MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
MMBT3904WT1/D

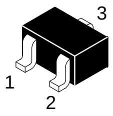
General Purpose Transistors

NPN and PNP Silicon

NPN
MMBT3904WT1
PNP
MMBT3906WT1

These transistors are designed for general purpose amplifier applications. They are housed in the SOT–323/SC–70 which is designed for low power surface mount applications.

GENERAL PURPOSE
AMPLIFIER TRANSISTORS
SURFACE MOUNT



CASE 419–02, STYLE 3
SOT–323/SC–70

MAXIMUM RATINGS

Rating		Symbol	Value	Unit
Collector–Emitter Voltage	MMBT3904WT1 MMBT3906WT1	V_{CEO}	40 –40	Vdc
Collector–Base Voltage	MMBT3904WT1 MMBT3906WT1	V_{CBO}	60 –40	Vdc
Emitter–Base Voltage	MMBT3904WT1 MMBT3906WT1	V_{EBO}	6.0 –5.0	Vdc
Collector Current — Continuous	MMBT3904WT1 MMBT3906WT1	I_C	200 –200	mAdc

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Total Device Dissipation[1] $T_A = 25°C$	P_D	150	mW
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	833	°C/W
Junction and Storage Temperature	T_J, T_{stg}	–55 to +150	°C

DEVICE MARKING

MMBT3904WT1 = AM
MMBT3906WT1 = 2A

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector–Emitter Breakdown Voltage[2] ($I_C = 1.0$ mAdc, $I_B = 0$) ($I_C = –1.0$ mAdc, $I_B = 0$)	 MMBT3904WT1 MMBT3906WT1	$V_{(BR)CEO}$	 40 –40	 — —	Vdc
Collector–Base Breakdown Voltage ($I_C = 10$ μAdc, $I_E = 0$) ($I_C = –10$ μAdc, $I_E = 0$)	 MMBT3904WT1 MMBT3906WT1	$V_{(BR)CBO}$	 60 –40	 — —	Vdc
Emitter–Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$) ($I_E = –10$ μAdc, $I_C = 0$)	 MMBT3904WT1 MMBT3906WT1	$V_{(BR)EBO}$	 6.0 –5.0	 — —	Vdc
Base Cutoff Current ($V_{CE} = 30$ Vdc, $V_{EB} = 3.0$ Vdc) ($V_{CE} = –30$ Vdc, $V_{EB} = –3.0$ Vdc)	 MMBT3904WT1 MMBT3906WT1	I_{BL}	 — —	 50 –50	nAdc
Collector Cutoff Current ($V_{CE} = 30$ Vdc, $V_{EB} = 3.0$ Vdc) ($V_{CE} = –30$ Vdc, $V_{EB} = –3.0$ Vdc)	 MMBT3904WT1 MMBT3906WT1	I_{CEX}	 — —	 50 –50	nAdc

1. Device mounted on FR4 glass epoxy printed circuit board using the minimum recommended footprint.
2. Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2.0%.

Thermal Clad is a trademark of the Bergquist Company.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) (Continued)

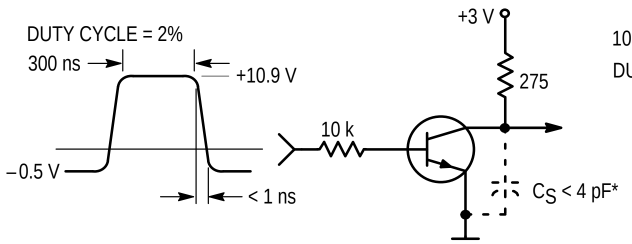
Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS(2)					
DC Current Gain		h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	MMBT3904WT1		40	—	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)			70	—	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)			100	300	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			60	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)			30	—	
(I_C = –0.1 mAdc, V_{CE} = –1.0 Vdc)	MMBT3906WT1		60	—	
(I_C = –1.0 mAdc, V_{CE} = –1.0 Vdc)			80	—	
(I_C = –10 mAdc, V_{CE} = –1.0 Vdc)			100	300	
(I_C = –50 mAdc, V_{CE} = –1.0 Vdc)			60	—	
(I_C = –100 mAdc, V_{CE} = –1.0 Vdc)			30	—	
Collector–Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)	MMBT3904WT1		—	0.2	
(I_C = 50 mAdc, I_B = 5.0 mAdc)			—	0.3	
(I_C = –10 mAdc, I_B = –1.0 mAdc)	MMBT3906WT1		—	–0.25	
(I_C = –50 mAdc, I_B = –5.0 mAdc)			—	–0.4	
Base–Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)	MMBT3904WT1		0.65	0.85	
(I_C = 50 mAdc, I_B = 5.0 mAdc)			—	0.95	
(I_C = –10 mAdc, I_B = –1.0 mAdc)	MMBT3906WT1		–0.65	–0.85	
(I_C = –50 mAdc, I_B = –5.0 mAdc)			—	–0.95	
SMALL–SIGNAL CHARACTERISTICS					
Current–Gain — Bandwidth Product		f_T			MHz
(I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	MMBT3904WT1		300	—	
(I_C = –10 mAdc, V_{CE} = –20 Vdc, f = 100 MHz)	MMBT3906WT1		250	—	
Output Capacitance		C_{obo}			pF
(V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	MMBT3904WT1		—	4.0	
(V_{CB} = –5.0 Vdc, I_E = 0, f = 1.0 MHz)	MMBT3906WT1		—	4.5	
Input Capacitance		C_{ibo}			pF
(V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	MMBT3904WT1		—	8.0	
(V_{EB} = –0.5 Vdc, I_C = 0, f = 1.0 MHz)	MMBT3906WT1		—	10.0	
Input Impedance		h_{ie}			k Ω
(V_{CE} = 10 Vdc, I_C = 1.0 mAdc, f = 1.0 kHz)	MMBT3904WT1		1.0	10	
(V_{CE} = –10 Vdc, I_C = –1.0 mAdc, f = 1.0 kHz)	MMBT3906WT1		2.0	12	
Voltage Feedback Ratio		h_{re}			X 10^{-4}
(V_{CE} = 10 Vdc, I_C = 1.0 mAdc, f = 1.0 kHz)	MMBT3904WT1		0.5	8.0	
(V_{CE} = –10 Vdc, I_C = –1.0 mAdc, f = 1.0 kHz)	MMBT3906WT1		0.1	10	
Small–Signal Current Gain		h_{fe}			—
(V_{CE} = 10 Vdc, I_C = 1.0 mAdc, f = 1.0 kHz)	MMBT3904WT1		100	400	
(V_{CE} = –10 Vdc, I_C = –1.0 mAdc, f = 1.0 kHz)	MMBT3906WT1		100	400	
Output Admittance		h_{oe}			μmhos
(V_{CE} = 10 Vdc, I_C = 1.0 mAdc, f = 1.0 kHz)	MMBT3904WT1		1.0	40	
(V_{CE} = –10 Vdc, I_C = –1.0 mAdc, f = 1.0 kHz)	MMBT3906WT1		3.0	60	
Noise Figure		NF			dB
(V_{CE} = 5.0 Vdc, I_C = 100 μAdc, R_S = 1.0 k Ω, f = 1.0 kHz)	MMBT3904WT1		—	5.0	
(V_{CE} = –5.0 Vdc, I_C = –100 μAdc, R_S = 1.0 k Ω, f = 1.0 kHz)	MMBT3906WT1		—	4.0	

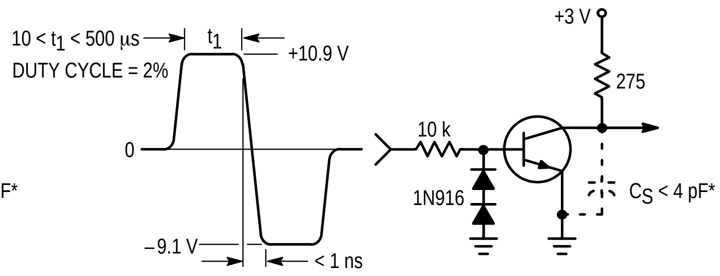
SWITCHING CHARACTERISTICS

Delay Time	(V_{CC} = 3.0 Vdc, V_{BE} = –0.5 Vdc)	MMBT3904WT1	t_d	—	35	ns
	(V_{CC} = –3.0 Vdc, V_{BE} = 0.5 Vdc)	MMBT3906WT1		—	35	
Rise Time	(I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	MMBT3904WT1	t_r	—	35	
	(I_C = –10 mAdc, I_{B1} = –1.0 mAdc)	MMBT3906WT1		—	35	
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc)	MMBT3904WT1	t_s	—	200	ns
	(V_{CC} = –3.0 Vdc, I_C = –10 mAdc)	MMBT3906WT1		—	225	
Fall Time	(I_{B1} = I_{B2} = 1.0 mAdc)	MMBT3904WT1	t_f	—	50	
	(I_{B1} = I_{B2} = –1.0 mAdc)	MMBT3906WT1		—	75	

2. Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MMBT3904WT1





* Total shunt capacitance of test jig and connectors

Figure 1. Delay and Rise Time Equivalent Test Circuit

Figure 2. Storage and Fall Time Equivalent Test Circuit

TYPICAL TRANSIENT CHARACTERISTICS

—— T_J = 25°C
— — T_J = 125°C

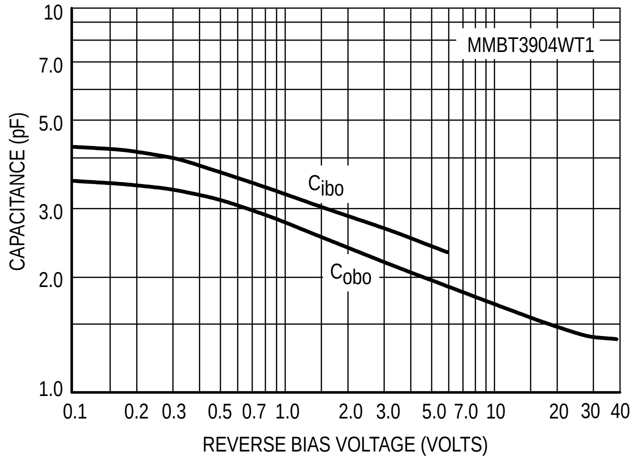


Figure 3. Capacitance

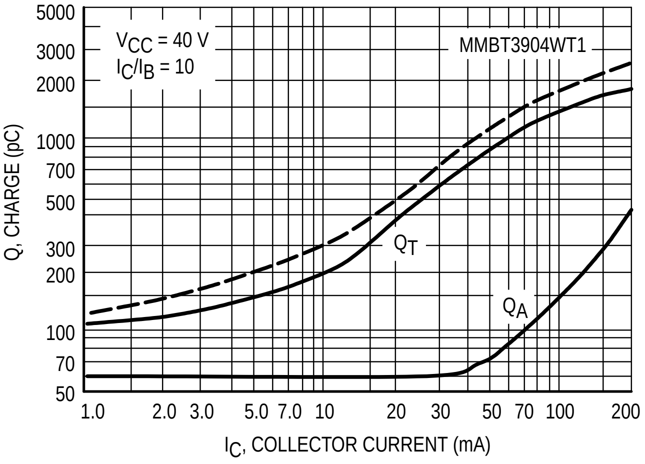


Figure 4. Charge Data

MMBT3904WT1

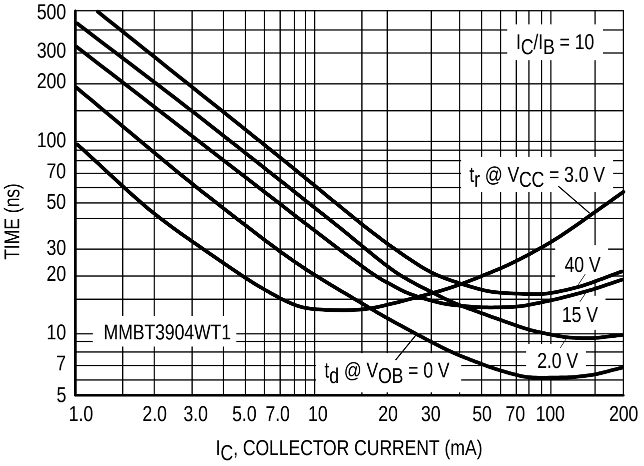


Figure 5. Turn–On Time

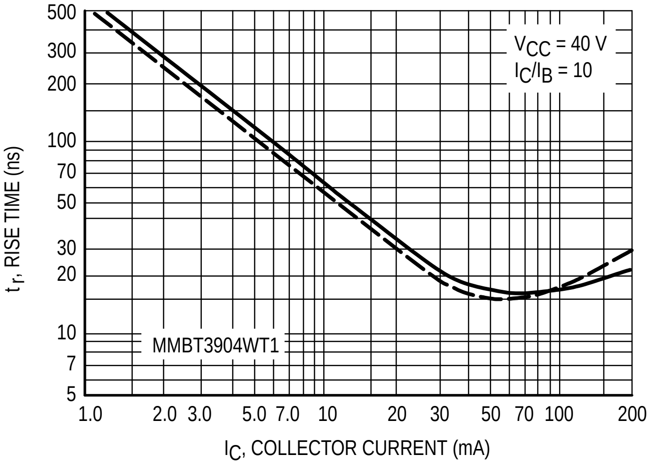


Figure 6. Rise Time

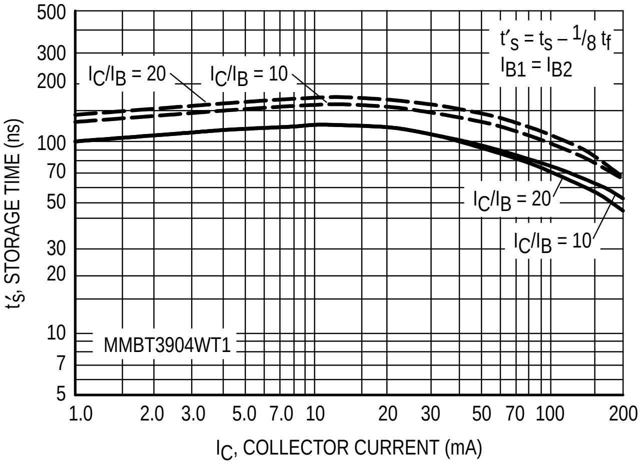


Figure 7. Storage Time

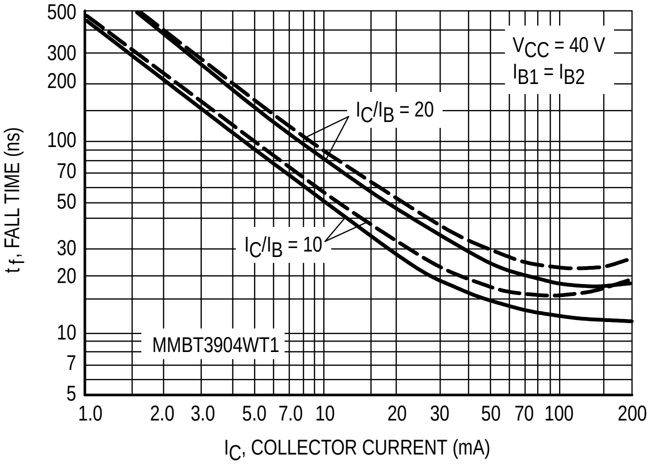


Figure 8. Fall Time

TYPICAL AUDIO SMALL–SIGNAL CHARACTERISTICS
NOISE FIGURE VARIATIONS

(V_{CE} = 5.0 Vdc, T_A = 25°C, Bandwidth = 1.0 Hz)

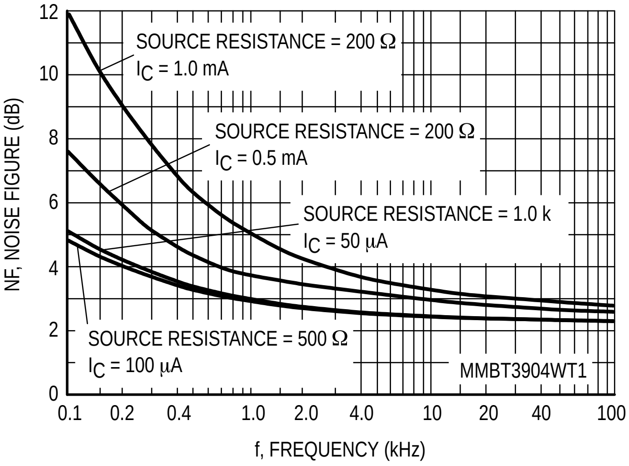


Figure 9. Noise Figure

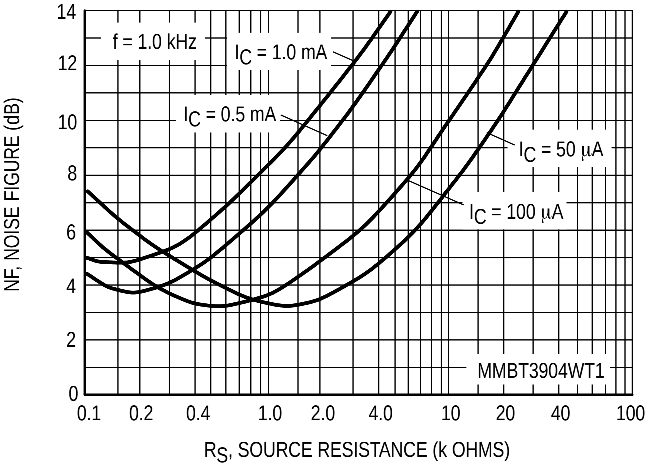


Figure 10. Noise Figure

MMBT3904WT1

h PARAMETERS

(V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C)

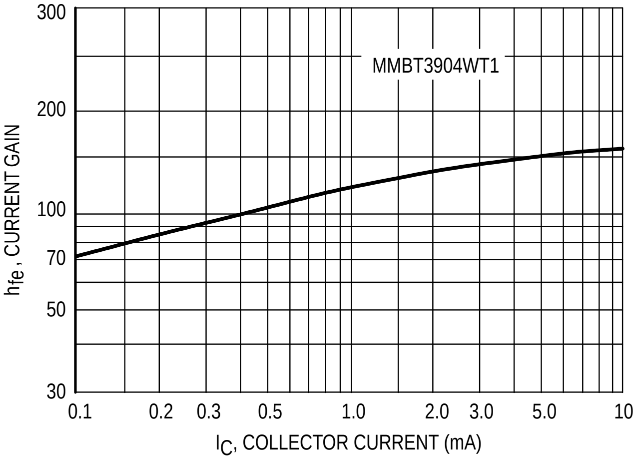


Figure 11. Current Gain

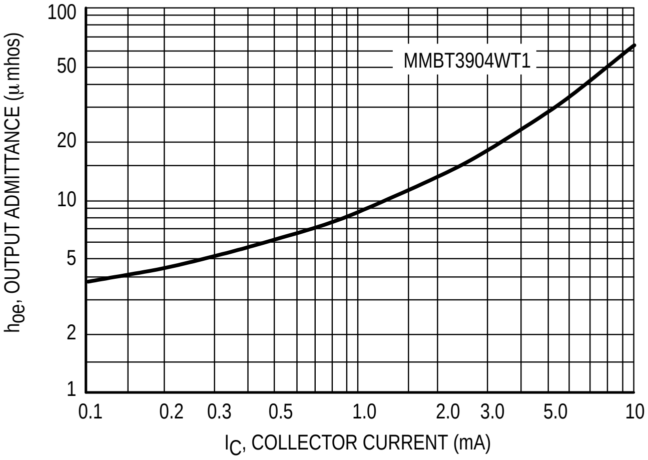


Figure 12. Output Admittance

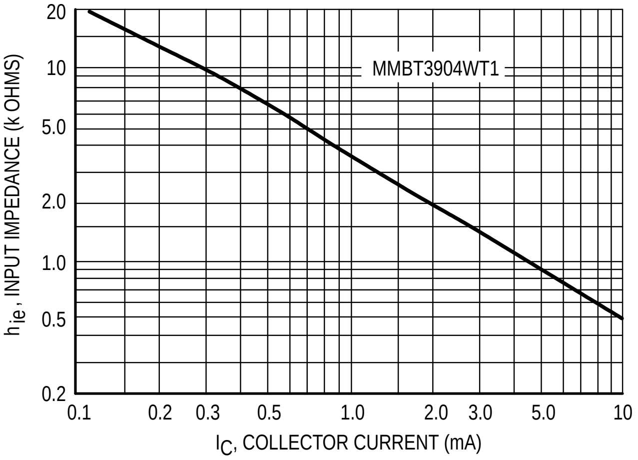


Figure 13. Input Impedance

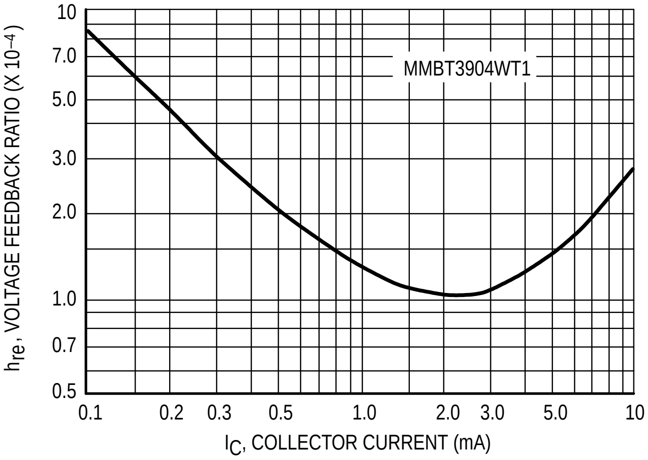


Figure 14. Voltage Feedback Ratio

MMBT3904WT1

TYPICAL STATIC CHARACTERISTICS

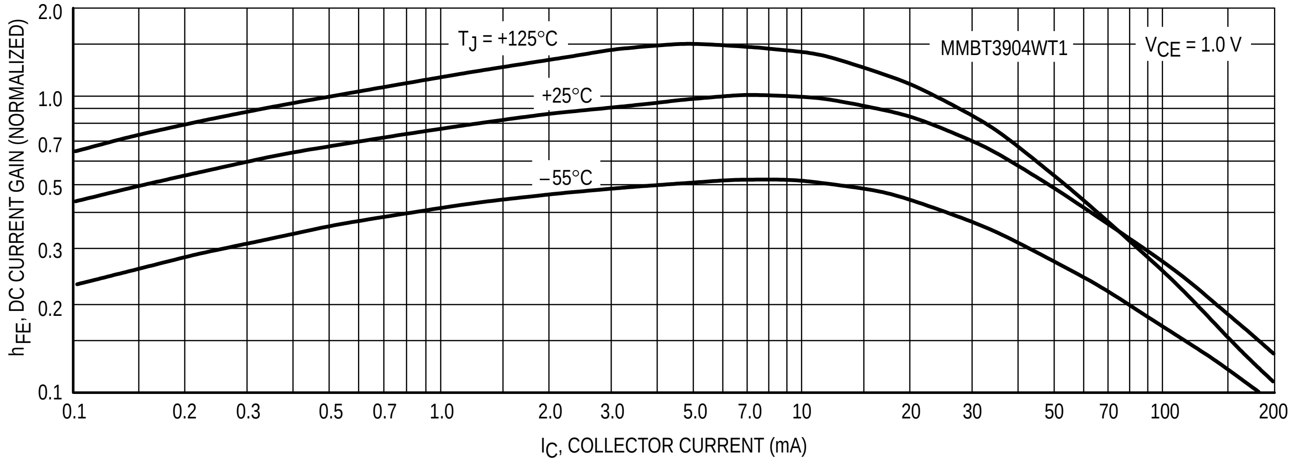


Figure 15. DC Current Gain

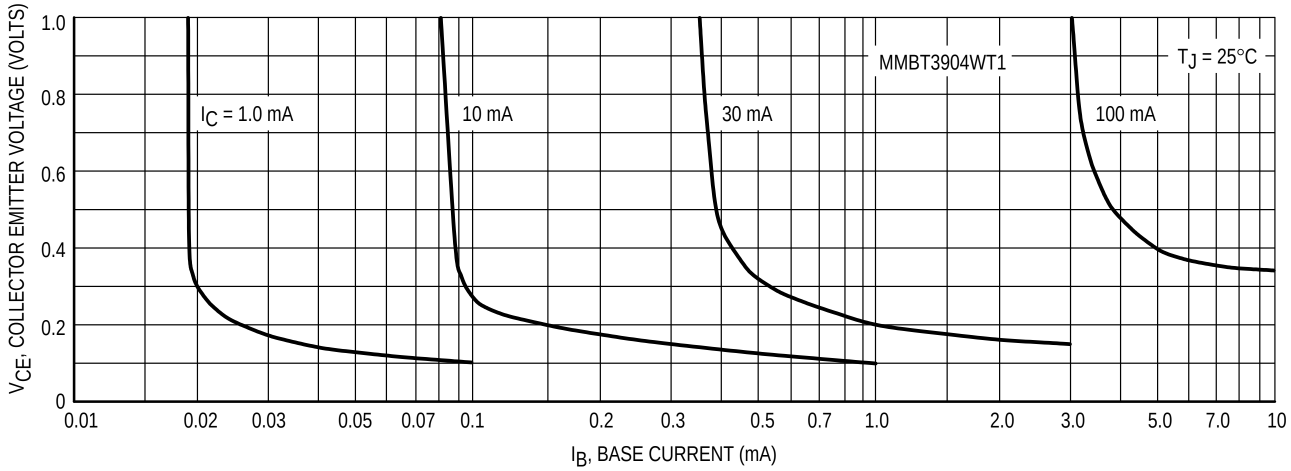


Figure 16. Collector Saturation Region

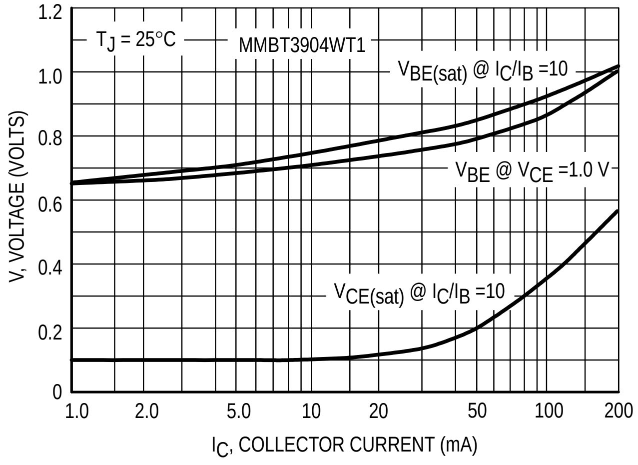


Figure 17. “ON” Voltages

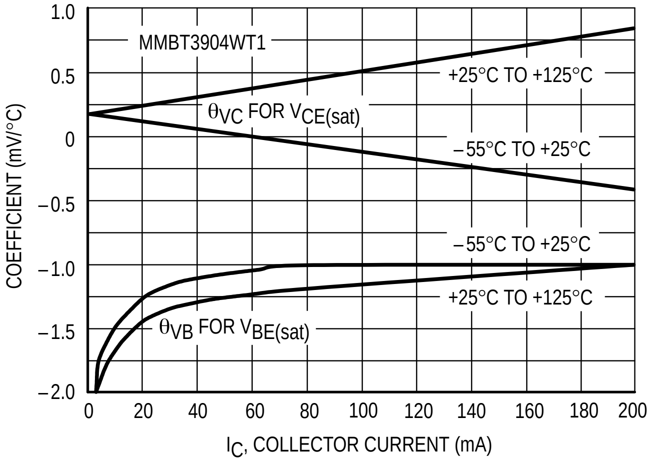
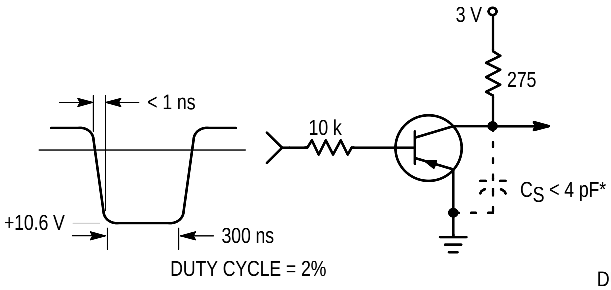
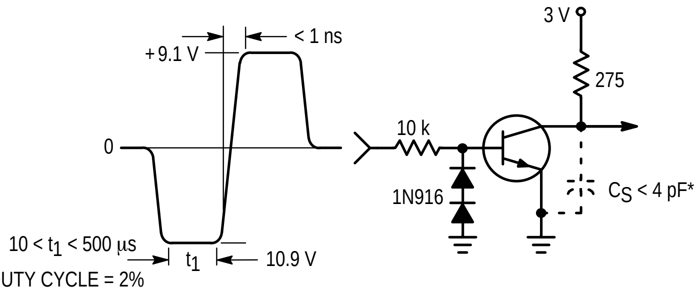


Figure 18. Temperature Coefficients

MMBT3906WT1





* Total shunt capacitance of test jig and connectors

Figure 19. Delay and Rise Time Equivalent Test Circuit

Figure 20. Storage and Fall Time Equivalent Test Circuit

TYPICAL TRANSIENT CHARACTERISTICS

— T_J = 25°C
– – T_J = 125°C

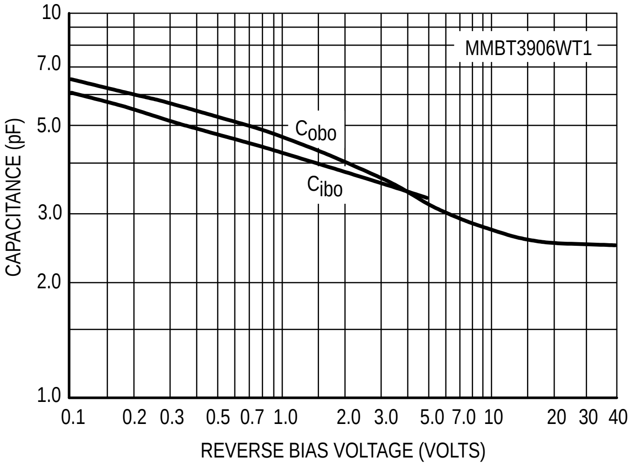


Figure 21. Capacitance

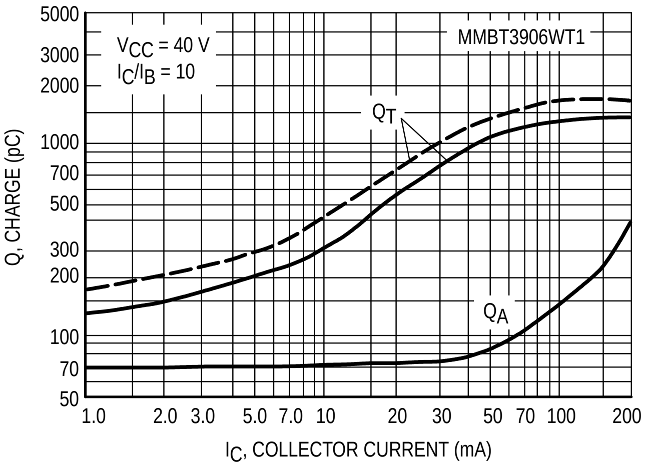


Figure 22. Charge Data

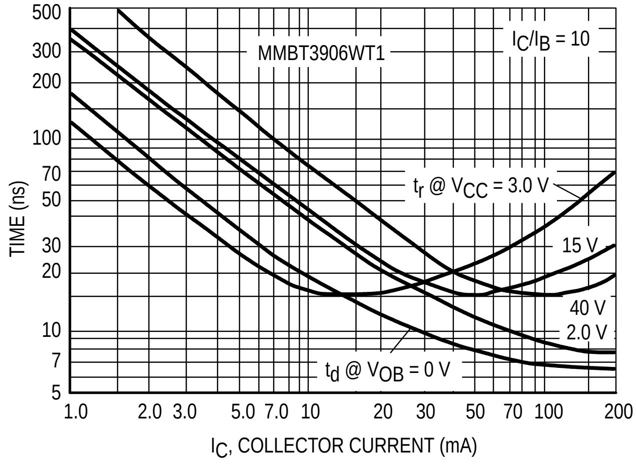


Figure 23. Turn–On Time

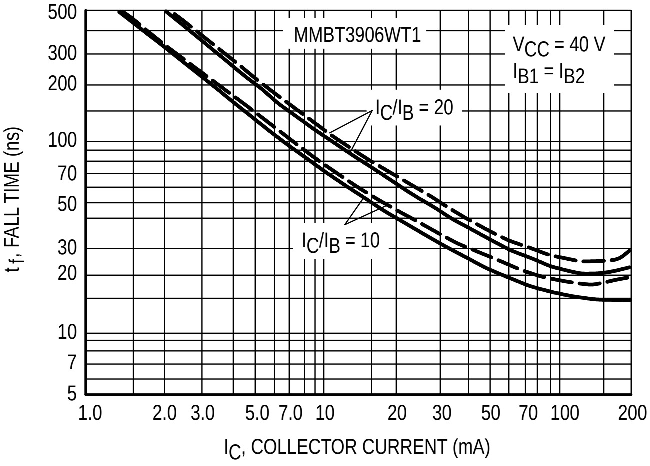


Figure 24. Fall Time

MMBT3906WT1

TYPICAL AUDIO SMALL–SIGNAL CHARACTERISTICS NOISE FIGURE VARIATIONS

(V_{CE} = –5.0 Vdc, T_A = 25°C, Bandwidth = 1.0 Hz)

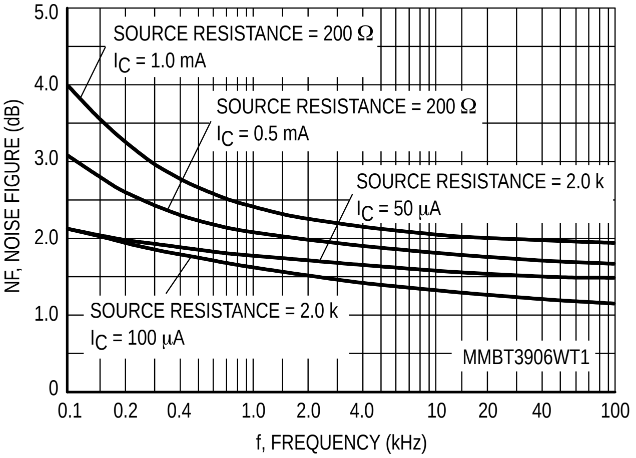


Figure 25.

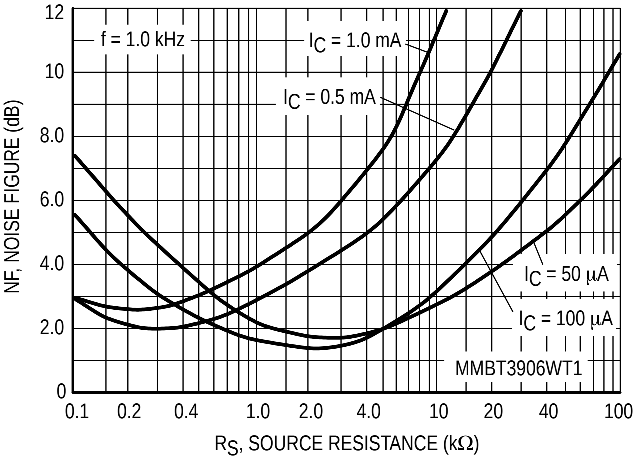


Figure 26.

h PARAMETERS

(V_{CE} = –10 Vdc, f = 1.0 kHz, T_A = 25°C)

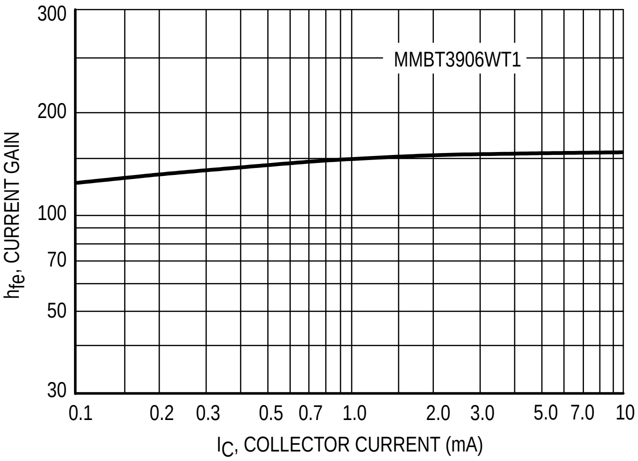


Figure 27. Current Gain

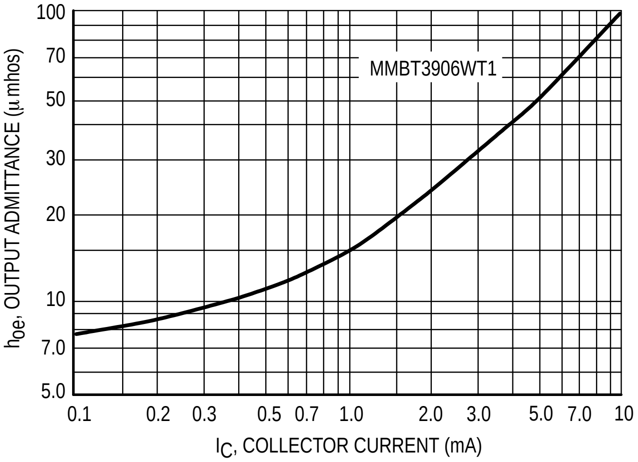


Figure 28. Output Admittance

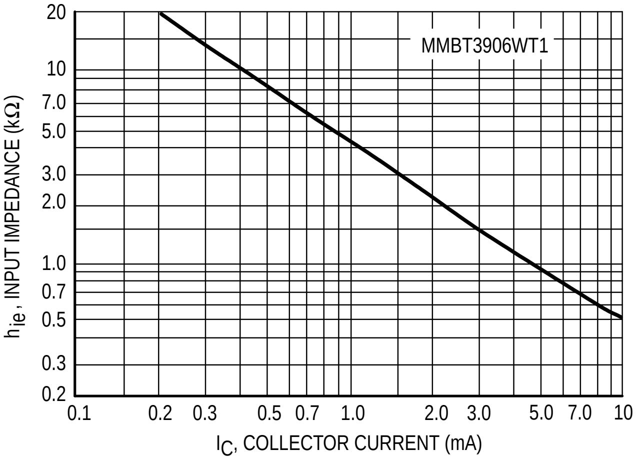


Figure 29. Input Impedance

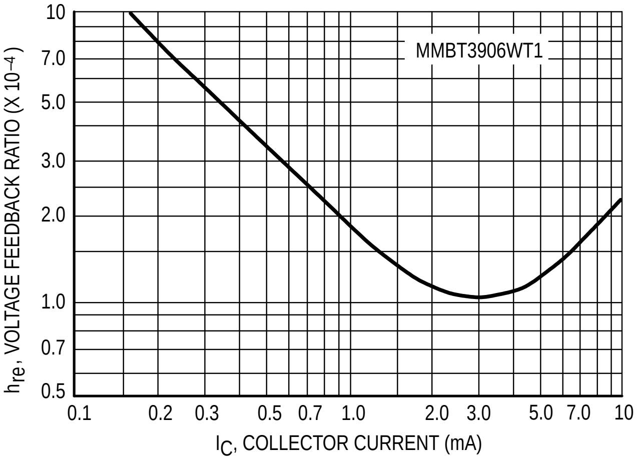


Figure 30. Voltage Feedback Ratio

MMBT3906WT1

STATIC CHARACTERISTICS

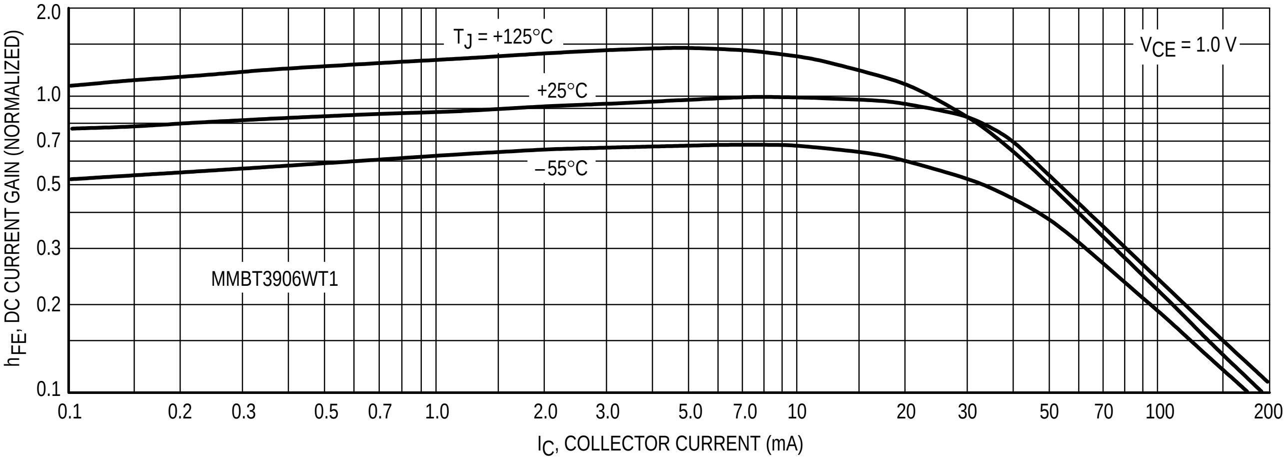


Figure 31. DC Current Gain

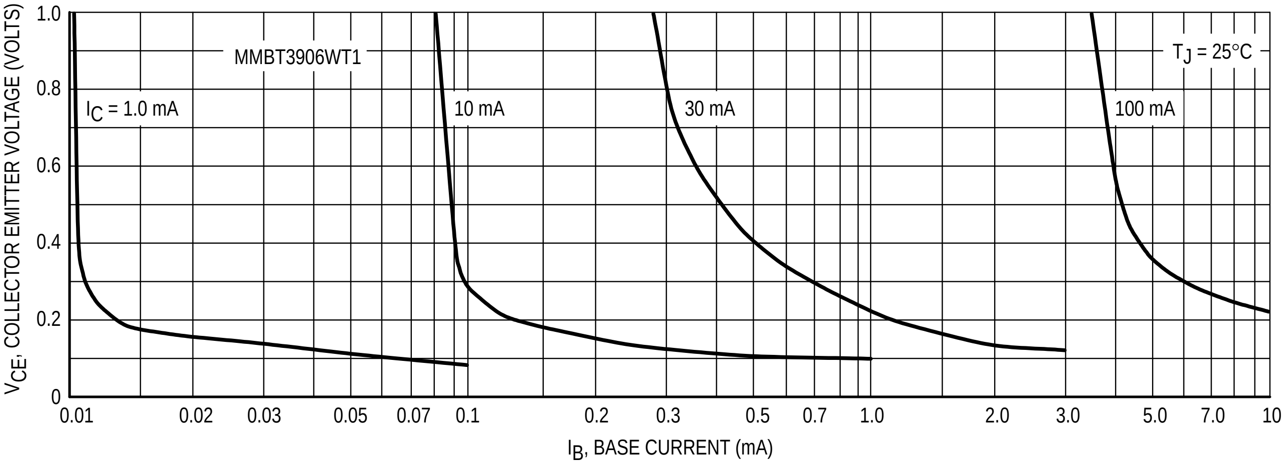


Figure 32. Collector Saturation Region

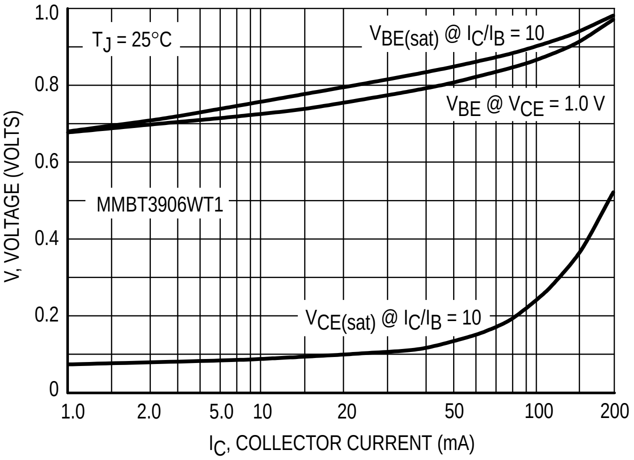


Figure 33. “ON” Voltages

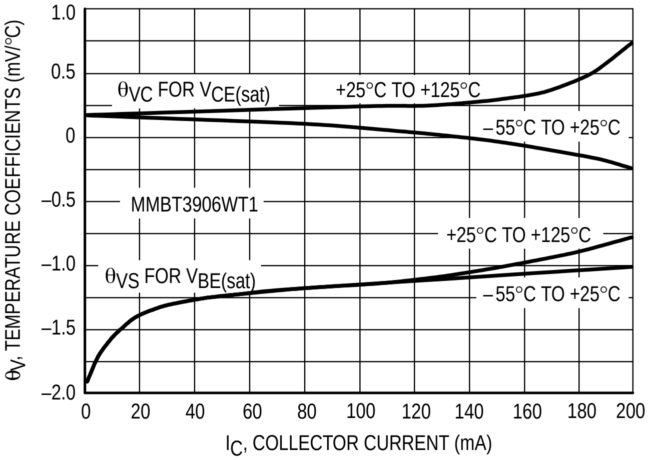
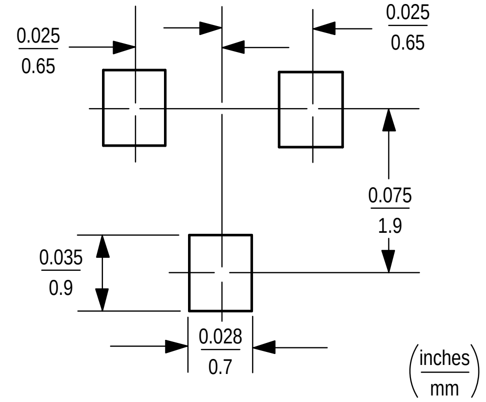


Figure 34. Temperature Coefficients

INFORMATION FOR USING THE SOT–323/SC–70 SURFACE MOUNT PACKAGE

MINIMUM RECOMMENDED FOOTPRINT FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the semiconductor packages must be the correct size to insure proper solder connection interface between the board and the package. With the correct pad geometry, the packages will self align when subjected to a solder reflow process.



SOT–323/SC–70

SOT–323/SC–70 POWER DISSIPATION

The power dissipation of the SOT–323/SC–70 is a function of the pad size. This can vary from the minimum pad size for soldering to a pad size given for maximum power dissipation. Power dissipation for a surface mount device is determined by $T_{J(max)}$, the maximum rated junction temperature of the die, $R_{\theta JA}$, the thermal resistance from the device junction to ambient, and the operating temperature, T_A. Using the values provided on the data sheet for the SOT–323/SC–70 package, P_D can be calculated as follows:

$$P_D = \frac{T_{J(max)} - T_A}{R_{\theta JA}}$$

The values for the equation are found in the maximum ratings table on the data sheet. Substituting these values into the equation for an ambient temperature T_A of 25°C, one can calculate the power dissipation of the device which in this case is 150 milliwatts.

$$P_D = \frac{150°C - 25°C}{833°C/W} = 150 \text{ milliwatts}$$

The 833°C/W for the SOT–323/SC–70 package assumes the use of the recommended footprint on a glass epoxy printed circuit board to achieve a power dissipation of 150 milliwatts. There are other alternatives to achieving higher power dissipation from the SOT–323/SC–70 package. Another alternative would be to use a ceramic substrate or an aluminum core board such as Thermal Clad™. Using a board material such as Thermal Clad, an aluminum core board, the power dissipation can be doubled using the same footprint.

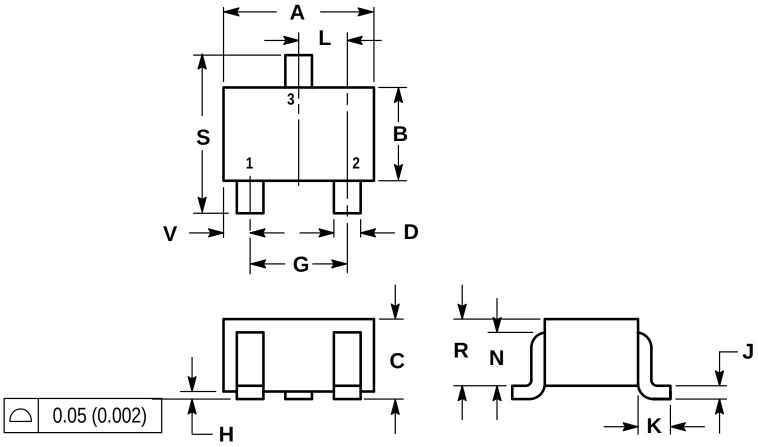
SOLDERING PRECAUTIONS

The melting temperature of solder is higher than the rated temperature of the device. When the entire device is heated to a high temperature, failure to complete soldering within a short time could result in device failure. Therefore, the following items should always be observed in order to minimize the thermal stress to which the devices are subjected.

- Always preheat the device.
- The delta temperature between the preheat and soldering should be 100°C or less.*
- When preheating and soldering, the temperature of the leads and the case must not exceed the maximum temperature ratings as shown on the data sheet. When using infrared heating with the reflow soldering method, the difference shall be a maximum of 10°C.
- The soldering temperature and time shall not exceed 260°C for more than 10 seconds.
- When shifting from preheating to soldering, the maximum temperature gradient shall be 5°C or less.
- After soldering has been completed, the device should be allowed to cool naturally for at least three minutes. Gradual cooling should be used as the use of forced cooling will increase the temperature gradient and result in latent failure due to mechanical stress.
- Mechanical stress or shock should not be applied during cooling.

* Soldering a device without preheating can cause excessive thermal shock and stress which can result in damage to the device.

PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.071	0.087	1.80	2.20
B	0.045	0.053	1.15	1.35
C	0.035	0.049	0.90	1.25
D	0.012	0.016	0.30	0.40
G	0.047	0.055	1.20	1.40
H	0.000	0.004	0.00	0.10
J	0.004	0.010	0.10	0.25
K	0.017 REF		0.425 REF	
L	0.026 BSC		0.650 BSC	
N	0.028 REF		0.700 REF	
R	0.031	0.039	0.80	1.00
S	0.079	0.087	2.00	2.20
V	0.012	0.016	0.30	0.40

STYLE 3:
PIN 1. BASE
2. EMITTER
3. COLLECTOR

CASE 419–02
ISSUE G
SOT–323/SC–70

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