Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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CURRENT MEASURING TECHNIQUES

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Introduction

Modern technology requires measurement capabilities in the fractional nanosecond (10^{-9} second) area. Diodes with switching times well under 100 picoseconds (10^{-12} second) and transistors with f_t (cut off frequency) of over 1000 Mc are presently available.

The sampling oscilloscope provides an excellent tool for the observation of these phenomena provided the signals are presented in a 50 Ω characteristic impedance system. However, it is very seldom that one can load a circuit with 50 Ω either in parallel or in series without disturbing it beyond use. Therefore, one has to provide means to extract the voltage and current waveforms from the circuit without disturbing the circuit to any great extent. The output of this device should present, to the sampling oscilloscope, an undistorted signal on a 50 Ω level.

In the case of voltage measurements, a good high frequency resistor (Ref. 1) may be selected. Provided it is placed in a proper environment, this type of series probe will perform rather well up to 1000 Mc. For the current waveforms, however, the solution is more complicated. Conventional current monitoring devices are restricted to relatively low frequencies either by basic limitations or by stray parameters. For example, the Hall potential in a Hall device is established in approximately 10^{-14} second. However, its inherent stray capacity and flux-linkage patterns prohibits its economical use above a few Mc.

The conventional current transformer with laminated core (Ref. 2) is useful up to a few kc. The tape wound version extends the frequency response and phase correlation to approximately 100 kc.

If the design of a current transformer is based on a TEM (Transverse Electromagnetic Mode) approach however, the basic frequency limitations are overcome and fractional nanosecond speeds can be achieved.

The TEM Current Transformer

A single turn circular winding is inserted in the space between the inner and outer conductor of a coaxial transmission line of impedance Z_0 (Figure 1). For simplicity only half of the lengthwise section is represented. The H (magnetic) field will terminate in a current sheath J in the circular winding.

$$\left(\text{Curl } H = \frac{\partial D}{\partial t} + J \text{ since } \frac{\partial D}{\partial t} = 0 \text{ inside the winding } \therefore \text{ curl } H = J.\right)$$

Also, since H is proportional to I, then $\oint J = I$ and a current I will flow in Z_1 for a single turn winding. At X_3 the current I in the single turn winding will

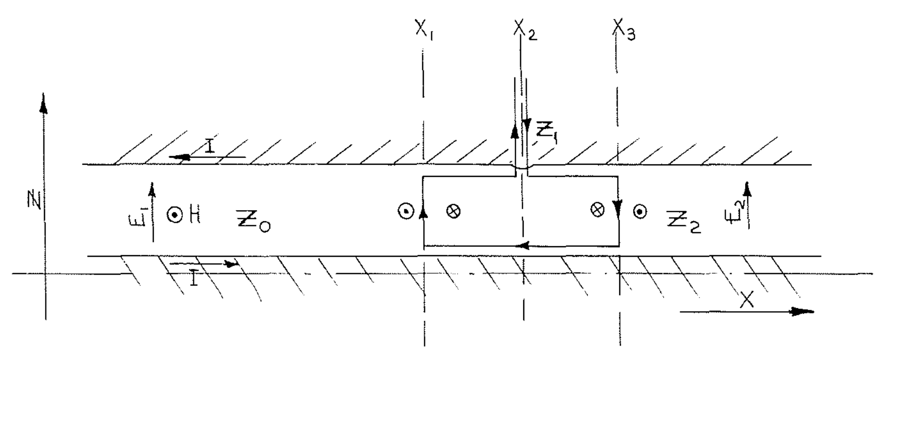


Figure 1. A single-turn winding inserted in the space between the inner and outer conductor of a coaxial transmission line of impedance Z_0.

regenerate H in equal magnitude and according to the principle of super-position $E_2 = E_1 - IZ_1$.

$$Z_o = \frac{E_1}{I}\ ;\ Z_2 = \frac{E_1 - IZ_1}{I} = Z_o - Z_1$$

indicating that the impedance Z_1 is effectively placed in series with Z_o. (Therefore, to maintain a first order matching, the ratio of the diameters of the inner and outer conductor past X_3 in the X direction should be reduced to be equal to Z_2.) A second order capacitive reflection occurs because the E field in going from X_1 to X_3 is confined between the inner conductor and the winding and between the outer conductor and the winding.

Neglecting the winding transit time, for an "n" turn winding $\oint J = I$ would still hold; however, I will be a current I/n per turn. The current through Z_1 is I/n and the series voltage drop reflected in the original E field is $\frac{\frac{I}{n}}{n} = \frac{I}{n^2}$

Therefore, $Z_2 =$

$$\frac{E_1 - \frac{I}{n^2} Z_1}{I} = Z_o - \frac{Z_1}{n^2}$$

The reflected impedance is proportional to $1/n^2$, similar to the conventional transformer. A true mathematical derivation of these results amounts to a double boundary value problem (Ref. 3 and 4) and is quite involved. However, this is not essential to achieve a basic understanding of the functioning of a TEM transformer.

Up to this point we really have not solved all basic limitations of the transformer, yet the preceding is essential for the understanding of the methods involved in solving them.

Outline of Limitations of Conventional TEM Transformer

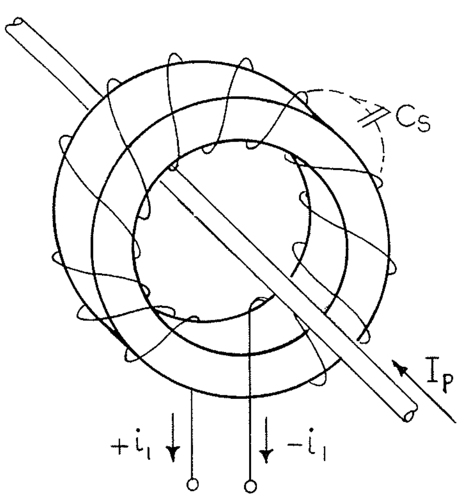


Figure 2. Twelve-turn transformer.

We have a transformer with one primary and n secondary turns (Figure 2). If we introduce a current step I in the primary winding, we will introduce a current step i_n at the *same* time and of equal magnitude in all n turns. The step i_n introduced in a particular turn will propagate in a transmission-line mode around the core in both directions and so will all steps in every turn. The resulting output waveforms at the secondary terminals of the transformer will, therefore, look like Figure 3 indicating a "push-pull" mode out-

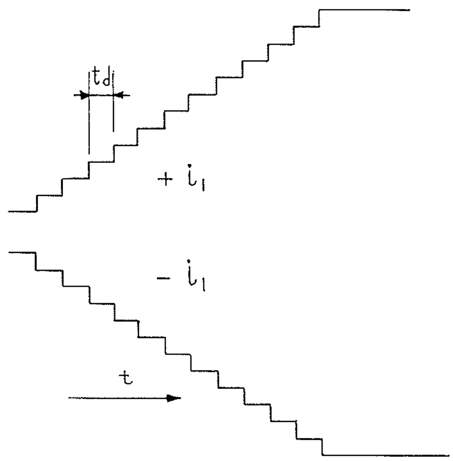


Figure 3. Output of twelve-turn transformer.

put. Here, then, we have the first basic limitation: the risetime of the output waveform will be approximately n times td, where td is the delay of one winding.

The second limitation of the conventional current transformer is the fact that there is a certain amount of stray capacitance (C_s) and inductance (L_s). This will form a distributed L-C circuit that will resonate at a frequency below $\frac{0.35}{n \times td}$ (equivalent 3-db point due to the first limitation) and, therefore, give a poor transient response especially when n is large.

Transmission Line Addition Technique

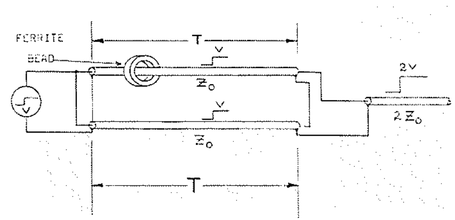


Figure 4. A step V, placed simultaneously on two Z_o cables, adds the two steps to a 2V step into a $2Z_o$ cable.

In Figure 4, if a step V is placed simultaneously on the two Z_o cables, one can add these two steps to a 2 V step into a $2\ Z_o$ cable, as shown. However, this will work only for a time equivalent to the double delay time (2T) in one Z_o cable because after that the generator will be shorted. One can extend this time span by placing an impedance in the short circuit loop — here done by means of a ferrite core (Refs. 6 and 7).

Solution to First Order Limitations

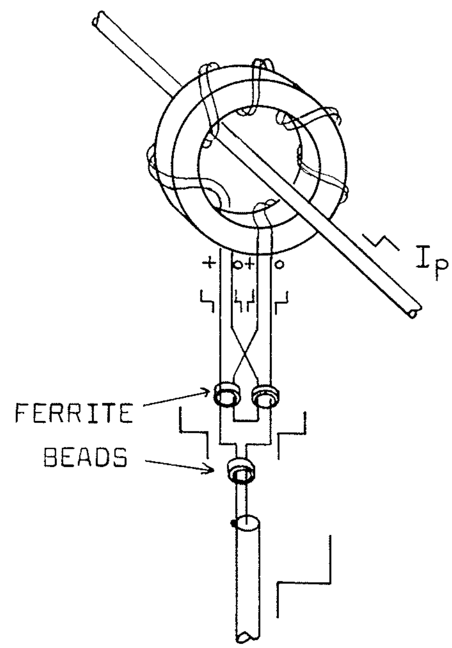
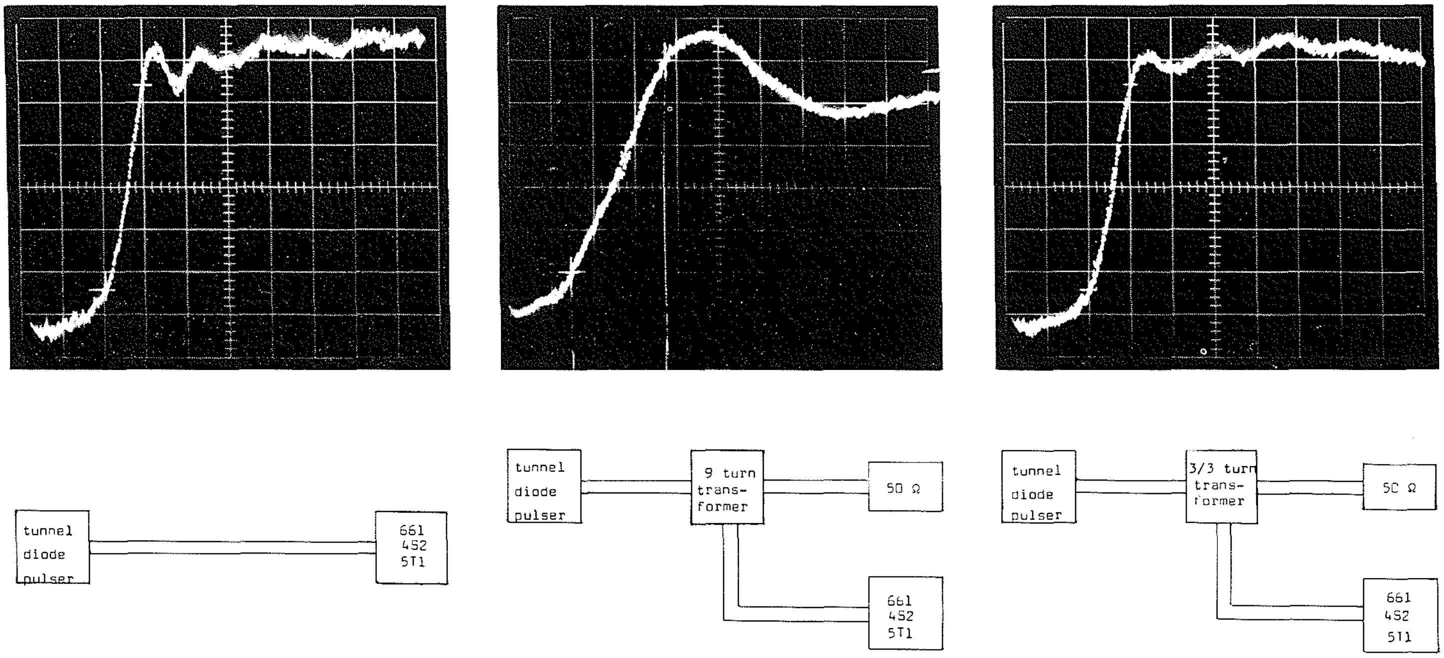


Figure 5. Twelve-turn bifilar winding.

In Figure 5, rather than wind an n turn single winding transformer, two windings each having $\frac{n}{2}$ turns have been wound bifilar, as shown. The four output voltages are then added and supply one single ended signal. The addition is performed with the transmission line addition technique. However, for practical reasons the wires are kept very short and, therefore, the double delay time (2T) is short. One depends mainly on the isolation provided by ferrite beads placed in the short circuit loop. Leads should be kept to the same length to assure time-coincident addition of the signals. By doing this we have achieved two improvements (Figure 6):

(a) The risetime of the output pulse, due to limitation one, has been reduced from n x td to n/2 x td. (This is not exact because the turns in this case will be slightly longer; therefore, td will be slightly greater. However, this effect is small.)



(a) Pulse direct to 4S2.

(b) Pulse coupled to 4S2 via a straight nine-turn transformer on a ½" dia. by ¼" core.

(c) Pulse coupled to 4S2 via 3 x 3-turn transformer on a ½" dia. by ¼" core [same core as used in (b)].

Figure 6. System used to obtain these waveform pictures: Tunnel diode pulser ($\approx$30 psec risetime), Type 661 Sampling Oscilloscope with a Type 4S2 Dual-Trace Sampling Unit and a Type 5T1 Timing Unit, and a Type C-19 Camera. Sweep Time/cm: 0.2 nsec.

(b) The transient response, due to limitation two, has been improved due to the fact that the stray capacitance has been reduced since the two windings at every point on the core move in the same manner voltage-wise [fr (resonant frequency) proportional to $1/\sqrt{c}$] while the inductance and resistance stay essentially the same.

Note that at DC the two windings are in series. The output voltage is the same as that of a conventional n turn transformer. One can use multiple turns through the isolation beads to obtain a large time constant. Note also that one is not limited to 2 windings of n/2 turns per winding. One can use n windings of 1 turn per winding (as long as n/a is greater than 1 and a real number). The limitation is n windings of 1 turn per winding and there the risetime is equivalent to 1 x td or the total propagation time around the core, whichever is greater (Figure 7).

One can build a transformer with a large number of turns to get a long time constant, but at the same time one can get a very fast risetime and good transient response, as will be explained later.

Core Material

Unless a core with a permeability >1 is inserted inside the windings, the transformer action is limited to the double transit time

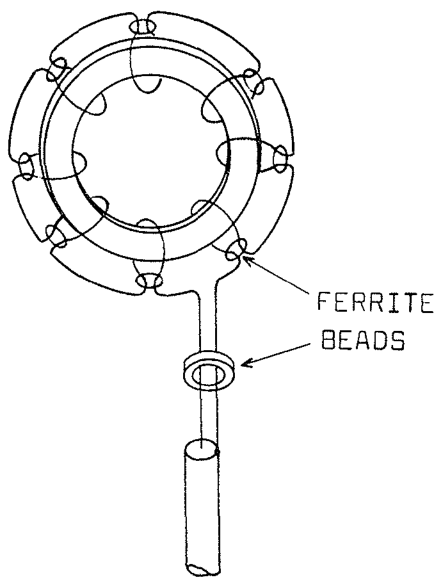


Figure 7. Eight-turn multifilar winding.

of the winding. To extend this time usually for high frequency applications a ferrite core material (Ref. 5) is used. Ferrites are sintered materials, generally of a basically spinel crystalline structure consisting of $MOFe_2O_3$ where M can be of any of the following elements: Co, Ni, Mn, Cu, Mg, Zn, Cd.

Generally the low permeability ferrites have a high resistivity and the high permeability ferrites a low resistivity. Therefore, the high permeability ferrites have higher loss than the low permeability versions. Some typical high frequency ferrite materials are:

		Permeability	*Rho* (Ω *cm*)
Ferroxcube	104	200-250	$>10^5$
	102	250-400	400-600
	101	300-700	250-450
Kearfott	MN30	4,000-6,000	300
	MN60	5,000-10,000	250

The Design of a TEM Current Transformer

In order to design a high speed current transformer, one has to consider several factors; transformer ratio, risetime, low frequency time constant, space available, impedance level, etc. The lumped constant equivalent circuit is represented in Figure 8. Here $R_1 = R_o n^2$; $L = L_o n^2$

R_o is assumed to be a constant proportional to the core losses and expressed in ohms/turn². In practice, however, one might have to use a different R_o for high frequency (and low frequency) calculations depending on material and bandwidth. The values given by the ferrite manufacturers generally refer to the low-frequency losses of the material. They have no consistent

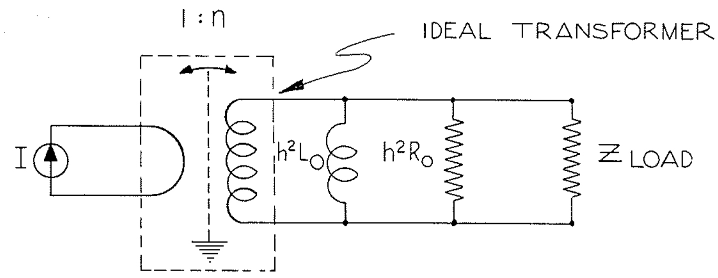


Figure 8. Lumped-constant equivalent circuit of a current transformer.

correlation with the frequency values of R_o. Therefore, these need to be measured for individual materials. Values vary from 20 Ω/n^2 to $>500\ \Omega/n^2$ depending on core material and dimensions.

L_o is a constant proportional to the permeability of the core, the cross section and the magnetic length. For a cylindrical core with outer diameter D, inner diameter d and length t, the inductance/turn² can be estimated by: $L_o = 0.2\ \mu t \ln D/d \times 10^{-8}\ \mu H/n^2$

Z_{in} = the transformed impedance.

The low frequency cut-off is determined by the L/R time constant.

The response will be 3-db down if: $\omega L = 2\pi fL = R$, where R is the total resistance R_p in parallel with L.

$$R_p = \frac{n^2R_oR_L}{n^2R_o + R_L}$$

$$f_{3db} = \frac{R_p}{2\pi L} = \frac{R_p}{2\pi n^2\ L_o}$$

At this point there will be a 45° phase shift through the transformer.

If accuracy of 1% is required in the transfer ratio, the low frequency response will be limited to a higher frequency. It can be readily verified that:

$$f_{1\%} = \frac{R_p}{.282\pi L_o n^2}$$

The phase shift will be approximately 8.1° at this frequency. If a maximum phase shift of 1° is required the lower frequency response should be limited to a still higher frequency. By performing the necessary calculations one finds:

$$f_{\theta=1^\circ} = \frac{R_p}{.0349\pi L_o n^2}$$

As a practical example, a transformer with a low frequency 3-db point of 10 kc will have a 1% amplitude accuracy above 70 kc and less than 1° phase shift above 570 kc.

From the low frequency point of view it is desirable to have a large number of turns to make L and R_l large. As previously shown, this limits the risetime.

By splitting the winding into several multifilar turns, as previously outlined, one can maintain the risetime for high speed operation and still have a large L and long time constant since at low frequencies the turns appear in series. The transformer may be used for current measuring purposes as well as for matching two points of different impedance levels. In either case, the transmission line will have a voltage waveform as well since the characteristic impedance is always greater than zero. In order to prevent capacitive coupling of the voltage waveform, the transformer has to be well shielded by a ground plane between the center conductor and the transformer. A perfect shield is not feasible, since this would amount to a shorted turn on the transformer. However, satisfactory shielding can practically be achieved by leaving a narrow gap in the shield.

References

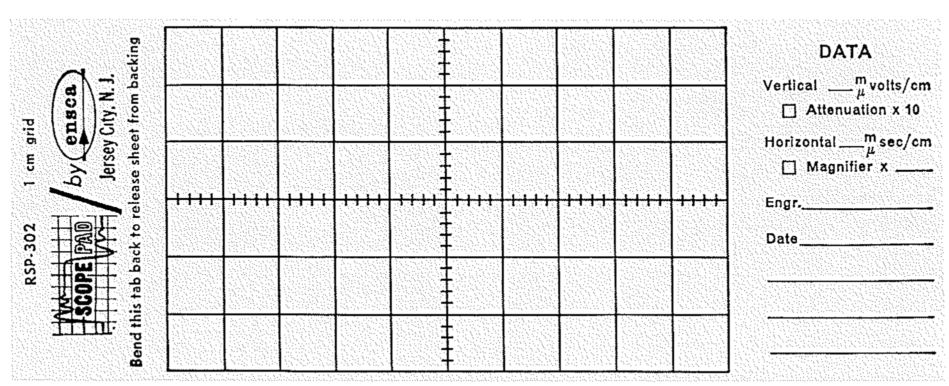
1. C. N. Winningstad, IN AND OUT OF CIRCUITS WITH PROBES, Proceedings of the National Electronic Conference; 1610, pp. 164, 1963
2. F. K. Harms, ELECTRICAL MEASUREMENTS, Wiley, pp. 542-564
3. Reitz - Milford, FOUNDATIONS OF ELECTRO-MAGNETIC THEORY, Addison Wesley, pp. 210-214
4. Morse - Feshbach, METHODS OF THEORETICAL PHYSICS
5. Polydoroff, HIGH-FREQUENCY MAGNETIC MATERIALS, Wiley
6. C. N. Winningstad, NANOSECOND PULSE TRANSFORMERS, IRE Transactions on Nuclear Science, March '59
7. Lewis - Wells, MILLIMICROSECOND PULSE TECHNIQUES, Pergamon Press

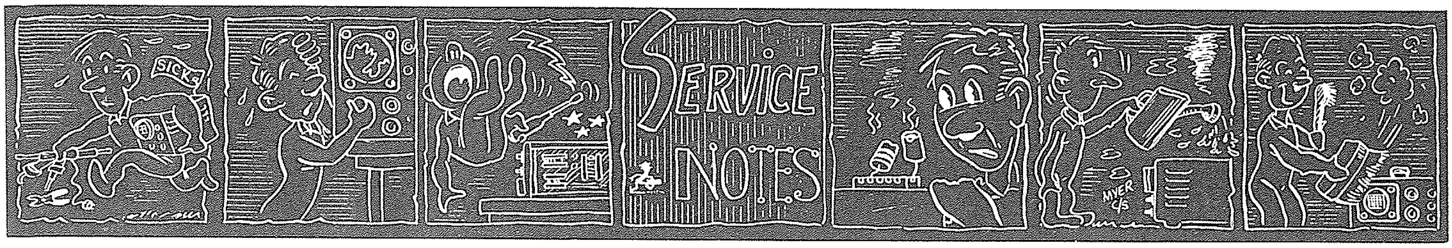
RECORDING WAVEFORMS WITHOUT A CAMERA

If you wanted to make a record of a repetitive waveform displayed on the crt of an oscilloscope and you didn't have a camera, you could stand back with easel and pen, hold up your thumb in Rembrandt-style and sketch away. Or, you could place a sheet of translucent paper over the face of the crt and trace the waveform. The difficulty here, of course, is trying to hold the paper firmly in place and at the same time make the tracing.

One solution to this problem is to use a sheet of "Scope Pad". This is a unique product manufactured and distributed by Ensca, Inc., P. O. Box 253, New York, New York 10023.

"Scope Pad" consists of twenty, translucent, adhesive-backed sheets ruled with a graticule-line grid. At the side of each sheet are spaces for time and amplitude data.





SHORTING PROBLEMS DURING TROUBLE SHOOTING

Chuck Miller of our Field Training group calls our attention to a serious problem that can exist when attempting to trouble-shoot an instrument incorporating high-density (tightly-notched) ceramic strips—see Figure 1.

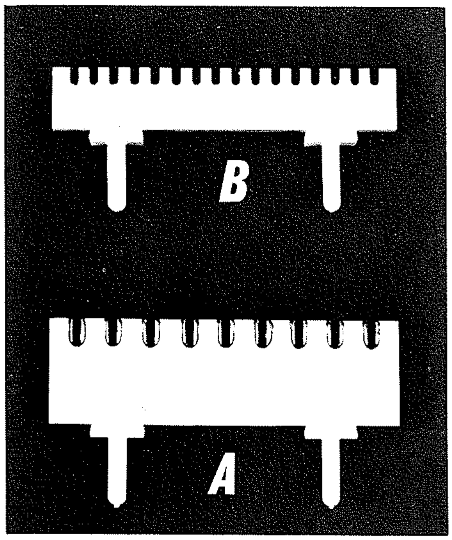


Figure 1. These two ceramic strips are the same length. The conventional strip (a) contains 9 notches, the high-density strip (b) contains 16 notches.

If, in this trouble-shooting, the probe employed uses a large tip—the old-style double-pincher tip for example—the danger exists of shorting out components and possibly destroying expensive transistors, diodes, etc.

A way to minimize this problem is to use the newer and thinner pincher tip (Tektronix Part Number 013-071—see Figure 2). This blade-like, single-pincher tip offers a greater margin of safety against the shorting out of components in crowded areas and the improved pincher tip has greater holding ability. The thin blade design causes a minimum of component displacement during trouble-shooting and facilitates checking difficult-to-reach test points.

This newer pincher tip is designed to be used with the following Tektronix probes:

P6000	P6004	P6008	P6023
P6001	P6005	P6009	P6027
P6002	P6006	P6017	P6028
P6003	P6007	P6022	

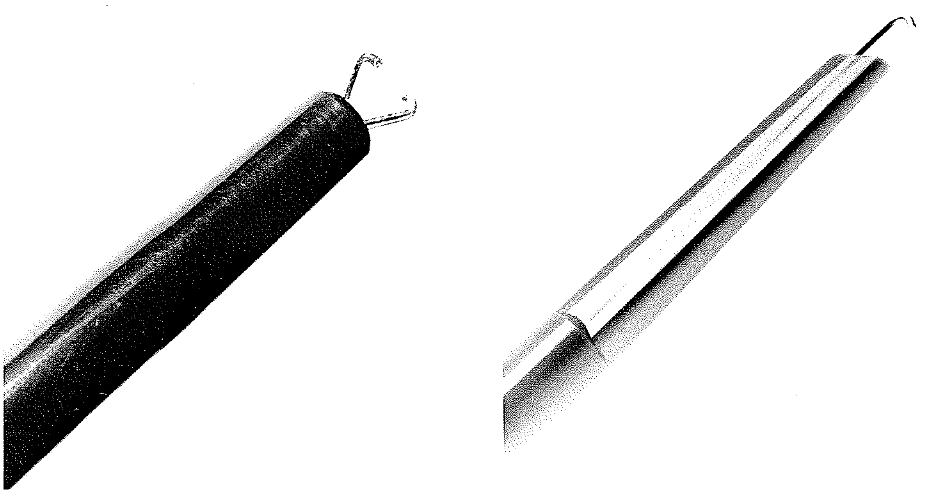


Figure 2. A comparison of the older double-pincher tip (left) and the new thin-blade, single-pincher tip (right). Both shown with pincher extended.

TYPE 575 TRANSISTOR CURVE TRACER — PEAK-VOLTS AUTO-TRANSFORMER IMPROVEMENT

Here is a service that if performed on the Peak-Volts autotransformer (T701 in the collector-sweep schematic) will improve its operation at low collector voltage when the HORIZONTAL VOLTS/DIV control is set to the 0.01 collector-volts position.

Prior to this service the PEAK VOLTS control will not turn down past around 5 cm of volts with the HORIZONTAL VOLTS/DIV control in the 0.01 position. After the service it will turn down to 2 cm of volts and the operation down to and up from this position will be very smooth.

The service consists of lowering the minimum voltage output of the autotransformer, T701. To do this, loosen the screw holding the rotational limit stops and adjust the stops so that counter-clockwise rotation can be made down to the last one or two windings. *Care must be exercised not to allow the contact to run off the end of the windings* as damage could result.

PLASTIC LIGHT SHIELD FOR RECTANGULAR CRT's

A plastic light shield, similar to that used in Tektronix instruments with 5" round crt's, is available for Tektronix instruments with 5" rectangular crt's.

The shield is designed to block any entrance of light onto the phosphor via the space between the crt shield and the front panel. Light escaping through this space can prove bothersome in some oscilloscope photography applications.

Designed specifically for the Type RM-561, the shield is equally useful in other Tektronix instruments employing a rectangular glass crt—the Type 567, Type RM567, Type 527, Type RM527 and the Type 561A MOD210C or 210E. This shield is not needed with the ceramic crt since light is shielded by the ceramic envelope and rubber boot.

Tektronix part number of the new light shield is 337-586. Order through your local Tektronix Field Office or your Tektronix Field Engineer.

POWER CONNECTOR BREAKAGE—PREVENTIVE MAINTENANCE

Breakage of the 3-wire power connector on instruments employing a detachable 3-conductor power cord can occur when the instruments are tilted or lifted from the front with the power cord connected.

This breakage can be prevented by recessing the power connector as shown in Figure 3.

Parts needed:

Qty.	Item	Tektronix Part No.
1	aluminum spacer	361-012
2	1¼", 6-32 screw	211-545
2	6-32 Keps nut	210-457

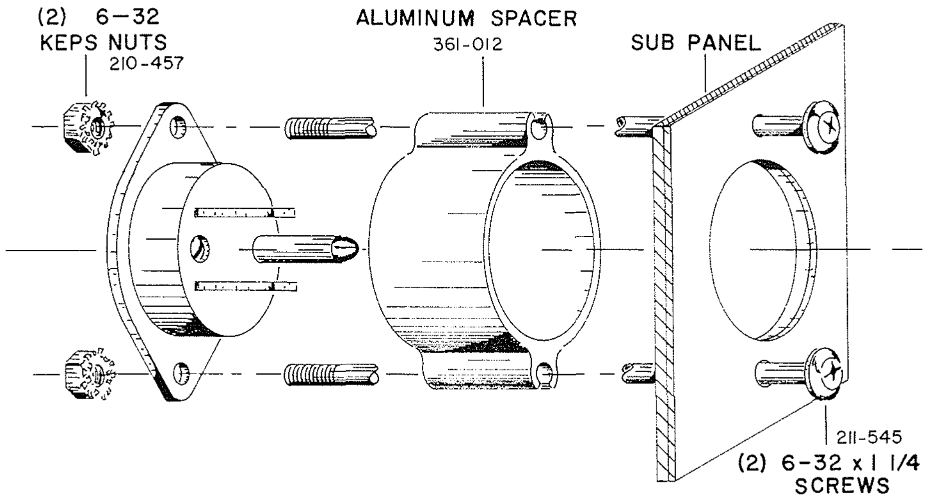


Fig. 3. Pictured instructions for recessing the 3-wire connector on instruments using a detachable, 3-conductor power cord.

TYPE 527 AND TYPE RM527 WAVEFORM MONITOR—VOLTAGE STRESS ON 6EW6 TUBES DURING TURN-ON

When the Type 527 or Type RM527 Waveform Monitor is first turned on, V444 and V544 (6EW6 tubes in the two-stage, push-pull input amplifier) are subjected to quite a voltage stress. This stress can cause excessive cathode deterioration which, in turn, will cause the tube to become gassy. Under this condition the input amplifier will not perform properly and the 6EW6 tubes in the input amplifier are doomed to early failure.

A simple modification to overcome this problem consists of replacing the 0.01 μf/47 k RC network in the grid circuit of both V444 and V544 with a 1N3605 diode (Tektronix Part Number 152-141)—See Figure 4. After the modification, R440, the 47 ohm parasitic resistor will connect directly from the rear wafer of the RESPONSE switch to pin 1 of V444 and the new diode will connect between pin 1 and 2 of V444. Be sure the cathode of the diode connects to pin 2. Repeat these changes in the grid circuit of V544 and the modification is complete.

Gassy 6EW6 tubes in the V444 and V544 positions cause hook and tilt in the displayed waveform. This malfunction is most apparent when viewing the vertical blanking pulse portion of the transmitted composite-video signal. To determine whether the fault is in the transmitted signal or in the Waveform Monitor, position the vertical-blanking-pulse waveform near either the top or bottom of the crt. This increases the current through either V444 or V544, and if they are gassy the hook and tilt will be much more pronounced.

If there is no appreciable change in hook or tilt, V444 and V544 are probably all right and the difficulty is most likely in the transmitted signal.

Type 527's with serial numbers above 744 and Type RM527's with serial numbers above 1189 have this modification installed at the factory. Also, the following serially numbered instruments were modified out of sequence:

Type 527:

645	724 through 726
646	739
674	

Type RM527:

730 through 732	1066
889	1071 through 1074
908	1097
980	1116
997	1121
1020	1122
1035	1138 through 1141
1036	1143 through 1145
1038	1147 through 1159
1042	1162 through 1188

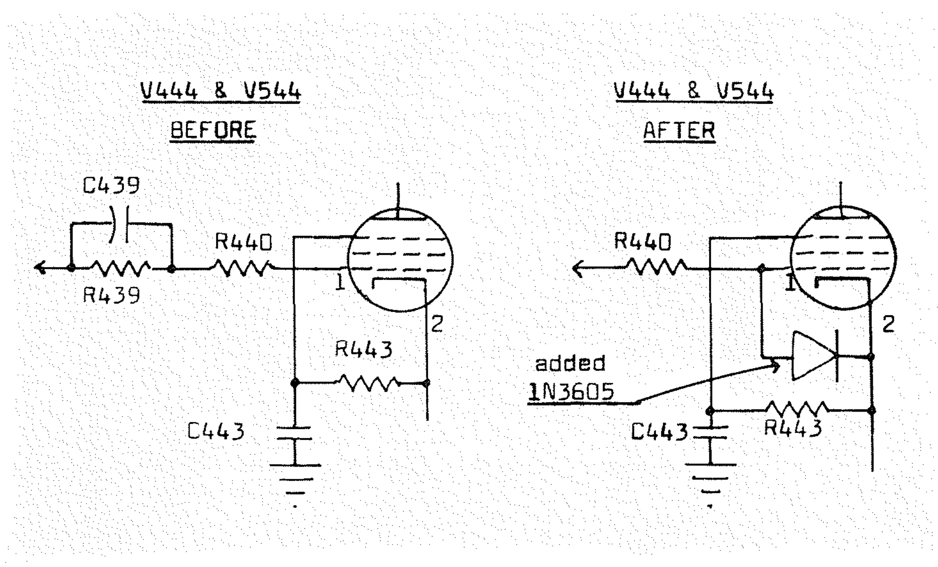


Figure 4. "Before" and "After" schematic for replacing the 0.01 μf/47 k RC network, in the grid circuit of both V444 and V544, with 1N3605 diodes.

USED INSTRUMENTS FOR SALE

1 Type 513D Oscilloscope, s/n 1672 with new crt. Ray Case, 8146 Matilija, Panorama City, California, phone 780-0322. Price: $350.

1 Type 317 Oscilloscope, s/n 346. Instrument like new. Will sacrifice for $500. Mr. Rising, 53 Hundreds Circle, Wellesley Hills, Massachusetts. Telephone: Area Code 617, 235-0385.

1 Type 535 Oscilloscope, s/n 6095 with a Type 53/54C Plug-In Unit, s/n 9668. Price: $1200. R. L. Bennett, Todd-AO Corporation, 1021 Seward Street, Hollywood, California. Phone: HO 3-1136.

1 Type 511AD Oscilloscope, s/n 4718 with P510 Attenuator Probe. Recently repaired, modified and recalibrated at Tektronix Repair Center. R. J. France, Control Science Corporation, 5150 Duke Street, Alexandria, Virginia.

1 Type 502 Oscilloscope, s/n 4211 and 2 Type 122 Preamplifiers, s/n's 5494 and 5495. Instruments have seen little use. C. R. Smith, President, Capital Sales Ltd., P. O. Box 266, Fredericton, New Brunswick.

1 Type 81 Plug-In Adapter (for use with Type 580 Series Oscilloscopes). New, never used. Dalmo Victor, Belmont, California, Attention: Mr. Wells.

1 Type 532 Oscilloscope, s/n 5100; 1 Type 53G Plug-In Unit, s/n 100 and 1 cart. Mr. Richardson, N.J.E. Corporation, 20 Boright Avenue, Kenilworth, New Jersey.

1 Type 67 Plug-In Unit, s/n 2596. Never used. In original packing. Mr. Leo Katz, Electronics Laboratory, Notre Dame Hospital, 1560 Sherbrooke Street East, Montreal 24, Quebec, Canada. Telephone 525-6363 — Local 576.

1 Type 190A, s/n 6048; and 1 Type 190B, s/n 6952 Constant-Amplitude Signal Generators. A. Samuelson, Electric Service Systems, 5555 Old Highway 5, Minneapolis 24, Minnesota. Telephone: 941-2200.

1 Type 517, s/n 508, High Speed Oscilloscope. For sale, lease or rent. Recently overhauled by Tektronix, Inc. Michael J. Haddad, Surface-Air Electronics, 138 Nevada Street, El Segundo, California. Telephone SP2-1469.

1 Type 82 Plug-In Unit, s/n 2307. Joel Backer, Magnetic Research Corporation, 3160 West El Segundo Boulevard, Hawthorne, California. Telephone: OS 5-1171.

1 Type 513D Oscilloscope, s/n 691. Price: $450. Donald Fleischer, 503 Tennis Avenue, Ambler, Pennsylvania. Telephone: MI 6-0580.

1 Type 502 MOD104 Oscilloscope, s/n 2840. Dr. Peckham, Eye Research Foundation, 8710 Old Georgetown Road, Bethesda, Maryland. Phone: 301-656-1527.

USED INSTRUMENTS WANTED

1 Type 310 Oscilloscope. E. C. Webb, Lakewood Manufacturing, 25100 Detroit, Westlake, Ohio. Telephone: Area 216-TR1-5000.

1 Type 321 Oscilloscope, John Sumner, 728 N. Sawtelle, Tucson, Arizona.

1 Type 515 or Type 515A Oscilloscope. William Macoughtry, Code 536, NASA, Goddard Space Flight Center, Greenbelt, Maryland.

1 Type 524AD Oscilloscope. H. Holland, H. W. H. Electronic Service, 7217 Gulf Boulevard, St. Petersburg Beach, Florida.

1 Type 310, 316 or 515 Oscilloscope. $225 maximum. George Reeves, 4273 W. Oak Avenue, Fullerton, California.

Mr. John Bowser of the Smith Corona Corporation at 301 N. Michigan Street, Chicago, Illinois, reports the theft of a Type 310A Oscilloscope, s/n 17926. The instrument disappeared from the car of one of their servicemen while it was parked in the back of their office building. Mr. Bowser would appreciate hearing from any of our readers who have any information on the whereabouts of this instrument.

Another car prowl, this one also in Chicago, produced a Type 516 MOD 108B for the vandals. Serial number of this instrument is 1930 and it is the property of the General Electric Company, 840 S. Canal Street, Chicago, Illinois. The theft occurred on Tuesday, November 26, 1963, while the car was parked outside their building. Information on the location of this instrument should be relayed to Mr. O. Nickerson of the General Electric Company at the address noted above.

This last report of a missing instrument concerns one that disappeared on January 1, 1963 and has just been called to our attention.

This oscilloscope, a Type 310A, s/n 012960, belongs to Huyck Systems located on Wolf Hill Road in Huntington, Long Island, New York.

Mr. Al Richert of Huyck Systems tells us that the oscilloscope was at Lockheed in Burbank, California at the time of its disappearance and he asks our readers in that area to be on the lookout for it.

Mr. Richert is the man to contact if you have any information about this oscilloscope.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 25 PRINTED IN U.S.A APRIL 1964

TELEVISION AND SINE-SQUARED TESTING

by Joseph E. Nelson
Tektronix Product Information Department

Electronic people, other than those engaged in television work, should also find this article of interest. Where there is a necessity for good resolution of phase characteristics, the sine-squared testing technique offers great potential in the evaluation of broad-band amplifier performance.

Editor's note — The major North American television networks now transmit a sine-squared signal for network-testing purposes. Test methods employing this signal easily detect small abnormalities in the linear-transmission performance of television links. Abnormalities that, although they greatly affect the quality of the television picture, are difficult to evaluate using conventional steady-state methods of signal testing.

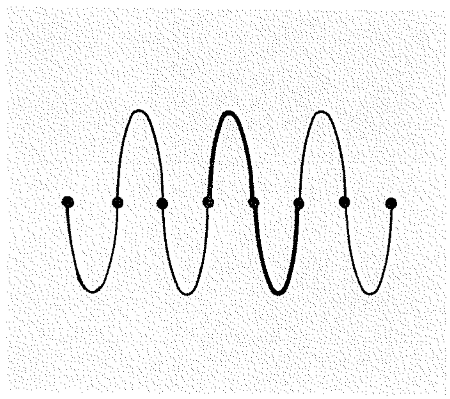


Figure 1. Sine wave with a single cycle indicated by the heavier line.

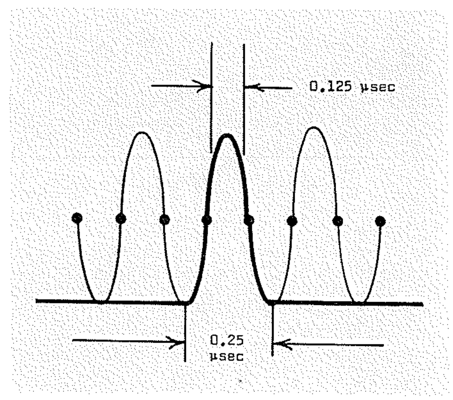


Figure 2. The single cycle of Figure 1 with the base line moved to the bottom.

When a television camera scans a vertical white line against a black background, the camera output resembles a sine-squared pulse. This pulse contains frequency components that extend toward the upper bandwidth of the TV system. For faithful reproduction of a televised picture, the entire TV system should be capable of passing this pulse without undue distortion or change in width or shape.

Since the reproduced condition of this pulse depends on the quality of the TV system, i.e., transient response, envelope and phase delay, it became apparent that a synthetically generated pulse of this type would make an ideal test signal. Thus the sine-squared pulse was born.

To make this type of test more complete, a low-frequency signal, the $\sin^2$ bar, was joined with the $\sin^2$ pulse to form a composite signal that can test the entire frequency spectrum of a TV system.

This composite signal, now available from commercial sine-squared generators, can be used in a number of ways. The test signal can be coupled directly into a camera, link amplifier, or transmitter, and the output examined on an oscilloscope. Or, during non-viewing hours of a TV network, the composite signal can be transmitted on each horizontal line of the camera scan, received at network affiliate stations, and examined for distortion. An additional method, used by all major networks, is to transmit the composite test signal during regular viewing hours but only include it in a single horizontal line during the vertical blanking period. With this latter method, the condition of the entire system can be constantly monitored throughout the transmission period. Since the test signal occurs on a single line during vertical blanking, an oscilloscope capable of displaying this line is necessary. The Tektronix Special-Model Type 527 or Special-Model Type RM527 TV Monitor can be used for this purpose.

$\sin^2$ Pulse and Bar

One can perhaps best visualize the shape of the $\sin^2$ pulse by thinking of a sine wave with the base line moved to the bottom (see Figure 1 and 2). The pulse width of the test pulse is made to be one-half of the period of one cycle of the upper cutoff frequency of the TV system. Thus the pulse width when used with a 4 megacycle system is 0.125 microsecond. This time (0.125 μsec) is designated by a capital T. A $\sin^2$ pulse with a width of 0.125 μsec is 6 db down at 4 megacycles and contains practically zero energy at 8 megacycles. For routine tests a $\sin^2$ pulse with a width of 2T (0.250 μsec) can be used. A $\sin^2$ T pulse is shown in Figure 3.

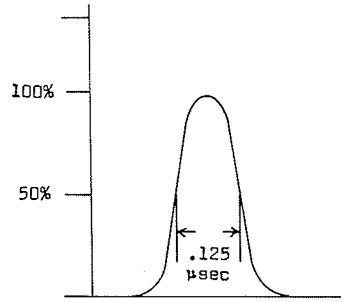


Figure 3. Sin² T pulse.

The $\sin^2$ bar, also called a white window, is a combination of a square-wave and a $\sin^2$ pulse. The risetime and falltime is the same as an integrated $\sin^2$ pulse while the flat-top is similar to a square-wave. Pulse width of the bar signal is 25 microseconds which is 0.4 H. (H is the time-length of one horizontal line, 63.5 μsec). The bar signal is shown in Figure 4.

The composite test signal, with typical time spacings is shown in Fig. 5.

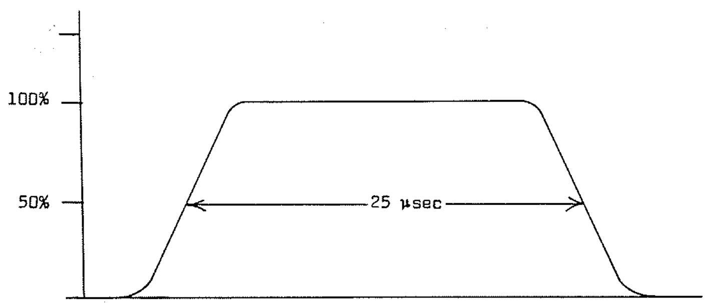


Figure 4. Sin² bar, a combination of a sin² pulse and a square wave.

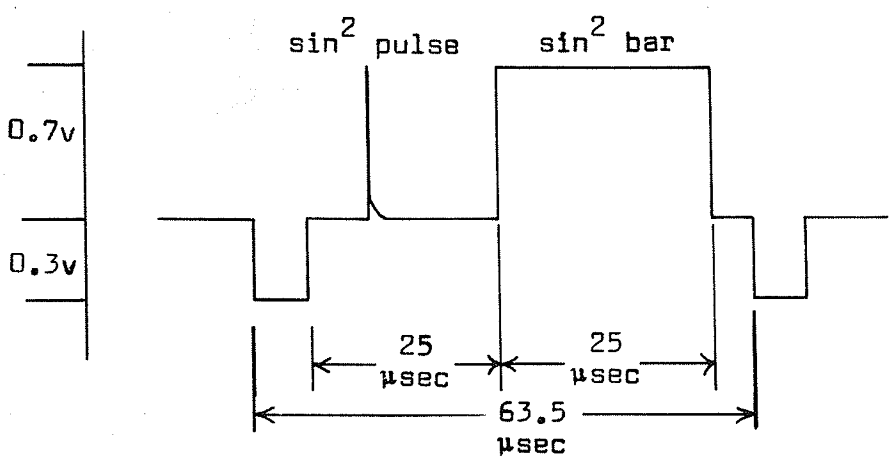


Figure 5. Composite test signal with typical time spacings.

The Oscilloscope and Sin²

The type of oscilloscope needed to examine the sine-square signal depends on the type of transmission. For example, within the studio, where a sine-square generator supplies the test signal continuously a triggered oscilloscope such as the Tektronix Type 524 with adjustable timebase can be used. However, when the test signal is present only on a single line of each frame, some method of selecting and examining this line must be used. The line selector feature of the Tektronix Special-Model Type 527 or Type RM527 allows the operator to select and examine any line within the television frame. Briefly, the line selector uses the principle of a delayed trigger. A trigger circuit phantastron is started by the vertical sync pulse of the received signal. The phantastron is mixed with each horizontal sync pulse of the signal and presented to a comparator. The voltage on the opposite side of the comparator can be adjusted to make the comparator switch on any one of the field horizontal sync pulses. The output of the comparator is a trigger pulse that starts the sweep in the oscilloscope.

When a single line that contains the $\sin^2$ pulse and bar is selected, the Type 527 sweep is set to 0.125 H/CM, and since the bar signal is 0.4H, it will occupy 3.2 horizontal centimeters. After the bar signal has been examined, the sweep control is switched to 0.005 H/CM and the $\sin^2$ pulse examined in detail.

Typical Sin² Response to Distortion

The change in shape and size of the composite $\sin^2$ test signal is a direct indication of the kind of distortion a system produces. Here are several examples of these changes.

1. Low-frequency distortion. This type of distortion has its greatest effect on the $\sin^2$ bar while little change is seen in the $\sin^2$ pulse. Depending on the time-constant of the circuit involved, the bar will show: undershoot, overshoot, or horizontal tilt. For example, a short time-constant undershoot is a leading-edge roll-off, as shown in Figure 6-a; while a long time-constant overshoot is a negative tilt (drop in amplitude from leading to trailing edge), as shown in Figure 6-b.

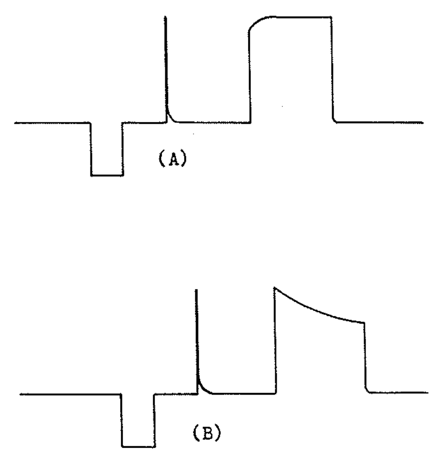


Figure 6. Sin² test signal showing: (a) short time constant undershoot, (b) long time constant overshoot.

2. Frequency Response irregularities. When the frequency response is not flat across the bandwidth of the system, we get dips and bumps. These dips and bumps on the test signal are actually ringing that is related to the frequency

Figure 7. Sin^2 test signal with dips and bumps caused by frequency response irregularities.

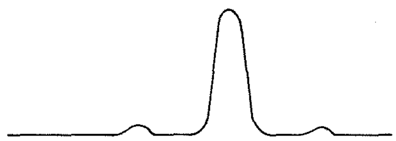


Figure 8. Sin^2 pulse showing a leading and a trailing reflection or echo.

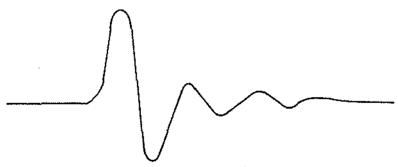


Figure 9. Sin^2 pulse showing distortion caused by high frequency roll off: reduced height, increased width, and decaying ringing.

irregularity (Figure 7). Once again the change in the test signal depends on the frequency.

3. Reflections. Since the sin^2 test signal can be transmitted (during the vertical blanking interval), the nature of reflections caused by multi-path signals can be measured. (See Figure 8.)

4. High-frequency roll-off (Figure 9). The most significant change caused by reduced bandwidth is the amplitude of the sin^2 pulse. And with this reduced amplitude, the pulse width increases since the area of the pulse represents a dc component that remains constant. From the appearance of the pulse, you can estimate the shape of the roll-off curve. For example, a slow roll-off produces a large reduction in amplitude with little, if any, ringing; while a rapid roll-off (almost a cutoff) affects the amplitude less, but does show considerable ringing.

CAPTURING POWER-LINE TRANSIENTS

by Ron Bell
Tektronix Field Engineer

Power-equipment engineers frequently find it necessary to measure transients on sixty-cycle power lines. The need arises, for example, when working with solid-state power-control equipment. Large voltage transients, introduced through the power line, can cause equipment malfunction or even semi-conductor failures. Circuit-breaker testing, where the sudden closure or opening of a circuit marks the beginning of a test, is another situation requiring transient measurements. In these circumstances, it is common for the engineer to display the transient on an oscilloscope; photographing the results for analysis.

But it is not always easy to photograph the transients.

The power-line waveform with simulated transients, shown in Figure 1, will serve to explain the operating problems. Notice first that transient A exceeds the peak line voltage; whereas transient B does not. Notice also that transient A is a positive-going impulse and transient B is negative going.

Photographing transient A would be rel-

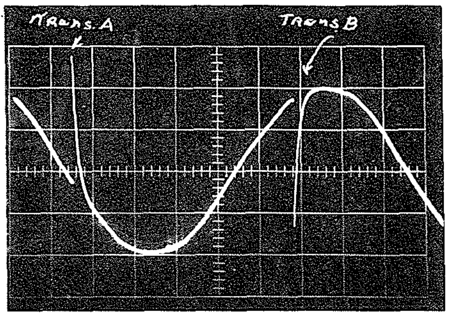


Figure 1. Power-line waveform with simulated transients.

atively easy. The oscilloscope triggering circuits could be adjusted to initiate a sweep (1) during a positive-going slope and (2) when the instantaneous voltage exceeds the peak-line voltage. If, however, the transient occurred later in the cycle, the instantaneous transient voltage would not exceed the instantaneous power-line voltage. As a result, condition (2) would prevent sweep triggering. Adjusting the trigger circuits for a lower triggering level would result in power-line waveform triggering.

To differentiate between transient voltages and the power-line waveform, the sixty-cycle component can be rejected from the trigger circuits. This is accomplished by operating in the AC LF-REJECT mode. In this mode, the triggering circuits respond to the transients as though they started at zero volts, regardless of when they occur during the power-line cycle.

Using the AC LF REJECT mode, transient B could be photographed by adjusting the trigger circuits for triggering during a negative slope. Obviously, it is rare that the polarity of a transient is known beforehand. In short, for any one setting of the triggering controls, we can display either transient A or B, but not both. If transients of both polarities are to be displayed, it is necessary that the triggering circuits respond to both concurrently.

This article describes a modification to permit triggering on plus and minus slopes concurrently. The circuit information applies specifically to the 530A-, 540A- and 550-series oscilloscopes. In general the circuit modification can be applied to other instruments (except those with solid-state triggering circuits) with only minor changes.

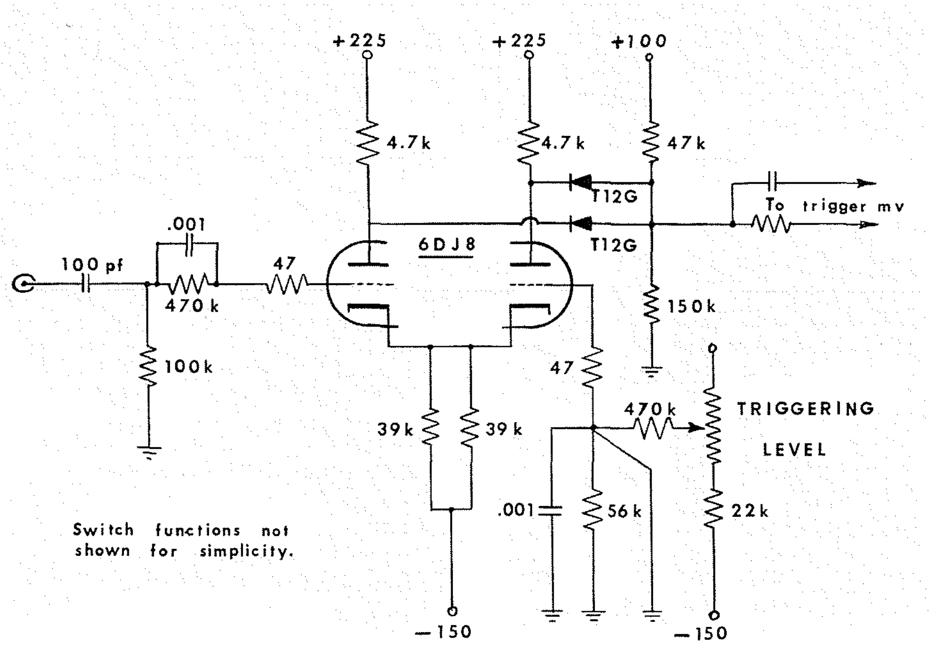


Figure 2. Modified Trigger-Amplifier Circuit of a Type 530 or Type 540 Series Oscilloscope.

The modified-circuit diagram is shown in Figure 2. Notice that the only additional parts required are two T-12G diodes, a 150 k resistor and a 47 k resistor. Notice also that the 47 pf capacitor normally connected across the plate-load resistor of the left-hand triode has been removed and that the grid of the right-hand triode is grounded.

Circuit operation is almost self-explanatory. The two T12G diodes are normally back-biased between the center-tap of the voltage divider and the quiescent triode plate voltages. The sixty-cycle power-line waveform (and, of course, the transient) is connected to the input connector.

The time constant of the 100 pf coupling capacitor and the 100 K input resistor is short enough to effectively block the sixty-cycle component; while at the same time, allowing fast-changing transient voltages to pass through to the input grid. The two triodes are operating as a paraphase inverter. If the input transient is positive-going, it will cause the left-hand plate voltage to go down. Similarly, if the input transient is negative-going, it will cause the right-hand plate to go down.

A negative-going voltage on either triode plate will cause the associated diode to go into conduction. When one of the diodes conducts, a negative-going voltage appears at the common-anode point. This negative-going voltage is coupled to the trigger multivibrator which, in turn, triggers the time-base generator.

Trigger sensitivity of the modified circuit is less than normal. Unmodified, the triggering circuit will respond to 0.1 volts or less. This circuit requires approximately 1.5 volts. For simplicity, the right-hand triode grid is grounded. Because of imbalance in the triodes and tolerance in the plate-load resistors, it is unlikely that the plate voltages will be equal. To avoid the possibility of no-signal diode conduction, the diode anode voltages are lower than necessary. This means the triggering voltage must overcome this back-bias before triggering can occur. This should not be a handicap, however, since ample triggering voltages are usually available in power-line testing.

Near-normal sensitivities can be realized by replacing the 150 k resistor in the divider with a 220 k resistor. It will be necessary to check the plate voltages for imbalance. Removing the ground from the right-hand triode grid will permit using the TRIGGERING LEVEL control to achieve perfect balance. Of course, the operator must be careful not to disturb this control once adjusted.

To adjust the circuits for correct operation, set the front-panel controls as follows:

TIME/CM	2 µsec
5X MAGNIFIER	Off
STABILITY	Preset
TRIGGERING LEVEL	0
VOLTS/CM	1
CALIBRATOR	5
TRIGGERING MODE	AC LF-REJECT
TRIGGER SLOPE	+ Int.

Connect the Calibrator output to the plug-in input. Starting with the Trig. Level Centering Control turned fully clockwise, turn it counter-clockwise for a display

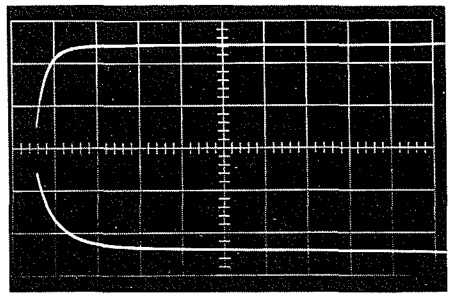
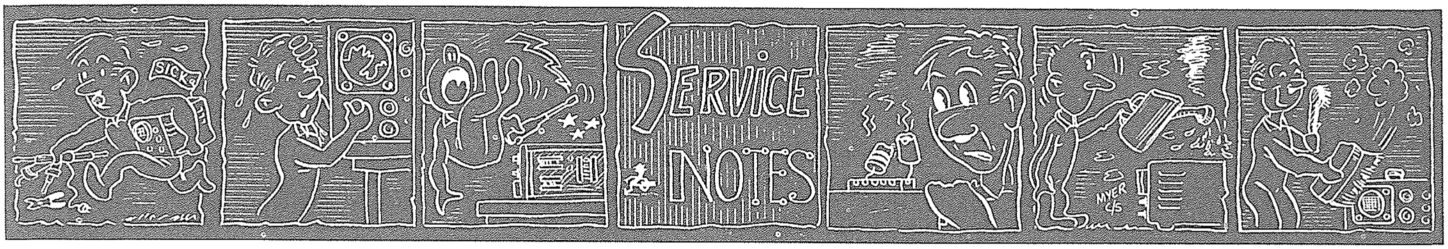


Figure 3. Initial display during adjustment procedure. The vertical deflection factor is 1 volt/cm. The sweep rate is 2 µsec/cm.

similar to Figure 3. Next, reduce the vertical deflection with the Volts/CM controls until either the upper or lower trace disappears. Turn the Trig. Level Centering Control CCW to restore the display. Continue to reduce the vertical deflection while adjusting the Trigger Level Centering Control until the two traces are separated by 1 cm or less.

To verify your adjustments, connect the calibrator output to the External Trigger Input connector. Set the Trigger Slope Switch to + Ext. You should be able to obtain displays similar to Figure 3 over a range of input voltages from 2 to 10 volts.

Details on how this modification might be installed in an oscilloscope are left to the inventiveness of the reader. Certainly, consideration should be given to how frequently it might be used. In those situations where this mode of operation would be used often, a permanent switch function would seem most convenient. On the other hand, for occasional "one-shot" applications, it might be simpler to "tack-in" the components as needed. On those instruments having an operator's manual compartment in the right-hand side panel, one shouldn't overlook the possibility of mounting a chassis directly underneath the compartment for easy access through the trap-door.



CERAMIC STRIP BREAKAGE TRACED TO EXCESS SOLDER

The newer high-density (tightly-notched) ceramic strips will sometimes break if the notches are over-filled with solder. The shrinking of the solder as it cools can cause stresses severe enough to crack the strip. The shrinking solder tries to pull the two ends of the strip together.

One should take care when soldering these strips to use just enough solder to cover the wires. The resulting connection will be just as electrically sound as when the notch is filled.

The use of Enthoven *silver-bearing* solder (instead of Divco), coupled with the use of solder in judicious amounts reduces the hazard of breakage to a minimum. Enthoven solder possesses a higher "creep-rate", i.e., it relaxes more quickly after hardening. Both Enthoven and Divco solder tend to cold-flow and relieve the tension, the Enthoven immediately, the Divco more slowly. Enthoven solder is identified by a star-shaped rosin core; Divco has a round core.

A recent change in the material used in the manufacture of our high-density ceramic strips should further alleviate this breakage problem. This new material offers increased flexural strength, tensile strength and compressive strength. It also has a lower thermal expansion which helps in thermal shock. An empirical test which we developed for checking thermal shock, consists of excessive loading of silver or solder in the notches. Under these test conditions, the new porcelain material displays a pronounced superiority over the old material.

NEW NE-23 NEONS VERSUS THE OLDER NE-2 NEONS

From time to time a problem arises within an instrument because a NE-2 neon refuses to immediately ionize upon application of voltage. Previously, all neons exhibited a touchiness about environmental conditions — sensitivity to temperature changes, light, radiation, etc. A new neon, the NE-23, offers a good solution to this problem. A tiny dot of radioactive material, added to the glass envelope during manufacture, guarantees the immediate ionization of the neon gas.

Modifications now in progress will change, wherever possible, the neons in instruments manufactured by Tektronix, Inc. to the new NE-23's. For the present, certain circuits will continue to use NE-2's for a specified voltage drop. As selected NE-23's become available for these circuits they will replace the NE-2 neons.

BLADE-TYPE ALIGNMENT TOOL IMPROVEMENT

Our thanks to Bob Nagler, Field Mainland, USAF with the PME Lab. in Ramstein AB, Germany, who offers this suggestion:

"When using blade-type alignment tools it is often difficult to position the blade to fit the slot since the blade cannot be seen from the top. To remedy this trouble, modify the tool as follows: Scribe a line across the top of the handle of the blade-type tool to indicate the position of the blade. The scribed line may be filled with paint to give better visibility."

We tried Sgt. Holland's suggestion (see Figure 1) and liked the result.

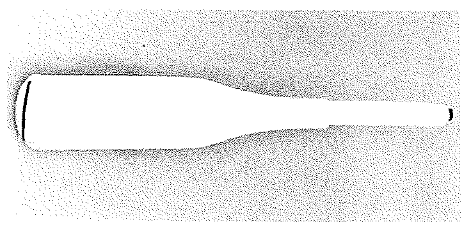


Figure 1. Scribed line on handle indicates position of blade.

TYPE 2B67 TIME-BASE UNIT—COMPROMISE SETTING OF STABILITY CONTROL CRITICAL

With the MODE control of the Type 2B67 Time Base Unit in the SINGLE SWEEP position, current drawn through R126 (a 220 k resistor) can cause the setting of the STABILITY control to become quite critical.

R126 functions to keep Q124 (a 2N2043 transistor) turned off when the sweep is "armed" and the READY light on (ready to be triggered). It may pull the plate of V135A (½ of a 6DJ8 tube) enough positive while in this condition to shift the triggerable range of the multivibrator considerably. In a typical instrument, the STABILITY control may offer a compromise setting (for operation in both NORM and SINGLE SWEEP modes) with a range of only about 0.5 volt.

The 220-k value of R126 was selected to prevent Q124 from turning itself on with collector-base leakage which, according to the manufacturer's spec sheet, can be 500 μamp at 71°C. However, experience in the field with this instrument indicates a much smaller typical value of leakage—so much so that most of the current from R126 simply goes to upset the sweep-gating multivibrator's hysteresis range.

Check the quiescent (READY) value of plate voltage at pin 1 of V135A. If plate voltage changes by more than about 5 volts as the MODE control is moved from NORM to SINGLE SWEEP, try changing R126 to a value between 470 k and 1 M. This will usually help considerably in making the compromise setting of the STABILITY control easier to find and more stable.

Our thanks to Bob Nagler, Field Maintenance Representative of the Toronto Field Office of Tektronix Canada, Ltd. for pointing up this problem and offering a solution.

TYPE 6R1 AND TYPE 6R1A DIGITAL UNIT CAUTION

Ben Franklin, or somebody, once said, "A word to the wise is sufficient". The word this time is: Always turn off the power when removing or replacing circuit cards in the Type 6R1 or Type 6R1A Digital Unit of a Type 567 Digital Readout Oscilloscope.

Failure to do so may cause destruction of some transistors and other components both in the replacement and other circuit cards of the Digital Unit.

Plugging a circuit card into the Digital Unit with the power on can cause the 2B67 Time Base Unit in the SINGLE voltage-carrying contacts in the connector to introduce voltage to the board's circuit (or circuits) a momentary instant before other contacts in the connector mate to establish a return-voltage path.

When this occurs, the momentary delay may cause a surge of power or generate a transient that exceeds the dissipation capabilities of certain transistors or other components in the Digital Unit's plug-in circuit cards.

TYPE 580 SERIES OSCILLOSCOPES—DIRECT CONNECTION TO CRT VERTICAL PLATES

Several circuit changes plus the construction of a balun will allow direct connection of signals to the vertical deflection plates of the crt in Type 580 Series Oscilloscopes. Input impedance is about 50 ohms (47½ ohms actual) and sensitivity is about 5 volts per centimeter depending on the crt. Risetime is essentially that of the crt deflection structure—about 1 nanosecond. Low-frequency cutoff L/R-risetime constant varies with signal amplitude from about 20 microseconds a centimeter step amplitude, to about 30 microseconds at ½ centimeter amplitude.

Returning the oscilloscope to normal operation will require rewiring the vertical output system to the original circuit.

Figure 2 shows the new vertical output

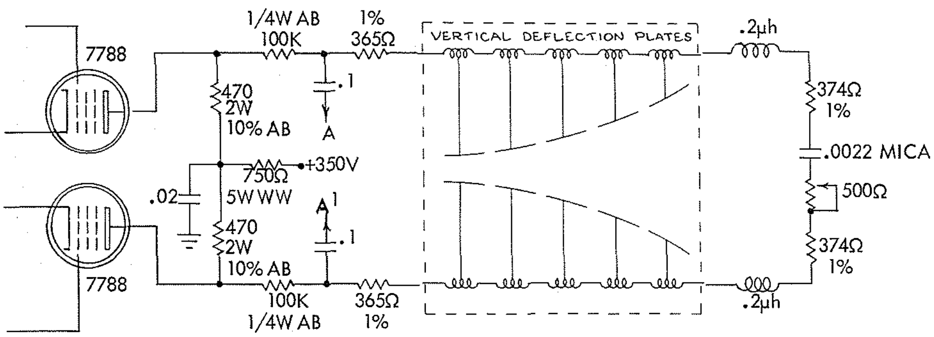


Figure 2. Type 580 Series Oscilloscope — Vertical-output circuit for direct connection to crt vertical plates.

circuit. Figure 3 shows the input connector, cables, balun and 107 ohm resistors. The cable from the input connector, through the balun and to the one deflection plate and the cable from the input connector to the other deflection plate *must be the same length, and as short as possible* (for minimum cable loss).

To construct the balun, first construct the transition by severing one of the pieces of 93 Ω cable at mid-point and reconnecting the severed pieces as shown in the "Transition detail" of Figure 3. Next, place the transition within the 101 ferrite core and pass each end of the cable through the core four times as shown in Figure 3. Each pass of the cable through the core constitutes a turn and each side of the transition is considered ½ a turn.

Parts required:

Qty.	Item	Tektronix Part No.
1	500 Ω pot.	311-056
1	0.0022 μfd Mica cap.	283-530
2	374 Ω, 1%, ½ w, Prec. res.	323-152
2	365 Ω, 1%, ⅛ w, Prec. res.	321-151
2	0.1 μf, Cer. Cap.	283-008
2	0.2 μf fixed coil	108-008
2	100 k, ¼ w, comp. res.	316-104
2	470 Ω, 2 w, comp. res.	305-471
1	750 Ω, 5 w, WW, res.	308-067
1	0.02 μf, Cer. cap.	283-004
1	GR connector	none
1	Ferrite core, 101	276-519
2	107 Ω, comp. res.	
2	pc's. 93 Ω cable of equal length	none

The 500 Ω pot installed in this modification takes the place of R1293 in the normal circuitry. Consult the "Adjust Vertical System High-Frequency Compensations" section of your Type 580 Series instruction manual for instructions on the function of this pot.

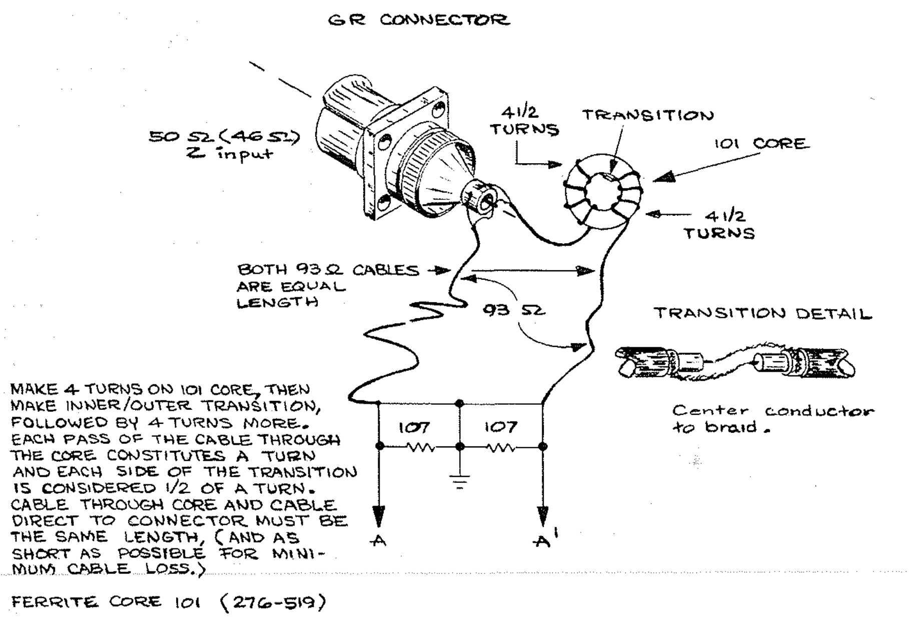
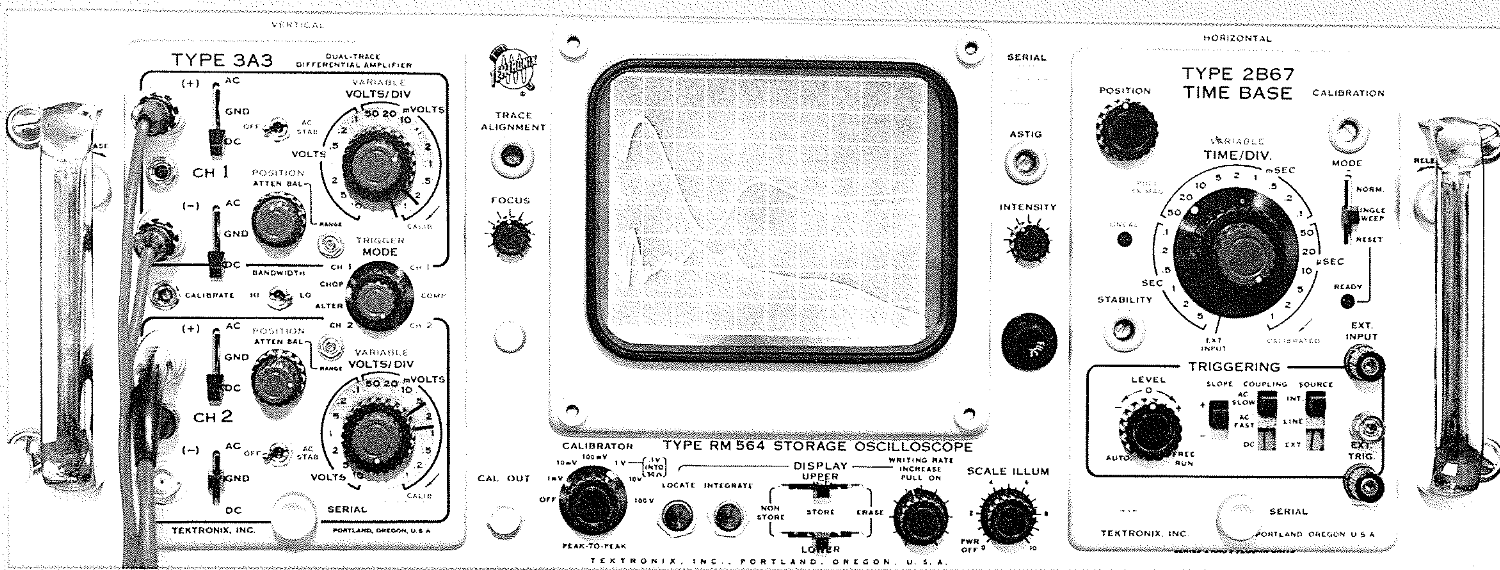


Figure 3. Connector detail for direct connection to crt vertical plates — Type 580 Series Oscilloscope.

PRESENTING THE TEKTRONIX

TYPE RM564

RACK-MOUNT STORAGE OSCILLOSCOPE



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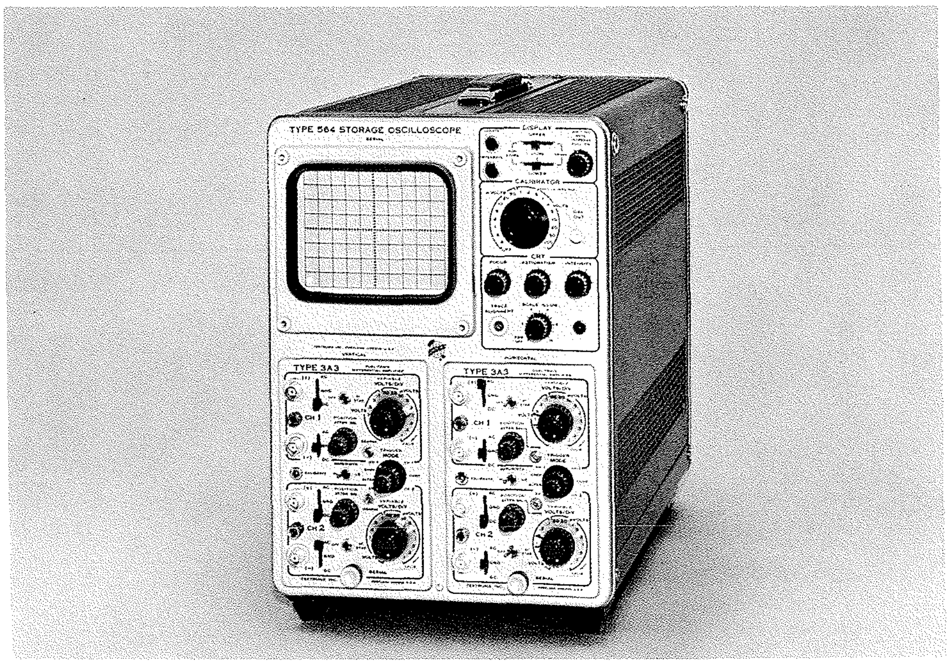
NUMBER 26 PRINTED IN U.S.A JUNE 1964

FREQUENCY COMPARISONS USING ROULETTE PATTERNS

Roulette patterns, because they retain their shape under conditions of slight oscillator frequency drift, offer a considerable advantage over the use of Lissajous figures in making frequency comparisons.



Type 564 Storage Oscilloscope with two Type 3A3 Dual-Trace Differential Plug-In Units, one in the vertical and one in the horizontal amplifier compartments.

High-ratio frequency comparisons by use of Lissajous figures are often difficult to observe. Any slight oscillator frequency drift causes the Lissajous figure to change shape. The display appears to rotate in a plane perpendicular to the face of the cathode-ray tube. Since the front and back portions of the figure are not separated, interpretation of the pattern becomes increasingly difficult as the frequency ratio increases.

Roulettes are much easier to interpret than are Lissajous figures because slight oscillator frequency drifts cause a pattern rotation in the plane of the crt screen without a change in pattern shape. Roulettes are readily displayed with oscilloscopes having differential inputs on both the horizontal and vertical amplifiers.

Several Tektronix Oscilloscopes and Oscilloscope/Plug-In combinations lend themselves to this application. The reference chart which appears elsewhere in this article lists these oscilloscopes and oscilloscope/plug-in combinations. It also gives their sensitivity and bandpass capabilities.

The waveforms illustrating this article were photographed using a Type 564 Storage Oscilloscope with two Type 3A3 Dual-Trace, Differential Plug-In Units—one in the vertical and one in the horizontal plug-in compartments. The storage feature of the Type 564 Oscilloscope makes this instrument the ideal choice for this application. As mentioned before, a slight drift in oscillator frequency will cause a rotation of the displayed roulette pattern. The rotation will be in the plane of the crt. The operator, by employing the Storage mode of Display, can "stop" this rotation for ease in counting the points of the roulette pattern. This count, which will be explained later, is a necessary part of the application procedure.

As for the other oscilloscope and oscilloscope/plug-in combinations listed on the reference chart, the best way to "stop" the roulette-pattern rotation on these instruments is to use an oscilloscope camera and photograph the display.

"Stopping" the roulette pattern's rotation is not, however, a necessary part of the application. One can usually control the drift in oscillator frequency to a point where the roulette pattern remains stable enough for an accurate point count.

How to set up roulette patterns

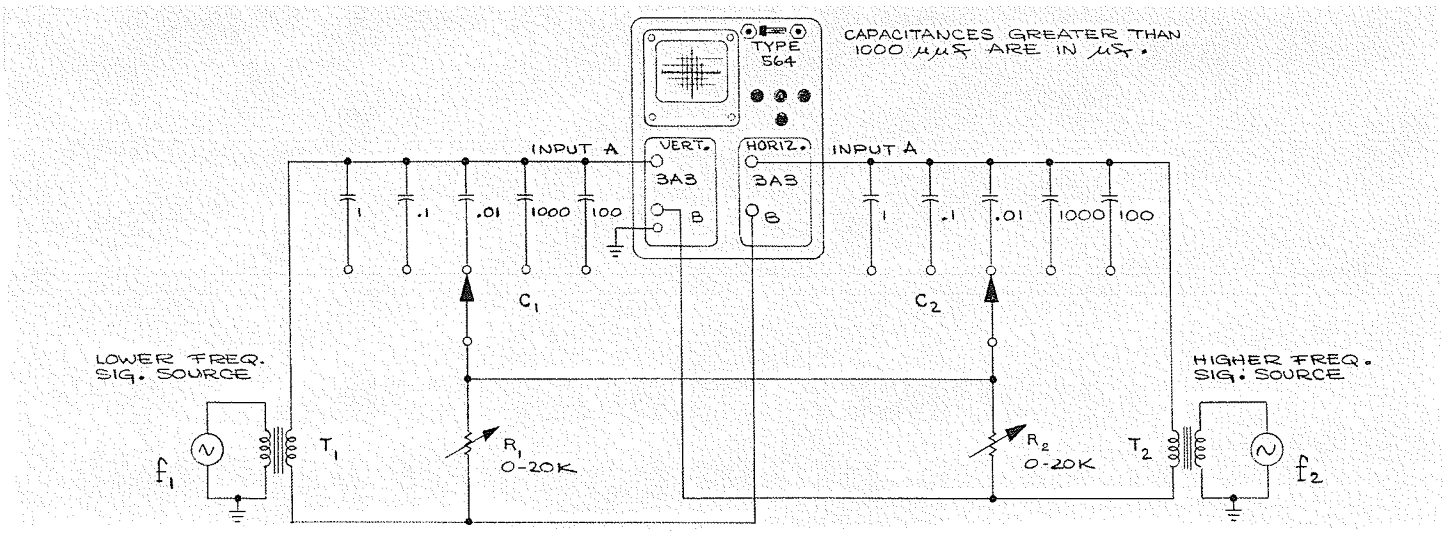


Fig. 1. Circuitry For Displaying Roulette Patterns.

Fig. 1 shows the circuit used in displaying roulette patterns. Transformers T_1 and T_2 provide isolation so that both of the signal sources can be operated with a common ground connection. In many applications either one or both of the transformers can be omitted, provided hum problems are not encountered. If isolation transformers are not used, the signal sources should be operated without a common ground connection. For convenience, we will discuss the display of roulette patterns at audio frequencies. You can use any signal source within the frequency range of your oscilloscope, however, stable radio-frequency displays are usually limited to crystal-controlled frequency sources. The circuit adjustment procedure is as follows:

1. Turn on the equipment and allow a few minutes for warm-up.
2. Using appropriate settings, adjust the plug-in units' V/CM controls to provide equal sensitivities for both the VERTICAL and HORIZONTAL channels. Should later readjustment be necessary, keep the sensitivities equal.
3. Set the output amplitude of both frequency sources to zero.
4. Advance the amplitude control on the higher-frequency generator until an elliptical trace appears on the crt screen. Adjust R_2 and C_2 until the ellipse becomes a circular shape. Return the output amplitude of the higher-frequency generator to zero.
5. Advance the amplitude control on the lower-frequency generator until an elliptical trace appears on the crt screen. Adjust R_1 and C_1 until the ellipse becomes a circular shape.
6. Readvance the amplitude control on the higher-frequency oscillator to obtain the desired roulette. Adjust the frequency of either oscillator for a stationary pattern.

Typical patterns for a 15:2 frequency ratio are shown in Fig. 2. The patterns differ only in that the output amplitude of the higher-frequency generator is greater in Fig. 2b.

To determine the frequency ratio, count the total number of points on the circumference of the pattern (17 points in Fig. 2a). Call this number N_1. Next, determine the

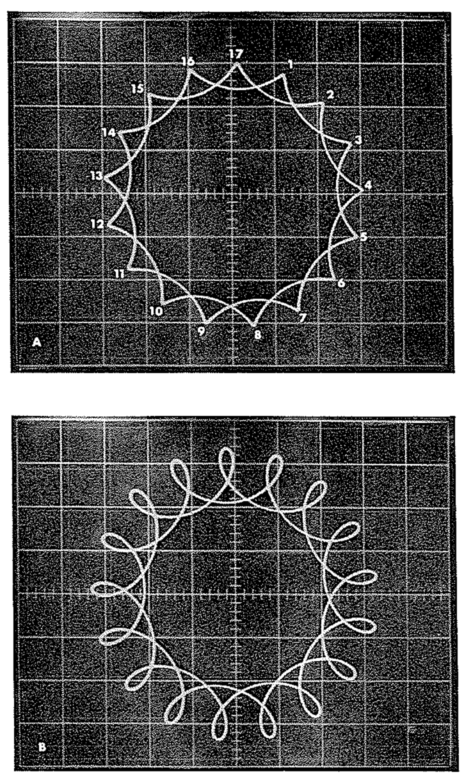


Fig. 2. Typical roulettes for a 15:2 frequency ratio.

number of points passed over in tracing from one point to another along the figure. For instance, in tracing from point 1 to point 3 in Fig. 2a, only one point (point 2) is crossed. Add one to this number and call it N_2. The ratio of the two frequencies is given by:

$$\frac{f_2}{f_1} = \frac{N_1 - N_2}{N_2} = \frac{(17 - 2)}{2} = 15:2 \text{ for Fig. 2a.}$$

When no points are crossed in moving from one point to another along the trace, the ratio of frequencies is a whole number (an integer), and the ratio is simply one less than the total number of points on the pattern circumference. Fig. 3 shows a 21 point pattern indicating a 20:1 frequency ratio.

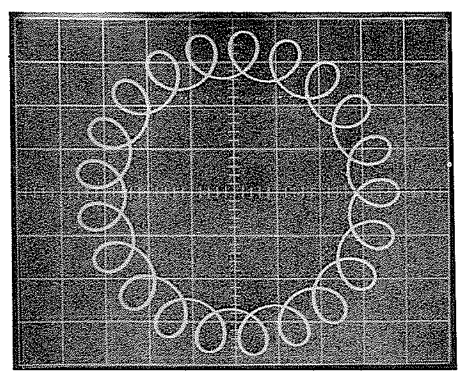


Fig. 3. Roulette pattern for a frequency ratio of 20:1.

Theory

The operation of the circuit of Fig. 1 is best understood by the application of superposition theory. We first determine the crt trace deflections produced by the signal sources operating separately, then we add the resultant deflections vectorially. Fig. 4a shows the circuit of Fig. 1 redrawn and slightly revised. Here, we have replaced the cathode-ray oscilloscope with the crt deflection plates corresponding to the amplifier input connectors. In addition, we have replaced the higher-frequency oscillator by its internal impedance Z_2. The impedances X_{C_2}, R_2 and Z_2 can usually be neglected when compared to the oscilloscope input resistances (1 megohm). Neglecting these impedances, we get the simplified equivalent circuit of Fig. 4b. If the magnitude of X_{C_1} equals R_1 at the frequency f_1, a circular trace appears on the crt screen. If generator f_2 is restored and generator f_1 is replaced by its internal impedance, the analysis outlined above may be repeated. With both f_1 and f_2 in operation, the actual deflection of the electron beam is the vector sum of the positions due to each of the frequency sources acting separately.

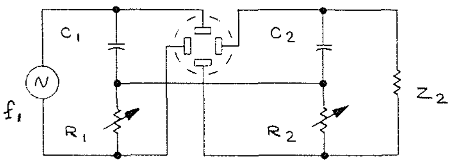


Fig. 4a. Equivalent circuit of Fig. 1, with the higher-frequency generator replaced by its internal impedance.

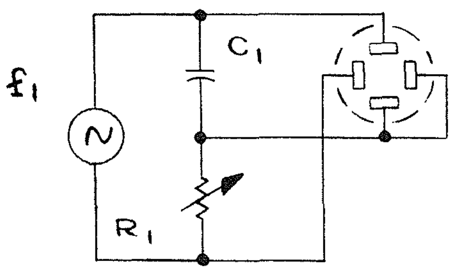


Fig. 4b. Further simplification of Fig. 4a.

The graphical addition of the deflections due to each of the frequency sources acting separately is not difficult. Assume, for example, a 3:2 frequency ratio. Assume, also, that the frequency sources, when applied individually, produce circles C and D as shown in Fig. 5. The numbers on the perimeter of the circles represent the hypothetical position of the beam on each circle at corresponding instants of time. By taking the vector sum of the displacements from the center, as indicated in Fig. 5, the actual position of the spot on the screen can be determined. The locus of many such determinations is the desired roulette. Fig. 6 shows the same pattern displayed on the crt screen.

Roulettes can be analyzed by geometrical analogy. The pattern of Fig. 2a is generated by a point on the surface of a cylinder rolling on the inside of another cylinder. Curves of this type are called hypocycloids. If you interchange one pair of RC elements in the circuit of Fig. 1, the patterns will be turned inside out. This is equivalent to having the generating circle roll on the outside of another cylinder. In this case, the point on the surface of the rolling cylinder generates a special form of inverted roulette called an epicycloid.

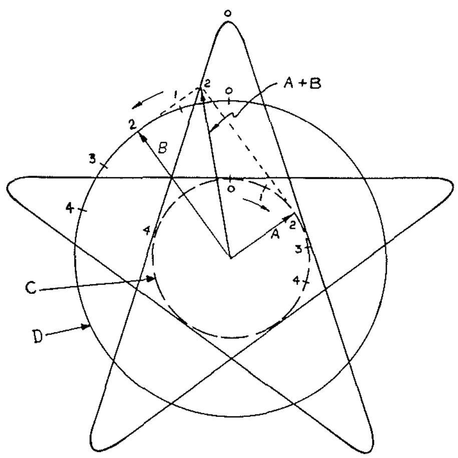


Fig. 5. Graphical construction of a roulette pattern for a frequency ratio of 3:2.

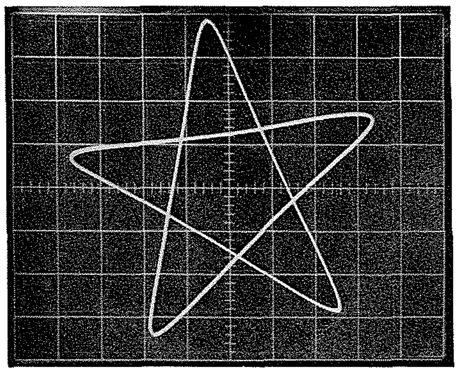


Fig. 6. Roulette pattern for a 3:2 frequency ratio.

Drift Measurements

When the ratio of the oscillator frequencies is not exactly integral (or fractional), the pattern rotates on the crt screen. The number of complete pattern rotations per second is proportional to the number of cycles per second that the lower-frequency oscillator differs from the frequency that gives an exact integral ratio. If the oscillator frequencies are initially adjusted for a stationary pattern, any subsequent rotation is a direct measure of the total frequency drift between the two oscillators. This method of measuring drift is best suited to oscillators that have very small drift rates.

You will usually find that it is easier to count the number of points passing a particular graticule line per second rather than to count the whole number of pattern rotations. The drift expressed in cycles per second of the lower-frequency oscillator is given by:

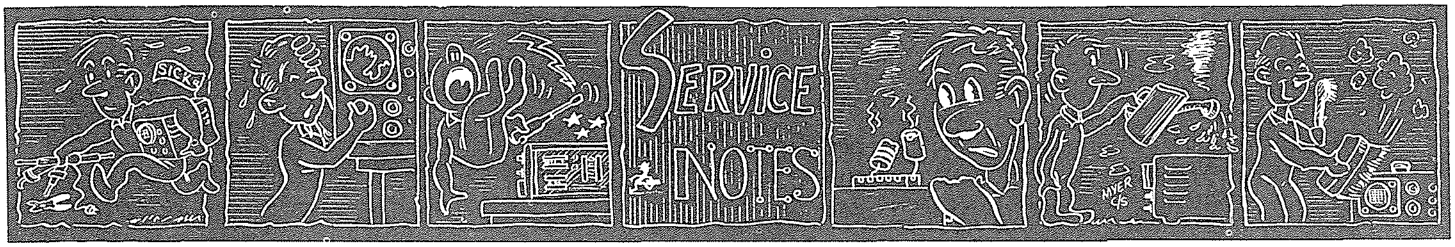
$$\text{Drift} = \frac{(N_2)\ (\text{No. of points per second passing a grat. line})}{(N_1)}$$

where N_2 and N_1 are as defined previously.

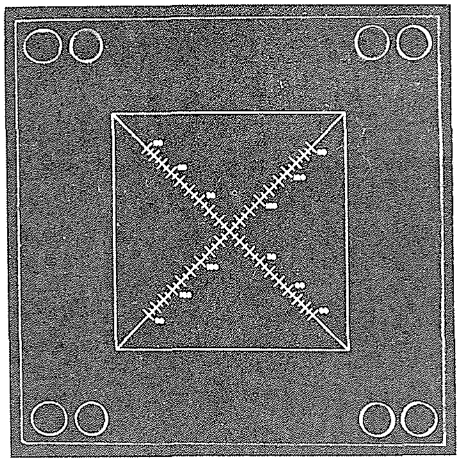
The equivalent drift of the higher-frequency oscillator can be determined by multiplying the equivalent drift of the lower-frequency oscillator by the frequency ratio.

OSCILLOSCOPE TYPE	AMPLIFIER UNIT (plug-in type)	SENSITIVITY	PASSBAND (at 3db down)
502A or RM502A		100 µv/cm	dc to 50 kc
		200 µv/cm	dc to 100 kc
		1 mv/cm	dc to 200 kc
		50 mv/cm	dc to 400 kc
		2 v/cm	dc to 1 mc
503 or RM503		1 mv/cm	dc to 450 kc
536	2-Type CA	0.05 v/cm	dc to 10 mc
	2-Type D	1 mv/cm	dc to 300 kc
		50 mv/cm	dc to 2 mc
	2-Type E	0.05 mv/cm	0.06 cps to 20 kc
		0.1 mv/cm	0.06 cps to 40 kc
		0.2 mv/cm	0.06 cps to 50 kc
		0.5 mv/cm	0.06 cps to 60 kc
	2-Type G	0.05 v/cm	dc to 10 mc
	2-Type Z	50 mv/cm	dc to 9 mc
561A RM561A 564 RM564	2-Type 2A61	0.01 mv/div	0.06 cps to 100 kc
		0.1 mv/div	0.06 cps to 300 kc
	2-Type 2A63	1 mv/div	dc to 300 kc
	2-Type 3A3	100 µv/div	dc to 500 kc

Reference chart of Tektronix Oscilloscopes and Oscilloscope/Plug-In Unit Combinations having vertical and horizontal amplifiers with differential inputs.



LISSAJOUS PHASE-MEASUREMENT GRATICULE



The 8 x 8 cm phase-measurement graticule (Tektronix part number 331-057), originally designed for use with the Type 536 X-Y Oscilloscope, will work equally well with the Type 661 Sampling Oscilloscope and the Type 504 X-Y Oscilloscope. This special graticule (see Figure 1) is useful in measuring phase differences from lissajous displays.

REPLACING CABLES CONTAINING COLOR-CODED WIRES

Here's a time saver when replacing cables containing color-coded wires. When you remove the old cable, cut the wires about ½ inch from their solder points. If you do this you then have the color codes to go by when installing the new cable.

Jim Hartley, Field Maintenance Engineer with our Orange Field Repair Center, offered this suggestion with the comment that he finds it saves a lot of time over other methods.

FILM-PACK BACK FOR TEKTRONIX CAMERAS

A new Film-Pack camera back adapts all Tektronix Trace-Recording Cameras to use Polaroid's® two recently introduced plastic film packs—3000 speed/Type 107 and Pola Color®/Type 108.

These new plastic film packs offer several advantages over the older roll-type film.

1. They load easier and faster—just slide the plastic pack in place, pull a tab and you're ready to shoot the first picture.
2. They allow you to shoot pictures faster—the exposed film develops the picture outside the camera (black and white in ten seconds, color in 50 seconds). You are free to keep shooting—no waiting for the picture to develop. This can be a big help when a rapid sequence of pictures is needed.
3. Unlike the roll-type film, the new film pack produces flat prints with no bothersome curl to straighten out.

The new Film-Pack camera back interchanges with either the Roll-Film back or the Graflok back. No tools required. Order through your local Tektronix Field Office, Field Engineer or Representative. Specify Tektronix part number 122-671.

TYPE 3B1 TIME BASE UNIT—DELAYED SWEEP TRIGGERS BEFORE END OF DELAY

A large external trigger can sometimes override the lockout circuit and trigger a delayed sweep before expiration of the delay period when the controls of the Type 3B1 are set as follows: MODE to DLY'D, TRIG.; SOURCE (DELAYED SWEEP TRIGGERING) to EXT.

It usually takes a trigger signal of about 20 volts in the non-attenuated external trigger (±15 volts) range to cause this to happen.

An easy cure is to replace R202, a 680 Ω, ¼ w, 5% resistor with a 1 k, ¼ w, 5% resistor (Tektronix part number 315-102).

This information applies to Type 3B1's with serial numbers *below* 2777. Instruments above this number have the change implemented at the factory.

TYPE 525 TELEVISION WAVEFORM MONITOR AND TYPE 526 COLOR-TELEVISION VECTORSCOPE — 6DB6 VACUUM TUBES REPLACED BY 6HZ6 TUBES

Manufacturers of the 6DB6 Vacuum tube have discontinued its manufacture. The 6DB6 was used in the V310 location of the Type 525 and the V14, V24, V304, V314, and V354 locations of the Type 526. As a replacement we recommend the 6HZ6 tube. It has characteristics similar to the discontinued 6DB6 and may be used as a direct replacement in the locations mentioned above. No modification required.

TYPE 517A, TYPE 517, AND TYPE 555 OSCILLOSCOPES — ADJUSTING THE 6.3 VOLT REGULATED HEATER SUPPLY

Setting the Reg. Htr. Adj. control of these instruments requires the use of an ac voltmeter having an iron-vane or dynamometer-type movement and a range of zero to 10 volts rms. A meter employing a d'Arsonval-Type movement—a vtvm, for instance—will not give the required accuracy for this measurement. In measuring ac voltage the accuracy of a meter with a d'Arsonval-type movement is predicated on the ac voltage waveform being a pure sine wave.

The Type 517, Type 517A and Type 555 Oscilloscopes incorporate a saturable reactor in their regulated-heater circuits. The ac-voltage waveform in passing through this saturable reactor undergoes alteration to the extent that it is no longer a pure sine wave. Therefore, the actual value of the regulated heater supply in these instruments, if set to 6.3 volts with a voltmeter of the d'Arsonval-movement type, will be 7.3 volts—1 volt too high.

This excess of 1 volt of filament power will considerably shorten the life expectancy of tubes and seriously degrade the instruments' reliability.

TEKTRONIX CIRCUIT COMPUTER

The Tektronix Circuit Computer, a circular slide-rule device, computes directly problems involving resistance, inductance, capacitance, frequency and time. Its primary design objective is to provide a means of quick computation of time values from other circuit dimensions.

With slide-rule ease the engineer or technician can compute:

1. Capacitive Reactance
2. Inductive Reactance
3. Resonance
4. RC Time Constant and Resistance
5. L/R Time Constant and Reactance

6. Filter Cut-off Frequency

7. Risetime

The computer consists of three circular decks—containing seven accurate scales—and a hairline indicator. Each scale is clearly identified and the scale graduations —jet black on pure white—stand out in vivid contrast and help to provide easily-read answers.

The computer is constructed of laminated plastic—light weight but durable. Mylar laminations over the three decks protect the printed information from wear and assure its remaining clearly legible under even the most strenuous use.

Overall diameter of the computer is 7¾″.

An 8½″ by 11″ booklet which accompanies the computer presents, in clearly-written and easily-understood steps, instructions for its use. The booklet also contains a short discussion of Risetime and Time Constant.

These computers are available through your Tektronix Field Engineer or local Field Office. The Tektronix Part Number for the computer is 003-023.

IDENTIFYING POLAROID PRINTS

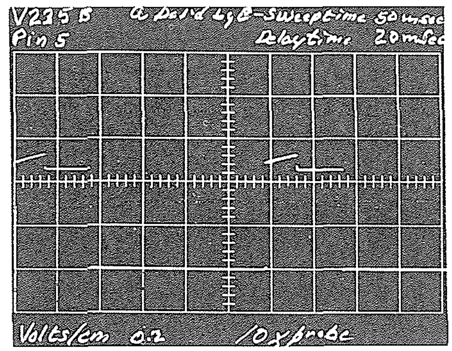


Figure 1. Information noted on Polaroid print with a hot soldering iron.

Ken Steele of the Hartman Electric Company in Mansfield, Ohio volunteers the information that a hot, 25 watt soldering iron employing a ⅛″ round tip supplies a convenient way of writing information on Polaroid* prints. Using the iron like a pencil, you just write on the black portion of the print. The information stands out in brilliant white (see Figure 1).

Following Mr. Steele's lead we experimented a bit further and learned that the pencil-type soldering irons in the 15 watt class work equally well and are a bit easier to write with.

Service Scope issues #17, December, 1962; and #13, June, 1962, contain additional suggestions for identifying information on Polaroid prints.

* Polaroid is a registered trademark of the Polaroid Corporation.

NUVISTOR PULLER

Here is a simple-to-make tool that facilitates the removal of Nuvistors from their sockets. Take a large alligator-clip cover and cut it off about an inch from the small end. Discard the large end and "presto" you have a Nuvistor puller.

Pliers, of course, should never be used to remove Nuvistors from sockets.

NEW FIELD MODIFICATION KITS

TYPE 541 AND TYPE 545 OSCILLOSCOPES — VERTICAL AMPLIFIER TUBES

This modification replaces the checked 6CB6 tubes in the distributed amplifier stage with Type 8136 tubes. The 8136 tubes deliver greater reliability, give higher gain and experience only negligible cathode interface over a long period of time.

The modification also changes: R1142, screen resistor in the vertical amplifier circuit, to 820 Ω (2 w, 10%) to provide a more suitable bias for the 8136 tubes; and R1021 and R1024, plate resistors in the input amplifier, to 500 Ω (½ w, 1%) to compensate for the increased gain delivered by the 8136 tubes.

This modification applies to Type 541's, serial numbers 101 through 6474; and Type 545's, serial numbers 101 through 9291.

Order through your local Tektronix Field Representative or Field Office. Specify Tektronix part number 040-360.

TYPE 564 STORAGE OSCILLOSCOPES —REMOTE ERASE FEATURE

This modification provides an external Remote-Erase feature for the Type 564 Storage Oscilloscope.

It installs a circuit assembly which contains two monostable multivibrators — one for the Upper display area and one for the Lower display area. When activated from either the front panel Erase controls or the Remote-Source Erase controls these multis erase their respective display areas. The Remote-Source Erase control can be any switch contact that can short a wire from the Type 564 to ground or any equipment that can provide a negative-going 5-to-10 volt pulse for the multi of each display area.

The external connections are brought out to a four-contact connector on the rear of the Type 564 and a mating connector is included to permit attachment of the Remote-Erase control.

This modification applies to Type 564 Storage Oscilloscopes, all serial numbers. Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-352.

TYPE 502A DUAL-BEAM OSCILLOSCOPE—VERTICAL SIGNAL OUT

This modification provides a rear-panel, direct-coupled Vertical Signal Out from each of the Type 502A's two vertical amplifiers. Output level is approximately 2 volts per centimeter of crt deflection, with an output impedance of approximately 200 ohms.

The modification replaces the 6AU6 Trigger-Pickoff tube (V493) and seven-pin socket with a 6DJ8 tube and a nine-pin socket. This new tube combines a Trigger-Pickoff cathode follower (CF) and a Vertical Output CF in a single tube.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-335.

TYPE 567 AND TYPE RM567 DIGITAL-READOUT OSCILLOSCOPES — POWER SUPPLY IMPROVEMENTS

This modification incorporates several refinements in the power supplies of the Type 567 and Type RM567 Digital-Readout Oscilloscopes.

1. It replaces the 1 w, 10 Ω fuse resistors R600, R660 and R661 with 2 w, 10 Ω fuse resistors and parallels the 1 w, 10 Ω fuse resistor R680 with an additional 1 w, 10 Ω fuse resistor (R681). This increase in wattage rating assures a longer resistor life.

2. It adds a potentiometer and a suitable divider network to the —12.2 volt supply. This provides a means for accurately adjusting the voltage of this supply.

3. It adds a 100 μf capacitor (C633) from the base of the transistor Q634 to ground to reduce ripple in the —12.2 supply.

4. It adds potentiometers and suitable divider networks to the +125-volt and +300-volt supplies to provide a means for more accurately adjusting these supplies.

This modification applies to Type 567's with serial numbers 101 through 407 and Type RM567's with serial numbers 101 through 149 with the following exceptions:

Type 567, serial numbers:

183	333	354	375	394
206	334	355	384	395
286	341	367	391	397
291	342	368	392	401
320	346	369	393	404

Type RM567, serial numbers:

129	136	141
131	137	144
134	138	147
135	140	148

These instruments had this modification installed at the factory.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-319.

TYPE 67 TIME-BASE UNIT—SWEEP LOCKOUT FOR SINGLE SWEEP OPERATION

This modification adds a sweep lockout feature to the Type 67 Time-Base Unit to allow the electron beam to sweep once after receiving a triggering pulse. The lockout circuitry then prevents any subsequent trigger pulse from activating the sweep until the operator resets or "arms" the sweep circuit by depressing the lever arm of the MODE switch. This feature allows the viewing of "one shot" (non-repetitive) phenomena. A front-panel READY light indicates when the sweep is armed and ready to fire on the next trigger pulse.

The modification adds a sweep-lockout transistor circuit and installs a new front panel and a MODE switch. It is applicable to Type 67 Time-Base Units, all serial numbers.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-318.

TYPE 3A1 DUAL-TRACE UNIT — INCREASED VERTICAL DEFLECTION

Installation of this modification increases the linear vertical deflection of the early Type 3A1's. It adds a linear hybrid amplifier to obtain this increase.

The following chart lists the oscilloscopes compatible with the Type 3A1 and notes the vertical scan before and after modification.

Instrument Type	Vertical Scan Area	
	Before	After
561* RM561* 567* RM567*	±2 cm (4 cm overall)	±3 cm (6 cm overall)
561A RM561A 564 RM564 565 RM565	±3 cm (6 cm overall)	±4 cm (8 cm overall)

* When used in these instruments it may be necessary, in some cases, to increase the internal 0.01 v/div and 0.02 v/div gain settings of the Type 3A1 to provide adequate front panel "Calib" control range for instruments with low-sensitivity crt's.

The modification also offers improved linearity by increasing the plate voltage of V364 and V374 (8233 tubes in the output amplifier) by 10 volts, and better stabilization of the correct voltage level at the cathode of the Trigger Pickoff cathode follower (V383A) by changing the values of resistors R381 and R382 in the grid circuit of this tube.

The modification applies to Type 3A1's, serial numbers 101 through 4327.

Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-349.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — IMPROVED VERTICAL-AMPLIFIER STANDARDIZATION

This modification is a combination of Field Modification Kits 040-275 and 040-324. *It should not be used if either of these kits has previously been installed.*

The modification standardizes the vertical amplifiers of the Type 581 and Type 585 for use with the Type 82 Dual-Trace Unit, Type 86 Unit, or any future Type 580-Series plug-in units by improving the impedance matching between the delay line and the termination networks. This improvement also enhances the transient response of the Vertical Amplifier.

Another benefit of the modification is decreased compression on the Vertical Amplifier output stage. V1284, a dual-tetrode 7699 tube, is replaced with two single-pentode 7788 tubes. The crt support bracket is also replaced.

Finally, the modification adapts the Type 80 Plug-In Units (serial numbers 101 through 3386) and the P80 Probe for use in the "standardized" Type 581 and Type 585 Oscilloscopes.

The modification applies to Type 581's, serial numbers 101 through 949 and Type 585's, serial numbers 101 through 2584.

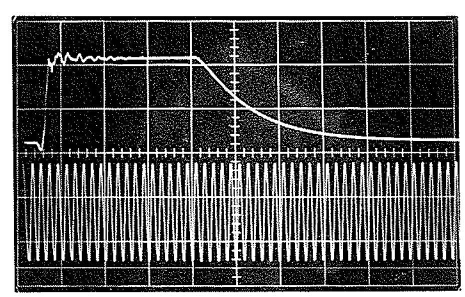
Order through your local Tektronix Field Engineer or Field Office. Specify Tektronix part number 040-364.

AUTOMATIC DISPLAY SWITCHING

Featured In The Type 547 Oscilloscope

Electronic switching between 2 wide-range time bases allows an alternate presentation of the same signal at 2 different sweep rates. Gallium Arsenide diodes in the switching circuit provide fast switching between time bases, and insure that only the desired time base is displayed at one time.

Two different signals can be alternately displayed at the same or different sweep rates with a dual-trace unit such as the new Type 1A1. In many applications, this dual-scope operation provides the equivalent of two oscilloscopes, and at a considerable savings. Since a single-gun tube is used, beam registration and geometry problems of dual-gun tubes are avoided. Dual displays are viewed with accuracy of the single-beam construction. Also, the full 6 x 10-cm screen area can be used to display signals on either time base. A trace separation control operates in conjunction with the normal vertical positioning to allow full control of dual displays.



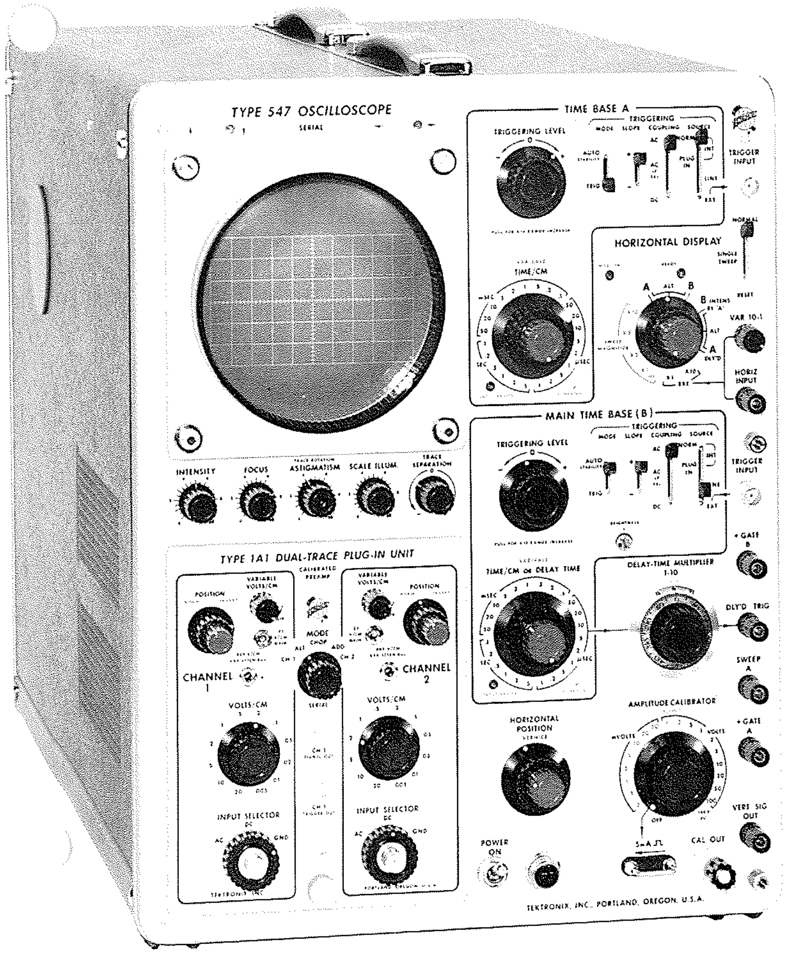
Dual-Scope Operation—independent control of each signal with Channel 1 of the Type 1A1 Dual-Trace Unit locked to Time Base A, and Channel 2 locked to Time Base B.

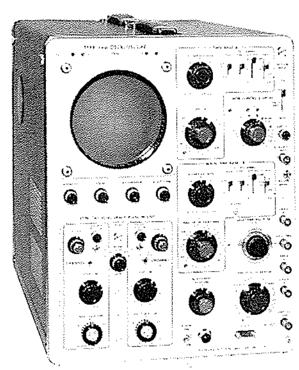
A NEW GENERATION

OF TEKTRONIX

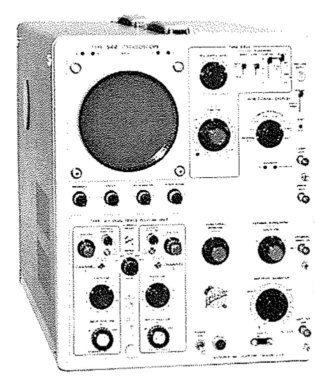
OSCILLOSCOPES

TYPE 540-SERIES





TYPE 546



TYPE 544

BRIGHT 6 x 10-CM DISPLAYS

ILLUMINATED NO-PARALLAX GRATICULE

SMALL SPOT SIZE, UNIFORM FOCUS

COMPLETELY NEW VERTICAL AMPLIFIER

FULL-PASSBAND TRIGGERING

WIDE SELECTION OF VERTICAL PLUG-INS

MAJOR CHARACTERISTICS

OSCILLOSCOPE	PASSBAND Ⓐ	SWEEP RANGE	SWEEP DELAY	SWEEP MAGNIFIER
Type 543B	DC to 33 MC	0.1 μsec/cm to 5 sec/cm in 24 calibrated steps, variable uncalibrated from 0.1 μsec to ≈ 12 sec/cm.	None	2, 5, 10, 20, 50, 100X
Type 545B			1 μsec to 10 sec	5X
Type 544	DC to 50 MC		None	2, 5, 10, 20, 50, 100X
Type 546			0.1 μsec to 50 sec.	2, 5, 10X
Type 547		Same characteristics as Type 546 plus Automatic Display Switching.		

Ⓐ Passband with Type 1A1 or 1A2 Dual-Trace Plug-In Units at 50 mv/cm sensitivity. Passband of the Type 1A1 at 5 mv/cm sensitivity is dc to 28 Mc with Type 547, 546, or 544, dc to 23 Mc with Type 543B and 545B.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 27 PRINTED IN U.S.A AUGUST 1964

THE CATHODE FOLLOWER

Because both its input-grid capacitance and its output-impedance are small, the cathode-follower circuit lends itself to many uses in electronics. This article discusses these and other useful characteristics of cathode-follower circuits.

Part I

The cathode follower is a circuit related to the familiar plate-loaded amplifier. In the plate-loaded amplifier the load resistance R_L is connected in the plate lead to the tube. But in the cathode follower, shown in Fig. 1, the load resistance R_k is connected in the cathode lead to the tube. Useful characteristics of the cathode follower include these:

1. The grid-input capacitance is small.

2. And the internal output impedance is small.

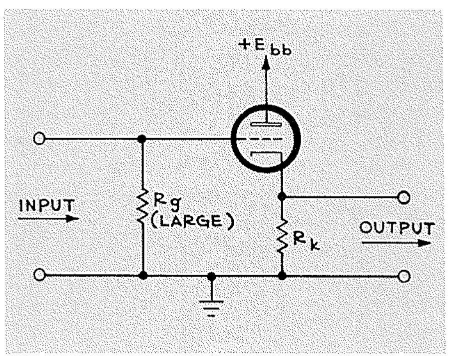


Fig. 1 — Basic cathode-follower circuit. Here the load resistor R_k is connected in the cathode circuit, rather than in the plate circuit as in the plate-loaded amplifier.

In this article we shall take up these and other cathode-follower characteristics in more detail. But first, let's consider some cases where we can take advantage of the two characteristics we have mentioned above.

Need for a device having a small input capacitance. Suppose we apply an input sig-

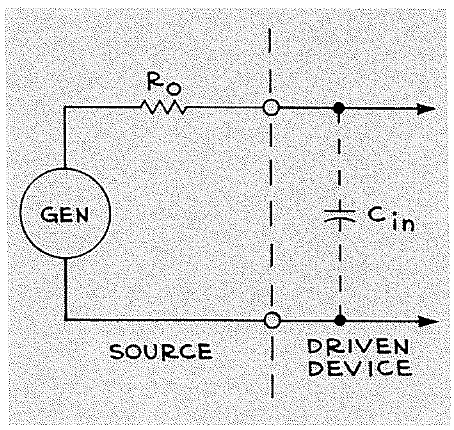


Fig. 2 — Here a signal source has an internal impedance R_o. The source drives a circuit whose input capacitance is C_{in}. If the time constant R_oC_{in} of this arrangement is small, then the risetime of the combination is short. One way to keep the time constant small is to make C_{in} very small. Then the risetime is short even if R_o is relatively large.

nal to a device whose input capacitance is C_{in}. And suppose that the source of the signal voltage has an internal output impedance (resistance) R_o (see Fig. 2). For simplicity, assume that C_{in} and R_o are the only impedances present in the source or in the circuit connected to the source. Then the time constant of the source-and-input circuit will be R_oC_{in}.

If we can keep the input capacitance C_{in} very small, then the time constant R_oC_{in} will be small — even though R_o might be quite large. And consequently the risetime of the R_oC_{in} circuit will be short.

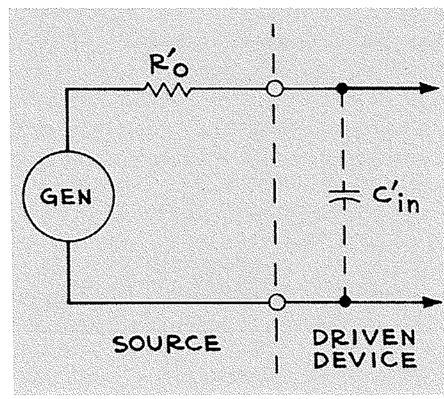


Fig. 3 — Here a second signal source whose internal impedance is R'_o drives a circuit whose input capacitance is C'_{in}. One way to keep the time constant $R'_oC'_{in}$ short is to make R'_o very small. Then the risetime is short even if C'_{in} is relatively large.

The input capacitance C_{in} of a cathode follower is small, for reasons that will be explained later. Consequently the cathode follower has the advantage that we can connect the cathode-follower input circuit to a signal source without greatly lengthening the risetime of the source itself.

Need for a device having a small internal output impedance. Suppose a signal source has an output impedance (resistance) R'_o that is very small. Imagine that we use this signal source to apply a signal voltage to another device whose input capacitance is C'_{in} (See Fig. 3). For simplicity, assume that C'_{in} and R'_o are the only impedance present in the source or in the circuit connected to the source. Then the time constant of the source-and-input circuit will be $R'_oC'_{in}$.

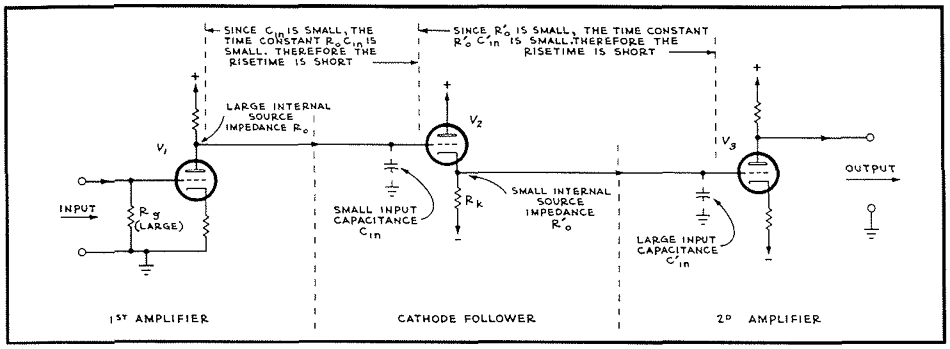


Fig. 4 — Here we want to apply a signal from the plate circuit of V_1 (representing a relatively large impedance R_o) to the grid circuit of V_3 (representing a relatively large capacitance C'_{in}). If we couple the plate of V_1 directly to the grid of V_3, the corresponding coupling-circuit time constant is a large value $R_oC'_{in}$. But if we insert the cathode follower V_2 as shown, we now have two coupling-circuit time constants in cascade. The first time constant is R_oC_{in}, where C_{in} is the very small input capacitance to the cathode-follower; thus, as indicated in Fig. 2, this first time constant is relatively small. The second time constant is $R'_oC'_{in}$, where R'_o is the very small output impedance of the cathode follower; thus, as indicated in Fig. 3, this second time constant is relatively small. By inserting the cathode follower we thus break up a large time constant $R_oC'_{in}$ into two much smaller time constants R_oC_{in} and $R'_oC'_{in}$. In this way we use the cathode follower to improve the coupling-circuit risetime.

If we can keep the source impedance R'_o very small, then the time constant $R'_oC'_{in}$ will be small — even though C'_{in} might be quite large. And consequently the risetime of the $R'_oC'_{in}$ circuit will be short.

The internal output impedance of a cathode follower is small, for reasons that will be explained later. Consequently the cathode follower has the advantage that we can use the cathode follower to drive a device that has appreciable input capacitance while still achieving a short risetime. As an example, we might use a cathode follower to drive a coaxial transmission line — where the capacitive effect of the line is appreciable — and still preserve a short-risetime characteristic.

Figure 4 shows an application that utilizes the advantages of both the small input capacitance and the small output impedance of the cathode follower. We desire to couple a rapidly changing signal from the plate of V_1 to the grid of V_3. In Fig. 4, we apply the output signal from the plate of V_1 to the grid of the cathode follower V_2. The internal source impedance of the amplifier stage that includes V_1 is ordinarily rather large. But the input capacitance of the cathode follower V_2 is small, so that we end up with only a short risetime T_{R1} associated with the circuit that couples the plate of V_1 to the grid of V_2. Now, the input capacitance of the amplifier stage that includes V_3 is ordinarily rather large. But we drive the grid of V_3 from the low-impedance output circuit of the cathode follower V_2. Thus we end up with only a short risetime T_{R2} associated with the circuit that couples the output of V_2 to the grid of V_3. The effective risetime of the cathode-follower coupling system between V_1 and V_3 will, by the equation $T_R — (T_{R1}^2 + T_{R2}^2)^{1/2}$, be shorter than the sum of the two individual risetimes T_{R1} and T_{R2}.

We see, then, that we can often shorten the risetime of an interstage-coupling system by inserting a cathode follower between one stage and the next.

Polarity of output signal from a cathode follower. Let us now consider some factors that tell us how a cathode follower actually operates.

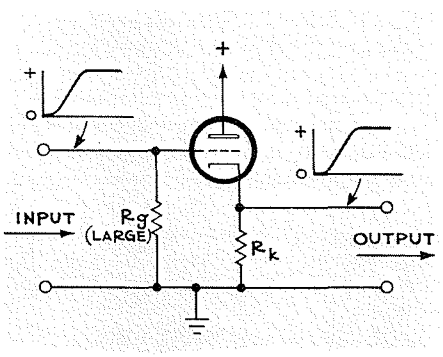


Fig. 5 — Illustrating that the polarity of the cathode-follower output-signal voltage is the same as that of the input-signal voltage — in contrast to the polarity reversal that occurs in the plate-loaded amplifier.

If we apply to the cathode-follower circuit of Fig. 5 a grid-input signal that makes the grid more positive, the cathode-to-plate electron flow will increase. Therefore the voltage drop across the cathode resistor R_k will increase, so that the voltage at the cathode of the tube will be farther removed from the potential of the grounded negative terminal of the power supply. That is, the voltage at the cathode output terminal of the cathode-follower stage will become more positive. Thus, in contrast to the action in the plate-loaded amplifier, *the polarity of the output signal from the cathode follower is the same as the polarity of the input signal:*

Output impedance. The internal output impedance of a cathode-follower stage is comparatively small (usually from less than 100 ohms to perhaps 200 or 300 ohms). This range of values represents impedances that are considerably smaller than the typical output impedances we would expect from plate-loaded amplifiers (from a few hundred to several thousand ohms).

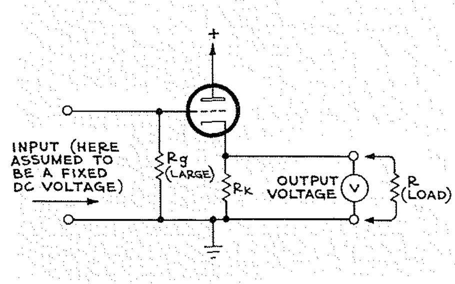


Fig. 6 — Illustrating that the internal output impedance of a cathode follower is small. A given cathode current makes the voltmeter V show a certain dc output voltage (the IR voltage drop across R_k). If we connect the external load R, we thereby reduce the total resistance in the cathode output circuit. Thus we might at first expect the voltmeter to show a sharply reduced output-circuit IR voltage drop. But this voltage drop is also the negative dc grid-to-cathode bias voltage — so that the tube allows a greater cathode current to flow. Therefore the new output voltage is the IR voltage drop produced by a larger current in a smaller total resistance. As a result, this new output voltage isn't much less than the original voltmeter reading. The fact that the output voltage changes only a little when we connect the load R shows that the internal source impedance of the cathode follower is small.

To see why the internal output impedance of a cathode follower is small, suppose we connect an external load resistor R across the output terminals of the cathode follower as shown in Fig. 6. Let the input grid-to-ground voltage be held constant. When we connect the external load resistor R, we effectively reduce the resistance in the cathode circuit. Suppose first that cathode current remains constant. Then the voltage drop across the cathode resistance decreases. Therefore, the grid-to-cathode voltage becomes less negative. But this actually allows more cathode current to flow. Thus the voltage drop across the paralleled cathode resistor and external load resistor tends to increase again to almost its original value. In effect, then, *the voltage across the output terminals doesn't depend greatly upon the amount of external load resistance we connect to these terminals.* This statement is equivalent to saying that a cathode follower is a source that has a small internal impedance.

The actual internal source impedance of a cathode-follower stage is not simply the value of the cathode resistor R_k. Instead, it consists of a parallel combination of R_k shunted by the internal impedance of the tube. We can see that this statement applies if we look at Fig. 7. Note that the power supply represents a short circuit to signal variations. Thus the signal output impedance of the cathode-follower stage, looking back into the output terminals, is made up of the tube impedance in parallel with the cathode resistor R_k.

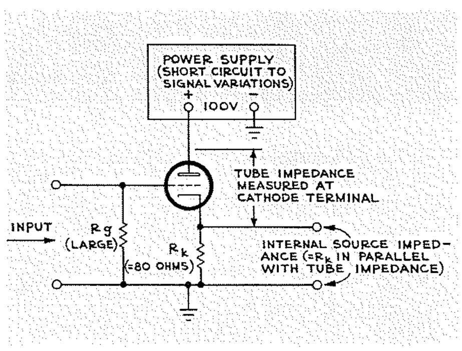


Fig. 7 — The internal source impedance of a cathode-follower stage includes the cathode resistor R_k. But for a varying signal, the cathode-to-plate dynamic impedance of the tube is connected (through the power supply) in parallel with R_k. This tube impedance is roughly $1/g_m$, and is therefore often quite low. For example, if the tube has the characteristic curve of Fig. 8, its cathode-to-plate impedance is about 80 ohms. With such a tube, the cathode-follower stage of Fig. 7 would have an internal source impedance of only about 40 ohms.

The impedance of the tube itself, at its cathode terminal, can be shown to be approximately $1/g_m$ (where g_m is the mutual conductance of the tube in mhos). But the value of g_m of a given tube depends upon the operating point at which the tube works. Suppose, for example, that we use a tube whose plate current-grid voltage characteristics is that shown in Fig. 8. For this particular tube, the operating point is that shown as point A in Fig. 8 when the tube is used as indicated in Fig. 7. The slope of the tangent line to the characteristic curve at the operating point A shows that g_m is 12,500 micromhos (= 0.0125 mho). Then the impedance of the tube, at its cathode terminal, is approximately 1/0.0125 = 80 ohms. Since the cathode resistor is also 80 ohms, the effective internal impedance of the cathode-follower stage of Fig. 7 is about 40 ohms.

Voltage Gain. In a plate-coupled amplifier stage, the varying output signal voltage may well be several times the varying input signal voltage. That is, a plate-coupled amplifier stage may have a voltage gain of several times.

But the voltage gain of the cathode follower cannot be as great as unity. In other words,

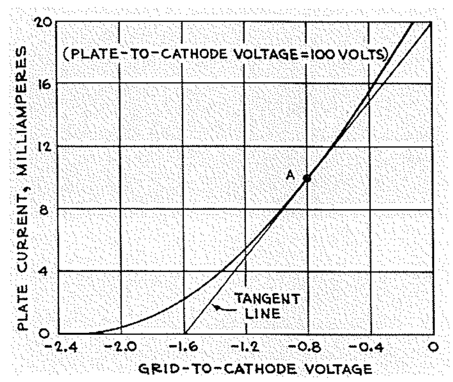


Fig. 8 — Assume that this curve represents the plate current-grid voltage characteristics of the tube in Fig. 7. Then we can use this curve to find the approximate internal impedance of the tube itself, measured at the cathode pin. First note that the 80-ohm cathode resistor R_k in Fig. 7 establishes the tube operating point as point A in Fig. 8. (To check this, observe that a current of 10 milliamperes in 80 ohms produces an 0.8-volt drop — the grid-to-cathode bias corresponding to point A). Next, to find the mutual conductance of the tube at operating point A, we draw a straight tangent line to the curve at point A. We see that the tangent line intercepts a base interval corresponding to 1.6 volts and a vertical interval corresponding to 20 milliamperes (0.02 ampere). Thus, at operating point A, the mutual conductance g_m is 0.02/1.6 = 0.0125 mho. Since the tube internal impedance at the cathode pin is approximately $1/g_m$, the tube whose characteristic curve is shown in Fig. 8 has an internal source impedance of about 1/0.0125 = 80 ohms.

the varying output signal voltage cannot be as great as the varying input signal voltage. This result springs from the fact that the cathode electron flow for a given plate voltage is controlled essentially by the grid-to-cathode voltage. Suppose, for example, that an input grid-to-ground signal-voltage change of +2 volts *could* change the electron flow sufficiently to vary the cathode-to-ground voltage by +2 volts (corresponding to a voltage gain of unity). But this change would involve no net change in grid-to-cathode voltage; therefore there would be no net change in electron flow — an absurdity. Thus the voltage gain of the cathode follower cannot be as great as unity.

Clearly, then the cathode follower is not useful directly in providing voltage gain. But as we have seen, the cathode follower can be very useful in improving the risetime characteristics of circuits that actually do produce voltage gain.

The voltage gain of a cathode-follower stage depends both upon the characteristics of the tube and upon the value of the cathode resistor R_k. When R_k is equal to the internal output impedance of the tube itself (approximately $1/g_m$, where g_m is in mhos), the gain of the stage is approximately one-half. Thus, with values shown in Fig. 7, we realize an output of about one-half volt for each volt of input grid-to-ground signal. If we use greater values of R_k, we can make the gain of the stage appreciably greater. We can make the voltage gain reach values between 0.9 and 0.99 by using large values of R_k.

Since the output signal from a cathode follower has the same polarity as the input signal, and since the output signal can be made almost as large as the input signal, we can consider that the output signal approximately duplicates the input signal. Hence the name *cathode follower.*

Part 2 of this article will appear in the October, 1964 issue of Service Scope.

The material for this article was taken from the book "Typical Oscilloscope Circuitry", published by Tektronix, Inc. The complete text is available from your Tektronix Field Engineer or Representative.

SOLDERING OF TEKTRONIX ETCHED CIRCUIT BOARDS

An Explanation and Technique
by Verne McAdams
Tektronix Manufacturing Staff Engineer

Soldering is an alloying process between two metals. In its molten state, solder chemically dissolves some of the metal with which it comes into contact. However, the metals to be soldered, are, more often than not, covered with a thin film of oxide that the solder cannot dissolve. A flux must be used to remove this oxide film from the area to be soldered. The solder used in most electronic work contains this flux as a center core which has a lower melting point than solder itself. The flux in its molten state cleans the metal and holds the oxides suspended in solution. The molten solder can then make contact with the cleaned metal and the solvent action of solder on metal can take place.

The soldering process then is the following:

1. The cored flux melts first and removes the oxide film on the metal to be soldered.
2. The solder melts, floating the lighter flux and the impurities suspended in it to the surface.
3. The solder dissolves some of the metal in the connection.
4. The solder cools and fuses with the metal.

To do a proper soldering job the following must be done:

1. The connection itself must become hot enough for the rosin to melt and clean the metal.
2. The cored solder must be applied directly to the heated connection so that the flux, which melts at a lower temperature than the solder, will melt first and clean the connection by the time the solder has melted. (If the solder is applied to the soldering-iron tip, the flux, being lighter, will float on top of the solder. It will be unable to reach the connection and clean it.)
3. A good easy flow of heat from the soldering-iron tip to the connection must be obtained by a clean, well-tinned soldering-iron tip. A thin film of molten solder will transfer heat rapidly.

In soldering techniques for etched circuit boards, the basic principles for soldering prevail. We are now interested in the difference in the soldering of etched circuit boards and normal soldering.

The first consideration of soldering to etched circuit boards is the limitations of the substrate of the boards. The Tektronix etched circuit boards have a substrate of fiber-glass epoxy, which has a temperature limitation of 530° F for not more than 5 minutes. Hotter temperatures reduce the time in inverse relationship; the hotter the temperature, the less time the boards will stand it before damage. (As an indication of damage, white flakes will first appear in the surface of the board. These white flakes indicate a decomposition of the fiber-glass epoxy substrate).

A second consideration is the soldering-iron-tip temperature, which is determined by the type of soldering iron and soldering-iron tip used. The wattage of the soldering iron and the configuration of the soldering-iron tip combined with the speed of soldering will determine the ultimate tip temperature as well as the working-tip temperature. Since we are here primarily concerned with the working tip temperature, the soldering iron and tip should be chosen so that the working tip temperature will at no time exceed the limitations of heat set forth above.

A third consideration in soldering of etched circuit boards is the type of solder used. The best type for use on the Tektronix etched circuit boards is a "eutectic"-type cored-wire solder of size #20 AWG, composed of 63% tin and 37% lead (as designated in FED. SPECS. QQ-S-571c as Sn63) with a central core of activated rosin flux (Divco X-25, or equivalent).

The fourth consideration is the technique of repair — repair in this case consisting of replacement of components. The Tektronix etched circuit boards consist of straight-through connections (no crimped connections) gold plated to facilitate soldering. Carelessness in reheating the solder connections for the removal and replacement of components is the only difficulty to be guarded against here. Caution must be taken not to overheat the substrate and this can best be accomplished with deft hands and by small applications of heat. If the removal or replacement is not accomplished in the first few seconds of heat application, avoid transferring too much heat to the substrate by *going to another connection or waiting a few minutes before reheating the connection.* Giving the connection these few minutes to cool will allow the heat to dissipate and help to avoid overheating the substrate. Heat dissipates quite slowly from some of the smaller connections and too long an application of the soldering iron will result in the overheating of the substrate.

Repair on the older phenolic-copper laminate boards is similar to that on the newer gold-plated fiber-glass epoxy boards with a cautionary remark that the problems of heat limitation applies even more so on the *older* boards. Their ultimate heat limitation is much lower than that of the newer boards and the copper laminate is glued to the board instead of being bonded to the substrate as in the case in the fiber-glass epoxy boards.

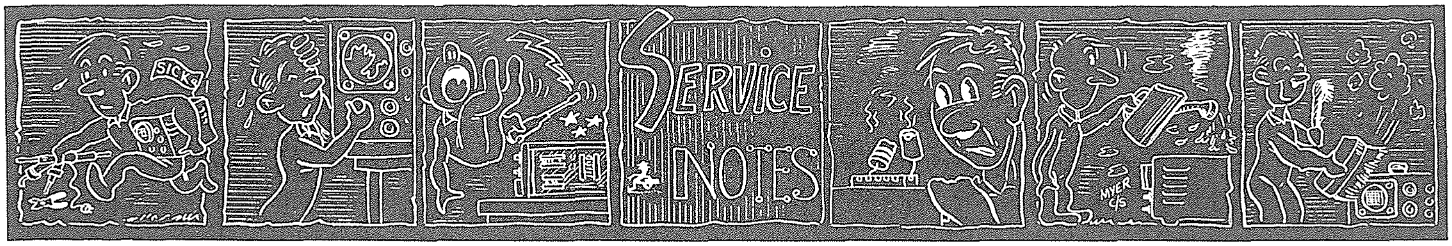
Some things to be considered in order to obtain a low working-tip temperature are:

1. At slow soldering speeds, a 25-watt iron and a 1/8" tip.
2. At medium soldering speeds, a 40-watt iron and a 3/16" tip.
3. At fast soldering speeds, a 50- or 60-watt iron and a 1/4" tip.

A recommendation for soldering tips is that they be made of copper and have a chisel or bevel shape.

There are two areas on an etched circuit board which might require different soldering techniques. One is the large copper area used as a common connection in contrast to the smaller spot connections. The larger areas will absorb heat much more rapidly than the smaller spot connection. This may necessitate a hotter iron and a larger tip for these areas than the smaller spot connections.

With these cautions and recommendations in mind you should encounter no trouble when soldering Tektronix etched circuit boards.



TYPE 551 OSCILLOSCOPES — CRT REPLACEMENT

The Type 551 (T57) crt (cathode ray tube), original equipment in Type 551 Oscilloscopes, s/n's 101 to 2031, has been discontinued. An improved crt, T5511, is offered as a replacement. This new crt is designed for use with a Horizontal Beam Registration control — an adjustment that allows you to compensate for stray fields to make the starting times of both beams coincide. For Type 551's with serial numbers below 2032 you will need to install a parts modification kit (Tektronix Part Number 050-026) in order to use the new T5511 crt. We will supply the modification kit at *no charge*. Please note that the T551 (T57) crt can no longer be supplied!

Although Type 551 Oscilloscopes before serial number 216 have a Horizontal Beam Registration control, the parts replacement modification kit 050-026 *must be installed.*

When necessary to order a replacement for your T551 (T57) crt, please order Parts Replacement Mod Kit 050-026 *plus* the T5511 crt with desired phosphor. See below:

Old crt	Tektronix Part No.	New crt	Tektronix Part No.
T551(T57)-P1	154-186	T5511-P1	154-186
T551(T57)-P2	154-160	T5511-P2	154-160
T551(T57)-P5	154-210	T5511-P5	154-210
T551(T57)-P7	154-189	T5511-P7	154-189
T551(T57)-P11	154-143	T5511-P11	154-143

TYPE E PLUG-IN UNIT — HIGH FREQUENCY OSCILLATION

The Type E Plug-In Unit, when used in a Type 547 Oscilloscope, tends to oscillate at about 200 Mc. You can overcome this tendency by adding one ferrite bead (Tektronix Part Number 276-532) on each signal output lead at pins 1 and 3 of the interconnecting plug. This Service Note applies to Type E instruments with serial numbers below 6490. Instruments with higher serial numbers have the ferrite beads installed at the factory.

TYPE 21A AND TYPE 22A TIME BASE UNITS — TRIGGER IMPROVEMENT

A recent production modification greatly improves triggering stability of the Type 21A and Type 22A Time Base Units. It also makes adjustment of TD BIAS and LOCKOUT LEVEL less critical. The modification is quite simple and can be installed in Type 21A's with serial numbers below 8398 and Type 22A's with serial numbers below 8400.

The modification consists of changing D40, a Type BD-1 diode in the Time Base trigger circuit, to a Type TD-2 diode (Tektronix Part Number 152-081) and R126, a 100 k, ½ w, 10% resistor in the Lockout multivibrator circuit, to a 47 k, ½ w, 10% resistor (Tektronix Part Number 302-473). Changing this resistor brings the nominal setting of the LOCKOUT LEVEL control to the center range of its adjustment.

After the modification, the TD BIAS and LOCKOUT LEVEL controls are set according to instructions in the Type 555 Instruction manual. The benefits of the modification are that one setting gives reliability of trigger and equal response to both sine waves and pulses.

TYPE 564 AND TYPE RM564 OSCILLOSCOPES — SOME PRECAUTIONARY MEASURES

Here are some precautionary measures which, if observed, will prolong the useful life of the storage screen in the Type 564 and Type RM564 Oscilloscopes.

First and foremost, take great care in the degree of writing-gun intensity you use. High writing-beam current can cause permanent damage to the storage target. Always use the minimum beam intensity required to produce a clear well-defined display. Special care should be taken during warm up or when using slow rates or sampling displays.

Use caution when storing fast-changing portions of a waveform. Beam current could then be too great on the slow-changing portions of the waveform.

Avoid repeated use of the same area of the screen for storing displays. Distributing the use will allow the storage target to "age" uniformly and will prolong the effective life of the storage tube.

Turn the intensity control to minimum when changing plug-in units. An undeflected spot on the crt screen can burn the storage target even at normal intensity.

Do not leave a display on the crt screen (either writing or stored) when the display is not needed.

Do not leave the DISPLAY switches at STORE when the storage mode is not needed.

"Negative images" (dark waveform images that appear as a darker background light level when the DISPLAY switch is at STORE) result from writing or storing a waveform in one position on the screen for a relatively long period of time. Negative images will usually disappear in a short time, but may cause a temporary decrease in writing speed of the affected areas.

"Bright burns" (bright waveform images that will not erase completely) are caused by excessive intensity of the writing-gun beam. Severe burns may remain indefinitely; a mild case which may only show when the writing speed enhancement circuit is used (Type 564, s/n 2000 and up, or RM-564), will slowly fade to normal over a period of a few days normal use.

"Dark burns" (spots or lines on the screen that will neither write nor store) result from destructive burning of the storage target by the writing-gun beam. Replacement of the storage tube will be required if dark burns impair operation of the instrument.

TEKTRONIX CIRCUIT COMPUTER — AN ADDITIONAL USE

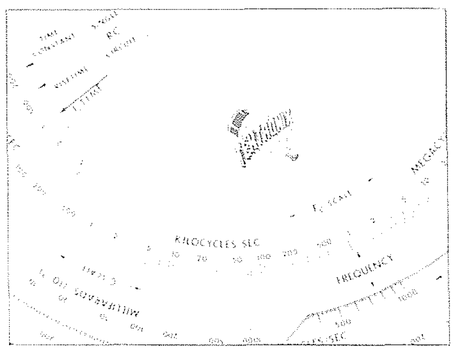


Figure 1. Shows location of new F_c TIME arrow on the top deck of the Tektronix Circuit Computer.

In this column of the June, 1964, issue of Service Scope, we describe the Tektronix Circuit Computer (Part Number 003-023), a circular slide-rule type of device.

Since then, Nelson R. Drew, K3RGH, of 906 7th Street in Laurel, Maryland, has written us telling about an additional use for this computer. By the addition of another "Time" arrow to the top deck of the computer you can read time as a reciprocal of frequency — in other words, solve the equation $T = \frac{1}{f}$.

You determine the location of the new arrow by positioning the top deck of the computer so that the 1-megacycle marker of the F_c scale is aligned with the FREQUENCY marker on the middle deck. Then, reading through the top-deck cut out, locate the 1-microsecond marker on the middle deck. Then, on the top deck opposite this 1-microsecond marker, scribe a short radial line to form the new "Time" arrow. Label this new arrow "F_c TIME". See Figure 1. Your computer will now solve the equation $T = \frac{1}{f}$. Example: Set F_c Scale to 5 megacycles; read 200 nanoseconds (through the top-deck cut out) opposite the new "F_c Time" arrow.

Our hearty thanks to Mr. Drew for his suggestion of a new use for the circuit computer.

THIN-BLADE, SINGLE-PINCHER PROBE TIP — INDEXING FOR PINCHER-TIP ORIENTATION

Indexing the barrel back near the finger flange identifies orientation of the pincher-tip hook (see Service Scope, issue 24, February, 1964) and so simplifies the probe removal when the tip is buried in a maze of wires. Red nail polish or lacquer shows up well on the plastic, see Figure 2.

H. I. Wilson of 40 Hillside Road, Beacon, New York, sent in this suggestion. Thank you, Mr. Wilson, for sharing your idea with our readers.

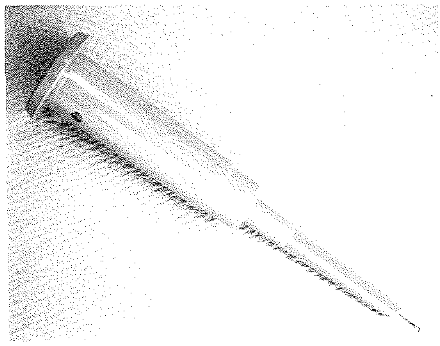


Figure 2. Adding a dot of red lacquer identifies orientation of pincher-tip hook.

PLUG-IN EXTENSION 013-055 — SUPPORT FOR EXTENSION

Here's another do-it-yourself project. Figure 3 shows a support that fits into the plug-in compartment of a Type 530, Type 540, Type 550 or Type 580 Series Oscilloscope. When using a Plug-In Extension (Tektronix Part Number 013-055), this support holds and aligns the outboard end of the extension so that a plug-in can be quickly and easily changed or installed. We made the one shown here (see Figure 3) from a one-inch thick piece of pine board.

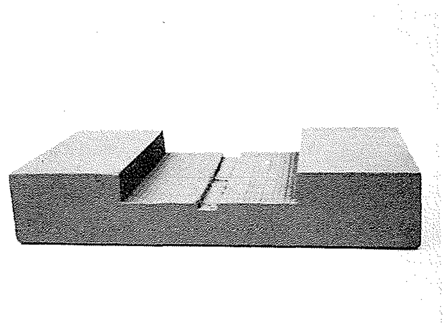


Figure 3. An easily-made support for the Tektronix Plug-In Extension (013-055).

The width of the support is 3 inches and the length is 5½ inches. The cut out portion of the support measures 2 7/16 inches wide by 7/16 of an inch deep. The narrow groove in the bottom of the cutout is 3/16 of an inch wide and 1/16 inch deep.

The support should fit snugly in the oscilloscope plug-in compartment and the plug-in extension should be a press fit into the cutout section of the support so that support and extension will stay in place when exchanging plug-ins.

Our thanks for this suggestion go to Mr. Ed Davis of Raytheon, HASCO, Ft. Bliss, Texas.

NEW FIELD MODIFICATION KITS

TYPE 131 CURRENT AMPLIFIER — UHF CONNECTOR

This modification supplies a special replacement UHF connector that will more perfectly fit a wider tolerance range of Type 131 housings. It helps to overcome and prevent the problem of the connector working loose.

Order through your local Tektronix Engineer, Field Office or Representative. Specify Tektronix Part Number 040-373.

TYPE 561 AND TYPE 561A OSCILLOSCOPES — POWER SUPPLY IMPROVEMENTS

This modification installs a means for accurately adjusting power supply voltages. It adds potentiometers to the divider network in the comparator circuits of the —12.2, +125, and +300-volt supplies. Installation involves the drilling of two holes and mounting a potentiometer assembly on the rear of the horizontal plug-in housing and changing several components in the —12.2, +125 and +300-volt supplies. A 10-Ω fuse resistor is added to limit surge currents and protect the +300-volt supply.

The modification is applicable to Type 561 Oscilloscopes, s/n's 101 through 5000; and Type 561A Oscilloscopes, s/n's 5001 through 6634. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-347.

TYPE 502 OSCILLOSCOPE — INTENSITY BALANCE CONTROL

This modification moves the Intensity Balance control to the front panel. It allows a more precise control of trace brightness — a useful feature in dual-trace photography.

A new front panel overlay makes room for the new control and supplies graduated markings for all five crt controls. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-350.

TYPE 527 AND TYPE RM527 WAVEFORM MONITORS — VERTICAL AMPLIFIER AND TRIGGER IMPROVEMENT

Installation of this modification brings four improvements to the Type 527 and Type RM527 instruments.

1. It improves triggering at low-level input signals by changing V24 (a 6EW6 tube in the Trigger amplifier) to a 6EJ7 tube. This 6EJ7 tube gives increased trigger gain.

2. It ac couples the Internal Sync amplifier tube (V14) to isolate the Internal Snyc signal from the DC Restorer feedback loop. This minimizes trace disappearance and distortion that may occur at low-level input signals.

3. It adds diodes between the grid and cathodes of V444 and V544 and from the cathode of V413 to ground. This gives warm up protection for the Vertical Amplifier tubes by limiting the positive grid-to-cathode potentials and eliminates the possibility of waveform distortion from damaged tubes.

4. It changes the time constant of the Gate Multi (V595). This minimizes Vertical DC-Restorer shift in the presence of color burst so that video will not occur during restoration time.

The modification applies to Type 527's s/n's 151 through 744 and Type RM527's*, s/n's 151 through 1189. Order through your local Tektronix Field Engineer, Field Office or Representative. Specify Tektronix Part Number 040-362.

*A few instruments in the following serial number ranges were modified at the factory: Type 527, s/n's 645 to 744; Type RM527, s/n's 730 to 1189. Consult your Tektronix Field Engineer or Representative before ordering if your instruments fall in these serial number ranges.

DC-TO-50 MC, 10 MV/CM

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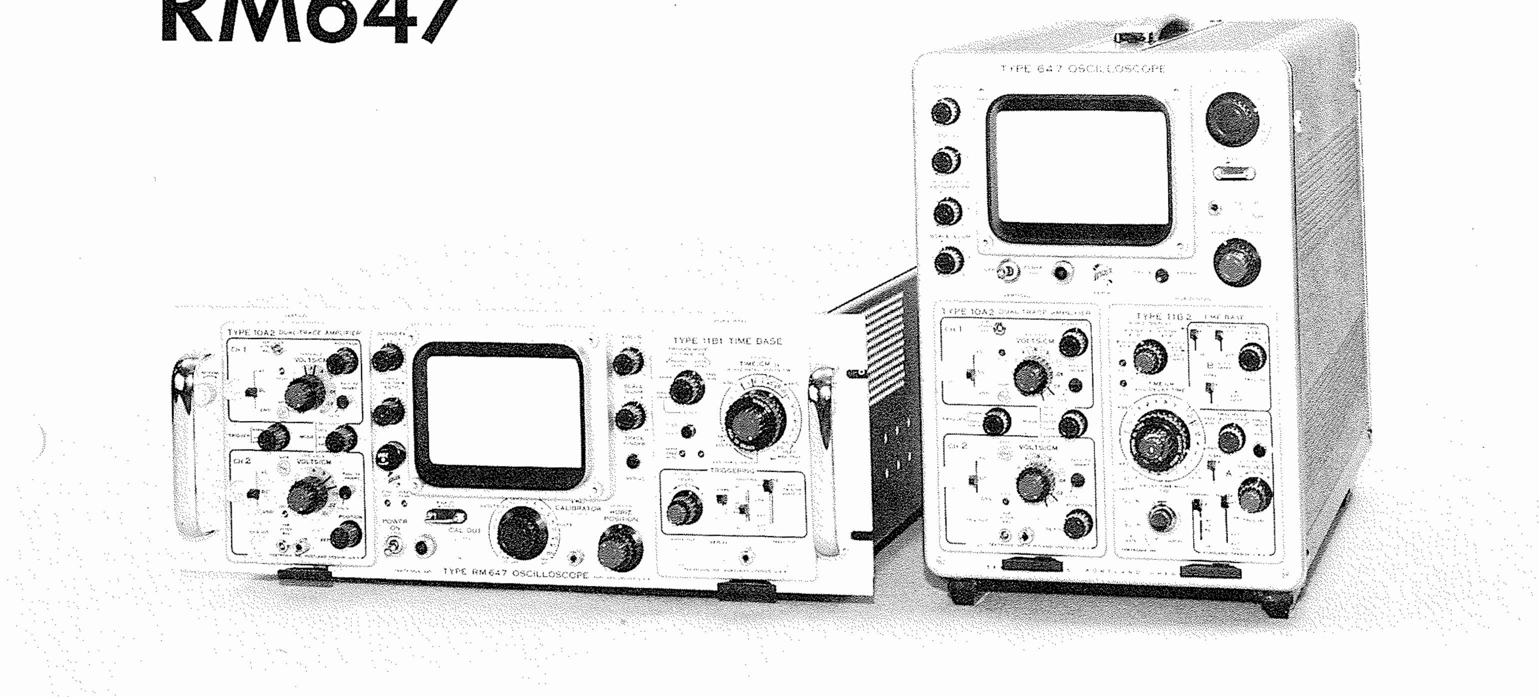
TYPE 647
RM647



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NUMBER 28 PRINTED IN U.S.A OCTOBER, 1964

THE CATHODE FOLLOWER

A continuation of the discussion on the cathode-follower circuit. Part 1 of this discussion, which appeared in the August, 1964, issue of Service Scope, covered the need for a device having a small input capacitance and a device having a small internal output impedance — two prime characteristics of the cathode-follower circuit. Also covered, were the polarity of the output signal and the voltage gain of the circuit.

Part 2

Input capacitance. The input capacitance of a cathode follower consists essentially of the effects of (1) the grid-to-cathode capacitance of the tube and (2) the grid-to-plate capacitance of the tube (see Fig. 9).

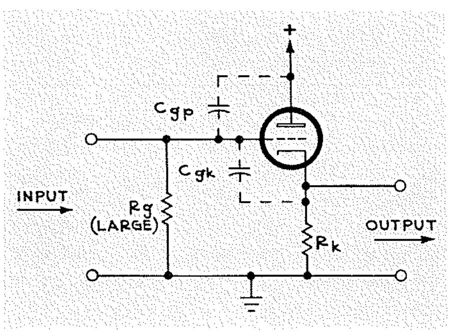


Fig. 9 — Illustrating that the input capacitance of a cathode-follower stage is small. If we apply a given grid-input voltage change, this input signal causes the cathode output voltage to change in the same direction. Since the voltage gain of the stage is commonly between 0.5 and 0.99, the new grid-to-cathode voltage (*with* the input signal applied) isn't much different from the original grid-to-cathode bias voltage that existed before we applied the signal. Since we haven't changed the voltage across the grid-to-cathode capacitance C_{gk} very much, this capacitance hasn't required much charging current. And therefore C_{gk} causes relatively little loading effect on the source. (As far as the grid-to-plate capacitance C_{gp} is concerned, C_{gp} acts simply as a shunting grid-to-ground capacitance since the positive power supply acts as a short circuit to signal variations.) The resulting total input capacitance is considerably less than for a plate-loaded amplifier using a similar tube.

To observe the effect of the grid-to-cathode capacitance C_{gk}, suppose that C_{gk} is 2 picofarads, and that the voltage gain of the stage is 0.9. If we apply an input signal-voltage change of +1 volt to the grid of the tube, then the cathode output voltage changes by +0.9 volt. Thus we change the voltage across C_{gk} by 0.1 volt — thereby changing the charge stored in C_{gk}. But this 0.1 volt change across the 2-picofarad capacitance C_{gp} alters the charge in coulombs exactly as much as a 1-volt change (the actual input signal) across a capacitance of only 0.2 picofarad. Therefore the actual grid-to-cathode capacitance (2 picofarads) loads the source only as much as if C_{gk} were a grid-to-ground capacitance of only 0.2 picofarad.

The grid-to-plate capacitance C_{gp} in Fig. 9 presents a simple shunt capacitance across the input terminals, since the power supply is a short circuit to signal variations.

Thus, as far as the signal source is concerned, *the input terminals of the cathode follower represent a capacitance equal to a fraction of the rated grid-to-cathode capacitance of the tube — plus the rated grid-to-plate capacitance.* The input capacitance of a plate-loaded amplifier is ordinarily considerably greater than the input capacitance of the cathode follower. We can make the effective input capacitance of the cathode follower even smaller by increasing R_k so that the voltage gain of the stage approaches unity.

Cathode-follower probes. Suppose we are using an oscilloscope to look at a waveform developed by a certain source. The vertical-input circuit of the oscilloscope causes a certain amount of resistive and capacitive loading on the source. Unless the internal impedance of the source is low, this loading might (1) distort the waveform, or (2) reduce the amplitude of the waveform, or both.

We can use a voltage-divider probe to reduce the loading and thus reduce the waveform distortion. But the voltage-divider probe also *attenuates* the signal we want to display. Consequently, if the signal is already small, the voltage-divider probe can attenuate the signal to a point where it no longer produces a useful display. Therefore the voltage-divider probe might not fill the bill when we need to look at a small waveform from a high-impedance source.

What we need for such purposes is a probe that (1) loads the source only lightly, but still (2) has a voltage gain as close as possible to unity. We can make such a probe by placing a cathode follower inside the probe body. The small input capacitance of the cathode follower puts only a light load on the source. But the voltage gain in the cathode follower can readily be between 0.5 and unity.

In Table 1, we compare the loading effects and the voltage gains that we might get (1) when we use a typical voltage-divider probe, and (2) when we use a typical cathode-follower probe.

TABLE 1

	Loading effect	Voltage gain
Typical voltage-divider probe	10 megohms 11.5 picofarads	0.1 (10X attenuation)
Typical cathode follower probe	40 megohms 4 picofarads	0.8 - 0.85

From this comparison, we might at first imagine that we should forget about the voltage-divider probe and simply use the cathode-follower probe for all our waveform observations. But there are some other considerations, including these:

1. A cathode-follower probe can readily be oveloaded by large input signals. This overloading causes waveform distortion. (For example, one type of cathode-follower probe introduces about 3 percent amplitude distortion when the input voltage exceeds about 5 volts. Some other cathode-follower probes can accommodate only much smaller input voltages.)

2. Attenuators are available that can be attached to the nose of the cathode-follower probe, for signals larger than those the probe can handle directly. (These attenuators affect both the input impedance and the frequency response of the probe.)

3. If an uninformed worker uses a cathode-follower probe in such a way that the probe is overloaded — as discussed above — he can get readings or waveforms that are very misleading.

4. Suppose we connect the cathode-follower-probe input to a waveform source whose internal impedance is inductive at some frequency. Then the cathode-follower-probe input impedance drops — perhaps sufficiently to change the amplitude or shape of the displayed waveform. If the Q of the source-and-probe circuit is high, the probe-input impedance can actually become negative at some frequency so that the cathode-follower-probe circuit oscillates.

5. The cathode-follower probe costs significantly more than the voltage-divider probe. Furthermore, the cathode-follower probe requires a stable, low-ripple power supply that is external to the probe. (Probe power supplies are available. Some oscilloscope types include probe-power connections.)

6. If the tube needs replacing in a cathode-follower probe, the new tube should be carefully selected and installed at the factory or by a technician trained in such work.

If you think a cathode-follower probe will help you, ask your Tektronix Field Engineer or Representative to help you select the probe and apply it to your work.

A method of increasing apparent input resistance. In order to reduce the loading on the signal source, we often want to make the resistive component of the input impedance of a stage very large. To accomplish this result, we might make the grid resistor R_g very large. But tube manufacturers often specify a maximum value of R_g that we should not exceed. This maximum value of R_g is based principally on grid-current considerations. A typical recommended maximum value for R_g is 1 megohm.

When we use a cathode resistor to obtain the negative grid-to-cathode bias voltage — as in the case of cathode followers and of many plate-loaded amplifiers — the upper limit for R_g is not so critical. (The tendency for grid current in R_g to make the dc plate current unstable is largely balanced out, since a change in plate current causes a change of bias voltage developed across the cathode resistor — and this bias-voltage change is in a direction that tends to bring the plate current back to its original value.) However, even with cathode-resistor bias, we cannot expect the tube to operate reliably in every case when we use indiscriminately large values of grid resistance R_g.

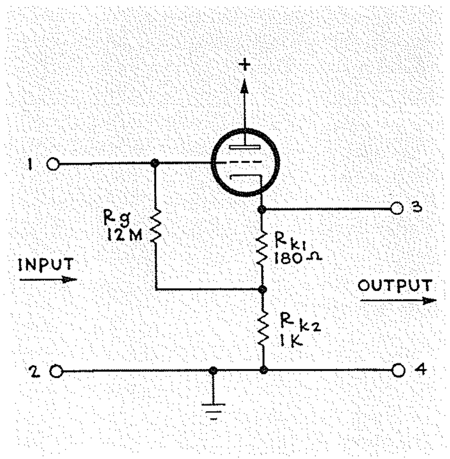


Fig. 10 — Means of increasing the apparent value of the grid resistor R_g in a cathode follower, to reduce the shunt loading effect on the signal source. R_{k1} and R_{k2} act as a voltage divider, applying most of the output-signal voltage to the lower terminal of the grid-return resistor R_g. Since the output-signal voltage at the cathode terminal is nearly as great as the input-signal voltage, only a small part of the signal voltage appears across R_g. In Fig. 10, the resulting signal current in R_g is so small that this 12-megohm resistor appears to the input-signal source as if it were a 40-ohm resistance between the input terminals.

A circuit like that of Fig. 10 can make the apparent grid-input-circuit resistance of a cathode follower very large — considerably larger than the actual value of R_g. In the figure, the actual value of R_g is 12 megohms. But the apparent resistance seen by a source that drives the grid circuit is about 40 megohms. Let us see how the circuit of Fig. 10 accomplishes this increase in apparent input resistance.

Suppose, for example, that we apply an input signal voltage of +1 volt to terminals 1 and 2 of the circuit of Fig. 10. Assume that the gain of the cathode follower is, say, 0.83. Then the output signal voltage that appears across terminals 3 and 4 will be 0.83 volt. Because of the voltage-divider action of the series cathode resistors R_{k1} and R_{k2}, only a part of this output-signal voltage will appear at the junction of R_{k1} and R_{k2}. In fact, since $R_{k1} = 180$ ohms and $R_{k2} = 1{,}000$ ohms, the signal voltage at the junction of these two resistors will be 1,000/1,180 times the output-signal voltage of 0.83 volt. Thus the signal voltage at the junction of R_{k1} and R_{k2} is about 0.7 volt.

Since the signal voltage at the lower end of R_g is 0.7 volt, and the signal voltage at the upper end of R_g is 1 volt, the signal voltage across R_g is only 0.3 volt. The resulting signal current in R_g is, by Ohm's law, equal to 0.3/12,000,000 ampere, or 0.025 microampere.

Thus the input circuit takes a signal current of 0.025 microampere when the source signal voltage is 1 volt. By Ohm's law, the apparent resistance of the input circuit is 1/0.000,000,025 ohms or 40 megohms. This increase in apparent grid-input-circuit resistance occurs simply because we connected the lower end of R_g to the junction of the two series cathode resistors rather than to ground. We should note, however, that there is a certain sacrifice in the voltage gain as compared to the gain we would get with the lower end of R_g grounded.

The circuit of Fig. 10 is actually used in some cathode-follower probes.

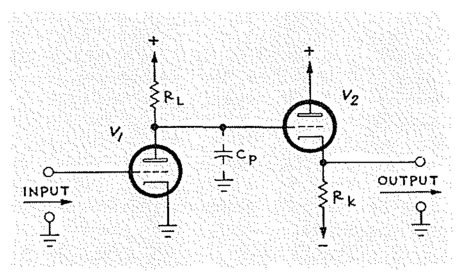


Fig. 11 — Here a plate-loaded amplifier V_1 drives the input of a cathode follower V_2. The plate-to-ground capacitance of V_1 (plus the small input capacitance of V_2) is represented by C_p. The risetime of the coupling circuit between V_1 and V_2 is determined by the time constant R_L C_p.

Bootstrap capacitor. Fig. 11 shows a plate-loaded amplifier V_1 that supplies a varying signal voltage to the grid-input circuit of a cathode-follower tube V_2. There

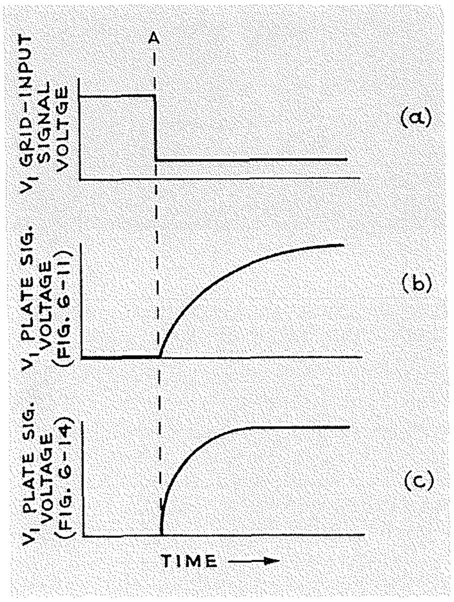


Fig. 12 — (a) An example of a grid-input signal voltage that we can apply to V_1 in Fig. 11 to observe the effect upon the output signal of the time constant R_L C_p in Fig. 11.

(b) V_1 plate signal voltage applied to the grid of V_2 in Fig. 11 when we apply to the grid of V_1 the waveform of diagram (a).

(c) Faster response of the coupling circuit between V_1 and V_2 to the input signal of diagram (a), achieved by the hypothetical method of Fig. 13 or by the practical method of Fig. 14.

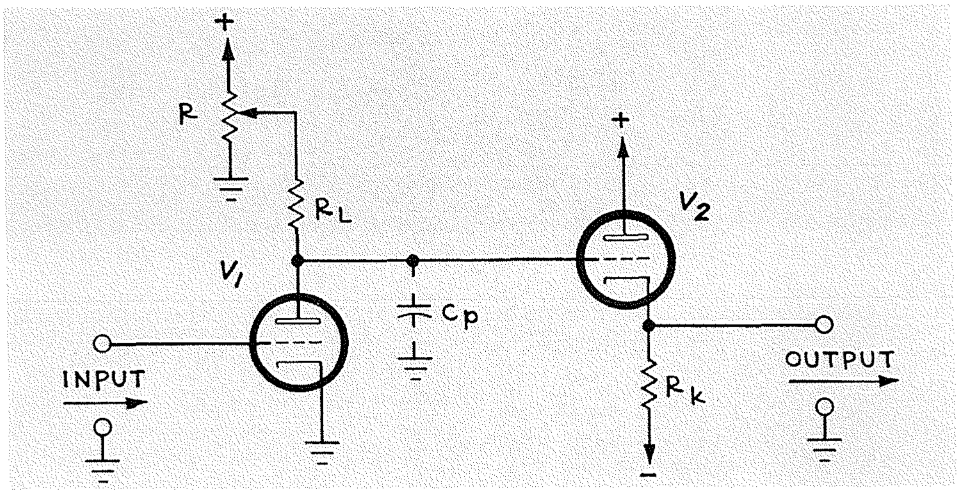


Fig. 13 — A hypothetical way to improve the speed of the response of the coupling circuit between V_1 and V_2 in Fig. 11. Here we apply the waveform of Fig. 12a to the grid of V_1. And we assume that we can provide some way by which a voltage rise at the plate of V_1 moves the variable contact on R upward. The resulting voltage rise at the upper end of R_L helps to charge C_p while the input waveform changes. Thus the voltage at the plate of V_1 can change more rapidly, as indicated in Fig. 12c.

will exist an unavoidable shunt capacitance C_p at the plate of the amplifier tube V_1. And the RC circuit composed of the plate-load resistor R_L and the shunt capacitance C_p might cause the risetime of the circuit to be longer than we can tolerate.

If, for example, we apply a negative-going input-voltage step (instant A, Fig. 12) to the grid of V_1, the plate current will be abruptly reduced. And the signal voltage at the plate of V_1 will rise according to a curve like Fig. 12b.

We can use peaking or compensating circuits to shorten the risetime. But another approach to shortening the risetime is shown in Fig. 13. Here the upper end of the plate-load resistor R_L is connected to the movable contact of a variable voltage divider R. Suppose we could provide some way by which the movable contact would automatically move toward the positive end of R when the signal voltage at the plate of V_1 tended to rise. If we could make this provision, then the stored charge in C_p would be more quickly removed so that the signal voltage at the plate of V_1 could rise more rapidly.

We cannot, of course, provide the mechanical arrangement just suggested—except possibly for signals that change quite slowly. But a system that operates in somewhat the same way can be arranged electronically, as follows:

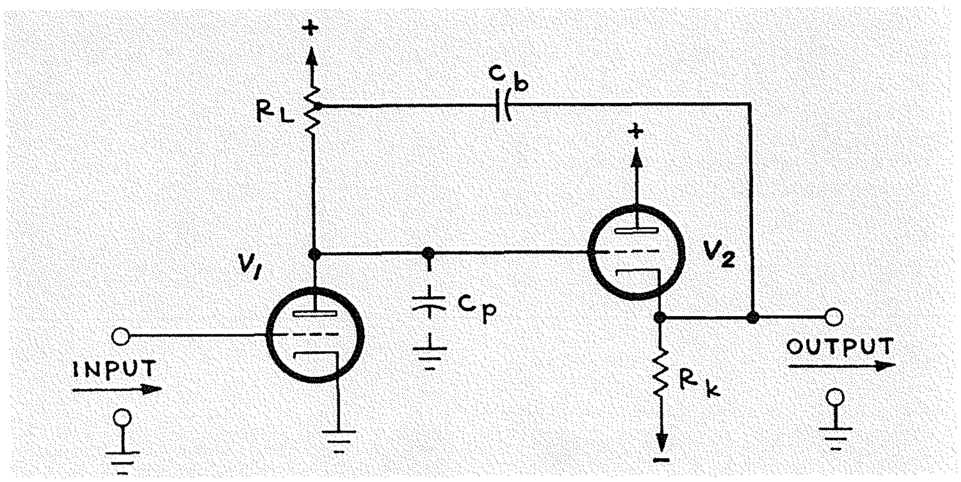


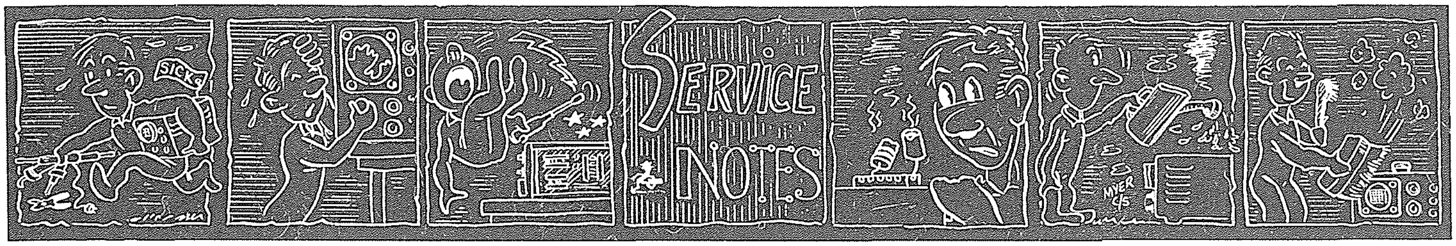
Fig. 14 — A practical way to achieve the result we considered in Fig. 13. Here the V_1 grid-input signal of Fig. 12a makes the voltage at the plate of V_1 rise. By cathode-follower action, V_2 couples this voltage rise to the cathode of V_2. The bootstrap capacitor C_b applies this voltage rise to the tap on the plate-load resistor R_L, helping to change C_p more rapidly. Therefore, in response to the input waveform of Fig. 12a, the voltage at the plate of V_1 can change relatively rapidly as indicated in Fig. 12c.

Fig. 14 shows a small capacitance C_b connected between the cathode output terminal of the cathode follower V_2 and a tap on the plate-load resistor R_L. When the signal output voltage at the plate of V_1 begins to rise, this voltage rise is applied to the grid of V_2. And the signal-voltage rise appears only slightly diminished at the cathode output terminal of V_2. The same signal-voltage rise is coupled through C_b to the tap on R_L, so that the voltage at the tap rises more rapidly than it would if the circuit through C_b were absent. Thus electrons are drawn away from C_b more rapidly than they would if C_b were absent. The action continues during the plate-voltage rise of V_1 — each increase in plate voltage causing a corresponding rise in voltage at the tap on R_L so that electrons can be drawn rapidly away from C_b. The corresponding output-voltage waveform at the plate of V_1 is therefore like that of Fig. 12c.

In thus improving the risetime of the response to a step-voltage input, we have also made the circuit of Fig. 14 capable of responding to other rapidly changing waveforms. Inasmuch as this improvement is actually intended to affect only waveforms that change rapidly, we make C_b small enough that its coupling action is negligible for slowly changing waveforms. We can refer to C_b as a *bootstrap* capacitor. It is, in general, necessary to select the value of C_b and the tap point on R_L so that optimum results are obtained.

The End

The material for this article was taken from the book "Typical Oscilloscope Circuitry", published by Tektronix, Inc. The complete text is available from your Tektronix Field Engineer or Representative. The price in the U.S.A. is $5.00.



TYPE 1A1 DUAL-TRACE PLUG-IN UNIT — OUTPUT-AMPLIFIER CARD IMPROVEMENTS

Depending upon the model of Output-Amplifier card in your Type 1A1, there are up to five improvements you can incorporate into the instrument. The Output-Amplifier cards affected by the improvements are models 2, 3 and 4. Cards with model numbers 5 and up have all the improvements installed at the factory. Model numbers are silk screened on the cards near the tube socket for the V464 NU-Vistor.

Installation of the improvements require the removal of the Output-Amplifier card. These are of the plug-in type and easily removed by first removing the securing rod. Next, un-plug the ground lead and the leads which individually plug into the card. Now un-plug the card itself from the Bendix connector.

Page 5-6 of the Type 1A1 Instruction Manual features a large photograph of the component side of the Output-Amplifier. Each component on this card is identified with its circuit number. Consulting this photo will aid you in physically locating the components replaced, changed or removed in making the improvements.

The first improvement is applicable to Output-Amplifier cards with model numbers 2, 3, and 4. It reduces the failure rate of the diodes D454, D453, D452, D451, D424, D423, D422 and D421 by replacing the original GaAs point-contact diodes with the Type 6153 Silicon Diodes (Tektronix Part Number 152-153). To do this, remove the original diodes from the card by lifting them from their clips. Next, using a 15 or 25 watt soldering iron heat each clip and lift it from the card. This will expose four soldering points (two per clip) for each diode position. Install a 6153 replacement diode in each position orienting the diode and soldering the axial leads in their locations as shown in Figure 1.

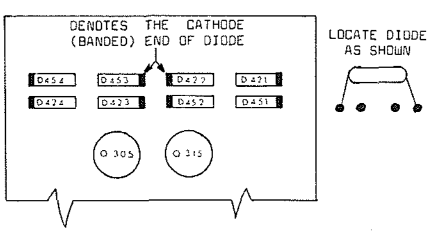


Figure 1. Showing orientation of replacement diodes and loction of diode leads on Type 1A1 Output Amplifier Cards Models 2, 3 and 4.

The second improvement is applicable to models 2 and 3 Output-Amplifier cards. It prevents the alternate-trace blocking oscillator from intermittently running twice on a sync pulse. The improvement adds a Type 6075 Germanium Diode (Tektronix Part Number 152-075) across the collector winding of T330. Circuit designation of this new diode is D330, see Figure 2. Figure 3 shows the physical location of D330 on the rear (soldered) side of the Output-Amplifier card.

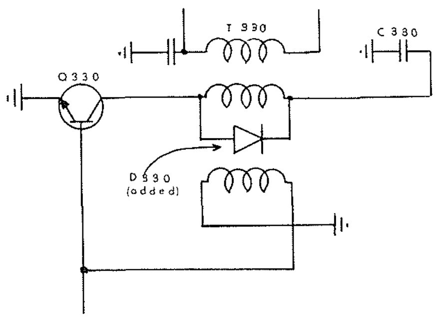


Figure 2. Partial schematic showing circuit location of the added Type 6055 Germanium diode (D330) across the collector windings of T330.

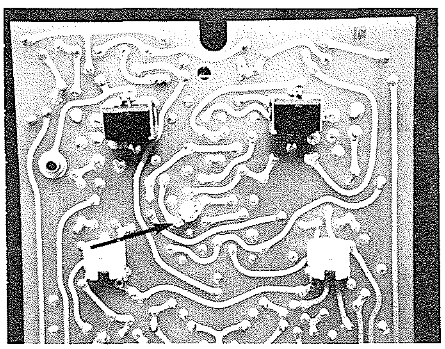


Figure 3. Partial view of Output Amplifier Card (rear or soldered side.) Arrow shows the physical location of the added Type 6055 Germanium diode (D330) and points to the anode end of the diode.

The third, fourth, and fifth improvements are applicable to the model 2 Output-Amplifier card. These improvements reduce abberations on the Chopped waveform, reduce field failure of Q353 and assure ALTERNATE trace operation in all units.

To Reduce Abberations on Chopped Waveform install a new 150 pf ceramic capacitor (Tektronix Part Number 281-524) in parallel with R343. Designate this new capacitor C344. Replace C491, a 0.001 µf capacitor located from pin 10 of V243 to ground, with a 0.1 µf ceramic capacitor (Tektronix Part Number 283-057) and add a 3/8 inch piece of #18 varglas to the lead at pin 10. V243 is located on a bracket directly behind the front sub-panel on the Channel 2 side of the Type 1A1. Install a new 0.1µf ceramic capacitor (Tektronix Part Number 283-057) from pin 21 of the Output Amplifier card's Bendix connector to the ground lug under R495, a 470 ohm, wire wound resistor, located on the rear frame plate of the Type 1A1. Designate this new capacitor C494. Remove and discard C260*, a 0.001 µf capacitor, located between pin X of the Channel 2 Input-Amplifier card's Bendix connector and a solder lug on the bracket supporting the rear end of this Bendix connector.

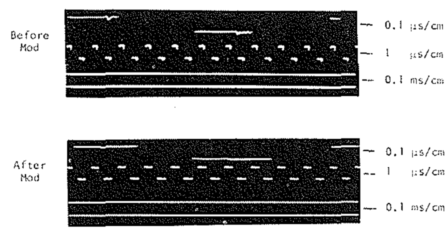


Figure 4 shows waveforms from a Type 1A1 in Chopped Mode before and after the improvement.

To Reduce Field Failure of Q353

On the rear wafer of the MODE switch locate a contact with a green-on-white wire and a second contact with a red-on-white wire. Install a 2.7 megohm*, ½ w, 10% resistor (Tektronix Part Number 302-275) between these two contacts. Designate this resistor R360.

To Insure ALTERNATE trace operation in all units

Replace C303 and C304, 0.001 µf capacitors, with 0.05 µf ceramic capacitors (Tektronix Part Number 283-010). Replace C306 and C316, 22 pf capacitors, with 47 pf, ceramic capacitors (Tektronix Part Number

281-518). Replace D303, a 6075 diode, with a 1N3605 diode (Tektronix Part Number 152-141). Replace Q305 and Q315, 2N964 transistors, with a pair of selected 2N964 transistors (Tektronix Part Number 153-530). These last two transistors are selected for a minimum Beta of 80 at 10 ma I_c.

Correct the schematics and parts list in your Type 1A1 Instruction Manual to conform to the improvements you have just made.

*Some Type 1A1 instruments in the field may have had these starred components removed or installed at the factory. If your instrument falls in this category, ignore these portions of the improvement procedure.

TYPE 180A FREQUENCY DOUBLER—MARKING TURN-AROUND

The Type 180A Frequency Doubler (Tektronix Part Number 015-013) — used for obtaining 100 Mc from the 50 Mc output of the Type 180A Time-Mark Generator — is intended to be coupled directly to the Type 180A, not at the end of a cable. The schematic on the case of the Frequency Doubler has confused some operators. The schematic markings implied that the female UHF connector was the input and the male connector the output. This interpretation is wrong. The *male connector* is the *input*. It connects directly to the 50 Mc Sine Wave output (a female UHF connector) of the Type 180A Time-Mark Generator.

TYPE 4S1, 4S2 and 4S3 DUAL-TRACE SAMPLING UNITS — "SLASH"-REDUCTION MODIFICATION INFORMATION

Here is a very simple solution to a problem that a few operators find troublesome. The problem occurs when using a Type 4S1, Type 4S2 or Type 4S3 to look at fast signals recurring at a very low rep rate. In this situation, there is such a long waiting period between samples that the Miller Memory usually drifts away from the level it was set to by the preceding sample before

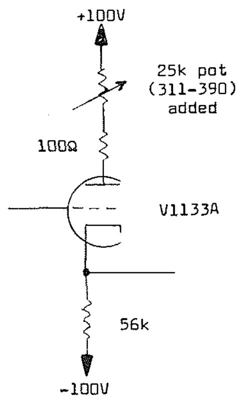


Figure 5. Partial schematic showing the addition of the 25 k potentiometer to the plate circuit of V1133A.

it is reset by a new sample. This creates vertically elongated "slashes" instead of dots. The addition of a 25 k potentiometer (Tektronix Part Number 311-390) in series with the plate of V1133A in the Memory circuit of these plug-ins will give you an adjustment with which you can virtually eliminate the tendency to drift and slash. Figure 5 shows a schematic of the new circuit.

Please note that the Types 4S1, 4S2 and 4S3 are dual-trace instruments. As such they have two input channels and each channel has its own Memory card. For single trace operation you need modify only the Memory card of the input channel you intend to use. For dual-trace operation you should modify the Memory cards of both channels.

The potentiometer may be installed on the lip of the Memory card chassis alongside the Smoothing Balance potentiometer. It will require the drilling of a ¼-inch hole. A nearby vacant slot in a ceramic strip simplifies rerouting the +100-volt supply lead through the new potentiometer before connecting it to the plate (pin 6) of V1133A via the 100-Ω suppressor resistor.

To adjust the pot, first be sure the DC-offset control for the channel used is set to zero volts. Monitor the voltage with a voltmeter at the monitoring jacks. Observe that adjustment of the potentiometer can reverse the direction of the spot (up or down) as well as the rate at which it drifts each time a free-running sweep is stopped. Set it so the spot remains in the same position as the trace each time the sweep is stopped from free-running.

There is some interaction with the Smoothing Balance Control so you may have to work back and forth between these controls a couple of times.

NE-23 NEONS RADIOACTIVE MATERIAL — A CORRECTION

In this column of the April, 1964, Service Scope we stated that the new NE-23 Neon lamps contained a tiny bit of radioactive material added to the glass envelope during manufacture. Mr. Charles Dougherty, Applications Engineer with the Miniature Lamp Department of General Electric Company, tells us that radioactive material is *not* added to the glass envelope. They do, however, add a radioactive gas with the neon mixture. This accomplishes the purpose which we cited as the reason for adding radioactive material to the glass — that of assuring immediate ionization of the neon gas. In addition, it minimizes dark effect in these neons.

To answer any question that you may have in regard to danger from this radioactive gas, Mr. Dougherty assures us that it offers no hazard to service people or users of equipment containing NE-23 neons.

TYPE 541, 545, RM41 and RM45 OSCILLOSCOPES — MODIFICATION TO PERMIT THE USE OF TYPE T543 CRT

A simple modification will permit the use of either the Type T54 (original equipment) crt or the Type T543 (used in Type 543 Oscilloscopes) in all Type 541, 545, RM41 and RM45 Oscilloscopes. Both the T54 and the T543 crt employ etched deflection plates. There are, however, two possible advantages in converting to the Type T543 crt. One is, facilities that use both the Type 543 instrument and other instruments in the older Type 540 Series (541, 545, RM41 and RM45) will need stock only one type of replacement crt — the Type T543. The other advantage is that the Type T543 crt reduces the effect of intensity change as a result of Astigmatism control changes.

Please note that this modification does not apply to the recently announced Type 544, Type 546 and Type 547, or to the Type 540A Series and Type 540B Series Oscilloscopes.

To make the modification:

1. Remove the crt from the instrument.

2. Disassemble the crt socket by removing the two screws.

3. Short pins 11 and 12 of the crt socket together. One method is to notch the rib between the ribs and short them with a piece of #22 bare wire; another, to use an external loop.

Steps 4, 6 and 7 apply to the following instruments only:

Type 541, s/n 101 - 6928, inclusive
545, s/n 101 - 11328, inclusive
RM41, s/n 101 - 135, inclusive
RM45, s/n 101 - 192, inclusive

4. Run a lead through hole #8 in the crt socket insert and solder it to pin #8. We suggest using a 9-inch length of #22 stranded wire, color-coded: white-orange-green-brown, which denotes the supply voltage to which the lead will be connected.

5. Re-assembly the crt socket.

6. Remove the high-voltage shield on the top left side of the instrument.

7. Run the free end of lead (Step 4) through a vacant hole in the high-voltage chassis (just above the crt socket) and solder it to the +350 volt point (white-orange-green-brown lead) on the rear ceramic strip.

8. Replace the high-voltage shield and install the crt.

Correct your Instruction Manual parts list and schematic as required.

Refer to your Instruction Manual and recalibrate your instrument as required.

SCOPE PADS BY ENSCA, INC. — ADDRESS INFORMATION

In the February, 1964, issue of Service Scope we told our readers about a product called "Scope Pad" distributed by Ensca, Inc., P.O. Box 253, New York, New York 10023 (Zip Code).

We are now informed that the address should include "Ansonia· Station" following the P.O. box number.

Several of our readers complained to us that inquiries to Ensca using the address as originally given were returned to them as undeliverable. Using the corrected address should solve these readers' problem. This Editor has contacted Ensca several times using the correct address.

Mr. Sidney, Sales Manager for Ensca, Inc., stresses the need to include the Zip Code in the address. New York postal people are becoming very emphatic about the inclusion of Zip Code Numbers.

NEW FIELD MODIFICATION KITS

TYPE 3T77 SAMPLING PLUG-IN UNIT — IMPROVED SINE-WAVE TRIGGERING

This modification improves the display stability when triggering on high-frequency sine waves.

A change in the trigger circuit supplies a means of switching to a "lock-on" type of triggered operation when displaying high-frequency sine waves. This eliminates the drift in recovery time and the subsequent display break-up.

A new front-panel RECOVERY control with a push-pull switch replaces the old RECOVERY control. Pulling the switch to the ON position activates the RECOVERY control to synchronize the circuit on sine waves above approximately 30 Mc. Pushed in, the RECOVERY control activates the circuit to trigger on signals below 30 Mc.

This modification is applicable to Type 3T77 Sampling Units with serial numbers 126 through 839.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-372.

TYPE 6R1 DIGITAL PLUG-IN UNIT — PEAK-TO-PEAK MEMORY AND IMPROVED COMPARATOR CARDS

This modification replaces the original Memory and Signal Comparator cards with new and improved cards. The new cards offer switch selection of Peak-to-Peak or Average Memory, switch selection of Fast or Slow charging rate, increased 100%-Zone adjustment and improved long term stability.

This modification also decouples the —12.2 volt supply to the Comparator Card. Installation requires changing some of the associated circuitry and includes some changes in the Vertical Input circuits to the Timing Start and Timing Stop switches.

This modification is applicable to Type 6R1 instruments with serial numbers 126 through 994. Please note, however, that instruments below serial number 695 must have the Series M Master Gate Card Modification (Tektronix Part Number 040-342) installed before this modification is performed.

Tektronix part number for the Peak-To-Peak Memory and Improved Comparator Card Modification Kit is 040-369. Order through your local Tektronix Field Engineer, Representative or Field Office.

TYPE 581 AND TYPE 585 OSCILLOSCOPES — SILICON RECTIFIER

This modification replaces the original selenium rectifier assembly with a silicon diode rectifier assembly. This new rectifier offers better reliability and longer life.

The modification also adds a fuse in series with one of the AC leads for protection from damage caused by an overload or component short.

This modification is applicable to Type 581 instruments with serial numbers 101 through 1300 and Type 585 instruments with serial numbers 101 through 3762*. Please note that this modification does not apply to instruments that have had the modification kit "Regulated DC Filaments in the Vertical Amplifier" installed.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-387.

*Some instruments within this serial number range were factory modified. A visual check of your instrument will determine if it is one of these.

TYPE 321 OSCILLOSCOPE — VERTICAL LINEARITY IMPROVEMENT

This modification gives the Type 321 improved vertical linearity, minimum AC-DC gain change and reduced DC shift.

The improvement in the vertical linearity is accomplished by electrically relocating the POSITION control to the Input Amplifier emitter circuit, by reducing post accelerator voltage and by thermally balancing the Input Amplifier. The input protection neon is moved from the +45-volt supply to ground. This reduces the small "dark current" in the neon that tends to introduce dc shift.

The modification is applicable to Type 321 Oscilloscopes with serial numbers 101 through 4267. However, instruments in the serial number range 101 through 719 should have the Nuvistor Modification Kit (Tektronix Part Number 040-309) installed before the Vertical Linearity Improvement Modification Kit (Tektronix Part Number 040-377) is installed.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-377.

RELAY RACK CRADLE ASSEMBLY

This modification provides a rear support cradle for mounting the listed instruments in a backless relay rack by means of slide-out tracks. The slide-out tracks, which must be ordered separately, allow the instrument to be pulled out of the rack like a drawer and locked in one of seven positions; horizontal, or 45°, 90°, or 105° above and below horizontal.

The modification is applicable to instruments in the following list. The list also gives the slide-out tracks required for mounting the instrument in a backless relay rack.

Instrument	Serial Number	Slide-out Track Tek. Part No.
Type 127	309-up	351-006 (1 each)
Type RM15	101-up	351-006 (1 each)
Type 526	101-up	351-010 (1 each) and 351-011 (1 each)
Type RM561	101-up	351-050 (1 each)
Type RM561A	101 to 105	351-050 (1 each)
Type RM561A	5001-up	351-050 (1 each)
Type RM564	100-up	351-050 (1 each)
Type RM647	100-up	351-006 (1 each)

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-344.

TYPE 121 PREAMPLIFIERS — SILICON RECTIFIER

This modification replaces the original selenium rectifier with a silicon-diode rectifier. The silicon-diode rectifier offers better reliability and longer life.

The modification applies to Type 121 instruments with serial numbers 101 and up.

Order through your local Tektronix Field Engineer, Representative or Field Office. Specify Tektronix Part Number 040-381.

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USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 29 PRINTED IN U.S.A DECEMBER, 1964

SIMPLIFYING TRANSISTOR LINEAR-AMPLIFIER ANALYSIS

By Larry Reierson, Instructor, Tektronix Product-Manufacturing Training Department, in collaboration with Ron Olson, Design Engineer, Tektronix Instrument Engineering Department

The complicated characteristic-family parameters for transistors are more useful for design purposes than for analysis. The best analytical tool is one that provides a means of quickly doing an adequate job of circuit analysis for trouble-shooting or evaluation purposes. This article suggests such a tool.

When a person thinks of a transistor amplifier, he usually thinks of a transistor in a circuit, behaving in some manner that depends on a set of measurements that have been made on the device. These measurements may be called h-parameter, r-parameter, or any of many other characteristic families. Each has its advantages, but they all have common disadvantages to the technician. They are complicated in nature and involve numerous variables. They are a means of measuring a transistor's charateristics, but say little about the circuit which uses that transistor. Published parameters are very general and, for a given type, will vary widely from one unit to another.

Designers have these variations in mind when they design a linear amplifier circuit, and some type of feedback is usually employed in order to make the circuit as independent of the transistor characteristics as is practical. Transistor parameters may vary 50% or more without appreciably altering the gain or linearity of a well designed amplifier.

As we will show later transistor parameters are more useful as a guide by which to judge the relative merits of one transistor against another than as an analytical tool. They also give the student of solid state theory some measurable quantities to identify, in order to grasp some of the more difficult concepts involved in semiconductor action.

The parameter families are more useful for design purposes than for analysis. The best analytical tool provides a means of quickly doing an adequate job of circuit analysis for trouble-shooting or evaluation purposes.

The approach we are about to present eliminates the use of published data, except for Beta. This by no means implies that the other parameters are not useful. It does say, however that it isn't necessary to apply all you know about transistors to get a general understanding of how an amplifier works. Anyone with a basic knowledge of transistor characteristics and of Ohm's law, will have no trouble applying this approach to transistor amplifiers.

Keep in mind that our approach is very general and is not intended for use where extreme accuracy is desired. You can expect an accuracy that varies no more than 10 to 20 percent from the true circuit values—depending upon how familiar you are with the transistor being used.

If a transistor is considered to be two PN junctions connected together, and if we then consider *only* the junction formed between emitter and base, we find that the E-I plot of that junction is roughly that shown in Figure 1. Line 1 on the graph is the plot of the Base-to-Emitter Voltage -vs- Base Current, and line 2 is the plot of Base-to-Emitter Voltage -vs- Emitter Current. If the slopes of the curves are measured at a

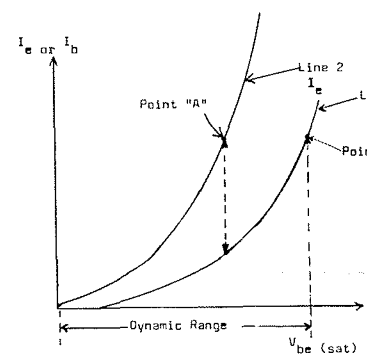


Figure 1 — Voltage -vs- current graph of the Base-to-emitter characteristics of a transistor. Line 1 is the plot of base current (I_b) -vs- Base-to-emitter voltage (V_{be}). Line 2 is the plot of emitter current (I_e) -vs- Base-to-emitter voltage (V_{be}). Point "A" indicates a typical operating point on the characteristic. With a common V_{be}, the ratio of I_e, to I_b at point "A" is: $I_e/I_b = \beta + 1$. Point "B" indicates the point at which the transistor goes into saturation. The area between $V_{be} = 0v$ and $V_{be\ sat}$ is the dynamic operating range of the device. The resistance represented by line 2 at any given point is approximately $0.026/I_e$. The resistance represented by line 1 at any given point is approximately $0.026/I_b$. Line 2 represents the resistance $1/gm$ and line 1 represents $1/gm\ (\beta+1)$.

common point in voltage (Point "A") there will be a considerable difference in the two. The slope of these curves is actually a plot of the dynamic resistance of the junction. The resistance shown by line 1 is approximately $(\beta+1)$ times that shown by line 2 for any point on the curve between the origin and point "β". If we can by some means determine the value of resistance represented by one line, and if we know β, then we can find the resistance represented by the other line.

The slope of line 2 at any point between the origin and point "β" is approximately equal to:

$\frac{0.026}{I_e}$ where I_e is the DC current at the point selected. (The value $0.026/I_e$ is justified in the basic physics of the device, and no further explanation is offered.)

To simplify the powers of ten involved, remember that the resistance shown by line 2 is:

$$\frac{26}{I_e \text{ expressed in ma.}}$$

(If $I_e = 10$ ma, then $r_{(\text{line } 2)} = \frac{26}{10} = 2.6\ \Omega$)

Now consider what this has to do with transistor circuits. Note that the slope of line 2 on the graph is:

$$\frac{\Delta V_{be}}{\Delta I_e}$$

(For a transistor in a common base configuration the slope represents:

$$\frac{\Delta E_{in}}{\Delta I_{in}}$$

which is input resistance.)

Assuming the transistor has a very high β, the input current (ΔI_e) will be approximately equal to the output current (ΔI_c). Then we can say that line 2 closely approximates the plot of:

$$\frac{\Delta E_{in}}{\Delta I_{out}}$$

In vacuum tube theory, $\frac{\Delta E_{in}}{\Delta I_{out}}$ is called 1/gm, so lets's just call the resistance represented by line 2 of Figure 1 by the same name — 1/gm.

All we've said so far is that the impedance looking into the emitter of a transistor is approximately equal to 1/gm of the device, and can be calculated by:

$$\frac{1}{gm} = \frac{26}{\text{DC value of emitter current in ma.}}$$

In series with 1/gm is a small resistance, R_{EB}, that is made up of the ohmic resistance of the leads and the semiconductor material. R_{EB} usually amounts to about $2\ \Omega$ to $5\ \Omega$. (For power transistors the value of R_{EB} may be as low as a few tenths of an ohm, while some special purpose and low performance types may have R_{EB}'s as large as $25\ \Omega$. The value of $2\ \Omega$ to $5\ \Omega$ fits most modern, high-performance, medium-power transistors.) For very low values of I_e, R_{EB} can be neglected since 1/gm will be fairly high. However, if the transistor is operating at several ma of emitter current, R_{EB} becomes an appreciable part of the total resistance from emitter to base, and must be added to 1/gm.

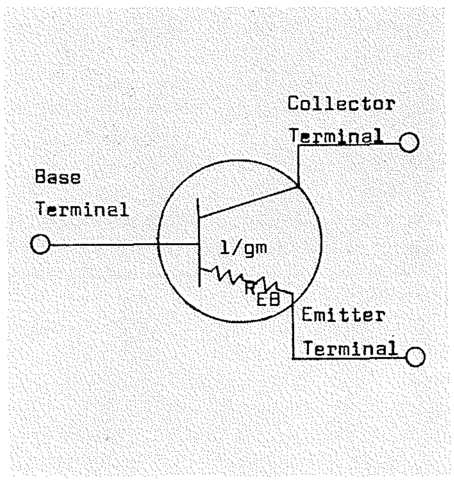


Figure 2 — Schematic equivalent of the emitter circuit of a transistor. 1/gm is the dynamic resistance of the junction due to carrier action and R_{EB} is the DC resistance in the leads and ohmic contacts of the leads within the transistor case.

Figure 2 shows what the transistor looks like between emitter and base. The sum of $R_{EB} + 1/gm$ is an operating characteristic of the device we shall call "transresistance". The notation for transresistance is r_{tr}.

An example of the application of this idea to circuit analysis can be seen by referring to the diagram in Figure 3 (a).

Assume the DC operating point has been solved for.

Since the driving voltage is on the base, the drive will be impressed across the transresistance of the device. Now, if we ignore the small error due to base current, (assume $i_c = i_e$) we have the relationship:

$$(1)\quad \frac{v_{in}}{r_{tr}} = \frac{v_{out}}{R_L}$$

From the relationship in (1) we obtain:

$$(2)\quad A_v = \frac{v_{out}}{v_{in}} = \frac{R_L}{r_{tr}}$$

The equivalent of the circuit in Figure 3 (a) is shown in Figure 3 (b).

For degenerative circuits, such as that shown in Figure 3 (c), the input voltage is developed across the transresistance and R_e in series. (The equivalent of the degenerative circuit is shown in Figure 3 (d).) The formula for voltage gain in this circuit is:

$$(3)\quad A_v = \frac{R_L}{r_{tr} + R_e}$$

When R_e is large with respect to r_{tr}, the gain is simply:

$$(4)\quad A_v = \frac{R_L}{R_e}$$

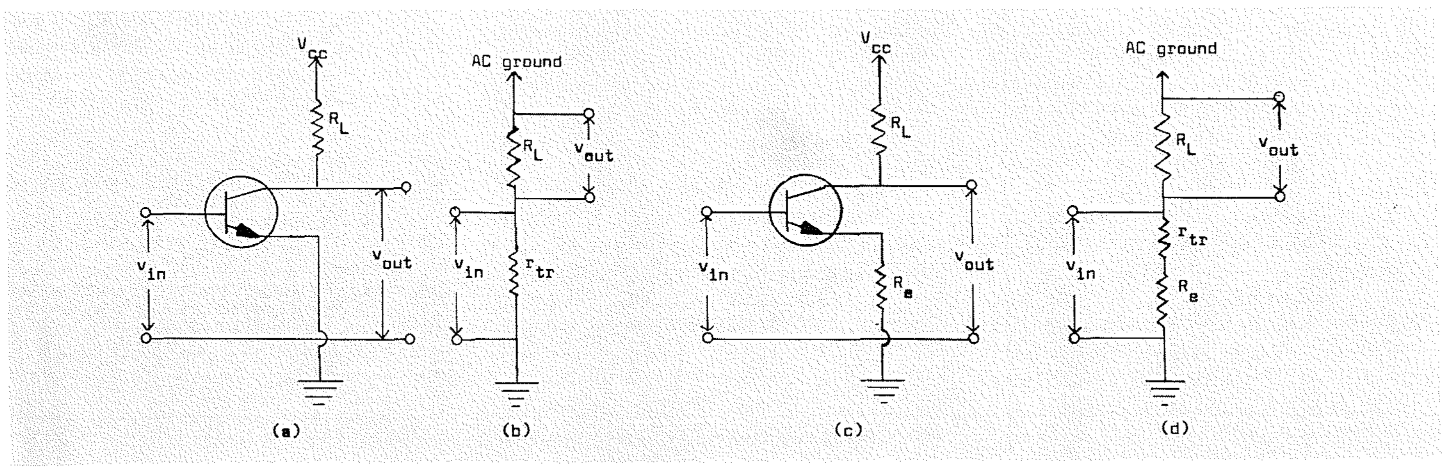


Figure 3 — (a) Common emitter voltage amplifier showing location of input and output terminals. (b) Equivalent circuit of 3(a) shows v_{in} impressed acorss r_{tr}. That voltage causes current through R_L that is approximately equal to the current through r_{tr}. Hence: $v_{out}/V_{in} = A_v = R_L/r_{tr}$. (c) Common emitter amplifier using degeneration in the emitter. (d) Equivalent circuit of 3(c) showing R_e in series with r_{tr} in the signal path. Voltage gain for this current: $A_v = R_L/r_{tr} + R_e$.

The above approach works very well for any configuration of amplifier, whether common base, common emitter or common collector. It also applies very well to paraphase and push-pull amplifiers, as long as the concept of transresistance is used to represent the resistance seen when looking into the emitter of the transistor. Of course the approach must be modified and added to, if it is to be applied at or near the frequency limits of the amplifier. Those modifications are beyond the intent of this writing and will be saved for a later discussion.

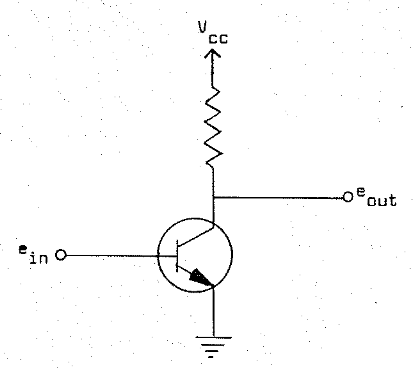


Figure 4 — Amplifier used as an example of the application of transresistance compared to h-parameters. The DC operating point is assumed to be set at $I_e = 5$ ma; $V_{ce} = 2.5$ v. The transistor is a 2N2475.

An example of how the foregoing method can be applied to amplifier analysis and how it compares to the h-parameter approach follows:

Figure 4 is a common emitter amplifier that uses a 2N2475 transistor. Table 1 gives the h-parameters for the transistor as measured on a Tektronix Type 575 Transistor Curve-Tracer.

TYPE 2N2475 TRANSISTOR	
I_e	5 ma
V_{ce}	2.5 ma
h_{ie}	1.4 k
h_{re}	1×10^{-4}
h_{fe}	180
h_{oe}	300 µv

Table 1 — List of the h-parameters for the Type 2N2475 transistor at $I_e = 5$ ma; $V_{ce} = 2.5$ v.

In this example we will determine voltage gain (A_v) and input resistance (r_{in}) using both the h-parameter method and the approach just described.

The solution using h-parameter follows:

$$(5)\ A_v = \frac{hfe\ R_L}{\Delta\ h_e R_L + h_{ie}}$$

$\Delta\ h_e$ is defined as:

$$(6)\ \Delta\ h_e = (hie)\ (hoe) - (hre)\ (hfe)$$

For the parameter in this example:

$$\Delta h_e = (1.4)\ (10^3\Omega)\ (3)\ (10^{-4}mho) - (180)\ (10^{-4})$$
$$= 0.42 - 0.018$$
$$= 0.402$$

Inserting circuit values in equation (5) yields:

$$A_v = \frac{(180)\ (100\ \Omega)}{(0.402)\ (100\ \Omega) + 1400\ \mu}$$
$$= 12.5$$

To find the input resistance:

$$(7)\ r_{in} = \frac{hie + \Delta\ h_e\ R_L}{1 + hoe\ R_L}$$

Putting in circuit values:

$$r_{in} = \frac{1400\ \Omega + (0.402)\ (100\ \Omega)}{1 + (3)\ (10^{-4}mho)\ (100\ \Omega)}$$
$$= 1.4\ k\Omega$$

Now let us solve for the same quantities using transresistance.

As we have shown:

$$(8)\ r_{tr} = 1/gm + R_{EB}$$

and:

$$(9)\ 1/gm = \frac{26}{I_e \text{ in ma.}}$$

R_{EB} is typically 2 Ω to 5 Ω for this type of transistor. For this example we will use $R_{EB} = 3\ \Omega$.

Therefore, for this circuit:

$$r_{tr} = \frac{26}{5\ ma} + 3\ \Omega$$
$$= 8.2\ \Omega$$

From equation 2:

$$A_v = \frac{R_L}{r_{tr}}$$

For this example:

$$A_v = \frac{100\ \Omega}{8.2\ \Omega}$$
$$= 12.2$$

To find input resistance using transresistance it must first be shown that any impedance that appears in the emitter of a transistor will be seen as that impedance multiplied by (β +1) when measured from the base. Transresistance appears in the emitter of the transistor—therefore:

$$(10)\ r_{in} = r_{tr}\ (\beta + 1)$$

For this example:

$$r_{in} = (8.2\ \Omega)\ (181)$$
$$= 1.4\ k\Omega$$

Comparing the two approaches we see that h-parameters give us:

$$A_v = 12.5$$
$$r_{in} = 1.4\ k\Omega$$

and the transresistance approach yields:

$$A_v = 12.2$$
$$r_{in} = 1.48\ k\Omega$$

As this shows, the results are very nearly the same regardless of the method used. The advantage of the transresistance method is that it didn't require the use of a set of parameters. Instead it was necessary only to know the beta of the transistor and to make one calculation. If R_{EB} had been assumed to be either of the two extreme values, the results would have still been within 20% of the answer given by h-parameters.

If we now take the same transistor and place it in a circuit such as the one in Figure 5, the voltage gain will be shown by equation 3.

$$A_v = \frac{R_L}{r_{tr} + R_e}$$

If we assume the DC operating point to be the same as that of the previous example, the voltage gain will be:

(Figure 5)

$$A_v = \frac{100\ \Omega}{8.2\ \Omega + 5\ \Omega}$$
$$= 7.6$$

The input resistance to this amplifier is now:

$$(11)\ r_{in} = (R_e + r_{tr})\ (\beta + 1)$$
$$= (13.2\ \Omega)\ (181)$$
$$= 2.38\ k\Omega$$

Note that the addition of R_e would require modification of the DC levels around the circuit in order to maintain the same DC operating point for the transistor.

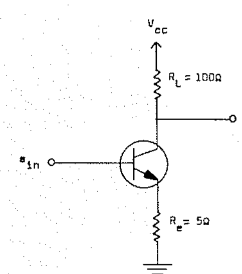


Figure 5 — Amplifier with the same type transistor set at the same operating point as that in Figure 4. This circuit has R_e added to reduce the voltage gain and increase the input resistance.

TYPE 530/540 SERIES OSCILLOSCOPES— SIMPLIFIED MAIN SWEEP TRIGGER ADJUSTMENTS

By Sandy Sanford, Field Engineer with Tektronix Product Information Department.

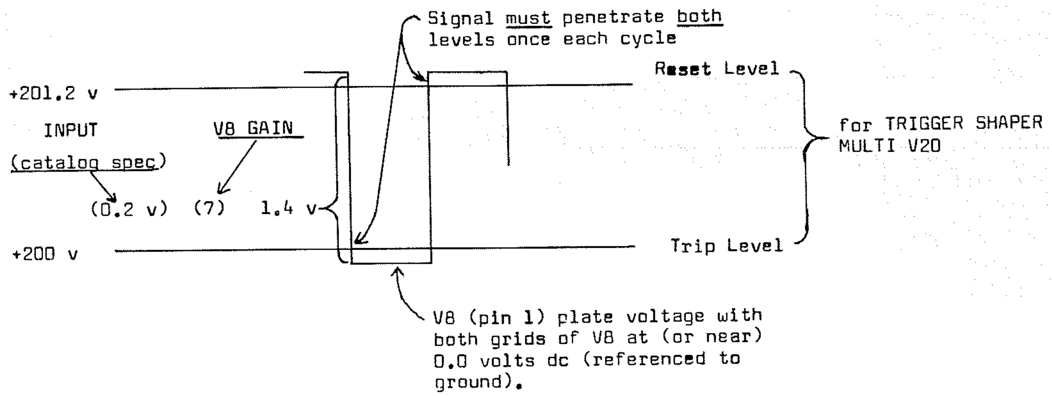


Figure 1. Graphic illustration of the three basic requirements of the trigger system; points a, b and c of this article.

Here is a systematic step-by-step adjustment procedure which will increase the length of time between necessary recalibrations of the MAIN SWEEP trigger circuits. As you work your way through these adjustments, any defective component or bad tube will be noticed—making your trouble-shooting easy.

By using this system you will satisfy three basic requirements of the trigger system:

a. Right-hand plate of V8 must not move up or down when grids of V8 are interchanged by turning the SLOPE switch.

b. Trip voltage level of the bistable multivibrator, V20, must be set to a few millivolts above the plate voltage of V8 as found above.

c. Width of the bistable multi hysteresis gap (difference in volts between the "trip" level and the "reset" level) must be set to about 1.2 volts.

In general, procedure set down here can be used to adjust similar trigger systems in many Tektronix oscilloscopes. The specifications will turn out to be different but the basic functions performed by each trigger system will be about the same.

I. Preset the front panel controls as follows:
- A. Sweep TIME/CM — 1 msec
- B. STABILITY control — Triggerable range (free-run less 10 degrees).
- C. TRIGGER SLOPE — +EXT.
- D. TRIGGERING MODE — DC.

II. Set TRIGGERING LEVEL:
- A. Connect 20,000 ohms/volt meter (first on 6 v range — then on 12 v range) across plates of trigger amplifier, pins 1 and 6 of V8.
- B. Turn TRIGGERING LEVEL control until meter reads "O".
- C. Change SLOPE switch to —EXT.
- D. Meter will read up scale or down scale. (If meter reads down scale, reverse the leads.)
- E. Voltage reading (on 12 v range):
  1. Turn TRIGGERING LEVEL control to ½ previous voltage reading.
  2. Now, moving from +EXT to —EXT should cause no change in voltage reading.
- F. Verify that white dot on TRIGGERING LEVEL knob is opposite the engraved Zero on the panel. If not, correct by loosening knob.

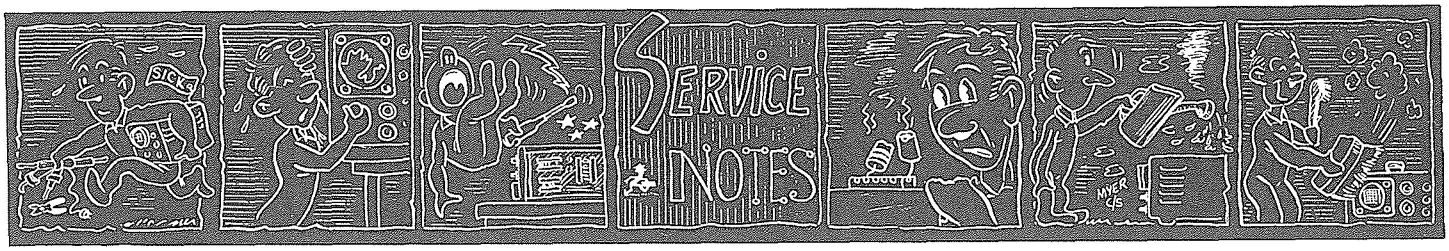
III. Check for grid current:
- A. With TRIGGER SLOPE +EXT
  1. Short EXT TRIGGER INPUT to ground (use 47-Ω resistor).
  2. Meter should move less than 100 mv (0.100).
- B. With TRIGGER SLOPE —EXT:
  1. Check for grid current as above.
  2. Replace tube if grid current is too high.

IV. INTERNAL TRIGGER DC LEVEL ADJ:
- A. Tie the vertical amplifier input to ground.
- B. Move spot to center of crt with HORIZONTAL POSITION control. Vertically position the spot or trace to the horizontal center-line of graticule.
- C. Set TRIGGER SLOPE to +INT.
- D. Turn INT. TRIG. DC LEVEL ADJ. pot until meter indicates voltage obtained in step II, E, 2.
  Note: Shifting from +INT to —INT to +EXT to —EXT should cause no change in meter voltage reading.

V. TRIGGER LEVEL CENTERING:
- A. Turn TRIGGER SENSITIVITY pot to mid-range.
- B. Turn TRIGGER LEVEL CENTERING pot:
  1. Clockwise to reset the Schmitt circuit (V20).
  2. Slowly counter-clockwise till Schmitt circuit has just triggered (this is indicated by one stroke of the sweep generator).
- C. If more than one stroke occurs, or if the Schmitt circuit triggers for both clockwise and counter-clockwise rotation of the TRIGGER LEVEL CENTERING POT, turn the TRIGGER SENSITIVITY pot 15° or 20° counter-clockwise from mid-range and recheck TRIGGER LEVEL CENTERING. The Schmitt circuit tube may need to be replaced.
- D. Remove meter leads.

VI. TRIGGER SENSITIVITY:
- A. Connect 200 mv calibrator square wave to VERTICAL INPUT *and* to EXT TRIGGER input.
- B. Set vertical VOLTS/CM switch for a 2 cm display.
- C. Reduce ac input (oscilloscope's line voltage) to 105 volts—or to a line voltage which just keeps all regulated power supplies functioning.
- D. Adjust TRIGGER LEVEL control slightly; system should trigger smoothly on 200 mv EXT. Square wave.
- E. Check that the trigger system will *not* trigger continuously on 100 mv—even with very careful adjustment of the TRIGGERING LEVEL control.
  Note: If oscilloscope triggers on 100 mv, turn TRIGGER SENSITIVITY counterclockwise 15° to 20° and recheck. Return oscilloscope's line voltage to 117 volts and again check the TRIGGER circuit for proper operation.

VII. PRESET STABILITY:
Follow procedure given in Instruction Manual.



TYPE 526 VECTORSCOPES — QUADRATURE PHASE DRIFT

Some Type 526 Vectorscopes have exhibited quadrature-phase-drift problems. The seat of the trouble seems to be L264, a 15-to-27 μh coil in the quadrature phasing circuit. In some environments this coil will absorb moisture during the periods the instrument is not in operation. The effect of L264 on the circuit will vary according to the amount of moisture absorbed and drift will occur as the heat from the instrument drives moisture from the coil during periods of operation.

Installation of a newly-designed moisture-resistant coil in the L264 position will help to correct this difficulty. For Type 526 instruments with serial numbers 101 through 511, with the exceptions of numbers 439, 477 and 492, specify Tektronix part number 050-210. For instruments with serial number 512 and up (and also serial numbers 439, 477 and 492) specify Tektronix part number 114-163. Order the new coil through your Tektronix Field Engineer or local Field Office.

TYPE 317 OSCILLOSCOPE — 120 CYCLE RIPPLE

Sometimes a Type 317 Oscilloscope will exhibit 120 cycles of ripple on the trace when the VOLTS/DIV switch is in the 10, 20, or 50 mv AC position. This may be due to a ground loop between C154 (a 500 μfd, ETM capacitor in the preamplifier circuit) and ground. Placing a short jumper between C154 and the front panel reduces the amount of ripple. By lifting the can of C154 above ground at its grounding strap and then running a separate ground from C154 to the shield of the Vertical Volts/Div switch you will completely eliminate the problem.

TYPE 545 OSCILLOSCOPE — POWER SUPPLY REGULATION

Do you have a stubborn problem of 60 cycle ripple in the 100-volt supply of your Type 545 Oscilloscope yet everything seems to check out as normal? If you do, try separating the common cathode and filament ground of V742, a 6AU6 tube in the low voltage power supply. Re-connect the filament lead to a separate ground lug of the tube socket. Sometimes, when the cathode and filament of this tube share the same ground lug, oxidation will occur between the ground lug and the chassis and allow the filament to modulate the cathode.

TYPE 502 OSCILLOSCOPE — LOW FREQUENCY DISTORTION

The recalibration instructions in the Type 502 Instruction Manual, under step 29 (Feedback Bal. Adj.), Figure 6-10 shows a typical low-frequency square-wave distortion. A simple modification will eliminate this distortion.

The distortion comes from the trigger pick-off cathode follower tube (V493) in the Upper and Lower-Beam Vertical amplifiers. Being single-ended, V493 produces a small change in current through the decoupling resistors R685 (or R686) when a signal is applied to the vertical amplifier. This change in current affects the nominal +100 volts enough to cause the distortion.

The modification returns the plates of V493 directly to the +100 volt supply (rather than through the decoupling network) and eliminates the difficulty.

Here are the instructions for making the modification:

Note: Follow this same procedure for both the Upper and Lower Beam Vertical Amplifiers.

1. Locate the two 1% resistors soldered to pin 1 of V493. (To make wiring easier, temporarily unsolder these resistors from pin 1 of V493 and bend them back out of the way.)
2. Unsolder the white-brown and the white-brown-black-brown wires from pin 5 of V493.
3. Unsolder the bare wire soldered to pin 2 of V493 and cut it off where it connects to pin 6.
4. Solder the two wires unsoldered in Step 2, to pin 2 of V493.
5. Solder one end of a length of #24 white-brown stranded wire to pin 5 of V493. Dress it along the underside of the cable leading to the +100 volt decoupling circuit (R685 and C685 or R686 and C686).
6. Solder the other end of the #24 white-brown stranded wire to the +100 volt supply at the rear of R685 or R686.
7. Resolder the two resistors unsoldered in Step 1.
8. Correct the schematic in your manual to conform to the work you have just done.
9. Refer to your Instruction Manual for the proper procedure and readjust the Feedback-Bal-Adj. Disregard Figure 6-10 in the manual.

P6038 DIRECT SAMPLING PROBE — REPAIR INFORMATION

The probe head of the P6038 Direct Sampling Probe (specifically designed for use with the Type 3S3 and 4S3 Sampling Plug-Ins) contains some rather delicate parts. These parts are critically arranged with some tolerances as close as 0.005 inches. Even the replacement of the diodes must be done with care and a jeweler's touch lest the diode clips be sprung. We suggest that P6038 probes in need of repair be returned to the factory via your local Tektronix Field Office. Here at the factory we have the necessary alignment jigs and special techniques to do a quick and efficient repair job.

AN INEXPENSIVE SURPLUS-SOLDER REMOVER

Art Baier, Maintenance Technician with the Tektronix Canada Ltd's Toronto Service Center, offers the following suggestion: Take a three or four inch length of ⅛" Teflon tubing and insert it in an ear syringe. This combination makes a useful tool for removing unwanted or excessive solder from connections and solder holes. It is particularly useful when replacing components on etched circuit boards. The tool can be used to either suck or blow the unwanted solder away from the connection. The heat resistance of the Teflon tubing is such that it will not melt from the soldering iron heat.

POTENTIAL CRT PROBLEM

The PME Lab at Ent Air Force Base in Colorado Springs, Colorado, reports a potential problem when using other than Tektronix crt's in Tektronix instruments. In the General Atronic's crt for the Type 545 Oscilloscope, pins 8 and 9 are shorted internally. If this crt is installed in the Type 545A Oscilloscope, there is a good chance of burning up the Astigmatism control—which they did!

The people at the PME Lab suggested that a note here in SERVICE SCOPE might prevent other Air Force Bases from making a similar mistake.

TYPE 310 AND TYPE 310A OSCILLOSCOPES — TRIGGER PROBLEM

If your Type 310 or 310A Oscilloscope reveals a lack of trigger capability after about ten minutes of operation, try replacing C671. This is a 0.01 μfd, 400 v, PT capacitor in the +300-volt circuit of the low-voltage supply. When it becomes leaky it can cause the difficulty described here. The replacement capacitor should be of the same value *and of Mylar or Di-Film construction*. The recommended replacement is Tektronix part number 285-511. Order through your Tektronix Field Engineer or local Field Office.

TYPE 527 TELEVISION WAVEFORM MONITOR — APPARENT DOUBLE TRIGGERING

Rick Ennis, Tektronix Field Engineer with our Greensboro, North Carolina, Field Office, calls our attention to a situation in which a Type 527 will appear to be double triggering. One of Rick's customers was interested in vertical-interval testing. However, when they attempted to monitor the signals with the DISPLAY switch in the VIT position, the Type 527 appeared to be double-triggering. They could not see the standard one or two interval test signals. Instead they noticed either two or four interval test signals. What they were seeing was the half-line interlace since the Type 527 was triggering at the field rate. To one not aware of this situation it does appear that the Type 527 is double-triggering. Much time can be wasted trying to correct the situation. As Rick explained, the indication was not double-triggering but in effect a meaure of the interlace.

To view the VIT signal you should go to the TWO FIELD position and set the MAGNIFIER to X25. This will show a single vertical-interval test signal.

NEW FIELD MODIFICATION KITS

TYPE 533, TYPE RM533, TYPE 543, AND TYPE RM543 OSCILLOSCOPE—SILICON RECTIFIER

This modification replaces the selenium rectifier SR752, used in the V152 heater supply, with silicon-diode rectifiers. The new rectifiers offer longer life and greater reliability. There is a difference in the voltage drop across the silicon rectifier and the selenium rectifier it replaces. To compensate for this difference a resistor is added in series with the silicon diodes.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-389.

NOTE: You may replace the remaining selenium rectifiers with silicon rectifiers in the above instruments by ordering Modification Kit 040-240.

TYPE 81 PLUG-IN ADAPTERS — GENERAL IMPROVEMENTS

This modification enhances the performance of the Type 81 Plug-In Adapter by:

1. Improving the transient response.
2. Decoupling power supply aberrations from the plug-in units.
3. Eliminating parasitic oscillations in the Type 581 or Type 585.
4. Eliminating the 75-volt supply oscillations which occur when using certain plug-ins.
5. Changing several components in the Vertical Amplifier.
6. Adding decoupling to the plug-in power supplies.
7. Changing two transistor types.
8. Elevating the plug-in filament supply.
9. Increasing the amplitude of the Alternate-Trace Sync pulse.

The modification applies to Type 81 Plug-In Adapters with serial number 101 through 4092.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-371.

TYPE RM647 OSCILLOSCOPE—RACK-MOUNT REAR SUPPORT

This modification supplies a rear support for the Type RM647, making it capable of withstanding 4G's of vibration. To complete the installation, the instrument must be fastened to the front rack rails with the RELEASE knobs and four screws.

This kit replaces Rackmount Rear Support Kit part number 016-065.

Please note, if the instrument is mounted in a backless rack using Relay Rack Cradle Assembly 040-344; or, if slide-out extensions are used, the instrument will not meet the 4G-vibration specification.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-394.

TYPE RM565 AND TYPE RM567 OSCILLOSCOPES — RELAY RACK CRADLE ASSEMBLY

This modification provides a rear-support cradle for mounting a Type RM565 or Type RM567 instrument in a backless relay rack on slide-out tracks. The slide-out track assemblies *are not* included in the modification. They must be ordered separately as follows:

Instrument	Quantity	Part Number
RM565 and RM567	1 pair	351-055

The slide-out tracks allow an instrument to be pulled out of the rack like a drawer. When pulled out, the instrument can be locked in any one of seven positions: horizontal, or 45°, 90°, or 105° above and below the horizontal.

The modification kit includes a detailed drawing giving all dimensions necessary to design a relay rack to support these instruments.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-346.

SOME CORRECTIONS

In the April, 1964 SERVICE SCOPE, the schematic on page 4 contains an error. The voltage to which the plate loads of 6DJ8 are returned is shown as +225 volts. If this were true, the T12G diodes would be held at about 74 volts and quiescently the 6DJ8 plates would be at about 205 volts. On receipt of a trigger large enough to cut off one half of the 6DJ8, the other plate would fall to about 185 volts. This would leave the diode back-biased by more than 100 volts and no signal could reach the trigger multivibrator. We don't believe the diode would like it much, either.

The voltage to which the plate loads of the 6DJ8 should be returned is 100 volts. Quiescently, then, the plate will sit at about 80 volts back-biasing the diode by some 5 volts. A trigger signal can then cause one plate to fall to nearly 60 volts allowing up to a 10-volt signal to reach the multivibrator —or had you already figured this out for yourself?!

In the October, 1964 SERVICE SCOPE, a typographical error occurred twice in the "Cathode Follower" article. On page 3, center column, the sentence "Thus electrons are drawn away from C_b more rapidly than they would if C_b were absent". The first C_b in this sentence should read C_p.

Reading on further (next sentence) "The action continues during the plate-voltage rise of V_1—each increase in plate voltage causing a corresponding rise in voltage at the tap of R_L so that electrons can be drawn rapidly away from C_b". Here, again, C_b should be changed to C_p. This is the capacitance which we are interested in changing terminal voltage on in a short period of time.

TEKTRONIX CANADA LTD. ANNOUNCES

A new uniform F.O.B.-DESTINATION price policy.

Because we are interested in our customers and the ease with which they may do business with us, Tektronix Canada Ltd. will absorb the p.o.e. (point-of-entry)-to-destination freight tariffs on Tektronix instruments purchased by our Canadian customers.

Prior to now, instrument prices were quoted f.o.b. point of entry (Toronto, Montreal or Vancouver) with the customer responsible for the expense of delivery from there to his location. Thus, the total cost of an instrument laid down at the customer's location could be at considerable variance with the quoted price.

The new price policy offers you, the customer, several distinct advantages:

You will find your purchase and budget planning problems considerably eased in so far as Tektronix instruments are concerned.

You will, with the quoted price, know the total cost of obtaining that instrument — no longer will you need concern yourself with bothersome insurance rates and difficult-to-figure freight charges.

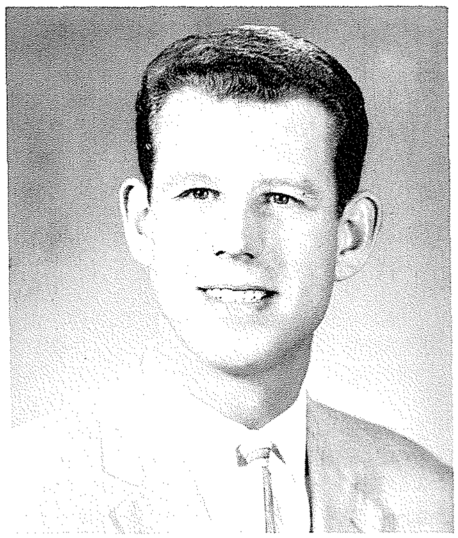
You will be relieved of the necessity to initiate and process possible claims for instruments damaged in transit. Although Tektronix has in the past volunteered to assist customers in this regard, it has until now remained an irksome chore that was primarily the customer's responsibility. Now, should you be unfortunate and receive a Tektronix instrument damaged in shipment you need only to notify Tektronix Canada Ltd., and the carrier handling the shipment. Then, hold for their inspection the carton and packing material in which the instrument was shipped. Tektronix guarantees delivery of a completely satisfactory and damage-free instrument.

In making this announcement we have saved the most important news until the last. A steadily increasing volume of Tektronix instruments shipped to Canada now allows us to route our freight to Canadian points-of-entry on a consolidated basis — and at some saving in expense. This saving we are passing on to you by making the F.O.B.-DESTINATION price policy available without an increase in instrument prices.

TEKTRONIX CANADA LTD. REPRESENTS ROHDE AND SCHWARZ IN CANADA

You can now enjoy for your Rohde and Schwarz instruments the same high degree of service, assistance and back-up support that you expect for your Tektronix instruments. On October 1, 1964 Tektronix Canada Ltd. assumed the responsibility for the sales and servicing of Rohde and Schwarz products in Canada.

Rohde and Schwarz, a West Germany-based electronic instrument manufacturer, enjoys an excellent worldwide reputation. Typical products are signal generators, impedance measuring devices, frequency standards, etc. These products, which so nicely complement the Tektronix line of instruments, will allow your Tektronix Canada Ltd. Field Representative to more completely serve your electronic-instrument needs.



Melle Zegel

The Tektronix Canada Ltd. policy of continuing assistance with any problem involving oscilloscopes — selection, operation, application, maintenance or modification — has been extended to include Rohde and Schwarz instruments.

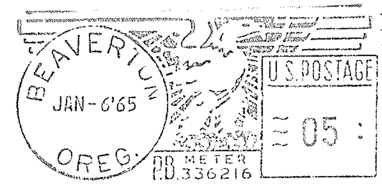
Melle Zegel, who recently joined Tektronix Canada Ltd., brings with him a vast fund of information and a comprehensive knowledge of Rohde and Schwarz instruments. Melle recently spent six months at their factory in Munich familiarizing himself with new instruments and attending their service and training school. The benefit of Melle's information and experience is available through your local Tektronix Field Representative. Please consult Melle and your Tektronix Field Representative whenever there is a need. They and Tektronix Canada Ltd. welcome every opportunity to assist you.

Service Scope

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon



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