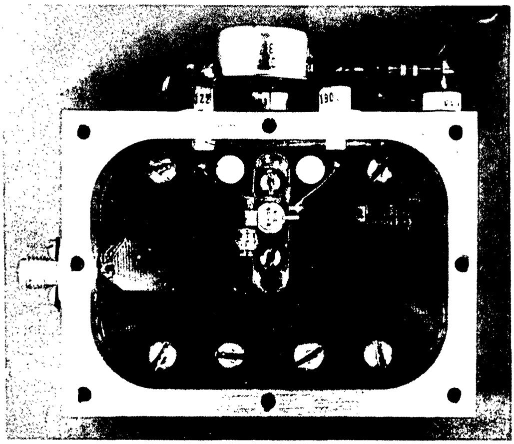


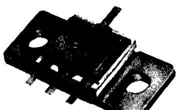
Fig. 6 – Photograph of 4.36-GHz oscillator.

RCA

Solid State Division

RF Power Transistors

RCA0610-30



RCA HF-55 Package

H-1822

30-W, Broadband, 620-to-960-MHz, Emitter-Ballasted, Gold-Metallized Transistor

Features:

- **GIGAMATCH stripline package:**
  Internal input-matching network; $Z_{IN} \approx (10 + j0)\ \Omega$
  External shunt matching at collector; $Z_{OUT} \approx (6 + j0)\ \Omega$ with shunt resonance
- **Emitter-ballasting and low $R_{\theta JC}$ for added reliablity**
- **Suitable for broadband operation (620 – 960 MHz)**
- **Gold metallization with barrier-layer protection**

Type RCA0610-30● is a multicell epitaxial silicon n-p-n planar transistor with overlay emitter construction. It uses integral silicon emitter-site ballast resistance for improved ruggedness and increased overdrive capability, internally mounted MOS capacitors for input matching, and gold metallization with barrier-layer protection for improved reliability. The RCA0610-30 is intended for high-power broadband uhf amplifiers.

The unique external shunt tuning is made possible by two additional leads from the collector. These leads allow the circuit designer to tune the output capacitance (C_{OB}) for optimum performance over a particular frequency range.

Approximately 75 per cent of the required inductance for full-bandwidth operation is contained within the package; the external circuit provides the additional inductance in the form of the two lengths of stripline that can be terminated to the ground plane by dc blocking capacitors.

For narrow-band operation the RCA0610-30 can be used without collector shunt tuning by clipping off the two external shunt leads.

● Formerly RCA Dev. No. TA8923.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		50	W
At case temperature above 75°C, derate at		0.4	W/°C
TEMPERATURE RANGE:			
Storage and Operating (Junction)		–65 to +200	°C

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25^{o}C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS			LIMITS		UNITS
		DC Collector Voltage (V)	DC Current (mA)				
		V_{CB}	I_E	I_C	Min.	Max.	
Collector-to-Base Reverse Current	I_{CBO}	28	0		–	5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0	25	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.5	0	3.5		V
Thermal Resistance (Junction-to-Case)	$R_{\theta JC}$				–	2.5	^{o}C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS		LIMITS		UNITS
		Frequency (f) – MHz	DC Collector Supply Voltage (V_{CC}) – V	Min.	Max.	
Output Power (P_{IB} = 4.75 W)	P_{OB}	620 – 960	28	30	–	W
Power Gain (P_{OB} = 30 W)	G_{PB}	620 – 960	28	8	–	dB
Collector Efficiency (P_{OB} = 30 W)	η_C	620 – 960	28	55	–	%
Collector-to-Base Capacitance (V_{CB} = 30 V)	C_{obo}	1 MHz		–	30	pF

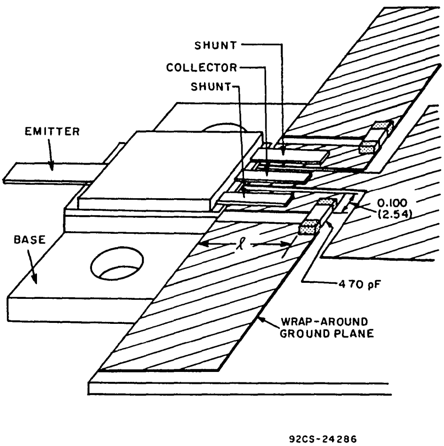


Fig.1 – Use of external shunt leads to tune the output capacitance of RCA0610-30.

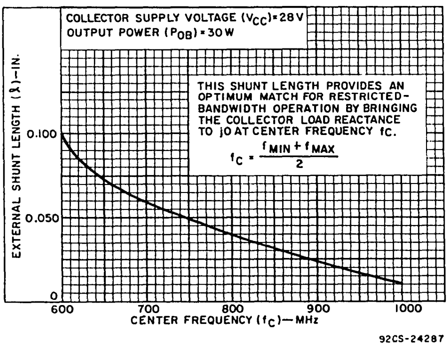


Fig.2 – Typical optimum length of shunts in external collector circuit vs. center frequency.

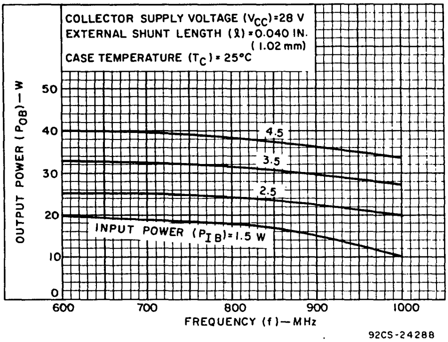


Fig.3 – Typical tuned output power vs. frequency for RCA0610-30 in the test set-up of Fig.8.

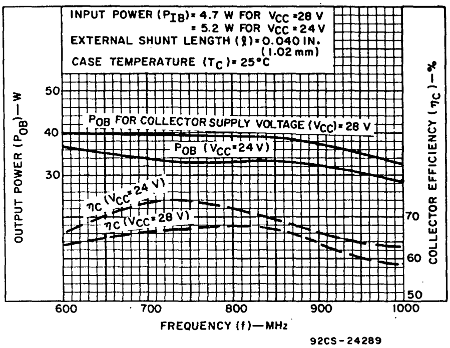


Fig.4 – Typical tuned output power and collector efficiency vs. frequency for RCA0610-30 in the test set-up of Fig.8.

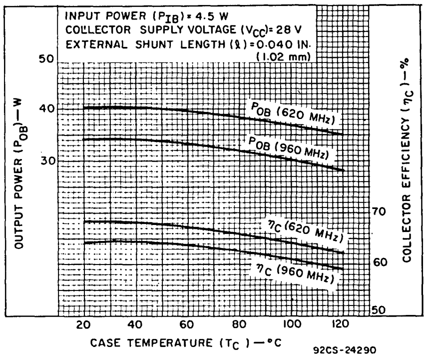


Fig.5 – Typical tuned output power and collector efficiency vs. case temperature for RCA0610-30 in the test set-up of Fig.8.

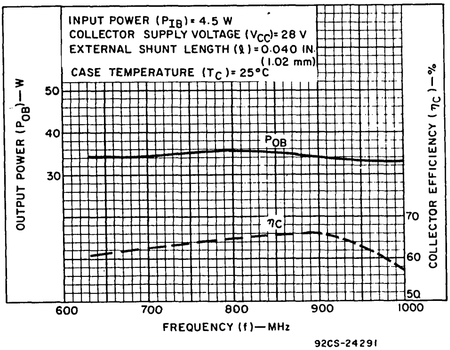


Fig.6 – Typical broadband output power and collector efficiency vs. frequency for RCA0610-30 in the circuit of Fig.11.

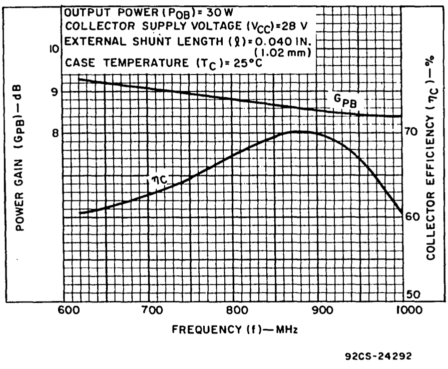


Fig.7 – Typical broadband power gain and collector efficiency vs. frequency for RCA0610-30 in the circuit of Fig.11.

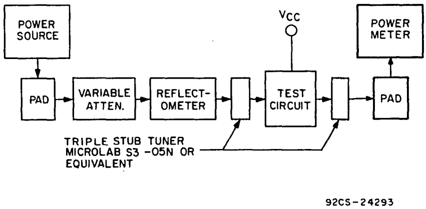


Fig.8 – Block diagram of test set-up for measuring tuned performance of RCA0610-30.

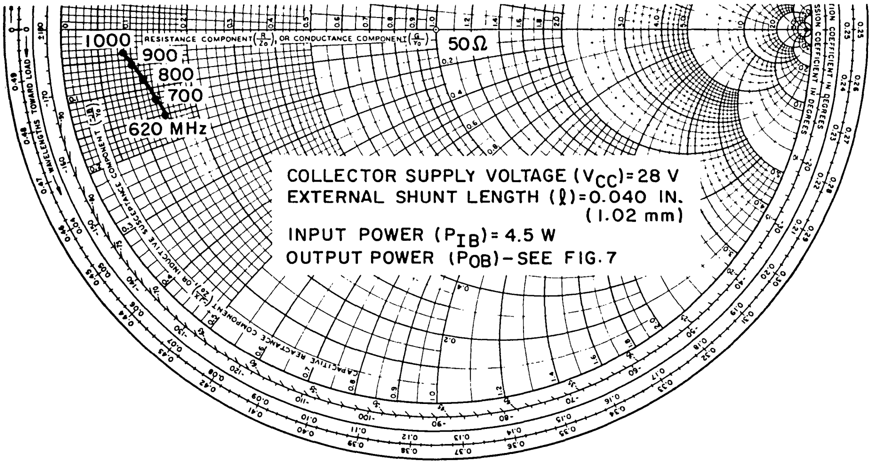


Fig.9 — Typical large-signal collector load impedance of RCA0610-30.

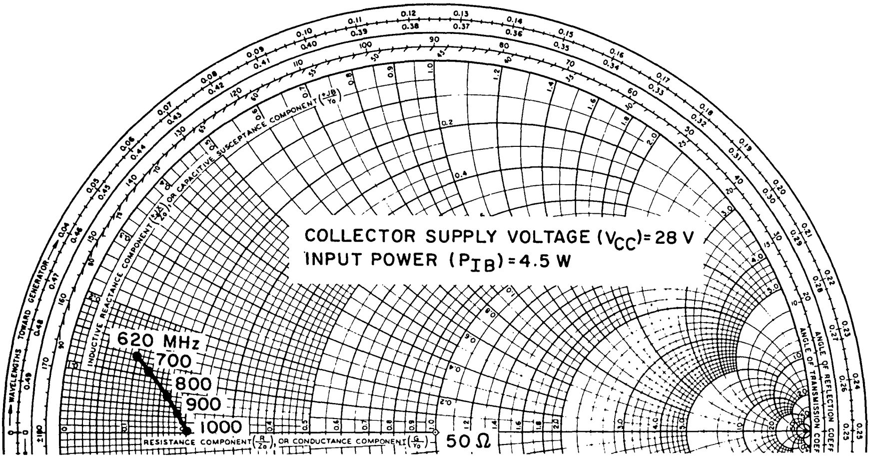
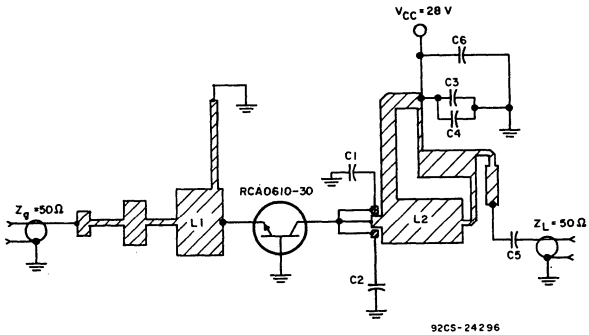


Fig.10 — Typical large-signal input impedance of RCA0610-30.



NOTE: Capacitors C_1 and C_2 are placed directly from pads to ground via wrap-around or low-inductance plated-through holes.

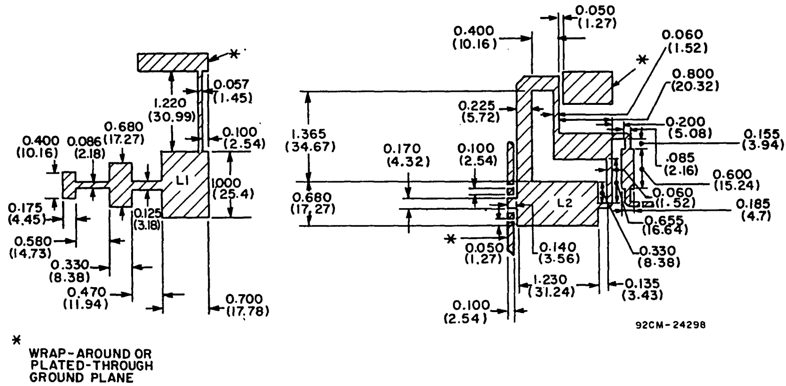
$C_1 - C_5$: 470 pF Vitramon Microwave Chip Capacitors (Vitramon, Inc. Box 544, Bridgeport, Ct. 06601)•

C_6: 25 μF, 50 V, electrolytic

L_1, L_2: See details of construction (Fig.12)

• Or equivalent.

Fig.11 – 620 – 1000 MHz broadband 30-watt amplifier circuit.



Dielectric material: 1/32-in. (0.79-mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6). L_1 and L_2 are produced by removing upper copper layer to dimensions shown.

Fig.12 – Construction details for L1 and L2 in 620 – 1000 MHz broadband amplifier circuit of Fig.11.

TERMINAL CONNECTIONS

Terminal 1 – Emitter
Terminal 2 – Base
Terminal 3 – Shunt
Terminal 4 – Collector
Terminal 5 – Shunt

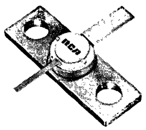
WARNING: The ceramic heat-sink portion of this device contains beryllium oxide. Do not crush, grind, or abrade this portion because the dust resulting from such action may be hazardous if inhaled, Disposal should be by burial.

RCA

Solid State
Division

RF Power Transistors

RCA2001



RCA HF-46
(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

1-W, 2-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For Use in Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- **1-W output with 7-dB gain (min.) at 2 GHz, 28 V**
- **Load VSWR capability of 10:1 at 2 GHz**
- **Emitter-ballasting resistors**
- **Stable common-base operation**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuits**

The RCA2001 is an emitter-ballasted epitaxial silicon n-p-n planar transistor that uses overlay multiple-emitter-site construction. It is designed especially for use in microwave communications, L- and S-band telemetry, microwave relay links, phased-array radar, distance-measuring equipment, transponders, and collision avoidance systems.

The ceramic-metal stripline package of the device has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

This transistor is especially suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	V
EMITTER-TO-BASE VOLTAGE.	V_{EBO}	3.5	V
TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		5	W
At case temperature above 75°C . . . . . Derate linearly at		0.04	W/°C
TEMPERATURE RANGE:			
Storage and operating (Junction)		−65 to +200	°C
LEAD TEMPERATURE (During soldering):			
At distances ≥ 0.02 in. (0.5 mm) from seating plane for 10 s max.		230	°C

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		Voltage V dc		Current mA dc		RCA2001		
		V_{CE}	V_{CB}	I_E	I_C	MIN.	MAX.	
Collector Cutoff Current: With emitter open	I_{CBO}		28	0		–	0.5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1	0	3.5	–	V
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	25	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		VOLTAGE V dc	FREQUENCY GHz	POWER W		RCA2001		
		V_{CC}	f	P_{IB}	P_{OB}	MIN.	MAX.	
Output Power	P_{OB}	28	2	0.2		1	–	W
Large-Signal Common-Base Power Gain	G_{PB}	28	2		1	7	–	dB
Collector Efficiency	η_C	28	2		1	30	–	%
Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	3	pF

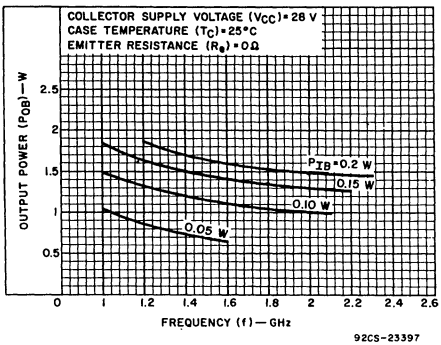


Fig.1 — Typical output power vs. frequency.

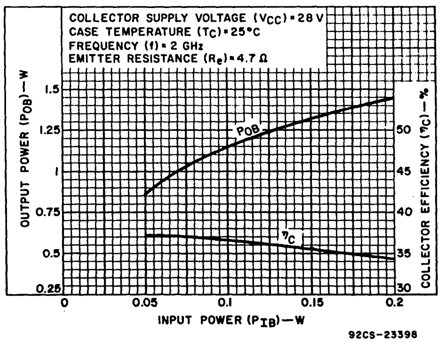


Fig.2 — Typical output power and collector efficiency vs. input power at 2 GHz.

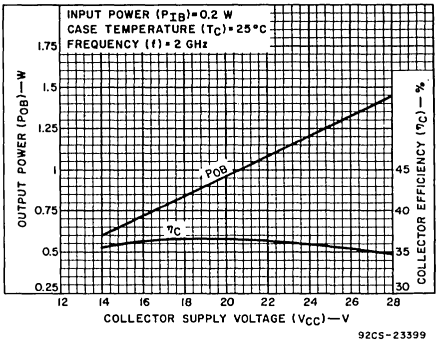


Fig.3 – Typical output power and collector efficiency vs. supply voltage.

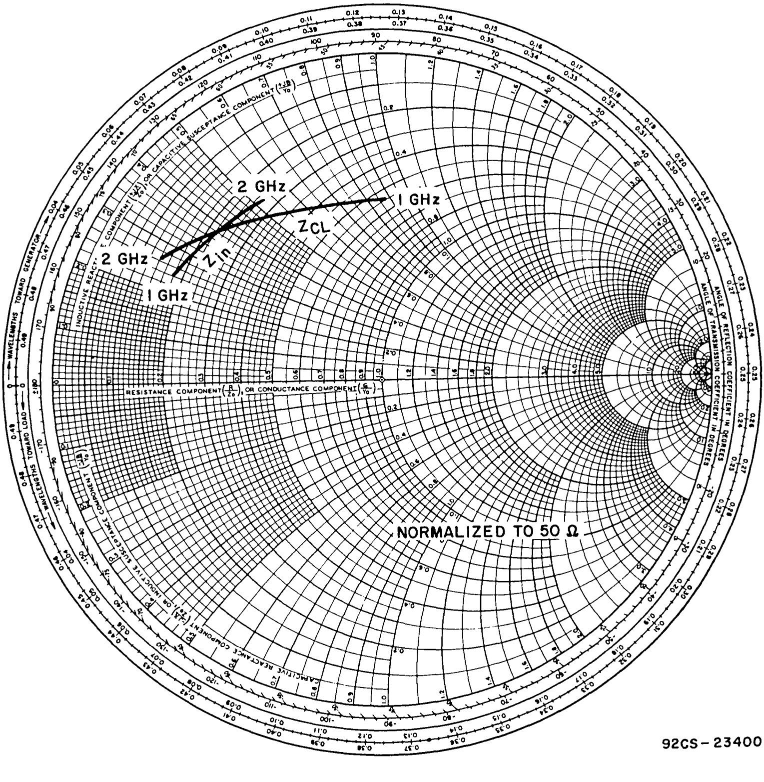
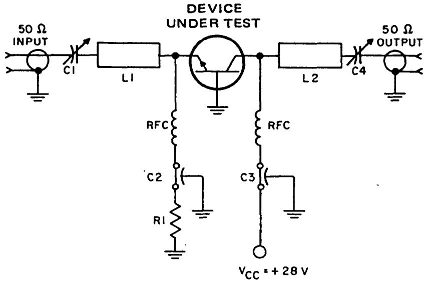


Fig.4 – Input and output impedances.



C1, C4: 0.35–3.5 pF, Johanson 4702 or equivalent
C2, C3: 470 pF feedthrough, Allen-Bradley FB28 or equivalent
L1: Microstripline, 0.031 in. (0.79 mm) Teflon-Fiberglas, 0.18 in. (0.45 mm) wide, 0.350 in. (0.889 mm) long, ϵ = 2.6
L2: Microstripline, 0.031 in. (0.79 mm) Teflon-Fiberglas, 0.18 in. (0.45 mm) wide, 0.66 in. (16.76 mm) long, ϵ = 2.6
RFC: 3 turns No. 32 wire, 0.0625 in. (1.58 mm) ID, 0.25 in. (6.35 mm) long
R1: 4.7 Ω

Fig.5 – 2-GHz test circuit for both types.

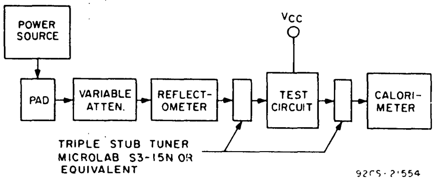


Fig.6 – Block diagram of test set-up for measurement of performance from 1- or 2-GHz common-base amplifier.

TERMINAL CONNECTIONS

Terminal 1 – Emitter
Terminals 2 & 4 – Base
Terminal 3 – Collector

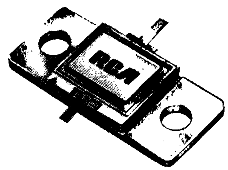
WARNING: The ceramic body of these devices contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

RCA

Solid State Division

RF Power Transistors

RCA2023-12



RCA HF-50 Package

H-1808R1

12.5-W, 22-V, Broadband (2.0-to-2.3-GHz) Emitter-Ballasted Transistor

Features:

- GIGAMATCH stripline package:
  Internal input-matching network (50 Ω nominal)
  Internal shunt tuning at collector
- G_{PB} = 7 dB (min.) at 22 V, 2.0 to 2.3 GHz
- Emitter ballasting and low $R_{\theta JF}$ for reliability and ruggedness
- Broadband operation (300-MHz bandwidth)
- Infinite load-VSWR capability at 22 V, 2.0 to 2.3 GHz
- P_{OB} = 15 W (typ.) at band edge

The RCA2023-12 is an epitaxial n-p-n planar transistor with overlay emitter construction. It employs integral silicon emitter-ballasting resistors for improved ruggedness and increased overdrive capability. The RCA2023-12 is internally matched for use in amplifier applications in the range from 2.0 GHz to 2.3 GHz with a 50-ohm (nominal) source and a supply voltage of 18 to 26 volts. It is intended for high-power broadband microwave communications, primarily telemetry and relay links in the 1.9-to-2.4-GHz range. The low thermal resistance of the hermetic stripline package of this transistor makes it suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	45	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		62.5	W
At case temperature above 75°C ... Derate linearly at		0.5	W/°C
TEMPERATURE RANGE:			
Storage and operating (Junction)		−65 to +200	°C
LEAD TEMPERATURE (During soldering):			
At distances ⩾ 0.02 in. (0.5 mm) from seating plane for 10 s max.		230	°C

TERMINAL CONNECTIONS

Terminal 1 — Collector
Terminals 2 & 4 — Base
Terminal 3 — Emitter

WARNING: The ceramic heat-sink portion of this device contains beryllium oxide. Do not crush, grind, or abrade this portion because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

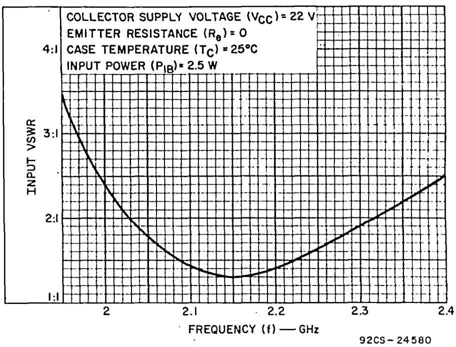


Fig. 1 — Typical input VSWR for RCA2023-12 driven by a 50-ohm (nominal) source.

ELECTRICAL CHARACTERISTICS, *at Case Temperature* $(T_C) = 25°C$

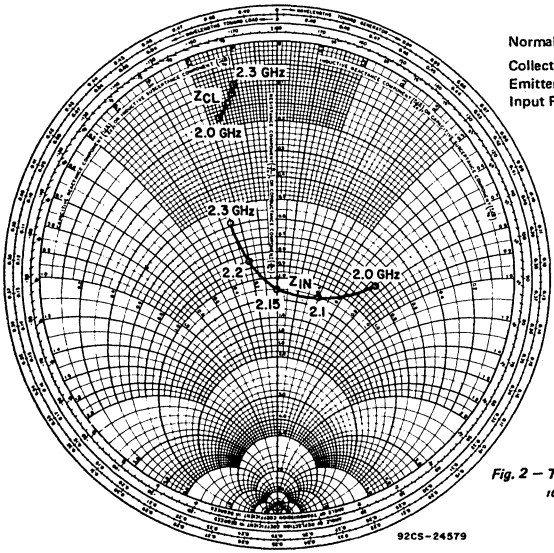
STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS			LIMITS		UNITS
		Voltage V dc	Current mA dc				
		V_{CB}	I_E	I_C	MIN.	MAX.	
Collector Cutoff Current	I_{CBO}	22	0		–	1.5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$		0	15	45	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$		0.5	0	3.5	–	V
Thermal Resistance (Junction-to-Flange)	$R_{\theta JF}$				–	2	°C/W

DYNAMIC

CHARACTERISTIC▲	SYMBOL	TEST CONDITIONS				LIMITS		UNITS
		VOLTAGE V dc	FREQUENCY GHz	POWER W				
		V_{CC}	f	P_{IB}	P_{OB}	MIN.	MAX.	
Output Power	P_{OB}	22	2.0 – 2.3	2.5		12.5	–	W
Power Gain	G_{PB}	22	2.0 – 2.3		12.5	7	–	dB
Collector Efficiency	η_C	22	2.0 – 2.3	2.5		40	–	%
Input VSWR		22	2.0 – 2.3	2.5		–	3:1	

▲Measured in the test circuit of Fig. 6 and the test set-up of Fig. 7.



Normalized to 50 Ω
Collector Supply Voltage $(V_{CC}) = 22$ V
Emitter Resistance $(R_e) = 0$
Input Power $(P_{IB}) = 2.5$ W

Fig. 2 – Typical large-signal input impedance and collector load impedance for RCA2023-12.

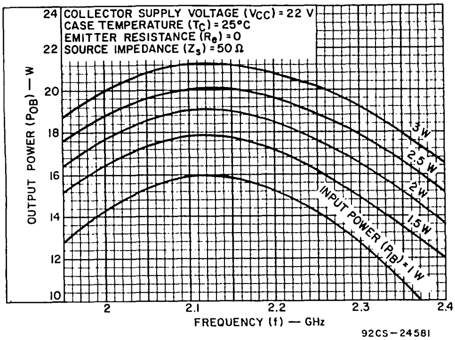


Fig. 3 — Typical narrow-band output power of RCA2023-12 as a function of frequency.

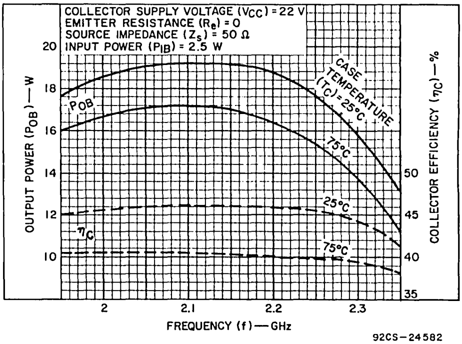


Fig. 4 — Typical broadband performance of RCA2023-12, measured in the circuit of Fig. 7.

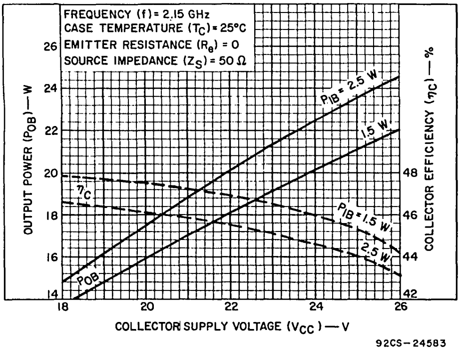
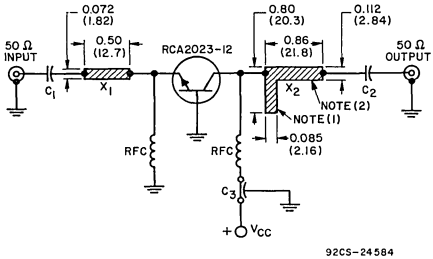


Fig. 5 — Typical narrow-band output power and collector efficiency of RCA2023-12, as functions of collector supply voltage.



C1, C2: 10 pF, ATC-100 or equivalent
RFC: 0.7 in. (17.8 mm) of No. 30 wire (lay on circuit board)
C3: Filtercon, Allen-Bradley SMFB-A1 or equivalent
X1, X2: 1/32-in. (0.79-mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6) lines. X1 and X2 are produced by removing upper copper layer to dimensions shown.
Note 1: Trim stub section length for optimum performance at 2.3 GHz (or use capacitive tuning screw).
Note 2: Trim transformer width for optimum performance at 2.0 GHz.

Fig. 6 — 2.0-to-2.3-GHz test circuit.

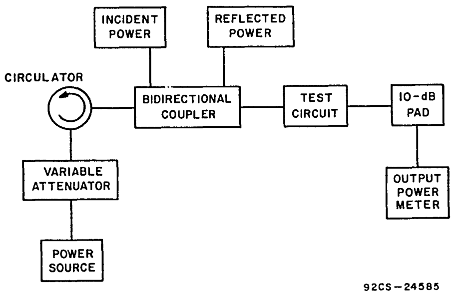
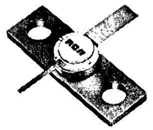


Fig. 7 — Test set-up for rf measurements.

RCA
Solid State
Division

RF Power Transistors

RCA2310



RCA HF-46
(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

10-W, 2.3-GHz, Emitter-Ballasted Silicon N-P-N Overlay Transistor

For Use in Microwave Power Amplifiers, Fundamental-Frequency Oscillators, and Frequency Multipliers

Features:

- **10-W output with 8.2-dB gain (min.) at 2.3 GHz, 24 V**
- **Load-VSWR capability of 10:1 at 2.3 GHz**
- **Emitter-ballasting resistors**
- **Stable common-base operation**
- **Especially suitable for S-band telemetry use**
- **Ceramic-metal hermetic stripline package with low inductance and low parasitic capacitances**
- **For stripline, microstripline, and lumped-constant circuits**

RCA2310● is an emitter-ballasted epitaxial silicon n-p-n planar transistor that uses overlay multiple-emitter-site construction. It is designed especially for use in microwave communications, L- and S-band telemetry, microwave relay links and transponders in the frequency range of 1.5 GHz to 2.4 GHz.

The ceramic-metal stripline package of this device has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

This transistor is especially suitable for S-band telemetry and other large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

● Formerly RCA Dev. No. TA8803.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	45	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	V
CONTINUOUS COLLECTOR CURRENT	I_C	3.5	A
TRANSISTOR DISSIPATION:	P_T		
At case temperature up to 75°C		41.7	W
At case temperature above 75°C ... Derate linearly at		0.333	W/°C
TEMPERATURE RANGE:			
Storage and operating (Junction)		−65 to +200	°C
LEAD TEMPERATURE (During soldering):			
At distances ⩾ 0.02 in. (0.5 mm) from seating plane for 10 s max.		230	°C

TERMINAL CONNECTIONS

Terminal 1 – Emitter
Terminals 2 & 4 – Base
Terminal 3 – Collector

WARNING: The ceramic heat-sink portion of this device contains beryllium oxide. Do not crush, grind, or abrade this portion because the dust resulting from such action may be hazardous if inhaled, Disposal should be by burial.

9-74

ELECTRICAL CHARACTERISTICS, *at Case Temperature* (T_C) = 25°C

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS Voltage V dc V_{CE}	Voltage V dc V_{CB}	Current mA dc I_E	Current mA dc I_C	LIMITS RCA2310 MIN.	LIMITS RCA2310 MAX.	UNITS
Collector Cutoff Current: With emitter open	I_{CBO}		28	0		–	0.5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	45	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1	0	3.5	–	V
Forward Current Transfer Ratio	h_{FE}	5			500	15	120	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	3	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS VOLTAGE V dc V_{CC}	FREQUENCY GHz f	POWER W P_{IB}	POWER W P_{OB}	LIMITS RCA2310 MIN.	LIMITS RCA2310 MAX.	UNITS
Output Power	P_{OB}	24	2.3	1.5		10	–	W
Large-Signal Common-Base Power Gain	G_{PB}	24	2.3		10	8.2	–	dB
Collector Efficiency	η_C	24	2.3		10	30	–	%
Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	16	pF

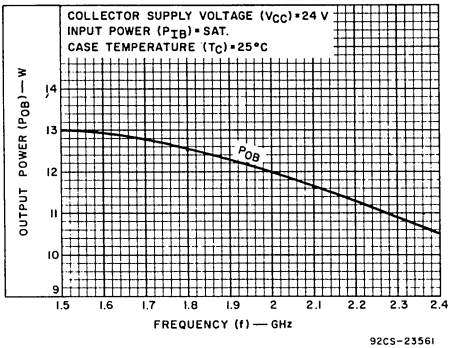


Fig. 1 — Typical saturated output power vs. frequency.

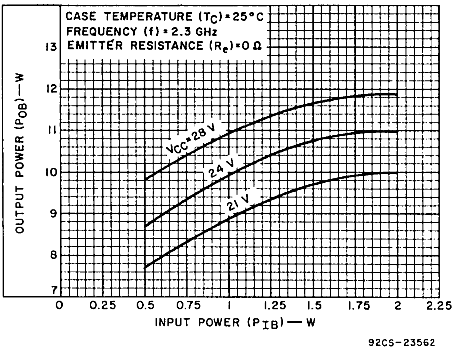


Fig. 2 — Typical output power vs. input power and supply voltage at 2.3 GHz.

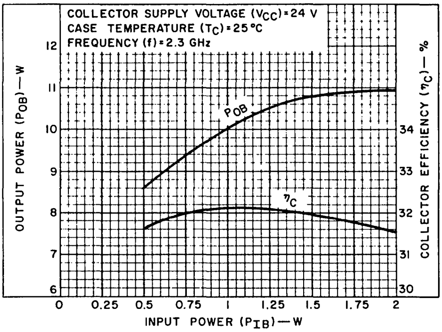


Fig. 3 — Typical output power and collector efficiency vs. input power at 2.3 GHz.

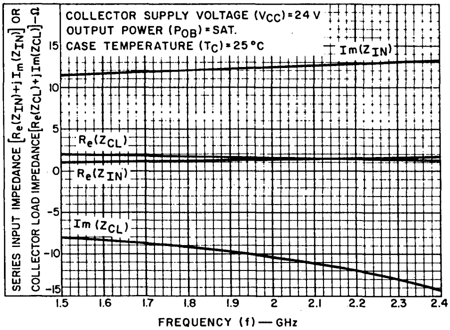
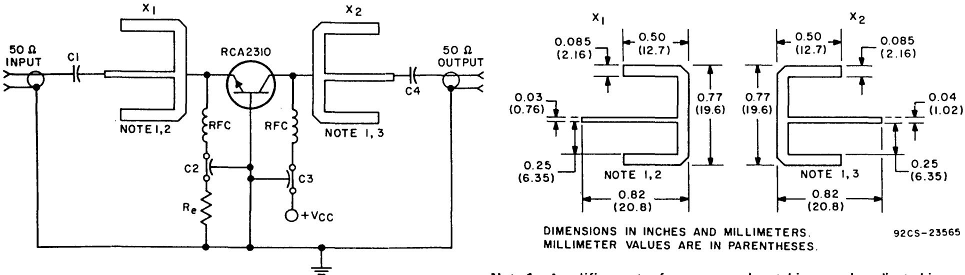


Fig. 4 — Typical input impedance and collector load impedance vs. frequency.



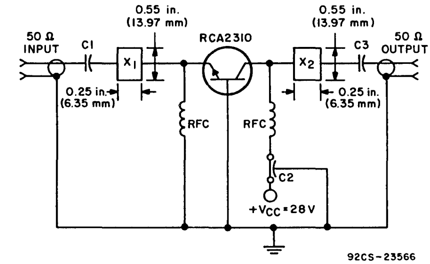
C1, C4: 10 pF, ATC-100, or equivalent
C2, C3: Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 3 turns No. 28 wire 0.0625 in. (1.58 mm) dia., 0.25 in. (6.35 mm) long
R_e: 0 to 0.24 Ω, 1 W, choose for best η_C
Dielectric Material: 0.031 in. (0.79 mm) thick Teflon-Fiberglas double-clad circuit board (ϵ = 2.6)

Note 1: Amplifier center frequency and matching may be adjusted in the 2.1-2.2 GHz range by trimming the stub lengths of X_1 and X_2.

Note 2: Input stubs may be replaced by a single 0.3-3.5 pF air dielectric variable capacitor.

Note 3: Output stubs may be replaced by a single 0.3-3.5 pF air dielectric variable capacitor.

Fig. 5 — Typical 40-MHz bandwidth, 2.15-GHz, 9-W amplifier using the RCA2310.



C1, C3: 10 pF, ATC-100, or equivalent
C2: Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 0.70 in. (17.8 mm) length of No. 32 wire (laid flat on circuit)
Dielectric Material: 0.031 in. (0.79 mm) thick Teflon-Fiberglas double-clad circuit board (ϵ = 2.6)

Fig. 6 — 2.3-GHz test circuit.

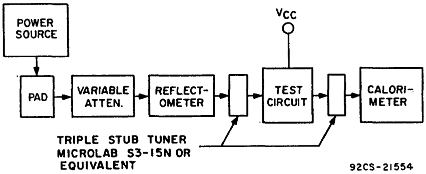
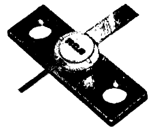


Fig. 7 — Block diagram of test set-up for measurement of performance of 2.3-GHz common-base amplifier.

Solid State Division

RF Power Transistors

RCA3001 RCA3003 RCA3005



RCA HF-46
(RCA HF-46 can also be supplied without flange upon request.)

H-1796R1

1-W, 2.5-W, and 4.5-W 3-GHz Emitter-Ballasted N-P-N Transistors

Features:

- 1-W output with 7-dB gain (min.) at 3 GHz (RCA3001)
- 2.5-W output with 5-dB gain (min.) at 3 GHz (RCA3003)
- 4.5-W output with 5-dB gain (min.) at 3 GHz (RCA3005)
- Emitter-ballasting resistors
- Stable common-base operation
- Hermetic stripline package with low inductances and low parasitic capacitances
- Load-VSWR capability of 10:1 at 3 GHz

RCA3001, RCA3003, and RCA3005 are emitter-ballasted epitaxial silicon n-p-n planar transistors that use overlay multiple-emitter-site construction. They are designed for use in microwave communications, S-band telemetry, microwave relay links, phased-array radars, transponders, and altimeters.

The hermetic stripline package of these devices has low parasitic capacitances and inductances, which afford stable operation in the common-base configuration.

These transistors are suitable for large-signal cw or pulsed applications in stripline, microstripline, and lumped-constant circuits.

MAXIMUM RATINGS, *Absolute-Maximum Values:*

		RCA3001	RCA3003	RCA3005	
COLLECTOR-TO-BASE VOLTAGE	V_{CBO}	50	50	50	V
EMITTER-TO-BASE VOLTAGE	V_{EBO}	3.5	3.5	3.5	V
TRANSISTOR DISSIPATION:	P_T				
At case temperature up to 75°C		5	8.34	14.7	W
At case temperature above 75°C . . . . Derate linearly at		0.04	0.067	0.118	W/°C
TEMPERATURE RANGE:					
Storage and operating (Junction)			−65 to +200		°C
LEAD TEMPERATURE (During soldering):					
At distances ⩾ 0.02 in. (0.5 mm) from seating plane for 10 s max.			230		°C

ELECTRICAL CHARACTERISTICS, *at Case Temperature (T_C) = 25°C*

STATIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: Voltage V dc V_{CE}	Voltage V dc V_{CB}	Current mA dc I_E	Current mA dc I_C	RCA3001 MIN.	RCA3001 MAX.	RCA3003 MIN.	RCA3003 MAX.	RCA3005 MIN.	RCA3005 MAX.	UNITS
Collector Cutoff Current: With emitter open	I_{CBO}		28	0		–	0.5	–	0.5	–	0.5	mA
Collector-to-Base Breakdown Voltage	$V_{(BR)CBO}$			0	5	50	–	50	–	50	–	V
Emitter-to-Base Breakdown Voltage	$V_{(BR)EBO}$			0.1	0	3.5	–	3.5	–	3.5	–	V
Forward Current Transfer Ratio	h_{FE}	5			100	15	120	15	120	15	120	
Thermal Resistance: (Junction-to-Case)	$R_{\theta JC}$					–	25	–	15	–	8.5	°C/W

DYNAMIC

CHARACTERISTIC	SYMBOL	TEST CONDITIONS: VOLTAGE V dc V_{CC}	FREQUENCY GHz f	POWER W P_{IB}	POWER W P_{OB}	RCA3001 MIN.	RCA3001 MAX.	RCA3003 MIN.	RCA3003 MAX.	RCA3005 MIN.	RCA3005 MAX.	UNITS
Output Power	P_{OB}	28	3	0.2		1.0	–	–	–	–	–	W
		28	3	0.8		–	–	2.5	–	–	–	
		28	3	1.4		–	–	–	–	4.5	–	
Large-Signal Common-Base Power Gain	G_{PB}	28	3		1.0	7	–	–	–	–	–	dB
		28	3		2.5	–	–	5	–	–	–	
		28	3		4.5	–	–	–	–	5	–	
Collector Efficiency	η_C	28	3		1.0	30	–	–	–	–	–	%
		28	3		2.5	–	–	30	–	–	–	
		28	3		4.5	–	–	–	–	30	–	
Collector-to-Base Output Capacitance	C_{obo}	V_{CB} = 28	1 MHz			–	3	–	5	–	7	pF

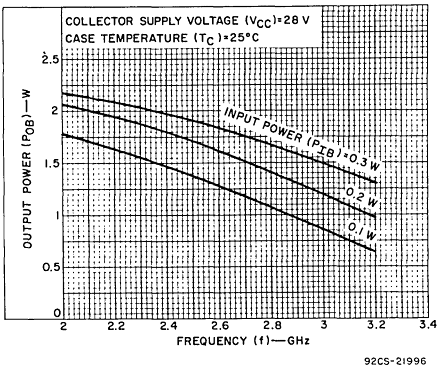


Fig.1 – Typical output power vs. frequency for RCA3001.

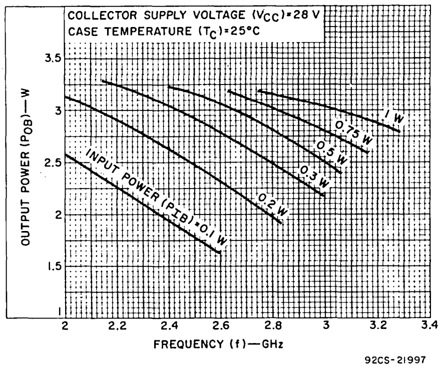


Fig.2 – Typical output power vs. frequency for RCA3003.

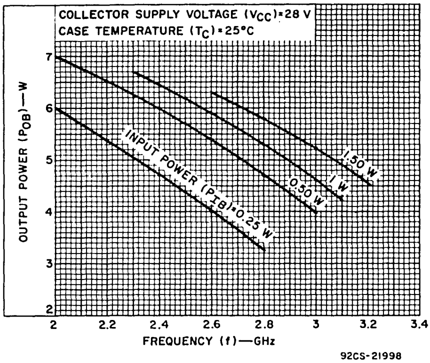


Fig.3 – Typical output power vs. frequency for RCA3005.

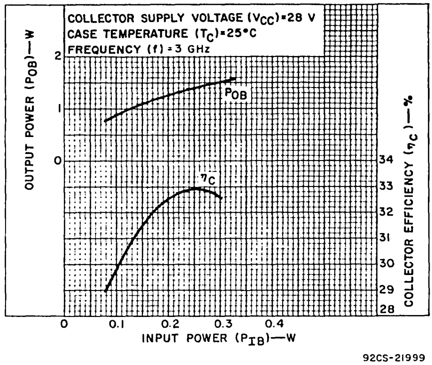


Fig.4 – Typical output power and collector efficiency vs. input power at 3 GHz for RCA3001.

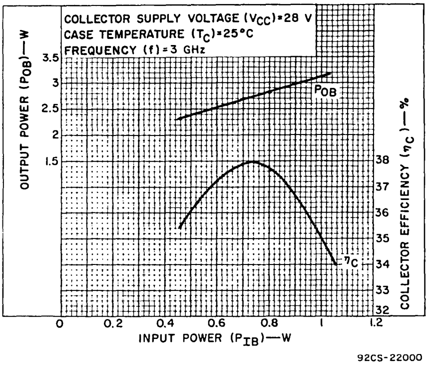


Fig.5 – Typical output power and collector efficiency vs. input power at 3 GHz for RCA3003.

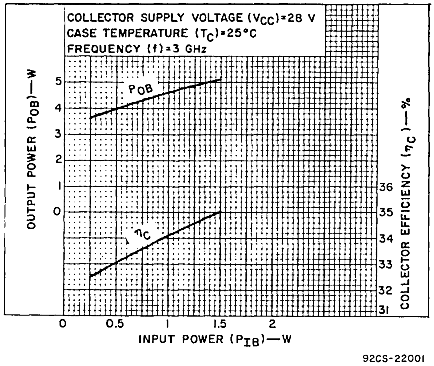


Fig.6 – Typical output power and collector efficiency vs. input power at 3 GHz for RCA3005.

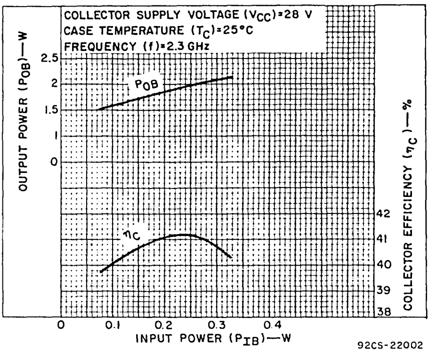


Fig.7 – Typical output power and collector efficiency vs. input power at 2.3 GHz for RCA3001.

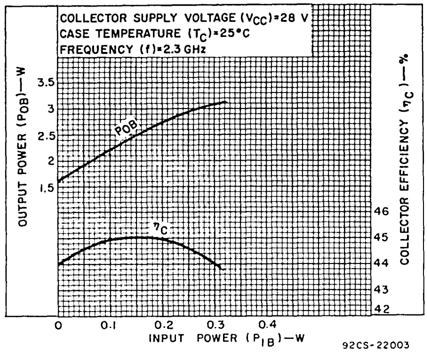


Fig.8 – Typical output power and collector efficiency vs. input power at 2.3 GHz for RCA3003.

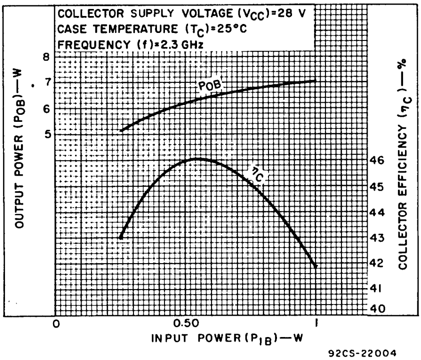


Fig.9 — Typical output power and collector efficiency vs. input power at 2.3 GHz for RCA3005.

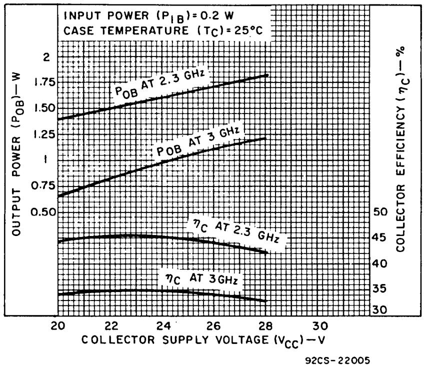


Fig.10 — Typical output power and collector efficiency vs. supply voltage at 2.3 GHz and 3 GHz for RCA3001.

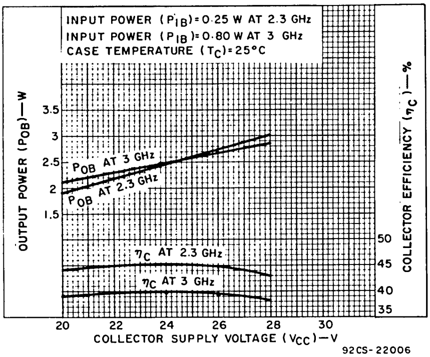


Fig.11 — Typical output power and collector efficiency vs. supply voltage at 2.3 GHz and 3 GHz for RCA3003.

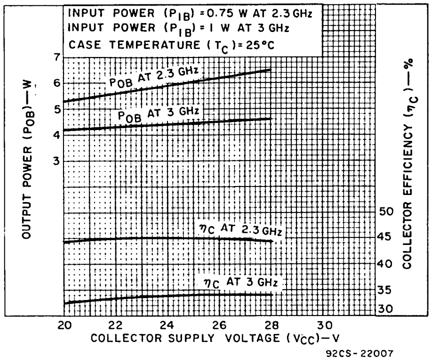


Fig.12 — Typical output power and collector efficiency vs. supply voltage at 2.3 GHz and 3 GHz for RCA3005.

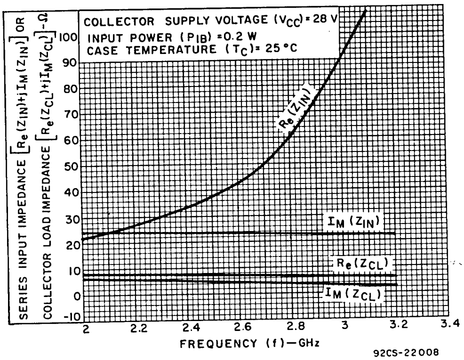


Fig.13 — Typical input impedance and collector load impedance vs. frequency for RCA3001.

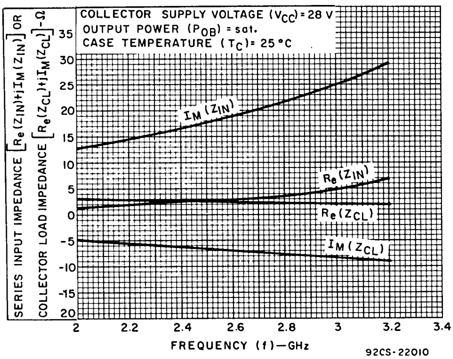


Fig.14 — Typical input impedance and collector load impedance vs. frequency for RCA3003.

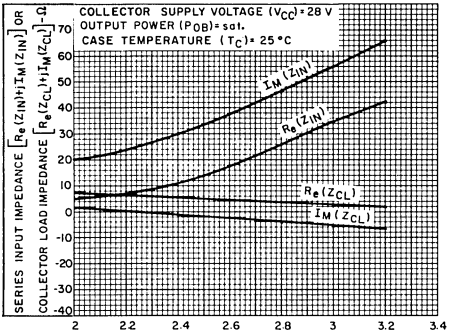
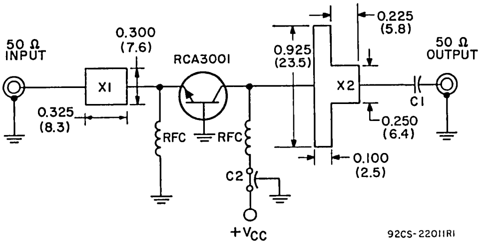


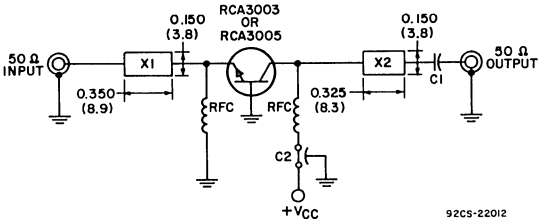
Fig. 15 — Typical input impedance and collector load impedance vs. frequency for RCA3005.



C1 : 5 pF, ATC-100 or equivalent
C2 : Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 0.70 in. (17.8 mm) of #32 wire (lay flat on circuit)

Dielectric material: 1/32-in. (0.79 mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

Fig. 16 — 3-GHz test circuit for RCA3001.



C1 : 5 pF, ATC-100 or equivalent
C2 : Filtercon, Allen-Bradley SMFB-A1 or equivalent
RFC: 0.70 in. (17.8 mm) of #32 wire (lay flat on circuit)

Dielectric material: 0.01-in. (0.25 mm) Teflon-fiberglass double-clad circuit board (ϵ = 2.6). Lines X_1 and X_2 are produced by removing upper copper layer to dimensions shown.

Fig. 17 — 3-GHz test circuit for RCA3003 and RCA3005.

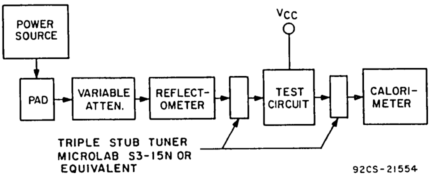


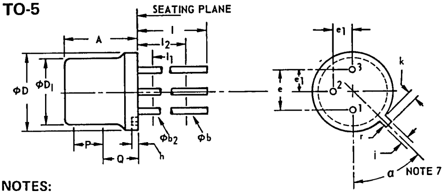
Fig. 18 — Block diagram of test set-up for measurement of performance from 2.3-GHz or 3-GHz common-base amplifier.

TERMINAL CONNECTIONS

Terminal 1 — Emitter
Terminals 2 & 4 — Base
Terminal 3 — Collector

WARNING: The ceramic body of these devices contains beryllium oxide. Do not crush, grind, or abrade these portions because the dust resulting from such action may be hazardous if inhaled. Disposal should be by burial.

TO-5



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
φb_2	0.016	0.019	0.406	0.483	2
φD	0.335	0.370	8.51	9.40	
φD_1	0.305	0.335	7.75	8.51	
e	0.200 T.P.		5.08 T.P.		4, 5
e_1	0.100 T.P.		2.54 T.P.		5
h	0.009	0.125	0.229	3.18	
i	0.028	0.034	0.711	0.864	5
k	0.029	0.045	0.737	1.14	3, 5
l	1.500	–	38.10	–	2
l_1	–	0.050	–	1.27	2
l_2	0.250	–	6.35	–	2
P	0.100	–	2.54	–	1
Q	–	–	–	–	6
r	–	0.007	–	0.179	
α	45° T. P.		–		5, 7

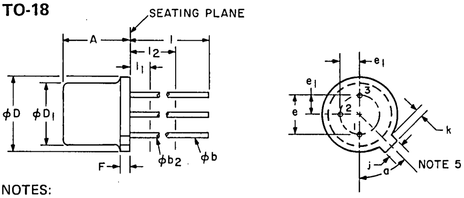
MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. This zone is controlled for automatic handling. The variation in actual diameter within the zone shall not exceed 0.010 in. (0.254 mm).
2. (Three leads) φb_2 applies between l_1 and l_2. φb applies between l_2 and 1.5 in. (38.20 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 1.5 in. (38.10 mm) from seating plane.
3. Measured from maximum diameter of the actual device.
4. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.25 mm) – 0.000 in. (0.000 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to the maximum-width tab.
5. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-1.
6. Details of outline in this zone optional.
7. Tab centerline.

92SS-3821

TO-18



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.170	0.210	4.32	5.33	
φb	0.016	0.021	0.406	0.533	1
φb2	0.016	0.019	0.406	0.483	1
φD	0.209	0.230	5.31	5.84	
φD1	0.178	0.195	4.52	4.95	
e	0.100 T.P.		2.54 T.P.		2, 4
e1	0.050 T.P.		1.27 T.P.		2, 4
F		0.030		0.762	
j	0.036	0.046	0.914	1.17	4
k	0.028	0.048	0.711	1.22	3
l	0.500		12.70		1
l1		0.050		1.27	1
l2	0.250		6.35		1
α	45° T.P.				5

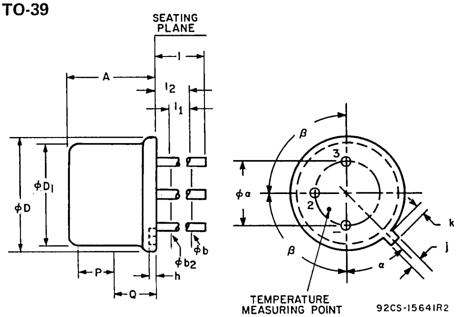
MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. (Three leads) φb_2 applies between l_1 and l_2. φb applies between l_2 and 0.5 in. (12.70 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 0.5 in. (12.70 mm) from seating plane.
2. Leads having maximum diameter 0.019 in. (0.483 mm) measured in gaging plane 0.054 in. (1.37 mm) + 0.001 in. (0.025 mm) – 0.00 in. (0.00 mm) below the seating plane of the device shall be within 0.007 in. (0.178 mm) of their true positions relative to a maximum-width tab.
3. Measured from maximum diameter of the actual device.
4. The device may be measured by direct methods or by the gage and gaging procedure described on gage drawing GS-2.
5. Tab centerline.

92CS-20223

TO-39



92CS-15641R2

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
φa	0.190	0.210	4.83	5.33	
A	0.240	0.260	6.10	6.60	
φb	0.016	0.021	0.406	0.533	2
φb2	0.016	0.019	0.406	0.483	2
φD	0.350	0.370	8.89	9.40	
φD_1	0.315	0.335	8.00	8.51	
h	0.009	0.125	0.229	3.18	
j	0.028	0.034	0.711	0.864	
k	0.029	0.040	0.737	1.02	3
l	0.500		12.70		2
l_1		0.050		1.27	2
l_2	0.250		6.35		2
P	0.100		2.54		1
Q					4
α	45° NOMINAL				
β	90° NOMINAL				

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

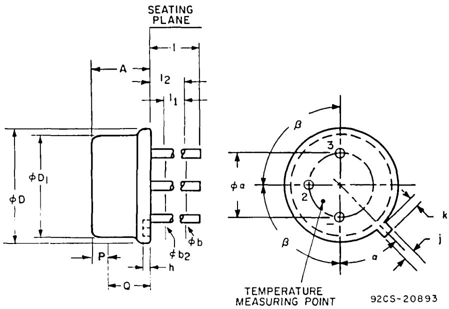
Note 1: This zone is controlled for automatic handling. The variation in actual diameter within this zone shall not exceed 0.010 in. (0.254 mm).

Note 2: (Three leads) φ b_2 applies between l_1 and l_2. φb applies between l_2 and 0.5 in. (12.70 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond 0.5 in. (12.70 mm) from seating plane.

Note 3: Measured from maximum diameter of the actual device.

Note 4: Details of outline in this zone optional.

"Low-Profile TO-39"



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕa	0.190	0.210	4.83	5.33	
A	0.160	0.180	4.07	4.57	
ϕb	0.016	0.021	0.406	0.533	2
ϕb_2	0.016	0.019	0.406	0.483	2
ϕD	0.350	0.370	8.89	9.40	
ϕD_1	0.315	0.335	8.00	8.51	
h	0.009	0.125	0.229	3.18	
j	0.028	0.034	0.711	0.864	
k	0.029	0.040	0.737	1.02	3
l	0.500		12.70		2
l_1		0.050		1.27	2
l_2	0.250		6.35		2
P					1
Q					4
α	45° NOMINAL				
β	90° NOMINAL				

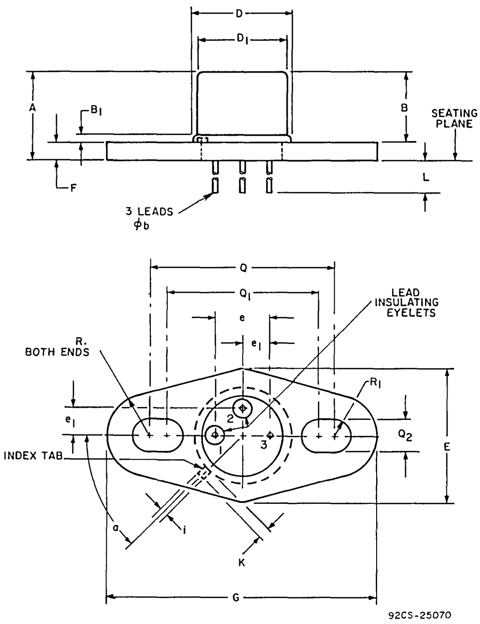
MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1: This zone is controlled for automatic handling. The variation in actual diameter within this zone shall not exceed 0.010 in. (0.254 mm).
2: (Three leads) ϕb_2 applies between l_1 and l_2. ϕb applies between l_2 and 0.5 in. (12.70 mm) from seating plane. Diameter is controlled in l_1 and beyond 0.5 in. (12.70 mm) from seating plane.
3: Measured from maximum diameter of the actual device.
4: Details of outline in this zone optional.

92CS-20893

TO-39 with Mounting Flange



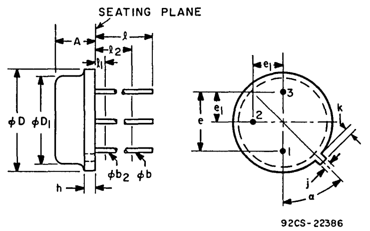
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	–	0.328	–	8.33	
B	0.240	0.260	6.10	6.60	
B_1	0.009	0.125	0.229	3.18	
ϕb	0.016	0.019	0.406	0.483	
D	0.335	0.370	8.51	9.40	
D_1	0.305	0.335	7.75	8.51	
E	0.495	0.505	12.57	12.83	
e	0.200 T.P.		5.08 T.P.		1
e_1	0.100 T.P.		2.54 T.P.		1
F	0.062	0.068	1.57	1.74	
G	0.995	1.005	25.27	25.53	
i	0.028	0.034	0.711	0.864	
k	0.029	0.045	0.737	1.14	
L	0.43	–	10.9	–	
Q	0.685	0.691	17.40	17.55	
Q_1	0.559	0.565	14.20	14.35	
Q_2	0.128	0.132	3.25	3.35	
R	0.156 T.P.		3.96 T.P.		1
R_1	0.064	0.066	1.63	1.67	
α	45° T.P.				1, 2

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. **True position.**
2. **Tab centerline.**

TO-46



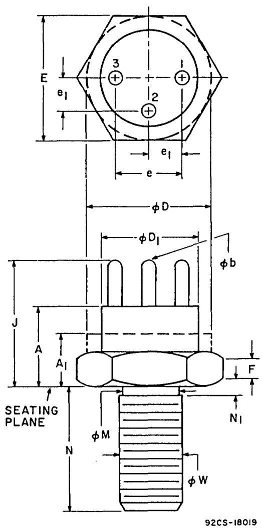
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.065	0.085	1.65	2.16	
φb	0.016	0.021	0.406	0.533	1
ϕb_2	0.012	0.019	0.305	0.483	1
φD	0.209	0.230	5.31	5.84	
ϕD_1	0.178	0.195	4.52	4.95	
e	0.100 T.P.		2.54 T.P.		2
e_1	0.050 T.P.		1.27 T.P.		2
h		0.040		1.02	
j	0.036	0.046	0.914	1.17	
k	0.028	0.048	0.711	1.22	4
ℓ	0.500		12.70		1
ℓ_1		0.050		1.27	1
ℓ_2	0.250		6.35		1
α	45° T.P.		45° T.P.		3, 5

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. (THREE LEADS) ϕb_2 APPLIES BETWEEN ℓ_1 AND ℓ_2. φb APPLIES BETWEEN ℓ_2 AND 0.5 IN. (12.70 MM) FROM SEATING PLANE. DIAMETER IS UNCONTROLLED IN ℓ_1 AND BEYOND 0.5 IN. (12.70 MM) FROM SEATING PLANE.
2. MAXIMUM DIAMETER LEADS AT A GAGING PLANE 0.054 IN. (1.37 MM) + 0.001 IN. (0.025 MM) - 0.000 IN. (0.000 MM) BELOW SEATING PLANE TO BE WITHIN 0.007 IN. (0.178 MM) OF THEIR POSITION RELATIVE TO MAXIMUM-WIDTH TAB AND TO THE MAXIMUM 0.230 IN. (5.84 MM) DIAMETER MEASURED WITH A SUITABLE GAGE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.
3. INDEX TAB FOR VISUAL ORIENTATION ONLY.
4. MEASURED FROM MAXIMUM DIAMETER OF THE ACTUAL DEVICE.
5. TAB CENTERLINE.

TO-60



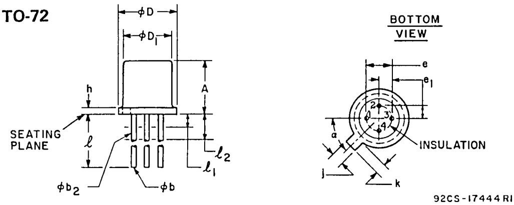
SYMBOL	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	NOTES
A	0.215	0.320	5.46	8.13	
A_1	–	0.165	–	4.19	2
φb	0.030	0.046	0.762	1.17	4
φD	0.360	0.437	9.14	11.10	2
ϕD_1	0.320	0.360	8.13	9.14	
E	0.424	0.437	10.77	11.10	
e	0.185	0.215	4.70	5.46	
e_1	0.090	0.110	2.29	2.79	
F	0.090	0.135	2.29	3.43	1
J	0.355	0.480	9.02	12.19	
φM	0.163	0.189	4.14	4.80	
N	0.375	0.455	9.53	11.56	
N_1	–	0.078	–	1.98	
φW	0.1658	0.1697	4.212	4.310	3, 5

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. Dimension does not include sealing flanges
2. Package contour optional within dimensions specified
3. Pitch diameter – 10-32 UNF 2A thread (coated)
4. Pin spacing perimts insertion in any socket having a pin-circle diameter of 0.200 in. (5.08 mm) and contacts which will accommodate pins with a diameter of 0.030 in. (0.762 mm) min., 0.046 in. (1.17mm) max.
5. The torque applied to a 10-32 hex nut assembled on the thread during installation should not exceed 12 inch-pounds.

TO-72



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.170	0.210	4.32	5.33	
ϕb	0.016	0.021	0.406	0.533	2
$ϕb_2$	0.016	0.019	0.406	0.483	2
ϕD	0.209	0.230	5.31	5.84	
$ϕD_1$	0.178	0.195	4.52	4.95	
e	0.100 T.P.		2.54 T.P.		4
e_1	0.050 T.P.		1.27 T.P.		4
h		0.030		0.762	
j	0.036	0.046	0.914	1.17	
k	0.028	0.048	0.711	1.22	3
l	0.500		12.70		2
l_1		0.050		1.27	2
l_2	0.250		6.35		2
α	45° T.P.		45° T.P.		4, 6

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

Note 1: (Four leads). Maximum number leads omitted in this outline, "none" (0). The number and position of leads actually present are indicated in the product registration. Outline designation determined by the location and minimum angular or linear spacing of any two adjacent leads.

Note 2: (All leads) $ϕb_2$ applies between l_1 and l_2. ϕb applies between l_2 and .500" (12.70 mm) from seating plane. Diameter is uncontrolled in l_1 and beyond .500" (12.70 mm) from seating plane.

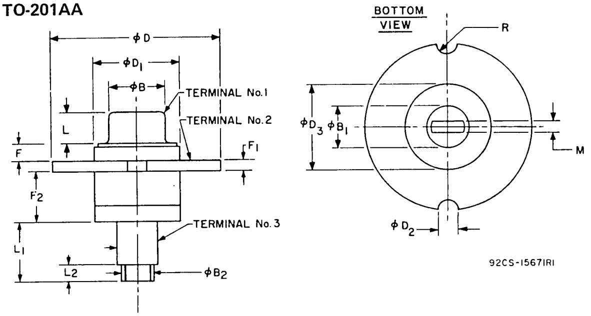
Note 3: Measured from maximum diameter of the product.

Note 4: Leads having maximum diameter .019" (.483 mm) measured in gaging plane .054" (1.37 mm) + .001" (.025 mm) – .000" (.000 mm) below the seating plane of the product shall be within .007" (.178 mm) of their true position relative to a maximum width tab.

Note 5: The product may be measured by direct methods or by gage.

Note 6: Tab centerline.

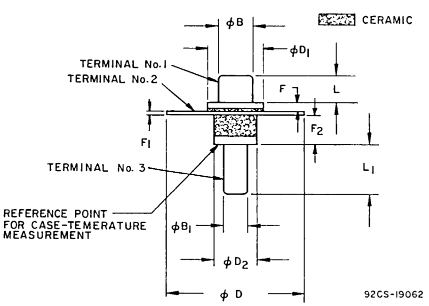
TO-201AA



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
ϕB	0.165	0.175	4.19	4.44
$ϕB_1$	0.115	0.125	2.92	3.17
$ϕB_2$	0.090	0.110	2.29	2.79
ϕD	0.495	0.505	12.57	12.83
$ϕD_1$	0.245	0.255	6.22	6.48
$ϕD_2$	0.055	0.065	1.39	1.65
$ϕD_3$	0.245	0.255	6.22	6.48
F	0.045	0.060	1.14	1.52
F_1	0.025	0.035	0.63	0.88
F_2	0.145	0.175	3.68	4.44
L	0.095	0.115	2.41	2.92
L_1	0.165	0.195	4.19	4.95
L_2	0.040	0.060	1.02	1.52
M	0.045	0.055	1.14	1.39
R	0.027	0.033	0.68	0.83

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

TO-215AA



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
ϕB	0.118	0.122	2.997	3.098	1
$ϕB_1$	0.090	0.094	2.286	2.387	2
ϕD	0.497	0.503	12.624	12.776	3
$ϕD_1$	0.180	NOM.	4.57	NOM.	
$ϕD_2$	0.162	NOM.	4.11	NOM.	
F	0.028	0.039	0.71	0.99	
F_1	0.009	0.011	0.229	0.279	
F_2	0.114	0.126	2.90	3.20	
L	0.098	0.104	2.49	2.64	
L_1	0.179	0.191	4.55	4.85	

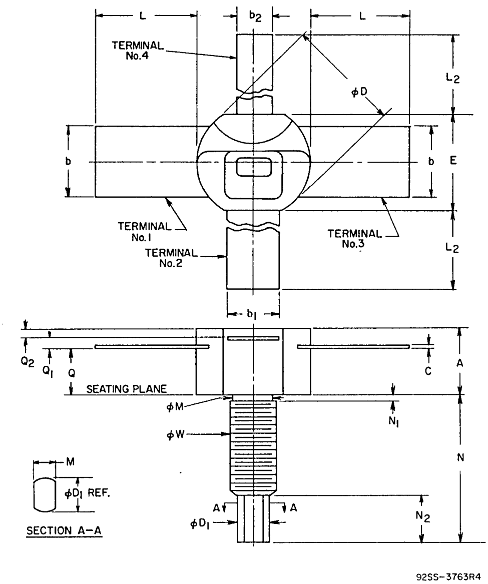
MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. **Silver or KOVAR***
2. **Solid silver**
3. **Gold-plated KOVAR**

***Trademark, Westinghouse Electric Corp.**

TO-216AA



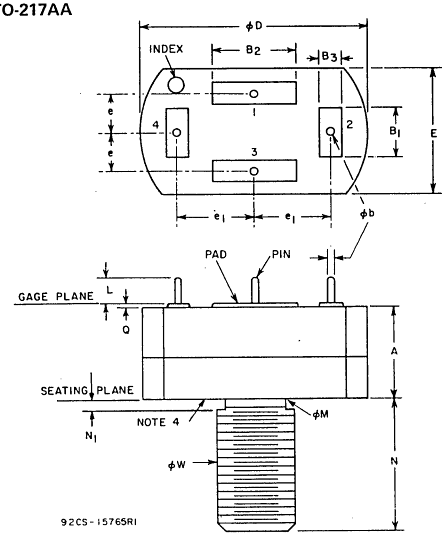
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.150	0.230	3.81	5.84	–
b	0.195	0.205	4.953	5.207	–
b_1	0.135	0.145	3.429	3.683	–
b_2	0.095	0.105	2.413	2.667	–
C	0.004	0.010	0.102	0.254	3
φD	0.305	0.320	7.75	8.12	5
$φD_1$	0.110	0.130	2.80	3.30	1
E	0.275	0.300	6.99	7.62	5
L	0.265	0.290	6.74	7.36	–
L_2	0.455	0.510	11.56	12.95	–
M	0.053	0.064	1.35	1.62	–
φM	0.120	0.163	3.05	4.14	–
N	0.425	0.470	10.80	11.93	–
N_1	–	0.078	–	1.98	4
N_2	0.110	0.150	2.80	3.81	–
Q	0.120	0.170	3.05	4.31	–
Q_1	0.025	0.045	0.64	1.14	–
Q_2	–	–	–	–	5
φW	–	–	–	–	2

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. 0.053 - 0.064 INCH (1.35 - 1.62 mm) WRENCH FLAT.
2. PITCH DIA. OF 8-32 UNC-2A COATED THREADS (REF: UNITED SCREW THREADS ANS B1.1 - 1960). THE APPLIED TORQUE SHOULD NOT EXCEED 5 IN.-LBS. CLAMPING FORCES MUST BE APPLIED ONLY TO THE FLAT SURFACES OF THE STUD.
3. TYPICAL FOR ALL LEADS.
4. LENGTH OF INCOMPLETE OR UNDERCUT THREADS OF φW.
5. BODY CONTOUR OPTIONAL WITHIN Q_2, φD, AND E.

TO-217AA



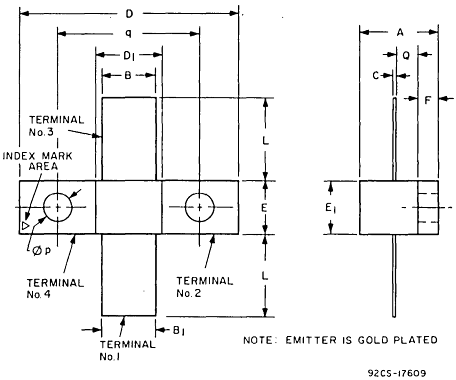
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.295	0.325	7.50	8.25	–
B_1	0.135	0.150	3.43	3.81	–
B_2	0.235	0.250	5.97	6.35	–
B_3	0.055	0.065	1.40	1.65	5
φb	0.020	0.025	0.508	0.635	4 Pins
φD	0.650	0.680	16.51	17.27	–
E	0.360	0.380	9.15	9.65	–
e	0.111	0.131	2.82	3.32	1
e_1	0.213	0.233	5.42	5.91	1
L	0.114	0.133	2.90	3.37	–
φM	0.220	0.249	5.59	6.23	–
N	0.420	0.460	10.67	11.68	–
N_1	–	0.090	–	2.28	–
Q	–	0.015	–	0.038	–
φW	–	–	–	–	2

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:

1. The pin center-to-center dimensions are measured at the gage plane.
2. ¼ in. 28 UNF 2A (Mod). Applied torque not to exceed 12 inch-pounds.
3. This device may be operated in any position.
4. Seating plate to be flat within 0.003 inches.
5. Typical 4 places.

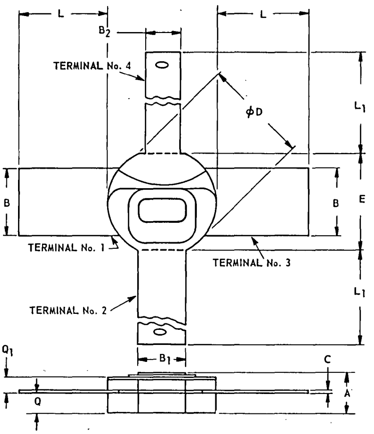
HF-28



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.225	0.250	5.72	6.35
B	0.145	0.160	3.69	4.06
B_1	0.165	0.180	4.20	4.57
C	0.004	0.010	0.102	0.254
D	0.657	0.667	16.69	16.94
D_1	0.190	0.210	4.83	5.33
E	0.155	0.165	3.94	4.19
E_1	0.140	0.165	3.56	4.19
F	0.058	0.063	1.48	1.72
L	0.235	0.265	5.97	6.73
ϕp	0.090	0.096	2.286	2.438
Q	0.062	0.077	1.58	1.95
q	0.420	0.440	10.67	11.17

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

HF-31



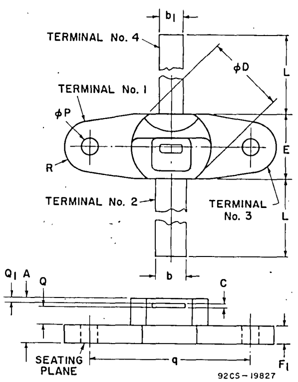
SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.090	0.135	2.29	3.42	–
B	0.195	0.205	4.96	5.20	–
B_1	0.135	0.145	3.43	3.68	–
B_2	0.095	0.105	2.42	2.66	–
C	0.004	0.010	0.11	0.25	1
ϕD	0.305	0.320	7.48	8.12	–
E	0.275	0.300	6.99	7.62	–
L	0.265	0.290	6.74	7.36	–
L_1	0.455	0.510	11.56	12.95	–
Q	0.055	0.070	1.40	1.77	–
Q_1	0.025	0.045	0.64	1.14	–

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTE: 1. TYPICAL FOR ALL LEADS

92SS-4462 R1

HF-32

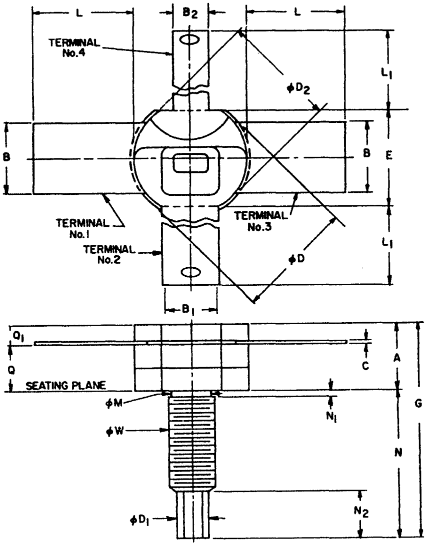


SYMBOL	INCHES		MILIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.160	0.210	4.07	5.33	
b	0.135	0.145	3.429	3.683	
b_1	0.095	0.105	2.413	2.667	
c	0.004	0.010	0.102	0.254	1
ϕD	0.305	0.320	7.75	8.12	
E	0.275	0.300	6.99	7.62	
F_1	0.057	0.067	1.448	1.701	
L	0.455	0.510	11.56	12.95	
ϕP	0.115	0.125	2.921	3.175	
Q	0.085	0.105	2.16	2.66	
Q_1	–	–	–	–	2
q	0.590	0.610	14.99	15.49	
R	0.115	0.125	2.921	3.175	

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES: 1. TYPICAL TWO LEADS.
2. BODY CONTOUR OPTIONAL WITHIN Q_1, ϕ D, AND E.

HF-36



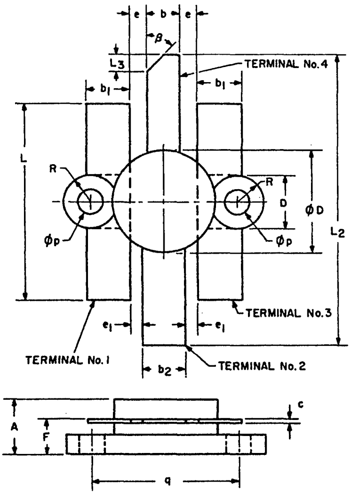
92CS-19419

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN.	MAX.	MIN.	MAX.	
A	0.185	0.240	4.70	6.11	–
B	0.195	0.205	4.96	5.20	–
B_1	0.135	0.145	3.43	3.68	–
B_2	0.095	0.105	2.42	2.66	–
C	0.004	0.010	0.11	0.25	3
ϕ D	0.319	0.335	8.12	8.52	–
ϕ D_1	0.033	0.065	0.84	1.65	1
ϕ D_2	0.305	0.320	7.48	8.12	–
E	0.275	0.300	6.99	7.62	–
G	0.635	0.730	16.11	18.51	–
L	0.265	0.290	6.74	7.36	–
L_1	0.455	0.510	11.56	12.95	–
ϕM	0.120	0.163	3.05	4.14	–
N	0.450	0.490	11.41	12.45	–
N_1	–	0.078	–	1.98	4
N_2	0.095	0.135	2.42	3.43	–
Q	0.145	0.170	3.68	4.31	–
Q_1	0.025	0.045	0.64	1.14	–
ϕW	0.1399	0.1437	3.531	3.632	2

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTES:
1. 0.053–0.064 INCH (1.35 – 1.62 mm) WRENCH FLAT.
2. PITCH DIA. OF 8-32 UNC-2A COATED THREAD. (ASA B1. 1-1960).
3. TYPICAL FOR ALL LEADS.
4. LENGTH OF INCOMPLETE OR UNDERCUT THREADS OF ϕW
5. RECOMMENDED TORQUE: 5 INCH-POUNDS

HF-40

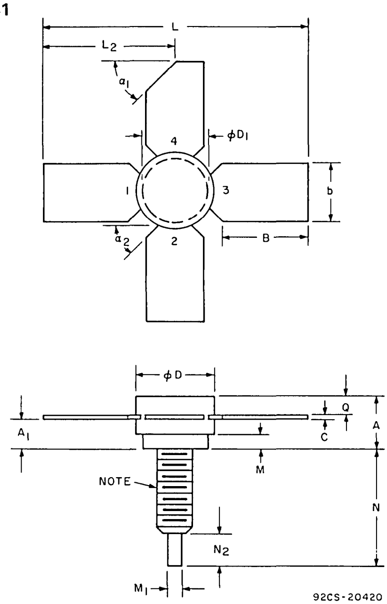


92CS-20666

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.260	0.280	6.604	7.112
b	0.153	0.157	3.866	3.987
b_1	0.210	0.220	5.334	5.588
b_2	0.203	0.207	5.156	5.257
c	0.006	0.007	0.153	0.178
D	0.240	0.250	6.096	6.350
ϕD	0.490	0.510	12.446	12.954
e	0.070	0.080	1.778	2.032
e_1	0.045	0.055	1.143	1.397
F	0.165	0.185	4.191	4.699
L	0.970	0.990	24.638	25.146
L_2	1.430	1.470	36.322	37.338
L_3	0.070	0.080	1.778	2.032
ϕP	0.115	0.125	2.921	3.175
q	0.723	0.728	18.364	18.491
R	0.120	0.130	3.048	3.302
B	45°		45°	

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

HF-41



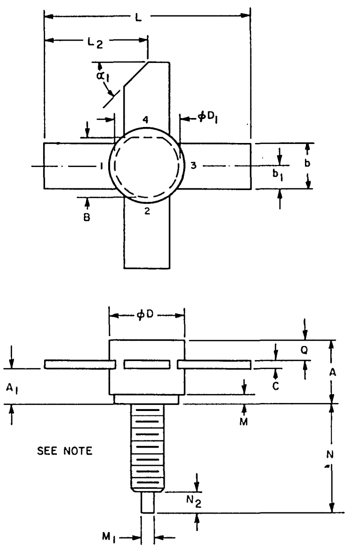
92CS-20420

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.185	0.215	4.70	5.46
A_1	0.114	0.122	2.90	3.10
B	0.380	0.390	9.66	9.90
b	0.220	0.230	5.58	5.84
C	0.002	0.008	0.05	0.20
ϕD	0.270	0.290	6.86	7.38
ϕD_1	0.245	0.255	6.22	6.48
L	1.040	1.060	26.42	26.93
L_2	0.520	0.530	13.20	13.45
M	0.058	0.062	1.47	1.57
M_1	0.056	0.064	1.42	1.62
N	0.445	0.455	11.29	11.55
N_2	0.125	0.135	3.18	3.43
Q	0.070	0.090	1.78	2.28
α_1	45° NOM.		45° NOM.	
α_2	45° NOM.		45° NOM.	

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTE: PITCH DIA. OF 8-32 UNF-2A COATED THREAD (ASA B1. 1-1960)

HF-44



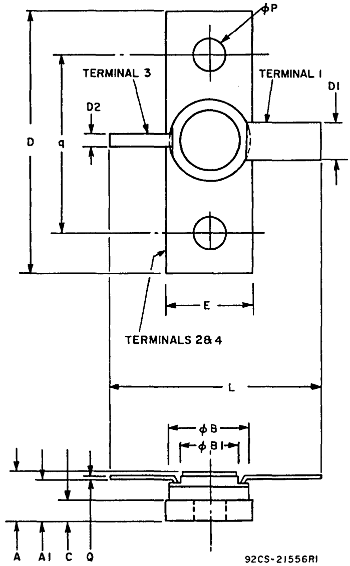
92CS-20106

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.250	0.275	6.35	6.98
A_1	0.163	0.173	4.141	4.394
B	0.299	0.307	7.595	7.797
b	0.221	0.229	5.614	5.816
b_1	0.110	0.115	2.794	2.921
C	0.0045	0.006	0.113	0.152
ϕD	0.370	0.390	9.40	9.90
ϕD_1	0.320	0.330	8.128	8.382
L	1.040	1.055	26.42	26.79
L_2	0.520	0.530	13.208	13.462
M	0.070	0.080	1.778	2.032
M_1	0.055	0.065	1.397	1.651
N	0.455	0.475	11.56	12.06
N_2	0.100	0.130	2.54	3.30
Q	0.085	0.095	2.159	2.413
α_1	45° NOM.		45° NOM.	

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

NOTE: PITCH DIA. OF 8-32 UNC-2A COATED THREAD (ASA B1. 1-1960)

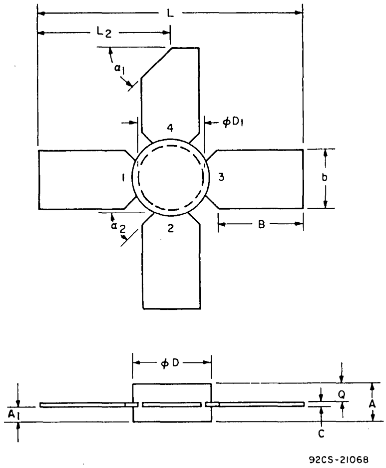
HF-46



SYMBOL	INCHES		MILLIMETERS	
	Min.	Max.	Min.	Max.
A	0.155	0.165	3.937	4.191
A1	0.120	0.140	3.05	3.55
ϕB	0.225	0.240	5.72	6.00
ϕB1	0.160	0.180	4.07	4.57
C	0.055	0.065	1.397	1.651
D	0.790	0.810	20.07	20.57
D1	0.113	0.117	2.871	2.971
D2	0.028	0.032	0.712	0.812
E	0.240	0.260	6.10	6.60
L	0.740	0.760	18.80	19.30
ϕP	0.120	0.132	3.26	3.35
Q	0.005 Nom.		0.127 Nom.	
q	0.557	0.567	14.15	14.40

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

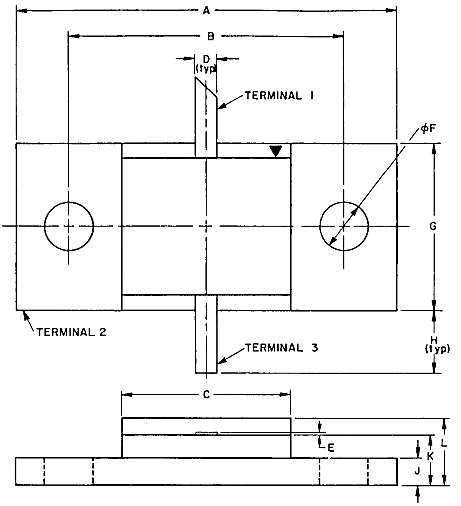
HF-47



SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.127	0.153	3.23	3.89
A_1	0.056	0.060	1.43	1.53
B	0.380	0.390	9.66	9.90
b	0.220	0.230	5.58	5.84
C	0.002	0.008	0.05	0.20
ϕD	0.270	0.290	6.86	7.38
ϕD_1	0.245	0.255	6.22	6.48
L	1.040	1.060	26.42	26.93
L_2	0.520	0.530	13.20	13.45
Q	0.070	0.090	1.78	2.28
α1	45° NOM.		45° NOM.	
α2	45° NOM.		45° NOM.	

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

HF-50

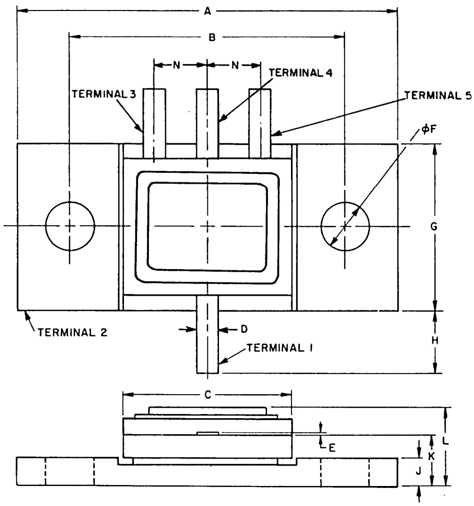


SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.890	0.910	22.61	23.11
B	0.645	0.655	16.39	16.63
C	0.390	0.410	9.91	10.41
D	0.045	0.055	1.14	1.35
E	0.004	0.010	0.10	0.25
ϕF	0.117	0.125	2.97	3.17
G	0.390	0.410	9.91	10.41
H	0.115	0.150	2.92	3.81
J	0.057	0.067	1.45	1.70
K	0.110	0.130	2.79	3.30
L	0.150	0.230	3.81	5.84

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

92CS-23888R1

HF-55

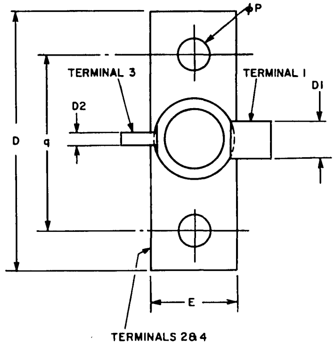


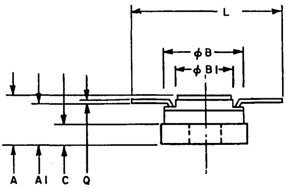
92CS-24297

SYMBOL	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.890	0.910	22.61	23.11
B	0.645	0.655	16.39	16.63
C	0.390	0.405	9.91	10.29
D	0.045	0.055	1.14	1.35
E	0.004	0.010	0.10	0.25
ϕF	0.117	0.125	2.97	3.17
G	0.390	0.410	9.91	10.41
H	0.115	0.150	2.92	3.81
J	0.057	0.067	1.45	1.70
K	0.110	0.130	2.79	3.30
L	0.150	0.230	3.81	5.84
N	0.135	0.145	3.23	3.68

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

HF-56





SYMBOL	INCHES		MILLIMETERS	
	Min.	Max.	Min.	Max.
A	0.155	0.165	3.937	4.191
A1	0.120	0.140	3.05	3.55
ϕB	0.225	0.240	5.72	6.00
ϕB1	0.160	0.180	4.07	4.57
C	0.055	0.065	1.397	1.651
D	0.790	0.810	20.07	20.57
D1	0.113	0.117	2.871	2.971
D2	0.028	0.032	0.712	0.812
E	0.240	0.260	6.10	6.60
L	0.440	0.460	11.18	11.68
ϕP	0.120	0.132	3.26	3.35
Q	0.005 Nom.		0.127 Nom.	
q	0.557	0.567	14.15	14.40

MILLIMETER DIMENSIONS ARE DERIVED FROM ORIGINAL INCH DIMENSIONS

92CM-23960R1

Application Notes

Operating Considerations for RCA Solid State Devices

Solid state devices are being designed into an increasing variety of electronic equipment because of their high standards of reliability and performance. However, it is essential that equipment designers be mindful of good engineering practices in the use of these devices to achieve the desired performance.

This Note summarizes important operating recommendations and precautions which should be followed in the interest of maintaining the high standards of performance of solid state devices.

The ratings included in RCA Solid State Devices data bulletins are based on the Absolute Maximum Rating System, which is defined by the following Industry Standard (JEDEC) statement:

Absolute-Maximum Ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in device characteristics.

The equipment manufacturer should design so that initially and throughout life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in device characteristics.

It is recommended that equipment manufacturers consult RCA whenever device applications involve unusual electrical, mechanical or environmental operating conditions.

GENERAL CONSIDERATIONS

The design flexibility provided by these devices makes possible their use in a broad range of applications and under many different operating conditions. When incorporating these devices in equipment, therefore, designers should anticipate the rare possibility of device failure and make certain that no safety hazard would result from such an occurrence.

The small size of most solid state products provides obvious advantages to the designers of electronic equipment. However, it should be recognized that these compact devices usually provide only relatively small insulation area between adjacent leads and the metal envelope. When these devices are used in moist or contaminated atmospheres, therefore, supplemental protection must be provided to prevent the development of electrical conductive paths across the relatively small insulating surfaces. For specific information on voltage creepage, the user should consult references such as the JEDEC Standard No. 7 "Suggested Standard on Thyristors," and JEDEC Standard RS282 "Standards for Silicon Rectifier Diodes and Stacks".

The metal shells of some solid state devices operate at the collector voltage and for some rectifiers and thyristors at the anode voltage. Therefore, consideration should be given to the possibility of shock hazard if the shells are to operate at voltages appreciably above or below ground potential. In general, in any application in which devices are operated at voltages which may be dangerous to personnel, suitable precautionary measures should be taken to prevent direct contact with these devices.

Devices should not be connected into or disconnected from circuits with the power on because high transient voltages may cause permanent damage to the devices.

TESTING PRECAUTIONS

In common with many electronic components, solid-state devices should be operated and tested in circuits which have reasonable values of current limiting resistance, or other forms of effective current overload protection. Failure to observe these precautions can cause excessive internal heating of the device resulting in destruction and/or possible shattering of the enclosure.

TRANSISTORS AND THYRISTORS WITH FLEXIBLE LEADS

Flexible leads are usually soldered to the circuit elements. It is desirable in all soldering operatings to provide some slack or an expansion elbow in each lead to prevent excessive tension on the leads. It is important during the soldering operation to avoid excessive heat in order to prevent possible damage to the devices. Some of the heat can be absorbed if the flexible lead of the device is grasped between the case and the soldering point with a pair of pliers.

TRANSISTORS AND THYRISTORS WITH MOUNTING FLANGES

The mounting flanges of JEDEC-type packages such as the TO-3 or TO-66 often serve as the collector or anode terminal. In such cases, it is essential that the mounting flange be securely fastened to the heat sink, which may be the equipment chassis. Under no circumstances, however, should the mounting flange of a transistor be soldered directly to the heat sink or chassis because the heat of the soldering operation could permanently damage the device. Soldering is the preferred method for mounting thyristors; see "Rectifiers and Thyristors," below. Devices which cannot be soldered can be installed in commercially available sockets. Electrical connections may also be made by soldering directly to the terminal pins. Such connections may be soldered to the pins close to the pin seals provided care is taken to conduct excessive heat away from the seals; otherwise the heat of the soldering operation could crack the pin seals and damage the device.

During operation, the mounting-flange temperature is higher than the ambient temperature by an amount which depends on the heat sink used. The heat sink must have sufficient thermal capacity to assure that the heat dissipated in the heat sink itself does not raise the device mounting-flange temperature above the rated value. The heat sink or chassis may be connected to either the positive or negative supply.

In many applications the chassis is connected to the voltage-supply terminal. If the recommended mounting hardware shown in the data bulletin for the specific solid-state device is not available, it is necessary to use either an anodized aluminum insulator having high thermal conductivity or a mica insulator between the mounting-flange and the chassis. If an insulating aluminum washer is required, it should be drilled or punched to provide the two mounting holes for the terminal pins. The burrs should then be removed from the washer and the washer anodized. To insure that the anodized insulating layer is not destroyed during mounting, it is necessary to remove the burrs from the holes in the chassis.

It is also important that an insulating bushing, such as glass-filled nylon, be used between each mounting bolt and the chassis to prevent a short circuit. However, the insulating bushing should not exhibit shrinkage or softening under the operating temperatures encountered. Otherwise the thermal resistance at the interface between device and heat sink may increase as a result of decreasing pressure.

PLASTIC POWER TRANSISTORS AND THYRISTORS

RCA power transistors and thyristors (SCR's and triacs) in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations. The following paragraphs provide guidelines for handling and mounting of these plastic-package devices, recommend forming of leads to meet specific mounting requirements, and describe various mounting arrangements, thermal considerations, and cleaning methods. This information is intended to augment the data on electrical characteristics, safe operating area, and performance capabilities in the technical bulletin for each type of plastic-package transistor or thyristor.

Lead-Forming Techniques

The leads of the RCA VERSAWATT in-line plastic packages can be formed to a custom shape, provided they are not indiscriminately twisted or bent. Although these leads can be formed, they are not flexible in the general sense, nor are they sufficiently rigid for unrestrained wire wrapping

Before an attempt is made to form the leads of an in-line package to meet the requirements of a specific application, the desired lead configuration should be determined, and a lead-bending fixture should be designed and constructed. The use of a properly designed fixture for this operation eliminates the need for repeated lead bending. When the use of a special bending fixture is not practical, a pair of long-nosed pliers may be used. The pliers should hold the lead firmly between the bending point and the case, but should not touch the case.

When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, make the bend at least 1/8 inch from the plastic case.
4. Do not use a lead-bend radius of less than 1/16 inch.
5. Avoid repeated bending of leads.

The leads of the TO-220AB VERSAWATT in-line package are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised.

Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed. The maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance not less than 1/8 inch from the plastic case. When wires are used for connections, care should be exercised to assure that movement of the wire does not cause movement of the lead at the lead-to-plastic junctions.

The leads of RCA molded-plastic high-power packages are not designed to be reshaped. However, simple bending of the leads is permitted to change them from a standard vertical to a standard horizontal configuration, or conversely. Bending of the leads in this manner is restricted to three 90-degree bends; repeated bendings should be avoided.

Mounting

Recommended mounting arrangements and suggested hardward for the VERSAWATT package are given in the data bulletins for specific devices and in RCA Application Note AN-4142. When the package is fastened to a heat sink, a rectangular washer (RCA Part No. NR231A) is recommended to minimize distortion of the mounting flange. Excessive distortion of the flange could cause damage to the package. The washer is particularly important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings; however, the holes should not be larger than necessary to provide hardware clearance and, in any case, should not exceed a diameter of 0.250 inch.

Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8 inch-pounds is specified. Care should be exercised to assure that the tool used to drive the mounting screw never comes in contact with the plastic body during the driving operation. Such contact can result in damage to the plastic body and internal device connections. An excellent method of avoiding this problem is to use a spacer or combination spacer-isolating bushing which raises the screw head or nut above the top surface of the plastic body. The material used for such a spacer or spacer-isolating bushing should, of course, be carefully selected to avoid "cold flow" and consequent reduction in mounting force. Suggested materials for these bushings are diallphtalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate. Unfilled nylon should be avoided.

Modification of the flange can also result in flange distortion and should not be attempted. The package should not be soldered to the heat sink by use of lead-tin solder because the heat required with this type of solder will cause the junction temperature of the device to become excessively high.

The TO-220AA plastic package can be mounted in commercially available TO-66 sockets, such as UID Electronics Corp. Socket No. PTS-4 or equivalent. For testing purposes, the TO-220AB in-line package can be mounted in a Jetron Socket No. DC74-104 or equivalent. Regardless of the mounting method, the following precautions should be taken:

1. Use appropriate hardware.
2. Always fasten the package to the heat sink before the leads are soldered to fixed terminals.
3. Never allow the mounting tool to come in contact with the plastic case.
4. Never exceed a torque of 8 inch-pounds.
5. Avoid oversize mounting holes.
6. Provide strain relief if there is any probability that axial stress will be applied to the leads.
7. Use insulating bushings to prevent hot-creep problems. Such bushings should be made of diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate.

The maximum allowable power dissipation in a solid state device is limited by the junction temperature. An important factor in assuring that the junction temperature remains below the specified maximum value is the ability of the associated thermal circuit to conduct heat away from the device.

When a solid state device is operated in free air, without a heat sink, the steady-state thermal circuit is defined by the junction-to-free-air thermal resistance given in the published data for the device. Thermal considerations require that a free flow of air around the device is always present and that the power dissipation be maintained below the level which would cause the junction temperature to rise above the maximum rating. However, when the device is mounted on a heat sink, care must be taken to assure that all portions of the thermal circuit are considered.

To assure efficient heat transfer from case to heat sink when mounting RCA molded-plastic solid state power devices, the following special precautions should be observed:

1. Mounting torque should be between 4 and 8 inch-pounds.
2. The mounting holes should be kept as small as possible.
3. Holes should be drilled or punched clean with no burrs or ridges, and chamfered to a maximum radius of 0.010 inch.
4. The mounting surface should be flat within 0.002 inch/inch.
5. Thermal grease (Dow Corning 340 or equivalent) should always be used on both sides of the insulating washer if one is employed.
6. Thin insulating washers should be used. (Thickness of factory-supplied mica washers range from 2 to 4 mils).
7. A lock washer or torque washer, made of material having sufficient creep strength, should be used to prevent degradation of heat sink efficiency during life.

A wide variety of solvents is available for degreasing and flux removal. The usual practice is to submerge components in a solvent bath for a specified time. However, from a reliability stand point it is extremely important that the solvent, together with other chemicals in the solder-cleaning system (such as flux and solder covers), do not adversely affect the life of the component. This consideration applies to all non-hermetic and molded-plastic components.

It is, of course, impractical to evaluate the effect on long-term device life of all cleaning solvents, which are marketed with numerous additives under a variety of brand names. These solvents can, however, be classified with respect to their component parts as either acceptable or unacceptable. Chlorinated solvents tend to dissolve the outer package and, therefore, make operation in a humid atmosphere unreliable. Gasoline and other hydrocarbons cause the inner encapsulant to swell and damage the transistor. Alcohol is an acceptable solvent. Examples of specific, acceptable alchols are isopropanol, methanol, and special denatured alcohols, such as SDA1, SDA30, SDA34, and SDA44.

Care must also be used in the selection of fluxes for lead soldering. Rosin or activated rosin fluxes are recommended, while organic or acid fluxes are not. Examples of acceptable fluxes are:

1. Alpha Reliaros No. 320-33
2. Alpha Reliaros No. 346
3. Alpha Reliaros No. 711
4. Alpha Reliafoam No. 807
5. Alpha Reliafoam No. 809
6. Alpha Reliafoam No. 811-13
7. Alpha Reliafoam No. 815-35
8. Kester No. 44

If the completed assembly is to be encapsulated, the effect on the molded-plastic transistor must be studied from both a chemical and a physical standpoint.

RECTIFIERS AND THYRISTORS

A surge-limiting impedance should always be used in series with silicon rectifiers and thyristors. The impedance value must be sufficient to limit the surge current to the value specified under the maximum ratings. This impedance may be provided by the power transformer winding, or by an external resistor or choke.

A very efficient method for mounting thyristors utilizing the "modified TO-5" package is to provide intimate contact between the heat sink and at least one half of the base of the device opposite the leads. This package can be mounted to the heat sink mechanically with glue or an expoxy adhesive, or by soldering, the most efficient method.

The use of a "self-jigging" arrangement and a solder preform is recommended. If each unit is soldered individually, the heat source should be held on the heat sink and the solder on the unit. Heat should be applied only long enough to permit solder to flow freely. For more detailed thyristor mounting considerations, refer to Application Note AN3822, "Thermal Considerations in Mounting of RCA Thyristors".

MOS FIELD-EFFECT TRANSISTORS

Insulated-Gate Metal Oxide-Semiconductor Field-Effect Transistors (MOS FETs), like bipolar high-frequency transistors, are susceptible to gate insulation damage by the electrostatic discharge of energy through the devices. Electrostatic discharges can occur in an MOS FET if a type with an unprotected gate is picked up and the static charge, built in the handler's body capacitance, is discharged through the device. With proper handling and applications procedures, however, MOS transistors are currently being extensively used in production by numerous equipment manufacturers in military, industrial, and consumer applications, with virtually no problems of damage due to electrostatic discharge.

In some MOS FETs, diodes are electrically connected between each insulated gate and the transistor's source. These diodes offer protection against static discharge and in-circuit transients without the need for external shorting mechanisms. MOS FETs which do not include gate-protection diodes can be handled safely if the following basic precautions are taken:

1. Prior to assembly into a circuit, all leads should be kept shorted together either by the use of metal shorting springs attached to the device by the vendor, or by the insertion into conductive material such as "ECCOSORB* LD26" or equivalent.
   (NOTE: Polystyrene *insulating* "SNOW" is not sufficiently conductive and should not be used.)
2. When devices are removed by hand from their carriers, the hand being used should be grounded by any suitable means, for example, with a metallic wristband.
3. Tips of soldering irons should be grounded.
4. Devices should never be inserted into or removed from circuits with power on.

RF POWER TRANSISTORS

Mounting and Handling

Stripline rf devices should be mounted so that the leads are not bent or pulled away from the stud (heat sink) side of the device. When leads are formed, they should be supported to avoid transmitting the bending or cutting stress to the ceramic portion of the device. Excessive stresses may destroy the hermeticity of the package without displaying visible damage.

Devices employing silver leads are susceptible to tarnishing; these parts should not be removed from the original tarnish-preventive containers and wrappings until ready for use. Lead solderability is retarded by the presence of silver tarnish; the tarnish can be removed with a silver cleaning solution, such as thiourea.

The ceramic bodies of many rf devices contain beryllium oxide as a major ingredient. These portions of the transistors should not be crushed, ground, or abraded in any way because the dust created could be hazardous if inhaled.

Operating

Forward-Biased Operation. For Class A or AB operation, the allowable quiescent bias point is determined by reference to the infrared safe-area curve in the appropriate data bulletin. This curve depicts the safe current/voltage combinations for extended continuous operation.

Load VSWR. Excessive collector load or tuning mismatch can cause device destruction by over-dissipation or secondary breakdown. Mismatch capability is generally included on the data bulletins for the more recent rf transistors.

See RCA RF Power Transitor Manual, Technical Series RMF-430, pp 39-41, for additional information concerning the handling and mounting of rf power transistors.

*Trade Mark: Emerson and Cumming, Inc.

INTEGRATED CIRCUITS

Handing

All COS/MOS gate inputs have a resistor/diode gate protection network. All transmission gate inputs and all outputs have diode protection provided by inherent p-n junction diodes. These diode networks at input and output interfaces protect COS/MOS devices from gate-oxide failure in handling environments where static discharge is not excessive. In low-temperature, low-humidity environments, improper handling may result in device damage. See ICAN-6000, "Handling and Operating Considerations for MOS Integrated Circuits", for proper handling procedures.

Mounting

Integrated circuits are normally supplied with lead-tin plated leads to facilitate soldering into circuit boards. In those relatively few applications requiring welding of the device leads, rather than soldering, the devices may be obtained with gold or nickel plated Kovar leads.* It should be recognized that this type of plating will not provide complete protection against lead corrosion in the presence of high humidity and mechanical stress. The aluminum-foil-lined cardboard "sandwich pack" employed for static protection of the flat-pack also provides some additional protection against lead corrosion, and it is recommended that the devices be stored in this package until used.

When integrated circuits are welded onto printed circuit boards or equipment, the presence of moisture between the closely spaced terminals can result in conductive paths that may impair device performance in high-impedance applications. It is therefore recommended that conformal coatings or potting be provided as an added measure of protection against moisture penetration.

In any method of mounting integrated circuits which involves bending or forming of the device leads, it is extremely important that the lead be supported and clamped between the bend and the package seal, and that bending be done with care to avoid damage to lead plating. In no case should the radius of the bend be less than the diameter of the lead, or in the case of rectangular leads, such as those used in RCA 14-lead and 16-lead flat-packages, less than the lead thickness. It is also extremely important that the ends of the bent leads be straight to assure proper insertion through the holes in the printed-circuit board.

Operating

Unused Inputs

All unused input leads must be connected to either V_{SS} or V_{DD}, whichever is appropriate for the logic circuit involved. A floating input on a high-current type, such as the CD4049 or CD4050, not only can result in faulty logic operation, but can cause the maximum power dissipation of 200 milliwatts to be exceeded and may result in damage to the device. Inputs to these types, which are mounted on printed-circuit boards that may temporarily become unterminated, should have a pull-up resistor to V_{SS} or V_{DD}. A useful range of values for such resistors is from 10 kilohms to 1 megohm.

Input Signals

Signals shall not be applied to the inputs while the device power supply is off unless the input current is limited to a steady state value of less than 10 milliamperes. Input currents of less than 10 milliamperes prevent device damage; however, proper operation may be impaired as a result of current flow through structural diode junctions.

Output Short Circuits

Shorting of outputs to V_{SS} or V_{DD} can damage many of the higher-output-current COS/MOS types, such as the CD4007, CD4041, CD4049, and CD4050. In general, these types can all be safely shorted for supplies up to 5 volts, but will be damaged (depending on type) at higher power-supply voltages. For cases in which a short-circuit load, such as the base of a p-n-p or an n-p-n bipolar transistor, is directly driven, the device output characteristics given in the published data should be consulted to determine the requirements for a safe operation below 200 milliwatts.

For detailed COS/MOS IC operating and handling considerations, refer to Application Note ICAN-6000 "Handling and Operating Considerations for MOS Integrated Circuits".

SOLID STATE CHIPS

Solid state chips, unlike packaged devices, are non-hermetic devices, normally fragile and small in physical size, and therefore, require special handling considerations as follows:

1. Chips must be stored under proper conditions to insure that they are not subjected to a moist and/or contaminated atmosphere that could alter their electrical, physical, or mechanical characteristics. After the shipping container is opened, the chip must be stored under the following conditions:
   A. Storage temperature, 40°C max.
   B. Relative humidity, 50% max.
   C. Clean, dust-free environment.
2. The user must exercise proper care when handling chips to prevent even the slightest physical damage to the chip.
3. During mounting and lead bonding of chips the user must use proper assembly techniques to obtain proper electrical, thermal, and mechanical performance.
4. After the chip has been mounted and bonded, any necessary procedure must be followed by the user to insure that these non-hermetic chips are not subjected to moist or contaminated atmosphere which might cause the development of electrical conductive paths across the relatively small insulating surfaces. In addition, proper consideration must be given to the protection of these devices from other harmful environments which could conceivably adversely affect their proper performance.

*Mil-M-38510A, paragraph 3.5.6.1 (a), lead material.

RCA
Solid State
Division

RF Power Transistors
Application Note

AN-3749

40-Watt Peak-Envelope-Power Transistor Amplifier for AM Transmitters in the Aircraft Band (118 to 136 MHz)

By

Boris Maximow

This Note describes a broadband amplifier for use in amplitude-modulated (AM) transmitters operating in the aircraft communication band (118 to 136 MHz). The amplifier circuit is simple and easy to duplicate and requires a minimum of adjustments. The design leaves ample room for modification, improvement, or adaptation to specific needs. Fig.1 shows the schematic diagram of the amplifier, Fig.2 shows its performance over the aircraft band, and Table I lists its features.

The amplifier shown in Fig.1 uses RCA 2N3866, 40290, 40291, and 40292 epitaxial silicon planar transistors of the "overlay" emitter-electrode construction. These transistors are intended for low-voltage, high-power operation in amplitude-modulated class C amplifiers. In addition to standard breakdown-voltage ratings, the 40290, 40291, and 40292 transistors have rf breakdown-voltage characteristics which assure safe operation with high rf voltages on the collector. The 40292 transistors used in the final amplifier stage are 100-per-cent tested for load mismatch at a VSWR of 3:1. During this test, the transistor is fully modulated to simulate actual operation for added reliability.

The amplifier is capable of delivering peak envelope power of 40 watts at a modulation of 95 per cent with a collector voltage of 12.5 volts dc. Unmodulated drive of 5 milliwatts is required at the input. The over-all efficiency of the amplifier is 48 to 53 per cent, and the envelope distortion is less than 5 per cent for amplitude modulation of 95 per cent.

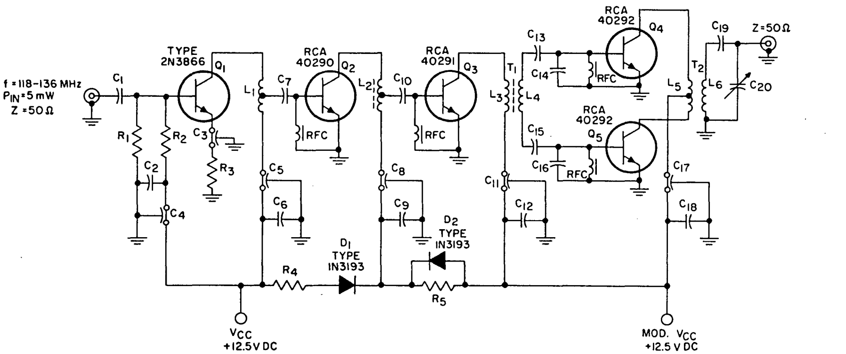
Load Mismatch Test

The suitability of 40292 transistors for use in the output stages of amplitude-modulated transmitters is determined by means of a load mismatch test which simulates the adverse load conditions that may occur in actual practice. The test setup is shown in Fig.3. The choice of C and L in the load circuit is dictated by practical values of these components. The circuit should resonate with the variable capacitor half-way in. With a variable reactive load, the impedance moves along the outer circle of a Smith Chart so that the loading changes between short and open circuit with intermediate values of capacitive and inductive reactances. The VSWR at the output of the transistor is limited to 3:1 by the 3-dB pad inserted between the variable load and the output of the test circuit. The transistor under test and the input drive are modulated to assure that the transistor operates near its full peak power capability.

At the start of the test cycle, the variable capacitor begins to rotate through its 360-degree range. When the capacitor plates are 50-per-cent engaged, the tuned circuit resonates. The resonant circuit presents an apparent short or open circuit to the 3-dB pad, depending on whether the $\lambda/4$ line is in or out of the circuit. All intermediate positions present reactances of varying amplitudes.

Output Power and Modulation

Because the only useful power in an AM transmitter is sideband power, it is reasonable to use this power as



C_1 –300 pF, silver mica, ARCO, or equiv.

C_2 – 0.005 μF ceramic

$C_3 C_4 C_5 C_8 C_{11} C_{17}$ –1000pF feedthrough

$C_6 C_9 C_{12} C_{18}$ – 0.5 μF ceramic

C_7 –50 pF, silver mica, ARCO, or equiv.

$C_{10} C_{13} C_{15}$ –82 pF, silver mica, ARCO, or equiv.

$C_{14} C_{16} C_{19}$ –150 pF, silver mica, ARCO, or equiv.

C_{20} –8-60 pF, ARCO # 404, or equiv.

R_1 –470ohms 0.5 W

R_2 – 1500 ohms 0.5 W

R_3 –47 ohms 0.5 W

R_4 –15 ohms 0.5 W

R_5 –33ohms 0.5 W

L_1 –7T. # 22-13/64" dia. 9/19" L. tap 1.5 T.

L_2 –5.5T. # 22-13/64" dia. Closely Wound tap 2.0 T.

L_3 –6T. # 22-13/64" dia. interwind W/L4

L_4 –4T. # 22-13/64" dia. interwind W/L3

(L_2, L_3, L_4: Cambion IRN-9 core mat'l or equiv.)

L_5 –5T. # 22-13/64" dia. C.T. interwind W/L6

L_6 –5T. # 22-13/64" dia. interwind W/L5

R.F.C. –1T. #28 ferrite bead Ferroxcube # 56-590-65/4B or equiv.

Fig.1 - A 40-watt peak envelope power transistor amplifier.

TABLE I - PERFORMANCE FEATURES OR 40-WATT PEAK ENVELOPE POWER TRANSISTOR AMPLIFIER

DC Supply Voltage	12.5	V
Peak Envelope Power	40	W
Modulation	95	%
Efficiency	48-53	%
Envelope Distortion for 95% AM	< 5	%
Second Harmonic	> 10	dB down

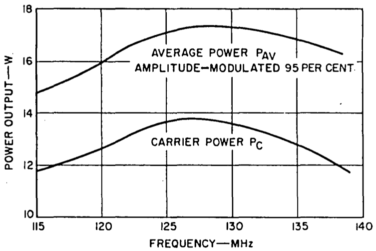


Fig.2 - Typical output power as a function of frequency.

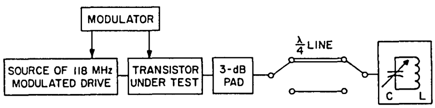


Fig.3 - Load mismatch test setup.

a reference in evaluation of the transmitter. When a single-tone sinusoidal modulating signal is used, the total sideband power P_{SB} in a modulated wave is given by

$$P_{SB} = P_{AV}\left(\frac{m^2}{2 + m^2}\right) \quad (1)$$

where P_{AV} is the average power and m is the modulation index. This relationship is convenient to use because P_{AV} is easy to measure and

$$P_{SB} = \frac{P_{AV}}{3}$$

for 100-per-cent modulation.

The performance of an AM transmitter can also be expressed in terms of peak envelope power P_{PE}. The peak envelope power is equal to 2.66 P_{AV} in a 100-per-cent modulated wave. The value of P_{PE} indicates the ultimate peak power-handling capabilities of the transistors being used.

It is unfortunate that carrier power is sometimes used as a reference in evaluation of the performance of AM transmitters, especially transistorized transmitters. Unlike the sideband power P_{SB}, the carrier power P_C does not always have a definite relationship to P_{AV} and P_{PE}. When the carrier is used for a reference, "carrier shift" and "upward modulation" must be considered. Use of these terms in conjunction with P_C to define transmitter modulation only complicates the definition of per-cent amplitude modulation. For example, Fig.4 shows an

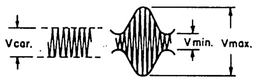


Fig.4 - The amplitude modulated wave; V_{car} is the amplitude of carrier before modulation.

amplitude-modulated wave. The amplitude modulation AM in per cent is defined as follows:

$$AM = \left(\frac{V_{max} - V_{min}}{V_{max} + V_{min}}\right) \times 100 \quad (2)$$

Use of this equation indicates that when $V_{min} = 0$, the wave is 100-per-cent modulated without reference to the carrier. The following expressions are based on carrier amplitude V_{car} or carrier power P_C:

$$AM = \left(\frac{V_{max}}{V_{car}} - 1\right) \text{X } 100 \quad (3)$$

$$P_{AV} = P_C\left(1 + \frac{m^2}{2}\right) \quad (4)$$

These expressions contain the tacit assumption that carrier level must not vary from the unmodulated state, which may not be the case. If the modulation is adjusted to 100 per cent by the use of Eq. (2) and P_{AV} is measured, values can easily be computed for P_{SB}, P_{PE}, and even P_C.

Design Considerations

The need for wideband performance in aircraft transmitters precludes the use of sharply tuned circuits to reduce harmonic power in the output; instead, low-pass filters are used. Any configuration of active devices that reduces the harmonic content in the output helps to ease the requirements placed upon these filters. One such configuration is a push-pull amplifier, which inherently has low even harmonics in the output. The higher input impedance of a push-pull stage as compared to a single-ended parallel combination of two transistors is also advantageous for obtaining wider bandwidths because only one-half as much current is injected into the input of push-pull transistors as into parallel devices during one-half cycle.

The coupling circuits in the amplifier of Fig.1 are basically double-tuned interstage circuits, as shown in Fig.5. R_1 and C_1 represent the collector output re-

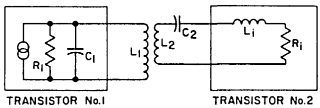


Fig.5 - A double-tuned interstage.

sistance and the collector output capacitance of the driver transistor. L_i and R_i represent the input series inductance and the input series resistance of a transistor. (For simplicity, coil resistances are omitted.) Q values for the two circuits shown in Fig.5 are expressed as follows:

$$Q_1 = \frac{R_1}{\omega L_1} \quad (5)$$

$$Q_2 = \frac{\omega (L_2 + L_i)}{R_i} \quad (6)$$

For large bandwidths, it is desirable that Q_1 be much larger than Q_2. L_2, C_2, and L_i are series resonant at some frequency f_o within the bandwidth; L_1 and C_1 can then be determined as follows:

$$L_1 C_1 = \frac{1}{(\omega_o)^2} \quad (7)$$

In practice, the resonant frequency f_o may not be exactly the center frequency of the passband, but may tend toward the high end of the bandwidth to compensate for degradation of the frequency response of the transistor itself. Normally, there is no problem obtaining relatively high values of Q_1 because transistors have large collector output resistance R_1. However, it is more difficult to obtain a low value of Q_2 in a transistor double-tuned interstage circuit because high-power transistors have low series input resistance R_i. Theontribution of the inductive series input reactance L_i may be sufficient to raise the value of Q_i to undesirable levels and thereby limit the obtainable bandwidth.

This problem can be solved by use of an L-section and its transforming properties. The inductive input impedance of a transistor may be represented by the solid lines of Fig.6.

The definite Q value associated with this input impedance may be represented as Q_i. If a capacitor C_i is added to the transistor input of Fig.6, as shown by the

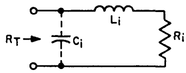


Fig.6 - Transistor input as an L-section.

dotted line, the resistance R_i can be transformed up by the L-section to a new value R_T, as follows:

$$R_T + R_i \; (Q_i^2 + 1) \qquad (8)$$

The value of the capacitor C_i is calculated as follows:

$$C_i = \frac{1}{\omega R_T} \sqrt{\frac{R_T}{R_i} - 1} = \frac{L_i}{\omega^2 L_i^2 + R_i^2} \qquad (9)$$

When an L-section is used in conjunction with a double-tuned interstage circuit, the value Q_2' of the second circuit is given by

$$Q_2' = \frac{\omega L_2}{R_T} \qquad (10)$$

This value is, of course, lower than that shown in Eq. (6). Consequently, an L-section can be used to match resistances of not-too-different magnitudes and at the same time maintain low values of Q. The value of L_i in the circuit is given by

$$L_i = \frac{R_i}{\omega} \sqrt{\frac{R_T}{R_i} - 1} \qquad (11)$$

There are limits to the results that can be accomplished with this type of transformation. For some combination of L_i and R_i, the required value of C_i may be too large to be practically realizable. In addition, R_T is a frequency-dependent parameter. For very low values of Q_i, the capacitor C_i loses its effectiveness because R_T becomes very nearly equal to R_i.

Double-tuned interstage coupling circuits were used throughout the amplifier shown in Fig.1. When it was necessary to use a two-winding transformer, as in the case of T_1 and T_2, bifiliar windings were employed for tighter coupling. In other cases, autotransformers with their high coefficient of coupling were used quite successfully. Eq. (7) was used as the starting point for determination of the inductances in the primaries of the double-tuned interstages; the collector to base capacitance $C_{CB}$of the transistor was substituted for C_1. Turn ratios were determined by the impedance levels to be transformed. The load resistance R_L for each stage was determined as follows:

$$R_L = \frac{(V_{CC})^2}{2Po} \qquad (12)$$

where V_{CC} is the collector supply voltage and P_o is the power output. The collector-emitter saturation voltage is omitted for simplicity.

A single 40292 transistor is capable of delivering 6 watts of output power with an input of 2 watts and a supply of 12.5 volts dc at 135 MHz. For these conditions, the load resistance R_L is given by

$$R_L = \frac{(12.5)^2}{12} = 13 \text{ ohms}$$

This value of 13 ohms from one-half of the primary winding of T_2 is transformed to 50 ohms in the secondary winding. This impedance level allows the use of a 1:1 transformer, which is convenient for bifilar winding. For 40292 transistors, R_i is approximately 6 ohms and X_{Li} is about 3 ohms. An L-section is used in the inputs to the 40292 transistors in the push-pull amplifier. To maintain a low value of Q_i, the leads on the base-to-emitter capacitors (C_{14} and C_{16}) were kept short and the capacitors were placed as close to the base and the emitter as possible. The values of C_{14} and C_{16} of Fig.1 were determined empirically. The effective capacitances may differ appreciably from the nominal value of 150 picofarads shown.

Drive power of about 3 to 3.5 watts is required for the push-pull amplifier. This power is provided by the 40291 driver transistor operating into a 24-ohm load,

$$\left[R_L = \frac{(V_{CE})^2}{2P_o} = (12.5)^2/65 \right]$$

Because the input resistance to the driver is sufficiently high (12 ohms), no L-section is used. The load resistance for the 40290 pre-driver transistor is selected to provide the required input to the driver of about 0.6 watt. The 100-milliwatt input required for the pre-driver stage is supplied by the 2N3866 class A input stage. Again, a double-tuned interstage circuit is used for coupling. The class A amplifier is biased to a quiescent current of 40 milliamperes for maximum gain, and has a load line of approximately 300 ohms, which is computed from

$$R_{\text{load line}} = \frac{V_{CC}}{I_C} \qquad (13)$$

An autotransformer is used to transform the 300-ohm load down to about 12 ohms at the predriver. The input of the 2N3866 stage is matched to the 50-ohm source. This stage has a gain of about 13 dB which increases the power from the 5-milliwatt input. The problem of subharmonic generation was solved by use of cores in the interstage transformers. Stable operation is obtained if the stages are kept 1.25 inches apart.

The final amplifier and the driver are modulated symmetrically about the carrier level. The predriver is modulated more in a positive direction as a result of the resistor-diode arrangement (R_4,R_5,D_1,D_2) shown in the circuit diagram.

Several precautions should be taken to avoid conditions which may lead to the destruction of transistors. For example, over-modulation should not be allowed to occur because excessive negative excursions of the collector voltage may forward-bias the collector-to-base junction to a destructive point. Also, when a transmitter is keyed off, a steady-state current flow of the order of 2 amperes is suddenly interrupted in the modulation transformer. The resulting transient voltages may easily exceed the transistor breakdown ratings. Use of a zener diode rated at twice the supply voltage in the collector circuit provides a protection from this type of transient. Finally, if the 3:1 VSWR in the output is likely to be exceeded, a load-mismatch protective device such as a VSWR detector circuit (described in Ref. 1) should be used.

Performance and Adjustment

The curves of Fig.2 show typical values of average modulated power P_{AV} at an amplitude modulation of 95 per cent, and carrier power P_C, as measured by a a bolometer-type power meter. The peak envelope power P_{PE} is computed as follows:

$$P_{PE} = P_{AV} \frac{(1 + m^2)}{1 + \frac{m^2}{2}}$$

Output-power variation across the aircraft band is about 0.5 dB for both curves shown in Fig.2. For this performance, the coil L_1 was stretched or compressed for maximum power output at 136 MHz and optimum bandwidth, and the trimmer C_{20} was adjusted for the best combination of output flatness and efficiency. Efficiency is somewhat better at higher than lower frequency; harmonic rejection is better at lower frequencies, and may be as good as 20 dB. A spectrum analyzer is required for detection of subharmonics when the slugs in L_2 and T_1 are adjusted.

Conclusion

Because of the normal variation in the transistor parameters, weaker drivers should be paired with "hotter" output transistors and vice versa for better uniformity in the output power. Because of their adaptability to broadband circuits, low working voltages, and small size, the above transistors are the logical choice for aircraft transmitters. The use of these transistors in aircraft transmitter requires no expensive tuning mechanisms such as those used with tubes that have inherently high-Q circuits and, consequently, narrow bandwidth.

Solid State
Division

RF Power Transistors Application Note

AN-3755

UHF Power Generation Using RF Power Transistors

by H.C. Lee

One major usage of rf power transistors is in uhf/microwave power generation. RF power transistors are widely used for both narrowband and broadband power amplification. Transistors suitable for power amplification must be capable of delivering power efficiently with sufficient gain at the frequency band of interest. The usefulness of an rf power transistor is not measured by its power-frequency product or its emitter geometry, but rather by its ability to meet cost limitations and over-all performance objectives including reliability requirements in a given application or circuit.

This Note discusses the use of rf power transistors in high-power generation that uses multiple transistors, pulse operation, and broadband power amplifiers. Operational principles and design approaches for these applications are presented, and practical and reliability aspects are discussed. The selection of an rf power transistor for a given application involves two steps: (1) determination of the rf capability of the device, and (2) establishment of the reliability of the device for its actual operation.

RF Performance Criteria

The important rf performance criteria in transistor power-amplifier circuits are power output, power gain, efficiency, and bandwidth. State-of-the-art single overlay transistors, as shown in Fig.1, can now produce cw power as follows:

Frequency (MHz)	Power (W)	Gain (dB)	Efficiency (%)
76	100	7	90
400	50	6	70
1200	10	10	50
2300	7	6	40

When transistor performances are compared, it is important to consider gain and efficiency, as well as power output and frequency, because additional gain can be achieved only at the expense of collector efficiency with the use of additional transistors. For example, Fig.2 demonstrates the use of two transistors which have the same power output, but different gain and collector efficiency. The high-gain unit shown in Fig.2(a) is capable of delivering an output of 2.5 watts at 1 GHz with a gain of 10 dB and a collector efficiency of 50 per cent. The low-gain unit shown in Fig.2(b) is also capable of 2.5 watts output at 1 GHz, but has a gain of only 5 dB and a collector efficiency of only 30 per cent. As shown in Fig.2, two low-gain transistors are required to provide the same performance as the high-gain, high-efficiency unit. Besides the use of an additional transistor, the system of Fig.2(b) requires twice as much dc power as that of Fig.2(a). In this case, the additional gain of 5 dB is achieved at the expense of 5.9 watts of dc power. From the practical point of view, the system of Fig.2(b) is more complex, and the dissipation of the output transistor is higher.

Package Considerations

The package is an integral part of an rf power transistor. A suitable package for uhf applications should have good thermal properties and low parasitic reactance. Package parasitic inductances and resistive losses have significant effects on circuit performance characteristics such as power gain, bandwidth, and stability. The most critical parasitics are the emitter and base lead inductances. Table I gives the inductances of some of the more important commercially available rf power-transistor packages. Photographs of the packages are shown in Fig.3. The TO-60 and TO-39 packages

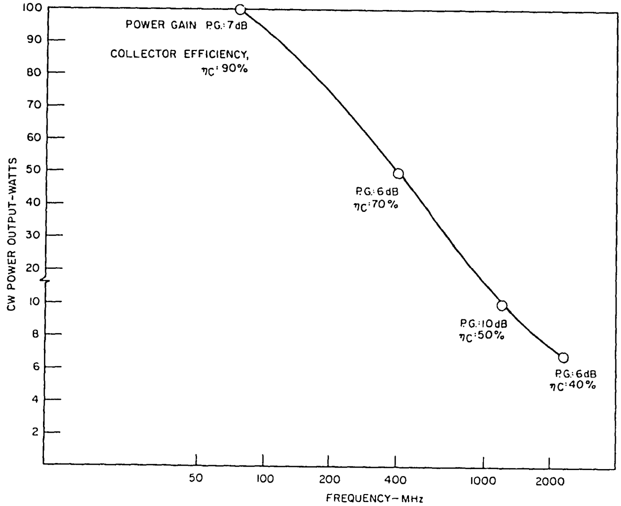


Fig.1 - State-of-the art power output of single rf power transistor as a function of frequency.

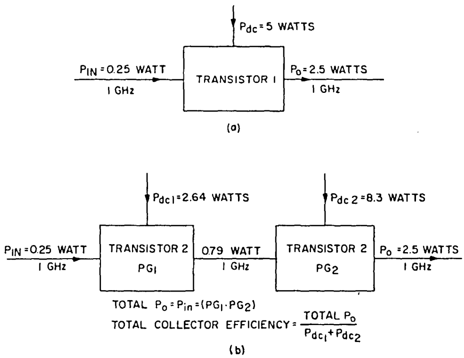
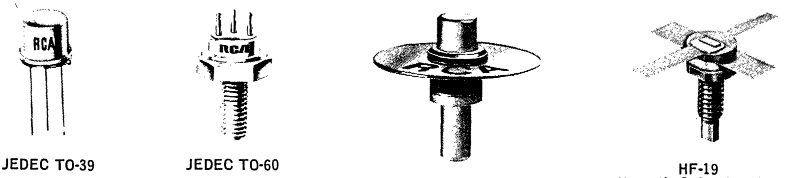


Fig.2 - A comparison of one-and two-transistor systems that have the same output power but different gain and collector efficiencies.

TABLE I - Inductances of Packages shown in Fig.3.

Package	Lead Inductances - nH L_e	L_b
TO - 39	3	3
TO - 60 (isolated emitter)	3	3
TO - 60 (grounded emitter)(2N5016)	0.6	2
HF - 19 (hermetic stripline)	Approximately Same	
HF - 11 (coaxial case) (2N5470)	0.1	0.1



JEDEC TO-39 JEDEC TO-60 HF-11 Coaxial Package HF-19 Hermetic Strip-Line Type Ceramic-to-Metal Package (Isolated Electrodes)

Fig.3 - Commercially available rf power transistor packages.

were first used in devices such as the 2N3375 and the 2N3866. The base and emitter parasitic inductance for both TO-60 and TO-39 packages is in the order of 3 nanohenries; this inductance represents a reactance of 7.5 ohms at 400 MHz. If the emitter is grounded internally to a TO-60 package (as in the 2N5016), the emitter lead inductance can be reduced to 0.6 nanohenry. The plastic stripline package (used in the 2N5017) has an emitter lead inductance of 0.4 nanohenry and a base lead inductance of 0.6 nanohenry. The main advantage of the rf plastic package is that a substantial reduction in parasitic inductance is achieved because the emitter and base leads can be placed closer to the transistor chip. Hermetic low-inductance radial-lead packages are also available. The HF-19 package introduced by RCA utilizes ceramic-to-metal seals and has rf performance comparable to that of an rf plastic package. The parasitic inductances can be reduced further in a hermetic coaxial package. The HF-11 package used in the 2N5470 has parasitic inductances in the order of 0.1 nanohenry.

Table II compares the performance of the TO-39 package, the HF-19 hermetric stripline package, and the HF-11 coaxial package with the same transistor chip. At a frequency of 1 GHz and an input power of 0.3 watt,

TABLE II - Package Inductances with same transistor chip.

Using Same Transistor Chip

	f-GHz	Pin-W	Po-W	P.G.-dB	η_c (28 V)-%
TO - 39	1	0.3	1	5	35
HF - 19	1	0.3	1.5	7	45
HF - 11	1	0.3	2.2	8.6	50
HF - 11	2	0.3	1	5	35

the coaxial package performs significantly better than either the stripline or the TO-39 package. The coaxial package results in an increase of output power by a factor of two as compared to the TO-39 package. In addition, the coaxial-package transistor is capable of delivering an output of more than 1 watt with a gain of 5 dB at 2 GHz. A well-designed coaxial package outperforms any other rf package currently available.

Reliability Consideration

When the rf capability of a transistor has been established, the next step is to establish the reliability of the device for its actual application. The typical acceptable failure rate for transistors used in commercial equipment is 1 per cent per 1,000 hours (10,000 MTBF); for transistors used in military and high-reliability equipment, it is 0.01 to 0.1 per cent per 1000 hours. Because it is not practical to test transistors under actual use conditions, dc or other stress tests are normally used to simulate rf stresses encountered in class B or class C circuits at the operating frequencies. Information derived from these tests is then used to predict the failure rate for the end use equipment. The tests generally used to insure reliability include high-temperature storage tests, dc and rf operating life tests, dc stress step tests, burn-in, temperature cycling, relative humidity, and high-humidity reverse bias. The end-point measurement for these tests should include collector-to-emitter voltage V_{CEO}, in addition to the common end points collector-to-emitter current I_{CEO}, collector-to-base voltage V_{CBO}, collector-to-emitter saturation voltage V_{CE}(sat), power output, and power gain.

One of the common failure modes in uhf/microwave power transistors is degradation of the emitter-to-base junction. The high-temperature storage life test and the dc and rf operating life tests can excite this failure mode. The failure mode can be detected by measurement of V_{EBO}, which is not included in most life-test end-point specifications.

Plastic uhf power transistors are more sensitive to emitter-to-base-junction degradation than similar hermetic devices. It is believed that the enhancement of this failure mode in plastic devices is caused by moisture penetration into the very close geometries used in uhf power transistors. Temperature cycling is also a problem that affects the reliability of uhf plastic power transistors because large thermal-expansion differences exist between the plastic and the fine bonding wires (usually 1 mil) used in the devices.

UHF power transistors are complex electrical, thermal, chemical, and mechanical systems. The well-designed uhf power transistor is a systems solution to the integration of these parameters. It appears that the plastic environment is a less viable solution to this systems problem than a hermetic approach. Although a plastic environment has been an excellent systems solution for low-frequency and vhf power transistors, in which much larger bonding wires, metallic strips, and rugged device geometries are used, it is not a completely satisfactory solution for uhf power transistors.

Safe-Area Curves for RF Operation

The important parameters of a transistor which are directly related to reliability and rf performance include rf breakdown voltages, thermal characteristic, and load-mismatch capability.

Although a safe-area curve to avoid second breakdown on the collector-current-vs-collector-to-emitter voltage (I_C - V_{CE}) plane can be established for forward-bias or class A operation, such a curve for class B, class C, or pulsed operation is difficult to define because the breakdown voltages under rf conditions are considerably higher than the dc breakdown voltages, and the thermal resistance is a function of V_{CE} and I_C. The safe operating area for class B or C conditions at rf frequencies is a function of these parameters, as well as the thermal time constant of the device. In general, the safe operating area for class C or B operation can be expected to be higher than that for dc conditions.

VSWR capability, or the ability of an rf power transistor to withstand a high VSWR load, is another important consideration. VSWR capability is a function of frequency of operation, operating voltage, and circuit configuration. A well-designed circuit operated at low supply voltage at a frequency at which power gain is not excessive is less prone to VSWR mismatch. Four modes of difficulty are experienced in the load-mismatch test, as follows:

(1) slow thermal failure as a result of low rf swing and very poor efficiency;

(2) high-speed failure as a result of the high positive peak value of rf swing;

(3) an instability (non-destructive) which occurs because the high value of V_{CE} causes avalanching (such a condition in the common-emitter configuration produces a negative resistance characteristic and results in a spurious signal generator);

(4) an instability caused by the negative overswing which can severely forward-bias the collector-base junction and trigger a low-frequency oscillation which resembles a motorboating or squelched oscillation.

Additional work is required for further characterization of transistor parameters, as related to VSWR capability, rf breakdown, and safe operating area.

Pulse Operation of RF Power Transistors

A large potential application for rf power transistors is in pulse equipments such as DME (distance measuring equipment), CAS (collision avoidance system), and radar. The ratio of peak to average or cw power obtainable with a transistor is much less than that which can be obtained with a vacuum tube because a transistor is a current-amplification device, while a vacuum tube is a voltage-amplification device. The ability of an rf power transistor to deliver higher pulsed output power than cw power depends on the transistor current-handling capability, thermal capability, and rf voltage capability. No significant improvement in power output or gain can be achieved if an rf power transistor is operated under pulse input conditions at the same supply voltage and the same input power level used under cw conditions. Fig.4 shows curves of peak output power as a function of duty cycle for two transistor types: the 2N5016 measured at 225 MHz and 400 MHz, and the 2N5470 measured at 2 GHz. These measurements were performed with a constant supply voltage of 28 volts and constant input-power pulses of 5-microsecond duration applied at various pulse repetition rates (PRR). At the same peak input power level, the gain and power output remain approximately the same for duty cycles ranging from 100 per cent (cw) down to 0.1 per cent.

Fig.5 shows the 2-GHz amplifier circuit used for the measurements shown in Fig.4. The 2N5470 transistor is placed in series with the center conductor of the line, or cavity, and its base is properly grounded to separate the input and output cavities. The input section consists of a 20-ohm line section and a capacitance C_1. The output section consists of a 36-ohm line section and capacitances C_2 and C_3. Direct coupling is used at both

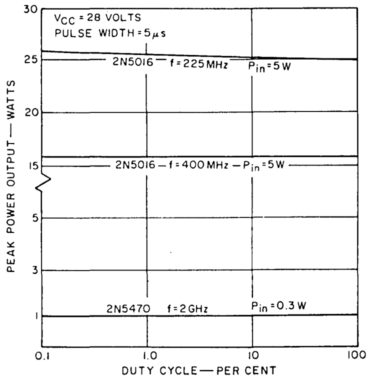


Fig.4 - Peak output power as a function of duty cycle for the 2N5016 and 2N5470 transistors at selected frequencies.

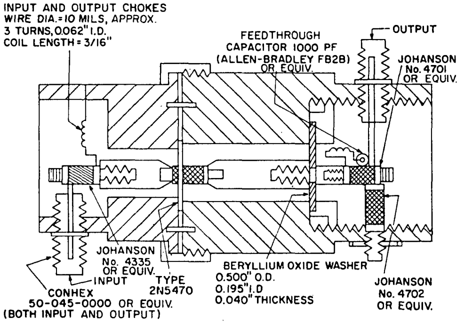
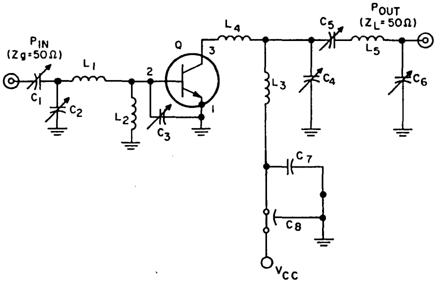


Fig.5 - A 2-GHz coaxial amplifier circuit that uses 2N5470 transistor.

input and output. Fig.6 shows the 400-MHz lumped-element amplifier circuit used for the 2N5016 pulse measurements.



C_1 = 1 to 10 pF, piston capacitor
C_2, C_3, C_4, C_5, C_6 = 1 to 30 pF, piston capacitors

C_7 = 0.01 μF, disc, ceramic
C_8 = 1000 pF, feedthrough
L_1 = 1/4-inch O.D. copper tubing; 1-1/4-inches long

L_2 = 12 μH, choke
L_3 = 0.27 ohm, wire wound
L_4 = 1/8-by 1/32-by 5/8-inch long copper strip
L_5 = 1/4-inch O.D. copper tubing, 2-1/4-inches long

Note 1 - L_1 and L_5 are mounted coaxially within a 1-5/8-by 1-5/8-by 6-inch box.
Note 2 - For optimum performance C_8 should be mounted between emitter and base with minimum lead lengths.

Fig.6 - A 400-MHz amplifier circuit that uses a 2N5016 transistor.

The major difference between cw and pulse operation, however, is that the input drive level can be increased substantially under pulsed input conditions. Fig.7 shows peak power output as a function of duty cycle for the 2N5470 at a frequency of 2 GHz and a

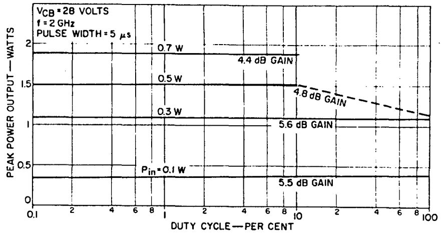


Fig.7 - Peak output power as a function of duty cycle for the 2N5470 transistor operating at 2 GHz.

constant supply voltage of 28 volts with input power as a parameter. Under cw operation in the 2-GHz amplifier circuit shown in Fig.5, an increase of input power from 0.3 to 0.5 watt does not result in an increase of power output, i.e., the power output seems to be saturated at 1.1 watts. However, under pulsed input conditions of 5-microsecond pulse duration and 10-per-cent duty cycle, the output power increases substantially from 1.1 watts to 1.9 watts as the input power increases from 0.3 to 0.7 watt. These requirements indicate that the power input to the 2N5470 transistor at 2 GHz under cw conditions is limited by thermal capability rather than by peak current or periphery. This transistor appears to be capable of operating at much higher peak current under pulse conditions than would be permissible under cw conditions. This improvement is possible because the pulse duration of 5 microseconds is probably smaller than the thermal time constant of the transistor, and the junction temperature is more a function of average device dissipation than of peak dissipation. A similar improvement in peak power output and gain can be obtained by pulse operation of the 2N5016 at 225 MHz, as shown in Fig.8, but the improvement is not as great as that obtained for the 2N5470.

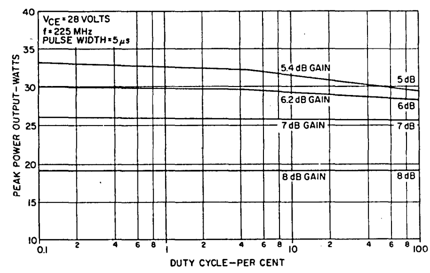


Fig.8 - Peak output power as a function of duty cycle for pulse operation of the 2N5016 transistor at 225 MHz.

A second major difference between cw and pulse operations is that a transistor can be operated at much higher voltage under pulse conditions. Fig.9 shows peak power output as a function of supply voltage V_{CC} for the same transistor types (the 2N5016 measured at 225 MHz and 400 MHz, and the 2N5470 measured at 2 GHz). These measurements were performed with constant peak input power pulses at 1-per-cent duty cycle and 5-microsecond pulse duration. At an input power level of 0.5 watt, the 2-GHz power output of the 2N5470 increases from 1.9 watts at 28 volts to 2.5 watts at 45 volts. At an input power of 9 watts, the 400-MHz power output of the 2N5016 increases from 25.5 watts at 28 volts to 40 watts at 45 volts. At 225 MHz, the increase in power is even greater. These results indicate that

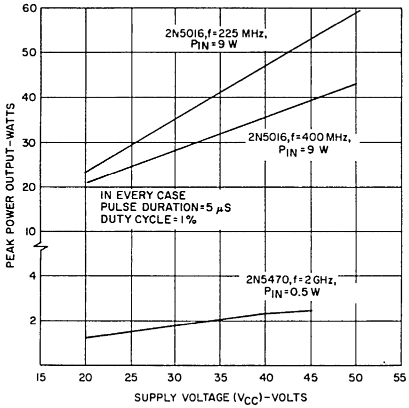


Fig.9 - Peak output power as a function of supply voltage V_{CC} for the 2N5470 and 2N5016 transistors at selected frequencies.

rf power transistors can be operated at much higher voltage under pulse conditions, and, consequently, can deliver more pulsed power. It appears that rf power transistors can withstand much higher voltage under short-pulse conditions without operating in the second-breakdown region. The average current resulting from short-pulse operation is much lower than that of cw operation.

Broadband Power Amplifier

RF power transistors are often used in broadband amplifier circuits for commercial and military applications. Transistor transmitters are superior to tube transmitters with respect to broadband capability, reliability, size, and weight. The aircraft communication bands of 116 to 152 MHz and 225 to 400 MHz are of interest for both military and commercial applications. Another area of interest is ECM (electronic countermeasures) applications. Transistors suitable for broadband applications must be capable of providing both the required power output within the entire frequency range of interest and constant gain within the passband. The bandwidth of a transistor power amplifier is limited by the following: intrinsic transistor structure, transistor parasitic elements, and external circuits such as input and output circuits.

Intrinsic Transistor Structure

The parameters which determine the inherent bandwidth of a transistor intrinsic structure are the emitter-to-collector transit time, the collector depletion-layer capacitance, and the base-spreading resistance. The emitter-to-collector transit time, which represents the sum of the emitter-capacitance charging delay, the base transit time, and the collector depletion-layer transit time, affects the over-all time of response to an input signal. Of particular importance is the emitter-capacitance charging delay, which is current-dependent and equal to $1/f_T$, where f_T is the gain-bandwidth product of the transistor. A high f_T is essential for broadband operation; in addition, a constant f_T with current level is required for large-signal operation. The ratio of the f_T to the product of the base-spreading resistance and the collector depletion-layer capacitance ($r_b C_c$) comprises the gain function of a transistor.

Under conjugate-matched input and output conditions, the power gain as a function of frequency (which is equal to $f_T/8\pi f^2 r_b C_c$) falls off at a rate of 6 dB per octave. In a power amplifier, the power gain usually decreases by less than 6 dB per octave, as shown in Fig.10(a), because the load resistance R_L presented to the collector is not equal to the output resistance of

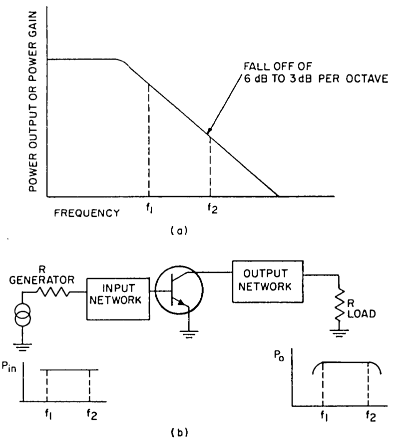


Fig.10(a) - Output power as a function of frequency in a power amplifier; (b) equivalent broadband amplifier.

the transistor, but is dictated by the required power output and the collector voltage swing. The curve in Fig.10(a) indicates that one approach for achieving a broadband transistor amplifier is to optimize the matching at the higher end of the frequency band and to introduce mismatch in the input, or output, or both at the lower end of the band so that a constant power output is obtained from f_1 to f_2, as shown in Fig.10(b). The power output that can be obtained in a transistor broadband amplifier is comparable to that measured at the high end of the band in a narrowband amplifier; efficiency and power gain are slightly lower than in a narrowband amplifier because the load and source impedance cannot be ideally matched to the transistor over a broad frequency band.

The disadvantage of this approach for broadbanding is the relatively high input VSWR at the low end of the band. A more sophisticated approach for achieving broadband performance is to consider the intrinsic transistor structure, the transistor parasitic elements, and the external circuits as part of the over-all band-pass structure, in which the input and output circuits are coupled together by the transistor feedback capacitance. This combined structure reproduces the power-output or power-gain curve of Fig.10(a) from f_1 to f_2. External feedback is then applied to control the input drive to flatten the power output over a broad frequency band.

Parasitic Limitations

Any discrete transistor contains parasitic elements which impose further limitations on bandwidth. The most critical parasitics are the emitter lead inductance L_e and the base inductance L_b. These parasitic inductances range from 0.1 to 3 nanohenries in commercially available rf power transistors. In the simple representation of a common-emitter equivalent transistor input circuit at high frequency shown in Fig.11, the inductance L_{in} represents

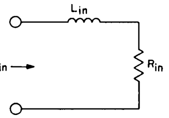


Fig.11 - Equivalent input circuit of an rf power transistor.

the sum of the base parasitic inductance and the reflected emitter parasitic inductance, and R_{in} is the dynamic input resistance. The real part R_{in} is inversely proportional to the collector area and, therefore, the power-output capability of the device; the higher the power output, the lower the value of R_{in}. A low ratio of the reactance of L_{in} to R_{in} is important as the first step in broadbanding and for ease of circuit design. Unless the reactance of L_{in} is appreciably lower than the input resistance R_{in}, the reactance must be tuned out and thus the bandwidth limited.

External Circuits

For a broadband amplifier circuit to deliver constant power output over the frequency range of interest, a proper collector load must be maintained to provide the necessary voltage and current swings, and the input matching network must be capable of transforming the low input impedance of the transistor to a relatively high source impedance.

Suitable output circuits for broadband amplifiers include constant-K low-pass filters, Chebyshev filters (both transmission-line and lumped-constant), baluns, and tapered lines. Fig.12(a) shows a conventional constant-K low-pass filter. The input impedance Z_{11} is substantially constant at frequencies below the cutoff frequency $\omega_c = 1/\sqrt{L_K C_K}$. A constant collector load resistance can be obtained if the shunt arm (1-1) of C_K is split into two capacitances, as shown in Fig.12(b); part of the capacitance represents the C_{ob} of the transistor, and the other part has a value which makes the total capacitance equal to C_K. Further improvement of bandwidth can be obtained by cascading of more sections.

Fig.12(c) shows a short-step microstrip impedance transformer which consists of short lengths of relatively-high-impedance transmission line alternating with short lengths of relatively-low-impedance transmission line. The sections of transmission line are all exactly the same length; the length of each is $\lambda/16$. A constant load resistance can be maintained across the collector-emitter terminals over a wide frequency band if the circuit is designed to have a Chebyshev transmission characteristic[1,2]. Fig.12(d) shows a lumped-equivalent

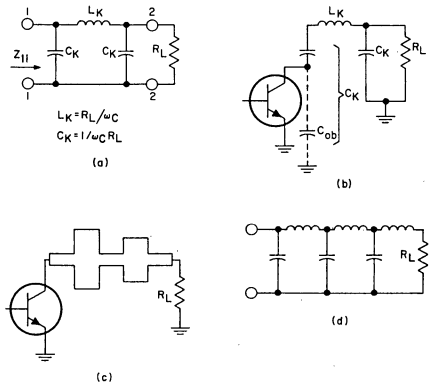


Fig.12(a) - A conventional constant-K low-pass filter; (b) a method of obtaining a constant-collector load resistance; (c) a short step microstrip impedance transformer; (d) a lumped-equivalent Chebyshev impedance transformer.

Chebyshev impedance transformer which consists of a ladder network using series inductances and shunt capacitances. Transmission-line as well as strip line baluns with different step-down ratios (4:1, 9:1, 16:1) can also be used in the output to provide the broadband impedance transformation.

One difficulty in broadbanding a transistor power amplifier is to maintain the desired bandwidth in an input circuit which provides the required impedance transformation from the extremely low input impedance of a transistor to a relatively high source impedance. The design of the input circuit depends on the approach chosen: optimizing the matching at the high end only, or using the transistor parasitic elements as part of a low-pass structure. A simple way of optimizing the matching at the high end is to introduce a capacitance between the base and the emitter terminals of the transistor to tune out the reactive part of the parallel equivalent input impedance of the transistor. The networks in Fig.13 show that the lower the inductance L_{in} or Q_{in}, the less frequency-sensitive is the equivalent parallel resistance R_{eq}. This arrangement also provides a first step-up transformation for the real part of the input impedance of the transistor. When a capacitance is connected to the network of Fig.13(a), the circuit has the same form as a half-section of a constant-K low-pass filter. If the cutoff frequency $\omega_c = 1/\sqrt{L_{in}C}$ is high as compared to the frequency of interest (f_2 in Fig.10), the total input impedance of the transistor input and the capacitance C combination is approximately equal to $R_{in}/(1-\omega^2/\omega_c^2)$ and is constant if $(\omega^2/\omega_c^2) \angle\angle 1$.

The remaining step is to design a proper network to provide the necessary impedance transformation over the entire frequency band. Circuits suitable for the input include multi-section constant-K filters, Chebyshev filters, and tapered lines. A more sophisticated approach to obtain a broadband transformation in the input is to treat the parasitic inductance L_{in} of Fig.11 as part of the transformation network. For example, L_{in} can be considered as one arm of the Chebyshev low-pass filter of Fig.12(d). For a given bandpass characteristic, the number of sections increases with the value of L_{in}. Again, therefore, low package parasitic inductance is important.

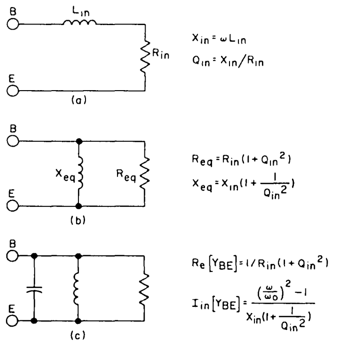


Fig.13(a) - Series equivalent input circuit of an rf power transistor; (b) equivalent parallel input; (c) equivalent parallel input circuit with external base-emitter capacitance.

The 2N5919 Transistor

At present, plastic uhf power transistors are used exclusively in 225-to-400-MHz broadband applications. UHF plastic packages have substantially lower parasitic inductances than either TO-60 or TO-39 packages, as discussed previously.

The introduction of the RCA hermetic low-inductance stripline package makes it possible to design broadband power amplifiers without compromising reliability. This new radial-lead package utilizing ceramic-to-metal seals is superior to uhf plastic packages in two respects: it has lower parasitic inductances, and it is hermetically sealed. For example, the RCA-2N5919 transistor, first in a series of hermetic radial-lead devices, has a dynamic input impedance of 1.5 + j1.2 at 400 MHz. Fig.14 shows typical curves of power output and efficiency as a function of input power for the 2N5919 at a frequency of 400 MHz and a collector-to-emitter voltage of 28 volts. This transistor is capable of delivering an output of 19 to 20 watts with gain of 6.5 dB and collector efficiency approaching 70 per cent at 400 MHz. One important feature of this device is that the power gain is linear with 1.6 dB at power levels between 7 and 20 watts. The 2N5919 is also capable of an output of 20 watts with gain of more than 10 dB at 225 MHz, as shown in Fig.15.

High-Power Generation

When more rf power is required than can be provided by a single transistor, combining techniques must be used. Two of the more commonly used methods of combining transistors to obtain high power are: (1) the "brute-force" method of paralleling several transistors at a single point, and (2) the use of hybrids to combine several individual amplifier chains or modules.

RF power transistors can be directly paralleled at a single point, as shown in Fig.16. All collectors and bases are connected together, and a single input matching circuit and a single output matching circuit are used. Although this arrangement offers circuit simplicity, it has several disadvantages. First, the transistors used must be matched for power output and power gain at the desired frequency to obtain good load sharing. Second, direct paralleling of a large number of transistors at a single point leads to poor reliability; a failure of one transistor usually causes a total failure of the over-all amplifier circuit.

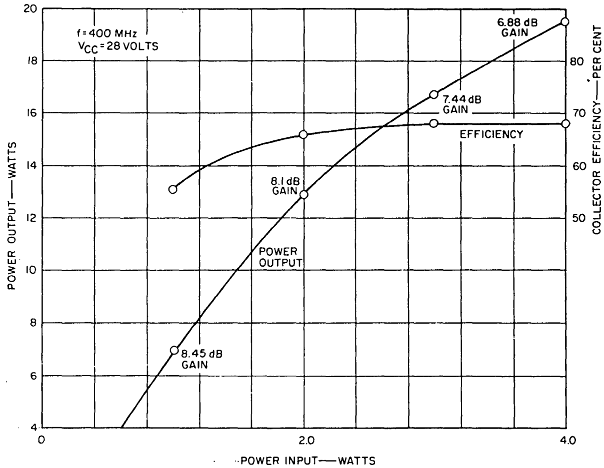


Fig.14 - Output power and efficiency as functions of input power for the RCA-2N5919 transistor at 400 MHz and 28 volts.

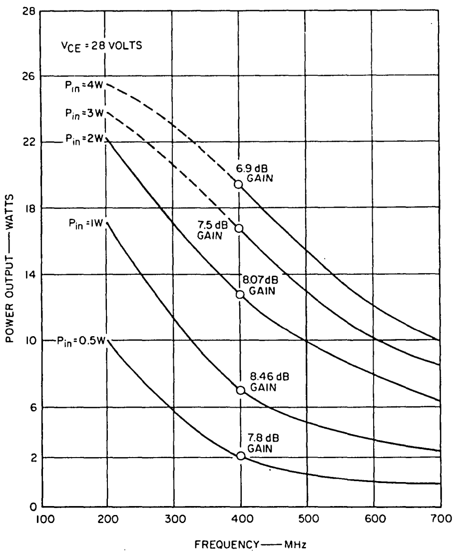


Fig.15 - Output power as a function of frequency in the RCA-2N5919 at 28 volts.

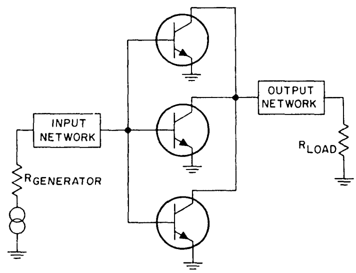


Fig.16 - A method of paralleling rf power transistors at a single point.

Of particular importance is the reduction in both input and output impedances resulting from paralleling transistors. The impedance level can be of the same order as the rf losses in the input and output elements. The input resistance of an rf power transistor at 400 MHz is typically 1 to 5 ohms. If a 0.1-microhenry inductor with an unloaded Q of 150 is used in the input circuit, the rf loss in the inductor at 400 MHz is 1.6 ohms ($R_{loss} = \omega L/Q$). This rf loss increases as more transistors are paralleled. Consequently, the total power output which can be obtained from several transistors paralleled at a single point is less than the calculated total power output.

Fig.17 shows the paralleling efficiency as a function of the number of transistors in direct parallel[3]. Paralleling efficiency is defined as the ratio of the measured total power output to the calculated total power output (i.e., the number of units multiplied by the power output of an individual unit). The paralleling efficiency decreases rapidly as the number of transistors increases. For example, when the 2N5016 is used at a frequency of 400 MHz and a collector-to-emitter voltage of 28 volts, the paralleling efficiency is 95 per cent for two transistors connected in parallel, 90 per cent for three transsistors, 85 per cent for four units, and 55 per cent for eight units.

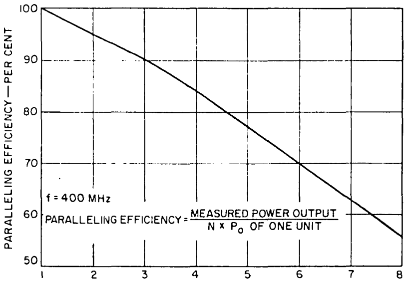


Fig.17 - Efficiency as a function of the number of transistor in parallel.

Most of the disadvantages of the "brute-force" direct-paralleling method can be avoided by a more sophisticated approach, shown in Fig.18, in which several amplifier modules or chains are combined by the use of an input hybrid divider and an output hybrid combiner. This arrangement provides a reliable and efficient method of achieving high vhf/uhf power. Reliable operation results because of the isolating properties of the hybrid. A failure of one amplifier chain or module reduces the total power output, but does not cause failure of the other amplifier chains or modules. In addition, this arrangement provides a highly efficient method of combining vhf/uhf power because the insertion loss of a hybrid is small.

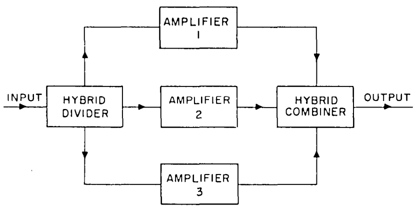


Fig.18 - Use of hybrids to combine several individual amplifiers.

A hybrid is an n-port network used as a constant-impedance circuit for power summing and dividing. It maintains phase and amplitude equality between any number of outputs, and also provides isolation between matched outputs. Fig.19(a) shows a two-way transmission-line hybrid power divider which consists of two quarter-wave transmission lines, each having a characteristic impedance of $Z_o = \sqrt{2}\, R_o$.[4] The generator port 1 and distribution ports 2 and 3 are terminated by resistors R_o. A lumped resistor of value R_o is connected from each of the distribution ports to a common point. When a signal is fed into the power divider (port 1), it divides by virtue of symmetry into two equiphase and equi-amplitude ports. No power is dissipated by the resistance R when matched loads are connected to the outputs because port 2 and 3 are at the same potential. The input (port 1) of the power divider is also matched when the conditions for isolation between the two outputs are satisfied. The input impedance of port 1 is the parallel combination of the two output loads R_o after each has been transformed through a quarter-wavelength of the line Z_o. If a reflection or mismatch occurs at one of the output ports, the reflected signal splits; part travels directly to the input, splits again, and then returns to the remaining output port. Thus, the reflected wave arrives at the remaining output port in two parts; the path-length difference between the two paths of travel is 180 degrees out of phase when the lines are $\lambda/4$ in length. The value of the resistor R is properly chosen ($R = R_o$) so that the two parts of the reflected wave are equal in amplitude and 180 degrees out of phase; thus, complete cancellation occurs. The hybrid shown in Fig.19(a) can also be used as a two-way combiner (i.e., power introduced at ports 2 and 3 will combine or add at port 1). The lumped equivalent of the quarter-wave transmission-line hybrid is shown in Fig.19(b).

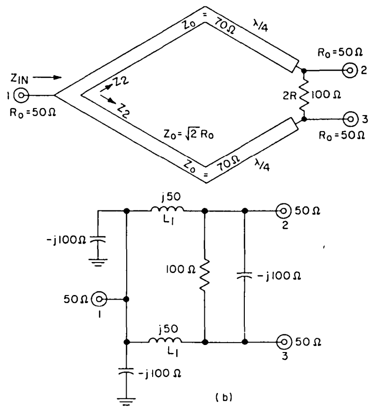


Fig.19(a)-A two-way, transmission-line, hybrid power divider; (b) a lumped-constant equivalent of this power divider.

The technique illustrated in Fig.19 can be extended to an n-way power divider or combiner, as shown in Fig.20.[4] The characteristic impedance of each quarter-wave line should have a characteristic impedance of $Z_o = \sqrt{n}\, R_o$, and the resistor R should have a value of R_o.

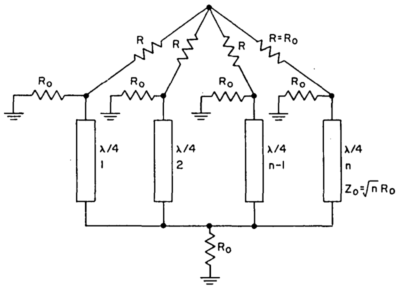


Fig.20 - N-way, quarter-wave hybrid.

Fig.21(a) shows another hybrid, the 6 λ/4 ring. Each port is separated from the adjacent port by a λ/4 section, except for the 3 λ/4 section between ports 3 and 4. Because of this arrangement, power introduced at port 1 appears at equal levels at the adjacent ports (2 and 4), but does not appear at the opposite port 3. In a similar way, power introduced at ports 2 and 4 combines or adds at port 1.

The VSWR and the isolation of both the 6 λ/4 hybrid ring of Fig.21(a) and the λ/4 hybrid of Fig.20 are sensitive to frequency deviations. A version of the hybrid ring which is less sensitive to frequency deviation is the quadrature hybrid. shown in Fig.21(b), in which the 3 λ/4 arm of the 6 λ/4 hybrid ring is replaced by a frequency-insensitive reversal of phase. Because the balance of this ring is not a function of frequency, its bandwidth can be expected to be wide. The quadrature hybrid accepts an input signal at any of its four ports, and distributes half to a second port and half to a third port with 90-degree or quadrature phase difference. The fourth port is isolated.

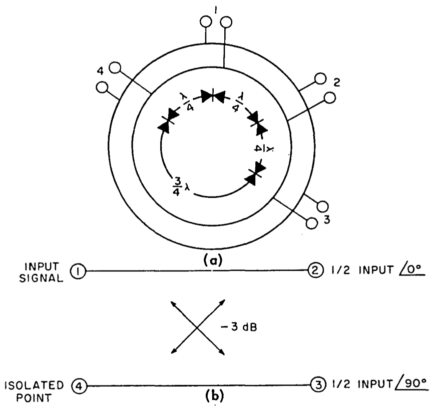


Fig.21(a) - A 6 λ/4 ring hybrid; (b) a quadrature hybrid.

The choice between hybrids and single-point paralleling for high-power generation depends on the required over-all performance, size, and cost. The most effective system usually employs hybrids to combine several amplifier chains in which several transistors are connected in parallel. Consideration must be given to both the paralleling efficiency (shown in Fig.17) and the insertion loss of the hybrid. As a rule of thumb, direct single-point paralleling should be used for applications in which maximum power output is essential up to a point where the reduction of output power caused by decreasing paralleling efficiency approaches that results from the insertion loss of the hybrids. Fig.22 demonstrates

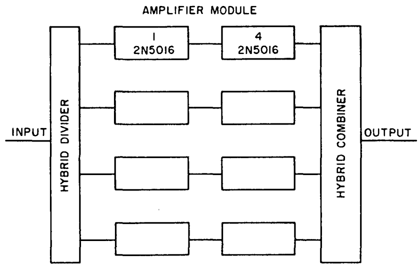


Fig.22 - Block diagrams of single-point paralleled and hybrid systems used to generate 200 watts of cw power at 400 MHz.

the use of such techniques to generate cw power of 200 watts at 400 MHz. The system consists of a four-to-one hybrid divider, four amplifier chains or modules, and a four-way hybrid combiner. Each individual amplifier module utilizes four 2N5016 units connected in parallel and driven by a single 2N5016. With a supply voltage of 28 volts, each module is capable of delivering output power of 54 watts at 400 MHz with gain of 12.4 dB and collector efficiency of 50 per cent. The four-to-one hybrid combines the output of four modules to produce cw power of 200 watts at 400 MHz.

A similar technique has been used successfully to generate cw power of more than 1000 watts at 400 MHz by use of sixty-four 2N5016 units, and power of 10 watts at 2.3 GHz by use of sixteen 2N5470's.[5] The use of hybrids in conjunction with single-point paralleling has become an accepted technique for generating vhf/uhf high power. Such techniques are now found in practical systems that deliver output power up to 300 watts in the low uhf range.

REFERENCES

1. Matthaei, George L., "Tables of Chebyshev Impedance Transforming Networks of Low-Pass Filter Form," **IEEE Transactions on Microwave Theory and Techniques,** Vol. MTT-14, August 1966.

2. Young, L., "Chebyshev-Filter Performance Tables," **Microwaves,** October 1967.

3. Minton, R., "Design-Trade -Offs for RF Transistor Power Amplifiers," **WESCON,** 1966.

4. Wilkinson, Ernest J., "An N-Way Hybrid Power Divider," **IRE Transactions on Microwave Theory and Techniques,** January 1960.

5. Blum, S. C., "A low S-Band Solid State Amplifier," **Solid-State Circuits Conference,** February 1968.

RCA
Solid State
Division

RF Power Transistors
Application Note
AN-3764

Microwave Amplifiers and Oscillators Using the RCA-2N5470 Power Transistor

by

G. Hodowanec, O. P. Hart, and H. C. Lee

The RCA-2N5470, the first commercially available 1-watt 2-GHz coaxial transistor, is designed for use in uhf/microwave power amplifiers, microwave fundamental-frequency oscillators, and frequency multipliers. Projected uses of this device should include sophisticated military and commercial applications such as L- and S-band power circuits, small-signal amplifiers, and microwave power oscillators.

This Note describes the capabilities and some of the uses of the 2N5470 in uhf/microwave amplifiers and oscillators which are the essential building blocks for solid-state microwave, radiosonde, and S-band telemetry equipment. Device and package construction and reliability considerations are discussed along with large- and small-signal operation at microwave frequencies. Detailed designs and performance data are given for practical circuits incorporating the 2N5470.

Device and Package Construction

An efficient microwave power transistor has a surface geometry and cross-sectional structure optimized for gain at a specific frequency, and is enclosed in a low-loss low-inductance package. The surface geometry of the 2N5470 is optimized for gain at 2 GHz; a 16-emitter-stripe overlay geometry is used in conjunction with shallow diffusions and thin epitaxial material. Although emitter and collector areas are minimized, enough emitter periphery is maintained to insure adequate current-handling capability at microwave frequencies.

The 2N5470 is hermetically sealed in the specially designed coaxial package shown in Fig. 1. This package is mechanically strong and has low parasitic inductance, low interelectrode capacitance, and good thermal properties. The top section of the package consists of a solid silver stud that serves as the collector terminal. An Al_2O_3 disc insulates the collector from the gold-plated Kovar flange which serves as the base terminal. Another Al_2O_3 disc separates the base flange and the gold-plated nickel emitter cap.

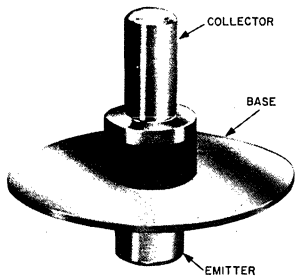


Fig. 1 - Specially designed, hermetically sealed, coaxial package for the 2N5470 rf power transistor.

Fig. 2 shows the bonding arrangement for the 2N5470. The pellet is mounted on the collector stud and is oriented to allow for two emitter- and two base-lead connections. Because each pair of leads is 180 degrees apart, mutual coupling is minimized between the leads and lead inductance is decreased. The base flange shields the collector output circuits from the emitter input circuits. The base parasitic inductance is of the order of 0.1 nanohenry; the emitter parasitic inductance is slightly higher. The interelectrode capacitances are 0.7 picofarad between collector and base, 1.5 picofarads between emitter and base, and 0.1 picofarad between collector and emitter. The extremely low parasitic feedback capacitance between collector and emitter makes the 2N5470 an ideal device for amplifier applications. In oscillator applications, the feedback required to sustain oscillation must be provided externally between collector and emitter.

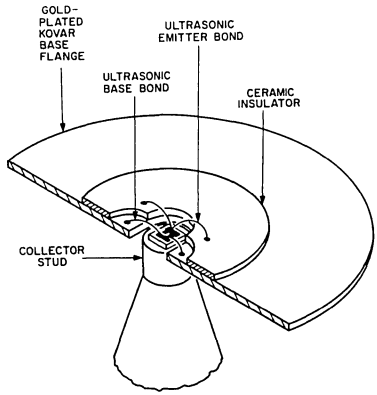


Fig. 2 - Bonding arrangement for the 2N5470.

RF Performance of the 2N5470

The introduction of the RCA-2N5470 transistor makes possible the design of class C amplifier circuits which supply a minimum power output of 1 watt at a frequency of 2 GHz with gain of 5 dB and collector efficiency of 35 per cent, or 2 watts at 1 GHz with gain of 10 dB and collector efficiency of 50 per cent. Fig. 3 shows typical power output and power gain as functions of frequency for a 2N5470 transistor in a

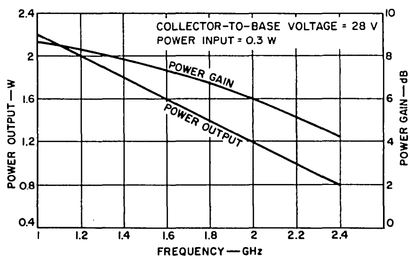


Fig. 3 - Power output and power gain as functions of frequency for a 2N5470 in a common-base amplifier configuration.

common-base amplifier configuration. Fig. 4 shows power output as a function of collector-to-base voltage at 2 GHz for a 2N5470 in the same configuration. The 2N5470 provides higher gain and is more stable in the common-base amplifier configuration than in the common-emitter configuration.

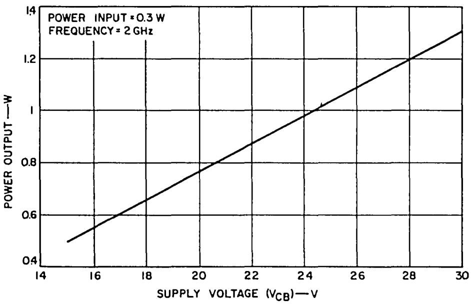


Fig. 4 - Power output as a function of collector-to-base voltage at 2 GHz for a 2N5470 in a common-base amplifier configuration.

In both high-power and small-signal operation at uhf and microwave frequencies, package parasitics must be considered an integral part of the transistor characteristics. In a common-emitter configuration, the relatively high extrinsic collector-to-base feedback capacitance can produce a negative input impedance. However, the degenerating effect of the emitter parasitic inductance helps to stabilize the feedback effect. The extrinsic collector-to-base feedback of the transistor chip can be overcome by use of the transistor in a common-base configuration in which the extrinsic collector-to-base capacitance is in shunt with the output circuit. In such arrangements, however, the degenerating effect of the base parasitic inductance can also produce a negative input impedance. Therefore, common-base operation of a transistor is possible only when the base-lead inductance is minimized as in the 2N5470.

An additional advantage of common-base operation of the 2N5470 is that burn-outs due to low-frequency oscillation are minimized. Low-frequency oscillations can occur in microwave transistors in any configuration because the gain of the transistor is much higher at low frequencies than at the operating frequency; however, the common-emitter configuration is particularly susceptible to the production of low-frequency oscillations because the gain at low frequency is much higher than that of the common-base configuration and the highly capacitive base-emitter junction and the input rf choke form a resonant circuit at low frequency. Low-frequency instability is minimized in the common-base configuration because the power gain of the transistor is substantially lower in this configuration than in the common-emitter configuration.

Because the 2N5470 is a stable amplifier device, fundamental-frequency oscillation must be sustained by the use of external feedback. In fundamental-frequency oscillator circuits such as those described in this Note, the 2N5470 can provide an output of 0.5 watt at 2 GHz and 1 watt at 1 GHz. The 2N5470 can also be used in class A linear amplifiers in which a wide dynamic range is required. Forward bias of the emitter-to-base junction is required for operation at input power levels below 50 milliwatts. When forward-biased, the 2N5470 should be operated at a supply voltage less than the 28 volts normally used for class C operation. The exact voltage value depends on the collector current to be used.

Reliability

Reliability of the 2N5470 is assured through environmental and mechanical tests including temperature-cycling, moisture-resistance, shock, constant-acceleration, vibration-fatigue, and vibration variable-frequency tests. Life tests include high-temperature storage, dc operation, and rf operation at 2 GHz. The rf life-test arrangement, shown in Fig. 5, consists of a 2-GHz fundamental-frequency oscillator with an output of 300 milliwatts followed by a 2-GHz amplifier with an output power of 1 watt.

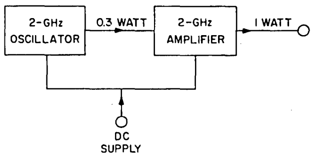


Fig. 5 - RF life-test arrangement for the 2N5470.

Large-Signal Amplifier Operation

The design of any large-signal rf power-amplifier circuit involves two steps: (1) the determination of load and input impedance under dynamic operating conditions, and (2) the design of properly distributed filtering and matching networks required for optimum circuit performance.

The large-signal impedances for the RCA-2N5470 transistor shown in Fig. 6 were measured under conditions of optimum circuit performance with the transistor connected in the common-base configuration. Slotted-line impedance determinations were made over the range of 1 to 2.3 GHz. Confirming vector voltmeter measurements were also made in the range of 1 to 1.4 GHz.

Microwave Power-Amplifier Design

One-step transformation network designs can be used in most narrow-band amplifier applications. However, most broadband amplifiers require two or more step transformations capable of transforming a large impedance ratio over a wider frequency range. In both instances, distributed-line design techniques are preferred.

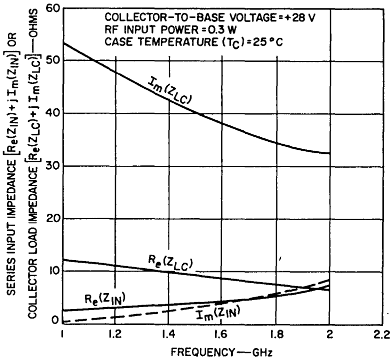


Fig. 6 - Dynamic impedance as a function of frequency for the 2N5470 in a common-base configuration.

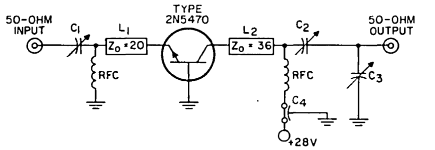
The use of quarter-wave or eighth-wave uniform transmission-line techniques results in simplified circuit designs which yield performance advantages. For example, quarter-wave transformer techniques may be used to transform the small, real parts of the dynamic impedances of the 2N5470 closer to that of the source (or load) resistance provided that the reactive parts of the impedances are tuned out. When the characteristic impedance of an eighth-wave line section is made equal to the magnitude of the complex terminating impedance, a complex impedance can be transformed to a real value with minimum line VSWR and, thus, minimum line loss. In some cases, it is advantageous to use shorter line sections which may transform a complex impedance directly to 50 ohms, where feasible, or to 50 ohms with an imaginary component which can be tuned out. Because the line lengths are generally very short, the higher line VSWR's in such cases do not necessarily result in excessive line losses. A Smith Chart is useful in determining the line lengths.

Direct complex-to-50-ohm transformations (by use of transmission-line techniques) usually have a 3-dB bandwidth of 10 per cent. When an additional transformation step is needed (e.g., a reactive divider network may be needed to match a real component which is not exactly 50 ohms to the 50-ohm source or load), the 3-dB bandwidth is generally reduced to about 5 to 6 per cent. Tapered transmission lines may be used for wider frequency-band response; these lines can be tapered directly to a desired real impedance. In addition, because of the nature of the TEM mode of propagation in these lines, substantial reductions in line lengths are possible. However, techniques required to accomplish this transformation are complex and only a circuit description is given in this Note.

The design principles discussed thus far are illustrated in the circuit designs given in the following pages.

2-GHz Coaxial-Line Power Amplifier

A coaxial-line circuit using the 2N5470 at 2 GHz is shown in Fig. 7. This circuit operates at 28 volts and can develop a power output of 1.2 watts with a drive power of 0.3 watt. Collector efficiency is in the order of 40 per cent. The coaxial transistor is in series with the center conductors of the coaxial air lines, and the



C_1 — 0-10 pF; Johanson 4355 or equiv.
C_2 — 0.35-3.5 pF; Johanson 4701 or equiv.
C_3 — 0.35-3.5 pF; Johanson 4702 or equiv.
C_4 — 1000 pF, feedthrough; Allen-Bradley FB2B or equiv.
RF chokes — 3 turns No. 30 wire, 1/16 in. (1.59 mm) ID, 3/16 in. (4.75 mm) long
L_1 L_2 — coaxial lines; see Fig. 8 for details

Fig. 7 - A 2-GHz coaxial-line power-amplifier circuit.

base is grounded in such a way that the input and output lines are separated as shown in Fig. 8. In Fig. 7, the input line L_1 has a characteristic impedance Z_0 of 20 ohms and is approximately 0.80 inch long. This line length (including the effects of the capacitive loading at the base flange and the fringe line effects introduced by capacitor C_1) is $0.21\lambda_g$ (where λ_g is the wavelength for a given circuit) and transforms the input impedance of 7.5 + j8 ohms to about 53 ohms of real

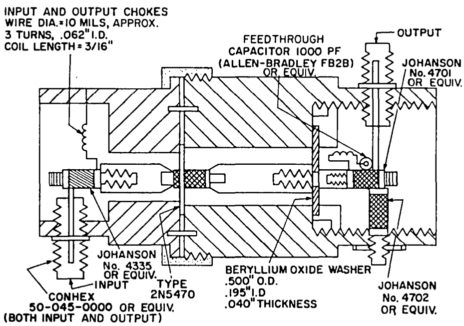


Fig. 8 - Construction details for the 2-GHz coaxial-line power amplifier shown in Fig. 7.

resistance. Capacitor C_1, in conjunction with the small fringe capacitance at the input end of the input line, acts as a reactive divider network for the final transformation to the 50-ohm resistance of the driving source.

The output load impedance required for the 1.2-watt output is approximately 6.5 + j35 ohms at 2 GHz and is transformed by L_2, which has an electrical length of approximately $3/8\lambda_g$ and an impedance of 36 ohms. The electrical length of L_2 is approximately 110 degrees when correction is made for capacitive loading effects at the collector end of the line, dielectric loading effects of the beryllium oxide heat-sink washer shown in Fig. 8, and fringing field effects at output capacitors C_2 and C_3. A $3/8\lambda$ line section was used in the output circuit in this particular design, rather than an eighth-wave section because of the difficulty of incorporating capacitor C_3 near the end of L_2 (which would be required for the step-up needed with the $\lambda/8$ line). The $3/8\lambda$ line section performs in the same manner as the eighth-wave line length, but has somewhat increased line losses as a result of the large increase in line length. Typical performance curves for a 2N5470 transistor in the circuit of Fig. 7 are shown in Fig. 9. Because a network transformation is used in this circuit, the 3-dB bandwidth is only of the order of 6 per cent.

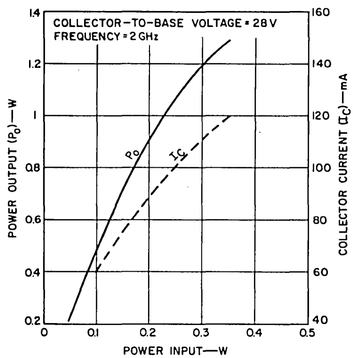


Fig. 9 - Typical performance curves for the 2N5470 in the 2-GHz coaxial-line power amplifier of Fig. 7.

1-GHz Coaxial-Line Power Amplifier

The design of a 1-GHz coaxial-line amplifier circuit is similar to that for the 2-GHz circuit and fixture shown in Fig. 7 and 8. However, because of the increased device dissipation at 1 GHz, the coaxial lines are loaded with boron nitride insulation to reduce the thermal resistance between the active device and the external heat sink as represented by the outer coaxial-line cylinder in Fig. 8. Boron nitride has thermal and electrical properties similar to those of Al_2O_3, and has the additional advantages of being readily machinable and non-toxic.

The input line of a 1-GHz coaxial-line power amplifier has an electrical length equal to 23 per cent of a wavelength and transforms the input impedance of approximately 3 + j1 ohms to a real component of about 49 ohms. Capacitor C_1 is used in conjunction with input stray capacitance to match the value of 49 ohms to the 50-ohm driving source. The actual line length, corrected for capacitive and dielectric loading effects as well as fringe line effects, is about 1 inch. The characteristic impedance of the line is about 30 ohms for an air line or about 13 ohms when the line is loaded with the boron nitride dielectric.

The output line is basically a $3/8\lambda$ transformer which transforms the complex output load impedance of about 12 + j53 ohms to a real component of about 270 ohms. Capacitors C_2 and C_3 are reactive dividers and step down this resistance to the 50 ohms required at the output. The actual line length, again corrected for loading and fringe field effects is about 1.64 inches The loaded output line impedance is approximately 27 ohms.

The use of the boron nitride dielectric makes possible the design of a 1-GHz coaxial-line amplifier circuit comparable in size to the 2-GHz coaxial-line circuit designed with air lines. Therefore, a substantial reduction in the size of the 2-GHz amplifier circuit is possible when the dielectric loading technique is used. In addition, improvement in power gain and efficiency can be expected because of the improved thermal resistance between the active device and the final heat sink.

The construction of a 1-GHz amplifier is, as mentioned above, similar to that shown in Fig. 8 except that the beryllium oxide washer is not used; press-fit boron nitride cylinders form the dielectric portion of the coaxial lines. In both circuits, the fixture is built with separate coaxial-line cavities for input and output; the cavities are locked together across the 2N5470 base flange by means of a locking nut. Although tuning of the amplifiers is not critical, some adjustment of the wire rf chokes (by spreading or closing of turns) may be required for optimum performance at each frequency. Thus, the rf chokes can be used as a fine adjustment of the terminating impedance.

1.6-GHz Stripline Power Amplifier

Although the 2N5470 transistor is designed primarily for coaxial-line use, it can also be adapted to stripline and microstripline circuits. Fig. 10 shows an experimental microstrip circuit capable of developing a power output of 900 milliwatts over the range of 1.6 to 2 GHz with a drive power of about 200 milliwatts. Collector efficiency at 1.6 GHz is of the order of 50 per cent with a collector supply voltage of 28 volts.

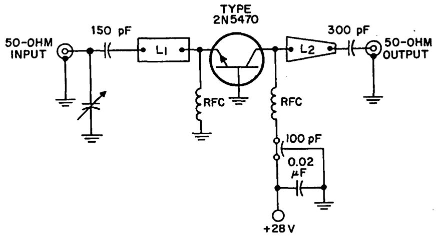


Fig. 10 - An experimental 1.6-to-2-GHz broadband microstripline amplifier.

The input line of this circuit has a characteristic impedance of 8 ohms, and is constructed of 5-mil copper sheet mounted on the circuit ground plane with 5-mil Dupont H-Film* as the dielectric. A conducting strip of the copper only $3/16$ inch wide is sufficient to provide the 8-ohm line impedance. The physical line length of 0.4 inch is equivalent to an electrical length of an eighth wave and transforms the complex input impedance of approximately 5.3 + j6 ohms to a real component of about 21 ohms. Capacitor C_1, a copper strip 5 mils thick located in the vicinity of the 150-picofarad dc blocking capacitor is used to reactively match the value of 21 ohms to the 50-ohm source impedance.

The output line is a tapered line section constructed of $1/32$-inch teflon-fiberglass board. The characteristic impedance at the collector end is 35 ohms and is approximately equal to the magnitude of the complex load impedance of the device at 2 GHz (under circuit operating conditions). The eighth-wave line section (approximately 0.3 inch long) is tapered to a characteristic impedance of 50 ohms at the output end of the line and thus matches the output directly; the 300-picofarad capacitor is used for dc-blocking purposes only.

The VSWR is low at both input and output ports over the range of 1.6 to 2 GHz. Below 1.6 GHz, the input and output VSWR increases because of mismatch conditions; however, circuit power output remains essentially constant because of increased device gain at the lower frequencies. As a result, the experimental 1.6-GHz stripline power amplifier exhibits a relatively flat output response of 900 milliwatts (with a 200-milliwatt drive) over the range of 1.2 to 2 GHz.

Pulse Operation of the 2N5470

One major difference between cw and pulse operation of a transistor is the substantial increase in input drive level possible under pulsed input conditions. The ability of a transistor to deliver higher pulsed-output power than cw power depends on the transistor

* Trademark of E.I. du Pont de Nemours and Co., Inc.

current-handling, thermal, and rf-voltage capabilities. No significant improvement in power output or gain can be achieved by operation of an rf power transistor under pulse input conditions at the same supply voltage and input power level used under cw conditions.

Fig. 11 shows peak power output as a function of duty cycle for the 2N5470 operating under pulse conditions. Peak power was measured at a frequency of 2 GHz; the constant supply voltage was 28 volts. Under pulsed input conditions with pulses of 2-microsecond duration and 10-per-cent duty cycle, the output power of a 2-GHz amplifier circuit such as the one shown in Fig. 8 increases substantially from 1.1 to 1.9 watts as the input power increases from 0.3 to 0.7 watt. When

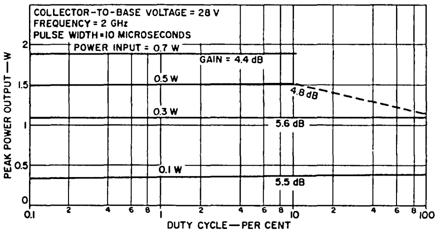


Fig. 11 - Peak power output as a function of duty cycle for the 2N5470 operating under pulsed conditions.

the same circuit operates under cw conditions, an increase in input power from 0.3 to 0.5 watt does not increase power output; in fact, power output stabilizes at 1.1 watts. These measurements indicate that the power input at 2 GHz under cw conditions is limited by thermal considerations rather than peak-current capabilities or emitter periphery. The 2N5470 transistor is thus be capable of operating at much higher peak current under pulse conditions than would be permissible under cw conditions.

A second major difference between cw and pulse operation of a transistor is the much higher voltage at which the transistor can be operated under pulse conditions. Fig. 12 shows the peak power output measured

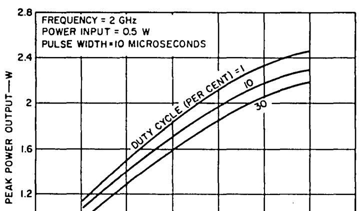


Fig. 12 - Peak power output at 2 GHz as a function of supply voltage for the 2N5470.

at 2 GHz as a function of supply voltage for the 2N5470. The measurements were performed at a constant peak input power with pulses of 10-microsecond duration and duty cycles of 1, 10, and 30 per cent. At 2 GHz and an input power level of 0.5 watt, the power output of the 2N5470 increases from 1.9 watts at 28 volts to 2.5 watts at 45 volts. These measurements indicate that the 2N5470 transistor can be operated at much higher voltage under pulse conditions than under cw conditions and, consequently, can deliver more pulsed power.

Microwave Power-Oscillator Design

The 2N5470 transistor is suitable for use in microwave power oscillators at L-band and low S-band frequencies. The 2N5470 has high power amplification, a necessary condition for good oscillator performance; however, because of the high degree of isolation that exists between the transistor chip and the case as a result of the coaxial design, an external feedback path must be provided to assure reliable oscillation at microwave frequencies. Except for this feedback loop, the design of oscillator circuits is similar to that discussed for amplifier circuits.

Fig. 13 shows the 2N5470 in its basic oscillator configuration, a Colpitts oscillator circuit. In this circuit, the collector is grounded for maximum heat dissipation; therefore, power output is taken from the base circuit.

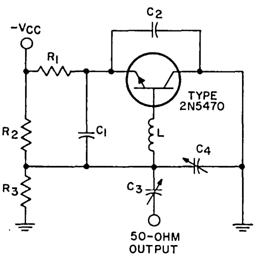


Fig. 13 - Basic oscillator configuration for the 2N5470, a Colpitts oscillator circuit.

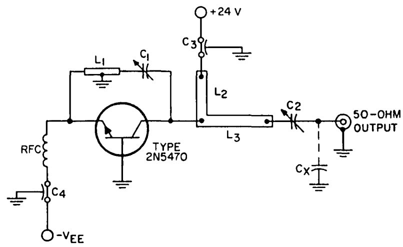
The parasitic elements of the 2N5470 (the parasitic inductance L and the parasitic capacitances C_1 and C_2) can be made use of in oscillator design. The internal package capacitance C_2 is usually insufficient to sustain oscillation and must be increased externally. The Colpitts circuit shown in Fig. 13 can be changed to a Hartley oscillator circuit if L and C_1 are made external components and C_1 is connected to the center point of the inductor.

Reliable starting conditions are assured by use of a slight forward bias in the common-base oscillator circuit through the bias network formed by resistors R_2 and R_3. Once oscillations have been started, the circuit is biased toward class C operation by the base current flowing through resistors R_1 and R_2. Resistor R_1 also serves as a limiting resistance which tends to maintain the bias point at stable oscillator power-output levels.

Although many oscillator designs are possible, the two circuits described in the following paragraphs are descriptive of the types employing the 2N5470 transistor.

2-GHz Microstripline Oscillator

The circuit shown in Fig. 14 is a 2-GHz microstripline oscillator which can deliver 300 to 350 milliwatts of rf power with a 24-volt collector supply. Although separate bias supplies are shown, a single "floating" bias supply can also be used.



C_1 C_2 — 0.35-3.5 pF; Johanson 4702 or equiv.
C_3 C_4 — 100 pF, feedthrough; Allen-Bradley FA5C or equiv.
L_1 — 50-ohm miniature coaxial line, 1.5 in. (38.1 mm) long
L_2 — microstrip line, 1/32 in. teflon-fiberglass, 0.08 in. wide, 0.43 in. long
L_3 — microstrip line, 1/32 in. teflon-fiberglass, 0.03 in. wide, 0.7 in. long
RF choke — 5 turns No. 33 wire, 1/16 in. (1.59 mm) ID, 3/16 in. (4.75 mm) long

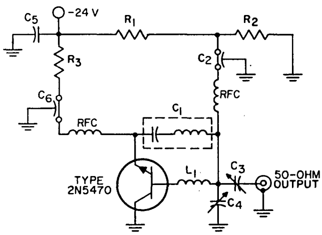
Fig. 14 - A 2-GHz microstripline oscillator.

A grounded-base configuration is used in the circuit; output power is taken from the collector circuit in the conventional manner. L_2 is a section of microstripline which provides the susceptance required to tune out the output capacitance of the 2N5470. The real part of the output load impedance (about 225 ohms) is transformed by a quarter-wave section of microstripline to a real component of about 53 ohms. Capacitor C_2, in conjunction with some stray capacitance C_x, is used to match the circuit output to the 50-ohm load. Correctly phased feedback is provided by the loop circuit formed by L_1 and C_1. Frequency adjustment over the range of 1.8 to 2.1 GHz is controlled by capacitor C_1.

The circuit of Fig. 14 is fabricated on a 1/32-inch teflon-fiberglass board. The 2N5470 is mounted with the base flange flat against the ground plane of the board; a beryllium oxide washer provides a thermal path between the collector post and the ground plane. The 1.5-inch line section L_1 is used to contact the base of the 2N5470 on the other side of the board.

2-GHz Lumped-Constant Power Oscillator

The circuit shown in Fig. 15 has a single bias supply and makes use of a grounded collector for better heat dissipation. The circuit is tunable over the range of 1.8 to 2.1 GHz and can deliver 300 milliwatts of output power at 2 GHz with a 21-volt power supply. Circuit operation is similar to that of a Hartley oscillator, with L_1 and the parasitic inductance of capacitor C_1 comprising the tapped inductance used in the feedback loop. Tuning is provided largely by capacitor C_4; C_3 is adjusted for optimum match to the load of 50 ohms. Resistor R_1 can be made variable (0 to 100 ohms) to permit optimum adjustment of bias conditions. Output power can be adjusted without great effect on the oscillator frequency by variation of the value of resistor R_3. A minimum supply of about 15 volts is sufficient for stable circuit operation.



C_1 — 0.82 pF, "gimmick"; Quality Components type 10% QC or equiv.
C_2 C_6 — 100 pF, feedthrough; Allen-Bradley FA5C or equiv.
C_3 C_4 — 0.35-3.5 pF, Johanson 4701 or equiv.
C_5 — 0.01 μF, disc, ceramic
L_1 — No. 22 wire, 3/64 in. (1.17 mm) long
RF chokes — 4 turns No. 33 wire, 1/16 in. (1.59 mm) ID, 3/16 in. (4.75 mm) long
R_1 — 51 ohms, 0.5 W
R_2 — 1200 ohms, 0.5 W
R_3 — 5-10 ohms, 0.5 W

Fig. 15 - A 2-GHz lumped-constant oscillator circuit.

Wideband Power Oscillator Circuits

Although the basic Colpitts oscillator circuit shown in Fig. 12 can be made a varactor-tuned wideband oscillator by use of a high-Q varactor in place of the inductance L, a simpler technique can be used with the 2N5470. Fig. 16 shows a proposed circuit using the 2N5470 which is capable of wideband single-screw tuning. Basically, the circuit is the oscillator arrangement of Fig. 14 with the broadband tapered-line output section of Fig. 10. Capacitor C_2 is selected for best output match at the center oscillator frequency desired, and capacitor C_1 is used to control the oscillator over a bandwidth of approximately 20 per cent.

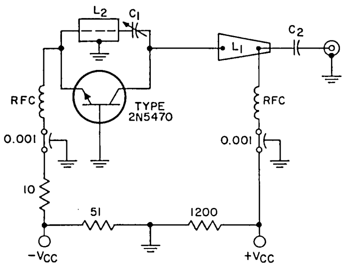


Fig. 16 - A wideband single-screw-tuned oscillator circuit.

Biasing Arrangement for Class A and Class B Operation

In addition to class C operation, the 2N5470 can be used in class A or B service when large dynamic range is required. Only common-base operation is discussed in this Note because the 2N5470 is constructed with the base connected to the flange. In such an arrangement, positive voltage must be supplied to the collector and negative voltage to the emitter to permit forward-biased operation. A 100- to 200-ohm resistor should be connected in series with the emitter to bias the emitter and to prevent excessive collector-current flow.

If one power supply with a grounded negative or positive line is used, the base of the 2N5470 must be dc-isolated from ground. One method of accomplishing this isolation is to use a thin tape material, such as 1-mil Mylar* tape, between the ground plane and the flange or base of the transistor. The resulting capacitance between the flange and the ground plane through the tape dielectric provides a satisfactory bypass for the base. A low-frequency bypass must also be provided along the base power-supply line. This biasing arrangement is shown in Fig. 17.

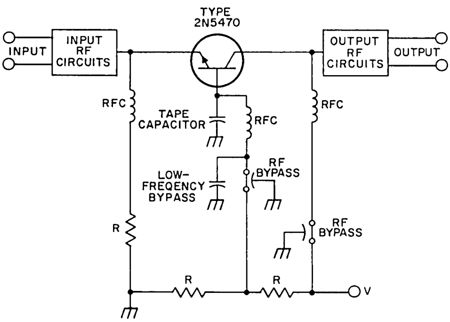


Fig. 17 - A bias circuit with the transistor base grounded.

* Trademark of E.I. du Pont de Nemours and Co., Inc.

Class A and Class B Power Gain

Figs. 18 and 19 show the power gain of a 2N5470 transistor in a common-base amplifier configuration at 1 and 2 GHz, respectively. In each case, a class C curve measured at a supply voltage of 15 volts is included for reference.

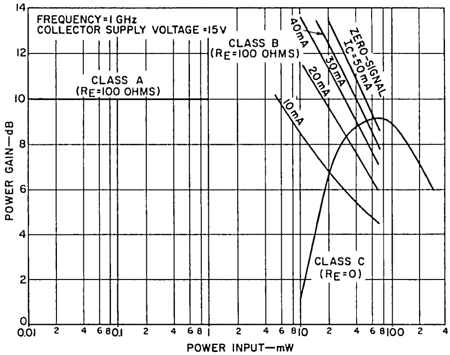


Fig. 18 - Power gain as a function of power input in a 1-GHz common-base amplifier configuration.

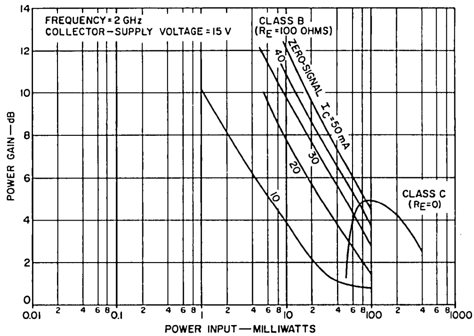


Fig. 19 - Power gain as a function of power input in a 2-GHz common-base amplifier configuration.

The collector-current values shown for class B operation represent quiescent current levels set for each test prior to the application of rf power. The true collector current for each test level is somewhat higher, the amount depending upon the level of the applied rf power. The circuit was returned for each test point to provide maximum power output and, therefore, maximum power gain.

Class A performance was measured with collector currents from 10 to 50 milliamperes. At these levels, class A gains exceeding the values shown can be readily obtained.

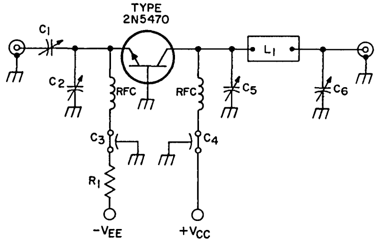
At 1 GHz with a supply voltage of 15 volts, the maximum class C power gain for a 2N5470 transistor is about 9 dB; maximum gain occurs with an input drive of about 75 milliwatts applied to the device. At 2 GHz with a 15-volt supply, the maximum class C power gain is about 5 dB with about 90 milliwatts of input power.

The selection of class B or class C operation and the appropriate operating conditions for a circuit in which power gain is important can be made for frequencies of 1 or 2 GHz with the help of the curves in Figs. 18 and 19. Class B gains in excess of 10 dB can be obtained at either frequency; however, the stability of the amplifier must also be considered.

1- and 2-GHz Lumped-Constant Common-Base Amplifiers

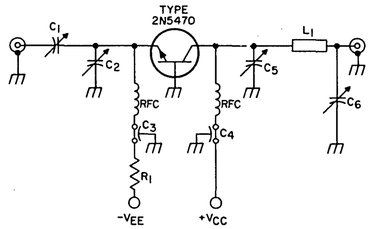
Lumped-constant common-base amplifiers using the 2N5470 have been designed for 1- and 2-GHz operation; circuit diagrams are shown in Figs. 20 and 21, respectively. Both amplifiers are designed for operation either with two power supplies or with one supply with neither positive nor negative line grounded. Both amplifiers are tuned by means of emitter terminal inductances and Johanson air-type dielectric tuning capacitors. These components step the impedance down from 50 ohms to that required by the transistor. The tuning range of the capacitors is sufficient to permit tuning for maximum gain or minimum noise.

A pi network is used in the output circuit of each amplifier so that the output impedance can be varied and thus the degree of mismatch controlled. With the line lengths shown, the circuits can be tuned to the desired frequencies with a large mismatch and provide stable class A operation. In class B or class C operation, when either a slight mismatch or matched conditions are needed, a reduction in the series inductance changes the transformed output impedance to a value closer to that required for matched conditions.



C_1 C_5 C_6 — 1-14 pF, air dielectric trimmer capacitor, Johanson 3901 or equiv.
C_2 — 0.35-3.5 pF; Johanson 4701 or equiv.
C_3 C_4 — 1000 pF, feedthrough
L_1 — 10-mil copper wire, 0.4 cm wide, 2.2 cm long, formed into open loop
RF chokes — 0.1 μH, Nytronics or equiv.

Fig. 20 - A 1-GHz lumped-constant common-base amplifier.



C_1 C_2 C_5 C_6 — 0.35-3.5 pF; Johanson 4701 or equiv.
C_3 C_4 — 1000 pF, feedthrough
L_1 — 10-mil copper strip, 0.3 cm wide, 1.3 cm long

Fig. 21 - A 2-GHz lumped-constant common-base amplifier.

RCA
Solid State
Division

RF Power Transistors Application Note

AN-4025

The Use of Coaxial-Package Transistors In Microstripline Circuits

by

H. C. Lee and G. Hodowanec

It is generally accepted that a well-designed coaxial transistor package (such as that used for the 2N5470) outperforms other transistor packages (including stripline packages) at the microwave frequencies. This performance is based on the low values of the parasitic elements and the excellent isolation between the input and output circuits associated with the coaxial configuration. As a result, microstrip or stripline amplifier circuits using the 2N5470 coaxial-package transistor can have thermal and electrical performance equal to that of coaxial-line circuits.

This Note describes the design, construction, and performance of microstripline circuits using 2N5470 coaxial transistors. Two complete circuits are described: a 1.5-GHz amplifier which can provide 1.5 watts of output power with 8.0-dB power gain and 50-per-cent collector efficiency and a 2-GHz amplifier which can provide 1.2 watts of output power with 6-dB power gain and 40-per-cent collector efficiency.

MOUNTING ARRANGEMENT

Fig.1 shows the circuit mounting arrangement of the 2N5470 coaxial transistor in microstripline and lumped-element circuits. The transistor is mounted vertically through a hole in the metal block which serves as both a heat sink and ground for the device. The bottom side of the metal block is counter-bored so that the base flange of the transistor is level with the surface of the block. The hole through the metal block has a somewhat larger diameter than that of the ceramic portion of the transistor which separates the base flange and the collector stud. This larger diameter permits insertion of a press-fit cylindrical sleeve of beryllium oxide or boron nitride between the transistor and the metal block to provide a heat-conducting path from the collector stud to the block. The diameters of the hole through the metal block and the cylinder of beryllium oxide (or boron nitride) are determined by the desired characteristic impedance of the short coaxial-line section which is formed by this mounting technique. Beryllium oxide and boron nitride have excellent heat conductivity and low electrical losses and thus provide satisfactory heat dissipation from the coaxial transistor without adversely affecting the rf performance.

The circuit arrangement shown in Fig.1 is excellent for isolation of the input and output circuits. The out-

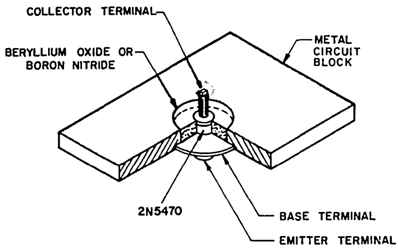


Fig.1 - Mounting arrangement for the 2N5470 in a microstripline circuit.

put circuit is constructed on the top portion of the metal block and the input circuit on the bottom portion. Fig.2 shows the construction of the microstripline circuit. The output circuit is constructed of standard microstripline mounted to the top surface of the metal block. The input circuit is constructed of another microstripline placed directly over the bottom surface of the metal block. A stripline circuit can be formed by placing another strip of dielectric material and ground plane above the conductor strips of Fig. 2.

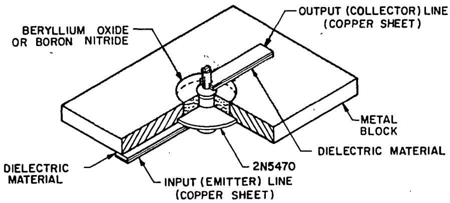


Fig.2 - Construction of the microstripline circuit.

DESIGN OF MICROSTRIP AMPLIFIER CIRCUITS

Fig.3 shows a basic microstripline transistor power-amplifier circuit. The input circuit consists of a

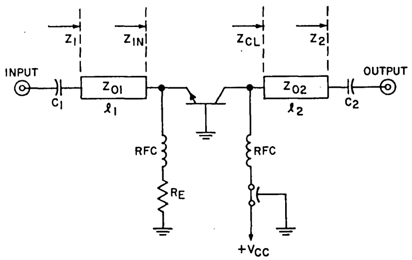


Fig.3 - Schematic of a basic microstripline transistor power amplifier.

line section ℓ_1 with a characteristic impedance Z_{01} and a capacitor C_1. The length of line ℓ_1 in conjunction with the capacitance C_1 transforms the input impedance of the transistor to the driving-source resistance of 50 ohms. The output circuit consists of a line section ℓ_2 with a characteristic impedance Z_{02} and a capacitor C_2. The combination of the line ℓ_2 and capacitance C_2 transforms the load resistance of 50 ohms to the required collector load impedance of the transistor, which is determined by the required power output at the frequency of interest. The two rf chokes and a small emitter resistance R_E complete the biasing arrangement of the transistor power amplifier.

The first step in the design of a 2-GHz power amplifier is to determine the input impedance Z_{in} and the collector load impedance Z_{CL} of the 2N5470 at 2 GHz under dynamic operating conditions. These values, obtained from the published values in the data sheet, are as follows:

$$Z_{in} = 7.5 + j8 \text{ ohms} \quad (1)$$

$$Z_{CL} = 6.5 + j33 \text{ ohms} \quad (2)$$

For the design of the input circuit, a characteristic impedance Z_o of 19.4 ohms is chosen. This value of Z_{o1} is calculated by use of the quarterwave transformer equation. The input impedance Z_{in} is normalized with respect to the characteristic impedance, as follows:

$$Z'_{in} = Z_{in}/Z_{o1} = (7.5 + j8)/19.4 = 0.386 + j0.414 \quad (3)$$

This impedance value point Z'_{in} is located on the Smith Chart shown in Fig.4. The point is then rotated about the constant VSWR circle toward the generator to the intersection of the 2.57 constant-resistance circle (the normalized 50-ohm driving-source resistance). This point is designated as Z_1' and has the value

$$Z_1' = 2.57 + j1.1 \quad (4)$$

The actual impedance Z_1 is then equal to

$$Z_1 = Z_{o1} Z_1' = 19.4 (2.57 + j1.1) = 50 + j21.3 \text{ ohms} \quad (5)$$

The line length required to transform the transistor input impedance from 7.5 + j8 ohms to a driving-source resistance of 50 ohms or from 50 ohms to 7.5 - j8 ohms, as determined from Fig.4, is equal to 0.155 λ_ϵ, where λ_ϵ is the wavelength in the dielectric. At 2 GHz, λ_ϵ is equal to 3.66 inches (for a dielectric constant $\epsilon = 2.6$); therefore, the length of the input line section ℓ_1 is calculated to be 0.56 inch. The width of the line for a characteristic impedance of 19.4 ohms when a 1/32-inch teflon* fiberglass board is used in determined[1] to be 0.27 inch. A capacitor C_1 with a reactance of 21.3 ohms is needed to complete the input circuit. This capacitor also provides dc isolation for the input bias network.

Fig.4 shows that a direct transformation between the input impedance of the transistor (7.5 + j8 ohms) and the driving source resistance of 50 ohms is also possible by proper choice of the characteristic impedance Z_{o1} and the length of the input line. The value of Z_{o1} can be determined from the Smith Chart. Because the input impedance Z_{in} at 2 GHz is inductive, the input line ℓ_1 must be less than a quarter-wave long to provide the necessary impedance transformation. The input

* Trademark of DuPont de Nemours, Inc.

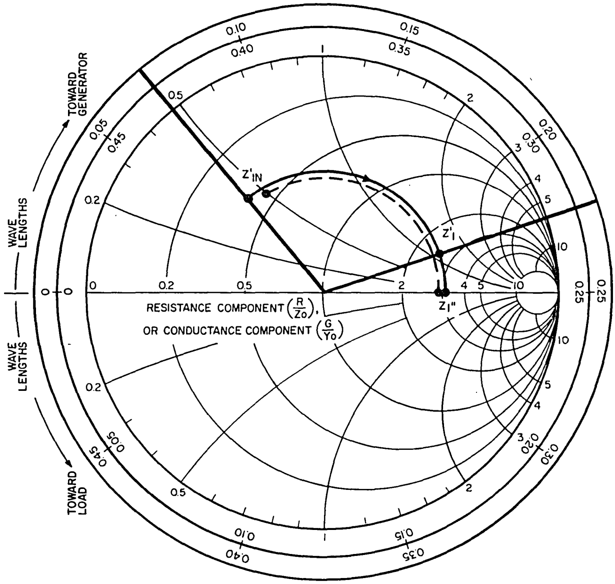


Fig.4 - Smith Chart diagram showing the direct transformation between the transistor input impedance and the driving source resistance made possible by proper selection of the characteristic impedance and length of the input line.

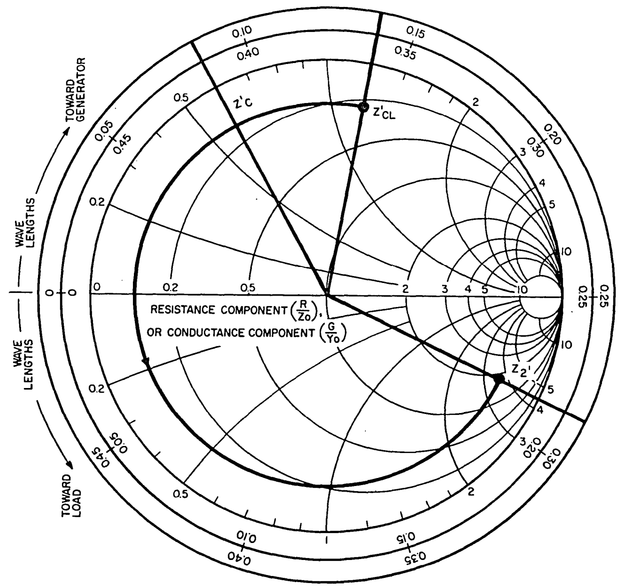


Fig.5 - Smith Chart diagram showing the length of line required to achieve the desired transformation between the transistor collector load impedance and the load-termination resistance.

impedance Z'_{in} is then rotated on the Smith Chart of Fig.4 toward the generator to intersect the zero-reactance line at point Z_1''. The normalized impedance at point Z_1'' is 3.1 ohms and, therefore, the impedance Z_1 is 60 ohms (3.1 x 19.4). The use of a value of Z_{o1} of 19.4 ohms results from direct transformation from 7.5 + j8 ohms to 60 ohms, which is 10 ohms higher than the required value. The reduction of Z_{o1} to 17.5 ohms with $\ell_1 = 0.17\ \lambda_\epsilon$, however, provides a direct transformation from 7.5 + j8 to 50 ohms.

The characteristic impedance Z_o and length ℓ of the transmission line required to provide direct transformation from a pure resistance R_1 to an impedance $Z_2 = R_2 + jX_2$ can also be determined by use of the following equations:

$$Z_o = \sqrt{R_1 R_2}\ \sqrt{1 - \frac{{X_2}^2}{R_2\,(R_1 - R_2)}} \qquad (6)$$

$$\tan \beta\ell = Z_o\ \frac{R_1 - R_2}{R_1\,X_2} \qquad (7)$$

If the impedance Z_2 is a resistance (i.e., $X_2 = 0$), Eq. (6) reduces to the quarter-wave transformer equation and $\ell = \lambda/4$.

For the design of the output circuit, direct transformation using a simple transmission line from 50 ohms to the required collector load impedance of Eq.(2) is not possible because the term ${X_2}^2/R_2\,(R_1 - R_2)$ of Eq.(6) is larger than unity. The characteristic impedance and the length of the output line must be chosen so that the capacitance C_2 shown in Fig.3 can have a reasonable value. The characteristic impedance Z_{o2} is chosen to be 28 ohms. The transistor collector load impedance Z_{CL} is first normalized as follows:

$$\begin{aligned} Z'_{CL} &= Z_{CL}/Z_{o2} = (6.5 + j33)/28 \\ &= 0.232 + j1.18 \end{aligned} \qquad (8)$$

The Z'_{CL} point is then located on the Smith Chart shown in Fig.5. The chart is then rotated about the constant VSWR circle toward the load to the point of intersection with the 1.78 constant-resistance circle (the normalized 50-ohm load resistance). This value, designated Z_2', is 1.78 - j3.6. The actual load impedance therefore, is equal to

$$\begin{aligned} Z_2 = Z_2' \cdot Z_{o2} &= 28\,(1.78 - j3.6) \\ &= 50 - j100 \text{ ohms} \end{aligned} \qquad (9)$$

The line length required to transform the 50-ohm load to the required collector load impedance Z_{CL} of 6.5 + j33 ohms is determined from Fig.5 to be 0.352 λ_ϵ. The width of the microstripline for 28-ohms characteristic impedance on a 1/32-inch teflon fiberglass board is 0.17 inch. A capacitor C_2 with a reactance value equal to 100 ohms again is needed to complete the output circuit.

The output circuit actually consists of two line sections: the short coaxial-line section formed by the transistor collector section mounted in the circuit block, as shown in Figs.1 and 2, and the output microstripline section shown in Fig.2. In the power amplifier shown in Fig.3, the output microstripline section ℓ_2 has a characteristic impedance of 28 ohms. To avoid complicated transformation determinations, it is desirable to make the characteristic impedance of the coaxial-line section as nearly equal to a nominal impedance of 28 ohms as practical.

Fig.6 shows a cross-sectional view of the 2N5470. The internal structure of the line section consists of a

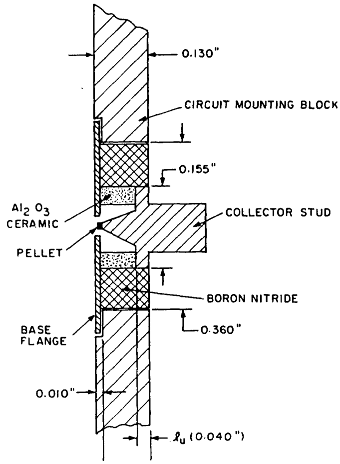


Fig. 6 - Cross-sectional view of the RCA 2N5470 transistor (output section).

tapered-line section and a very short uniform line section ℓ_u. The tapered-line section is surrounded by an air space which is enclosed by the Al_2O_3 ceramic insulator of the 2N5470 package and the boron nitride sleeve.* The section designated ℓ_u extends directly to the boron nitride sleeve. For the dimensions shown in Fig.6, a characteristic impedance in the order of 28 ohms requires that the outer conductor of the line section ℓ_u have an

* An average characteristic impedance and electrical length can be calculated for this tapered-line section, or this section can be considered as contributing a small inductive component which can be calculated from its physical dimensions.

inside diameter of the order of 0.36 inch.[1] This coaxial-line section transforms the normalized load impedance Z'_{CL} to the point Z'_C, as shown on the Smith Chart of Fig.5. This transformation length must also be considered in designing the output network. The length of microstripline needed to continue the transformation between points Z'_C and Z_2' of Fig.5, therefore, is 0.300 λ_ϵ. For the 1/32-inch teflon fiberglass board, the length 0.300 λ_ϵ corresponds to 1.10 inches.

Fig.7 shows the complete schematic for the 2-GHz amplifier. In practice, the calculated lengths of the input and output microstriplines are reduced by 20 per cent to account for the fringe-line effects resulting from the length of piston-type capacitors C_1 and C_2, and the inductance effects caused by the connecting leads of the device to the stripline sections.

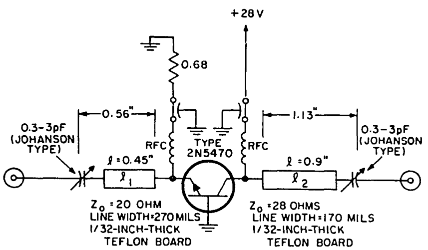


Fig.7 - Schematic of a 2-GHz microstripline transistor amplifier.

PERFORMANCE OF THE 2-GHz AMPLIFIER

The 2-GHz amplifier is constructed by use of the layout shown in Fig. 1 and the configuration and dimensions shown in Fig.7. The metal block is aluminum. The input and output circuits are constructed on 1/32-inch teflon fiberglass board, which is mounted atop the aluminum so that the input and output lines are on opposite sides of the aluminum block. Fig.8 shows a photograph of the output-circuit section. When operated at 28 volts, this circuit can deliver cw power output of 1.2 watts with a gain of 6 dB and a collector efficiency of 43 per cent. The 3-dB bandwidth is 12 per cent. The performance of this microstripline amplifier is equivalent to that of a cavity or coaxial-line amplifier circuit.

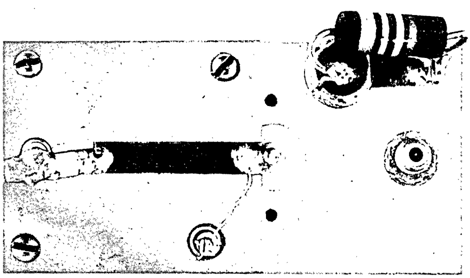


Fig.8 - Photograph of the output-circuit section of the 2-GHz amplifier shown in Fig.7.

PERFORMANCE OF THE 1.5-GHz AMPLIFIER

The same procedure was used to design the 1.5-GHz amplifier circuit shown in Fig.9. The output circuit, as shown in Fig.10, is constructed on 1/16-inch teflon board which is mounted on one surface of an aluminum block. The input line is constructed on the opposite side of the aluminum block, which serves as the ground plane of the line. The input line is formed by mounting a 5-mil copper sheet over a 5-mil-thick dielectric material (DuPont H-film) which is placed directly over the aluminum-block surface. The width of required input line can be determined from Fig. 9. The required line impedance must be increased about 6 per cent to allow for fringe-field effects resulting from the use of a 5-mil line thickness.

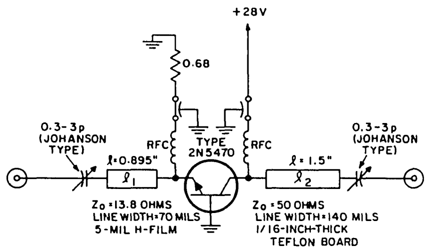


Fig.9 - Schematic of a 1.5-GHz microstripline transistor amplifier.

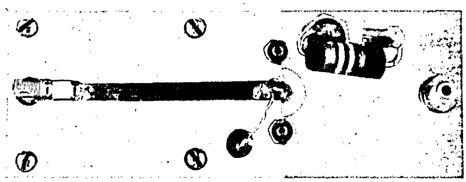


Fig.10 - Photograph of the output-circuit section of the amplifier shown in Fig.9.

This amplifier circuit, which operates at 28 volts and uses a typical 2N5470 transistor, provides 1.5 watts of output power with 8.0-dB gain and 50-per-cent collector efficiency. The 3-dB bandwidth of this amplifier is in the order of 10 per cent.

CONCLUSION

The performance of the two amplifier circuits described in this Note clearly demonstrates the advantages offered by coaxial-packaged transistors in microstrip or stripline circuits. The coaxial package provides thermal and electrical performance equal to that of coaxial-line circuits. In addition, the mounting arrangement of coaxial-package transistors results in a built-in heat sink for the device and improved isolation between inputs and outputs. Similar techniques have been used successfully to obtain 6 watts of cw output power at 2.0 GHz by use of a coaxial-package higher-power transistor, RCA-2N5921.

REFERENCE

1. Reference Data for Radio Engineers, International Telephone and Telegraph Corp., New York, N.Y. March 1957.

RCA
Solid State
Division

RF Power Transistors Application Note

AN-4421

16- and 25-Watt Broadband Power Amplifiers Using RCA-2N5918, 2N5919, and 2N6105 UHF/Microwave Power Transistors

by C. Leuthauser and B. Maximow

The advent of uhf power transistors has made possible broadband amplification of large rf signals without use of ganged tuned circuits, which have very limited bandwidths and mechanical complexity. Wide bandwidths are now attainable as a result of improved intrinsic transistor characteristics, as well as package design. In a 225-to-400-MHz broadband high-power amplifier, good transistor package design is of special importance. Low parasitic inductances are essential because the real part of the transistor input impedance is inherently low.

The RCA-2N5918, 2N5919, and 2N6105, which feature a stripline package, are examples of improved rf power transistors designed specifically for use in high-power broadband amplifiers in the 225-to-400-MHz frequency range. The development of rf transistor packages has progressed from the early hermetic TO-60-style configuration through the stripline plastic package, to the highly reliable, ceramic-to-metal, hermetic stripline package used in these types. This Note discusses general design considerations for broadband rf amplifiers, and describes the design of a 2N5919 amplifier that provides a constant power output of 16 watts with gain variation within 1 dB over a bandwidth of 225 to 400 MHz. The 2N5919 amplifier can be connected in direct cascade with a 2N5918 driver amplifier, or two 2N5919 amplifiers can be connected in parallel, to provide a constant power output of 25 watts from 225 to 400 MHz. A single TA7706 can be used in a similar configuration to provide 25 to 30 watts of rf power across the same frequency band.

The schematic diagram for the 2N5919 amplifier is shown in Fig. 1, and broadband performance of the 2N5919 in the circuit is shown in Fig. 2. Performance is shown for class C operation, which is basic for high-power amplification. In the case of an amplitude-modulated system, linearity requirements are met by either envelope correction or slight forward-biasing, or both.

GENERAL DESIGN CONSIDERATIONS

Broadbanding a transistor rf amplifier is difficult because changes in output loading affect the input impedance and may cause errors in the input-network design if the design is based on narrowband input-impedance information. The design of a broadband amplifier, therefore, should begin with the output network.

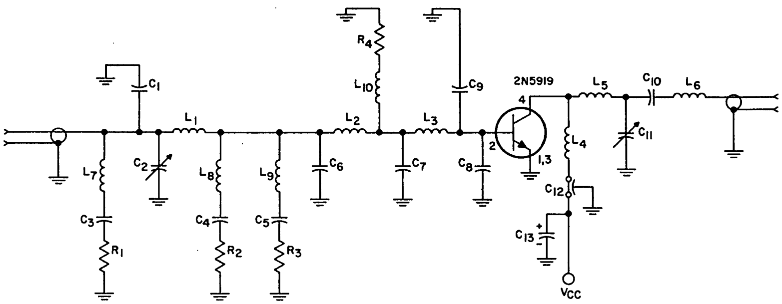
Evaluation Circuit

A quick method of evaluating the design of an output network is to construct an amplifier which uses the particular output circuit and a tunable narrowband input circuit. Over the required frequency band, the resulting amplifier should display smooth gain and collector-efficiency characteristics. Sharp changes in either of these characteristics indicate improper loading of the collector and can result in higher thermal resistance than would normally be anticipated. Under improper loading conditions, the transistor dissipation is not spread uniformly across the device pellet; as a result there is heat concentration and an equivalent increase in thermal resistance.

The interim circuit described above can also be used to determine the broadband input impedance of the rf transistor by measuring the input-circuit impedance at the device terminals at each frequency of interest. In each case, the input network should present a good 50-ohm match to the generator during tuneup and should be terminated (source side) by 50 ohms when the impedance measurement is made. The device impedance is then the conjugate of the circuit impedance.

Package Design

If the upper frequency of operation is in the uhf range, the imaginary part of the input impedance usually appears inductive. For good broadband performance, package



C_1 - 10 pF silver mica
C_2 - 0.8-10 pF, Johanson 3957*
C_3 - 2.2 pF, Quality Components type 10% QC, "gimmick"*
C_4 - 1.0 pF, Quality Components type 10% QC, "gimmick"*
C_5 - 1.5 pF, Quality Components type 10% QC, "gimmick"*
C_6 - 36 pF, ATC-100*
C_7 - 51 pF, ATC-100*
C_8 - 47 pF, ATC-100*
C_9 - 68 pF, ATC-100*
C_{10} - 12 pF, silver mica
C_{11} - 0.8-20 pF, Johanson 4802*
C_{12} - 1000 pF feedthrough type, Allen-Bradley FA5C*
C_{13} - 1 μF electrolytic

L_1 - 1-1/2 turns▲
L_2 - Copper strip 5/8 in. (15.875 mm) L; 5/32 in. (3.96 mm) W
L_3 - Transistor base lead, 3/6 in. (4.74 mm) L
L_4, L_6 - 3 turns▲
L_5 - 2 turns▲
L_7, L_8, L_9 - 0.18 μH RFC, Nytronics, P.#DD-0.18
L_{10} - 0.1 μH RFC, Nytronics, P.#DD-0.10
R_1 - 100 Ω, 1 W, carbon
R_2, R_3 - 100 Ω, 1/2 W, carbon
R_4 - 5.1 Ω, 1/2 W, carbon

* Or equivalent
Allen-Bradley Co., Milwaukee, Wis.
American Technical Ceramics, Huntington Station, N. Y. 11746
Johanson Mfg. Corp., Boonton, N. J. 07005
Nytronics, Inc., Berkeley Heights, N. J.
▲All coils are 5/32 in. (3.96 mm) I. D. =18 wire, 12 turns per inch.

Fig. 1 – 16-watt broadband amplifier circuit using the 2N5919.

parasitics must be low enough to allow the series input inductance to be used by the first section of the input matching network. If the inductance is lower than the input network requires, additional inductance (a little extra lead) can be added; however, excess inductance cannot be removed.

The 2N5919 package is designed to provide reliable hermetic-package performance with parasitics low enough for suitable broadband performance. In comparison with earlier metal and plastic packages housing the same pellet, the input inductance has been reduced by a factor of four and the gain increased by 1.5 dB. The present package consists of alternate layers of ceramic and metal in a hermetic sandwich structure. Prior to assembly, all electrical parts are silverplated. The heat-sinking stud is brazed to the bottom-layer ceramic (beryllium oxide), which serves to isolate the pellet (collector) from the stud and yet provide good heat transfer. The emitter lead is then sandwiched by another ceramic piece that serves as an insulator and support for the base and collector leads. Electrical connection for the collector is made with a pin through a small hole in the top ceramic; this hole is sealed by the collector lead itself. A larger hole in both the top ceramic and the base lead serves for electrical and physical access to the transistor pellet. A solid silver cap covers the hole in the base lead and provides the final seal.

Gain and VSWR Control

Various approaches may be used to achieve low input VSWR and power-gain flatness in a broadband amplifier. Roll-off of transistor gain can be compensated for by designing a given amount of mismatch into the input network. However, this technique also increases the input VSWR at the low end of the band and results in stressing of the lower-level driving stages. An alternate method is to employ a gain-leveling loop around the entire amplifier chain to compensate for the low-end turnover, and to design each stage for minimum input VSWR. The gain-leveling loop may also be used for envelope correction when low-distortion amplitude modulation is required.

Lossy input-network design can also be used to provide gain and VSWR control. In this case, dissipative loss is introduced in the input network at lower frequencies of operation by selective RLC networks. This method should be reserved for the input circuits, and preferably for lower-level stages, to avoid excessive heat generation.

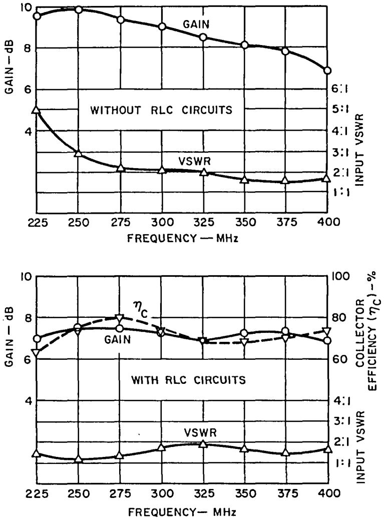


Fig. 2 – Typical performance of circuit of Fig. 1 from 225 to 400 MHz.

Hybrid Combiners

Four-port hybrid combiners have been the most successful approach to higher-power broadband structures. Combination of power at the 50-ohm level is more easily accomplished than direct paralleling of transistors and design of matching networks to accommodate a lower impedance. Hybrid combining also provides isolation between the paralleled amplifiers and avoids destruction of adjacent transistors in the event of a single transistor failure.

Two forms of hybrid junctions can be used to provide various phasing between the paralleled amplifiers. The "Magic T" combiner, when connected for zero-degree phasing, sums (or splits) the powers of the two side ports. The fourth port is terminated to dissipate any power unbalance. The Magic T can also be connected so that the two side ports are 180 degrees out of phase. A pair of amplifiers paralleled in this mode operates in push-pull, and all even harmonics are dissipated in the fourth port.

A quadrature combiner sums or splits signals 90 degrees out of phase. When used at the input and output of two parallel amplifiers, this hybrid junction delivers the input reflected power of each amplifier to the fourth port of the input combiner. The input to the amplifier pair then appears matched and presents no problem to the driving amplifier. Because of this characteristic, quadrature hybrid junctions are the most widely used combiners in the 225-to-400-MHz band.

Amplitude Modulation

A majority of amplifiers used in the 225-to-400-MHz band must handle amplitude modulation. Low-level modulation followed by linear amplification is generally preferred to high-level collector modulation because (1) collector modulation can result in circuit instability as a result of varying collector supply voltage, and (2) low-level modulation does not require a high-power modulator and can, therefore, result in a size and weight reduction. Linear amplification for AM signals is efficiently accomplished by class AB operation, in which the transistor emitter-base junction is slightly forward-biased during a zero-signal (quiescent) condition. In some cases, the forward bias is sufficient to cause a quiescent collector-current flow. The bias must be allowed to degenerate under peak drive conditions to allow efficient operation and to avoid device destruction. Bias degeneration can be provided by use of dc emitter or base resistance; it must be temperature-compensated to match the device transconductance changes with temperature.

CIRCUIT DESIGN

Output Circuit

The design of the output circuit of a broadband rf power transistor amplifier depends on two basic premises: (1) that the real part of the collector load is of constant (frequency-independent) magnitude, determined by the collector voltage and the output power, and (2) that the output capacitance is also of constant (frequency-independent) magnitude, determined by the collector-to-base capacitance C_{obo}. These premises have theoretical foundation and have been verified experimentally at least to the first-order approximation. The collector load resistance for a particular transistor and its large-signal parallel equivalent output capacitance are usually specified in published data. If these values are not available, the following well known approximations can be used for the output-network design:

$$R_L = \frac{[V_{CC} - V_{CE}(sat)]^2}{2P_o}$$

where R_L is the parallel equivalent of the real part of the collector load, V_{CC} is the supply voltage, V_{CE} (sat) is the high-frequency collector-to-emitter saturation voltage, and P_o is the expected output power. The value of V_{CE} (sat) usually is not known, but a value of 3 volts is a good approximation for the power level of the 2N5919. The large-signal parallel equivalent output capacitance C_o is given by $C_o = K\ C_{obo}$, where C_{obo} is the collector-to-base capacitance and the constant K is between 1 and 1.5 for class C operation.

The design of the output circuit then reduces to the matching of two resistances over a given frequency band: the real load presented to the collector, which is usually the smaller of the two resistances for an rf power-transistor amplifier, and the 50-ohm load. The choice of circuit configuration to be used for this purpose is somewhat restricted by the presence of a capacitance across the smaller resistance. Fig. 3 shows a circuit which transforms a smaller

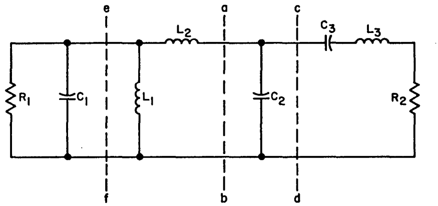


Fig. 3 — Broadband transformation circuit.

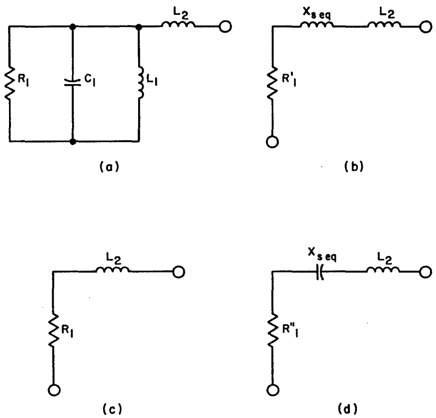


Fig. 5 — Frequency effect on the parallel-to-series transformation: (a) physical circuit, (b) series equivalent circuit below resonance, (c) series equivalent circuit at resonance, (d) series equivalent circuit above resonance.

resistance R1 into a larger resistance R2 over almost an octave. Although the transformation is not complete with large bandwidths, the circuit can be designed to favor the higher frequencies of the band. The small degree of mismatch at lower frequencies can be compensated by the higher gain of the transistor.

It is often advantageous to consider a network problem qualitatively, even with an oversimplification at first, so that the physical phenomena can be perceived before they become obscured by the formulas, tabulations, and graphs which may be required in exact numerical analysis. This approach can also provide a starting point for an exact solution, indicate the type of circuit, and yield approximate magnitudes and the range of component values to be used. As an example, the following paragraphs discuss the design of the output circuit of the 16-watt broadband amplifier shown in Fig. 1.

Perhaps the simplest way to explain the operation of the output circuit is to consider an L-section such as that shown in Fig. 4. For transformation of R1 into R2, the magnitudes of the reactances X_L and X_C are determined solely by R1 and R2, regardless of frequency, as follows:

$$X_L = \left(R1\ R2 - R1^2\right)^{1/2}$$

$$X_C = R2\left(\frac{R1}{R2 - R1}\right)^{1/2}$$

If it is desired to transform R1 into R2 over a band of frequencies, therefore, X_L and X_C should be kept constant over the band. Although this conclusion is an apparent contradiction of the fact that X_L = WL and X_C = 1/WC are frequency-dependent parameters, the circuits of Figs. 5 and 6 provide the steps for an approximate solution to the problem.

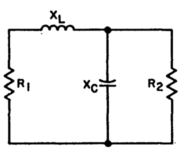


Fig. 4 — L-section.

In the circuit of Fig. 5 (a), if C1 and L1 are selected to resonate within the band, the effective value of the series inductance is increased below resonance, as shown in Fig. 5 (b); it remains equal to L2 at resonance, as shown in Fig. 5 (c), and is decreased above resonance, as shown in Fig. 5 (d). Because of the presence of C1 and L1, R1 is transformed into lower series equivalent values (R1′, R1″, R1‴, and so on) which are different at each frequency. At resonance, R1 retains its original value in the series equivalent circuit. Although the exact conditions of Fig. 4 are not met, the general trend in the variation of the equivalent series reactance is in a favorable direction, i.e., toward greater effective inductance at the lower end of the band and smaller effective inductance at the upper end of the band.

A shunt capacitance can also be made to vary by use of a series resonant circuit, as shown in Fig. 6. C3 and L3 in the circuit of Fig. 6 (a) are selected to resonate at the high end of the band and have no effect at that point, as shown in Fig. 6 (b). Below resonance, C3 and L3 provide a net parallel equivalent capacitance C_p, as shown in Fig. 6 (c), which adds to C2 of Fig. 3. As the frequency is decreased, C_p assumes greater effective values.

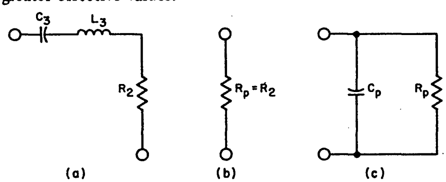


Fig. 6 — Frequency effect on the series-to-parallel transformation: (a) physical circuit, (b) parallel equivalent circuit at resonance, (c) parallel equivalent circuit below resonance.

The circuits of Figs. 5 and 6 can be combined to form the circuit shown in Fig. 3. The component values are selected in the following manner:

R1 is the real part of the collector load.

C1 is the shunt output capacitance of the transistor.

L1 is selected to resonate with C1 around mid-band.

L2 and C2 are selected to make the L-section transformation at the frequency where the best matching is desirable, i.e., 400 MHz.

L3 and C3 are selected to resonate at the highest frequency and to provide the maximum equivalent parallel capacitance at the lowest frequency.

When the component values have been selected, the L-section transformation can be computed at any frequency for the part of the circuit of Fig. 3 which is to the left of the a-b line. The resultant L-section is shown in Fig. 7. Table I lists the results of computer solution for component values at 25-MHz intervals. Rp is the value of parallel resistance into which the collector load is transformed by the resultant L-section for given values of C1, L1, and L2. The capacitance Cp is the value of capacitance necessary to make the transformation complete.

The extent to which the part of the circuit to the right of the c - d line in Fig. 3 is effective in providing a variable capacitor is shown in Table II. Values for equivalent parallel resistances and capacitance are computed at 25-MHz intervals. Comparison of the results in Tables I and II is helpful in determining the component values for the circuit of Fig. 3.

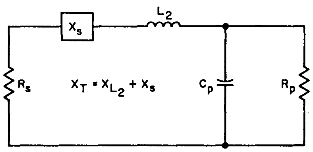


Fig. 7 — Resultant L-section for left part of Fig. 3.

TABLE I — Transformed Component Values for L-Section shown in Fig. 7. (For $R_1 = 20\Omega$, $C_1 = 16$ pF, $L_1 = 13$ nH, $L_2 = 11$ nH in Fig. 3)

F-MHz	Rs-Ω	Xs-Ω	XT-Ω	Q	Rp-Ω	Cp-pF
225	14.24	9.06	24.61	1.73	56.76	21.53
250	16.30	7.77	25.05	1.54	54.80	17.86
275	17.06	6.06	25.07	1.40	52.95	15.26
300	19.13	4.08	24.81	1.30	51.30	13.41
325	19.80	1.98	24.44	1.23	49.97	12.10
350	20.00	-0.08	24.11	1.21	49.06	11.17
375	19.80	-2.00	23.92	1.21	48.69	10.53
400	19.29	-3.71	23.94	1.24	49.00	10.08

TABLE II — Transformed Component Values for Circuit shown in Fig. 6(c) (For $R_2 = 50\Omega$, $L_3 = 13$ nH, $C_3 = 12$ pF in Fig. 3)

F-MHz	Rp-Ω	Cp-pF
225	82.91521	6.95
250	71.29604	5.85
275	63.27814	4.75
300	57.76598	3.62
325	54.06837	2.58
350	51.73186	1.63
375	50.44882	0.80
400	50.00470	0.08

Table III gives the transformed admittance/impedance values for the entire circuit of Fig. 3 to the right of the e - f line. These values represent the collector load applied to the transistor over the 225-to-400-MHz band and are given as parallel and series equivalent values.

Circuit Impedances

Knowledge of the input and output impedances of a transistor is an invaluable aid in designing rf amplifiers and is essential when broadband operation is required. However, transistors operating in class C or class B at high frequencies are not readily adaptable to equivalent-circuit analysis in which input, output, and transfer parameters are specified. Fortunately, this problem can be resolved by specifying the circuit impedances of the input and the output networks of an amplifier. These impedances are measured at the transistor terminals after the amplifier has been optimized, the transistor removed, and the circuit terminated with 50 ohms. Because transistor input impedance depends to some extent upon the output circuit, some variation of impedances obtained in this manner should be expected in different circuit configurations.

The Input Circuit

The input impedance of the 2N5919 transistor varies from 2.5 + j0 ohms at 225 MHz to 1.5 + 1.7 ohms at 400 MHz. In matching this varying impedance to a 50-ohm source, certain assumptions and approximations facilitate the problem by using already developed techniques. One such technique is the "Tables of Chebyshev Impedance-Transforming Networks of Low-Pass Filter Form" compiled by George L. Matthaei.[1] These tables permit selection of values for the filter elements to obtain a given performance. The tables assume constant impedances across the band. Although the input impedance of an rf power transistor varies with frequency (especially its reactance), the tables provide a good starting point. The following discussion is based on the Matthaei Tables.

For this discussion, R_i represents a real part of the transistor input impedance and R_s a resistive source impedance of 50 ohms. It is assumed that R_i has a value of 1.65 ohms and is constant across the band of interest. The value of 1.65 ohms is selected because it falls between 1.5

TABLE III – Transformed Admittance/Impedance Values for Circuit shown in Fig. 3. (For $R_2 = 50\Omega$, $C_3 = 12$ pF, $C_2 = 10$ pF, $L_1 = 13$ nH, $L_2 = 11$ nH, $L_3 = 13$ nH in Fig. 3.)

F-MHz	G-mhos	B-mhos	Rp-Ω	Xp-Ω	Rs-Ω	Xs-Ω
225	0.03	-0.02	35.62	40.48	20.08	17.66
250	0.04	-0.02	27.39	47.85	20.63	11.81
275	0.04	-0.02	22.61	47.54	18.44	8.77
300	0.05	-0.02	20.08	41.42	16.26	7.88
325	0.05	-0.03	19.00	34.94	14.66	7.97
350	0.05	-0.03	18.82	30.28	13.58	8.44
375	0.05	-0.04	19.17	27.29	12.84	9.02
400	0.05	-0.04	19.78	25.41	12.31	9.59

and 2.5 ohms, the real parts of the transistor input impedance at 400 MHz and 225 MHz, and yields an impedance transformation ratio of 30, for which the values for the filter elements can be taken directly from the tables without the need of interpolation.

The parameters to be used are the transformation ratio r; the fractional bandwidth w, and the number of filter elements n. The bandwidth w is defined as follows:

$$w = \frac{f_b - f_a}{f_m}$$

where f_a is the low-frequency cutoff, f_b is the high-frequency cutoff, and f_m is the midband frequency.

Table IV gives values for the filter elements as computed from the Matthaei Tables for values of w = 0.8, n = 8, and r = 30, where L's and C's are as defined in Fig. 8. The value of 0.8 was selected for the fractional bandwidth rather than a smaller value to permit computation of filter-element values for midband frequencies of both 310 MHz and 400 MHz. It is often useful to try other values for n.

Several observations can be made from Table IV. First, the value of L1 is so low that C1 must be placed as close as possible to the transistor base so that the inductive part of the transistor input impedance at 400 MHz is part of L1.

TABLE IV - Values for Filter Elements of Input Circuit as Computed from Matthaei Tables[1] (L's and C's are defined in Fig. 8)

f_m	310	400	MHz
L_1	1.07	0.4	nH
C_1	200	157	pF
L_2	3.2	2.48	nH
C_2	98.4	77	pF
L_3	8.1	6.27	nH
C_3	39	30	pF
L_4	16.6	12.8	nH
C_4	13	10.3	pF

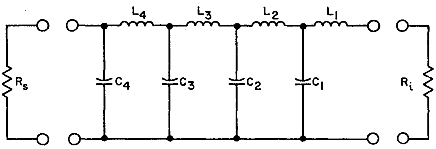


Fig. 8 – Definition of filter elements for values given in Table IV.

Second, the values of C1 and C2 are so high that hardly any inductance can be tolerated in series with these capacitors. Third, L2 and L3 are very small and appear to be critical. Physical dimensions of commercially available components make it difficult to separate two capacitors with an inductor of 3.2 or 2.5 nanohenries. Therefore, some experimentation may be required before acceptable performance can be obtained. For example, a copper strip 0.14 inch wide and 0.4 inch long has an inductance of about 5 nanohenries. When lower values of inductance are needed, the length of the strip becomes about the same as the width. This fact, coupled with the physical size of the capacitors, makes experimentation unavoidable.

Plotting the values of Table IV on a Smith Chart shows the impedance variations along the filter from R_{in} to R_s. Fig. 9 shows such a plot for three frequencies: 225 MHz, 310 MHz, and 400 MHz. This chart can be used to study the effect of each element in the filter on the over-all matching. For example, reducing L4 improves matching at 400 MHz and 225 MHz, but has an opposite effect in matching at 310 MHz. The component values in the practical circuit shown in Fig. 1 were selected to be closer to those computed for 400 MHz in Table IV because it was desired to optimize the gain at that frequency.

Reducing VSWR

The amplifier designed by use of the procedure described has much higher gain at 225 MHz than at 400 MHz. For full utilization of the transistor gain capabilities at 400 MHz, the amplifier is adjusted for the best match at 400 MHz. Inevitably some VSWR appears at other frequencies. Ideally, the circuit is designed for the highest VSWR at the frequency where maximum gain occurs (i.e., 225 MHz). The forward power, as well as the reflected power, is then attenuated by introducing a resistive element in shunt with a node in the input network. The greater the ratio of the forward power to the reflected power, the smaller the VSWR. The attenuator is made frequency-selective, i.e., it is a series RLC circuit. These RLC networks can be staggered in frequency. By selection of R's and L's, the amount of attenuation and Q's can be controlled. However, a series LC circuit appears to be capacitive below resonance and may limit the maximum size of a capacitor. For this reason, shunt RLC circuits which resonate at frequencies higher than 225 MHz are placed at the second node where the shunt capacitor is larger.

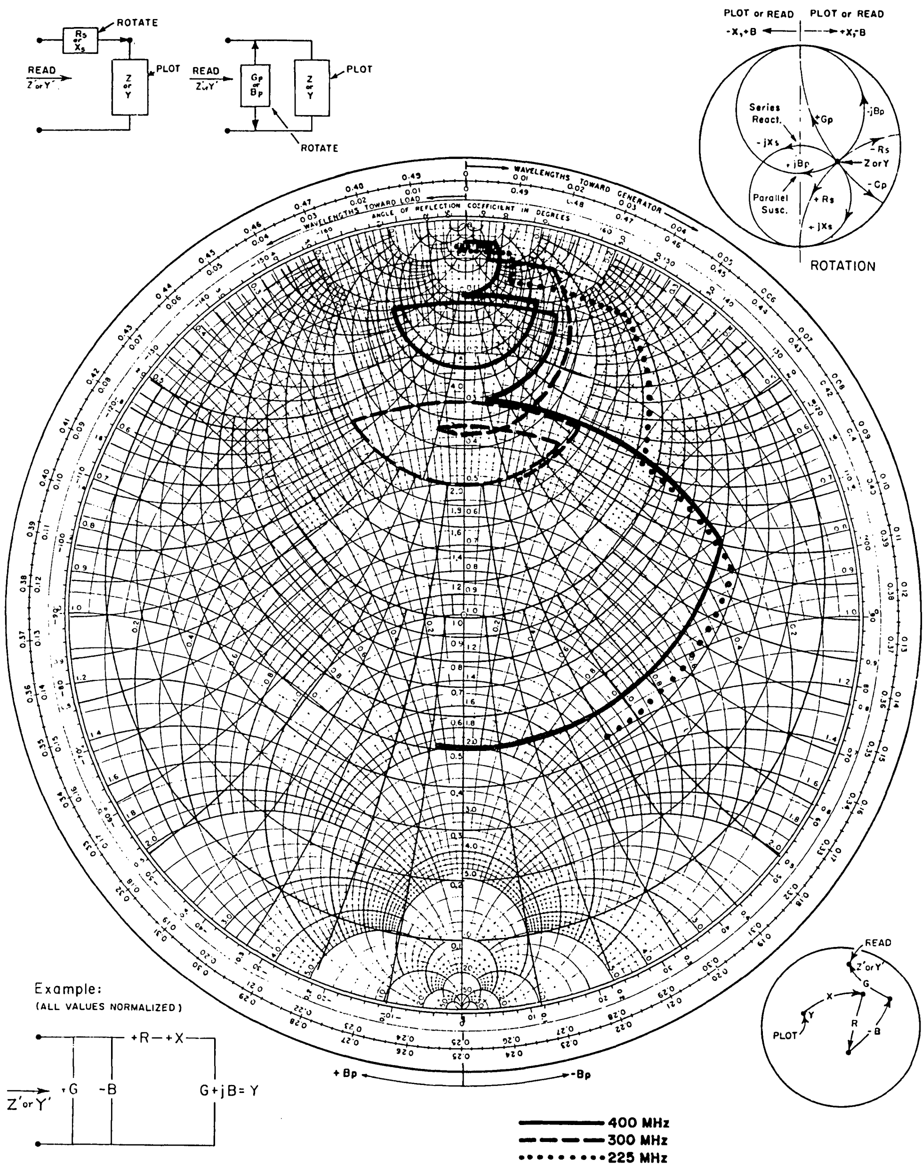


Fig. 9 – Smith chart showing impedance variations along filter from R_{in} to R_s

CIRCUIT PERFORMANCE

The basic amplifier developed by use of the technique described is a 16-watt, one-stage, 225-to-400-MHz broadband amplifier using the 2N5919 transistor. This circuit requires a driving power of 3 to 4 watts, which would normally be supplied by a cascaded chain of transistors. The performance of two amplifiers in cascade is also described to demonstrate this technique. When the required power exceeds the capability of the largest transistor in the chain, paralleling can be used to develop larger outputs.

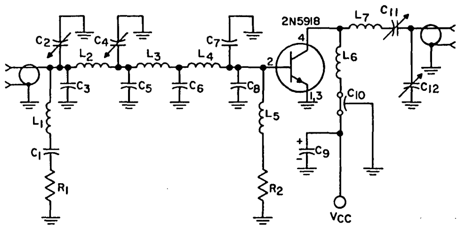
16-Watt Amplifier

Fig. 1 shows the schematic diagram of the 2N5919 amplifier, which can be considered the main "building block" of the chain. Typical amplifier performance is shown in Fig. 2. For a constant power output of 16 watts, response is fairly flat; the gain variation is within 1 dB across the band. Maximum input VSWR is 2:1. Such flatness of response and low input VSWR were obtained by designing for the best possible match across the band and then dissipating some of the power at the low end of the band through dissipative RLC networks. The effectiveness of this technique can be evaluated by comparison of the gain and input VSWR curves in Fig. 2 (a) with those in Fig. 2 (b). The flatter the response, the smaller the dynamic range required in the output leveling system. Low input VSWR is necessary for protection of the driving stage in a cascade connection. The collector efficiency is not constant, but has a minimum value of about 63 per cent. The second harmonic of the 225-MHz signal is 12 dB down and that of the 400-MHz signal is 30 dB down from the fundamental. Further reduction of the second harmonic of the 225-MHz signal is difficult to obtain because the amplifier bandwidth covers almost an octave.

Cascade and Parallel Connections

In a cascade arrangement, a lower-power transistor, the 2N5918, is used to drive the 2N5919. The output circuit for the driver is modified to accommodate a higher collector load. The input circuit remains essentially the same as for the 2N5919. The 2N5918 amplifier schematic is shown in Fig. 10, and the performance of the two amplifiers connected in cascade is shown in Fig. 11. When the two stages are connected together, the broadband characteristics of the amplifiers minimize the number of adjustments required.

A parallel combination of two 2N5919 transistors can be achieved by use of two quadrature couplers, as shown in Fig. 12 (a). Fig. 12 (b) shows gain and efficiency curves for such a combination for a constant power output of 25 watts. The input VSWR curve is omitted because it is very small and independent of the magnitude of the reflected power at each amplifier input as a result of the properties of the 90-degree combiners.



C_1 -3pF, ATC-100*
C_2 -0.8-10pF, JOHANSON 3957*
C_3 -5pF SILVER MICA
C_4 -2-18 pF, AMPEREX HTIOMA/218*
C_5 -24pF, SILVER MICA
C_6 -51 pF, ATC-100*
C_7 -47pF, ATC-100*
C_8 -68pF, ATC-100*
C_9 -1μF, ELECTROLYTIC
C_{10} -1000 pF, FEEDTHROUGH TYPE, ALLEN-BRADLEY FA5C*
C_{12} -1.5-20 pF, ARCO 402*
C_{11} -0.9-7 pF, ARCO 400*

L_1 -0.12μH RFC, NYTRONICS, P. No. DD-0.18*
L_2 -No.18 WIRE, 0.64 IN. LONG
L_3 -COPPER STRIP 5 MILS THICK, 150 MILS W., 670 MILS L.
L_4 -TRANSISTOR BASE LEAD, 0.16 IN. LONG
L_5 -0.1μH RFC, NYTRONICS, P. No. DD-0.10*
L_6 -No.18 WIRE, 1.08 IN. LONG
L_7 -2 TURNS, 5/32 IN. I.D. No.18 WIRE, 12 TURNS PER IN.
R_1 -100Ω, 1/2 W, CARBON
R_2 -5.1Ω, 1/4 W, CARBON

* OR EQUIVALENT

Fig. 10 – Driver amplifier using the 2N5918.

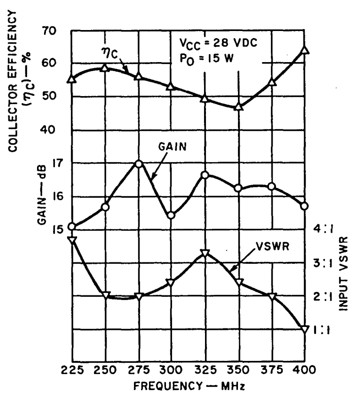


Fig. 11 – Performance characteristics of amplifiers shown in Figs. 1 and 10 connected in cascade.

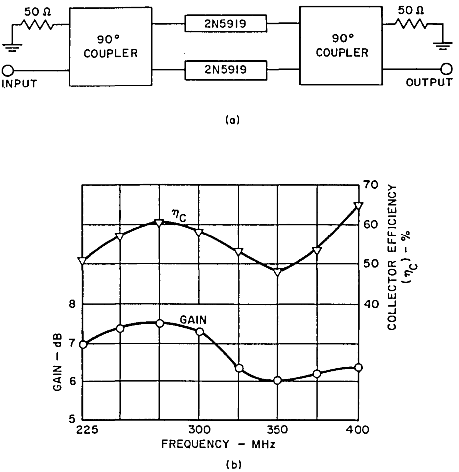


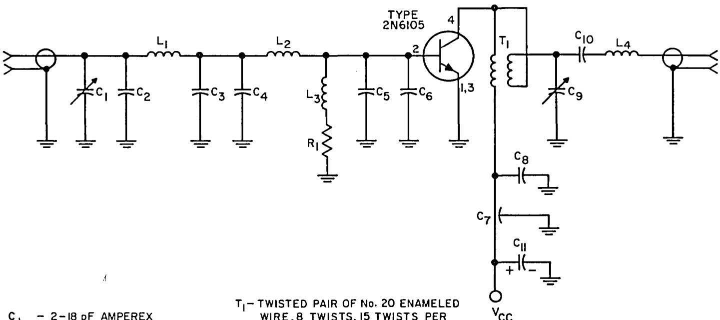
Fig. 12 – Performance of two 2N5919 transistors connected in parallel by use of quadrature couplers.

TA7706 25-Watt Amplifier

Fig. 13 shows the schematic diagram of a 25-watt, 225-to-400-MHz broadband amplifier using a 30-watt, 400-MHz transistor, the RCA type 2N6105 Amplifier performance is shown in Fig. 14.

This amplifier includes some modifications in the matching circuits which represent a somewhat different design approach. For example, the input Chebyshev filter uses three sections rather than four. As a result, there is a poorer match at 225 MHz, with a resulting increase in the input VSWR and a consequent loss of gain. Some loss of amplifier gain can be tolerated at 225 MHz because of the transistor gain reserve at that frequency. The increased input VSWR is not a problem if the amplifier is used in conjunction with quadrature couplers because low input VSWR is then not nearly as important as in a direct cascade connection.

The collector load resistance for the 2N6105 should be about 10 ohms, half of that for the 2N5919. Therefore it appears that a 4:1 transformer can be used in the output. The circuit shown in Fig. 13 uses a twisted wire pair connected as a 4:1 autotransformer. The length of the transformer is determined primarily by the amount of



C_1 – 2-18 pF AMPEREX
C_2,C_3 – 10 pF, SILVER MICA
C_4 – 33 pF ATC-100■
C_5 – 61.5 pF ATC-100■
C_6 – 66 pF ATC-100■
C_7 – 1000 pF FEED THROUGH ALLEN-BRADLEY FA5C■
C_8 – 1000 pF ATC-100■
C_9 – 1-20 pF JOHANSON 4882■
C_{10} – 12 pF, SILVER MICA
C_{11} – 1 μF ELECTROLYTIC
R_1 – 5.1 Ω 1/2 WATT

T_1 – TWISTED PAIR OF No. 20 ENAMELED WIRE, 8 TWISTS, 15 TWISTS PER INCH, CROSS CONNECTED AND FORMED IN A LOOP
L_1 – 1 TURN No. 20 WIRE, WOUND IN 9/64 IN. ID.
L_2 – INDUCTANCE OF BASE LEAD 5/16 IN. LONG.
L_3 – 0.12 μH RFC
L_4 – 2 TURNS No. 20 WIRE, WOUND IN 9/64 IN. DIA.

■ – OR EQUIVALENT
ALLEN-BRADLEY Co., MILWAUKEE, WIS.
AMERICAN TECHNICAL CERAMICS, HUNTINGTON STATION, N.Y. 11746
JOHANSON MFG. CORP., BOONTON, N.J. 07005

Fig. 13 – 2N6105 broadband amplifier circuit.

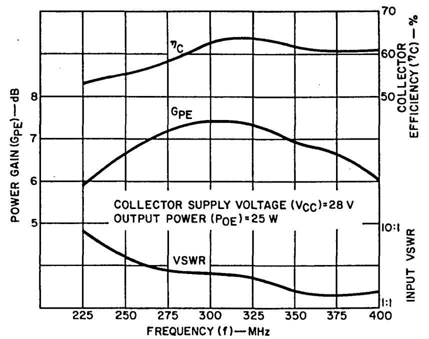


Fig. 14 — Performance of 2N6105 in the circuit of Fig. 13.

inductance required to tune out the output capacitance at 400 MHz. Collector efficiency is somewhat poorer at the 225-MHz end of the band as a result of incomplete tuning out of the output capacitance at the lower frequencies. Although twisted-wire transformers are rather difficult to analyze, experiments have shown that they have large bandwidths and can be successfully used in the output of high-power broadband amplifiers.

References

1. G.L. Matthaei, "Tables of Chebyshev Impedance – Transforming Neworks of Low-Pass Filter Form," *Proceedings of the IEEE*, August 1964.

RCA
Solid State
Division

RF Power Transistors Application Note AN-4591

Use of the RCA-2N6093 HF Power Transistor in Linear Applications

by Z.F. Chang and J.F. Locke

The rapidly growing technology in semiconductor devices has resulted in the development of power transistors designed especially for use in hf single-sideband (SSB) equipment. Unlike most commercially available rf power transistors, which are designed primarily for class C operation, the RCA-2N6093 provides a high degree of linearity for class AB operation, emitter ballast resistance for stabilization and low distortion, and an internally mounted temperature-sensing diode for bias compensation.

This Note discusses the advantages of single-sideband operation, some basic transistor characteristics and trade-offs involved in the choice of a transistor for linear applications, broadband matching networks, and the basic performance of the RCA-2N6093 in narrowband and broadband applications. The design features that make this device suitable for linear amplification are described.

SINGLE SIDEBAND

Single-sideband communication systems have many advantages over AM and FM systems.[1] In applications where reliability of transmission and power conservation are of prime concern, SSB transmitters are usually employed. Advantages of SSB include reduced power consumption for effective transmission and reduced channel width, which permits more transmitters to be operated within a given frequency range. Any discussion of SSB operation includes the terms "intermodulation distortion" and "peak envelope power"; these terms are defined below.

Intermodulation Distortion

For an amplifier to be linear, the output power must be directly proportional to the input power at all signal amplitudes. Alternatively, for a fixed load the amplifier must maintain a constant gain within its useful power range. An approximate check on the linearity of an rf power amplifier is a curve of power output as a function of power input. The curve in Fig. 1(a) shows two regions that depart from linear operation: region A, high-power operation with current saturation; and region B, low-power operation with insufficient forward bias.

The P_O-P_{IN} graph requires measurement at several power levels, which is cumbersome and time-consuming, and yields results that are only approximate. For final equipment testing, the most widely accepted test method requires the use of a two-tone signal. The two tones have equal amplitude and are separated by an audio frequency. The output waveforms can be displayed on a spectrum analyzer to show the two tones and the intermodulation-distortion (IMD) product. The ratio of the amplitude of the strongest distortion product to the amplitude of one of the test signals is called the IMD ratio. A distortion specification of -30 dB, for example, means that the strongest distortion product will be less than 0.1 per cent of a signal output level for any two-tone signal at power levels up to the peak envelope power rating of the amplifier. Fig. 1(b) is a typical curve of IMD as a function of output power; the increased distortion in regions A and B are readily noted.

The important intermodulation-distortion products are those close to the desired output frequencies, because they fall within the passband and cannot be filtered out by normal tuned circuits. If f_1 and f_2 are the two desired output signals, third-order IMD products take the form $(2f_1 - f_2)$ and $(2f_2 - f_1)$. The other third-order terms, $(2f_1 + f_2)$ and $(2f_2 + f_1)$, correspond to frequencies near the third-harmonic output of the amplifier and are greatly attenuated by tuned circuits. It is important to note that only odd-order distortion products appear near the fundamental frequencies. The frequency spectrum shown in Fig. 2 illustrates the frequency relationship of some distortion products to the test signal.

Even-order distortion products do not occur near the desired frequencies f_1 and f_2; all are either in the difference-frequency region or in the harmonic regions of the original frequencies. Therefore, filters following the nonlinear elements can effectively remove all products generated by the even-order components of curvature, and the second-order component that produces second harmonics will produce no distortion in an SSB linear amplifier.

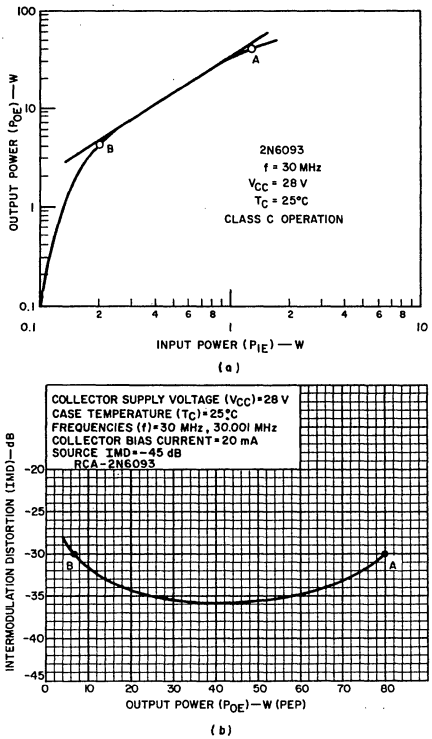


Fig. 1— Two ways to evaluate power amplifier linearity: (a) output power as a function of input power; (b) intermodulation distortion as a function of output power.

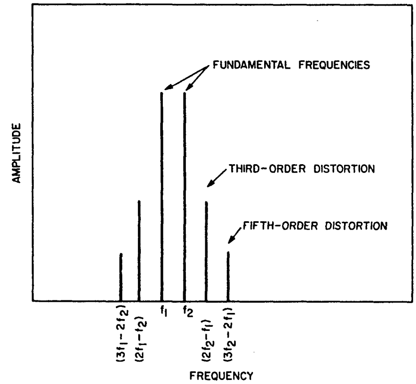


Fig. 2— Frequency spectrum of intermodulation-distortion products.

Peak-Envelope-Power Rating

The maximum power that a device can deliver is usually limited by its current and voltage ratings. When a cw signal is used, the output is a constant, undistorted, sinusoidal waveform that is not suitable for linearity testing. If a two-tone signal is used in which the amplitude of each tone equals one half of the cw amplitude, and if the two tones are separated by a small frequency, the two tones add or subtract depending on the phase relationship. When in phase, the two tones add to yield an amplitude equal to the cw amplitude. When out of phase, the two tones subtract; the resultant amplitude becomes zero. Essentially the resultant is an undulating wave that varies from zero to maximum amplitude at the rate of the difference frequency. Because each tone of the two-tone signal has an amplitude equal to one half of the cw amplitude, the power contained in one tone is only one quarter of the power in the cw signal. The total average power in a two-tone signal, therefore, is one half of the power in the cw wave. Because peak power occurs when the two tones are in phase, the peak-envelope-power (PEP) rating of an amplifier is equal to twice the average reading obtained from a power meter such as a calorimeter. For a signal of three equal-amplitude tones, the PEP-to-average-power ratio is 3 to 1.

TRANSISTOR OPERATION

In a class B amplifier the transistor conducts half of the time and the average collector current is directly proportional to the amplitude of the signal voltage. This fact implies that the circuit is linear for the fundamental components. A class A amplifier conducts all of the time. It provides the most linear amplification and is characterized by high gain, low distortion, and low efficiency. The low-level stages of a power-amplifier chain commonly operate in class A. Because of its high quiescent collector current, class A operation is seldom used for a power amplifier, particularly in portable equipment where high efficiency and light weight are the design goals. Therefore, if the primary design goal is to achieve low IMD with the highest efficiency possible, the transistor should be operated at a power level low enough to avoid the nonlinear saturation region, and a bias level beyond the nonlinear base-to-emitter "turn-on" region. Fig. 3 shows the reduction in IMD with increase in bias. When the 2N6093 is operated at a PEP output level of 50 watts, it can have an IMD of less than -40 dB.

For bias currents above 60 milliamperes, the reduction in IMD becomes less significant. To avoid catastrophic transistor failures caused by forward-bias second breakdown, the bias current should not be set much beyond the level required to meet the power and distortion design objectives. Furthermore, once the bias current has been established the designer must make sure that the collector quiescent point is within the safe dc operating curve of the transistor.

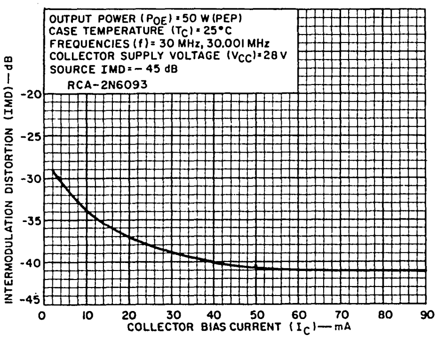


Fig. 3— Typical intermodulation-distortion as a function of collector bias current for the RCA-2N6093.

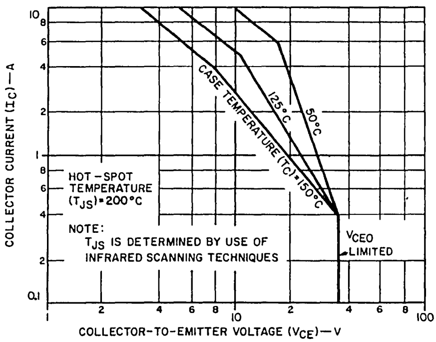


Fig. 4— Safe area for dc operation of the RCA-2N6093.

TRANSISTOR SELECTION

To date, most high-frequency power transistors have been designed for class C operation. Forward-biasing into class B or class AB places such devices in a region where second breakdown may occur. The susceptibility of a transistor to second breakdown is frequency-dependent; experimental results indicate that the higher the frequency response of a transistor, the more severe its second-breakdown limitations. Physically, second breakdown is a local thermal-runaway effect induced by severe current concentrations. Improving the safe dc operating region of a transistor, therefore, must be the first step in providing a rugged device suitable for SSB application.

The RCA-2N6093 is a power transistor designed specially for use as a linear amplifier. This transistor can be forward-biased into class AB and has a good high-frequency response. Improvement of second breakdown is accomplished by subdividing the emitter and resistively ballasting the individual sites. The transistor has an overlay[2,3] structure, with the emitter sites interconnected by metal fingers in parallel. Current-limiting resistors are placed in series with each emitter site between the metallization and emitter-to-base junction.

The maximum operating area of a forward-biased 2N6093 is illustrated in Fig. 4 for various case temperatures. If the device is operated within the curves of Fig. 4 under dc conditions, second breakdown will not occur and the junction temperature will not exceed 200°C at any point. The hot-spot temperature for these curves were determined by infrared scanning.

Emitter Ballast Resistance.

To show the effect of emitter ballast resistance on second breakdown, three groups of high-V_{CEO}(sus) overlay transistors were made with different ballast-resistor values. The collector-to-emitter voltage needed to cause each transistor to go into second breakdown at a collector current of one ampere, measured on a curve tracer with a single base step, is shown in Table I. These data indicate that the addition of resistors improves device second-breakdown capability. A relatively large value of ballast resistance prevents second breakdown, improves thermal stability, and provides linear transfer characteristics. However, excessive ballasting can seriously degrade the rf performance of the transistor. The ballast resistors are in series with the load; therefore, in a high-frequency power amplifier with low supply voltage, the emitter resistance can be an appreciable portion of the reflected load at the collector, and thereby limit the output power. The power loss in the emitter resistance should be taken into account when the resistance value is decided; a compromise must be made empirically to obtain sufficient second-breakdown protection without seriously affecting rf performance. The ballast resistance can be measured by use of a Tektronix 576 curve tracer equipped with a Kelvin probe.

Because the value of V_{BE} at the transistor base-to-emitter terminals includes the voltage drop across the ballast resistance, the transistor transconductance is affected by the value of ballast resistance. The curves of I_C as a function of V_{BE} in Fig. 5 for three different values of resistance show that ballast resistance improves the linearity of the device; the resistance also reduces the input Q.

The adverse effects of high ballast resistance are reduced rf output power and increased saturation voltage. Viewed

Table I - Effect of Emitter Resistance on Second-Breakdown Voltage

Total Emitter Resistance (ohms)	Second-Breakdown Voltage (volts)
0.005	50
0.013	65
0.08	108

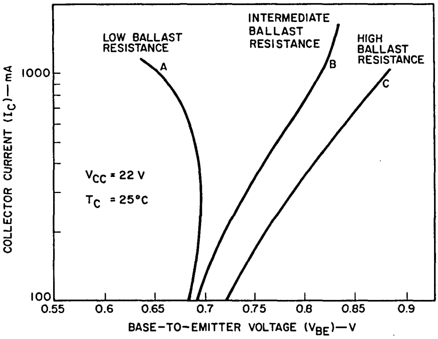


Fig. 5— Current-voltage characteristics at various ballast-resistance levels.

externally, the total saturation voltage includes the voltage drop across the ballast resistance. This additional voltage makes the "soft" output characteristics of a transistor at high current even softer. As a result, it limits the available linear region through which the signal can swing.

An attempt to make a transistor more linear by increasing the forward bias causes the collector efficiency to decrease and results in increased transistor dissipation. Dissipation produces heat, which causes V_{BE} to decrease at the rate of about 0.002 volt per °C, and can cause thermal runaway unless temperature compensation is used to maintain collector current relatively constant over a wide temperature range.

As discussed above, some transistors fail when the bias current is increased for class AB operation. Investigations of the failures revealed that these devices exhibited a maximum V_{BE} and then went into a negative-resistance region as shown in Fig. 6. The onset of negative resistance, called bend-back, results in a runaway condition that ultimately destroys the transistor.

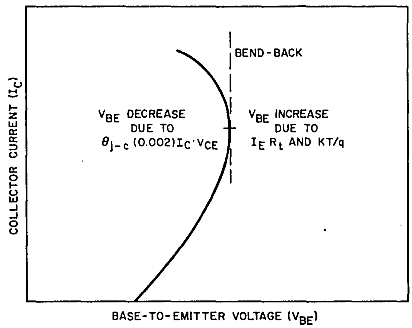


Fig. 6— The bend-back phenomenon.

In most linear applications where the operating point of the device is biased with a voltage source, this I_C-V_{BE} curve becomes an accurate means of predicting device stability. It is difficult to maintain a stable quiescent point of a transistor with low bend-back. Laboratory results indicate that a minimum bend-back current of 1 ampere at 22 volts is needed for a transistor to operate safely at 40-per-cent efficiency with approximately 50 watts of dissipation.

Bend-back occurs when the increase of V_{BE} with collector current is just balanced by the decrease in V_{BE} caused by junction-temperature rise. Therefore at bend back

$$KT/_q + I_E R_t = \theta_{j\text{-}c}(0.002V/_{^oC})\, I_C \;\; V_{CE} \qquad (1)$$

where

KT/q = 0.032 volt @ 100°C

R_t = total ballast resistance

$\theta_{j\text{-}c}$ = junction-to-case thermal resistance

$0.002V/_{^oC}$ = base-to-emitter junction temperature coefficient

I_E = emitter current

I_C = collector current

V_{CE} = collector-to-emitter voltage

If $I_C = I_E$, Eq (1) can be solved to find I_E at bend-back:

$$I_E = \frac{-KT/_q}{R_t - \theta_{j\text{-}c}\,(0.002V/^oC)V_{CE}} \qquad (2)$$

Thermal runaway can be attributed to the fact that the base-to-emitter junction of a transistor has a negative temperature coefficient. For example, the RCA-2N6093 transistor is forward-biased by 0.65 volts to produce a quiescent collector current of about 20 milliamperes at V_{CC} = 28 volts. This operating point is shown as point A in Fig. 7. When rf drive is applied, the collector current increases to 3 amperes. If the efficiency is 40 per cent, the power dissipated in the transistor is given by

$$P_{diss.} = 28 \times 3\,(1 - 0.40) = 50 \text{ watts.}$$

If the ambient temperature is 25°C, the case temperature is 50°C, and the thermal resistance is 1.5 °C per watt, the junction temperature is given by

$$T_j = T_{case} + P_{diss.}\,\theta_{j\text{-}c}$$

$$= 50 + 50 \times 1.5 = 125^oC.$$

The junction temperature is thus 100°C above ambient temperature. At this junction temperature the V_{BE} required to maintain a collector current of 20 milliamperes is only

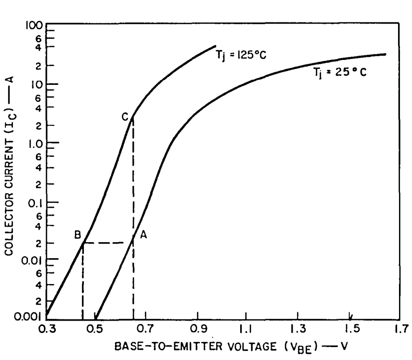


Fig. 7– Collector current as a function of base-to-emitter voltage in the RCA-2N6093 for two values of junction temperature.

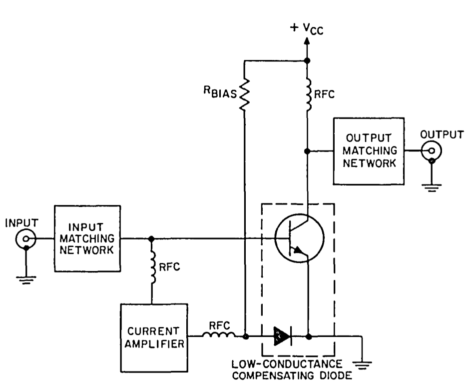


Fig. 8– Block diagram of 30-MHz amplifier with temperature compensation.

0.65 – 100 x 0.002 = 0.45 volt, as shown at point B. If the bias voltage is fixed at 0.65 volt, however, and the drive is removed instantaneously, the quiescent current will no longer be 20 milliamperes. Instead, the collector current will move to point C, where the operating point falls outside of the safe area of Fig. 4. Therefore catastrophic failure will occur as a result of thermal runaway.

Compensating Diode

To provide a bias voltage that varies with temperature in the same manner as V_{BE} of the transistor, the 2N6093 incorporates a compensating diode as shown in Fig. 8. To insure fast thermal response time, this diode is mounted on the same beryllia disc as the transistor chip. The diode, forward-biased through R_{Bias}, serves as a temperature-sensing element. The voltage developed across the diode is amplified to provide a "stiff" bias-voltage source.

A bias-compensation circuit is included in the 30-MHz, 75-watt (PEP) amplifier shown in Fig. 9. The current amplifier uses Q1 and Q2 in a differential-amplifier arrangement so that the output voltage is independent of ambient-temperature variations. Q3 and Q4 provide the necessary current amplification. The bias current in rf transistor Q5 can be adjusted by varying R1.

As shown in Fig. 10, with no rf signal the forward-biased transistor is statically stable up to a case temperature of 160°C. The dashed line in Fig. 10 shows that without temperature compensation the transistor tends to thermal runaway around 80°C. To further show the effectiveness of compensation, the third-order distortion and output power are plotted as a function of case temperature in Fig. 11. The decrease in output power at high temperatures is caused by a drop in high-frequency gain and an increase in rf saturation voltage. The decrease in h_{fe} produces a soft saturation knee that causes the degradation of distortion.

BROADBAND CIRCUIT DESIGN

Transistor Parameters

Before any circuit can be designed, the transistor input impedance and the collector load impedance over the required frequency band and at the desired levels of output power, IMD, case temperature, and collector supply voltage must be known or measured. The circuit designer must also know the transistor power gain over the same band. Curves of these characteristics for the RCA-2N6093 are shown in Figs. 12-14. A broadband transistor should be selected for minimal impedance variation and low input Q across the frequency band. A transistor with f_t well above the highest operating frequency, if available, can provide constant gain under broadband operation; such a transistor eliminates the need for additional gain-leveling circuitry. Because circuit optimization becomes more difficult with high-power broadband operation, the need for thermal stability becomes more acute and the necessity of diode compensation at high output powers becomes greater. To provide this stability, the transistor should have an internally mounted compensating diode.

The advantages which especially suit the 2N6093 for broadbanding are its low input Q and its internally mounted compensating diode. Its main disadvantage is a 15-dB gain decrease from 2-30 MHz due to operation on a power-gain slope of 6 dB per octave.

Transmission Line Transformers[4,5,6]

After selection of the transistor and measurement of its broadband parameters, the next step is to select the circuit approach. The most practical broadbanding method to provide an effective impedance transformation over four octaves (2-30 MHz) is a transmission-line-transformer/ferrite-core combination. The major disadvantage of a transmission line transformer is the limited number of impedance

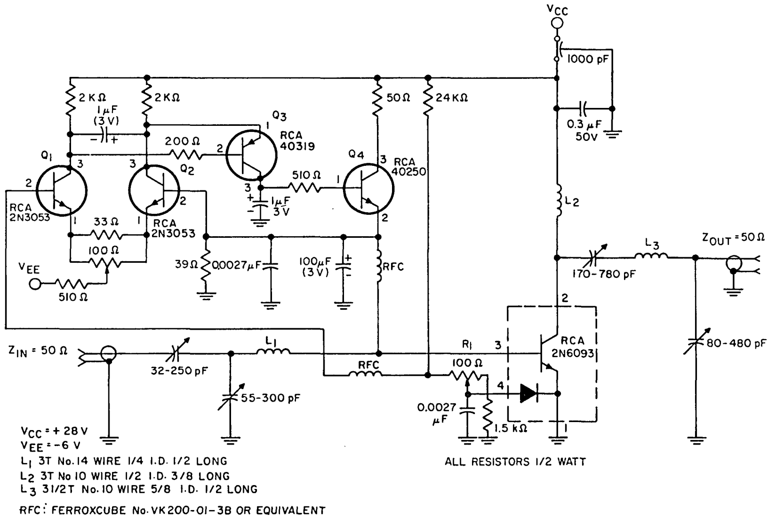


Fig. 9— Use of the RCA-2N6093 in a 30-MHz, 75-watt (PEP) amplifier with temperature compensation.

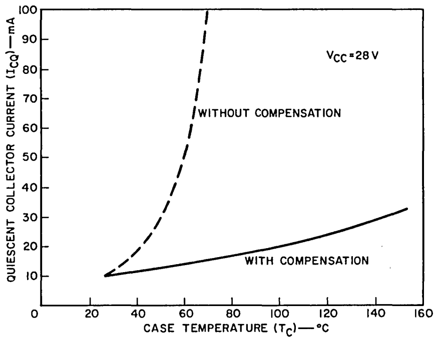


Fig. 10— Quiescent collector current in the RCA-2N6093 as a function of case temperature with and without temperature compensation.

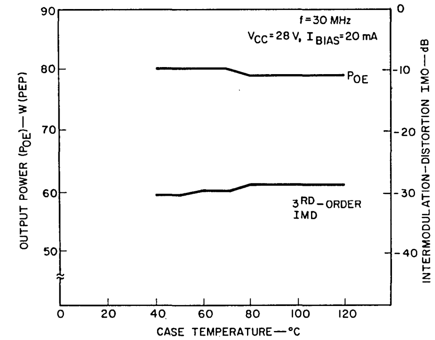


Fig. 11— Output power and intermodulation-distortion as a function of case temperature for the RCA-2N6093 amplifier shown in Fig. 9.

transformations available: 1:1, 4:1, 9:1, etc. The two fundamental configurations are the 1:1 reversing transformer and the 4:1 impedance transformer shown in Fig. 15.

Ferrite Cores

At low frequencies, a high primary reactance can be obtained with a few turns of transmission line on a high-permeability ferrite core. At high frequencies where length becomes critical the permeability of the core decreases, thereby maintaining approximately the same levels of reactance with a short length of transmission line. Ferramic-Q core material[7] is available in three high-frequency grades; a tabulation of their useful properties is given in Table II. Because the transformer performance is less

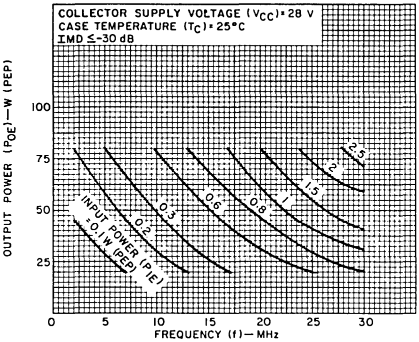


Fig. 12— Typical output power as a function of frequency for the RCA-2N6093.

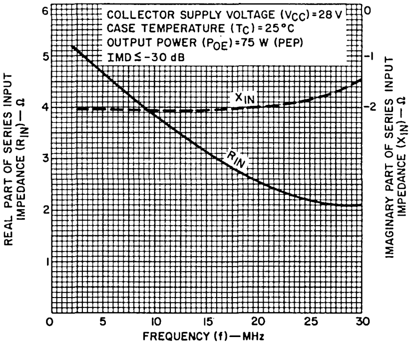


Fig. 13— Typical large-signal series input impedance (R_{in} + jX_{in}) as a function of frequency for the RCA-2N6093.

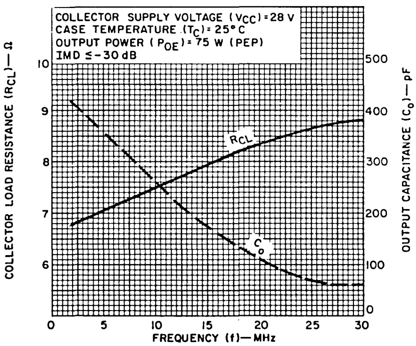


Fig. 14— Typical large-signal parallel collector load resistance and parallel output capacitance as a function of frequency for the RCA-2N6093.

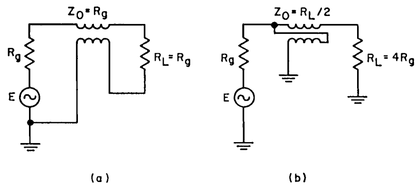


Fig. 15— Transmission-line transformers: (a) 1:1 reversing/isolating transformer; (b) 4:1 impedance transformer.

Table II - Permeability and Frequency Dependence of Ferramic-Q Materials

Material	Permeability	Approximate Frequency at which core losses increase by a factor of 10 (MHz)
Q-1	125	10
Q-2	40	90
Q-3	16	225

dependent on core material at the higher-frequency end of its useful range, the poor intrinsic Q of Q-1 material above 20 MHz does not degrade the transformer operation at 30 MHz. Q-2 material, having lower permeability, requires more turns for operation at the lower frequencies.

Hybrid Combiner/Dividers

Hybrid combiner/dividers can be made by use of combinations of the 1:1 and 4:1 transformers on ferrite cores to provide high impedance transformation ratios[6]. As an example, Fig. 16 shows a 180°-phase hybrid divider that matches a 50-ohm source to a 3.12-ohm push-pull configuration. Two 1:1 transformers are used to make the 4:1 transformation, rather than one 4:1 transformer, to provide the balanced output needed for a push-pull configuration. An equivalent transformation also can be made with one 1:1 transformer and one 4:1 transformer, as shown in Fig. 17.

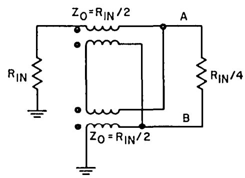


Fig. 16— A 4:1 broadband transformation network that uses two 1:1 transformers to provide a balanced output.

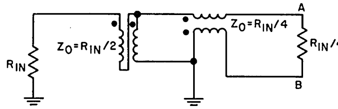


Fig. 17– A 4:1 broadband transformation network that uses a 1:1 transformer and a 4:1 transformer to provide a balanced output.

Fig. 18 shows a 16:1 broadband transformation network for a push-pull configuration. The circuitry to the left of V2 is the same as in Fig. 16; to the right of V2, an extra transformer and dissipating resistor have been added. Points A and B are transistor base inputs, R2 represents the resistive input to a conducting transistor, and R3 is a resistor much larger than R2 that is connected in shunt with each base-to-emitter junction. (Thus A-to-ground represents a conducting transistor, while B-to-ground represents a cut-off transistor, in Fig. 18.) R1 dissipates any imbalances in power or phasing.

To find the input resistance to the network of Fig. 18, the network equations are written as follows:

$I_1 = I_2 = I_3 = I_4$ $\qquad V_2 - V_4 = V_4 - V_3$

$I_5 = I_6 = 2I_1$ $\qquad V_1 = 2(V_2 - V_3)$

$I_7 = I_5 - I_8$ $\qquad V_4 = R_1 I_{10}$

$I_8 = I_9$ $\qquad V_2 = I_7 R_2$

$I_{11} = I_9 + I_6$ $\qquad V_3 = R_3 I_{11}$

$I_{10} = I_8 + I_9$

These equations yield V_1/I_1 as a function of R_1, R_2, and R_3:

$$R_{IN} = \frac{V_1}{I_1} = 16\left(\frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{4R_1 + R_2 + R_3}\right)$$

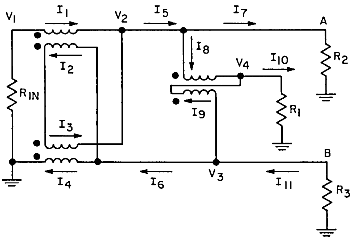


Fig. 18– A 16:1 broadband transformation network with balanced output.

If $R_1 = 1/2\ R_2$ and $R_3 = 5R_2$, $R_{IN} = 16\ R_2$. Thus the 3.12-ohm transistor resistance is transformed to 50 ohms.

Because of symmetrical loading, the same hybrid configuration provides an 8:1 impedance transformation when used as a 180°-phase power combiner at the transistor collectors. This combiner operation of the network is shown in Fig. 19; the output resistance is given by

$$R_{OUT} = \frac{V_{OUT}}{I_{OUT}} = 16\left(\frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{4R_1 + R_2 + R_3}\right)$$

If the collector load-line resistance is R_L, let $R_1 = \frac{1}{2} R_L$ and $R_2 = R_3 = R_L$. Then

$$R_{OUT} = 8R_L$$

Thus each collector is provided with a 6.25-ohm load-line for R_{OUT} = 50 ohms. The inductance of the transmission line and its connectors is utilized to tune out both input and output negative reactances.

2-to30-MHz Broadband Circuit Design

The push-pull configuration is used not only because the 180°-phase hybrids provide a high transformation ratio, but also because this configuration suppresses second harmonics and thus minimizes filter requirements at the output. Knowing the output power level and the input and output impedance values at that power level, the circuit designer can use a combination of 180°-phase hybrids, hybrid resistance values, and additional transmission-line transformers to complete the proper transformation at the input and output. After the transformation closest to optimum match at the highest operating frequency has been selected, individual transformers are wound and measured over the desired frequency band. The HP 4815A vector impedance meter, RX Boonton Meter, or a similar instrument can be used for these measurements.

A 150-watt (PEP) linear amplifier for the 2-to-30-MHz frequency range has been built with a pair of RCA-2N6093 transistors in push-pull, 180°-phase hybrid power combiner/dividers, and single-ended 4:1 transformers. The block diagram of this amplifier is shown in Fig. 20, and the circuit diagram and parts list are given in Fig. 21.

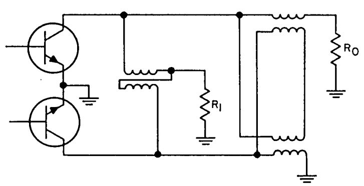


Fig. 19– The network of Fig. 18 used as a 180°-phase power combiner.

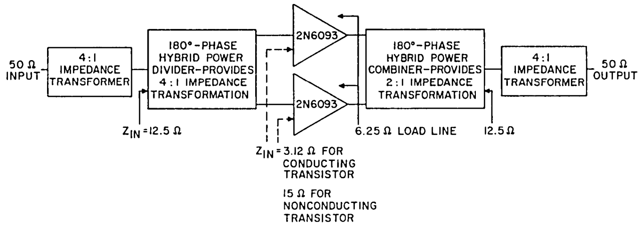
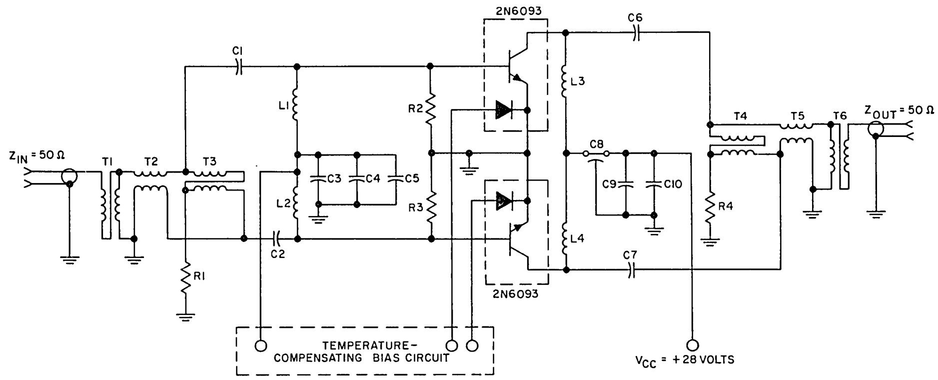


Fig. 20– Block diagram of push-pull linear amplifier that provides 150 watts PEP at 2 to 30 MHz.



C1 = C2 = 0.15 μF ELECTROLYTIC
C3 = C9 = 0.04 μF CERAMIC
C4 = 0.0027 μF CERAMIC
C5 = 100 μF ELECTROLYTIC
C6 = C7 = 0.1 μF ELECTROLYTIC
C8 = 1000 pF FEEDTHROUGH ALLEN BRADLEY FA5C
C10 = 5 μF ELECTROLYTIC

R1 = 2.7 Ω, 0.5 WATT PARALLELED WITH 3.3 Ω, 0.5 WATT
R2 = R3 = 30 Ω, 0.5 WATT PARALLELED WITH 30 Ω, 0.5 WATT
R4 = 2.7 Ω, 1 WATT

L1 = L2 = 0.75 μH RFC
L3 = L4 = 7 TURNS NO. 20 WIRE ON Q1 CF 111 INDIANA GENERAL FERRITE CORE.

T1 = T2 = T6 = NO. 26 WIRE. TWO TWISTED PAIRS (9 TURNS/IN.) PARALLELED (8 TURNS/IN.) 8" TOTAL LENGTH. FIVE TURNS ON Q1 CF 111 INDIANA GENERAL CORP. FERRITE CORE.

T3 = T4 = T5 = TWO COPPER STRIPS (WIDTH = 85 MILS, THICKNESS = 8 MILS PARALLELED, 3.5" TOTAL LENGTH). FIVE TURNS ON Q1 CF 106 INDIANA GENERAL CORP. FERRITE CORE.

Fig. 21– Circuit diagram and parts list for 150-watt, 2-to-30-MHz push-pull linear amplifier.

Typical performance of this amplifier across the hf band is shown in Fig. 22. The power gain exhibits the same 6-dB-per-octave slope at mid-band and low-frequency roll-off noted in the narrowband measurements (Fig. 12). Total gain variation is approximately 15 dB.

The intermodulation distortion exceeds -30 dB at frequencies below 6 MHz. The circuit is capable of -35 dB IMD over a good portion of the band if operated at the reduced output power of 100 to 110 watts PEP, as would be expected from the curve of Fig. 3. If the same circuit components and transformation networks are utilized, the efficiency is somewhat reduced at the reduced power level because the collector circuit is optimized for higher power.

The efficiency of the amplifier is 40 to 50 per cent across the band. When operated at 150 watts PEP with V_{CC} of 28 volts, the amplifier becomes current limited at frequencies below 3 MHz. The increase in VSWR is related to the increase in the real part of the transistor input impedance (see Fig. 13).

Fig. 23 shows the performance of the 150-watt PEP amplifier as a function of case temperature at 30 MHz.

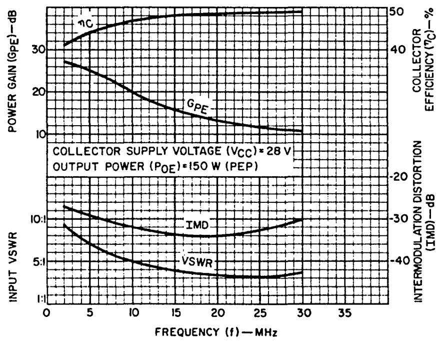


Fig. 22– Typical performance of the broadband 150-watt (PEP) amplifier with two RCA-2N6093 transistors.

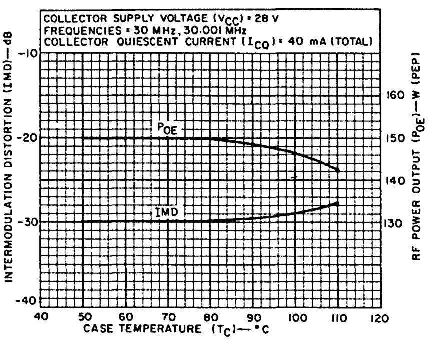


Fig. 23– Performance of the 150-watt PEP amplifier as a function of case temperature at 30 MHz.

The main advantages of this type of circuit are its simplicity and compactness. The disadvantages are lack of gain leveling and low efficiency at lower frequencies because of increased VSWR.

Because the real value of the transistor input impedance increases with decreasing frequency, which affects both VSWR and IMD, a resistance-inductance series combination placed in parallel with the 50-ohm input or placed from base to base aids the transformation network in making a practical match at low frequencies. The impedance match is improved and some input power is absorbed at low frequencies; therefore the VSWR improves and some gain leveling occurs. Other methods of gain leveling include collector-to-base feedback and loop feedback; for high-power circuits, the loop feedback system shown in Fig. 24 would be the most effective. In this system, input and output signals are compared and gain differences are compensated by commensurate increases in input attenuation.

For higher powers, modules of push-pull pairs can be pyramided by the same hybrid-combining techniques.

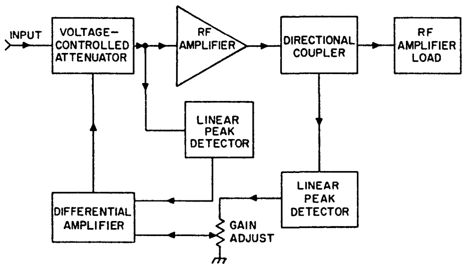


Fig. 24-- A loop feedback system for gain-leveling.

REFERENCES

1. E.W. Pappenfus, W.B. Bruene, and I.O. Schoenike, *Single-Sideband Principles and Circuits,* chapter 4, McGraw-Hill, New York; 1964.

2. D. Carley, P. McGeough, and J. O'Brien, "The Overlay Transistor," *Electronics,* vol. 23, no. 17, pp. 70-77; August 23, 1965.

3. D.J. Donahue and B. A. Jacoby, "Putting the Overlay to Work," *Electronics,* vol. 23, no. 17, pp. 78-81; August 23, 1965.

4. J. Tatum, "RF Large-Signal Transistor Power Amplifiers; Part III – Matching Networks," *Electronic Design News,* vol. 10, no. 8, pp. 66-80; July 1965.

5. C.L. Ruthroff, "Some Broadband Transformers," *Proc. IRE,* vol. 47, pp. 1337-1342; August 1959.

6. O. Pitzalis, Jr. and T. Course, "Broadband Transformer Design for RF Transistor Power Amplifiers," *Proceedings of 1968 Electronic Components Conference,* pp. 207-216.

7. R. Turrin, "Broadband Balun Transformers," *QST,* vol. 48, no. 8, pp. 33-35; August 1964.

RCA
Solid State
Division

RF Power Transistors
Application Note
AN-4774

Hotspotting in RF Power Transistors

by C. B. Leuthauser

Some rf power transistors can suffer a long-term deterioration of performance during linear operation (class A or AB) or when operated with high collector supply voltage or into a high load VSWR, even though the dissipation is within the limit set by the classical junction-to-case thermal resistance. This performance degradation is caused by a localized heating effect called "hotspotting". Hotspotting results from local current concentrations in the active areas of the transistor; it can cause catastrophic thermal runaway as well as long-term failure.

The presence of hotspots can make virtually useless the present method of calculating junction temperature by measurements of average thermal resistance, case temperature, and power dissipation. However, by use of an infrared microscope, the spot temperature of a small portion of an rf transistor pellet can be determined accurately under actual or simulated device operating conditions. The resultant peak temperature information is used to characterize the device thermally in terms of junction-to-case hotspot thermal resistance, $\Theta_{JS\text{-}C}$.

The hotspot thermal resistance can be used in reliability predictions, particularly for devices involved in linear or mismatch service.

DC Safe Area

The safe area determined by infrared techniques represents the locus of all current and voltage combinations within the maximum ratings of a device that produce a specified spot temperature (usually 200°C) at a fixed case temperature. The shape of this safe area is very similar to the conventional safe area in that there are four regions, as shown in Fig. 1: constant current, constant power, derating power, and constant voltage. The dotted lines denote a three-region form of safe-area plot, in which the fourth region is outside of V_{CEO} or $I_C(max)$.

Regions I and IV, the constant-current and constant-voltage regions, respectively, are determined by the maximum collector current and V_{CEO} ratings of the device. Region II is dissipation-limited; in the classical safe area

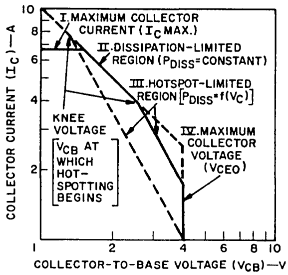


Fig. 1— Safe area curve for an rf power transistor, determined by infrared techniques.

curve, this region is determined by the following relationship:

$$P_{max} = \frac{T_J(max) - T_C}{\Theta_{J\text{-}C}} \quad (1)$$

where $T_J(max)$ is the maximum allowed junction temperature, T_C is the case temperature, and $\Theta_{J\text{-}C}$ is the junction-to-case thermal resistance.

This relationship holds true for the infrared safe area; P_{max} may be slightly lower because the reference temperature $T_J(max)$ is a peak value rather than an average value. The hotspot thermal resistance ($\Theta_{JS\text{-}C}$) may be calculated from the infrared safe area by use of the following definition:

$$\Theta_{JS\text{-}C} = \frac{T_{JS} - T_C}{P_{diss}} \quad (2)$$

where T_{JS} is highest spot temperature [$T_J(max)$ for the safe area] and P_{diss} is the dissipated power (=I x V product in Region II).

The collector voltage at which regions II and III intersect, called the knee voltage V_k, indicates the collector voltage at which power constriction and resulting hotspot formation begins. For voltage levels above V_k, the allowable power decreases. Region III is very similar to the second-breakdown region in the classical safe area curve except for magnitude. For many rf power transistors, the hotspot-limited region can be significantly lower than the second-breakdown locus. Generally V_k decreases as the size of the device is increased.

Fig. 2 shows the temperature profiles of two transistors with identical junction geometries that operate at the same dc power level. If devices are operated on the dissipation-limited line of their classical safe areas, the profiles show that the temperature of the unballasted device rises to values 130°C in excess of the 200°C rating. Temperatures of this magnitude, although not necessarily destructive, seriously reduce the lifetime of the device.

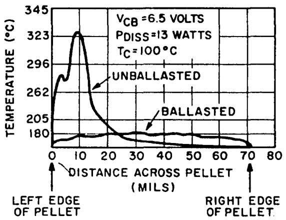


Fig. 2– Thermal profiles of a ballasted and an unballasted power transistor during dc operation.

Emitter Ballasting

The profiles shown in Fig. 2 also demonstrate the effectiveness of emitter ballasting in the reduction of power (current) constriction. In the ballasted device, a biasing resistor is introduced in series with each emitter or small groups of emitters. If one region draws too much current, it will be biased towards cutoff, allowing a redistribution of current to other areas of the device.

The amount of ballasting affects the knee voltage, V_k, as shown in Fig. 3. A point of diminishing returns is reached as V_k approaches V_{CEO}.

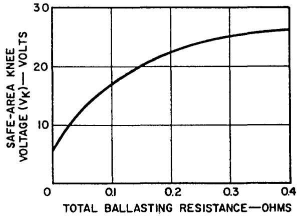


Fig. 3– Safe-area knee voltage for an rf power transistor as a function of total ballasting resistance.

RF Operation

In normal class C rf operation the hotspot thermal resistance is approximately equal to the classical average thermal resistance. If the proper collector loading (match) is maintained, $\Theta_{JS\text{-}C}$ is independent of output power at values below the saturated- or slumping-power level, and is independent of collector supply voltage at values within +30 per cent of the recommended operating level.

Power constriction in rf service normally occurs only for collector load VSWR's greater than 1:1. A transistor that has a mismatched load experiences temperatures far in excess of device ratings, as shown in Fig. 4 for VSWR of 3:1. For comparison, the temperature profile for the matched condition is also shown in Fig. 4.

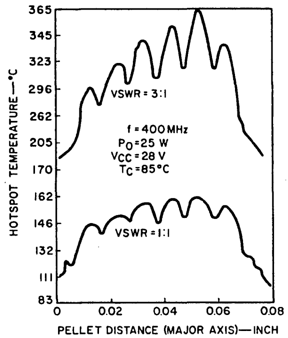


Fig. 4– Thermal profile of a power transistor during rf operation under mismatched conditions and under matched conditions.

Fig. 5 is a typical family of thermal resistance curves that indicate the response of a device to various levels of VSWR and collector supply voltage. $\Theta_{JS\text{-}C}$ responds to even slight increases in VSWR above 1:1 and saturates at a VSWR in the range of 3:1 to 6:1. The saturated level increases with increasing supply voltage. Devices with high knee voltages tend to show smaller changes of $\Theta_{JS\text{-}C}$ with VSWR and supply voltage. $\Theta_{JS\text{-}C}$ under mismatch is independent of frequency and power level, and reaches its highest values at load angles that produce maximum collector current. Power level does, however, influence the temperature rise and probability of failure.

Device failure can also occur at a load angle that produces minimum collector current. Under this condition, collector voltage swing is near its maximum, and an avalanche breakdown can result. This mechanism is sensitive to frequency and power level, and becomes predominant at lower frequencies because of the decreasing rf-breakdown capability of the device.

Broadband Operation

The amount of hotspotting produced by wideband operation of a transistor depends upon both device and

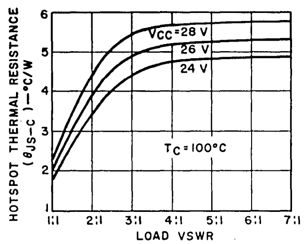


Fig. 5— Mismatch-stress thermal characteristics for the RCA-2N5071.

network characteristics. The output network in a broadband rf amplifier usually does not provide ideal collector loading across the entire range of frequencies. Therefore the hotspot thermal performance is characterized for these devices when terminated by a specified output network.

The RCA-2N5071 is a 24-watt transistor developed for wideband applications in the frequency band from 30 to 76 MHz. In the wideband circuit shown in Fig. 6, this transistor has a nominal collector efficiency of 50 per cent and an rf gain that varies from 13.5 dB at 30 MHz to 9 dB at 76 MHz for a power output of 20 watts. The hotspot thermal characteristics for the 2N5071 in this circuit are shown in Fig. 7 for a matched load and for a 3:1 VSWR (worst-case phase angle) load condition. The high case temperature, 100°C, simulates actual environmental conditions.

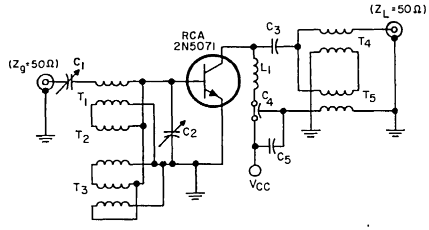
The RCA-2N6105, a 30-watt transistor, is similarly characterized for use in the 225-to-400-MHz band. In the wideband circuit shown in Fig. 8 this device has a nominal collector efficiency of 75 per cent and an rf gain that varies from 7.5 dB at 250 MHz to 6 dB at 400 MHz for a power output of 30 watts. The hotspot thermal performance of the 2N6105 is shown in Fig. 9 for matched and 3:1 VSWR load conditions with a case temperature of 85°C.

Case-Temperature Effects

The thermal resistance of both silicon and beryllium oxide, two materials that are commonly used in rf power transistors, increases about 70 per cent as the temperature increases from 25 to 200°C. Other package materials such as steel, kovar, copper, or silver, exhibit only minor increases in thermal resistance (about 5 per cent). The over-all increase in $\Theta_{JS\text{-}C}$ of a device depends on the relative amounts of these materials used in the thermal path of the device; typically the increase of $\Theta_{JS\text{-}C}$ ranges from 5 per cent to 70 per cent. Fig. 10 shows the rf and dc thermal resistance coefficients for two typical rf transistors. For both cases, the coefficient is referenced to a 100°C case and is defined as follows:

$$K_{\Theta 100} = \frac{\Theta_{JS\text{-}C}}{\Theta_{JS-C} \text{ at } T_C = 100^oC} \quad (3)$$

The rf coefficient changes more than the dc coefficient, because of power constriction that occurs in rf operation at elevated case temperature.



C1, C2: 55-300 pF trimmer capacitor, ARCO 427, or equivalent

C3, C5: 0.47 μF ceramic

C4: 1000 pF feedthrough

L1: Ferroxcube No. VK200 01-3B, or equivalent

T1, T2, T3: 6 twisted pairs (10 turns/in.) of No. 28 wire connected in parallel. 3 1/2 turns on Indiana General CF-108-02 ferrite core, or equivalent

T4, T5: 2 lengths of RG-196A/U cable connected in parallel. 7 turns on Indiana General CF-111-Q1 ferrite core, or equivalent.

Fig. 6— Wideband rf amplifier circuit for operation from 30 to 76 MHz.

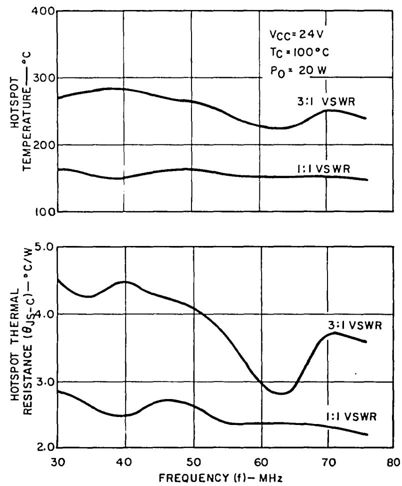
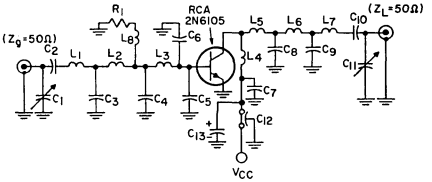


Fig. 7— Broadband thermal performance of the RCA-2N5071 in the circuit of Fig. 6.



C1: 0.8-10 pF, Johanson 2954*
C2: 15 pF silver mica
C3: 33 pF chip, Allen-Bradley B163301*
C4: 47 pF chip, Allen-Bradley B164701*
C5: 62 pF chip, ATC-100*
C6: 68 pF chip, ATC-100*
C7, C10: 1000 pF chip, Allen-Bradley B161021*
C8: 22 pF chip, Allen-Bradley B162201*
C9: 6.7 pF chip, Allen-Bradley B166791*
C11: 1-20pF, Johanson 5502*
C12: 1000 pF feedthrough
C13: 1 μF electrolytic
L1: 2 turns, 5/32-in. I.D. No. 20 wire
L2: 17/32-in. length No. 20 wire
L3: 5/32-in. length transistor base lead
L4, L6: 13/16-in. length No. 20 wire
L5: 9/16-in. length No. 20 wire
L7: 7/8-in. length No. 20 wire
L8: RFC 1 μH Nytronics*
R1: 5.1 ohms, 0.25 watt

* or equivalent

Fig. 8— Wideband rf amplifier circuit for operation from 225 to 400 MHz.

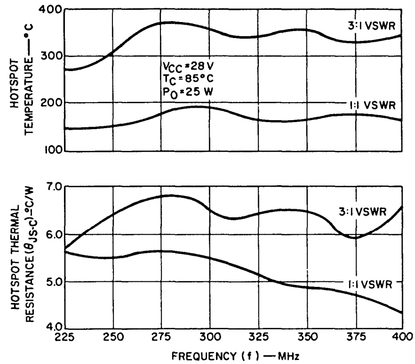


Fig. 9— Broadband thermal performance of the RCA-2N6105 in the circuit of Fig. 8.

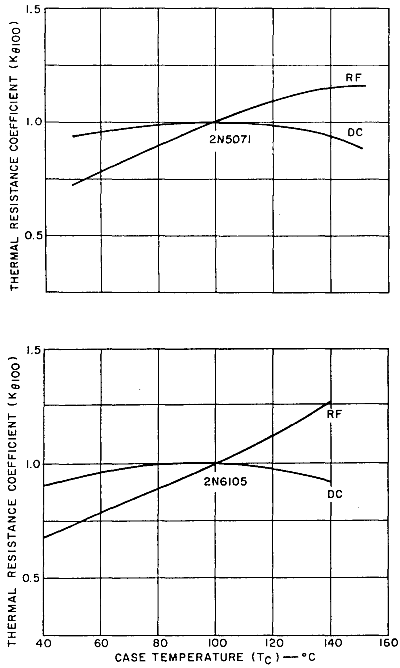
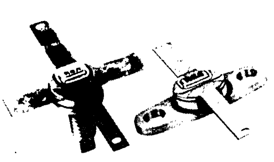


Fig. 10— Thermal resistance coefficients of the RCA-2N5071 and RCA-2N6105.

RCA
Solid State
Division

RF Power Transistors

Application Note
AN-6010



Characteristics and Broadband (225-to-400-MHz) Applications of the RCA-2N6104 and 2N6105 UHF Power Transistors

by Boris Maximow

The 2N6104 and 2N6105 uhf power transistors feature the silicon overlay multiple-emitter-site construction with internal ballasting resistors connected in series with the emitter structure. These transistors, which are electrically identical, are intended primarily for use in large-signal, high-power cw and pulsed amplifiers in vhf and uhf equipment at frequencies up to 600 MHz. The 2N6104 is supplied in the RCA HF-32 flanged ceramic-metal hermetic stripline package, and the 2N6105 is supplied in the RCA HF-19 (JEDEC TO-216AA) studded ceramic-metal hermetic stripline package. These packages are characterized by low parasitic inductance and are ideally suited for use in either microstripline or lumped-constant vhf and uhf power amplifiers.

This Note describes basic performance characteristics and specific circuit design details related to the application of the 2N6104 and 2N6105 transistors in broadband uhf power amplifiers intended for use over the frequency band from 225 to 400 MHz. The circuit designs shown in this Note use 2N6105 transistors. Equivalent performance can also be achieved, however, when 2N6104 transistors are used in the designs provided that adequate consideration is given to the mechanical differences of the package.

Overdrive Capability

The 2N6104 and 2N6105 transistors are made more electronically rugged by use of emitter ballasting. The electronic ruggedness of rf power transistors is manifested by their overdrive capability and by their ability to withstand the effects of load-pulling. Overdrive tests, rather than load-pulling tests, are used to define the electronic ruggedness of rf power transistors, however, because load-pulling tests are destructive and the results obtained have poor repeatability. Despite these shortcomings, load-pulling tests can still be very useful. For example, load-pulling experiments have shown that the capability of the 2N6104 and 2N6105 transistors to withstand load-mismatch conditions is at least 1.5 times greater for operation under pulsed conditions with a duty factor of 50 per cent than for cw operation. This factor is important for applications in which amplitude modulation is employed.

Overdrive specifications are extremely important for rf power transistors because in many applications the transistors are subjected to inputs that are substantially larger than those specified for normal operation. The 2N6104 and 2N6105 transistors are required to withstand overdrive tests in which an input drive of 12 watts is applied. This input drive is 25 per cent larger than the normal input drive of 9.5 watts recommended for these devices at 400 MHz. The ability of the transistors to operate safely under these overdrive conditions is effectively controlled by careful definition of the amount and type of emitter ballasting employed in them. The emitter ballasting resistance is provided by a polycrystalline silicon layer between the active emitter regions and the emitter bond pads. This layer is doped to obtain a positive temperature coefficient of resistivity so that the effective amount of ballasting increases with a rise in temperature.

Hot-Spot Thermal Resistance

The classic definition of the thermal resistance of a transistor assumes that the pellet is uniformly heated whenever power is dissipated in the device. Recent investigations, however, have shown that the voltage-current combinations in a power transistor during rf operation may cause hot spots to be developed in localized areas across the transistor pellet. These hot spots severely restrict the maximum power dissipation of the transistors. The classic thermal resistance, therefore, cannot be used to provide accurate predictions of the power-dissipation capability of rf power transistors. This thermal resistance continues to be very useful, however, because it serves as the basis for the determination of the required size of the transistor pellet and provides an indication of the effectiveness of the thermal bond of the pellet to the metallized pad.

The hot-spot thermal resistance of an rf power transistor takes into account the nonuniform temperature profile across the pellet. This thermal resistance is determined on the basis of the highest temperature of the entire pellet. The hot spots in an rf power transistor are a function of the operating frequency, the degree of load mismatch, the case temperature, and the collector voltage. Figs. 1 through 4 show the relationship of each of these factors to the hot-spot temperature and thermal resistance of the 2N6104 and 2N6105 transistors. The use of emitter ballast resistors in these transistors results in a more uniform temperature profile across the pellet so that the formation of hot spots is substantially reduced. The peaks in the curve shown in Fig. 1 indicate emitter regions, and the valleys indicate base regions.

The curves shown in Figs. 1 through 4 were obtained by infrared scanning measurements of the pellet temperature. For these measurements, the sealing cap was removed from

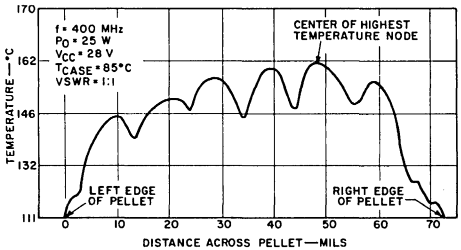


Fig. 1— Typical thermal profile across a 2N6104 or 2N6105 pellet during rf operation.

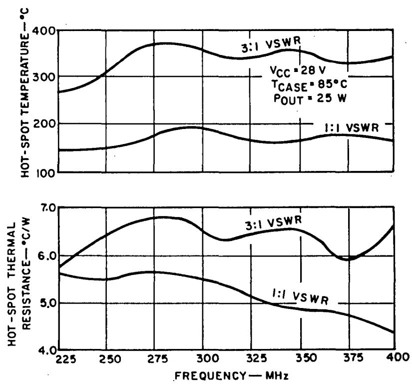


Fig. 2— Hot-spot temperature and hot-spot thermal resistance of a 2N6104 or 2N6105 as a function of frequency.

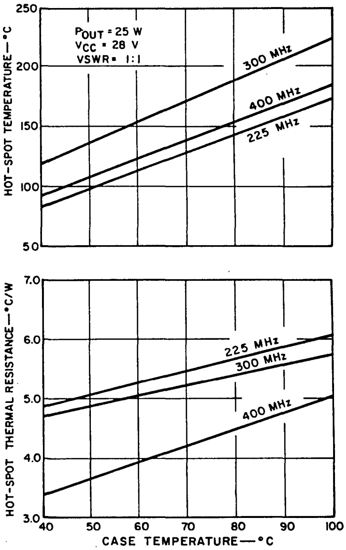


Fig. 3— Hot-spot temperature and hot-spot thermal resistance of a 2N6104 or 2N6105 as a function of case temperature.

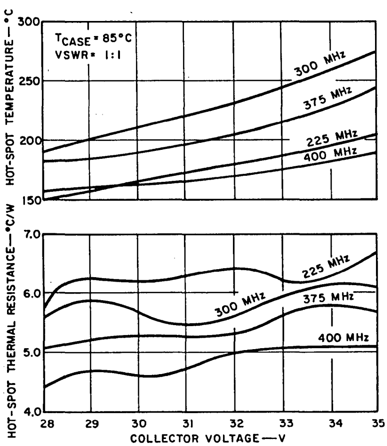
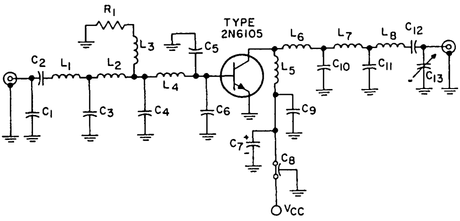


Fig. 4— Hot-spot temperature and hot-spot thermal resistance of a 2N6104 or 2N6105 as a function of collector voltage.

the top of the transistor. Removal of the sealing cap results in some reduction in transistor gain. As a result, the hot-spot measurements are somewhat conservative because the over-all operating efficiency would be increased for the normally higher transistor gain. These measurements were taken with the transistor operated in the broadband circuit shown in Fig. 5. (A broadband circuit does not always present an ideal load for the transistor.)



C_1: 8.2 pF chip, Allen-Bradley•
C_2: 18 pF silver mica
C_3: 33 pF chip, Allen-Bradley•
C_4: 47 pF chip, Allen-Bradley•
C_5: 68 pF chip, ATC-100°
C_6: 62 pF chip, ATC-100°
C_7: 1 μF electrolytic
C_8: 1000 pF feedthrough
C_9, C_{12}: 1000 pF chip, Allen-Bradley•
C_{10}: 22 pF chip, Allen-Bradley•
C_{11}: 6.9 pF chip, Allen-Bradley•
C_{13}: 0.8-10 pF variable air, Johanson No. 3957•
L_1: 2 turns, 5/32 in. I.D. coil
L_2: 17/32 in. long wire
L_3: RFC, 0.1 μH, Nytronics•
L_4: 5/32 in. long transistor base lead
L_5, L_7: 13/16 in. long wire
L_6: 9/16 in. long wire
L_8: 7/8 in. long wire
R_1: 5.0 Ω, 1/4 W
All wire is No. 20 AWG

•Or equivalent.

Fig. 5— 225-to-400-MHz broadband power amplifier.

type of load circuit into which the transistor operates. The supply-voltage limits recommended for the 2N6104 and 2N6105 transistors are determined on the basis of dynamic voltage breakdown tests in which the devices are subjected to an "all phase" load-mismatch condition during pulsed operation. Experimental results obtained from pulsed operation of these transistors are shown in Fig. 6. These results were measured with the transistors operated in the 400-MHz microstripline amplifier circuit shown in Fig. 7. For the load-mismatch conditions of the tests, the transistors demonstrated the ability to handle peak rf power outputs in excess of 70 watts when operated from a collector supply of 40 volts. For the transistors to survive these output levels, the test circuit must be non-oscillatory.

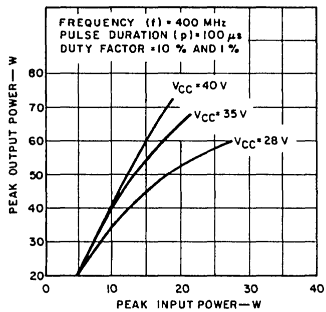


Fig. 6— Pulse operation of the 2N6104 or 2N6105.

Pulsed Operation

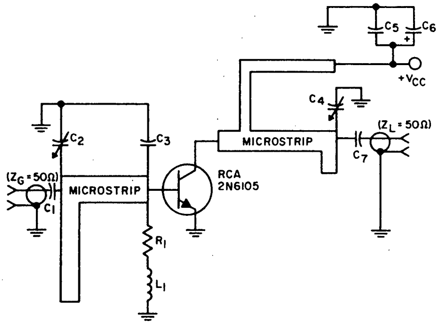
Two factors contribute to the increased capability of a transistor to handle rf power with changes from operation in the cw mode to pulsed operation at lower duty factors. For a given peak power level, the transistor dissipation decreases significantly with a reduction in the duty factor; consequently, a substantial increase in power-handling capability results. A moderate increase in power-handling capability also results because the peak current-handling capability of the transistor improves as the duty factor becomes smaller.

Although the power-handling capability of an rf transistor increases with decreases in duty factor, the transistor power gain is independent of duty factor. Full utilization of the increased rf power-handling that results from pulsed transistor operation, therefore, requires that the collector supply voltage be increased to assure that the gain is maintained at reasonable levels. Care must be taken, however, to assure that the breakdown voltages of the transistor are not exceeded. The maximum collector supply voltage that can be safely applied to an rf power transistor without breakdown levels being exceeded is a function of the

Broadband Circuit Design Approach

In general, either of two basic approaches is used in the design of broadband high-power rf amplifier chains. In one approach, each stage of the chain consists of a pair of transistors combined by use of quadrature combiners. In the other approach, a single-ended configuration is used for each stage throughout the chain except for those stages in which the power-output requirements exceed the capability of a single transistor. In such stages, combined pairs of transistors must be used. The block diagrams of the three-stage amplifier chains shown in Fig. 8 illustrate the basic configurations that result from each design approach.

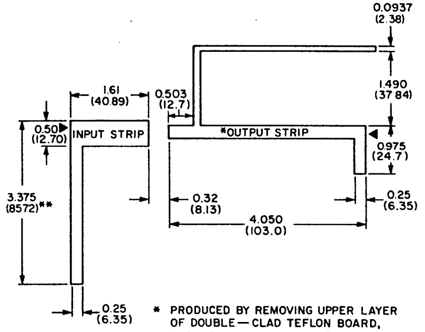
Obviously, the use of combined pairs of transistors in each stage, as shown in Fig. 8(a), is the more complex design approach. With this approach, the space requirements of the amplifier chain are greater, and a larger number of transistors and combiners are used. Moreover, each time a combiner is used, the gain and efficiency of the over-all circuit are reduced. For these reasons, the approach that uses a single-ended configuration per stage is generally preferred. One definite advantage of the combined-transistor-pair



C_1, C_5, C_7: 1000 pF chip, ATC-100●
C_2, C_4: 1-20 pF air variable, Johanson 4802●
C_3: 15 pF silver mica
C_6: 1 μF electrolytic
L_1: 0.1 μH RF choke
R_1: 5.1 Ω 1/2 W

●Or equivalent.

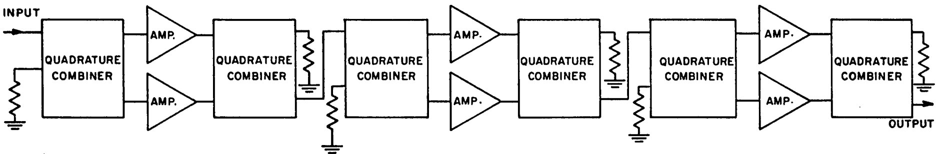
NOTE: POINTS OF APPLICATION FOR C_1 AND C_7 ARE SHOWN ON THE INPUT AND OUTPUT STRIPS IN THE DRAWING AT RIGHT (▶)



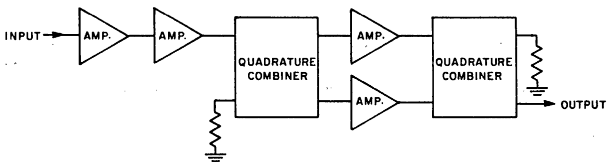
* PRODUCED BY REMOVING UPPER LAYER OF DOUBLE—CLAD TEFLON BOARD, 1 OZ., 1/32 IN. THICK, (ε=2.6), OR EQUIVALENT

** DIMENSIONS IN PARENTHESES ARE MILLIMETERS.

Fig. 7—400-MHz amplifier test circuit for measurement of output power.



(a)



(b)

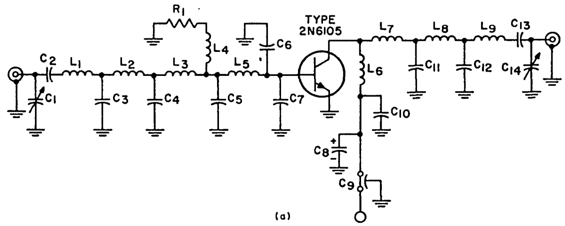
Fig. 8—Broadband power amplifier chains: (a) cascade of combined-pair amplifier stages; (b) cascade of two single-amplifier stages and one amplifier-pair stage.

approach, however, is that cascading of successive stages in the chain is relatively simple and straightforward. Each stage is a building block that, because of the properties of the quadrature combiners, has a very low input VSWR across the entire frequency band, an essential requirement for trouble-free cascading.

In the single-ended-configuration approach shown in Fig. 8(b), a low input VSWR across the entire frequency band is much more difficult to attain, and each stage of the amplifier chain must be very carefully designed. The increased over-all gain, higher efficiency, smaller size, and reduced cost made possible by the successful cascading of single-ended stages usually provides sufficient justification for the additional engineering effort required in this approach to the design of broadband rf power-amplifier chains.

Single-Ended Amplifier

Insofar as the function of the output network of a high-power broadband uhf amplifier is to provide proper loading for the transistor, the design of this network is essentially the same whether the amplifier is to be used singly or is to be combined with another amplifier by use of quadrature combiners. In the design of a 225-to-400-MHz power amplifier, the first step may be to design a broadband Chebyshev filter to match the real part of the transistor parallel equivalent load impedance (approximately 10 ohms for the 2N6105 transistor) to the output impedance (usually 50 ohms) over the specified frequency band.[1,2] After the component values for the filter have been computed, these values are plotted on a Smith chart and are changed as required to compensate for the capacitive output of the transistor. This admittedly tedious process, when supplemented by laboratory experimentation, yields highly acceptable results. The effectiveness of this approach is illustrated by a plot of the output network of the broadband amplifiers shown in Figs. 5 and 9 on the Smith chart shown in Fig. 10. The curves on this chart should be compared with the output-impedance trace obtained on a circuit analyzer, shown in Fig. 11. This comparison indicates that some of the components in the output network may require precise values.

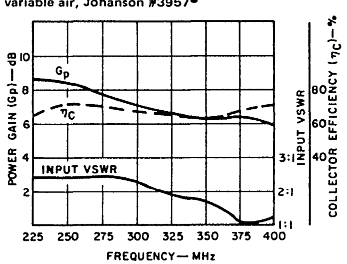


(a)

C_1: 0.8-18 pF variable, Amperex
C_2: 24 pF, silver mica
C_3: 22 pF chip, Allen-Bradley•
C_4: 33 pF chip, Allen-Bradley•
C_5: 47 pF chip, Allen-Bradley•
C_6: 62 pF chip, ATC-100
C_7: 68 pF chip, ATC-100
C_8: 1 μF, electrolytic
C_9: 1000 pF feedthrough
C_{10}, C_{13}: 1000 pF chip, Allen-Bradley
C_{11}: 6.9 pF chip, Allen-Bradley•
C_{12}: 6.9 pF chip, Allen-Bradley•
C_{14}: 0.8-10 pF variable air, Johanson #3957•

L_1: 2 turns, 5/32 in. I.D.
L_2: 1/2 in. long wire
L_3: 13/32 in. long wire
L_4: RFC, 0.1 μH, Nytronics
L_5: 5/32 in. long transistor base lead
L_6, L_8: 13/16 in. long wire
L_7: 9/16 in. long wire
L_9: 7/8 in. long wire
R_1: 5.0 Ω, 1/4 W
All wire is No. 20 AWG

•Or equivalent.



(b)

Fig. 9—Broadband 225-to-400-MHz amplifier with input network designed for minimum input VSWR; (a) circuit diagram; (b) performance data.

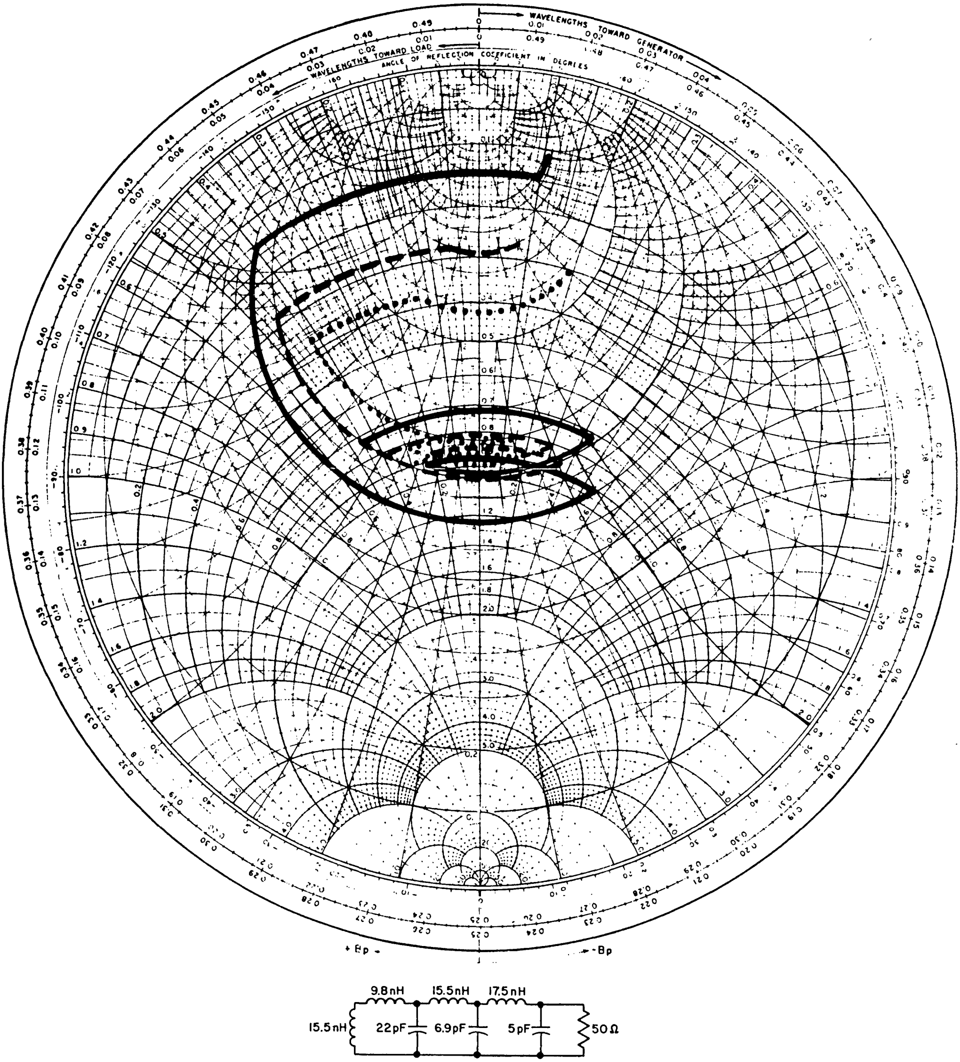


Fig. 10—Smith Chart design curves and circuit diagram for broadband output network.

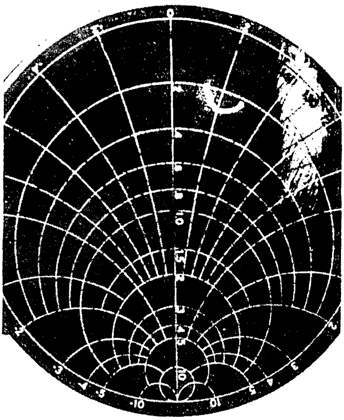


Fig. 11— Circuit-analyzer output-impedance trace for broadband amplifiers using output network shown in Fig. 10.

The design of the input network for a single-ended broadband amplifier depends, to a large extent, on the final application intended for the amplifier. If the amplifier is to be combined with another identical amplifier by use of quadrature combiners, the major design objective is flatness of response, and the input VSWR is of lesser importance. For a single-ended amplifier that is to be used in a cascade connection, a low input VSWR is the main requisite for successful cascading of individual stages.

In one approach to the design of broadband input networks for high-power transistor rf amplifiers, lossy elements are introduced into the network to equalize the gain across the specified frequency band.[1] This technique should be reversed for amplifiers stages that operate at moderate power levels. The inconvenience that results from the use of large resistors in the input network would probably be the limiting factor for this approach.

In general, the input matching network for a high-power amplifier should use only reactive components and should be designed for a minimum input VSWR across the band. The achievement of a minimum input VSWR across the band, however, is accompanied by some degradation in the flatness of the amplifier gain-frequency response. The input network of the 225-to-400-MHz amplifier shown in Fig. 9(a) is designed to reduce the input VSWR across the band. The performance data for the amplifier, shown in Fig. 9(b), reveals that this approach results in a gain variation of as much as 3 dB across the band. In a chain of such stages in cascade, the excess gain is cumulative with the number of stages. The cumulative excess gain may result in an excess output within the amplifier chain that may possibly overdrive a following stage to destruction. Consequently, it is advantageous to introduce some method of gain equalization between adjacent stages. The output leveling schemes employed are usually looped about several stages and have no control over the gain of individual stages.

Gain Equalizer

Fig. 12 shows a suggested broadband gain equalizer. When this equalizer is used with the broadband amplifier shown in Fig. 9, the resultant stage has a very low input

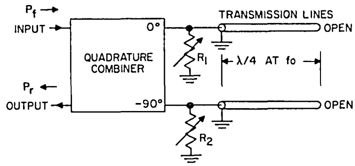


Fig. 12— Gain equalizer for broadband uhf power amplifier.

VSWR and a gain response that is essentially flat. The basic amplifier-equalizer connection and the performance of the resultant circuit are shown in Fig. 13. A comparison of the gain curve shown in Fig. 9 with that shown in Fig. 13 indicates the effectiveness of the gain equalizer.

The gain equalizer shown in Fig. 12 makes use of the frequency-selective characteristics of two open-ended transmission lines. The 0-degree and 90-degree ports of the quadrature combiner are shorted at the operating frequency f_0 for which each transmission line is one-quarter wavelength long. Consequently, at this frequency, the resistors R1 and R2 have no effect on the circuit, and all the input power is reflected from the 0- and 90-degree ports and appears at the output. At other frequencies, some input power is dissipated

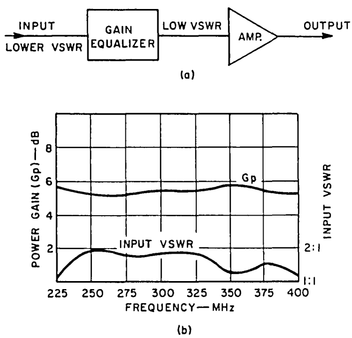


Fig. 13— Typical amplifier/gain equalizer-connection and performance data.

in resistors R1 and R2, so that only a fraction of the input reaches the output, i.e., the input is effectively attenuated to some extent. The amount of attenuation gradually increases as the operating frequency deviates from the frequency f_o. The amount of attenuation at any given frequency and the rate of change of attenuation across the frequency band is determined by the values of resistors R1 and R2. The total amount of input power the device can handle is determined by the characteristics of the quadrature combiner and the dissipation capabilities of resistors R1 and R2.

The design of a gain equalizer is illustrated by the following example in which the amplifier to be equalized is assumed to have a low input VSWR and a gain that gradually increases toward the low-end of the band at which point it is 3-dB higher than at the high end. In order that the output power from the equalizer is 3-dB less than the input power at any given frequency, both the 0- and 90-degree ports must be terminated so that they present a VSWR that results in a reflected power equal to the expected output power from the equalizer. This VSWR is expressed by the following relationship:

$$\text{VSWR} = \frac{1 + \sqrt{P_r/P_f}}{1 - \sqrt{P_r/P_f}}$$

where P_f is the input power and P_r is the power (disregarding any insertion losses) that is reflected to the output.

For an attenuation of 3 dB (i.e., $P_r = 0.5\ P_f$), the VSWR presented by the 0- and 90-degree ports should be 5.8 to 1. A semicircle that corresponds to a VSWR of 5.8 to 1 is plotted on the capacitive side of the Smith chart shown in Fig. 14. The electrical length of the transmission lines connected to the 0- and 90-degree ports of the quadrature combiner is

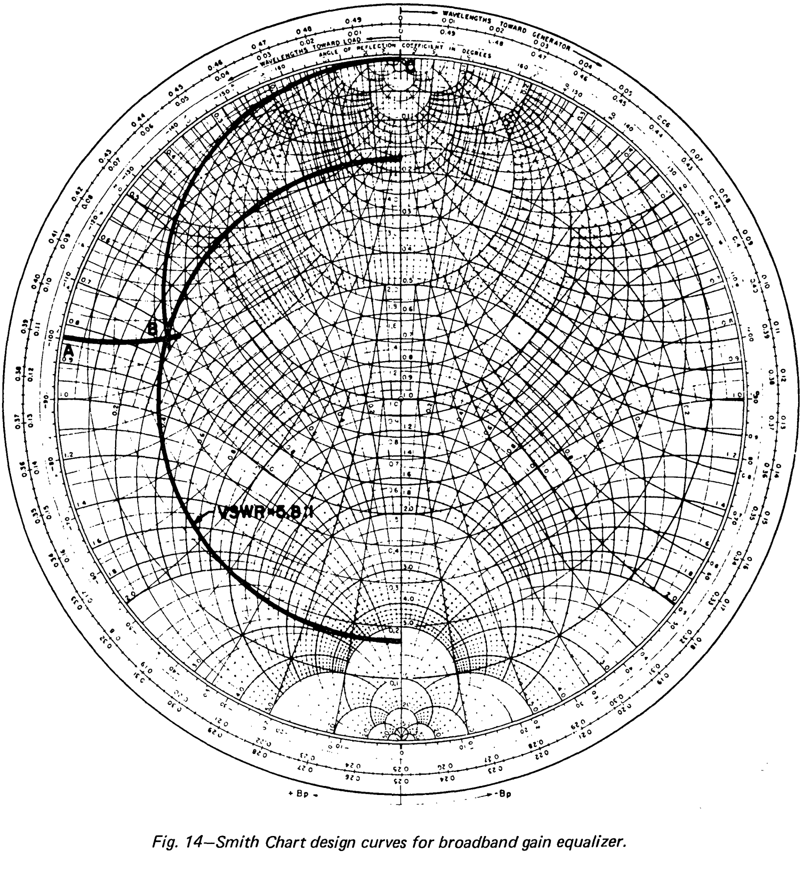


Fig. 14—Smith Chart design curves for broadband gain equalizer.

one-quarter wavelength at 400 MHz. At 225 MHz, the electrical length of these lines is reduced to 0.14 wavelength (i.e., 0.25 λ x 225/400 = 0.14 λ).

The point A shown on the Smith chart corresponds to a distance of 0.14 wavelength from the open end of the line at 225 MHz. The point B shown on the Smith chart is determined by the intersection of the constant susceptance circle drawn through point A and the circle for a VSWR of 5.8 to 1. The normalized admittance at point B defines the resistor value, as follows:

$$R = \frac{50 \text{ ohms}}{0.45} \approx 100 \text{ ohms}$$

The amount of attenuation at any frequency can be determined from the VSWR values on the constant admittance circle through points B and C. The 225-to-400-MHz frequency band is represented by the shorter arc between these points.

Combined-Transistor Stage

In many instances, the power-output requirements of transmitters far exceed the capability of a single transistor; the circuit designer is then forced to use combinations of transistors. Quadrature combiners have the ability to channel the reflected power from an amplifier into the waste port of the combiner. The mismatch at the input of the individual amplifiers is of small concern except for the reduction in gain that results. The individual amplifiers in the combination can be made simpler than the amplifiers used in a direct cascade of single-ended stages. This simplification can be effected only in the input matching network. As mentioned previously, the requirements of the output matching network are the same for both single-ended and combined-pair transistor stages.

In the simplification of the individual amplifiers of a combined-pair stage, the first step can be to reduce the number of circuit elements in the input matching network. This simplification is apparent from a comparison of the input networks for the circuits shown in Figs. 5 and 9. The resulting deterioration in the performance at the low end of the frequency band is relatively unimportant provided that the gain in this region is not less than that at the high end of the band.

When transistors are to be combined by use of quadrature combiners, several factors must be considered. An amplitude unbalance of ±0.5 dB exists between the 0- and 90-degree ports. The relative power levels at these ports varies over the frequency band as shown in Fig. 15. As a result of these variations, the individual amplifiers of a

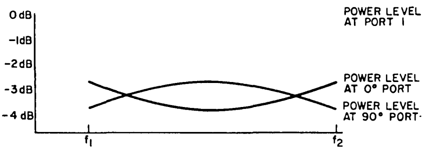


Fig. 15— General coupling characteristics of a quadrature combiner over an octave bandwidth.

combined pair, such as shown in Fig. 16, are subjected to unequal operating conditions. Moreover, the amplifier that is driven harder at the low and high ends of the bands will have the lighter drive at mid-band. For the other amplifier, the converse conditions are applicable.

The performance data shown in Fig. 16 show the effects of combining two amplifiers. These data were obtained with an input duty factor of 50 per cent and a constant peak output power of 55 watts. Further combinations do not require the use of quadrature combiners because there are no high VSWR's and, therefore, no high reflected power to be dissipated. For such conditions, simpler and less expensive combiners may be used. Other power combiners that may be used include the Wilkinson type, i.e., a simple transmission-line network formed by quarter-wavelength (at 400 MHz) 70-ohm lines that are jointed at one end and separated by 100 ohms at the other ends. Fig. 17 shows the circuit configuration and performance data for an amplifier chain that uses the latter type of power combiner. This amplifier chain can be driven to provide up to 110 watts of peak output power at a duty factor of 50 per cent.

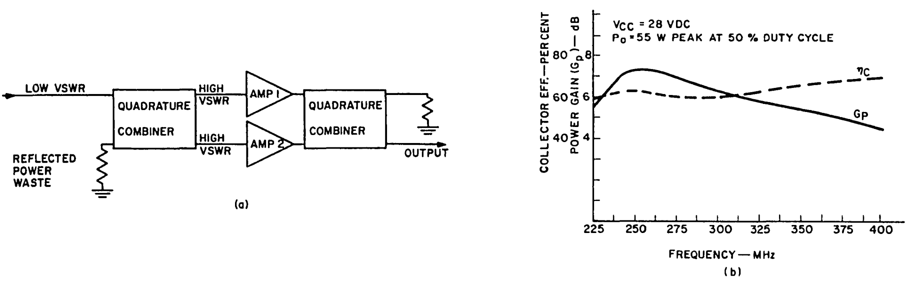


Fig. 16—Two broadband amplifiers combined by use of two quadrature combiners to obtain a low input VSWR: (a) circuit configuration; (b) performance data.

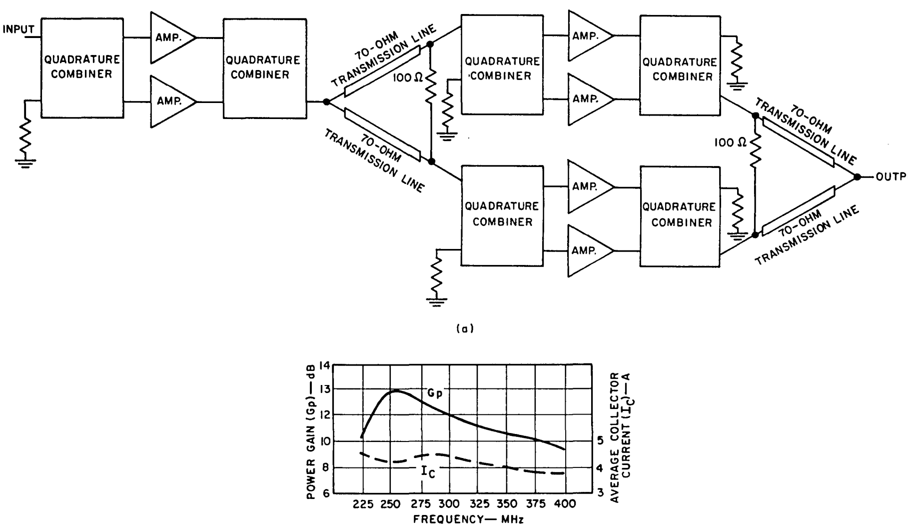


Fig. 17—110-watt broadband amplifier chain using transistor combinations: (a) circuit diagram; (b) performance data.

References

1. C. Leuthauser and B. Maximow "16- and 25-Watt Broadband Power Amplifiers Using RCA-2N5918, 2N5919, and TA7706 UHF/Microwave Power Transistors," Application Note AN-4421, RCA Solid State Division, Somerville, N.J.
2. G.L. Matthaei, "Table of Chebyshev Impedance-Transforming Networks of Low-Pass Filter Form," *Proc. IEEE*, August 1964.
3. F. Katnack, "High-Power VHF-UHF Communication-Surveillance Transistors," Final Report, Contract DAAB07-69-0327, U.S. Army Electronics Command, Fort Monmouth, N.J.

RCA
Solid State Division

RF Power Transistors

Application Note AN-6084

High-Power Transistor Microwave Oscillators

G. Hodowanec

Low-power transistor oscillators that provide power outputs of up to several hundred milliwatts have become important components in microwave communications and test systems. Microwave transistors are rapidly replacing electron tubes in fundamental-frequency signal sources and local oscillators at L- and S-band frequencies. Such transistors are also available for frequency-doubler oscillators and fundamental-frequency oscillators that drive frequency multipliers in C- and X-band power sources. Low-level transistor signal sources that feature low residual FM noise, good frequency stability, and a capability for voltage tuning and phase locking are currently being produced at relatively low cost. These sources, which are very competitive with the newer diode and bulk devices, are available in a wide range of options from a growing number of commercial suppliers.

During recent years, a growing interest has evolved in higher-power signal sources that can supply several watts of fundamental-frequency oscillator power at L- and S-band frequencies. If the low noise level and frequency stability of the low-level signal sources can be maintained, such higher-level sources will simplify system requirements and consequently reduce system costs, and the system reliability and performance required in today's highly competitive communications and test-equipments systems can still be retained.

This Note describes a rather novel, simplified approach to the design of transistor microwave power oscillators. This approach, which may be considered an extension of the more familiar techniques used in the design of large-signal class C power amplifiers, has resulted in the design of L- and S-band power sources that provide power output of 1 to 10 watts. These power sources offer high efficiency, apparently have low residual FM noise and very good frequency stability, and are readily adapted to voltage-tuning and phase-locking techniques.

GENERAL CONSIDERATIONS

In selecting a transistor for a power oscillator, the circuit designer should realize that any transistor capable of power amplification is also suitable for power oscillation. The basic requirements of a transistor oscillator, shown in Fig. 1, are very similar to those of a class C transistor power amplifier. In each case, the transistor must provide power gain at the desired operating frequency. The major difference is that the oscillator must include a feedback network that couples a portion of the power output back to the input circuit in the proper phase to sustain oscillations. The oscillator power delivered to the load is the equivalent amplifier power output less the amount of power fed back to the input circuit and any power loss in the feedback network. In the design of an oscillator circuit, therefore, the approach used can be very similar to that employed in the design of an amplifier, but must be extended to include the design of the required feedback network.

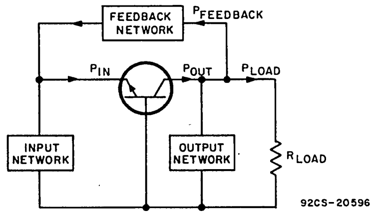


Fig. 1—Basic requirements of a transistor oscillator.

The choice of the proper transistor and the optimum circuit configuration for a transistor microwave oscillator are largely determined by the circuit power output and efficiency required over the frequency range of interest. In general, these requirements will be similar to those necessary for good amplifier performance.

The common-emitter configuration has moderate input and output impedances, and thus simplifies matching requirements in the feedback loop. The high power gains of this configuration, together with lower feedback losses, can result in a highly efficient oscillator circuit. This mode of operation, however, is generally limited to frequencies much below the gain-bandwidth product (f_T) of the transistor because operation of this configuration at higher frequencies may result in power-output and frequency instabilities that can be avoided in the other configurations.

The common-base configuration has the lowest input impedance and the highest output impedance. This impedance relationship results in high amplifier power gains, especially at frequencies above the f_T of the transistor for which the current gain is still appreciable. The feedback loop, however, must match significantly different impedances. Unless this match is maintained, the feedback loop can be lossy. More feedback energy may be provided to compensate for this loss, but the circuit then becomes less efficient. A relatively easy start for self-excited oscillations can be achieved with the common-base configuration because this type of oscillator configuration initially operates under the class A conditions. Once oscillations start, bias conditions can be arranged for a shift to class B or C conditions to obtain higher circuit efficiencies.

The common-collector configuration has a high input impedance and a moderate output impedance. Matching requirements in the feedback loop, therefore, are not as severe as those of the common-base configuration. The common-collector circuit requirements are similar to the common-base requirements. The fact that the collector terminal can be grounded results in a significant advantage for the common-collector configuration. As a result of this factor, packaged devices can be constructed with very low thermal resistance; the power-handling capability of the devices, therefore, is substantially increased.

BASIC MICROWAVE OSCILLATOR CIRCUITS

At microwave frequencies, the most effective transistor configuration for an amplifier is the common-base type. This type of configuration can provide higher gains, efficiencies, and stabilities at higher frequencies (frequencies above the transistor f_T) than any other configuration. Because an oscillator may be considered as a regenerative-feedback amplifier, these conditions also apply to the oscillator under well-designed conditions. The basic microwave oscillator circuit considered in this Note is the common-base feedback oscillator shown in block form in Fig. 1. The feedback network can be an external loop, an internal loop, or a combination of internal and external elements. Although many variations of the feedback networks are possible, three general families of oscillators, shown in Fig. 2, are found to be effective at microwave frequencies.

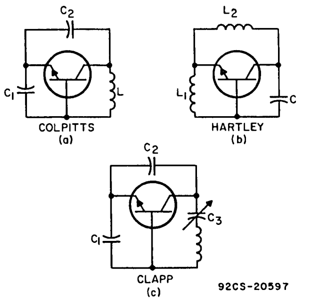
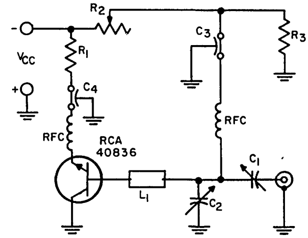


Fig. 2—Basic transistor oscillator circuits: (a) Colpitts, (b) Hartley, and (c) Clapp.

The **Hartley** oscillator circuit employs an amplifying element together with a tapped-inductor tuned circuit. The **Colpitts** oscillator uses an amplifying element with a capacitive voltage divider in the tuned circuit. The **Clapp** oscillator is simply a modified Colpitts circuit in which another capacitance is added in series with the tuned-circuit inductance. This modification results in improved frequency stability, but does not alter the feedback mechanism. In all these cases, the feedback elements form a part of the resonant LC circuit which determines the frequency of oscillation. In practice, the frequency-determining tuned circuit is also part of the output impedance-matching network as well as the feedback loop. On the basis of these requirements, the basic Hartley and Colpitts oscillators must satisfy a number of conditions simultaneously if the circuit is to be an efficient oscillator. Because of the difficulty involved in the construction of high-Q tapped inductors at the low inductance values required for microwave oscillations, the Colpitts type of oscillator circuit has generally been preferred at microwave frequencies. In many cases, the parasitic capacitances of the packaged transistor can be used to advantage in establishment of the required capacitive divider employed in the feedback network.

A typical Colpitts oscillator circuit that uses lumped-circuit elements is shown in Fig. 3. This circuit, which uses an RCA-40836 transistor, can develop a power output of 0.6 watt at



C_1 C_2 = 0.35 to 3.5 pF, Johanson 4701 or equivalent
C_3 C_4 = 100 pF, feedthrough, Allen Bradley FA5C or equivalent
L_1 = 0.18-by 0.30-by 0.005-inch copper strap
R_1 = 10 ohms, 1/2 watt
R_2 = potentiometer, 500 ohms
R_3 = 1200 ohms, 1/2 watt
RFC = 11-mil wire, 0.30 inch long   92CS-20598

Fig. 3—A lumped-element circuit that requires no external feedback loops for sustained oscillation.

2.0 GHz, and has an over-all circuit efficiency of 22 per cent when operated from a 21-volt supply. No external feedback loop is required. The feedback required to sustain oscillation is provided by the parasitic capacitances of the package of the 40836 transistor. In the oscillator circuit shown in Fig. 3, the collector of the transistor is grounded, and this transistor, at first glance, appears to be connected in a common-collector configuration. In this circuit, however, the collector of the transistor is grounded to improve the heat dissipation of the device, and the circuit is actually a common-base configuration, as is apparent when the basic elements of the circuit are redrawn as shown in Fig. 4(a). The circuit is then recognizable as the basic Clapp circuit shown in Fig. 2(c). The equivalent tuned circuit for this oscillator is shown in Fig. 4(b). In the common-base configuration, the feedback signal is returned between emitter and base. As the emitter goes negative, the collector also goes negative, and potentials are developed across the feedback capacitors C_{CE} and C_{EB}

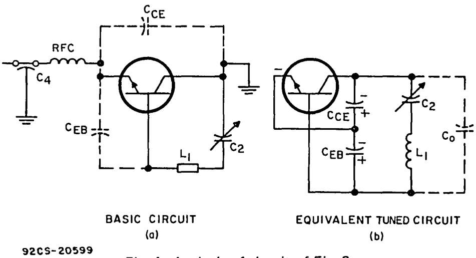


Fig. 4—Analysis of circuit of Fig. 3.

as shown. The feedback voltage across the capacitor C_{EB}, which is across the emitter-base junction, also goes negative. The required in-phase relationship at the emitter is, therefore, maintained in this common-base oscillator circuit.

Several limitations of the basic Colpitts oscillator circuit can be observed from the equivalent circuit shown in Fig. 4(b). For example, the dynamic output capacitance C_O of the transistor appears across the feedback capacitances C_{CE} and C_{EB}. The series combination of C_{CE} and C_{EB} can be made small at microwave frequencies; the highest frequency of oscillation (within limits of the device parameters) is then established largely by the values of C_O and the minimal inductances present in this configuration.

The ratio of the collector-to-emitter capacitance C_{CE} to the emitter-to-base capacitance C_{EB} also establishes the impedance match between input and output in the feedback loop. The large impedance ratios of the common-base configuration require that the reactance of C_{EB} be very low compared to that of C_{CE}. The collector-to-emitter feedback capacitance C_{CE} of a microwave packaged transistor is usually very small; in some cases, however, it may be necessary to increase the value of C_{EB} externally to assure proper feedback levels in the common-base configuration. This adjustment in C_{EB} (and possibly C_{CE}), needed for feedback matching, can result in an effective increase in feedback losses and may impose another limitation on the high-frequency performance of this oscillator. In addition, the series LC circuit, L_1 and C_2, together with capacitor C_1, must also satisfy the requirements of an impedance match to the external load of this oscillator, as is apparent from Fig. 3.

The previous discussion indicates that many diverse and frequency-sensitive requirements are demanded of the complex output tuned circuit of typical Colpitts (or Hartley) oscillators. These requirements, to a large measure, can be satisfied over a limited frequency range with low-power transistors which have relatively large input and output impedances. With careful design and choice of the proper transistor, wide-band oscillator performance with reasonable efficiencies is also possible. However, for high-power transistor oscillators, in which the impedance-matching ratios for both the feedback and output networks are so great that it becomes more and more difficult to satisfy the diverse requirements of the basic Colpitts tuned circuit, it is necessary to return to the basic oscillator concept shown in Fig. 1. The oscillator-frequency-determining resonant circuit is placed in a portion of the feedback loop and is divorced from the output matching network. In this way, both the feedback and output matching networks can be optimized, and the oscillator design becomes simpler so that the basic "regenerative feedback" amplifier design concepts can be applied.

RESONANT FEEDBACK-LOOP OSCILLATORS

An examination of Fig. 1 indicates that the frequency-determining portion of the oscillator can be separated from the output matching network by placement of a high-Q LC resonant network in the collector-to-emitter feedback network, the input matching network, or the base-to-ground circuit. In each case, the output network can be designed from large-signal class-C collector-load conditions, while the feedback network can be treated essentially independently of this network. Because of these degrees of freedom, large-signal (i.e., high-power) oscillators can be designed from large-signal amplifier parameters given by most power-transistor manufacturers. The design conditions for placement of the resonant network in the input (emitter-to-base) circuit and in the collector-to-emitter feedback network, the two most useful arrangements at microwave frequencies, are analyzed in the following paragraphs.

Resonance in Emitter-to-Base Circuit

Large-signal impedances are generally specified by most transistor manufacturers as an input impedance and a collector-load impedance. Analysis of a large-signal oscillator can be simplified if the output of the transistor is considered as a dependent generator that has an internal impedance equal to the conjugate of the specified load impedance. For a typical microwave power transistor operating at L-band frequencies, the large-signal simplified model for the transistor is as shown in Fig. 5(a). The input impedance is usually inductive. The output dependent generator is generally capacitive at low L-band frequencies, but may become inductive in a packaged device at S-band frequencies. In Fig. 5(b), the model is converted to its parallel equivalent, and the feedback capacitance C_{CE} is added to the model. At resonance (i.e., the frequency of oscillation), the input inductance is tuned out by an external high-Q capacitor C, so that only the real component $R_{IN}{}^1$ of the complex impedance remains in the model. The dynamic output capacitance $C_O{}'$ is also tuned out by the output matching network which introduces the external shunt element $X_O{}'$. The simplified model for the resonant condition, shown in Fig. 5(c), indicates that the output voltage developed across the new collector load resistance, $R_L{}''$, is fed back to the emitter [in phase, as shown in Fig. 5(d)] by the RC network formed by $R_{IN}{}^1$ and C_{CE}. In this manner, the desired portion of the output power can be returned to the input to sustain oscillations. The ratio of X_{CCE} to R_{IN}' determines the level of the feedback. Minor changes in the value of R_{IN}' can be achieved by adjustment of the X_{IN}' component of the input impedance, i.e., by adjustment of package lead lengths. However, more meaningful adjustments can be made by variation in the feedback capacitance C_{CE}. Because of the RC time constant involved in the feedback network in this mode, the method is generally limited to L-band and lower oscillator frequencies for which this time constant is not a limiting factor.

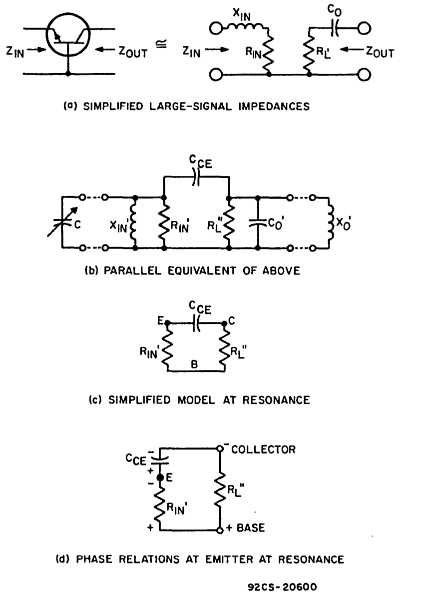


Fig. 5—Analysis of emitter-to-base resonant-loop circuit.

Resonance in Collector-to-Emitter Circuit

When the resonant portion of the feedback network is placed in the collector-to-emitter circuit, higher frequency of oscillation is possible. This increased frequency capability is attributed largely to the removal of any limiting time constants in the feedback network. Fig. 6(a) shows the large-signal impedances for this type of oscillator arrangement. Operation is assumed to be at S band; the output dependent generator is, therefore, inductive because of package parasitics. An external LC feedback loop is connected across the collector-to-emitter terminals of the transistor as shown in Fig. 6(b). The values of the inductance L and the capacitance C are chosen so that the series combination of these components and the reactances X_{IN} and X_O is still slightly inductive at the operating frequency. Capacitor C serves to "tune" this inductance so that the resultant is the variable inductance L′ that shunts the feedback capacitance C_{CE}' as shown in Fig. 6(c). In a practical circuit, capacitor C also provides dc blocking between the input and output bias networks. The feedback capacitor C_{CE} and the equivalent inductance L′ can be made very small; the resonance frequency of this combination, therefore, can be made very high. At resonance, a real impedance R_O appears across the tuned circuit formed by L′ and C_{CE}. The value of the real impedance depends upon the Q of this tuned circuit and any circuit losses. As shown in Fig. 6(d), the voltage developed across the collector load R_L' is fed back, in phase, to the emitter by a purely resistive voltage divider. Both R_{IN} and R_O can be adjusted externally to some extent, independently of the collector-load resistance R_L', to obtain the optimum feedback match. Because the feedback network does not involve any time constants and the parasitic elements of the packaged device can be "lost" in this feedback network, this arrangement is capable of operating at a much higher oscillator frequency than the previous case. Feedback losses are low; oscillator efficiency, therefore, can be made only slightly less than that obtained for class-C amplifier conditions.

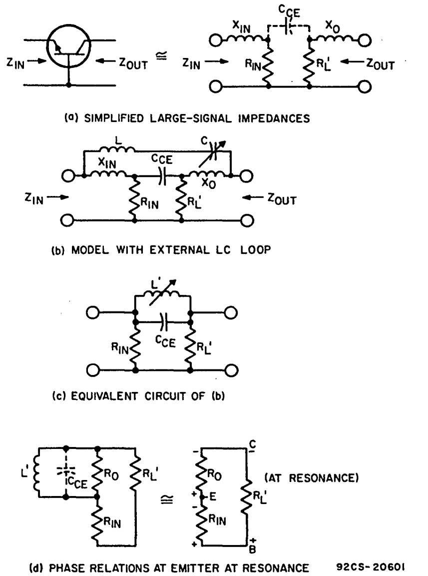


Fig. 6—Analysis of collector-to-emitter resonant-loop circuit.

DESIGN EXAMPLE (4-watt, 420-MHz Power Oscillator)

The approach employed in the design of practical high-power transistor microwave oscillators can be illustrated by use of a design example. In this example, the objective is to design a transistor oscillator circuit that provides a power output of 4 watts at an operating frequency of 420 MHz. A tuning range of 400 to 450 MHz (i.e., a bandwidth of 12 per cent) is also desired.

The 2N3375 rf power transistor is suitable for use in the oscillator circuit. The published data on the 2N3375 indicate that the transistor can provide a power output of 4 watts and a power gain of 6 dB at 400 MHz when operated from a collector supply of 28 volts. The input and output impedances of the 2N3375 transistor at 420 MHz, determined from the large-signal parameters specified in the published data, are as follows:

$$Z_{in} \cong 8 + j13 \text{ ohms}$$
$$Z_{out} \cong 17 - j25 \text{ ohms}$$

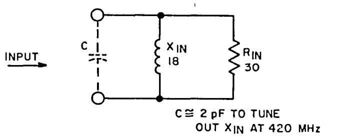
These impedance values are determined for saturated collector currents in the order of 400 milliamperes.

A resonant feedback loop which is tuned in the emitter-to-base branch was chosen as the optimum configuration to achieve the desired frequency tuning range of 400 MHz to 450 MHz. Because of the requirement for a 1-dB bandwidth of 12 per cent, a tapered-line section was chosen to transform the 17-ohm real collector-load impedance to the 50-ohm terminal impedance.[1] The 25-ohm capacitive reactance of the output dependent generator was "tuned out" with a lumped inductance (i.e., a proper length of 20-mil wire) of approximately 13 nanohenries.

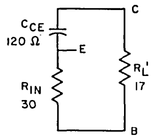
The input impedance of approximately 8 + j13 ohms is converted to its parallel equivalent as shown in Fig. 7(a). A capacitance of approximately 2 picofarads is required to tune out the input reactance X_{IN} at 420 MHz. A high-Q air-piston variable (1-to-10 picofarad) capacitor was chosen for this frequency-tuning element.

The measured value of feedback capacitance C_{CE} for the TO-60 package that houses the 2N3375 transistor is in the order of 3 picofarads. The reactance of this capacitance at 420 MHz is in the order of 120 ohms, as shown in Fig. 7(b). The ratio of $X_{C_{CE}}$ to R_{IN}, therefore, is approximately 4 to 1. In other words, one-fourth of the output power, in the proper phase, is available at the input of the transistor. This amount of feedback should be adequate because, under class C conditions, the 2N3375 transistor provides a power gain of 6 dB at 400 MHz. The time constant $C_{CE}R_{IN}$, which is very much shorter than a quarter cycle at 420 MHz, can be neglected.

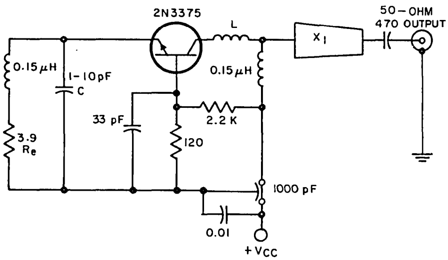
The test oscillator shown in Fig. 7(c) employs a common-base configuration. Forward bias of a few mils is established by the 2200- and 120-ohm resistor network. The base of the 2N3375 transistor is returned to electrical ground through a 33-picofarad ceramic-disc capacitor. This capacitor is broadly self-resonant at 420 MHz. The emitter resistor R_e is used to establish class-C bias conditions once the rf oscillations have



(a) INPUT CONDITIONS FOR 2N3375 AT 420 MHz



(b) FEEDBACK NETWORK FOR 2N3375 AT 420 MHz



(c) TEST OSCILLATOR CIRCUIT 92CS-20602

Fig. 7—Design of a 4-watt, 420-MHz oscillator.

started. The transformer X_1 is a tapered-line section over which the impedance varies from 17 to 50 ohms.

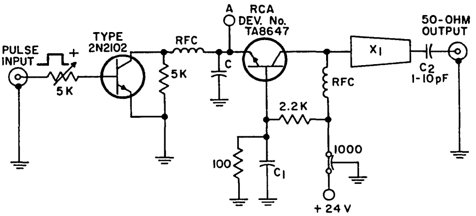
Evaluation of the test oscillator indicates that adjustment of capacitor C provides a tuning range of 380 to 490 MHz. The test oscillator develops a power output greater than 4 watts over the range of 400 to 450 MHz, and has an over-all circuit efficiency that exceeds 40 per cent over this frequency range. The output power is free of any spurious responses, and the FM noise, on the basis of spectrum-analyzer comparisons with known low-FM-noise sources, appears to be low. A power output of 5.2 watts at the design frequency of 420 MHz was achieved by optimization of the inductance L and the line section X_1. For this condition, the circuit efficiency was in the order of 48 per cent.

SAMPLE CIRCUITS

Several sample oscillators that illustrate the effectiveness of the techniques described in this Note have been constructed and evaluated. Circuit description and performance are given below. In addition, some proposed oscillator circuits are also described.

Pulsed Oscillator

Fig. 8 shows an oscillator circuit that can be cleanly pulsed with pulse lengths as short as 10 microseconds and that has a duty factor of 1 per cent. Power output can be controlled with the pulse input voltage, or with the 5000-ohm series potentiometer control to the 2N2102 switch if a fixed pulse input is used. A positive pulse polarity is required. The oscillator frequency is controllable over the range of about 1.1 to 1.4 GHz. Power output is between 3 and 4 watts over this frequency range. The RCA Dev. No. TA8647 transistor used in this circuit is a stud-mounted stripline transistor which is bonded in the common-emitter configuration. In the pulsed oscillator, however, this transistor is connected to operate in the common-base mode. The oscillator output is clean with very good frequency stability. The frequency remains essentially constant with supply-voltage variations from 18 to 28 volts. The frequency of the oscillator is also relatively immune to wide variations in the load terminating the oscillator. Injection phase-locking can be achieved at point A.



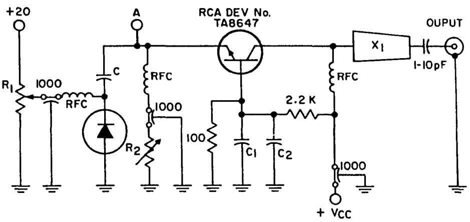
C: 0.3–3.5 pF (frequency control)
C_1: Choose to be broadly self-resonant at f_o
X_1: Complex-to-real tapered-line transformer
C_2: Output match tuning (fine control)

92CS-20603

Fig. 8–Pulsed oscillator that can supply a power output of 3 to 4 watts over a frequency range of 1.1 GHz to 1.4 GHz.

Voltage-Controlled Oscillator

The oscillator circuit shown in Fig. 9 is a modification of that shown in Fig. 8. In the modified circuit, a varactor diode is included in the emitter-to-base tuning circuit. The tuning range is limited by the output matching network to about 300 MHz. Frequency control is provided by potentiometer R_1. A power output control R_2 is included in the circuit to set the level of the oscillator output. With this method, power output is controlled without affecting the frequency of oscillation. Injection phase-locking can be achieved at point A.



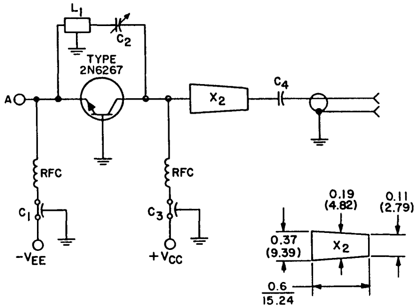
C: DC blocking capacitor
C_1: Choose for self-resonance at low end of tuning range.
C_2: Choose for self-resonance at upper end of tuning range.
R_1: Frequency control
R_2: P_{out} level control

92CS-20604

Fig. 9– Voltage-controlled oscillator.

1.7-GHz Oscillator Circuit

Fig. 10 shows a typical oscillator circuit in which the resonant feedback loop is placed in the collector-to-emitter circuit. As pointed out above, higher-frequency performance is possible with this mode of operation. Evaluation of this circuit shows that a power output of 5 to 6 watts is obtainable at 1.7 GHz when a 28-volt supply is used. Frequency stability at 1.7 GHz is better than 0.1 per cent for voltage or current excursions of ±25 per cent. Oscillation (essentially on frequency) starts as soon as any collector current is drawn. Frequency drift is less than 1 MHz from cold-start to the stabilized conditions of one hour of operation. The second-harmonic power output is more than 45 dB down from the fundamental. Evaluations of this oscillator with a microwave spectrum analyzer indicate that the FM noise is very low, although direct measurements have not been made on the circuit. Phase-locking can be achieved at point A.



92CS-20605

C_1, C_3: Filtercon, Allen-Bradley SMFB-A1, or equivalent
C_2: 0.3–3.5 pF, Johanson 4700, or equivalent
C_4: 300 pF, ATC–100 or equivalent
L_1: 1.0 in. section miniature 50 Ω cable, or microstrip equivalent
RFC: 3 turns, No. 32 wire, 1/16 in. ID, (1.59 mm) ID, 3/16 in. (4.76 mm) long
X_2: 13-mil thick Teflon-Kapton double-clad circuit board
Line X_2 is exponentially tapered
NOTE: Oscillator is single-screw tunable 1.6 GHz to 1.8 GHz

Typical Performance

f_o	V_{cc}	P_{out}	I_c	η_c
1.7 GHz	20.0 V	4.0 W	550 mA	36%
1.6 GHz	12.5 V	2.3 W	480 mA	37%

Fig. 10–Typical 1.7-GHz oscillator circuit.

Oscillator-Doubler/Tripler

Because oscillators that use the techniques described in this Note operate as true class C circuits (with the feedback and frequency control independent of the output matching network), it is logical to assume that ordinary amplifier-doubler or tripler techniques could also be applied to these oscillators. Fig. 11 shows a proposed circuit of an oscillator/tripler that uses the TA8647 transistor. Idler circuits for f_1 and f_2, as well as the filter and matching network for f_3, can be realized in microstrip form. This oscillator-multiplying action has been confirmed with uhf transistors in previous tests.

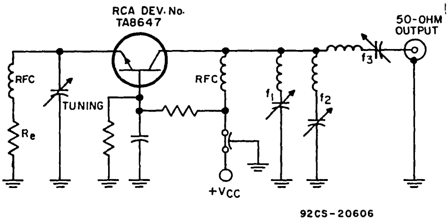


Fig. 11—Proposed oscillator/tripler microwave power source.

1.68-GHz Oscillator Circuit

Fig. 12 shows a simple 1.68-GHz oscillator circuit suitable for radiosonde service. This circuit, which uses the TA8647 transistor, is an example of a circuit in which the high-Q frequency-determining network is placed in the base-to-ground circuit. Capacitor C is selected to be series-resonant with the common-base inductance at the operating frequency. The base, therefore, is effectively placed at rf ground at this frequency only. At 1.68 GHz, the collector load of the TA8647 transistor is effectively about 5.5 ohms real impedance, which simplifies the design of this oscillator. A 5.5-ohm-to-50-ohm tapered-line output transformer is used to keep the second-harmonic output more than 40 dB down from the fundamental output power. Package parasitics provide the correct level of capacitor feedback to sustain oscillations at 1.68 GHz, with no further external circuit adjustments needed for the range of about 1.4 to 1.8 GHz.

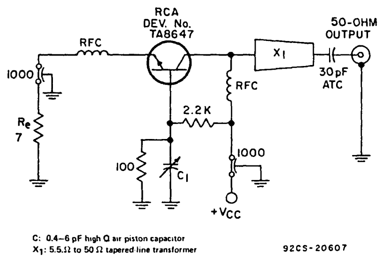


Fig. 12—1.68-GHz radiosonde oscillator.

Evaluation of this oscillator at 1.678 GHz shows that the oscillator frequency remains constant at 1.678 GHz over a range of supply voltages from 20 to 28 volts. For operation at the design value of 24 volts, power output at 1.678 GHz is 1.2 watts, and the circuit efficiency is 29 per cent for an emitter resistance R_e of 7 ohms. At 28 volts, power output is 1.9 watts, and the circuit efficiency is 28 per cent. At 20 volts, the power output is decreased to 0.4 watt, and the circuit efficiency is reduced 20 per cent. However, this performance can be substantially improved simply by modifying the output transformer for operation under the new load conditions for this transistor at the 20-volt supply level.

CONCLUSIONS

Although the techniques described for achieving high power from transistor oscillators are not new, they have not been well understood in the past. The evaluation made in this Note of these oscillator circuits has shown not only that high-powered oscillators with good circuit efficiency are obtainable, but that good frequency stability and low noise can also be expected. An understanding of the techniques discussed in this Note will make possible the design of a wide variety of power sources at very low cost without sacrifice of the performance required in the most advanced system.

REFERENCE

1. Womack, C. P., "The Use of Exponential Transmission Lines in Microwave Components," **IEEE Transactions on Microwave Theory and Techniques**, Vol. MTT-11, March, 1962.

RCA
Solid State
Division

RF Power Transistors

Application Note
AN-6118

10-, 16-, 30-, and 60-Watt Broadband (620-to-960-MHz) Power Amplifiers Using the RCA-2N6266 and 2N6267 Microwave Power Transistors

by J. Locke

This Note describes basic broadband circuit design and the design of the following 620-to-960-MHz, 28-volt-V_{CC} amplifiers:

(1) a 10-watt 2N6266 driver amplifier capable of 10 ±0.8-dB power gain, 42- to 55-percent collector efficiency, and a maximum input VSWR of 3.4:1 at an input power of 1 watt.

(2) a 16-watt 2N6267 power amplifier capable of 8±0.5-dB power gain, 42- to 55-percent efficiency, and a maximum input VSWR of 2.5:1 at an input power of 2.5 watts.

(3) a quad coupler design.

(4) a 30-watt module producing 15.9±0.4-dB power gain, 42- to 49-percent collector efficiency, and a maximum input VSWR of 2.6:1 at an input power of 0.75-watt.

(5) a 60-watt module producing 15±0.5-dB power gain, 26- to 34-percent collector efficiency, and an input VSWR of 1:1 at an input power of 1.75 watts.

Broadband Design

The following broadbanding steps are well established:

1. Determine the required broadband operating conditions.
2. Select the proper transistor and predict the tradeoffs.
3. Estimate broadband impedance variations.
4. Design tunable narrowband circuits for the band of interest.
5. Optimize transistor performance in narrowband circuits and accurately measure the impedance variations with frequency.
6. Choose the broadband approach to satisfy the impedance variations obtained.
7. Design broadband circuitry and probe for the predicted impedance variations.
8. Confirm circuit design with rf performance.

CIRCUIT DESIGN AND PERFORMANCE

10-Watt 2N6266 Driver Amplifier

In the design of the driver amplifier (the fabricated amplifier is shown Fig. 1), initial impedance values were obtained from the impedance curves in the 2N6266 data sheet; the curves are specified under saturated-output power conditions. These impedance values were then utilized as a starting point for the design of the driver amplifier. Three narrowband test circuits were designed that would be capable of matching the impedance of the 2N6266 at the end- and mid-frequency points of the 620-to-960-MHz frequency spectrum. The circuit impedances were measured by slotted-line techniques at the optimum operating condition to determine the exact impedance variation across the frequency band. Narrowband optimization at the band end points and at three points equally distributed within the band provided the impedance variations shown in Fig. 2.

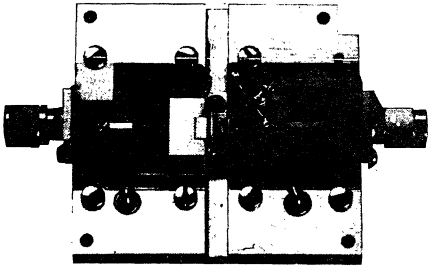


Fig. 1– Assembled 2N6266 driver amplifier.

Because of the moderate cost, reproducibility, small size, and availability of broadbanding techniques, a hybrid combination of stripline and lumped elements on alumina was utilized. The broadband amplifier circuit is shown in Fig. 3. The following is a synopsis of the input and output transformation designs utilized:

Input Circuit: The initial design is derived from two stages of two-step 1/16λ Chebyshev transformation networks based on the Matthaei tables.[1] By using the Matthaei tables with a nominal transistor input-impedance value of 1.67 ohms, the following values are obtained for the parameters listed:

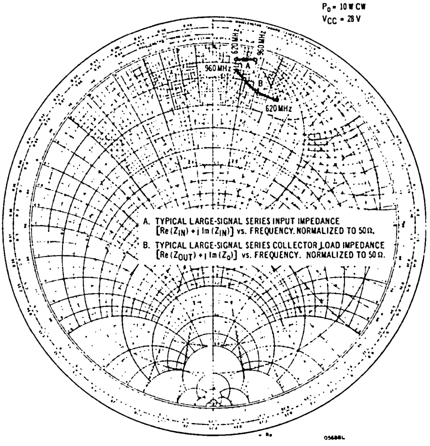


Fig. 2— Impedance variations of the 2N6266.

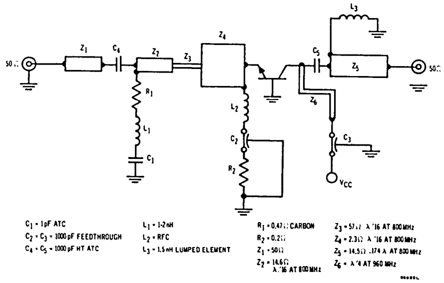


Fig. 3— Schematic diagram of the 2N6266 620- to 960-MHz broadband amplifier.

	1st section (Two-Step Chebyshev)	2nd section (Two-Step Chebyshev)
Ripple attenuation (L_{AV}) =	0.1113	0.6361
Number of steps (n) =	2	2
Transformation ratio (r) =	3	10
Fractional bandwidth (W) =	0.3	0.3

Then, from the same tables:

Z_1 = 14.6 ohms

Z_2 = 57 ohms

Z_3 = 2.32 ohms

Z_4 = 12 ohms

Since the input inductance of the transistor may be utilized as the last Chebyshev $1/16\lambda$ transformation step, Z_1 through Z_3 can provide the transformation to conjugate match the range of measured transistor input impedances.

Numerous articles[2-6] relating the characteristic impedance of stripline to its dielectric and thickness are available. An equation which has been empirically fitted to design curves[7] is the following:

$$Z_O = \frac{377\,h}{\sqrt{\epsilon w}\left[1 + 1.735\,\epsilon^{-0.0724}\left(\frac{w}{h}\right)^{-0.836}\right]}$$

where Z_O is the characteristic impedance of the stripline, ϵ is the dielectric constant, h is the thickness of the dielectric and w is the width of the dielectric. Selection of the dielectric can be made with available curves or the above relationship.

Output Circuit: The initial stripline output transformation is designed to transform with less than a $\lambda/4$ throughout the 620-to-960-MHz range to a capacitance variation (nominal 10-ohm real value). This variation is combined with an inductive shunt to produce an impedance load variation, Fig. 4, consistent with the required load. The required load impedance is shown by line A in Fig. 4. As indicated by the actual impedance load variation, line B, a double-noded rf performance response is expected; this performance is illustrated in Fig. 5. At a frequency somewhat above 620 MHz and at a second frequency close to 960 MHz, the rf performance (output power, collector efficiency) is optimum.

A point-by-point impedance measurement of the completed broadband circuit can be made by slotted-line, polar-display, or computer-aided methods. Results of measurements of a preliminary output transformation design by

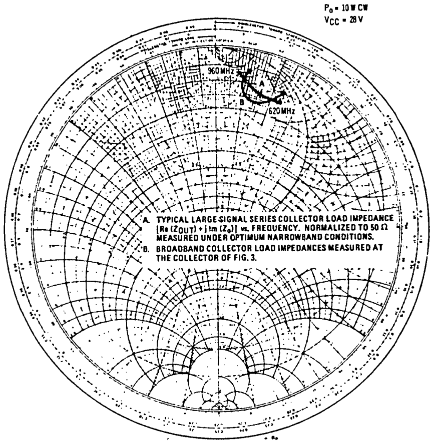


Fig. 4— 2N6266 driver amplifier transformation.

means of a computer-aided automatic network analyzer are shown in Table I. The amplifier was optimized for the rf performance shown in Fig. 5 by adjusting L3 for optimum collector efficiency and output power across the band. The stripline input, Z_4 in Fig. 3, was then adjusted in length to provide minimum input VSWR at the frequency-band end having the lowest gain capability. The series $R_1L_1C_1$ circuitry[8] was utilized to improve the input VSWR and to level the gain capability at other frequencies within the band.

Table I — Computer-Aided Analysis of Preliminary Output Transformation Design

Impedance (Ohms) — 50.0 Ohm System

FREQ	MAGN	ANGLE	REAL	IMAG
550.0	9.15	75.4	2.31	8.85
570.0	10.27	72.0	3.17	9.77
600.0	11.37	63.5	5.07	10.18
625.0	10.53	39.8	8.09	6.74
650.0	6.94	62.4	3.21	6.15
675.0	9.68	66.3	3.89	8.86
700.0	10.79	59.7	5.45	9.31
725.0	11.65	51.4	7.26	9.11
750.0	11.53	42.6	8.50	7.80
775.0	10.88	34.1	9.01	6.10
800.0	9.92	26.8	8.85	4.48
825.0	8.77	23.6	8.03	3.52
850.0	7.75	21.1	7.23	2.80
875.0	6.88	22.8	6.35	2.66
900.0	6.03	23.0	5.55	2.36
925.0	5.37	32.0	4.55	2.84
950.0	5.34	36.0	4.32	3.14
975.0	5.28	41.4	3.96	3.49
1000.0	5.14	45.4	3.61	3.66

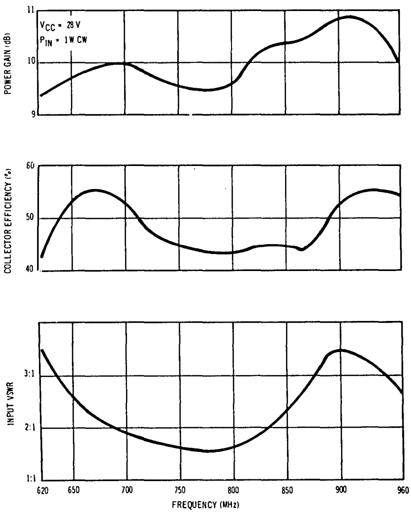


Fig. 5— RF performance of the circuit of Fig. 3.

16-Watt 2N6267 Power Amplifier

Narrowband test circuits were optimized for maximum 2N6267 rf performance within the 620-to-960-MHz frequency range by using the same impedance-measuring procedures as those described for the 2N6266. Saturated-output power levels at 18-watts cw provided the impedance variations shown in Fig. 6. The amplifier schematic is shown in Fig. 7; the fabricated amplifier is shown in Fig. 8.

The following is a synopsis of the input and output transformation designs utilized:

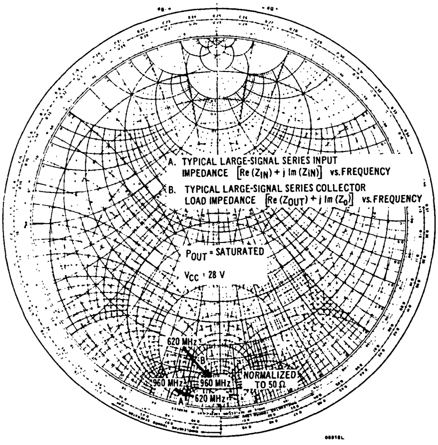


Fig. 6— Impedance variations of the 2N6267.

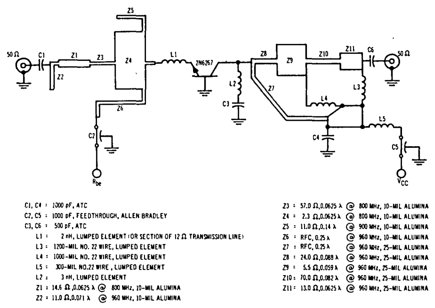


Fig. 7— Schematic diagram of the 2N6267, 16-watt power amplifier.

Input Circuit: The input circuit design for the amplifier is the same as that for the driver described above. Open-stub transmission-line sections were added to provide a lower real value of the conjugate match presented to the 2N6267.

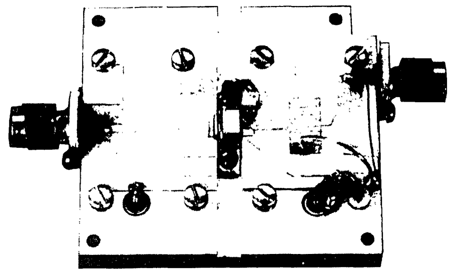


Fig. 8— Fabricated 2N6267, 16-watt power amplifier.

Output Circuit: To supply to the collector the load/frequency variation measured under optimum narrowband conditions, a four-stage stripline hybrid transformation was designed. The initial starting point for the collector transformation design is derived from a four-step (λ/16) transformation network based on the Matthaei tables.[1] By using the Matthaei tables and a nominal transistor load impedance of 6.25 ohms, the following values are obtained:

Ripple attenuator (L_{AV}) = 0.0344

Number of steps (n) = 4

Fractional bandwidth (W) = 0.4

Transformation ratio (r) = 8

Then, from the same tables:

Z_0 = 6.25 ohms

Z_1 = 24.2 ohms

Z_2 = 4.43 ohms

Z_3 = 70.5 ohms

Z_4 = 12.92 ohms

Z_5 = 50 ohms

By maintaining the characteristic impedance values and designing the electrical lengths to match the required load variation, the hybrid-collector-circuit transformation shown in Fig. 7 was produced. The transformation process, illustrated on the Smith chart of Fig. 9, is outlined below:

1. Normalize 50 ohms to 12.92 ohms, combine the lumped-element shunt inductance, and transform 0.0625λ at 960 MHz.
2. Re-normalize to 70.5 ohms, and transform 0.082λ at 960 MHz. Combine with lumped-element shunt inductance.
3. Re-normalize to 4.43 ohms, and transform 0.059λ at 960 MHz.
4. Re-normalize to 24.2 ohms, and transform 0.088λ at 960 MHz. Re-normalize to 50 ohms.
5. Combine with 1.5 nanohenries in shunt at collector. The variation shown at point 5 in Fig. 9 represents those impedances presented to the transistor collector from 620 to 960 MHz. The dashed line represents the optimum load measured under narrowband conditions.

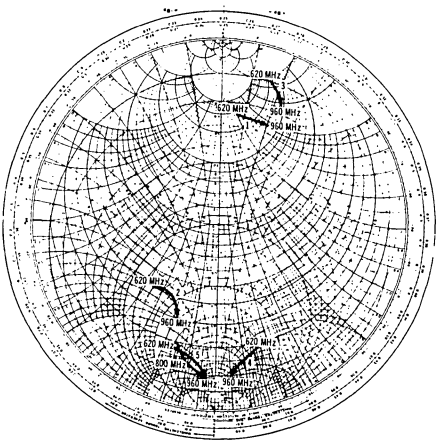


Fig. 9— 2N6267 output transformation.

Fig. 10 shows the actual input/output circuit variation as probed by the Hewlett-Packard network analyzer. Fig. 11 illustrates the HP4810A network analyzer test setup. The rf performance for the 2N6267 alumina power-amplifier is shown in Fig. 12.

30-Watt Module

By combining two final amplifiers as shown in Fig. 13, the rf performance shown in Fig. 14 was produced. The 2N6267 circuit configuration was utilized in the driver position shown in Fig. 15 to provide maximum power gain and input VSWR capability. With an input power of 0.75 watt and a V_{CC} of 28 volts, the configuration shown in Fig. 15 provided the typical performance shown in Fig. 16; the assembled module is shown in Fig. 17. A summary of the performance shown in Fig. 16 is as follows:

Power gain = 15 ±0.4 dB

Power output = 26.5 to 32 watts

Collector efficiency at output = 42 to 49 percent

Module efficiency = 33 to 38.5 percent

Input VSWR – 2.6:1 to 1.5:1

Frequency = 620 to 960 MHz

60-Watt Module

The performance for two combined 30-watt modules operating at an input power of 1.75 watts and a V_{CC} of 28 volts is shown in Fig. 18 and summarized below:

Power gain = 15.0 ±0.5 dB

Power output = 50 to 62 watts

Module efficiency = 26 to 34 percent

Input VSWR = 1:1

Frequency = 620 to 960 MHz

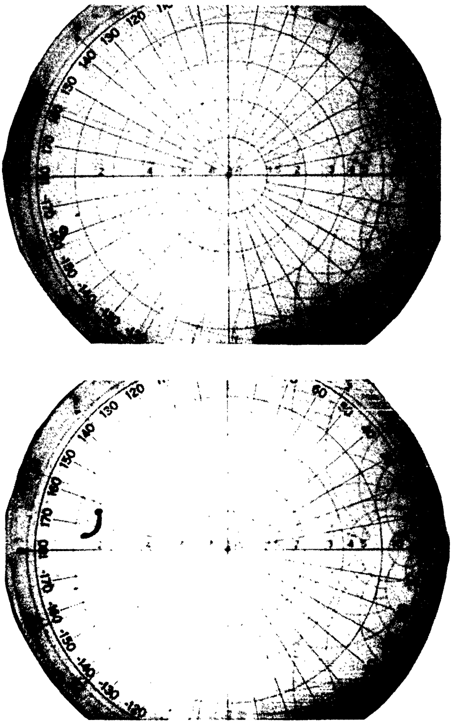


Fig. 10– Actual input and output transformations of the 2N6267 power amplifier as measured on the network analyzer.

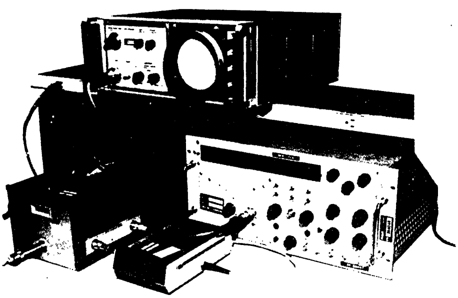


Fig. 11– The HP8410A Network Analyzer.

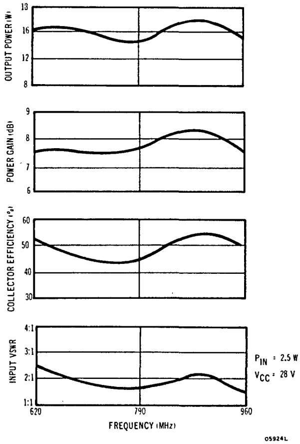


Fig. 12– RF performance of the 2N6267 power amplifier.

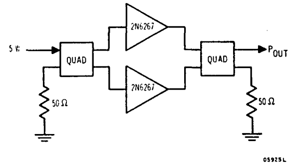


Fig. 13– Combination of two 2N6267 amplifiers to form a 30-watt, 7.5-dB module.

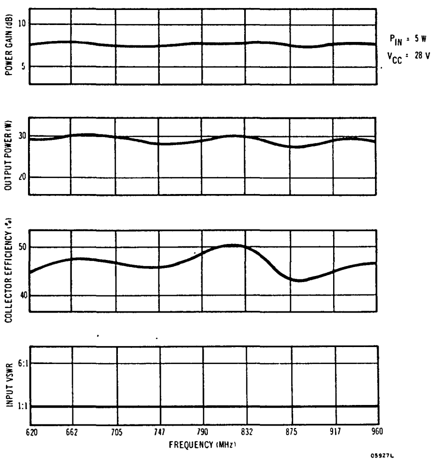


Fig. 14– RF performance of the circuit of Fig. 13.

Coupler Design

Although commercial couplers were utilized for the modules described in this note, custom couplers could be designed that would reduce cost and space requirements. A synchronous branch-line coupler was designed and fabricated on 25-mil-thick, 1-inch by 1-inch alumina; the coupler is shown in Fig. 19. The design, based upon data given by Matthaei, et al, is for a 3-dB coupler that has an R of 5.84 ohms and a bandwidth-contraction factor, β, of 0.62. For the desired 45-percent coupler bandwidth, therefore,

$$W_q = \frac{0.45}{\beta} = \frac{0.45}{0.62} = 0.8$$

Wq is the fractional bandwidth. Coupler impedances are:

$Z_1 = 37.1$ ohms

$Z_2 = 91.2$ ohms

$Z_3 = 53.4$ ohms

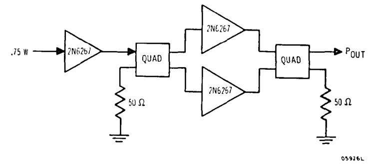


Fig. 15– Combination of two 2N6267 amplifiers to form a 30-watt, 16-dB module.

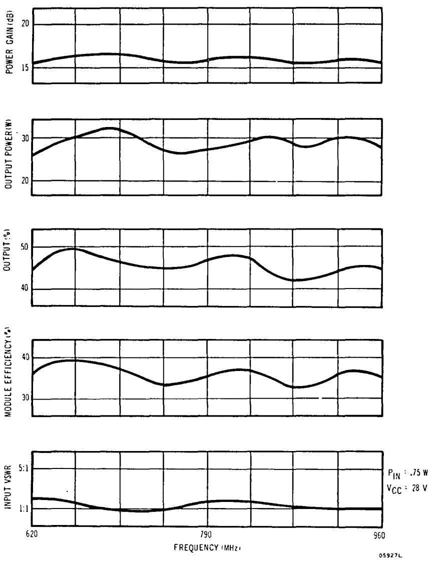


Fig. 16– RF performance of the circuit of Fig. 15.

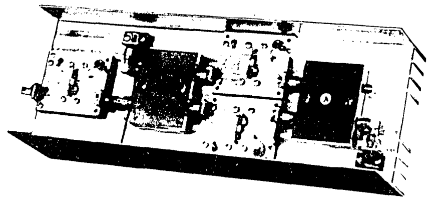


Fig. 17– Assembled 30-watt module.

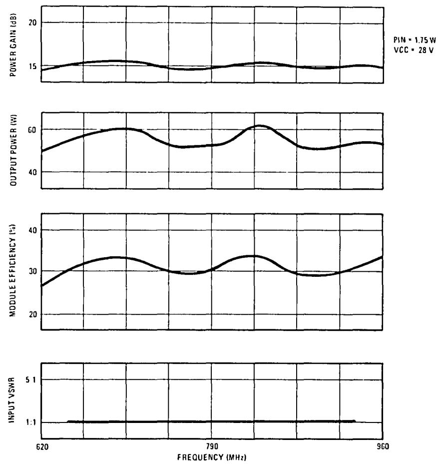


Fig. 18– The performance of two 30-watt modules combined to form a 60-watt module.

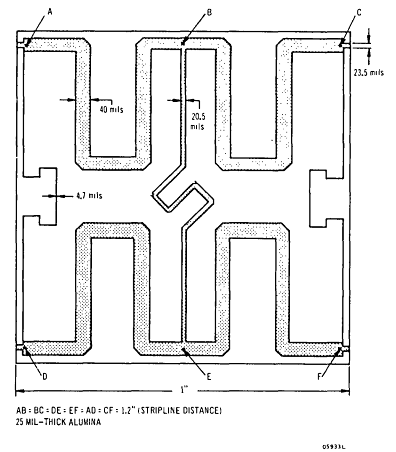


Fig. 19– Design of a synchronous branch-line coupler.

Acknowledgements

The author thanks J.J. Walsh for his work in the construction and testing of the broadband modules discussed in this Note.

References

1. G. L. Matthaei, "Short-Step Chebyshev Impedance Transformes", *IEEE Transactions,* Vol. MTT-14, No. 8, 372-383, August 1966.
2. H. A. Wheeler, "Transmission-Line Impedance Curves", *Proceedings of the IRE,* December 1950.
3. A. Presser, "RF Properties of Microstrip Line", *Microwaves,* March 1968.
4. M. Caulton, J. J. Hughes, H. Sobol, "Measurements on the Properties of Microstrip Transmission Lines for Microwave Integrated Circuits", *RCA Review,* September 1966.
5. H. A. Wheeler, "Transmission-Line Properties of Parallel Strips Separated by a Dielectric Sheet", *IEEE Transactions on Microwave Theory and Techniques,* 172, March 1965.
6. H. A. Wheeler, "Transmission-Line Properties of Parallel Wide Strips by Conformal-Mapping Approximations", *IEEE* MTT, 280, May 1964.
7. H. Sobol, "Extending IC Technology to Microwave Equipment," *Electronics,* March 20, 1967.
8. C. Leuthauser and B. Maximow, "16- and 25-Watt Broadband Power Amplifiers using RCA-2N5918, 2N5919, and TA7706 UHF/Microwave Power Transistors", RCA Application Note AN-4421, October 1970.
9. Matthaei, Young, Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures,* Section 13.12, pp 825-833, McGraw-Hill (New York), 1969.

RCA
Solid State
Division

RF Power Transistors

Application Note AN-6126

60 - and 100-Watt Broadband (225-to-400-MHz) Push-Pull RF Amplifiers Using RCA-2N6105 VHF/UHF Power Transistors

by B. Maximow

In many applications of rf power transistors, the output-power requirements are greater than can be realized by any single transistor, and combinations of transistors are inevitable. In such cases, successful circuit operation is critically dependent upon proper choice of the rf power transistors to be employed in the combinations and selection of circuit configurations that provide high combining efficiency. RCA-2N6105 vhf/uhf power transistors offer features, such as high output-power capability, high collector efficiency, and internal emitter ballasting, that make them well suited for use in rf power amplifiers. In addition, the low parasitic reactances and package dimensions of these transistors result in exceptional broadband capabilities that make possible useful power outputs over more than an octave in the vhf and uhf ranges.

This Note discusses the use of 2N6105 transistors in push-pull rf power amplifiers designed for operation over the frequency range from 225 MHz to 400 MHz. The design and performance of a basic single-stage push-pull amplifier and use of combined pairs of this basic circuit to obtain higher output-power levels are explained. An improved version of the basic push-pull circuit is also described.

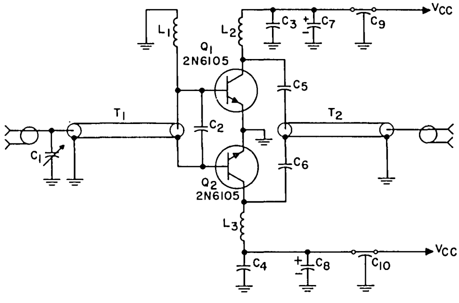
CIRCUIT DESIGN APPROACH

Two RCA-2N6105 transistors can be combined in a push-pull circuit to obtain a highly efficient broadband amplifier that can supply an output power of 60 watts in the frequency range from 225 MHz to 400 MHz. Two such push-pull amplifiers combined by use of quadrature combiners can provide an output power of 100 watts in this frequency range.

The push-pull circuit is an excellent configuration for use in applications that require combinations of transistors. The basic push-pull circuit includes a combination of two transistors and, therefore, eliminates the need for two extra combiners that would be required with two single-ended amplifiers. In multiple transistor combinations, the push-pull approach requires two less combiners for each pair of transistors used in the total combination. In addition, the inherent low second-harmonic component of the push-pull circuit significantly facilitates filter design, a desirable feature in amplifiers that have bandwidths that approach or exceed an octave.

The collector-to-collector load resistance in the push-pull amplifier is twice the collector load resistance of a single-ended amplifier, and the collector-to-collector output capacitance is smaller than the collector output capacitance of a single-ended amplifier. These features result in a lower transformation ratio in the critical output circuit and, therefore, in easier impedance matching for a given bandwidth.

The push-pull circuit design approach described in this Note results in a very simple circuit, as shown in Fig. 1. The circuit and the transistors, however, must be viewed as



C_1 - 2 TO 18 pF VARIABLE, AMPEREX HT 10 MA/218 OR EQUIV.
C_2 - 56 pF, CHIP, ATC-100 OR EQUIV.
C_3, C_4, C_5, C_6 - 1000 pF, CHIP, ALLEN-BRADLEY OR EQUIV.
C_7, C_8 - 1 μF, ELECTROLYTIC
C_9, C_{10} - 1000 pF, FEEDTHROUGH
L_1 - RFC, 0.18 μH, NYTRONICS OR EQUIV.
L_2, L_3 - 0.75 INCH. LONG, NO. 20 WIRE
T_1 - COAXIAL LINE, TEFLON DIELECTRIC, Z_0 = 25 OHMS, 3.75 INCHES LONG*
T_2 - COAXIAL LINE, TEFLON DIELECTRIC, Z_0 = 25 OHMS, 4.5 INCHES LONG*

*SHIELED TEFLON CABLES SUCH AS ALPHA WIRE TYPE 2831, DABUN ELECTRONICS AND CABLE CORP. TYPE 2455 OR EQUIV. 92CS-20772

Fig. 1— Circuit diagram for the basic push-pull amplifier.

inseparable parts because each must complement the other. For example, transistor parasitics reactances must be designed into the circuit very carefully, and the transistor package dimensions should be such as to enable the designer to layout his circuit so that parasitic reactances complement the external elements of the over-all amplifier circuit.

The basic 60-watt push-pull circuit shown in Fig. 1 can be used as the building block for a variety of power amplifiers. Combinations of these blocks can be formed by use of either quadrature or Wilkinson types of combiners to attain higher output-power levels.

AMPLIFIER PERFORMANCE

Fig. 2 shows the typical broadband performance of a pair of 2N6105 transistors used in the basic push-pull amplifier, and Fig. 3 shows the physical layout of this simple amplifier circuit. The performance data show that the collector efficiency is highest at the upper end of the frequency band. This factor is important because the transistor dissipation is the function of the amplifier efficiency. This efficiency is computed on the basis of the total (rf and dc) power input to the transistor. At the high end of the band, the rf component of the input power is greater than at the low end because of the gain difference. Consequently, higher collector efficiency compensates for the high rf power input. The computation shows an amplifier efficiency of 63 per cent at 225 MHz, of 56 per cent at 300 MHz, and of 67 per cent at 400 MHz. These results show that the difference between the over-all efficiency at the low end of the frequency band and that at the high end is not nearly as great as the difference in the collector efficiency at these frequency extremes.

Fig. 4 shows the linearity characteristics of the basic push-pull amplifier (i.e., the power gain of the amplifier as a function of the input power) at the extremes of the frequency band and at mid-band. The harmonic content of the output is also shown for the fundamental frequency of 225 MHz, which is considered most critical frequency in terms of output-filter design.

The basic amplifier shown in Fig. 1 has a relatively high input VSWR and, therefore, is best suited for use with quadrature combiners. Fig. 5 shows a block diagram of the

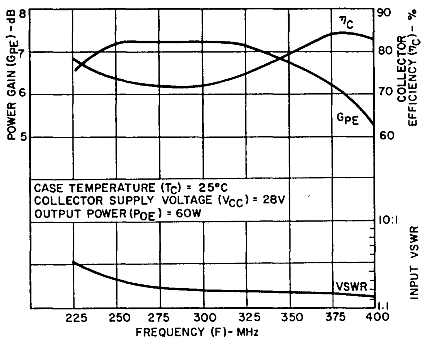


Fig. 2– Typical performance of the pair of 2N6105 transistors used in the basic push-pull amplifier.

Fig. 3– Physical layout of the basic (60-watt) broadband push-pull amplifier: (a) top view; (b) bottom view.

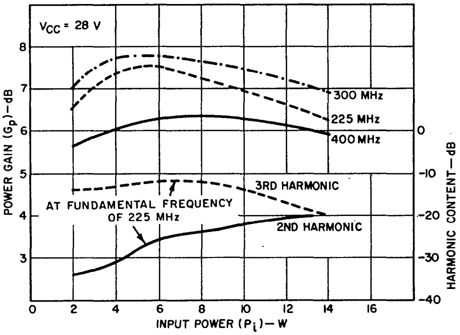


Fig. 4– Power gain and harmonic content of the basic push-pull amplifier at 225 MHz as a function of input power.

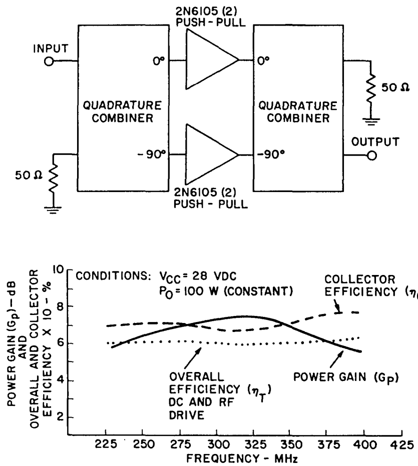


Fig. 5– 100-watt amplifier using combined pair of push-pull stages: (a) block diagram; (b) performance curves.

circuit arrangement and the performance of such a combination. Fig. 6 shows a photograph of the complete amplifier which uses four 2N6105 transistors and two quadrature combiners. This circuit provides an output of 100 watts in the frequency range from 225 MHz to 400 MHz. The over-all efficiency for this amplifier, shown in Fig. 5, differs from the amplifier efficiency of the single push-pull stage discussed previously. For the single push-pull amplifier, only the actual rf input to transistors was considered as a contributing factor

Fig. 6— Physical layout of the 100-watt push-pull amplifier.

to the device dissipation. In the curve of over-all efficiency shown in Fig. 5, the entire rf input, part of which is dissipated in the waste ports of quadrature combiners, is taken into account. Any collector-current imbalance among transistors that exist in a push-pull amplifier before combining is somewhat aggravated by the characteristics of the quadrature combiners. For comparison, two tables of actual readings are given. For these readings, the collector current of each transistor was monitored. Table I shows the data for the push-pull amplifier, and Table II shows the data for the two push-pull amplifiers combined as shown in Fig. 5.

The single push-pull amplifier shown in Fig. 1 because of its high input VSWR, is not very suitable to be driven directly by another transistor amplifier. The input VSWR, however, can be improved to about 2.7:1 by addition of simple LC series network, as shown in Fig. 7. This improvement in input VSWR is accompanied by a corresponding increase in gain. Fig. 8 shows performance for the modified circuit. The gain-frequency response, which shows a difference in power gain of about 3 dB between high and low ends of the frequency band, can be flattened by use of

Table I — Forward Input Power (P_f), Reflected Power (P_r), and Collector Current (I_C) for an Improved Version (Fig. 7) of the Basic Push-Pull Amplifier

	V_{CC} = 28 V; P_o = 60 W				V_{CC} = 28; P_o = 60 W			
f (MHz)	P_f (W)	P_r (W)	I_{C1} (A)	I_{C2} (A)	P_f (W)	P_r (W)	I_{C1} (A)	I_{C2} (A)
400	13.6	0.1	1.13	1.08	17.6	0.0	1.28	1.25
375	12.2	0.6	1.27	1.23	15.5	0.7	1.41	1.38
350	11.6	1.2	1.40	1.37	14.6	1.6	1.57	1.52
325	10.6	1.5	1.48	1.43	14.2	2.0	1.68	1.60
300	9.8	1.6	1.48	1.43	13.0	2.1	1.70	1.60
275	8.8	1.6	1.43	1.38	11.4	2.1	1.63	1.56
250	7.5	1.3	1.32	1.28	9.6	1.7	1.48	1.45
225	5.8	1.2	1.19	1.20	7.8	1.6	1.35	1.35

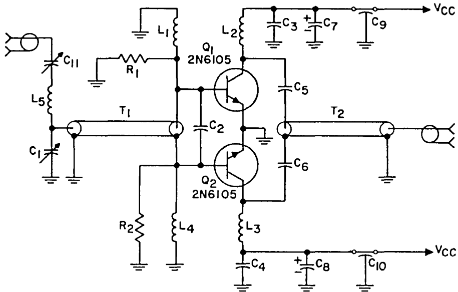
Table II — Input Power and Collector Currents for the 100-Watt Push-Pull-Amplifier Combination

V_{CC} = 28 V; P_o = 100 W					
f (MHz)	P_{IN} (W)	I_{C1} (A)	I_{C2} (A)	I_{C3} (A)	I_{C4} (A)
400	28.2	1.12	1.09	1.19	1.19
375	24.1	1.16	1.14	1.19	1.21
350	21.9	1.32	1.33	1.20	1.23
325	19.7	1.40	1.38	1.20	1.23
300	19.0	1.40	1.36	1.25	1.30
275	20.0	1.26	1.20	1.23	1.38
250	23.1	1.14	1.06	1.37	1.44
225	27.2	1.26	1.16	1.32	1.42

broadband gain-equalizer techniques[1] provided that an insertion loss of approximately 0.7 dB can be tolerated. Fig. 7 also shows that, in addition to the LC series network, two base-to-ground resistors and one base-to-ground choke are added in the modified circuit. These components are helpful in suppression of spurious responses which can occur (usually at lower power levels) at some frequencies. The added components do not affect other performance characteristics of the amplifier.

AMPLIFIER DESIGN

A necessary prerequisite for a push-pull amplifier is a balun transformer. This balun transformer must provide the



C_1 – 2 TO 18 pF VARIABLE, AMPEREX HT 10 MA/218 OR EQUIV.
C_2 – 56 pF, CHIP, ATC-100 OR EQUIV.
C_3, C_4, C_5, C_6 – 1000 pF, CHIP, ALLEN-BRADLEY OR EQUIV.
C_7, C_8 – 1 μF, ELECTROLYTIC
C_9, C_{10} – 1000 pF FEEDTHROUGH
C_{11} – 20 pF, VARIABLE, JOHANSON OR EQUIV.
L_1, L_4 – RFC, 0.18 μH, NYTRONICS OR EQUIV.
L_2, L_3 – 0.75 INCH LONG, NO. 20 WIRE
L_5 – 0.5 INCH LONG, NO. 20 WIRE
R_1, R_2 – 100 OHMS, 1/2 WATT.
T_1 – COAXIAL LINE, TEFLON DIELECTRIC, Z_o = 25 OHMS, 3.75 INCHES LONG*
T_2 – COAXIAL LINE, TEFLON DIELECTRIC, Z_o = 25 OHMS, 4.5 INCHES LONG*

* SHIELDED TEFLON CABLES SUCH AS ALPHA WIRE TYPE 2831, DABURN ELECTRONICS AND CABLE CORP. TYPE 2455 OR EQUIV.

92CS-20776

Fig 7— Circuit diagram for improved single-stage push-pull amplifier.

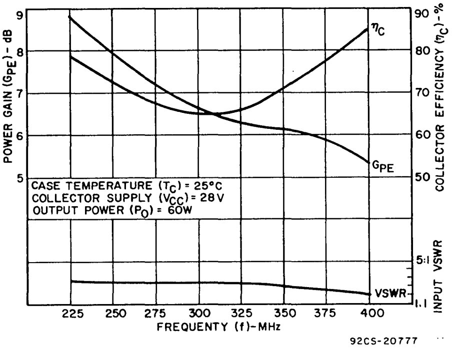


Fig. 8— Performance curves for the improved push-pull amplifier.

necessary impedance-matching transformation. In high-power rf broadband amplifiers, such transformations always involve complex impedances and almost never have transformation ratios, such as 4:1 or 9:1, which are associated with a certain standard types of broadband balun transformers. In the broadband rf power amplifier described in this Note, a coaxial transmission is used as the required balun transformer. The coaxial line, when supplemented by lumped-constant components, is the simplest and most versatile type of impedance-matching device with balun properties. The transformation properties of this type of transformer are frequency dependent, but the balun property is not.

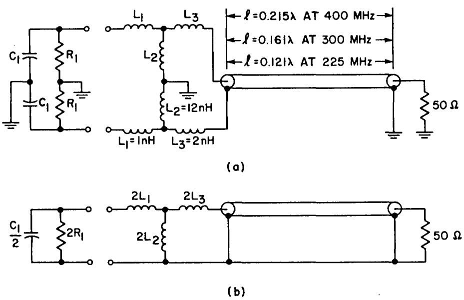
The coaxial transmission-line type of balun transformer offers three major advantages. First, the transmission line can match almost any two impedances, if the length and the characteristic impedance of the line are properly chosen. Second, a coaxial transmission line is a perfect balun. The grounded braid end of the coaxial cable makes an unbalanced termination. and the floating-braid end makes a balanced termination. The voltages on the center conductor and the braid have a 180-degree phase relationship to each other at any given point along the line. These voltages are also evenly split, because apparently no rf leakage currents exist between the floating part of the braid and the ground to any appreciable degree. (This assumption was verified in an actual amplifier by reversal of the input line at the bases of transistors. No evidence of any change in the drive levels to either transistor was detected.) Finally, in the frequency range of 225 to 400 MHz, the line lengths required for proper transformations are convenient and do not present any layout problems.

A graphical design approach to the design of the amplifier transformations consists of making a model for the matching network, reducing this model to a form that can be plotted on a Smith Chart, and then plotting component reactances. This approach involves a trial-and-error type of iterative process that is tedious and time-consuming. Unfortunately, it does not seem likely that this design method can be easily reduced to a set of steps and procedures that invariably lead to a prescribed broadband impedance match.

Output Circuit

Fig. 9 shows a diagram of a model that simulates the output circuit of two 2N6105 transistors operated into a 50-ohm load impedance. This diagram shows that the push-pull circuit requires a collector-to-collector load resistance that is twice the value of the collector load resistance required by a single-ended amplifier. The collector-to-collector capacitance of the push-pull amplifier should be less than the output capacitance of transistor in a single-ended amplifier. This latter factor should be helpful in the achievement of broadband amplifier characteristics. Some of the components shown in the diagram can be either measured or computed, and other components must be determined by approximations. The approximations are believed to be reasonable and therefore admissible, because the purpose of this exercise is not to compute exactly the transformation made by this rather complex network, but to ascertain whether this circuit-design approach could provide a broad estimate of the load impedance. An optimum impedance match can then be effected by experimentation.

Fig. 9(a) illustrates a balanced-to-unbalanced impedance transformation showing the minimum of critical components. The capacitors C1 represent the output capacitance of a transistor. The resistor R1 is the real part of the collector load impedance. Although the transistor output does not require the conjugate match, for the purposes of computation, the output can be treated as though such a match is required by assignment of the value of a real part of the collector load impedance to the real part of the source impedance. The inductor L1 is the parasitic inductance of the package made up by the path from the pellet to the



NOTES:
VALUES FOR R, AND C, ARE TAKEN FROM 2N6105 DATA SHEET AND ARE ALSO GIVEN IN TABLE III
THE TRANSMISSION LINE USES A TEFLON DIELECTRIC AND HAS A Z_0=25 OHMS
OTHER COMPONENT VALUES AS SHOWN

92CS-20778

Fig. 9— Output-circuit model with assumed component values.

connecting point of L2. The inductor L2 is the shunt inductance which also serves as the dc feed. The inductor L3 consists of a transistor collector lead in series with a 1000-picofarad blocking capacitor and the unavoidable lengths of the center conductor and the braid at the end of the coaxial line.

The transmission line, L2, and, to some extent, L3 are controlled by the designer; the other components are not, except by collector voltage variation. For the suggested graphical approach to be useful, the circuit scheme is simplified to the one shown in Fig. 9(b). The simplified value of the output capacitance is approximated by (C1)/2. Admittedly, the exact way in which the output capacitors combine in a class C push-pull transistor amplifier is somewhat obscure, but the approximation seems reasonable. The 2N6105 data sheet indicates the load impedance for three frequencies. The values of these impedances are tabulated in the left-hand column of Table III. The

Table III – Collector-to-Collector Load Resistances and Output Capacitances for 60-Watt Broadband Push-Pull Amplifier

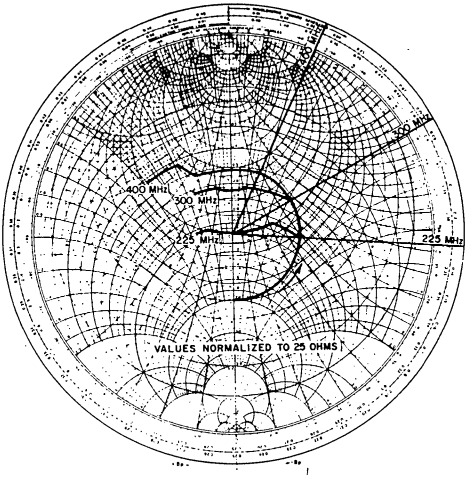
Desired Values			Values Obtained from Fig. 10	
f (MHz)	R_{CL} (ohms)	C_o (pF)	R_{CL} (ohms)	C_o (pF)
225	28	17.5	26	10.0
300	22	17.0	18	11.7
400	16	15.0	24	18.6

impedance plot shown in Fig. 10 uses the assumed values given in Fig. 9. The impedance plot starts at 50 ohms and goes towards the load so that it ends on the capacitive side of the chart at a point that represents the source for the circuit shown in Fig. 9. If the data-sheet values for the 2N6105 and the assumed approximations in the model of Fig. 9 are not taken as something inviolate, but rather as very good approximations for design guidance, then the two sets of values in Table III come close enough to each other to indicate that the proposed method warrants a trial.

Input Circuit

Matching requirements in the input circuit are very similar to those in the output although there are some significant differences. First, a conjugate match at the base is required for maximum power transfer. Second, the maximum-power-transfer condition is most desirable at upper frequencies, because some reflected power can be tolerated at lower frequencies. In fact, the greater the difference in transistor gain at the low and high ends of the frequency band, the greater the amount of reflected power that can be tolerated at lower frequencies. These statements are valid for a single-stage amplifier provided that means are available to handle the reflected power.

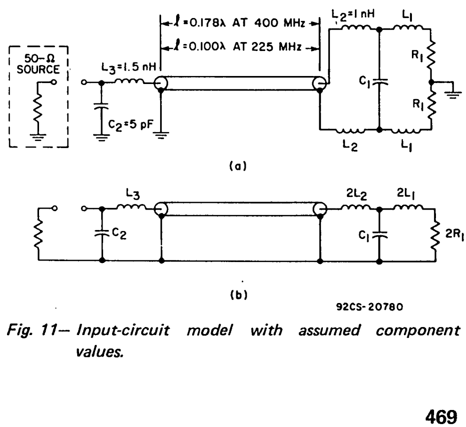
If a graphical method similar to that used for output matching is employed in the design of the input circuit, a



92CS-20779

Fig. 10– Output-circuit impedance/admittance chart.

model with assumed values, such as shown in Fig. 11, is devised. With the 50-ohm source used as the starting point, values are chosen to match the source to the load at 400-MHz. (In this case, the load is the input to the transistors.) Once the match is obtained, all the values are rescaled to 225-MHz, and the plotting steps are retraced from the load towards the source. The impedance plot in Fig. 12 shows a transformation from 50 ohms to 2.5 + j 3.25 at 400-MHz. However, the 225-MHz load-to-source retrace shows an input VSWR referenced to 50 ohms of 9 to 1. With this VSWR, approximately 65 per cent of the total forward power will be reflected. Six watts of input power is needed to obtain 60 watts in the output from two 2N6105 transistors at the gain of 10 dB at 225 MHz. For an input VSWR of 9 to 1, a total forward power of 17 watts would be



92CS-20780

Fig. 11– Input-circuit model with assumed component values.

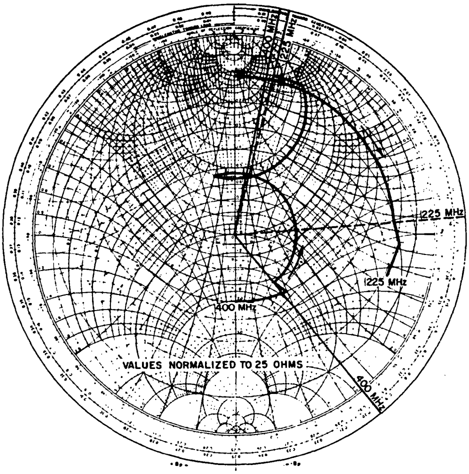


Fig 12– Input-circuit impedance/admittance chart.

required. At 400 MHz, an input of 16 watts is required, to obtain an output of 60 watts from a pair of typical 2N6105 transistors. These results provide enough impetus for laboratory trial. In fact, the experimental results yielded considerably better performance than anticipated by these calculations. Further refinements, such as the series-resonant LC circuit added to the amplifier shown in Fig. 7, and the resultant performance improvement are achieved by extention of the graphical method outlined above. This extension technique consists of determining circuit changes that improve the match at lower frequencies without any degradation in the match at 400 MHz.

LAYOUT CONSIDERATIONS

An examination of the circuit models and the Smith Chart plots for them provides some indication of the extreme importance of the circuit layout. For example, the base-to-base capacitor value is indicated as 56 picofarads. This value is very high for use at 400 MHz; consequently, care must be excercised in the placement of this capacitor to assure a minimum of lead length. Another critical area is that near the transistor collectors. When inductance values of 1 to 2 nanohenries are significant, extreme care must be excercised in the placement of components. A suggested layout for the pair of 2N6105 transistors is shown in Fig. 13. Placement of the transistors further apart than indicated may present problems in the critical areas mentioned above.

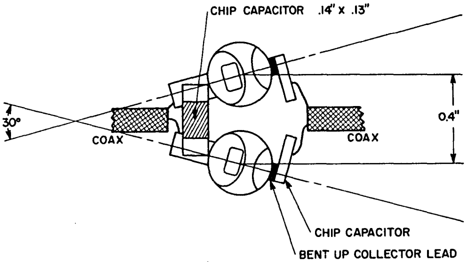


Fig. 13– Suggested layout for a pair of 2N6105 transistors employed in a broadband push-pull rf amplifier.

REFERENCE

1. B. Maximow, "Characteristics and Broadband (225-400-MHz) Applications of the RCA 2N6104 and 2N6105 UHF Power Transistors," RCA Application Note AN-6010, RCA Solid State Division, Somerville, N.J., May 1972.

ACKNOWLEDGMENT

The author is grateful to D.A. McClure and R. Risse of RCA Communications Systems Division for their suggestion of the use of a coaxial cable for push-pull amplifiers.

Microwave Power-Transistor Reliability as a Function of Current Density and Junction Temperature

by S. Gottesfeld

Questions concerning the effect of electromigration-related failure modes on the life of microwave power transistors using an aluminum metallization system are frequently asked. This Note answers these questions as they pertain to RCA microwave power transistors. First, the design aspects of these transistors which aid in reducing the incidence of electromigration failure to a negligible level under normal operating conditions are discussed. Second, supporting life-test data on commercial-level RCA microwave power transistors is presented. The lifetime of the products in this line can be predicted from the data as a function of current density and junction temperature – the two main factors involved in electromigration failure modes.

Electromigration

Electromigration of the aluminum in the presence of high-current densities and elevated temperatures is well known[1] and results from the mass transport of metal by momentum exchange between thermally activated metal ions and conducting electrons. As a consequence, the original uniform aluminum film reconstructs to form thin conductor regions and extruded-appearing hillocks that may cause device degradation.

The electromigration process can be accompanied by the dissolution of silicon into the aluminum. This dissolution usually occurs during heat treatments employed in transistor manufacturing until the aluminum-silicon saturation point is reached. Therefore, little silicon can dissolve when the device is in *normal* operation. At high-current densities and elevated temperatures, however, the silicon ions which were diffused into the aluminum during the manufacturing process can be transported along with the aluminum ions undergoing electromigration away from the silicon-aluminum interface and into the aluminum. This situation allows further diffusion of silicon into the aluminum and leads to the eventual failure of the transistor junctions[2].

RELIABILITY DESIGN FEATURES

Overlay-Transistor Construction

The basic transistor construction used by RCA for rf power transistors is the "overlay" design. The emitters in this type of device are separated into many discrete sites which are paralleled for high-power performance. The overlay configuration provides the high ratio of effective emitter periphery to base area[3] needed for high-power generation at microwave frequencies. In addition, this structure has the advantage of permitting lower current densities in the emitter metallizing stripes than other high-frequency structures. This advantage results from the relatively broad emitter-metal stripes which interconnect the discrete emitters. These stripes are typically 35 microns wide compared to 3 to 5 microns for other interdigitated or matrix designs. Furthermore, the separation of the emitter- and base-metal fingers is 3 to 4 times greater in the overlay structure than competitive structures. This separation permits the deposition of thicker metal layers with greater cross-sectional areas; and further reduces current densities.

Polycrystalline Silicon Layer (PSL)

Another advantage of the overlay transistor structure with its broad emitter fingers and non-critical metal-definition is that it is readily adaptable to the introduction of additional conducting and insulating layers between the aluminum metallization and the shallow diffused emitter sites required for microwave performance. RCA has developed a polycrystalline silicon layer (PSL), shown in Fig.1, which is deposited over the emitter sites and under the aluminum metallization. The PSL forms a barrier between the aluminum emitter finger and the oxide insulating layer over the base; the barrier minimizes failures caused by the interaction of aluminum with silicon dioxide. In addition, the PSL layer helps to minimize thermally induced failure modes by providing a barrier between the aluminum and the shallow-emitter diffused region to prevent "alloy spike" failures; PSL also increases the distance that the silicon ions must travel from emitter-site region to metallization, Fig.1. Therefore, the amount of silicon that can be diffused into the aluminum is limited, and the possibility of device failure as a result of the electromigration of the silicon in the aluminum is reduced.

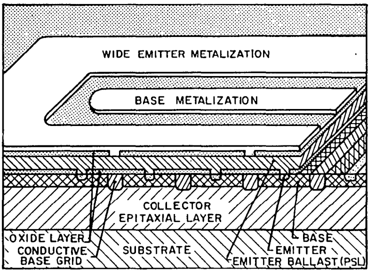


Fig. 1 – Cross section of an overlay transistor showing the polysilicon layer (PSL) between the metallization and emitter sites, and how emitter ballasting may be placed in series with each emitter site by controlling the doping and contacting geometry of the PSL.

Emitter-Site Ballasting

RCA has utilized the PSL technology as a medium to introduce emitter-site ballasting into its microwave power transistors. Emitter-site ballasting permits more uniform injection across the transistor chips by reducing hot-spotting. By controlling the resistivity of the PSL and restricting the contacting geometry of the aluminum to the PSL layer, a ballast resistor is placed in series with each emitter site, as shown in Fig.1. These resistors function as negative-feedback elements to control that portion of the transistor that is drawing excessive current. Since the overlay construction results in an emitter that is segmented into many sites which are connected in parallel, each hot-spot may be isolated and controlled. Furthermore, the large number of resistors in parallel minimize the effects of excessive emitter resistance on input impedance and gain. In fact, one microwave transistor, the type 2N5921, which had low levels of emitter-site ballasting added to its structure, exhibited a 35-percent improvement in power output for the same drive level. At the same time, the measurement of the dc safe-operating area, as defined by a 200°C hot-spot junction temperature (infrared measurement), indicated an approximate doubling of the allowable current at 15 volts (see Fig.2).

It is also known that hot-spotting under rf conditions increases as the VSWR increases[4]. Device failures which occur under high VSWR conditions at the output are often related to a forward-bias second-breakdown failure mechanism which is characterized by extremely high localized currents. Thus, it could be expected that an emitter-ballasted transistor would have greater resistance to failure under high VSWR conditions, such as those encountered in some broadband amplifiers. In fact, the 2-gigahertz power transistors which are site-ballasted, types 2N6265 and 2N6266, have been characterized for their ability to withstand ∞:1 VSWR at all phases at rated power; the 2N6267 has been characterized at a 10:1 VSWR. The 3-gigahertz chain of microwave power devices are also site-ballasted, and are also rated at a 10:1 VSWR capacity.

Glass-Passivated-Aluminum Metallization

The standard metallization system used on all commercial RCA microwave power transistors consists of an evaporated aluminum-silicon film which is defined by means of photolithographic and chemical-etching techniques. The addition of silicon to the aluminum brings the state of the metallization closer to the aluminum-silicon saturation point and retards the electromigration of silicon into the aluminum. Aluminum electromigration is also significantly retarded by the deposition of a glass passivation layer over the aluminum film subsequent to the definition procedures. It has been shown[1] that the use of glass passivation results in a 40-percent increase in the activation energy required before electromigration can begin. The silicon-dioxide layer also protects the aluminum from contamination and from scratches or smears that may occur during device assembly.

OPERATING-LIFE-TEST PROGRAM

Test Conditions

An accelerated operating-life-test program was undertaken to study the effects of electromigration at various current densities on the lifetime of RCA microwave power transistors. DC current-voltage conditions were used since electromigration is responsive to the dc components of the total waveform used in rf applications, i.e., electromigration is effected by the unidirectional components of the field. Tests were run at three different emitter-stripe current densities (J_E) with each current density in turn run at three different peak junction temperatures (T_j); all tests represented stress levels above normal-

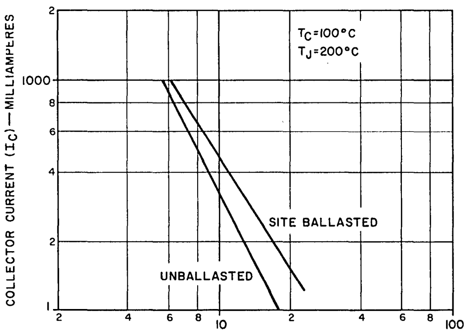


Fig.2 – DC infrared safe-area for ballasted and unballasted microwave transistor (2N5921 coaxial packaged).

use conditions. Peak junction temperature was determined by infrared scanning of the transistor pellet at each life-test condition. Table I shows the matrix of test conditions. The sample size per test condition ranged between 10 and 15 units. A total of 114 units were tested.

TABLE I – ACCELERATED LIFE-TEST CONDITIONS

Collector Current (Amperes)	Emitter Current (Amperes)	Emitter Stripe Current Density (A/cm^2)	Peak Junction Temperature* (°C) T_j1	T_j2	T_j3
1	1.02	8.5×10^4	300	280	254
2	2.07	1.7×10^5	283	258	230
3	3.22	2.7×10^5	300	273	240

* Represents peak temperature as averaged over several devices at each life-test condition. External heat-sink size was adjusted to achieve the differences in junction temperature on the life test.

Test Vehicle

A type 2N6267 device manufactured by RCA was used as the test vehicle because it operates at one of the highest current densities in the microwave family. This device incorporates all the design features described in the prior sections of this Note, and is considered representitive of the microwave family. All the transistors used on test were commercial-level devices, i.e., they were not subjected to conventional hi-rel screening prior to life testing.

Failure Mode

The accelerated test conditions produced failures due to electromigration of aluminum and silicon as described in the introductory section. The failure indicator was degraded or shorted transistor junctions. RF power output measured at frequent life-test down-periods prior to device junction failure exhibited only slight degradation (typically 8 percent); this performance is excellent considering the severity of the test conditions.

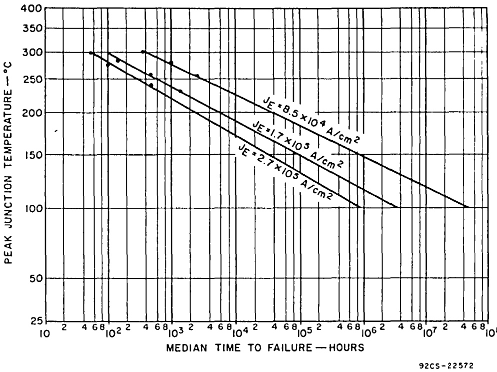


Fig.3 – Arrhenius plot showing extrapolation to lower temperatures from the life-test MTF points for the 2N6267.

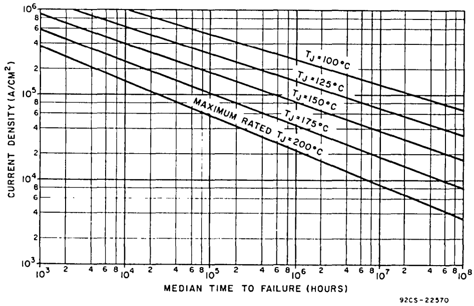


Fig.4 – MTF as a function of current density and junction temperature. In applying this chart, it is recommended that no device be used above its maximum ratings as specified in the published data sheet.

Data

An Arrhenius plot (1/T, log scale) of the log-normal median-time-to-failure (MTF) obtained from each test is shown in Fig.3. The curves are extrapolated down from the data points to enable prediction of MTF at operating junction temperatures below the maximum rated 200°C. An estimated MTF of 9.5×10^5 hours (or greater than 100 years) is predicted for the 2N6267 device under test at its typical-application current density of 8.5×10^4 A/cm^2 and junction temperature of 150°C.

Points from each curve in the Arrhenius plot were taken in the temperature range of 200°C to 100°C and replotted on a log-log scale, Fig.4, for extrapolation over various current densities. Fig.4 shows the general plot of MTF as a function of emitter-current density and peak-junction temperature. This chart can be used to estimate the MTF for each microwave transistor at its typical operating-current density. Table II lists the transistor types currently in the microwave family, and shows the predicted MTF for typical-application values of emitter current, emitter-stripe current density, and peak junction temperature.

TABLE II – ESTIMATED MTF FOR MICROWAVE FAMILY AT TYPICAL-APPLICATION CURRENT DENSITIES

Package	Operating Frequency (GHz)	Type	Typical Operating Conditions I_E (Amperes)	J_E (10^4A/cm^2)	Estimated MTF (10^6 hours) @ T_j = 150°C
HF-11 Coaxial	1	2N5470	0.119	5.2	4.0
	2	2N5920	0.180	5.5	3.5
HF-21 Coaxial	2	2N5921	0.450	3.5	12.0
HF-28 Stripline	2	2N6265	0.215	6.5	2.0
	2	2N6266	0.540	4.2	7.0
	2	2N6267	1.02	8.5	0.95
	2.3	2N6268	0.275	8.3	1.0
	2.3	2N6269	0.920	7.2	1.5
HF-46 Stripline	2	RCA2003	0.300	9.0	0.80
	2	RCA2005	0.540	4.2	7.0
	2	RCA2010	1.02	8.5	0.95
	3	RCA3001	0.120	3.8	10.0
	3	RCA3003	0.300	9.0	0.80
	3	RCA3005	0.540	8.0	1.1

CONCLUSIONS

The life-test data presented in this Note shows that the design features of RCA microwave-power transistors assure reliable operation at the current densities and junction temperatures normally encountered in typical applications. Under these operating conditions, the lifetime of these devices in terms of failure due to electromigration is estimated at approximately 100 years.

ACKNOWLEDGMENT

The author acknowledges the assistance of D. S. Jacobson in providing information concerning the transistor design descriptions, C. B. Leuthauser in providing microwave-transistor application information, and L. J. Gallace for his comments regarding the reliability aspects of this Application Note.

REFERENCES

1. J. R. Black, "Electromigration Failure Modes in Aluminum Metallization for Semiconductor Devices," Proc. IEEE, Vol. 57, pp. 1587–1594, September 1969.
2. J. R. Black,"RF Power Transistor Metallization Failure," IEEE Trans. Electron Devices, Vol. ED-17, No. 9, pp. 800–803, September 1970.
3. D. S. Jacobson, "What are the Trade-Offs in RF Transistor Design?," Microwaves, Vol. 11, No.7, July 1972.
4. C. B. Leuthauser,"Hotspotting in RF Power Transistors," RCA Application Note AN-4774.

For basic transistor theory, circuits, and application information, refer to "RCA Solid State Power Circuits Designer's Handbook", SP-52, or "RCA Transistor, Thyristor, & Diode Manual", SC-15.

Microwave Transistor Oscillators

by G. Hodowanec

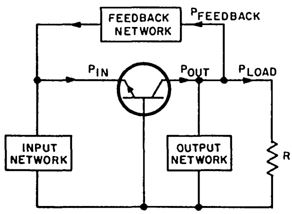
INTRODUCTION

Bipolar transistor oscillators have now become important components in many present day commercial communications and test systems as well as the more highly specialized military systems. These transistor sources, which feature low residual FM noise, very good frequency stability, and a capability for voltage tuning and phase locking, are currently available in a wide range of options from a growing number of suppliers. Sources are available as fundamental oscillators, frequency doublers, and as frequency multipliers. Power outputs range from the milliwatt levels needed for fixed-tuned or broadband local oscillators used in receiver or test systems to the much higher power levels (order of watts) needed in the commercial telecommunications and specialized military systems. While transistors are now available for use as fundamental oscillators at about 12 GHz[1], frequency-doublers or multipliers are generally used with lower frequency devices to achieve source power at the higher frequencies. Transistor sources in the L- and S-band frequency range are competitive in cost and performance with most other sources generally available in this frequency range. While IMPATT and TRAPATT diode oscillators can also develop adequate powers in this frequency range, the diodes generally require much higher bias voltages and are also less efficient. The noise performance of the diodes is also poorer, especially in the free-running modes. The higher-efficiency TRAPATT mode requires more critical circuitry compared to bipolar oscillators. Bipolar oscillators are also less sensitive to spurious modes than the diode oscillators. In addition, bipolar devices are rapidly developing a history of high reliability in this frequency range. Therefore, emphasis in this Note is placed on current L- and S-band transistor oscillator techniques.

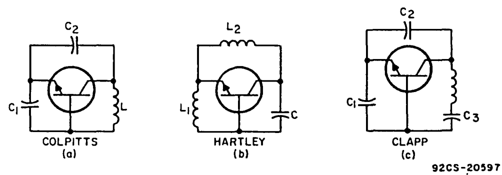
TRANSISTOR OSCILLATOR BASICS

At microwave frequencies, the most effective transistor configuration for an amplifier is the common-base mode of operation. This configuration provides higher gains, efficiencies, and stability at higher frequencies (frequencies above the transistor f_T) then the other possible configurations. Since an oscillator may be considered as a regenerative feedback amplifier (or a negative conductance amplifier), these conditions also apply to the oscillator mode under well-designed conditions.

The basic microwave oscillator circuit considered here is shown in block diagram form in Fig. 1(a). Requirements similar to a power amplifier are seen. In each case, the transistor must provide gain at the desired operating frequency under matched input and output conditions. The main difference is that the oscillator must include a feedback network that couples a portion of the output power back to the input circuit in the proper phase and level to sustain oscillations. The oscillator power delivered to the load is the equivalent amplifier power output less the amount of power fed back to the input circuit and any losses in the feedback



a. common-base feedback oscillator



b. common-base oscillator configurations

Fig. 1 – Basic requirements for 2-bipolar transistor oscillator.

network. The feedback network can be an external loop, an internal loop, or a combination of internal and external elements. Although many variations of the feedback networks are possible, the three general variants shown in Fig. 1(b) have been found to be also effective at microwave frequencies.

The Hartley circuit utilizes a tapped-inductor in the output tuned network to provide the correct level and phase of the feedback to the input circuit. The Colpitts circuit makes use of a tapped-capacitor in the output tuned circuit to provide the correct feedback. The Clapp circuit is but a high-stability version of the Colpitts circuit. In each case, the frequency of oscillation is established by the output tuned circuit which must also incorporate the feedback network as an integral part of this network.

A closer examination of Fig. 1(a) also indicates that the frequency determining portion of the oscillator can be separated from the output matching network by placement of a high–Q LC resonant network in the collector-to-emitter feedback network, the input matching network, or the common base-to-ground circuit. The output network can then be designed from large-signal amplifier load conditions, while the feedback network can be treated essentially independently. This technique is especially suitable for the simplified design of stable, high-power transistor oscillator circuits.[2]

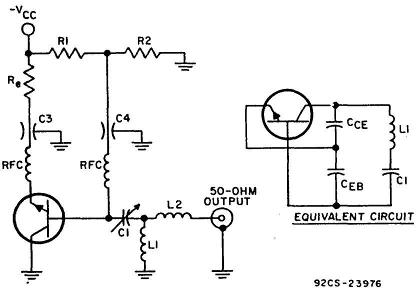
LUMPED-CONSTANT OSCILLATORS

A typical Colpitts type oscillator circuit using lumped-constant circuit elements is shown in Fig. 2(a). As seen in the "equivalent circuit" shown, it is also of the Clapp type. Using the RCA 40836 transistor, this circuit can develop a power output of 0.6 watts at 2.0 GHz and has an overall efficiency of 20-25 percent when operated from a 21-volt supply. No external feedback elements are required. The feedback required to sustain oscillations is provided by the parasitic capacitances of the package housing the 40836 device. The collector of the transistor is grounded and thus appears, at first glance, to be connected in the common-collector mode. However, the collector was grounded to improve collector heat dissipation and to reduce the collector-base loop inductance. The circuit still operates common-base since the feedback is from collector-base to the emitter-base circuits utilizing the parasitic capacitances C_{CE} and C_{EB}.

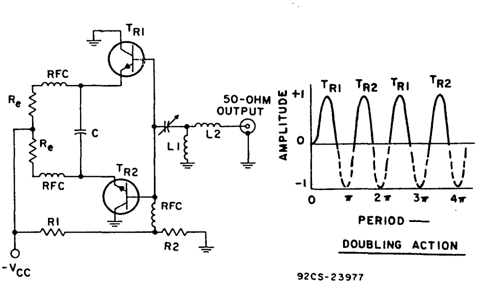
The circuit of Fig. 2(a) is readily adaptable to voltage tuning. Tuning capacitor C_1 may be replaced with a proper varactor diode including the necessary bias feed and isolation . Tuning range of one octave (i.e., 1-2 GHz) is obtainable with tuning voltages in the order of 0-25 volts. Inductors L_1 and L_2 can be a low-loss strap type in this frequency range. Proper choice of these elements enables matching over this entire frequency range.

The circuit of Fig. 2(a) can also be adapted to push-push doubler service as shown in Fig. 2(b). In this mode, two oscillators are operated 180° out of phase (phased by capacitor C) in the input circuits while the outputs are essentially paralleled. The output frequency is doubled by the "doubling action" depicted in Fig. 2(b) while maintaining the power levels and collector efficiencies of the fundamental mode. Other variations of this technique are also possible. Such techniques can make the 1-2-GHz oscillator into a 2-4-GHz oscillator without need for a higher frequency device. Use of higher frequency devices, of course, can extend operation to even higher frequencies. As with the single oscillator, voltage tuning can also be incorporated here. Voltage-tuned (i.e., varactor-tuned) sources are, in general, low cost and have reasonably low FM noise. However, harmonic content (even order) is high unless further output filtering (band-pass type) is used.

The simple transistor oscillator shown in Fig. 2(a) can be directly multiplied to higher multiples using the nonlinear output capacitance of the device as a varactor element, or if perferred, an external varactor element may be used.[3] More commonly today, transistor multipliers couple the fundamental output of the transistor through a low-pass impedance transformer to a step-recovery-diode (SRD).[4] An output bandpass filter matches the SRD to the load and also serves to short circuit (circulate) all harmonics other than the desired output frequency. Therefore, harmonic suppression is good (order of 50 dB) but residual noise in the fundamental oscillator is multiplied by the SRD. Such circuits can make extremely low-cost high-frequency sources.



a. typical Colpitts oscillator of the Clapp type



b. push-push version of oscillator (a)

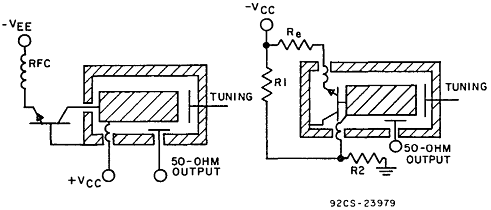
Fig. 2 – Typical lumped-constant microwave oscillators.

CAVITY-TYPE OSCILLATORS

Microwave cavity oscillators are generally used where high spectral purity and good frequency stability are required. The frequency-controlling element is a high-Q cavity (which is sometimes made of INVAR) to provide frequency stabilities of about ±0.05 percent over a wide temperature range. Typical coaxial-cavity circuits are shown in Fig. 3(a). Most cavities are of the fore-shortened quarter-wave coaxial-line type with the characteristic impedance in the order of 72 ohms. Mechanical tuning is possible with a movable probe at the capacitive end of the cavity. Power output is taken either from a capacitive probe or an inductive loop suitably positioned within the cavity.

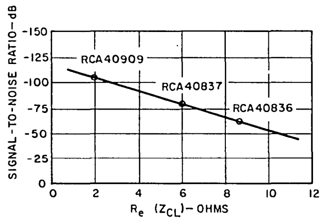
devices as measured in a 3-kHz slot (based on a 200 kHz rms deviation reference) for baseband frequencies of 70 kHz to 5 MHz.[5] The noise ratios are plotted also as a function of the relative base output impedances, giving an indication that the noise performance is a strong function of the cavity loaded Q. In this case, the higher powered device, the RCA 40909, has appreciably better noise performance than the RCA 40837 device, since the loaded Q's are approximately 15 and 5, respectively.

Voltage-tuning of the coaxial-cavity type oscillators are possible, but somewhat more complicated than the simpler lumped-constant circuits discussed previously. The same general techniques shown above may also be applied to microstripline, rectangular-coaxial, or slabline circuits as well.



(1) grounded-base version *(2) grounded-collector version*

a. typical cavity oscillators



b. typical FM noise performance for oscillator (2).

Fig. 3 – Coaxial-cavity microwave oscillators.

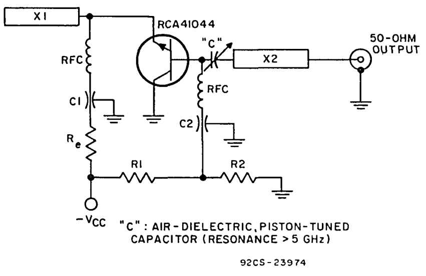
Two oscillator versions are shown in Fig. 3. The grounded-base version, either directly grounded as shown in (1) or RF-grounded with a bypass capacitance (to utilize a single bias supply) generally requires a device with sufficient internal feedback to perform efficiently. The grounded-collector version shown in (2) has proven to be much more efficient, not only due to the effective heat sinking of the collector, but also to the fact that the feedback mechanism is now an integral part of the microwave cavity.

In these oscillators, the device impedance appears in series with the low impedance end of the cavity and thus directly affects the oscillator loaded Q. The loaded Q directly affects the oscillator output FM noise spectrum. Shown in Fig. 3(b) are typical signal-to-noise ratios for RCA coaxial transistor

MICROSTRIP OSCILLATORS

Microwave oscillators which are possible in lumped-constant form are generally duplicable in microstrip form also. At the higher frequencies, the microstrip form is preferred since the microstrip equivalent elements are reasonable in both physical size and also electrical losses. Shown in Fig. 4 is a typical microstrip oscillator operating at about 4.35 GHz. This circuit uses the RCA 41044 device which contains a 5-GHz chip bonded in the common-collector configuration in a stripline package. This bonding arrangement is used to improve the collector heat dissipation and to reduce the collector-base loop inductance.

Operation of the circuit of Fig. 4 is still in the common-base



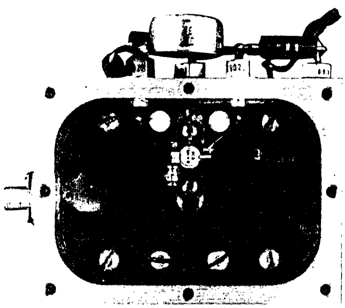


Fig. 4 – 4.35-GHz microstrip oscillator.

mode. The oscillation frequency is primarily established by resonating the collector-to-emitter feedback capacitance with an inductive stub element X_1. The output circuit is matched with an in-line impedance transformer X_2, with capacitor "C" providing for fine tuning and dc isolation for this network. The output network must be properly centered in frequency in this case if it is not to have strong frequency pulling effects on the oscillating frequency which should be primarily established by stub section X_1.

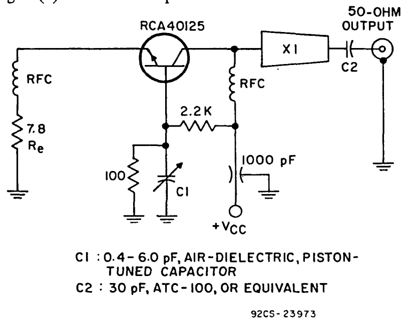
The RCA 41044 in this circuit typically develops about 400 mW of output power at 4.35 GHz with an overall efficiency of 15-20 percent when a 20-volt bias supply is used.

HIGH-POWER OSCILLATORS

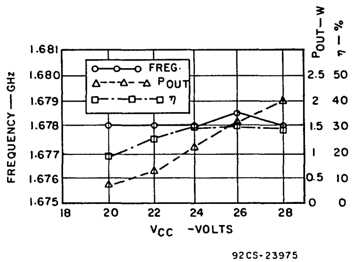
There is a need for higher-power signal sources in specialized applications where the requirements for extreme stability or very low noise are not really necessary. Such oscillators can be readily designed using simplified large-signal design techniques[2] and can approach the large-signal power output and efficiency performance of the parent amplifier design.

Fig. 5(a) shows a simple 1.68-GHz oscillator suitable for radiosonde service. This circuit, which uses the RCA 41025 device, is an example of a circuit in which a high-Q frequency determining network is placed in the base-to-ground circuit. Capacitor C_1 series resonates the common-base inductance at the operating frequency. The base is effectively at RF ground at this frequency only. At 1.68 GHz, the collector load of the 41025 transistor is effectively about 5.5 ohms real. A simple 5.5-ohm to 50-ohm tapered-line output matching transformer, using the methods of Womack,[6] is used to keep the output network broadband in response and to keep second harmonic output more than 40 dB down. Package parasitics provide the correct level of capacitive feedback over the range of about 1.4 GHz to 1.8 GHz. This is also the effective tuning range of capacitor C_1.

Performance of this oscillator at the 1.68-GHz radiosonde frequency is given in Fig. 5(b). It is to be noted that the frequency remains essentially constant over a range of supply voltages of 20 to 28 volts. The overall circuit efficiency remains essentially constant over the range of 24 to 28 volts. The rapid falloff in power and efficiency at the lower voltages can be corrected with the redesign of the output network for the collector loads developed at these lower voltages.



a. 1.68-GHz radiosonde oscillator



b. performance of oscillator (a)

Fig. 5 — Typical high-power microwave oscillator.

HYBRID THIN-FILM MICROWAVE OSCILLATORS

Microwave-integrated circuits (thin-film) form a large portion of present-day microwave circuitry. Hybrid thin-film techniques are well established and can also be readily applied to microwave oscillators. Hybrid oscillators, using packaged bipolar transistors (which have correct parasitic capacitances), are easily incorporated into thin-film circuitry. The present trend, however, is to use transistor "chips" bonded into thin-film circuitry, since reduced costs and further circuit miniaturization is now possible.

Shown in Fig. 6 is a typical hybrid thin-film oscillator circuit. Coupled-lines, X_2 and X_3, are used in the output to establish the resonant frequency and the output match. The circuit is of the Colpitts type with feedback from the output to the emitter base being established by the collector-emitter capacitance formed by stub section X_1 and the emitter-base capacitance formed by the fringing fields between stub sections X_1 and X_2. Since there is very little coupling across a transistor "chip", it is necessary to resort to some sort of external coupling methods as indicated in this example.

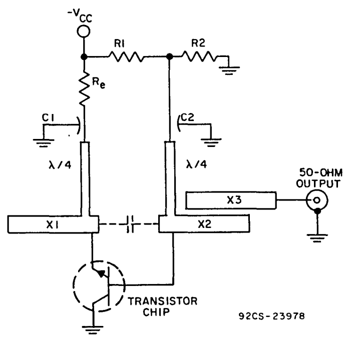


Fig. 6 — Typical hybrid thin-film microwave oscillator.

RCA has refined and extended these techniques in the development of a hybrid thin-film radiosonde oscillator.[7] This oscillator, the type S254, delivers a minimum of 50 mW over the 1600 - 1700-MHz range. It can maintain a 4-MHz frequency stability throughout a 10-volt change in input voltage (from 30V to 20V) and over the -70° to $+70^{\circ}$C temperature range. The frequency of this oscillator has been stabilized with the incorporation of an additional high-Q resonator which is seen in the photograph of this oscillator (Fig. 7).

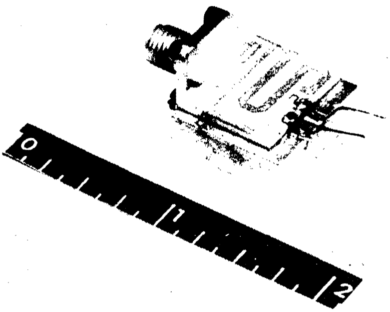


Fig. 7 – Prototype of hybrid thin-film radiosonde oscillator.

CONCLUSIONS

Bipolar transistor oscillators are used extensively in applications from the VHF frequency range to X-band. Power outputs from milliwatts to several watts are available with a wide range of options in terms of tuning range, stability, noise performance, and flexibility. Bipolar transistor oscillators are reliable and cost competitive in this frequency range. Highly efficient operation at low bias voltages in relatively simple and easily understood circuitry is probably the greatest advantage of bipolar devices over negative resistance diode devices in the range of VHF through X-band. Therefore, it is concluded that bipolar transistor oscillators will continue to dominate this frequency range for many years to come.

REFERENCES

1. Chen, P.T., Int'l Sol St Circ Conf, Phila. 1974.
2. RCA Application Note, AN-6084, "High Power Microwave Transistor Oscillators".
3. RCA Technical Series, SP-52, "Frequency Multipliers," pp 550-562.
4. Hall, R., "Step-Recovery Diodes Add Snap to Frequency Multiplication," Microwaves, Sept 1965, pp 70-75.
5. Hall J. A., G. E. Corp. Lynchburg, Va., Private Communication.
6. Womack, C. P., "The Use of Exponential Transmission Lines in Microwave Components," IEEE Trans on MTT, Vol MTT-11, Mar 1962.
7. Askew, R., "Hybrid Thin-Film Radiosonde," Elec Components Conf. Washington, DC, 1971.

ACKNOWLEDGMENT

The author wishes to thank J. Walsh for the fabrication and evaluation of the 4.35-GHz microstrip oscillator and R. Askew for data and photographs on the hybrid thin-film radiosonde oscillator. This Note originally appeared as an article of the same title in THE MICROWAVE JOURNAL.

RCA

Solid State Division

RF Power Transistors

Application Note AN-6307

Microwave Amplifiers and Oscillators Using RCA3000-Series Transistors

by G. Hodowanec

This Note describes several experimental microstripline circuits which employ RCA3001, RCA3003, or RCA3005 transistors at frequencies of 1.7 to 2.7 GHz.[1] The RCA3000-series transistors are emitter-ballasted, silicon, n-p-n devices packaged in the hermetic stripline package (HF-46) shown in Fig. 1. They are designed for use in microwave communications, telemetry, relay links, transponders, and radionavigation or radiolocation systems which operate in the frequency range of approximately 1.7 to 3.2 GHz. These transistors, which are employed primarily in the common-base mode of operation, are suitable for small-signal class A and large-signal class B or C cw or pulsed applications in stripline, microstripline, or lumped-constant circuits.

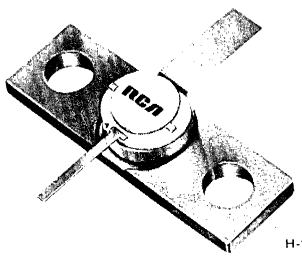


Fig. 1 – Hermetic stripline package, HF-46, housing the RCA3000-series transistors.

The hermetic stripline package which houses the transistors has relatively low parasitic capacitances and inductances, characteristics which afford stable operation in the common-base mode. In general, microstrip circuit elements are used in the circuits described, and the unavoidable package parasitics are incorporated into the matching networks to yield good performance with reasonable operating bandwidths. Although there are many ways of designing matching networks, this Note emphasizes only a few methods which have demonstrated both simplicity in design and good performance in the frequency range of interest. Therefore, the circuits and design approaches discussed should be considered primarily as guidance for the circuit designer and not necessarily as optimum designs.

RCA3001 Circuits

The RCA3001 transistor is intended for low-level pre-driver or oscillator applications and is capable of about 1.3 watts of saturated power output at 3 GHz and 2 watts at 2 GHz when operated with a 28-volt collector supply. The low input and output Q's for this device in the range of 1.7 to approximately 2.7 GHz facilites its application in broadband circuits operating over this frequency range. With the techniques shown, the broadband performance approaches the narrowband performance obtainable from this device.

Amplifier Designs

The input impedance of the RCA3001 transistor can be matched over the range of about 1.7 to 2.6 GHz with better than 1-dB gain flatness using relatively simple input-circuit networks. Two circuit approaches are considered: an in-line tapered-line transformer based upon the methods of Womack[2], and a more conventional two-step network which also shows broadband capability.

TAPERED-LINE DESIGN

Fig. 2 shows an RCA3001 transistor in a circuit constructed on a 1/32-inch Teflon-fiberglass circuit board. The circuit is composed of a broadband tapered-line input transformer and an output matching network consisting of a conventional single-step uniform-line matching transformer.[3] The circuit is designed to operate at a center frequency of 2.3 GHz with fixed input drive and a 28-volt collector supply. The typical performance of the input

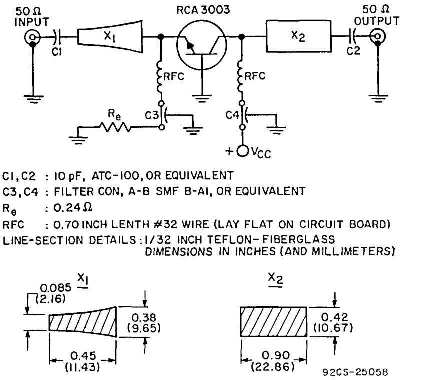


Fig.2 – 2.3 GHz tapered-line (broadband input) circuit using the RCA3001 transistor.

network is determined by optimally matching the output network over a wide frequency range by use of a triple-stub tuner section.

The performance of the input circuit is shown by the solid curves in Fig. 3. The data indicates the potential 1-dB bandwidth of the input circuit to be greater than 800 MHz. The power output and collector efficiency are relatively constant in the range of about 1.8 to 2.4 GHz; therefore, approximately 1.3 to 1.5 watts of output power with an 8- to 9-dB power gain and a collector efficiency in the order of 40 percent can be expected from these devices in this frequency range. The performance of the uniform-line output transformer is given by the dashed curves of Fig. 3. The narrower bandwidth of the uniform-line matching section is obvious in this plot, the 1-dB bandwidth now being in the order of 175 MHz. The overall performance of the circuit of Fig. 2 is similar to that of the dashed-line curves of Fig. 3 since the circuit performance is limited by the narrow-band filter characteristics of the output network.

While the circuit shown in Fig. 2 is intended for operation at 2.3 GHz, it can be operated anywhere in the range of 1.7 to 2.6 GHz (without changing the input network design) simply by redesigning the output network for the new frequency range. Performance of the circuit of Fig. 2 with the collector supply at 22 volts is given in Fig. 4. Slight circuit modifications to better match the 22-volt impedances will improve this performance.

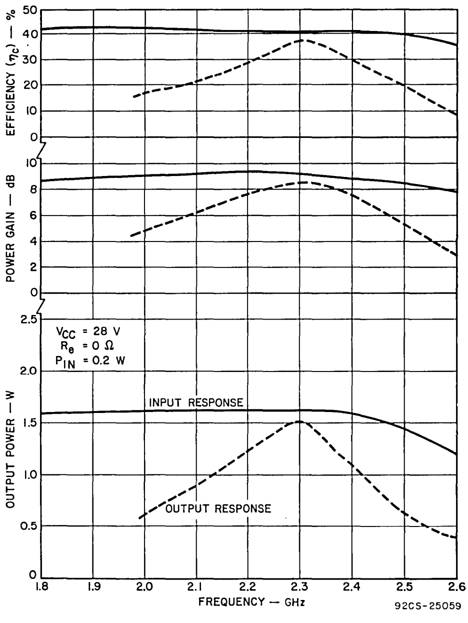


Fig.3 – Performance of the circuit of Fig. 2 with V_{CC} = 28 V.

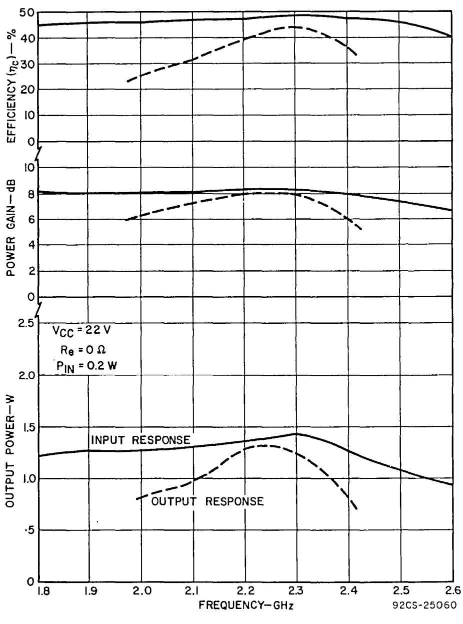


Fig.4 – Performance of the circuit of Fig. 2 with V_{CC} = 22 V.

TWO-STEP NETWORK DESIGN

Fig. 5 shows an RCA3001 transistor in a circuit that uses a two-step network to achieve broadband performance at

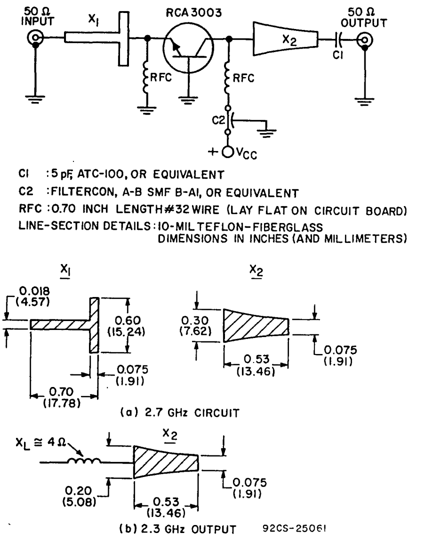


Fig.5 – 2.5 GHz (two-step input) circuit using the RCA3001 transistor.

the input to the device. A capacitive stub section is used to tune out the inductive reactance of the input impedance, and the resulting real impedance is transformed to the 50-ohm source impedance with a quarter-wave matching section. Although this circuit is constructed on 10-mil Teflon-fiberglass circuit board to better define the stub sections, it can also be constructed on 1/32-inch board.

The performance of the two-step input network under "tuned" output conditions is given by the solid curves of Fig. 6. The potential 1-dB performance of this input design is about 1.8 to 2.5 GHz. The original output circuit, shown in Fig. 5(a), utilizes a tapered-line section designed for a center frequency of 2.5 GHz. Performance of the output circuit (and thus also the basic circuit) is given by the dashed-line curves of Fig. 6.

The circuit performance at 2.5 GHz appeared to be limited by the input response at this frequency. Therefore, the output circuit was modified to a center frequency of 2.3 GHz, as shown in Fig. 5(b). Some additional inductive reactance was needed at the output of the device to make up for the additional electrical length needed to drop the filter response approximately 200 MHz (utilizing the original circuit-board length dimensions). Performance of the revised output circuit is given by the dashed (long and short) curves of Fig. 6. The 1-dB bandwith is now approximately 2.1 to 2.4 GHz. Power gain and collector

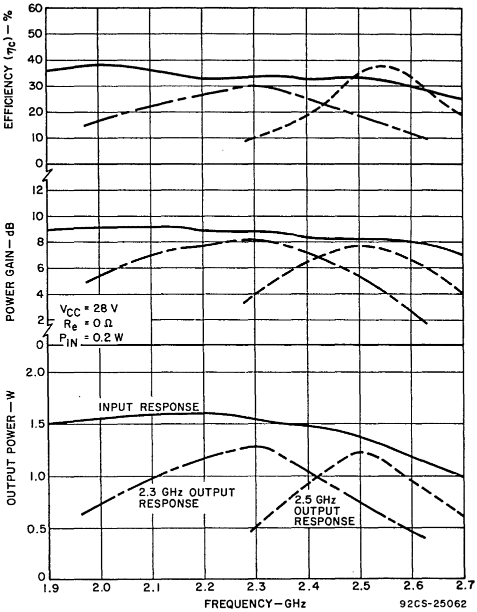


Fig.6 – Performance of the circuits of Fig. 5 with V_{CC} = 28 V.

efficiency with this modification is slightly degraded, probably as a result of losses in the series inductance added to lower the output filter characteristics. The input VSWR for both the tapered-line network and the two-step network are typically less than 1.5:1 in the 1-dB bandwidth range.

Oscillator Design

Shown in Fig. 7 is an oscillator design that uses the

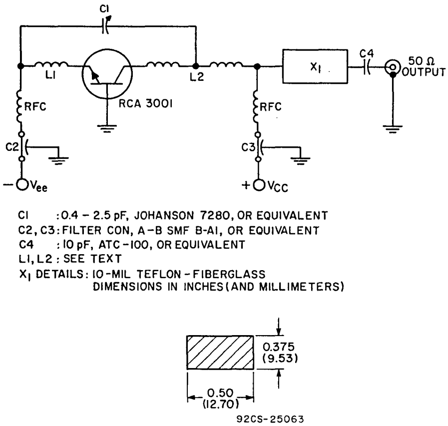


Fig.7 – 2- to 2.2-GHz oscillator circuit using the RCA3001 transistor.

RCA3001 device in a simple resonant-feedback-loop circuit.[4] With a 15-volt supply, better than 1 watt of output power is developed over the range of 2 to 2.2 GHz with the collector efficiency in the order of 50 percent. The feedback network consists of inductors L_1, L_2 and capacitor C_1. Inductor L_1 is formed by bending the emitter lead back over the top ceramic of the RCA3001 device; inductor L_2 is formed from a 0.20-inch length of collector lead bent down to the output line-transformer section of the circuit. Capacitor C_1 connects these two inductors (from the end of L_1 to the center of L_2) and is the tuning element (f_o) for this circuit. The output network consists of a half portion of L_2 and the uniform-line transformer, X_1. Capacitor C_4 is selected so that it is self-resonant above 2.15 GHz, and thus serves as a dc block. The tuning range of this circuit is limited by the feedback network as well as the limited response of the uniform-line output transformer. The high collector efficiency is the direct result of the efficient feedback system used in this oscillator design.

RCA3003 Circuits

The RCA3003 transistor is intended for use in higher-level driver stages and oscillator applications as well as in applications with low-level output-device requirements. This device is capable of approximately 3 watts of saturated power output at 3 GHz and 4 watts at 2 GHz when operated with a 28-volt collector supply. The relatively low input and output Q's for this device permit reasonable broadband operation in the range of 1.7 to 2.5 GHz. Broadband performance in the circuits shown approaches the narrowband performance obtainable under highly-tuned conditions.

Amplifier Designs

The design approaches used in the experimental RCA3003 circuits shown are similar to those used with the RCA3001 devices. A design using a tapered-line input section and a uniform-line output section is shown in Fig. 8. Performance of this circuit is shown in Fig. 9. The

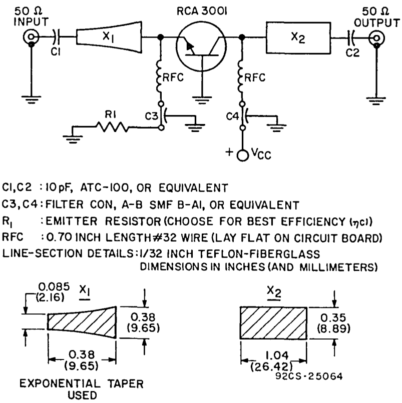


Fig.8 — 2.1-GHz circuit using the RCA3003 transistor (tapered-line).

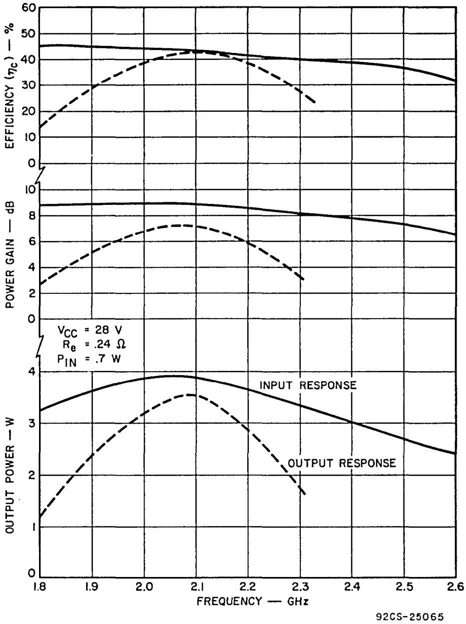


Fig.9 — Performance of the circuit of Fig. 8.

potential 1-dB bandwidth response of the input (center frequency of 2.1 GHz) is about 1.7 to 2.4 GHz, or 700 MHz. The 1-dB response of the output circuit is 1.95 to 2.2 GHz, or 250 MHz. Power gain is about 7-dB and collector efficiency is in the order of 40 percent for this frequency range.

Fig. 10 shows a circuit originally designed for a center frequency of 2.7 GHz. A two-step matching network was used in the input and a tapered-line section in the output. The output circuit was later modified to a center frequency of 2.3 GHz. The performance of these circuits is shown in Fig. 11. The broadband response of the input network is shown by the solid curves. Moreover, a 1-dB bandwidth greater than 400 MHz was obtained from the 2.3 GHz circuit at both the 28-volt and 22-volt collector supply levels. Response of the 2.3 GHz circuits is limited mainly by the output filter characteristics, while the 2.7 GHz circuit is also limited by the input response.

Oscillator Design

The oscillator design shown in Fig. 7 can also be used with the RCA3003 device. With a 20-volt collector supply, a power output in the order of 2.5 watts over the range of 1.9 to 2.1 GHz is obtained; the collector efficiency remains in the order of 50 percent. Again, the tunable frequency range is limited by the feedback-loop characteristics and the narrow-band response of the output network.

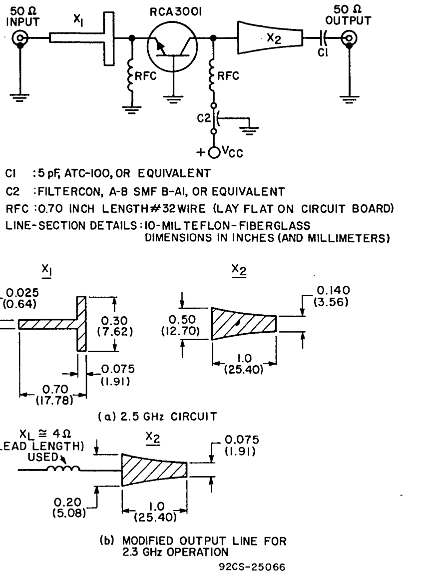


Fig. 10 – 2.3- and 2.7-GHz circuits using the RCA3003 with broadband input and output matching networks.

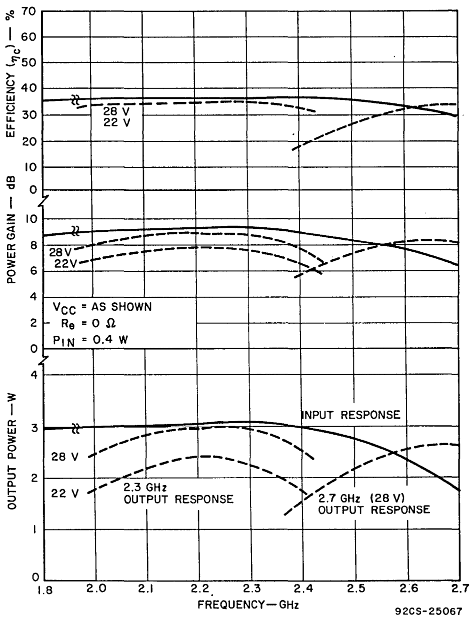


Fig. 11 – Performance of the circuit in Fig. 10.

RCA3005 Circuits

The RCA3005 is intended for use in high-level driver stages or as the output stage of an amplifier. This device is capable of about 5 watts of saturated output power at 3 GHz and 7 watts at 2 GHz when operated with a 28-volt collector supply. Because of the higher Q's for this device, broadband operation generally requires a two-step matching network, where the first step "tunes out" at least a portion of the reactive terms of the device impedances.

Amplifier Designs

A two-step input network (similar to those used with RCA3001 and RCA3003 devices) is used to obtain a 1-dB bandwidth of approximately 500 MHz for the input section of the RCA3005 device. The test circuit, shown in Fig. 12(a) was originally designed for a center frequency of approximately 2.1 GHz. A 10-mil Teflon-fiberglass circuit board was chosen to better define the microstrip stub sections and to achieve low transformer impedances with reasonable line dimensions.

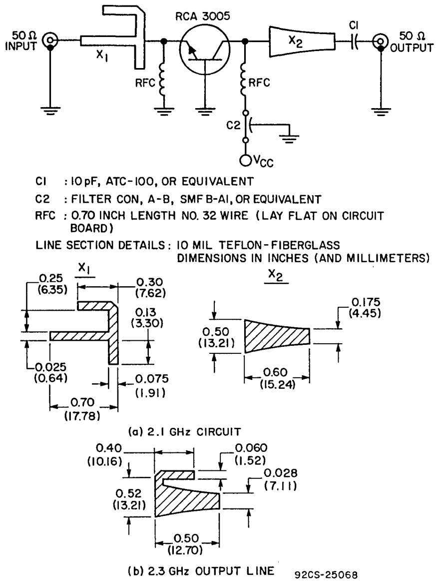


Fig. 12 – Amplifier circuit using the RCA3005 transistor.

The tapered-line output transformers were also evaluated. The first design, shown in Fig. 12(a), matches the collector load impedance at a center frequency of 2.1 GHz. The performance of this output section is shown by the dashed-line curves of Fig. 13. The output 1-dB bandwidth was limited to about 200 MHz, as a result, in part, of the higher output Q of the RCA3005.

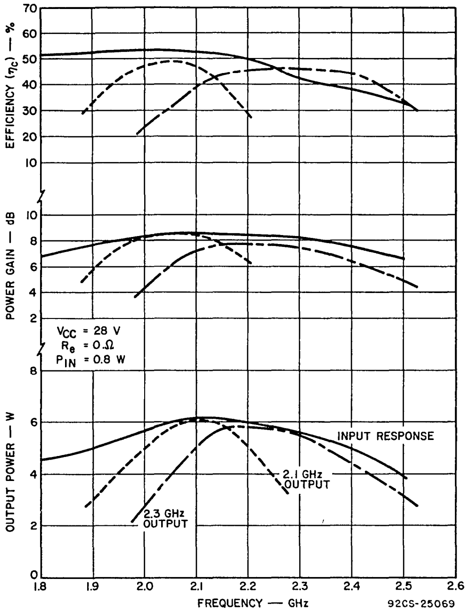


Fig. 13 – Performance of the circuit of Fig. 12.

In the output circuit of Fig. 12(b), a microstrip capacitive-stub section is used to "tune out" some of the excess output inductance, and the tapered-line transformer is redesigned for a center frequency of 2.3 GHz. The response of this output circuit is shown by the dashed (long and short) curves of Fig. 13. The 1-dB bandwidth has been increased to about 350 MHz, and covers the range of approximately 2.05 to 2.4 GHz. The power output, power gain, and collector efficiency of these circuits closely approaches the performance obtainable under narrowband conditions.

Oscillator Designs

No attempt was made to evaluate the performance of the RCA3005 as an oscillator. However, performance similar to that of the RCA3001 and RCA3003 can be expected. For example, 5 watts of output power at 2.0 GHz can be expected of the RCA3005 device in oscillator service.

Other Designs

Not all possible design techniques have been evaluated above. The more conventional techniques, such as two-step in-line transformers[5] and ladder or Chebyshev-type networks (using lumped or distributed elements), could be used to obtain reasonable bandwidths. In addition, further size reduction could be achieved through the use of alumina circuit boards. Alumina boards could also be expected to further improve the bandwidth of tapered-line transformers.

The circuit dimensions given in this Note are based on the characteristics of circuit boards available to the author. Variations in the characteristics of these boards from different suppliers as well as variations in device characteristics may require some adjustment of circuit dimensions for proper circuit operation.

REFERENCES

1. Characteristics and performance data for the RCA3000-series transistors are given in RCA Data File No. 657.
2. Womack, C.P., "The Use of Exponential Transmission Lines in Microwave Components", IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-11, March 1962.
3. French, G.N., Fooks, E.H., "The Design of Stepped Transmission-Line Transformers", IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-16, October 1968.
4. "High-Power Transistor Microwave Oscillators", Hodowanec, G., RCA Application Note AN-6084.
5. French, G.N., and Fooks, E.H., "Double Section Matching Transformers", IEEE Transactions on Microwave Theory and Techniques.

Subject Index

Subject Index

Subject Index