Instruction Manual

Tektronix, Inc.

P. O. Box 500 • Beaverton, Oregon

Type 281

TDR PULSER

865 070-0515-00

Type 281 Time-Domain Reflectometry Pulser

SECTION 1
CHARACTERISTICS

General Information

The Type 281 TDR Pulser has been designed for Time Domain Reflectometry (TDR) applications. It is a free-running rectangular current generator with approximately an 18-ma output which is rapidly switched off in less than a nanosecond, and remains off for a period of at least 5 μsec. After this "off" period, the current is re-established to a constant 18 ma for a period of time of at least 5 μsec, after which the cycle repeats.

The generator has two 50-ohm GR type output connectors, both of which are connected in parallel. Except for a small amount of shunt capacitance loading, the generator does not attenuate low amplitude nanosecond risetime signals passing in through one connector and out through the other.

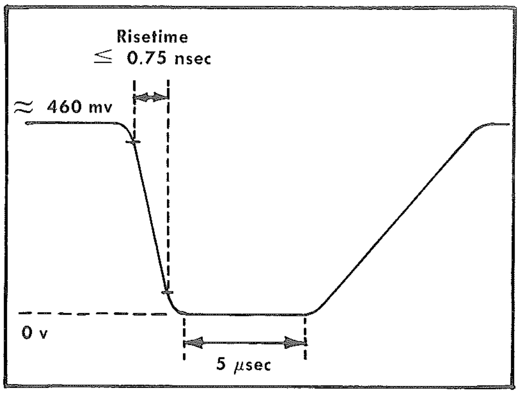


Fig. 1-1. Risetime of the negative-going edge.

TABLE 1-1

Characteristics	Performance Requirement	Supplemental Information
Amplitude		
Pulse Current.	18.5 ma ±1.5 ma	
Pulse Voltage.		Approximately 460 mv as measured on negative-going edge of pulse, with test point of reflection line terminated into 50 ohms.
Risetime		
Negative-going edge.	Less than or equal to 0.75 nsec.	Measured between 90% and 10% points. See Fig. 1-1.
Pulse Width		
Positive-going edge to negative-going edge.	Greater than or equal to 5 μsec.	
Flatness	Less than or equal to ±2% of overshoot and ringing following the negative-going edge of the pulse. Less than or equal to ±0.5% of waveform aberration will appear 10 nsec after negative-going edge and 0.5 μsec after positive-going edge of the pulse.	
Loading effect on 50-ohm system.	Less than or equal to a 10% capacitive reflection.	Risetime (driving pulse) is equal to 0.75 nsec.

Electrical Characteristics

NOTE

The characteristics listed in Table 1-1 apply only when both the Type 281 TDR Pulser 50-ohm GR connectors are terminated into 50 ohms.

Compatibility

The Type 281 TDR Pulser can be used with any Type 1S1, 4S1, or 3S76 vertical sampling unit. The Type 281 may be used with other sampling units than those listed above, but it will require additional hardware for operation.

Included Accessories

1—Instruction Manual 070-0515-00

SECTION 2
OPERATING INSTRUCTIONS

Introduction

This section covers connecting the Type 281, obtaining a display, operating precautions, and display interpretation in 50-ohm systems.

Connecting the Type 281

Connect one of the Type 281 50-ohm output GR connectors to the appropriate input connector on the vertical sampling unit. Connect the Type 281 power plug to a probe power connector on the vertical sampling unit.

Obtaining a Display

NOTE

The control settings listed below have been generalized to fit the various vertical sampling and time base units which might be used.

Set the vertical sampling unit control for the channel in use as follows:

Position	Midrange
Smoothing	Normal
Mode	Set to channel being used
Norm/Inv	Normal
DC Offset	0 volt
Mv/Div	200
Triggering	Set to channel being used

Set the time base unit controls as follows:

Position	Midrange
Time Position	Midrange
Samples/Div	100
Time/Div	5 nsec
Trigger Source	— Internal
Display Mode	Normal
Trigger Sensitivity	Adjusted for triggered display.

Adjust the time position control so the negative transient (fall) time of the waveform can be seen. Connect a 5-nanosecond coaxial cable to the free 50-ohm GR connector on the Type 281 and observe the display shown in Fig. 2-1.

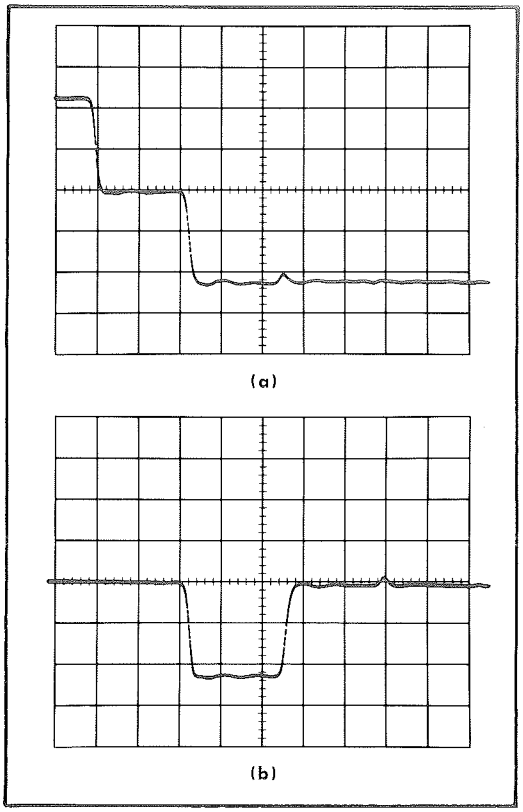


Fig. 2-1. Waveforms obtained with 5 nsec coaxial cable connected to Type 281 and unconnected end of coaxial cable; (a) open; (b) shorted.

Operating Precautions

The case of the Type 281 normally gets perceptibly warm to the touch. This amount of heat will not affect the operation of the Type 281.

NOTE

One of the 50-ohm GR output connectors should always be connected to the vertical sampling unit when power is applied to the Type 281. Failure to do this will cause the Type 281 to run hotter than normal and may shorten its operating life.

Display Interpretation

Refer to the Applications section in this manual for a complete discussion on interpreting displays.

SECTION 3
APPLICATIONS

TIME DOMAIN REFLECTOMETRY

General

In electronic circuitry, it is often necessary to transmit a signal between two points in a system with the least possible change in the wave shape or amplitude of the signal. In high-speed circuitry involving nanosecond time considerations, this is especially important. Signal transmission with minimum distortion of waveshape or amplitude is accomplished by maintaining uniform characteristic impedance (Z_o) throughout the system, and by the use of correct line termination; that is, by making the resistive load (R) equal to line impedance (Z_o). Two-conductor coaxial or strip transmission lines are customarily used, with the propagation mode known as transverse electromagnetic (TEM).

To determine the efficiency of a transmission system, it is necessary to measure and test transmission line impedance and termination. One means of testing involves measuring the voltage standing wave ratio (VSWR) as a function of the frequency applied to the unit under test. A uniform line properly terminated will show a VSWR of 1.00 at any frequency. Any other value of VSWR shows non-uniformity in characteristic impedance, or a discontinuity in the system.

Another method of transmission line measurement is the time domain method. Here, the variable is the ratio of reflected voltage to incident voltage — defined by the voltage reflection coefficient ρ. With the reflection method, a fast-rising voltage pulse is sent into the transmission line under test, and the returning reflections are observed. The amplitude of the reflection as related to that of the applied pulse describes the size of the non-uniformity, and the time delay after initial application of the pulse locates its position within the system. An advantage of the time domain method of measurement is that the graph of voltage reflection coefficient ρ as a function of time is equivalent to a plot of transmission line impedance (Z_o) as a function of position on the line.

Very accurate pulse reflection measurements can be made with sampling type oscilloscope systems. A sampling oscilloscope with a dynamic range of several volts and sensitivity measurable in millivolts is capable of resolving voltage reflections to better than 1 part in 100. A system that is able to resolve time into fractions of nanoseconds can locate points only a few centimeters apart on a transmission line.

The reflection system generates a step function with a pulser, propagates the step function in a length of transmission line, then observes the voltage at the input point of the test line with an oscilloscope. The applied step function may be very long — in which case, the reflections appear added to the amplitude of the step input.

Description of Type 281 System

In the system shown in Fig. 3-1, the Type 281 Time Domain Reflectometry Pulser originates a repetitive short risetime current pulse having a minimum pulse duration of 5 μsec. This TDR Pulser is designed to operate with Tektronix 50-ohm vertical sampling units, and does not need additional coaxial hardware to make high resolution TDR measurements in a 50-ohm system. The pulser, acting like a current source, does not appreciably alter the characteristics of a signal passing through it; it does add a small capacitive bump to the coaxial line at its point of insertion.

The reflections from the test line are observed with a sampling oscilloscope. This instrument obtains its characteristic gain and risetime by reconstructing small samples taken from each of many identical repetitive input signals. Hundreds or thousands of repetitions may be required to generate a single displayed equivalent pulse. Each repetition and sample requires the generation of an internal time base within the oscilloscope system, with the internal time base starting at the same time for each input repetition. This is done by extracting some of the energy of each input pulse for routing to the time base triggering circuitry of the sampling oscilloscope.

Three typical sampling oscilloscope systems are:

Tektronix Type 661 system. The Type 661 oscilloscope contains the power supplies, indicator and plug-in compartments. The Type 5T1A or 5T3 is the time base generator, and Type 4S1 is the 50-ohm vertical signal sampling unit.

Tektronix Type 1S1 system, consisting of Type 540B-Series oscilloscope containing power supplies, indicator and plug-in compartment, and Type 1S1 which is both time base generator and 50-ohm vertical signal sampling unit.

Tektronix Type 3S76 system, consisting of Type 561A oscilloscope containing power supplies, indicator and plug-in compartments; Type 3T77 or 3T4 time base generator, and Type 3S76 50-ohm vertical signal sampling unit.

System Calibration

The Type 281 TDR Pulser has been adjusted at the factory so it will provide a pulse of slightly less than 0.5-volt amplitude into a 50-ohm system. By using the variable millivolts/division control on the various sampling systems, amplitude calibration in terms of graticule divisions is easily obtained for system-to-system comparison.

In this pulse reflection system, the two basic transmission line properties to be measured are characteristic impedance and distance. The reflection method converts characteristic impedance to voltage reflection coefficient, and distance to time. The extreme of voltage reflection is when all applied voltage is returned to the observation point. This is defined as unity reflection coefficient. (Reflection coefficient ρ is $+1.00$ or -1.00.) Total reflection occurs when the reflection line is unterminated (open), or when it is shorted.

The system time base may be calibrated by inserting a known electrical length of trans-

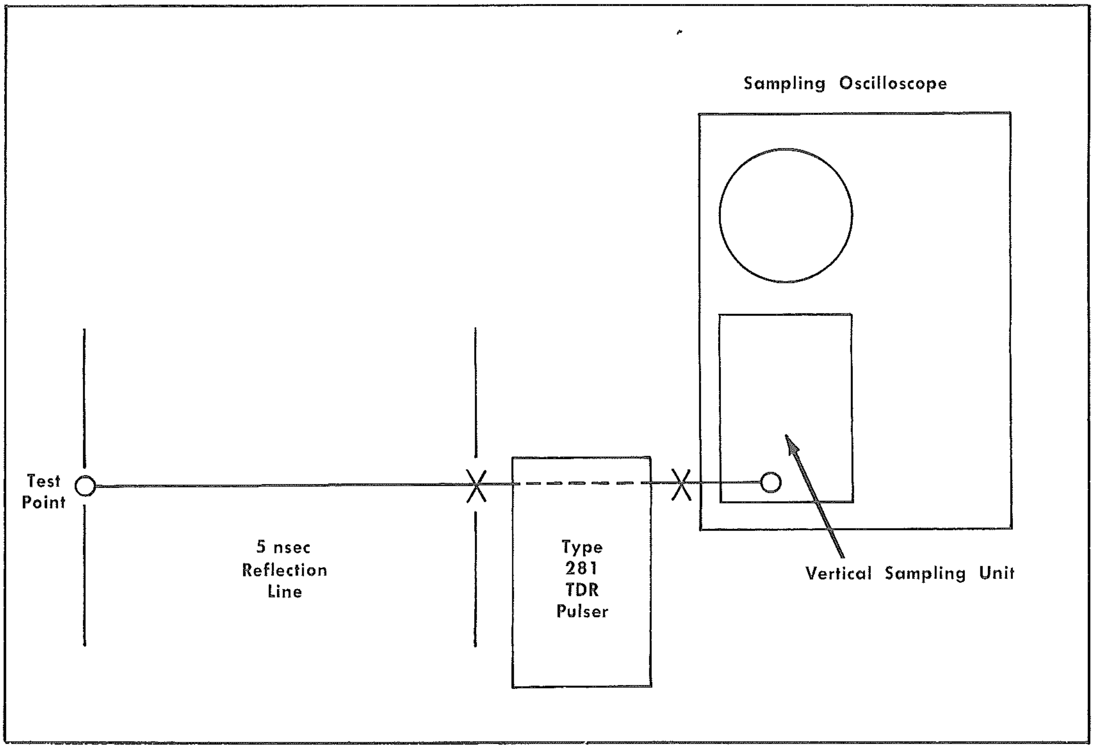


Fig. 3-1. Block diagram of TDR setup. The Type 281 produces 5 μsec pulses which travel down the reflection line and are reflected by the unknown connected at the test point. The sampling oscilloscope displays both the input and reflected pulses. When properly calibrated, the display can be directly related to impedance and distance along the line.

mission line in the reflection path, and observing the time shift of some discontinuity. The typical standard of signal delay is 30 cm of air dielectric coaxial line, which has a single transit time of 1 nanosecond.

To standardize the vertical response of the system, the vertical sampling unit step attenuator is set to 100 mv/cm, and the variable control is adjusted until the incident step occupies a vertical display height on the crt of 5 cm. This operation should be done with the Type 281 TDR Pulser terminated into an accurate 50-ohm load. This method of calibration is valid for measurements made on relatively short lengths of 50-ohm transmission line on which losses are negligible. For quantitive measurements on long lines where losses may be significant, the losses must be taken into account.

To make quantitive measurements on discontinuities shorter than the reflected risetime of the step from a short circuit, it is necessary to measure the risetime (10% to 90% points) of the fast transition of the reflection. This is the system risetime (T_r), which will be used in calculations to follow.

Measurement of Transmission Lines

The oscilloscope display is a plot of voltage reflection coefficient, (vertical distance) which can be easily converted to characteristic impedance. Transmission line reflections can be classed in two general groups. The first consists of reflections with duration longer than system risetime. These are considered impedance measurements, because the unknown Z_o can be derived quickly from the reflection amplitude. The second group consists of reflections with a duration less than system risetime. These reflections must be treated differently than direct impedance measurements.

Impedance Measurements

The reflection coefficient from the test point of the reflection line will be in the range of +1.00 to —1.00, indicating an impedance load at that point ranging from open (infinite resistance) to shorted (zero resistance). If the reflection line is then terminated in its characteristic impedance by addition of more line, or by correct resistance, the reflection coefficient will be zero. Reflection coefficient for a step change of impedance in a transmission line is given by:

$$\rho = \frac{Z_L - Z_o}{Z_L + Z_o}$$

Where Z_o is the nominal line impedance ahead of the test point, and Z_L is the impedance load placed at the test point transition.

For a 50-ohm reflection line, the deviation in ohms at a step impedance change is given by:

$$Z_L - 50 = \frac{100\,\rho}{1 - \rho}$$

When Z_L is nearly equal to 50 ohms, each ohm of difference causes a 1% reflection.

Measurement of Small Discontinuities

Each small discontinuity in the test line causes an impulse-type reflection, with the observed magnitude being dependent upon actual impedance deviation, physical length of the non-uniform line section, and risetime of the pulse system. These reflections are reduced in amplitude and smeared in time (to approximately system T_r) by integration in the test system.

In a section concerning impedance determination of a connector in a transmission line, Lewis and Wells[1] state that, given a small but constant impedance deviation, with a double transit time very short compared to the test system risetime, the observed voltage reflection coefficient will be less than the actual ρ of the deviant section.

Stated simply: $\rho_{obs} = \frac{2\,T}{T_r}\,\rho_{act}$

where: ρ_{obs} is the observed voltage reflection coefficient.

$2\,T$ is the double transit time of the discontinuity.

T_r is the test system risetime.

$\rho_{act} = \frac{Z_s - Z_o}{Z_s + Z_o}$ is the actual voltage reflection coefficient of the section in error.

Z_s is the characteristic impedance of the section in error.

Z_o is the system characteristic impedance.

In this relationship, ρ_{act} is reduced to ρ_{obs} by the ratio of the discontinuity double transit time to the system risetime.

Locations of Discontinuities

Discontinuities along the reflection line appear on the observing oscilloscope to have twice their actual physical separation. This is due to double signal transit nature of the reflection method; the input pulse travels the length of the line in one direction, and reflections cover the same path in the opposite direction.

The oscilloscope will display the time between discontinuities in the test line as $\frac{2L}{V_p}$, where L is the physical separation. (A length L along the reflection line will have a delay time of $\frac{L}{P}$, where V_p is the propagation velocity.) Thus, positions which are 30 cm apart in air dielectric coaxial line will appear 2 nanoseconds apart in the reflection display. To locate accurately the position of a small, short-duration discontinuity, a small discontinuity can be added near the original. (Slight separation of coax connectors will usually add series inductance; holes drilled in the outer wall of coaxial line will permit adding shunt capacitance, or clamping pliers on semirigid coaxial line will make an obvious increase in shunt capacitance.) If the added reflection is of opposite polarity and of nearly equal magnitude to the unknown disturbance, the location of the unknown will be adjacent to the position of the added reflection, resulting in a minimum over-all reflection. This is a null method which can be done quite accurately. If the position is not correct, the resulting reflection will generally have zero average deviation, but will not be minimized (see Fig. 3-2). To cancel completely, the magnitude and position must both be correct simultaneously.

Sugarman[2] has derived a relationship between ρ (observed) and a single lumped reactive element in a continuous transmission line, where the observing system has a limited risetime.

$$\rho_{obs} = \frac{C\ Z_o}{2\ T_r}$$

Where C is the magnitude of lumped capacitance shunted to ground in a continuous system of impedance Z_o. T_r is system risetime.

Also, for inductive discontinuities,

$$\rho_{obs} = \frac{L}{2\ T_r Z_o}$$

An impedance in a transmission line will always have a finite length. It is convenient, however, to refer to short length of line (short compared to system risetime) as having an equivalent lumped amount of reactance. If the impedance of a particular section is low, that portion will exhibit an equivalent shunt capacitance (ρ will be negative). If impedance is high, it will have an equivalent series inductance (ρ will be positive).

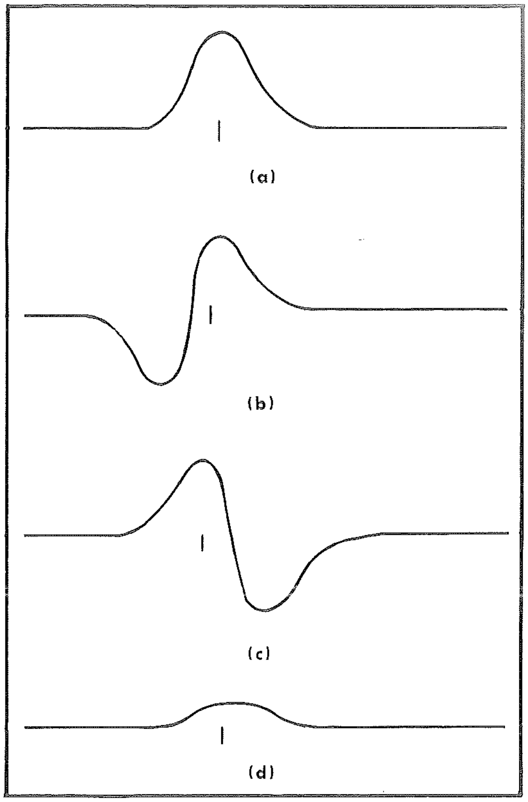


Fig. 3-2. The location of a discontinuity on a line can be determined by adding a known discontinuity that cancels the original to give no reflection. The original discontinuity is shown in (a). If a discontinuity is added ahead of the orignal, the effect is as in (b). If the added discontinuity is behind the original, the waveform in (c) results. If the added discontinuity is correctly placed, but of insufficient magnitude, the result is as in (d).

Using the Type 281 TDR Pulser for Systems Other Than 50 Ohms

The Type 281 pulser can be used to check systems which have impedances above 50 ohms by using a GR type 874-X insertion unit, Tektronix Part No. 017-0030-00.

Into the insertion unit is soldered a precision resistor whose value is equal to the impedance of the system being checked minus 50 ohms (vertical sampling unit impedance); for example, to check a 300-ohm system a 250-ohm resistor would be soldered into the insertion unit. The insertion unit is then connected between the input connector on the vertical sampling unit and the Type 281.

Measurements are then made as if a 50-ohm system were being checked.

To check systems whose impedance is below 50 ohms, connect the Type 281 directly onto the vertical sampling unit, then use the formula found in the paragraphs under "Impedance Measurements" in this section to determine the impedance of the reflection.

References:

(1) Lewis and Wells, "Millimicrosecond Pulse Techniques", Second Edition, Pergamon Press 1955, p. 31.

(2) Sugarman, R. and Merritt, F., "Reflections Coefficient of 125-ohm Amphenol Connectors", Brookhaven National Laboratory, March 1958.

SECTION 4
CIRCUIT DESCRIPTION

Normally a current of approximately 18 ma flows from Pin D of J10 (+100 volts) through R43, D40, Q44, R45 and into the load. The load is formed by two parallel 50-ohm coaxial connectors which have been connected to form a 50-ohm air line section.

Q44 acts as a non-saturated current switch which switches the current available to the load from 18 to zero ma. Q44 is driven by tunnel diode D22. Tunnel diode D22 along with L25, R11, R22 and R23 forms a free-running monostable (one-shot) oscillator.

Current for the free-running monostable oscillator is obtained from pins B and C of J10. Since the voltage available from pins B and C of the Probe Power connector on the various vertical sampling units differs, R10 has been installed in the circuit to insure that pin C of J10 will always be approximately 12 volts more positive than pin B.

When D22 switches to its high state, it causes Q44 to quickly turn off, since its cathode is ac coupled to the emitter of Q44 by C34. D22 is also dc coupled to the emitter of the grounded base switch Q34 through L34. Q34 saturates, reverse-biasing D40, holding off Q44.

After about 5 μsec, D22 switches back to its low state, at which time it pulls up the emitter of Q44 about 0.4 volt. This action would cause an aberration to appear on the display, except that the emitter of Q44 had been reverse biased 0.5 volt by the discharge action of R34 on C34 during the 5 μsec interval.

When D22 has reverted to its low state, Q34 changes from its saturated condition to its cutoff condition (it takes about 1 μsec to do this); Q44 then turns on and the 18-ma current is reestablished in the load.

SECTION 5
MAINTENANCE

Visual Inspection

If trouble occurs in the Type 281 TDR Pulser, make sure the associated equipment is operating and the controls are properly set. If it is determined that the trouble is definitely in the Type 281, a visual check may reveal the cause. Defects such as loose or broken connections, frayed or broken cables, damaged connectors, and burned components can generally be detected by a visual inspection. Except for heat-damaged components the remedy for such defects is obvious. Overheating of components is usually a sympton of other, less apparent troubles in the circuit. For this reason, it is essential to determine the actual cause of overheating before the damaged parts are replaced; otherwise, the damage may be repeated.

Etched-Wiring Circuit Board

Removal. Remove the four screws (two screws in each side) holding the two castings together. With one hand, grasp the Type 281 so the two plastic covers are held against the casting with the cable; using the other hand, disengage the other casting by pulling gently on the GR connector. The etched-wiring circuit board is now separated from the remaining casting by grasping the edge of the plastic cover between the etched-wiring circuit board and the casting in one hand, and the GR connector on the remaining casting in the other hand and pulling the two straight apart.

To completely remove the etched-wiring circuit board, one end of the cable must be unsoldered.

NOTE

Do not twist, turn, or pull the two castings, or the etched-wiring circuit board and casting apart at any angle other than a straight angle.

Attachment. Resolder the cable if it has been unsoldered, then affix a plastic cover into place on each casting. Now guide one end of the center pin, which protrudes from both sides of the etched-wiring circuit board, into the center hole on the back side of the GR connector mounted on the casting. Press the etched-wiring circuit board firmly into place.

Install the second casting in the same manner as the first. Then reinstall the four screws into the castings.

Parts Removal and Replacement

Most parts in the Type 281 can be replaced without detailed instructions. Some, however, are best removed and replaced by using definite procedures contained in the following paragraphs. (Parts ordering information is included in the Parts List section of this manual.)

Leadless Ceramic Capacitor Replacement. Care must be exercised in soldering the ceramic capacitors into place as unevenly applied heat will cause the capacitor to shatter. It is recommended that the procedure described below be followed in replacing the ceramic capacitors.

Apply enough heat to the top of the ceramic capacitor to allow the components which are soldered to it to be removed. Remove any components mounted directly on the opposite side of the etched-wiring circuit board from the ceramic capacitor being replaced.

Apply the tip of the soldering iron to the area directly on the opposite side of the etched-wiring circuit board from the ceramic capacitor to be replaced. Apply only enough heat to the etched-wiring circuit board to allow the leadless ceramic capacitor to be removed and the new leadless ceramic capacitor to be attached. Resolder the remaining components back into their original positions.

NOTE

Silver-bearing solder is used to establish a bond to the leadless ceramic capacitors. This bond may be broken by repeated use of ordinary tin-lead solder.

Transistor Replacement. Transistors should not be replaced unless they are actually defective. Transistor defects usually take the form of the transistor opening, shorting, or developing excessive leakage. To check a transistor for these and other defects, use a transistor curve display instrument such as a Tektronix Type 575. However, if a good transistor checker is not available, a defective transistor can

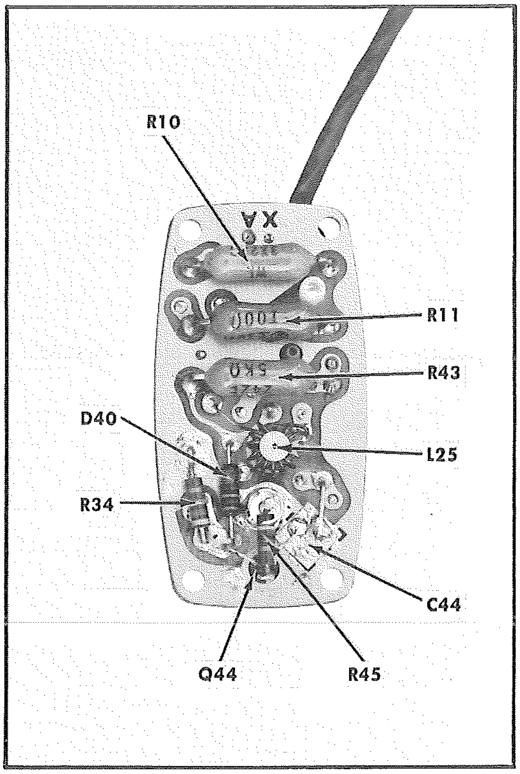


Fig. 5-1. Component locations on front side of etched-wiring circuit board.

be found by measuring the transistor forward-to-back resistance using proper ohmmeter resistances, or by using the substitution method. A component location guide is given in Figs. 5-1 and 5-2.

To check a transistor using an ohmmeter, know your ohmmeter ranges, the currents they deliver, and the internal battery voltage(s). If your ohmmeter does not have sufficient resistance in series with its internal voltage source, excessive current will flow through the transistor under test. Excessive current and/or high internal source voltage may permanently damage the transistor.

NOTE

As a general rule, use the R×1 k range where the current is usually limited to less than 2 ma and the internal voltage is usually 1½ volts. You can quickly check the current and voltage by inserting a multimeter between the ohmmeter leads and measuring the current and voltage for the range you intend to use.

When you know which ohmmeter ranges will not harm the transistor, use those ranges to measure the resistance with the ohmmeter connected both ways as given in Table 5-1.

TABLE 5-1

Transistor Resistance Checks

Ohmmeter Connections*	Resistance Readings That Can Be Expected Using the R×1k Range
Emitter-Collector	High reading both ways (about 60 k to around 500 k).
Emitter-Base	High reading one way (about 200 k or more). Low reading the other way (about 400 Ω to 2.5 k).
Base-Collector	High reading one way (about 500 k or more). Low reading the other way (about 400 Ω to 2.5 k).

***Test prods from the ohmmeter are first connected one way to the transistor leads and then the test prods are reversed (connected the other way). Thus, the effects of the polarity reversal of the voltage applied from the ohmmeter to the transistor can be observed.**

If there is doubt about whether the transistor is good or not, substitute a new transistor, but first be certain the circuit voltages applied to the transistor are correct before making the substitution.

When checking transistors by substitution, be sure that the voltages and loads on the transistor are normal before making the substitution. If a transistor is substituted without first checking out the circuit, the new transistor may immediately be damaged by some defect in the circuit.

Tunnel Diode Replacement. If the tunnel diode is replaced, it may be necessary to select a new value for R22 and R25.

CAUTION

The tunnel diode is very sensitive to heat. Extreme care must be used in soldering or unsoldering it. A heat sink such as a pair of long nose pliers should be attached to the case of the tunnel diode and minimum heat should be used to make the solder connection.

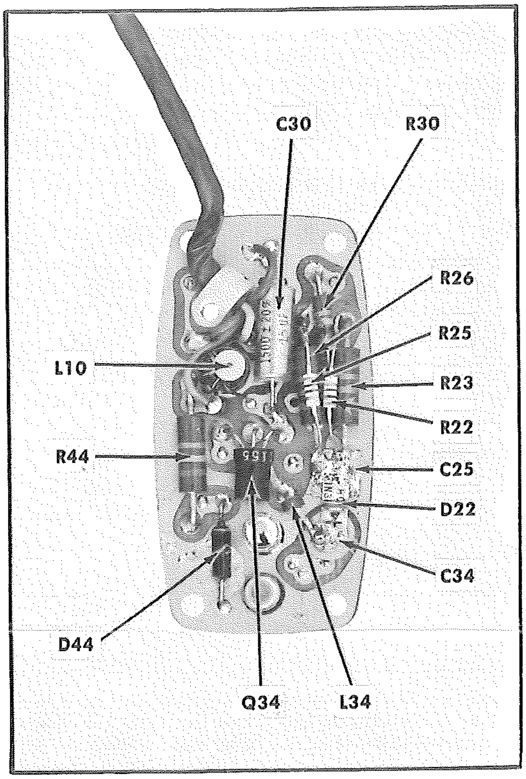


Fig. 5-2. Component locations on back side of etched-wiring circuit board.

R22 is selected to allow the free-running monostable (one-shot) oscillator to run at the proper duty factor and to match the peak voltage of tunnel diode D22.

R25 is selected to match the "on" voltage of tunnel diode D22 to Q34.

Soldering Precautions and Procedures. Premium workmanship and materials are used in the construction of the etched-wiring circuit board. Each component hole is "through-plated" to the opposite side of the card, giving it strength and resoldering durability. With care, components can be removed and replaced on the etched-wiring circuit board numerous times without lifting the etched-wiring circuit from the glass laminate.

Use solder containing 3% silver (Tektronix Part No. 251-0514-00) and a 35- to 40-watt soldering iron with a small wedge-shaped tip for soldering and unsoldering components. Let the iron reach operating temperature. Use needle nose pliers to grip the component lead next to its body before applying heat. Apply heat and lift the lead out of its mounting hole.

When installing a new component, bend the leads to match the length and position of the leads of the removed part. Heat the solder in the mounting hole to a liquid state and shake out the excess. Tin the prepared leads of the new part, then install the leads in the mounting holes. When soldering, do not apply excessive heat nor leave the soldering iron on the etched-wiring circuit board an undue length of time. Use sufficient heat, however, along with a small amount of new solder, to establish a full flow, clean joint.

SECTION 6
PARTS LIST AND SCHEMATICS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix Field Office.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number including any suffix, instrument type, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix Field Office will contact you concerning any change in part number.

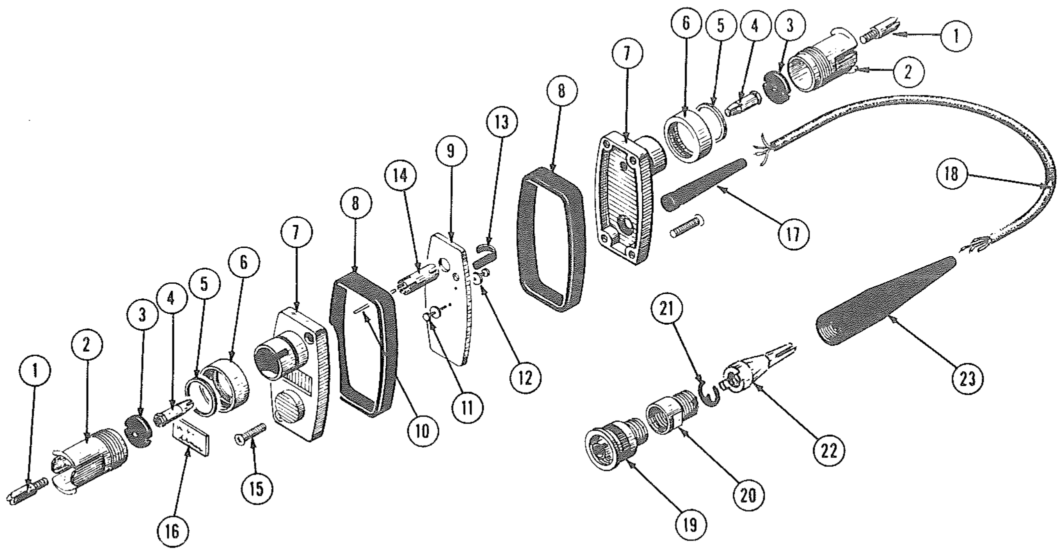
ABBREVIATIONS AND SYMBOLS

a or amp	amperes
BHS	binding head steel
C	carbon
cer	ceramic
cm	centimeter
comp	composition
cps	cycles per second
crt	cathode-ray tube
CSK	counter sunk
dia	diameter
div	division
EMC	electrolytic, metal cased
EMT	electroyltic, metal tubular
ext	external
f	farad
F & I	focus and intensity
FHS	flat head steel
Fil HS	fillister head steel
g or G	giga, or 10^9
Ge	germanium
GMV	guaranteed minimum value
h	henry
hex	hexagonal
HHS	hex head steel
HSS	hex socket steel
HV	high voltage
ID	inside diameter
incd	incandescent
int	internal
k or K	kilohms or kilo (10^3)
kc	kilocycle
m	milli, or 10^{-3}
mc	megacycle
mm	millimeter
meg or M	megohms or mega (10^6)
met.	metal
μ	micro, or 10^{-6}
n	nano, or 10^{-9}
Ω	ohm
OD	outside diameter
OHS	oval head steel
p	pico, or 10^{-12}
PHS	pan head steel
piv	peak inverse voltage
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
Prec	precision
PT	paper tubular
PTM	paper or plastic, tubular, molded
RHS	round head steel
rms	root mean square
sec	second
Si	silicon
S/N	serial number
t or T	tera, or 10^{12}
TD	toroid
THS	truss head steel
tub.	tubular
v or V	volt
Var	variable
w	watt
w/	with
w/o	without
WW	wire-wound

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number.
000X	Part removed after this serial number.
*000-000	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, or reworked or checked components.
Use 000-000	Part number indicated is direct replacement.
(screwdriver symbol)	Internal screwdriver adjustment.
(box symbol)	Front-panel adjustment or connector.

MECHANICAL PARTS



REF. NO.	PART NO.	SERIAL/MODEL NO. EFF.	SERIAL/MODEL NO. DISC.	Q T Y.	DESCRIPTION
1	132-0029-00			2	INNER CONDUCTOR
2	132-0002-00			2	SLEEVE, conductor
3	132-0028-00			2	INSULATOR
4	132-0122-00			2	INNER TRANSITION
5	132-0007-00			2	SNAP RING
6	132-0001-00			2	NUT, coupling
7	204-0227-01			1	BODY, input
	204-0227-02			1	BODY, output
8	354-0284-00			2	HOLDER, etched circuit board
9	388-0673-02			1	ASSEMBLY, etched circuit board, wired
	- - - - - -			-	includes:
10	214-0648-00			1	CONTACT, electrical
11	214-0565-00			2	FASTENER, pin press
12	132-0114-00			2	WASHER, teflon
13	343-0088-00			1	CLAMP, cable
	388-0673-01			1	BOARD, etched circuit
	- - - - - -			-	includes:
14	337-0795-00			1	SHIELD, contact
	388-0673-00			1	BOARD, etched circuit
15	211-0115-00			4	SCREW, 2-56 x $\frac{1}{2}$ inch, OHS phillips slot
16	334-1001-00			1	PLATE, identification (INPUT)
	334-1002-00			1	PLATE, identification (OUTPUT)
17	200-0488-00			1	COVER, relief cable
18	175-0342-00			FT	CABLE, 4 conductor, 15 inches
19	131-0268-00			1	CONNECTOR, Bendix
20	103-0039-00			1	ADAPTER, grounding
21	354-0224-00			1	RING, ground
22	343-0128-00			1	CLAMP, cable
23	200-0650-00			1	CABLE NIPPLE, electrical

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ELECTRICAL PARTS

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Description				

Capacitors

C25	283-0072-00	0.01 μf	Cer	w/o leads		20%
C30	290-0135-00	15 μf	EMT		20 v	20%
C34	283-0121-00	0.001 μf	Cer	w/o leads		20%
C44	283-0072-00	0.01 μf	Cer	w/o leads		20%

Diodes

D22	152-0078-00	Tunnel, 1N3130 50 ma
D40	*152-0185-00	Silicon, replaceable by 1N3605
D44	152-0034-00	Zener, 1N753, 0.4 w, 6.2 v, 10%

Inductors

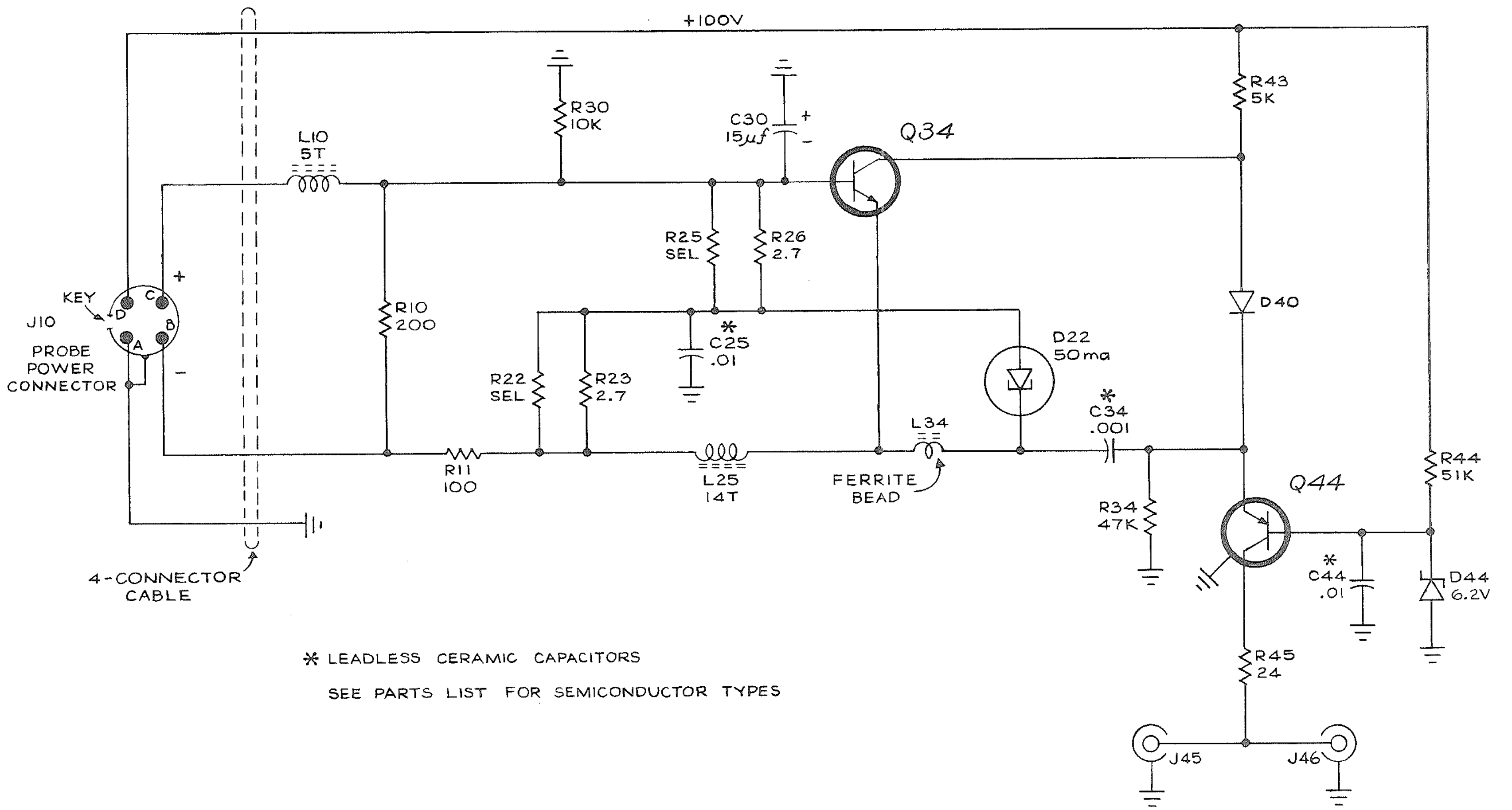
L10	*120-0407-00	Toroid, 5 turn
L25	*120-0382-00	Toroid, 14 turn single
L34	276-0543-00	Core, ferrite

Transistors

Q34	*151-0155-00	Replaceable by 2N2925
Q44	*153-0537-00	Checked 2N3546

Resistors

R10	308-0385-00	200 Ω	3 w	WW	5%
R11	308-0075-00	100 Ω	3 w	WW	20%
R22	Selected		1/10 w	Comp	5%
R23	307-0051-00	2.7 Ω	½ w	Comp	5%
R25	Selected		1/10 w	Comp	5%
R26	307-0051-00	2.7 Ω	½ w	Comp	5%
R30	315-0103-00	10 k	¼ w	Comp	5%
R34	315-0473-00	47 k	¼ w	Comp	5%
R43	308-0307-00	5 k	3 w	WW	1%
R44	301-0513-00	51 k	½ w	Comp	5%
R45	315-0240-00	24 Ω	¼ w	Comp	5%



* LEADLESS CERAMIC CAPACITORS

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

GTN
665

TYPE 281

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TDR PULSER