



# Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

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## TRANSISTORS IN DEGENERATIVE FEEDBACK COMBINATIONS

By

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"Gain" in the vernacular of electronics is a loose term; generally understood (unless otherwise stated) to mean "voltage gain." Another common meaning is "power gain" and another, though less common meaning is "current gain." If we generalize "gain" to "transfer," we can then include "voltage-to-current" gain (transadmittance), and "current-to-voltage" gain (transimpedance). These symbols will then apply:  $T_v$  (voltage transfer or "gain"  $e_o/e_{in}$ );  $T_i$  (current transfer or "gain",  $i_o/i_{in}$ );  $T_y$  (transadmittance or voltage-to-current "gain",  $i_o/e_{in}$ );  $T_z$  (transimpedance or current-to-voltage "gain",  $e_o/i_{in}$ ); and  $T_p$  (power "gain").

For example, an amplifier whose transfer is  $T_z = 10^6$  is a transimpedance type of amplifier. It requires a current input and gives a voltage output, the value of which is determined by multiplying the input current by  $10^6$ .

Table 1 summarizes the four possible ways to arrange voltages and currents as inputs and outputs for these three-port devices.

A practical example of the considerations in Table 1 is in the case of a low voltage source remotely located from a voltage sensitive load. A preamplifier is desirable

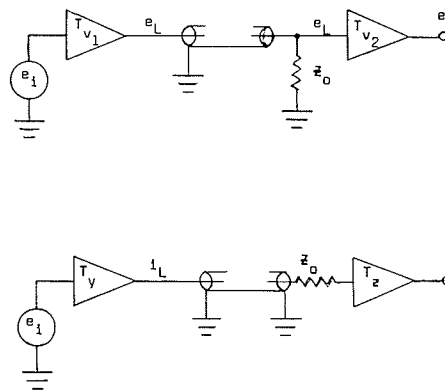


FIGURE 1

at the source before transmitting the signal to the output amplifier. Here one could use a *voltage* preamplifier and a *voltage* output amplifier: ( $e_L$  is the transmission line voltage)  $T_{v1} \times T_{v2} = e_L/e_{in} \times e_o/e_L = e_o/e_{in}$ . Or, one could also use a *transadmittance* preamplifier and a *transimpedance* output amplifier: ( $i_L$  is the line current)  $T_y \times T_z = i_L/e_{in} \times e_o/i_L = e_o/e_{in}$ . Which system is best— $T_{v1} \times T_{v2}$  or  $T_y \times T_z$ ? Figure 1 illustrates the above problem.

Although either will do the job well, first-order signal-to-noise ratio or power consumption may be important. If the transmission line suffers mainly from magnetically-induced noise voltages, then the  $T_y \times T_z$  combination will prove best—the high output impedance of the transadmittance preamplifier will not allow the magnetically-induced voltages to produce a current which could affect the current-sensitive input of the transimpedance output amplifier. If, on the other hand, the transmission line suffers mainly from electrostatically-induced noise currents, then the  $T_{v1} \times T_{v2}$  combination will prove best—the low output impedance of the voltage preamplifier will not allow the induced currents to develop a voltage which would effect the voltage-sensitive input of the output voltage amplifier.

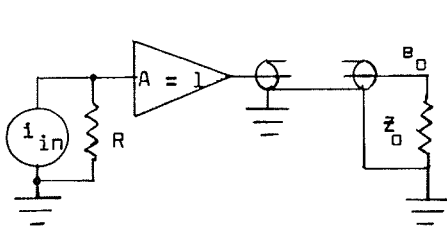
Another example is a remotely located current source of pulses which must be amplified with reasonable fidelity. Here the capacity of a transmission line usually requires a terminated mode of operation to avoid both reflections and capacitive loading. A large resistor (compared to  $Z_o$ ) at the current source and a gain-of-one line driver would work. However, it would require large amounts of power to drive the line termination to the large output voltage. A better method would be to use a low input impedance amplifier (such as the transimpedance or the current amplifier types) with an appropriate series resistor to terminate the cable and use the large resistor in the output feedback position. This reduces the power requirements considerably and places the amplifier back at the load. The signal-to-noise ratio is considerably better than if the cable were simply terminated at the load, and then a voltage or transadmittance amplifier was used. Figure 2 illustrates four cases.

In considering transistors as degenerative feedback "singles"—that is, a single transistor used to perform transfer with either internal or external feedback—Table II summarizes the four useful possibilities.

Input		Output		Name
Signal	Impedance	Signal	Impedance	And Symbol
Voltage	High	Voltage	Low	Voltage Gain $e_o/e_{in} = T_v$
Current	Low	Current	High	Current Gain $i_o/i_{in} = T_i$
Voltage	High	Current	High	Transadmittance $i_o/e_{in} = T_y$
Current	Low	Voltage	Low	Transimpedance $e_o/i_{in} = T_z$

TABLE 1

**Tektronix Instrument-Repair Facilities:** There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.

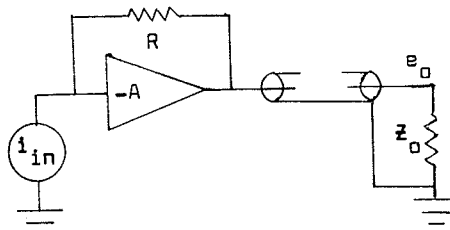


$Z_o$  is less than  $R$ ,  $A$  is greater than  $R_o/Z_o$  except in (a)

$$e_o = i_{in} R \quad P_o = i_{in}^2 R \times \frac{R}{Z_o}$$

$$P_i = i_{in}^2 R \quad T_p = \frac{R}{Z_o}$$

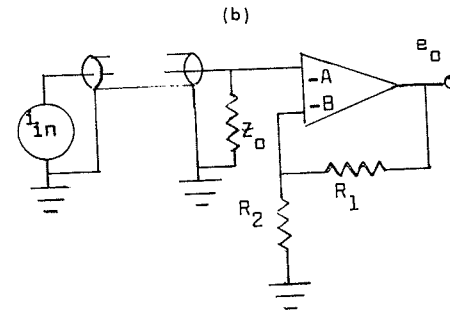
Output power requirement large, good signal/noise



$$e_o = -i_{in}^2 R \quad P_o = i_{in} R \frac{R}{Z_o} + 1$$

$$P_{in} \approx 0 \quad T_p \approx \infty$$

Output power requirement largest, good signal/noise

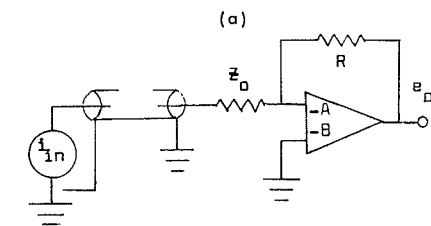


$$R_1 + R_2 = R, R_2 = Z_o, R_1 = R + Z_o$$

$$e_o = i_{in} R \quad P_o = i_{in}^2 R$$

$$P_{in} = i_{in}^2 Z_o \quad T_p = \frac{R}{Z_o}$$

Same power as (c), but signal/noise difficult with small current.



$$e_o = -i_{in}^2 R \quad P_o = i_{in}^2 R$$

$$P_o = i_{in}^2 R \quad T_p = \frac{R}{Z_o}$$

Lower power output required, reasonable signal/noise with currents to  $10^{-6}$  amps and negative cycle bandwidth.

(a)

(d)

FIGURE 2

Transistors considered as degenerative feedback pairs are more numerous and more flexible, in that current and voltage gains may be greater than 1. Table III lists all possibilities in descending order of usefulness, by type (voltage, current, admittance, or impedance transfer).

Note that  $T_i$  can be converted to a  $T_z$  by the use of a known load resistor. Similarly a  $T_v$  can be converted to a  $T_v$ . Then,  $T_i$  can be converted to  $T_y$ , and  $T_z$  to a  $T_v$  by placing a known resistor in series at the input (source  $Z$  assumed to be low). Again, a  $T_v$  converts to a  $T_y$  and a  $T_z$  to a  $T_i$  when a known resistor is placed in series with the output (load  $Z$  assumed low). And finally, a  $T_v$  converts to a  $T_z$  and a  $T_y$  to a  $T_i$  when a known resistor is placed in shunt with the input (source  $Z$  assumed high). Table IV presents the above information in chart form.

Going beyond transistor pairs is difficult, if high loop gains are desired. This is due to Nyquist troubles mainly associated with the transistors themselves. The most easily successful transistor triplets involve the addition of an emitter follower to one of the existing listed pairs. Usually the emitter follower is added to example 1, 3, 8, 9, or 10 (Table III) to lower the output impedance; or, added to the input of 2, 3, or 12 to increase the input impedance (also provides temperature compensation for 2 and 12).

We hate to be old fashioned, but we are compelled for completeness to point out that the foregoing applies also to (you should pardon the expression) "vacuum tube"\* amplifiers.

\* Fleming Valves

Circuit Example	Transfer	Good	Bad
	Transadmittance (1) $T_y = -\frac{1}{R}$ High input Z Low output Z	High output Z High input Z	Transfer $\propto$ dependent
	Transimpedance (2) $T_z = -R$ Low input Z Low output Z	Low input Z	Loop gain strongly load dependent with $R_L < R$ .
	Voltage gain (3) $T_v \approx 1$ High input Z Low output Z	Low output Z High input Z	Input impedance load dependent
	Current Gain (4) $T_i \approx 1$ Low input Z High output Z	Low input Z High output Z	Transfer $\propto$ dependent

TABLE II

REMINDING YOU

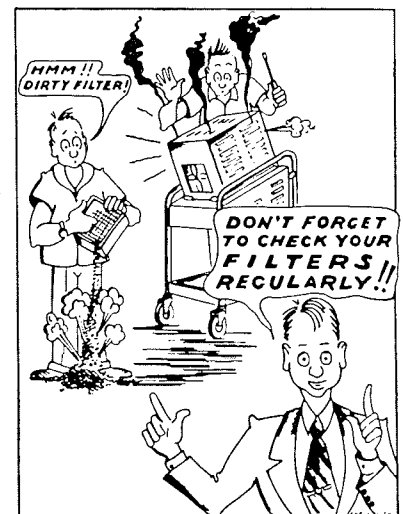


TABLE III

TRANSFER	CIRCUIT EXAMPLE	GOOD POINTS	BAD POINTS	USUALLY USEFUL
<p>Voltage Gain</p> $T_L = \frac{R_1 + R_2}{R_2}$ <p>High input Z Low output Z</p>		<p>(1) High input Z. Open circuit gain predictability.</p>	<p>Output Z could be lower. Loop gain strongly load dependent when <math>R_L &lt; R_1 + R_2</math>.</p>	<p>Yes</p>
		<p>(2) Output Z low.</p>	<p>Input Z a bit low.</p>	<p>Output</p>
		<p>(3)</p>	<p>Input Z a bit low. Loop gain strongly load dependent when <math>R_L &lt; R_1 + R_2</math>.</p>	<p>No</p>
<p>Current Gain</p> $T_i = \frac{R_1 + R_2}{R_2}$ <p>Low input Z High output Z</p>		<p>(4) Low input Z High output Z</p>	<p>Transfer <math>\propto</math> dependent.</p>	<p>Yes</p>
		<p>(5) Temp. Compensated</p>	<p>Loop gain load dependent (likes low Z load). Input Z bit high. Output Z bit low.</p>	<p>Low Z load, Large <math>R_1 // R_2</math></p>
		<p>(6)</p>	<p>Output Z a bit low. Loop loaded by emitter. Loop gain load dependent.</p>	<p>No</p>

TABLE III Continued

<p>Transimpedance</p> $T_z = -R$ Low input Z Low output Z		(7) Low input Z. Low output Z. Open circuit gain predictability.		Yes	
		(8) Temperature comp	Loop gain strongly load dependent when $R_L < R$ . Output Z a bit high.		Input
		(9)	Poor loop gain. Output Z bit high. Input Z not low enough. D. C. awkward.		No
		(10)	Loop loaded by input emitter, low loop gain.		No
<p>Transadmittance</p> $T_y = -\frac{1}{R}$ High input Z High output Z		(11) High input Z	Output Z bit low; transfer $\propto$ dependent. Loop gain dependent — likes low Z load.	Input	
		(12) High output Z	Input Z bit low, transfer $\propto$ dependent.		Output

Known resistor used in:	Source Z	Converts			
		$T_i$	$T_z$	$T_r$	$T_v$
Load		→		→	
Series with input	assumed low	→		→	
Series with output	assumed low	←		←	
Series with input	assumed high	←		←	

TABLE IV

### USED INSTRUMENTS FOR SALE

One Type 570 Electron Tube Curve Tracer, s/n 5303. New condition. Reasonably priced. Fred Pack, Technical Materiel Corp., 700 Fenimore Road, Mamaroneck, New York. The Univac Division of the Sperry Rand Corporation at 311 Turner Street in Utica, New York, offers the following instruments for sale:

- 2— 315D Oscilloscopes
- 4— 512 Oscilloscopes
- 1— 514 Oscilloscopes
- 11— 531 Oscilloscopes
- 1— 532 Oscilloscopes
- 7— 533 Oscilloscopes
- 19— Preamplifiers consisting of an assortment of Type 53C, Type 53/54C and a few Type CA Plug-In Units.

All instruments will be repaired and recalibrated before shipment to any buyer. Contact Art Ebberhart at the above address for serial number ranges and prices.

One (1) Tektronix oscilloscope, model RM15, s/n 106—brand new. In original Tektronix packing case—never uncrated or placed in service. Has been in storage since 1957. Address inquiries to Schlumberger Well Surveying Corporation, P. O.

Box 2175, Houston 1, Texas. Attention: Purchasing-Surplus.

1 Type 517 Oscilloscope complete, s/n 789. Also, 1 Type 513 Oscilloscope. StuartEx Enterprises, 7626 Lexington Avenue, Los Angeles 46, California. Telephone OL 6-9940.

1 Type 502 Oscilloscope, s/n 6635. Approximately one year old. William Simpson, Sound and Audio Electronics, 1902 Euclid Avenue, Cleveland 15, Ohio. Telephone 861-3907.

1 Type 512 Oscilloscope, s/n 578. Recently reconditioned. Set spare matched amplifier tubes included. A. C. Wall, 36 Beach Drive, Norton, Connecticut. Telephone 203-655-4218.

1 Type 53/54K Plug-In Unit, s/n 867. Very good condition. B. Stapler, Columbia Technical Corporation, Woodside, New York. Telephone YE 2-0800.

1 Type 535A Oscilloscope, 1 Type CA and 1 Type D Plug-In Units. All instruments are less than one year old. Tom Summers, 407 Harvard S. E., Albuquerque, New Mexico.

### MISSING INSTRUMENTS

Apparently those sly and slippery individuals who use the "midnight requisition" to "purchase" their oscilloscopes are on a buying (?) strike.

Since our April issue of Service Scope, we've received only one report of a missing instrument. That report concerned a Type 310A, s/n 013798, apparently stolen from an automobile belonging to a service representative of the General Electric Company, X-Ray Department.

The instrument disappeared early in April and the apparent theft occurred in the immediate Chicago area.

The General Electric people have requested that we ask our readers to be on the alert for this instrument. Information you may have regarding this scope should be relayed to Mr. R. M. Landis, General Electric Company, X-Ray Department, 1061 W. Jackson Blvd., Chicago, Illinois.

1 Type 515A, s/n 5477. Phil Fullerton, Electramatic, Inc., 3324 Hiawatha Avenue, Minneapolis 6, Minnesota. Telephone PA 1-5074.

1 Type 517A Oscilloscope, s/n 1106. Will sell or trade for other Tektronix equipment. Electronic Laboratory Supply Company, 7208 Germantown Avenue, Philadelphia 19, Pennsylvania. Telephone: Area Code 215, CH 8-2700.

1 Type 190 Constant-Amplitude Signal Generator, s/n 5116. 1 Type 108 Fast-Rise Mercury Pulser, s/n 251. 1 Type 107 Square-Wave Generator, s/n 106. Harry Bishop, Bishop Enterprises, Inc., P. O. Box 236, Westminster, Colorado.

1 Type 513D Oscilloscope, s/n 1584. Asking price \$350.00. Thomas L. Dinsmore, Buyer, Thomas A. Edison Research Laboratory, Division of McGraw-Edison Company, West Orange, New Jersey. Telephone REDwood 6-1000.

1 Type 517A Oscilloscope, s/n 1047. George Moore, 542 Hurt Road, Smyrna, Georgia.

1 Type 561A Oscilloscope (round-face crt), 1 each Type 63, Type 67 and Type 75 Plug-In Unit. Serial numbers not given. Dave Rutland, 2185 Alisos Drive, Montecito, California. Telephone WO 9-3657.

## USED INSTRUMENTS WANTED

1 Type 512 Oscilloscope. Walter R. Nass, Consulting Engineer, Route 3, Box 505, Escondido, California. Telephone SHERwood 5-7437.

1 Type 514 or Type 514D Oscilloscope. Prefer one or the other of these scopes but will consider a Type 310A. M. Perez & Sons, 6475 Main Street, Long Hill, Connecticut.

1 Type 317 Oscilloscope. Don Costello, 8279 West Winnamac, Chicago, Illinois.

1 Type 515 or Type 515A Oscilloscope, any condition, price commensurate thereto. G. Summers, 1511 LeVee, Dallas 7, Texas.

1 Type 514 Oscilloscope. Condition not important. Kenneth H. King, 16210 May Creek Road, Renton, Washington.

1 Type 535 or Type 545 Oscilloscope, Ronald Silver, 2576 East Wren Road, Salt Lake City 17, Utah. Telephone CR 7-1697.

1 Type 515 or a similar 10 Mc Oscilloscope. David Fraser, Dyna Sciences Corporation, Fort Washington, Pennsylvania. Telephone MI 6-6247.

## NEW FIELD MODIFICATION KITS

**TYPE 661 OSCILLOSCOPE DELAYED-PULSE GENERATOR IMPROVEMENTS KIT** — For Type 661 Oscilloscopes with s/n's 101 to 361 inc.

This modification reduces to a minimum radiation of the pulse (produced by the Delayed-Pulse Generator) into the vertical circuitry after the signal delay. This radiated pulse causes disturbances in the time region from approximately 100 nsec before the step output of the Delayed-Pulse Generator up to the step.

The modification adds a shield to the rear of the DELAYED-PULSE connector and utilizes a torroid transformer to isolate the tunnel diode pulse from the delay line and bias circuit.

The modification also improves the delayed pulse risetime of those instruments using a 1N3130 tunnel diode in the D992 position by incorporating changes that permit the use of a TD 1081 tunnel diode in the D992 position.

Please note: this mod kit does *not* include a TD 1081 tunnel diode. This diode (Tek part number 152-099) must be ordered separately if your instrument does not already have one.

If your instrument has a serial number 271 or higher, it will have a factory-installed TD 1081 in the D992 position. If your instrument is in the 101-to-270 serial number range, and has had the tunnel diode in the D992 position replaced since the instrument was delivered, it may have been replaced with a TD 1081. A visual check will determine this for you. If the tunnel diode

in this position is a 1N3130, it will measure about 0.020" in thickness. If it is a TD 1081 it will measure about 0.050" in thickness.

Order through your Tektronix Field Engineer or local Field Office. Specify Tektronix part number 040-307. Price: \$25.20.

Remember, if you need the TD 1081 tunnel diode you will also have to order it. Specify Tektronix part number 152-099. Price: \$21.00.

**TYPE M PLUG-IN UNIT 'A' SIGNAL-OUT IMPROVEMENT** — For Type M Plug-In Units with s/n's 101 to 2759 inc.

This modification replaces transistor Q5344 and its related circuitry with a temperature-stabilized dual-transistor comparator circuit. This replacement effects improvements in the 'A' Signal Out circuit as follows:

- (a) Stabilizes the 'A' Signal Out dc level to reduce temperature variations and changes which result from transferring the unit from one oscilloscope to another.
- (b) Reduces chopping transients appearing at the 'A' Signal Out connector.
- (c) Improves bandpass.
- (d) Changes the range of the DC BAL control to allow compensation for low-bias Nu Vistors.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-308. Price: \$22.40.

**TYPE O PLUG-IN UNIT OPERATIONAL AMPLIFIER IMPROVEMENTS** — For Type O Plug-In Units with s/n's 101 to 813 inc.

This modification incorporates several refinements in the operational amplifiers of the Type O Plug-In Unit. The modification and its instructions are divided into four sections (A, B, C, & D). Any part of the modification may be performed separately. Benefits of the modification are:

1. Sections A and B improve the temperature-sensitive drift characteristics of the 'A' and 'B' amplifiers.
2. Section C improves the cross-talk characteristics by relocating several wires and changing the decoupling arrangement.
3. Section D increases the accuracy of the output amplifier when  $Z_I$  is set at 10 pF and the INTEGRATOR L.F. REJECT is set to OFF.

Note: This section applies only to the instruments with serial numbers 101 to 318 with the exception of a few instruments in this serial number range that were modified at the factory. Consult your Tektronix Field Engineer if you are not sure of your instruments status.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-301. Price \$44.20.

**TYPE 507 OSCILLOSCOPE CRT FILAMENT ISOLATION TRANSFORMER** — For Type 507 Oscilloscopes with s/n's 101 to 427 inc.

This modification installs a special oil-filled isolation transformer (T702) between the crt filament and the filament transformer (T701). This eliminates the possibility of breakdown in the crt-filament winding of transformer T701.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-304. Price \$43.10.

**TYPE 581 AND TYPE 585 OSCILLOSCOPES REGULATED DC FILAMENTS MOD KIT** — For Type 581 Oscilloscopes with s/n's 101 to 1331 inc. and Type 585 Oscilloscopes with s/n's 101 to 3763 inc.

Installation of this modification materially reduces variations in vertical gain due to changes in line voltage. The modification makes the following improvements in the instrument:

- (a) Changes the vertical-amplifier filament supply from elevated 6 volts ac to regulated 12.6 volts dc.
- (b) Rewires the filaments into a series parallel arrangement.
- (c) Increases the filter capacitance in the 12.6 volt and 100 volt supplies.
- (d) Adds fuses between the vertical amplifier and the 100, 225 and 350 volt supplies to protect components in the event of tube shorts.
- (e) Increases the decoupling to the -150 and +350 volt supplies and the screen of the Miller-Runup tube (V161). This helps to prevent aberrations (caused by high current pulses from the sweep generator) in the displayed waveform.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-303. Price \$39.05

**TYPE 519 OSCILLOSCOPE MAXIMUM INTENSITY MOD KIT** — For Type 519 Oscilloscopes with s/n's 101 to 383 inc.

This modification adds a Maximum-Intensity potentiometer to the high-voltage circuit and limits the range of the front-panel INTENSITY control. This lessens the chance of accidentally burning the crt phosphor because of a too-high INTENSITY-control setting. It also helps to prolong the life of the crt cathode.

In addition, the modification adds several other refinements such as: eliminating oscillations of the neon voltage regulator, assuring the start of neon ionization in complete darkness and improving the regulation of the high voltage supply.

Order through your local Tektronix Field Office or Field Engineer. Specify Tektronix part number 040-302. Price is \$6.35.

## SUBSTITUTING 6BL8'S FOR 6U8'S

In the August 1962 issue of *SERVICE SCOPE*, we stated that the 6U8 tubes were no longer recommended as a satisfactory replacement for 6BL8 tubes in the Type 503 and Type 504 Oscilloscopes and the Type 67 Plug-In Units. That statement is still valid. However, several of our customers after reading the statement raised the question, "Wouldn't 6BL8 tubes make a more satisfactory replacement for 6U8 tubes located in the trigger, trigger pickoff and delay-pickoff circuits of the Type 530 and 540 Series Oscilloscopes?"

To determine the answer, we asked our Manufacturing Staff Engineering Department to run some tests using 6BL8 tubes in place of 6U8's in the circuits in question. The tests revealed that in each application the 6BL8's showed no apparent short com-

ings. While they have a lower output rating than the 6U8 tube, they operate well within their ratings in all the Type 530/540 series instruments except the Type 532.

In the trigger amplifier circuit of the Type 532, a 6BL8 tube must operate at cutoff because of the higher operating bias of the triode section. As a result, output is insufficient to allow correct triggering on 1 cm of signal with the TRIGGERING LEVEL control set to 0. Also, these tubes fail to operate satisfactorily in the trigger multi circuit of the Type 532; with normal adjustment of the Trigger Sensitivity and the TRIGGER MODE switch in the AUTO position, the multi will not free run in the absence of a signal.

In all other Type 530/540 Series instruments the 6BL8 tubes perform satisfactorily.

Trigger output was slightly greater and the trigger circuits set up very well.

The Manufacturing Staff Engineer also tested the E80CF tube (Telefunken and Amperex). They, too, gave satisfactory performances in these circuits. Life tests were not conducted for either the 6BL8 or E80CF tubes.

Our conclusion is that despite the slight gain in trigger output (about 6 to 10%), we do not feel that the advantage gained is great enough to recommend wholesale replacement of the 6U8 tubes in the trigger circuits of the Type 530/540 Series Oscilloscopes. We prefer to go no farther than to say that 6BL8 and E80CF tubes can be used in these circuits with no apparent disadvantages.

## HIGH REP-RATE BURSTS FROM MULTIPLES OF TYPE 111 PULSE GENERATORS

In some applications, two or more closely-spaced pulses will prove nearly as useful as pulses from a high-rep-rate generator. Two or more Type 111 Pretrigger Pulse Generators will, when coupled together, supply such closely-spaced pulses. They will also supply many other pulse trains. The pulses may be, as desired, of either positive or negative polarity and of various spacings and widths. Such pulses are useful in many forms of logic testing.

Tektronix Field Engineer Jim Johnson has used three Type 111's to provide a means of testing high speed scalars.

Figure 1 shows a suggested setup for three Type 111 Pulse Generators. In this example, unit number 1 acts as a master unit to set the rep rate of the bursts and to provide one of the pulses. The RANGE switch in the Pulse Generator block of the other Type 111's should be set to EXT TRIG. The VARIABLE control in the Trigger To Pulse Time Difference block allows you to space the pulses in the bursts.

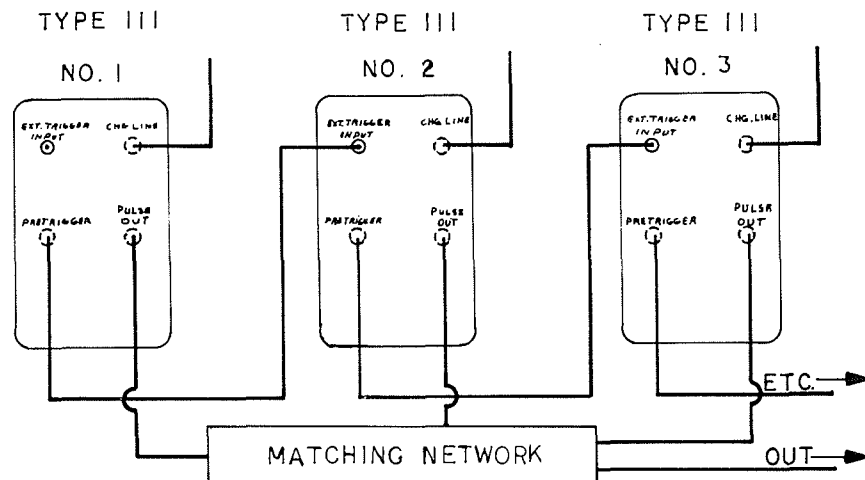


FIGURE 1

Output polarity and pulse widths may be different for each Type 111.

Norm Winningstad, of our Instrument Engineering group, suggests the matching network shown in Figure 2 for reflection-free mixing of any number of  $Z_0$  transmission lines. Any one of the branches may be used as an output.

The maximum transfer ( $\alpha$  max) between input and output occurs when  $r$  becomes infinite. Then for  $N$  branches:

$$R = \frac{N - 2}{N} Z_0$$

$$\alpha \text{ max} = \frac{1}{N - 1}$$

If less transfer than  $\alpha$  max is desired,  $r$  becomes finite and  $R$  increases from values given above — impedance matching is retained. If  $\alpha$  is the desired transfer (i.e.,  $E_{out}/E_{in} = \alpha$ ,  $\alpha < \alpha \text{ max}$ ) then:

$$R = \frac{1 - \alpha}{1 + \alpha} Z_0$$

$$r = \frac{1 - (R/Z_0)^2}{2 + N \left( \frac{R}{Z_0} - 1 \right)} Z_0$$

Two small limitations exist in this setup:

1. The more channels used, the smaller the output pulse.
2. When combining positive and negative pulses, there could be inter-triggering via the pulse output connector of each network. If, for instance, a negative pulse of 5 volts or so reaches a Type 111 set to a positive polarity, it could force the emitter of the avalanche transistor down enough to cause it to avalanche. Generally, though, a network with  $\alpha$  of 0.3 or less should eliminate this problem.

If you wish, you can connect all the pulses together in an unmatched network using GR874 "T's". If you get involved in inter-triggering from alternate plus polarities, use 5-to-1 attenuators—but, beware of reflections.

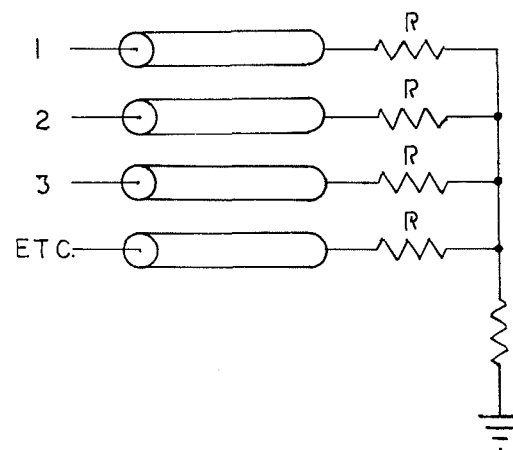


FIGURE 2



# *Service Scope*

USEFUL INFORMATION FOR

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