TEKTRONIX®

TYPE 284

PULSE GENERATOR

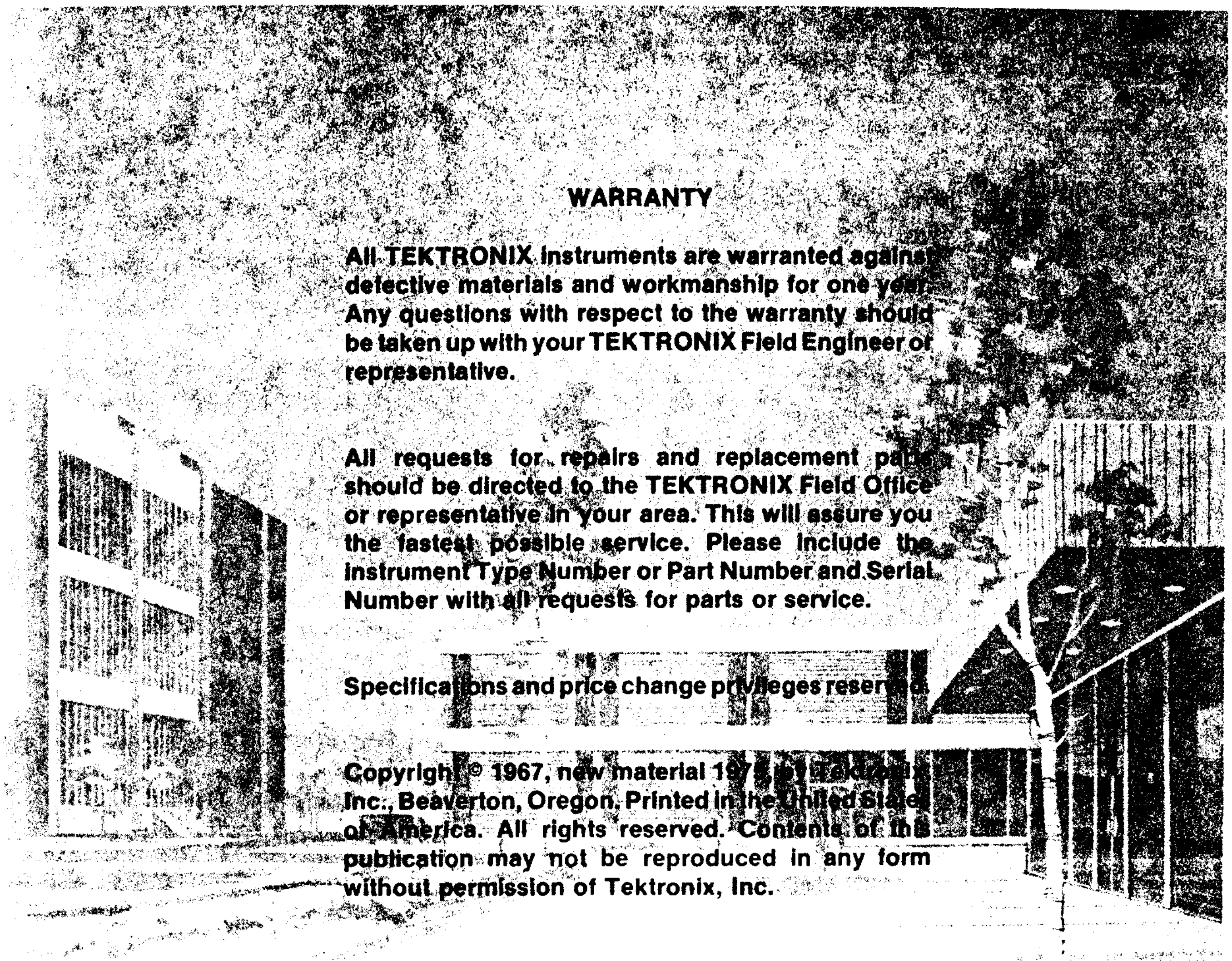
INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

Serial Number ____________________

070-0754-01

1067



WARRANTY

All TEKTRONIX instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your TEKTRONIX Field Engineer or representative.

All requests for repairs and replacement parts should be directed to the TEKTRONIX Field Office or representative in your area. This will assure you the fastest possible service. Please include the instrument Type Number or Part Number and Serial Number with all requests for parts or service.

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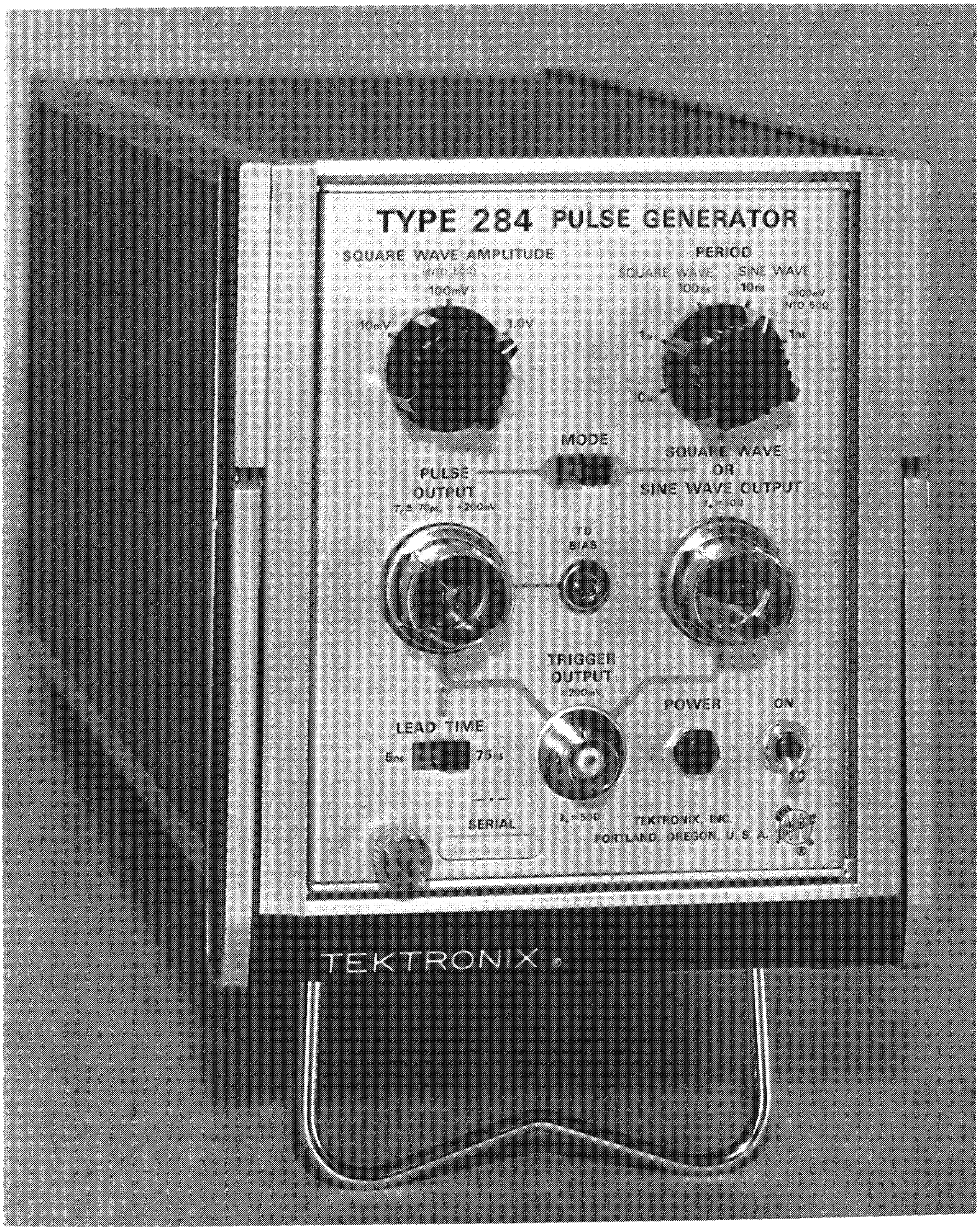


Fig. 1-1. Type 284 Pulse Generator.

SECTION 1
SPECIFICATION

Introduction

The Tektronix Type 284 Pulse Generator provides specialized signals that are defined sufficiently to allow them to be used to verify the performance of fast general purpose and sampling oscilloscopes. Specifically, the signals allow a check of the vertical amplifier risetime, deflection factor accuracy, transient response and pulse flatness deviation (aberrations); plus checking upon the accuracy of horizontal sweep rates. The fast pulse may be used as a signal source for testing the risetime of transistors and amplifiers, or for Time Domain Reflectometry.

Each signal provides a trigger signal for externally triggering an oscilloscope time base generator. The fast pulser also generates a trigger in advance of the fast step, providing the pretrigger signal necessary for some sampling oscilloscopes.

Regulated DC power supplies assure stable operation over a wide range of line voltage and frequency. Circuits are temperature compensated to maintain both amplitude and frequency accuracies over a wide temperature range.

The electrical characteristics that follow are divided into two categories. Information listed in the Performance Requirement column applies directly to the instrument performance and is a commitment by Tektronix, Inc., to the customer. Information listed in the Operational Information column is for clarification and operator convenience and is not to be used to specify any performance limits for the instrument. Characteristics listed in the Performance Requirement column are checked by the Performance Check procedure, Section 5, of this manual. Any instrument not meeting these performance limits can be brought within specifications by performing the Calibration Procedure, also in Section 5 of this manual. The performance requirements apply over an ambient temperature range of 0°C to +50°C, at altitudes up to 5000 feet, with upper temperature limit decreased by 1°C per 1000 feet from 5000 feet to 15,000 feet, after a warm up period of five minutes, providing the convection cooling holes (bottom and both sides) are not obstructed. The unit may be stored in temperatures from −40°C to +65°C.

ELECTRICAL CHARACTERISTICS

Characteristic	Performance Requirement	Operational Information
SINE WAVE OR SQUARE WAVE OUTPUT		
Calibrated PERIOD Signals		
Square Wave	10 µs, 1 µs and 100 ns	For checking sweep rates.
Sine Wave	10 ns and 1 ns	
Signal Amplitude Into 50 Ω		
Square Wave	1 V, 100 mV and 10 mV	For checking deflection factors.
Sine Wave	100 mV	For checking horizontal timing only.

Accuracies		SIGNAL					SIGNAL		
		Square Wave			Sine Wave		Square Wave		
	PERIOD	10 µs	1 µs	100 ns	10 ns	1 ns	10µs	1 µs	100 ns
Timing		±0.5%	±0.5%	±0.1%	±1%	±1%	Amplitude accuracies in this column are based upon DC testing of attenuators.		
Amplitude	1 V	±0.5%	±0.5%	±2%[1]					
	100 mV				±20%	±20%	±1%	±1%	±2.5%[1]
	10 mV						±1.5%	±1.5%	±3%[1]

Characteristic	Performance Requirement	Operational Information
Square Wave Duty Factor	48% to 52%	
Trigger Output Signal Amplitude, into 50 Ω		
Square Wave	+200 mV, ±20%	
Sine Wave	≥ 120 mV peak to peak	

[1]**Measured 20 ns after transition.**

ELECTRICAL CHARACTERISTICS (cont)

PULSE GENERATOR

Characteristic	Performance Requirement	Operational Information
Repetition Rate	50 kHz, ±10%	20 μs period
Risetime, 10% to 90%	≤70 ps	
Amplitude into 50 Ω	≥+200 mV	Step beginning adjusted to zero volts during calibration.
Pulse Flatness Deviation	With S-6 Sampling Head. During first 1.2 ns from step: ≤+3%, −7% for a total of ≤10% p-p. From 1.2 ns to 2 ns: ≤+6%, −6% for a total of ≤10% p-p. After 2 ns: ≤+2%, −2% for a total of ≤2% p-p. With S-2 Sampling head. During first 2 ns from step: ≤+5%, −5% for a total of ≤10% p-p. After 2 ns: ≤+2%, −2% for a total of ≤2% p-p.	Aberrations
Pulse Duration, 50% to 50%	1 μs, +100%, −0%	

TRIGGER OUTPUT SIGNAL WHEN USING PULSE GENERATOR

Amplitude	+200 mV, ±20%	
Risetime, 10% to 90%	≤3 ns	
Pulse Duration, 50% to 50%	≥10 ns	
Trigger Pulse Occurrence In Advance of PULSE OUTPUT Signal	5 ns or 75 ns ±5 ns or 150 ns, ±7 ns[2]	Selectable by LEAD TIME switch

POWER LINE REQUIREMENTS

Line Voltage Ranges		
115 Volt Line	90 VAC to 136 VAC	
230 Volt Line	180 VAC to 272 VAC	
Frequency Range	48 Hz to 440 Hz	
Maximum Power Consumption	Approximately 6.5 Watts at 115 VAC 60 Hz	
Fuse Data	Use Fuses listed in Parts List	

MECHANICAL CHARACTERISTICS

Dimensions

Height 6¾ inches

Width 4½ inches

Length 15 inches

[2]Serial numbers B010100-B020235; 5 ns or 50 ns, ±5 ns.
Serial numbers B07000 and up; 5 ns or 75 ns or 150 ns.

Approximate dimensions include knobs and connectors.

Construction—Aluminum alloy chassis with epoxy laminated circuit boards. Front panel is anodized aluminum.

Accessories—An illustrated list of the accessories supplied with the Type 284 is at the end of the Mechanical Parts List pullout pages.

SECTION 2
OPERATING INSTRUCTIONS

General

This section of the manual provides the basic information required for operation of the Type 284. Instructions include function of the front panel controls and connectors, first time operation, general operating information, and basic applications.

AC Power Considerations

The Type 284 can be operated from either a 115 or a 230-volt line, at frequencies from 48 to 440 Hz. The AC line voltage selector panel and fuse holder is located on the rear panel of the Type 284.

CAUTION

The Type 284 should not be operated with the voltage selector in an incorrect position for the nominal line voltage applied. Operation of the instrument in a wrong voltage range will either provide incorrect operation or damage the instrument.

The AC line voltage selector panel on the rear of the Type 284 indicates nominal line voltage selected. See Fig. 2-2. Check to see that the plastic indicating tab of the line selector is protruding through the selector panel, indicating that its position is proper for applied nominal line voltage (115 or 230 AC Volts).

The selector assembly cover can be removed to change the nominal line from 115 Volts to 230 Volts or vice versa, or to replace the fuses. Use the following procedure:

1. Disconnect the instrument from the power source.

2. Loosen the two captive screws which hold the cover onto the voltage selector assembly, then pull to remove the cover.

3. To convert from 115-volt to 230-volt nominal line voltage or vice versa, pull out the Voltage line selector switch bar; turn it 180° and plug it back into the remaining holes. Change the line cord to fit the power source receptacle or use a line cord adapter.

4. It is not necessary to change fuses if the range is changed; however, in the 230 volt range both fuses are in use. Also in checking the fuses, the upper fuse (1/10 A) for the 115 volt range has a nominal resistance of approximately 80 ohms, and the lower fuse (1/16 A) for the 230 volt range has a nominal resistance of approximately 150 ohms.

5. Re-install the selector assembly cover and tighten the two captive screws.

6. Before applying power to the instrument, check that the indicating tab of the line selector is protruding through the selector panel indicating that its position is proper for the applied nominal line voltage range (115 or 230). In the 115 volt nominal range, the regulating range is from 90 to 136 volts. In the 230 volt nominal range the regulating range is from 180 to 272 volts.

Handle and Stand

The bail-type handle of the Type 284 can be pulled out for convenient carrying of the instrument. When not in use, the handle folds out of the way into the trim of the instrument cabinet. See Fig. 2-1.

The bail-type stands are mounted beneath the cabinet. The stands permit the Type 284 to be tilted for convenient operation as shown in Fig. 2-1. The instrument may also be set on the rear feet either for operation or storage.

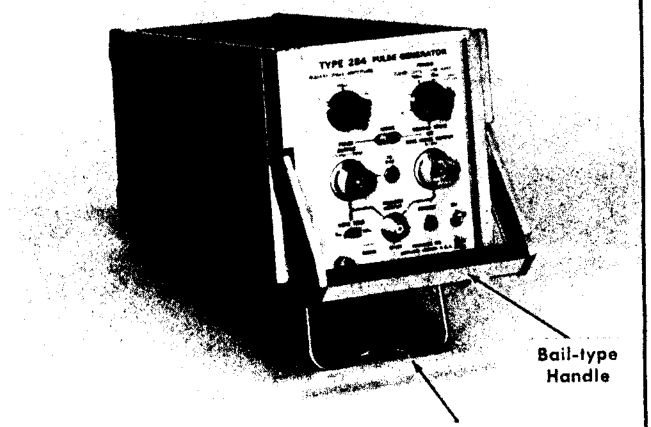
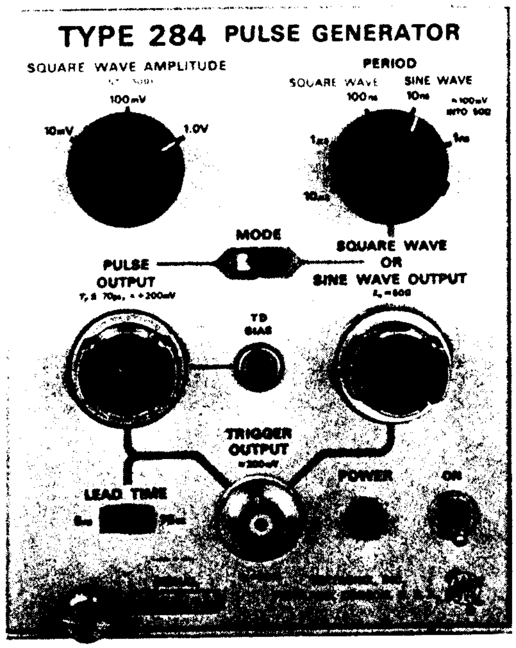


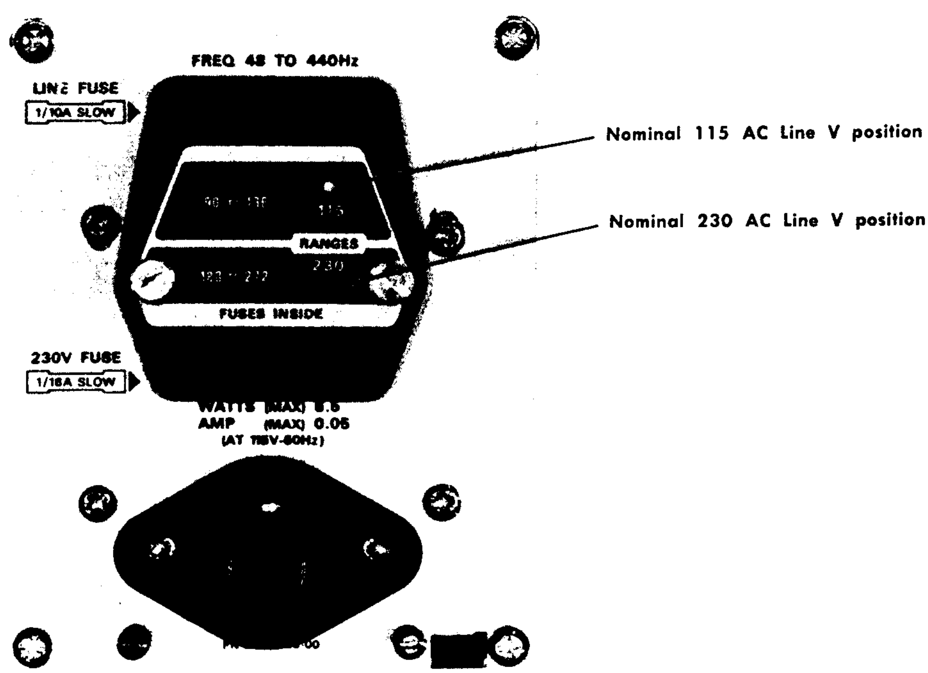
Fig. 2-1. Type 284 showing handle and stand.

CONTROLS AND CONNECTORS

A brief description of the function and operation of the front and rear panel controls and connectors follows. Fig. 2-2 shows the front and rear panels of the instrument. More detailed operation is given in this section under General Operating Information.



(A) Front Panel



(B) Rear Panel

Fig. 2-2. Front and rear-panel controls and connectors.

Front Panel

SQUARE WAVE AMPLITUDE	Selects three amplitudes of square wave output signal voltages: 10 mV, 100 mV, and 1 V (into a 50 Ω load).
PERIOD	Selects the time periods of the SQUARE WAVE OR SINE WAVE outputs. The SQUARE WAVE output time periods are 10 μs, 1 μs and 100 ns with amplitude selected by the SQUARE WAVE AMPLITUDE switch. The SINE WAVE time periods are 10 ns and 1 ns with approximate amplitudes of 100 mV (into a 50 Ω load).
MODE	Selects either the PULSE OUTPUT or the SQUARE WAVE OR SINE WAVE OUTPUT to their respective connectors.
PULSE OUTPUT	Output connector for the PULSE OUTPUT (rise time $\leq$ 70 ps, amplitude $\geq$ 200 mV).
TD BIAS	Adjusts the bias of the tunnel diode affecting the PULSE OUTPUT.
LEAD TIME	Selects either 5 ns or 75 ns of LEAD TIME of the TRIGGER OUTPUT signal with reference to the PULSE OUTPUT signal.
TRIGGER OUTPUT	Output connector for the trigger signal pickoff, a portion of the signal from either the PULSE OUTPUT or the SQUARE WAVE OR SINE WAVE OUTPUT depending upon the position of the MODE switch.
SQUARE WAVE OR SINE WAVE OUTPUT	Output connector for the SQUARE WAVE OR SINE WAVE OUTPUT as selected by the SQUARE WAVE AMPLITUDE and PERIOD switches.
POWER	Light: Indicates when POWER switch is ON and the instrument is connected to a power source. Switch: Applies power to the instrument.

Rear Panel

Line voltage selector	Switching assembly to select the nominal operating voltage (115 V or 230 V). This assembly also includes the line fuses.
Power Connector	Input connector for line power.

NOTE

Some of the equipment presently used in the Operating Instructions is no longer available from Tektronix, Inc.; following is a list of equipment that may be substituted. The equipment setups throughout the Operating Instructions will vary depending on which equipment is used. The substituted equipment is presently being used in the Performance Check/Calibration Procedure.

Sampling Applications: 7T11 Sampling Sweep Unit, two 7S11 Sampling Sweep Units, and Sampling Heads S-1, S-2, S-6.

TDR Applications: 7S12 TDR and General Purpose Sampler with S-6 Sampling Head and S-52 Pulse Generator Head.
A 7000 series mainframe is needed for the plug-ins listed above.

FIRST-TIME OPERATION

The following steps will demonstrate the use of the controls and connectors of the Type 284. It is recommended that this procedure be followed for familiarization with this instrument. In this procedure a Tektronix Type 561A Oscilloscope is used with a Type 3S1 Dual-Trace Sampling Unit and a Type 3T2 Sampling Sweep Unit. If other equipment is used the control settings and the procedure will be different. If you are not familiar with the operation of the oscilloscope with its sampling plug-in units, read the First Time Operation portions of the manuals for these instruments before proceeding.

Setup information

1. Set controls as follows:

Type 284

SQUARE WAVE AMPLITUDE	1.0 V
PERIOD	10 μs
MODE	SQUARE WAVE OR SINE WAVE OUTPUT (to right)
LEAD TIME	5 ns

Type 3S1

Display Mode switch	Chan A
Smooth-Normal switch	Normal
A Position	Midrange
B Position	Midrange
DC Offset ±1 V, Channel A	Midrange (5 turns from one end)
DC Offset ±1 V, Channel B	Midrange (5 turns from one end)
mVolts/Div, Channel A	200
mVolts/Div, Channel B	200
Variable mVolts/Div (both channels)	Cal
Invert-Norm switch, Channel A	Norm
Invert-Norm switch, Channel B	Norm
Internal Trigger	Off
Sampling Mode	Triggered

Type 3T2

Time Position	Fully Clockwise
Time Position Fine	Fully Clockwise
Horiz Position	Midrange
Samples/Div	Midrange
Range	10 μs

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Start Point	With Trigger
Display Mag	×1
Time Magnifier	×1
Time Magnifier Variable	Cal
Display Mode	Normal
Trigger Sensitivity	Fully Clockwise
Recovery Time	Midrange
Polarity	—
Source	Ext
Samples/Div (an Internal Switch)	100 (up position)

2. Connect the Type 284 to a power source that meets the voltage and frequency requirements of the instrument. Check to see that the plastic indicating tab on the line selector panel on the rear of the instrument is protruding through the selector panel indicating that its position is proper for the applied nominal line voltage (115 V or 230 V). See AC Power Considerations in this section for instructions to change the nominal line voltage if necessary.

3. Set the Power switch to ON on the Type 284 and also on the Test Oscilloscope, and allow five minutes warm up before proceeding.

Square wave output

4. Connect the Type 284 SQUARE WAVE OUTPUT signal through a 50 Ω coaxial cable with GR type connectors to the A input Connector on the Type 3S1. Connect the TRIGGER OUTPUT signal through a 50 Ω BNC type coaxial cable to the 50 Ω Trigger Input connector on the Type 3T2.

5. Turn the Trigger Sensitivity fully counterclockwise, then slowly clockwise until a stable display is obtained. See Fig. 2-3A. Normal slight changes of the Samples/Div control on the Type 3T2, the A Position control on the Type 3S1 may be necessary to display this waveform.

6. Change the Type 284 PERIOD switch to 1 μs and change the Type 3T2 Range switch to 1 μs (Time/Div 100 ns). Observe a similar display to that in preceeding step.

7. Change the Type 284 PERIOD switch to 100 ns and change the Type 3T2 Range switch to 100 ns (Time/Div 10 ns). Observe a display similar to Fig. 2-3B.

8. Change the Type 284 SQUARE WAVE AMPLITUDE switch to 100 mV and change the Type 3S1 Channel A mVolts/Div switch to 50. Observe a 2 division display similar to the 5 division display in Fig. 2-3B.

9. Change the Type 284 SQUARE WAVE AMPLITUDE switch to 10 mV and change the Type 3S1 Channel A mVolts/Div switch to 5. Observe 2 divisions of display with the normal noise of the Type 3S1 showing up at this sensitivity.

Sine Wave Output

10. Move the trigger signal coaxial cable on the Type 3T2 from the 50 Ω input connector to the 1 MΩ/UHF Sync connector. Set the Type 284 PERIOD switch to 10 ns SINE WAVE and set the Channel A mVolts/Div switch on the Type 3S1 to 50. Slight change in the Trig. Sensitivity control on the Type 3T2, and in the A Position control on the Type 3S1 may be necessary to obtain a display similar to Fig. 2-4A.

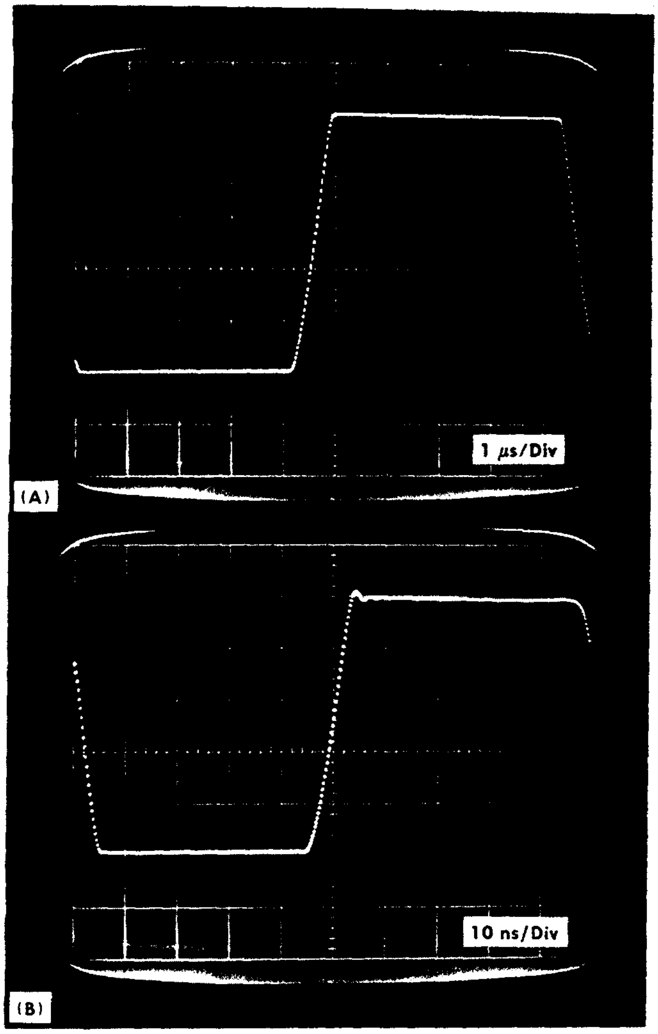

Fig. 2-3. Typical SQUARE WAVE OUTPUT display (1 Volt into 50 Ω load) for two time periods.

11. Set the PERIOD switch to 1 ns SINE WAVE on the Type 284 and set the Time Magnifier switch on the Type 3T2 to ×10 (Time/Div 1 ns). Observe the 1 ns period sine wave similar to Fig. 2-4B. Slight change in the Trig. Sensitivity control, and the Recovery Time control on the Type 3T2 may be necessary to obtain a stable display.

Pulse Output

12. Move the signal coaxial cable on the Type 284 to the PULSE OUTPUT connector, and set the MODE switch to the PULSE OUTPUT position (to the left). Set the Time Magnifier switch on the Type 3T2 to ×1 (Time/Div 10 ns), and turn the Trig. Sensitivity switch fully counterclockwise then clockwise for a stable trace. Change the LEAD TIME switch to 75 ns position and note the change in delay time of approximately 70 ns as shown in Fig. 2-5B.

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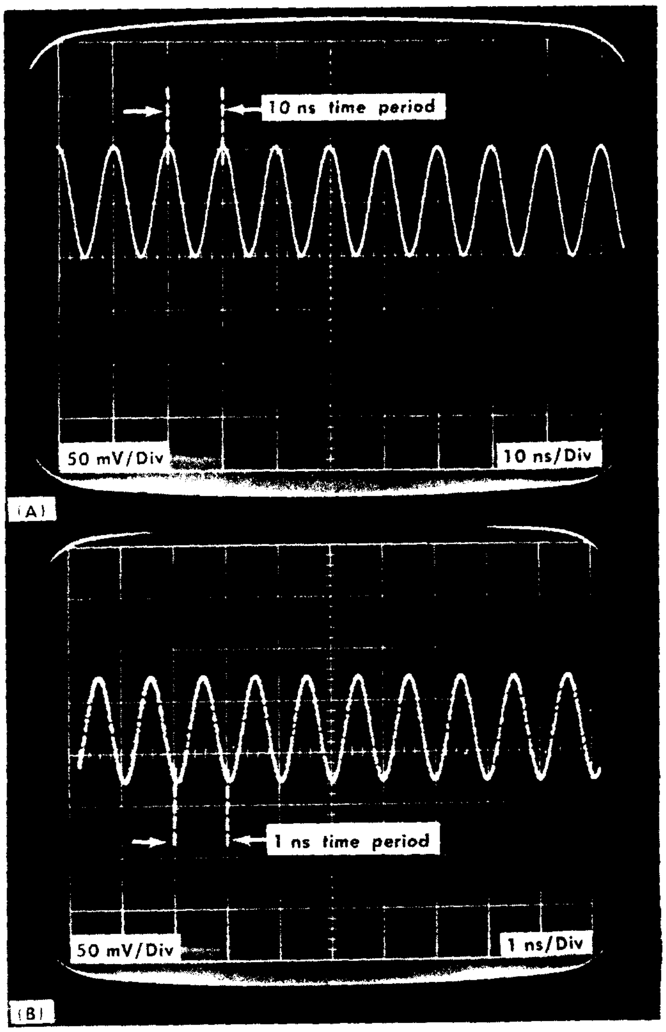


Fig. 2-4. Typical SINE WAVE OUTPUT display showing (A) 10 ns and (B) 1 ns time period.

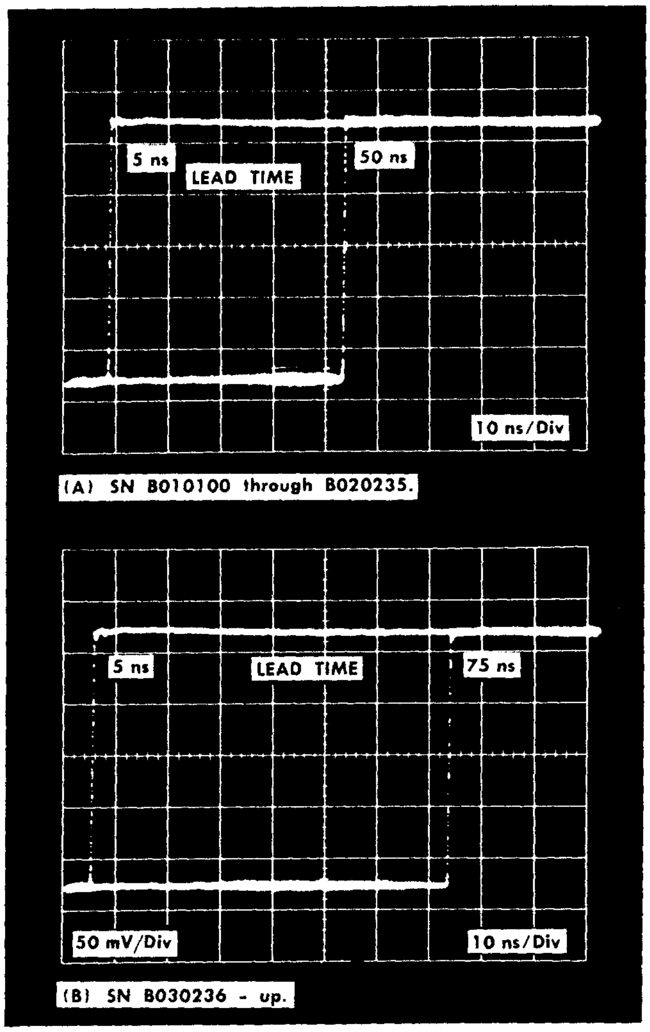


Fig. 2-5. Typical PULSE OUTPUT display, showing a double exposure of two positions of LEAD TIME switch.

NOTE

Since the tunnel diode pulse generator is an integral part of the PULSE OUTPUT connector, mechanical strain on the PULSE OUTPUT connector will cause slight mechanical changes in the tunnel diode assembly. Slight adjustment of the TD BIAS control, a screwdriver adjustment on the front panel, will correct the display. For the TD BIAS adjustment procedure see the General Operating Instructions.

CONTROL SETUP CHART

Fig. 2-6 is a control setup chart for the front panel of the Type 284. This figure may be reproduced and used as a test setup record for special applications or procedures. It may also serve as a training aid to facilitate control operation.

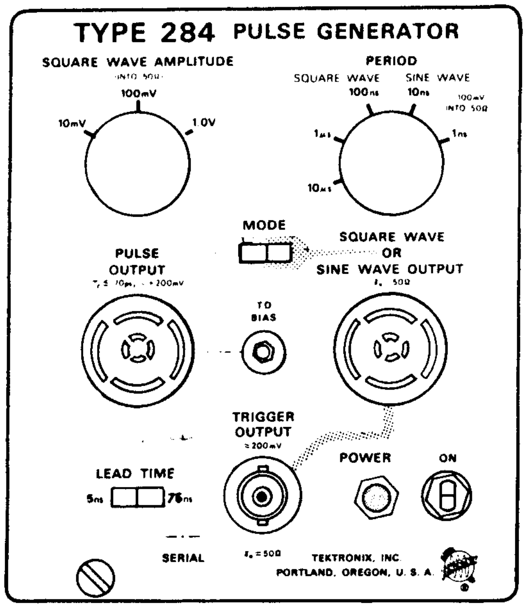
GENERAL OPERATING INFORMATION

Mode Switch

The MODE switch selects one output with its trigger signal. The MODE switch always turns the power off on one output which prevents both trigger signals from appearing at the TRIGGER OUTPUT at the same time.

Square Wave Output

The SQUARE WAVE OUTPUT amplitude is selected by the SQUARE WAVE AMPLITUDE switch, and the time period is selected by the PERIOD switch on three of its positions. Note that the other two positions of the PERIOD switch select the SINE WAVE time period. In order to maintain the output selected by the SQUARE WAVE AMPLITUDE switch,



(A) FRONT PANEL

Fig. 2-6. Control setup chart.

an output load of 50 Ω is required. For further loads use the following formula to calculate the output voltage:

$$E_{out} = \frac{R_{load}}{R_{load} + 50} \times 2E \qquad (1)$$

(E is the Voltage selected by the SQUARE WAVE AMPLITUDE switch)

Fig. 2-7 shows the time period and amplitude measurement points. In this display the output of the Type 284 is properly terminated by being coupled to the 50 Ω input of a sampling oscilloscope. Disregard the overshoot at the top corner of the square wave in making amplitude measurements. The time period measurement (here a period of 100 ns) is the time of one cycle of the square wave.

The square wave output desired can be selected for amplitude from 1 V, 100 mV or 10 mV and for the time period from 10 µs, 1 µs or 100 ns.

Sine Wave Output

The SINE WAVE OUTPUT is selected by the PERIOD switch. The period switch selects either a 10 ns or a 1 ns sine wave time period. The time period is the time of one cycle of the sine wave. The amplitude is approximately 100 mV when it is connected into a 50 Ω load.

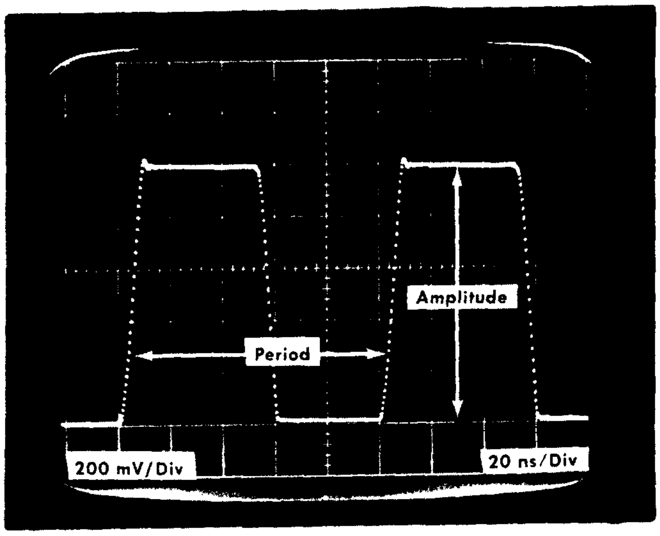


Fig. 2-7. Typical display showing amplitude and period measurements. A 1 Volt amplitude, 100 ns time period pulse from the Type 284 into 50 Ω input of Sampling oscilloscope.

Pulse Output

The Pulse Output power is turned on by setting the Mode switch to its left position. The pulse is generated by a tunnel diode in a coaxial environment and connected directly to the PULSE OUTPUT connector. A screwdriver adjustment marked TD BIAS (tunnel diode bias) on the front panel is used to adjust the optimum voltage of the tunnel diode. Mechanical strain on the front panel connector may change the tunnel diode environment and a slight adjustment of the TD BIAS may be necessary. To obtain the power adjustment of the TD BIAS, it is necessary to observe the display on a sampling oscilloscope. Following is a setup procedure using a Tektronix Type 561A with a Type 3S1 Dual-Trace Sampling Unit and a Type 3T2 Sampling Sweep Unit. If other equipment is used, the control settings and the procedure will be different.

NOTE

An internal TD Bias adjustment (R133) is provided for coarse adjustment of tunnel diode bias. If the tunnel diode is replaced or if the front panel control doesn't provide a satisfactory setting adjust the TD Bias (internal) in the manner given in the Calibration section of this manual.

1. Set the controls as follows:

Type 284

MODE switch	Pulse Output (to (left)
LEAD TIME	5 ns
POWER	ON

Type 3S1

Display Mode switch	Chan A
Smooth-Normal switch	Normal
A Position	Midrange
DC Offset ±1 V, Channel A	Midrange (5 turns from one end)
mVolts/Div, Channel A	50
Variable mVolts/Div (Channel A)	Cal
Invert-Norm switch, Channel A	Norm
Sampling Mode switch	Triggered

Type 3T2

Time Position	fully clockwise
Time Position Fine	fully clockwise
Horiz Position	Midrange
Samples/Div	Midrange
Range	100 ns
Start Point	with Trigger
Display Mag	×1
Time Magnifier	×1
Time Magnifier Variable	Cal
Display Mode	Normal
Trigger Sensitivity	Fully clockwise
Polarity	+
Source	Ext
Samples/Div (an internal switch)	100 (up position)

2. Connect the Type 284 PULSE OUTPUT signal through a 50 Ω coaxial cable with GR type connectors to the A input connector on the Type 3S1. Connect the TRIGGER OUTPUT signal through a 50 Ω BNC type coaxial cable to the 50 Ω Trigger Input connector on the Type 3T2.

3. If the TD BIAS is at optimum adjustment you will observe an untriggered display of about 4 divisions or about 200 mV peak to peak as in Fig. 2-8A, and upon turning the Trigger Sensitivity control almost fully counterclockwise, observe a clean triggered step display similar to Fig. 2-8B. Normal slight changes to the Type 3T2 Samples/Div control and the Type 3S1 A Position control may be necessary to display this waveform.

4. If upon turning the Trigger Sensitivity control almost fully counterclockwise a trace display appears showing the position of the upper portion of the pulse, this indicates that the TD BIAS control is clockwise from the optimum adjustment. See Fig. 2-8C (upper trace). Slight counterclockwise rotation of the TD BIAS control will be necessary to obtain a display similar to Fig. 2-8B.

5. Fig. 2-8C (lower trace) display indicates that the TD BIAS control is counterclockwise from the optimum adjustment. If the display as in Fig. 2-8B cannot be attained with clockwise rotation of TD BIAS control, refer to the calibration section of this manual.

The PULSE OUTPUT of the Type 284 has an amplitude of approximately +200 mV into a 50 Ω load. The pulse width is approximately 1 μs out of a pulse period of about 20 μs. The rise time of the pulse is equal to or less than 70 ps. With these specifications, several precautions should be considered when connecting the Type 284 PULSE OUTPUT signal to a test device or to a display oscilloscope.

Cable Considerations

The cables that conduct the output to the device under test should be low-loss 50 Ω coaxial cables to assure that all information contained in the pulse will be delivered to the test point without distortion. The physical and electrical

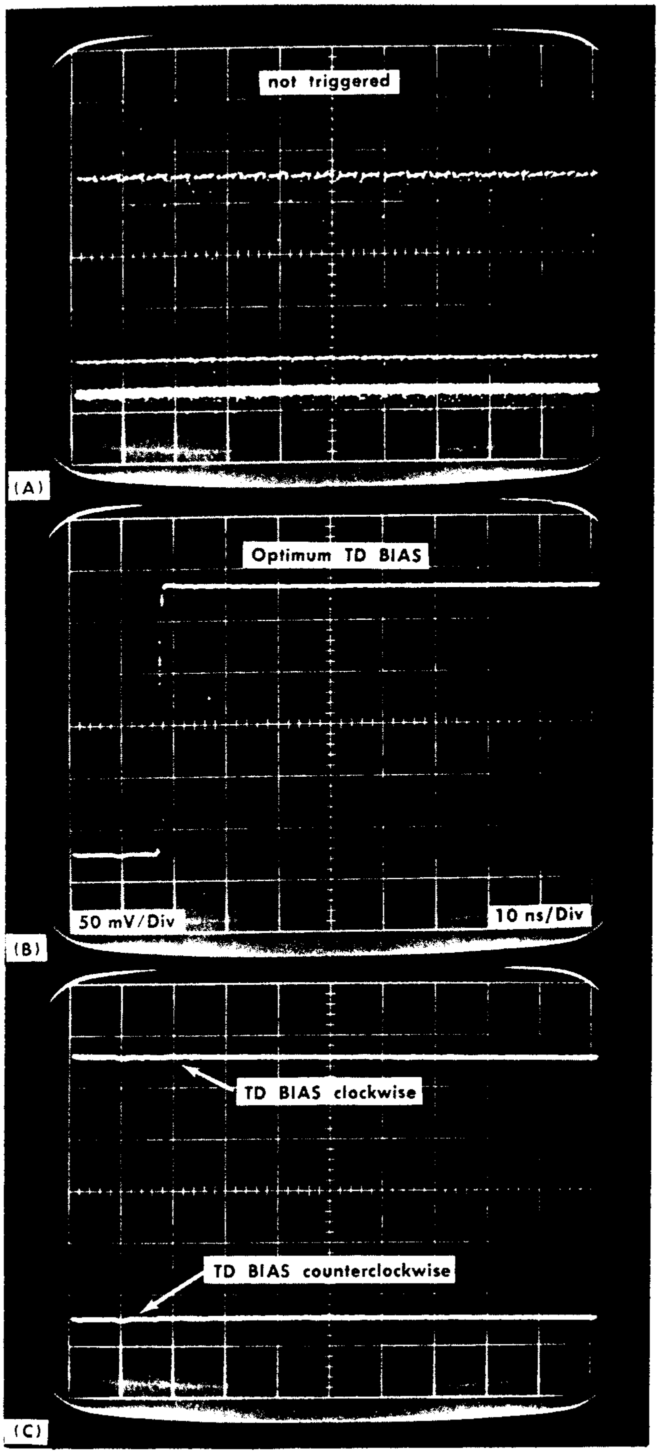


Fig. 2-8. Typical display showing adjustment of TD BIAS control.

characteristics of the cable determine the characteristic impedance, velocity of propagation and nature of signal loss. Since the signal losses caused by energy dissipation in the dielectric are proportional to the signal frequency, any very high frequency information in a fast-rise pulse will be lost in a very few feet of cable. Therefore it is important to use cables or airlines that are as short as possible.

Impedance Matching

To provide a smooth transition between devices of different characteristic impedance, each device must encounter a total impedance that is equal to its own characteristic impedance. Thus, when the OUTPUT PULSE signal of the Type 284 is applied to a load other than 50 Ω, a suitable impedance matching device must be provided. If the impedances are not matched, reflections and standing waves in the cables will result in distortion of the signal at the load. In many cases the load required will be 50 Ω, then with the use of available attenuators, 2×, 5× and 10× (10× Attenuator, Tektronix Part No. 017-0078-00) will attenuate the signal and provide the impedance match.

Fig. 2-9 illustrates a simple resistive impedance-matching network that provides minimum attenuation. To match impedances with the network, the following conditions must exist:

$\frac{(R_1 + Z_2)\,R_2}{(R_1 + Z_2) + R_2}$ must equal Z_1; and $R_1 + \frac{Z_1 R_2}{Z_1 + R_2}$ must equal Z_2.

Therefore:

$$R_1 R_2 = Z_1 Z_2 \text{ and } R_1 Z_1 = R_2 (Z_2 - Z_1)$$

$$\text{or } R_1 = Z_2 (Z_2 - Z_1);$$

$$\text{and } R_2 = Z_1 \frac{Z_2}{Z_2 - Z_1}$$

As an example, to match a 50-ohm system to a 125-ohm system:

$Z_1 = 50$ ohms; and $Z_2 = 125$ ohms.

Therefore:

$R_1 = 125\ (125 - 50) = 96.8$ ohms

$$R_2 = 50 \frac{125}{125 - 50} = 64.6 \text{ ohms}$$

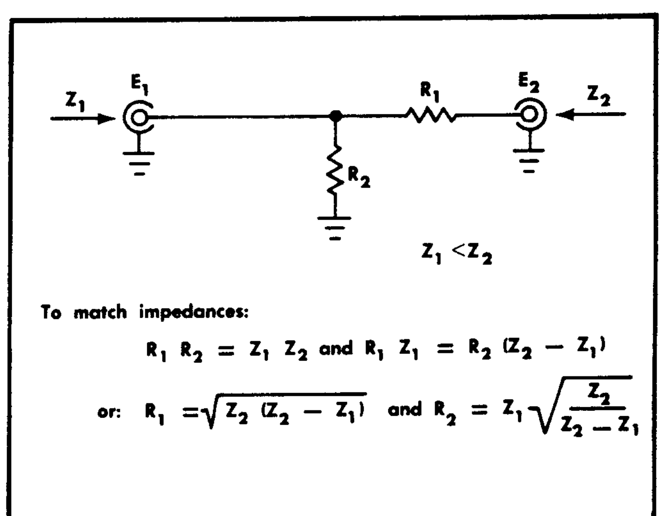


Fig. 2-9. Simple resistive impedance-matching network providing minimum attenuation.

Though the network in Fig. 2-9 provides minimum attenuation for a purely resistive impedance-matching device, the attenuation as seen from one end does not equal that seen from the other end. A signal applied from the lower impedance source (Z_1) encounters a voltage attenuation (A_1) that may be determined as follows:

$$\text{Since: } I_{R1} = I_{Z2};\ \frac{E_1 - E_2}{R_1} = \frac{E_2}{Z_2}$$

$$\text{Therefore: } A_1 = \frac{E_1}{E_2} = \frac{R_1}{Z_2} + 1;\ (1 < A_1 < 2)$$

A signal applied from the higher impedance source (Z_2) will encounter a greater voltage attenuation (A_2) that may be determined similarly:

$$\text{Since } I_{R1} = I_{R2} + I_{Z1};\ \frac{E_2 - E_1}{R_1} = \frac{E_1}{R_2} + \frac{E_1}{Z_1}$$

Therefore:

$$A_2 = \frac{E_2}{E_1} = \frac{R_1}{R_2} + \frac{R_1}{Z_1} + 1;\ (1 < A_2 < \frac{2Z_2}{Z_1})$$

In the example of matching 50 ohms to 125 ohms,

$$A_1 = \frac{96.8}{125} + 1 = 1.77;$$

$$\text{and } A_2 = \frac{96.8}{64.6} + \frac{96.8}{50} + 1 = 4.44$$

Note that if the 50-ohm source were used for pulsing a high-impedance load, R_1 would approximately equal the impedance of the load (high R) and R_2 would approximately equal the 50 ohms of the pulse source. In this situation, voltage attenuation would be about 2.

If a low-impedance load (< 50 ohms) were to be encountered, the 50-ohm pulse source would be the Z_2 source. If the load impedance were to approach 0 ohms, the value of R_1 would then approach the load impedance (low R). Voltage attenuation in this case would become quite significant;

$$\text{Attenuation} = \frac{2Z_2}{Z_L} = \frac{100}{Z_L}\ \text{(very high)}$$

The illustrated network can be modified to provide different attenuation ratios by adding another resistor (< R_1) in series between Z_1 and the junction of R_1 and R_2.

Risetime Considerations

If the PULSE OUTPUT signal from the Type 284 is to be used for determining the risetime of a test device or a display oscilloscope, the risetime of the Type 284 may have to be taken into consideration. Generally the risetime of the applied pulse (Type 284 PULSE OUTPUT) should be four times or more faster than the risetime to be measured. If the risetime of the applied pulse approaches the risetime of the system under test the actual risetime may be approximated from the following equation:

$$T_r \text{ measured} \approx \sqrt{(T_r \text{ pulse})^2 + T_r \text{ (system)}^2} \qquad (2)$$

Calculations are not necessary if the oscilloscope system or device system under test or a combination of the device system under test and the oscilloscope system has a risetime of more than four times the applied pulse (70 ps—Type 284) or 280 ps. The above system includes a short coaxial connecting cable and matching attenuators. For long coaxial cables, a display measurement is recommended because of the losses introduced by different types of cables.

Trigger Output

The TRIGGER OUTPUT signal is selected with the MODE switch at the same time and synchronized with either the PULSE OUTPUT or the SQUARE WAVE OR SINE WAVE OUTPUT. The amplitude of the TRIGGER OUTPUT signal is about 200 mV into a 50 Ω load in all positions. With the SQUARE WAVE OUTPUT, the 200 mV square wave trigger signal facilitates easy triggering, especially for the 10 mV SQUARE WAVE AMPLITUDE. The TRIGGER OUTPUT signal is a 1 or 10 ns sine wave, when the PERIOD and the MODE switch are selected for 1 or 10 ns SINE WAVE OUTPUT.

With the MODE switch in the PULSE OUTPUT position, the TRIGGER OUTPUT signal leads the PULSE OUTPUT signal by 5 ns or 75 ns as selected by the LEAD TIME switch. See Fig. 2-10.

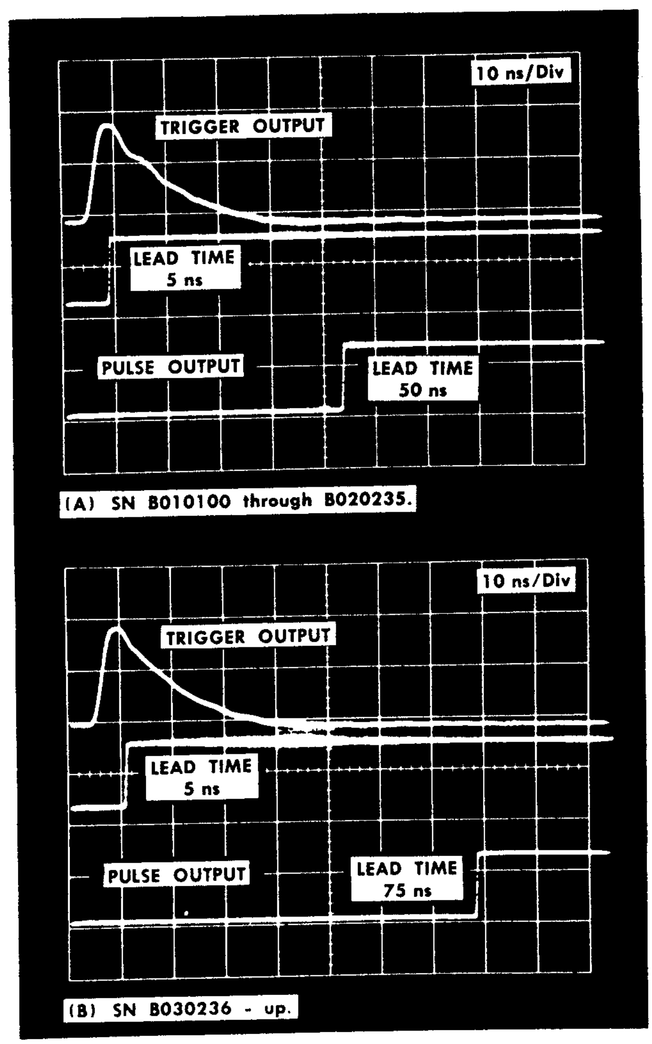


Fig. 2-10. Typical display showing TRIGGER OUTPUT signal, with PULSE OUTPUT signal in two positions of the LEAD TIME switch.

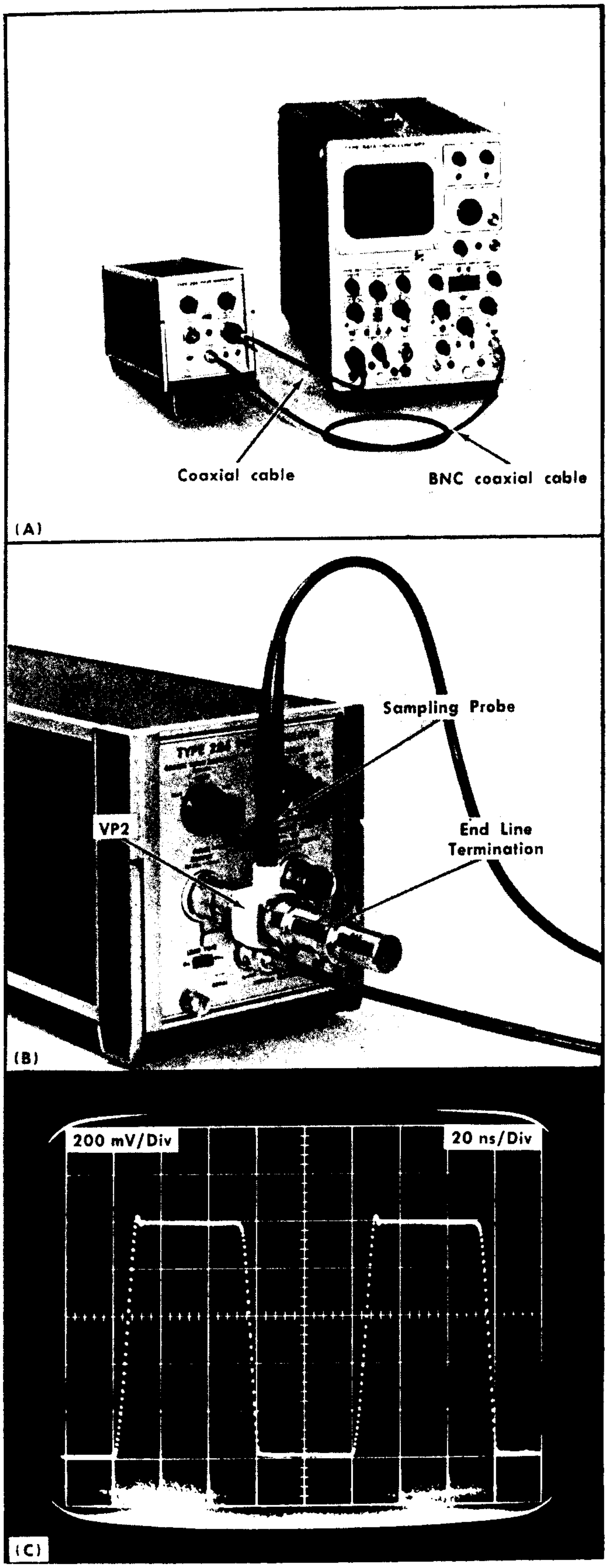


Fig. 2-11. Setup for Amplitude checks for (A) 50 Ω system, (B) Sampling Probe and (C) Typical waveform.

BASIC APPLICATIONS

General

The Type 284 is a source of Square Wave, Sine Wave and Pulse output signals useful to verify the deflection factor and timing accuracies of Sampling Oscilloscopes. It is also useful as a signal source for other applications. This part of the operating instructions will show basic uses of the Type 284.

Checking Amplitude

The Type 284 SQUARE WAVE OUTPUT signal amplitudes are 1 V, 100 mV, and 10 mV into 50 Ω with a selection of the time PERIOD of 10 μs, 1 μs, and 100 ns.

Fig. 2-11A shows Type 284 connected to the Channel A input of the Type 3S1 Dual Trace Sampling Unit, used in the Type 561A Oscilloscope with the Type 3T2 Sampling Sweep Unit. The vertical deflection factor of other 50 Ω input oscilloscope can be checked with this simple connection. Since the Type 284 uses the input of the Sampling unit as a load, the accuracy of the voltage presented to the input depends upon the accuracy of the input resistance. The DC input resistance can be measured with an accurate bridge with the oscilloscope power off. If external attenuators are used, their accuracies must be taken into account. Externally triggering the sampling oscilloscope from the Type 284 permits higher trigger amplitude (200 mV) with 100 mV and 10 mV square wave output.

Fig. 2-11B shows a method of connecting into sampling oscillosopes with a high impedance input or sampling probe. The Type VP-2 voltage pickoff adapter permits use of the high impedance sampling probe to look at signals within a closed 50 Ω system, with a minimum effect upon the signal. Then by using an accurate end line termination with the VP-2, accurate amplitudes are conveyed to the Sampling Probe. Other high impedance input oscilloscopes can be checked with the Type 284 if an accurate 50 Ω termination is provided and the proper adapter is connected to the oscilloscope input.

Fig. 2-11C shows a typical display of a 1 Volt Square Wave Output 100 ns signal used in checking the vertical deflection of the sampling units.

Checking Equivalent Time Bases

Signals available from the Type 284 for checking time bases include square waves with time periods of 10 μs, 1 μs, and 100 ns, and sine waves with time periods of 10 ns and 1 ns. The amplitude of the signal is not important in checking equivalent time bases as long as the signal is adequate to obtain a stable display; however, with the SQUARE WAVE output, amplitude as well as time verification can be made.

An example of fast verification of the amplitude and time checks is shown with the Type 1S2 Sampling Plug-In Fig. 2-12B. A display is shown of the Type 284 SQUARE WAVE OUTPUT of 1 volt amplitude at a time period of 100 ns. The SQUARE WAVE signal is connected through a 50 Ω coaxial cable to one of the Thru Signal Channel 50 Ω connectors on the Type 1S2. The other Thru Channel 50 Ω connector is terminated with the End Line termination (Tektronix Part No. 017-0083-00). The Trigger Output signal from the Type 284 is connected through a BNC coaxial cable and a BNC to GR adapter to the Ext. Trig Input connector on the Type 1S2. See Fig. 2-12A.

Fig. 2-12C is a display of the 10 ns PERIOD SINE WAVE on the Type 1S2. The Type 1S2 is set for 10 ns/Div (Horizontal Units) with .05 Volts/Div (Vertical Unit).

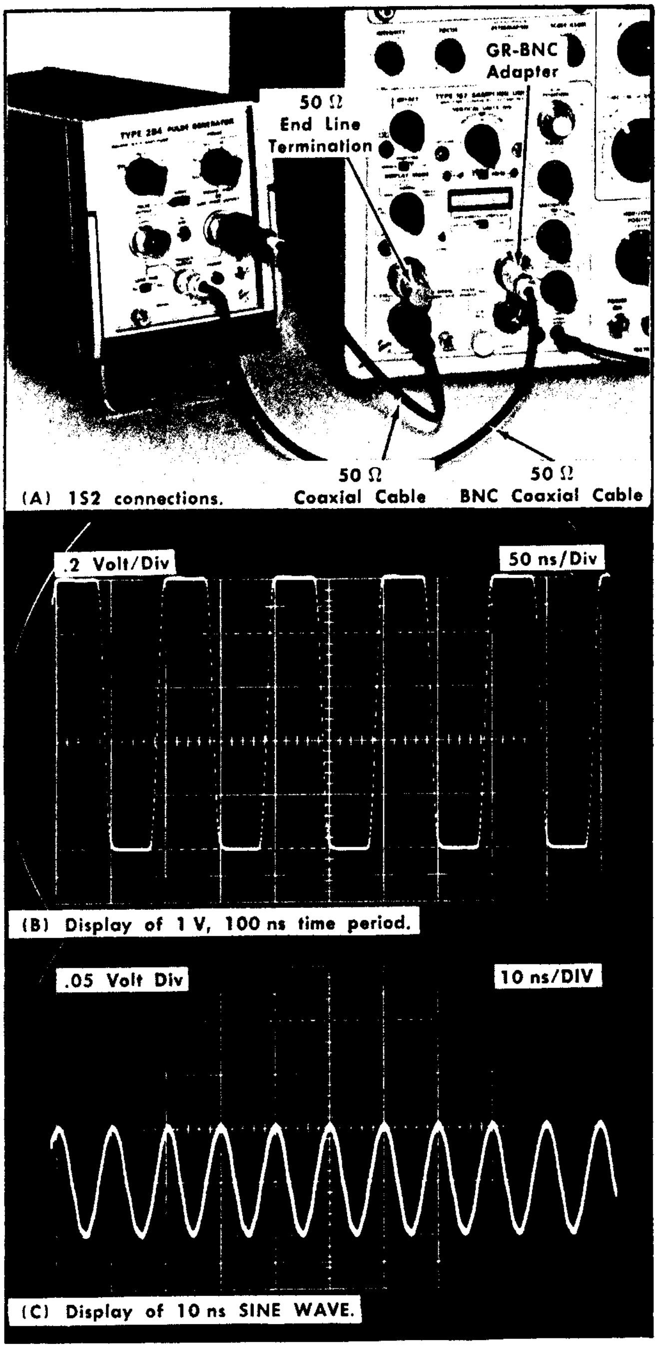


Fig. 2-12. Setup for display showing timing and Amplitude measurements for Type 1S2.

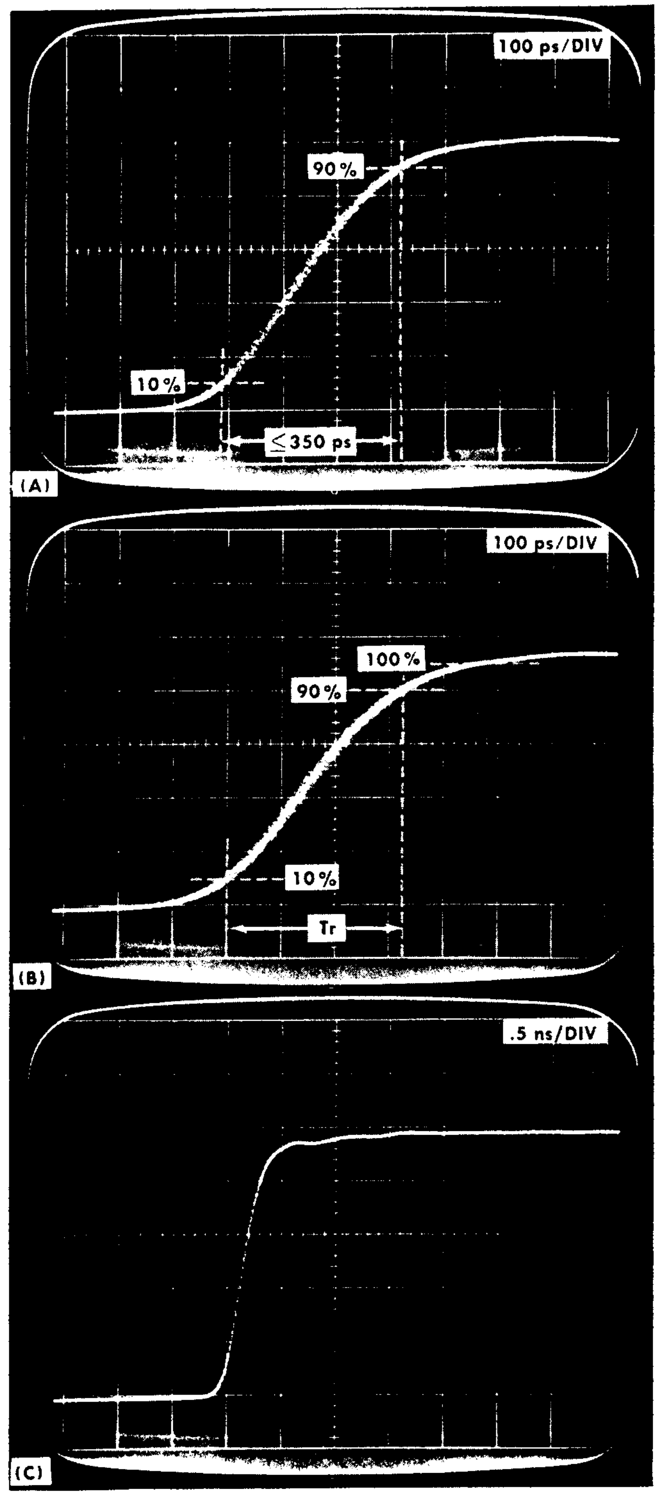


Fig. 2-13. Typical displays showing risetime checks.

Checking Risetime

The Pulse output from the Type 284 has a risetime of ≤70 ps, a width of about 1 μs, and a repetition rate of about 50 kHz. Risetime verification of Vertical Sampling units with risetimes equal to or longer than four times the Type 284 applied pulse can be made without calculations. At four times greater risetime, the error (by using equation 2 in this section) is +3% of the displayed signal. Four times 70 ps (Type 284 risetime) or about 280 ps, or slower risetime verticals units can be verified directly.

Fig. 2-13A shows a typical display with the Type 284 Pulse Output signal connected through a 5 ns coaxial cable to one input connector of the Type 3S1. A Type 561A Oscilloscope with a Type 3T77A Sampling Sweep Unit was used with the

Type 3S1. The risetime is verified from 10% to 90% of the full amplitude to be equal to or less than 350 ps. Fig. 2-13B shows a display of the Pulse Output signal fed through a 60 ns 50 Ω coaxial cable. Here the measurement of the display risetime is taken from the 10% to 90% points of a lower amplitude. The Pulse does not reach full amplitude in this display of 100 ps/div.

By changing the equivalent time to 5 times slower or .5 ns/div, note the long, gradual slope (Fig. 2-13C) after the initial rise in the waveform. This distortion is referred to as "dribble up" characteristic of the coaxial cable. The risetime is measured from the 10% to the 90% points of the initial ramp portion of the displayed signal not including the dribble up portion. The risetime, dribble up and other characteristics of coaxial cables can be evaluated with a known risetime generator and sampling oscilloscope system.

Risetime verification of a system including the display oscilloscope whose risetime approaches the risetime of the Type 284 applied pulse, can be approximated by equation (2) in this section.

Checking Fast Oscilloscope Vertical Response to a Fast Step Pulse

A fast step pulse will show up various responses in amplifiers due to terminations, mechanical layout, and characteristics of input circuits. The following displays (Fig. 2-14 through 2-21) were taken showing the characteristics of some vertical amplifiers when subjected to the Type 284 Pulse. The Pulse Output signal of the Type 284 is connected through a 20 Cm, 50 Ω Airline (Tektronix Part No. 017-0084-00) to the 50 Ω input sampling oscilloscopes. External triggering was used with the trigger signal from the Type 284 Trigger output connector through a BNC coaxial cable to the External Input of the sampling sweep unit. With the sampling probe type of sampling oscilloscopes, the output of the Type 284 is connected to a Type VP-2, and an End Line Termination (Tektronix Type 017-0081-00). The Sampling Probe was inserted in the Type VP-2.

Other high impedance oscilloscopes required an accurate 50 Ω termination and an adapter to connect to the input.

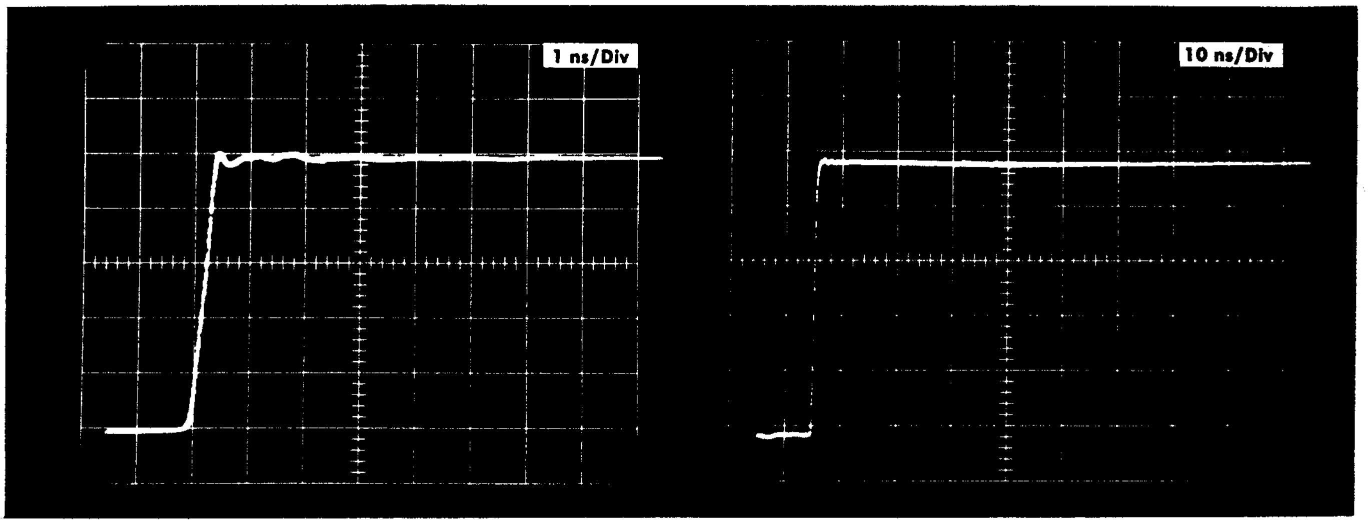


Fig. 2-14. Typical Type 284 PULSE OUTPUT signal display using Type 4S1 Vertical Sampling Unit.

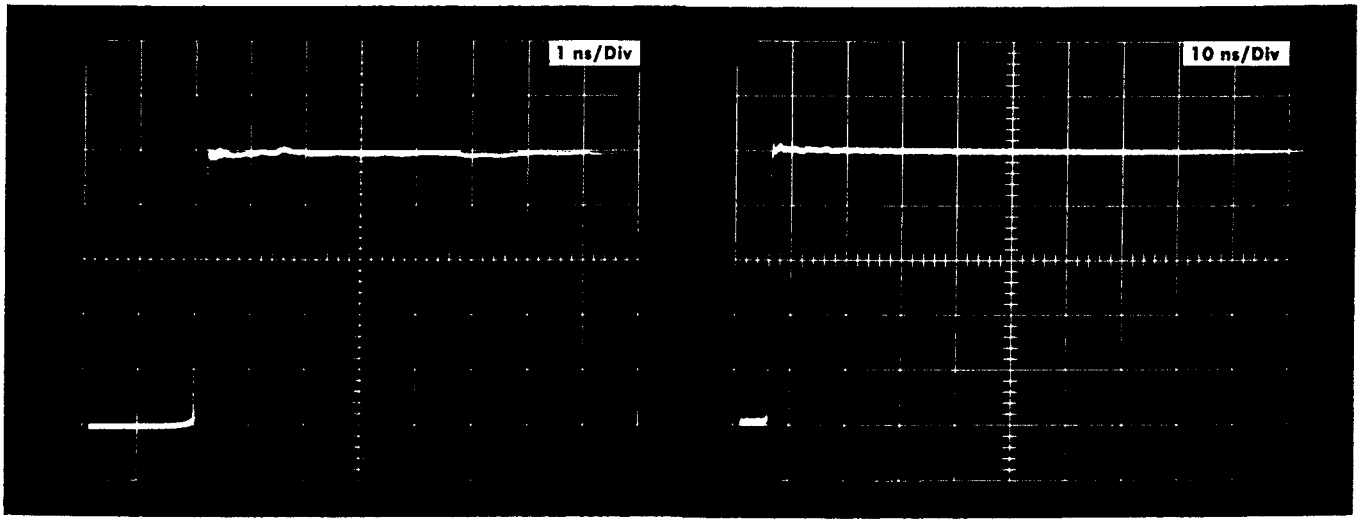


Fig. 2-15. Typical Type 284 PULSE OUTPUT signal display using Type 4S2A Vertical Sampling Unit.

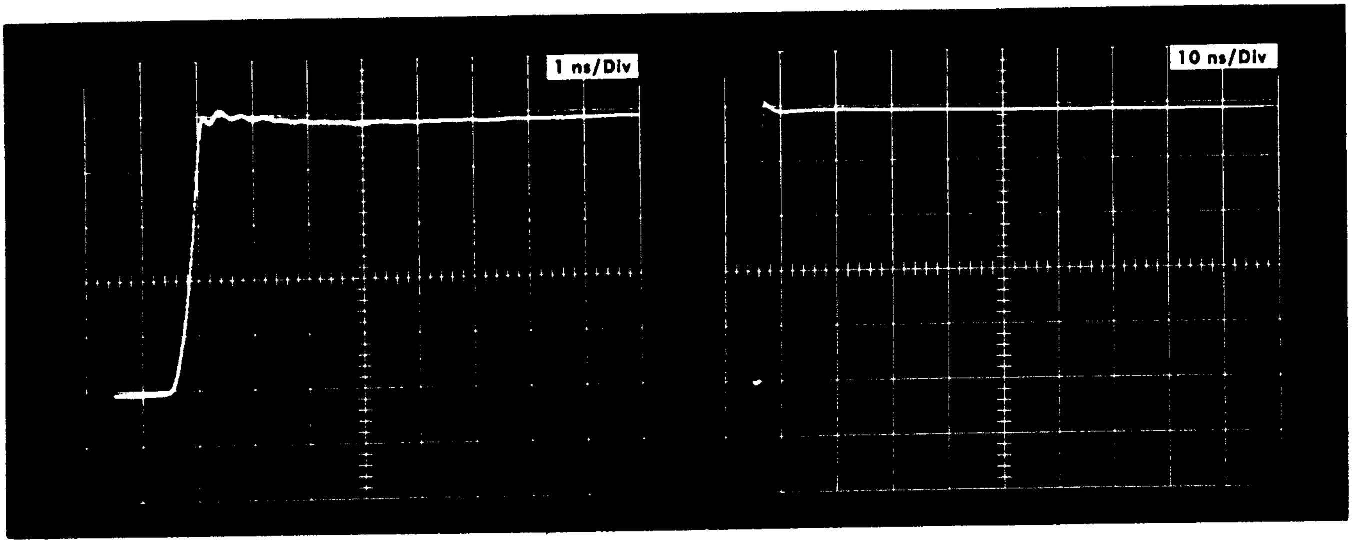


Fig. 2-16. Typical Type 284 PULSE OUTPUT signal display using Type 4S3 Vertical Sampling Unit.

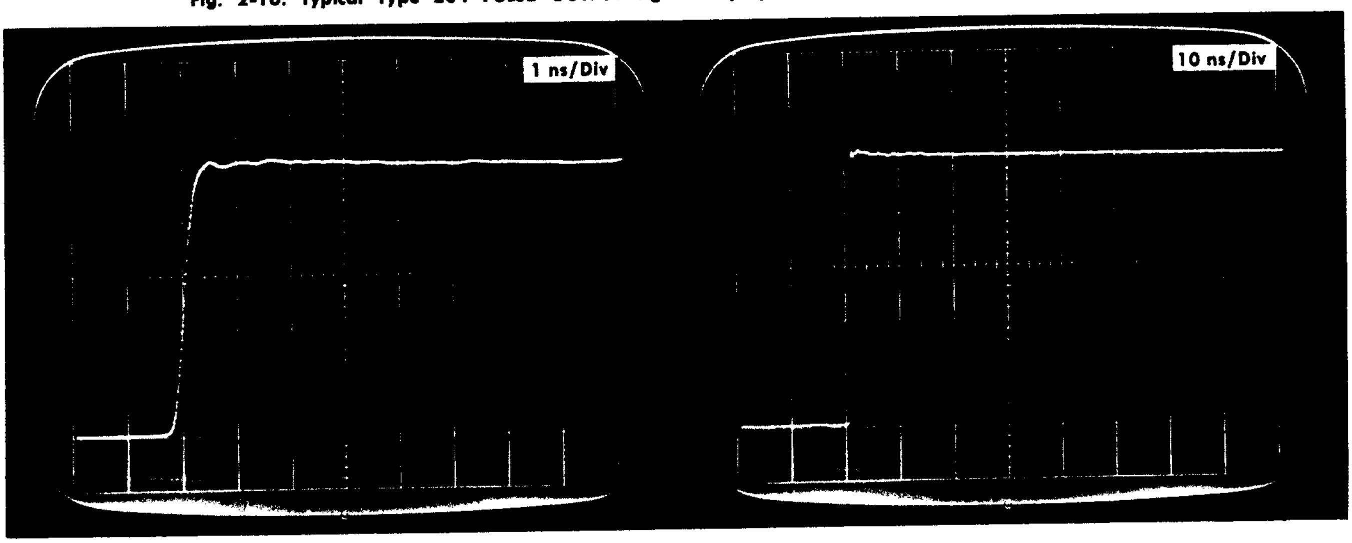


Fig. 2-17. Typical Type 284 PULSE OUTPUT signal display using Type 3S1 Vertical Sampling Unit.

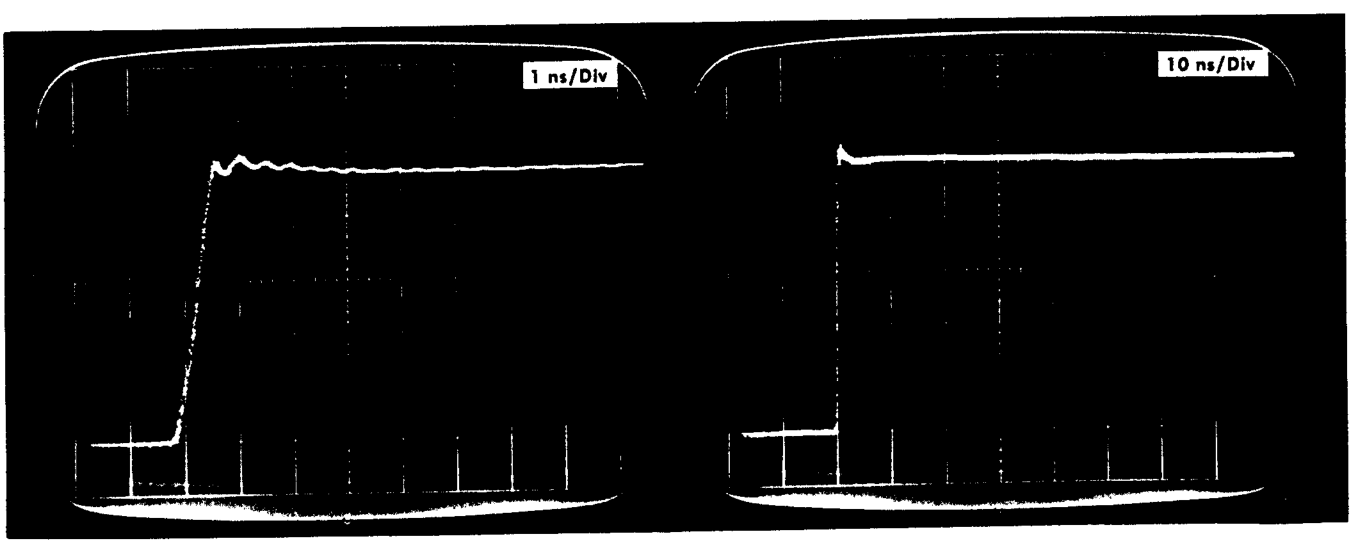


Fig. 2-18. Typical Type 284 PULSE OUTPUT signal display using Type 3S3 Vertical Sampling Unit.

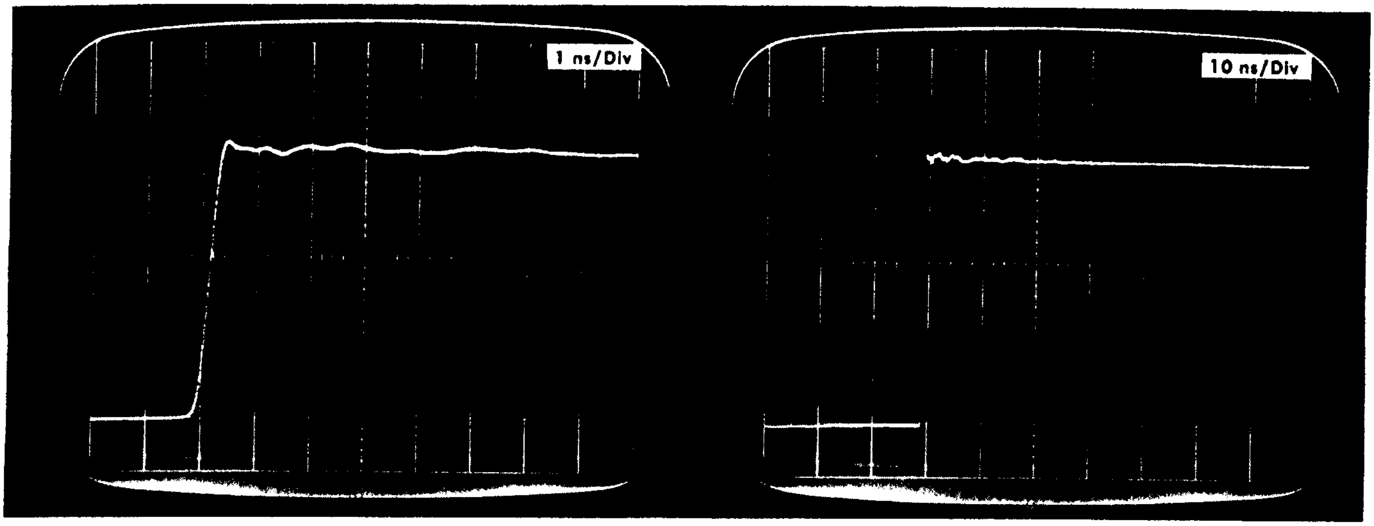


Fig. 2-19. Typical Type 284 PULSE OUTPUT signal display using Type 3S76 Vertical Sampling Unit.

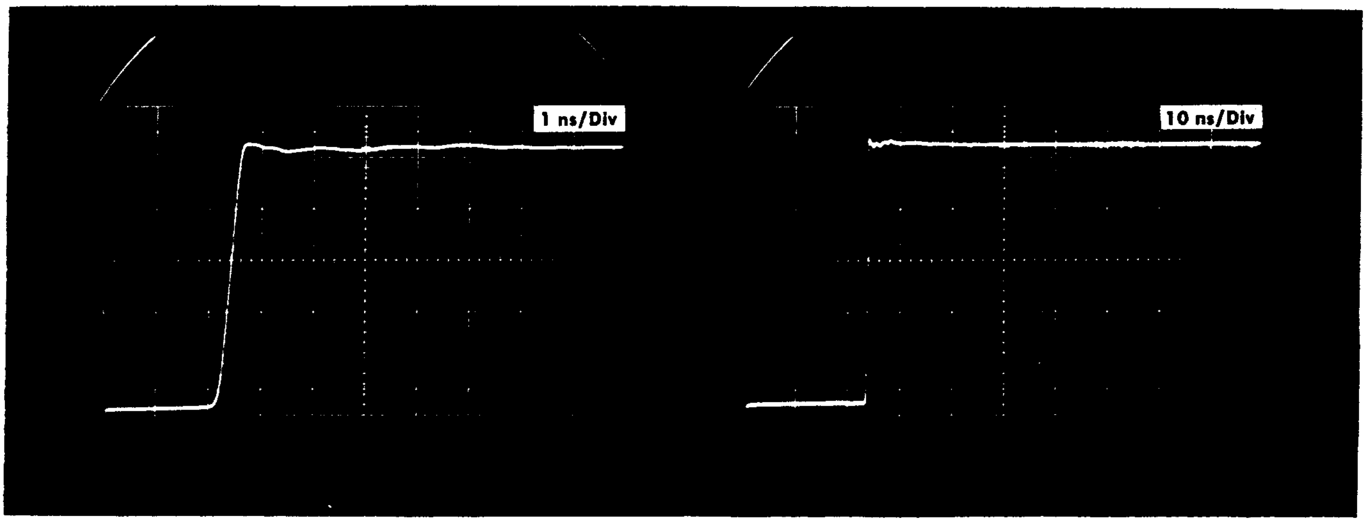


Fig. 2-20. Typical Type 284 PULSE OUTPUT signal display using Type 1S1 Sampling Unit.

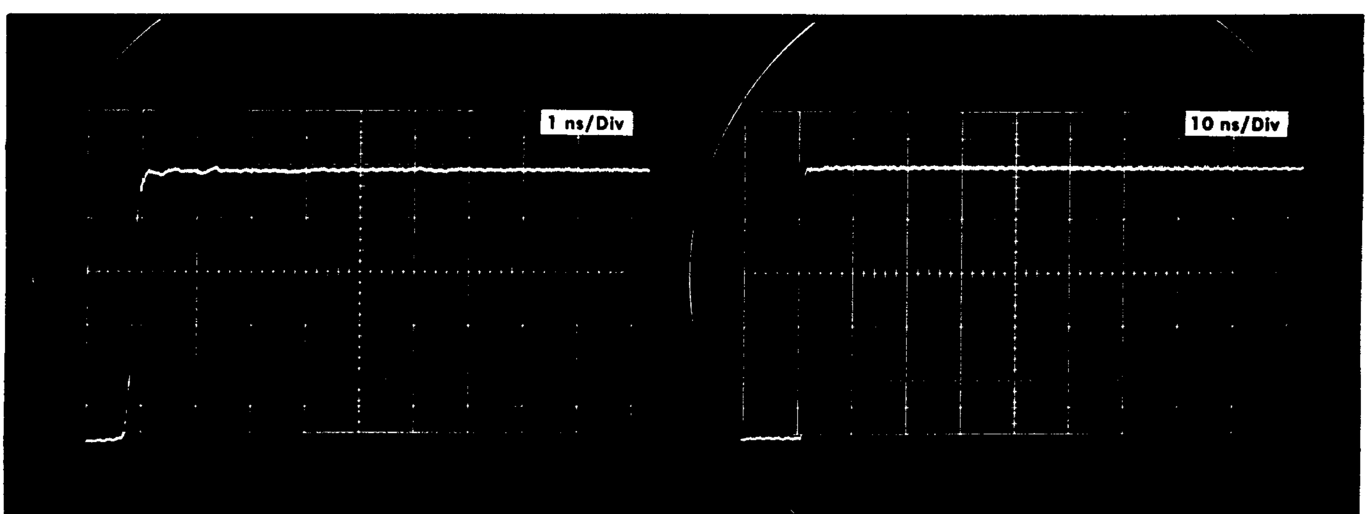


Fig. 2-21. Typical Type 284 PULSE OUTPUT signal display using Type 1S2 Reflectometer and Sampling Unit.

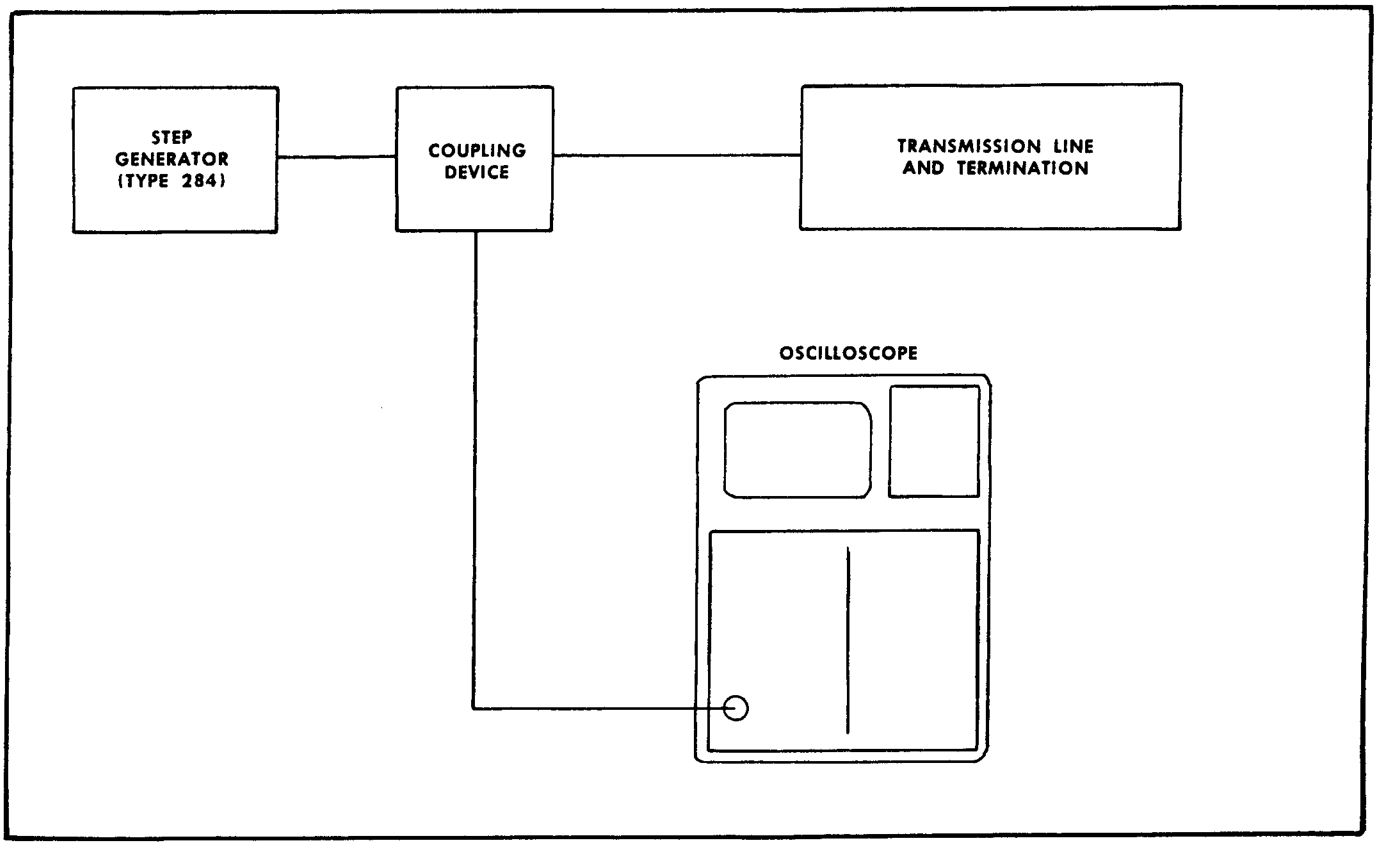


Fig. 2-22. A Time Domain Reflectometry (TDR) system.

TDR APPLICATIONS

Introduction

This part of the operating instructions contains information on the use of the Type 284 for Time Domain Reflecttal Units) with .05 Volts/Div (Vertical Unit).

ometry (TDR). It consists of basic TDR theory and how to calibrate two 50 Ω systems.

Basic TDR Theory

TDR is useful for measuring transmission line characteristic impedance, signal propagation velocity, losses, termination resistance and the location of discontinuities within a transmission line. It can be used to measure discrete capacitors, inductors, and resistors, and identify their spatial location. It can measure the resistance and inductance per turn of ferrite cores and measure the output resistance of signal sources and the input resistance of amplifiers.

A typical TDR system (Fig. 2-22) consists of 1) a step-signal generator, 2) a coupling device, 3) the transmission line under test and its output load, and 4) an oscilloscope to monitor the voltage at the transmission line input.

Limitations of a TDR system depend upon 1) the capabilities of the step generator to provide a fast-risetime, low distortion pulse, 2) the fidelity of coupling the step signal to the transmission line and the oscilloscope, 3) resistive and high frequency losses of the transmission line, and 4) oscilloscope sweep rate, risetime, sensitivity and noise, each affecting its ability to monitor the reflected signals accurately.

A simple DC anology of a TDR system is shown in Fig. 2-23. The battery represents the open circuit voltage of the step generator; R_g is the internal generator resistance, and R_L is the transmission line characteristic impedance. Closing the switch provides a fast-rise voltage step to the transmission line R_L.

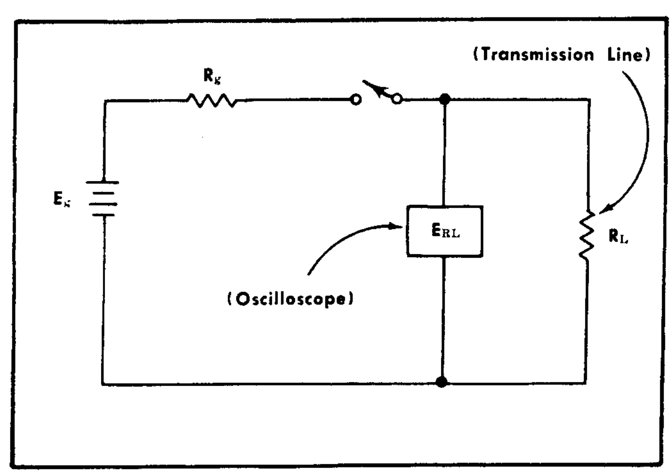


Fig. 2-23. Circuit showing DC analog of TDR.

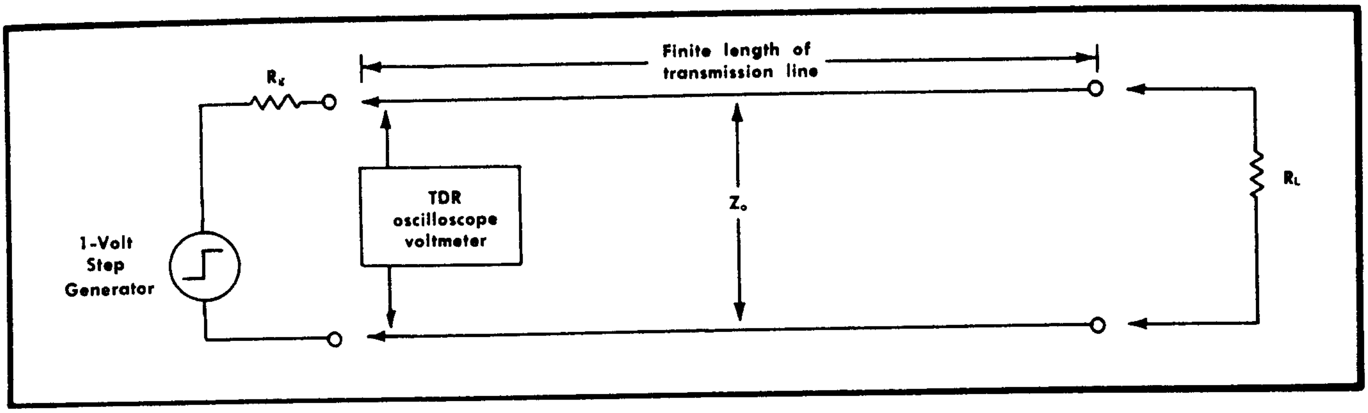


Fig. 2-24. Adding the time dimension to the circuit of Fig. 2-23.

When the switch is closed, R_g and R_L form a voltage divider across the battery terminals. The voltage across R_L is then stated by formula (3);

$$E_{RL} = \frac{R_L}{R_g + R_L} \times E_g \qquad (3)$$

Formula (3) shows that a change in R_L directly changes E_{RL}. Since E_{RL} is the voltage observed by the oscilloscope, any change in R_L (the impedance of the transmission line) will produce a change in oscilloscope vertical deflection. In formula (3) we assume that R_g is equal to R_L, and that E_{RL} is not loaded by the oscilloscope. However, these factors are considered in the coupling device in Fig. 2-22. Consider R_L shorted, then E_{RL} will be zero. Conversely consider R_L open, then E_{RL} will be equal to E_g (the open circuit generator voltage).

Adding the Time Dimension

Fig. 2-24 substitutes a step generator for the battery and switch of Fig. 2-23. The step generator and R_g drive a finite length (lossless) transmission line has a characteristic impedance of Z_o. The transmission line has output terminals that permit connecting a load R_L. An oscilloscope voltmeter measures the voltage signal(s) at the input end of the transmission line.

Assume that no load resistance is connected to the transmission line output terminals ($R_L = \infty$) and that $R_g = Z_o$ (Z_o acts exactly as if it were a DC resistor). As the step generator applies its 1-volt step signal to R_g, the oscilloscope voltmeter indicates 0.5 volt. The oscilloscope voltmeter will continue to indicate a 0.5 volt signal until the wave has traveled down the line to the open end, doubled in amplitude due to no current into R_L ($R_L = \infty$) and is then reflected back to the generator end of the line. The oscilloscope finally indicates a signal of 1 volt after the measureable period of time required for the step signal to travel down and back the finite length of open ended transmission line.

Reflection Signal Amplitudes

Fig. 2-25 shows TDR oscilloscope (voltmeter) displays related to the value of R_L vs the value of the transmission line Z_o. For values of R_L not equal to Z_o, use formula (3) to compute the reflection voltage. The final display voltage is the reflection voltage alegebraically added to the incident step voltage.

A more convenient method of handling signal reflections is to consider the reflection as having been added to or subtracted from the incident pulse. This permits establishing a ratio between the incident and reflected signals which is called the reflected coefficient, rho (ρ). The value of ρ is simply the reflected pulse amplitude (the display total amplitude minus the incident pulse amplitude) is divided by the incident pulse amplitude. Fig. 2-25 shows the two parts of the display, the incident step and the reflected signal. When $\rho = 0$, the transmission line is terminated in a resistance equal to its characteristic impedance Z_o. If the line is terminated in $R_L > Z_o$, then ρ is positive. If the line is terminated in $R_L < Z_o$, the ρ is negative. The dependence of ρ on the transmission line load is

$$\rho = \frac{R_L - Z_o}{R_L + Z_o} \qquad (4)$$

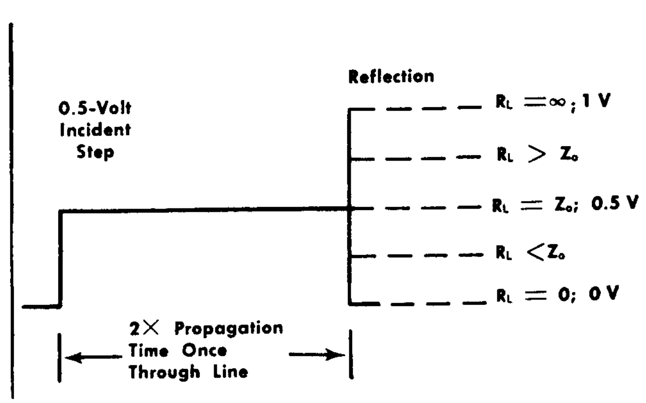


Fig. 2-25. TDR oscilloscope voltmeter displays for circuit of Fig. 2-24, dependent upon value of R_L vs Z_o.

Calibrating the System Rho

Correct setting of the oscilloscope vertical gain permits the TDR reflection displays to be calibrated in rho per vertical division. Two types of vertical units are discussed below for use with a 50 Ω transmission line.

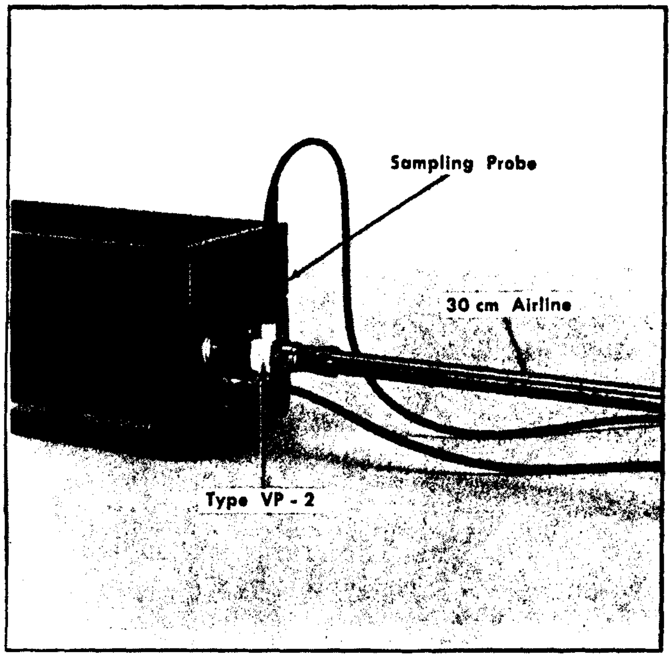


Fig. 2-26. TDR setup fpr P6038 Sampling Probe.

Using a Sampling Probe Unit. Fig. 2-26 shows the Type 284 pulse output signal applied through a Type VP-2 voltage pickoff unit. The cable under test can be attached to the end of the 50 Ω reference 30 cm airline, or connected directly to the VP-2. As an initial setup example, the 30 cm airline is used and left unterminated.

Insert the P6038 Sampling Probe (from the Type 4S3 or Type 3S3) into the Type VP-2. Set the timing unit for a sweep rate of 1 ns/div, and for external triggering, AC coupled. Connect the Type 284 TRIGGER OUTPUT connector to the timing unit 50 Ω trigger unit connector through a 50 Ω coaxial cable. Set the vertical unit for a deflection factor of 100 mV, and adjust the Variable millivolts/div control for a displayed waveform similar to that of Fig. 2-27.

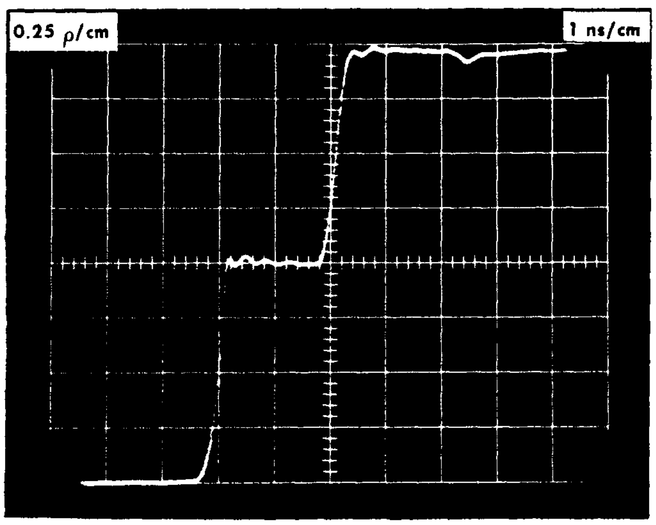


Fig. 2-27. Typical display for calibrating the system ρ.

The first 4 div rise in Fig. 2-27 is the generator step followed by the 2 div flat portion representing the time for the signal to go down and back in the 30 cm airline. The second 4 div rise is a +1 ρ reflection showing that the airline is unterminated. The incident pulse 4 div display of +1 ρ has a deflection factor of 0.25 ρ/div (1 ρ ÷ 4 div = 0.25 ρ/div). To obtain other ρ deflection factors, leave the Variable (millivolts/div) control as set for 4 divisions of incident displayed pulse, and change the sampling unit mV/div switch. Table 2-1 lists various ρ deflection factors obtainable for both a 4 div and a 5 div incident pulse display.

TABLE 2-1

ρ/div Deflection Factors Using VP-2 and a Sampling Probe Unit

Millivolts/div switch[2]	ρ/div with 4 cm incident display. (Fig. 2-27)	ρ/div with 5 cm incident display.
100	0.25	0.2
50	0.125	0.1
20	0.05	0.04
10	0.025	0.02
5	0.125	0.01
2	0.005	0.004

[2]After Variable control is properly set.

If a line is terminated in its characteristic impedance no reflection can be observed, and the line end cannot be determined from the display. One procedure to locate the end of a terminated line is to make a small change in the termination and thus cause a reflection. As an example, the 50 Ω termination on a 30 cm airline was not inserted fully onto the airline. This incorrect mating caused a small reflection which is displayed in Fig. 2-28A. Fig. 2-28B shows increased vertical deflection of the oscilloscope making the end-line fault more obvious and thus easy to find.

Using a 50 Ω Power Divider. Calibrating a 50 Ω power divider TDR system is different than the Probe system described above. The fully 50 Ω sampling system requires an attenuator coupling device, such as the GR 874-TPD shown in Fig. 2-29. The signal losses in the power divider must be considered when adjusting the oscilloscope vertical deflection sensitivity to obtain a calibrated ρ/div deflection factor. The setup for this calibration is shown in Fig. 2-29. The power divider matches the Type 284 50 Ω output to both the oscilloscope 50 Ω input and the 50 Ω transmission line under test. The loss between any two of the power divider connectors is 6 dB (half voltage) when each connector has a 50 Ω circuit connected.

Set the timing unit for 1 ns/div, externally triggered from the Type 284. Set the oscilloscope vertical mVolts/div switch to 50 and adjust the Variable mVolts/div control somewhat clockwise to obtain a display amplitude like that of Fig. 2-30. The display has an incident signal amplitude of 4 divisions. This represents the same amplitude as the signal being fed to the 30 cm airline. However, the amplitude of any reflection is reduced one half by the power divider. Fig. 2-30 shows the open line reflection as ½ the incident amplitude. Thus the reflection signal ρ/div is 0.5 (instead of 0.25 for the incident signal). Other mVolts/div switch settings are now calibrated in ρ/div as shown in Table 2-2.

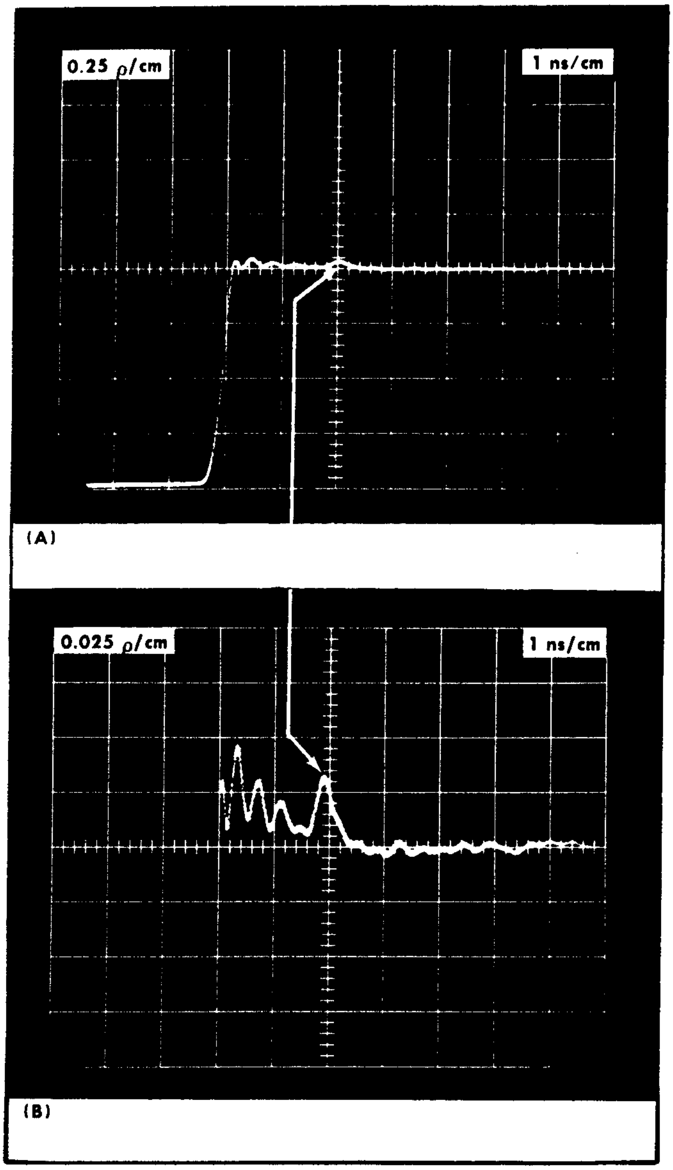


Fig. 2-28. Reflections from incorrectly installed termination.

TABLE 2-2

50 Ω Power Divider Reflected Signal ρ

mVolts/div switch[3]	ρ/div with 4 Div Incident deflection. (see Fig. 2-30)	ρ/div with 2 Div Incident deflection.
100	1.0	2.0
50	0.5	1.0
20	0.2	0.4
10	0.1	0.2
5	0.05	0.1
2	0.02	0.04

[3]After Variable control is properly set.

Finding R_L From ρ

If ρ is known, R_L can be found by rearranging formula (4);

$$R_L = Z_o \left(\frac{1 + \rho}{1 - \rho} \right) \qquad (5)$$

Formula (5) applies to any display that results from a purely resistive load. The load is assumed to be at the end of a lossless coaxial transmission line.

Substituting 50 Ω for Z_o in formula (5), calculations for small values of ρ show that each division of reflected signal is approximately equal to a certain number of ohms. Table 2-3 lists the ohms per division for vertical deflection factors of 0.005 ρ, 0.01 ρ and 0.02 ρ. Or, for R_L values near 50 Ω, you may use the approximation formula:

$$R_L \approx 50 + 100\rho$$

This approximation formula has an error of $\leq$ 2.2% for absolute values of $\rho \leq 0.1$ and an error of $\leq$ 8% for absolute values of $\rho \leq 0.2$.

R_L for reflections with ρ up to essentially +1 or −1 can be quickly determined using the graph of Fig. 2-31. Fig. 2-31 is based upon a transmission line characteristic impedance of 50 Ω just prior to the discontinuity that causes the reflection signal. The graph of Fig. 2-31 may be photographically reproduced without special permission of Tektronix.

TABLE 2-3

R_L Approximations For Reflection Coefficients of 0.005, 0.01 and 0.02 Related to a 50 Ω Transmission Line

ρ/div	Ω/div	Error/div
0.005	½	~0.016 Ω
0.01	1	~0.066 Ω
0.02	2	~0.2 Ω

Timing

In order to use TDR to measure the physical length of a transmission line, the oscilloscope sweep rate must be adjusted to match the signal velocity of propagation within the line. (Measurement of electrical length can be done using the oscilloscope calibrated sweep rates directly.)

The velocity of signal propagation in an air dielectric transmission line is 30 cm (one way) in 1 ns, or round trip in 2 ns. Solid, or semi-solid dielectric lines have propagation velocities slower than that of air. Table 2-4 lists three

TABLE 2-4

Coaxial Transmission Line Signal Velocity of Propagation (Vp) Compared to the Speed of Light (c)

Transmission Line Dielectric	Vp
Air	1.0 × c = 30 cm/ns[4]
TFE[5]	0.695 × c = 20.85 cm/ns
Polyethylene[5]	0.659 × c = 19.77 cm/ns

[4]cm × 0.3937 = inches.
[5]Solid (not foamed) dielectric material.

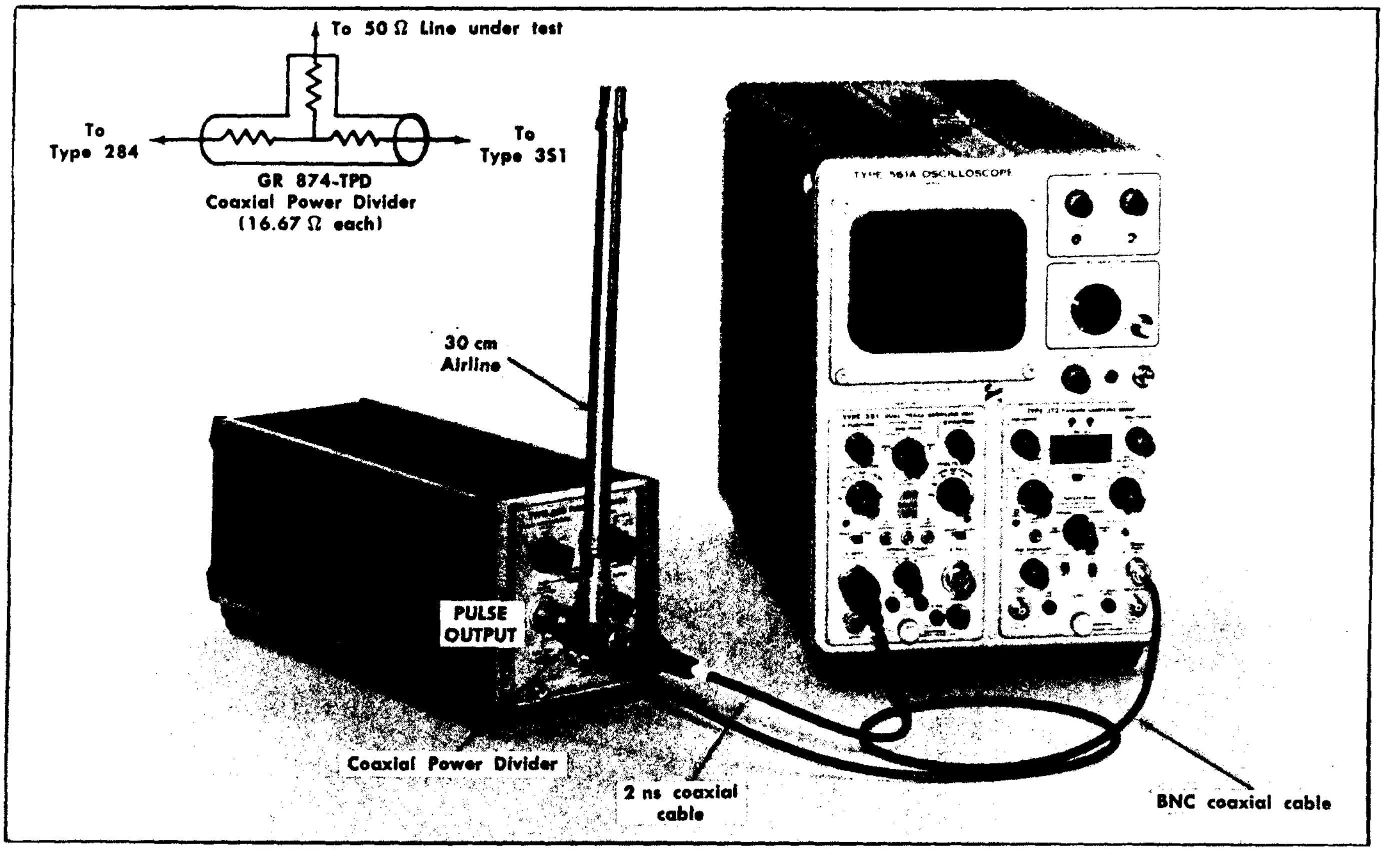


Fig. 2-29. TDR setup for 50 Ω Input Sampling oscilloscope.

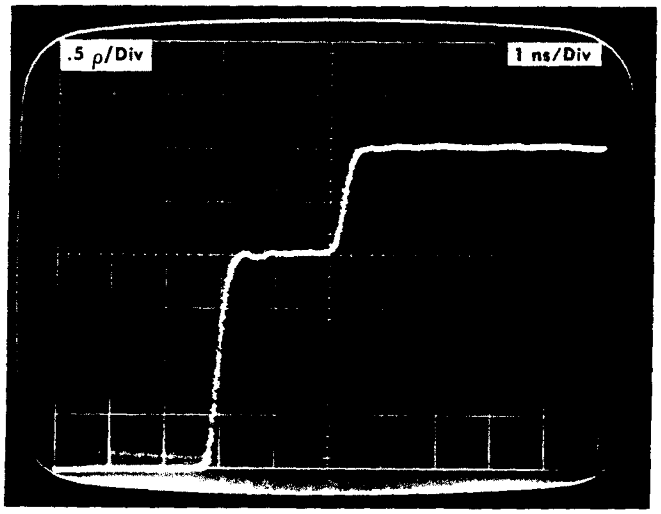


Fig. 2-30. Display for calibrating a 50 Ω system reflected signal reflection coefficient when using a GR power divider.

common velocities of signal propagation in transmission lines. Even though the figures are given to the 3rd place after the decimal, variations in manufacture may create variations of the individual cable signal velocity.

Table 2-5 lists special horizontal sweep rates in units of meters per division for the special case where the sweep rate variable control is adjusted to display a transmission line length of one meter in ten divisions. The initial system includes a 30 cm airline on the test side of either the VP-2 or the Power Divider (as shown in Fig. 2-26 or Fig. 2-29). The 30 cm airline gives a "clean" time reference for the positioning of the oscilloscope display at the CRT graticule left edge.

TABLE 2-5

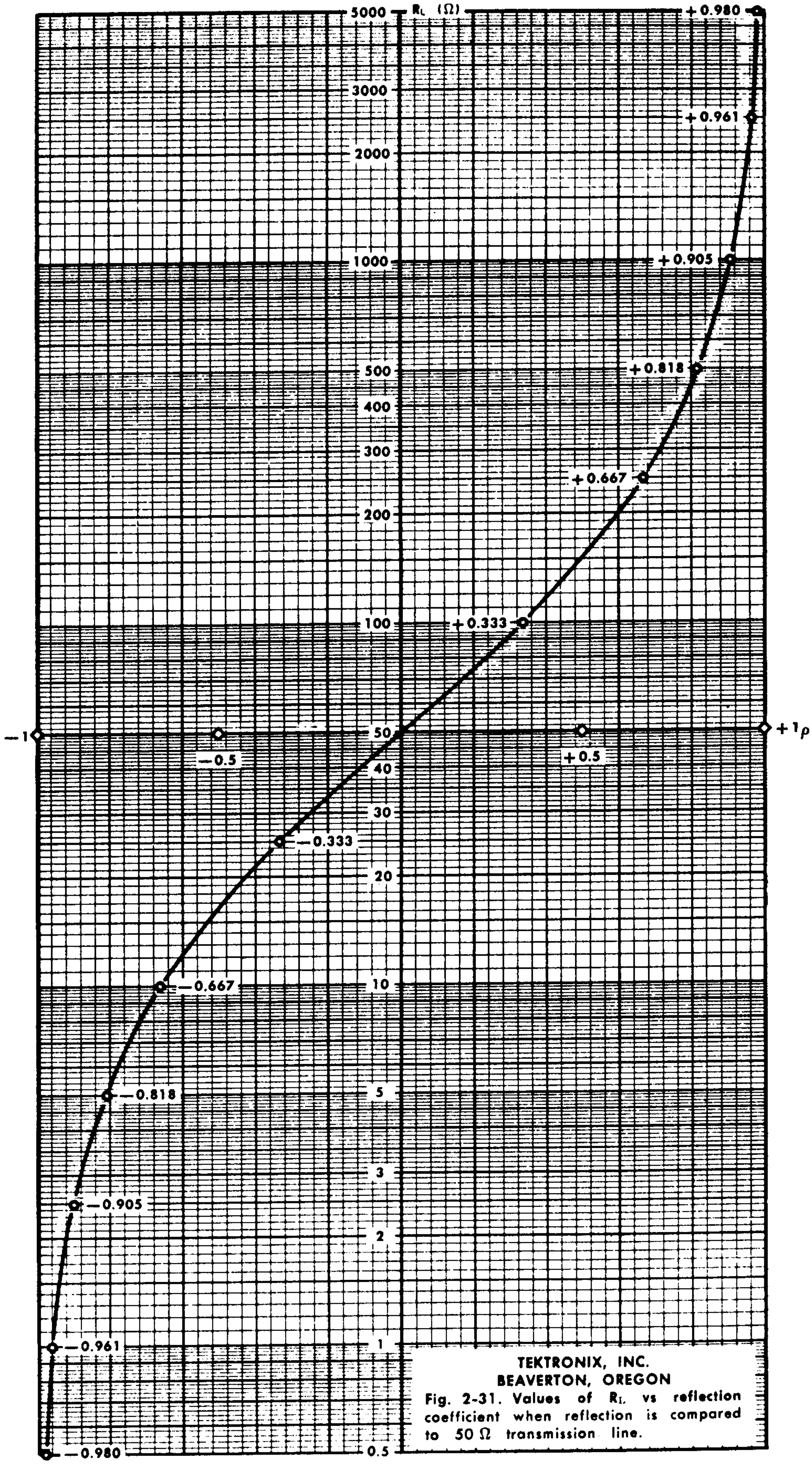
Special Distance Sweep Rates when Sweep is Calibrated to Display One Meter in 10 Div

Time/Div Switch[6]	Distance/Div
.2 ns	1 cm
1 ns	5 cm
2 ns	10 cm
10 ns	0.5 meter
20 ns	1 meter
.1 μs	5 meters
.2 μs	10 meters
1 μs	50 meters

[6]Calibrated with Variable control as above at 2 ns.

Procedure

Connect a GR 874-WN short circuit termination to the 30 cm airline end. Set the oscilloscope vertical for a deflec-



TEKTRONIX, INC.
BEAVERTON, OREGON
Fig. 2-31. Values of R_L vs reflection coefficient when reflection is compared to 50 Ω transmission line.

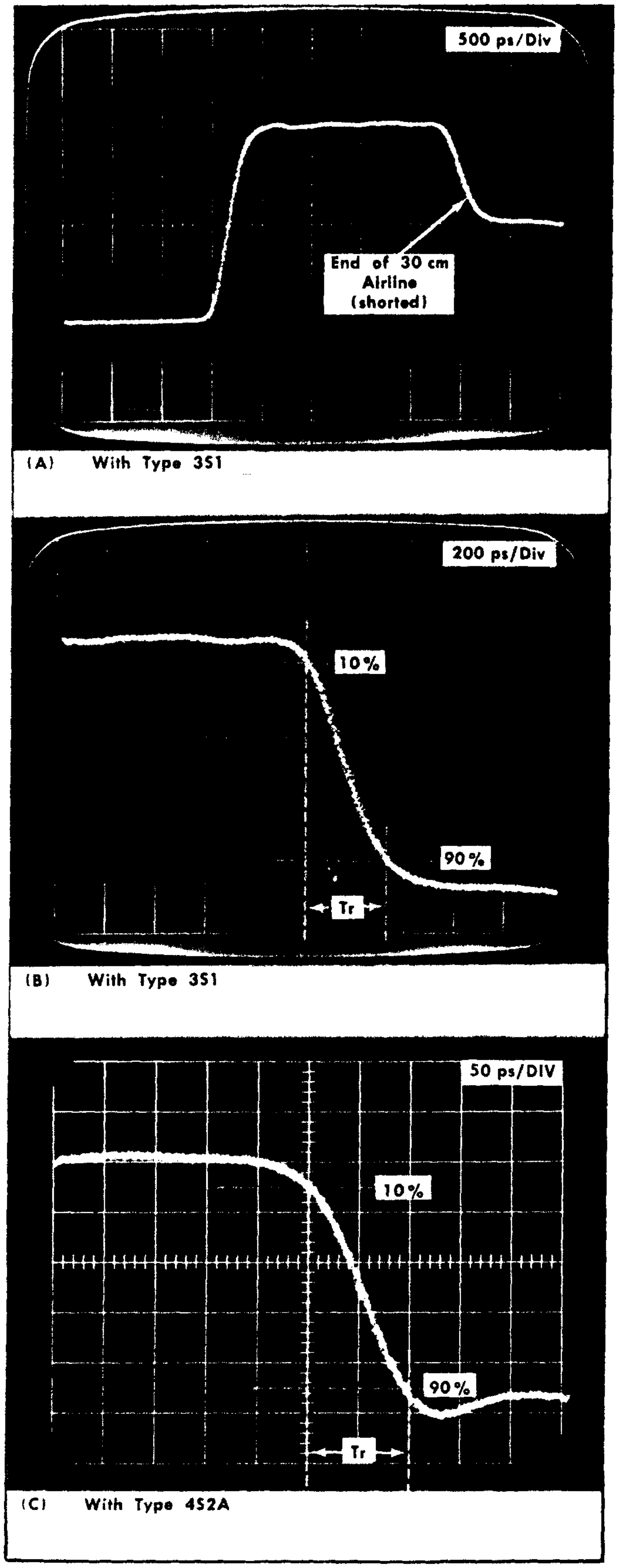


Fig. 2-32. Typical displays showing method of checking system risetime.

tion factor of 0.5 ρ/div, and the horizontal time/div control to 2 ns. Obtain a display of the short circuit, and position the negative step to the graticule left edge. Remove the short circuit and install the one-meter length of test cable to the 30 cm airline. Install the short at the one-meter cable outer end. Adjust the timing unit Variable control to speed up the sweep rate so the short circuit display falls at the graticule right edge.

Changing the timing unit Variable control may move the 30 cm airline short circuit display position. Thus it is necessary to repeat the above procedure two or three times to be certain that the graticule ten divisions truly represents one meter of transmission line. Now refer to Table 2-5 for other sweep rates for other positions of the time/div switch.

NOTE

The Type 284 output pulse minimum time duration of 1 μs provides a maximum cable length observation of about 150 meters of airline and about 100 meters of solid Polyethylene dielectric line.

Special TDR Applications

Many special measurements are possible with a fast-rise TDR system. Several of these types of applications are discussed in detail in an article on TDR published in the August 1967 Tektronix Service Scope. That article related specifically to use of the Tektronix Type 1S2 Sampling Unit. However, the Type 284 Pulse Generator provides an output pulse that is fast enough to permit it to be used for fast-rise measurements discussed for the Type 1S2.

A fast-rise TDR system that includes the Type 284 as the pulse source must use an oscilloscope with a vertical risetime in the order of 70 to 100 ps. Such a system will include the Tektronix Type 4S2A, Type 5T3 and Type 661.

Lower rate-of-rise measurements that include the testing of long (or lossy) transmission lines are also possible using the Type 284 as the pulse source. This TDR system can use an oscilloscope with a vertical risetime of 350 ps. Such a system will include the Tektronix Type 3S1 (or Type 3S76), Type 3T2 (or Type 3T77A) and a 560-series Oscilloscope.

No attempt is made here to present the application discussed in the TDR article mentioned above. However, if the TDR system uses the Type 284 and a power divider, the measurement of system risetime required for some measurements is different than discussed in the article and therefore presented here.

Checking the TDR System Risetime Using the Type 284 and A Power Divider

Fig. 2-32 shows three TDR oscilloscope displays that were made to measure the risetime of a system using a Power Divider. Fig. 2-32A shows the general type of display when measurements are made at the end of a 30 cm airline. The airline was short circuited by a GR 874-WN Short Circuit Termination.

Fig. 2-32B and Fig. 2-32C are examples of expanded vertical and horizontal deflection factors that permit the reflected signal (thus the system) risetime to be measured. The short circuit is used when testing system risetime to obtain a more accurate reading than can be obtained by an open circuit. (Energy is radiated from an open circuit, causing an error in reflected signal risetime if the system has a risetime in the order of 100 ps or less.) Fig. 2-32B is the display used to check the risetime of a "fairly slow" system, in the order of 350 ps. Fig. 2-32C is the display from a fast system whose vertical unit has a risetime of 90 ps. Responses must be considered as part of the system and any fast risetime measurements are thus made from the 50 Ω point to the first negative peak at the 0 Ω point.

Once the system risetime is known (with whatever length and type of coaxial line used between the Power Divider and the test point) then accurate TDR measurements listed in the Service Scope article can be performed.

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