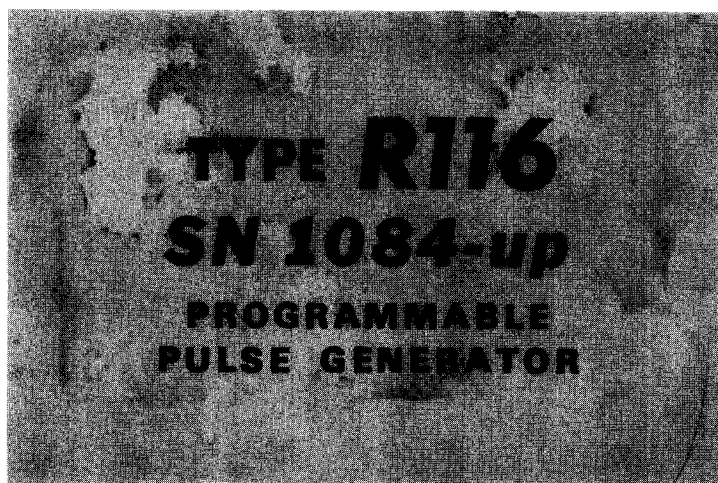


# INSTRUCTION MANUAL

Serial Number \_\_\_\_\_



*Tektronix, Inc.*

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070-1042-00



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Fig. 1-1. Type R116 Programmable Pulse Generator.

# **PART 1**

# **OPERATION**

Information necessary to operate the Type R116 either at a test bench or in a programmable system is provided in Part I, Operation, of this manual. The information is divided into four sections:

1. Specification
2. Operating Instructions
3. Programming
7. Rackmounting

## **NOTE**

See the Performance Check/Calibration section in Part II of this manual for a performance check procedure for use during incoming inspection.

Abbreviations and symbols used in this manual are based on or taken directly from IEEE Standard 260 "Standard Symbols for Units", MIL-STD-12B and other standards of the electronics industry. Change information, if any, is located at the rear of this manual.

# SECTION 1

## SPECIFICATION

Change information, if any, affecting this section will be found at the rear of the manual.

### GENERAL

The Type R116 Programmable Pulse Generator is a multi-purpose instrument which generates pulses with a variety of controllable characteristics. It has a maximum repetition rate of 10 MHz, a maximum amplitude of  $\pm 10$  volts and a minimum risetime and falltime of 10 ns. All functions of the Type R116 are programmable, making the instrument appropriate for applications requiring a variety of pulse characteristics that can be changed in rapid sequence. The Type R116 can also be operated entirely from the front panel (using the calibrated front-panel controls) or with a combination of remote programming and front-panel operation.

Those pulse characteristics which are controllable are: repetition rate, width, amplitude, risetime, falltime, DC offset and polarity. The instrument has five modes of operation which include an undelayed pulse, a delayed pulse (with a calibrated delay, paired pulses, an externally triggered burst of pulses and an externally gated burst of pulses. In addition to the output pulse, there is an undelayed and a delayed trigger output.

The following electrical and environmental characteristics are valid on instruments operated at an ambient temperature between  $+20^{\circ}\text{C}$  and  $+30^{\circ}\text{C}$  after an initial warm-up period of 20 minutes, assuming the instrument is properly calibrated. Section 6, Performance Check/Calibration Procedure, gives a procedure for checking and adjusting the Type R116 with respect to the following specifications.

TABLE 1-1

### ELECTRICAL CHARACTERISTICS

#### Pulse Output

Characteristic	Performance
Pulse Period (TRIGGER SOURCE switch set to INTERNAL)	100 ns to at least 11 ms in 5 ranges; continuously variable within each range.
Period Accuracy	Within 3% of PERIOD control settings in all ranges except 100 $\mu\text{s}$ range; within 5% in 100 ns range.
Pulse Delay or Burst Time	50 ns to at least 550 $\mu\text{s}$ in 4 ranges; continuously variable within each range.
Delay Accuracy	Within 3% plus 10 ns of DELAY CR BURST TIME control settings. Refer to Minimum Pulse Separation characteristic.
Pulse Width	50 ns to at least 550 $\mu\text{s}$ in 4 ranges; continuously variable within each range.

Characteristic	Performance
Width Accuracy	Within 3% of WIDTH control settings in all ranges except 10 ns range, with risetime and falltime set at minimum and AMPLITUDE MULTIPLIER set at 10; within 5% in 10 ns range.
Pulse Risetime (10% to 90%)	10 ns to 110 $\mu\text{s}$ in 4 ranges; continuously variable within each range.
Risetime Accuracy	Within 5% of risetime value set by risetime controls and AMPLITUDE MULTIPLIER with RISE TIME FALLTIME RANGE switch set to 100 ns or 1 $\mu\text{s}$ ; within 10% with switch set to 1 ns or 10 ns. Control indications of risetimes less than 10 ns are uncalibrated.
Pulse Falltime (90% to 10%)	10 ns to 110 $\mu\text{s}$ in 4 ranges; continuously variable within each range.
Falltime Accuracy	Within 5% of falltime value set by falltime controls and AMPLITUDE MULTIPLIER with RISE TIME FALLTIME RANGE switch set to 100 ns or 1 $\mu\text{s}$ ; within 10% with switch set to 1 ns or 10 ns. Control indications of falltimes less than 10 ns are uncalibrated.
Pulse Amplitude	0.4 volts to 10 volts (into 50 $\Omega$ load) either polarity; continuously variable within each range.
Amplitude Accuracy	AMPLITUDE RANGE Accuracy
	1 volt Within 3% of Amplitude controls settings $\pm 50$ mV
	.5 volts Within 3% of Amplitude controls settings $\pm 25$ mV
	.2 volts Within 3% of Amplitude controls settings $\pm 15$ mV
Pulse DC Offset	0 V to at least $\pm 5$ V in 3 ranges; continuously variable within each range. Full DC offset in either direction and full pulse amplitude of either polarity are permitted simultaneously.

## Specification—Type R116 (SN 1084-up)

Characteristic	Performance
DC Offset Accuracy	Within 5% of AMPLITUDE RANGE Switch and DC OFFSET control settings, $\pm 200$ mV.
Pulse Aberrations	No more than +3%, -3% or 3% peak-to-peak of a $\pm 10$ V pulse.
Minimum Pulse Separation	100 ns between 50% amplitude level on fall of one pulse and 50% level on rise of next pulse, with risetime and falltime set to minimum.
Maximum Duty Factor	At least 75% (limited by Minimum Pulse Separation characteristic).

### Additional Output Signals

Pretrigger Output	At least +2 V into 1 k $\Omega$
Delayed Trigger Output	At least +2 V into 1 k $\Omega$

### Input Signal Requirements

External Trigger Input Frequency	Pulse: At least 0.5 V per 1 $\mu$ s rate of rise. Sinewave: From 1 kHz to 10 MHz.
External Trigger Input Amplitude	Pulse: Between +2 V and +20 V maximum, decreasing to +4 V at 10 MHz. Sinewave: Between 2 V and 20 V peak from 1 kHz to 5 MHz, decreasing to a maximum between 3 V and 4 V peak at 10 MHz.
Gate Pulse Input	Between +2 V and +10 V.

### Programming

Remote control of pulse output signal characteristics is available when appropriate front-panel switches are set to REMOTE or REMOTE PROGRAM. Digital and Analog control information is applied through rear panel connector J10.

Characteristic	Performance	
	Analog Function (Multiplier)	Digital Function (Switch)
General	A front panel multiplier function is programmed remotely by connecting a resistor between an Analog Program line and a power supply line on the rear panel remote program connector.	A front panel switch function is programmed remotely by connecting a Digital Program line to a true DC logic level at the rear panel remote program connector. Digital logic levels are as follows: True (1) 0 V to 0.8 V. False (0) +9.5 V to +12 V.
Remote Program Accuracy	Within 2% of specified front panel control accuracy plus error in program resistor	

Characteristic	Performance	
Mode		False on all four mode program lines provides Single mode. True on one (only) of the four mode program lines provides the corresponding pulse output mode: Delayed Single, Double, Burst or Gated Output.
Polarity		False on —polarity program line provides +polarity of pulse output. True on —polarity program line provides —polarity of pulse output.
Trigger Source		False on trigger source program line provides internal trigger source. True on trigger source program line, Type R116 requires external on manual trigger source.
Amplitude	Connect resistance, equal to 1.109 k $\Omega$ times multiplier value —2, between amplitude analog program line and signal ground line.	False on both amplitude digital program lines provides 0.2 V amplitude range. True on one (only) of the two program lines provides the corresponding amplitude range: 0.5 V or 1 V.
Risetime	Connect resistance, equal to 343 $\Omega$ times risetime multiplier —1 between risetime analog program line and +25 V line.	False on all three risetime-falltime digital program lines provides 1 ns risetime-falltime range. True on one (only) of the three risetime-falltime program lines provides the corresponding risetime-falltime range: 10 ns, 100 ns or 1 $\mu$ s.
Falltime	Connect resistance, equal to 343 $\Omega$ times falltime multiplier —1, between falltime analog program line and —27 V line.	

Characteristic	Performance	
Width	Connect resistance, equal to $177.4\ \Omega$ times width multiplier $-5$ , between width analog program line and $-27\text{ V}$ line.	False on all three width digital program lines provides $10\text{ ns}$ width ranges. True on one (only) of the three width program lines provides corresponding width range: $100\text{ ns}$ , $1\ \mu\text{s}$ or $10\ \mu\text{s}$ .
Delay or Burst Time	Connect resistance, equal to $177.4\ \Omega$ times delay multiplier $-5$ , between delay analog program line and $-27\text{ V}$ line.	False on all three delay digital program lines provides $10\text{ ns}$ delay ranges. True on one (only) of the three delay program lines provides the corresponding delay range: $100\text{ ns}$ , $1\ \mu\text{s}$ or $10\ \mu\text{s}$ .
Period	Connect resistance, equal to $1.69\text{ k}\Omega$ times period multiplier $-1$ , between period analog program line and $-6\text{ V}$ lines.	False on all four period digital program lines provides $100\text{ ns}$ period ranges. True on one (only) of the four period program lines provides the corresponding period range: $1\ \mu\text{s}$ , $10\ \mu\text{s}$ or $1\text{ ms}$ .
DC Offset	Connect resistance, equal to $887\ \Omega$ times DC offset multiplier $-5$ , between DC offset analog program line and signal ground line.	

**Power Requirements**

Characteristic	Performance
Power Source	This instrument has been designed to be operated on an unbalanced-to-ground power source. For safe op-

Characteristic	Performance
	eration, the power line neutral (white or "identified conductor") must be connected to the instrument neutral (unfused). The power plug safety ground (green conductor) must return to ground through a different path than the power line neutral.
Line Voltage Ranges	
115 V	94.5 VAC to 137.5 VAC
230 V	189 VAC to 275 VAC
Line Frequency	48 to 66 Hz
Maximum Power Consumption	100 watts, 0.87 A at 115 V, 60 Hz

**TABLE 1-2**  
**ENVIRONMENTAL CHARACTERISTICS**

Characteristic	Information
Ambient Temperature	Specified: from $+20^{\circ}\text{C}$ to $+30^{\circ}\text{C}$
Operating	Useful: from $0^{\circ}\text{C}$ to $+50^{\circ}\text{C}$
Non-Operating	From $-40^{\circ}\text{C}$ to $+65^{\circ}\text{C}$
Altitude	
Operating	To 10,000 feet
Non-Operating	To 50,000 feet
Transportation	Qualified under National Safe Transit Committee Test Procedure 1A, Category 11 (24 inch drop).

**TABLE 1-3**  
**MECHANICAL CHARACTERISTICS**

Characteristic	Description
Dimensions	
Height	$\approx 5\frac{1}{4}$ inches
Width	$\approx 19$ inches
Depth	$\approx 17\frac{1}{2}$ inches from back of front panel $\approx 19$ inches overall
Weight	$\approx 25\frac{3}{4}$ pounds
Finish	
Cabinet	Anodized aluminum
Front Panel	Aluminum

## NOTES

[illegible]

## SECTION 2

# OPERATING INSTRUCTIONS

Change information, if any, affecting this section will be found at the rear of the manual.

This section of the instruction manual provides information necessary for operating the Type R116 and using it in various applications. Included are handling and setup procedures, a description of the Type R116 controls and connectors, a first time operation procedure, definitions of pulse characteristics, a discussion of output pulse selection, and a discussion of the use of the Type R116 with other instruments.

### INITIAL CONSIDERATIONS

#### Rackmounting

Instructions for rackmounting the Type R116 are given in Section 7. Fig. 2-1 shows the instrument installed in a cabinet-type rack. After the slideout tracks have been installed in the rack, the Type R116 can be removed or re-inserted at any time as described in the Rackmounting section.

#### Bench Mounting

Four mounting feet are provided for operating the Type R116 on a test bench or table. To bench mount the Type R116,

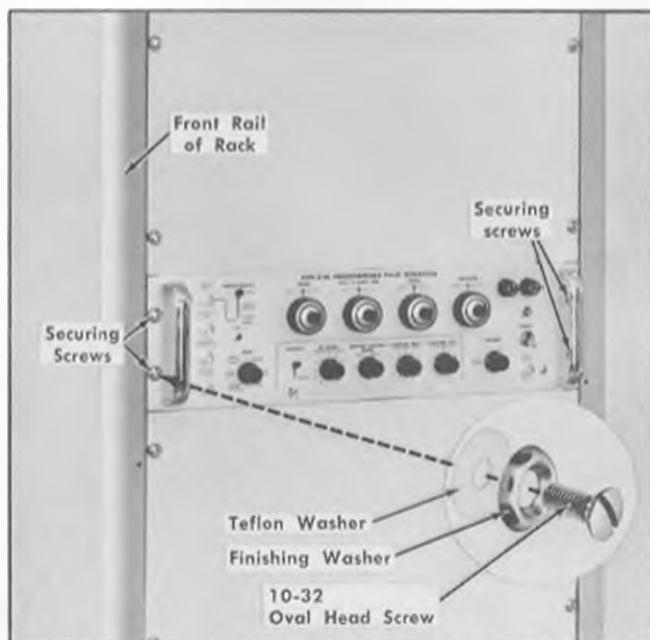


Fig. 2-1. The Type R116 is secured into the rack with 4 screws and washers, assembled as indicated in the insert photo. Remove these screws to extend the Type R116 in its slide-out track. (Refer to the foldout Rackmounting Instructions at the rear of this manual for installing the slide-out tracks.)

remove the bottom dust cover from the instrument and install the feet on the dust cover as shown in Fig. 2-2. Replace the cover on the bottom of the instrument. The feet must be removed before inserting the Type R116 into a rack if there is another instrument or panel immediately below the Type R116.

#### Cooling

The fan at the rear of the instrument provides forced-air cooling. A free flow of air in the temperature range from  $+20^{\circ}\text{C}$  to  $+30^{\circ}\text{C}$  ( $+68^{\circ}\text{F}$  to  $+86^{\circ}\text{F}$ ) should be provided for proper cooling of the Type R116. A thermal cutout in the instrument provides thermal protection by disconnecting the power to the instrument if the internal temperature exceeds a safe operating level. Power is automatically restored when the temperature returns to a safe level.

Normally the fan is operated as an intake fan to provide filtering of the air; however, it can be operated as an exhaust fan if necessary by reversing the entire fan assembly. The direction of air flow should be selected to provide the best cooling, depending on the temperature of the surrounding air and on the direction of air flow through adjacent instruments. In general, all instruments in one rack should have

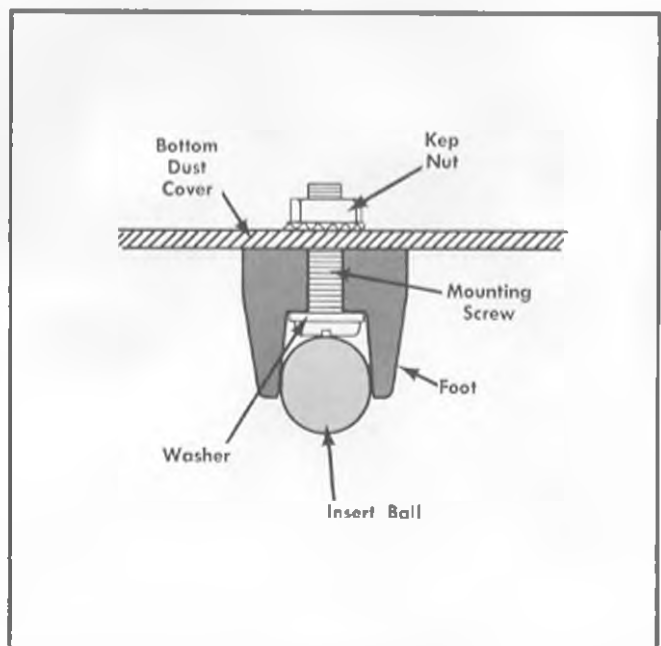


Fig. 2-2. Mounting each of the four feet for operating the Type R116 on a test bench or table.



Fig. 2-3. Front- and rear-panel controls and connectors on the Type R116.



the same direction of air flow to prevent recirculation of over-heated air. Some method of rack ventilation must be provided for removal or cooling of the heated air.

## Selecting Line Voltage

This instrument is designed to operate on a line voltage of either 115 volts or 230 volts AC RMS, depending on the position of the 115 V-230 V selector switch on the rear panel. A small screwdriver may be used to operate the switch. For 115-volt operation (94.5 volts to 137.5 volts), set the switch to the (115 V) position (see Fig. 2-3). For 230-volt operation (189 volts to 275 volts), set the switch to the (230 V) position.

## CONTROLS AND CONNECTORS

All controls and connectors required for the normal operation of the Type R116 are located on the front and rear panels of the instrument (see Fig. 2-3). To use the instrument effectively, the operator should become familiar with the function and use of each of these controls and connectors. These functions are described briefly in the following table and in more detail later in this section.

Controls	Function
MODE Switch	Selects mode of operation of instrument to produce different types of outputs at PULSE OUTPUT connector.  SINGLE—Identical, equally-spaced output pulses with no delay.  DLY'D SINGLE—Identical, equally-spaced output pulses having delay adjustable with respect to start of undelayed output pulse.  DOUBLE—Identical, equally-spaced pairs of output pulses; second pulse of each pair having adjustable delay time with respect to start of first pulse of the pair.  BURST—Identical, equally-spaced bursts of output pulses. Each burst is started by external trigger applied to + TRIGGER INPUT connector or by pressing TRIG button. Duration of each burst is controlled by DELAY OR BURST TIME controls.  GATED OUTPUT—Identical, equally-spaced bursts of output pulses. Start and duration of each burst is controlled by external gate applied to + GATE IN connector.  REMOTE PROGRAM—Digital remote control inputs applied through rear-panel REMOTE PROGRAM connector provide selection of operation mode.
TRIGGER SOURCE Switch	Selects how output pulses will be triggered in single, delayed single or double pulse modes.  INTERNAL—Output pulses triggered by internal, free-running period generator.

REMOTE PROGRAM—External digital remote control input applied through REMOTE PROGRAM connector provide selection of trigger source.

EXTERNAL OR MANUAL—Output pulses or bursts of output pulses (Burst mode) triggered by external triggers applied to + TRIGGER INPUT connector or by manual triggers applied by pressing TRIG button.

Manual TRIG Button

Pressed—Triggers one output pulse cycle (single, delayed single, double or burst) when external trigger amplifier is enabled. Release—Rearms.

PERIOD RANGE Switch and MULTIPLIER Control

Select time duration between start of one output pulse cycle and start of next cycle in single, delayed single and double pulse modes; select period of individual output pulses within each burst or gated burst; or permit remote selection of output pulse period. Period is continuously variable and calibrated from 100 ns through 11 ms in 5 (decade) ranges. MULTIPLIER control provides  $\times 1$  through  $\times 11$  multiplication of range selected by PERIOD RANGE switch. When PERIOD RANGE switch is set to REMOTE, period range and multiplier are determined by digital and analog remote control inputs.

DELAY OR BURST TIME RANGE Switch and MULTIPLIER Control

Select delay-time duration between corresponding points on single (undelayed) output pulse and delayed single output pulse or permit remote selection of delay time. Also determine duration of burst in BURST mode and approximate time interval between pretrigger and delayed trigger signals. Delay interval is continuously variable and calibrated from 50 ns through 550  $\mu$ s in 4 (decade) ranges. MULTIPLIER control provides  $\times 5$  through  $\times 55$  multiplication of range selected by DELAY OR BURST TIME RANGE switch. When DELAY OR BURST TIME RANGE switch is set to REMOTE, delay or burst time range and multiplier are determined by digital and analog remote control inputs.

WIDTH RANGE Switch and MULTIPLIER Control

Select width of individual pulses generated in single, delayed single or double pulse modes; select width of individual pulses within each burst or gated burst; or permit remote selection of output pulse width. Width is measured at 50% amplitude level with risetime and falltime at minimum. Width is continuously variable from 50 ns through 550  $\mu$ s in 4 (decade) ranges. MULTIPLIER control provides  $\times 5$  through  $\times 55$  multiplication of range selected by WIDTH RANGE switch. When WIDTH RANGE switch is set to REMOTE, width range and multiplier are determined by digital and analog remote control inputs.

## Operating Instructions—Type R116 (SN 1084-up)

Controls	Function		
AMPLITUDE RANGE Switch and MULTIPLIER Control	Select amplitude of output pulses or bursts, or permit remote selection of pulse or burst amplitude. Amplitude is continuously variable and calibrated (into a 50 $\Omega$ load) from $\pm 400$ mV through $\pm 10$ volts in 3 ranges. MULTIPLIER control provides $\times 2$ through $\times 10$ multiplication of amplitude range selected by AMPLITUDE RANGE switch. When AMPLITUDE RANGE switch is set to REMOTE, amplitude range and multiplier are determined by digital and analog remote control inputs.	RISETIME MULT Control	Adjusts risetime multiplication factor from $\times 1$ to $\times 11$ over range set by RISETIME FALLTIME RANGE switch and AMPLITUDE MULTIPLIER control. When PROGRAM switch is set to REMOTE, risetime multiplier is determined by analog remote control input.
POLARITY Switch	Selects either positive-going (+) or negative-going (—) output pulses or bursts, or permits remote selection of polarity. When set to REMOTE PROGRAM, polarity of output pulses is determined by digital remote control input.	FALLTIME MULT Control	Adjusts falltime multiplication factor from $\times 1$ to $\times 11$ over range set by RISETIME FALLTIME RANGE switch and AMPLITUDE MULTIPLIER control. When PROGRAM switch is set to REMOTE, falltime multiplier is determined by analog remote control input.
PROGRAM Switch	Selects either front-panel or remote control of offset, risetime and falltime of output pulses.  INT—front panel controls determine the pulse characteristics.  REMOTE—characteristics are determined by digital and analog remote control inputs.	POWER Switch	Applies power to transformer for operation of instrument with switch set to upward position; disconnects power in downward position.
DC OFFSET Control	Allows continuous adjustment of DC voltage level of output pulse or burst baselines within range set by AMPLITUDE RANGE switch: $-1$ to $+1$ volt in .2 V amplitude range; $-2.5$ to $+2.5$ volts in 5 V amplitude range; and $-5$ to $+5$ volts in 1 V amplitude range. When PROGRAM switch is set to REMOTE, DC offset (within range set by AMPLITUDE switch) is determined by analog remote control input	Power Indicator Light	Indicates when power is applied to power transformer primary.
RISETIME FALLTIME Range Switch	Selects risetime-falltime range of individual pulses from 10% to 90% amplitude level and from 90% to 10% level respectively, in single, delayed single and double pulse modes. Selects risetime-falltime range of individual output pulses in each burst or gated burst output. Switch setting must be multiplied by AMPLITUDE MULTIPLIER and RISETIME MULT or FALLTIME MULT control setting to determine the actual output pulse risetime or falltime. Risetime and falltime are continuously variable from 10 ns through 110 $\mu$ s in 4 (decade) ranges. Ratio of pulse risetime to falltime can be varied from 1:11 to 11:1. <sup>1</sup> When PROGRAM switch is set to REMOTE, risetime-falltime range is determined by digital remote control inputs.	115 V-230 V Selector Switch (on rear panel)	Selects either 115-volt or 230-volt operation of instrument, as indicated by rear-panel marking. Also selects correct fuse arrangement for selected operating voltage.
		<b>Connectors</b>	
		+TRIGGER INPUT Connector	Permits application of external DC-coupled signal having an amplitude between $+2$ and $+20$ volts for triggering output pulses in single, delayed single, double and burst modes when the external trigger amplifier is enabled.
		+PRETRIGGER OUT Connector	Provides approximate $+2$ -volt trigger pulse into 1 k $\Omega$ load, preceding single (undelayed) pulse or first pulse of double pulse and each individual pulse of a burst or gated burst output for triggering external equipment. Pretrigger precedes output pulse by a lead time ranging from approximately 30 ns to 45 $\mu$ s depending on pulse risetime.
		+DELAYED TRIGGER OUT Connector	Provides approximate $+2$ -volt trigger pulse into 1 k $\Omega$ load preceding delayed single pulse or second pulse of double pulse and at approximately the end of each burst in burst mode, for triggering external equipment. Delayed trigger is delayed with respect to pretrigger by approximately the delay time set by DELAY OR BURST TIME controls. Delayed trigger precedes delayed single pulse by lead time from approximately 30 ns to 45 $\mu$ s depending on pulse risetime.
		+GATE IN Connector	Permits application of external DC-coupled gate signal having an amplitude between $+2$ and $+10$ -volts for determining start and duration of gated burst output.

<sup>1</sup>Risetime-falltime ratio can be extended at a sacrifice of linearity by using remote operation of risetime and/or falltime multipliers.

Controls	Function
	With risetime set to minimum, output burst starts within 100 ns after gate exceeds +2-volt level (above chassis ground) and continues until gate drops below +2-volt level. Input impedance is approximately 1 k $\Omega$ .
PULSE OUTPUT Connector	Provides DC-coupled output pulse signal with characteristics determined by front-panel controls or remote programming. Output pulse must be applied to a 50 $\Omega$ load for pulse characteristics to be within specifications.
Fuses	Limit current through power transformer primary for protection of instrument. Fuse(s) selected for correct operating range by 115 V-230 V selector switch: two fuses for 115-volt operation and one fuse for 230-volt operation.
REMOTE PROGRAM Connector J10 (on rear panel)	Permits application of remote digital and analog information for remote programming of instrument. Provides chassis ground connection for remote digital logic (switch) and all necessary power supply voltages for remote analog functions (multipliers). See Remote Programming section of this manual for required connections.
Power Plug J401 (on rear panel)	Permits application of line power to instrument power transformer.

## FIRST-TIME OPERATION

The Type R116 is ready to be installed and operated when received. The following procedure illustrates the use of the front-panel controls in the various pulse modes to familiarize the operator with the instrument. This procedure may also be used at any time to set up the instrument to generate a particular output pulse or to check for an apparent malfunction. Since remote operation of the instrument merely duplicates front-panel operation, it will not be demonstrated here. Section 3 of this manual discusses the special considerations of programming.

### Setup Procedure

1. With the Type R116 installed in a rack or placed on a test bench, apply power to it and to a test oscilloscope. The test oscilloscope should have at least 15 MHz bandpass and preferably an  $\approx$  1 kHz calibrator signal.
2. Allow the instruments to warm up for a few minutes.
3. Connect a 50- $\Omega$  coaxial cable (terminated with a 5 watt 50- $\Omega$  termination) from the Type R116 PULSE OUTPUT connector to the Channel 1 vertical input of the test oscilloscope.
4. Set the instrument controls as follows:

#### Type R116

MODE SINGLE

TRIGGER SOURCE	INTERNAL
PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1
DELAY OR BURST TIME RANGE	1 $\mu$ s
MULTIPLIER	10
WIDTH RANGE	1 $\mu$ s
MULTIPLIER	5
AMPLITUDE RANGE	1 V
MULTIPLIER	10
POLARITY	+
PROGRAM	INT
DC OFFSET	0
RISETIME FALLTIME RANGE	100 ns
RISETIME MULT	1
FALLTIME MULT	1

#### Test Oscilloscope

Sweep Rate	10 $\mu$ s/cm
Triggering	+, Internal
Vertical Deflection Factor (Channel 1)	2 volts/cm
Input Coupling	DC
Amplitude Calibrator	Off

### First-time Operation Procedure

1. Adjust the test oscilloscope triggering, CRT and positioning controls to obtain a stable display of the pulse output signals, as shown in Fig. 2-4A.
2. Turn the Type R116 PERIOD MULTIPLIER control throughout its range and note the time interval change between leading edges of adjacent pulses in the waveform (see Fig. 2-4B).
3. Set the PERIOD MULTIPLIER control to the 5 position.
4. Turn the WIDTH MULTIPLIER control throughout its range and observe the change in pulse width (see Fig. 2-4C). Note that as the pulse width approaches the time interval between pulses, the waveform changes as the pulse generator begins to count down.
5. Return the WIDTH MULTIPLIER control to the 5 position.
6. Turn the AMPLITUDE MULTIPLIER control throughout its range and observe the change in display amplitude.
7. Set the AMPLITUDE MULTIPLIER control to 10.
8. Connect a coaxial cable from the +PRETRIGGER OUT connector to the External Trigger Input of the test oscilloscope.
9. Set the oscilloscope for external triggering.
10. With the oscilloscope Vertical Position control, position the baseline of the waveform to the horizontal centerline of the CRT graticule.
11. Set the Type R116 POLARITY switch to —. Since the oscilloscope is triggered with the Type R116 pretrigger sig-

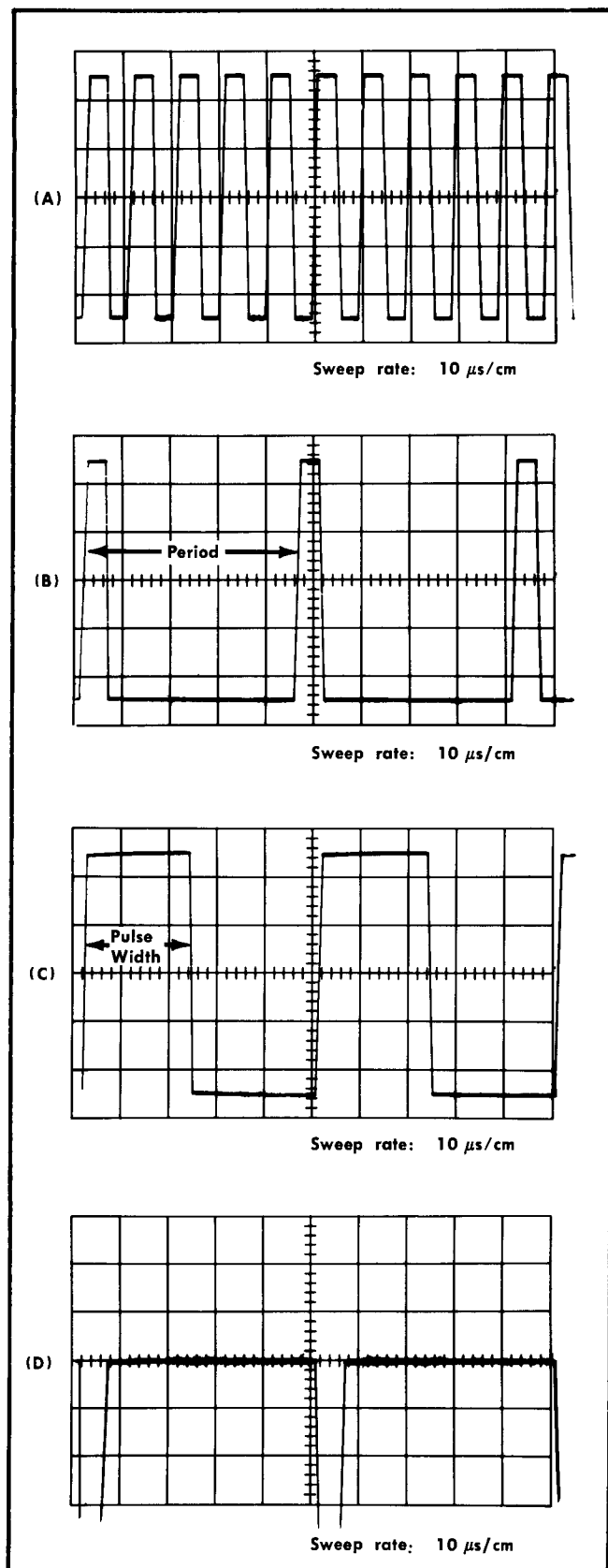


Fig. 2-4. Test oscilloscope displays obtained during first-time operation: (A) 10  $\mu$ s period, 5  $\mu$ s width; (B) effect of PERIOD MULTIPLIER Control; (C) effect of WIDTH MULTIPLIER control; (D) negative-going pulse, POLARITY switch set to —.

nal, no re-adjustment of triggering controls is required (see Fig. 2-4D).

12. Return the POLARITY switch to +.

13. Turn the Type R116 DC OFFSET control throughout its range and observe the DC positioning capability of the DC OFFSET control.

14. Set the DC OFFSET control to 0.

15. Center the waveform on the CRT screen with the oscilloscope Vertical Position Control.

16. Set the RISETIME FALLTIME RANGE switch to 10 ns.

17. Set the oscilloscope sweep rate to 2  $\mu$ s/cm.

18. Turn the RISETIME MULT control clockwise and observe the change in the pulse rise (see Fig. 2-5A). Note that the width of the pulse appears to decrease as the risetime is increased. This effect will be discussed later under Selection of Output Pulse Characteristics.

19. Set the RISETIME MULT control to the 10 position.

20. Turn the FALLTIME MULT control clockwise and observe the change in the falling edge of the pulse. Note that the width of the pulse increases as the falltime is increased.

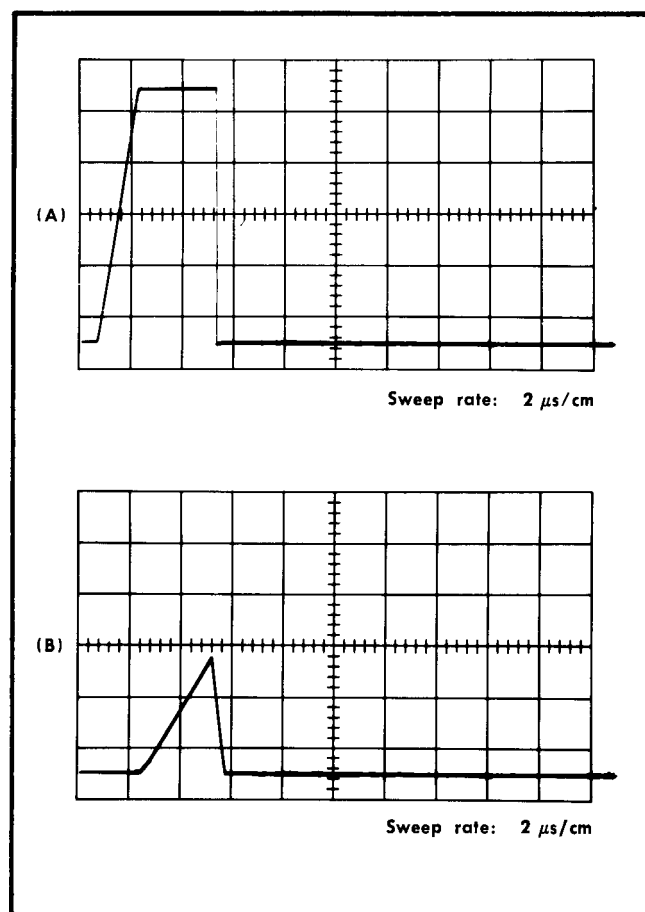


Fig. 2-5. Effects of RISETIME MULT control: (A) Risetime is increased as control is turned clockwise; (B) pulse disappears if risetime is made too long.

21. Set the FALLTIME MULT control to the 10 position. The pulse width at the 50% amplitude with both controls at 10 should be approximately the same as the original width with both controls at 1.

22. Return the RISETIME MULT and FALLTIME MULT controls to the 1 position.

23. Set the RISETIME FALLTIME RANGE switch to 100 ns.

24. Turn the RISETIME MULT control slowly clockwise. Notice that the pulse disappears as the risetime becomes as long as the pulse width (see Fig. 2-5B). This demonstrates one of the control operations that can produce an apparent condition of no output signal.

25. Return the RISETIME MULT control to the 1 position.

26. Set the oscilloscope sweep rate to 10  $\mu\text{s}/\text{cm}$ .

27. Set the MODE switch to DLY'D SINGLE.

28. Turn the DELAY OR BURST TIME MULTIPLIER control slowly through its range of operation. Note that the waveform moves across the CRT screen as the delay time changes between the Type R116 pretrigger pulse which is triggering the test oscilloscope and the Type R116 output pulse. Also note that the waveform changes when the delay time becomes as great as the time interval between pulses, and the pulse generator begins to count down.

29. Set the DELAY OR BURST TIME MULTIPLIER control to the 10 position.

30. Set the MODE switch to DOUBLE and observe that the displayed waveform now consists of pairs of pulses.

31. Turn the MODE switch between the SINGLE, DLY'D SINGLE and DOUBLE positions. Note that the left pulse of each pair is at the position of the undelayed (Single) pulse, and the right pulse of each pair is at the delayed (Dly'd Single) pulse position (see Fig. 2-6).

32. With the MODE switch at DOUBLE, turn the DELAY OR BURST TIME MULTIPLIER control slowly through its range and observe the change in pulse separation. Note that the second pulse disappears as the delay time is decreased to minimum, and that the delay generator begins to count down when the delay time is increased to equal the time interval between pulses.

33. Set the oscilloscope sweep rate to 0.2 ms/cm.

34. Reset the following Type R116 controls:

MODE	SINGLE
PERIOD RANGE	100 $\mu\text{s}$
MULTIPLIER	1
DELAY OR BURST TIME RANGE	10 $\mu\text{s}$
MULTIPLIER	35
WIDTH RANGE	10 $\mu\text{s}$
MULTIPLIER	5
RISETIME FALLTIME RANGE	1 $\mu\text{s}$

35. Note the appearance of the internally triggered waveform (see Fig. 2-7A).

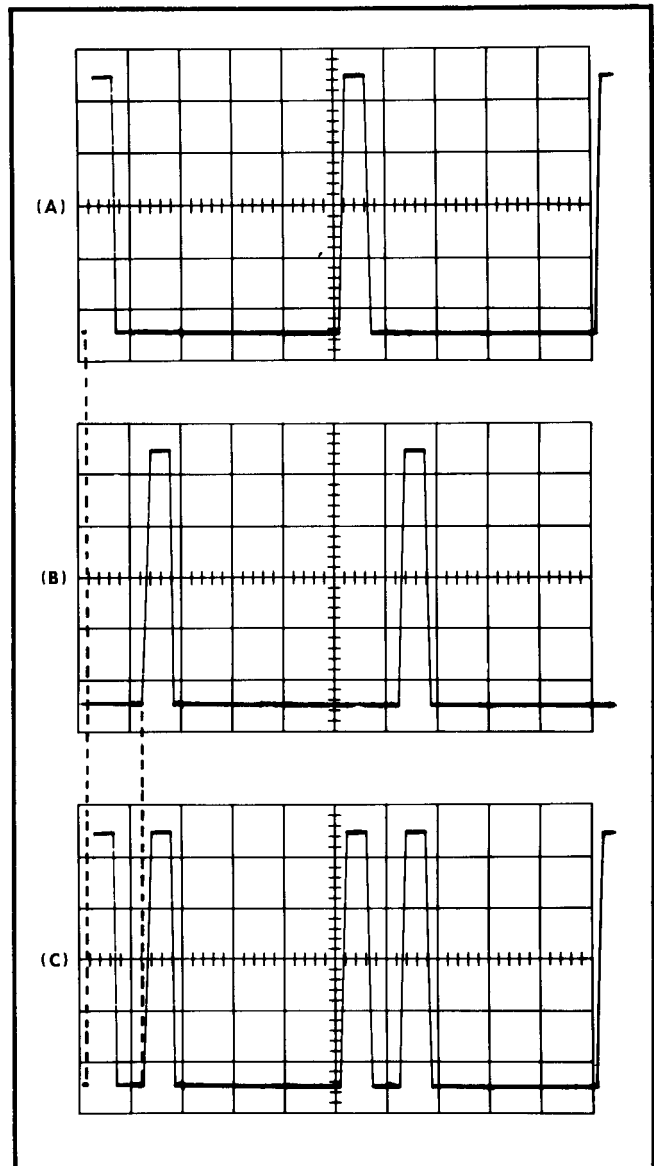


Fig. 2-6. Time comparison of output signals in three modes of operation: (A) Single (undelayed). (B) Delayed Single; and (C) Double.

36. Set the Type R116 TRIGGER SOURCE switch to EXTERNAL OR MANUAL.

37. Press the TRIG button. Note that each time the button is pressed, a single pulse, identical to the pulses generated in step 35, is produced.

38. Connect the oscilloscope calibrator waveform ( $\approx 1$  kHz) to the +TRIGGER INPUT connector of the Type R116.

39. Set the calibrator amplitude to 5 volts and note that the period of the output waveform is now controlled by the triggering signal from the calibrator (see Fig. 2-7B).

40. Set the MODE switch to the DLY'D SINGLE and DOUBLE positions. Note that the operation of the pulse generator is essentially the same, whether it is triggered from the free-running period generator or from an external triggering source.

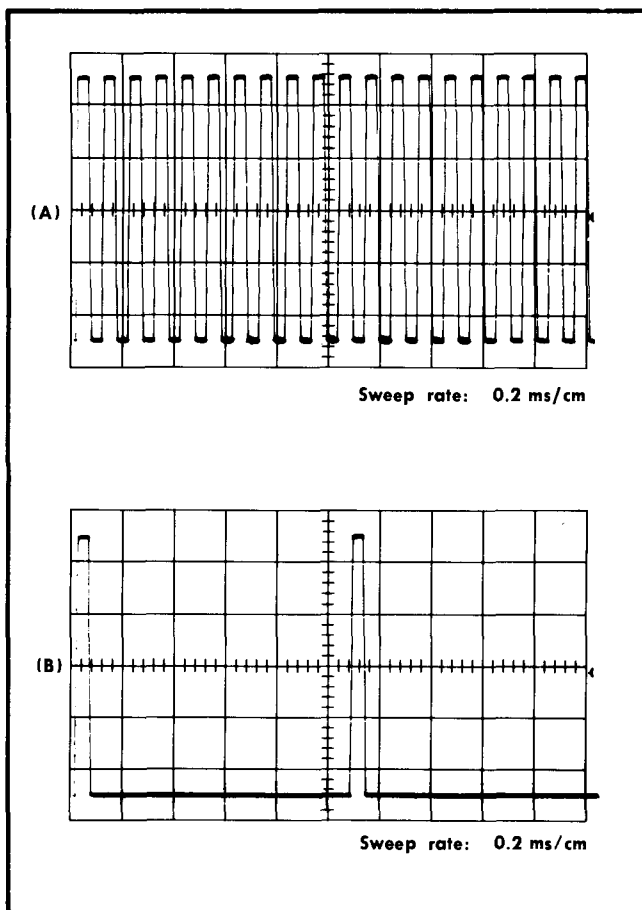


Fig. 2-7. Appearance of 50  $\mu$ s-wide pulse. (A) Triggered internally by period generator at 100  $\mu$ s period and (B) triggered externally by 1 kHz calibrator signal.

41. Disconnect the coaxial cable from the Type R116 +PRETRIGGER OUT connector.

42. Connect the oscilloscope calibrator signal through a T connector and two coaxial cables to the Type R116 +TRIGGER INPUT connector and the test oscilloscope External Trigger Input.

43. Reset the following Type R116 controls:

MODE	BURST
TRIGGER SOURCE	INTERNAL
PERIOD RANGE	100 $\mu$ s

44. Note the bursts of output pulses triggered at the frequency of the amplitude calibrator (see Fig. 2-8A).

45. Turn the DELAY OR BURST TIME MULTIPLIER control and note the change in the burst width.

46. Set the DELAY OR BURST TIME MULTIPLIER control to 35.

47. Increase the oscilloscope sweep rate to 20  $\mu$ s/cm and observe the pulse waveform making up the bursts. Characteristics of the waveform during the burst time are controlled by the Period, Width, etc. controls in the usual manner.

48. Set the MODE switch to GATED OUTPUT.

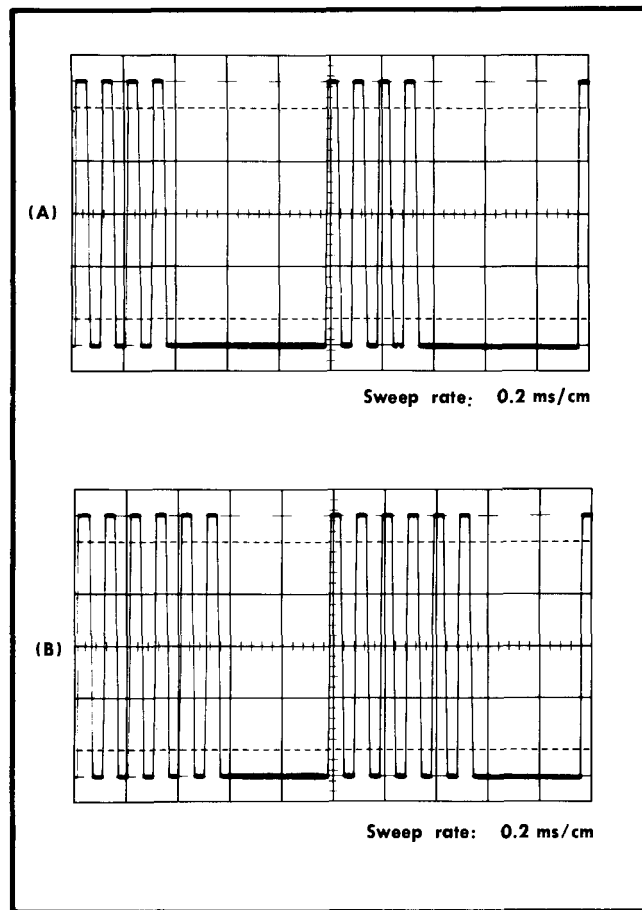


Fig. 2-8. Output pulse bursts: (A) Externally triggered burst, Burst mode; (B) Externally gated burst, Gated Output mode.

49. Disconnect the calibrator signal from the Type R116 +TRIGGER INPUT connector and connect it to the +GATE IN connector.

50. Reset the oscilloscope sweep rate to 0.2 ms/cm.

51. Note the bursts of output pulses during the gate intervals provided by the calibrator waveform. The pulses within these bursts are controlled by the Period, Width, etc. controls as in burst mode.

52. Set the MODE switch to SINGLE. This completes the demonstration of front-panel controls. The input and output signal cables may be disconnected.

## DEFINITIONS OF PULSE CHARACTERISTICS

In the following discussion the various characteristics of a Type R116 output pulse are defined and illustrated (see Fig. 2-9) as they are used in this manual.

**Period**—The time interval between the start of one cycle and the start of the next cycle. In the case of a burst, both the burst and the individual pulses within the burst have periods.

**Delay Time**—The time interval between corresponding points on the leading (or trailing) edges of the undelayed

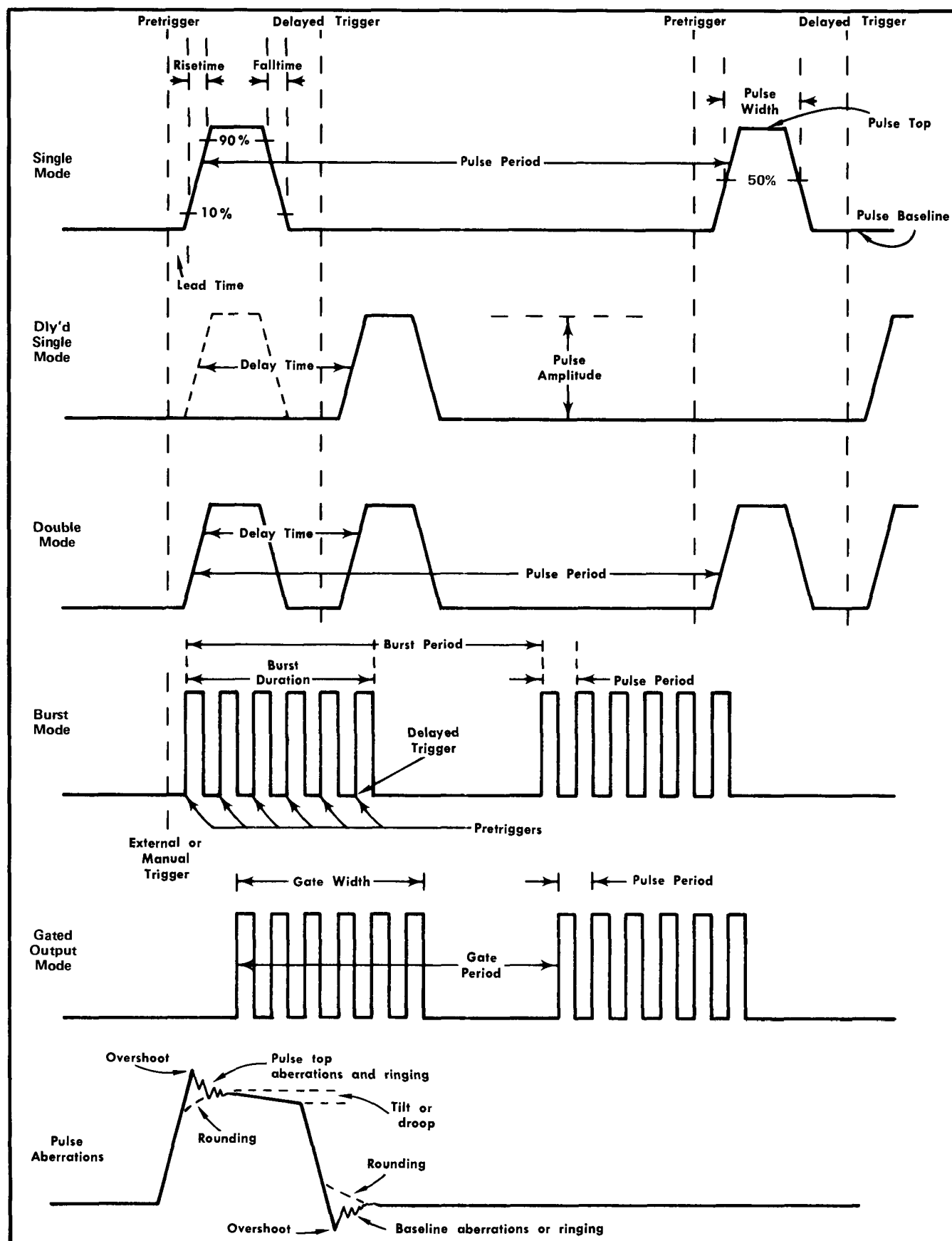


Fig. 2-9. Pulse waveforms illustrating the 5 modes of operation and the various pulse characteristics.

## Operating Instructions—Type R116 (SN 1084-up)

pulse and the delayed pulse. Also the approximate interval of time between the pretrigger and the delayed trigger.

**Lead Time**—The time interval between the output of a pretrigger (delayed trigger) and the start of an undelayed (delayed) output pulse. Lead time is dependent on pulse risetime.

**Burst**—A group of undelayed pulses followed by a pause when no pulses are generated.

**Burst Duration**—The time duration from the start of the first individual pulse of a burst to the fall of the last individual pulse of the burst.

**Burst Period**—The time interval between the start of one burst and the start of the next. In burst mode the burst period is the same as the period of the externally applied trigger. In gated mode the burst period is the same as the period of the externally applied positive-going gate.

**Width**—The time duration from the 50% amplitude level of the leading edge of a pulse to the 50% level of the trailing edge.

**Amplitude**—The voltage difference between the pulse baseline and the pulse top.

**Baseline**—The quiescent DC voltage level (including DC offset) at the PULSE OUTPUT connector when no pulse has been generated.

**DC Offset**—DC voltage level of pulse baseline with respect to the zero voltage level (ground).

**Pulse Top**—The constant voltage level to which the pulse rises from the baseline.

**Polarity**—The direction of the initial pulse excursion from the baseline, either positive-going (+) or negative-going (−).

**Risetime**—The amount of time required for the pulse amplitude to move from the 10% to the 90% level of the trailing edge of a pulse.

**Falltime**—The amount of time required for the pulse amplitude to move from the 90% to the 10% level of the trailing edge of a pulse.

**Aberration**—Deviations by the actual pulse from an ideal square-cornered pulse shape, i.e., overshoot, undershoot or rounding, ringing and tilt or droop.

**Overshoot**—The part of a pulse rise extending above the normal amplitude, or the part of a pulse fall extending below the baseline.

**Undershoot or Rounding**—The part of a pulse rise rounding off before it reaches normal amplitude or the part of the pulse fall rounding before it reaches the baseline.

**Tilt or Droop**—A long-term aberration in which the pulse top changes amplitude between the end of the pulse rise and the start of the pulse fall.

## SELECTION OF OUTPUT PULSE CHARACTERISTICS

### General

The versatility provided by the Type R116 controls allow pulses with a wide variety of characteristics to be obtained.

As has been noted in the first-time operating procedure, however, some undesirable pulse characteristics are also obtainable. There are many combinations of front-panel control settings which yield no pulse at all. The following discussion has been provided to help obtain only the desired pulse characteristics.

These general rules should be kept in mind whenever setting up a pulse:

1. The pulse risetime must be less than the pulse width.
2. The pulse falltime must be at least 100 ns less than the interval between pulses (period minus width, assuming equal risetime and falltime).
3. The pulse width at the baseline must be less than the period (75% maximum duty cycle).
4. In the delayed pulse or paired pulses modes, the pulse period must be greater than the delay time.
5. In the paired pulses mode the delay time must be greater than the pulse width.

When setting the controls while monitoring the output pulse with a test oscilloscope, it is often helpful to set the risetime and falltime controls to minimum until the other pulse characteristics have been established. This eliminates the problem of having no output pulse as a result of a slow risetime and/or falltime.

### Mode

The MODE switch determines what type of output pulse will appear at the OUTPUT PULSE connector. Five different operating modes are available with the Type R116, each one providing a different type of output pulse signal. The single output pulse is the basis of each of the Type R116 modes of operation. Its amplitude, width, period, risetime, falltime, delay, DC offset, and polarity can all be adjusted by front-panel controls and/or remote control inputs. The five different modes of operation are obtained by generating the single pulse in various arrangements.

**Single.** Identical, equally-spaced pulses with no delay appear at the OUTPUT PULSE connector.

**Delayed Single Pulse.** Identical, equally-spaced pulses with an adjustable delay appear at the OUTPUT PULSE CONNECTOR. The delay is determined by the Delay or Burst Time controls and is referenced to the start of the undelayed pulse.

**Double Pulse.** Identical, equally-spaced pairs of output pulses appear at the OUTPUT PULSE connector. The second pulse of each pair is delayed with respect to the first by an adjustable delay time determined by the Delay or Burst Time controls. The double pulse mode is actually a combination of the single and the delayed single pulse modes.

**Burst of Pulses.** Equal-duration, equally-spaced bursts of output pulses appear at the OUTPUT PULSE connector. Each burst cycle consists of a group of undelayed (single) pulses followed by a pause. Each burst is triggered by an external trigger pulse applied to the +TRIGGER INPUT connector or a manual trigger and the duration of each burst is determined by the Delay or Burst Time controls. The



characteristics of the individual pulses within the burst and thus the number of output pulses which can be generated for a given burst duration are determined by the Type R116 front-panel controls and/or the other remote control inputs.

**Gated Burst of Pulses.** Bursts of output pulses time-coincident with an input gate appear at the OUTPUT PULSE connector. Each gated burst cycle consists of a group of undelayed (single) pulses followed by a pause. The triggering of the gated burst, the burst duration and the burst period are determined by the width and period of a positive-going gate signal applied to the + GATE IN connector. The characteristics of the individual pulses within the gated burst and thus the number of output pulses which can be generated for a given gated burst duration are determined by the Type R116 front-panel controls and/or remote control inputs.

When the MODE switch is set to the REMOTE PROGRAM position, the operating mode is determined by remote control inputs received through the rear-panel REMOTE PROGRAM connector.

## Trigger Source

The TRIGGER SOURCE switch determines whether the repetition rate of the output pulse is to be controlled internally by the free-running period generator or externally by an external trigger applied to the + TRIGGER INPUT connector. Also a single cycle may be obtained when the TRIGGER SOURCE switch is set to EXTERNAL OR MANUAL by pressing the TRIG button.

In the single pulse, delayed single pulse, or double pulse modes of operation, the TRIGGER SOURCE switch may be set to either INTERNAL or EXTERNAL OR MANUAL depending on which method of triggering is desired. In the burst or gated burst modes of operation, the choice of triggering is determined by the MODE switch and the TRIGGER SOURCE switch has no control.

When the trigger source switch is set to REMOTE PROGRAM, the type of triggering is determined by a digital remote control input received through the rear-panel REMOTE PROGRAM connector.

## Polarity

The POLARITY switch determines whether the output pulse will be positive-going or negative-going. Except for polarity, the pulse characteristics are the same in either switch position and switching polarity does not change the baseline level.

When the POLARITY switch is set to REMOTE PROGRAM, the pulse polarity is determined by a digital remote control input received through the rear-panel REMOTE PROGRAM connector.

## Amplitude

Pulse amplitude is determined by the settings of the AMPLITUDE RANGE and MULTIPLIER controls. The amplitude into  $50\ \Omega$  is continuously variable and calibrated from 400 mV to 10 volts in three ranges. The calibration does not ap-

ply if the impedance of the output load is other than  $50\ \Omega$ . The AMPLITUDE MULTIPLIER control provides  $\times 2$  to  $\times 10$  multiplication of the AMPLITUDE RANGE switch setting and also affects the pulse risetime and falltime.

Example: If the AMPLITUDE RANGE switch is set to .5 V and the AMPLITUDE MULTIPLIER control is set to 4, the pulse amplitude is 2 volts.

When the AMPLITUDE RANGE switch is set to the REMOTE position, the amplitude range and multiplication factor are determined by digital and analog remote control inputs applied through the REMOTE PROGRAM connector.

## Risetime and Falltime

The risetime and falltime of the output pulses are determined by the settings of the RISETIME FALLTIME RANGE switch, the RISETIME MULT or FALLTIME MULT controls and the AMPLITUDE MULTIPLIER control. For a given settings of the risetime-falltime controls, the rise rate and fall rate of the pulse remain constant. The AMPLITUDE MULTIPLIER control setting must be considered when determining risetime and falltime, therefore, because for a given setting of the risetime-falltime controls, the actual risetime and falltime varies (10% to 90% amplitude level and 90% to 10% level respectively) with changes in the AMPLITUDE MULTIPLIER setting.

Risetime and falltime are continuously variable and calibrated (at maximum AMPLITUDE MULTIPLIER setting) from 10 ns to  $10\ \mu\text{s}$  in four ranges. Within each of these ranges, the risetime and falltime are independently variable from  $\times 1$  to  $\times 11$  the setting of the RISETIME FALLTIME RANGE switch, using the RISETIME MULT and the FALLTIME MULT controls, respectively. The possible risetime-falltime ratios are from 1:11 to 11:1. Calibration of the switch and dial readings is within 5% (10% on the 10 ns and 1 ns ranges). The linearity of the rise rate and fall rate is typically within 2% of an ideal ramp, except when the RISETIME AND FALLTIME RANGE switch is set to 10 ns or 1 ns.

Example: If the RISETIME FALLTIME RANGE switch is set to 100 ns, the RISETIME MULT control set to 2, the FALLTIME MULT control set to 4 and the AMPLITUDE MULTIPLIER control set to 5, the pulse risetime will be  $1\ \mu\text{s}$  (or  $100\ \text{ns} \times 2 \times 5$ ) and the falltime will be  $2\ \mu\text{s}$  (or  $100\ \text{ns} \times 4 \times 5$ ). It is important to remember that the risetime must be less than the duration of the width gate and the falltime must be less than the pulse period minus the duration of the width gate, as was illustrated in Fig. 2-10.

When the PROGRAM switch is set to the REMOTE position, the risetime-falltime range is determined by digital remote control inputs and the risetime and falltime multiplication factors are determined by analog remote control inputs received through the REMOTE PROGRAM connector.

## Width

The output pulse width is determined primarily by the settings of the WIDTH RANGE and MULTIPLIER controls, but is affected in some cases by the risetime, the falltime and the

<sup>2</sup>The Type R116 generates current pulses (with peaks ranging from 8 mA to 200 mA  $\pm 100$  mA offset current). The accuracy of the pulse amplitude in voltage, therefore, is dependent on the load resistance.

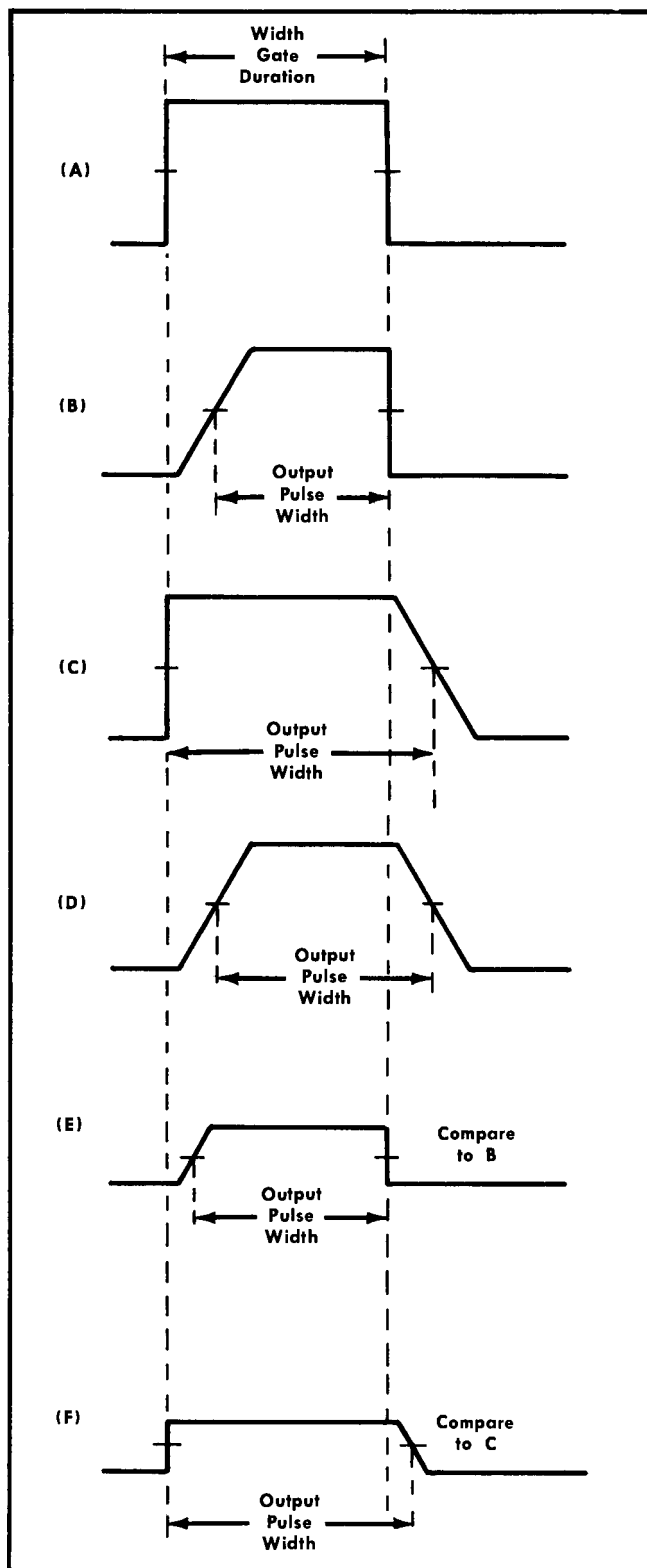


Fig. 2-10. Effects of risetime, falltime and amplitude on pulse width; (A)  $3\text{ }\mu\text{s}$  pulse with AMPLITUDE MULTIPLIER at 10 and risetime and falltime at minimum; (B) pulse width is decreased by increase in risetime; (C) width is increased by increase in falltime; (D) width is approximately equal to initial pulse width with equal risetime and falltime; (E) width is increased by decrease in amplitude if risetime is greater than falltime; (F) width is decreased by decrease in amplitude if risetime is shorter than falltime.

pulse amplitude. Calibration of the width controls applies only when the risetime and falltime are set for minimum; but if the risetime and falltime are equal, the width reading is still approximately correct.

The width is continuously variable and calibrated from 50 ns to  $550\text{ }\mu\text{s}$  in 4 ranges. The WIDTH MULTIPLIER control provides  $\times 5$  to  $\times 55$  multiplication of the WIDTH RANGE switch setting, with calibrated dial readings within 3% (5% on the 10 ns range). The width jitter is typically 0.05% or less of the pulse width plus 2 ns regardless of the mode of operation, except when the delay or burst time control settings exceed the period control settings.

Example: With the RISETIME FALLTIME RANGE switch set to 1 ns and the RISETIME MULT and FALLTIME MULT controls set to 1, if the WIDTH RANGE switch is at 100 ns and the WIDTH MULTIPLIER is at 30, the pulse width at the 50% level is  $3\text{ }\mu\text{s}$ .

If the risetime and falltime are not equal, the actual pulse width may be quite different from the width indicated by the width controls. The variation in pulse width; when the risetime and falltime are unequal, is caused by interaction between the risetime and falltime controls and the width gate, as shown in Fig. 2-10. As described in the Circuit Description, the output pulse is generated when a fast-rising, fast falling width gate (the width being determined by the width controls) enters the pulse shaper. The initial rise of the width gate causes a linear ramp to rise from the base-line to an amplitude determined by the amplitude controls. The fall of the width gate causes a linear ramp to fall from the given amplitude back to the baseline. The actual output pulse width, therefore, is dependent on the settings of the risetime and falltime controls. Fig. 2-10B shows that when the risetime exceeds the falltime, the pulse width decreases and Fig. 2-10C shows that when the risetime is less than the falltime, the pulse width increases.

The easiest way of setting a precise pulse width when the risetime and falltime are not minimum and the AMPLITUDE MULTIPLIER control is not set to 10, is by displaying the output pulse on a test oscilloscope and adjusting the controls for the desired characteristics. However, to set up the width controls (or remote program values) without the use of an oscilloscope, purely numerical calculations can be used to establish the approximate settings ( $\pm 10\%$ – $20\%$ ), as follows:

1. If the risetime is longer than the falltime, the pulse width (with the AMPLITUDE MULTIPLIER at 10) is **decreased** by an amount approximately equal to  $\frac{1}{2}$  the difference between the risetime and the falltime.

2. If the risetime is shorter than the falltime, the pulse width (with the AMPLITUDE MULTIPLIER at 10) is **increased** by an amount approximately equal to  $\frac{1}{2}$  the difference between the risetime and the falltime.

3. If the AMPLITUDE MULTIPLIER control is to be set to a position less than 10 and the risetime and falltime are not equal, the pulse width at the 50% level is changed by an additional amount, approximately equal to  $\frac{1}{2}$  the difference between the risetime and the falltime, times  $\frac{1}{8}$  the difference between 10 and the desired AMPLITUDE MULTIPLIER setting. This change is in addition to the decrease or increase just mentioned.

The following two equations illustrate these three principles:

Risetime longer than falltime:

$$\text{Width decrease} = \frac{1}{2} (T_r - T_f) \times \frac{1}{8} (10 - \text{AMPLITUDE MULTIPLIER})$$

Risetime shorter than falltime:

$$\text{Width increase} = \frac{1}{2} (T_r - T_f) \times \frac{1}{8} (10 - \text{AMPLITUDE MULTIPLIER})$$

When the WIDTH RANGE switch is set to REMOTE, the width range and multiplication factor are determined by digital and analog remote control inputs received through the rear-panel REMOTE PROGRAM connector.

## Delay or Burst Time

The DELAY OR BURST TIME RANGE and MULTIPLIER controls affect the delay time and the burst time of the output pulses and bursts when the Type R116 is operating in the delayed single, double or burst modes.

In the delayed single or double modes, the Delay or Burst Time controls determine the delay time between the start of the delayed single pulse (or the second pulse of a double pulse) and the start of the undelayed (single) pulse. In the burst mode the duration of the burst is determined by these controls. The delay or burst time controls also determine the approximate delay time between the pretrigger and the delayed trigger.

The delay or burst time is continuously variable and calibrated from 50 ns to 550  $\mu$ s in 4 ranges. The DELAY OR BURST TIME MULTIPLIER control provides  $\times 5$  to  $\times 55$  multiplication of the DELAY OR BURST TIME RANGE switch setting, with calibrated dial readings within 3%  $\pm 10$  ns. The delay jitter is typically 0.05% or less of the pulse delay plus 2 ns. When in the delayed single pulse mode, the delay time must be 100 ns less than the pulse period. When in the double mode this condition holds true and in addition the delay must be greater than the baseline pulse width plus 100 ns. In burst mode the burst duration must be longer than the period of the individual pulses within the burst and the burst period minus the burst time must exceed the baseline width of the individual pulses within the burst.

Example 1: With the MODE switch set to DOUBLE, if the DELAY OR BURST TIME RANGE switch is set to 100 ns and the DELAY OR BURST TIME MULTIPLIER control is set to 10, the time interval between corresponding points on the two pulses of each pair is 1  $\mu$ s.

Example 2: With the MODE switch set to BURST, if the DELAY OR BURST TIME RANGE switch is set to 100 ns and the DELAY OR BURST TIME MULTIPLIER control is set to 10, the time duration of the burst will be approximately 1  $\mu$ s and the number of output pulses within the burst will be determined by the settings of the period and width controls.

In Gated Output mode, the duration of the output burst is not determined by the Delay or Burst Time controls, but rather by the width of an external positive-going gate signal applied through the +GATE IN connector. The width of the gate signal is measured at the +2-volt level.

When the DELAY OR BURST TIME RANGE switch is set to REMOTE, the delay or burst time range and multiplication

factor are determined by digital and analog remote control inputs applied through the REMOTE PROGRAM connector.

## Period

The period between output pulses is determined either by an internal free-running period generator or by an external or manual triggering signal.

When operated internally in the single, delayed single or double mode with the TRIGGER SOURCE switch set to INTERNAL, the pulse period is selected by means of the PERIOD RANGE and MULTIPLIER controls. The period is continuously variable and calibrated from 100 ns to 11 ms in five ranges. The PERIOD MULTIPLIER control provides  $\times 1$  to  $\times 11$  multiplication of the PERIOD RANGE switch setting, with calibrated dial readings within 3% (5% on the 100 ns range). The period jitter is typically 0.05% or less of the pulse period plus 2 ns except when the Delay or Burst Time control settings exceed the PERIOD control settings, regardless of the mode of operation. In the burst or gated output modes, the period of the pulses within each burst is also set by the PERIOD RANGE and MULTIPLIER controls.

Example: If the PERIOD RANGE switch is set to 1  $\mu$ s and the MULTIPLIER control is set to 5.5, the pulse period is 5.5  $\mu$ s (providing the width controls are set to be less than the pulse period).

Since the pulse period is the reciprocal of its frequency, any pulse frequency from 91 Hz to 10 MHz can be obtained by calculating the period of the desired signal frequency and setting the period controls accordingly.

With the TRIGGER SOURCE switch set to EXTERNAL OR MANUAL (in the single, delayed single or double modes), the period is set by the period of an external triggering signal applied through the +TRIGGER INPUT connector. Single pulses (or pairs) may also be obtained by means of the manual TRIG button.

When the PERIOD RANGE switch is set to REMOTE, the period range and multiplication factor are determined by digital and analog remote control inputs applied through the REMOTE PROGRAM connector.

## DC Offset

The DC OFFSET control allows DC positioning of the pulse baseline, providing up to  $\pm 5$  volts of DC offset (AMPLITUDE RANGE switch set to 1 V). The dial reading of the DC OFFSET must be multiplied by the AMPLITUDE RANGE switch to obtain the value of DC offset which has been added to the output pulse signal. The range of the DC OFFSET control is, therefore, from  $-1$  to  $+1$  V with the AMPLITUDE RANGE switch set to .2 V; from  $-2.5$  to  $+2.5$  V with the switch set to .5 V; and from  $-5$  to  $+5$  V with it set to 1 V.

The DC OFFSET control allows an output pulse to be positioned with respect to ground voltage on a DC-coupled oscilloscope or other display device, or allows the DC level of the pulse signal to be made positive or negative with respect to ground for application to a test device.

When the PROGRAM switch is set to REMOTE, the DC offset multiplication factor is determined by an analog remote control input received through the REMOTE PROGRAM connector.

## Triggering the Type R116

The Type R116 can be triggered either by the internal, free-running period generator; an external trigger applied to the +TRIGGER INPUT connector; or a manual trigger. The mode of operation determines which methods of triggering are possible and the TRIGGER SOURCE switch allows the choice of the method to be used. In addition, the instrument can be triggered by a positive-going gate applied to the +GATE IN connector.

In the single, delayed single, and the double pulse modes, when the TRIGGER SOURCE switch is set to INTERNAL, the output pulses are triggered by the free-running period generator within the Type R116. The repetition rates available with internal triggering are from approximately 91 Hz to 10 MHz (11 ms to 100 ns period). In these modes, when the TRIGGER SOURCE switch is set to the EXTERNAL OR MANUAL position, triggering is provided either by an external signal applied through the front-panel +TRIGGER INPUT connector or by a manual trigger pulse obtained by pressing the TRIG button. With external triggering, repetition rates from DC to 10 MHz can be obtained.

In the burst mode, the bursts are triggered by external signals applied through the +TRIGGER INPUT connector (or manual triggers), but the internal free-running period generator still triggers the individual pulses within each burst. If the burst duration is longer than the time intervals between externally applied trigger pulses, each burst will occur following the first trigger after the end of the preceding burst.

In the gated output mode, each burst is started and ended by the gating signal applied to the +GATE IN connector. Each pulse within a gated burst is still triggered by the internal period generator as in the burst mode.

### External Trigger Input

To trigger the Type R116 through the +TRIGGER INPUT connector a signal with an amplitude between +2 and -20 volts is required. If the input signal has a DC component which prevents it from moving into the +2-volt range, it should be capacitively coupled. The time constant of the coupling should be very short if the full repetition rate of the instrument is to be used. See Section 1 for characteristics of signals which are suitable for input at the +TRIGGER INPUT connector.

The most desirable way to connect a trigger signal to the +TRIGGER INPUT connector is through a 50  $\Omega$  coaxial cable with BNC-connectors and suitable attenuators to bring the signal amplitude within the +2 to +20-volt range. For some applications, a probe can be connected to a desired trigger source. A 1 $\times$  probe should be used for triggering signals from +2 volts to +20 volts and a 10 $\times$  probe for signals from +20 to +200 volts in amplitude. For best results, a 10 $\times$  probe should be compensated after installation. (This may be done by connecting the probe tip to a 20-volt square-wave source and adjusting the probe compensation while monitoring the signal with another probe connected just inside the +TRIGGER INPUT connector.)

### +Gate Input

To generate a gated burst when the Type R116 is in the gated mode of operation, a gated pulse, with an amplitude

between +2 and +10 volts must be applied to the +GATE INPUT connector. Each burst begins when the gate signal exceeds the +2-volt level and ends when the gate returns below the +2-volt level.

The most desirable way to connect a gate signal to the +GATE INPUT connector is through a coaxial cable with BNC connectors and appropriate attenuators to ensure that the gate is within the +2 to +10 volt range. If the gate signal has a DC component which shifts the pulse out of the +2 to +10 volt range, the signal will have to be applied through a coupling capacitor. The time constant of the coupling must be long enough to keep the signal above +2 volts for the duration of the gate. The input impedance of the +GATE IN connector is 1 k $\Omega$  or more.

## Manual Triggering

In the single, delayed single, and double pulse modes, when the TRIGGER SOURCE switch is set to the EXTERNAL OR MANUAL position and no external signal is applied to the +TRIGGER INPUT, a single output pulse (or pair of pulses) may be obtained by pressing the manual TRIG button. In the burst mode, a single burst of output pulses is obtained when the TRIG button is pressed, with no external signal applied. The TRIGGER SOURCE switch is not operational in the burst or gated burst modes and may be in any position.

## Remote Operation

When the TRIGGER SOURCE switch is set to REMOTE PROGRAM, selection of the trigger source is provided by a digital, remote control input applied through the rear-panel REMOTE PROGRAM connector. Remote trigger selection in the various modes is the same as for front-panel operation. For example, the external triggering signal is still applied through the +TRIGGER INPUT connector.

## TRIGGERING EXTERNAL EQUIPMENT WITH THE TYPE R116

### General

The positive-going triggers appearing at the +PRETRIGGER OUT and the +DELAYED TRIGGER OUT connectors of the Type R116 allow a test oscilloscope or other external device to be time-referenced to the output pulse. In the case of an oscilloscope, these trigger pulses allow the oscilloscope sweep to be started before the Type R116 output pulse arrives, as well as allowing time-positioning of the output pulse on the oscilloscope CRT with the Type R116 delay controls. These trigger pulses also provide the convenience of a constant amplitude triggering signal that eliminates the need for adjusting triggering controls.

When the Type R116 pretrigger is connected to a test oscilloscope external trigger input, the oscilloscope sweep is time-referenced to the beginning of the undelayed (single) output pulse. If the MODE switch is set to DLY'D SINGLE, the delayed output pulse displayed on the test oscilloscope CRT can be time positioned using the Delay or Burst Time controls.

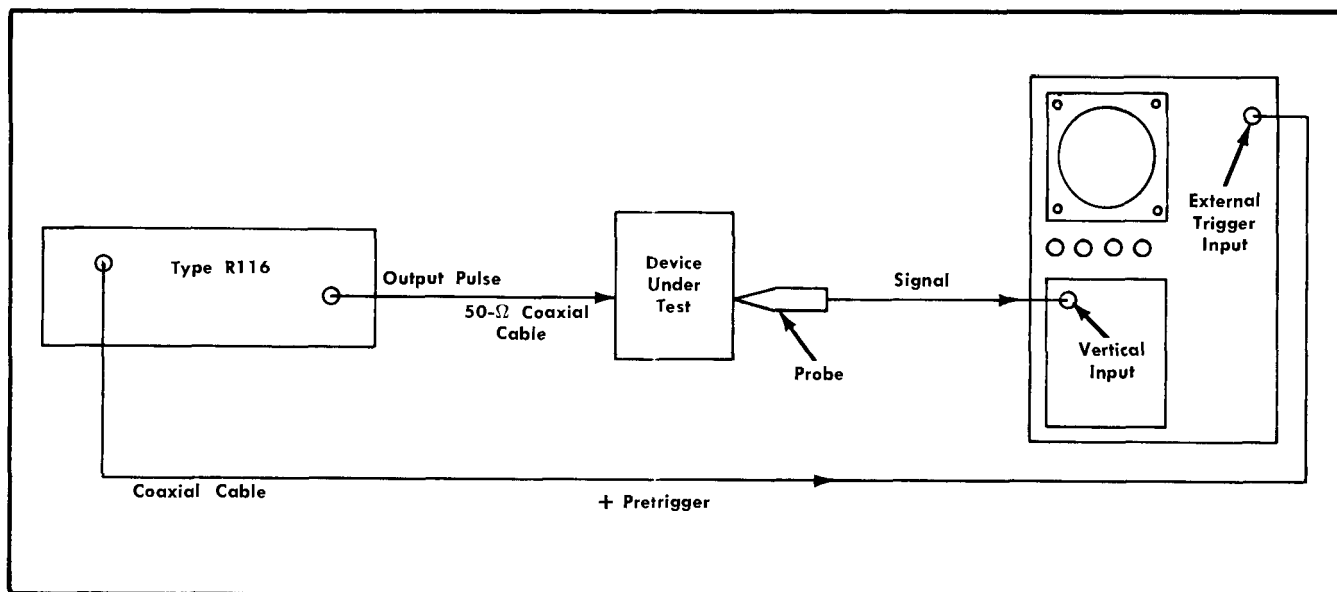


Fig. 2-11. Normal test setup using the Type R116 pretrigger signal to trigger the test oscilloscope.

### Pretrigger Output

The pretrigger output pulse which appears at the +PRE-TRIGGER OUT connector is a positive-going pulse which precedes by 30 ns or more the undelayed (single) output pulse, the first pulse of a double pulse and each individual pulse in a burst or gated burst. The pretrigger precedes the delayed pulse in the delayed single pulse mode by approximately the delay time and also precedes the delayed trigger appearing at the +DELAYED TRIGGER OUT connector by approximately the delay time. The amplitude of the pretrigger is 2 volts or more into 1 k $\Omega$  and the risetime is typically 10 ns. The pretrigger serves as a good time reference for all the output pulses of the Type R116 and also the internal signals of the instrument.

### Delayed Trigger Output

The delayed trigger output pulse which appears at the +DELAYED TRIGGER OUT connector is a positive-going pulse which precedes by 30 ns or more the delayed (delayed single) output pulse and the second pulse of a double pulse. In the burst mode, the delayed trigger appears at approximately the end of each burst. It also appears at approximately the delay time after the pretrigger. The amplitude of the delayed trigger is 2 volts or more into 1 k $\Omega$  and the risetime is typically 10 ns. The delayed trigger signal provides a convenient time reference for viewing delayed output pulses from the Type R116 and for time-positioning undelayed output pulses on the test oscilloscope CRT graticule.

### The Type R116 as a Test Device

A common use of the Type R116 is in testing external equipment or electronic components. A sample setup of this type is shown in Fig. 2-11. In the usual application, the Type R116 pretrigger is used to trigger a test oscilloscope sweep and the Type R116 output pulse is applied to a device un-

der test. An output signal from the device under test is then connected to the vertical input of the test oscilloscope allowing it to be monitored on the CRT.

### OUTPUT PULSE CONNECTIONS

The output stage of the Type R116 has been designed to work into a 50- $\Omega$  load and is calibrated in amplitude and DC offset only when working into a 50  $\Omega$  load. Loads higher than 50  $\Omega$  will produce higher voltage amplitudes and greater DC offset, but may also cause reflections and ringing in the output connecting cables. Loads less than 50  $\Omega$  will produce lower amplitudes and less offset but will not overload the output circuit of the Type R116.

### Basic Precautions

Certain precautions should always be observed when connecting the Type R116 output signal to a device under test or when connecting the output of a device under test to a display oscilloscope.

1. Use high-quality coaxial cables and connectors for all signal connections.
2. Make sure that all connections are tight and that all connectors are tightly assembled.
3. Keep signal cables as short as possible to preserve the signal quality.
4. Use attenuators as needed to limit the signal amplitude applied to sensitive circuits.
5. Use terminations and impedance-matching devices to suit the application.
6. Use only attenuators, terminations, etc., that have power ratings suitable for the 5 watts maximum output from the Type R116. (Power output is determined by the offset current and the duty cycle of the output pulse current.)

## Risetime Considerations

If the output pulse signal from the Type R116 is to be used for determining the risetime of a device under test, the risetime of the Type R116 output pulse may have to be taken into consideration.

In general, if the risetime of the device under test is at least 10 times as long as the combined risetimes of the Type R116 and the monitoring oscilloscope and cables, the error introduced into the measurement will not be more than about 1% and therefore can be considered negligible.

However, if the risetime of the device under test is less than 10 times as long as the combined risetime of the testing system, the observed risetime will not be a true measurement of the risetime of the tested device. In this case, the risetime of the tested device will have to be determined from the risetime of the various components making up the system.

Normally, the overall risetime of the system is equal to the square root of the sum of the squares of the individual risetimes. Thus the risetime of the tested device can be determined if the risetime of all the other components are known. Since the minimum risetime of the Type R116 is 10 ns, the practical lower limit of risetime measurements is 10 ns.

## Cabling Considerations

The cables that conduct the output pulse of the device under test should be low-loss 50  $\Omega$  coaxial cables to ensure that all information contained in the pulse will be delivered to the test point without distortion. The physical and electrical characteristics of the cable determine 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 that are as short as possible.

When making signal-comparison measurements or time difference determinations, the two response signals from the test device should travel through coaxial cables that have identical loss characteristics and identical time delay.

If there is a DC voltage across the output load, a coupling capacitor should be used to prevent DC offset compression of the Type R116 output pulse. The choice of time constant of the coupling will be dependent on the duty cycle of the pulse output. The time constant must be long enough to ensure minimum decay of the pulse top but short enough to allow adequate recovery time before the start of the next pulse. If a coupling capacitor is not used, when there is a DC voltage across the load, the output pulse amplitude will be compressed if the DC voltage is less than  $\pm 10$  volts and will possibly be shorted out if the voltage present exceeds  $\pm 10$  volts.

## Impedance Matching

To provide a smooth transition between devices of different characteristic impedances, each device must encounter a total impedance that is equal to its own characteristic impedance at the input or output point. The following discussion provides a method for matching impedance networks

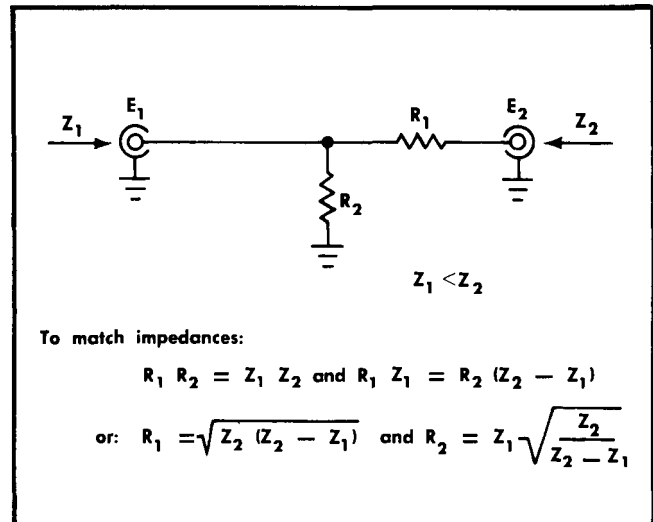


Fig. 2-12. Simple impedance-matching network providing minimum attenuation.

which have relatively low impedances. If the Type R116 is operating into a high impedance system such as the 1 M $\Omega$  input of an oscilloscope, this type of impedance matching is not necessary as long as the 50  $\Omega$  termination is connected very close to the high impedances.

A simple resistive impedance-matching network that provides minimum attenuation is illustrated in Fig. 2-12. To match impedances with the illustrated network, the following conditions must exist:

$$\frac{(R_1 + Z_2) R_2}{(R_1 + Z_2) + R_2} \text{ must equal } Z_1^3$$

and

$$R_1 + \frac{Z_1 R_2}{Z_1 + R_2} \text{ must equal } Z_2$$

Therefore:

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

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

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

As an example, to match a 50- $\Omega$  system to a 125- $\Omega$  system,  $Z_1$  equals 50  $\Omega$  and  $Z_2$  equals 125  $\Omega$ .

Therefore:

$$R_1 = \sqrt{125 (125 - 50)} = 96.8 \text{ ohms}$$

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

When constructing such a device, the environment surrounding the components should also be designed to provide a transition between the impedances. Keep in mind that the

<sup>3</sup>In the case of the Type R116,  $Z_1$  is the source impedance which varies with respect to the position on the AMPLITUDE RANGE switch. It varies as follows: 1 position—at least 500  $\Omega$ ; .5 position—50  $\Omega$ , within 5%; .2 position—50  $\Omega$  within 5%.

characteristic impedance of a coaxial device is determined by the ratio between the outside diameter of the inner conductor and the inside diameter of the outer conductor ( $Z_0 = 138 \log_{10} D_1/D_2$ ).

Though the network in Fig. 2-12 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 ( $E_1$ ) encounters a voltage attenuation ( $A_1$ ) which is greater than 1 and less than 2, as follows:

$$A_1 = \frac{E_1}{E_2} = \frac{R_1}{Z_2} + 1$$

A signal applied from the higher impedance source ( $Z_2$ ) encounters a voltage attenuation ( $A_2$ ) which is greater than 1 and less than 2  $Z_2/Z_1$ :

$$A_2 = \frac{E_2}{E_1} = \frac{R_1}{R_2} + \frac{R_1}{Z_1} + 1$$

In the example of matching 50  $\Omega$  to 125  $\Omega$ ,

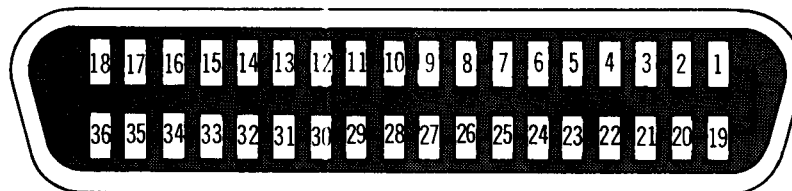
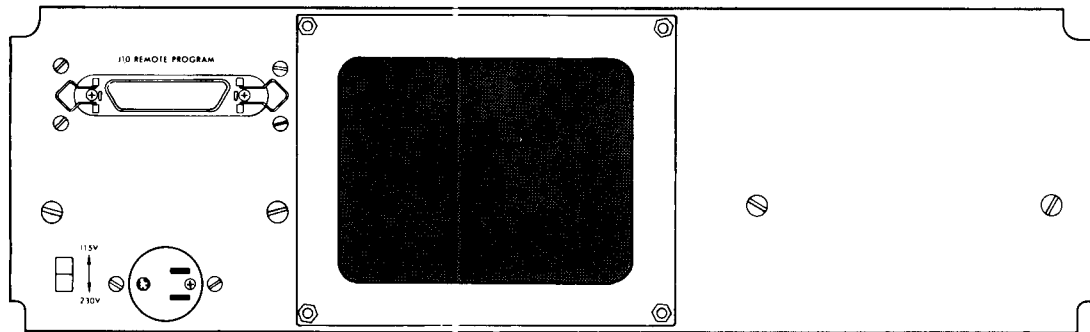
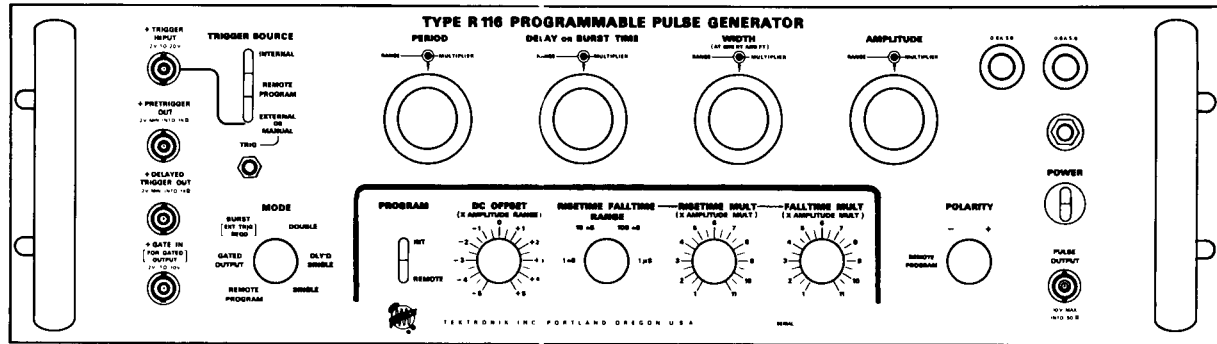
$$A_1 = \frac{96.8}{125} + 1 = 1.77$$

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

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

## CONTROL SETUP CHART

Fig. 2-13 shows the front- and rear-panel controls and connectors of the Type R116. This chart may be reproduced and used as a test-setup record for special measurements, applications or procedures, or may be used as a training aid for familiarization with the Type R116.



**Fig. 2-13. Control setup chart for the Type R116.**



# SECTION 3

## REMOTE PROGRAMMING

Change information, if any, affecting this section will be found at the rear of the manual.

### Introduction

The general principles of programming the Type R116 are discussed in this section. Since the actual methods of programming will vary with the application of the instrument and the programming devices available, this section is presented only as a general guideline to programming.

The Type R116 is designed to be used either as part of a program system or as an independent instrument. All front-panel operations can be remotely programmed by information received through the 36-terminal remote program connector on the rear panel. Schematic No. 10 shows the connections to the REMOTE PROGRAM connector (J10). Since all front-panel switches are independent of other switches, any combination of front-panel operation and remote operation can be used. Any characteristic that does not need to be changed during the program can be set with the front-panel control and left at that preset value. Unnecessary program connections can be avoided by programming only the functions that need to be changed. Very few applications will require that all functions be remotely programmed. The Type R116 can be programmed by a variety of external programming devices. When it is automatically sequenced, the Type R116 is able to operate up to a rate of approximately 25 programs per second.

Front-panel switches, which determine both ranges and modes of operation, are controlled by reed-relay switches. Reed-relay switches are actuated by energizing a relay coil. To remotely program a switch function, a contact on the rear-panel J10 REMOTE PROGRAM connector is connected to ground, which energizes a relay coil. Front-panel dials, which are potentiometers that determine multiplier values, are programmed by connecting a resistor between a contact and a power supply on the J10 REMOTE PROGRAM connector. Whenever one of the front-panel switches is set to REMOTE or REMOTE PROGRAM, both the range and the multiplier associated with that switch must be remotely programmed.

If completely digital remote operation is desired, the analog information required for programming the multiplier controls must be supplied by a digital-to-analog converter. A simple type of converter that may be used for this purpose is described later in this section.

### Programming Switch Functions

Whenever a front-panel switch is set to REMOTE or RE-

MOTE PROGRAM, its function is automatically set to a basic mode or range. This mode or range is automatically programmed with no contact closures to ground. If a different mode or range on the switch is desired, a program line (for making a ground closure) is required between the Type R116 and an external programming device. To be able to program all the front-panel switch positions, a total of 21 program lines are needed. In addition, a current-return path is required from the programmer to the Type R116 chassis ground (connected through terminal #36 of the REMOTE PROGRAM connector). In some cases, diode switching may be designed into the programmer to reduce the number of contacts required. The program lines may be connected with insulated #22 stranded copper wire and the return lead to ground may be insulated with #18 stranded copper wire.

To aid in programming, the following logic has been devised. Connecting a program line to ground (or a DC voltage level within 0.8 volt of chassis ground) constitutes a logical 1, and an open circuit on the program line (or a DC voltage level from +9.5 to +12 volts above chassis ground) constitutes a logical 0. For each group of program lines associated with a single switch, only one logical 1 is permissible. Each group may have 0's on all program lines (when the basic remote mode or range is desired) or a 1 on one line and 0's on all other lines, but a group may not have a 1 on more than one line. Since each of the digital (switch) program lines connects into the Type R116 through a buffer amplifier, less than 1 mA of current is required for a logical 1.

### Programming Analog Functions

Whenever a front-panel switch function is remotely programmed, its associated front-panel multiplier control must also be programmed.

Each front-panel multiplier (analog) control that is to be programmed requires one program resistance connected between an analog program line and a DC voltage supplied by the Type R116 through the REMOTE PROGRAM connector. The program resistors may be  $\frac{1}{8}$ -watt resistors with the tolerance selected on the basis of the desired multiplier accuracy. A total of 7 analog functions can be remotely programmed by means of analog resistances, requiring a total of 7 program lines and 4 power supply leads. Each of the program lines and power supply leads may be connected with insulated #22 stranded copper wire.

## Remote Programming—Type R116 (SN 1084-up)

### NOTE

The analog program voltages must be referenced to the Type R116. The program resistors, therefore, must be connected to the power supply voltages provided by the Type R116. External voltage supplies cannot be used for this purpose.

### PROGRAM SEQUENCE

The following pages describe the programming of each

of the pulse characteristics. Due to the interdependence of several pulse characteristics (amplitude, risetime, falltime and width) it is suggested that the switch and analog functions be programmed in the order shown. If a particular pulse characteristic is not to be programmed, the page describing the corresponding function can be disregarded. Each page includes formulas and a table for determining the proper logic for switch functions and formulas and graphs for determining the correct analog resistors for multiplier functions.

**PULSE MODE, TRIGGER SOURCE AND POLARITY****Pulse Mode**

When the MODE switch is set to REMOTE PROGRAM, the pulse mode must be externally programmed. The desired mode is obtained by connecting one (or none for Single mode) of the four terminals, #20, #21, #22 or #23, on the J10 REMOTE PROGRAM connector to chassis ground, terminal #36. Table 3-1 shows the proper terminal connections corresponding to the five pulse modes on the front panel.

**TABLE 3-1**

Desired Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)			
	Terminal #20 (Dly'd Single)	Terminal #21 (Double)	Terminal #22 (Burst)	Terminal #23 (Gated Output)
SINGLE	0	0	0	0
DLY'D SINGLE	1	0	0	0
DOUBLE	0	1	0	0
BURST	0	0	1	0
GATED OUTPUT	0	0	0	1

**Trigger Source**

When the TRIGGER SOURCE switch is set to REMOTE PROGRAM, the pulse trigger source must be externally programmed. The desired trigger source is obtained by connecting or not connecting terminal #19 to chassis ground, terminal #36. Table 3-2 shows the proper terminal connections corresponding to the two trigger sources on the front panel.

**TABLE 3-2**

Desired Triggering	Digital Logic Information Through REMOTE PROGRAM Connector (J10)	
	Terminal #19 (External or Manual)	
INTERNAL	0	
EXTERNAL OR MANUAL	1	

**Pulse Polarity**

When the POLARITY switch is set to REMOTE, the pulse polarity must be externally programmed. The desired polarity is obtained by connecting or not connecting terminal #18 to chassis ground, terminal #36. Table 3-3 shows the proper terminal connections corresponding to plus or minus polarity.

**TABLE 3-3**

Desired Polarity	Digital Logic Information Through REMOTE PROGRAM Connector	
	Terminal #18 (—Polarity)	
+	0	
—	1	

PULSE AMPLITUDE

When the AMPLITUDE RANGE switch is set to REMOTE, both the range (switch function) and the multiplier (analog function) must be remotely programmed. The relationship between the pulse amplitude and the amplitude range and amplitude multiplier is shown by equation 3-1. Note that one amplitude can be obtained with several different values of the amplitude range or multiplier.

$$A' = A \times a$$

Eq. 3-1

Where:  
A' = Desired Amplitude  
A = Amplitude Range  
a = Amplitude Multiplier

Range

The desired range is obtained by connecting one (or none for the .2 V range) of the two terminals, #24 or #25, on the J10 REMOTE PROGRAM connector to chassis ground, terminal #36. Table 3-4 shows the proper terminal connections corresponding to the three amplitude ranges on the front panel.

TABLE 3-4

Desired Amplitude Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)	
	Terminal #24 (.5 V)	Terminal #25 (1 V)
.2 V	0	0
.5 V	1	0
1 V	0	1

Multiplier

The amplitude multiplier is programmed by connecting a 1/8-watt 1% resistor between terminals #27 and #1. The resistor can be chosen either by use of the graph, Fig. 3-1, or equation 3-2. In both cases the value of the amplitude multiplier must be known. This number can be found either by adjusting the R116 controls to obtain the desired waveform and reading the multiplier off the front panel or by use of equation 3-1. Once the multiplier has been determined, the proper resistance  $R_a$  can be obtained from Fig. 3-1 or equation 3-2.

$$R_a = (a - 2) (1.11 \text{ k}\Omega \text{ per unit})$$

Eq. 3-2

NOTE

If terminals #27 and #1 are left open, zero amplitude is programmed. This occurs only on the amplitude and DC offset analog lines.

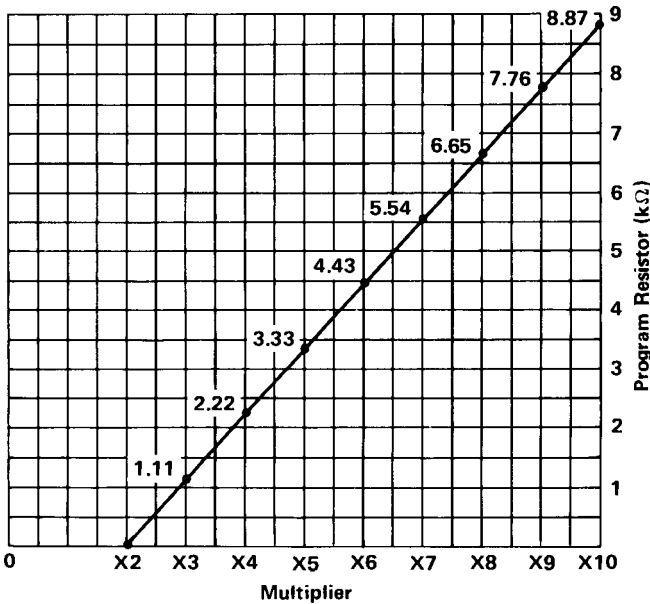


Fig. 3-1. Amplitude Multiplier vs. Program Resistor Value.

## PULSE RISETIME AND FALLTIME

When the PROGRAM switch is set to REMOTE, both the risetime-falltime range (switch function) and the risetime and falltime multipliers (analog functions) must be remotely programmed. The relationship between the pulse risetime (or falltime) and the risetime-falltime range, the risetime multiplier (or falltime multiplier) and the amplitude multiplier are shown by equations 3-3 and 3-4.

$$T'_r = T_{rf} \times tr \times a \quad \text{Eq. 3-3}$$

$$T'_f = T_{rf} \times tf \times a \quad \text{Eq. 3-4}$$

Where:

$T'_r$  = Desired Risetime                       $tr$  = Risetime Multiplier  
 $T'_f$  = Desired Falltime                       $tf$  = Falltime Multiplier  
 $T_{rf}$  = Risetime-Falltime Range            $a$  = Amplitude Multiplier

TABLE 3-5

Desired Risetime- Falltime Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)		
	Terminal #28 (10 ns)	Terminal #29 (100 ns)	Terminal #30 (1 $\mu$ s)
1 ns	0	0	0
10 ns	1	0	0
100 ns	0	1	0
1 $\mu$ s	0	0	1

## Range

The desired range is obtained by connecting one (or none for the 1 ns range) of the three terminals, #28, #29 and #30, on the J10 REMOTE PROGRAM connector to chassis ground (terminal #36). Table 3-5 shows the proper terminal connections corresponding to the four risetime-falltime ranges on the front panel.

## Multiplier

The risetime and falltime multipliers are programmed by connecting 1/8-watt 1% resistors between terminals #31 and #2 and between terminals #32 and #3 respectively. The resistors can be chosen either by use of a graph, Fig. 3-2, or equations 3-5 and 3-6. In both cases the value of the risetime and falltime multipliers must be known. These numbers can be found either by adjusting the R116 controls to obtain the desired waveform and reading the multipliers off the front panel or by use of equations 3-3 and 3-4. Once the multipliers have been determined the proper resistance  $R_{tr}$  and  $R_{tf}$  can be obtained from Fig. 3-2 or the following equations:

$$R_{tr} = (tr - 1) (0.343 \text{ k}\Omega \text{ per unit}) \quad \text{Eq. 3-5}$$

$$R_{tf} = (tf - 1) (0.343 \text{ k}\Omega \text{ per unit}) \quad \text{Eq. 3-6}$$

Note that the risetime and falltime of a pulse do not have to be equal. A maximum ratio between risetime and falltime of 11 to 1 can be obtained by using analog resistance values found on Fig. 3-2 or from Eq. 3-5 and 3-6. Greater ratios can be obtained; however, for ratios greater than 11 to 1, Fig. 3-2 or Eq. 3-5 and Eq. 3-6 provide resistance values which will produce only approximately the risetime and falltime desired.

Care should be taken in selecting risetimes and falltimes. It is possible to select risetimes so long that the pulse never reaches the programmed amplitude. This problem occurs when the risetime is about equal to the pulse width, or greater. It is possible to select a falltime so long that it never reaches the baseline. This problem occurs whenever the falltime is equal to the interval between pulses (period minus width), or greater.

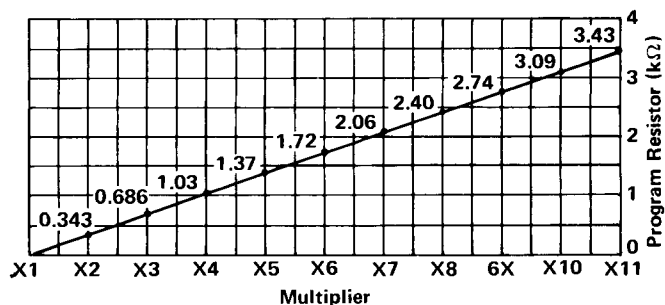


Fig. 3-2. Risetime Multiplier or Falltime Multiplier vs. Program Resistor values.

## PULSE WIDTH

When the WIDTH RANGE switch is set to REMOTE, both the range (switch function) and multiplier (analog function) must be remotely programmed. The desired pulse width is dependent on the risetime and falltime multipliers and on the amplitude multiplier. The width to be programmed, different than the desired width, can be determined from equation 3-7.

$$W'_2 = W' - 1.25 T'_f (1/2 + 2/a) + 1.25 T'_r (1/2 + 2.33/a) \quad \text{Eq. 3-7}$$

Where:

$W'_2$  = Width to be programmed

$W'$  = Desired Width

$T'_f$  = Falltime Desired

$T'_r$  = Risetime Desired

$a$  = Amplitude Multiplier

The width to be programmed is related to the width range and the width multiplier by the following equation:

$$W'_2 = W \times w \quad \text{Eq. 3-8}$$

Where:

$W$  = Width Range

$w$  = Width Multiplier

## Range

The desired range is obtained by connecting one (or none for the 50 ns range) of the three terminals, #14, #15 or #16, on the J10 REMOTE PROGRAM connector to chassis ground, terminal #36. Table 3-6 shows the proper terminal connections corresponding to the four width ranges on the front panel.

TABLE 3-6

Desired Width Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)		
	Terminal #14 (100 ns)	Terminal #15 (1 $\mu$ s)	Terminal #16 (10 $\mu$ s)
10 ns	0	0	0
100 ns	1	0	0
1 $\mu$ s	0	1	0
10 $\mu$ s	0	0	1

## Multiplier

The width multiplier is programmed by connecting a 1/8-watt 1% resistor between terminals #17 and #3. The resistor can be chosen either by use of a graph Fig. 3-3 or equation 3-9. In both cases the value of the width multiplier must be known. This number can be found either by adjusting the R116 controls to obtain the desired waveform and reading the multiplier off the front panel or by use of equation 3-8. Once the multiplier has been determined the proper resistance  $R_w$  can be obtained from Fig. 3-3 or the following equation:

$$R_w = (w - 5) (0.177 \text{ k}\Omega \text{ per unit}) \quad \text{Eq. 3-9}$$

The width must be chosen so that it is less than the period or delay (in the case of delayed pulses and double pulses). When the width is longer than the period, successive pulses tend to run into each other.

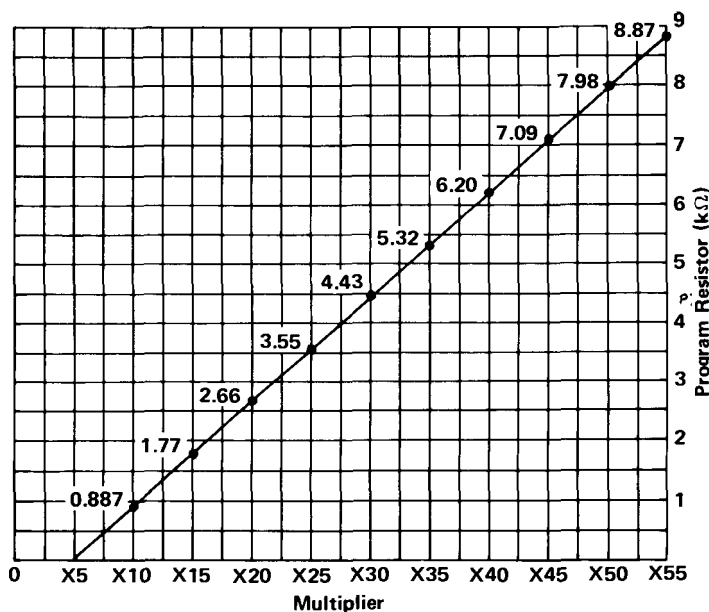


Fig. 3-3. Width Multiplier vs. Program Resistor value.

## PULSE DELAY OR BURST TIME

When the DELAY OR BURST TIME RANGE switch is set to REMOTE, both the range (switch function) and the multiplier (analog function) must be remotely programmed. The relationship between the pulse delay and the delay range and delay multiplier is shown by equation 3-10.

$$D' = D \times d$$

Eq. 3-10

Where:

$D'$  = Desired Delay

$D$  = Delay Range

$d$  = Delay Multiplier

## Range

The desired range is obtained by connecting one (or none for the 50 ns range, of the three terminals, #10, #11 or #12, on the J10 REMOTE PROGRAM connector to chassis ground, terminal #36. Table 3-7 shows the proper terminal connections corresponding to the four delay ranges on the front panel.

TABLE 3-7

Desired Delay Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)		
	Terminal #10 (100 ns)	Terminal #11 (1 $\mu$ s)	Terminal #12 (10 $\mu$ s)
10 ns	0	0	0
100 ns	1	0	0
1 $\mu$ s	0	1	0
10 $\mu$ s	0	0	1

## Multiplier

The delay multiplier is programmed by connecting a 1/8-watt 1% resistor between terminals #13 and #3. The resistor can be chosen either by use of a graph, Fig. 3-4 or equation 3-11. In both cases the value of the delay multiplier must be known. This number can be found either by adjusting the R116 controls to obtain the desired waveform and reading the multiplier off the front panel or by use of equation 3-10. Once the multiplier has been determined the proper resistance  $R_d$  can be obtained from Fig. 3-4 or the following equation:

$$R_d = (d - 5) (0.177 \text{ k}\Omega \text{ per unit})$$

Eq. 3-11

The above discussion holds if the desired delay is to be between corresponding points on the undelayed and the delayed output pulse. If, however, the delay desired is from the +Pretrigger to the 50% level of the delayed pulse rise, the following equation should be used to determine the correct delay to be programmed.

$$D'_2 = D' - 1.25 \text{ tr} (1/2 + 2.33/a) \quad \text{Eq. 3-12}$$

Where:

$D'_2$  = Delay to be programmed

$\text{tr}$  = Risetime Multiplier

$a$  = Amplitude Multiplier

This new value of delay determined from the desired delay, risetime multiplier and amplitude multiplier should be used in equation 3-10 to determine values for the delay range and multiplier.

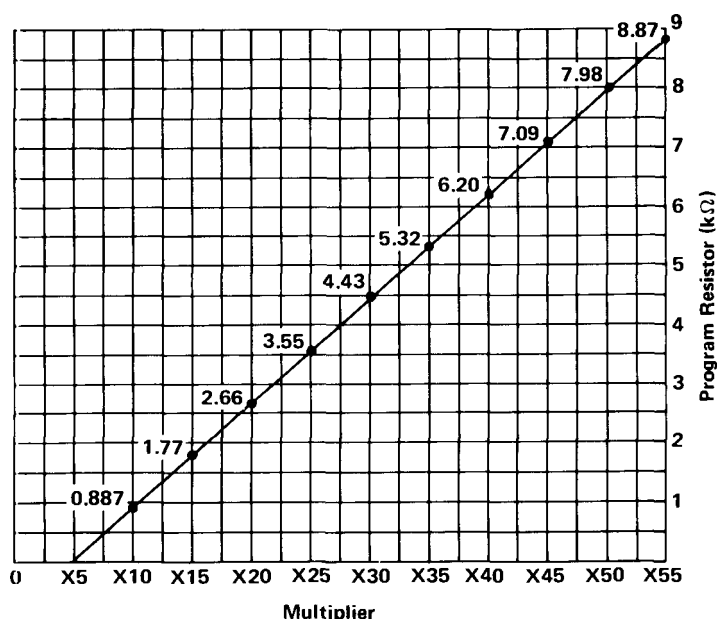


Fig. 3-4. Delay or Burst Time Multiplier vs. Program Resistor value.

## PULSE PERIOD

When the PERIOD RANGE switch is set to REMOTE, both the range (switch function) and the multiplier (analog function) must be remotely programmed. The relationship between the pulse period and the period range and period multiplier is shown by equation 3-13.

$$P' = P \times p \quad \text{Eq. 3-13}$$

Where:

$P'$  = Desired Period

$P$  = Period Range

$p$  = Period Multiplier

## Range

The desired range is obtained by connecting one (or none for the 100 ns range) of the four terminals, #5, #6, #7 or #8, on the REMOTE PROGRAM J10 plug to chassis ground, terminal #36. Table 3-8 shows the proper terminal connections corresponding to the five period ranges on the front panel.

TABLE 3-8

Desired Period Range	Digital Logic Information Through REMOTE PROGRAM Connector (J10)			
	Terminal #5 (1 $\mu$ s)	Terminal #6 (10 $\mu$ s)	Terminal #7 (100 $\mu$ s)	Terminal #8 (1 ms)
100 ns	0	0	0	0
1 $\mu$ s	1	0	0	0
10 $\mu$ s	0	1	0	0
100 $\mu$ s	0	0	1	0
1 ms	0	0	0	1

## Multiplier

The period multiplier is programmed by connecting a 1/8-watt 1% resistor between terminals #9 and #34. The resistor can be chosen either by use of a graph Fig. 3-5 or equation 3-14. In both cases the value of the period multiplier must be known. This number can be either found by adjusting the R116 controls to obtain the desired waveform and reading the multiplier off the front panel or by use of equation 3-13. Once the multiplier has been determined the proper resistance  $R_p$  can be obtained from Fig. 3-5 or the following equation:

$$R_p = (p - 1) (1.69 \text{ k}\Omega \text{ per unit}) \quad \text{Eq. 3-14}$$

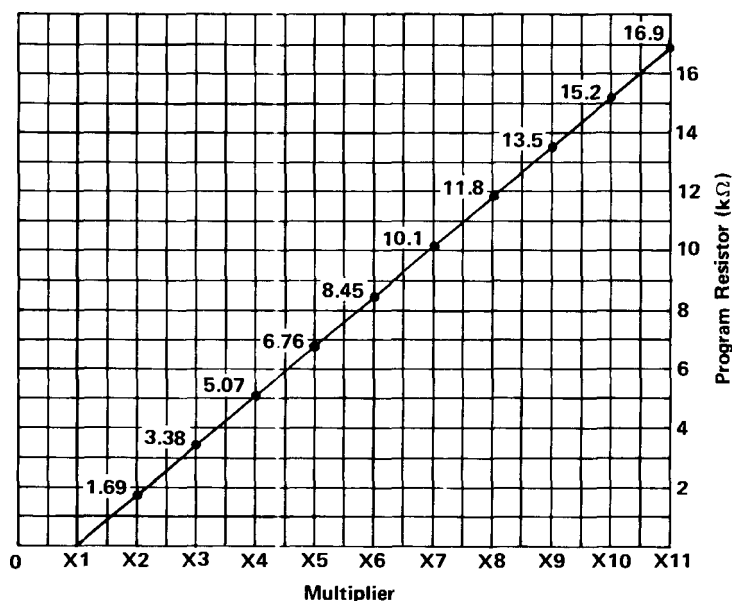


Fig. 3-5. Period Multiplier vs. Program Resistor value.



## PULSE OFFSET

When the PROGRAM switch is set to REMOTE, the DC Offset multiplier (analog function) must be remotely programmed. The desired pulse offset is dependent on the amplitude range switch and the offset multiplier. This relationship is shown by equation 3-15.

$$O' = o \times A \quad \text{Eq. 3-15}$$

Where:

$O'$  = Desired Offset  
 $o$  = Offset Multiplier  
 $A$  = Amplitude Range

## Multiplier

The offset multiplier is programmed by connecting a 1/8-watt 1% resistor between terminals #33 and #1. The resistor can be chosen either by use of a graph, Fig. 3-6, or equation 3-16. In both cases the value of the offset multiplier must be known. This number can be found either by adjusting the R116 controls to obtain the desired baseline offset and reading the multiplier off the front panel or by use of equation 3-15. Once the multiplier has been determined the proper resistance  $R_O$  can be obtained from Fig. 3-6 or the following equation:

$$R_O = (5 - o) (0.887 \text{ k}\Omega \text{ per unit}) \quad \text{Eq. 3-16}$$

### NOTE

*If terminals #33 and #1 are left open, zero offset is programmed. This occurs only on the DC offset and amplitude analog lines.*

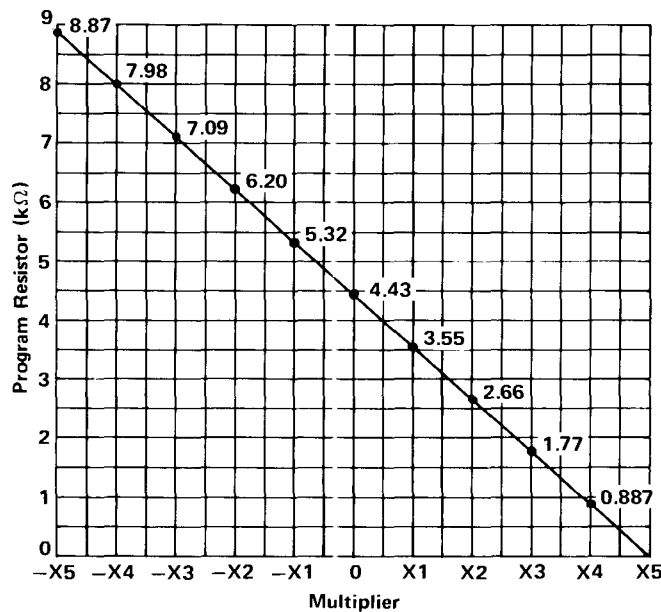


Fig. 3-6. DC Offset Multiplier vs. Program Resistance values.

## SAMPLE PROGRAM

To demonstrate the use of the remote programming techniques presented in the preceding discussion, a pulse output signal with the following characteristics will be set up using only remote controls.

Mode	Double
Trigger Source	Internal
Polarity	+
Amplitude	4 volts
Risetime	2 $\mu$ s
Falltime	4 $\mu$ s
Delay or Burst Time	35 $\mu$ s
Width	15 $\mu$ s
Period	100 $\mu$ s
DC Offset	—4 volts

**Mode.** To program a double pulse, terminal #21 must be connected to chassis ground, terminal #36, producing a logical 1. Terminals #20, #22 and #23 should be left unconnected, producing logical 0's on all three.

**Trigger Source.** To program an internal trigger source terminal #19 should be left open, producing a logical 0 on that terminal.

**Polarity.** Terminal #18 is left open to obtain + polarity.

**Amplitude.** To obtain an amplitude of 4 volts the one volt range can be used. Eq. 3-1 gives the following value for the multiplier:

$$a = \frac{A'}{A} = \frac{4 \text{ volts}}{1 \text{ volt}} = 4$$

The amplitude analog resistor can be determined from Eq. 3-2:

$$R_a = (a-2) (1.11 \text{ K}) = (4-2) (1.11 \text{ K}) = 2.22 \text{ k}\Omega$$

A pulse with an amplitude range of 1 volt is obtained by connecting terminal #25 to chassis ground and a multiplier of 4 is obtained by connecting a 2.22 k $\Omega$  resistor between terminals #27 and #1.

Note that a 4 volt pulse amplitude can also be obtained by using the 0.5 volt range with a multiplier of 8.

**Risetime.** When a risetime of 2  $\mu$ s is desired, Eq. 3-3 provides the correct value for the risetime-falltime range times the risetime multiplier.

$$T_{rf} \times tr = T_r'/a = 2000 \text{ ns}/4 = 500 \text{ ns}$$

with  $T_{rf}$  set at 100 ns,  $tr$  is 5. The risetime analog resistor determined from Eq. 3-5 is:

$$R_{tr} = (tr-1) (0.343 \text{ K}) = (5-1) (0.343 \text{ K}) = 1.372 \text{ k}\Omega$$

Connecting terminals #29 and #36 provides a risetime-falltime range of 100 ns and connecting a 1.372 k $\Omega$  resistor between terminals #31 and #2 provides a risetime multiplier of 5.

**Falltime.** A falltime of 4  $\mu$ s requires a falltime multiplier of 10, as determined from Eq. 3-4.

$$tf = T_f'/(T_{rf} \times a) = 4000 \text{ ns}/100 \text{ ns} (4) = 10$$

(The risetime-falltime range has already been programmed.) The falltime analog resistor determined from Eq. 3-6 is:

$$R_{tf} = (tf-1) (0.343 \text{ k}\Omega) = (10-1) (0.343 \text{ k}\Omega) = 3.087 \text{ k}\Omega$$

To program the falltime multiplier, a 3.087 k $\Omega$  falltime analog resistor must be connected between terminals #32 and #3.

It should be noted that if the 0.5 volt amplitude range and amplitude multiplier of 8 were used to obtain a 4 volt pulse amplitude, the risetime-falltime range and risetime multiplier (or falltime multiplier) product ( $T_{rf} \times tr$ ) would be doubled. This circumstance is due to the dependence of risetime and falltime on the amplitude multiplier.

**Width.** In determining the width we must take into consideration the desired risetime, falltime and the amplitude multiplier. A width to be programmed must first be found using Eq. 3-7:

$$\begin{aligned} W_2' &= W' - 1.25 T_r' (1/2 + 2/a) + 1.25 T_f' (1/2 + 2.33/a) \\ &= 15 \mu\text{s} - 1.25 (4 \mu\text{s}) (1/2 + 2/4) + 1.25 (2 \mu\text{s}) \\ &\quad (1/2 + 2.33/4) \\ &= 12.96 \mu\text{s} \end{aligned}$$

Since the Type R116 pulse width accuracy does not allow specifying widths to this tolerance, 12.96  $\mu$ s should be rounded off to 13  $\mu$ s. The 1  $\mu$ s width range should be used to obtain this pulse width to be programmed. The multiplier can be determined from Eq. 3-8.

$$w = W_2'/W = 13 \mu\text{s}/1 \mu\text{s} = 13$$

Eq. 3-9 can be used to find the correct width analog resistor.

$$R_w = (w-5) (0.177 \text{ k}) = (13-5) (0.177 \text{ k}) = 1.41 \text{ k}\Omega$$

Connect terminals #15 and #36 to set the width range to 1  $\mu$ s and connect a 1.41 k $\Omega$  resistor between terminals #17 and #3 to obtain a multiplier of 13.

**Delay or Burst Time.** To obtain a delay of 35  $\mu$ s the delay range must be set to 1  $\mu$ s. The correct delay multiplier from Eq. 3-10 is:

$$d = D'/D = 35 \mu\text{s}/1 \mu\text{s} = 35$$

Substituting the delay multiplier into Eq. 3-11, the correct value of the delay analog resistor is:

$$R_d = (d-5) (0.177 \Omega) = (35-5) (0.117 \Omega) = 5.31 \text{ k}\Omega$$

A delay range of 1  $\mu$ s is obtained by connecting terminals #11 and #36. A delay multiplier of 35 is obtained by connecting a 5.31 k $\Omega$  resistor between terminals #13 and #3.

**Period.** The period range should be set to 100  $\mu$ s with a multiplier of 1 to obtain a pulse period of 100  $\mu$ s. No calculations are necessary since a multiplier of 1 is obtained by shorting together terminals #9 and #34. A period range of 100  $\mu$ s is obtained by connecting terminal #7 to ground.

**DC Offset.** Offset is dependent on the amplitude range. Eq. 3-15 is used to determine the DC offset multiplier, given an amplitude range of 1 V.

$$o = 0'/A = -4V/1V = -4$$

The correct analog resistor may be obtained from Eq. 3-16.

$$R_o = (5-o) (0.887 k) = (5+4) (0.887 k) = 7.98 k\Omega$$

An offset of  $-4$  volts can be obtained by connecting a 7.98 k $\Omega$  resistor between terminals #33 and #1.

## SIMPLE DIGITAL TO ANALOG CONVERTER

Relay-operated networks of series resistors may be used to convert the programming of the Type R116 to completely digital operation. By using a shorting switch across each resistor, any combination of values in the series can be chosen. One such series is required for each analog function to be programmed. The number of resistors to be used is determined by the desired resolution. For example, with 8 resistors, as many as 256 increments can be obtained between the minimum and maximum multiplication factors of the control.

Various resistance-ratio codes can be used in the digital-to-analog converter.<sup>1</sup> For any given number of bits (resistors), maximum resolution is obtained with straight binary

code. There are also several binary coded decimal (BCD) conversion codes that can be used.

Multiplication factors in  $\times 0.1$  steps can be obtained by selecting resistor values such that the total series resistance is maximum for the particular function when the code total is 100. Fig. 3-7 shows a simple digital-to-analog converter connected for remote selection of multiplication factors with 1% resolution (multiplication factor steps of  $\times 0.1$ ), and Table 3-9 gives the binary equivalents of the various multiplication factors for the converter to show which of the relays should be activated to obtain any desired multiplication factor. The amplitude analog network in this converter is designed with the maximum resistance value for the function at the 80 code position so that each of the 8 major divisions (from  $\times 2$  to  $\times 10$ ) can be divided into 10 minor divisions (see Table 3-9). Most applications will not require the degree of resolution provided by the illustrated converter nor the degree of accuracy that is implied by the use of exact resistance values. Since the accuracy of each programmed function is specified to be within 2% of the front-panel calibration plus any program resistance error, it is not practical to use program resistors with closer than 1% tolerance unless the instrument is calibrated in remote program mode. If the instrument is calibrated in the remote program mode, the front-panel accuracy will be within 2% of the remote accuracy.

<sup>1</sup>See *Digital Computer Fundamentals* by Thomas C. Bartee for some examples of codes.

TABLE 3-9

Correlation of multiplication factors and binary equivalents for simple digital to analog converter shown in Fig. 3-7

PERIOD		DELAY OR BURST TIME and WIDTH		AMPLITUDE		DC OFFSET		RISETIME and FALLTIME		Decimal Equivalent	Binary Equivalent
Mult. Factor	Resistance	Mult. Factor	Resistance	Mult. Factor	Resistance	Mult. Factor	Resistance	Mult. Factor	Resistance		
$\times 1.0$	0 $\Omega$	$\times 5.0$	0 $\Omega$	$\times 2.0$	0 $\Omega$	$\times +5.0$	0 $\Omega$	$\times 1.0$	0 $\Omega$	0	0
$\times 1.1$	169 $\Omega$	$\times 5.5$	88.7 $\Omega$	$\times 2.1$	111 $\Omega$	$\times +4.9$	88.7 $\Omega$	$\times 1.1$	34.3 $\Omega$	1	1
$\times 1.2$	338 $\Omega$	$\times 6.0$	177 $\Omega$	$\times 2.2$	222 $\Omega$	$\times +4.8$	177 $\Omega$	$\times 1.2$	68.7 $\Omega$	2	2
$\times 1.3$	507 $\Omega$	$\times 6.5$	266 $\Omega$	$\times 2.3$	333 $\Omega$	$\times +4.7$	266 $\Omega$	$\times 1.3$	103 $\Omega$	3	2,1
$\times 1.4$	676 $\Omega$	$\times 7.0$	355 $\Omega$	$\times 2.4$	443 $\Omega$	$\times +4.6$	355 $\Omega$	$\times 1.4$	137 $\Omega$	4	4
$\times 1.5$	845 $\Omega$	$\times 7.5$	443 $\Omega$	$\times 2.5$	554 $\Omega$	$\times +4.5$	443 $\Omega$	$\times 1.5$	172 $\Omega$	5	4,1
$\times 1.6$	1.01 k $\Omega$	$\times 8.0$	532 $\Omega$	$\times 2.6$	665 $\Omega$	$\times +4.4$	532 $\Omega$	$\times 1.6$	206 $\Omega$	6	4,2
$\times 1.7$	1.13 k $\Omega$	$\times 8.5$	620 $\Omega$	$\times 2.7$	776 $\Omega$	$\times +4.3$	620 $\Omega$	$\times 1.7$	240 $\Omega$	7	4,2,1
$\times 1.8$	1.35 k $\Omega$	$\times 9.0$	709 $\Omega$	$\times 2.8$	887 $\Omega$	$\times +4.2$	709 $\Omega$	$\times 1.8$	275 $\Omega$	8	8
$\times 1.9$	1.52 k $\Omega$	$\times 9.5$	798 $\Omega$	$\times 2.9$	998 $\Omega$	$\times +4.1$	798 $\Omega$	$\times 1.9$	309 $\Omega$	9	8,1
$\times 2.0$	1.69 k $\Omega$	$\times 10.0$	887 $\Omega$	$\times 3.0$	1.11 k $\Omega$	$\times +4.0$	887 $\Omega$	$\times 2.0$	343 $\Omega$	10	10
$\times 3.0$	3.38 k $\Omega$	$\times 15.0$	1.77 k $\Omega$	$\times 4.0$	2.22 k $\Omega$	$\times +3.0$	1.77 k $\Omega$	$\times 3.0$	687 $\Omega$	20	20
$\times 4.0$	5.07 k $\Omega$	$\times 20.0$	2.66 k $\Omega$	$\times 5.0$	3.33 k $\Omega$	$\times +2.0$	2.66 k $\Omega$	$\times 4.0$	1.03 k $\Omega$	30	20,10
$\times 5.0$	6.76 k $\Omega$	$\times 25.0$	3.55 k $\Omega$	$\times 6.0$	4.43 k $\Omega$	$\times +1.0$	3.55 k $\Omega$	$\times 5.0$	1.37 k $\Omega$	40	40
$\times 6.0$	8.45 k $\Omega$	$\times 30.0$	4.43 k $\Omega$	$\times 7.0$	5.54 k $\Omega$	$\times 0$	4.43 k $\Omega$	$\times 6.0$	1.72 k $\Omega$	50	40,10
$\times 7.0$	10.1 k $\Omega$	$\times 35.0$	5.32 k $\Omega$	$\times 8.0$	6.65 k $\Omega$	$\times -1.0$	5.32 k $\Omega$	$\times 7.0$	2.06 k $\Omega$	60	40,20
$\times 8.0$	11.3 k $\Omega$	$\times 40.0$	6.20 k $\Omega$	$\times 9.0$	7.76 k $\Omega$	$\times -2.0$	6.20 k $\Omega$	$\times 8.0$	2.40 k $\Omega$	70	40,20,10
$\times 9.0$	13.5 k $\Omega$	$\times 45.0$	7.09 k $\Omega$	$\times 10.0$	8.87 k $\Omega$	$\times -3.0$	7.09 k $\Omega$	$\times 9.0$	2.75 k $\Omega$	80	80
$\times 10.0$	15.2 k $\Omega$	$\times 50.0$	7.98 k $\Omega$	...	...	$\times -4.0$	7.98 k $\Omega$	$\times 10.0$	3.09 k $\Omega$	90	80,10
$\times 11.0$	16.9 k $\Omega$	$\times 55.0$	8.87 k $\Omega$	...	...	$\times -5.0$	8.87 k $\Omega$	$\times 11.0$	3.43 k $\Omega$	100	80,20

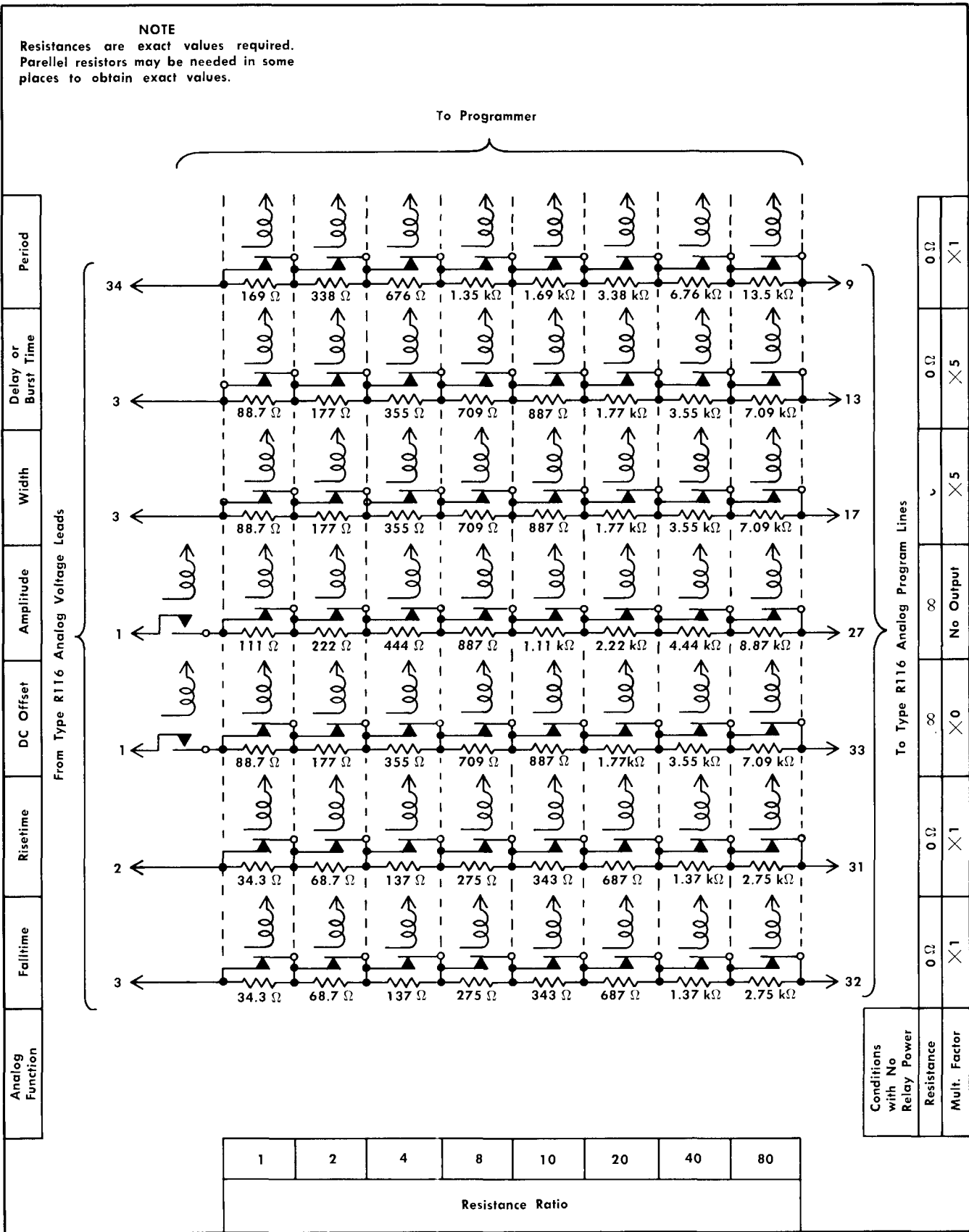


Fig. 3-7. Simple 1-2-4-8 BCD (Binary Coded Decimal) digital to analog converter with X0.1 multiplier increments and 1% accuracy as described in text. Power for relay coils should be provided from external power supply through small series resistors ( $\approx 270 \Omega$ ).

## Remote Programming—Type R116 (SN 1084-up)

In addition to the required degree of resolution (number of steps) and accuracy (resistor tolerance), consideration should also be given to the normal state of the converter when no activating power is applied to the program relays. In the illustrated converter, the period, delay or burst time, width, risetime and falltime multipliers are all at minimum multiplication factors with no relay power applied. This is accomplished by using all normally-closed relays for zero resistance. Notice, however, that the amplitude and DC offset networks have normally-open relay switches in series to open the circuits when no power is applied. This takes advantage of the Type R116 circuitry that is designed to provide zero pulse output when the amplitude analog line is open and zero volts offset ( $\pm 1$  volt) when the DC offset analog line is open.

When changing programs, the relay power is momentarily shut off. The amplitude and DC offset analog lines are therefore open during this time, preventing any transients from appearing at the Type R116 output. (A 10-volt transient may possibly appear if the amplitude range were set at 1 V).

If other values of resistance are desired when no relay power is applied, normally-open relays may be used across the appropriate resistances. For example, to obtain a pulse

amplitude of 10 volts with no relay power, omit the series relay switch in the amplitude network and place a normally-open switch across the resistor in the 80 position of the network. This provides  $0.87\text{ k}\Omega (\times 10)$  when no relay power is applied.

### NOTE

If both normally-open and normally-closed relay-operated switches are used, the relay-actuating logic circuits (not shown in the illustrated converter) will have to be designed accordingly.

### MOD 703L

A specially modified Type R116 is available which allows complete digital programming of the Type R116 using the Type 240/Type 250 Program Units. This modification includes digital-to-analog converters for all analog functions and provides up to 100 programmable increments per function on all analog functions except the amplitude and DC offset. Information about the Type R116 MOD 703L can be obtained from Tektronix catalog or any local Tektronix Field Office.

## NOTES

[illegible]

# **PART II**

# **MAINTENANCE**

Information necessary to maintain, troubleshoot and calibrate the Type R116 is provided in Part II, Maintenance, of this manual. The information is divided into six sections:

4. Circuit Description
5. Maintenance
6. Performance Check/Calibration
7. Rackmounting
8. Electrical Parts List
9. Diagrams
10. Mechanical Parts List

## **NOTE**

A picture of each circuit card showing the location of the electrical parts on the card by circuit number is shown at the end of Section 5, Maintenance.

## NOTES

[illegible]



# SECTION 4

## CIRCUIT DESCRIPTION

Change information, if any, affecting this section will be found at the rear of the manual.

### General

This circuit description has been written in two parts: the Block Diagram Description and the Circuit Description. The Block Diagram Description discusses briefly the generation of the undelayed output pulse and the effect of each major circuit on its characteristics. Also described are the five modes of operation and the input and output pulses related to them. The Circuit Description gives a more precise discussion of the operation of each major circuit.

An overall block diagram of the Type R116 circuitry can be found at the beginning of Section 9. Detailed block diagrams of the major circuits are included within the text of the circuit description. These block diagrams along with the Section 9 schematics will greatly aid in the reading and understanding of the circuit description.

### BLOCK DIAGRAM DESCRIPTION

#### The Undelayed Output Pulse

The undelayed output pulse is the basis of any output pulse obtained at the PULSE OUTPUT connector. The period, width, amplitude, risetime, falltime, polarity and the DC offset of the undelayed output pulse are determined by the front-panel controls (or remotely). The output pulses related to the five different modes of operation are produced by causing the Type R116, by means of the MODE switch, to generate the undelayed pulse in various time arrangements.

The undelayed pulse (see Fig. 4-1) begins at the period generator which free runs at a calibrated repetition rate set by the PERIOD RANGE and MULTIPLIER controls. The period generator produces a positive-going trigger at the end of each cycle which appears at the +PRETRIGGER OUT con-

ductor and a negative-going trigger which goes to the width generator.

The width generator when triggered by the negative-going period trigger produces a fast rising and falling gate of calibrated width which is transmitted to the pulse shape generator circuit. The width of this gate is set by the WIDTH RANGE and MULTIPLIER controls.

The pulse shape generator, when triggered by the rise of the width gate, starts the rise of the output pulse. The rate of rise is regulated by the RISETIME FALLTIME RANGE switch and the RISETIME MULT control. The pulse rises to an amplitude of between 200 mV and 5 V, as determined by the AMPLITUDE MULTIPLIER control, where it is clamped until the pulse begins to fall. The fall of the width gate triggers the fall of the output pulse, the rate of which is controlled by the RISETIME FALLTIME RANGE switch and the FALLTIME MULT control.

The shaped pulse is transmitted to the output stage. In the output stage it is amplified by the output amplifier and is offset either in a positive or a negative direction by current supplied by the offset current generator. The DC OFFSET control determines the amount of offset current to be added. If the POLARITY switch is in the — position, the pulse is inverted by the inverter circuit of the output stage before it enters the output amplifier. The final shaped, amplified, and offset output pulse passes through attenuators, controlled by the AMPLITUDE RANGE switch, and appears at the PULSE OUTPUT connector. The AMPLITUDE RANGE switch attenuates both the pulse amplitude and DC offset.

#### Modes of Operation

The MODE switch determines the type of output pulse which appears at the PULSE OUTPUT connector. The five

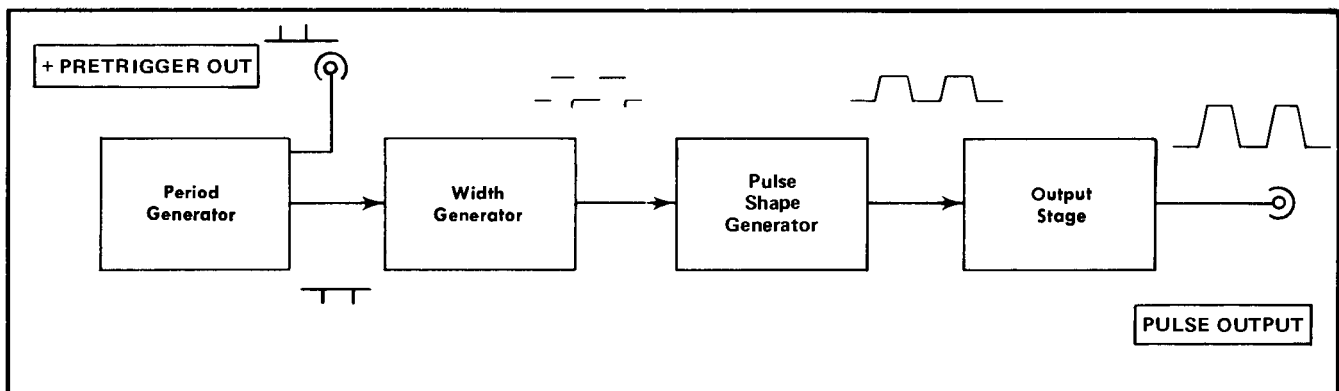


Fig. 4-1. Simplified block diagram of the generation of an undelayed pulse.

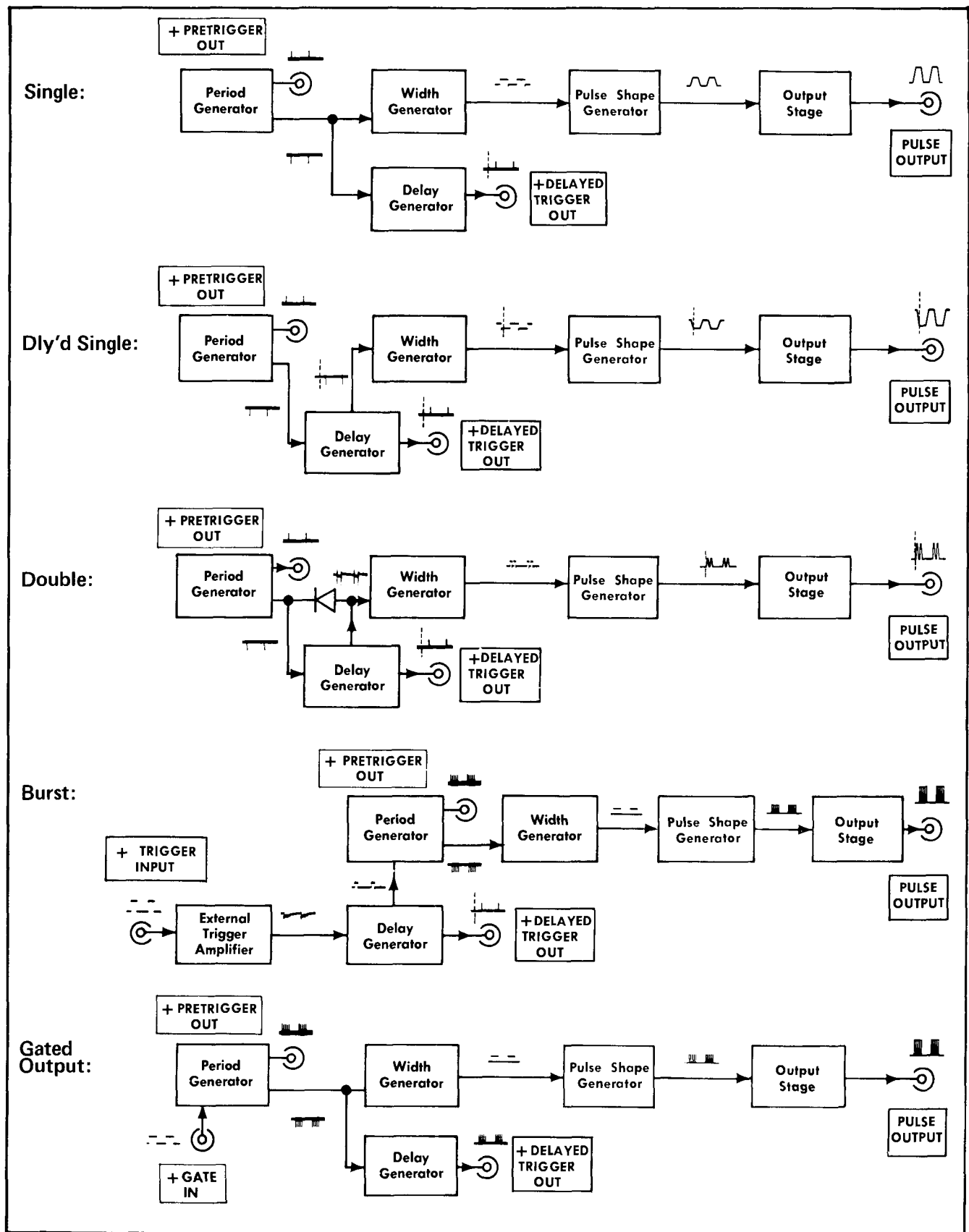


Fig. 4-2. Simplified block diagram illustrating the five basic pulse modes.

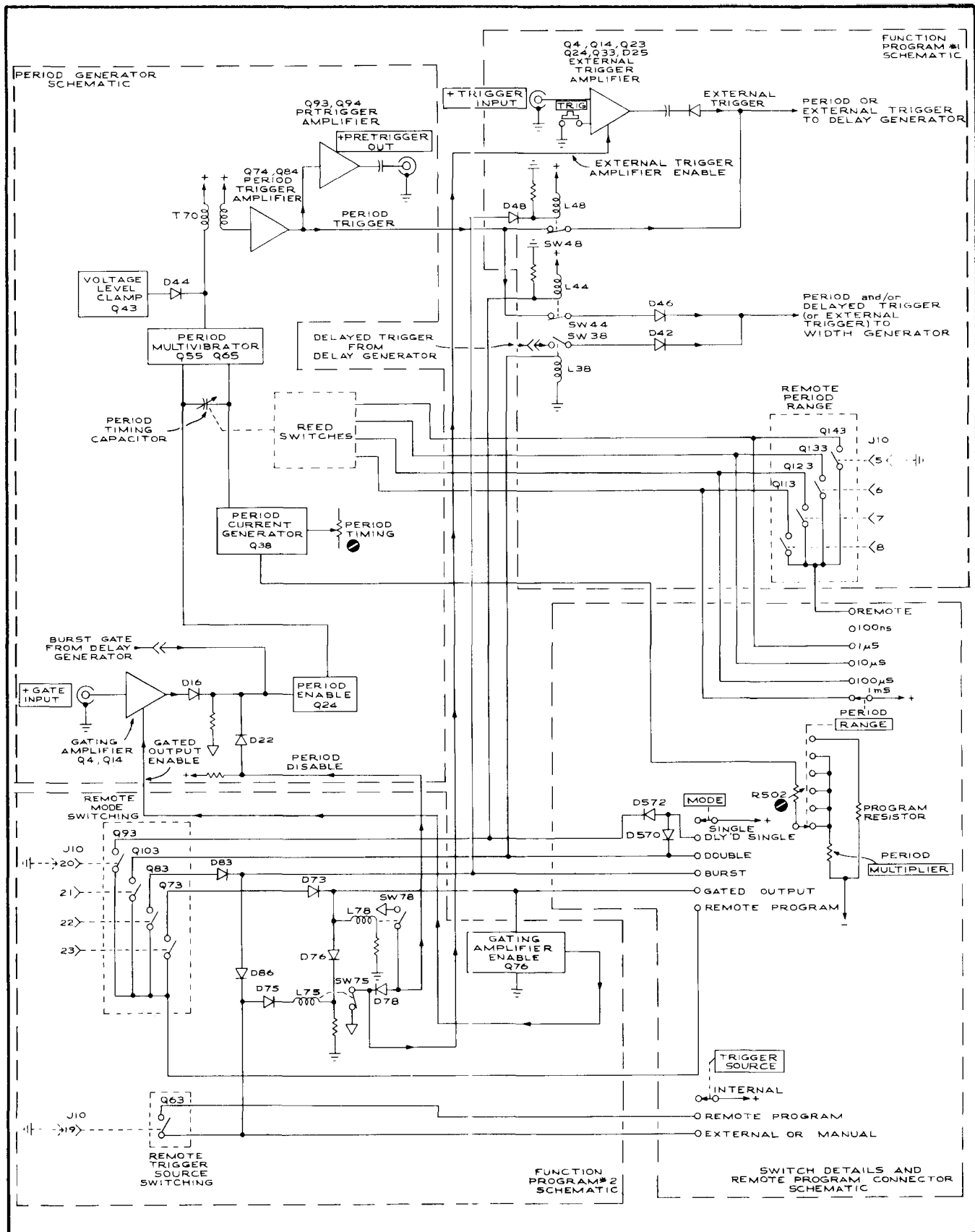


Fig. 4-3. Block diagram of the period generator, external trigger amplifier, and mode and trigger switching circuitry.

## Circuit Description—Type R116 (SN 1084-up)

modes of operation are: SINGLE, DLY'D SINGLE, DOUBLE, BURST, GATED OUTPUT and REMOTE PROGRAM (see Fig. 4-2).

**Single Pulse.** In the single pulse mode the basic undelayed pulse is generated as has been previously described.

**Delayed Single Pulse.** When the mode switch is in the DLY'D SINGLE position, the negative-going period triggers go to the delay generator rather than the width generator. A calibrated delay time after it is triggered by a period trigger, the delay generator produces a negative-going delayed trigger pulse which is transmitted to the width generator. The delay time is determined by the DELAY OR BURST TIME RANGE and MULTIPLIER controls. The delay generator also produces a positive-going delayed trigger, which appears at the + delayed trigger out connector. The delayed output pulse is delayed with respect to the undelayed output pulse by the delay time set by the delay or burst time controls.

**Double Pulse.** When the mode switch is set to DOUBLE, both period triggers and delayed triggers are transmitted to the width generator. The result is two output pulses occurring within the period set by the period controls, separated by the delay time set by the delay or burst time controls.

**Burst of Pulses.** When the MODE switch is set to BURST, the period generator is inhibited. When an external trigger, from the +TRIGGER INPUT connector or from the manual trigger button, is applied to the delay generator, a period generator enabling gate (burst gate) is produced by the delay generator. The duration of this gate is determined by the delay or burst time controls. Whenever the period generator is gated on by the burst gate, period triggers are applied to the width generator. The result is groups of undelayed pulses, called bursts, each burst being followed by a pause, or period of time during which the period generator is disabled. The duration of each burst is set, approximately, by the delay or burst time controls and the period of each burst cycle is determined by the repetition rate of the externally applied triggers. The characteristics of each pulse within a burst are determined by the front-panel control settings. When the burst gate falls, a positive-going delay trigger appears at the +DELAYED TRIGGER OUT connector.

**Gated Burst of Pulses.** When the MODE switch is set to GATED, the output is again bursts of pulses. The duration and period of each gated burst in this case is determined by an external positive-going gate applied to the +GATE IN connector. This external gate enables the period generator in the gated output mode as the burst gate does in the burst mode. Also as in the burst mode, the characteristics of the individual pulses within each gated burst are set by the Type R116 front panel controls.

**Remote Program.** When the MODE switch is set to REMOTE PROGRAM, selection of the pulse made is made by means of digital remote control inputs applied through the rear-panel J10 REMOTE PROGRAM connector. (See the Remote Programming section of this circuit description.)

## CIRCUIT DESCRIPTION

This circuit description discusses each major circuit within the instrument. It is assumed that the reader has a knowledge of basic electronics; therefore, any section of the cir-

cuitry that can be considered basic electronics is discussed only briefly. It is suggested that the pull-out schematics in the rear of the manual as well as the block diagrams within this section be referred to while reading the descriptions.

The following description pertains primarily to instruments having serial numbers 1084 and up and to all circuit cards compatible with these chassis. (See the caution under circuit card replacement in the Maintenance Section for information concerning the significance of series letters and model numbers of the plug-in circuit cards.) Any circuit configuration differences for the various instrument serial number ranges will be noted in the description of the circuit in terms of the chassis serial number or the circuit card series letter.

All the circuitry in this instrument is referenced to a floating common which is referred to as signal ground. Signal ground is displaced from chassis ground by an amount varying from 0 to +18 V, depending on the pulse polarity and DC offset. Chassis ground is used only as a reference for the switching relays and for input and output circuits that connect to external equipment. Further discussion of the relationship between signal and chassis ground is found in the output stage and power supply sections of this circuit description.

Throughout this discussion references to current are in terms of electron flow; that is, current flowing from a negative potential to a positive potential.

## Pulse Timing and Mode Switching

**Period Generator.** The period generator consists of multivibrator Q55 and Q65 (see Fig. 4-3), current source Q38, enabling circuit Q24, clamping circuit Q43, timing capacitors, and trigger amplifier stage Q74, Q84, Q93, and Q94. Transistors Q55 and Q65 (see the Period Generator schematic) form an astable, unsymmetrical multivibrator. It is unsymmetrical in the sense that Q65 is turned on and Q55 is turned off the majority of the time. The cycle of the multivibrator, and thus the period of the output pulse, is dependent on the capacitance of the timing capacitor switched into the circuit by the PERIOD RANGE switch and the amount of current conducted by Q38.

When Q24 is turned on, the period generator is enabled. Initially, Q55 and D44 are off and Q65 (referenced to the +25-volt supply through R50 and T70) is on. The emitter of Q65, which is connected to one end of the timing capacitor, is held at a constant voltage of about 18.5 V. With Q55 off, Q38 charges the other side of the timing capacitor with constant current set by PERIOD TIMING adjustment R34, PERIOD MULT CAL adjustment R502 (see Switch Details and Remote Program Connector schematic) and the PERIOD MULTIPLIER control, R504. The capacitor charges until the voltage at the junction of R38 and R52 is low enough to turn on Q55. When Q55 begins conducting, the voltage at its collector drops rapidly, forward biasing D44 and clamping the collector voltage of Q55 at approximately +19 V as set by Q43. The rapid transition of the Q55 collector voltage, as Q55 turns on, causes a period trigger pulse to be induced through T70 at the base of Q74.

The voltage drop at the collector of Q55 also is felt at the emitter of Q65 as it tries to follow its base down. The constant voltage at the emitter of Q65, however, does not allow the emitter to go down more than 0.5 V and Q65 becomes reversed biased and turns off. The voltage at the

junction of R38 and R52 is now held constant by Q55 which acts as a constant voltage source. With Q65 now turned off, its emitter voltage is free to move down, which it does as the current conducted by Q24 charges the timing capacitor in the opposite direction. The charging in this case is rapid, causing the voltage at the emitter of Q65 to drop rapidly until Q65 is again turned on. With Q65 conducting, the voltage at its emitter starts to go up. This change in voltage is coupled through the timing capacitor, raising the voltage at the emitter of Q55 until it turns off. The voltage at the emitter of Q65 now is free to go to its stable conducting voltage of about +17 V and the circuit begins another cycle.

The negative-going period trigger induced at the base of Q74 is amplified and shaped by Q74 and Q84 and transmitted to the width and/or delay generators (depending on the position of the MODE switch) and the base of pretrigger amplifier Q94. Q94 and Q93 invert, shape, and further amplify the period trigger and it appears as a positive-going trigger at the +PRETRIGGER OUT connector. The repetition rate of the period generator ranges from 91 Hz to 10 MHz.

**External Trigger Amplifier.** The external trigger amplifier allows the output pulse period or burst period to be controlled externally. A pulse with an amplitude between +2V to +20 V, when applied to the +TRIGGER INPUT connector, is shaped and amplified by the external trigger amplifier circuit. The resulting trigger is transmitted to the width and/or delay generators according to the position of the MODE switch. This circuit can also receive a pulse from the MANUAL TRIG button.

The external trigger amplifier circuit consists of input pulse amplifier Q4 and Q14 (see the Function Program #1 schematic), tunnel diode D25, output amplifier Q24 and output complementary emitter follower circuit Q23 and Q33. When the TRIGGER SOURCE switch is set to MANUAL OR EXTERNAL, the period generator is disabled and the emitter of Q24 is connected to signal ground (see SW75 in Fig. 4-3) thereby enabling the external trigger amplifier. Quiescently, both Q4 and Q14 are off, D8 is reversed biased and D14 is conducting, setting the voltage at its anode at about +7.6 V. A trigger pulse having an amplitude between +2 V and +20V applied to the +TRIGGER INPUT connector turns on Q4, which begins conducting current through D8, setting the voltage at the collector of Q4 to about +6.4 V. Current through Q4 also is conducted by R8 which forward biases Q14, turning it on and turning off D14. When Q14 begins conducting, the current through D25 increases, causing it to switch to its high state and present a pulse to the base of Q24. The tunnel diode may also be triggered by the manual trigger button, SW10 (see Switch Details and Remote Program Connector schematic), which when pushed, connects the +25 V supply to the anode of D25 through R15 and R16. This trigger is also presented to the base of Q24. Inductor L20 momentarily blocks the external or manual trigger from shunting D25, thus allowing the total pulse voltage to trigger the tunnel diode.

The pulse from D25 is amplified and inverted by Q24 and applied to the complementary emitter followers Q23 and Q33. Q23 and Q33 act in a push-pull manner and produce a negative-going pulse at their emitters, which is differentiated into a negative-going trigger by C33 and transmitted to the width and/or the delay generator.

**Delay Generator.** The delay generator consists of input amplifier Q14 (see Fig. 4-4), multivibrator Q15, Q24 and

Q25, current source Q38, timing capacitors, burst gate amplifier Q53, clamping circuit Q64 and output stage Q73, Q83 and Q94. Transistors Q15, Q24 and Q25 form a monostable multivibrator with Q24 and Q25 conducting and Q15 turned off in the quiescent condition. The delay time, from the initial triggering of the delay generator to the output of the delayed trigger, is dependent upon the capacitance of the timing capacitor switched into the circuit by the DELAY OR BURST TIME RANGE switch and the amount of current conducted by Q38.

When Q25 is conducting, D50 (see the Delay Generator schematic) is forward biased and the voltage at the collector of Q25 is set by Q64. Q25 conducts current from both Q24 and Q38. The timing capacitor switched into the circuit is charged to the voltage at the junction of R24 and R25. TRIG SENS adjustment R22 sets the quiescent base voltage of Q24 and Q25 so that the multivibrator will be monostable and switch whenever a negative-going trigger is applied to Q14. A negative going trigger applied to the delay generator turns on Q14 and applies a 2 V negative-going trigger to the bases of Q24 and Q25, turning them off. When Q25 turns off, the voltage at its collector rises, reverse biases D50 and allows Q15 to begin conducting. Current through Q15 holds the voltage at its collector down, which keeps Q24 and Q25 off by holding down the voltage at their bases. Current source Q38 now charges the timing capacitor with constant current determined by DELAY TIMING adjustment R41, DELAY OR BURST TIME MULT CAL adjustment R512 (see Switch Details and Remote Program Connector schematic) and the DELAY OR BURST TIME MULTIPLIER control, R514. When the DELAY OR BURST TIME RANGE switch is in the 10 ns position, the delay timing is also influenced by C32 and 50 ns DELAY adjustment R513.

As the timing capacitor charges, the voltage at the emitter of Q25 goes down until Q25 again turns on. With Q25 on, Q15 turns off, releasing the bases of Q24 and Q25 and turning on Q24. When Q25 turns on, D50 again becomes forward biased and the voltage at the collector of Q25 is clamped to about +2.4 V by Q64. The delay generator is now in its quiescent state and is ready for another period or external trigger.

As Q25 turns on after the charging of the timing capacitor, Q64 begins conducting more heavily. The resulting negative transition at the collector of Q64 is applied to the base of Q73 where it is transmitted to Q94 causing it to conduct more heavily. The negative-going pulse appearing at the collector of Q94 is differentiated by C95 and the resulting negative-going delayed trigger is applied to the width generator. The positive-going pulse at the collector of Q73 is transmitted by emitter follower Q83 and differentiated by C85. The resulting positive-going trigger appears at the +DELAYED TRIGGER OUT connector.

When Q25 is turned off at the beginning of the delay cycle, the base of Q53 rises approximately 4 volts. In the burst mode this positive gate, called the burst gate, is transmitted by emitter follower Q53 through SW55 to the base of Q24 (in the period generator circuit) enabling the period generator. When Q25 again turns on, the burst gate falls, disabling the period generator. The period generator, in the burst mode, is thus enabled for the duration of the delay time set by the delay generator.

**Input Gate Amplifier.** The purpose of the input gate amplifier is to change the reference of an input gate from

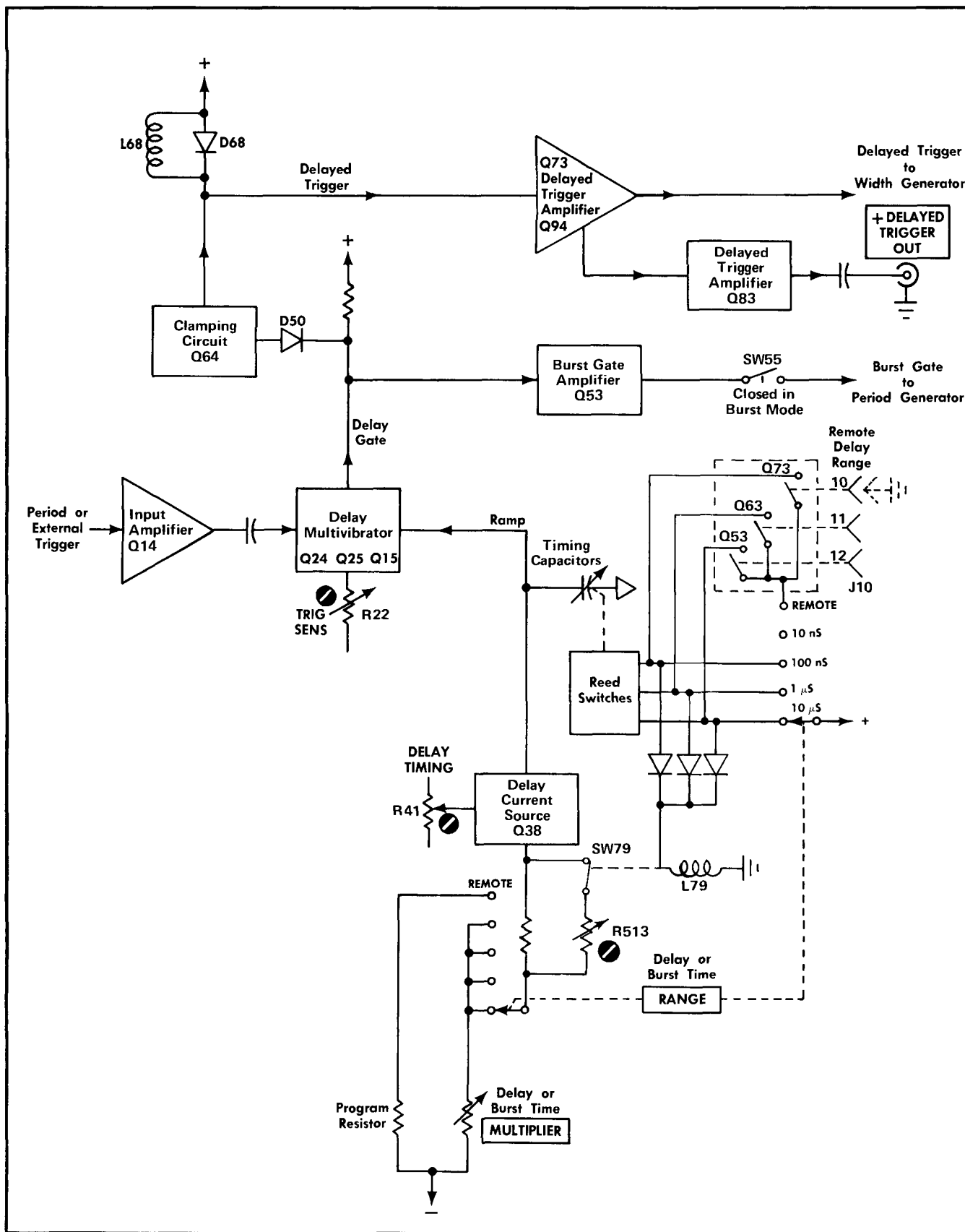
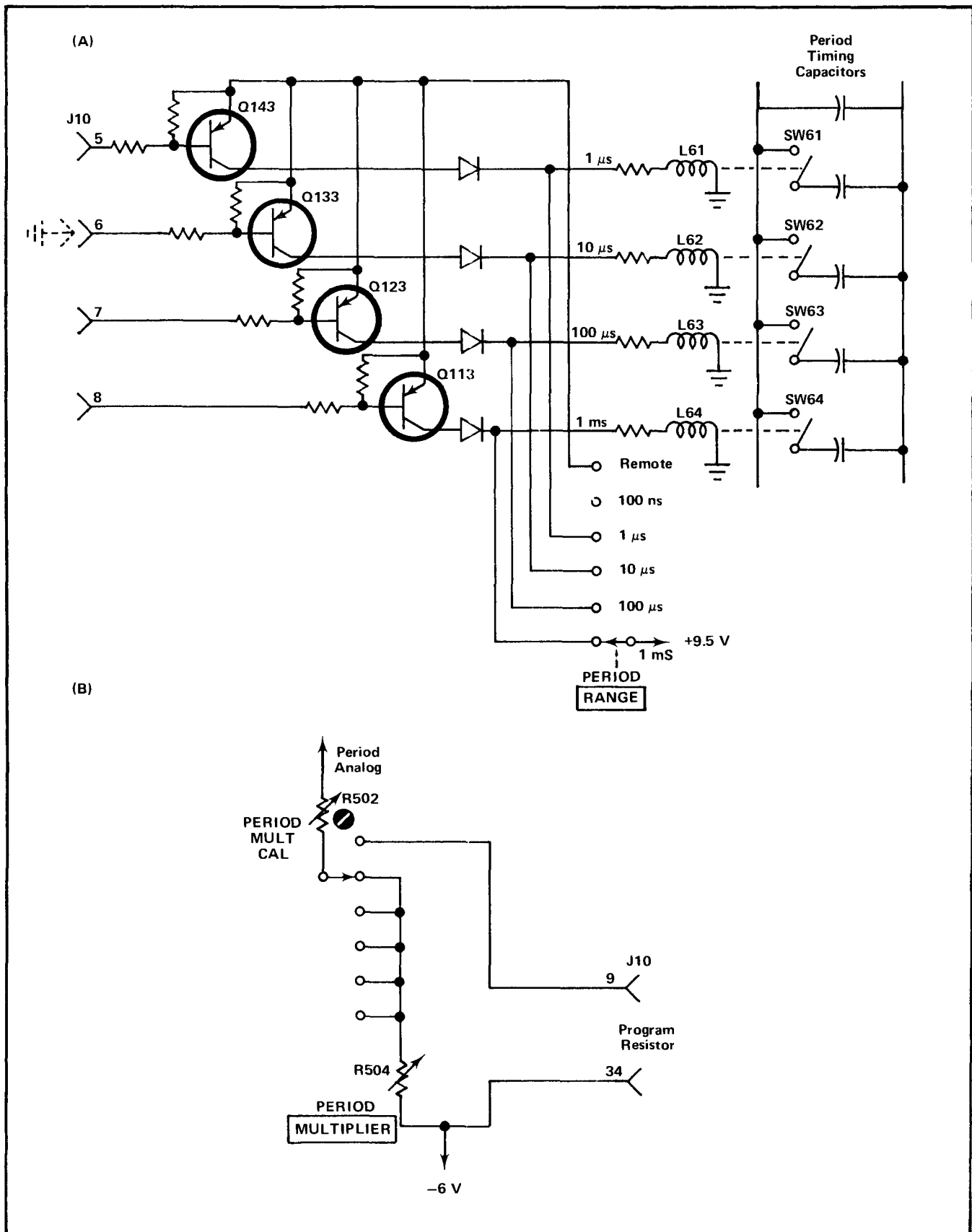


Fig. 4-4. Block diagram of the delay generator circuit.



**Fig. 4-5. Simplified schematic of remote programming of: (A) Period Range and (B) Period Multiplier.**

## Circuit Description—Type R116 (SN 1084-up)

chassis ground to signal ground and to produce a gate of large enough amplitude to enable the period generator. When the MODE switch is set to GATED OUTPUT, the emitter of Q4 is connected to chassis ground through Q76 (see Fig. 4-3), thus enabling the input gate amplifier. When a positive-going gate pulse having an amplitude between +2 V and +20 volts is applied to the +GATE IN connector, Q4 and Q14 (see the Period Generator schematic) are turned on and go into saturation. As Q4 and Q14 turn on, a 10-volt positive-going gate pulse is generated, forward biasing D16 and enabling the period generator. The period generator then remains enabled until the input gate falls, turning off Q4 and Q14.

**Mode and Trigger Switching.** The preceding discussion has described the formation of various timing triggers and gates. The period trigger is produced either by the free-running period generator or the external trigger amplifier; the delay trigger and burst gate are produced by the delay generator; and the gated mode gate is produced by the input gate amplifier. The MODE and TRIGGER SOURCE switches and their associated switching circuitry (found on the two function program circuit cards) determine how these various circuits are enabled to produce these triggers and gates and also determines when and where these assorted signals are applied.

When the MODE switch is in the SINGLE position and the TRIGGER SOURCE switch is set to INTERNAL, SW55 (see Delay Generator circuit diagram), SW75 (see Fig. 4-3), and SW78 are open, enabling the period generator. Also in this case, SW38 and SW48 are open and SW44 is closed, allowing the negative-going period triggers to be transmitted directly to the width generator and the positive-going period triggers to be transmitted to the +PRETRIGGER OUT connector. (Positive-going period triggers always appear at the +PRETRIGGER OUT connector when the period generator is operating.) When the MODE switch is reset to DLY'D SINGLE, SW44 is opened and SW48 is closed, allowing period triggers to be applied to the delay generator but not to the width generator. Also SW38 is closed, allowing the negative-going delay triggers to be applied to the width generator. Whenever a delayed trigger is generated, a positive-going delay trigger appears at the +DELAYED TRIGGER OUT connector. When the mode of operation is switched to DOUBLE, period triggers are applied to both the delay and width generators (SW44 and SW48 are closed) and the width generator receives triggers from both the period and delay generators (SW38 is closed). When the TRIGGER SOURCE switch is set to MANUAL OR EXTERNAL for the three previous modes of operation, SW75 is closed which disables the period generator and enables the external trigger amplifier. Negative-going period triggers, in this case, originate from the external trigger amplifier output. These triggers are applied to the delay and width generators according to the mode of operation, as if they had originated from the period generator. These triggers are also applied to the base of Q94 through SW48 in the single and double pulse modes to produce positive-going triggers at the +PRETRIGGER OUT connector.

In the burst mode the TRIGGER SOURCE switch may be in either the INTERNAL or the MANUAL OR EXTERNAL position. The period generator is automatically inhibited by the MODE switch, which closes SW75. Triggers from the external trigger amplifier are applied to the delay generator, producing a burst gate, which is used to enable the period gen-

erator. The burst gate is applied to the base of Q24 through SW55, which is closed. The enabled period generator then applies triggers to the width generator for the duration of the burst gate.

The gated output mode is identical to the burst mode except that the period generator is disabled by closing SW78 (the external trigger amplifier is not enabled) and the period generator enabling gate comes from the input gate amplifier through D16 rather than from the delay generator.

## Remote Programming Circuitry

**General.** Most pulse characteristics are controlled by both a front-panel switch and a multiplier control. As has been illustrated in the pulse timing and the mode switching description, the switches control relays which in turn control how timing pulses are distributed or control the size of a timing capacitor in a circuit. The multipliers are potentiometers which control the amount of current supplied by a current source. To remotely program a switch function, buffer amplifiers are used to activate relays which are ordinarily activated by front-panel switches. Multiplier functions are remotely programmed by externally substituting appropriate analog resistance values for the front-panel multipliers.

**Buffer Amplifiers.** The remote programming of switch functions is done through buffer-transistor amplifiers. Buffer amplifiers provide both isolation of the internal circuitry from the outside world and standardized programming (ground closure) which requires a minimum of external current. In addition, the connect-to-ground programming allows remote operation of switch functions without requiring external power inputs. The buffer amplifiers, along with the mode and trigger switching relays and the external trigger amplifier, which have already been discussed, are found on the two function program circuit cards. The diagrams for these circuits are shown on the Function Program #1 and the Function Program #2 circuit diagrams and in the block diagrams of the various circuits throughout this section of the manual.

To enable a switch function for remote operation, the associated front-panel switch must be set to its remote position, which connects the emitters of its associated buffer amplifiers to the +9.5 volt supply (see Fig. 4-5A). Since the bases of these transistors are connected through resistors to the emitters, they are quiescently held off due to their zero biased base-emitter junctions. To program a particular switch position, the buffer transistor associated with that position must be turned on, which activates a relay. A buffer transistor is turned on by externally connecting its base to chassis ground through the J10 REMOTE PROGRAM connector, thus forward biasing the base-emitter junction. Using the example given in Fig. 4-5A, if the base of Q133 were grounded through terminal 6 of J10, Q133 would be turned on and the current conducted by it would energize L62 and actuate relay SW62 on the Period Generator circuit card. Actuating this relay connects the 10  $\mu$ s period timing capacitor into the period generator circuit, thus selecting this range of operation for the period generator. It should be noted that each switch function has one position which is automatically programmed when the front-panel switch is set to its remote position (the 100 ns range for the PERIOD RANGE switch). Since this position is automatically programmed, no buffer amplifier is required to remotely program it.



**Analog Program Lines.** When a switch function is being programmed remotely through its buffer amplifiers, its associated multiplier must also be remotely programmed. For front-panel operation, multiplier functions are controlled by potentiometers which control the amount of current supplied by a current source. By externally substituting a resistor for its associated potentiometer, a multiplier function may be remotely programmed. This method of programming is called analog programming. The value of the resistor substituted is determined by the multiplication factor desired. For remote operation, two analog lines (one connected to a power supply and the other connected to the current source transistor), between which a resistor can be connected, are substituted for each front-panel multiplier control. These analog lines appear at the J10 REMOTE PROGRAM connector. Fig. 4-5B shows that when the PERIOD RANGE switch is set to remote, the analog program lines which appear at terminals #9 and #34 on the J10 REMOTE PROGRAM connector are substituted for the PERIOD MULTIPLIER control. By connecting analog program resistors between these two terminals, the period multiplier function may be remotely programmed.

## Pulse Shaping

**Width Generator.** The width generator is identical in operation to the delay generator except that it has no trigger amplifier stage. The only output of the width generator is a width gate. The width generator consists of input amplifier Q14 (see Fig. 4-6), multivibrator Q15, Q24 and Q25, current source Q38, clamp circuit Q63 and width gate amplifier Q53.

Quiescently Q24 and Q25 are on and Q15 is off (see the Width Generator schematic). The quiescent voltage levels at the bases of Q24 and Q25 are set by TRIG SENS adjustment R22. When a negative-going trigger, transmitted through Q14, is applied to the bases of Q24 and Q25, they turn off and Q15 turns on. With Q25 turned off the voltage at its collector rises, reverse biasing D50 and producing a fast rising transition, the start of the width gate, at the base of Q53. With Q24 and Q25 off, the timing capacitor, switched into the circuit by the WIDTH RANGE switch, charges until the voltage at the junction of R24 and R25 has gone low enough to turn on Q25. As Q25 turns on, its collector voltage falls, forward biasing D50 and producing a negative-going transition, the end of the width gate, at the base of Q53. The width gate is transmitted through emitter follower Q53 and applied to the pulse shaper circuit where it determines the width of the output pulse. The duration of the width gate is determined by the charge time of the timing capacitor which is dependent on the current conducted by current source Q38. The current conducted by Q38 is controlled by WIDTH TIMING adjustment R41, WIDTH MULT CAL adjustment R522 and the WIDTH MULTIPLIER control, R524. When the WIDTH RANGE switch is set to 10 ns, C32 and 50 ns WIDTH adjustment R523 also affect the pulse width.

**Pulse Shape Generator.** It is in the pulse shape generator circuit where the shape of the output pulse is formed. The width and period of the pulse are determined by the preceding circuitry, but its risetime, falltime and amplitude are formed by the pulse shape generator. This circuit can be divided into two sections: the risetime-falltime generator and the amplitude clamps. The risetime-falltime generator

consists of current steering transistors Q14, Q24, Q34 and Q44 (see Fig. 4-7), current sources Q58 and Q68, and the timing capacitors switched into the circuit by the RISETIME-FALLTIME RANGE switch. The amplitude clamps consist of voltage reference Q88, unity gain and feedback amplifier Q114 and Q124, open circuit amplitude clamp Q94 and Q104, emitter followers Q123, Q13, Q23, amplitude clamp D10 and baseline clamp Q24. The pulse shape generator circuit shapes a pulse by charging a timing capacitor with constant current, raising the pulse voltage from the baseline clamp voltage to the amplitude clamp voltage, and then discharging the capacitor with constant current, returning the pulse voltage to the baseline level. This process forms the voltage rise, amplitude, and fall of the pulse.

Quiescently, Q14 and Q44 are conducting, and Q24 and Q34 are off (see the Pulse Shape Generator schematic). A fast rising width gate from the width generator raises the voltage at the base of Q14 to about +12 volts which turns off Q14 and turns on Q34. At the same time the voltage at the base of Q24 is raised to about +5 volts, turning on Q24 and switching current from Q44 into Q24.  $T_r$  CENTERING adjustment R32 and  $T_r$  CENTERING adjustment R42, by setting the base voltage of Q34 and Q44, respectively, determine the voltage levels on the bases of Q14 and Q24 necessary to cause the transistors to switch. The amount of current conducted by Q34 is determined by  $T_r$  TIMING adjustment R64, RISETIME MULT CAL adjustment R564 and the RISETIME MULT control, R562. The current through Q34 charges the timing capacitor (switched into the circuit by the RISETIME FALLTIME RANGE switch) at a constant rate. The charging of the timing capacitor forms the leading edge of the pulse shape generator output pulse (at the emitter of Q23 on the Output Amplifier schematic). The pulse rises until D10 (see the Output Amplifier circuit diagram) is forward biased and the pulse amplitude is clamped by the amplitude clamp circuitry. The pulse will remain at this clamped amplitude until the width gate falls.

As the width gate falls, the voltage goes negative at the base of Q24 turning it off and turning on Q44. At the same time the voltage at the base of Q14 goes negative turning on Q14 and causing Q34 to turn off. As Q44 begins conducting, the timing capacitor starts discharging at a constant current rate as determined by  $T_r$  TIMING adjustment R54, FALLTIME MULT CAL adjustment R554 and the FALLTIME MULT control, R552. The pulse at the emitter of Q23 falls until it forward biases D22 and is clamped at a predetermined baseline voltage. The pulse shaper is now in its quiescent state and is ready for another width gate.

The amplitude of the pulse generator output pulse at which D10 becomes forward biased is determined by RANGE CAL adjustment R85, AMPLITUDE MULT CAL adjustment R532 and the AMPLITUDE MULTIPLIER control, R534. These controls determine the collector voltage of Q88 which is coupled through Q114 and D120, and sets the voltage at the cathode of D10. Q114 and Q124 form a feedback amplifier with a gain of 1. Any increase in current through D10 increases current through Q114 and causes Q124 to conduct more heavily. The extra current conducted through Q124 flows through D10 and allows the voltage at the cathode of D10 to remain constant. After D10 has been forward biased, the pulse amplitude will remain at 0.6 volts above the voltage set at the collector of Q124. As the voltage continues to rise at the base of Q13, Q13 turns off and disconnects

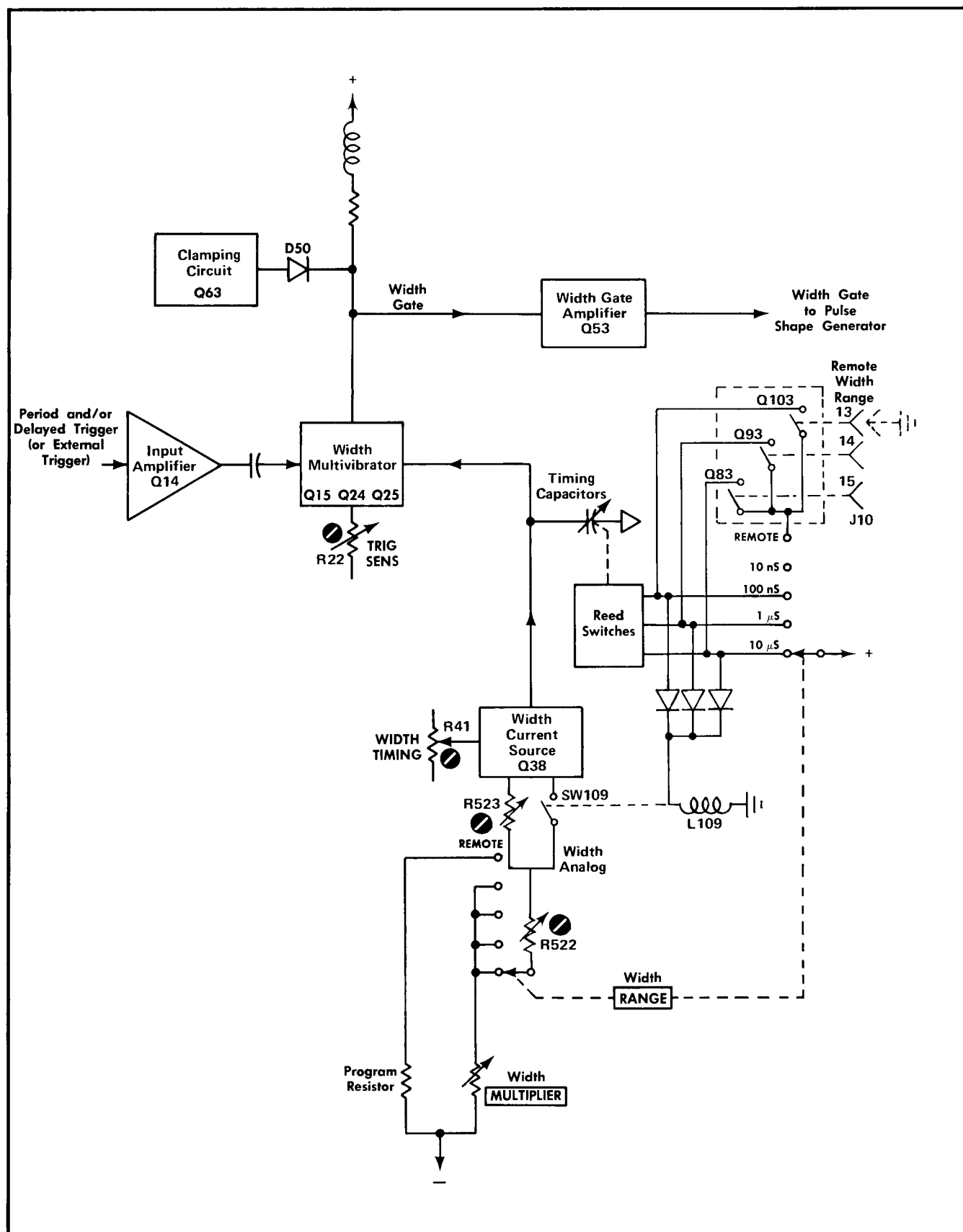


Fig. 4-6. Block diagram of the width generator circuit.

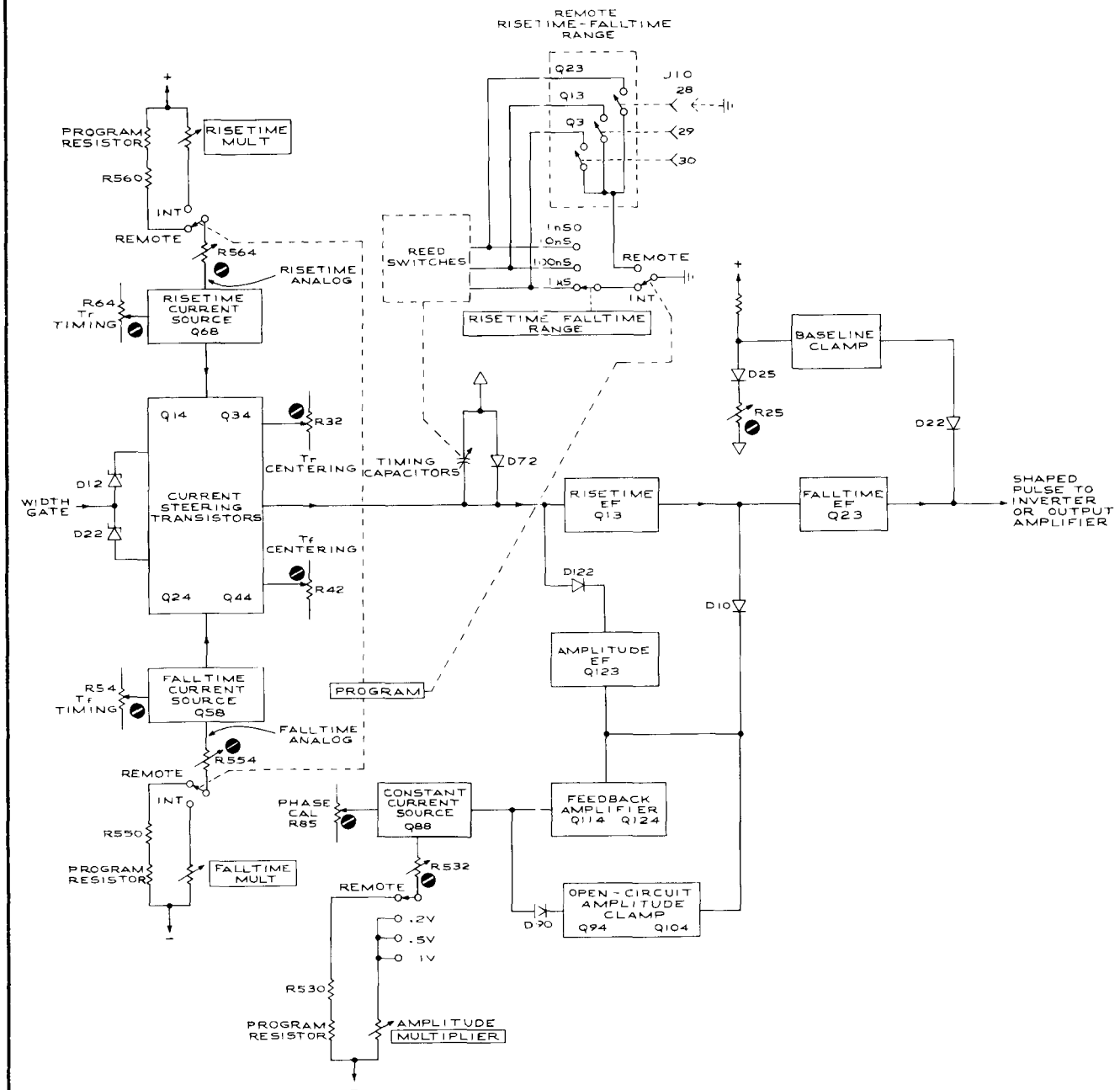


Fig. 4-7. Block diagram of the pulse shaping circuits.

## Circuit Description—Type R116 (SN 1084-up)

the risetime-falltime generator circuitry from the output pulse. With Q13 off, a constant current is conducted through D10 which helps create a flat output pulse top. When the voltage at the base of Q13 rises more than 1.8 volts above the pulse amplitude voltage, D122 becomes forward biased, protecting Q13 from base-emitter break-down. Q123 provides current when D122 is forward biased.

It should be noted that two factors affect the risetime and falltime of an output pulse. One factor is the rate of rise of the leading edge of a pulse and the rate of fall of the falling edge of a pulse. The rate of rise is controlled by the RISETIME FALLTIME RANGE switch and the RISETIME MULT control. The rate of fall is controlled by the RISETIME FALLTIME RANGE switch and the FALLTIME MULT control. The other factor affecting the risetime and falltime of an output pulse is the AMPLITUDE MULTIPLIER control. Since the rate of rise and rate of fall of a pulse are constant, for given settings of the RISETIME FALLTIME RANGE switch and the RISETIME MULT and FALLTIME MULT controls, the actual risetime and falltime of the pulse is dependent on the amplitude which the pulse rises to and falls from. For example, the risetime of a pulse is equal to a rate of rise of the leading edge multiplied by the time it takes the leading edge of a pulse to rise from the 10% amplitude point to the 90% amplitude point of the pulse.

As the pulse begins to fall, D122 becomes reversed biased, Q13 again begins to conduct and D10 becomes reversed biased. As the voltage falls low enough to forward bias D22, the pulse will be clamped to a baseline voltage set by BASELINE CLAMP adjustment R25. As the pulse continues to fall, Q23 becomes reversed biased, which disconnects the risetime-falltime generator from the pulse generator output pulse. When the voltage at the base of Q23 falls more than 1.6 volts below the pulse baseline, D72 turns on and protects Q23.

When a pulse has been formed by the Pulse Shaping circuits, it is transmitted to the output stage through relays SW

28A and SW28B. The amplitude of this pulse is variable from approximately +200 mV to +5 V.

It should be noted that due to the turning on and off of Q13, and D122, and Q23 and D72, the pulse appearing at the junction of R38 and R48 is approximately 3.4 volts higher in overall amplitude than the pulse applied to the output stage (see Fig. 4-8). As shown in Fig. 4-8, this 3.4 volts is distributed both above and below the pulse applied to the output stage. The effect of this amplitude difference is that when D22 reverse biases and the pulse begins to rise at the beginning of the output stage, it has already risen 1.6 volts above the quiescent voltage at the junction of R38 and R48 and is already on a linear portion of the rising ramp. This method of starting pulses ensures few aberrations and a more linear pulse rise (see linearity specifications Section 1). When the pulse applied to the output stage reaches its maximum amplitude and forward biases D10, the rising ramp continues rising 1.8 volts higher at the junction of R38 and R48. This continuation of the pulse rise causes a sharper cutoff of the rising ramp when D10 forward biases, and therefore minimizes the front corner aberrations of the output pulse. The same reasoning applies to the falling edge of the pulse.

Also from the above discussion, there is a varying time delay between the start of the pulse at the R38-R48 junction and the start of the pulse applied to the output stage (which is also the pulse appearing at the PULSE OUTPUT connector). The delay is varying because it is dependent on the rise rate of the pulse. The pulse rise will always have to travel 1.6 volts from the quiescent voltage at the R38-R48 junction before a pulse is seen at the output connector. The time required for the rise of the pulse to travel the 1.6 volts depends on the rate of rise of the pulse.

## Output Stage

**General.** When the shaped pulse has been generated by the pulse shape generator circuit, it is applied to the output stage. The output stage consists of the inverter, the output amplifier, the offset current generator and the attenuators.

The output stage operates in a current mode, generating a current pulse and DC offset current to be applied to a 50  $\Omega$  load. The output amplifier current amplifies the shaped pulse to as high as 200 mA. The offset current generator supplies from  $-75$  mA to  $+330$  mA of offset current to the output, which offsets the output pulse from  $-5$  volts to  $+5$  volts in both polarities.

All the internal circuitry of the Type R116 is referenced to signal ground and the output pulse is referenced to chassis ground (see Fig. 4-9). The variable power supply is the circuit which controls the referencing of an internal pulse to the outside world. Understanding the inter-relationship of the output stage to the variable supply is basic to understanding how the Type R116 generates an output pulse. The variable supply controls the voltage separation between signal ground (common) and chassis ground and varies this voltage from 0 to +18 volts. Both the variable supply and the offset current generator are controlled by the DC OFFSET control and the POLARITY switch.

The existence of a variable voltage separation between the internal circuitry common (signal ground) and the chassis ground performs two functions. It allows pulse polarity

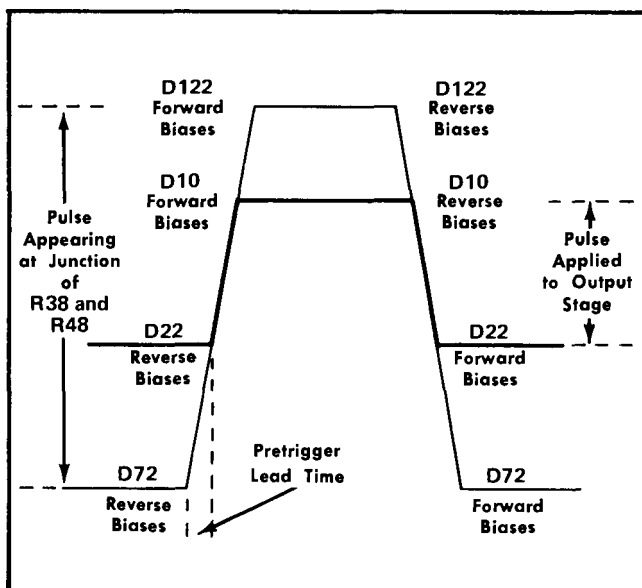


Fig. 4-8. Relationship between various amplitude and baseline clamps and varying time delay between the start of the output pulse and the pretrigger.

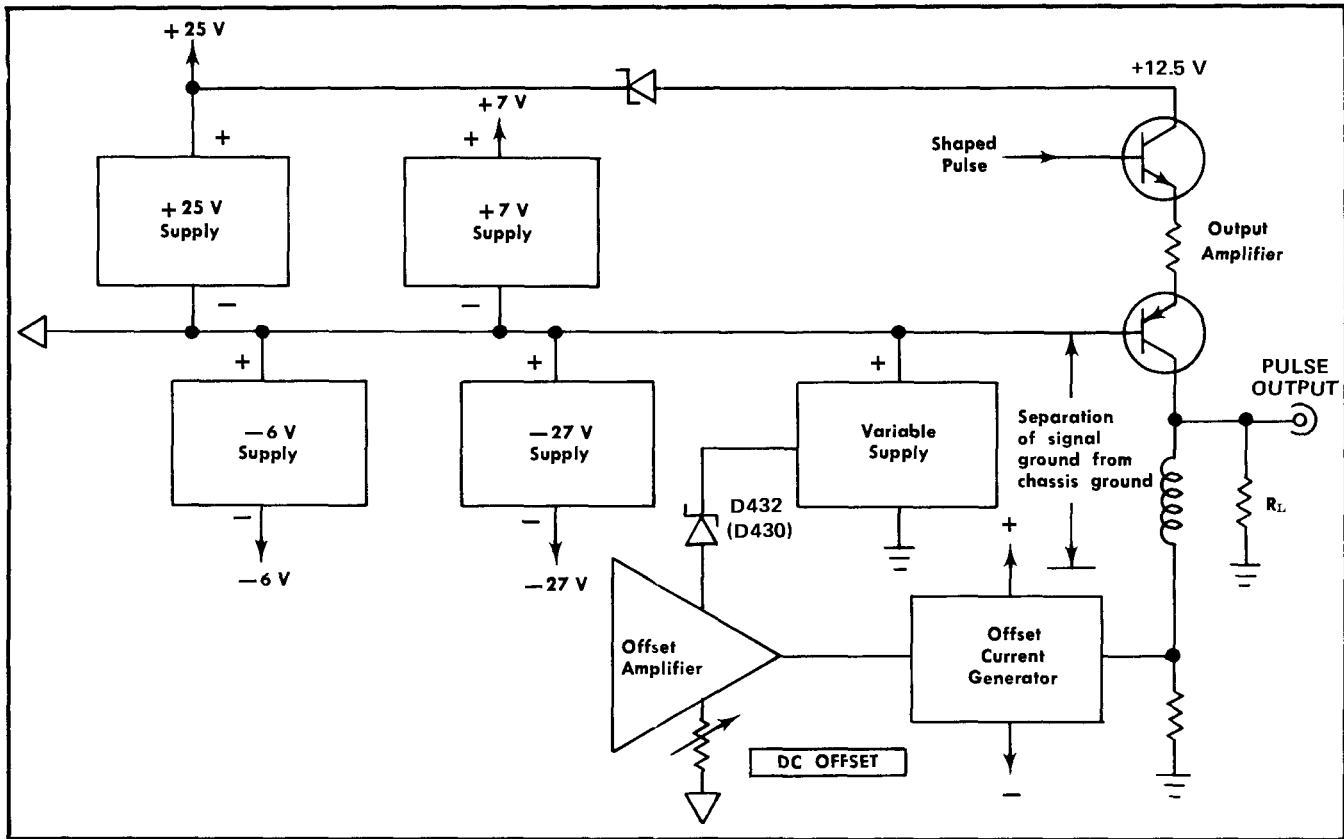


Fig. 4-9. Block diagram of the relationship of the variable supply to the output stage and the floating power supply.

switching with no change in the DC level of the output pulse baseline (discussed later in the section on the output amplifier) and it maintains a consistent DC output pulse shape in both polarities and for all levels of DC offset.

A consistent output pulse shape is obtained by maintaining a constant  $V_{CB}$  on output transistors Q84, Q94 and Q104 for all values of DC offset (see Fig. 4-9). The base voltage of each output transistor is held at signal ground, while the collector voltage is determined by the voltage level of the output pulse. For a positive-going pulse with 0 DC offset, the variable supply voltage is 15 volts, causing a 15 volt separation between signal ground and chassis ground. The  $V_{CB}$  of the output transistors with no pulse generated (quiescently) is, therefore, 15 volts. When an output pulse is generated, the collector voltage of the output transistors increases and their  $V_{CB}$  decreases. For a 10 volts pulse,  $V_{CB}$  is 5 volts. If the DC offset of the output pulse is increased to +5 volts, the variable supply voltage is also increased by +5 volts, causing a 20 volt separation between signal ground and chassis ground. The  $V_{CB}$  of the output transistors is thus held at 15 volts quiescently. In the case of negative DC offset,  $V_{CB}$  is still held at 15 volts quiescently, however, it is done by reducing the variable supply voltage rather than increasing it. Since the  $V_{CB}$  of the output transistors is held at 15 volts quiescently, for all values of DC offset, the  $V_{CB}$  vs. pulse amplitude is constant for all values of DC offset. This constant  $V_{CB}$  to pulse amplitude relationship ensures a consistent pulse shape over the range of the DC OFFSET control. The same process of providing constant  $V_{CB}$  vs. pulse amplitude occurs for negative-going

pulses as well, except that the quiescent  $V_{CB}$  is 5 volts and may increase to as high as 15 volts when a pulse is generated.

**Inverter.** The inverter circuit receives the positive-going shaped pulse from the pulse shape generator circuit and inverts it, while maintaining the original pulse amplitude. This circuit consists of inverting amplifier Q44 (see the Output Amplifier schematic), amplitude and DC level setting circuit Q33 and Q34, and output emitter follower Q43.

When the POLARITY switch is set to  $-$ , the positive-going shaped pulse from the pulse shape generator is applied through SW28 to the base of Q44. Q44 inverts the pulse and applies it through output emitter follower Q43 to the output amplifier. The gain of the inverter circuit is adjusted to  $-1$  by varying the degenerative gain of Q34 through  $-$ AMPLITUDE adjustment R42. Q33 raises the level of the inverted pulse by 10 volts so that the pulse applied to the output amplifier varies within the same DC voltage envelope regardless of the polarity of the pulse.  $-$ DC LEVEL adjustment R34 controls the output level of the inverted pulse.

**Output Amplifier.** The output amplifier consists of input transistor Q53, three parallel connected emitter followers Q54, Q64 and Q74, and three parallel connected common base amplifiers Q84, Q94 and Q104.

The positive- or negative-going shaped pulse from SW27 is applied to emitter follower Q53.  $+PULSE$  OVERSHOOT adjustment C50 regulates the front corner of the pulse and is adjusted for the squarest possible corner. C82 regulates the tilt of the pulse top. Transistors Q54, Q64, and Q74 apply the pulse to the emitters of Q84, Q94, and Q104. Each

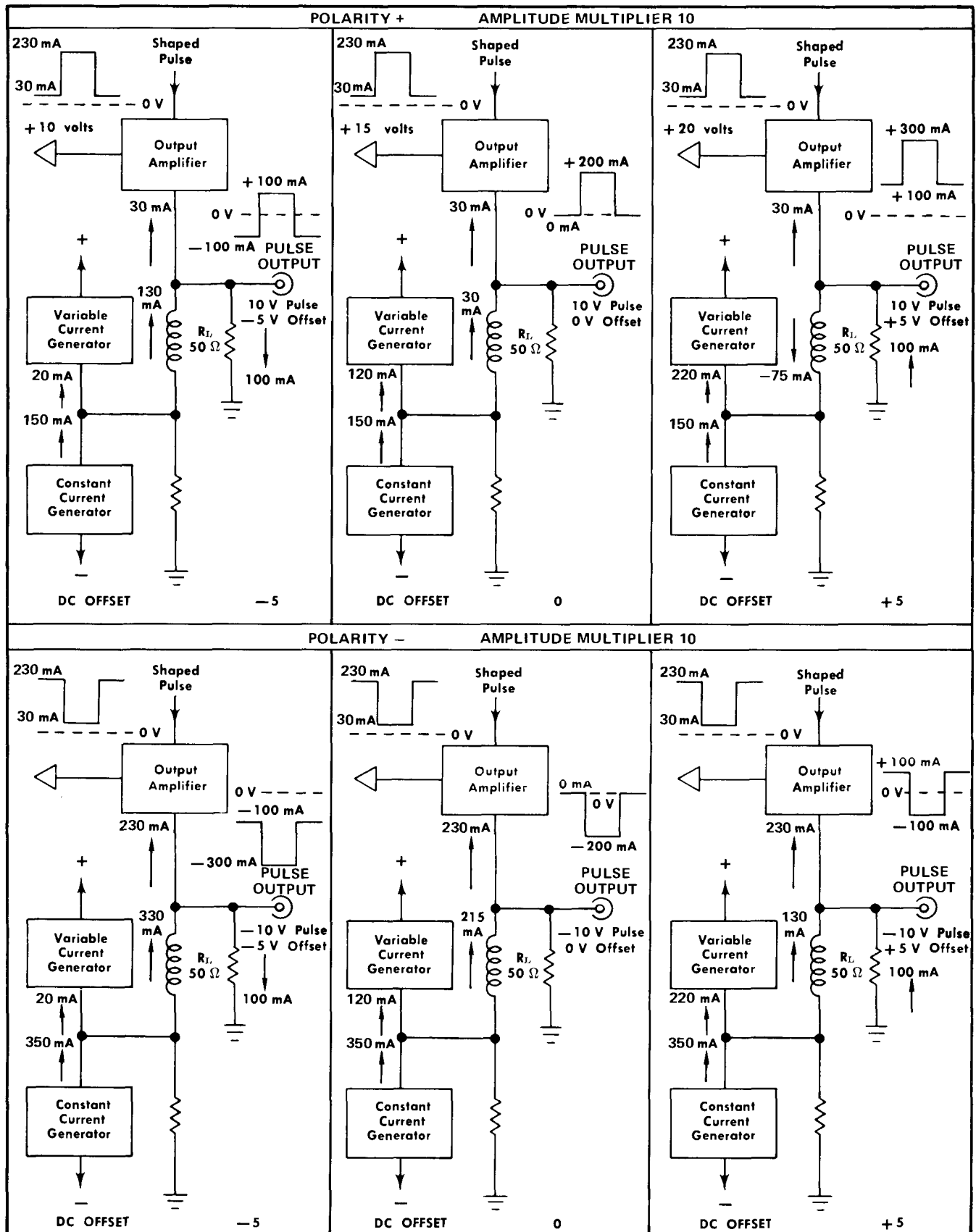


Fig. 4-10. Block diagram of the output amplifier and the offset current generator showing the DC currents and the pulse currents due to different conditions of the POLARITY switch and the DC OFFSET control.

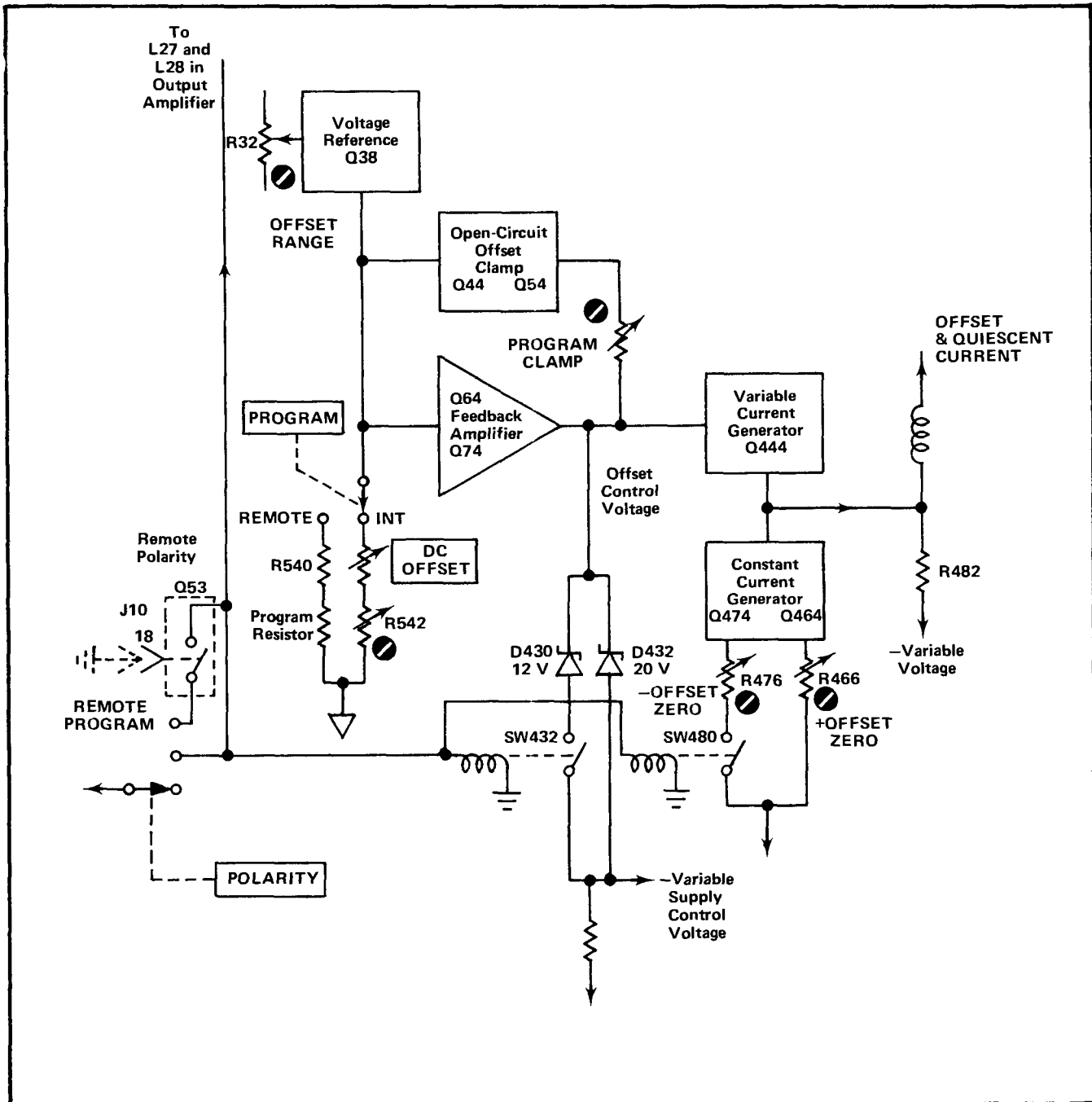


Fig. 4-11. Block diagram of the offset current generator.

emitter-follower, common-base amplifier combination current amplifies the pulse by an amount equal to the load impedance  $\div 75 \Omega$ , or by  $2/3$ . The total current gain of the output amplifier into a  $50 \Omega$  load is therefore 2. As mentioned in the preceding section, the  $V_{CB}$  vs. pulse amplitude of the common base amplifiers is the same over all DC levels of operation of the instrument.

When the POLARITY switch is in the + position, the output amplifier is conducting about 30 mA of quiescent current from the offset current generator. When a positive-going pulse is applied to emitter followers, the circuit conducts as

much as 230 mA in order to get a 200 mA (10 V) output pulse. If a negative-going pulse were applied to the circuit while it was quiescently conducting only 15 mA, the output transistors would turn off. To get a negative going pulse, 200 mA of additional offset current is switched into the output amplifier when the POLARITY switch is switched to the — position. As a result, the total quiescent current conducted by the output amplifier is about 230 mA and a negative-going pulse applied to the emitter followers may reduce the current conducted by the output stage by as much as 200 mA (10 V negative-going pulse). The baseline of the negative-going pulse is held at the same DC level as that of the

## Circuit Description—Type R116 (SN 1084-up)

positive-going pulse by reducing the separation between signal ground and chassis ground. The separation is reduced by 10 V when the POLARITY switch is switched to the — position (see the preceding discussion of the output stage under General).

**Offset Current Generator.** The offset current generator (see the Attenuator and Offset Current Gen circuit diagram) produces DC current varying from  $-75\text{ mA}$  to  $+330\text{ mA}$ , part of which provides quiescent operating levels for the output amplifier and part of which provides variability of the DC offset level of the output pulse. This circuit consists of variable voltage reference circuit Q38 (see Fig. 4-11), unity gain feedback amplifier Q64 and Q74, open circuit offset clamp Q44 and Q54, variable current generator Q444, and constant current generator Q464 and Q474.

The offset current generator consists of a constant current generator which supplies constant DC current and a variable current generator which regulates the flow of this constant current into, and in some cases, out of, the output amplifier and output load (see Fig. 4-10). The constant current generator supplies two different amounts of constant current:  $150\text{ mA}$  with the POLARITY switch set to + and an additional  $200\text{ mA}$  with the switch set to —. + OFFSET ZERO adjustment R466 sets the constant current through Q464 with the POLARITY switch set to + and — OFFSET ZERO adjustment R476 in conjunction with R466 sets the current of the constant current generator when the POLARITY switch is in the — position. Q474 provides feedback control of the current conducted by Q464 by regulating the base voltage of Q464 in opposition to changes in its emitter current.

The amount of current conducted by Q444, the variable current generator, is determined by the voltage level at its base. The base voltage of Q444 is set by the collector voltage of Q38 which is coupled through Q64 and D70. The DC OFFSET control, R542, and DC OFFSET CAL adjustment R544 control the collector voltage of Q38 by varying its collector series resistance. OFFSET RANGE adjustment R32 determines the range of the DC OFFSET control.

Transistors Q64 and Q74 form a feedback amplifier with a gain of 1, which helps keep the voltage constant at the base of Q444. When the POLARITY switch is in the — position, D430 is switched into the circuit, causing additional current to flow through R432. Q74 compensates for this increasing current to hold the current through R74 and thus the base voltage of Q444 essentially constant.

The purpose of the open circuit offset clamp, Q44 and Q54, is to hold the DC offset voltage to 0 volts in remote operation when the offset analog line is open. When the offset analog program line is open, the voltage at the emitter of Q44 tends to go rapidly in the positive direction. This rapid transition causes transistor Q44 to turn on, causing Q54 to saturate and clamp the voltage at the base of Q444 at a value as set by PROGRAM CLAMP adjustment R54. R54 is adjusted so that the offset voltage of the output pulse is approximately 0 volts when the offset analog line is open.

The inductors at the output of the offset current generator circuit isolate the output amplifier from the collector capacitance of the current generator transistors, permitting the output stage to switch rapidly.

**DC Offset, Positive-Going Pulse.** See Fig. 4-10 while reading the following. For a positive-going pulse with

0 DC offset, the constant current generator conducts  $150\text{ mA}$ ,  $120\text{ mA}$  of which is conducted by the variable current generator and the remaining  $30\text{ mA}$  is conducted by the output amplifier as quiescent current. No offset current is conducted by the  $50\ \Omega$  output load; therefore, there is 0 DC offset. For + offset, the variable current source conducts as much as  $220\text{ mA}$ , thus drawing as much as  $100\text{ mA}$  from the output load.  $100\text{ mA}$  through the output load produces  $+5\text{ V}$  DC offset. For a — offset positive-going pulse, as little as  $20\text{ mA}$  of current may be conducted by the variable current generator and up to  $100\text{ mA}$  may be drawn by the output load. A  $-100\text{ mA}$  current through the output load produces a  $-5\text{ V}$  DC offset. In all preceding cases the output amplifier conducts approximately  $30\text{ mA}$  of quiescent current.

**DC Offset, Negative-Going Pulse.** The output amplifier requires about  $230\text{ mA}$  of quiescent current to transmit a negative-going pulse, as explained in the description of the output amplifier circuit. The additional  $200\text{ mA}$  of quiescent current is supplied by the constant current generator which conducts about  $350\text{ mA}$  when the POLARITY switch is set to —. For 0 DC offset, about  $120\text{ mA}$  is conducted by the variable current source and  $230\text{ mA}$  is conducted by the output amplifier. No offset current is conducted by the output load, producing 0 DC offset. For a + offset, negative-going pulse, as much as  $220\text{ mA}$  may be conducted by the variable current generator and up to  $100\text{ mA}$  may be drawn from the output load producing up to  $+5\text{ V}$  DC offset. For — DC offset as little as  $20\text{ mA}$  may be conducted by the variable current generator and as much as  $100\text{ mA}$  may be drawn by the output load.  $-100\text{ mA}$  of DC offset current produces a  $-5\text{ V}$  DC offset. In all levels of DC offset the quiescent current of the output amplifier is  $230\text{ mA}$ .

**Attenuators.** When the final pulse (with offset) has been generated it may pass through an attenuator before appearing at the PULSE OUTPUT connector. The AMPLITUDE RANGE switch transmits the pulse straight through to the PULSE OUTPUT connector when the switch is in the 1 position. When the switch is in either the .5 V or .2 V positions, the pulse goes through either a  $\div 2$  or a  $\div 5$  attenuator, respectively, before it appears at the PULSE OUTPUT connector. It should be noted that these attenuators attenuate the pulse offset as well as the pulse amplitude.

## Power Supply

**General.** The Type R116 can be operated either from a  $115\text{ V}$  or a  $230\text{ V}$  line voltage source. The power supply (see Fig. 4-12) consists of a single transformer which has three secondaries and produces 5 regulated voltages:  $+25\text{ V}$ ,  $+12.5\text{ V}$ ,  $+7\text{ V}$ ,  $-27\text{ V}$  and  $-6\text{ V}$ . As discussed in the description of the output stage, the power supply is floating in the sense that all the voltages produced are referenced to signal ground which moves up and down with respect to chassis ground. Also included in the power supply is the variable supply and the relay power supply. The variable supply is referenced to chassis ground and provides variable separation between signal ground (the internal circuitry common reference) and chassis ground. The relay supply is also referenced to chassis ground and provides power for operation of the relays within the instrument.

**Input Circuit.** When the POWER switch is set to ON, line current flows from the input, J401 (see the Power Supply schematic), through fuses F403 and F404, line filter FL401,



thermal cutout TK402, POWER switch SW401, fuses F401 and F402, the 115 V — 230 V selector switch, and into the primary windings of power transformer T401. The 115 V — 230 V selector switch allows operation of the instrument from either 115 V or 230 V line voltage sources. For 115 V operation the switch connects the two primaries in parallel and for 230 V operation connects them in series. For 230 V operation F420 is disconnected and only F401 is used. The fan and power indicator light B403 are connected between terminals 1 and 3 of the transformer primary.

**+25 Volt Supply.** The +25 V supply consists of diode bridge D405A, B, C and D, filter capacitor C405, comparator circuit Q6 and Q16, emitter follower Q23 and series regulator Q407. Nine-volt zener diode D2 sets the base voltage of comparator transistor Q6 while the quiescent voltage at the base of Q16 is set by +25 VOLTS adjustment R14. Any variation in the +25 V supply is compared by Q6 and Q16. The resulting rise or fall in voltage across Q6 is transmitted by Q23 to the base of series regulator Q407. Any change in voltage of the +25 V supply will be opposed by a change in current through the series regulator.

**+7 Volt Supply.** Zener diode D30 sets the voltage at the base of Q33 at about 7.5 volts and holds its emitter at about 6.9 volts. The current through R36 is relatively constant. Any change in supply voltage will change the base emitter voltage of Q33 and more or less current will be conducted to the +7 volt supply as needed.

**—27 Volt Supply.** The —27 volt supply consists of diode bridge D420A, B, C and D, filter capacitor C420, comparator Q66 and Q76, emitter follower Q83, and series regulator Q427. The circuit regulates the —27 volt supply in essentially the same manner as the +25 volt supply circuit operates.

**—6 Volt Supply.** The —6 volt supply consists of comparator Q46 and Q56, emitter follower Q53 and series regulator Q417. The base of Q46 is held at signal ground by resistive divider R42 and R44 and the voltage at the base of Q56 is also held at signal ground by divider R56 and R57. Any variation in the —6 volt supply is compared by Q46 and Q56 and transmitted by Q53 to the base of series regulator Q417. Any change in the voltage of the —6 volt supply will be opposed by a change in current through the series regulator.

**Relay Power Supply.** The relay power supply produces a regulated +9.5 volt supply voltage which is referenced to chassis ground. The supply consists of diode bridge rectifier D410A, B, C and D, filter capacitor C410, zener reference diode D413, and emitter followers Q413 and Q423. The negative lead of the supply is connected to chassis ground. The reference voltage for Q423 is set by zener diode D413 and transistor Q413. Any change in the supply load will change the bias of Q423 and cause more or less collector current to flow as needed. The supply voltage is thus held at approximately +9.5 volts. The sole use of the

relay power supply is to energize coils for actuating the relay contacts in the circuitry.

Chassis ground is used as a reference voltage so that contact closures can be actuated conveniently in remote operation by connecting a remote program line to chassis ground.

**Variable Supply.** As has been stated previously, the variable supply provides a means of varying the voltage separation between signal ground and chassis ground. This separation will vary from approximately 0 volt to +18 volts with respect to chassis ground: +8 to +18 volts in + polarity and 0 to +10 volts in — polarity. When the DC OFFSET control is set for 0 offset, the output voltage of the variable supply is about +13.5 volts in + polarity and +5 volts in —polarity.

The variable supply consists of comparator circuit Q96 and Q106, emitter follower Q103, and series regulators Q113 and Q437. Control current from the offset current generator, which is determined by the DC OFFSET control, is conducted through pin J of J9 and R92 to the base of Q96. Through the operation of Q96 and Q106 as a comparator, variations in current at the base of Q96 are transformed into voltage variations at the base of Q103, which when coupled through to its emitter, sets the voltage at the bases of series regulators Q113 and Q437. As this voltage moves up or down with respect to chassis ground, as determined by the DC OFFSET control, Q113 and Q437 will turn on and off, one or the other always being on. They are never both on except at approximately the 0 DC offset level when cross-over occurs. D103 and D108 help keep both Q113 and Q437 conducting slightly at this cross-over point.

As the voltage at the bases of the series regulators rises above the cross-over level (chassis ground), Q437 turns off and Q113 turns on. Any rise in voltage at the base of Q113, while it is on, causes an increase in conduction of the transistor and a decrease in voltage separation between signal ground and chassis ground i.e., between the collector and the emitter of Q113. As the voltage moves in a negative direction at the bases of the series regulators and passes through the cross-over level, Q113 turns off and Q437 turns on. Any additional downward movement of voltage at the base of Q437 while it is on causes an increase in conduction of the transistor and a decrease in voltage separation between chassis ground and the —27 volts supply. The —27 volt regulator circuitry provides a constant voltage separation of 27 volts between the —27 volts supply and signal ground. Any decrease in voltage separation between chassis ground and the —27 volts supply, therefore, causes an increase in voltage separation between signal ground and chassis ground. Considering chassis ground as reference, the action of the series regulators move signal ground and the —27 volt supply up and down with respect to chassis ground while 27 volts separation between signal ground and the —27 volt supply is maintained by the —27 volt supply.

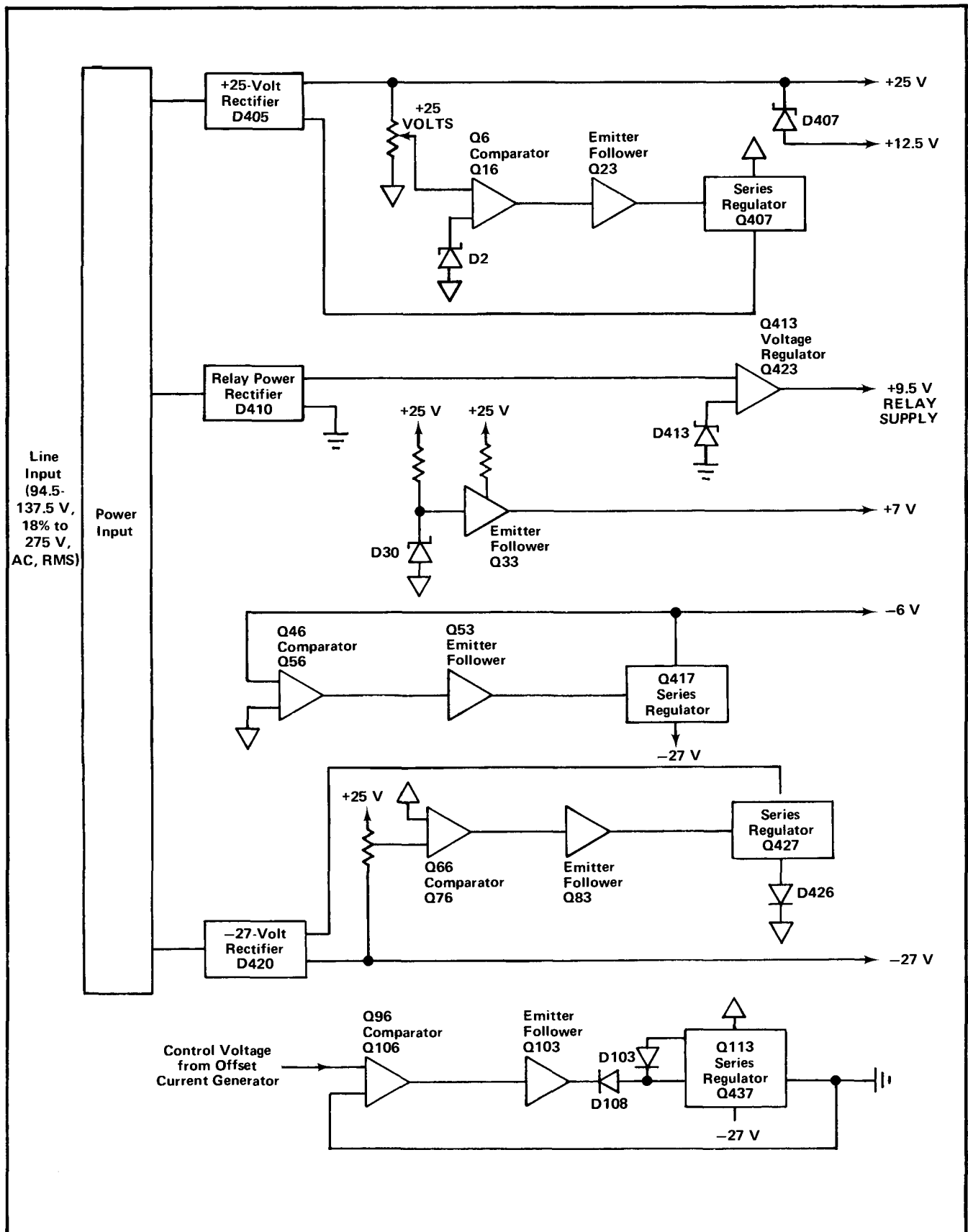


Fig. 4-12. Block Diagram of power supply.

# SECTION 5

## MAINTENANCE

Change information, if any, affecting this section will be found at the rear of the manual.

### Introduction

This section of the manual provides information for use in preventive maintenance, troubleshooting and corrective maintenance of the Type R116.

### PREVENTIVE MAINTENANCE

#### General

Preventive maintenance consists of cleaning, visual inspection, lubrication, etc. Preventive maintenance performed on a regular basis will improve the reliability of this instrument. The severity of the environment to which the Type R116 is subjected determines the frequency of maintenance.

#### Dust Cover Removal

The top and bottom dust covers of the Type R116 can be easily removed for access to the internal circuitry. The covers are fastened to the frame with small slothead fasteners that can be released by turning each fastener  $\frac{1}{4}$  turn counterclockwise with a small coin. For normal operation, the covers should be left on the instrument to keep out dust and to correctly distribute the flow of air.

#### Cleaning

The Type R116 should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It can also provide an electrical conduction path.

**Air Filter.** The air filter should be visually checked every few weeks and cleaned or replaced if dirty. More frequent inspections are required under severe operating conditions. If the filter is to be replaced, order new air filters from your local Tektronix Field Office or representative. The following procedure is suggested for cleaning the filter:

1. Remove the filter by pulling it out of the retaining frame on the rear panel. Be careful not to drop any of the accumulated dirt into the instrument.
2. Flush the loose dirt from the filter with a stream of hot water.
3. Place the filter in a solution of mild detergent and hot water and let it soak for several minutes.
4. Squeeze the filter to wash out any dirt which remains.
5. Rinse the filter in clear water and allow it to dry.

6. Re-install the filter in the retaining frame.

**Exterior.** Loose dust accumulated on the outside of the Type R116 can be removed with a soft cloth or small paint brush. The paint brush is particularly useful for dislodging dirt on and around the front-panel controls. Dirt which remains can be removed with a soft cloth dampened in a mild detergent and water solution. Abrasive cleaners should not be used.

**Interior.** Dust in the interior of the instrument should be removed occasionally to prevent electrical conductivity under high-humidity conditions. The best way to clean the interior is to blow out the accumulated dust with dry, low-velocity air. Remove any dirt which remains with a soft paint brush or a cloth dampened with a mild detergent and water solution. A cotton-tipped applicator is useful for cleaning in narrow spaces or for cleaning ceramic terminal strips and circuit boards.

#### CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. Avoid chemicals which contain benzene, toluene, zylene, acetone or similar solvents.

#### Lubrication

**General.** The reliability of potentiometers, rotary switches, and other moving parts can be maintained if they are kept properly lubricated. Use a cleaning-type lubricant (such as Tektronix Part No. 006-0218-00) on shaft bushings and switch contacts. Lubricate switch detents with a heavier grease (such as Tektronix Part No. 006-0219-00). Potentiometers that are not sealed should be lubricated with a lubricant which will not affect electrical characteristics (such as Tektronix Part No. 006-0220-00). Do not use excessive lubrication. A lubrication kit containing the necessary lubricants and instructions is available from Tektronix, Inc. Order Tektronix Part No. 003-0342-00.

**Fan Oiling.** During periodic servicing, the fan motor should be lubricated with a few drops of light machine oil (Anderol L826 available from Lehigh Company or Rotron Distributors is recommended.) An industrial hypodermic syringe and needle is used to insert the oil through the rubber seal, as shown in Fig. 5-1. With the needle held at a  $45^\circ$  angle, pierce the rubber seal, then insert the needle about  $\frac{1}{4}$  inch and depress the syringe plunger far enough to inject 3 or 4 drops of oil into the bearing. If a syringe and needle cannot be obtained locally, they may be ordered from Tektronix (Tektronix Part Number 003-0282-00 for the syringe; 003-0285-00 for the needle).

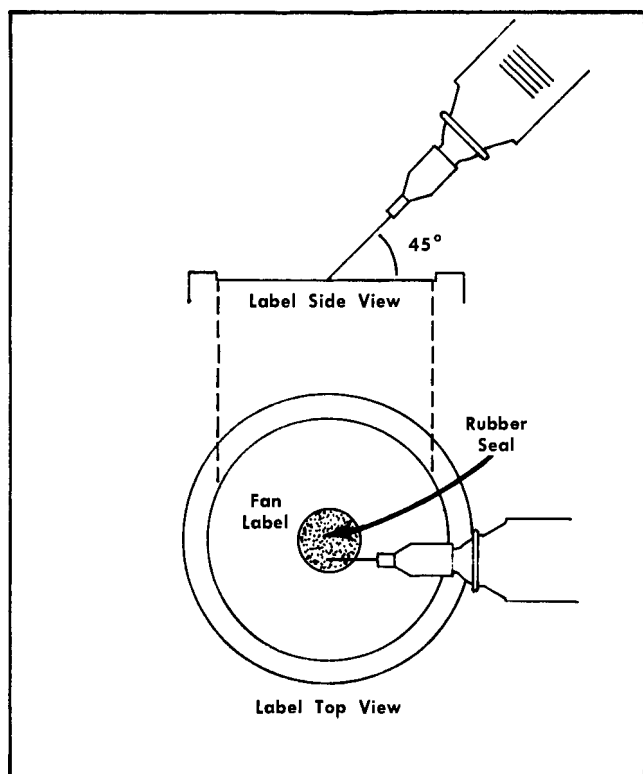


Fig. 5-1. Oiling the fan motor with a hypodermic.

## Visual Inspection

The Type R116 should be inspected occasionally for such defects as broken connections, loose pin connections, broken or damaged ceramic strips, improperly seated transistors, damaged circuit boards and heat-damaged parts.

The corrective procedures for most visible defects is obvious; however, particular care must be taken if heat-damaged components are found. Overheating usually indicates other trouble in the instrument; therefore, it is important that the cause of overheating be corrected to prevent recurrence of the damage.

## Transistor Checks

Periodic checks of the transistors in the Type R116 are not recommended. The best check of a transistor's performance is its actual operation in the instrument. More details on checking transistor operation are given under Troubleshooting.

## Recalibration

To ensure accurate measurements, check the calibration of this instrument after each 1000 hours of operation or, if used infrequently, every 6 months. In addition, replacement of components may necessitate recalibration of the affected circuits. Complete calibration instructions are given in the Performance Check/Calibration section. This procedure may also be helpful in localizing certain troubles in the instrument. In some cases, minor troubles may be revealed and/or corrected by recalibration.

## TROUBLESHOOTING

### Introduction

The following information is provided for use with the other sections of this manual to facilitate troubleshooting of the Type R116. An understanding of the operation of the Type R116 circuitry is also helpful for locating troubles. See the Circuit Description section for complete information.

### Troubleshooting Aids

**Diagrams.** A complete set of circuit diagrams is given on fold-out pages in Section 9. The circuit number and electrical value of each component in this instrument is shown on the appropriate diagram. The sequence of diagrams is the same as that of the circuit cards in the instrument; the circuitry of each circuit card is on a separate diagram. Chassis-mounted components are shown on the related card diagrams.

**Circuit Card Illustrations.** Pictures of all the circuit cards are located at the end of this section. On these pictures, each electrical component on the card is identified by its circuit number. These pictures, when used along with the circuit diagrams, will aid in physically locating circuit card mounted components.

**Parts List.** Section 8 of this manual contains the electrical parts list for the entire instrument. This list is divided into the separate circuit boards and one list of chassis-mounted components. These separate lists are arranged according to circuit number. It should be noted that one circuit number may be found on more than one circuit card. For example, the circuit number R1 is found on almost all the circuit cards. Due to this duplication of circuit numbers, it is important when referring to a circuit number to always designate the circuit card it is located on.

**Serial Numbers.** Due to various modifications made on the Type R116 since its first production, it is necessary to note the serial number of the instrument which this manual is being used to maintain or calibrate. Each circuit card within this instrument may have more than one circuit configuration, each of which is compatible with only certain chassis. The compatibility of a particular circuit configuration with a chassis serial number range is denoted by a series letter. For example: the Series B Period Generator circuit card is compatible with those chassis with serial numbers from 1084 through 1359, and the Series Q Period Generator circuit card is compatible with those chassis with serial numbers from 1360 and up. Each Series may have various Model numbers, indicating that minor changes have been made in the circuitry. All cards with the same series letter, regardless of the model number, are electrically interchangeable in the Type R116. Table 5-1 gives chassis serial numbers and the circuit card series letter which are compatible with them.

**Wiring Color Code.** All insulated wire in the Type R116 is color coded for convenience in circuit tracing. Signal carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage using the EIA resistor color code, as given in Table 5-2. A white background color

**TABLE 5-1**  
**CIRCUIT CARD SERIES LETTERS AND**  
**THEIR ASSOCIATED CHASSIS SERIAL NUMBERS**

Circuit Card	Chassis Serial Number		
	Series Letter		
	1084-1207	1208-1359	1360-up
Function Program #2	K	K	K
Period Generator	B	B	Q
Delay Generator	C	O	O
Function Program #1	L	L	L
Width Generator	E	P	R
Pulse Shape Generator	F	F	F
Output Amplifier	M	M	M
Attenuator & Offset	N	N	N
Current Generator			
Power Supply	I	I	I

**TABLE 5-2**  
**POWER-SUPPLY LEADS**

Supply	Back-ground Color	1st Stripe (widest)	2nd Stripe	3rd Stripe (narrowest)	Bus-Wire Terminals (J1-J9)
Signal ground	White	Black	none	none	1 and A
—27-volt	Tan	Red	Black	Black	2 and B
—6-volt	Tan	Black	Blue	Black	3 and C
+7-volt	White	Black	Violet	none	26 and DD*
+25-volt	White	Red	Black	Black	4 and D
Chassis ground	White	none	none	none	28 and FF

\*Not connected to J6.

indicates a positive voltage and a tan background indicates a negative voltage. All voltages except the relay-power supply are referenced to signal ground. The relay-power supply is referenced to chassis ground. All voltage supplies are connected to the plug-in cards through bus wires located on the bottom of the instrument.

**Resistor Color Code.** In addition to the brown composition resistors, some metal-film resistors (identifiable by their gray body color) and some wire-wound resistors (usually light blue or gray-green) are used in the Type R116. The resistance value of a wire-wound resistor is printed on the body of the component. The resistance value of a composition resistor or metal-film resistor is color-coded on the component with EIA color-code (some metal-film resistors may have the value printed on the body). The color-code is read starting with the stripe nearest the end of the resistor. Composition resistors have four stripes which consist of two significant figures, a multiplier and a tolerance value (see Fig. 5-2). Metal-film resistors have five stripes consisting of three significant figures, a multiplier and a tolerance value.

**Capacitor Marking.** The capacitance value of a common disc capacitor or small electrolytic is marked in microfar-

ads on the side of the component body. The white ceramic capacitors used in the Type R116 are color coded in picofarads using a modified EIA code (see Fig. 5-2).

**Diode Color Code.** The cathode end of each glass enclosed diode is indicated by a stripe, a series of stripes or a dot. For most silicon or germanium diodes with a series of stripes, the color-code identifies the Tektronix Part Number using the resistor color-code system (e.g., a diode color-coded blue or pink-brown-gray-green indicates Tektronix Part Number 152-0185-00). The cathode and anode ends of metal-encased diodes can be identified by the diode symbol marked on the body.

**Transistor Lead Configuration.** Fig. 5-3 shows the lead configurations of the transistors used in this instrument. This view is as seen from the bottom of the transistor.

## Troubleshooting Equipment

The following equipment is useful for troubleshooting the Type R116.

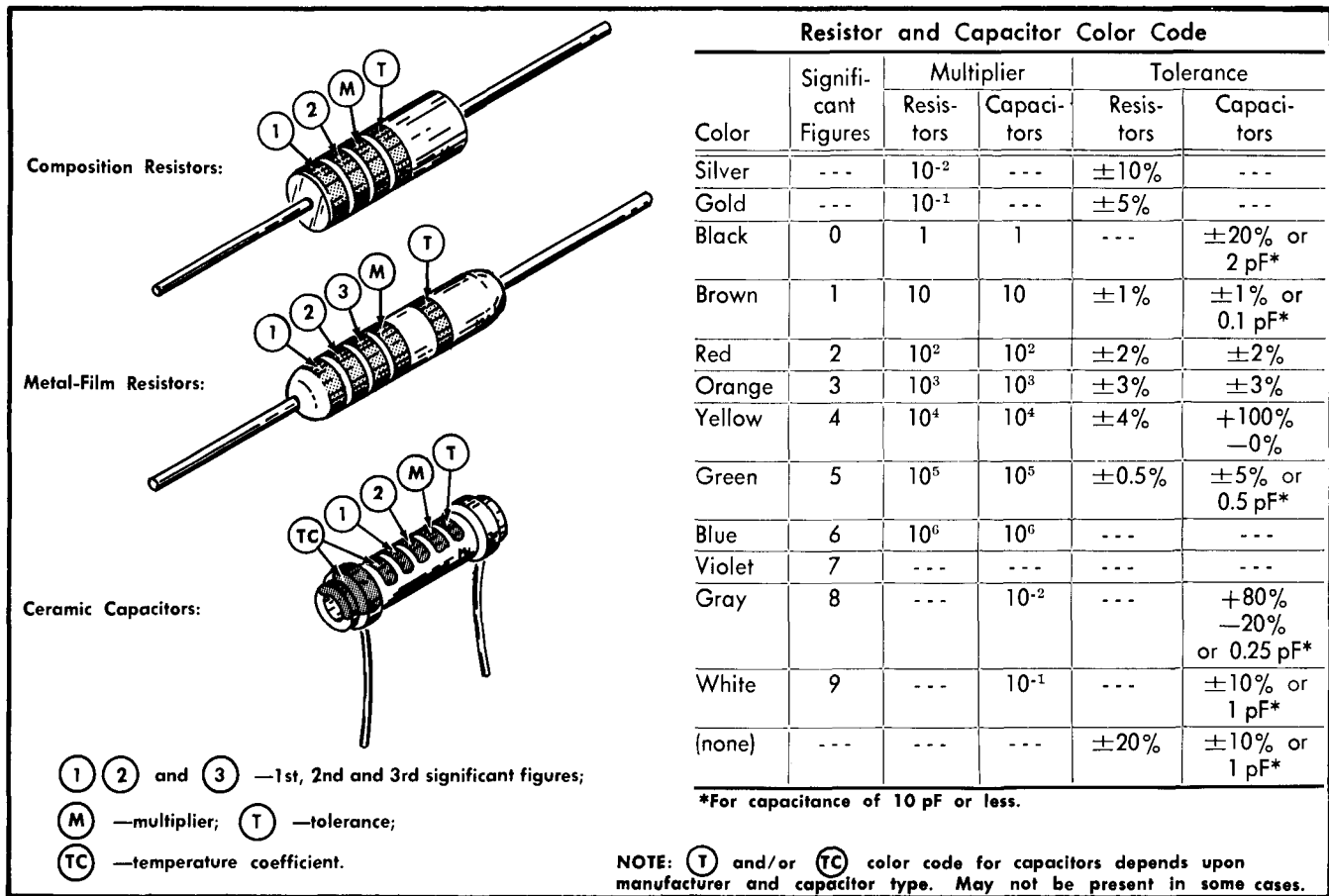


Fig. 5-2. Color-code for resistors and ceramic capacitors.

1. **Transistor Tester**—Some means of testing the semiconductors used in the instrument is helpful. A transistor-curve tracer such as the Tektronix Type 575 or 576 will give the most complete information.

2. **DC Voltmeter and Ohmmeter**—A voltmeter for checking voltages within the circuit and an ohmmeter for checking resistors and diodes are required. A VTVM with 10 megohm input impedance and 0 to 50 volts range, and an ohmmeter with 0 to 20 megohm range are suggested. A 20,000 ohm/volt VOM can be used to check voltages, if allowances are made for the circuit loading of a VOM at high-impedance points.

3. **Test Oscilloscope**—A test oscilloscope is required to view waveforms at different points in the circuit. An oscilloscope with DC to 20 MHz frequency response and 100 millivolts to 10 volts/division vertical deflection factor is suggested. A 10X probe should be used to reduce circuit loading.

## Troubleshooting Techniques

This troubleshooting procedure is arranged in an order which checks the simple trouble possibilities before proceeding with extensive troubleshooting. The first few checks ensure proper connection, operation and calibration. If the trouble is not located by these checks, the remaining steps

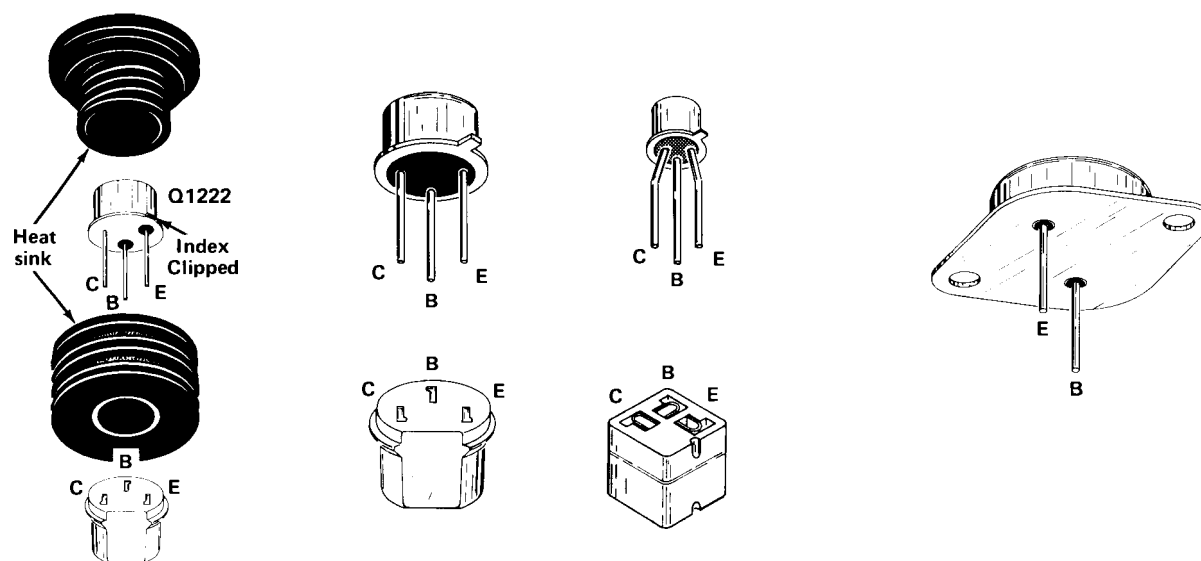
aid in locating the defective component. When the defective component is located, it should be replaced following the replacement procedure given under Corrective Maintenance.

1. **Check Control Settings.** Incorrect control settings can indicate a trouble that does not exist. If the instrument is being operated remotely, check that the remote programming information applied to the rear panel connector is correct. A convenient method of checking remote operation is by resetting the front-panel controls for front-panel operation and checking if the malfunction still exists. If there is any question about the correct function or operation of any control, see the Operating Instructions section of this manual.

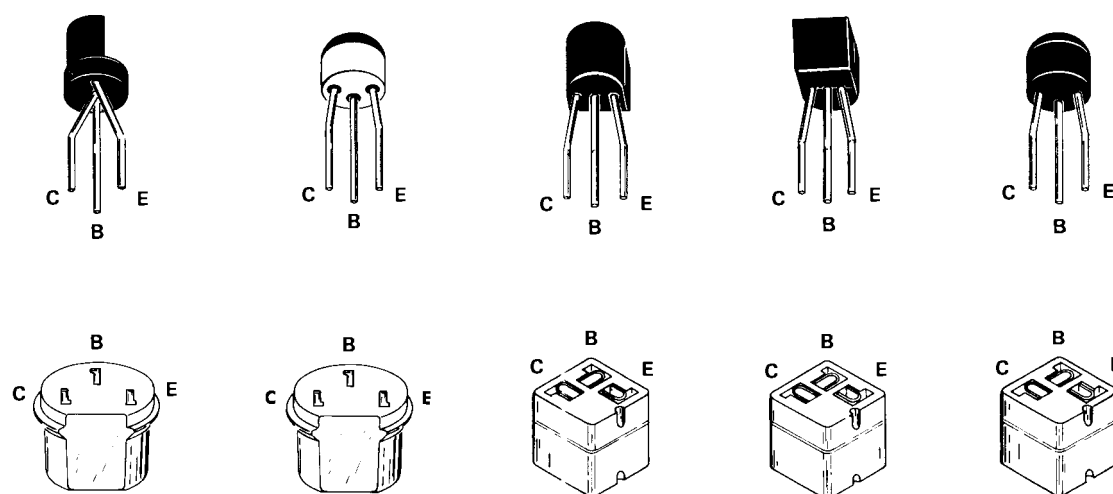
2. **Check Associated Equipment.** Before proceeding with the troubleshooting of the Type R116, check that the equipment used with this instrument is operating correctly. Check that the signals are properly connected and that the interconnecting cables are not defective. Also, check the power source.

3. **Check Instrument Calibration.** Check the calibration of this instrument or of the affected circuit if the trouble is known to exist in one particular circuit. The apparent trouble may be only a result of misadjustment and may be corrected by calibration. Complete calibration instructions are given in the Performance Check and Calibration section of this manual.

### Metal Cased Transistors



### Epoxy Cased Transistors



**Fig. 5-3. Electrode configurations for socket-mounted transistors.**

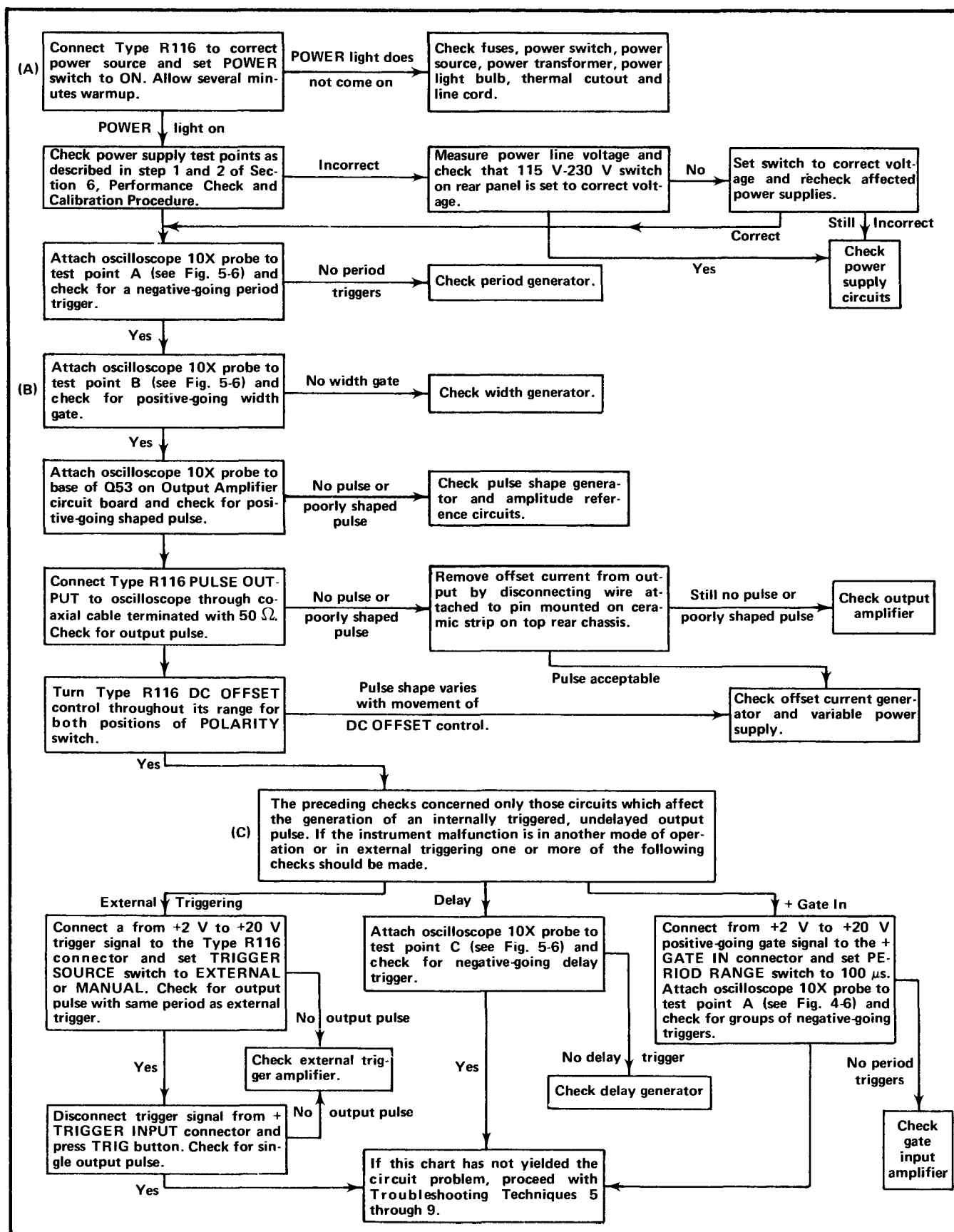


Fig. 5-4. Troubleshooting chart.



**4. Pinpoint Malfunctioning Circuits.** To pinpoint the source of a malfunction in instrument operation, the trouble symptom will often indicate the identity of the faulty circuit(s). For example, if a proper output pulse appears in the undelayed pulse mode but not in the delayed pulse mode, the fault is probably in the delay generator.

If the trouble symptom does not indicate which circuit(s) is causing the problems, as would be the case if no pulse appeared at the output connector in any mode, a more systematic troubleshooting procedure is necessary. Fig. 5-4 provides a general guide for pinpointing circuits and the troubles within them which are causing instrument malfunctions.

The chart first covers the circuits which affect the generation of an internally-triggered undelayed pulse: the power supply, the internal pulse and trigger generators and the output stage. A further extension of the chart provides a troubleshooting method for determining trouble spots when the problem lies in obtaining pulses in different modes of operation or in obtaining proper external triggering.

The following preliminary procedure ensures that the instrument malfunction is not caused by improper control settings, remote programming or remote program logic, and helps determine where to begin on the troubleshooting chart:

A. Set the Type R116 controls for front-panel operation and to the settings given at the beginning of the First Time Operation Instructions of Section 2. (Set test oscilloscope sweep rate to  $2 \mu\text{s}/\text{cm}$ .)

B. Connect the Type R116 output pulse through a coaxial cable terminated in  $50\text{-}\Omega$  to the vertical input of the oscilloscope.

C. Turn on the Type R116 and observe the oscilloscope display of the pulse:

- a. If no pulse appears, start at the beginning of the troubleshooting chart, point (A).
- b. If a pulse appears but is improperly shaped (compared to Fig. 5-5), start at point (B) of the troubleshooting chart.

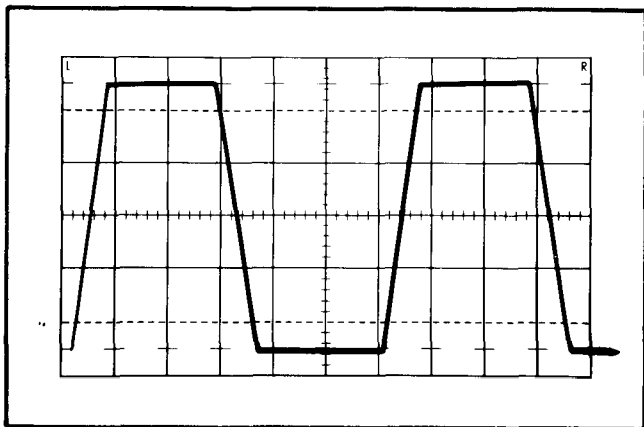


Fig. 5-5. Type R116 output pulse which should be obtained if instrument is operating properly.

c. If the undelayed pulse is similar to the pulse seen in Fig. 5-5 but a problem arises in other modes of operation or in external triggering, start at point (C) on the troubleshooting chart according to the trouble symptom.

d. If the Type R116 is generating a pulse properly using the front-panel controls, but is malfunctioning when programmed remotely, check the remote logic circuits found on the function program circuit cards and the coils and relays found on the other circuit cards.

After the defective circuit has been located, proceed with steps 5 through 9 to locate and repair the faulty components.

**5. Visual Check.** Visually check the portion of the instrument in which the trouble is located. Many troubles can be located by visual indications such as unsoldered connections, broken wires, damaged circuit boards, damaged components, etc.

**6. Check Voltages and Waveforms.** Often the defective component can be located by checking for the correct voltages and waveforms as given in blue on the circuit diagrams in the back of this manual.

#### NOTE

Voltages and waveforms given on the diagrams are not absolute and may vary slightly between instruments. To obtain operating conditions similar to those used to take these readings, see the beginning of the diagram section.

**7. Check Circuit Description.** If checking the voltages and waveforms do not indicate the source of the malfunction, more detailed information about how the circuit is supposed to operate may be necessary. The Circuit Description provides a circuit analysis of all the major circuits in the instrument. The emphasis in this section is on the operation of active components and the signals and voltages which may be expected at various points within the circuits.

**8. Check Individual Components.** The following procedures describe methods of checking individual components in the Type R116. Components which are soldered in place are best checked by disconnecting one end. This isolates the measurement from the effects of surrounding circuitry.

**A. TRANSISTORS.** The best check of transistor operation is actual performance under operating conditions. If a transistor is suspected of being defective, it can best be checked by substituting a new component or one which has been checked previously. However, be sure that circuit conditions are not such that a replacement transistor might also be damaged. If substitute transistors are not available, use a semiconductor tester (such as a Tektronix Type 575 or Type 576).

#### CAUTION

The POWER switch must be turned off before removing or replacing transistors.

If a semiconductor tester is not available, an ohmmeter will usually indicate when a transistor is totally bad. As a general rule, use the  $R \times 1 \text{ k}$  range where the current is usually limited to less than  $2 \text{ mA}$  and the internal voltage is usually  $1\frac{1}{2}$  volts. Check the current and voltage of the ohmmeter by inserting a multimeter between the ohmmeter leads and measuring the current and voltage of the various

ranges. After it has been determined which ohmmeter ranges will not harm the transistor, use those ranges to measure the transistor's resistance. Check the resistance in both directions through the junctions as listed in Table 5-3.

**TABLE 5-3**  
**TRANSISTOR RESISTANCE CHECKS**

Ohmmeter Connections <sup>1</sup>	Resistance Readings That Can Be Expected Using the $R \times 1\text{ k}$ Range
Emitter-Collector	High readings both ways (about 60 k $\Omega$ to around 500 k $\Omega$ ).
Emitter-Base	High reading one way (about 200 k $\Omega$ or more). Low reading the other way (about 400 $\Omega$ to 2.5 k $\Omega$ ).
Base-Collector	High reading one way (about 500 k $\Omega$ or more). Low reading the other way (about 400 $\Omega$ to 2.5 k $\Omega$ ).

<sup>1</sup>Reverse the test lead connections to make the second reading. Reversal of the applied voltage polarity causes the junction to shift between being reverse and forward biased, as indicated by the difference in resistance.

**B. DIODES.** A diode can be checked for an open or shorted condition by measuring the resistance between terminals. With an ohmmeter scale having an internal source of between 800 millivolts and 3 volts, the resistance should be very high in one direction and very low when the leads are reversed. To measure reverse leakage, a semiconductor tester is necessary. When unsoldering leads, be sure to provide a heat shunt so that the diode is not damaged.

## CAUTION

Do not use an ohmmeter that has a high internal current. High currents may damage the diode. Do not measure tunnel diodes with an ohmmeter; use a semiconductor tester.

**C. RESISTORS.** Resistors can be checked with an ohmmeter. Check the Electrical Parts List for the tolerance of the resistors in this instrument. Resistors normally do not need to be replaced unless the measured value varies widely from the specified value.

**D. INDUCTORS.** Check for open inductors by checking continuity with an ohmmeter. Shorted or partially shorted inductors can usually be found by checking the waveform response when high-frequency signals are passed through the circuit. Partial shorting often reduces high-frequency response causing rounding. Check toroids and Ferrite beads for cracks.

**E. CAPACITORS.** A leaky or shorted capacitor can best be detected by checking resistance with an ohmmeter on the highest scale. Do not exceed the voltage rating of the capacitor. The resistance reading should be high after the capacitor has charged. An open capacitor can best be detected with a capacitance meter or by checking to see if the capacitor passes AC signals.

**F. REED SWITCHES.** Check the reed switches with a voltmeter while the instrument is operating, to be sure that the reed is closed when actuated and open when not actuated.

**G. REED-DRIVE COILS.** The reed-drive coils can be checked for correct operation as follows (coil has four mounting leads for rigidity; make measurements between the two leads on either end of the coil): 1) With the instru-

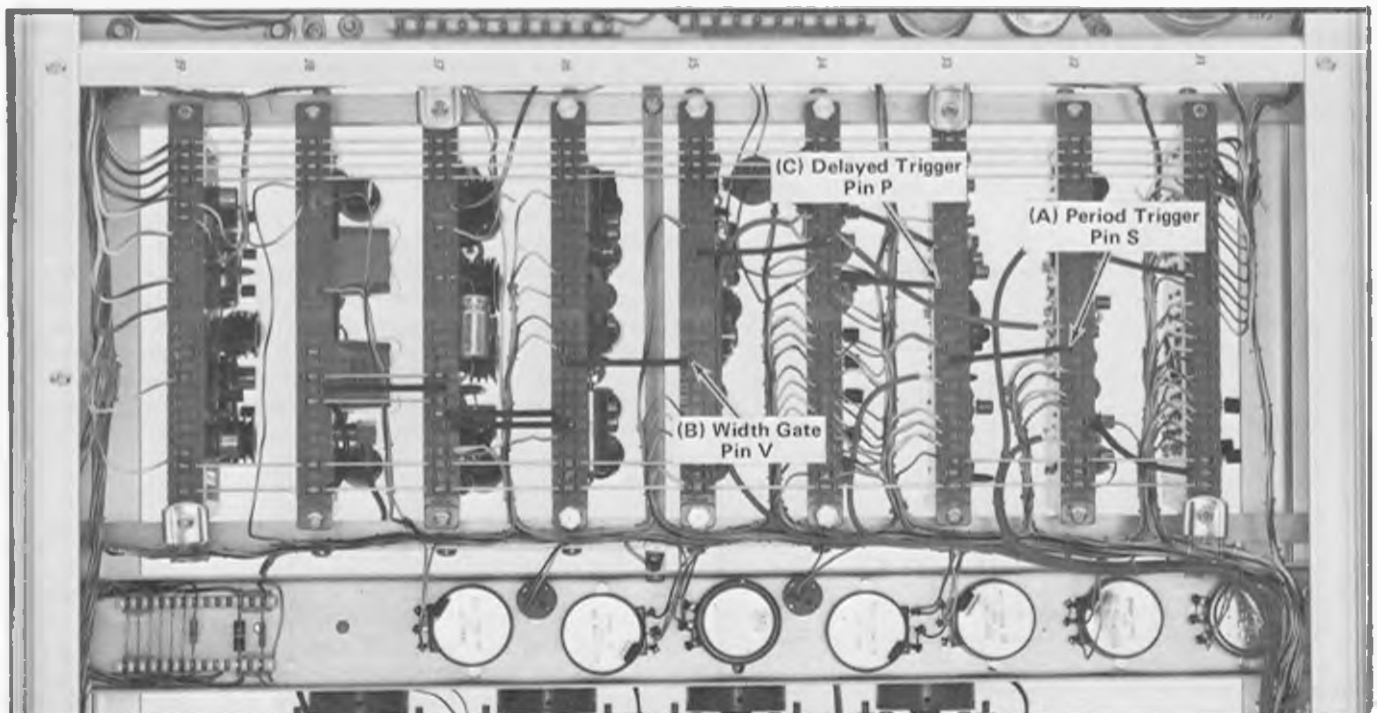


Fig. 5-6. Test points on the bottom of the Type R116 for use with the troubleshooting chart in Fig. 5-4.

ment power off, check the DC resistance of the coil with an ohmmeter; typical resistance values are given in the electrical parts list. 2) With the instrument power on, check the DC voltage drop across the coil when the actuating level is applied. 3) If both the resistance and voltage are correct, the coil can be assumed to be correct; 4) If the resistance is incorrect (take into account surrounding circuitry), disconnect the coil and check the resistance again. 5) If the voltage across the coil is incorrect but the coil resistance is correct check the circuit originating the actuating level.

**9. Repair and Readjust the Circuit.** If any defective parts are located, follow the replacement procedures given in this section. Be sure to check the performance of any circuit that has been repaired or that has had any electrical components replaced. If a component has been replaced, recalibration is usually necessary.

## CORRECTIVE MAINTENANCE

### General

Corrective maintenance consists of component replacement and instrument repair. Special techniques required to replace components in this instrument are given here.

### Obtaining Replacement Parts

**Standard Parts.** All electrical and mechanical part replacements for the Type R116 can be obtained through your local Tektronix Field Office or representative. However, many of the standard electronic components can be obtained locally in less time than is required to order them from Tektronix, Inc. Before purchasing or ordering replacement parts, check the parts list for value, tolerance, rating and description.

#### NOTE

When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect its performance, particularly at the upper frequency limits of the instruments. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance.

**Special Parts.** In addition to the standard electronic components, some special parts are used in the Type R116. These parts are manufactured or selected by Tektronix, Inc. to meet specific performance requirements, or are manufactured for Tektronix, Inc. in accordance with our specifications. Each special part is indicated in the electrical parts list by an asterisk preceding the part number. Most of the mechanical parts used in this instrument have been manufactured by Tektronix, Inc. Order all special parts directly from your local Tektronix Field Office or representative.

**Ordering Parts.** When ordering replacement parts from Tektronix, Inc., include the following information.

1. Instrument Type.
2. Instrument Serial Number.
3. Circuit card series letter and model number (if part is mounted on a circuit card).

4. A description of the part (if electrical, include circuit number).

5. Tektronix Part Number.

## Soldering Techniques

### WARNING

Disconnect the instrument from the power source before soldering.

**Circuit Cards.** Use ordinary 60/40 solder and a 15-watt pencil type soldering iron on the circuit cards. The tip of the iron should be clean and properly tinned for best heat transfer to the solder joint. A higher wattage soldering iron may separate the printed circuit alloy from the base material.

The following technique should be used to replace a component on a circuit card:

1. Remove the circuit card from the instrument.
2. Grip the component lead with long-nose pliers. Touch the soldering iron to the lead at the solder connection. Do not lay the iron directly on the card, as it may damage the card.
3. When the solder begins to melt, pull the lead out gently. This should leave a clean hole in the card. If not, the hole can be cleaned by reheating the solder and placing a sharp object such as a toothpick into the hole to clean it out. A vacuum-type desoldering tool can also be used for this purpose.
4. Bend the leads of the new component to fit the holes in the card. Insert the leads into the holes in the card so the component is firmly seated against the card (or as positioned originally). If it does not seat properly, heat the solder and gently press the component into place.
5. Touch the iron to the connection and apply a small amount of solder to make a firm solder joint. To protect heat-sensitive components, hold the lead between the component body and the solder joint with a pair of long-nose pliers or other heat sink.
6. Clip off the excess lead that protrudes through the card.
7. Clean the area around the solder connection with a flux-remover solvent. Be careful not to remove information printed on the card.
8. Replace the circuit card in the instrument. If more than one card has been removed, be sure the series letter on the circuit card matches the letter printed on the chassis adjacent to the card holder. When the card is in place, the components should face the left side of the instrument when viewed from the front-top.

**Ceramic Terminal Strips.** Solder used on the ceramic terminals strips should contain about 3% silver. Use a 40- to 75-watt soldering iron with a  $\frac{1}{8}$  inch wide wedge-shaped tip. Ordinary solder can be used occasionally without damage to the ceramic terminal strips. However, if ordinary solder is used repeatedly or if excessive heat is applied, the solder-to-ceramic bond may be broken.

## Maintenance—Type R116 (SN 1084-up)

A sample roll of solder containing about 3% silver is mounted on the chassis of this instrument next to L664. Additional solder of the same type should be available locally, or it can be purchased from Tektronix, Inc. in one-pound rolls; order by Tektronix Part No. 251-0514-00.

Observe the following precautions when soldering to a ceramic terminal strip:

1. Use a hot iron for a short time. Apply only enough heat to make the solder flow freely.
2. Maintain a clean, properly tinned tip.
3. Avoid putting pressure on the ceramic terminal strip.
4. Do not attempt to fill the terminal-strip notch with solder; use only enough solder to cover the wires adequately.
5. Clean the flux from the terminal strip with a flux-remover solvent.

**Metal Terminals.** When soldering to metal terminals (e.g., switch terminals, potentiometers, etc.), ordinary 60/40 solder can be used. Use a soldering iron with a 40- to 75-watt rating and a  $\frac{1}{8}$  inch wide wedge-shaped tip.

Observe the following precautions when soldering to a metal terminal:

1. Apply only enough heat to make the solder flow freely.
2. Apply only enough solder to form a solid connection. Excess solder may impair the function of the part.
3. If a wire extends beyond the solder joint, clip off the excess.
4. Clean the flux from the solder joint with a flux-remover solvent.

## Component Replacement

### WARNING

Disconnect the instrument from the power source before replacing components.

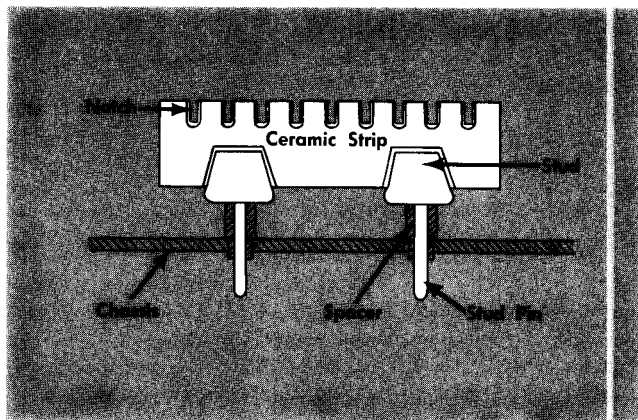


Fig. 5-7. Ceramic terminal strip assembly.

**Ceramic Terminal Strip Replacement** A complete ceramic terminal strip assembly is shown in Fig. 5-7. Replacement strips (including studs) and spacers are supplied under separate part numbers. However, the old spacers may be reused if they are not damaged. The applicable Tektronix Part Numbers for the ceramic strips and spacers used in this instrument are given in the Mechanical Parts List.

To replace a ceramic terminal strip, use the following procedure.

### REMOVAL:

1. Unsolder all components and connections on the strip. To aid in replacing the strip, it may be advisable to mark each lead or draw a sketch showing the location of the components and connections.
2. Pry or pull the damaged strip from the chassis.
3. If the spacers come out with the strip, remove them from the stud pins for use on the new strip (spacers should be replaced if they are damaged).

### REPLACEMENT:

1. Place the spacers in the chassis holes.
2. Carefully press the studs of the strip into the spacers until they are completely seated. If necessary, use a soft mallet and tap lightly, directly over the stud, to seat the strip completely.
3. If the studs on the new ceramic strip are longer than those on the old one, cut off the excess length after the new strip is put in place.
4. Replace all components and connections. Observe the soldering precautions given under soldering Techniques in this section.

**Circuit Card Replacement.** If one of the plug-in circuit cards is damaged and cannot be repaired, it should be replaced with a new card assembly. Replacement cards may be ordered either with or without circuit components wired in place. The Tektronix Part Numbers are given in the Mechanical Parts List. To obtain a replacement card with the solder-on components in place, be sure to order the replacement card assembly. (An assembly does not include socket-mounted transistors.)

### CAUTION

When replacing circuit cards in the Type R116 always observe the following:

1. Insert all cards into their holders with the components on the left side, as viewed from the front and top of the instrument. A CAUTION to this effect is printed on the chassis.
2. Install each card only in the correct series slot. The series letter (e.g., C) is printed on the top front corner of the card and on the instrument chassis adjacent to the card holder. Installation in any other position may damage the instrument. (The card may have any MODEL number, as long as the series letter is correct.)

After any plug-in card has been replaced, that portion of the circuitry must be calibrated and any closely-related cir-

cuits should be checked. If a series N circuit card is replaced, be sure to reconnect the wire or coaxial cable to the connector on the card.

**Transistor Replacement.** Transistors should not be replaced unless they are actually defective. If removed from their sockets during routine maintenance, return them to their original sockets. Unnecessary replacement or exchange of transistors may affect the calibration of this instrument. When transistors are replaced, check the operation of that part of the instrument which may be affected.

#### CAUTION

**POWER switch must be turned off before removing or replacing transistors.**

Replacement transistors should be of the original type or a direct replacement. Fig. 5-3 shows the lead configuration of the transistors used in this instrument. Some plastic case transistors have lead configurations which do not agree with those shown here. If a transistor is replaced by one which is made by a different manufacturer than the original, check the manufacturer's basing diagram for correct basing. All transistor sockets in this instrument are wired for the basing used for metal-case transistors. Use silicone grease when replacing transistors which have heat radiators or are mounted on the chassis. Replace the silicone grease when replacing these transistors.

#### WARNING

Handle silicone grease with care. Avoid getting silicone grease in the eyes. Wash hands thoroughly after use.

**Fuse Replacement.** The power-line fuses are located on the rear panel in the Voltage Selector Assembly. Power-supply fuses are located beside the power transformer. See the electrical parts list for the values of the fuses.

**Glass Reed-Switch Replacement.** The glass reed-switches used in this instrument are pressurized and can easily be broken. To avoid damage to the reed-switch, do not apply stress to the metal-glass bond. When it is necessary to bend a lead, use two pair of long-nose pliers, one next to the glass to hold the lead and one to bend the lead. Before replacing a reed-switch, be sure the actuating circuitry is not at fault. See Troubleshooting procedure for methods of checking the circuit. It is important that the replacement reed-switch be correctly positioned within the drive-coil assembly with the same lead length as the original to provide similar magnetic characteristics.

#### REMOVAL:

1. Observe the physical position of the glass bulb and the leads of the old reed-switch.

2. Unsolder the leads of the old reed-switch from the solder posts.

3. Pull the old reed-switch out of the drive-coil.

#### REPLACEMENT:

1. Bend and clip the leads of the new reed-switch to duplicate those of the old one. Be careful not to stress the glass.

2. Slip the new reed-switch into the drive-coil.

3. Position the new reed-switch in exactly the same physical position as the old one.

4. Position the leads correctly and solder the new reed-switch to the solder posts. Avoid excessive heat on the reed-switch; use a heat sink on the leads.

**Rotary Switches.** Individual wafers or mechanical parts of rotary switches are normally not replaceable. If a switch is defective, replace the entire assembly. Replacement switches can be ordered either wired or unwired; refer to the Electrical Parts List for the applicable part number.

When replacing a switch, tag the leads and switch terminals with corresponding identification tags as the leads are disconnected. Then, use the old switch as a guide for installing the new one. An alternative method is to draw a sketch of the switch layout and record the wire color at each terminal. When soldering to the new switch be careful that the solder does not flow beyond the rivets of the switch terminals. Spring tension of the switch contact can be destroyed by excessive solder.

**Power Transformer Replacement.** The power transformer in this instrument is warranted for the life of the instrument. If the power transformer becomes defective, contact your local Tektronix Field Office or representative for a warranty replacement (see the Warranty note in the front of this manual). Be sure to replace only with a direct replacement Tektronix transformer.

#### NOTE

When removing the transformer, tag the leads with the terminal numbers to aid in connecting the new transformer.

#### Recalibration After Repair

After any electrical component has been replaced, the calibration of the associated circuit should be checked, as well as the calibration of other closely related circuits. Since the Power supply affects all circuits, calibration of the entire instrument should be checked if work has been done in the Power supply or if the power transformer has been replaced. The Performance Check and Calibration Procedure in Section 6 provides a means of checking instrument operation and making necessary adjustment.



The Series B circuit card  
is identical in appearance  
to this circuit card

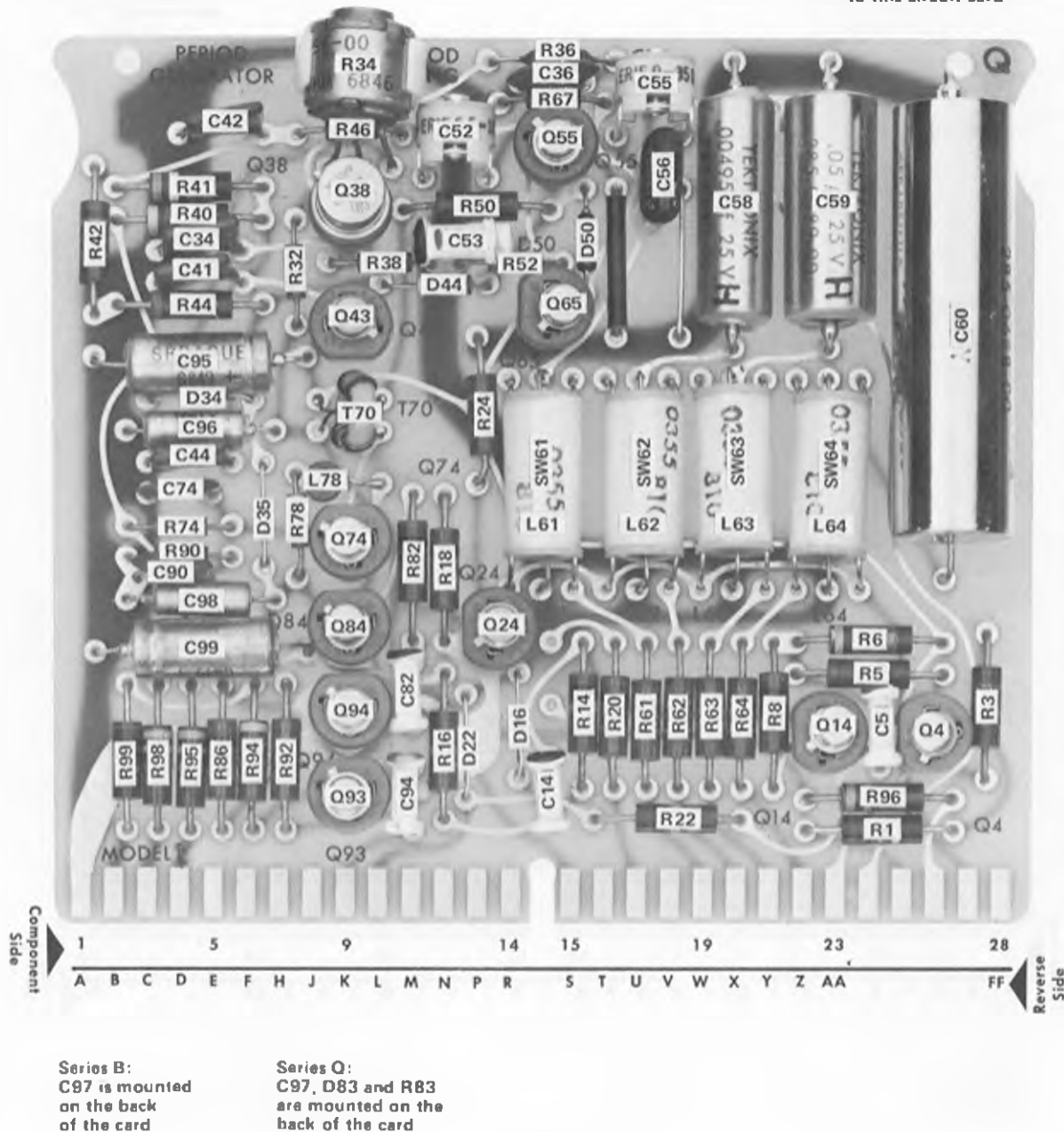
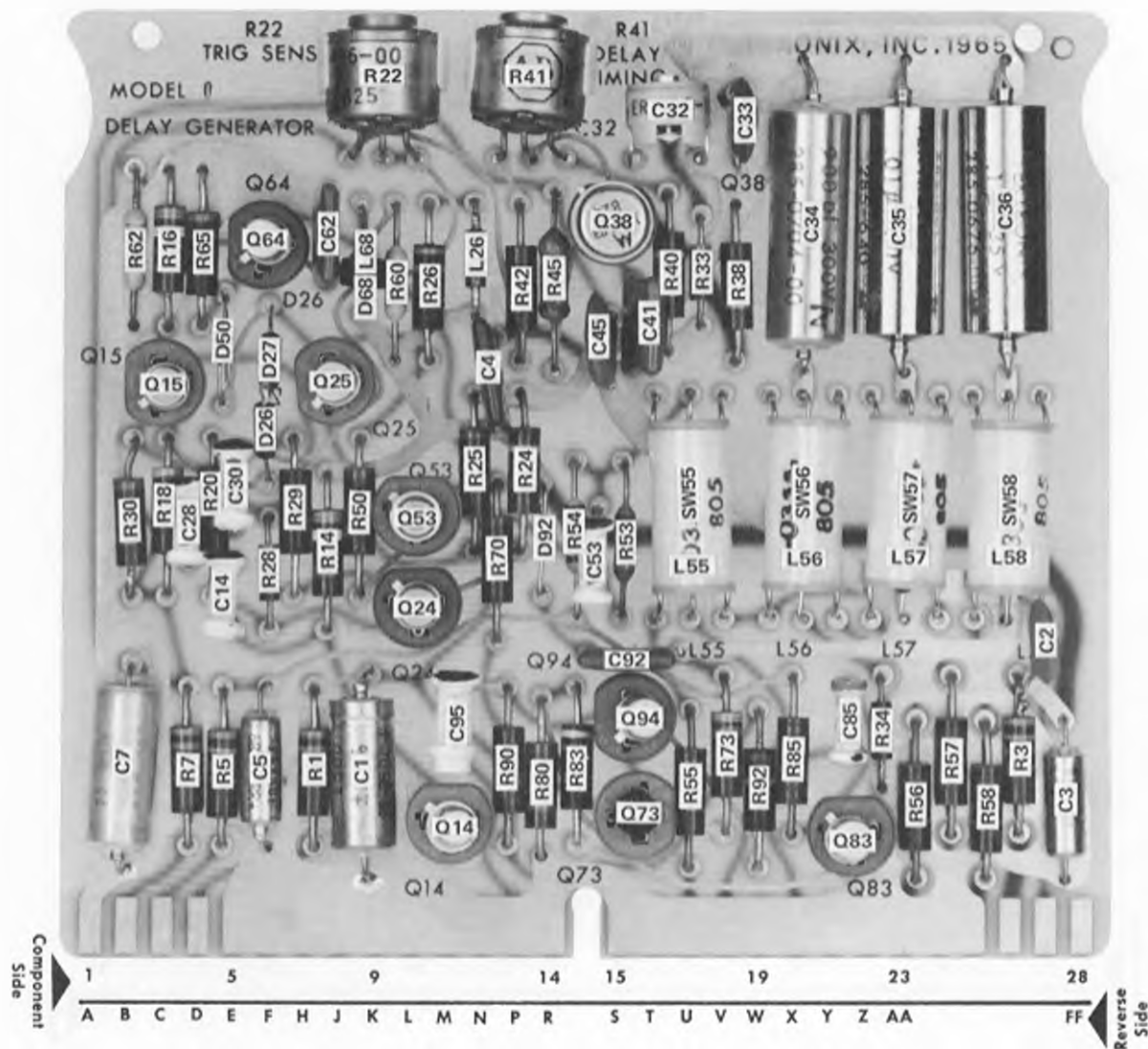


Fig. 5-9. Location of circuit components on Period Generator circuit card, Series B, Models 2 through 5, and Series Q, Model 1.



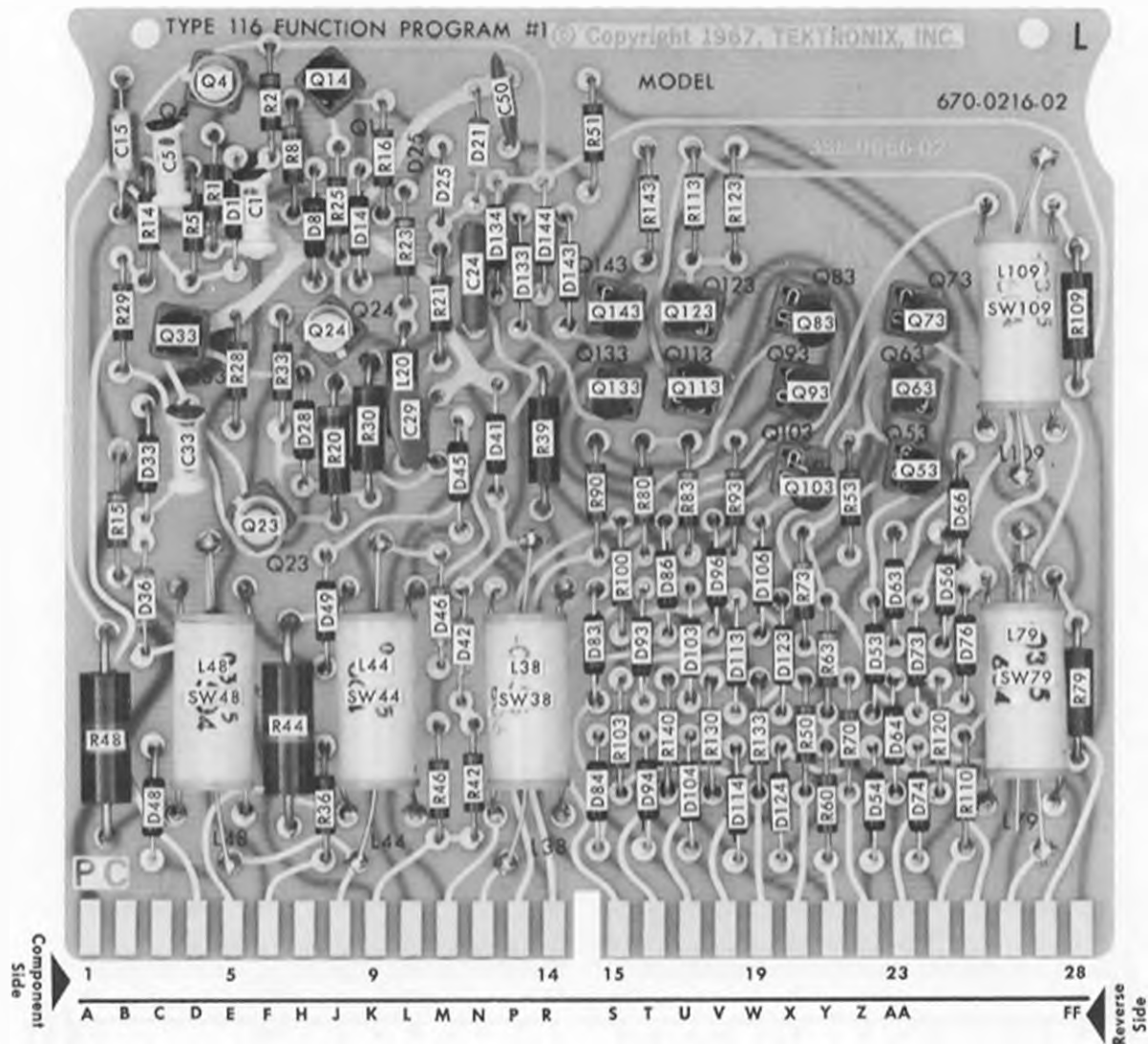
**The Series C circuit card identical in appearance to this circuit card.**



**Series O:**  
R95 is mounted  
on the back of  
the card.

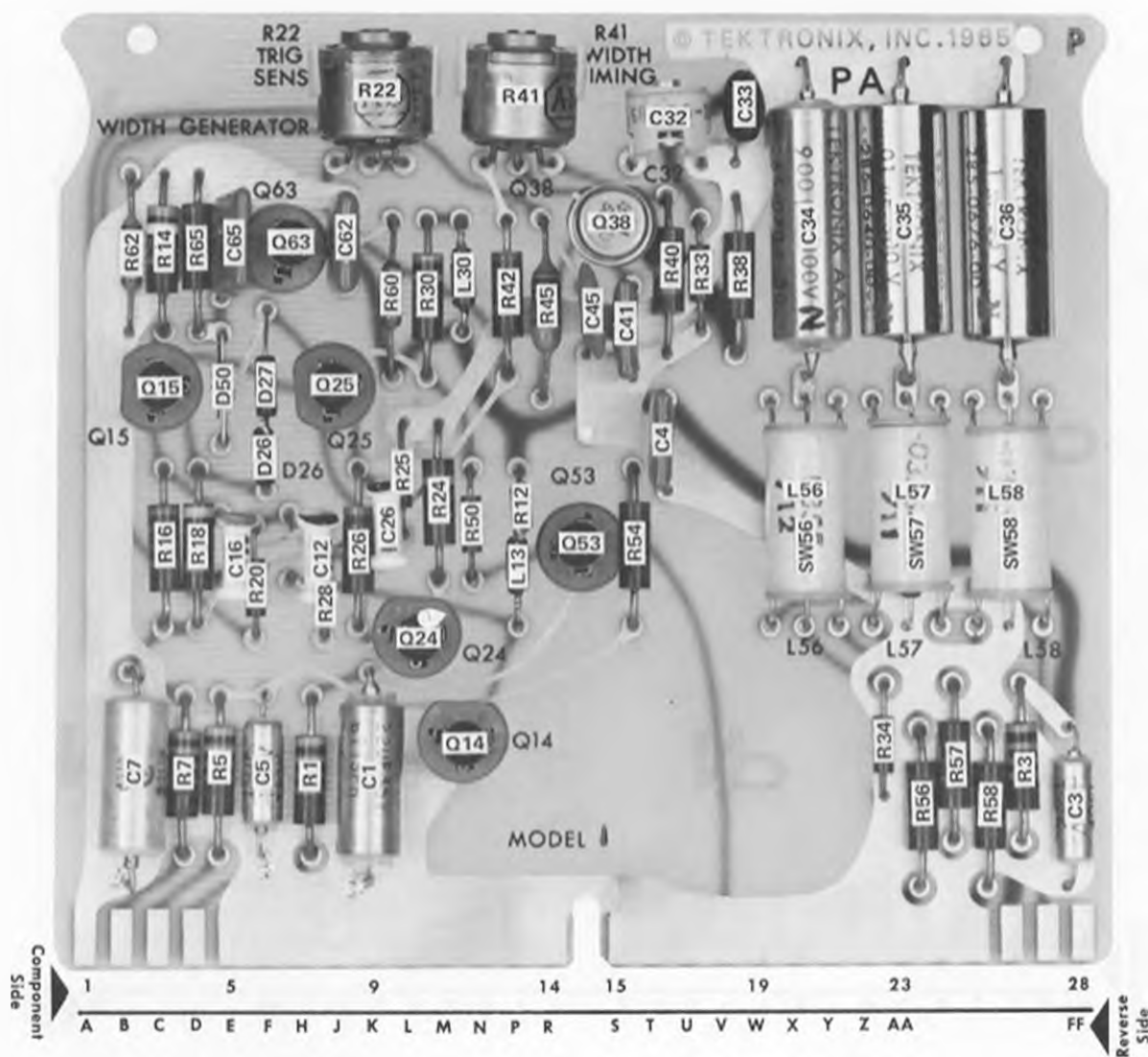
Fig. 5-10. Location of circuit components on Delay Generator circuit card, Series C, Model 3, and Series O, Models 1 and 2.





C97 is mounted  
on back of circuit  
card

Fig. 5-11. Location of circuit components on Function Program #1 circuit card, Series 1, Models 1 and 2.



D15 and L15 are mounted on the back of the card.

Fig. 5-12. Location of circuit components on Width Generator circuit card, Series P, Models 1 through 3.

The Series E circuit card is identical in appearance to this circuit card.

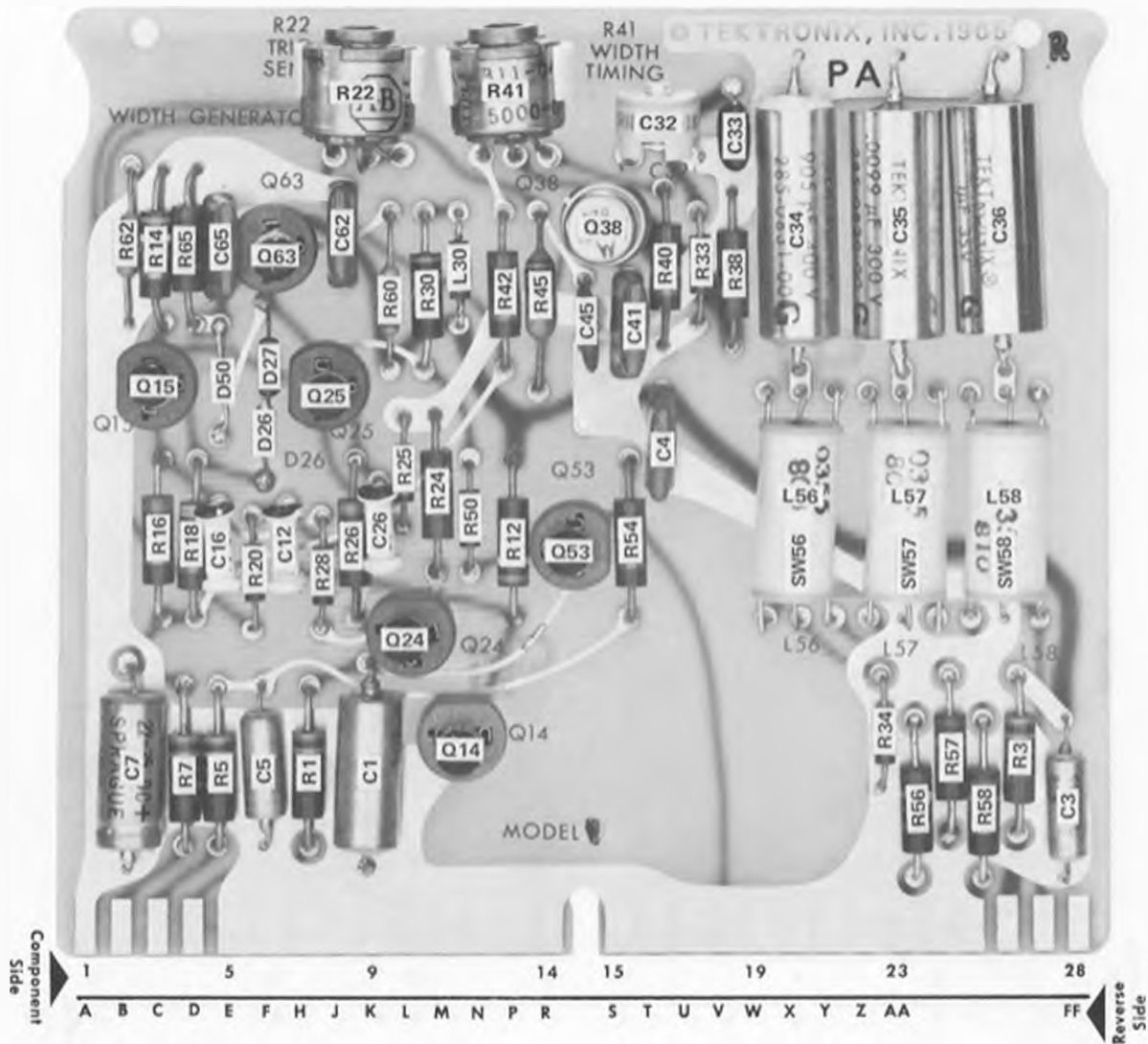


Fig. 5-13. Location of circuit components on Width Generator circuit card, Series E, Model 3, and Series R, Model 1.

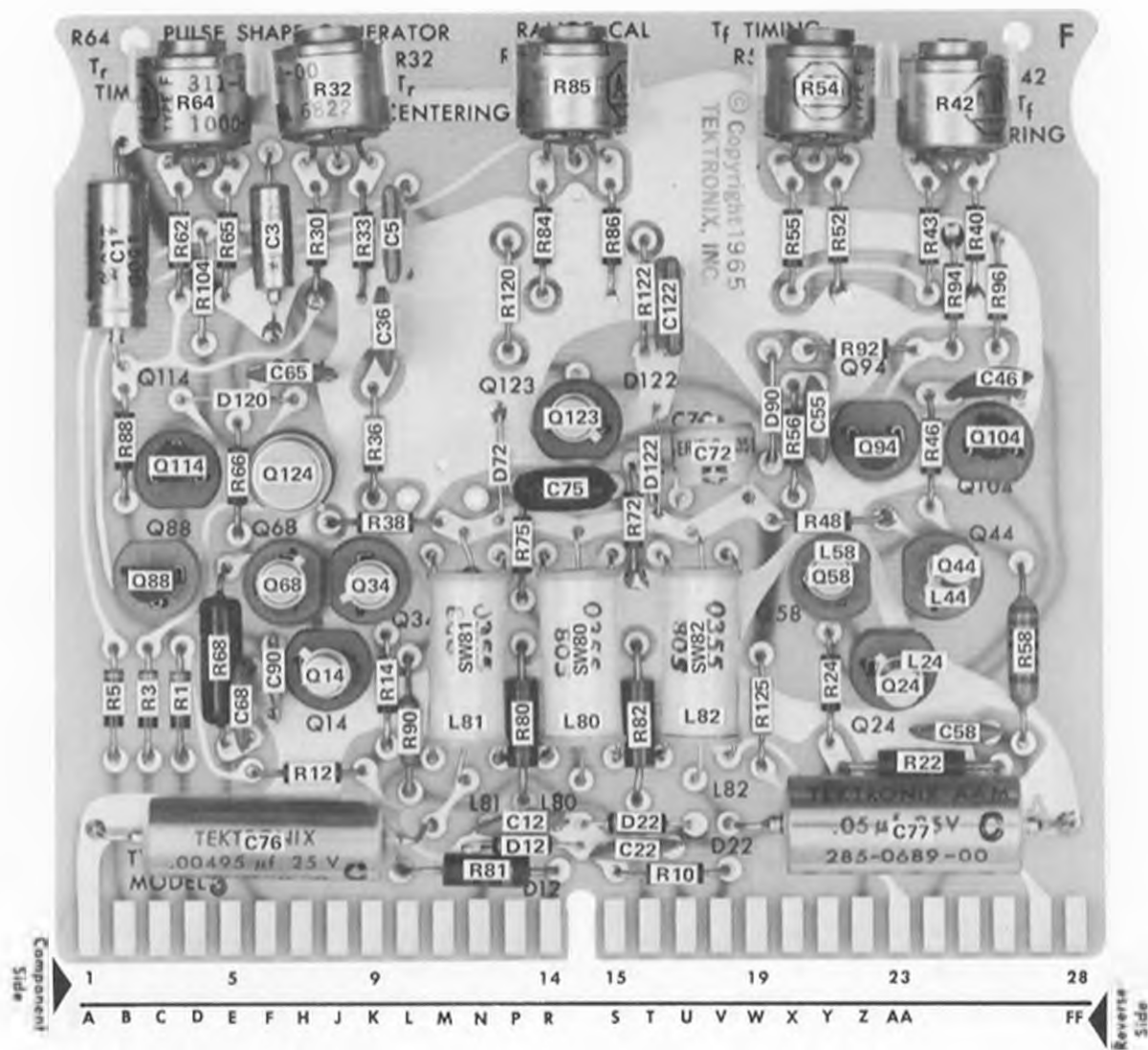


Fig. 5-14. Location of circuit components on Pulse Shape Generator circuit card, Series F, Models 3 and 4.

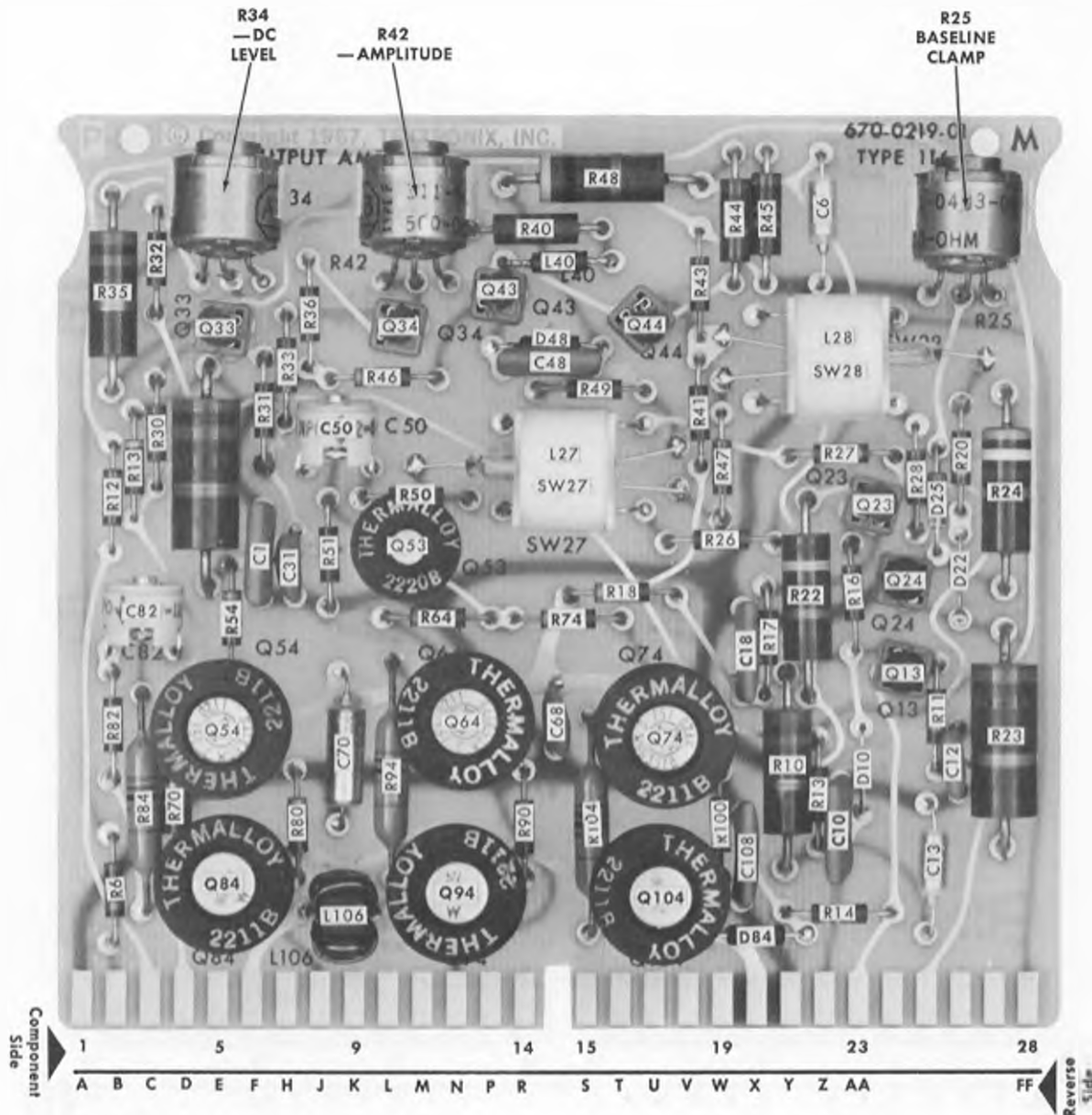


Fig. 5-15. Location of circuit components on Output Amplifier circuit card, Series M, Models 1 through 3.

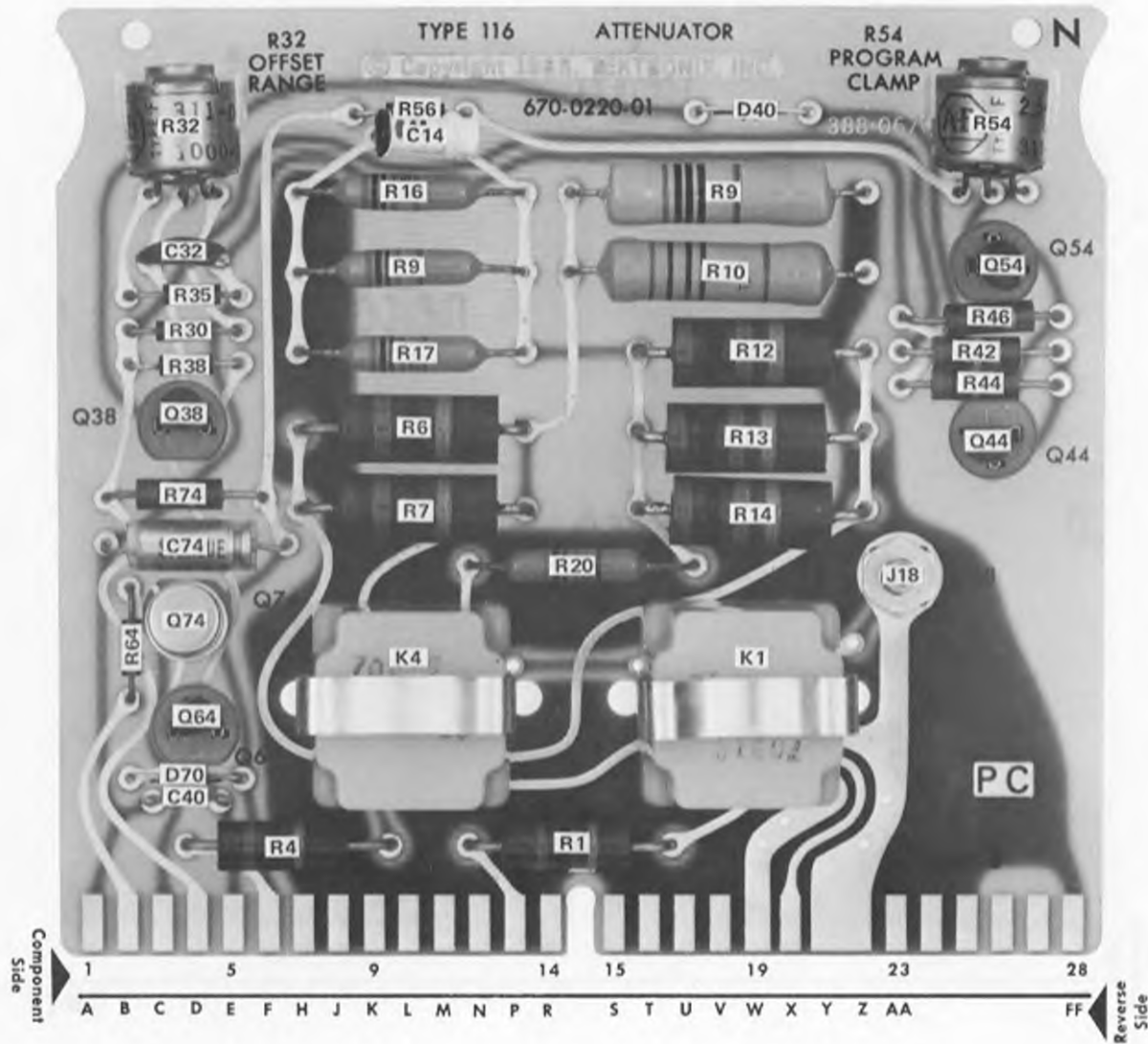


Fig. 5-16. Location of circuit components on Attenuator circuit card, Series N, Models 1 and 2.



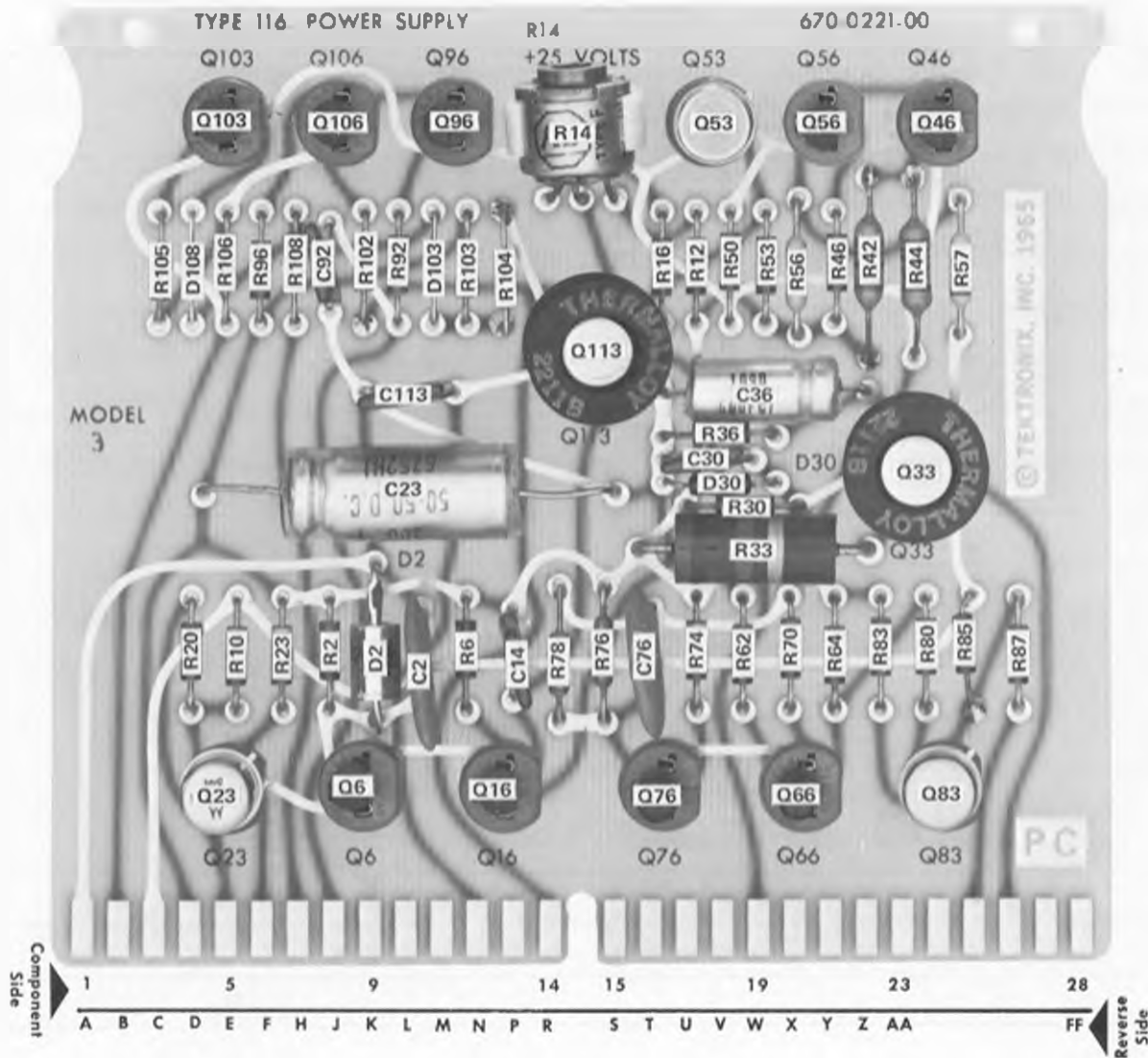


Fig. 5-17. Location of circuit components on Power Supply circuit card, Series I, Model 3.

[illegible]



# SECTION 6

## PERFORMANCE CHECK / CALIBRATION

Change information, if any, affecting this section will be found at the rear of the manual.

### GENERAL

This combined Performance Check and Calibration Procedure provides methods of comparing the instrument to the performance requirements given in the Specification section and methods of adjusting instrument characteristics which do not meet specifications. The Type R116 should be checked and recalibrated after each 1000 hours of operation or at least once every six months to ensure that it is operating properly. In addition, portions of the instrument will require recalibration if components are replaced or other electrical repairs are made.

The step by step instructions in this procedure furnish an orderly approach to the isolation of possible malfunctions and thus serve as an aid in troubleshooting the instrument. Any maintenance that is known to be needed should be performed before starting the calibration procedure. If any troubles become apparent during calibration, these also should be corrected before proceeding. Repair and servicing information is given in the Maintenance section.

A performance check/calibration record and index is included at the beginning of this procedure. It may be used as a check list to verify calibration and correct operation of the Type R116 or as a guide for quick calibration by an experienced calibrator. It may also be used as an index to indicate where a particular adjustment procedure is located.

### EQUIPMENT REQUIRED

The following (or equivalent) items of equipment are required for a complete calibration of the Type R116. The equipment is illustrated in Fig. 6-1. If substitute equipment is used, its accuracy must exceed the tolerances to be measured by at least 4 times in order to make an accurate measurement. If the tolerance to be measured is less than 1%, the accuracy of the test equipment must exceed the tolerance by at least 10 times.

1. Test Oscilloscope, Tektronix Type 547 with Type 1A1 Dual-Trace Plug-In Unit. Minimum alternate requirements: bandwidth from DC to 40 MHz; sweep rate from 5 ms/cm to 10 ns/cm (0.1  $\mu$ s/cm magnified by 10); internal and external triggering; amplitude calibrator output available (approximately 1 kHz); vertical deflection factors from 0.2 V/cm to 2 V/cm; alternate-trace switching.

2. Differential Comparator Plug-In Unit, Tektronix Type W, compatible with Type 547 Oscilloscope. Minimum alternate requirements (with oscilloscope): 2 differential inputs; bandwidth from DC to 15 MHz; internal comparison voltage provided with accuracy within 0.75%; vertical deflection factors from 2 mV/cm to 2 V/cm; voltage accuracy of display within 3%. (Differential inputs not required for Performance Check Only procedure.)

3. Sampling Oscilloscope, Tektronix Type 568 with Type 3S6 (or 3S5) Sampling Unit and 2 Type S1 Sampling Heads, and with Type 3T6 (or 3T5) Sampling Sweep Unit. Minimum alternate requirements: 2 vertical input channels; risetime of 350 ps or less; vertical deflection factors from 10 mV/div to 200 mV/div; voltage accuracy of display within 3%; front corner aberrations of  $\pm 0.75\%$  or less; peak-to-peak aberrations of 0.75% or less; sweep positioning capability (time delay).

4. Variable auto transformer (e.g., General Radio Variac Type W10MT3W for 115-volt operation, or Type W20HMT3A for 230-volt operation). Output voltage variable from 94.5 volts to 137.5 volts AC RMS for 115-volt operation or from 189 volts to 275 volts AC RMS for 230-volt operation; output power rating at least 0.1 kVA. If a monitor voltmeter is not included, a separate AC voltmeter is required. (Autotransformer not required for Performance Check Only procedure.)

5. Time-Mark Generator, Tektronix Type 184. Minimum alternate requirements: time-mark outputs from 0.1  $\mu$ s to 10 ms; sine-wave output of 2 ns, 10 ns, 20 ns and 50 ns; accuracy of output within 0.75%.

6. DC Voltmeter. Minimum requirements: voltage range from 6 volts to 27 volts; basic accuracy within 3%; accuracy at 25 volts and 27 volts within 1%; sensitivity 20,000  $\Omega$ /V. (This item not needed for Performance Check Only procedure.)

7. Two 1 $\times$  Test Probes, Tektronix P6011, with BNC connectors. Tektronix Part No. 010-0192-00.

8. 50  $\Omega$  in-line termination with BNC connectors, 5 watt. Tektronix Part No. 011-0099-00. (Included with the Type R116.)

9. 50  $\Omega$  in-line termination with BNC connectors, 1 watt. Tektronix Part No. 011-0049-00.

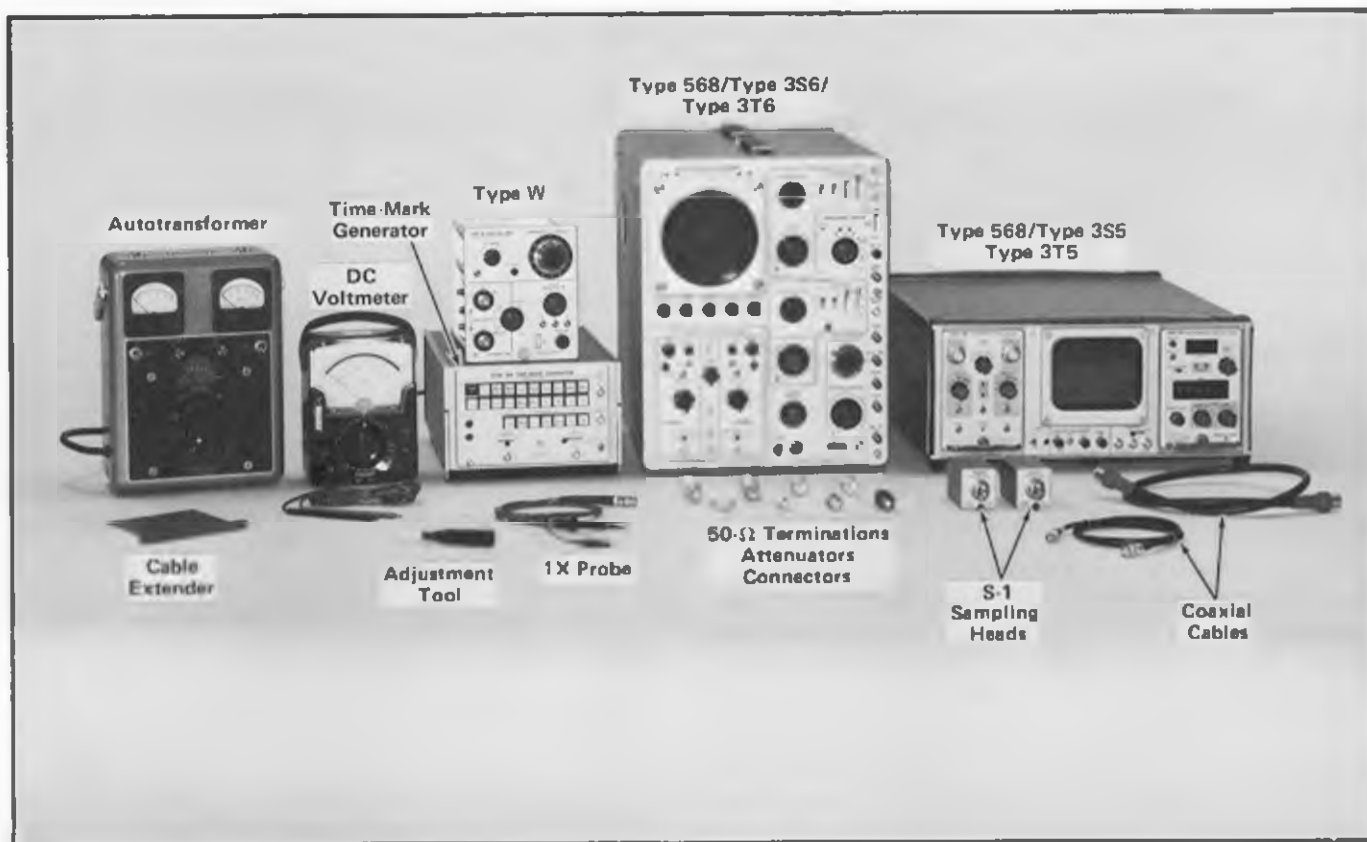


Fig. 6-1. Type R116 and test equipment.

10. Coaxial T connector with BNC connectors. Tektronix Part No. 103 0030-00.

11. 50  $\Omega$  10X attenuator with GR connectors. Tektronix Part No. 017 0078-00.

12. 50  $\Omega$  10X attenuator with GR connectors. Tektronix Part No. 017-0079-00.

13. 50  $\Omega$  10X attenuator with BNC connectors. Tektronix Part No. 011-0059-00.

14. BNC male to GR connector adapter. Tektronix Part No. 017-0064-00.

15. BNC female to GR connector adapter. Tektronix Part No. 017-0063-00.

16. Three 42-inch coaxial cables. Characteristic impedance approximately 50  $\Omega$ ; BNC connectors. Tektronix Part No. 012-0057-01. (One of these cables is included with the Type R116.)

17. 5 ns coaxial cable. Characteristic impedance approximately 50  $\Omega$ ; GR connectors. Tektronix Part No. 017-0502-00.

18. 56-terminal circuit card extender. Tektronix Part No. 012 0078 00.

19. Plastic screwdriver adjustment tool. Tektronix Part No. 003 0000-00.

20. If the Type R116 is being checked and/or adjusted for remote operation, some means of remotely programming the instrument during this procedure is necessary. If the programming device used during normal operation is not available for use in calibration, it will be necessary to construct a programmer. Fig. 6-2 shows a schematic of a remote programmer which can be constructed in varying degrees of complexity. The resistor values shown in Table 6-1 have been obtained from the programming section of this manual. To construct this programmer the following parts are needed:

- a. 36 terminal plug; Tektronix Part No. 131-0293-00.
- b.  $\frac{1}{8}$ th watt, 1% metal film resistors; see Table 6-1.
- c. No. 22 wire.
- d. Switches or patch cords and connectors.

Fig. 6-2. Circuit diagram of remote programmer.

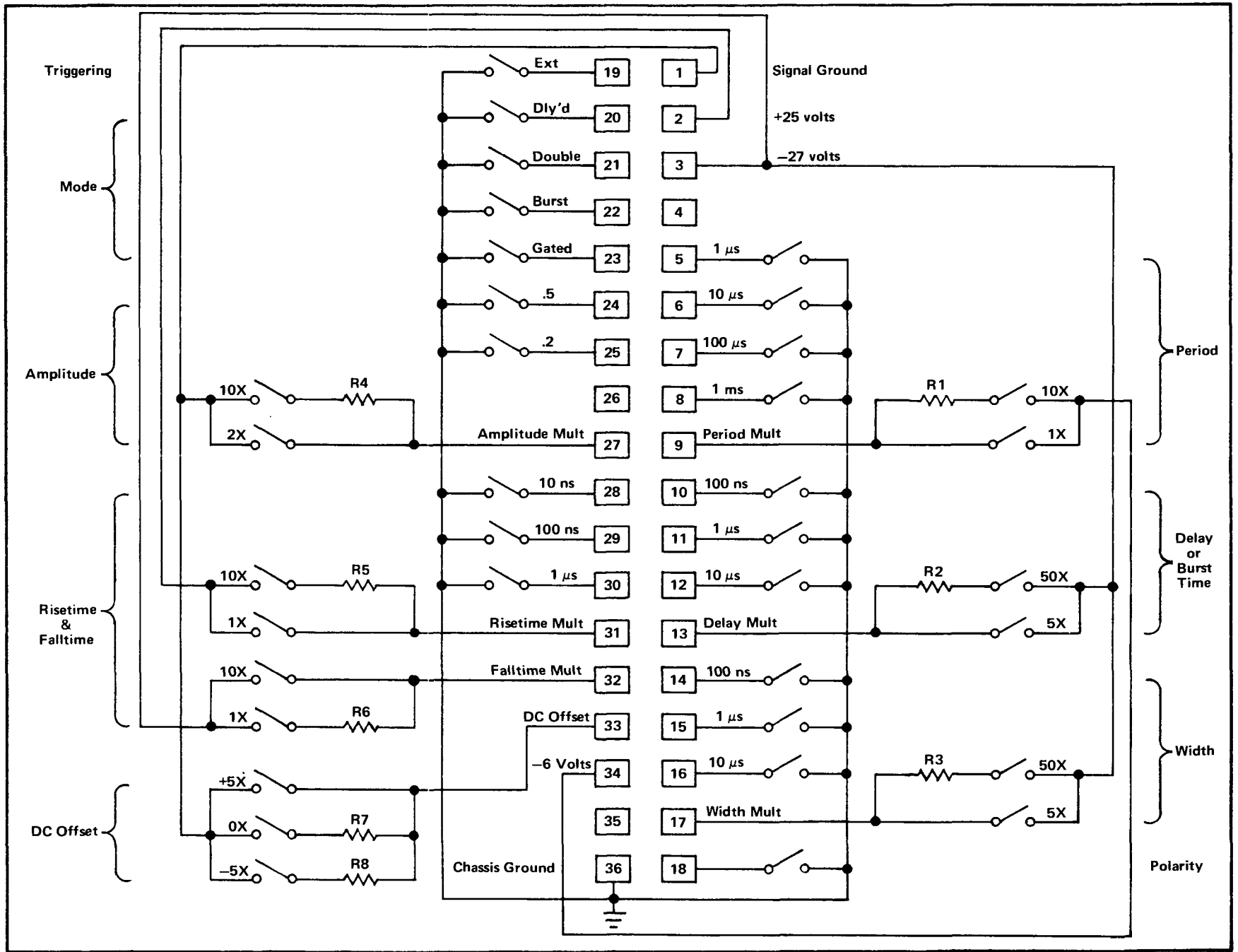


TABLE 6-1

Resistor Values for Remote Programmer

Circuit Number	Value
R1	15.2 k $\Omega$
R2	7.98 k $\Omega$
R3	7.98 k $\Omega$
R4	8.87 k $\Omega$
R5	3.09 k $\Omega$
R6	3.09 k $\Omega$
R7	4.43 k $\Omega$
R8	8.87 k $\Omega$

## FRONT-PANEL AND/OR REMOTE OPERATION

The Type R116 can be operated using either front-panel controls, remote programming or a combination of the two. For maximum pulse accuracy, it is desirable to control each function of the instrument, while making checks and/or adjustment, using the type of control (front panel or remote) to be used during normal operation. This ensures maximum pulse accuracy, since a function calibrated for use in one mode of operation may be as much as 2% less accurate when operated in the other mode of operation.

This performance check/calibration procedure has been designed for calibration using front-panel controls. If a function is being calibrated for remote operation, it should be remotely programmed for the same value given in the procedure for the front-panel control. To obtain the most accurate calibration for remote operation, the Type R116 should be programmed during calibration by the same remote programming device that is used during normal operation. Using this programmer allows the analog functions of the Type R116 to be programmed using the same program resistors which are used to program the functions in normal operation. It also provides a check of the operation of the programming unit. If this device is not available for use during calibration, a programming device may be constructed as described in the Equipment Required List.

## PERFORMANCE CHECK/CALIBRATION RECORD AND INDEX

Type R116, Serial No. \_\_\_\_\_

Performance Check/Calibration Date \_\_\_\_\_

Checked/Calibrated By \_\_\_\_\_

### Power Supply

- ☐ 1. Adjust +25-Volt Supply Page 6-6  
Adjust R14 on Power Supply circuit card.
- ☐ 2. Check Power Supply Voltages Page 6-7  
Check other power supply voltages (see Table 6-2).
- ☐ 3. Check Regulation Page 6-8  
See Table 6-2.

### Preliminary Adjustments

- ☐ 4. Adjust Risetime and Falltime Centering Page 6-8  
Adjust R32 and R42 on Pulse Shape Generator circuit card.
- ☐ 5. Check Width and Delay Trigger Sensitivity Page 6-9
- ☐ 6. Adjust Width and Delay Trigger Sensitivity Page 6-11  
Adjust R22 on the Width Generator circuit card; adjust R22 on the Delay Generator circuit card.
- ☐ 7. Pre-Adjust Offset Adjustments Page 6-11  
Adjust R32 on Attenuator circuit card; adjust R466 and R476 on chassis.
- ☐ 8. Adjust Baseline Clamp Page 6-12  
Adjust R25 on Output Amplifier circuit card.
- ☐ 9. Adjust Offset Registration Page 6-12  
Adjust R544 on chassis.

### Offset and Amplitude

- ☐ 10. Adjust Offset Zero (+ Polarity) Page 6-13  
Adjust R466 on chassis.
- ☐ 11. Adjust +Amplitude Page 6-13  
Adjust R85 on Pulse Shape Generator circuit card; adjust R532 on chassis.
- ☐ 12. Adjust Amplitude and DC Offset Page 6-13  
(— Polarity)  
Adjust R42 and R34 on Output Amplifier circuit card; adjust R476 on chassis.
- ☐ 13. Adjust Program Clamp Page 6-15  
Adjust R54 on Attenuator circuit card.
- ☐ 14. Check Offset Accuracy Page 6-15
- ☐ 15. Check Amplitude Accuracy Page 6-16

### Slow Risetime and Falltime

- ☐ 16. Adjust Slow Risetime and Falltime Page 6-17  
Adjust R64 and R54 on Pulse Shape Generator circuit card; adjust R564 and R554 on chassis.
- ☐ 17. Check Slow Risetime and Falltime Page 6-18  
Accuracy

### Pulse Shape, Fast Risetime and Falltime

- ☐ 18. Adjust Pulse for Minimum Aberrations Page 6-19  
Adjust C50 and C82 on Output Amplifier circuit card.
- ☐ 19. Check Pulse Aberrations Page 6-20
- ☐ 20. Adjust Fast Risetime and Falltime Page 6-20  
Adjust C72 on Pulse Shape Generator circuit card.
- ☐ 21. Check Fast Risetime and Falltime Page 6-21.  
Accuracy

### Width Generator

- ☐ 22. Adjust Width Timing Page 6-22  
Adjust R41 and C32 on Width Generator circuit card; adjust R522 and R523 on chassis.
- ☐ 23. Check Width Accuracy Page 6-23

### Delay Generator

- ☐ 24. Adjust Delay Timing Page 6-24  
Adjust R41 and C32 on Delay Generator circuit card; adjust R512 and R513 on chassis.
- ☐ 25. Check Delay Accuracy Page 6-25

### Period Generator

- ☐ 26. Adjust Period Timing Page 6-26  
Adjust R34, C52 and C55 on Period Generator circuit card; adjust R502 on chassis.
- ☐ 27. Check Period Accuracy Page 6-27


### Modes of Operation, Triggers and Triggering

- ☐ 28. Check Pretrigger and Delayed Trigger Page 6-28
- ☐ 29. Check Single, Delayed Single and Double Pulse Modes Page 6-28
- ☐ 30. Check External and Manual Triggering Page 6-29
- ☐ 31. Check Burst Mode Page 6-29
- ☐ 32. Check Gated Output Mode Page 6-30

## PERFORMANCE CHECK/CALIBRATION PROCEDURE

The following procedure is arranged to allow: (1) checking of the performance of Type R116 with respect to tolerances given in Section 1; (2) complete or partial adjustment of the Type R116 internal controls without a complete performance check; or (3) a complete recalibration of the Type R116, which includes adjustment of all the internal controls and a complete performance check. To perform any of the above operations, use one of the following methods:

**Performance Check Only.** Start with the PRELIMINARY PROCEDURE-Performance Check Only and perform only those steps with titles starting with the word "check", through the main procedure or the Performance Check/Calibration Record and Index.

**Adjustment Only.** Start with the PRELIMINARY PROCEDURE-Calibration Only and perform only those steps with titles starting with the word adjust, throughout the main procedure or the Performance Check/Calibration Record and Index. These titles have a large adjust symbol  in the adjacent margin.

**Calibration.** Start with the PRELIMINARY PROCEDURE-Calibration Only and perform all the steps throughout the main procedure or the Performance Check/Calibration Record and Index.

When doing a complete calibration or a complete adjustment of internal controls of the instrument, the best overall performance will be obtained if each adjustment is made to the exact setting, even if the observed performance is within tolerance. When doing only a partial adjustment, however, do not readjust any controls unless the observed performance is not within tolerance. In either case, do not preset any of the adjustments unless they are known to be significantly out of adjustment or unless repairs have been made in the circuit. In these instances, set the particular controls to midrange.

A complete list of initial control settings for the Type R116 and significant control settings for the test instruments is given at the beginning of the Performance Check/Calibration procedure. Partial lists of initial control settings are also provided at various places in the main body of the text. Any control setting not listed in a partial list should be set as designated in the complete list at the beginning of the procedure. These control settings apply to all three of the procedures. If adjustments and/or checks are made without following one of the three procedures, start with the list of control settings preceding the desired adjustment or check and follow the sequence up to the desired step, making changes in control settings as indicated.

## PRELIMINARY PROCEDURE

### Performance Check Only

1. Set the 115 V-230 V Selector switch on the Type R116 rear panel in accordance with the line voltage source to be used.
2. Connect the Type R116 to the line voltage source.
3. Install the Type W Plug-In Unit in the Type 547 Oscilloscope and connect the instrument to a suitable power source.
4. Connect a 50  $\Omega$  coaxial cable, terminated with a 5 watt, 50  $\Omega$  termination (Tektronix Part No. 011-0099-00), from the Type R116 PULSE OUTPUT connector to the Channel A vertical input of the test oscilloscope.

## Performance Check/Calibration—Type R116 (SN 1084-up)

5. Connect a 50  $\Omega$  coaxial cable between the Type R116 + PRETRIGGER OUT connector and the test oscilloscope External Trigger Input.

6. Turn on the Type R116 and the test oscilloscope. Allow at least 20 minutes warm-up at an ambient temperature of +25° C,  $\pm 5^\circ$  C (+77° F,  $\pm 9^\circ$  F) before making any checks.

7. Set the instrument controls as indicated in the partial list of control settings preceding step 14 on page 6-15 and start the performance check procedure with step 14.

### Calibration Only

1. Remove the dust covers from the Type R116.
2. Set the 115 V-230 V Selector switch on the Type R116 rear panel in accordance with the line voltage source to be used.
3. Connect the autotransformer and other test instruments to a suitable power source.
4. Connect the Type R116 to the autotransformer output.
5. Turn on the autotransformer and adjust its output voltage for the line voltage chosen in preliminary step 2.
6. Install the Type W Plug-In Unit in the Type 547 Oscilloscope.
7. Connect a 50  $\Omega$  coaxial cable terminated with a 5 watt, 50  $\Omega$  termination (Tektronix Part No. 011-0099-00), to the Type R116 PULSE OUTPUT connector.
8. Turn on the Type R116 and the test instruments.
9. Allow at least 20 minutes warm-up at an ambient temperature of +25° C,  $\pm 5^\circ$  C (+77° F,  $\pm 9^\circ$  F) before making any checks or adjustments.
10. Connect the two 1 $\times$  test probes to the vertical inputs of the test oscilloscope.
11. Set the instrument controls as given in the complete list of control settings at the beginning of the procedure and start the adjustment or calibration procedure with step 1 on this page.

### Control Settings

#### Type R116

MODE	SINGLE
TRIGGER SOURCE	EXTERNAL OR MANUAL
PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1

DELAY OR BURST TIME RANGE	10 ns
MULTIPLIER	5
WIDTH RANGE	1 $\mu$ s
MULTIPLIER	5
AMPLITUDE RANGE	1 V
MULTIPLIER	10
POLARITY	+
PROGRAM	INT
DC OFFSET	0
RISETIME FALLTIME RANGE	1 ns
RISETIME MULT	1
FALLTIME MULT	1

#### Test Oscilloscope

Horizontal Display	A
Time/Cm	5 ms
Triggering	Trig, +, AC, Line
Vertical Display	A-B
Input Attenuation	1
Millivolts/Cm	10 (Calibrated)
Input Coupling	AC (Both channels)
Vc Range	0
Comparison Voltage	0.000
Amplitude Calibrator	Off

### Power Supply

#### NOTE

The power supply voltages and the ripple tolerances listed in the following 3 steps are guides to correct instrument operation; not instrument performance requirements. Actual measured values may vary from the listed voltages with no loss in pulse accuracy, providing the instrument meets the performance requirements in Section 1 as tested in this procedure.

#### 1. Adjust +25-Volt Supply



a. Position the Type R116 on its side, so that both the top and bottom are accessible.

b. Connect the negative lead of the DC voltmeter to the signal ground test point (see Fig. 6-3) and the positive lead to the +25-volt test point.

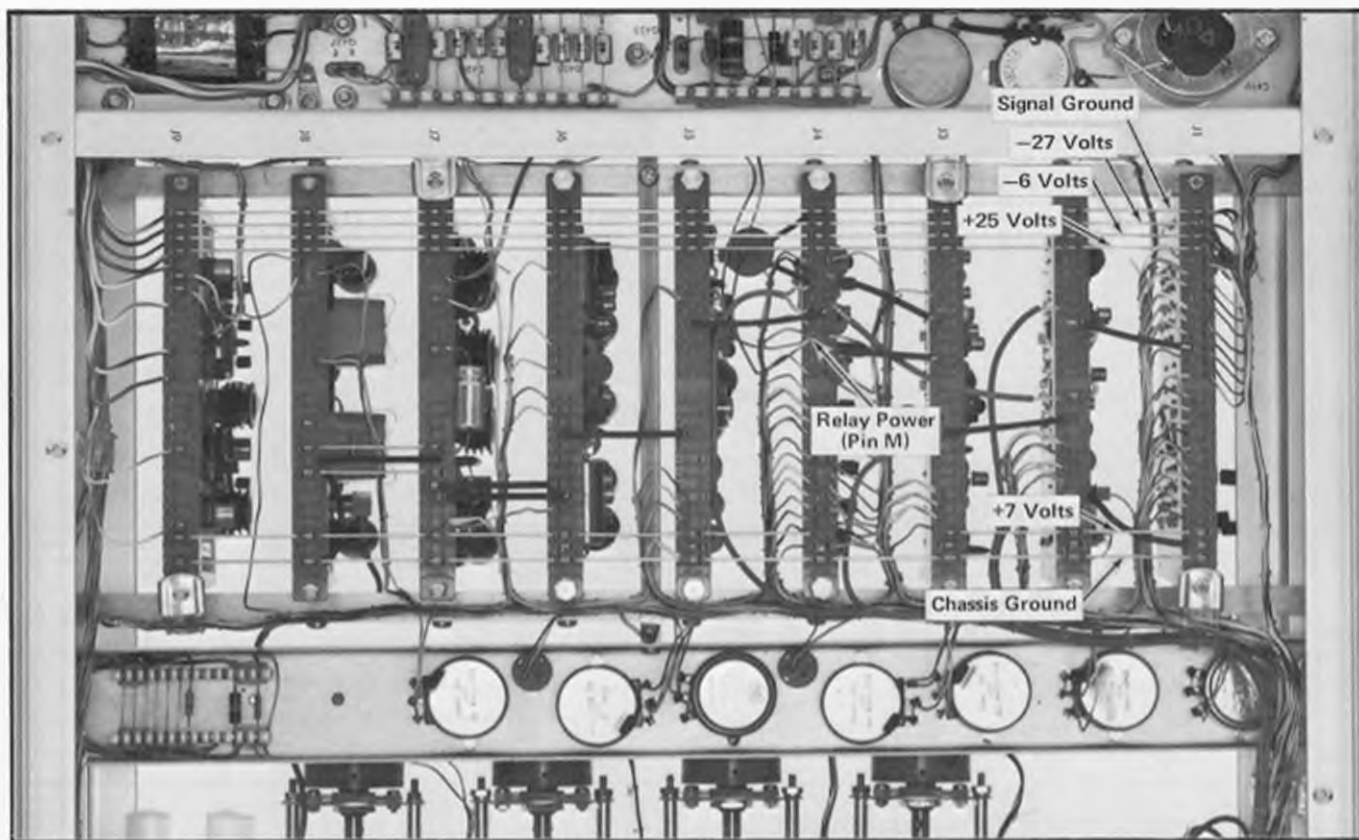


Fig. 6-3. Power supply test points.

**CAUTION**

Whenever checking the supply voltages or when working with these voltages at the REMOTE PROGRAM connector, be careful not to short the supplies together or to signal ground. These lines are not short protected and, if shorted, can damage the power supply circuit.

c. CHECK FOR—DC voltmeter reading of 25 volts with respect to signal ground.

**NOTE**

The voltage level of the +25-volt supply affects the calibration of the entire instrument. Any adjustment of R14 will probably cause all other instrument adjustments to require readjustment.

d. ADJUST—R14, the +25 VOLTS adjustment on the Power Supply circuit card (see Fig. 6-4), if the voltage is not correct.

e. (If doing only the Adjust steps, disconnect the meter leads and go to Step 4.)

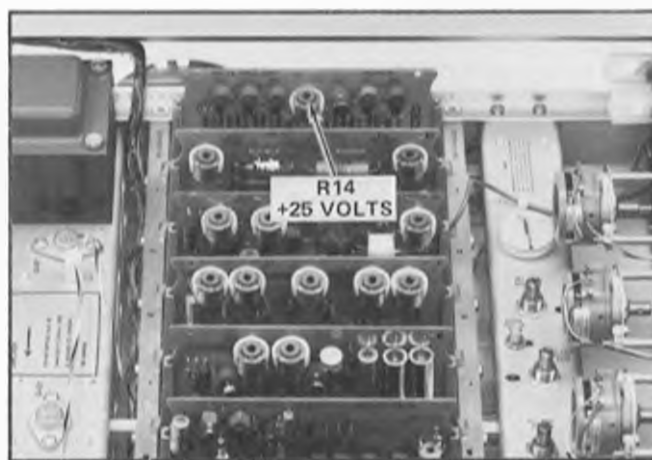


Fig. 6-4. Location of R14, and +25 VOLTS adjustment on the Power Supply circuit card.

**2. Check Power Supply Voltages****NOTE**

All voltages except the relay-power supply are measured with respect to signal ground. The relay-power supply is measured with respect to chassis ground.

## Performance Check/Calibration—Type R116 (SN 1084-up)

- a. Move the positive lead of the differential voltmeter to the +7-volt test point (see Fig. 6-3).
- b. CHECK FOR—Meter reading of 7 volts with respect to signal ground.
- c. Move the positive lead of the differential voltmeter to the signal ground test point (or reverse the polarity of the meter).
- d. Move the negative lead to the -27-volt test point (see Fig. 6-3).
- e. CHECK FOR—Meter reading of 27 volts with respect to signal ground.
- f. Move the negative lead to the -6-volt test point (see Fig. 6-3).
- g. CHECK FOR—Meter reading of 6 volts with respect to signal ground.
- h. Move the negative lead to the chassis ground test point (see Fig. 6-3).
- i. While observing the DC voltmeter reading, turn the Type R116 DC OFFSET control throughout its range, then set the POLARITY switch to — and again turn the DC OFFSET control throughout its range.
- j. CHECK FOR—Meter reading ranging from approximately +8 volts to +18 volts in +polarity and from +0 volt to +10 volts in -polarity.
- k. Leave the negative lead of the meter connected to the chassis ground test point and move the positive lead of the meter to the Relay-Power test point (see Fig. 6-3).
- l. CHECK FOR—Meter reading of +9.5 volts with respect to chassis ground.
- m. Disconnect the voltmeter.
- n. Set the DC OFFSET control to the 0 position.

### 3. Check Regulation

- a. Trigger the test oscilloscope on the internal line signal.
- b. Connect the Channel B 1× test probe to the signal ground test point (see Fig. 6-3).

#### CAUTION

Do not connect the probe ground clip to signal ground. This will ground the power supply causing incorrect operation and possible damage of the instrument.

- c. Connect the ground clips of both test probes to chassis ground.
- d. Connect the Channel A 1× test probe to each of the test points given in Table 6-2 and shown in Fig. 6-3.
- e. With the probe connected to each test point, observe the test oscilloscope display while varying the autotrans-

former output voltage from 137.5 volts to 94.5 volts (or from 275 volts to 189 volts for 230-volt operation).

- f. CHECK FOR—Test oscilloscope display of power-supply ripple with line frequency ripple amplitude not exceeding the maximum value given in Table 6-2.

- g. Disconnect the probe tips and ground clips from the Type R116.

- h. Remove the two 1× probes from the test oscilloscope vertical inputs.

- i. Disconnect the Type R116 from the autotransformer and connect it directly to the power line (or set the autotransformer output voltage to the line voltage at which the Type R116 has been set to operate).

**TABLE 6-2**  
**POWER SUPPLY REGULATION CHECKS**

Voltage Test Point (Fig. 6-4)	Ripple (60 Hz or 120 Hz Component)	
	Voltage (peak-to-peak)	Display Amplitude
+25 volts	15 mV	1.5 cm
+7 volts	50 mV	5 cm
-6 volts	30 mV	3 cm
-27 volts	15 mV	1.5 cm
Chassis Ground	20 mV	2 cm

### Preliminary Adjustments

#### 4. Adjust Rise-time and Fall-time Centering

- a. Set the Type R116 TRIGGER SOURCE switch to INTERNAL.
- b. Reset the following test oscilloscope controls to the settings given.

Time/Cm	1 $\mu$ s
Trigger Source	Ext
Vertical Display	A-Vc
Input Attenuation	100
Millivolts/Cm	20
Input Coupling (Ch A)	DC

- c. Connect the Type R116 output pulse through the terminated 50  $\Omega$  coaxial cable to the Channel A vertical input of the test oscilloscope.

- d. Connect a 50  $\Omega$  coaxial cable between the Type R116 +PRETRIGGER OUT connector and the test oscilloscope External Trigger Input.

- e. Turn off the Type R116 and position the instrument right side up.

- f. Extend the Pulse Shape Generator circuit card on the circuit card extender as shown in Figure 6-5. Turn on the Type R116.



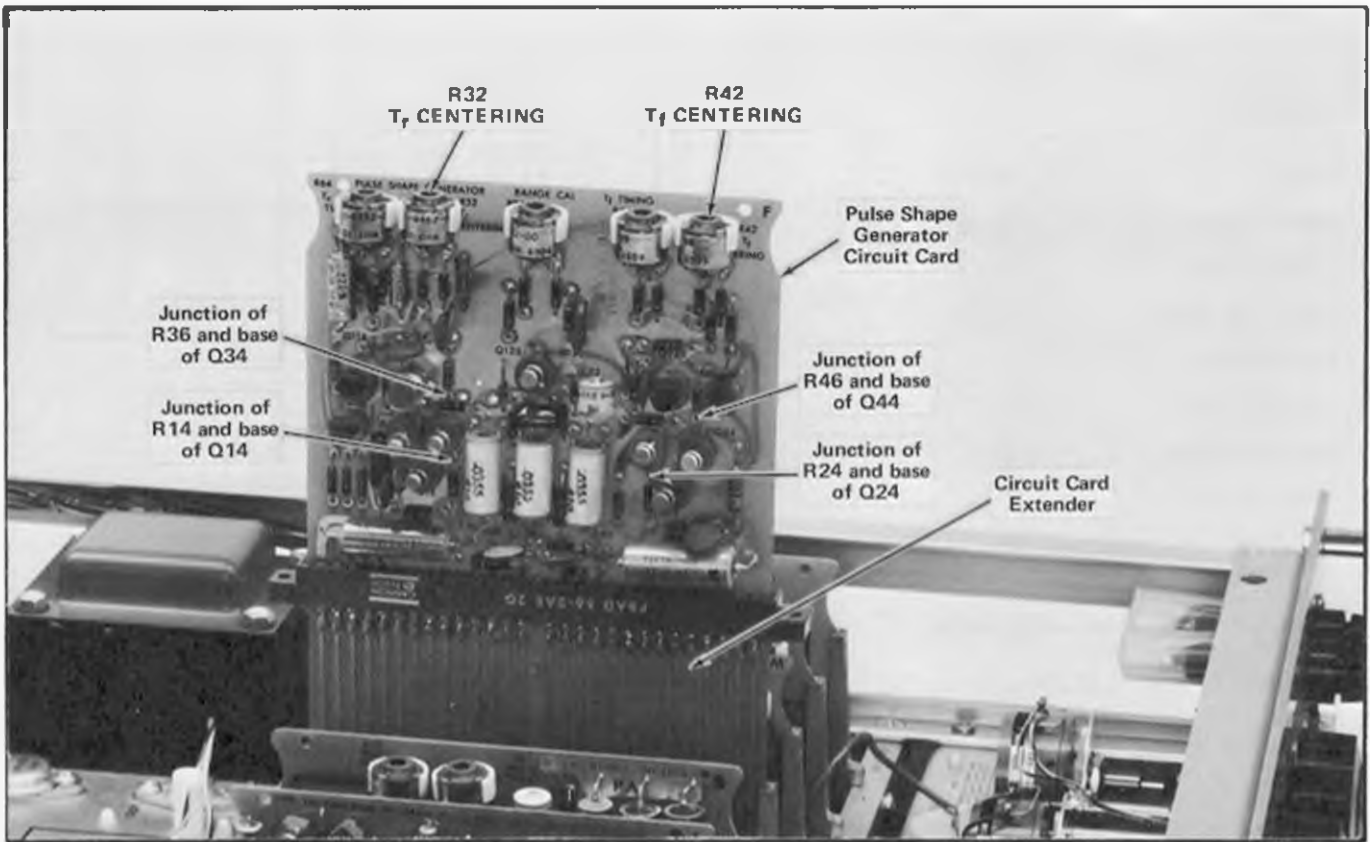


Fig. 6-5. Location of test points and adjustments for setting risetime centering and falltime centering.

- g. Trigger the test oscilloscope display.
- h. Adjust the test oscilloscope Time/Cm Variable control so that one cycle of the Type R116 output pulse extends over the 10 centimeters of the test oscilloscope graticule.
- i. Check that the negative going transition of the waveform occurs exactly at the center vertical graticule line. If not, set the Type R116 WIDTH RANGE switch to 100 ns and adjust the WIDTH MULTIPLIER control to obtain the correct display.
- j. Connect the negative lead of the DC voltmeter to the junction of R14 and the base of Q14 on the extended Pulse Shape Generator circuit card [see Fig. 6-5] and connect the positive lead to the junction of R16 and the base of Q34.
- k. CHECK FOR—Meter reading of approximately 0 volt.
- l. ADJUST—R32, the T<sub>1</sub> CENTERING adjustment on the Pulse Shape Generator circuit card [see Fig. 6-5], if the voltage is not correct.
- m. Connect the negative lead of the DC voltmeter to the junction of R24 and the base of Q24 [see Fig. 6-5] and connect the positive lead to the junction of R46 and the base of Q44.

- n. CHECK FOR—Meter reading of approximately 0 volt.
- o. ADJUST—R42, the T<sub>1</sub> CENTERING adjustment on the Pulse Shape Generator circuit card [see Fig. 6-5], if the voltage is not correct.
- p. Disconnect the DC voltmeter leads.
- q. Turn off the Type R116, remove the circuit card extender, reinsert the Pulse Shape Generator circuit card into its connector and turn on the Type R116.

## 5. Adjust Width and Delay Trigger Sensitivity

### NOTE

If the instrument is being calibrated for operation using remote programming, front panel controls may be used to perform this step with no loss of pulse accuracy. If the whole instrument is being remotely programmed, only the Period, Delay or Burst Time, Width, and Mode controls need be changed from remote to front-panel operation.

## Performance Check/Calibration—Type R116 (SN 1084-up)

a. Reset the Type R116 WIDTH RANGE switch to 10 ns. If the instrument is being programmed for remote operation, reset the following R116 controls from REMOTE to the settings listed below:

MODE	SINGLE
PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1
DELAY OR BURST	10 ns
TIME RANGE	
MULTIPLIER	5
WIDTH RANGE	10 ns
MULTIPLIER	5

b. Set the test oscilloscope sweep rate to 0.2  $\mu$ s/cm.

c. Trigger the test oscilloscope display.

d. Set the Type R116 MODE switch to DLY'D SINGLE.

e. Observe the test oscilloscope display (see Fig. 6-6) while performing the following four operations.

1. Turn the DELAY OR BURST TIME MULTIPLIER control slowly clockwise to the fully clockwise position.

2. Turn the WIDTH MULTIPLIER control slowly clockwise to the fully clockwise position.

3. Turn the DELAY OR BURST TIME MULTIPLIER control slowly counterclockwise back to the 5 position.

4. Turn the WIDTH MULTIPLIER control slowly counterclockwise back to the 5 position.

f. Reset the following Type R116 controls:

TIME RANGE	
------------	--

PERIOD RANGE	1 ms
MULTIPLIER	Fully clockwise
DELAY OR BURST	1 $\mu$ s
TIME RANGE	
WIDTH RANGE	10 $\mu$ s

g. Set the test oscilloscope sweep rate to 0.2 ms/cm.

h. Repeat step e at these control settings.

i. CHECK FOR—Stable pulse throughout these checks. If the pulse is not present, is unstable or disappeared during any of these checks, adjust the width and delay trigger sensitivity as described in step 6. If the pulse is stable, go to step 7.

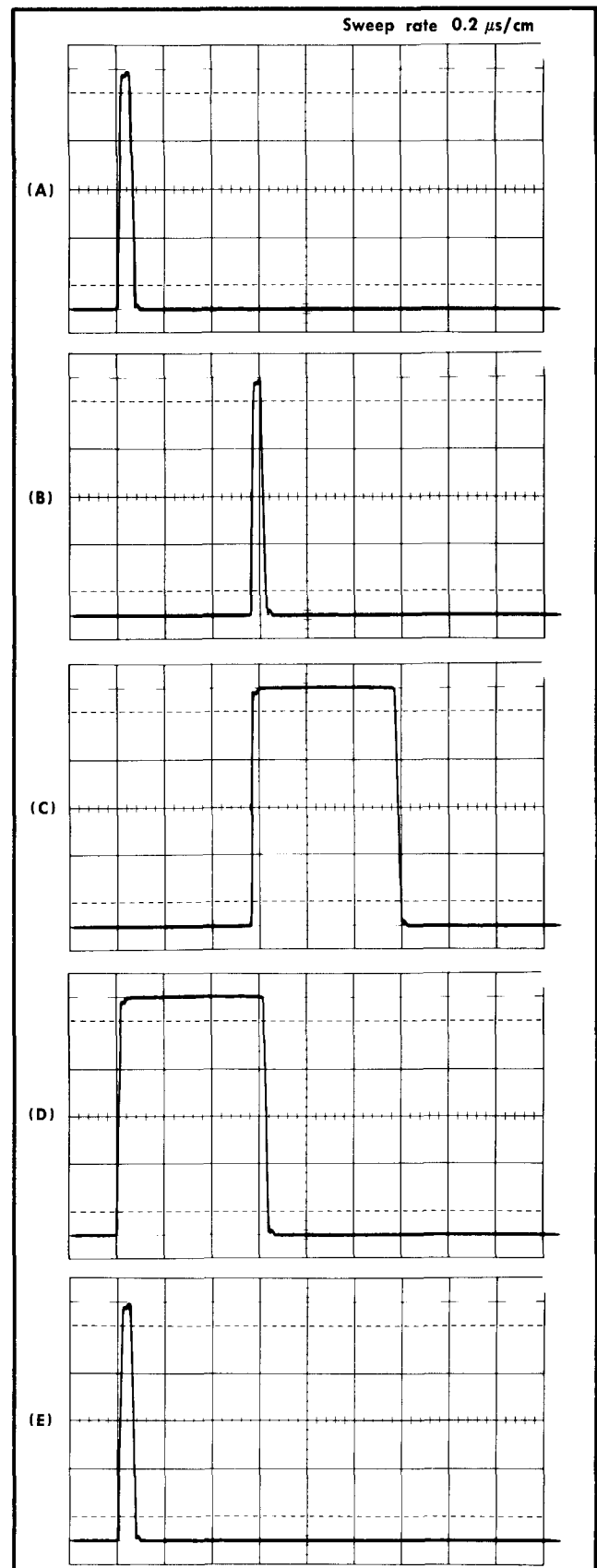


Fig. 6-6. Typical test oscilloscope displays obtained during check of width and delay trigger sensitivity adjustments.

**6. Adjust Width and Delay Trigger Sensitivity** ①

- a. Reset the following Type R116 front panel controls:

MODE	SINGLE
PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1
DELAY OR BURST	100 ns
TIME RANGE	
MULTIPLIER	5
WIDTH RANGE	10 ns
MULTIPLIER	Fully clockwise

- b. Set the test oscilloscope Time/Cm switch to 0.2  $\mu$ s.

c. Turn R22, the WIDTH TRIG SENS adjustment on the Width Generator circuit card (see Fig. 6-5), fully clockwise, then counterclockwise until one stable pulse appears on the test oscilloscope CRT. Note the position of R22.

- d. Set the WIDTH MULTIPLIER control to 5.

e. Reset the Type R116 MODE switch to DOUBLE. Two pulses should appear on the test oscilloscope CRT. If not, adjust R22, the DELAY TRIG SENS adjustment on the Delay Generator circuit card (see Fig. 6-5) to obtain two pulses. (It should be noted that both the Width Generator and Delay Generator circuit cards have R22 adjustments.)

f. Turn R22, on the Width Generator circuit card, fully counterclockwise. If either or both of the pulses disappear, turn R22 clockwise until two stable full amplitude pulses appear. Note the position of R22 (this may be fully clockwise).

g. ADJUST—R22, the WIDTH TRIG SENS adjustment, for a final setting halfway between the two positions noted.

- h. Reset the listed Type R116 front panel controls as follows:

MODE	DLY'D SINGLE
DELAY OR BURST	10 ns
TIME RANGE	
MULTIPLIER	Fully clockwise

i. Turn R22, the DELAY TRIG SENS adjustment on the Delay Generator circuit card, fully clockwise, then counterclockwise until one stable pulse appears on the test oscilloscope CRT.

j. ADJUST—R22, the DELAY TRIG SENS adjustment, for a setting as far clockwise as possible without causing the pulse to become unstable.

k. Turn the Type R116 DELAY OR BURST TIME MULTIPLIER control slowly counterclockwise to the 5 position. The pulse should remain stable if the adjustment is correct.

l. Recheck the width and delay trigger sensitivities as given in step 5.

**7. Pre-Adjust Offset Adjustments** ①**NOTE**

If the Type R116 is being calibrated for remote operation, the following adjustments should be made using remote programming.

- a. Reset the following Type R116 controls:

MODE	SINGLE
PERIOD RANGE	1 ms
MULTIPLIER	1
WIDTH RANGE	10 $\mu$ s
MULTIPLIER	5
AMPLITUDE MULTIPLIER	2
RISETIME FALLTIME RANGE	1 $\mu$ s
DC OFFSET	+5

- b. Reset the following test oscilloscope controls to the settings given.

Time/Cm	20 $\mu$ s/cm
Input Atten	10
Vc Range	+1.1
Comparison Voltage	5.000

- c. Position the pulse baseline to the center horizontal line of the CRT graticule.

- d. Set the Type R116 DC OFFSET control to —5.

- e. Set the test oscilloscope Vc Range switch to —1.1.

f. CHECK FOR—Test oscilloscope display with the pulse baseline within  $\pm 2.5$  cm of the center horizontal graticule line.

g. ADJUST—R32, the OFFSET RANGE adjustment on the Attenuator circuit card (see Fig. 6-7), if the offset range is not correct.

h. If R32 required adjustment, set the Type R116 DC OFFSET control to +5, the test oscilloscope Vc Range switch to +1.1 and repeat parts c through g of this step.

- i. Reset the following test oscilloscope controls:

AMPLITUDE RANGE	.2 V
DC OFFSET	0

- j. Reset the following test oscilloscope controls:

Vc Range	0
Input Coupling (Channel A)	Gnd

k. Position the test oscilloscope trace to the center horizontal line of the CRT graticule.

l. Set the test oscilloscope Channel A Input Coupling switch to DC.

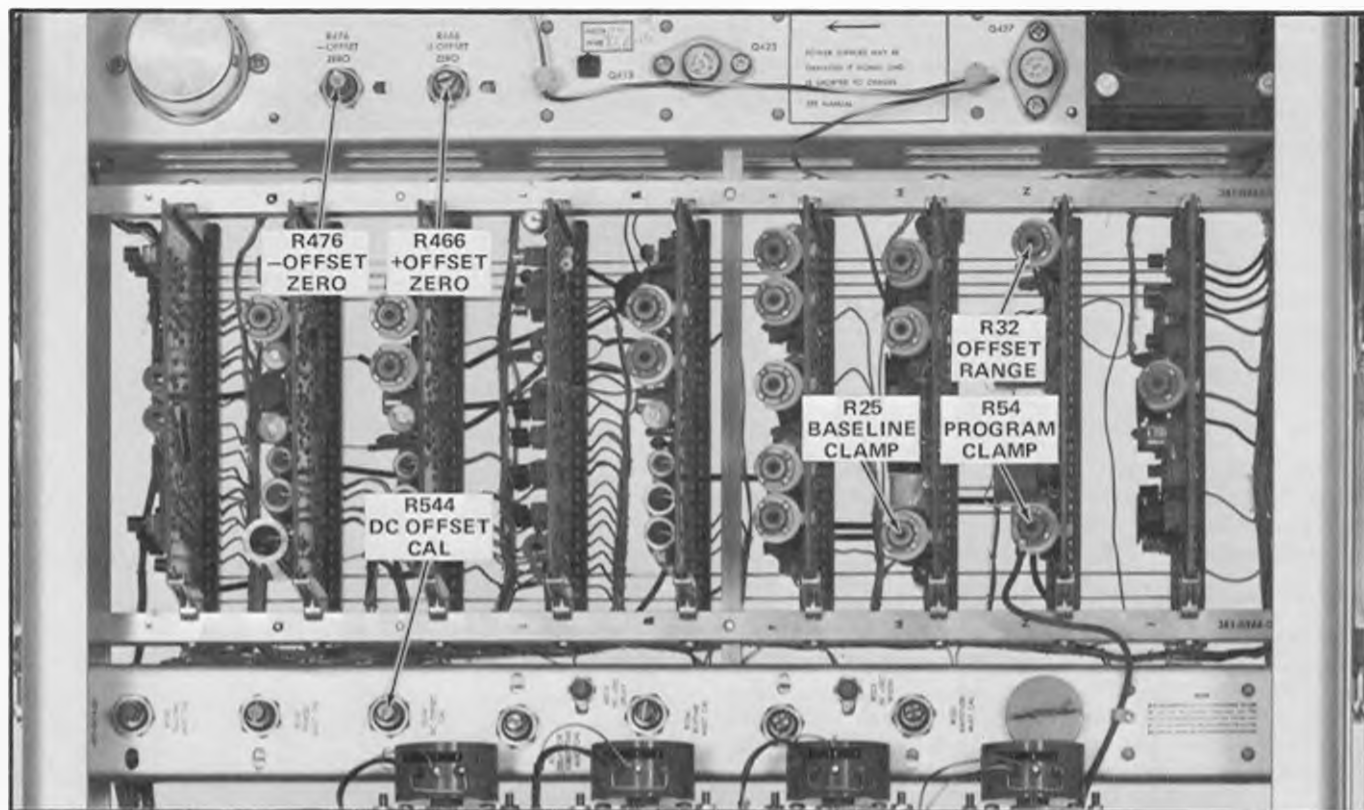


Fig. 6-7. Location of offset and baseline clamp adjustments on Attenuator and Output Amplifier circuit cards and on Type R116 chassis.

m. CHECK FOR—Test oscilloscope display with the pulse baseline within  $\pm 1$  cm of the center horizontal graticule line (0 volts  $\pm 200$  mV).

n. ADJUST—R466, the + OFFSET ZERO adjustment on the Type R116 chassis (see Fig. 6-7), if the offset level is not correct.

o. Set the Type R116 POLARITY switch to —.

p. Set the test oscilloscope Channel A Input Coupling switch to Gnd.

q. Position the test oscilloscope trace to the center horizontal line of the CRT graticule.

r. Reset the test oscilloscope Channel A Input Coupling switch to DC.

s. CHECK FOR—Test oscilloscope display with the baseline of the negative-going pulse within  $\pm 1$  centimeter of the center horizontal graticule line (0 volts  $\pm 200$  mV).

t. ADJUST—R476, the — OFFSET ZERO adjustment on the Type R116 chassis (see Fig. 6-7), if the offset level is not correct.

## 8. Adjust Baseline Clamp

a. Set the Type R116 POLARITY switch to +.

b. Position the pulse baseline to the center horizontal line of the test oscilloscope CRT graticule.

c. Set the Type R116 AMPLITUDE RANGE switch to 1 V.

d. CHECK FOR—Test oscilloscope display of the pulse baseline within  $\pm 1$  centimeter ( $\pm 200$  mV) of the center horizontal graticule line.

e. ADJUST—R25, the BASELINE CLAMP adjustment on the Output Amplifier circuit card (see Fig. 6-7), if the baseline level is not correct.

f. If R25 required adjustment, set the AMPLITUDE RANGE switch to .2 V and repeat parts a through f of this step until there is no change in the baseline level as the position of the AMPLITUDE RANGE switch is changed.

## Pulse Offset and Amplitude

### 9. Adjust Offset Registration

#### NOTE

The use of both front panel and remote controls is required to perform the following step. The step must be done, however, only if the DC OFFSET control is being calibrated for both front-panel and remote operation.

a. Check that the below listed Type R116 controls are set (both front-panel and remote) as follows:

AMPLITUDE RANGE	1 V
DC OFFSET	0
RISETIME FALLTIME RANGE	1 $\mu$ s
RISETIME MULT	1
FALLTIME MULT	1

b. Set the Type R116 PROGRAM switch to REMOTE.

c. Position the baseline of the pulse display to the center horizontal line of the test oscilloscope CRT graticule.

d. Set the Type R116 PROGRAM switch to INT.

e. CHECK FOR—Test oscilloscope display with the pulse baseline at the horizontal center line  $\pm 1$  centimeter ( $\pm 200$  mV).

f. ADJUST—R544, the DC OFFSET CAL adjustment on the Type R116 chassis (see Fig. 6-7), if the display is not correct.

g. (If calibrating for remote operation) reset the Type R116 PROGRAM switch to REMOTE.

## Offset and Amplitude

### 10. Adjust Offset Zero (+ Polarity) ①

a. Reset the test oscilloscope Input Coupling switch to Gnd.

b. Position the trace to the center horizontal line of the CRT graticule.

c. Set the test oscilloscope Input Coupling switch to DC.

d. CHECK FOR—Test oscilloscope display with the positive-going pulse baseline at the center horizontal line  $\pm 1$  cm ( $\pm 200$  mV) with the DC OFFSET control set to 0.

e. ADJUST—R466, the + OFFSET ZERO adjustment on the Type R116 chassis (see Fig. 6-7), if the baseline level is not correct.

### 11. Adjust + Amplitude ①

a. Set the Type R116 AMPLITUDE MULTIPLIER to 10.

b. Set the test oscilloscope Comparison Voltage to 10.000.

c. Position the pulse baseline on the center horizontal line of the CRT graticule.

d. Set the test oscilloscope Vc Range switch to +1.1.

e. CHECK FOR—Test oscilloscope display of the pulse top with the flattest portion at the center horizontal line of the CRT graticule  $\pm 1.75$  cm (10 volts  $\pm 3\%$ ,  $\pm 50$  mV).

f. ADJUST—R85, the RANGE CAL adjustment on the Pulse Shape Generator circuit card (see Fig. 6-7), if the pulse amplitude is not correct.

g. Set the Type R116 AMPLITUDE MULTIPLIER control to 2.

h. Reset the following test oscilloscope controls as listed:

mV/Cm	5
Vc Range	0
Comparison Voltage	2.000

i. Position the pulse baseline to the center horizontal line of the test oscilloscope CRT graticule. (Use the Type R116 DC OFFSET control, if necessary.)

j. Set the test oscilloscope Vc Range switch to +1.1.

k. CHECK FOR—Test oscilloscope display of the pulse top with the flattest portion at the center horizontal line of the CRT graticule  $\pm 2.2$  cm (2 V  $\pm 3\%$ ,  $\pm 50$  mV).

l. ADJUST—R532, the AMPLITUDE MULT CAL adjustment on the Type R116 chassis (see Fig. 6-7), if the display is not correct.

m. If R532 requires adjustment, set the test oscilloscope Millivolts/Cm switch to 20 and repeat parts a through l.

### 12. Adjust Amplitude and DC Offset (— Polarity) ①

a. Reset the following Type R116 controls as listed:

AMPLITUDE MULTIPLIER	10
POLARITY	—
DC OFFSET	0

b. Reset the following test oscilloscope controls to the new settings given:

Input Atten	10
mV/Cm	20
Vc Range	0
Comparison Voltage	10.000

c. Position the pulse baseline to the center horizontal line of the CRT graticule.

d. Set the test oscilloscope Vc Range switch to —1.1.

e. CHECK FOR—Test oscilloscope display of the negative going pulse top, the flattest portion on the center horizontal line of the CRT graticule  $\pm 1.75$  cm ( $-10$  volts  $\pm 3\%$ ,  $\pm 50$  mV).

f. ADJUST—R42, the — AMPLITUDE adjustment on the Output Amplifier circuit card (see Fig. 6-8), if the negative-going amplitude is not correct. While making the adjustment, switch the Vc Range switch between the —1.1 and 0 positions. When the — AMPLITUDE control is properly adjusted, the alternate appearances of the pulse top and baseline will be displayed at the same level on the graticule.

g. Set the Vc Range switch to 0.

h. Disconnect the terminated cable from the vertical input of the test oscilloscope.

i. Install two 1 $\times$  probes on the test oscilloscope vertical input connectors.

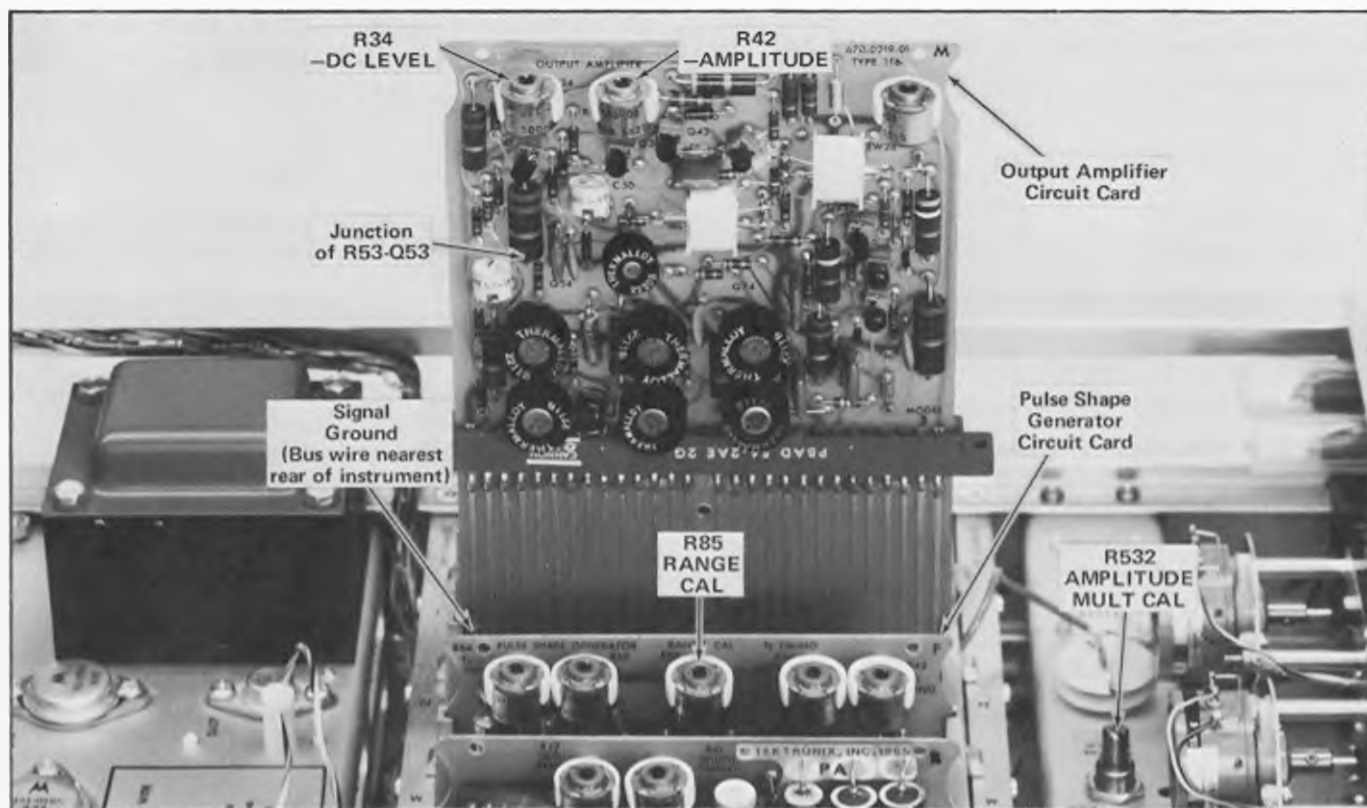


Fig. 6-8. Location of test points and adjustments for checking amplitude and —DC level on Pulse Shape Generator and Output Amplifier circuit cards and on Type R116 chassis.

j. Reset the following test oscilloscope controls:

Vertical Display	A-B
Input Atten	100

k. Reset the Type R116 POLARITY switch to +.

l. Turn off the Type R116 and extend the Output Amplifier circuit card on the circuit card extender (see Fig. 6-8).

m. Connect the Channel A test probe tip to the junction of R53 and the emitter of Q53 on the Output Amplifier circuit card (see Fig. 6-8).

n. Connect the Channel B test probe tip to signal ground (see Fig. 6-8).

o. Turn on the Type R116.

p. Position the pulse baseline 1 cm below the center horizontal line of the CRT graticule.

q. Set the Type R116 POLARITY switch to —.

r. CHECK FOR—Test oscilloscope display with the signal envelope of the negative going pulse at the same level as that of the positive going pulse  $\pm 1$  mm (see Fig. 6-9).

s. ADJUST—R34, the —DC LEVEL adjustment on the Output Amplifier circuit card (see Fig. 6-8), if the signal level is not correct.

t. Turn off the Type R116.

u. Disconnect the two probes from the Type R116 and from the vertical input connectors of the test oscilloscope.

v. Reconnect the Type R116 output pulse to the Channel A vertical input connector of the test oscilloscope.

w. Turn on the Type R116.

x. If R42 and/or R34 have been adjusted, recheck the adjustments made in parts a through s.

y. Turn off the Type R116, remove the circuit card extender, re-insert the Output Amplifier circuit card into its connector and turn on the Type R116.

z. Reset the following test oscilloscope controls:

Vc Range	0
Input Atten	10
Input Coupling	Gnd

aa. Position the trace to the center horizontal line of the CRT graticule.

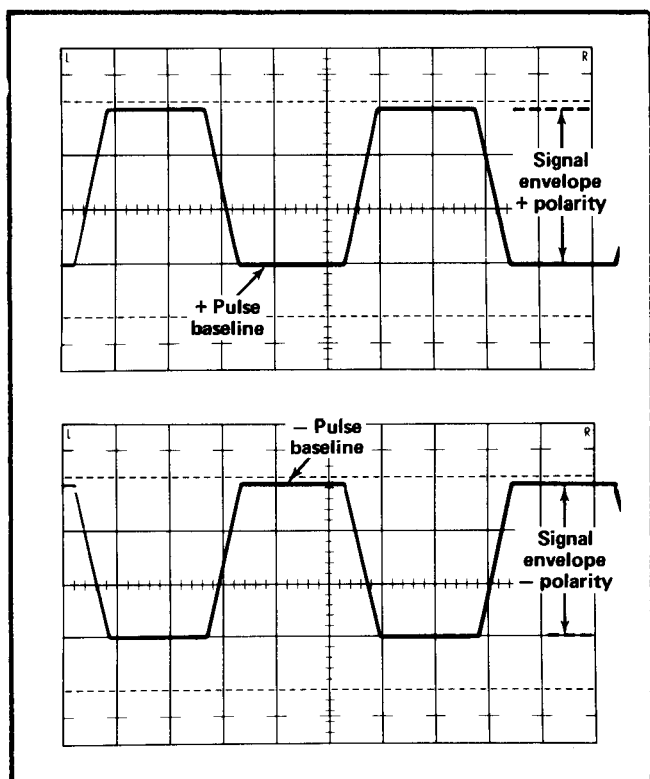


Fig. 6-9. Test oscilloscope display for checking adjustment of negative-going pulse DC level.

ab. Set the test oscilloscope Input Coupling switch to DC.

ac. CHECK FOR—Test oscilloscope display of the baseline of the negative-going pulse at the center horizontal line on the CRT graticule  $\pm 1$  cm ( $\pm 200$  mV) with the Type R116 DC OFFSET control set to 0.

ad. ADJUST—R476, the — OFFSET ZERO adjustment on the Type R116 chassis (see Fig. 6-7) if the offset is not correct.

ae. Set the Type R116 POLARITY switch to +.

### 13. Adjust Program Clamp

a. Set the Type R116 PROGRAM switch to REMOTE. (If calibrating for remote operation, turn off the Type R116, disconnect the remote program cable from the J10 REMOTE PROGRAM connector on the Type R116 rear panel and turn on the Type R116.)

b. Reset the following test oscilloscope controls:

Input Atten	100
Millivolts/Cm	10
Input Coupling	Gnd

c. Position the trace to the center horizontal line of the CRT graticule.

d. Set the test oscilloscope Input Coupling switch to DC.

e. CHECK FOR—Test oscilloscope display with the pulse baseline at the center horizontal line of the CRT graticule  $\pm 1$  cm ( $\pm 1$  V).

f. ADJUST—R54, the PROGRAM CLAMP adjustment on the Attenuator circuit card (see Fig. 6-7), if the display is not correct.

g. Set the Type R116 POLARITY switch to —.

h. CHECK FOR—Test oscilloscope display with the pulse baseline at the center horizontal line of the CRT graticule  $\pm 1$  cm ( $\pm 1$  V).

i. ADJUST—R54 for a compromise setting between both positions of the Type R116 POLARITY switch if the display is not correct.

j. Reconnect the remote program cable to Type R116 rear panel if it had previously been removed. (Turn off the Type R116 before making this connection.)

k. If doing only Adjust steps, make the following equipment changes:

1. Disconnect the  $50\ \Omega$  termination from the vertical input of the test oscilloscope.
2. Remove the Type W Plug-In Unit from the test oscilloscope and insert the Type 1A1 or Type 1A2 Plug-In Unit.
3. Allow several minutes for the plug-in to warm-up before continuing with the procedure.

### Control Settings (Partial List)

#### Type R116

TRIGGER SOURCE	INTERNAL
PERIOD RANGE	1 ms
WIDTH RANGE	$10\ \mu\text{s}$
RISETIME FALLTIME RANGE	$1\ \mu\text{s}$

#### Test Oscilloscope

Time/Cm	$20\ \mu\text{s}$
Triggering	Trig, +, AC, Ext
Vertical Display	A-Vc
Input Attenuation	10
Millivolts/Cm	20 (Calibrated)
Input Coupling (Ch A)	DC
Comparison Voltage	0.000

### 14. Check Offset Accuracy

a. Set the Type R116 and the test oscilloscope controls as shown in the Initial Control Settings list with changes as shown in the preceding partial list.

b. Set the Type R116 DC OFFSET control, the POLARITY switch and the test oscilloscope Vc Range switch as given in Table 6-3.

c. For each check, position the trace to the center horizontal graticule line with the test oscilloscope Vc Range switch set to 0 and the Input Coupling switch at Gnd, then set the Input Coupling switch to DC and the Vc Range switch as indicated in the table.

## Performance Check/Calibration—Type R116 (SN 1084-up)

d. CHECK FOR—Test oscilloscope display of the pulse baseline at the center horizontal graticule line  $\pm$  the tolerances indicated in the Offset column of Table 6-3.

e. If the offset is outside the required tolerance limits in any of the preceding checks, readjust R32, R466, or R476 as indicated in steps 7, 10 and 12 to bring all offset levels within tolerance.

f. Set the POLARITY switch to + and the DC OFFSET control to 0.

### 15. Check Amplitude Accuracy

a. Set the Type R116 AMPLITUDE RANGE and AMPLITUDE MULTIPLIER, and the test oscilloscope comparison voltage and deflection factor as given in Table 6-4.

b. For each check, position the pulse baseline to the hori-

zontal centerline of the test oscilloscope CRT screen while the Vc Range switch is set to 0, then set the switch to  $\pm 1.1$ .

c. CHECK FOR—Test oscilloscope display of the pulse tops with the flattest portion of the tops at the horizontal centerline, with the Vc Range switch at  $\pm 1.1$ .

d. If the pulse amplitude is not within the required tolerance in any of the preceding checks, readjust R85, or R532, R42 and R34 in steps 11 and 12 as necessary to bring the amplitude within tolerance on all ranges.

e. Disconnect the 50  $\Omega$  termination from the vertical input of the test oscilloscope.

f. Remove the Type W Plug-In Unit from the test oscilloscope and insert the Type 1A1 or 1A2 Plug-In Unit.

g. Allow several minutes for the plug-in unit to warm up before continuing with the procedure.

**TABLE 6-3**  
Offset Accuracy Check

DC OFFSET	POLARITY	Vc Range	Offset	
			Voltage	Displacement from Centerline
-5	+	$\pm 1.1$	-5 V $\pm 450$ mV	$\pm 2.25$ cm
-5	-	$\pm 1.1$	-5 V $\pm 450$ mV	$\pm 2.25$ cm
0	-	0	0 V $\pm 200$ mV	$\pm 1$ cm
0	+	0	0 V $\pm 200$ mV	$\pm 1$ cm
+5	+	$\pm 1.1$	+5 V $\pm 450$ mV	$\pm 2.25$ cm
+5	-	$\pm 1.1$	+5 V $\pm 450$ mV	$\pm 2.25$ cm

**TABLE 6-4**  
Amplitude Accuracy Check

AMPLITUDE RANGE	AMPLITUDE MULTIPLIER	Input Atten.	mV/Cm	Comp. Voltage	Amplitude	
					Voltage	Displacement from Centerline
1 V	10	10	20	10.000	10 V $\pm 3\%$ $\pm 50$ mV	$\pm 1.75$ cm
.5 V	10	10	10	5.000	5 V $\pm 3\%$ $\pm 25$ mV	$\pm 1.75$ cm
.2 V	10	10	5	2.000	2 V $\pm 3\%$ $\pm 15$ mV	$\pm 1.50$ cm
.2 V	2	1	10	4.000	400 mV $\pm 3\%$ $\pm 15$ mV	$\pm 2.70$ cm
.5 V	2	10	2	1.000	1 V $\pm 3\%$ $\pm 25$ mV	$\pm 2.75$ cm
1 V	2	10	5	2.000	2 V $\pm 3\%$ $\pm 50$ mV	$\pm 2.20$ cm



## Control Settings (Partial List)

## Type R116

TRIGGER SOURCE	INTERNAL
PERIOD RANGE	1 ms
MULTIPLIER	5
DELAY OR BURST TIME	
RANGE	10 $\mu$ s
MULTIPLIER	5
WIDTH RANGE	10 $\mu$ s
MULTIPLIER	50
RISETIME FALLTIME RANGE	1 $\mu$ s
RISETIME MULT	10
FALLTIME MULT	10

## Test Oscilloscope

Time/Cm	20 $\mu$ s
Triggering	Trig, +, AC, Int
Vertical Mode	Channel 2
Volts/Cm Channel 1	2
Volts/Cm Channel 2	1
Input Coupling (Both Channels)	DC

## Slow Risetime and Falltime

## 16. Adjust Slow Risetime and Falltime



a. Set the Type R116 and test oscilloscope controls as shown in the Initial Control Settings list on page 6-6 with changes as shown in the partial list preceding this step.

b. Connect the terminated Type R116 output pulse to the test oscilloscope Channel 1 vertical input.

c. Connect the time-mark generator marker output through a coaxial cable and a 50  $\Omega$  termination to the test oscilloscope Channel 2 vertical input.

d. Set the time-mark generator for a 10  $\mu$ s marker output.

e. Trigger the test oscilloscope display.

f. If the test oscilloscope display does not contain exactly 2 markers/cm over the center 8 cm, adjust the variable sweep rate control to provide correct timing, (see Fig. 6-10A).

g. Set the test oscilloscope Vertical Mode switch to Channel 1.

h. Set the RISETIME MULT and FALLTIME MULT controls exactly to the 10 position.

i. If the display amplitude is not exactly 5 cm, adjust the test oscilloscope Variable Volts/Cm control to provide the correct amplitude for measuring risetime and falltime.

j. Trigger the test oscilloscope display to observe the rise of the Type R116 output pulse, as shown in Fig. 6-10B.

k. CHECK FOR—Test oscilloscope display of the pulse rise with a risetime of 100  $\mu$ s  $\pm$  5% (5 cm  $\pm$  2.5 mm).

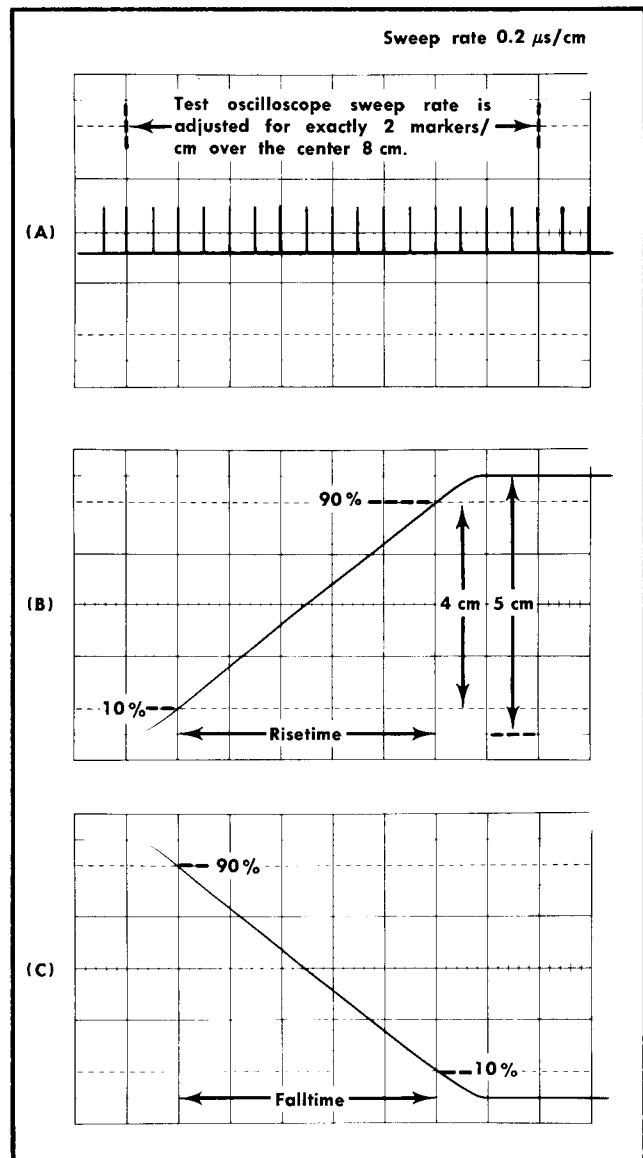


Fig. 6-10. Typical test oscilloscope displays for checking risetime and falltime of the output pulse.

l. ADJUST—R64, the  $T_r$  TIMING adjustment on the Pulse Shape Generator circuit card (see Fig. 6-11), if the display is not correct.

m. Set the test oscilloscope trigger slope switch to —.

n. Trigger the test oscilloscope on the negative-going slope of the waveform (see Fig. 6-10C).

o. CHECK FOR—Test oscilloscope display of the pulse fall with a falltime of 100  $\mu$ s  $\pm$  5% (5 cm  $\pm$  2.5 mm).

p. ADJUST—R54, the  $T_f$  TIMING adjustment, on the Pulse Shape Generator circuit card (see Fig. 6-11), if the falltime is not correct.

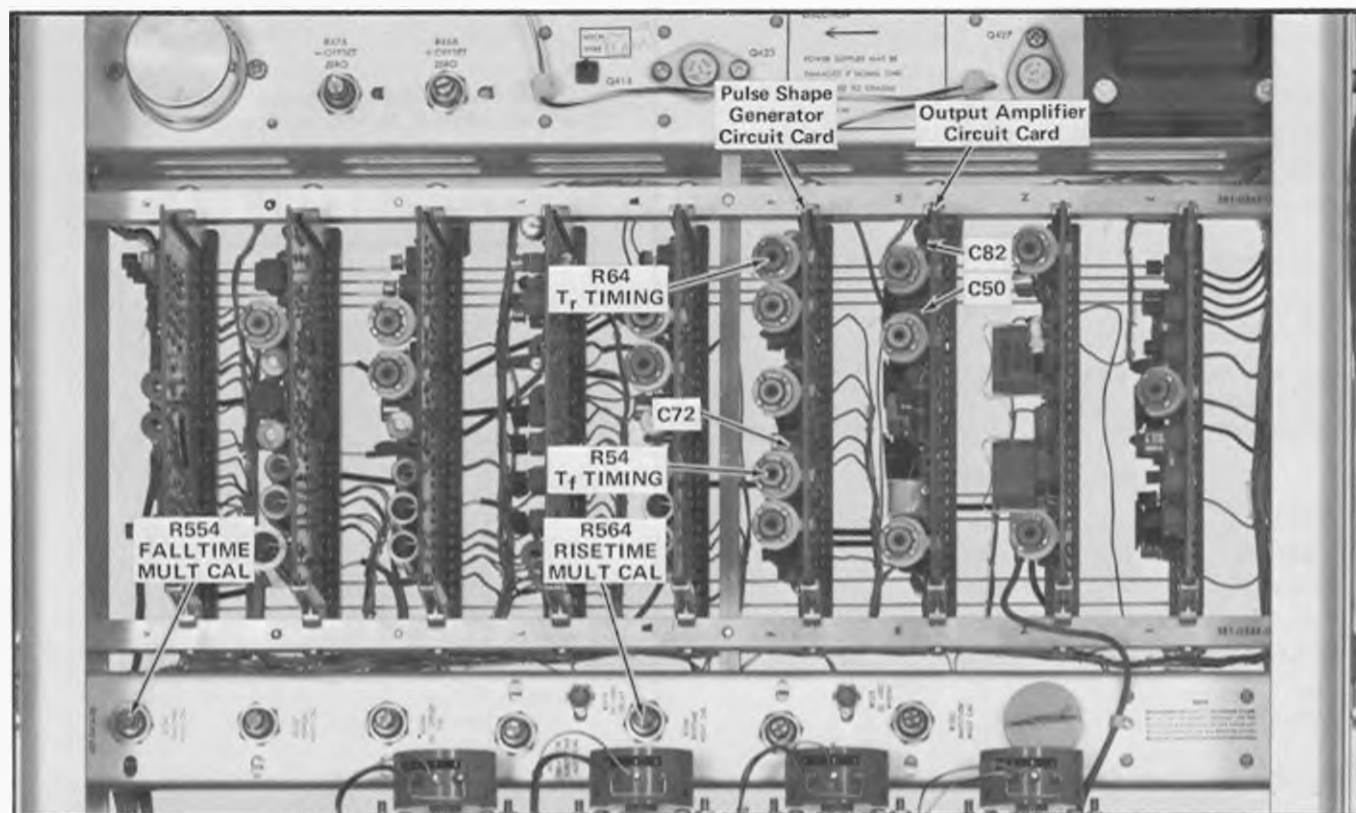


Fig. 6-11. Location of risetime and falltime, and pulse shape adjustments on Pulse Shape Generator circuit card and Type R116 chassis.

q. Set the Type R116 RISETIME MULT and FALLTIME MULT controls to the 1 position.

r. Reset the following test oscilloscope controls:

Sweep Rate	2 $\mu$ s/cm
Trigger Slope	+
Vertical Mode	Channel 2

s. Set the time mark generator for a 1- $\mu$ s marker output.

t. Check the test oscilloscope display for exactly 2 markers/cm over the center 8 cm and adjust the test oscilloscope variable sweep rate control if necessary.

u. Set the test oscilloscope Vertical Mode switch to Channel 1.

v. Trigger the test oscilloscope on the pulse rise.

w. CHECK FOR—Test oscilloscope display of the pulse rise with a risetime of 10  $\mu$ s  $\pm$ 5% (5 cm  $\pm$ 2.5 mm).

x. ADJUST—R564, the RISETIME MULT CAL adjustment on the Type R116 chassis (see Fig. 6-11), if the risetime is not correct.

y. Set the test oscilloscope trigger slope switch to —.

z. Adjust the test oscilloscope triggering to display the negative-going portion of the waveform.

aa. CHECK FOR—Test oscilloscope display of the pulse fall with a falltime of 10  $\mu$ s  $\pm$ 5% (5 cm  $\pm$ 2.5 mm).

ab. ADJUST—R554, the FALLTIME MULT CAL adjustment on the Type R116 chassis (see Fig. 6-11), if the falltime is not correct.

ac. If R564 and/or R554 are adjusted, recheck the adjustment of R64 and R54 in steps a through p.

## 17. Check Slow Risetime and Falltime Accuracy

a. Set the Type R116 and test oscilloscope controls as shown in the Initial Control Settings list on page 6-6 with changes as shown in the partial list preceding step 16.

b. For each check, set the Type R116 controls, the time-mark generator and the test oscilloscope controls as given in Table 6-5. On each sweep rate, check the display timing by observing the time-mark signal (Channel 2) and adjusting the variable sweep rate control if necessary, then display the Type R116 output pulse.

c. CHECK FOR—Test oscilloscope displays of the pulse rise or fall with risetimes and falltimes as indicated in Table 6-5.

d. If the risetime and/or falltime are out of tolerance in any of the preceding checks, readjust R64, R54, R564 or R554 (step 16) as required to bring the timing within tolerance over the 1- $\mu$ s to 110- $\mu$ s range.

TABLE 6-5

## Slow Risetime and Falltime Accuracy Check

RISETIME FALLTIME RANGE	RISETIME MULT and FALLTIME MULT	Time Markers	Oscilloscope		Risetime or Falltime	
			Sweep Rate	Trig Slope	Time	Display
1 $\mu$ s	10	10 $\mu$ s	20 $\mu$ s/cm	+	100 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
	10			—	100 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
<sup>1</sup> 100 ns	10	1 $\mu$ s	2 $\mu$ s/cm	+	10 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
	10			—	10 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
<sup>1</sup> 1 $\mu$ s	1	1 $\mu$ s	2 $\mu$ s/cm	+	10 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
	1			—	10 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
<sup>1</sup> 100 ns	1	0.1 $\mu$ s	0.2 $\mu$ s/cm	+	1 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm
	1			—	1 $\mu$ s $\pm$ 1 ns $\pm$ 5%	5 cm $\pm$ 2.5 mm

<sup>1</sup>Set PERIOD RANGE switch to 100  $\mu$ s position and the WIDTH MULTIPLIER to the 5 position for these settings of the risetime and falltime controls.

## Control Settings (Partial List)

## Type R116

TRIGGER SOURCE	INTERNAL
PERIOD RANGE	1 $\mu$ s
DELAY OR BURST TIME RANGE	10 $\mu$ s
WIDTH RANGE	10 ns

## Sampling Oscilloscope

## Type 568

Calibrator	Off
CRT Cathode Selector	Chopped Blanking

## Type 356 (or 355)

Mode	Channel A
DC Offset (A and B)	Pulse Vertically Centered
Millivolts/Div (A and B)	200
Invert Pull	Not pulled

## Type 3T6 (or 3T5)

Time/Div	20 ns
Horizontal Position	Centered
Samples/Sweep	1000
Delay	Pulse Horizontally Centered
Trigger Sensitivity	Stable Display
Recovery Time	Stable Display
Trigger Mode	+, Ext
Program Selector	Internal or External

## Pulse Shape, Fast Risetime and Falltime

18. Adjust Pulse for Minimum Aberrations ①

a. Set the Type R116 controls as shown in the Initial Control Settings list on page 6-6 with changes shown in the partial list preceding this step. Set the sampling oscilloscope controls as shown in the preceding partial list.

b. Disconnect the Type R116 output pulse and pretrigger from the test oscilloscope.

c. Connect the Type R116 output pulse signal through a 5 ns coaxial cable and a 10 $\times$  attenuator to the Channel A Type S1 Sampling Head which has been installed in the Type 3S6) Programmable Sampling Unit. (50  $\Omega$  Termination is not required because the input to the Type S1 is 50- $\Omega$ .)

d. Connect the Type R116 pretrigger pulse through a 50  $\Omega$  coaxial cable terminated by a 50  $\Omega$  10 $\times$  attenuator to the External Trigger Input connector on the Type 3T6 Sampling Sweep Unit.

e. Trigger the sampling oscilloscope display.

f. Reset the Type 3T6 (3T5) Time/Div switch to 10 ns.

g. Position the pulse on the CRT graticule with the Type 3T6 decade Delay control.

h. Reset the Type 3S6 Millivolts/Div switch to 10.

i. Vertically position the pulse baseline immediately following the pulse fall onto the CRT with the Type 3S6 DC Offset control (see Fig. 612A).

j. CHECK FOR—Sampling oscilloscope display of the pulse fall and baseline with no more than 3 cm (3%) of overshoot, short-time rounding, tilt or droop and with total aberrations of no more than 3 cm (3%) peak-to-peak.

## Performance Check/Calibration—Type R116 (SN 1084-up)

k. ADJUST—C50, the PULSE OVERSHOOT adjustment on the Output Amplifier circuit card (see Fig. 6-11), for the fastest falltime with minimum aberrations. Adjust C82 (Pulse Tilt) for the flattest possible baseline.

l. Vertically position the pulse top on the CRT with the Type 3S6 DC Offset control (see Fig. 6-12B).

m. CHECK FOR—Sampling oscilloscope display of the pulse rise and pulse top with no more than 3 cm (3%) of overshoot, short-time rounding, tilt or droop and with total aberrations of no more than 3 cm (3%) peak-to-peak.

n. ADJUST—C50 and C82 for the fastest possible risetime with minimum aberrations. (Adjustments should be a compromise between parts j and m).

### 19. Check Pulse Aberrations

(If step 18 has just been completed, go to part m of this step.)

a. Set the Type R116 controls as shown in the Initial Control Settings list on page 6-6 with changes shown in the partial list preceding step 18. Set the sampling oscilloscope controls as shown in the partial list.

b. Disconnect the Type R116 output pulse and pretrigger from the test oscilloscope.

c. Connect the Type R116 output pulse signal through a 5 ns coaxial cable and a 10 $\times$  attenuator to the Channel A Type S1 Sampling Head which has been installed in the Type 3S6 Programmable Sampling Unit. (50  $\Omega$  termination is not required because the input to the Type S1 is 50- $\Omega$ .)

d. Connect the Type R116 pretrigger pulse through a 50- $\Omega$  10 $\times$  attenuator to the External Trigger Input connector on the Type 3T6 Sampling Sweep Unit.

e. Trigger the sampling oscilloscope.

f. Reset the Type 3T6 Time/Div switch to 10 ns.

g. Position the pulse onto the CRT with the Type 3T6 decade Delay control.

h. Reset the Type 3S6 Millivolts/Div switch to 10.

i. Vertically position the pulse baseline immediately following the pulse fall on the CRT with the Type 3S6 DC Offset control (see Fig. 6-12A).

j. CHECK FOR—Sampling oscilloscope display of the pulse fall and baseline with no more than 3 cm (3%) of overshoot, short-time rounding, tilt or droop and with total aberrations of no more than 3 cm (3%) peak-to-peak.

k. Vertically position the pulse top onto the CRT with the Type 3S6 DC Offset control (see Fig. 6-12B).

l. CHECK FOR—Sampling oscilloscope display of the pulse rise and pulse top with no more than 3 cm (3%) of overshoot, short-time rounding, tilt or droop and with total aberrations of no more than 3 cm (3%) peak-to-peak.

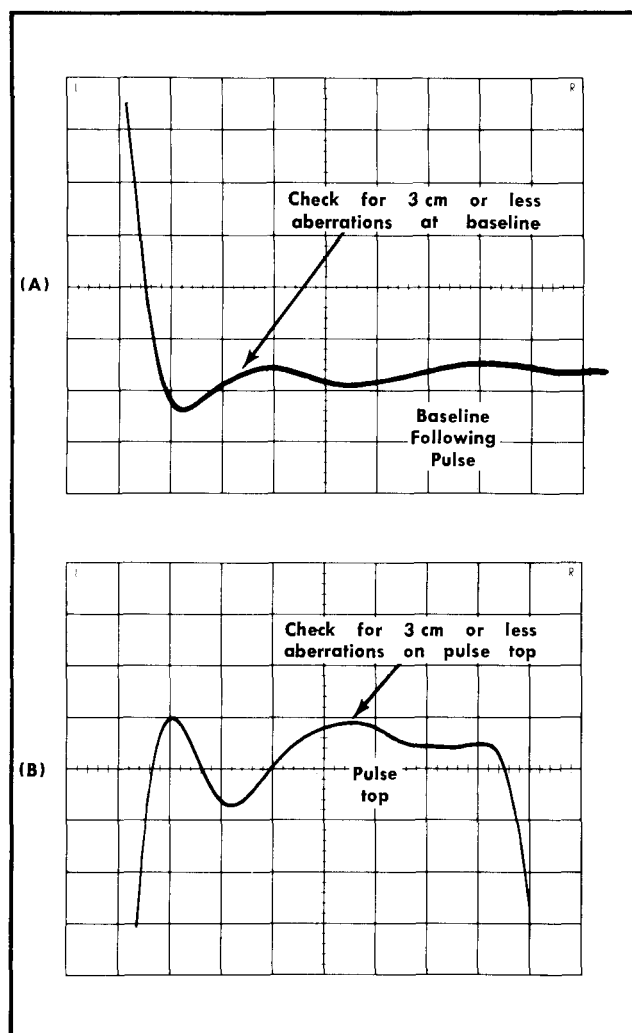


Fig. 6-12. Typical sampling oscilloscope displays for checking and adjusting pulse aberrations.

m. Set the Type R116 POLARITY switch to —.

n. Repeat parts i through l for the negative-going pulse.

o. If the pulse aberrations are out of tolerance in any of the preceding checks, adjust C50 and C82 as described in Step 18 to bring the pulse aberrations within tolerance.

p. Set the Type R116 POLARITY switch to +.

### 20. Adjust Fast Rise/Time and Falltime

a. Reset the Type R116 PERIOD MULTIPLIER to 5 and the POLARITY switch to +.

b. Connect the time-mark generator marker output to the Channel B Type S1 Sampling Head through a 50- $\Omega$  coaxial cable and a 5 $\times$  attenuator.

c. Set the time-mark generator for a 2-ns sinewave output.

## Performance Check/Calibration—Type R116 (SN 1084-up)

d. Reset the indicated sampling oscilloscope controls as follows:

Vertical Mode	Channel B
Time/Div	2 ns
Millivolts/Div (Channel A)	200

e. Trigger the sampling oscilloscope.

f. Check the sampling oscilloscope display for 1 cycle/cm. If the timing is not correct, either adjust the Type 3T6 Horizontal Gain adjustment (screwdriver adjustment) or note the error for use in part l.

g. Reset the sampling oscilloscope Vertical Mode switch to Channel A.

h. Trigger the sampling oscilloscope display.

i. Check that the display amplitude is exactly 5 cm and adjust the Millivolts/Div Variable, if necessary, for correct deflection to measure risetime.

j. Position the display with the Type 3T6 decade Delay control to observe the pulse rise.

k. CHECK FOR—Sampling oscilloscope display of the pulse rise with a risetime of  $10 \text{ ns} \pm 10\%$  ( $5 \text{ cm} \pm 0.5 \text{ cm}$ ).

l. ADJUST—C72 on the Pulse Shape Generator circuit card (see Fig. 6-11) if the risetime is not correct. Remove the adjustment tool while observing the risetime.

m. Time-position the display with the Type 3T6 decade Delay control to observe the falling edge of the pulse.

n. CHECK FOR—Sampling oscilloscope display of the pulse fall with a falltime of  $10 \text{ ns} \pm 10\%$  ( $5 \text{ cm} \pm 0.5 \text{ cm}$ ).

o. If the falltime is not correct, readjust C72 for a compromise setting so that both the risetime and falltime are within specification.

p. If doing Adjust steps only, make the following equipment changes:

1. Disconnect the Type R116 output pulse and the time-mark generator output from the sampling oscilloscope.

2. Reconnect the Type R116 output pulse through a  $50\text{-}\Omega$  termination to the Channel 1 input of the test oscilloscope.

3. Reconnect the time-mark generator marker output through a  $50\text{-}\Omega$  coaxial cable terminated in  $50 \Omega$  to the Channel 2 input of the test oscilloscope.

### 21. Check Fast Risetime and Falltime Accuracy

a. Connect the time-mark generator marker output to the Channel B Type S1 Sampling Head which has been installed in the Type 3S5 (3S6) through a  $50\text{-}\Omega$  coaxial cable and a  $5\times$  attenuator.

b. Reset the Type R116 controls listed as follows:

PERIOD RANGE	$1 \mu\text{s}$
MULTIPLIER	1
WIDTH RANGE	100 ns
MULTIPLIER	5

c. Set the Type R116, the sampling oscilloscope and time-mark generator as shown in Table 6-6. On each sweep rate, check the display timing, by observing the time-mark signal (Channel 2) and adjusting the Type 3T6 Horizontal Gain screwdriver adjustment control or noting the error if necessary, then display the Type R116 output pulse. Use the sampling oscilloscope decade Delay control to position the pulse rise or fall onto the CRT.

d. CHECK FOR—Test oscilloscope displays of the pulse rise or pulse fall with risetimes and falltimes as indicated in the table.

**TABLE 6-6**  
Fast Risetime and Falltime Accuracy Check

RISETIME FALLTIME RANGE	RISETIME MULT and FALLTIME MULT	Time Markers	Oscilloscope		Risetime or Falltime	
			Sweep Rate	Trig Slope	Time	Display
1 ns	1	$2 \text{ ns}^1$	2 ns/cm	+	$10 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
				—	$10 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
10 ns	1	$10 \text{ ns}^2$	20 ns/cm	+	$100 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
				—	$100 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
1 ns	10	$10 \text{ ns}^2$	20 ns/cm	+	$100 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
				—	$100 \text{ ns} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
$10 \text{ ns}^3$	10	$1 \mu\text{s}^2$	200 ns/cm	+	$1 \mu\text{s} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$
				—	$1 \mu\text{s} \pm 1 \text{ ns} \pm 5\%$	$5 \text{ cm} \pm 2.5 \text{ mm}$

<sup>1</sup>Check sweep rate with 1 marker/cm.

<sup>2</sup>Check sweep rate with 2 markers/cm.

<sup>3</sup>Set PERIOD RANGE switch to  $10 \mu\text{s}$  and WIDTH RANGE switch to  $1 \mu\text{s}$  for this setting of the risetime and falltime controls.

## Performance Check/Calibration—Type R116 (SN 1084-up)

e. If the risetime and/or falltime are out of tolerance: in any of the preceding checks, readjust C72 in step 20 as required to bring the timing within tolerance over the 10 ns to 1.1  $\mu$ s range.

f. Disconnect the Type R116 output pulse and the time-mark generator output from the sampling oscilloscope.

g. Reconnect the Type R116 output pulse through a 50- $\Omega$  coaxial cable terminated with a 50- $\Omega$  termination to the Channel 1 input of the test oscilloscope.

h. Reconnect the time-mark generator marker output through a 50- $\Omega$  coaxial cable terminated in 50  $\Omega$  to the Channel 2 input of the test oscilloscope.

### Control Settings (Partial List)

#### Type R116

TRIGGER SOURCE	INTERNAL
PERIOD RANGE	1 ms
DELAY OR BURST TIME RANGE	10 $\mu$ s
MULTIPLIER	50
WIDTH RANGE	10 $\mu$ s
MULTIPLIER	50

#### Test Oscilloscope

Time/Cm	0.1 ms (Unmagnified)
Triggering	Trig, +, AC, Int
Vertical Mode	Alternate
Volts/Cm (Channel 1)	2
Volts/Cm (Channel 2)	1
Input Coupling (Both Channels)	DC

### Width Generator

#### 22. Adjust Width Timing

a. Set the Type R116 and the test oscilloscope controls as shown in the Initial Control Settings list on page 6-6 with changes as shown in the partial list preceding this step.

b. Set the time-mark generator for a 50- $\mu$ s marker output.

c. Trigger the test oscilloscope display.

d. Center the two alternately displayed waveforms vertically and position the pulse rise to the 1-cm graticule line (see Fig. 6-13A).

e. CHECK FOR—Test oscilloscope display of a 500- $\mu$ s pulse width (at the 50% amplitude level) within 3% of the time mark waveform ( $\pm 1.5$  mm over 5 cm).

f. ADJUST—R41, the WIDTH TIMING adjustment on the Width Generator circuit card (see Fig. 6-14), if the display is not correct.

g. Set the WIDTH MULTIPLIER control to 5.

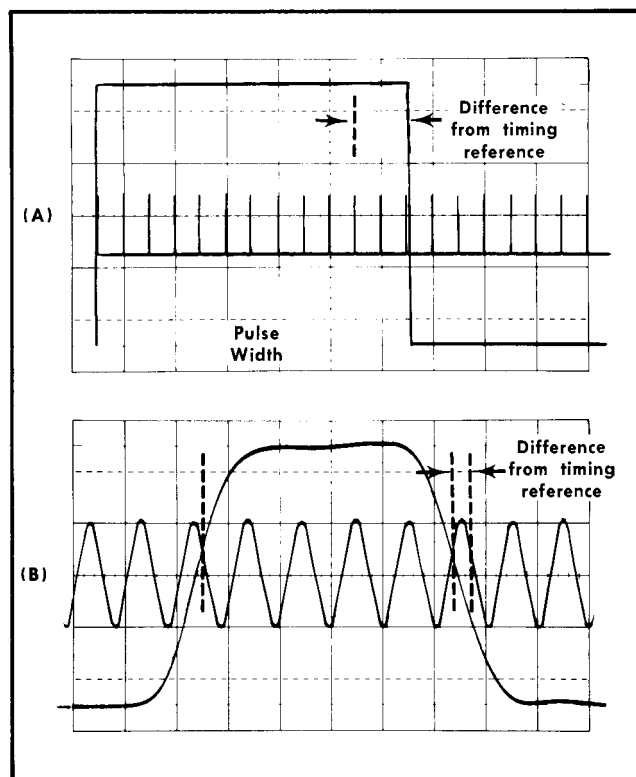


Fig. 6-13. Typical test oscilloscope displays for checking pulse width: (A) 500- $\mu$ s pulse width; (B) 50-ns pulse width.

h. Set the test oscilloscope sweep rate to 10  $\mu$ s/cm.

i. Set the time-mark generator for a 5- $\mu$ s marker output.

j. Trigger the test oscilloscope display.

k. CHECK FOR—Test oscilloscope display of a 50- $\mu$ s pulse width (at the 50% amplitude level) within 3% of the time mark waveform ( $\pm 1.5$  mm over 5 cm).

l. ADJUST—R522, the WIDTH MULT CAL adjustment on the Type R116 chassis (see Fig. 6-14), if the display is not correct.

m. If R522 is adjusted, recheck the adjustments in steps a through l.

n. Reset the following Type R116 controls:

PERIOD RANGE	1 $\mu$ s
WIDTH RANGE	10 ns
MULTIPLIER	50

o. Set the test oscilloscope sweep rate to 0.1  $\mu$ s/cm.

p. Set the time-mark generator for a 50-ns sine wave output.

q. CHECK FOR—Test oscilloscope display of a 500-ns pulse width, at the 50% amplitude level, within 5% of the reference waveform ( $\pm 2.5$  mm over 5 cm).

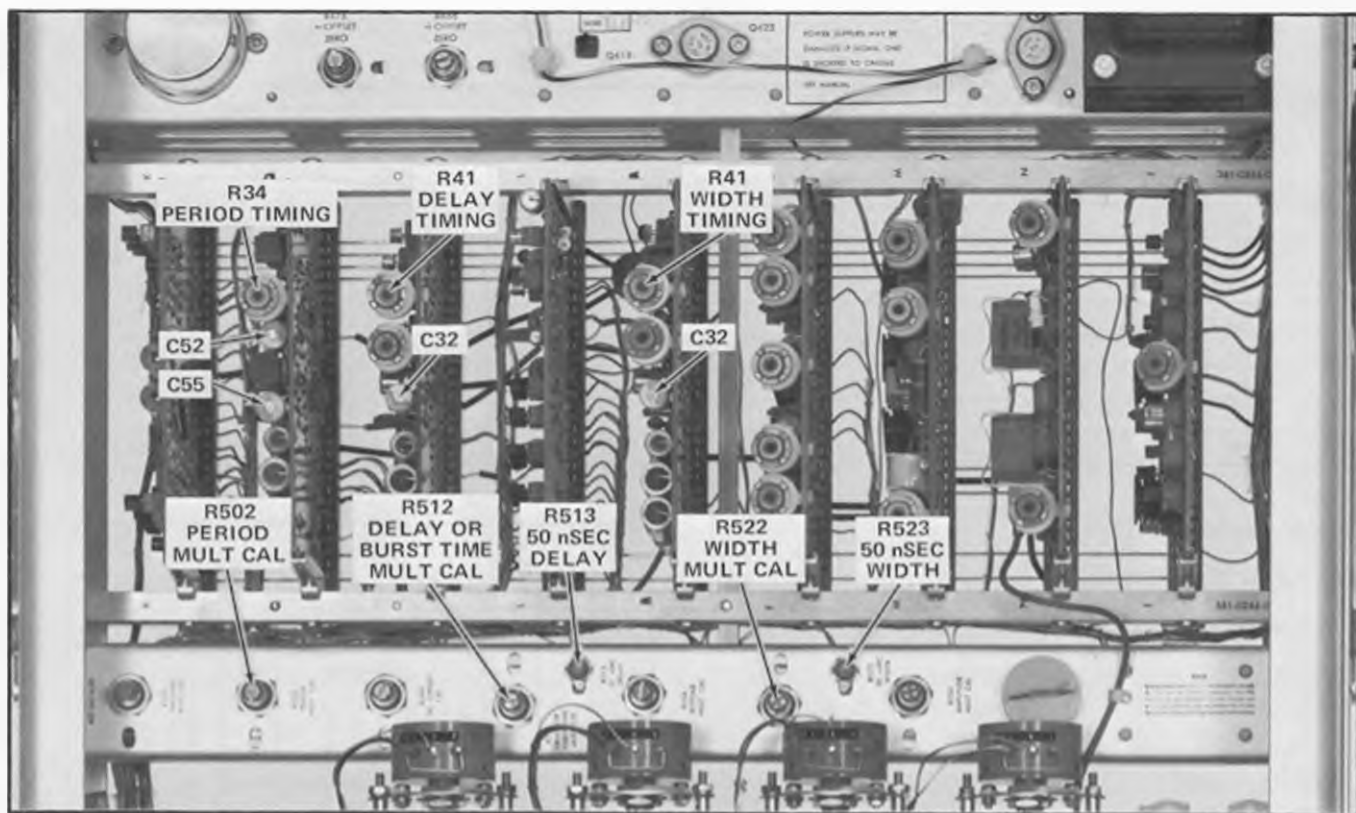


Fig. 6-14. Location of width, delay and period timing adjustments on Width Generator, Delay Generator and Period Generator circuit cards and on the Type R116 chassis.

r. ADJUST—C32 on the Width Generator circuit card (see Fig. 6-14), if the display is not correct.

s. Set the Type R116 WIDTH MULTIPLIER control to 5.

t. Reset the following test oscilloscope controls:

Sweep Rate                      10 ns/cm [0.1  $\mu$ s/cm  
magnified by 10]

Deflection Factor              0.5 V/cm  
(CH 2)

u. Set the time-mark generator for a 10-ns sine wave output.

v. CHECK FOR—Test oscilloscope display of 50-ns pulse width, at the 50% amplitude level, within 5% of the reference waveform ( $\pm 2.5$  mm over 5 cm).

w. ADJUST—R523, the 50-nSEC WIDTH adjustment on the Type R116 chassis (see Fig. 6-14), if the display is not correct.

x. If R523 required readjustment check adjustment of C32 in steps n through r.

### 23. Check Width Accuracy

a. Set the Type R116 and the test oscilloscope controls as shown in the Initial Control settings list with changes as shown in the partial list of control settings preceding step 22.

b. Set the Type R116 controls, the time-mark generator output and the test oscilloscope sweep rate as indicated in Table 6-7.

c. CHECK FOR—Test oscilloscope displays of the pulse width, at the 50% amplitude level, with respect to the time mark waveform as indicated in the last column of Table 6-7.

d. If the width timing is out of tolerance in any of the preceding checks readjust R522, R41, C32, and/or R523 in step 22 as required to bring the width timing within tolerance on all ranges.

**TABLE 6-7**  
Width Timing Accuracy Check

PERIOD RANGE	WIDTH RANGE	MULTIPLIER WIDTH	Time Markers	Oscilloscope Sweep Rate	Pulse Width	
					Time	Difference from Reference
1 ms	10 $\mu$ s	5	5 $\mu$ s	10 $\mu$ s/cm	50 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
100 $\mu$ s	1 $\mu$ s	5	0.5 $\mu$ s	1 $\mu$ s/cm	5 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
10 $\mu$ s	100 ns	5	50 ns	0.1 $\mu$ s/cm	500 ns $\pm 3\%$	$\pm 1.5$ mm over 5 cm
1 $\mu$ s	10 ns	5	10 ns	10 ns/cm	50 ns $\pm 5\%$	$\pm 2.5$ mm over 5 cm
1 $\mu$ s	10 ns	50	50 ns	0.1 $\mu$ s/cm	500 ns $\pm 5\%$	$\pm 2.5$ mm over 5 cm
100 $\mu$ s	100 ns	50	0.5 $\mu$ s	1 $\mu$ s/cm	5 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
1 ms	1 $\mu$ s	50	5 $\mu$ s	10 $\mu$ s/cm	50 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
1 ms	10 $\mu$ s	50	50 $\mu$ s	0.1 $\mu$ s/cm	500 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm

## Delay Generator

### 24. Adjust Delay Timing

- a. Reset the below listed Type R116 controls as follows:

MODE	DOUBLE
PERIOD RANGE	1 ms
MULTIPLIER	10
WIDTH RANGE	1 $\mu$ s
MULTIPLIER	25

- b. Set the test oscilloscope sweep rate to 0.1 ms/cm (unmagnified).

- c. Set the time-mark generator for a 50- $\mu$ s marker output.

- d. Trigger the test oscilloscope display.

- e. CHECK FOR—Test oscilloscope display of the double pulse waveform with a delay period of 500  $\mu$ s between corresponding points on the two pulses (see Fig. 6-15), with 3%  $\pm 10$  ns of the reference waveform ( $\pm 1.5$  mm over 5 cm).

- f. ADJUST—R41, the DELAY TIMING adjustment on the Delay Generator circuit card (see Fig. 6-14), if the delay interval is not correct.

- g. Set the DELAY OR BURST TIME MULTIPLIER control to 5.

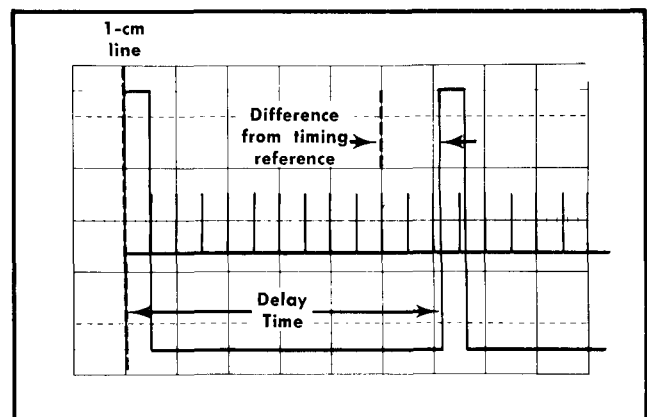
- h. Set the test oscilloscope sweep rate to 10  $\mu$ s/cm.

- i. Set the time-mark generator for a 5- $\mu$ s marker output.

- j. Trigger the test oscilloscope display.

- k. CHECK FOR—Test Oscilloscope display of the double pulse waveform with a delay period of 50  $\mu$ s between corresponding points on the two pulses, within 3%  $\pm 10$  ns of the reference waveform ( $\pm 1.5$  mm over 5 cm).

- l. ADJUST—R512, the DELAY OR BURST TIME MULT CAL adjustment on the Type R116 chassis (see Fig. 6-14), if the delay interval is not correct.



**Fig. 6-15.** Typical test oscilloscope display for checking delay timing adjustments; 500  $\mu$ s delay time.

- m. If R512 requires adjustment, recheck the adjustments in parts a through l.

- n. Set the test oscilloscope sweep rate to 0.1  $\mu$ s/cm.

- o. Reset the indicated Type R116 controls as listed below:

PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1
DELAY OR BURST TIME RANGE	10 ns
MULTIPLIER	50
WIDTH RANGE	10 ns
MULTIPLIER	5

- p. Set the time-mark generator for a 50-ns marker output.

- q. CHECK FOR—Test oscilloscope display of the double pulse with a delay time of 500 ns, within 3%  $\pm 10$  ns of the reference waveform (5 cm  $\pm 1.6$  mm).

- r. ADJUST—C32 on the Delay Generator circuit card (see Fig. 6-14) if the delay time interval is not correct.



s. Connect the Type R116 + PRETRIGGER OUT pulse to the test oscilloscope External Trigger Input connector through a 50- $\Omega$  coaxial cable.

t. Reset the Type R116 MODE switch to SINGLE and the DELAY OR BURST TIME MULTIPLIER to 5.

u. Reset the listed test oscilloscope controls as follows:

Sweep Rate	10 ns/cm (0.1 $\mu$ s/cm magnified by 10)
------------	---

Vertical Mode	Channel 2
---------------	-----------

Volts/Cm (Channel 2)	.2
----------------------	----

v. Set the time-mark generator for a 10-ns marker output

w. Trigger the test oscilloscope display and check the test oscilloscope sweep timing. Adjust the variable sweep rate control if required.

x. Set the test oscilloscope Trigger Source switch to Ext and the Vertical Mode switch to Channel 1.

y. Trigger the test oscilloscope display of the undelayed output pulse.

z. Position a reference point on the rise of the pulse to the 1-cm vertical line of the CRT graticule (see Fig. 6-16A)

aa. Set the Type R116 MODE switch to DLY'D SINGLE.

ab. CHECK FOR—Test oscilloscope display of the delayed pulse with the corresponding point on the delayed pulse rise (corresponding to the reference point used in part z) at the 6-cm vertical line of the CRT graticule  $\pm 0.15$  cm  $\pm 1$  cm (see Fig. 6-16B). This display indicates a delay time of 50 ns  $\pm 3\%$   $\pm 10$  ns.

ac. ADJUST—R513, 50 nSEC DELAY adjustment on the Type R116 chassis (see Fig. 6-14) if the delay time interval is not correct.

ad. If R513 required adjustment, reset the Type R116 MODE switch to DOUBLE and the DELAY OR BURST TIME MULTIPLIER to 50.

ae. Reset the below listed test oscilloscope controls as follows:

Sweep Rate	0.1 $\mu$ s/cm (unmagnified)
------------	------------------------------

Trigger Source	Int
----------------	-----

Vertical Mode	Alternate
---------------	-----------

Volts/Cm (Channel 2)	.5
----------------------	----

af. Recheck the adjustments in parts p through ac.

## 25. Check Delay Accuracy

(If step 24 has just been completed go to part j of this step.)

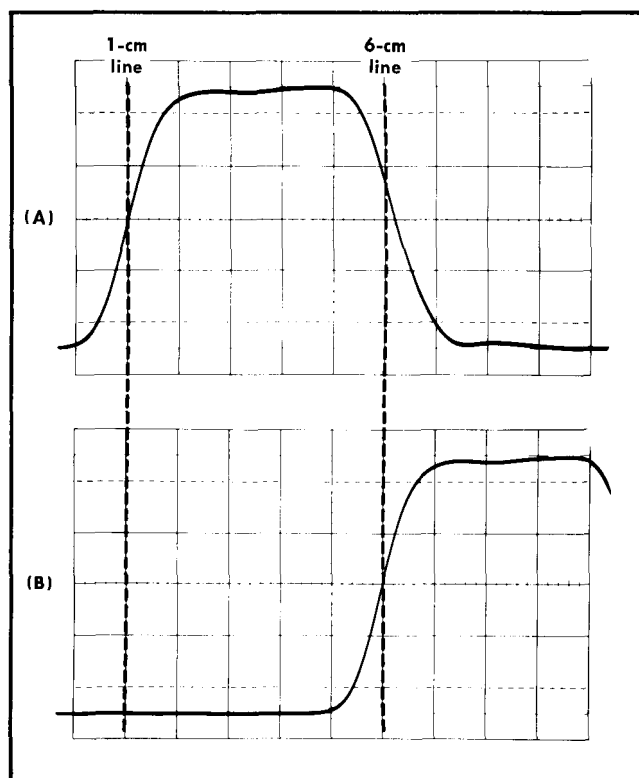


Fig. 6-16. Test oscilloscope displays for checking the 50-ns delay time adjustment.

a. Set the below listed Type R116 controls as follows:

MODE	SINGLE
------	--------

PERIOD RANGE	10 $\mu$ s
MULTIPLIER	1

DELAY OR BURST TIME RANGE	10 ns
MULTIPLIER	5

WIDTH RANGE	10 ns
MULTIPLIER	5

b. Reset the following test oscilloscope controls as indicated.

Sweep Rate	10 ns/cm (0.1 $\mu$ s/cm magnified by 10)
------------	---

Trigger Source	Ext
----------------	-----

Vertical Mode	Channel 2
---------------	-----------

Volts/Cm	.2
----------	----

c. Set the time-mark generator for a 10-ns marker output.

d. Trigger the test oscilloscope display and check the test oscilloscope sweep timing. Adjust the variable sweep rate control if required.

**TABLE 6-8**  
**DELAY OR BURST TIME ACCURACY CHECK**

PERIOD RANGE	DELAY OR BURST TIME RANGE	DELAY OR BURST TIME MULTIPLIER	WIDTH RANGE	Time Markers	Oscilloscope Sweep Rate	Delay Interval	
						Time	Difference from Reference Waveform
1 $\mu$ s	100 ns	5	10 ns	50 ns	0.1 $\mu$ s/cm	500 ns $\pm 3\%$ $\pm 10$ ns	$\pm 2.5$ mm over 5 cm
10 $\mu$ s	1 $\mu$ s	5	100 ns	0.5 $\mu$ s	1 $\mu$ s/cm	5 $\mu$ s $\pm 3\%$ $\pm 10$ ns	$\pm 1.6$ mm over 5 cm
100 $\mu$ s	10 $\mu$ s	5	1 $\mu$ s	5 $\mu$ s	10 $\mu$ s/cm	50 $\mu$ s $\pm 3\%$ $\pm 10$ ns	$\pm 1.5$ mm over 5 cm
1 ms	10 $\mu$ s	50	10 $\mu$ s	50 $\mu$ s	0.1 ms/cm	500 $\mu$ s $\pm 3\%$ $\pm 10$ ns	$\pm 1.5$ mm over 5 cm
100 $\mu$ s	1 $\mu$ s	50	1 $\mu$ s	5 $\mu$ s	10 $\mu$ s/cm	50 $\mu$ s $\pm 3\%$ $\pm 10$ ns	$\pm 1.5$ mm over 5 cm
10 $\mu$ s	100 ns	50	100 ns	0.5 $\mu$ s	1 $\mu$ s/cm	5 $\mu$ s $\pm 3\%$ $\pm 10$ ns	$\pm 1.6$ mm over 5 cm
1 $\mu$ s	10 ns	50	10 ns	50 ns	0.1 $\mu$ s/cm	500 ns $\pm 3\%$ $\pm 10$ ns	$\pm 2.5$ mm over 5 cm

e. Set the test oscilloscope Vertical Mode switch to Channel 1.

f. Trigger the test oscilloscope display of the undelayed output pulse.

g. Position a reference point on the rise of the pulse to the 1-cm vertical line of the CRT graticule (see Fig. 6-16A).

h. Set the Type R116 MODE switch to DLY'D SINGLE.

i. CHECK FOR—Test oscilloscope display of the delayed pulse with the corresponding point on the delayed pulse rise (corresponding to the reference point used in part g) at the 6-cm vertical line of the CRT graticule  $\pm 0.15$  cm  $\pm 1$  cm (see Fig. 6-16B). This display indicates a delay time of 50 ns  $\pm 3\%$   $\pm 10$  ns.

j. Reset the following Type R116 controls:

MODE	DOUBLE
PERIOD MULTIPLIER	10

k. Reset the following test oscilloscope controls:

Vertical Mode	Alternate
Trigger Source	Trig, +, AC, Int

l. Set the Type R116 controls, the time-mark generator output and the test oscilloscope sweep rate as given in Table 6-8.

m. CHECK FOR—Test oscilloscope displays with a delay period between corresponding points on the two pulses (see Fig. 6-15), as indicated in the last column of Table 6-8.

n. If the delay time is out of tolerance in any of the preceding checks, readjust R512, R513, R41, and/or C32 in step 25 as necessary to bring the delay time within tolerance on all ranges.

## Period Generator

### 26. Adjust Period Timing

a. Reset the following Type R116 controls:

MODE	SINGLE
PERIOD RANGE	1 ms
MULTIPLIER	10
WIDTH RANGE	10 $\mu$ s

b. Reset the following test oscilloscope controls:

Sweep Rate	10 ms/cm (unmagnified)
Triggering	Trig, +, AC, Int
Vertical Mode	Alternate
Volts/Cm (Channel 2)	1

c. Set the time-mark generator for a 10-ms marker output.

d. Trigger the test oscilloscope display.

e. CHECK FOR—Test oscilloscope display with equal time intervals between the Type R116 pulses and the reference time-mark signals,  $\pm 2.7$  mm over the first 9 cm of the test oscilloscope graticule (90 ms  $\pm 3\%$ ).

f. ADJUST—R34, the PERIOD TIMING adjustment on the Period Generator circuit card (see Fig. 6-14) if the display is not correct.

g. Set the PERIOD MULTIPLIER control to 1.

h. Set the test oscilloscope sweep rate to 1 ms/cm.

i. Set the time-mark generator for a 1-ms marker output.

j. CHECK FOR—Test oscilloscope display of equal time intervals between the Type R116 and the reference waveforms,  $\pm 2.7$  mm over the first 9 cm (9 ms  $\pm 3\%$ ).

k. ADJUST—R502, the PERIOD MULT CAL adjustment on the Type R116 chassis (see Fig. 6-14) if the display is not correct.

**TABLE 6-9**  
**PERIOD ACCURACY CHECK**

PERIOD RANGE	PERIOD MULTIPLIER	WIDTH RANGE	Time Markers	Oscilloscope Sweep Rate	Period	
					Time	Difference from Reference Waveform
100 ns	1	10 ns	0.1 $\mu$ s	0.1 $\mu$ s/cm	100 ns $\pm 5\%$	$\pm 4.5$ mm over 9 cm
1 $\mu$ s	1	10 ns	1 $\mu$ s	1 $\mu$ s/cm	1 $\mu$ s $\pm 3\%$	$\pm 2.7$ mm over 9 cm
10 $\mu$ s	1	10 ns	10 $\mu$ s	10 $\mu$ s/cm	10 $\mu$ s $\pm 3\%$	$\pm 2.7$ mm over 9 cm
100 $\mu$ s	1	100 ns	0.1 ms	0.1 ms/cm	100 $\mu$ s $\pm 3\%$	$\pm 2.7$ mm over 9 cm
1 ms	1	1 $\mu$ s	1 ms	1 ms/cm	1 ms $\pm 3\%$	$\pm 2.7$ mm over 9 cm
100 ns	10	10 ns	0.1 $\mu$ s	0.2 $\mu$ s/cm	1 $\mu$ s $\pm 5\%$	$\pm 2.5$ mm over 5 cm
1 $\mu$ s	10	10 ns	1 $\mu$ s	2 $\mu$ s/cm	10 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
10 $\mu$ s	10	100 ns	10 $\mu$ s	20 $\mu$ s/cm	100 $\mu$ s $\pm 3\%$	$\pm 1.5$ mm over 5 cm
100 $\mu$ s	10	1 $\mu$ s	0.1 ms	0.2 ms/cm	1 ms $\pm 3\%$	$\pm 1.5$ mm over 5 cm
1 ms	10	10 $\mu$ s	1 ms	2 ms/cm	10 ms $\pm 3\%$	$\pm 1.5$ mm over 5 cm

l. If R502 is adjusted, reset the period multiplier and oscilloscope sweep rate controls as given in parts a and b and recheck the period timing adjustments as in steps c through k.

m. Reset the following Type R116 controls:

PERIOD RANGE                      100 ns  
MULTIPLIER                          1

WIDTH RANGE                      10 ns

n. Set the test oscilloscope sweep rate to 0.1  $\mu$ s/cm.

o. Set the time-mark generator for a 0.1  $\mu$ s marker output.

q. ADJUST—C52 on the Period Generator (circuit) card vals between the Type R116 and the reference waveforms  $\pm 4.5$  mm over the first 9 cm (900 ns  $\pm 5\%$ ).

q. ADJUST—C52 on the Period Generator circuit card (see Fig. 6-14) if the display is not correct. Remove the adjusting tool from the capacitor while checking the display.

r. Set the PERIOD RANGE switch to 1  $\mu$ s.

s. Set the test oscilloscope sweep rate to 1  $\mu$ s/cm.

t. Set the time-mark generator for a 1  $\mu$ s marker output.

u. CHECK FOR—Test oscilloscope display of equal time intervals between the two waveforms,  $\pm 2.7$  mm over the first 9 cm (9  $\mu$ s  $\pm 3\%$ ).

v. ADJUST—C55 on the Period Generator circuit card (see Fig. 6-14) if the display is not correct.

## 27. Check Period Accuracy

a. Set the Type R116 WIDTH MULTIPLIER control to 5.

b. Set the Type R116 controls, the time-mark generator marker output and the test oscilloscope sweep rate as given in Table 6-9.

c. Trigger the test oscilloscope display and position both waveforms near the center of the CRT screen.

d. CHECK FOR—Test oscilloscope display with equal time intervals between the pulses in the Type R116 waveform and those in the reference time-mark signal (over the first 9 cm) for the 1 position of the PERIOD MULTIPLIER (see Fig. 6-17A), and displays with the second Type R116 pulse at the 12th marker for the 11 position of the MULTIPLIER (see Fig. 6-17B).

e. If the period timing is out of tolerance in any of the preceding checks, readjust R34, R502, C52, and/or C55 in step 26 as necessary to bring the timing within tolerance on all ranges.

## Control Settings (Partial List)

### Type R116

TRIGGER SOURCE                      INTERNAL

### Test Oscilloscope

Time/Cm                                  0.1  $\mu$ s  
Triggering                                Trig, +, AC, Ext  
Vertical Mode                            Alternate  
Volts/Cm (Channel 1)                   2 V  
Volts/Cm (Channel 2)                   2 V  
Input Selector                            DC  
Amplitude Calibrator                   Off

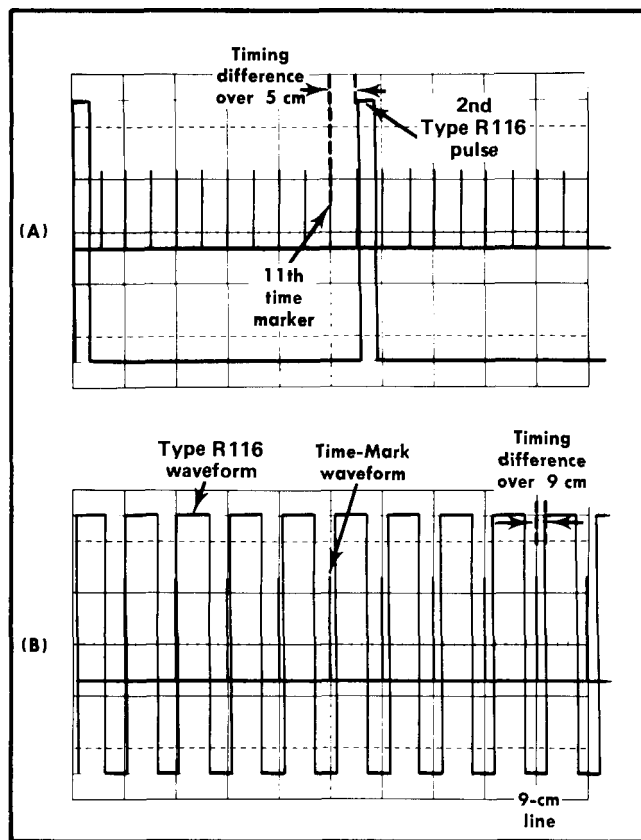


Fig. 6-17. Typical test oscilloscope displays for checking period timing; (A) PERIOD MULTIPLIER control set to 10; (B) PERIOD MULTIPLIER control set to 1.

## Modes of Operation, Triggers and Triggering

### 28. Check Pretrigger and Delayed Trigger

- Set the Type R116 and the test oscilloscope controls as shown in the Initial Control Settings list on page 6 with changes as shown in the partial list preceding this step.
- Disconnect the terminated coaxial cable from the Channel 1 input of the test oscilloscope and connect it to the Trigger Input connector.
- Connect a 50- $\Omega$  coaxial cable between the Type R116 + PRETRIGGER OUT connector and the test oscilloscope Channel 1 input.
- Connect a 50- $\Omega$  coaxial cable between the Type R116 + DELAYED TRIGGER OUT connector and the test oscilloscope Channel 2 input.
- Trigger the test oscilloscope.
- Position the pulses on the CRT so that they do not overlap (see Fig. 6-18).
- CHECK FOR—Test oscilloscope display of the two pulses, each with an amplitude of at least 2 volts.
- Turn the DELAY OR BURST TIME MULTIPLIER slowly to the fully clockwise position.

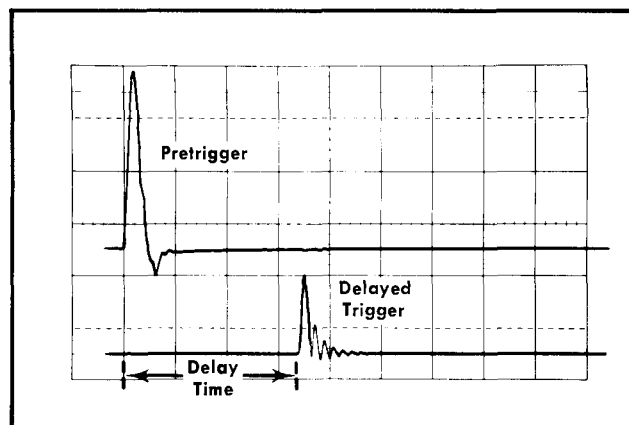


Fig. 6-18. Test oscilloscope display for checking pretrigger and delayed trigger output pulses.

- CHECK FOR—Test oscilloscope display with the delayed trigger moving at least 5.5 cm (550 ns) to the right of the pretrigger.

### 29. Check Single, Delayed Single and Double Pulse Modes

- Disconnect all the 50  $\Omega$  coaxial cables from the test oscilloscope vertical inputs.
- Reconnect the 50  $\Omega$  coaxial cable, terminated in 50  $\Omega$ , 5 watts, between the Type R116 OUTPUT connector and the Channel 1 input.
- Reconnect the 50  $\Omega$  coaxial cable between the Type R116 + PRETRIGGER OUT connector and the Trigger Input connector on the test oscilloscope.
- Reset the following Type R116 controls to:
 

PERIOD RANGE	1 mS
DELAY OR BURST TIME RANGE	10 $\mu$ S
MULTIPLIER	5
WIDTH	10 $\mu$ S
RISETIME, FALLTIME RANGE	1 $\mu$ S
- Reset the following test oscilloscope controls:
 

Time/Cm	0.2 ms
Vertical Mode	Channel 1
- Trigger the test oscilloscope display.
- CHECK FOR—Test oscilloscope display of an undelayed (single) output pulse with an approximate period of 1 ms (see Fig. 6-19A).
- Set the Type R116 MODE switch to DLY'D SINGLE.
- Turn the DELAY OR BURST TIME MULTIPLIER control slowly clockwise while observing the test oscilloscope display.
- CHECK FOR—Test oscilloscope display of the delayed pulse with the delay time controlled by the DELAY OR BURST TIME MULTIPLIER control.

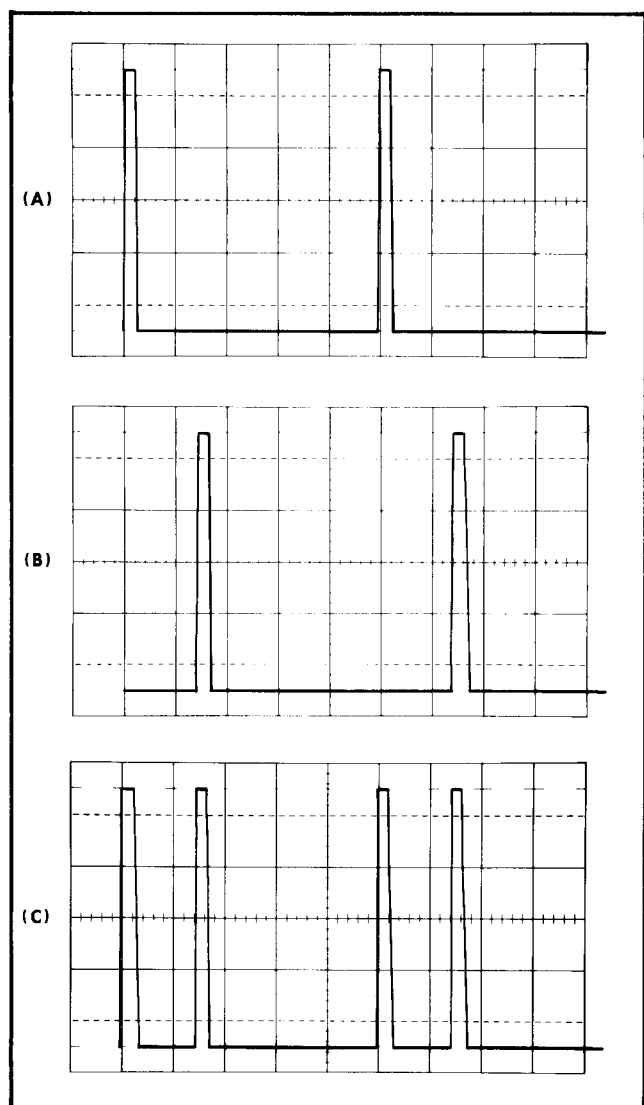


Fig. 6-19. Test oscilloscope displays for checking first three modes of operation: (A) Single pulse; (B) Delayed Single pulse; (C) Double pulse.

k. Set the DELAY OR BURST TIME MULTIPLIER control so that the rise of the delayed pulse is about 1.5 cm from the beginning of the sweep (see Fig. 6-19B).

l. Set the Type R116 MODE switch to DOUBLE.

m. CHECK FOR—Test oscilloscope display of pairs of pulses with the second pulse of each pair delayed with respect to the first by an amount controlled by the DELAY OR BURST TIME MULTIPLIER control (see Fig. 6-19C).

### 30. Check External and Manual Triggering

a. Connect the BNC-T connector to the test oscilloscope Amplitude Calibrator Output connector.

b. Disconnect the 50- $\Omega$  coaxial cable from the Type R116 + PRETRIGGER OUT connector and reconnect it to one arm of the T-connector.

c. Connect another 50- $\Omega$  coaxial cable between the other arm of the T-connector and the Type R116 + TRIGGER INPUT connector.

d. Set the Type R116 TRIGGER SOURCE switch to EXTERNAL OR MANUAL.

e. Set the test oscilloscope Amplitude Calibrator for 20 volts.

f. CHECK FOR—Test oscilloscope display of the externally triggered Type R116 waveform.

g. Set the test oscilloscope Amplitude Calibrator for 2 volts.

h. CHECK FOR—Test oscilloscope display of the externally triggered Type R116 waveform as observed in part f.

i. Disconnect the 50- $\Omega$  coaxial cable connected between the Amplitude Calibrator Output connector and External Trigger Input of the test oscilloscope from the Amplitude Calibrator Output and reconnect it to the + PRETRIGGER OUTPUT connector on the Type R116.

j. Reset the below listed Type R116 controls as follows:

MODE	SINGLE
TRIGGER	INTERNAL
WIDTH MULTIPLIER	50

k. Reset the following test oscilloscope controls as listed.

Amplitude Calibrator	Off
Triggering Mode	Triggered

l. Trigger the test oscilloscope.

m. Set the Type R116 TRIGGER SOURCE switch to EXTERNAL OR MANUAL.

n. Press the Type R116 MANUAL TRIG button.

o. CHECK FOR—Test oscilloscope display of manually triggered output pulse.

### 31. Check Burst Mode

a. Disconnect the 50- $\Omega$  coaxial cable from the Type R116 + PRETRIGGER OUTPUT connector and reconnect it to the vacant arm of the T-connector on the test oscilloscope Amplitude Calibrator Output.

b. Reset the following Type R116 controls to:

MODE	BURST
PERIOD RANGE	100 $\mu$ S
DELAY OR BURST	50
TIME MULTIPLIER	
WIDTH MULTIPLIER	5

## Performance Check/Calibration—Type R116 (SN 1084-up)

c. Set the test oscilloscope Amplitude calibrator to 20 volts.

d. Trigger the test oscilloscope display.

e. CHECK FOR—Test oscilloscope display of burst of output pulses, with the burst duration set by the DELAY OR BURST TIME VARIABLE controls and the burst period set by the test oscilloscope Amplitude Calibrator signal. The characteristics of each individual pulse within a burst are determined by the other Type R116 front-panel controls (see Fig. 6-20A).

f. Turn the DELAY OR BURST TIME MULTIPLIER through-out its range while observing the change in burst duration.

### 32. Check Gated Output Mode

a. Disconnect the 50- $\Omega$  coaxial cable from the Type R116 + TRIGGER INPUT connector and reconnect it to the + GATE IN connector.

b. Set the Type R116 MODE switch to GATED OUTPUT.

c. CHECK FOR—Test oscilloscope display of the gated burst of output pulses, with the burst duration and the burst period set by the test oscilloscope Amplitude Calibrator signal. The characteristics of each pulse within a burst are determined by the other Type R116 controls (see Fig. 6-20B).

d. Decrease the test oscilloscope Amplitude Calibrator output to 2 volts.

e. CHECK FOR—Test oscilloscope display of the gated burst outputs, as observed in part c of this step.

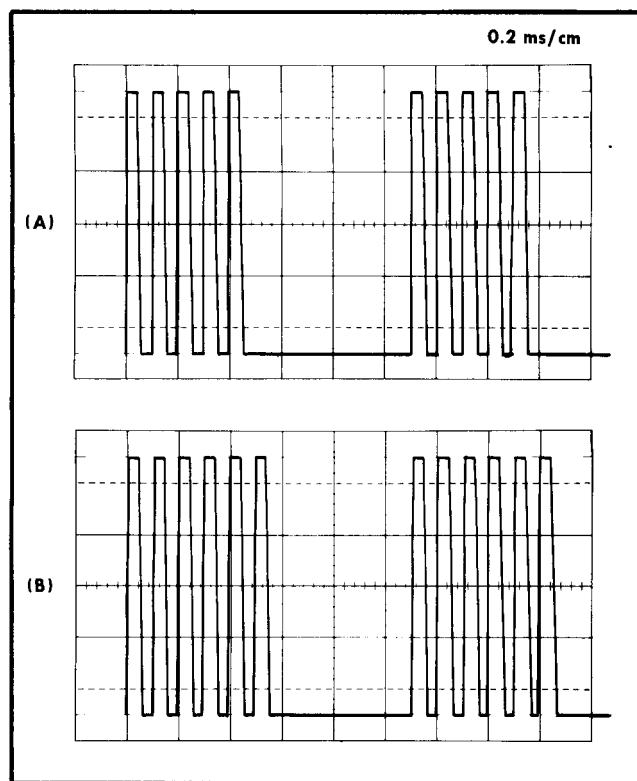


Fig. 6-20. Test oscilloscope display for checking burst; (A) Externally triggered burst; (B) Gated burst.

This completes the calibration and performance check procedure of the Type R116. Test equipment may be disconnected and turned off.

# SECTION 7

## RACKMOUNTING

### General Information

The Type R116 is designed to be mounted on slideout tracks in any 19-inch wide rack that has both front and rear rails and conforms to standard EIA universal rack dimensions. A complete dimensional drawing of the Type R116 is provided on a separate foldout page of this section. If a rack with alternate hole spacing is used, 2 mounting holes will have to be drilled in each rail.

Minimum width of the opening between the left and right front rails (see Fig. 7-1) is either  $17\frac{5}{8}$  inches or  $17\frac{3}{4}$  inches depending on the mounting position to be used, as described later in this section. At least  $5\frac{1}{2}$  inches of vertical space is required for the front panel of the instrument and a total depth of at least 20 inches is needed—17 inches for the Type R116 and 3 inches or more for power and program cables and for the circulation of air. Refer to the Operating Instructions section of this manual for cooling requirements.

### Slideout Tracks

Fig. 7-1 shows the Type R116 installed in a cabinet-type rack with the side panels removed. The slideout tracks provided with the Type R116 permit it to be extended for maintenance and calibration without removing the instrument from the rack. At the fully extended position, the Type R116 can be tilted and locked in any one of seven position—horizontal or  $45^\circ$ ,  $90^\circ$  or  $105^\circ$  above or below the horizontal position. If the Type R116 is expected to be operated in an extended position, it should be installed with power and program cables that are long enough for that purpose. When not extended, the instrument is held into the rack with four securing screws that screw into the front rails of the rack (see Fig. 7-1B).

The slideout tracks consist of two assemblies—one for the left side of the instrument and one for the right side. Fig. 7-2 shows the parts of the slideout track assemblies. The stationary section of each assembly attaches to the front and rear rails of the rack and the chassis section is attached to the instrument. The intermediate section slides between the stationary and chassis sections and allows the Type R116 to be extended fully out of the rack. When the instrument is shipped, the stationary and intermediate sections of the tracks are packaged as matched sets and should not be separated. The right and left tracks can be identified by noting the position of the automatic stop flanges (see Fig. 7-2). The automatic stop on each track should be at the top when mounted in the rack. The chassis sections of both assemblies are installed on the instrument and adjusted at the factory prior to shipment.

The small hardware components provided for mounting the stationary sections to the rack are shown in Fig. 7-3. Since this hardware is intended to make the tracks compatible with a variety of racks, not all of it will be needed for this installation and some parts will be left over. Use only the hardware that is required for the particular method of mounting.

### Mounting Positions

The front flanges of the stationary sections may be mounted in front of or behind the front rails of the rack. The mounting position to be used is selected on the basis of the desired effective panel thickness from the surface of the panel to the front rails, on the **width** of the opening between the rails of the rack and on the depth of the rack between rails.

**Minimum Panel Thickness.** By countersinking the mounting screws in the front rails and mounting the front flanges of the tracks **behind** the front rails as shown in Fig. 7-4A the minimum effective panel thickness of approximately  $\frac{1}{8}$  inch may be obtained. In this case, the effective thickness is the actual thickness of the Type R116 front panel. (Do not countersink the holes if the rails are made of thin metal.) If BHS screws are used instead of countersunk flathead screws, the effective panel thickness will be approximately  $\frac{7}{32}$  inch. In either case, with the front flanges mounted behind the front rails and the rear bracket flanges mounted in front of the rear rails, the minimum distance required between the two front rails is  $17\frac{5}{8}$  inches and the minimum distance required from the front rails to the back rails is  $17\frac{5}{8}$  inches (maximum depth between rails is about 26 inches). This mounting position is the normal position if the mounting holes are not tapped for 10-32 screws, or if the spacing between the front rails is less than  $17\frac{3}{4}$  inches. If this mounting position is desired but the holes are tapped for 10-32, the threads may be drilled out with a  $\frac{3}{16}$ -inch bit.

**Maximum Panel Thickness.** When the flanges of the stationary sections are mounted **in front** of the rails with BHS screws as shown in Fig. 7-5, the maximum effective panel thickness of approximately  $\frac{1}{4}$  inch is obtained. If the tracks are to be mounted in this position, the minimum width of the opening between the two front rails is  $17\frac{3}{4}$  inches. This is the normal mounting position if the mounting holes in the front rails are tapped for 10-32 screws. If the width of the opening between the rear rails is also  $17\frac{3}{4}$  inches, or more, depth of the rack between front and rear rails may be from  $10\frac{1}{2}$  to 26 inches.

### NOTE

The mounting position shown in Fig. 7-5 for use with tapped mounting holes may also be used with untapped holes by placing bar nuts behind the front rails in a manner similar to the method shown in Fig. 7-4.

### Instrument Installation

Use the following procedure to install the Type R116 in a rack:

1. Select the proper front-rail mounting holes for the stationary sections using the measurements shown in Fig. 7-6.

## Rackmounting—Type R116 (SN 1084-up)

2a. If the front flanges of the stationary section are to be mounted **behind** the front rails, mount each stationary section as shown in Fig. 7-4 for the left track.

2b. If the front flanges of the stationary sections are to be mounted **in front** of the front rails, mount each section as shown in Fig. 7-5 for the left track.

3. Visually check that the left and right stationary sections are parallel with each other.

4. Referring to Fig. 7-9, insert the instrument into the rack but do not connect the power or program cables and do not install the securing screws until the following adjustments have been made.

### Track Adjustments

To provide the best possible operation, adjust the slideout tracks as follows:

1. Position instrument as shown in Fig. 7-7.
2. Adjust the front ends of the stationary sections according to the procedure outlined in Fig. 7-7.
3. After adjusting the front ends of the tracks, slide the instrument all the way into the rack. If the tracks do not slide smoothly, loosen the screws that hold the rear brackets

to the rear rails, then push the instrument all the way into the rack and tighten the screws. The front panel of the Type R116 should now be parallel with the front rails. If the instrument still does not slide easily in the rack or if the front panel does not fit correctly, one or both of the chassis sections of the tracks may require readjustment as shown in Fig. 7-8.

4. When the adjustments have been completed and the slideout tracks operate smoothly, connect the power and program cables to the connectors on the rear panel and secure the instrument into the rack with the securing screws and washers as shown in Fig. 7-9.

### Removing or Inserting the Type R116

After the slideout tracks have initially been installed and adjusted in the rack, the Type R116 can be removed or reinserted at any time by following the procedures given in Fig. 7-9. No further adjustments are normally required.

### Maintenance

The slideout tracks require no lubrication. The special finish on the sliding surfaces provides permanent lubrication. If the tracks tend to become harder to operate after a period of use, a thin coating of paraffin may be rubbed onto the sliding surfaces for additional lubrication.

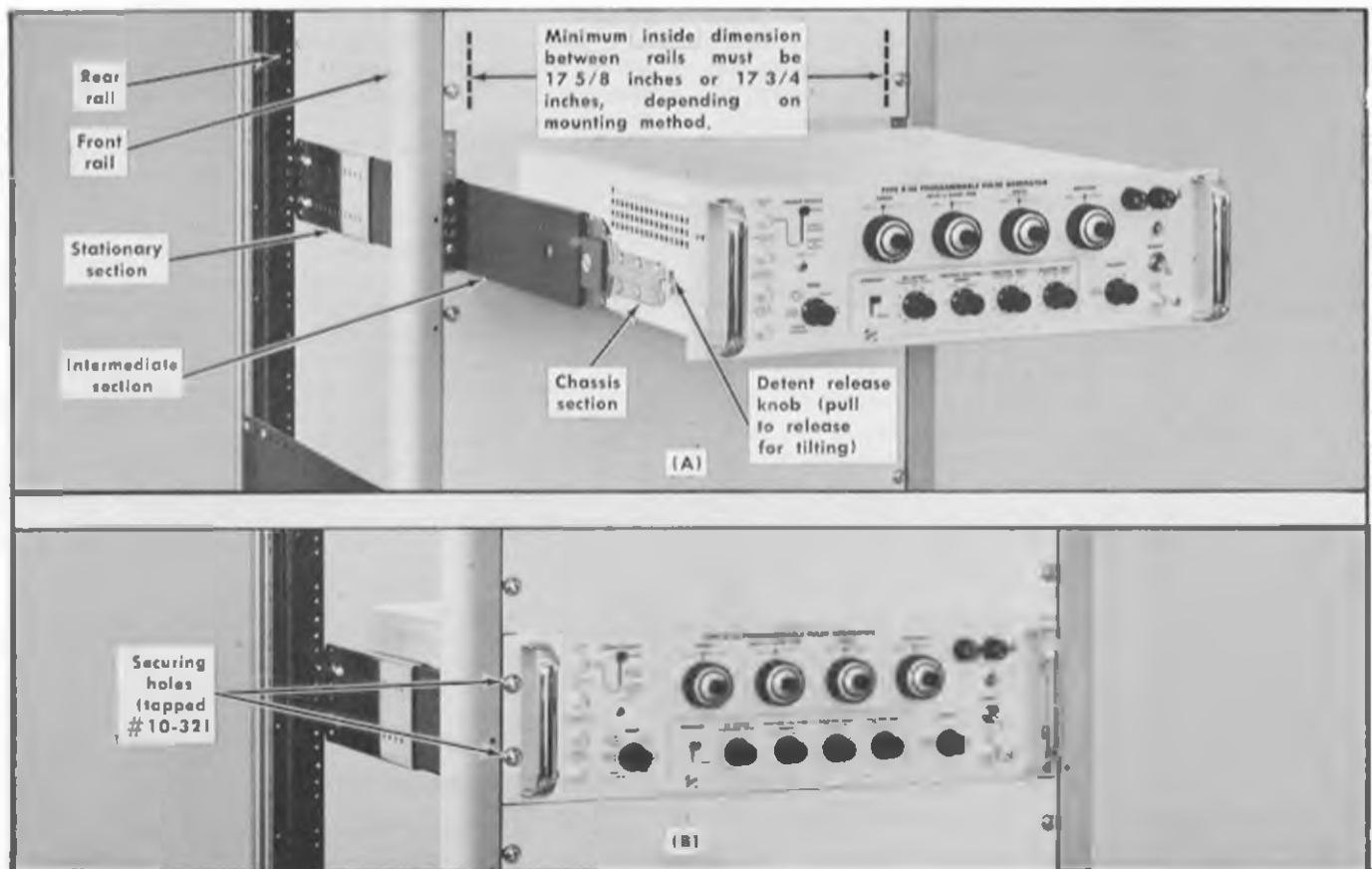


Fig. 7-1. The Type R116 installed in a cabinet-type rack with the slides removed: (A) Extended on the slideout tracks; (B) held into the rack with securing screws.



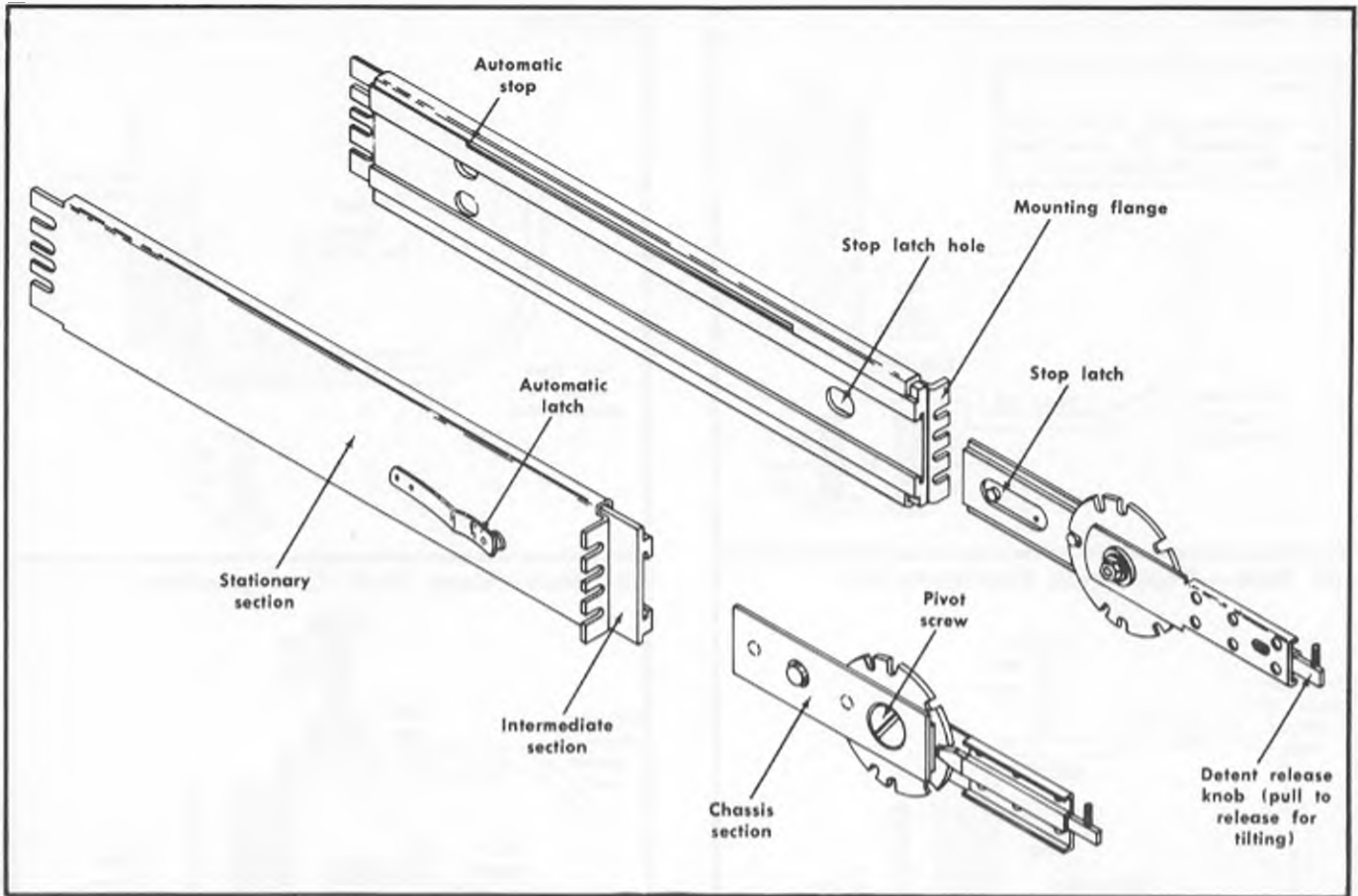


Fig. 7-2. Slideout track assembly for the left side of the instrument.

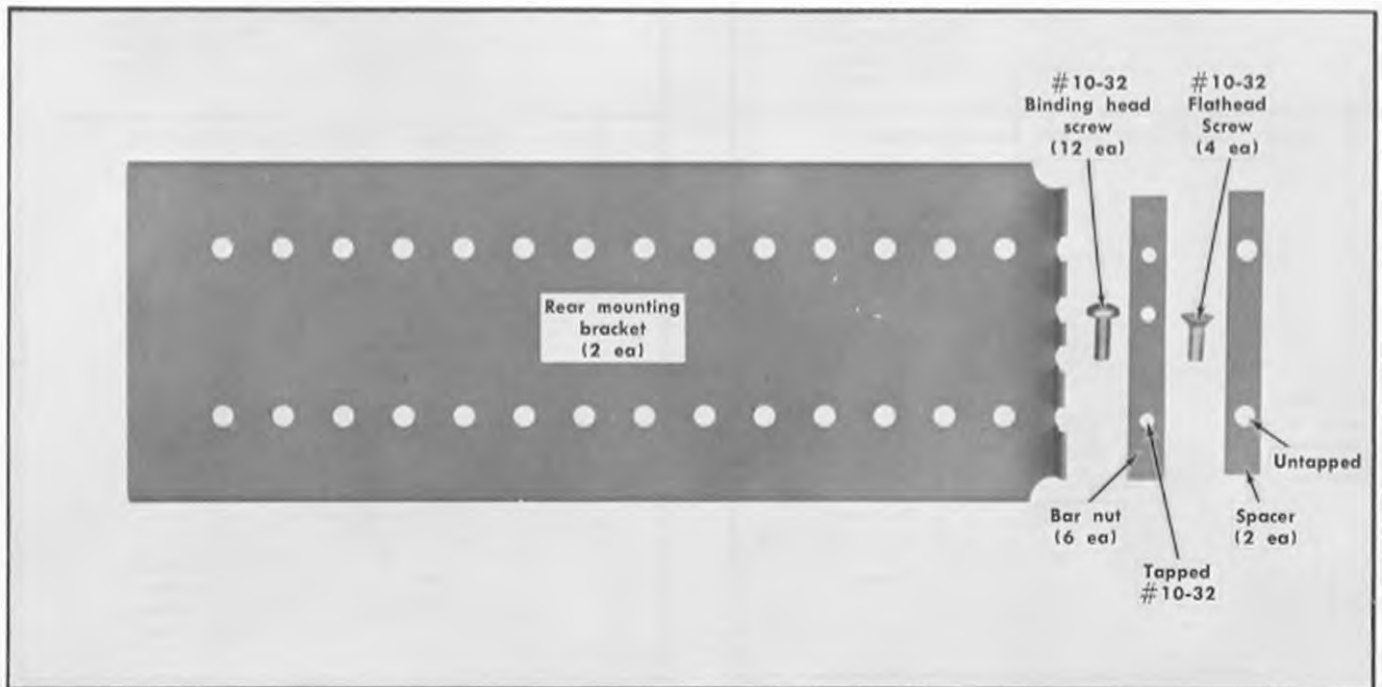


Fig. 7-3. Small hardware components provided for attaching the stationary sections of the slideout tracks to the cabinet-rack rails.

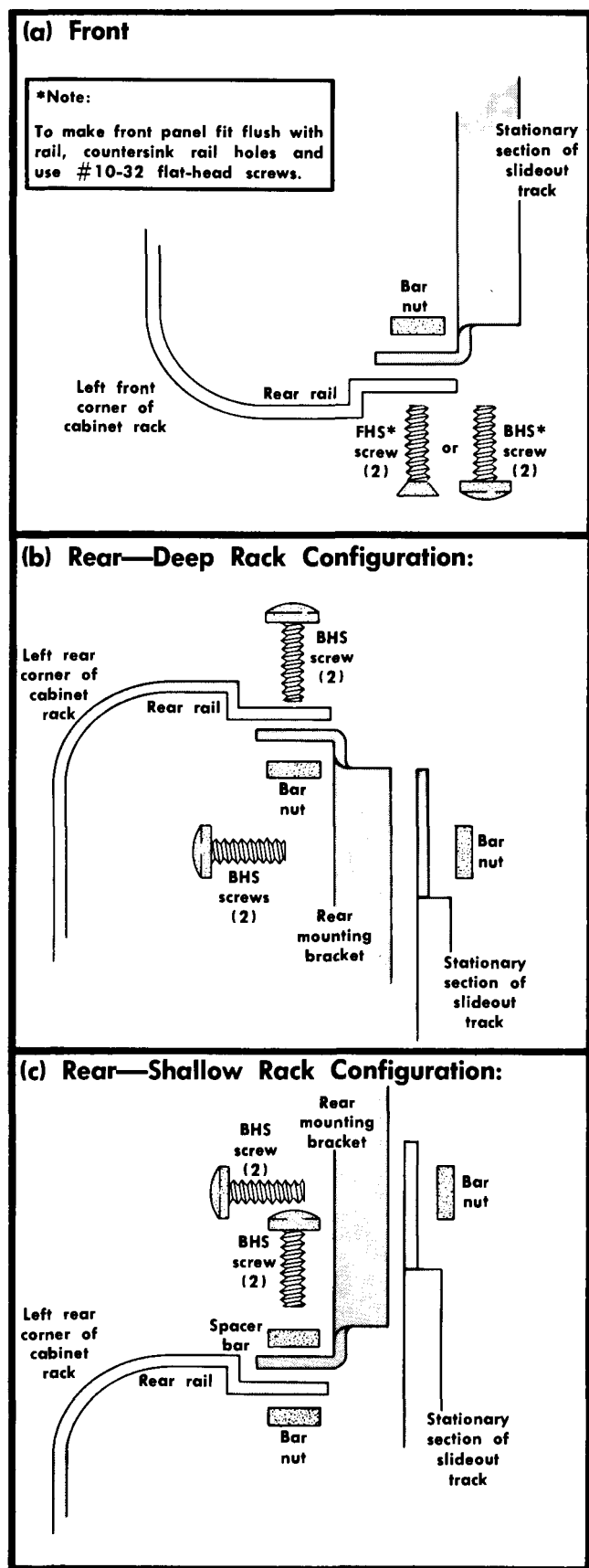


Fig. 7-4. Normal mounting position of the left stationary section for the minimum panel thickness.

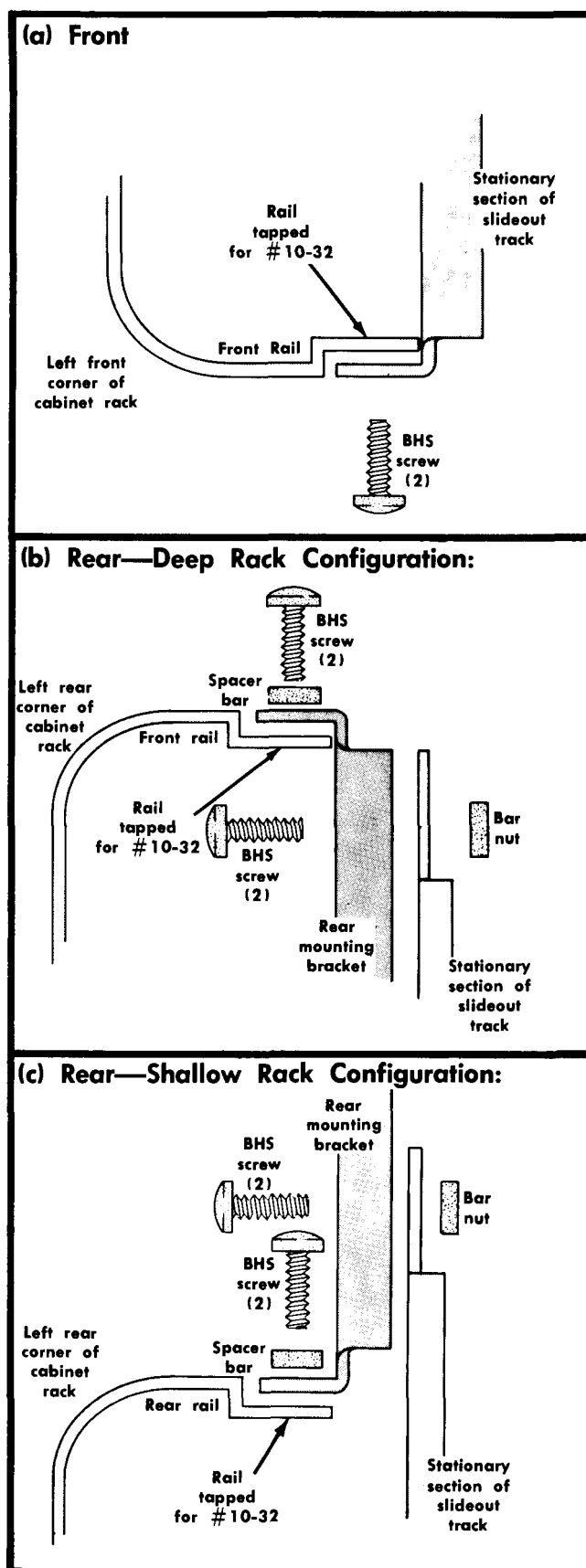


Fig. 7-5. Normal mounting position of the left stationary section if the mounting holes are tapped for 10-32 screws.

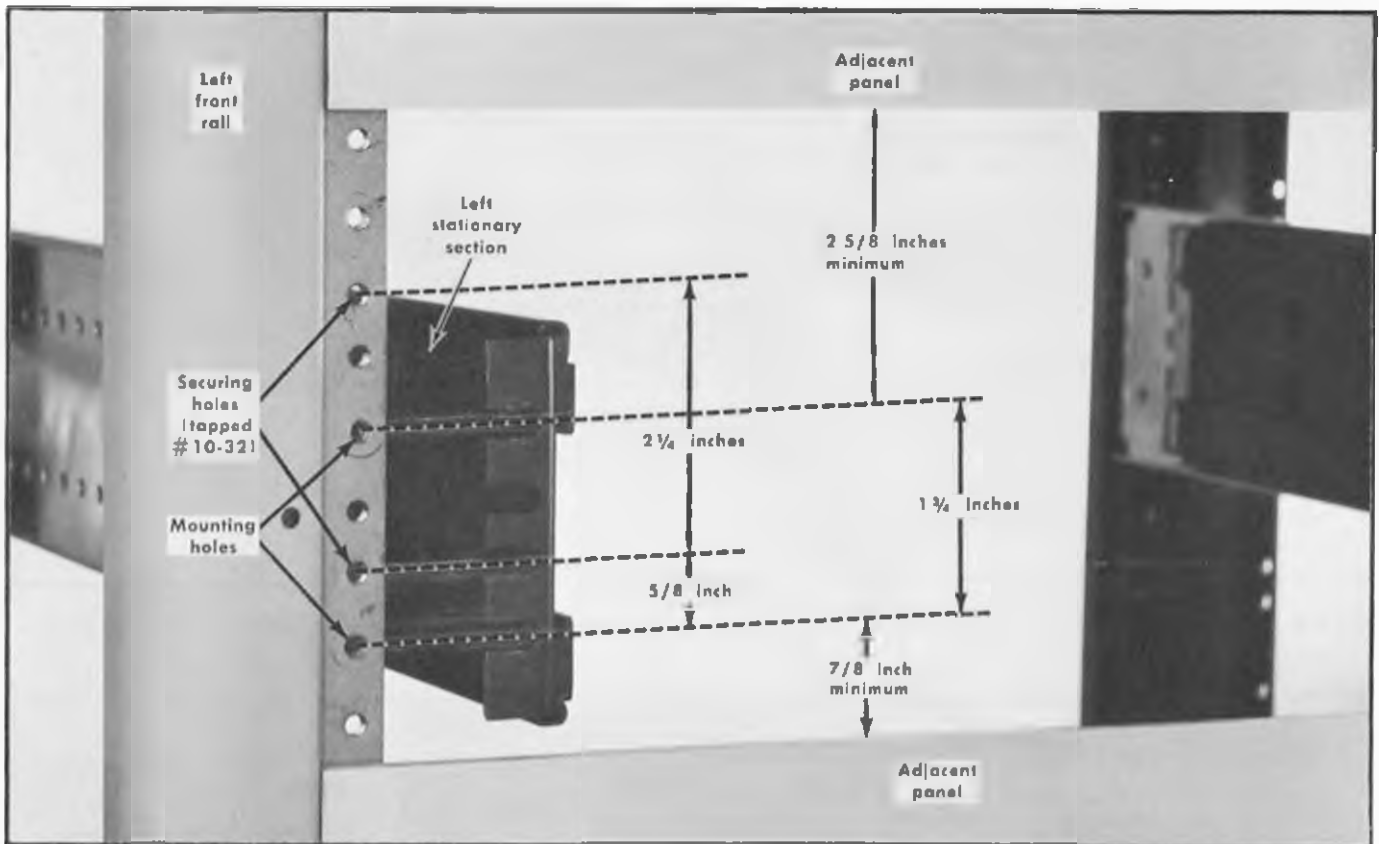


Fig. 7-6 Vertical mounting position of the stationary section. The same dimensions apply for mounting the right stationary section.

#### To adjust the front-end alignment:

1. Position the instrument with the pivot screws approximately even with the front rails.
2. Loosen the mounting screws at the front end of both stationary sections (only the left side is shown).
3. Allow the two slides to seek their normal width positions with the instrument centered in the rack.
4. Tighten the mounting screws.
5. Push the instrument all the way into the rack.
6. Check the vertical positioning of the Type R116 front panel with respect to adjacent instruments or panels. If the position is not correct, readjust the mounting screws as necessary.



Fig. 7-7 Stationary section front-end adjustments.

**To adjust a chassis section:**

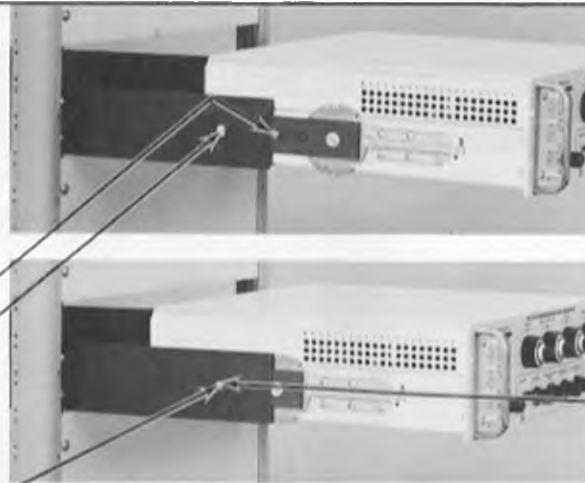
1. Remove the bottom dust cover from instrument.
2. Loosen the eccentric pivot screw nut (located inside the instrument) so the screw can be turned.
3. Adjust the pivot screw to align the slide with the bottom of the instrument. (This adjustment may also be made to position the front panel vertically or to obtain additional adjustment of the stationary sections.)
4. Hold the pivot screw in position and retighten the nut.
5. Repeat steps 2, 3 and 4 for the chassis section on the other side of the instrument if necessary.
6. Reinstall the bottom dust cover.



Fig. 7-8. Chassis section adjustments (if required). Perform only if proper positioning is not obtained with stationary section adjustments.

**To insert the Type R116:**

1. Pull the intermediate section of each slideout track out to its fully extended position.
2. Insert the chassis sections (fastened to the instrument) into the intermediate sections.
3. Press both stop latches and push the instrument into the rack until the latches snap into their holes.
4. Connect the power cord and program cable to the connectors on the rear panel of the instrument.
5. Again press the stop latches and push the instrument all the way into the rack. The automatic stop latches will disengage when the instrument is pushed in.
6. To secure the Type R116 into the rack, insert the 4 securing screws (with finishing washers and teflon washers) through the slots in the instrument front panel and screw them into the front rails of the rack.



**To remove the Type R116:**

1. Remove the securing screws and washers.
2. Pull the instrument outward until the automatic stops catch and the stop latches snap into their holes.
3. Disconnect the power cord and program cable from the instrument.
4. Press both stop latches and pull the instrument out of the rack.
5. Press the automatic stop latches and push the intermediate sections into the rack.

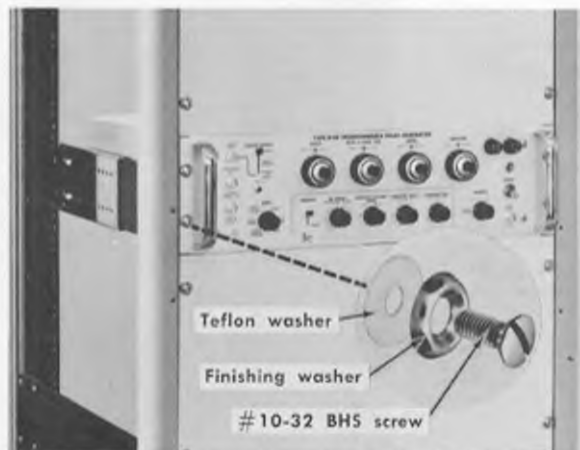


Fig. 7-9. Procedures for inserting the instrument and for removing it from the rack after the slideout tracks have been installed.

## PARTS LIST ABBREVIATIONS

BHB	binding head brass	int	internal
BHS	binding head steel	lg	length or long
cap.	capacitor	met.	metal
cer	ceramic	mtg hdw	mounting hardware
comp	composition	OD	outside diameter
conn	connector	OHB	oval head brass
CRT	cathode-ray tube	OHS	oval head steel
csk	countersunk	P/O	part of
DE	double end	PHB	pan head brass
dia	diameter	PHS	pan head steel
div	division	plstc	plastic
elect.	electrolytic	PMC	paper, metal cased
EMC	electrolytic, metal cased	poly	polystyrene
EMT	electrolytic, metal tubular	prec	precision
ext	external	PT	paper, tubular
F & I	focus and intensity	PTM	paper or plastic, tubular, molded
FHB	flat head brass	RHB	round head brass
FHS	flat head steel	RHS	round head steel
Fil HB	fillister head brass	SE	single end
Fil HS	fillister head steel	SN or S/N	serial number
h	height or high	S or SW	switch
hex.	hexagonal	TC	temperature compensated
HHB	hex head brass	THB	truss head brass
HHS	hex head steel	thk	thick
HSB	hex socket brass	THS	truss head steel
HSS	hex socket steel	tub.	tubular
ID	inside diameter	var	variable
inc	incandescent	w	wide or width
		WW	wire-wound

## **PARTS ORDERING INFORMATION**

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

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, instrument type or number, serial or model number, and modification number if applicable.

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

## **SPECIAL NOTES AND SYMBOLS**

×000	Part first added at this serial number
00×	Part removed after this serial number
*000-0000-00	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, Inc., or reworked or checked components.
Use 000-0000-00	Part number indicated is direct replacement.

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# SECTION 8

## ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part No.	Description	S/N Range
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### CHASSIS

#### Bulb

B403	150-0019-00	Neon, w/translucent lens in holder	
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#### Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C2	283-0111-00	0.1 $\mu$ F	Cer	50 V		
C110	290-0137-00	100 $\mu$ F	EMT	30 V	+75%—15%	X1240-up
C405	290-0310-00	2000 $\mu$ F	EMC	75 V	+75%—10%	
C410	290-0086-00	2000 $\mu$ F	EMC	30 V		
C413	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%	
C417A,B,C	290-0068-00	3 x 75 $\mu$ F	EMC	150 V		
C420	290-0310-00	2000 $\mu$ F	EMC	75 V	+75%—10%	
C437	283-0000-00	0.001 $\mu$ F	Cer	500 V		
C460	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%	
C464	283-0000-00	0.001 $\mu$ F	Cer	500 V		

#### Diodes

D405A,B,C,D(4)	152-0066-00	Silicon	1N3194			
D407	152-0089-00	Zener	10M12.6Z5	10 W, 12.6 V, 5%		
D410A,B,C,D(4)	152-0066-00	Silicon	1N3194			
D413	152-0055-00	Zener	1N962B	0.4 W, 11 V, 5%		
D420A,B,C,D(4)	152-0066-00	Silicon	1N3194			
D426	152-0066-00	Silicon	1N3194			
D430	152-0236-00	Zener	1N963B	0.4 W, 12.5 V, 4%		
D432	152-0119-00	Zener	1N969A	0.4 W, 22 V, 10%		1084-1269 1270-up
D432	152-0281-00	Zener	1N969B	0.4 W, 22 V, 5%		
D460	152-0166-00	Zener	1N753A	0.4 W, 6.2 V, 5%		
D482	*152-0185-00	Silicon	Replaceable by 1N4152			
D484	*152-0185-00	Silicon	Replaceable by 1N4152			
D570	*152-0185-00	Silicon	Replaceable by 1N4152			
D572	*152-0185-00	Silicon	Replaceable by 1N4152			

#### Fuses

F401	159-0043-00	0.6 A, 3AG, Slo-Blo	
F402	159-0043-00	0.6 A, 3AG, Slo-Blo	
F403	159-0053-00	5 A, Fast-Blo w/Pig Tail	X1159-1499X
F404	159-0053-00	5 A, Fast-Blo w/Pig Tail	X1159-1499X



## CHASSIS (cont)

Ckt. No.	Tektronix Part No.	Description	S/N Range
<b>Filter</b>			
FL401	119-0028-00	Line filter 250 V AC	1084-1499
FL401	119-0028-04	Line filter 250 V AC	1500-up
<b>Connectors</b>			
J1	131-0292-00	56 pin, for circuit card	1084-1139
J1	131-0292-01	56 pin, for circuit card	1140-up
J2	131-0292-00	56 pin, for circuit card	1084-1139
J2	131-0292-01	56 pin, for circuit card	1140-up
J3	131-0292-00	56 pin, for circuit card	1084-1139
J3	131-0292-01	56 pin, for circuit card	1140-up
J4	131-0292-00	56 pin, for circuit card	1084-1139
J4	131-0292-01	56 pin, for circuit card	1140-up
J5	131-0292-00	56 pin, for circuit card	1084-1139
J5	131-0292-01	56 pin, for circuit card	1140-up
J6	131-0292-00	56 pin, for circuit card	1084-1139
J6	131-0292-01	56 pin, for circuit card	1140-up
J7	131-0292-00	56 pin, for circuit card	1084-1139
J7	131-0292-01	56 pin, for circuit card	1140-up
J8	131-0292-00	56 pin, for circuit card	1084-1139
J8	131-0292-01	56 pin, for circuit card	1140-up
J9	131-0292-00	56 pin, for circuit card	1084-1139
J9	131-0292-01	56 pin, for circuit card	1140-up
J10	131-0294-00	36 pin, female	
J15	131-0352-00	BNC	
J20	131-0352-00	BNC	
J28	131-0352-00	BNC	
J80	131-0352-00	BNC	
J90	131-0352-00	BNC	
J401	*131-0430-01	Motor Base Assembly	1084-1199
J401	*131-0430-02	Motor Base Assembly	1200-up
<b>Inductors</b>			
L432	*108-0355-00	Coil, Reed Drive	
L437	276-0507-00	Core, Ferramic Suppressor	X1208-up
L480	*108-0355-00	Coil, Reed Drive	
L484A	108-0344-00	8.6 mH	
L484B	*108-0354-00	5 mH	
L484C	*108-0353-00	1.3 mH	
<b>Plug</b>			
P18	131-0375-00	Connector, coaxial, right angle, female	
<b>Transistors</b>			
Q407	151-0165-00	2N3614	
Q413	*151-0195-00	Replaceable by MPS-6515	
Q417	151-0165-00	2N3614	
Q423	151-0149-00	2N3441	
Q427	*151-0148-00	Selected (RCA 40250)	

**CHASSIS (cont)**

Ckt. No.	Tektronix Part No.	Description	S/N Range
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**Transistors (cont)**

Q437	151-0165-00	2N3614
Q444	151-0227-00	2N3741
Q464	151-0226-00	2N3767
Q474	151-0190-00	2N3904

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R403	301-0104-00	100 k $\Omega$	$\frac{1}{2}$ W			5%
R405	308-0165-00	0.5 $\Omega$	5 W		WW	5%
R410	307-0093-00	1.2 $\Omega$	$\frac{1}{2}$ W			5%
R413	302-0152-00	1.5 k $\Omega$	$\frac{1}{2}$ W			
R420	308-0165-00	0.5 $\Omega$	5 W		WW	5%
R431	301-0221-00	220 $\Omega$	$\frac{1}{2}$ W			5%
R432	301-0622-00	6.2 k $\Omega$	$\frac{1}{2}$ W			5%
R440	*310-0628-00	85 $\Omega$	8 W		Prec	1%
R442	*310-0526-00	102.9 $\Omega$	2 W		Prec	0.2%
R444	315-0470-00	47 $\Omega$	$\frac{1}{4}$ W			5%
R460	303-0102-00	1 k $\Omega$	1 W			5%
R464	315-0470-00	47 $\Omega$	$\frac{1}{4}$ W			5%
R466	311-0262-00	50 $\Omega$		Var	WW	
R468	306-0330-00	33 $\Omega$	2 W			
R476	311-0238-00	30 $\Omega$		Var	WW	5%
R478	304-0180-00	18 $\Omega$	1 W			
R478	308-0344-00	18.2 $\Omega$	3 W		WW	1%
R480	301-0221-00	220 $\Omega$	$\frac{1}{2}$ W			5%
R482	301-0822-00	8.2 k $\Omega$	$\frac{1}{2}$ W			5%
R484	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W			5%
R485	315-0682-00	6.8 k $\Omega$	$\frac{1}{4}$ W			5%
R486	301-0153-00	15 k $\Omega$	$\frac{1}{2}$ W			5%
R488	315-0182-00	1.8 k $\Omega$	$\frac{1}{4}$ W			5%
R502	311-0006-00	1 k $\Omega$		Var		
R504	311-0537-01	20 k $\Omega$		Var	WW	1%
R512	311-0006-00	1 k $\Omega$		Var		
R513	311-0598-00	500 $\Omega$		Var		
R514	311-0536-01	10 k $\Omega$		Var	WW	1%
R522	311-0006-00	1 k $\Omega$		Var		
R523	311-0598-00	500 $\Omega$		Var		
R524	311-0536-01	10 k $\Omega$		Var	WW	1%
R530	321-0162-00	475 $\Omega$		Selected (nominal value)		
R532	311-0006-00	1 k $\Omega$		Var		
R534	311-0536-01	10 k $\Omega$		Var	WW	1%

# Electrical Parts List—Type R116 (SN 1084-up)

## CHASSIS (cont)

Ckt. No.	Tektronix Part No.	Description	S/N Range
<b>Resistors (cont)</b>			
R536	315-0122-00	1.2 k $\Omega$	5% 1084-1239X
R540	321-0197-00	1.1 k $\Omega$	
R542	311-0536-01	10 k $\Omega$	
R544	311-0006-00	1 k $\Omega$	
R552	311-0543-01	4 k $\Omega$	
R554	311-0521-00	250 $\Omega$	1% WW
R562	311-0543-01	4 k $\Omega$	
R564	311-0521-00	250 $\Omega$	

## Switches

	Unwired	Wired			
SW1	260-0705-00	1084	1429	Rotary	PERIOD
SW1	260-0705-01	1430		Rotary	PERIOD
SW2	260-0706-00	1084	1429	Rotary	DELAY OR BURST TIME
SW2	260-0706-01	1430		Rotary	DELAY OR BURST TIME
SW3	260-0706-00	1084	1429	Rotary	WIDTH
SW3	260-0706-01	1430		Rotary	WIDTH
SW4	260-0707-00	1084	1429	Rotary	AMPLITUDE
SW4	260-0707-01	1430		Rotary	AMPLITUDE
SW5	260-0708-00			Rotary	MODE
SW6	260-0490-00			Lever	TRIGGER SOURCE
SW7	260-0709-00			Rotary	POLARITY
SW8	260-0710-00			Rotary	RISETIME FALLTIME RANGE
SW9	260-0711-00			Lever	PROGRAM
SW10	260-0247-00			Push-Button	TRIG
SW401	260-0199-00			Toggle	POWER ON
SW402	260-0675-00			Slide	
SW432	260-0552-00			Reed	
SW480	260-0552-00			Reed	

## Thermal Cutout

TK402	260-0618-00	Thermal Cutout 140°F $\pm$ 5°
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## Transformer

T401	*120-0457-00	Power
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## FUNCTION PROGRAM #2 CARD—Series K

Ckt. No.	Tektronix Part No.	Description	Model No.
	*670-0213-01	Complete Card	
<b>Diodes</b>			
D3	*152-0185-00	Silicon	Replaceable by 1N4152
D4	*152-0185-00	Silicon	Replaceable by 1N4152
D13	*152-0185-00	Silicon	Replaceable by 1N4152
D14	*152-0185-00	Silicon	Replaceable by 1N4152
D23	*152-0185-00	Silicon	Replaceable by 1N4152

## FUNCTION PROGRAM #2 CARD—Series K (cont)

Ckt. No.	Tektronix Part No.	Description		Model No.
Diodes (cont)				
D24	*152-0185-00	Silicon	Replaceable by 1N4152	X2-up
D33	*152-0185-00	Silicon	Replaceable by 1N4152	
D34	*152-0185-00	Silicon	Replaceable by 1N4152	
D43	*152-0185-00	Silicon	Replaceable by 1N4152	
D44	*152-0185-00	Silicon	Replaceable by 1N4152	
D53	*152-0185-00	Silicon	Replaceable by 1N4152	
D73	*152-0185-00	Silicon	Replaceable by 1N4152	
D74	*152-0185-00	Silicon	Replaceable by 1N4152	
D75	*152-0185-00	Silicon	Replaceable by 1N4152	
D76	*152-0185-00	Silicon	Replaceable by 1N4152	
D78	*152-0185-00	Silicon	Replaceable by 1N4152	
D83	*152-0185-00	Silicon	Replaceable by 1N4152	
D84	*152-0185-00	Silicon	Replaceable by 1N4152	
D86	*152-0185-00	Silicon	Replaceable by 1N4152	
D93	*152-0185-00	Silicon	Replaceable by 1N4152	
D94	*152-0185-00	Silicon	Replaceable by 1N4152	
D95	*152-0185-00	Silicon	Replaceable by 1N4152	
D100	*152-0185-00	Silicon	Replaceable by 1N4152	
D103	*152-0185-00	Silicon	Replaceable by 1N4152	
D104	*152-0185-00	Silicon	Replaceable by 1N4152	

**Inductors**

L75	*108-0355-00	Coil, Reed Drive
L78	*108-0355-00	Coil, Reed Drive

**Transistors**

Q3	151-0164-00	Silicon	2N3702
Q13	151-0164-00	Silicon	2N3702
Q23	151-0164-00	Silicon	2N3702
Q33	151-0164-00	Silicon	2N3702
Q43	151-0164-00	Silicon	2N3702
Q53	151-0164-00	Silicon	2N3702
Q63	151-0164-00	Silicon	2N3702
Q73	151-0164-00	Silicon	2N3702
Q76	151-0190-00	Silicon	2N3904
Q83	151-0164-00	Silicon	2N3702
Q93	151-0164-00	Silicon	2N3702
Q103	151-0164-00	Silicon	2N3702

## FUNCTION PROGRAM #2 CARD—Series K (cont)

Ckt. No.	Tektronix Part No.	Description			Model No.
Resistors					
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.					
R1	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	1, 2 3-up
R3	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R10	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	
R13	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R20	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	
R23	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R30	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W	5%	
R33	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R40	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W	5%	
R43	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R50	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W	5%	
R53	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R60	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	
R63	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R70	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W	5%	
R73	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R75	303-0221-00	220 $\Omega$	1 W	5%	
R75	304-0121-00	120 $\Omega$	1 W		
R76	315-0472-00	4.7 k $\Omega$	$\frac{1}{4}$ W	5%	
R77	315-0102-00	1 k $\Omega$	$\frac{1}{4}$ W	5%	
R78	301-0221-00	220 $\Omega$	$\frac{1}{2}$ W	5%	
R80	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W	5%	
R83	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R90	315-0392-00	3.9 k $\Omega$	$\frac{1}{4}$ W	5%	
R93	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	
R95	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	
R100	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%	
R103	315-0333-00	33 k $\Omega$	$\frac{1}{4}$ W	5%	

**Switches**

	Unwired	Wired	
SW75	260-0552-00		Reed
SW78	260-0552-00		Reed

## PERIOD GENERATOR CARD—Series B

\*670-0214-00 Complete Card (Used on Instrument S/N 1084-1359)

**Capacitors**Tolerance  $\pm 20\%$  unless otherwise indicated.

C5	281-0516-00	39 pF	Cer	500 V	10%
C14	281-0509-00	15 pF	Cer	500 V	10%
C34	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%
C36	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C41	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%

## PERIOD GENERATOR CARD—Series B (cont)

Ckt. No.	Tektronix Part No.	Description				Model No.
Capacitors (cont)						
C42	283-0059-00	1 $\mu$ F	Cer		500 V	+80%—20%
C44	283-0059-00	1 $\mu$ F	Cer		500 V	+80%—20%
C52	281-0096-00	5.5-18 pF	Air	Var		
C53	281-0512-00	27 pF	Cer		500 V	10%
C55	281-0097-00	9-35 pF	Cer	Var		
C56	283-0628-00	410 pF	Mica		500 V	1%
C58	*295-0091-00	0.005 $\mu$ F	(matched set)			
C59		0.05 $\mu$ F				
C60		0.5 $\mu$ F				
C74	283-0003-00	0.01 $\mu$ F	Cer		150 V	
C82	281-0511-00	22 pF	Cer		500 V	10%
C90	283-0003-00	0.01 $\mu$ F	Cer		150 V	
C94	281-0543-00	270 pF	Cer		500 V	10%
C95	290-0162-00	22 $\mu$ F	EMT		35 V	
C96	290-0135-00	15 $\mu$ F	EMT		20 V	
C97	283-0080-00	0.022 $\mu$ F	Cer		25 V	+80%—20%
C98	290-0135-00	15 $\mu$ F	EMT		20 V	
C99	290-0162-00	22 $\mu$ F	EMT		35 V	

**Diodes**

D16	*152-0185-00	Silicon	Replaceable by 1N4152			
D22	*152-0185-00	Silicon	Replaceable by 1N4152			
D34	*152-0185-00	Silicon	Replaceable by 1N4152			
D35	*152-0185-00	Silicon	Replaceable by 1N4152			
D44	152-0071-00	Germanium	ED-2007			
D50	152-0034-00	Zener	1N753	0.4 W, 6.2 V, 10%		2,3,4
D50	152-0280-00	Zener	1N753A	0.4 W, 6.2 V, 5%		5-up

**Inductors**

L61	*108-0355-00	Coil, Reed Drive
L62	*108-0355-00	Coil, Reed Drive
L63	*108-0355-00	Coil, Reed Drive
L64	*108-0355-00	Coil, Reed Drive
L78	276-0541-00	Core, Ferrite

**Transistors**

Q4	*151-0108-00	Replaceable by 2N2501
Q14	*151-0133-00	Selected from 2N3251
Q24	*151-0127-00	Selected from 2N2369
Q38	*151-0103-00	Replaceable by 2N2219
Q43	*151-0127-00	Selected from 2N2369

## PERIOD GENERATOR CARD—Series B (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
<b>Transistors (cont)</b>			
Q55	*151-0127-00	Selected from 2N2369	2
Q55	*151-0108-00	Replaceable by 2N2501	3-up
Q65	*151-0127-00	Selected from 2N2369	
Q74	151-0221-00	2N4258	2
Q74	*151-0133-00	Selected from 2N3251	3-up
Q84	*151-0127-00	Selected from 2N2369	
Q93	*151-0108-00	Replaceable by 2N2501	
Q94	*151-0133-00	Selected from 2N3251	

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R1	301-0102-00	1 k $\Omega$	$\frac{1}{2}$ W	5%
R3	301-0512-00	5.1 k $\Omega$	$\frac{1}{2}$ W	5%
R5	301-0153-00	15 k $\Omega$	$\frac{1}{2}$ W	5%
R6	301-0471-00	470 $\Omega$	$\frac{1}{2}$ W	5%
R8	301-0102-00	1 k $\Omega$	$\frac{1}{2}$ W	5%
R14	301-0103-00	10 k $\Omega$	$\frac{1}{2}$ W	5%
R16	301-0223-00	22 k $\Omega$	$\frac{1}{2}$ W	5%
R18	301-0202-00	2 k $\Omega$	$\frac{1}{2}$ W	5%
R20	301-0101-00	100 $\Omega$	$\frac{1}{2}$ W	5%
R22	301-0203-00	20 k $\Omega$	$\frac{1}{2}$ W	5%
R24	301-0561-00	560 $\Omega$	$\frac{1}{2}$ W	5%
R32	315-0302-00	3 k $\Omega$	$\frac{1}{4}$ W	5%
R34	311-0496-00	2.5 k $\Omega$		
R36	321-0204-00	1.3 k $\Omega$	$\frac{1}{8}$ W	1%
R38	307-0108-00	6.8 $\Omega$	$\frac{1}{4}$ W	5%
R40	301-0471-00	470 $\Omega$	$\frac{1}{2}$ W	5%
R41	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W	5%
R42	301-0162-00	1.6 k $\Omega$	$\frac{1}{2}$ W	5%
R44	301-0682-00	6.8 k $\Omega$	$\frac{1}{2}$ W	5%
R46	315-0820-00	82 $\Omega$	$\frac{1}{4}$ W	5%
R50	301-0751-00	750 $\Omega$	$\frac{1}{2}$ W	5%
R52	307-0108-00	6.8 $\Omega$	$\frac{1}{4}$ W	5%
R61	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W	5%
R62	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W	5%
R63	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W	5%
R64	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W	5%
R67	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W	5%
R74	315-0302-00	3 k $\Omega$	$\frac{1}{4}$ W	5%
R78	315-0910-00	91 $\Omega$	$\frac{1}{4}$ W	5%
R82	301-0102-00	1 k $\Omega$	$\frac{1}{2}$ W	5%

Var

Prec

## PERIOD GENERATOR CARD—Series B (cont)

Ckt. No.	Tektronix Part No.	Description			Model No.
Resistors (cont)					
R86	301-0102-00	1 kΩ	½ W	5%	
R90	315-0471-00	470 Ω	¼ W	5%	
R92	301-0471-00	470 Ω	½ W		2,3
R92	301-0182-00	1.8 kΩ	½ W	5%	4-up
R94	301-0102-00	1 kΩ	½ W		2,3
R94	301-0471-00	470 Ω	½ W	5%	4-up
R95	307-0053-00	3.3 Ω	½ W	5%	
R96	307-0053-00	3.3 Ω	½ W	5%	
R98	307-0053-00	3.3 Ω	½ W	5%	
R99	301-0100-00	10 Ω	½ W	5%	

**Switches**

	Unwired	Wired	
SW61	260-0552-00		Reed
SW62	260-0552-00		Reed
SW63	260-0552-00		Reed
SW64	260-0552-00		Reed

**Transformer**

T70	*120-0417-00	Toroid, 6 turns, bifilar
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## PERIOD GENERATOR CARD—Series Q

\*670-0214-01 Complete Card (Used on Instrument S/N 1360-up)

**Capacitors**Tolerance  $\pm 20\%$  unless otherwise indicated.

C5	281-0516-00	39 pF	Cer	500 V	10%
C14	281-0509-00	15 pF	Cer	500 V	10%
C34	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%
C36	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C41	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%
C42	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%
C44	283-0059-00	1 $\mu$ F	Cer	500 V	+80%—20%
C52	281-0096-00	5.5-18 pF	Air	Var	
C53	281-0512-00	27 pF	Cer	500 V	10%
C55	281-0097-00	9-35 pF	Cer	Var	
C56	283-0628-00	410 pF	Mica	500 V	1%
C58	*295-0091-00	0.005 $\mu$ F	(matched set)		
C59		0.05 $\mu$ F			
C60		0.5 $\mu$ F			
C74	283-0003-00	0.01 $\mu$ F	Cer	150 V	



## PERIOD GENERATOR CARD—Series Q (cont)

Ckt. No.	Tektronix Part No.	Description				Model No.
Capacitors (cont)						
C82	281-0511-00	22 pF	Cer	500 V	10%	
C90	283-0003-00	0.01 $\mu$ F	Cer	150 V		
C94	281-0543-00	270 pF	Cer	500 V	10%	
C95	290-0162-00	22 $\mu$ F	EMT	35 V		
C96	290-0135-00	15 $\mu$ F	EMT	20 V		
C97	283-0080-00	0.022 $\mu$ F	Cer	25 V	+80%—20%	
C98	290-0135-00	15 $\mu$ F	EMT	20 V		
C99	290-0162-00	22 $\mu$ F	EMT	35 V		
Diodes						
D16	*152-0185-00	Silicon	Replaceable by 1N4152			
D22	*152-0185-00	Silicon	Replaceable by 1N4152			
D34	*152-0185-00	Silicon	Replaceable by 1N4152			
D35	*152-0185-00	Silicon	Replaceable by 1N4152			
D44	152-0071-00	Germanium	ED-2007			
D50	152-0280-00	Zener	1N753A 0.4 W, 6.2 V, 5%			
D83	*152-0185-00	Silicon	Replaceable by 1N4152			
Inductors						
L61	*108-0355-00	Coil, Reed Drive				
L62	*108-0355-00	Coil, Reed Drive				
L63	*108-0355-00	Coil, Reed Drive				
L64	*108-0355-00	Coil, Reed Drive				
L78	276-0541-00	Core, Ferrite				
Transistors						
Q4	*151-0108-00	Replaceable by 2N2501				
Q14	*151-0133-00	Selected from 2N3251				
Q24	*151-0127-00	Selected from 2N2369				
Q38	*151-0103-00	Replaceable by 2N2219				
Q43	*151-0127-00	Selected from 2N2369				
Q55	*151-0108-00	Replaceable by 2N2501				
Q65	*151-0127-00	Selected from 2N2369				
Q74	*151-0133-00	Selected from 2N3251				
Q84	*151-0127-00	Selected from 2N2369				
Q93	*151-0108-00	Replaceable by 2N2501				
Q94	*151-0133-00	Selected from 2N3251				
Resistors						
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.						
R1	301-0102-00	1 k $\Omega$	$\frac{1}{2}$ W		5%	
R3	301-0512-00	5.1 k $\Omega$	$\frac{1}{2}$ W		5%	
R5	301-0153-00	15 k $\Omega$	$\frac{1}{2}$ W		5%	
R6	301-0471-00	470 $\Omega$	$\frac{1}{2}$ W		5%	
R8	301-0102-00	1 k $\Omega$	$\frac{1}{2}$ W		5%	

## PERIOD GENERATOR CARD—Series Q (cont)

Ckt. No.	Tektronix Part No.		Description			Model No.
Resistors (cont)						
R14	301-0103-00	10 kΩ	1/2 W			5%
R16	301-0223-00	22 kΩ	1/2 W			5%
R18	301-0202-00	2 kΩ	1/2 W			5%
R20	301-0101-00	100 Ω	1/2 W			5%
R22	301-0203-00	20 kΩ	1/2 W			5%
R24	301-0561-00	560 Ω	1/2 W			5%
R32	315-0302-00	3 kΩ	1/4 W			5%
R34	311-0496-00	2.5 kΩ		Var	Prec	
R36	321-0204-00	1.3 kΩ	1/8 W			
R38	307-0108-00	6.8 Ω	1/4 W			
R40	301-0471-00	470 Ω	1/2 W			5%
R41	301-0391-00	390 Ω	1/2 W			5%
R42	301-0162-00	1.6 kΩ	1/2 W			5%
R44	301-0682-00	6.8 kΩ	1/2 W			5%
R46	315-0820-00	82 Ω	1/4 W			5%
R50	301-0751-00	750 Ω	1/2 W			5%
R52	307-0108-00	6.8 Ω	1/4 W			5%
R61	301-0271-00	270 Ω	1/2 W			5%
R62	301-0271-00	270 Ω	1/2 W			5%
R63	301-0271-00	270 Ω	1/2 W			5%
R64	301-0271-00	270 Ω	1/2 W			5%
R67	315-0123-00	12 kΩ	1/4 W			5%
R74	315-0302-00	3 kΩ	1/4 W			5%
R78	315-0910-00	91 Ω	1/4 W			5%
R82	301-0182-00	1 kΩ	1/2 W			5%
R83	315-0123-00	12 kΩ	1/4 W			5%
R86	301-0102-00	1 kΩ	1/2 W			5%
R90	315-0471-00	470 Ω	1/4 W			5%
R92	301-0182-00	1.8 kΩ	1/2 W			5%
R94	301-0471-00	470 Ω	1/2 W			5%
R95	307-0053-00	3.3 Ω	1/2 W			5%
R96	307-0053-00	3.3 Ω	1/2 W			5%
R98	307-0053-00	3.3 Ω	1/2 W			5%
R99	301-0100-00	10 Ω	1/2 W			5%

**Switches**

	Unwired	Wired	
SW61	260-0552-00		Reed
SW62	260-0552-00		Reed
SW63	260-0552-00		Reed
SW64	260-0552-00		Reed

## PERIOD GENERATOR CARD—Series Q (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
<b>Transformer</b>			
T70	*120-0417-00	Toroid, 6 turns, bifilar	

## DELAY GENERATOR CARD—Series C

\*670-0215-00 Complete Card (Used on Instrument S/N 1084-1207)

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V	
C2	283-0080-00	0.22 $\mu$ F	Cer	25 V	+80%—20%
C3	290-0135-00	15 $\mu$ F	EMT	20 V	
C4	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C5	290-0135-00	15 $\mu$ F	EMT	20 V	
C7	290-0162-00	22 $\mu$ F	EMT	35 V	
C14	281-0504-00	10 pF	Cer	500 V	10%
C28	281-0592-00	4.7 pF	Cer		$\pm 0.5$ pF
C30	281-0558-00	18 pF	Cer	500 V	
C32	281-0096-00	5.5-18 pF	Air	Var	
C33	283-0113-00	56 pF	Cer	500 V	1%
C34	*295-0092-00	925 pF	(matched set)		
C35		0.01 $\mu$ F			
C36		0.1 $\mu$ F			
C41	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C45	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C53	281-0540-00	51 pF	Cer		5%
C62	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C85	281-0523-00	100 pF	Cer	500 V	
C92	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C95	281-0523-00	100 pF	Cer	500 V	

## Diodes

D26	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D27	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D50	*152-0322-00	Silicon	Tek Spec	
D68	152-0071-00	Germanium	ED-2007	
D92	*152-0185-00	Silicon	Replaceable by 1N4152	

## Inductors

L26	*108-0170-01	0.5 $\mu$ H	
L55	*108-0355-00	Coil, Reed Drive	
L56	*108-0355-00	Coil, Reed Drive	
L57	*108-0355-00	Coil, Reed Drive	
L58	*108-0355-00	Coil, Reed Drive	
L68	276-0557-00	Core, Toroid Ferrite	

## DELAY GENERATOR CARD—Series C (cont)

Ckt No.	Tektronix Part No.	Description			Model No.
Transistors					
Q14	*151-0108-00	Replaceable by 2N2501			
Q15	*151-0127-00	Selected from 2N2369			
Q24	*151-0127-00	Selected from 2N2369			
Q25	*151-0127-00	Selected from 2N2369			
Q38	*151-0103-00	Replaceable by 2N2219			
Q53	*151-0108-00	Replaceable by 2N2501			
Q64	*151-0127-00	Selected from 2N2369			
Q73	151-0221-00	2N4258			
Q83	*151-0127-00	Selected from 2N2369			
Q94	*151-0127-00	Selected from 2N2369			
Resistors					
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.					
R1	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R3	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R5	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R7	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R14	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R16	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R18	301-0472-00	4.7 k $\Omega$	$\frac{1}{2}$ W		5%
R20	301-0162-00	1.6 k $\Omega$	$\frac{1}{2}$ W		5%
R22	311-0496-00	2.5 k $\Omega$		Var	
R24	301-0241-00	240 $\Omega$	$\frac{1}{2}$ W		5%
R25	307-0060-00	6.8 $\Omega$	$\frac{1}{2}$ W		5%
R26	301-0331-00	330 $\Omega$	$\frac{1}{2}$ W		5%
R28	315-0362-00	3.6 k $\Omega$	$\frac{1}{4}$ W		5%
R29	301-0510-00	51 $\Omega$	$\frac{1}{2}$ W		5%
R30	301-0681-00	680 $\Omega$	$\frac{1}{2}$ W		5%
R33	307-0110-00	3 $\Omega$	$\frac{1}{4}$ W		5%
R34	315-0220-00	22 $\Omega$	$\frac{1}{4}$ W		5%
R38	301-0510-00	51 $\Omega$	$\frac{1}{2}$ W		5%
R40	301-0242-00	2.4 k $\Omega$	$\frac{1}{2}$ W		5%
R41	311-0462-00	1 k $\Omega$		Var	
R42	301-0202-00	2 k $\Omega$	$\frac{1}{2}$ W		5%
R45	322-0151-00	365 $\Omega$	$\frac{1}{4}$ W	Prec	
R50	301-0101-00	100 $\Omega$	$\frac{1}{2}$ W		5%
R53	321-0165-00	511 $\Omega$	$\frac{1}{8}$ W	Prec	
R54	321-0209-00	1.47 k $\Omega$	$\frac{1}{8}$ W	Prec	
R55	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R56	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R57	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R58	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R60	321-0163-00	487 $\Omega$	$\frac{1}{8}$ W	Prec	

## DELAY GENERATOR CARD—Series C (cont)

Ckt. No.	Tektronix Part No.		Description	Model No.
Resistors (cont)				
R62	321-0165-00	511 $\Omega$	$\frac{1}{8}$ W	Prec 1%
R65	301-0821-00	820 $\Omega$	$\frac{1}{2}$ W	5%
R70	301-0820-00	82 $\Omega$	$\frac{1}{2}$ W	5%
R73	301-0432-00	4.3 k $\Omega$	$\frac{1}{2}$ W	5%
R80	301-0101-00	100 $\Omega$	$\frac{1}{2}$ W	5%
R83	301-0470-00	47 $\Omega$	$\frac{1}{2}$ W	5%
R85	301-0202-00	2 k $\Omega$	$\frac{1}{2}$ W	5%
R90	301-0511-00	510 $\Omega$	$\frac{1}{2}$ W	5%
R92	301-0123-00	12 k $\Omega$	$\frac{1}{2}$ W	5%

**Switches**

	Unwired	Wired	
SW55	260-0552-00		Reed
SW56	260-0552-00		Reed
SW57	260-0552-00		Reed
SW58	260-0552-00		Reed

## DELAY GENERATOR CARD—Series O

\*670-0215-01 Complete Card (Used on Instrument S/N 1208-up)

**Capacitors**Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V		
C2	283-0080-00	0.22 $\mu$ F	Cer	25 V	+80%—20%	
C3	290-0135-00	15 $\mu$ F	EMT	20 V		
C4	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%	
C5	290-0135-00	15 $\mu$ F	EMT	20 V		
C7	290-0162-00	22 $\mu$ F	EMT	35 V		
C14	281-0504-00	10 pF	Cer	500 V	10%	
C28	281-0592-00	4.7 pF	Cer		$\pm 0.5$ pF	
C30	281-0558-00	18 pF	Cer	500 V		
C32	281-0096-00	5.5-18 pF	Air	Var		
C33	283-0113-00	56 pF	Cer		500 V	1%
C34 } C35 } C36 }	*295-0092-00	925 pF	(matched set)			1
		0.01 $\mu$ F				
		0.1 $\mu$ F				
C34 } C35 } C36 }	*295-0092-00	905 pF	(matched set)			2-up
		0.0099 $\mu$ F				
		0.1 $\mu$ F				

## DELAY GENERATOR CARD—Series O (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
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**Capacitors (cont)**

C41	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C45	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C53	281-0540-00	51 pF	Cer		5%
C62	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C85	281-0523-00	100 pF	Cer	500 V	
C92	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C95	281-0519-00	47 pF	Cer	350 V	10%

**Diodes**

D26	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D27	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D50	*152-0322-00	Silicon	Tek Spec	
D68	152-0071-00	Germanium	ED-2007	
D92	*152-0185-00	Silicon	Replaceable by 1N4152	

**Inductors**

L26	*108-0170-01	0.5 $\mu$ H
L55	*108-0355-00	Coil, Reed Drive
L56	*108-0355-00	Coil, Reed Drive
L57	*108-0355-00	Coil, Reed Drive
L58	*108-0355-00	Coil, Reed Drive
L68	276-0557-00	Core, Toroid Ferrite

**Transistors**

Q14	*151-0108-00	Replaceable by 2N2501
Q15	*151-0127-00	Selected from 2N2369
Q24	*151-0127-00	Selected from 2N2369
Q25	*151-0127-00	Selected from 2N2369
Q38	*151-0103-00	Replaceable by 2N2219
Q53	*151-0108-00	Replaceable by 2N2501
Q64	*151-0127-00	Selected from 2N2369
Q73	151-0221-00	2N4258
Q83	*151-0127-00	Selected from 2N2369
Q94	*151-0127-00	Selected from 2N2369

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R1	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W	5%
R3	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W	5%
R5	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W	5%
R7	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W	5%
R14	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W	5%

## DELAY GENERATOR CARD—Series O (cont)

Ckt. No.	Tektronix Part No.		Description		Model No.	
Resistors (cont)						
R16	301-0391-00	390 Ω	1/2 W	Var		5%
R18	301-0472-00	4.7 kΩ	1/2 W			5%
R20	301-0162-00	1.6 kΩ	1/2 W			5%
R22	311-0496-00	2.5 kΩ				
R24	301-0241-00	240 Ω	1/2 W			5%
R25	307-0060-00	6.8 Ω	1/2 W			5%
R26	301-0331-00	330 Ω	1/2 W			5%
R28	315-0362-00	3.6 kΩ	1/4 W			5%
R29	301-0510-00	51 Ω	1/2 W			5%
R30	301-0681-00	680 Ω	1/2 W			5%
R33	307-0110-00	3 Ω	1/4 W			5%
R34	315-0220-00	22 Ω	1/4 W			5%
R38	301-0510-00	51 Ω	1/2 W			5%
R40	301-0242-00	2.4 kΩ	1/2 W	Var		5%
R41	311-0462-00	1 kΩ				
R42	301-0202-00	2 kΩ	1/2 W		Prec	5%
R45	322-0151-00	365 Ω	1/4 W			1%
R50	301-0101-00	100 Ω	1/2 W			5%
R53	321-0165-00	511 Ω	1/8 W		Prec	1%
R54	321-0209-00	1.47 kΩ	1/8 W		Prec	1%
R55	301-0271-00	270 Ω	1/2 W			5%
R56	301-0271-00	270 Ω	1/2 W			5%
R57	301-0271-00	270 Ω	1/2 W			5%
R58	301-0271-00	270 Ω	1/2 W			5%
R60	321-0163-00	487 Ω	1/8 W		Prec	1%
R62	321-0165-00	511 Ω	1/8 W		Prec	1%
R65	301-0821-00	820 Ω	1/2 W			5%
R70	301-0820-00	82 Ω	1/2 W			5%
R73	301-0432-00	4.3 kΩ	1/2 W			5%
R80	301-0101-00	100 Ω	1/2 W			5%
R83	301-0470-00	47 Ω	1/2 W			5%
R85	301-0202-00	2 kΩ	1/2 W			5%
R90	301-0511-00	510 Ω	1/2 W			5%
R92	301-0123-00	12 kΩ	1/2 W			5%
R95	315-0391-00	390 Ω	1/4 W			5%

**Switches**

	Unwired	Wired	
SW55	260-0552-00		Reed
SW56	260-0552-00		Reed
SW57	260-0552-00		Reed
SW58	260-0552-00		Reed

## FUNCTION PROGRAM #1 CARD—Series L

Ckt. No.	Tektronix Part No.	Description					Model No.
	*670-0216-02	Complete Card					
Capacitors							
Tolerance $\pm 20\%$ unless otherwise indicated.							
C1	281-0511-00	22 pF	Cer	200 V	10%		
C5	281-0511-00	22 pF	Cer	200 V	10%		1X
C15	290-0267-00	1 $\mu$ F	EMT	35 V	+80%—20%		1
C15	290-0175-00	10 $\mu$ F	EMT	35 V			2-up
C19	281-0526-00	1.5 pF	Cer	500 V	$\pm 0.5$ pF		X2-up
C24	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%		
C29	283-0004-00	0.02 $\mu$ F	Cer	150 V			1
C29	283-0111-00	0.1 $\mu$ F	Cer	50 V			2-up
C33	281-0638-00	240 pF	Cer	500 V	5%		
C50	283-0004-00	0.02 $\mu$ F	Cer	150 V			1
C50	290-0135-00	15 $\mu$ F	EMT	20 V			2-up
Diodes							
D1	*152-0185-00	Silicon	Replaceable by 1N4152				
D8	*152-0185-00	Silicon	Replaceable by 1N4152				
D14	*152-0185-00	Silicon	Replaceable by 1N4152				
D21	*152-0075-00	Germanium	Tek Spec				
D25	152-0093-00	Tunnel	1N3716 4.7 mA				
D28	*152-0185-00	Silicon	Replaceable by 1N4152				
D33	*152-0185-00	Silicon	Replaceable by 1N4152				
D36	*152-0075-00	Germanium	Tek Spec				
D41	*152-0185-00	Silicon	Replaceable by 1N4152				
D42	*152-0075-00	Germanium	Tek Spec				
D45	*152-0185-00	Silicon	Replaceable by 1N4152				
D46	*152-0075-00	Germanium	Tek Spec				
D48	*152-0185-00	Silicon	Replaceable by 1N4152				
D49	*152-0185-00	Silicon	Replaceable by 1N4152				
D53	*152-0185-00	Silicon	Replaceable by 1N4152				
D54	*152-0185-00	Silicon	Replaceable by 1N4152				
D56	*152-0185-00	Silicon	Replaceable by 1N4152				
D63	*152-0185-00	Silicon	Replaceable by 1N4152				
D64	*152-0185-00	Silicon	Replaceable by 1N4152				
D66	*152-0185-00	Silicon	Replaceable by 1N4152				
D73	*152-0185-00	Silicon	Replaceable by 1N4152				
D74	*152-0185-00	Silicon	Replaceable by 1N4152				
D76	*152-0185-00	Silicon	Replaceable by 1N4152				
D83	*152-0185-00	Silicon	Replaceable by 1N4152				
D84	*152-0185-00	Silicon	Replaceable by 1N4152				
D86	*152-0185-00	Silicon	Replaceable by 1N4152				
D93	*152-0185-00	Silicon	Replaceable by 1N4152				
D94	*152-0185-00	Silicon	Replaceable by 1N4152				
D96	*152-0185-00	Silicon	Replaceable by 1N4152				
D103	*152-0185-00	Silicon	Replaceable by 1N4152				



## FUNCTION PROGRAM #1 CARD—Series L (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
<b>Diodes (cont)</b>			
D104	*152-0185-00	Silicon	Replaceable by 1N4152
D106	*152-0185-00	Silicon	Replaceable by 1N4152
D113	*152-0185-00	Silicon	Replaceable by 1N4152
D114	*152-0185-00	Silicon	Replaceable by 1N4152
D123	*152-0185-00	Silicon	Replaceable by 1N4152
D124	*152-0185-00	Silicon	Replaceable by 1N4152
D133	*152-0185-00	Silicon	Replaceable by 1N4152
D134	*152-0185-00	Silicon	Replaceable by 1N4152
D143	*152-0185-00	Silicon	Replaceable by 1N4152
D144	*152-0185-00	Silicon	Replaceable by 1N4152

**Inductors**

L20	*108-0148-00	2.5 $\mu$ H
L38	*108-0355-00	Coil, Reed Drive
L44	*108-0355-00	Coil, Reed Drive
L48	*108-0355-00	Coil, Reed Drive
L79	*108-0355-00	Coil, Reed Drive
L109	*108-0355-00	Coil, Reed Drive

**Transistors**

Q4	*151-0108-00	Replaceable by 2N2501
Q14	151-0221-00	2N4258
Q23	*151-0108-00	Replaceable by 2N2501
Q24	*151-0127-00	Selected from 2N2369
Q33	151-0221-00	2N4258
Q53	151-0164-00	Silicon 2N3702
Q63	151-0164-00	Silicon 2N3702
Q73	151-0164-00	Silicon 2N3702
Q83	151-0164-00	Silicon 2N3702
Q93	151-0164-00	Silicon 2N3702
Q103	151-0164-00	Silicon 2N3702
Q113	151-0164-00	Silicon 2N3702
Q123	151-0164-00	Silicon 2N3702
Q133	151-0164-00	Silicon 2N3702
Q143	151-0164-00	Silicon 2N3702

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R1	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W	5%
R2	315-0103-00	10 k $\Omega$	$\frac{1}{4}$ W	5%
R5	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W	5%
R8	315-0332-00	3.3 k $\Omega$	$\frac{1}{4}$ W	5%
R14	315-0272-00	2.7 k $\Omega$	$\frac{1}{4}$ W	5%

## FUNCTION PROGRAM #1 CARD—Series L (cont)

Ckt. No.	Tektronix Part No.	Description			Model No.
Resistors (cont)					
R15	315-0301-00	300 Ω	1/4 W	5%	1 2-up
R16	315-0152-00	1.5 kΩ	1/4 W	5%	
R16	315-0392-00	3.9 kΩ	1/4 W	5%	
R20	301-0332-00	3.3 kΩ	1/2 W	5%	
R21	315-0360-00	36 Ω	1/4 W	5%	
R23	315-0330-00	33 Ω	1/4 W	5%	
R25	315-0100-00	10 Ω	1/4 W	5%	
R28	315-0102-00	1 kΩ	1/4 W	5%	
R29	315-0100-00	10 Ω	1/4 W	5%	
R30	301-0152-00	1.5 kΩ	1/2 W	5%	
R33	315-0242-00	2.4 kΩ	1/4 W	5%	
R36	315-0101-00	100 Ω	1/4 W	5%	
R39	301-0221-00	220 Ω	1/2 W	5%	
R42	315-0101-00	100 Ω	1/4 W	5%	
R44	303-0221-00	220 Ω	1 W	5%	
R46	315-0101-00	100 Ω	1/4 W	5%	
R48	303-0221-00	220 Ω	1 W	5%	
R50	315-0123-00	12 kΩ	1/4 W	5%	
R51	315-0100-00	10 Ω	1/4 W	5%	
R53	315-0333-00	33 kΩ	1/4 W	5%	
R60	315-0123-00	12 kΩ	1/4 W	5%	
R63	315-0333-00	33 kΩ	1/4 W	5%	
R70	315-0123-00	12 kΩ	1/4 W	5%	
R73	315-0333-00	33 kΩ	1/4 W	5%	
R79	301-0271-00	270 Ω	1/2 W	5%	
R79	301-0111-00	110 Ω	1/2 W	5%	1, 2 3-up
R80	315-0123-00	12 kΩ	1/4 W	5%	
R83	315-0333-00	33 kΩ	1/4 W	5%	
R90	315-0123-00	12 kΩ	1/4 W	5%	
R93	315-0333-00	33 kΩ	1/4 W	5%	
R100	315-0123-00	12 kΩ	1/4 W	5%	1, 2 3-up
R103	315-0333-00	33 kΩ	1/4 W	5%	
R109	301-0271-00	270 Ω	1/2 W	5%	
R109	301-0111-00	110 Ω	1/2 W	5%	
R110	315-0123-00	12 kΩ	1/4 W	5%	
R113	315-0333-00	33 kΩ	1/4 W	5%	
R120	315-0123-00	12 kΩ	1/4 W	5%	
R123	315-0333-00	33 kΩ	1/4 W	5%	
R130	315-0123-00	12 kΩ	1/4 W	5%	
R133	315-0333-00	33 kΩ	1/4 W	5%	
R140	315-0123-00	12 kΩ	1/4 W	5%	
R143	315-0333-00	33 kΩ	1/4 W	5%	

## FUNCTION PROGRAM #1 CARD—Series L (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
		<b>Switches</b>	
	Unwired	Wired	
SW38	260-0552-00	Reed	
SW44	260-0552-00	Reed	
SW48	260-0552-00	Reed	
SW79	260-0721-00	Reed, Double	
SW109	260-0552-00	Reed	

## WIDTH GENERATOR CARD—Series E

\*670-0217-00 Complete Card (Used on Instrument S/N 1084-1207)

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V	
C3	290-0135-00	15 $\mu$ F	EMT	20 V	
C4	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C5	290-0135-00	15 $\mu$ F	EMT	20 V	
C7	290-0162-00	22 $\mu$ F	EMT	35 V	
C12	281-0504-00	10 pF	Cer	500 V	10%
C16	281-0509-00	15 pF	Cer	500 V	10%
C26	281-0592-00	4.7 pF	Cer		$\pm 0.5$ pF
C32	281-0096-00	5.5-18 pF	Air	Var	
C33	283-0629-00	62 pF	Mica	500 V	
C34	*295-0092-00	925 pF	(matched set)		
C35		0.01 $\mu$ F			
C36		0.1 $\mu$ F			
C41	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C45	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C62	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C65	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%

## Diodes

D26	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D27	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D50	152-0141-00	Silicon	1N4152	

## Inductors

L30	*108-0170-01	0.5 $\mu$ H
L56	*108-0355-00	Coil, Reed Drive
L57	*108-0355-00	Coil, Reed Drive
L58	*108-0355-00	Coil, Reed Drive

## WIDTH GENERATOR CARD—Series E (cont)

Ckt No.	Tektronix Part No.	Description			Model No.
Transistors					
Q14	*151-0108-00	Replaceable by 2N2501			
Q15	*151-0127-00	Selected from 2N2369			
Q24	*151-0127-00	Selected from 2N2369			
Q25	*151-0127-00	Selected from 2N2369			
Q38	*151-0103-00	Replaceable by 2N2219			
Q53	*151-0108-00	Replaceable by 2N2501			
Q63	*151-0127-00	Selected from 2N2369			
Resistors					
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.					
R1	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R3	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R5	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R7	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R12	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R14	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R16	301-0681-00	680 $\Omega$	$\frac{1}{2}$ W		5%
R18	301-0472-00	4.7 k $\Omega$	$\frac{1}{2}$ W		5%
R20	315-0132-00	1.3 k $\Omega$	$\frac{1}{4}$ W		5%
R22	311-0496-00	2.5 k $\Omega$		Var	
R24	301-0241-00	240 $\Omega$	$\frac{1}{2}$ W		5%
R25	307-0108-00	6.8 $\Omega$	$\frac{1}{4}$ W		5%
R26	301-0362-00	3.6 k $\Omega$	$\frac{1}{2}$ W		5%
R28	307-0113-00	5.1 $\Omega$	$\frac{1}{4}$ W		5%
R30	301-0331-00	330 $\Omega$	$\frac{1}{2}$ W		5%
R33	315-0510-00	51 $\Omega$	$\frac{1}{4}$ W		5%
R34	315-0100-00	10 $\Omega$	$\frac{1}{4}$ W		5%
R38	301-0510-00	51 $\Omega$	$\frac{1}{2}$ W		5%
R40	301-0123-00	12 k $\Omega$	$\frac{1}{2}$ W		5%
R41	311-0463-00	5 k $\Omega$		Var	
R42	301-0822-00	8.2 k $\Omega$	$\frac{1}{2}$ W		5%
R45	322-0612-00	500 $\Omega$	$\frac{1}{4}$ W	Prec	1%
R50	315-0271-00	270 $\Omega$	$\frac{1}{4}$ W		5%
R54	301-0751-00	750 $\Omega$	$\frac{1}{2}$ W		5%
R56	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R57	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R58	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R60	321-0163-00	487 $\Omega$	$\frac{1}{8}$ W	Prec	1%
R62	321-0165-00	511 $\Omega$	$\frac{1}{8}$ W	Prec	1%
R65	301-0182-00	1.8 k $\Omega$	$\frac{1}{2}$ W		5%

## WIDTH GENERATOR CARD—Series E (cont)

Ckt. No.	Tektronix Part No.		Description	Model No.
			<b>Switches</b>	
	<b>Unwired</b>	<b>Wired</b>		
SW56	260-0552-00		Reed	
SW57	260-0552-00		Reed	
SW58	260-0552-00		Reed	

## WIDTH GENERATOR CARD—Series P

\*670-0217-01 Complete Card (Used on Instrument S/N 1208-1359)

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V	
C3	290-0135-00	15 $\mu$ F	EMT	20 V	
C4	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C5	290-0135-00	15 $\mu$ F	EMT	20 V	
C7	290-0162-00	22 $\mu$ F	EMT	35 V	
C12	281-0504-00	10 pF	Cer	500 V	10%
C16	281-0509-00	15 pF	Cer	500 V	10%
C26	281-0592-00	4.7 pF	Cer		$\pm 0.5$ pF
C32	281-0096-00	5.5-18 pF	Air	Var	
C33	283-0629-00	62 pF	Mica	500 V	
C34 } C35 } C36 }	*295-0092-00	925 pF 0.01 $\mu$ F 0.1 $\mu$ F		(matched set)	1,2
C34 } C35 } C36 }	*295-0092-00	905 pF 0.0099 $\mu$ F 0.1 $\mu$ F		(matched set)	3-up
C41	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C45	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C62	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C65	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%

## Diodes

D15	*152-0185-00	Silicon	Replaceable by 1N4152		
D26	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%	
D27	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%	
D50	152-0141-00	Silicon	1N4152		1
D50	152-0141-02	Silicon	1N4152		2-up

## Inductors

L13	*108-0215-00	1.1 $\mu$ H		
L15	*108-0215-00	1.1 $\mu$ H		
L30	*108-0170-01	0.5 $\mu$ H		
L56	*108-0355-00	Coil, Reed Drive		
L57	*108-0355-00	Coil, Reed Drive		
L58	*108-0355-00	Coil, Reed Drive		

## WIDTH GENERATOR CARD—Series P (cont)

Ckt No.	Tektronix Part No.	Description		Model No.
Transistors				
Q14	151-0225-00	Silicon	2N3563	
Q15	151-0225-00	Silicon	2N3563	
Q24	151-0225-00	Silicon	2N3563	
Q25	151-0225-00	Silicon	2N3563	
Q38	*151-0103-00	Silicon	Replaceable by 2N2219	
Q53	151-0225-00	Silicon	2N3563	
Q63	151-0225-00	Silicon	2N3563	
Resistors				
Resistors are fixed, composition, ±10% unless otherwise indicated.				
R1	307-0053-00	3.3 Ω	½ W	5%
R3	307-0053-00	3.3 Ω	½ W	5%
R5	307-0053-00	3.3 Ω	½ W	5%
R7	307-0053-00	3.3 Ω	½ W	5%
R12	315-0201-00	200 Ω	¼ W	5%
R14	301-0391-00	390 Ω	½ W	5%
R16	301-0681-00	680 Ω	½ W	5%
R18	301-0472-00	4.7 kΩ	½ W	5%
R20	315-0132-00	1.3 kΩ	¼ W	5%
R22	311-0496-00	2.5 kΩ	Var	
R24	301-0241-00	240 Ω	½ W	5%
R25	307-0108-00	6.8 Ω	¼ W	5%
R26	301-0362-00	3.6 kΩ	½ W	5%
R28	307-0113-00	5.1 Ω	¼ W	5%
R30	301-0331-00	330 Ω	½ W	5%
R33	315-0510-00	51 Ω	¼ W	5%
R34	315-0100-00	10 Ω	¼ W	5%
R38	301-0510-00	51 Ω	½ W	5%
R40	301-0123-00	12 kΩ	½ W	5%
R41	311-0463-00	5 kΩ	Var	
R42	301-0822-00	8.2 kΩ	½ W	5%
R45	322-0612-00	500 Ω	¼ W	Prec 1%
R50	315-0271-00	270 Ω	¼ W	5%
R54	301-0751-00	750 Ω	½ W	5%
R56	301-0271-00	270 Ω	½ W	5%
R57	301-0271-00	270 Ω	½ W	5%
R58	301-0271-00	270 Ω	½ W	5%
R60	321-0163-00	487 Ω	⅛ W	Prec 1%
R62	321-0165-00	511 Ω	⅛ W	Prec 1%
R65	301-0182-00	1.8 kΩ	½ W	5%
Switches				
	Unwired	Wired		
SW56	260-0552-00		Reed	
SW57	260-0552-00		Reed	
SW58	260-0552-00		Reed	

## WIDTH GENERATOR CARD—Series R

Ckt No.	Tektronix Part No.	Description	Model No.
	*670-0217-02	Complete Card (Used on Instrument S/N 1360-up)	

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V	
C3	290-0135-00	15 $\mu$ F	EMT	20 V	
C4	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C5	290-0135-00	15 $\mu$ F	EMT	20 V	
C7	290-0162-00	22 $\mu$ F	EMT	35 V	
C12	281-0504-00	10 pF	Cer	500 V	10%
C16	281-0509-00	15 pF	Cer	500 V	10%
C26	281-0592-00	4.7 pF	Cer	Var	
C32	281-0096-00	5.5-18 pF	Air		$\pm 0.5$ pF
C33	283-0629-00	62 pF	Mica	500 V	
C34 } C35 } C36 }	*295-0092-00	905 pF 0.0099 $\mu$ F 0.1 $\mu$ F		(matched set)	
C41	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C45	283-0004-00	0.02 $\mu$ F	Cer	150 V	
C62	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C65	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%

## Diodes

D26	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D27	152-0149-00	Zener	1N961B	0.4 W, 10 V, 5%
D50	152-0141-02	Silicon	1N4152	

## Inductors

L30	*108-0170-01	0.5 $\mu$ H
L56	*108-0355-00	Coil, Reed Drive
L57	*108-0355-00	Coil, Reed Drive
L58	*108-0355-00	Coil, Reed Drive

## Transistors

Q14	151-0225-00	Silicon	2N3563
Q15	151-0225-00	Silicon	2N3563
Q24	151-0225-00	Silicon	2N3563
Q25	151-0225-00	Silicon	2N3563
Q38	*151-0103-00	Silicon	Replaceable by 2N2219
Q53	151-0225-00	Silicon	2N3563
Q63	151-0225-00	Silicon	2N3563

## WIDTH GENERATOR CARD—Series R (cont)

## Resistors

Ckt. No.	Tektronix Part No.	Description			Model No.
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.					
R1	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R3	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R5	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R7	307-0053-00	3.3 $\Omega$	$\frac{1}{2}$ W		5%
R12	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R14	301-0391-00	390 $\Omega$	$\frac{1}{2}$ W		5%
R16	301-0681-00	680 $\Omega$	$\frac{1}{2}$ W		5%
R18	301-0472-00	4.7 k $\Omega$	$\frac{1}{2}$ W		5%
R20	315-0132-00	1.3 k $\Omega$	$\frac{1}{4}$ W		5%
R22	311-0496-00	2.5 k $\Omega$		Var	
R24	301-0241-00	240 $\Omega$	$\frac{1}{2}$ W		5%
R25	307-0108-00	6.8 $\Omega$	$\frac{1}{4}$ W		5%
R26	301-0362-00	3.6 k $\Omega$	$\frac{1}{2}$ W		5%
R28	307-0113-00	5.1 $\Omega$	$\frac{1}{4}$ W		5%
R30	301-0331-00	330 $\Omega$	$\frac{1}{2}$ W		5%
R33	315-0510-00	51 $\Omega$	$\frac{1}{4}$ W		5%
R34	315-0100-00	10 $\Omega$	$\frac{1}{4}$ W		5%
R38	301-0510-00	51 $\Omega$	$\frac{1}{2}$ W		5%
R40	301-0123-00	12 k $\Omega$	$\frac{1}{2}$ W		5%
R41	311-0463-00	5 k $\Omega$		Var	
R42	301-0822-00	8.2 k $\Omega$	$\frac{1}{2}$ W		5%
R45	322-0612-00	500 $\Omega$	$\frac{1}{4}$ W	Prec	1%
R50	315-0271-00	270 $\Omega$	$\frac{1}{4}$ W		5%
R54	301-0751-00	750 $\Omega$	$\frac{1}{2}$ W		5%
R56	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R57	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R58	301-0271-00	270 $\Omega$	$\frac{1}{2}$ W		5%
R60	321-0163-00	487 $\Omega$	$\frac{1}{6}$ W	Prec	1%
R62	321-0165-00	511 $\Omega$	$\frac{1}{6}$ W	Prec	1%
R65	301-0182-00	1.8 k $\Omega$	$\frac{1}{2}$ W		5%

## Switches

	Unwired	Wired	
SW56	260-0552-00		Reed
SW57	260-0552-00		Reed
SW58	260-0552-00		Reed



## PULSE SHAPE GENERATOR CARD—Series F

Ckt. No.	Tektronix Part No.	Description	Model No.
	*670-0218-00	Complete Card	

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C1	290-0162-00	22 $\mu$ F	EMT	35 V	
C3	290-0135-00	15 $\mu$ F	EMT	20 V	
C5	283-0059-00	1 $\mu$ F	Cer	25 V	+80% —20%
C12	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C22	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C36	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C46	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C55	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C58	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C65	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C68	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C72	281-0097-00	9-35 pF	Cer	Var	
C75	Use 283-0622-00	450 pF	Mica	300 V	1%
C76 } C77 }	*295-0093-00	0.005 $\mu$ F 0.05 $\mu$ F		(matched set)	
C90	283-0000-00	0.001 $\mu$ F	Cer	500 V	
C122	283-0059-00	1 $\mu$ F	Cer	25 v	+80% —20%

## Diodes

D12	152-0127-00	Zener	1N755A, 0.4 W, 7.5 V, 5%	
D22	152-0149-00	Zener	1N961B 0.4 W, 10 V, 5%	
D72	152-0141-00	Silicon	1N4152	3
D72	152-0141-02	Silicon	1N4152	4-up
D90	*152-0185-00	Silicon	Replaceable by 1N4152	
D120	*152-0185-00	Silicon	Replaceable by 1N4152	
D122	*152-0161-00	GaAs	Tek Made	1, 2, 3, 4
D122	*152-0322-00	Silicon	Tek Spec	5-up

## Inductors

L14	276-0528-00	Core, Ferramic Suppressor
L24	276-0528-00	Core, Ferramic Suppressor
L44	276-0528-00	Core, Ferramic Suppressor
L58	276-0528-00	Core, Ferramic Suppressor
L68	276-0528-00	Core, Ferramic Suppressor

## PULSE SHAPE GENERATOR CARD—Series F (cont)

Ckt. No.	Tektronix Part No.	Description	Model No.
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**Inductors (cont)**

L80	*108-0355-00	Coil, Reed Drive	
L81	*108-0355-00	Coil, Reed Drive	
L82	*108-0355-00	Coil, Reed Drive	

**Transistors**

Q14	*151-0133-00	Selected from 2N3251	
Q24	*151-0127-00	Selected from 2N2369	
Q34	*151-0133-00	Selected from 2N3251	
Q44	*151-0127-00	Selected from 2N2369	
Q58	*151-0127-00	Selected from 2N2369	
Q68	*151-0133-00	Selected from 2N3251	
Q88	151-0164-00	2N3702	
Q94	151-0164-00	2N3702	
Q104	*151-0153-00	Replaceable by 2N3923	
Q114	151-0164-00	2N3702	
Q123	*151-0133-00	Selected from 2N3251	
Q124	*151-0136-00	Replaceable by 2N3053	

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R1	307-0104-00	3.3 $\Omega$	$\frac{1}{4}$ W	5%
R3	307-0104-00	3.3 $\Omega$	$\frac{1}{4}$ W	5%
R5	307-0104-00	3.3 $\Omega$	$\frac{1}{4}$ W	5%
R10	315-0220-00	22 $\Omega$	$\frac{1}{4}$ W	5%
R12	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W	5%
R14	315-0101-00	100 $\Omega$	$\frac{1}{4}$ W	5%
R22	301-0202-00	2 k $\Omega$	$\frac{1}{2}$ W	5%
R24	315-0101-00	100 $\Omega$	$\frac{1}{4}$ W	5%
R30	315-0332-00	3.3 k $\Omega$	$\frac{1}{4}$ W	5%
R32	311-0462-00	1 k $\Omega$		Var
R33	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W	5%
R36	315-0470-00	47 $\Omega$	$\frac{1}{4}$ W	5%
R38	315-0180-00	18 $\Omega$	$\frac{1}{4}$ W	5%
R40	315-0221-00	220 $\Omega$	$\frac{1}{4}$ W	5%
R42	311-0462-00	1 k $\Omega$		Var
R43	315-0222-00	2.2 k $\Omega$	$\frac{1}{4}$ W	5%
R46	315-0470-00	47 $\Omega$	$\frac{1}{4}$ W	5%
R48	315-0180-00	18 $\Omega$	$\frac{1}{4}$ W	5%
R52	315-0302-00	3 k $\Omega$	$\frac{1}{4}$ W	5%
R54	311-0462-00	1 k $\Omega$		Var

**PULSE SHAPE GENERATOR CARD—Series F (cont)**

Ckt. No.	Tektronix Part No.		Description			Model No.
Resistors (cont)						
R55	315-0751-00	750 Ω	¼ W			5%
R56	315-0330-00	33 Ω	¼ W			5%
R58	322-0136-00	255 Ω	¼ W		Prec	1%
R62	315-0751-00	750 Ω	¼ W			5%
R64	311-0462-00	1 kΩ		Var		
R65	315-0302-00	3 kΩ	¼ W			5%
R66	315-0330-00	33 Ω	¼ W			5%
R68	322-0133-00	237 Ω	¼ W		Prec	1%
R72	307-0113-00	5.1 Ω	¼ W			5%
R75	315-0220-00	22 Ω	¼ W			5%
R80	301-0271-00	270 Ω	½ W			5%
R81	301-0271-00	270 Ω	½ W			5%
R82	301-0271-00	270 Ω	½ W			5%
R84	315-0102-00	1 kΩ	¼ W			5%
R85	311-0462-00	1 kΩ		Var		
R86	315-0302-00	3 kΩ	¼ W			5%
R88	315-0153-00	15 kΩ	¼ W			5%
R90	321-0217-00	1.78 kΩ	⅛ W		Prec	1%
R92	315-0153-00	15 kΩ	¼ W			5%
R94	315-0103-00	10 kΩ	¼ W			5%
R96	315-0222-00	2.2 kΩ	¼ W			5%
R104	315-0223-00	22 kΩ	¼ W			5%
R120	315-0103-00	10 kΩ	¼ W			5%
R122	315-0472-00	4.7 kΩ	¼ W			5%
R125	315-0271-00	270 Ω	¼ W			5%

**Switches**

	Unwired	Wired	
SW80	260-0552-00		Reed
SW81	260-0552-00		Reed
SW82	260-0552-00		Reed

**OUTPUT AMPLIFIER CARD—Series M**

\*670-0219-01 Complete Card

**Capacitors**

C1	283-0059-00	1 $\mu$ F	Cer	25 V	
C6	290-0267-00	1 $\mu$ F	EMT	35 V	
C10	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C12	283-0080-00	0.022 $\mu$ F	Cer	25 V	+80%—20%
C13	290-0267-00	1 $\mu$ F	EMT	35 V	

**OUTPUT AMPLIFIER CARD—Series M (cont)**

Ckt. No.	Tektronix Part No.	Description				Model No.
Capacitors (cont)						
C18	283-0059-00	1 $\mu$ F	Cer		25 V	+80%—20%
C31	283-0080-00	0.022 $\mu$ F	Cer		25 V	+80%—20%
C48	283-0059-00	1 $\mu$ F	Cer		25 V	
C50	281-0089-00	2-8 pF	Cer	Var		
C68	283-0080-00	0.022 $\mu$ F	Cer		25 V	+80%—20%
C70	290-0134-00	22 $\mu$ F	EMT		15 V	
C82	281-0096-00	5.5-18 pF	Air	Var		
C108	283-0059-00	1 $\mu$ F	Cer		25 V	+80%—20%

**Diodes**

D10	*152-0322-00	Silicon	Tek Spec			
D22	*152-0322-00	Silicon	Tek Spec			
D25	152-0141-00	Silicon	1N4152			1,2
D25	152-0141-02	Silicon	1N4152			3-up
D48	152-0212-00	Zener	1N936 9 V, 5% TC			
D84	*152-0185-00	Silicon	Replaceable by 1N4152			

**Inductors**

L27	*108-0357-00	Coil, Reed Drive				
L28	*108-0357-00	Coil, Reed Drive				
L40	*108-0215-00	1.1 $\mu$ H				
L106	*108-0417-00	110 $\mu$ H				

**Transistors**

Q13	*151-0221-00	2N4258				
Q23	*151-0198-00	Replaceable by MPS-918				
Q24	*151-0221-00	2N4258				
Q33	*151-0188-00	2N3906				
Q34	*151-0198-00	Replaceable by MPS-918				
Q43	*151-0198-00	Replaceable by MPS-918				
Q44	*151-0198-00	Replaceable by MPS-918				
Q53	*151-0167-00	Selected from XF737				
Q54	*151-0211-00	Selected from 2N3866				
Q64	*151-0211-00	Selected from 2N3866				
Q74	*151-0211-00	Selected from 2N3866				
Q84	*151-0235-00	Tek Spec				
Q94	*151-0235-00	Tek Spec				
Q104	*151-0235-00	Tek Spec				

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R1	307-0106-00	4.7 $\Omega$	$\frac{1}{4}$ W	5%
R6	315-0100-00	10 $\Omega$	$\frac{1}{4}$ W	5%
R10	303-0182-00	1.8 k $\Omega$	1 W	5%
R11	307-0113-00	5.1 $\Omega$	$\frac{1}{4}$ W	5%
R12	315-0101-00	100 $\Omega$	$\frac{1}{4}$ W	5%

## OUTPUT AMPLIFIER CARD—Series M (cont)

Ckt. No.	Tektronix Part No.		Description		Model No.		
Resistors (cont)							
R13	315-0100-00	10 Ω	¼ W		5%	1,2,3,4 5-up	
R14	315-0244-00	240 kΩ	¼ W		5%		
R14	315-0124-00	120 kΩ	¼ W		5%		
R16	315-0101-00	100 Ω	¼ W		5%		
R17	307-0113-00	5.1 Ω	¼ W		5%		
R18	315-0330-00	33 Ω	¼ W		5%	1,2,3 4-up	
R20	315-0510-00	51 Ω	¼ W		5%		
R22	303-0242-00	2.4 kΩ	1 W		5%		
R23	305-0122-00	1.2 k	2 W		5%		
R24	303-0392-00	3.9 kΩ	1 W		5%		
R25	311-0433-00	100 Ω		Var			1,2,3 4-up
R25	311-0442-00	250 Ω		Var			
R26	315-0270-00	27 Ω	¼ W		5%		
R27	315-0151-00	150 Ω	¼ W		5%		
R28	315-0181-00	180 Ω	¼ W		5%		
R30	315-0152-00	1.5 kΩ	¼ W		5%		
R31	315-0220-00	22 Ω	¼ W		5%		
R32	315-0221-00	220 Ω	¼ W		5%		
R33	315-0220-00	22 Ω	¼ W		5%		
R34	311-0480-00	500 Ω		Var			
R35	303-0182-00	1.8 kΩ	1 W		5%		
R36	315-0221-00	220 Ω	¼ W		5%		
R40	301-0561-00	560 Ω	½ W		5%		
R41	315-0274-00	270 kΩ	¼ W		5%		
R42	311-0480-00	500 Ω		Var			
R43	315-0153-00	15 kΩ	¼ W		5%		
R44	301-0752-00	7.5 kΩ	½ W		5%		
R45	301-0821-00	820 Ω	½ W		5%		
R46	315-0390-00	39 Ω	¼ W		5%		
R47	315-0620-00	62 Ω	¼ W		5%		
R48	303-0302-00	3 kΩ	1 W		5%		
R49	315-0181-00	180 Ω	¼ W		5%		
R50	315-0181-00	180 Ω	¼ W		5%		
R51	307-0113-00	5.1 Ω	¼ W		5%		
R53	305-0112-00	1.1 kΩ	2 W		5%		
R54	315-0330-00	33 Ω	¼ W		5%		
R64	315-0330-00	33 Ω	¼ W		5%		
R70	307-0051-00	2.7 Ω	½ W		5%		
R74	315-0330-00	33 Ω	¼ W		5%		
R80	315-0330-00	33 Ω	¼ W		5%		
R82	315-0222-00	2.2 k	¼ W		5%	1 2-up	
R84	323-0085-00	75 Ω	½ W	Prec	1%		
R84	303-0750-00	75 Ω	1 W		5%		
R90	315-0330-00	33 Ω	¼ W		5%		
R94	323-0085-00	75 Ω	½ W	Prec	1%		

**OUTPUT AMPLIFIER CARD—Series M (cont)**

Ckt. No.	Tektronix Part No.		Description	Model No.		
Resistors (cont)						
R94	303-0750-00	75 $\Omega$	1 W	Prec	5%	2-up
R100	315-0330-00	33 $\Omega$	$\frac{1}{4}$ W		5%	
R104	323-0085-00	75 $\Omega$	$\frac{1}{2}$ W		1%	1
R104	303-0750-00	75 $\Omega$	1 W		5%	2-up

**Switches**

	Unwired	Wired	
SW27	260-0721-00		Reed, Double
SW28	260-0721-00		Reed, Double

**ATTENUATOR CARD—Series N**

\*670-0220-01 Complete Card

**Capacitors**

Tolerance  $\pm 20\%$  unless otherwise indicated.

C14	281-0512-00	27 pF	Cer	500 V	10%
C32	283-0003-00	0.01 $\mu$ F	Cer	150 V	
C40	283-0000-00	0.001 $\mu$ F	Cer	500 V	
C74	290-0121-00	2 $\mu$ F	EMT	25 V	

**Diodes**

D40	*152-0185-00	Silicon	Replaceable by 1N4152
D70	*152-0185-00	Silicon	Replaceable by 1N4152

**Connector**

J18	131-0391-00	50 $\Omega$ , coaxial, male
-----	-------------	-----------------------------

**Relays**

K1	148-0025-00	Armature Relay	6 V DC
K4	148-0025-00	Armature Relay	6 V DC

## ATTENUATOR CARD—Series N (cont)

Ckt. No.	Tektronix Part No.	Description			Model No.
Transistors					
Q38	151-0164-00	2N3702			
Q44	151-0164-00	2N3702			
Q54	*151-0153-00	Replaceable by 2N2923			
Q64	151-0164-00	2N3702			
Q74	*151-0136-00	Replaceable by 2N3053			
Resistors					
Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.					
R1	303-0680-00	68 $\Omega$	1 W	5%	1
R1	303-0510-00	51 $\Omega$	1 W	5%	2-up
R4	303-0680-00	68 $\Omega$	1 W	5%	1
R4	303-0510-00	51 $\Omega$	1 W	5%	2-up
R6	305-0510-00	51 $\Omega$	2 W	5%	
R7	305-0510-00	51 $\Omega$	2 W	5%	
R9	324-0097-00	100 $\Omega$	1 W	Prec 1%	
R10	324-0097-00	100 $\Omega$	1 W	Prec 1%	
R12	305-0101-00	100 $\Omega$	2 W	5%	
R13	305-0101-00	100 $\Omega$	2 W	5%	
R14	305-0101-00	100 $\Omega$	2 W	5%	
R16	323-0606-00	60 $\Omega$	$\frac{1}{2}$ W	Prec 1%	
R17	323-0606-00	60 $\Omega$	$\frac{1}{2}$ W	Prec 1%	
R18	323-0606-00	60 $\Omega$	$\frac{1}{2}$ W	Prec 1%	
R20	323-0047-00	30.1 $\Omega$	$\frac{1}{2}$ W	Prec 1%	
R30	315-0202-00	2 k $\Omega$	$\frac{1}{4}$ W	5%	
R32	311-0462-00	1 k $\Omega$		Var	
R35	315-0272-00	2.7 k $\Omega$	$\frac{1}{4}$ W	5%	
R38	315-0103-00	10 k $\Omega$	$\frac{1}{4}$ W	5%	
R42	301-0103-00	10 k $\Omega$	$\frac{1}{2}$ W	5%	
R44	301-0103-00	10 k $\Omega$	$\frac{1}{2}$ W	5%	
R46	301-0222-00	2.2 k $\Omega$	$\frac{1}{2}$ W	5%	
R54	311-0496-00	2.5 k $\Omega$		Var	
R56	315-0221-00	220 $\Omega$	$\frac{1}{4}$ W	5%	
R64	315-0273-00	27 k $\Omega$	$\frac{1}{4}$ W	5%	
R74	301-0222-00	2.2 k $\Omega$	$\frac{1}{2}$ W	5%	

## POWER SUPPLY CARD—Series I

\*670-0221-00 Complete Card

## Capacitors

Tolerance  $\pm 20\%$  unless otherwise indicated.

C2	283-0081-00	0.1 $\mu$ F	Cer	25 V	+80%—20%
C14	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C23	290-0117-00	50 $\mu$ F	EMT	50 V	
C30	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%
C36	290-0158-00	50 $\mu$ F	EMT	25 V	+75%—15%

**POWER SUPPLY CARD—Series I (cont)**

Ckt. No.	Tektronix Part No.	Description				Model No.
Capacitors (cont)						
C76	283-0081-00	0.1 $\mu$ F	Cer	25 V	+80%—20%	
C92	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%	
C113	283-0059-00	1 $\mu$ F	Cer	25 V	+80%—20%	

**Diodes**

D2	152-0105-00	Zener	1N2620	TC		
D30	152-0127-00	Zener	1N755A,	0.4 W, 7.5 V, 5%		
D103	*152-0185-00	Silicon	Replaceable by	1N4152		
D108	*152-0185-00	Silicon	Replaceable by	1N4152		

**Transistors**

Q6	151-0164-00	2N3702				
Q16	151-0164-00	2N3702				
Q23	*151-0134-00	Replaceable by	2N2705			
Q33	*151-0136-00	Replaceable by	2N3053			
Q46	151-0164-00	2N3702				
Q53	*151-0134-00	Replaceable by	2N2705			
Q56	151-0164-00	2N3702				
Q66	*151-0153-00	Replaceable by	2N2723			
Q76	*151-0153-00	Replaceable by	2N2723			
Q83	*151-0136-00	Replaceable by	2N3053			
Q96	151-0164-00	2N3702				
Q103	151-0164-00	2N3702				
Q106	151-0164-00	2N3702				
Q113	*151-0136-00	Replaceable by	2N3053			

**Resistors**Resistors are fixed, composition,  $\pm 10\%$  unless otherwise indicated.

R2	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W		5%
R6	315-0242-00	2.4 k $\Omega$	$\frac{1}{4}$ W		5%
R10	315-0432-00	4.3 k $\Omega$	$\frac{1}{4}$ W		5%
R12	315-0682-00	6.8 k $\Omega$	$\frac{1}{4}$ W		5%
R14	311-0462-00	1 k $\Omega$		Var	
R16	315-0392-00	3.9 k $\Omega$	$\frac{1}{4}$ W		5%
R20	315-0563-00	56 k $\Omega$	$\frac{1}{4}$ W		5%
R23	315-0472-00	4.7 k $\Omega$	$\frac{1}{4}$ W		5%
R30	315-0182-00	1.8 k $\Omega$	$\frac{1}{4}$ W		5%
R33	306-0121-00	120 $\Omega$	2 W		



## POWER SUPPLY CARD—Series I (cont)

Ckt. No.	Tektronix Part No.	Description			Model No.
Resistors (cont)					
R36	315-0751-00	750 $\Omega$	$\frac{1}{4}$ W		5%
R42	322-0258-00	4.75 k $\Omega$	$\frac{1}{4}$ W	Prec	1%
R44	322-0261-00	5.11 k $\Omega$	$\frac{1}{4}$ W	Prec	1%
R46	315-0752-00	7.5 k $\Omega$	$\frac{1}{4}$ W		5%
R50	315-0103-00	10 k $\Omega$	$\frac{1}{4}$ W		5%
R53	315-0682-00	6.8 k $\Omega$	$\frac{1}{4}$ W		5%
R56	321-0631-00	12.5 k $\Omega$	$\frac{1}{8}$ W	Prec	1%
R57	321-0239-00	3.01 k $\Omega$	$\frac{1}{8}$ W	Prec	1%
R62	315-0302-00	3 k $\Omega$	$\frac{1}{4}$ W		5%
R64	315-0123-00	12 k $\Omega$	$\frac{1}{4}$ W		5%
R70	315-0622-00	6.2 k $\Omega$	$\frac{1}{4}$ W		5%
R74	315-0472-00	4.7 k $\Omega$	$\frac{1}{4}$ W		5%
R76	321-0258-00	4.75 k $\Omega$	$\frac{1}{8}$ W	Prec	1%
R78	321-0261-00	5.11 k $\Omega$	$\frac{1}{8}$ W	Prec	1%
R80	315-0751-00	750 $\Omega$	$\frac{1}{4}$ W		5%
R83	315-0221-00	220 $\Omega$	$\frac{1}{4}$ W		5%
R85	315-0152-00	1.5 k $\Omega$	$\frac{1}{4}$ W		5%
R87	315-0101-00	100 $\Omega$	$\frac{1}{4}$ W		5%
R92	315-0511-00	510 $\Omega$	$\frac{1}{4}$ W		5%
R96	315-0822-00	8.2 k $\Omega$	$\frac{1}{4}$ W		5%
R102	315-0511-00	510 $\Omega$	$\frac{1}{4}$ W		5%
R103	315-0682-00	6.8 k $\Omega$	$\frac{1}{4}$ W		5%
R104	315-0510-00	51 $\Omega$	$\frac{1}{4}$ W		5%
R105	315-0511-00	510 $\Omega$	$\frac{1}{4}$ W		5%
R106	315-0103-00	10 k $\Omega$	$\frac{1}{4}$ W		5%
R108	315-0510-00	51 $\Omega$	$\frac{1}{4}$ W		5%

# SECTION 9

## DIAGRAMS and

## MECHANICAL PARTS ILLUSTRATIONS

Change information, if any, affecting this section will be found at the rear of the manual.

### General Information

The following section contains circuit diagrams of all the circuits in the Type R116. These diagrams show the location of each electrical part in the circuit. A block diagram is provided to show the relationship of each major circuit to the total instrument circuitry. Reference standard for the diagrams is Graphic Symbol standard USAS 32.2-1967. The following special symbols are also used:

Screwdriver adjustment.

Front-, side- or rear-panel control or connector.

Clockwise control in direction of arrow.

Refers to the indicated diagram.

Connection soldered to circuit board.

Blue line encloses components located on circuit board.

Test point.

Chassis ground.

Signal ground.

Electrical components shown on the diagrams are in the following units unless noted otherwise:

Capacitors	Values one or greater are in picofarads (pF).  Values less than one are in microfarads ( $\mu$ F).
Resistors	Ohms ( $\Omega$ ).

TABLE 9-1

**Location of Chassis Mounted Components in the Diagrams**

Circuit Numbers	Diagram
430 to 499	Attenuator & Offset Current Gen
400 to 439	Power Supply & Chassis
500 to 599	Switch Details & Remote Program Connector

**Circuit Diagrams and the Electrical Parts List.** To locate a component in the electrical parts list from a circuit number on a circuit diagram, or vice versa, note the series letter (if the component is located on a circuit card) or the instrument serial number (if on the instrument chassis). Table 9-1 shows the diagrams on which the chassis mounted components are located.

Electrical components are identified in the circuit diagrams by their circuit numbers and electrical values (only circuit numbers are given for active components). For more complete information about an electrical component or for parts ordering information, see the Electrical Parts List, Section 8.

**Circuit Diagrams and the Circuit Card Pictures.** To locate a component (physically) in the instrument from a circuit number from a circuit diagram, or vice versa, refer to the circuit pictures at the end of Section 5, Maintenance. Circuit cards may be located within the instrument by their series letters which are printed both on the cards and on the chassis next to the connectors into which the cards are inserted. These series letters are also printed on the pullout tabs on the circuit diagrams. (See the Troubleshooting Aids in the Maintenance section, for information on the significance of the series letters.) Most chassis mounted components have their circuit numbers silk screened near them on the chassis.

### Voltages and Waveforms

Typical voltage measurements and waveform photographs are shown in blue on the diagrams. These voltages and waveforms are not absolute and may vary between instruments because of differing component tolerances, internal calibration or front-panel settings.

The typical voltage measurements and waveform photographs were obtained under the following conditions unless noted otherwise on the individual diagrams:

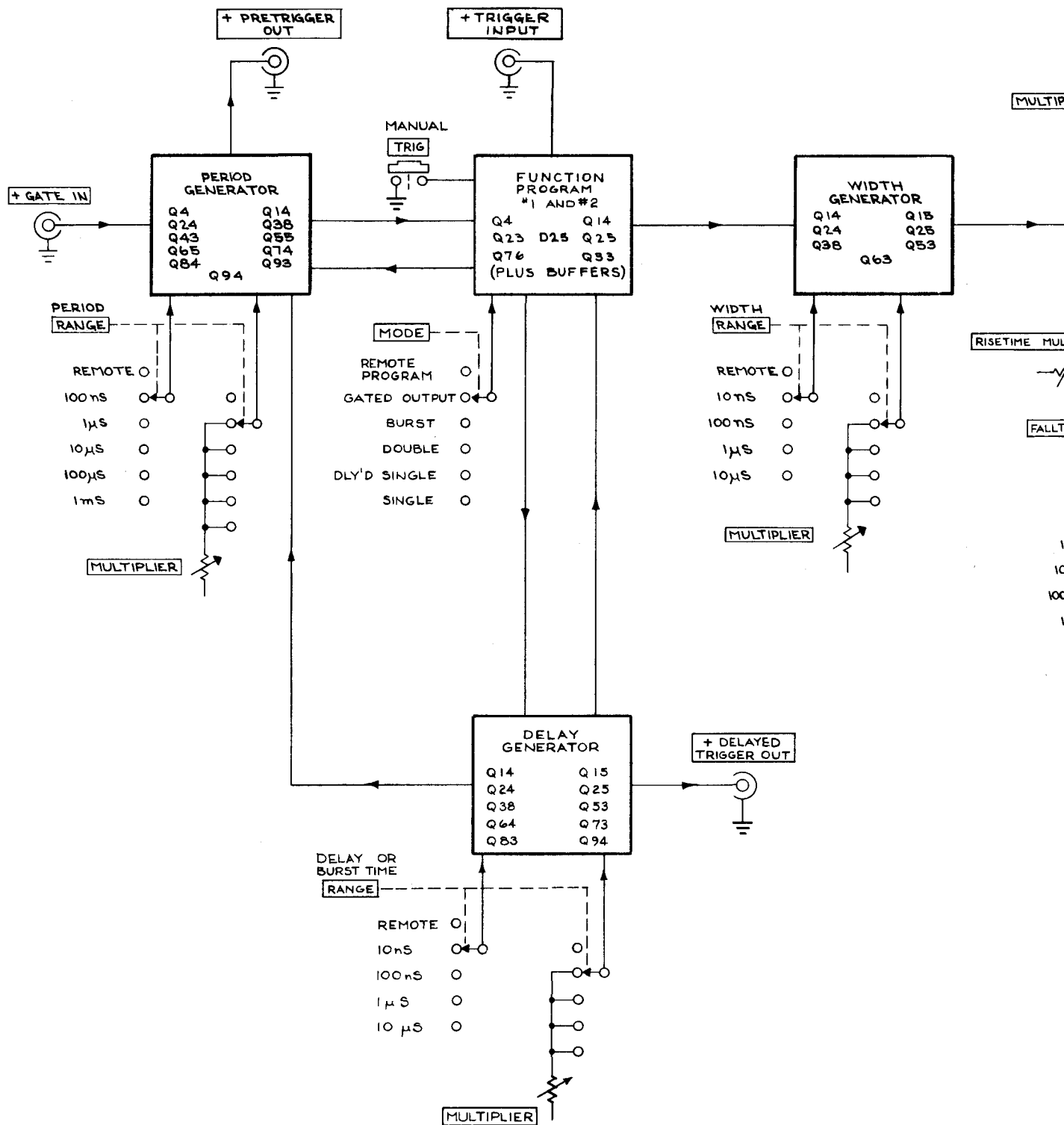
**Type R116 (SN 1084-up)**

Test Oscilloscope, with 10× Probe:	
Bandwidth	DC to 50 MHz
Probe Input Impedance	10 Megohms, 7 picofarads
Probe Ground	Clipped to Type R116 chassis ground.
Triggering	External from point indicated on diagram (to show time relationship between signals)
DC Voltmeter	
Type	Volt-Ohmmeter
Sensitivity	20,000 ohms/volt
Reference Voltage	Signal ground
Type R116 Conditions:	
PULSE OUTPUT Connector	Terminated in 50 ohms
Other Connectors	No connections
Circuit Card Installation	Each card extended on plug-in card extender while taking voltages and waveforms
Type R116 Control Settings:	
MODE	DOUBLE
TRIGGER SOURCE	INTERNAL
PERIOD RANGE	100 μS

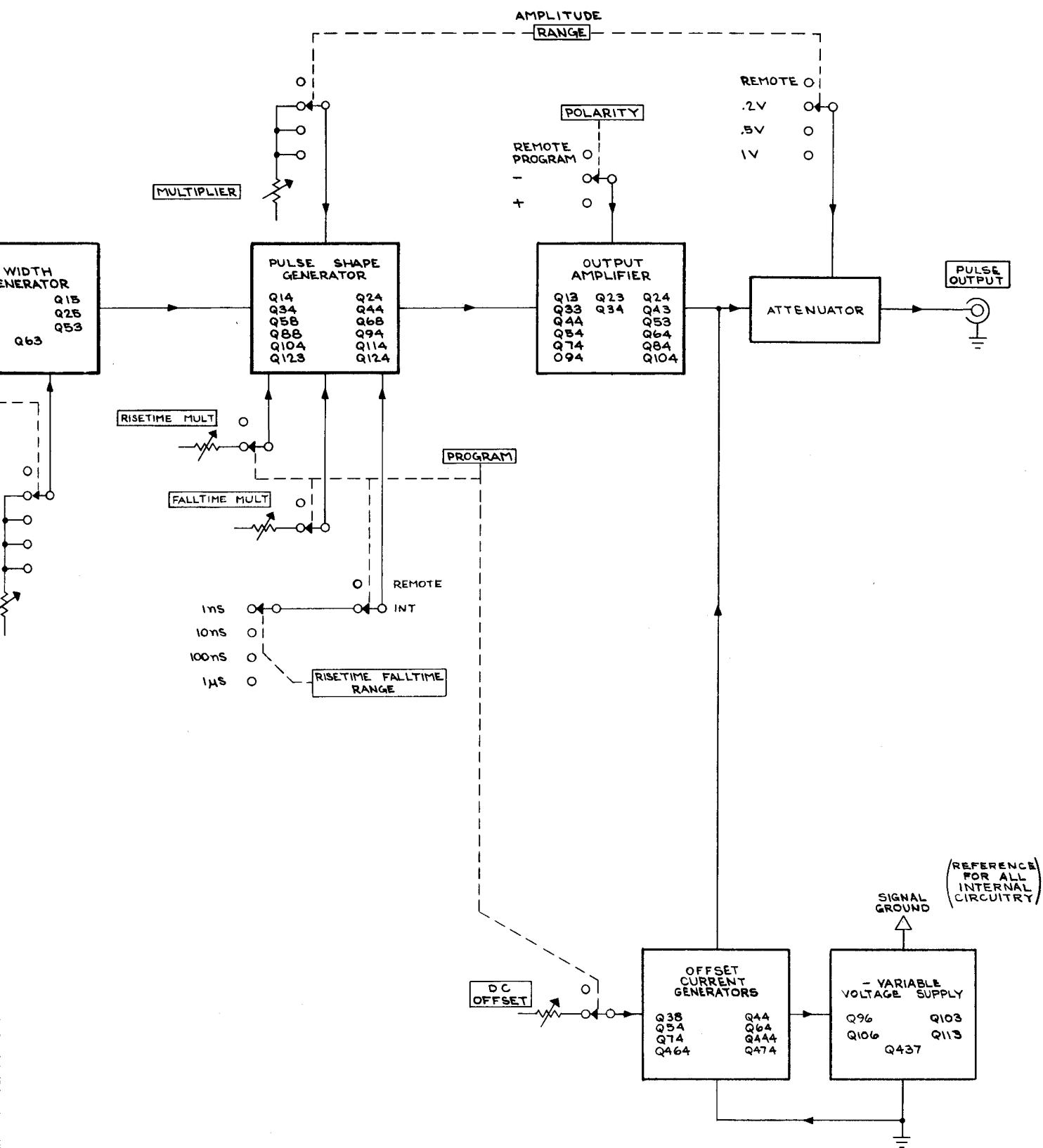
MULTIPLIER	1
DELAY OR BURST TIME RANGE	1 μS
MULTIPLIER	15
WIDTH RANGE	1 μS
MULTIPLIER	5
AMPLITUDE RANGE	1 V
MULTIPLIER	10
POLARITY	+
PROGRAM	INT
DC OFFSET	0
RISETIME FALLTIME RANGE	100 nS
RISETIME MULT	1
FALLTIME MULT	1

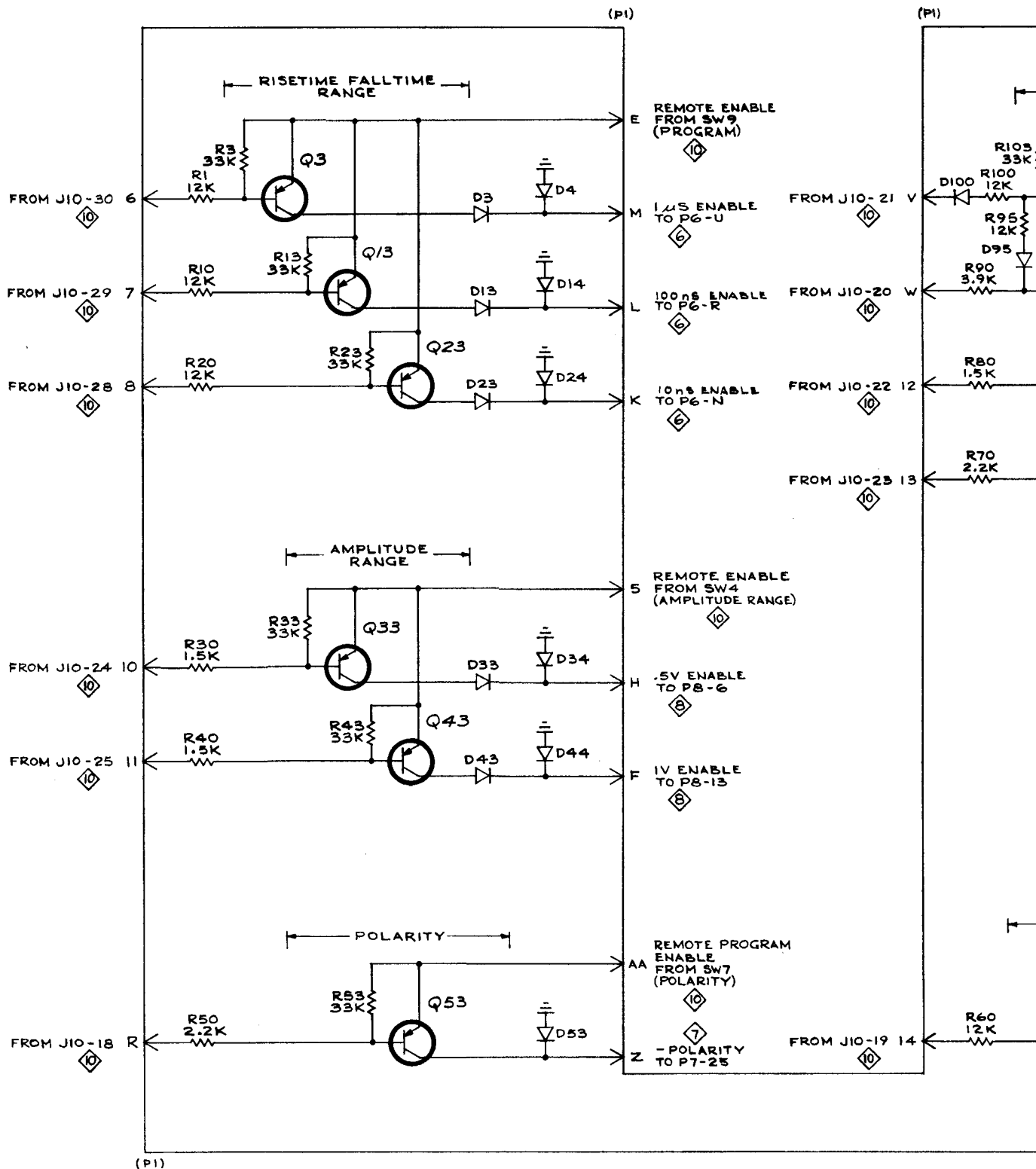
Voltages are given in volts DC, measured with respect to SIGNAL GROUND. (The +9.5 V Relay Supply is referenced to chassis ground.) Voltage measurements taken in any particular Type R116 may vary somewhat from those given, due to normal differences in component characteristics.

Waveform photographs were taken with a Tektronix Oscilloscope Camera System and Projected Graticule. DC voltage levels, where shown on waveforms, are measured with respect to chassis ground.



TYPE R116 PROGRAMMABLE PULSE GENERATOR





ALL VOLTAGES EXCEPT +9.5V RELAY SUPPLY  
ARE REFERENCED TO SIGNAL GND

+9.5V RELAY SUPPLY IS REFERENCED TO  
CHASSIS GND

SEE PARTS LIST FOR  
SEMICONDUCTOR TYPES

Not all diagrams in this manual apply to your instrument:

Refer to diagrams with Serial Number ranges corresponding to  
your instrument Serial Number.

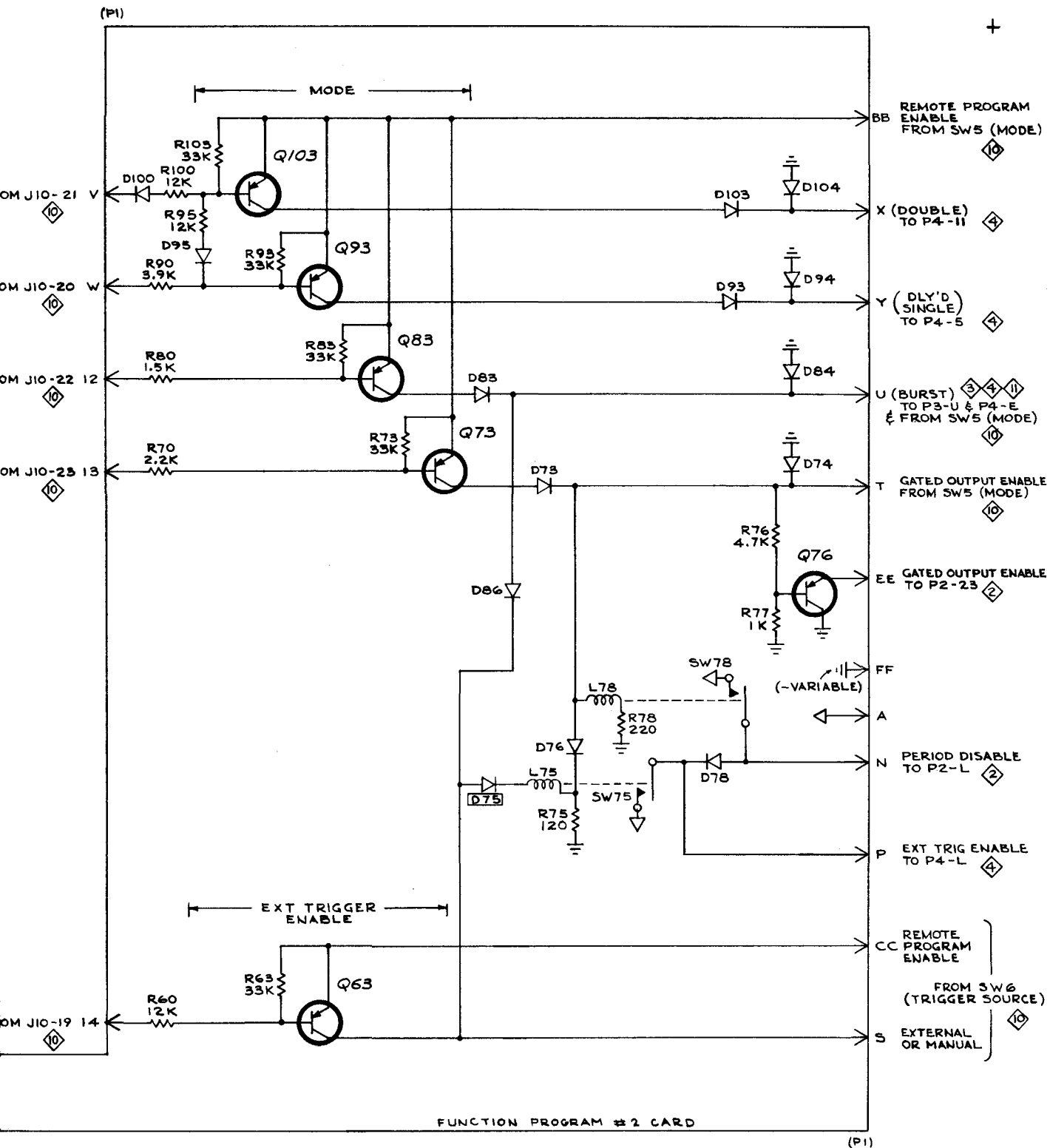
Refer to circuit card diagrams with Series letters corresponding to  
those of cards in your instrument. (Series letters are located on  
corner of each card and on card holder support bar.)

TYPE R116 PROGRAMMABLE PULSE GENERATOR

+

A

REF  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11



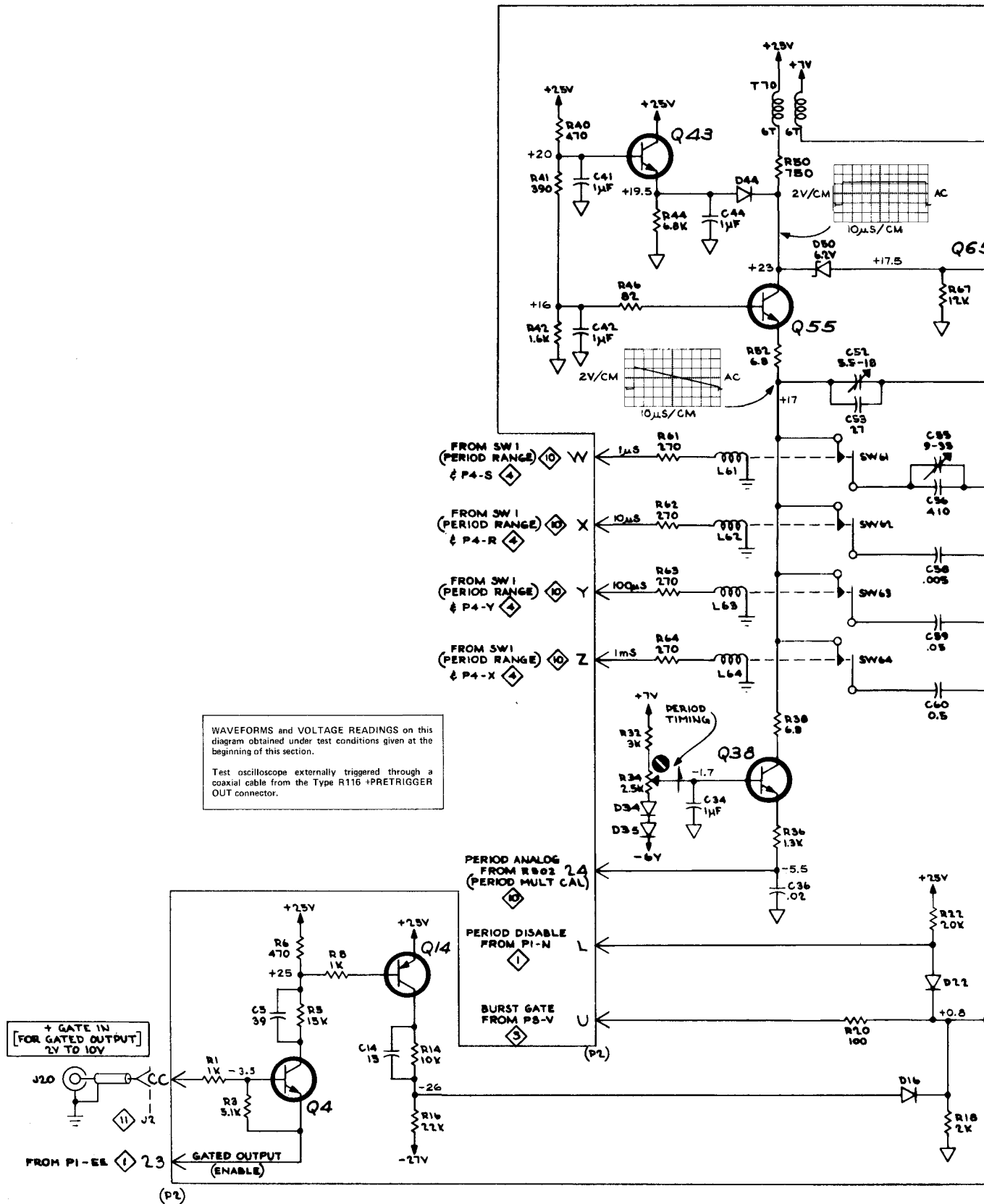
# REFERENCE DIAGRAM:

- ② PERIOD GENERATOR
- ③ DELAY GENERATOR
- ④ FUNCTION PROGRAM #1
- ⑤ PULSE SHAPE GENERATOR
- ⑦ OUTPUT AMPLIFIER
- ⑧ ATTENUATOR & OFFSET CURRENT GENERATOR
- ⑩ SWITCH DETAILS & REMOTE PROGRAM CONNECTOR
- ⑪ INTERCONNECTING DIAGRAM

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

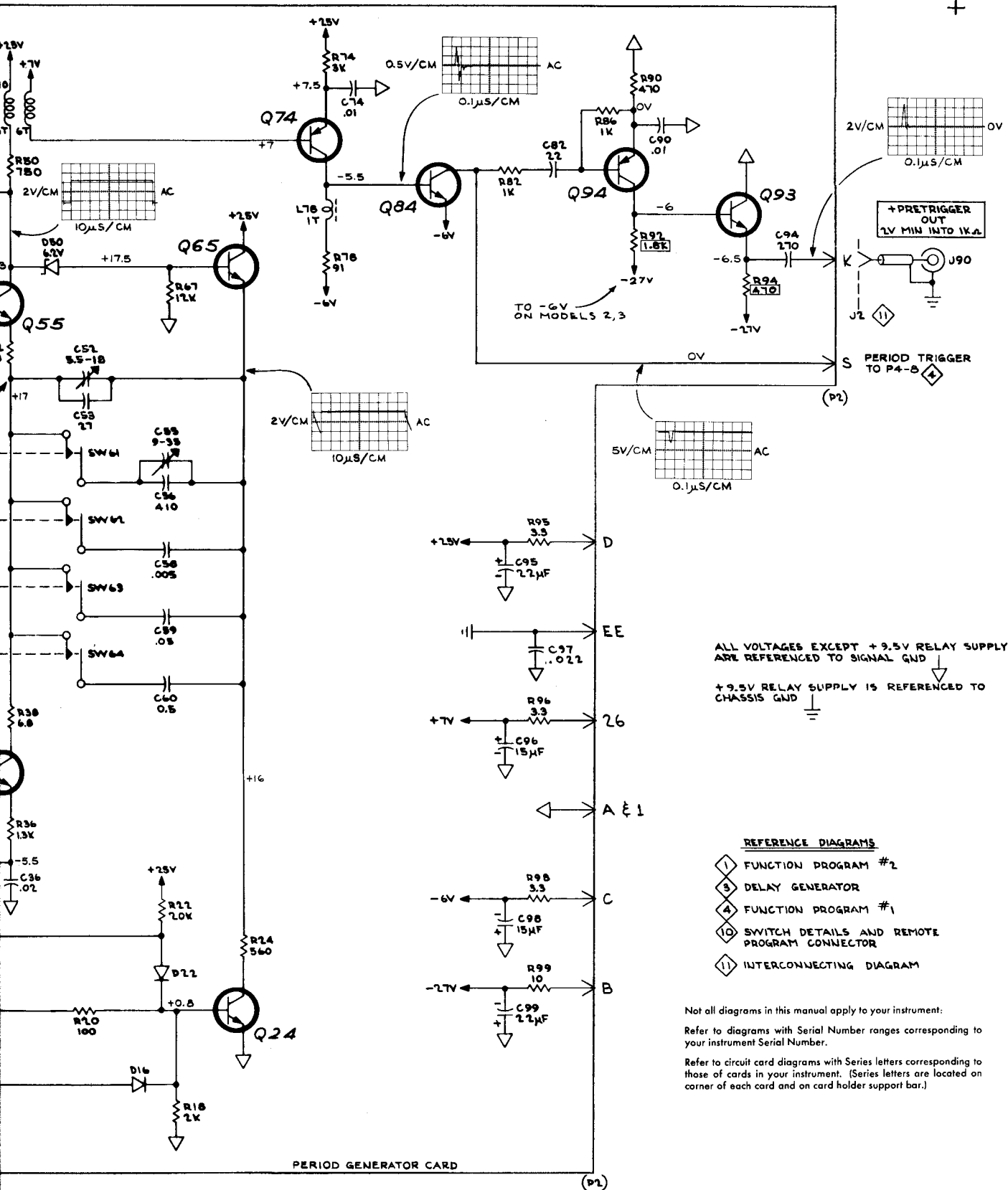
FUNCTION PROGRAM #2  
SERIES K MODELS 1,2&3  
SN 1084-UP

1169



TYPE R116 PROGRAMMABLE PULSE GENERATOR





ALL VOLTAGES EXCEPT +9.5V RELAY SUPPLY ARE REFERENCED TO SIGNAL GND

+9.5V RELAY SUPPLY IS REFERENCED TO CHASSIS GND

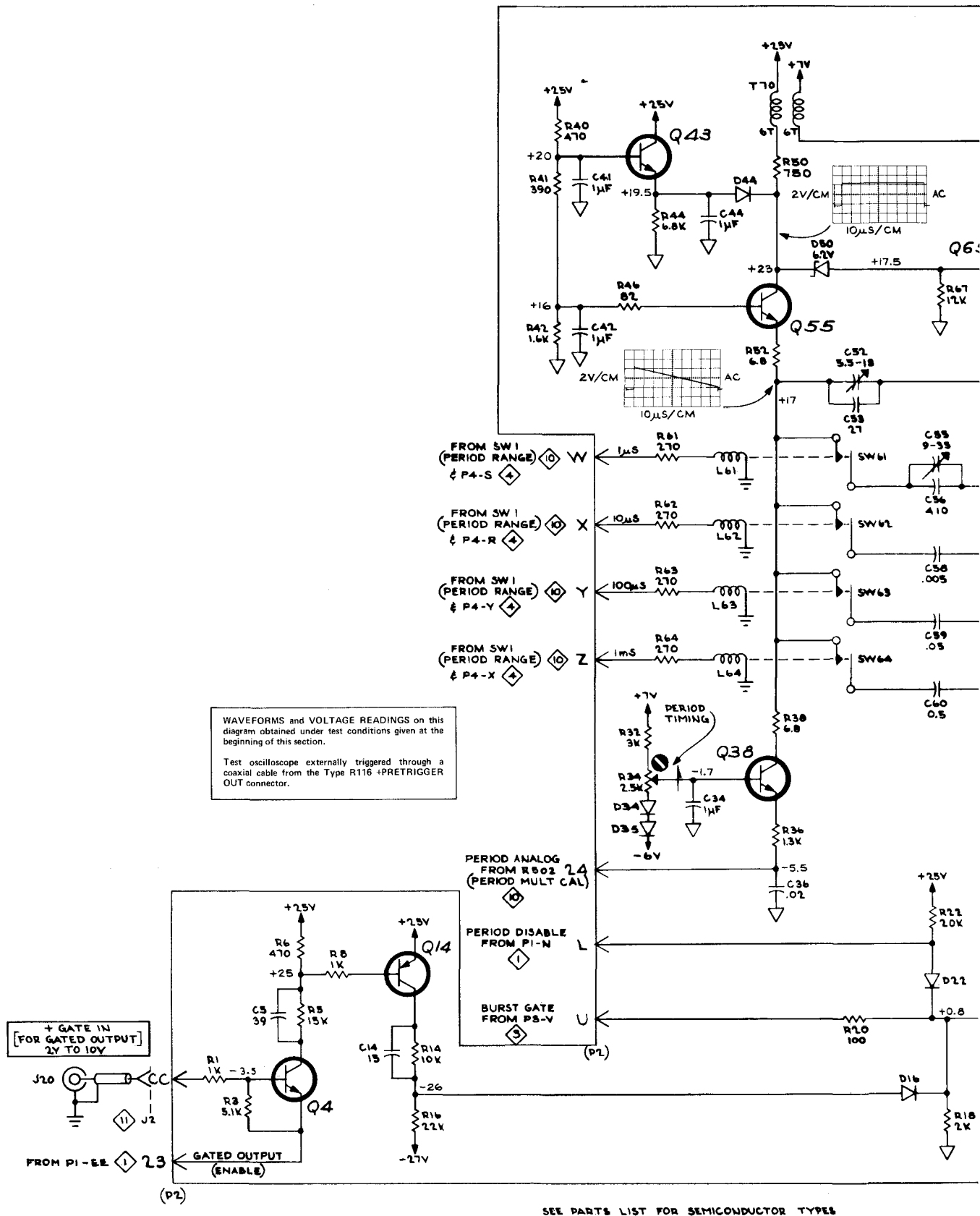
#### REFERENCE DIAGRAMS

- ① FUNCTION PROGRAM #2
- ② DELAY GENERATOR
- ③ FUNCTION PROGRAM #1
- ④ SWITCH DETAILS AND REMOTE PROGRAM CONNECTOR
- ⑤ INTERCONNECTING DIAGRAM

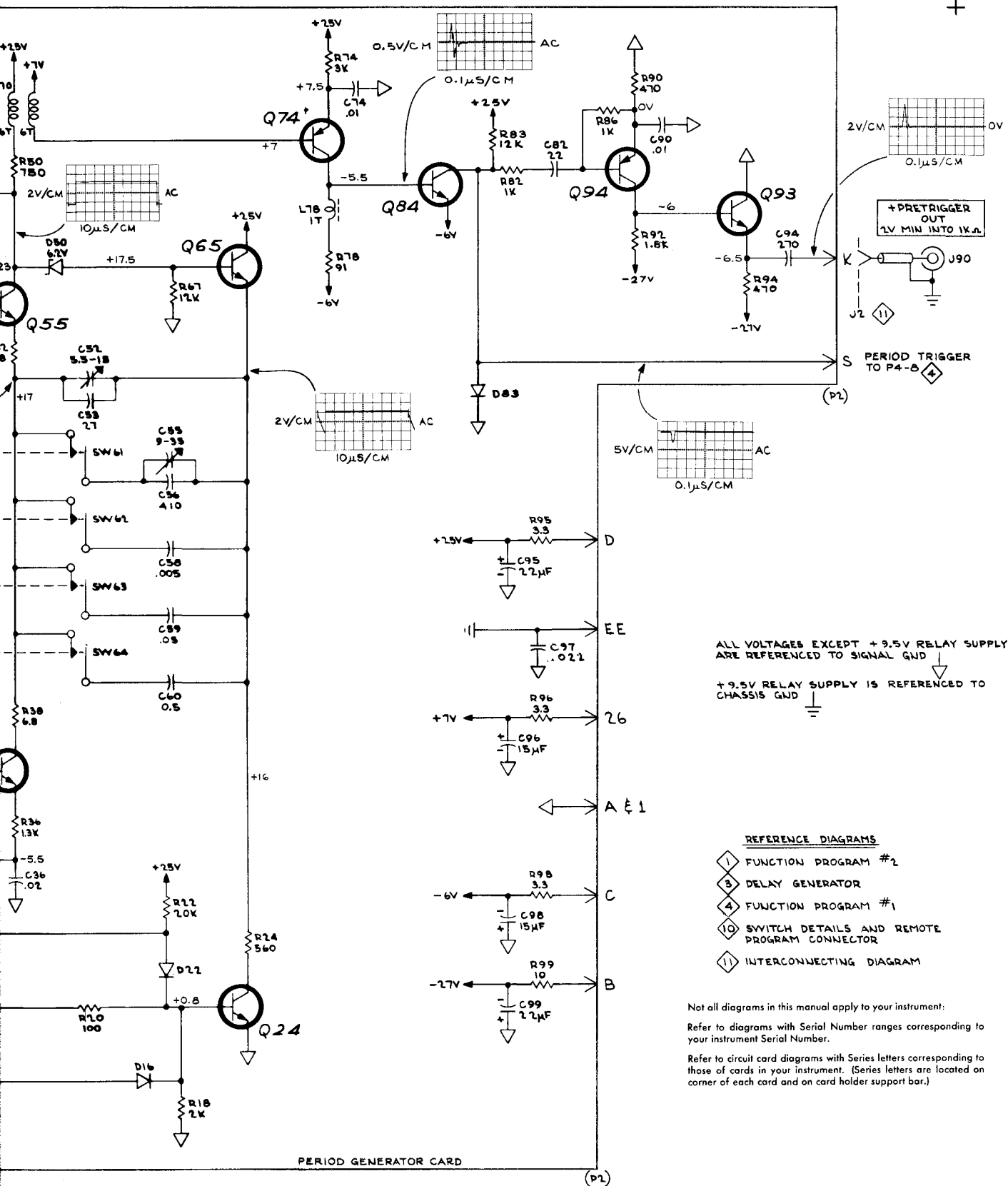
Not all diagrams in this manual apply to your instrument:

Refer to diagrams with Serial Number ranges corresponding to your instrument Serial Number.

Refer to circuit card diagrams with Series letters corresponding to those of cards in your instrument. (Series letters are located on corner of each card and on card holder support bar.)



TYPE R116 PROGRAMMABLE PULSE GENERATOR



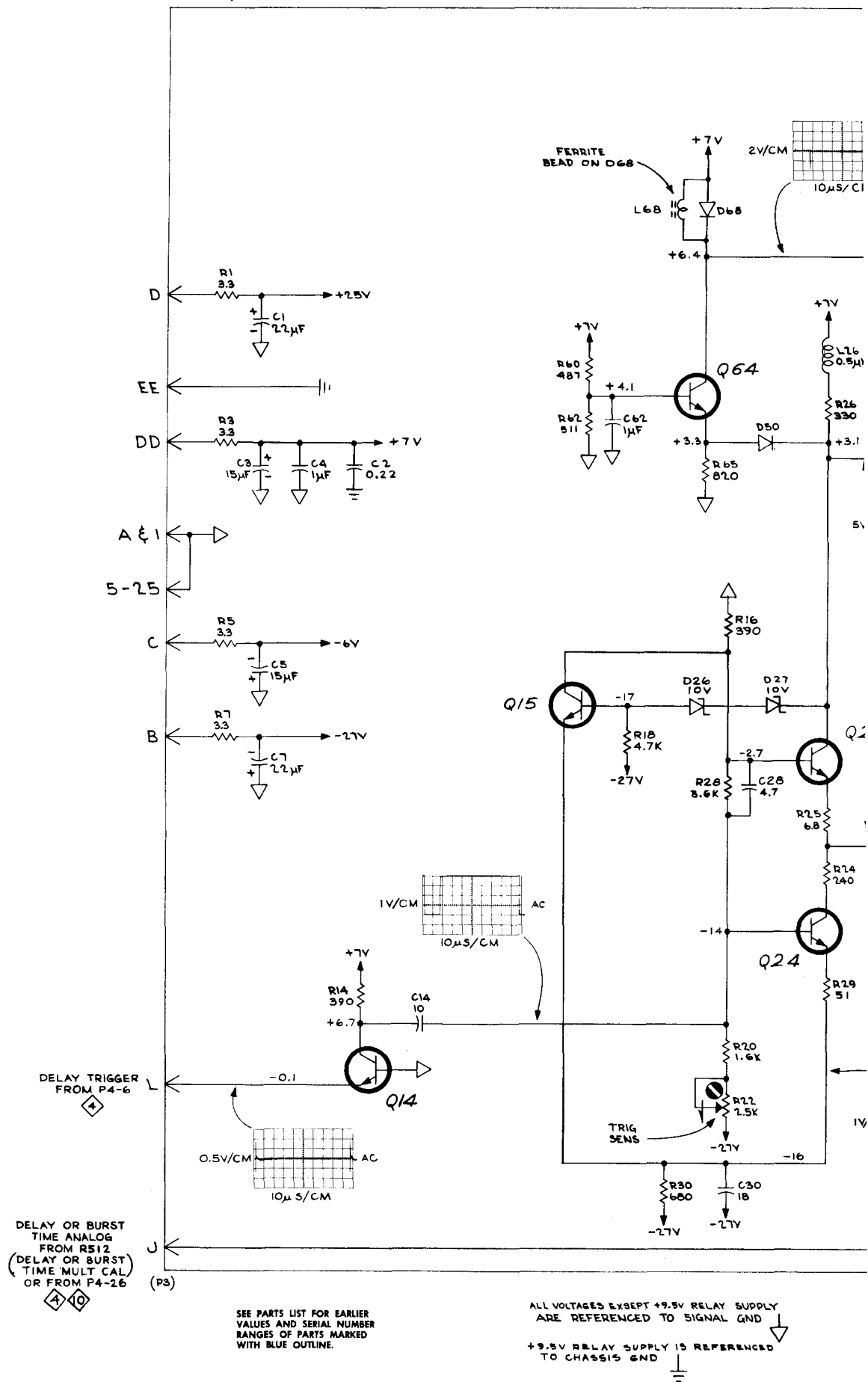
CTOR TYPES

A

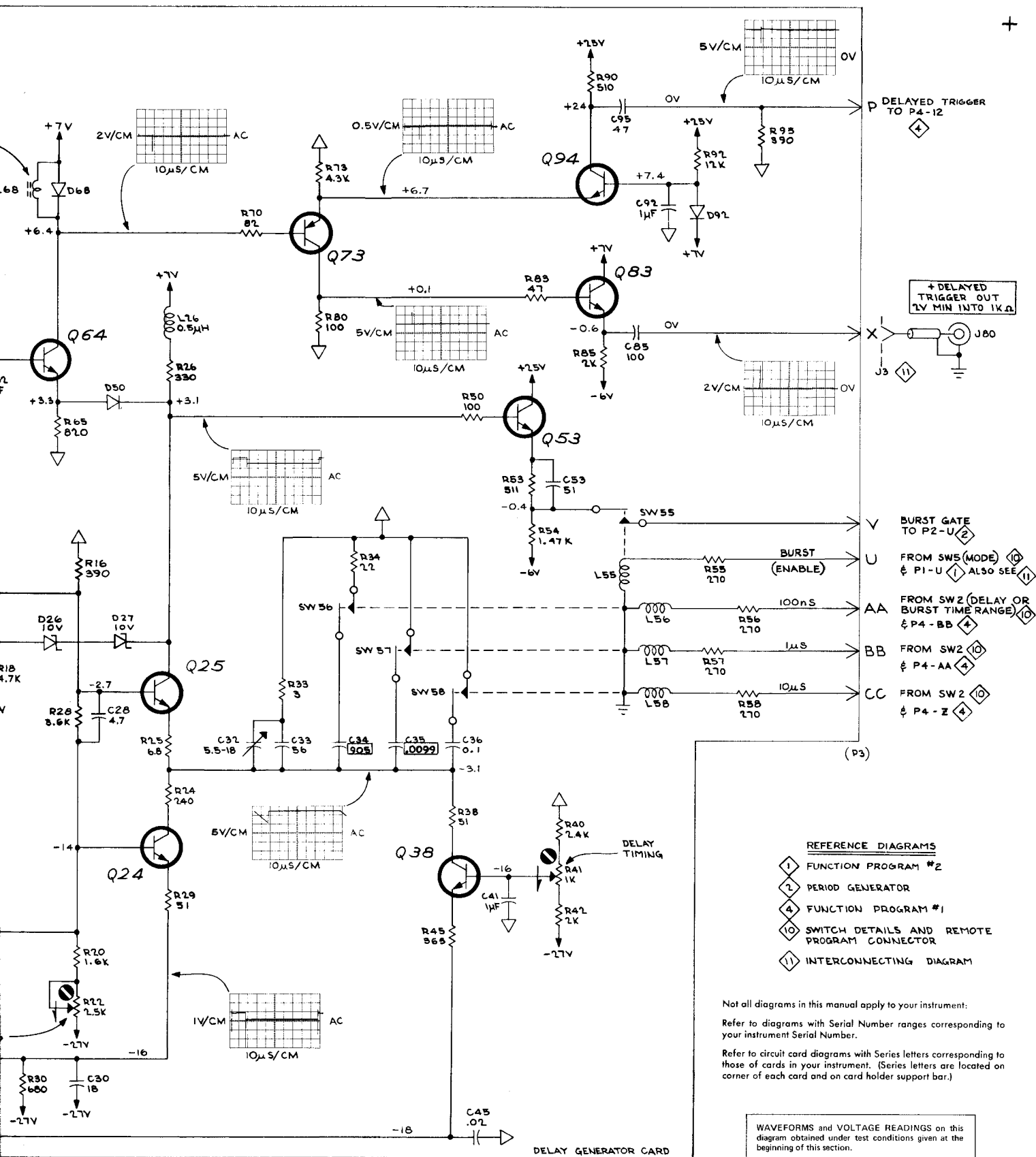
PERIOD GENERATOR  
SERIES Q MODEL 1  
SN1359-UP

1169

2



TYPE RI16 PROGRAMMABLE PULSE GENERATOR



PT +9.5V RELAY SUPPLY  
ED TO SIGNAL GND  
PPLY IS REFERENCED  
ND

SEE PARTS LIST FOR  
SEMICONDUCTOR TYPES

1169  
DELAY GENERATOR 3  
SERIES 0 MODELS 1 & 2  
SN1208-UP

WAVEFORMS and VOLTAGE READINGS on this diagram obtained under test conditions given at the beginning of this section.

Test oscilloscope externally triggered through a coaxial cable from the Type R116 +PRETRIGGER OUT connector.

DELAY OR BURST  
TIME ANALOG  
FROM SW2  
(DELAY OR BURST  
TIME RANGE  
THRU R512  
OR FROM P4-26  
(P3)

DELAY TRIGGER  
FROM P4-6  
(P3)

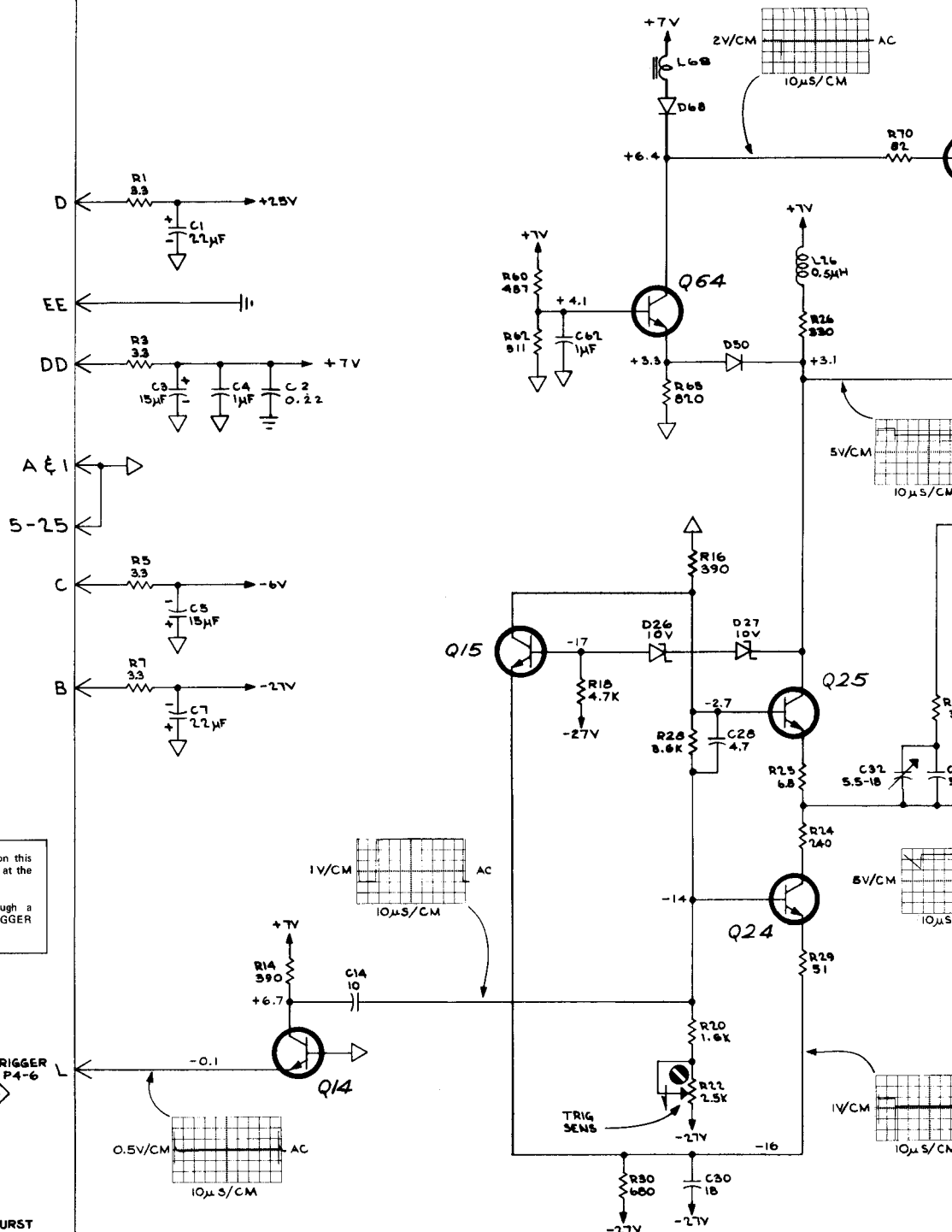
ALL VOLTAGES EXCEPT +9.5V RELAY SUPPLY  
ARE REFERENCED TO SIGNAL GND

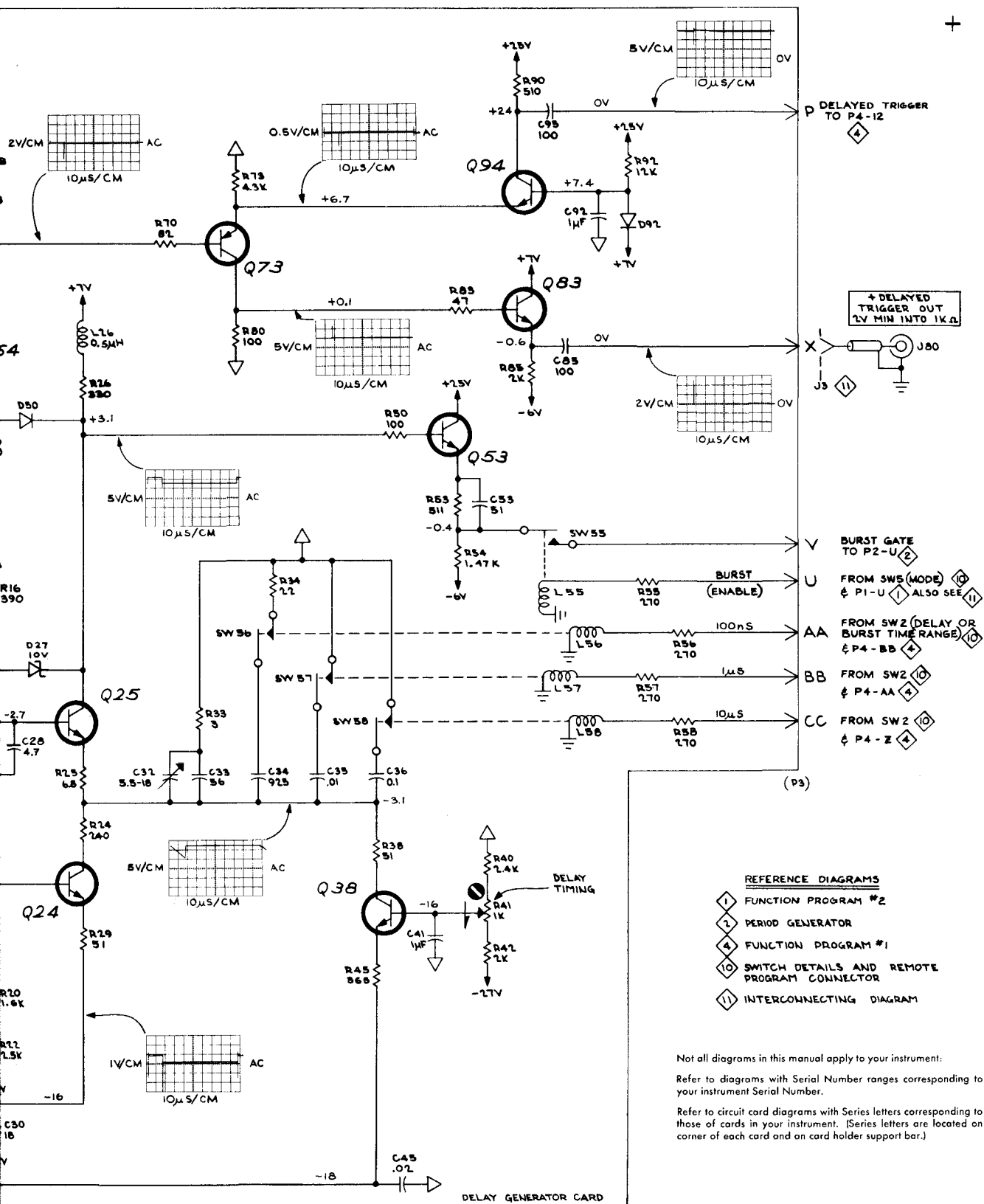
+9.5V RELAY SUPPLY IS REFERENCED  
TO CHASSIS GND

TYPE R116 PROGRAMMABLE PULSE GENERATOR

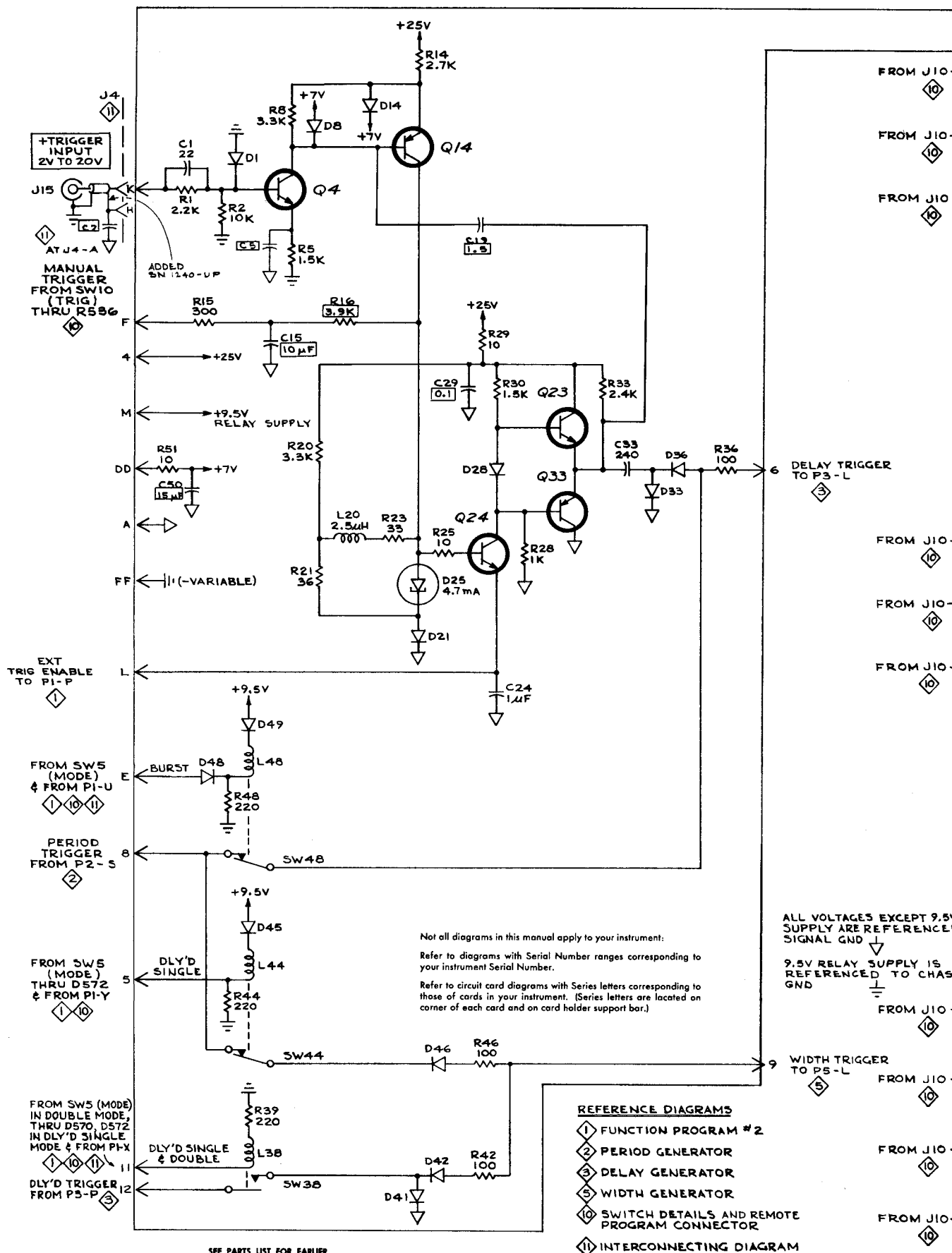
+

A



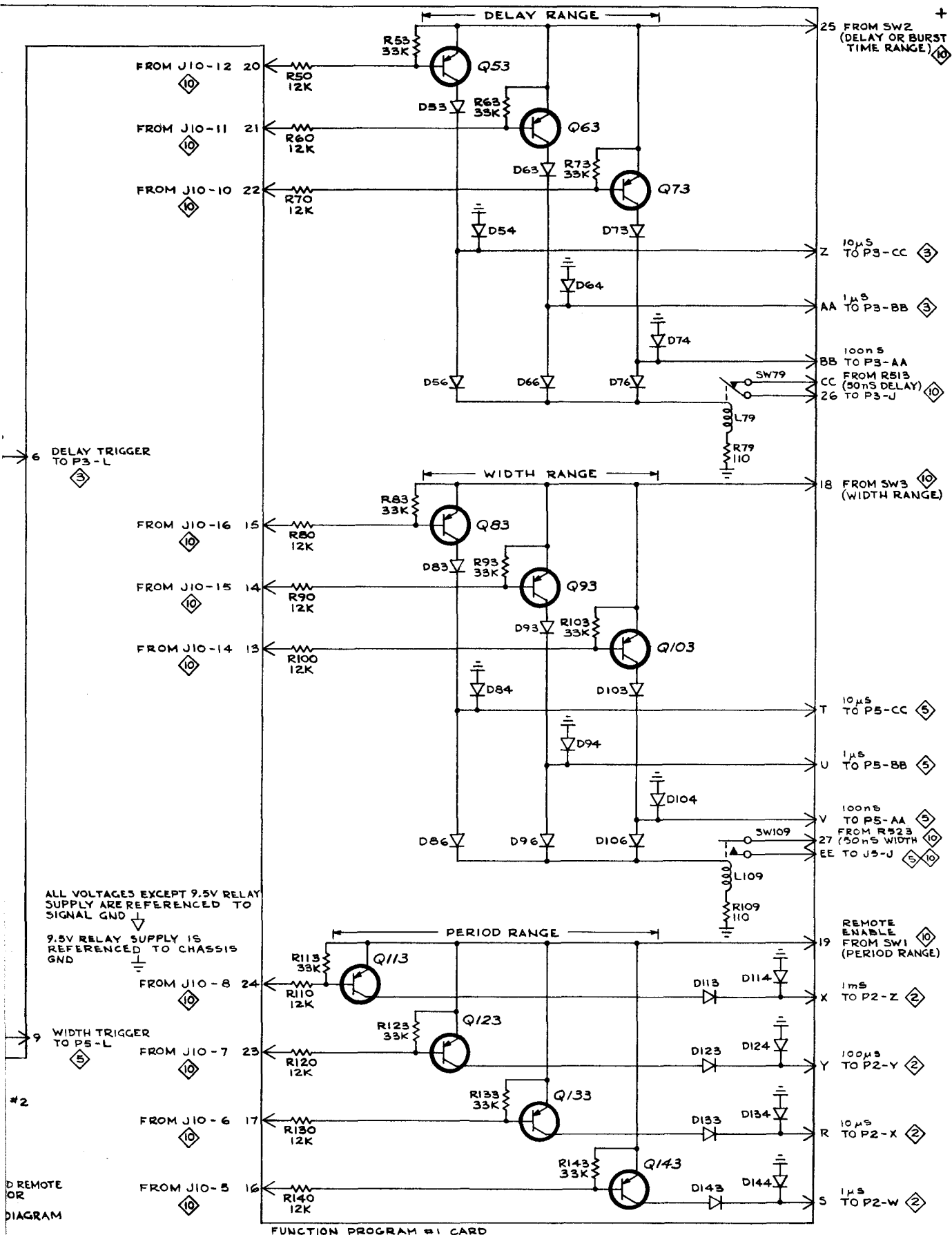


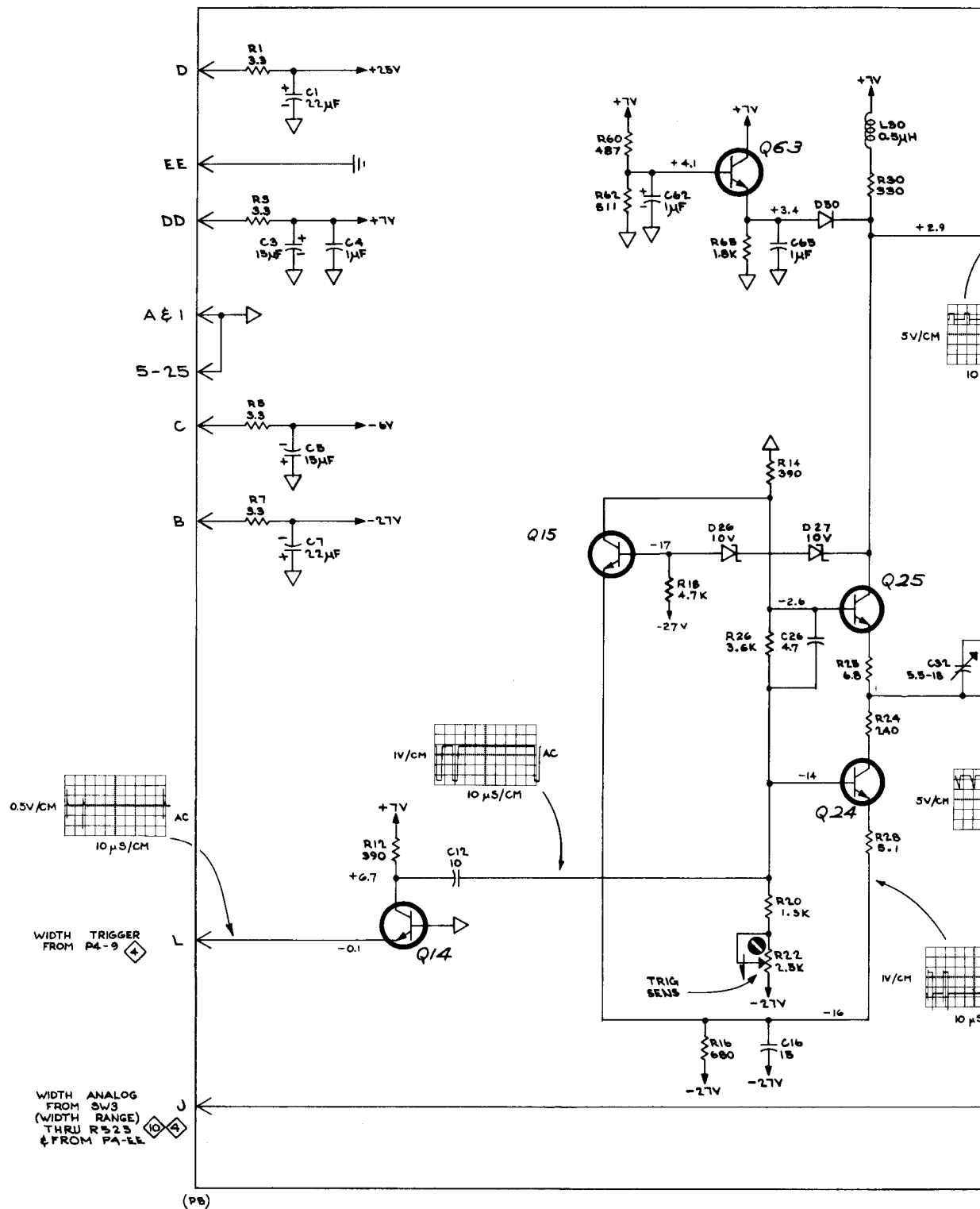
1169  
 DELAY GENERATOR 3  
 SERIES C MODEL 3  
 SNI084-1207



TYPE RI16 PROGRAMMABLE PULSE GENERATOR





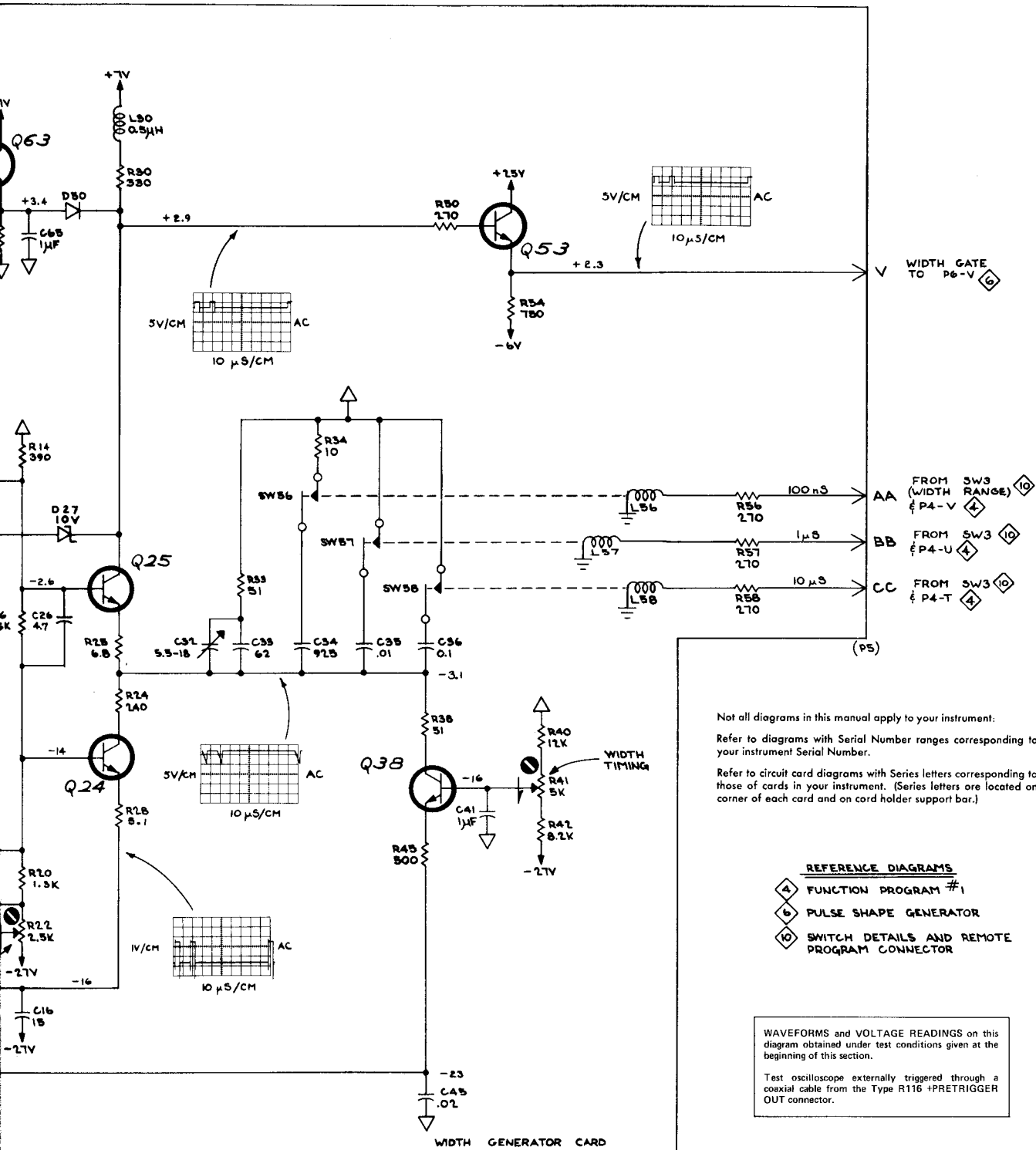


ALL VOLTAGES EXCEPT +9.5V RELAY SUPPLY  
ARE REFERENCED TO SIGNAL GND

+9.5V RELAY SUPPLY IS REFERENCED  
TO CHASSIS GND

TYPE R116 PROGRAMMABLE PULSE GENERATOR

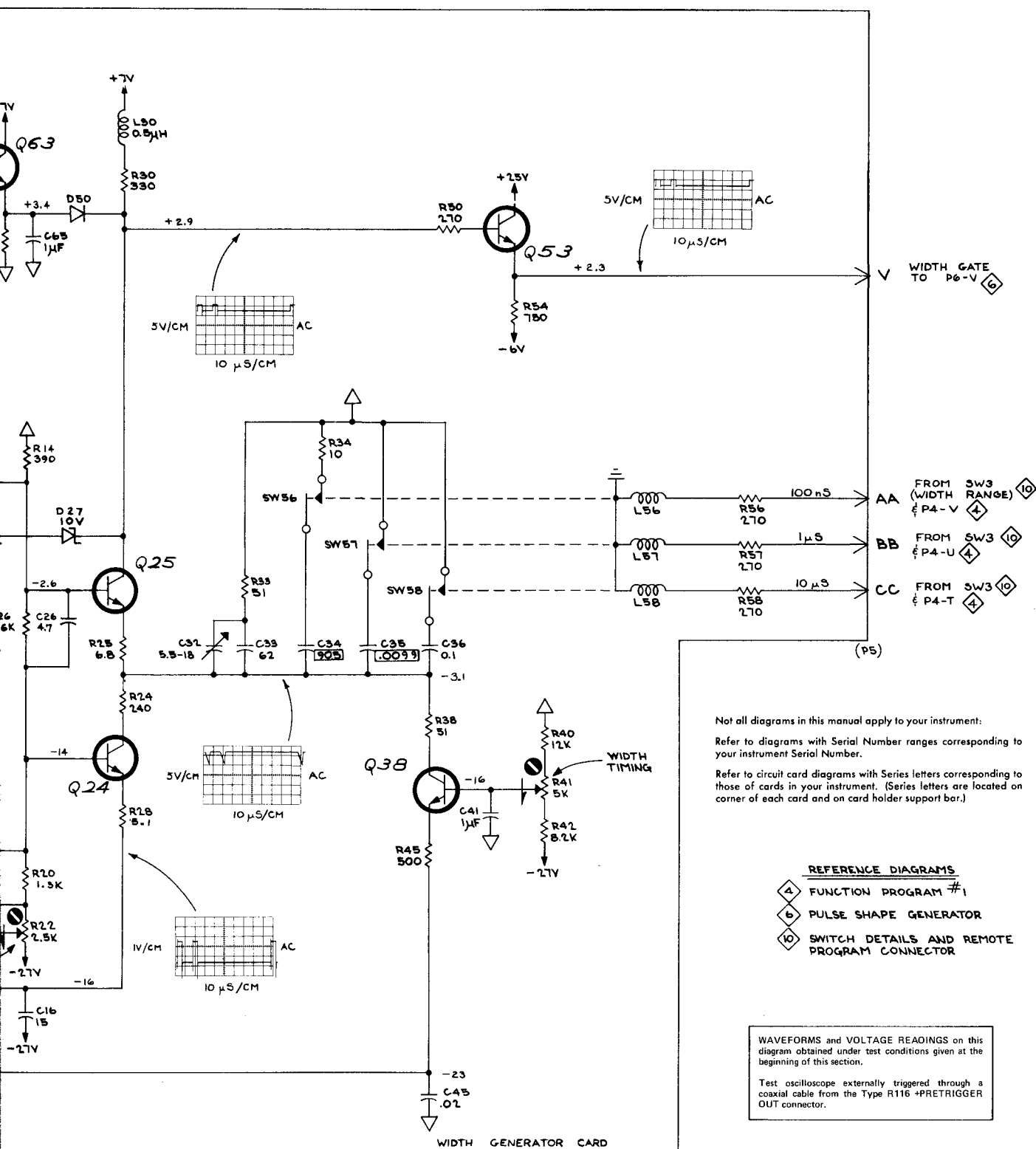
A



WIDTH GENERATOR  
 SERIES E MODEL 3  
 SN1084-1207

5





SEE PARTS LIST FOR  
SEMICONDUCTOR TYPES

SEE PARTS LIST FOR EARLIER  
VALUES AND SERIAL NUMBER  
RANGES OF PARTS MARKED  
WITH BLUE OUTLINE.

1169

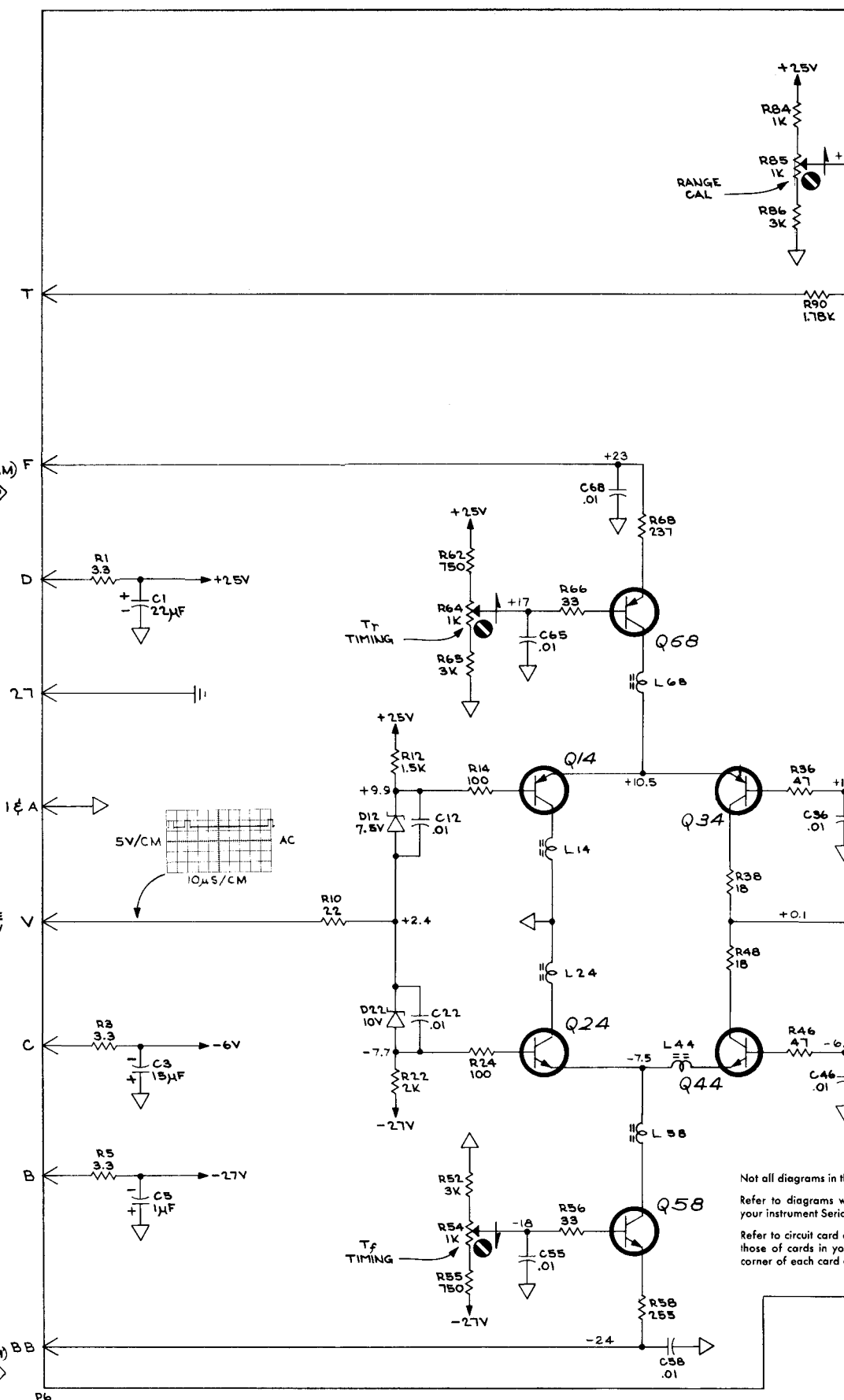
WIDTH GENERATOR 5  
SERIES P MODELS 1, 2, 3  
SN1208-1359  
& SERIES R MODEL 1  
SN1360-UP

AMPLITUDE ANALOG  
FROM SW4  
(AMPLITUDE RANGE)  
THRU R532

RISETIME ANALOG  
FROM SW9 (PROGRAM)  
THRU R564

WIDTH GATE  
FROM PS-V

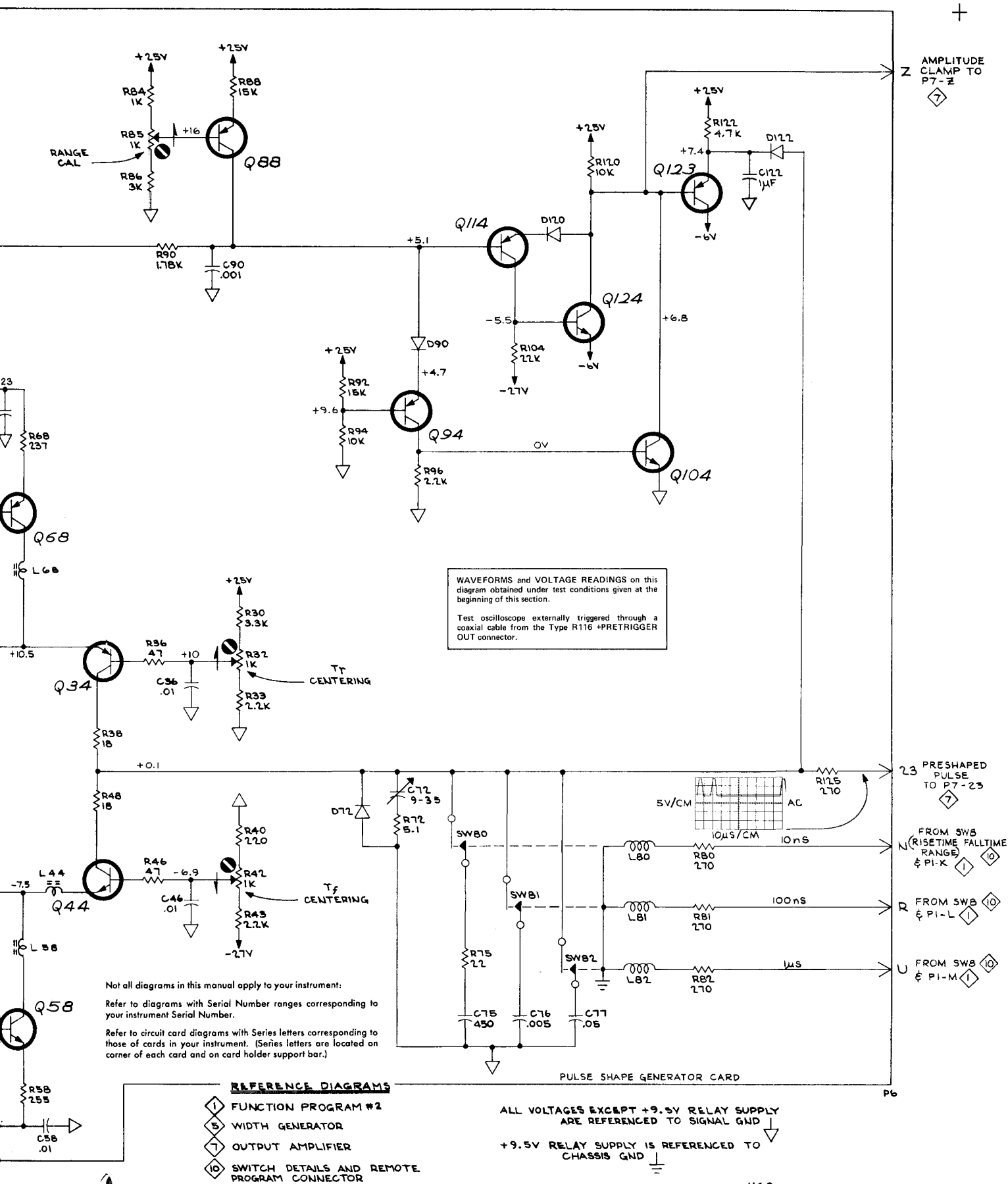
FALLTIME ANALOG  
FROM SW9 (PROGRAM)  
THRU R554



SEE PARTS LIST FOR SEMICONDUCTOR TYPE

TYPE R116 PROGRAMMABLE PULSE GENERATOR

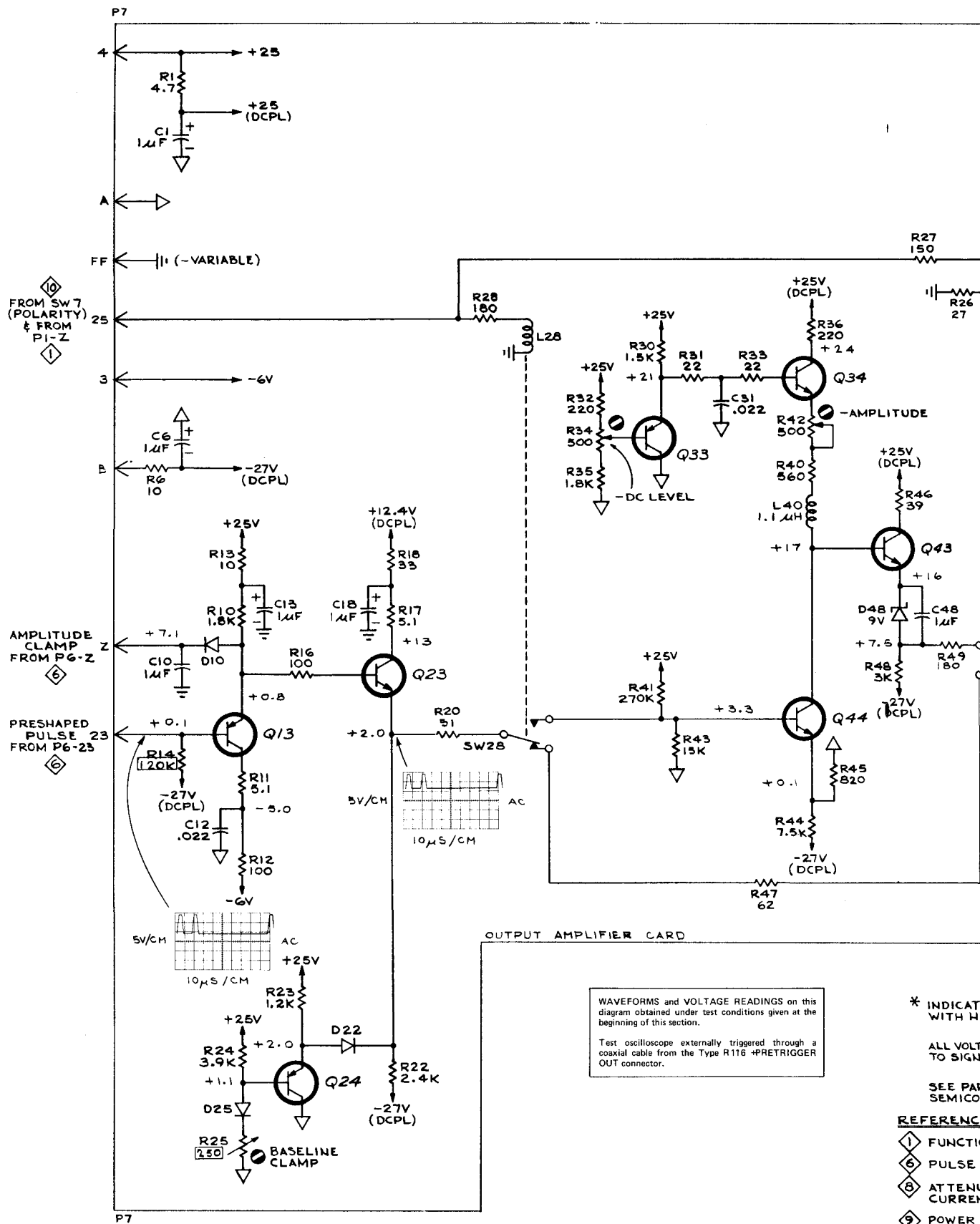
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SEMICONDUCTOR TYP.

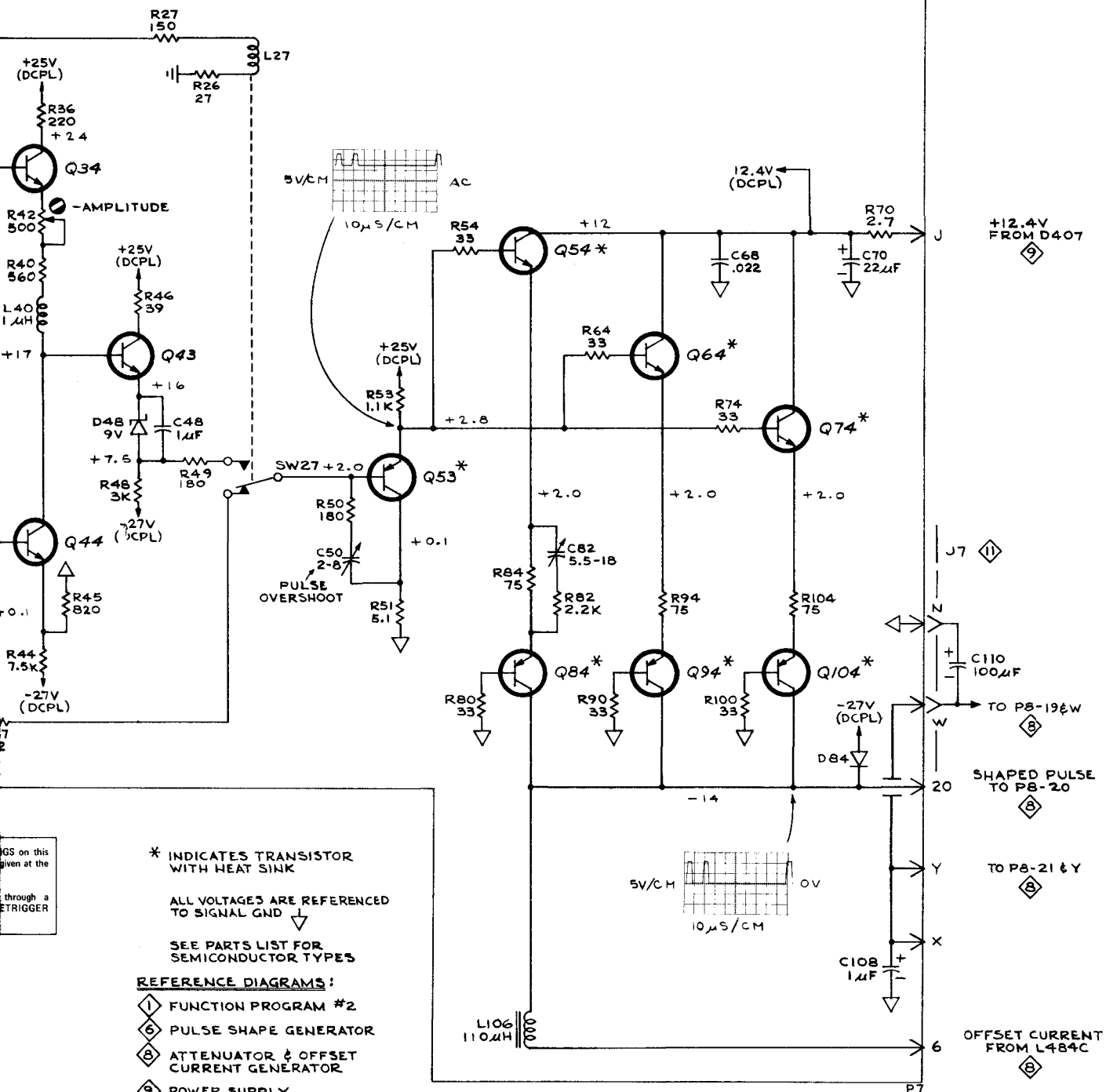
A

6



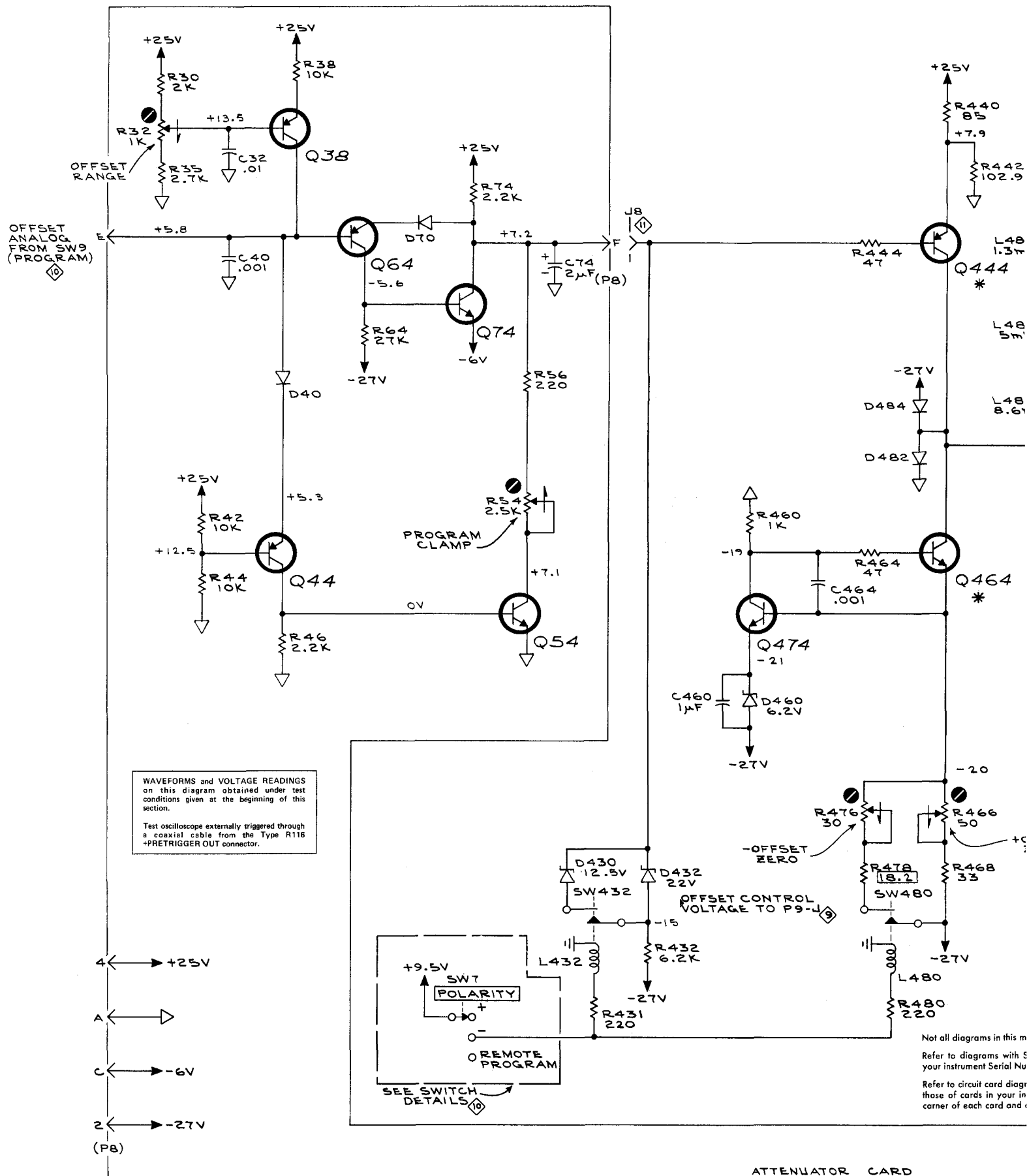
TYPE R116 PROGRAMMABLE PULSE GENERATOR



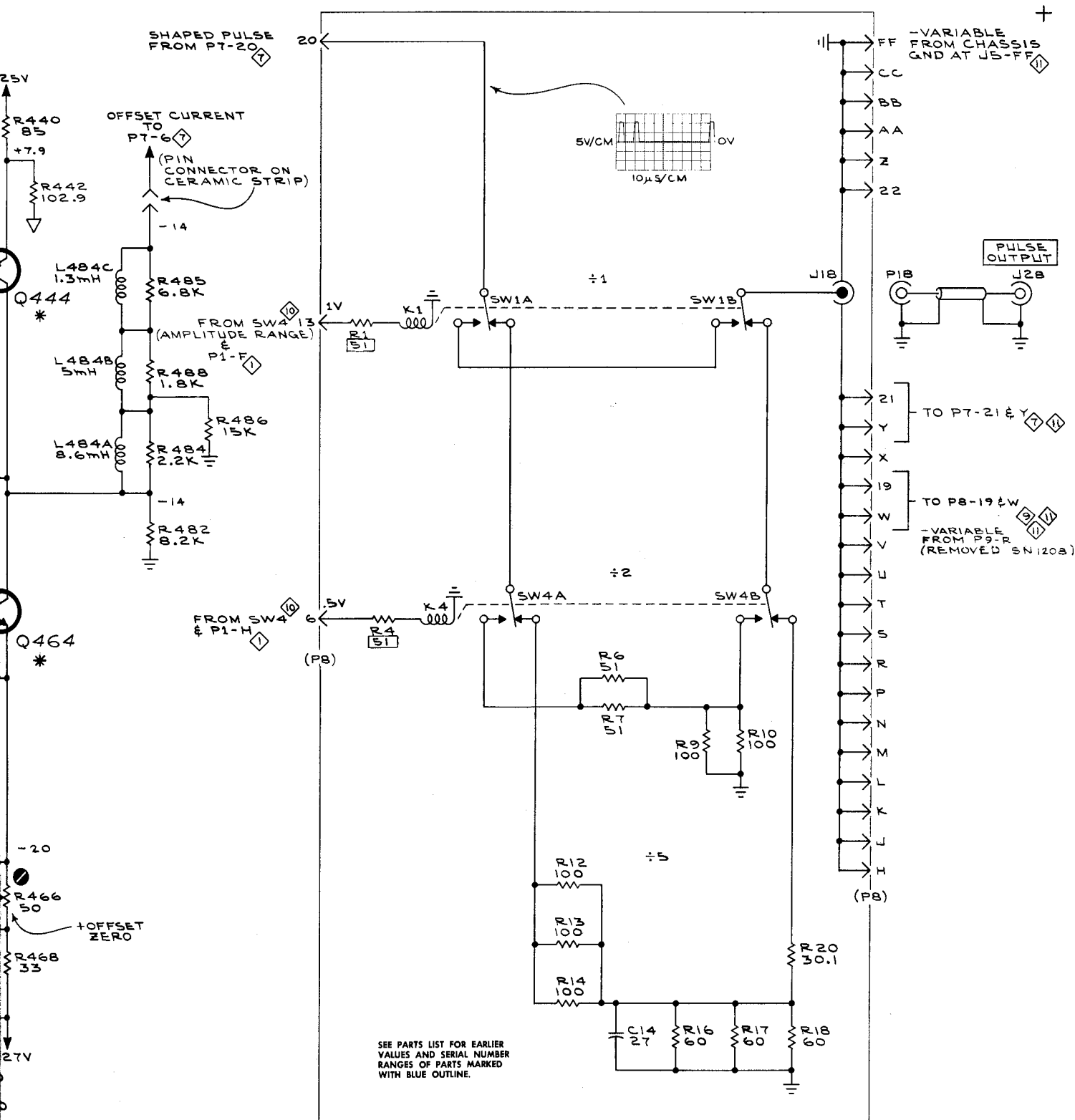


# OUTPUT AMPLIFIER ⑦ SERIES M MODELS 1, 2, 3 SN1084-UP

1169



TYPE R116 PROGRAMMABLE PULSE GENERATOR



All diagrams in this manual apply to your instrument:  
 1. For diagrams with Serial Number ranges corresponding to your instrument Serial Number.  
 2. For circuit card diagrams with Series letters corresponding to the location of cards in your instrument. (Series letters are located on the top of each card and on card holder support bar.)

ALL VOLTAGES EXCEPT +9.5V RELAY SUPPLY ARE REFERENCED TO SIGNAL GND

+9.5V RELAY SUPPLY IS REFERENCED TO CHASSIS GND

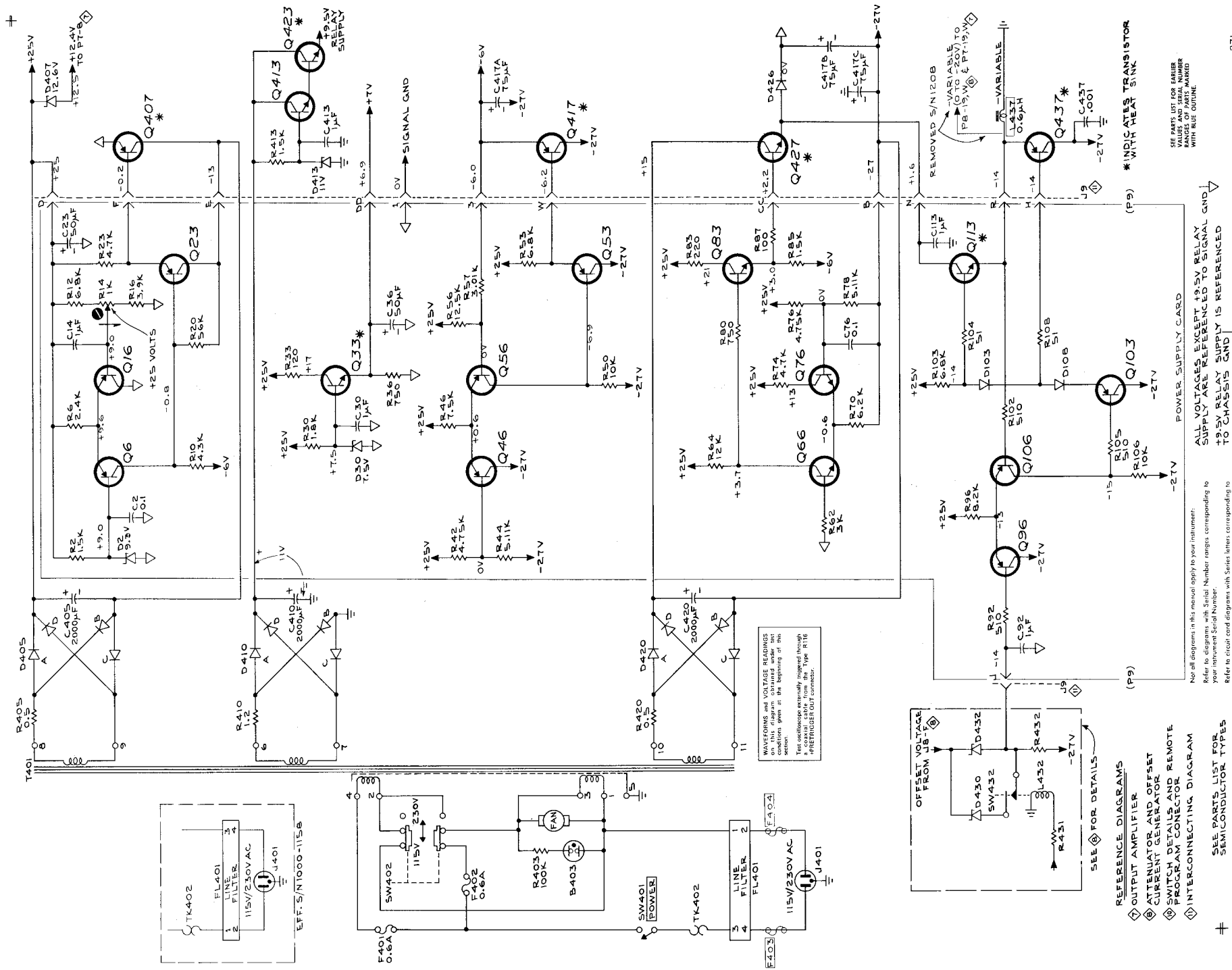
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

\*INDICATES TRANSISTOR WITH HEAT SINK

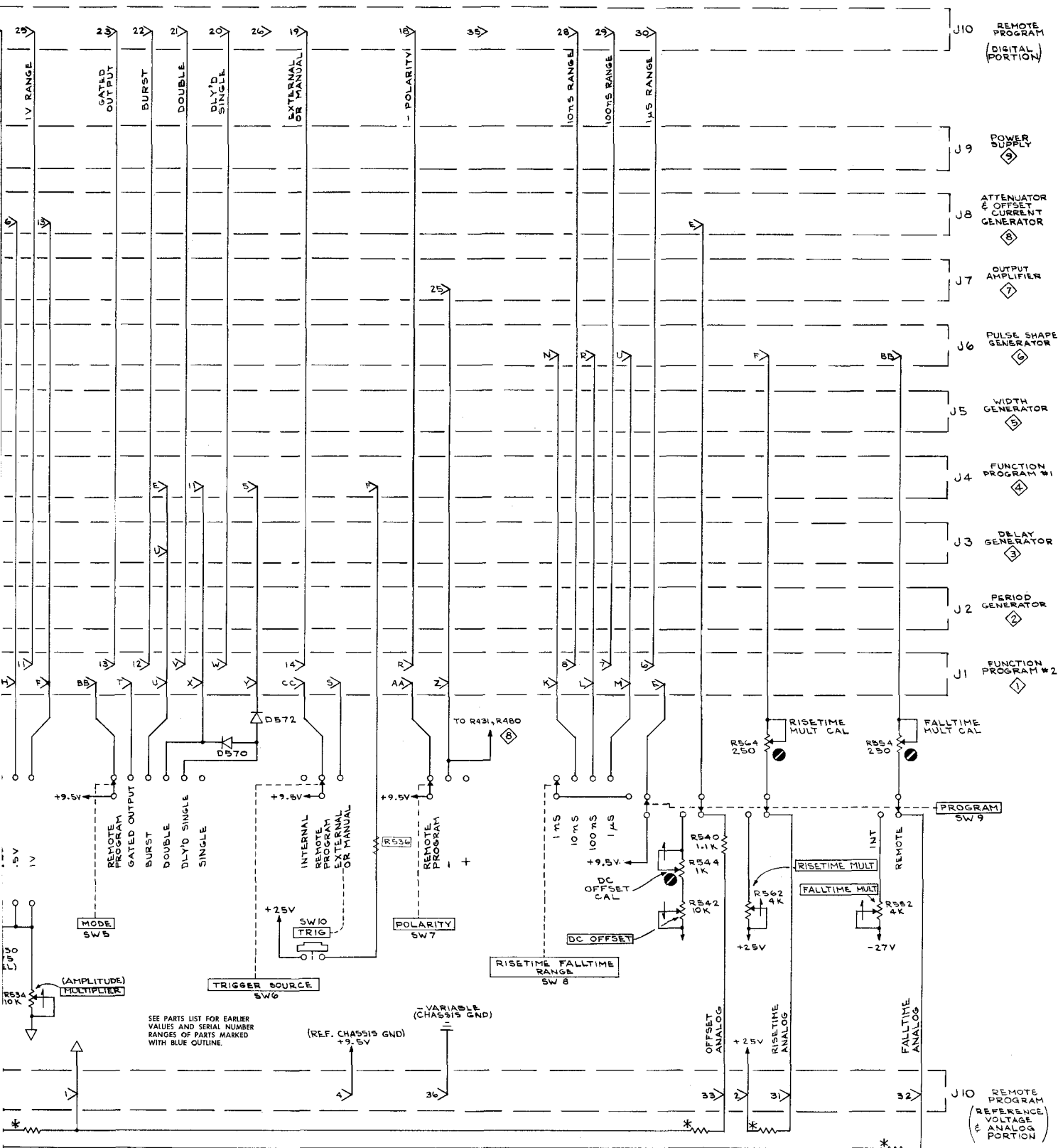
#### REFERENCE DIAGRAMS

- ① FUNCTION PROGRAM #2
- ② OUTPUT AMPLIFIER
- ③ POWER SUPPLY
- ④ SWITCH DETAILS AND REMOTE PROGRAM CONNECTOR
- ⑤ INTERCONNECTING DIAGRAM

ATTENUATOR SERIES N MODELS 1 & 2  
 & OFFSET CURRENT GENERATOR SN1084-UP

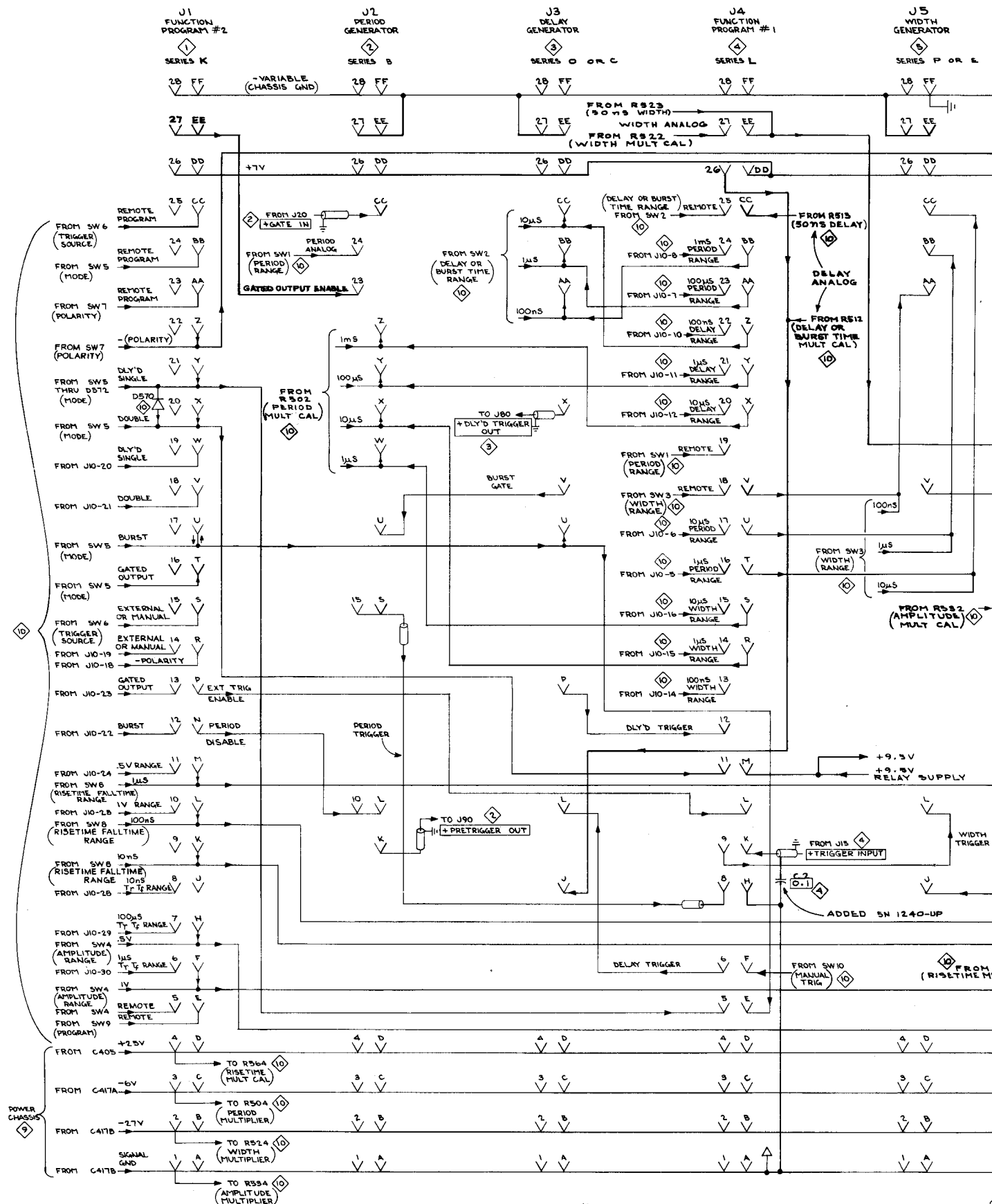




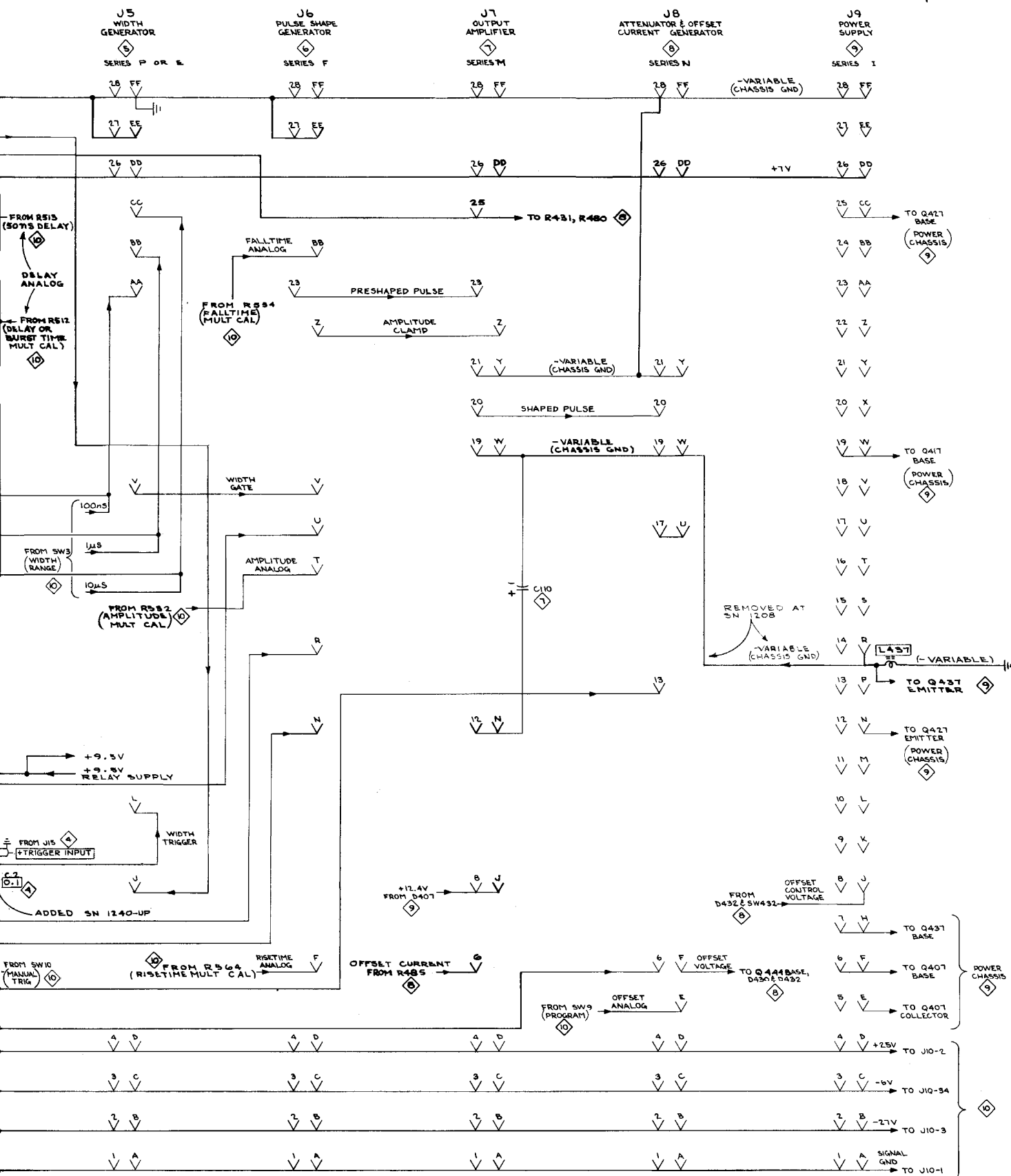


- Legend for the diagram:
- 1 FUNCTION PROGRAM #2
  - 2 PERIOD GENERATOR
  - 3 DELAY GENERATOR
  - 4 FUNCTION PROGRAM #1
  - 5 WIDTH GENERATOR
  - 6 PULSE SHAPE GENERATOR
  - 7 OUTPUT AMPLIFIER
  - 8 ATTENUATOR & OFFSET CURRENT GENERATOR
  - 9 POWER SUPPLY
  - 10 INTERCONNECTING DIAGRAM

SWITCH DETAILS AND  
REMOTE PROGRAM CONNECTOR  
SN 1084-UP



TYPE R116 PROGRAMMABLE PULSE GENERATOR



## REFERENCE DIAGRAMS

- |   |                       |    |   |
|---|-----------------------|----|---|
| 1 | FUNCTION PROGRAM #1   | 7  | OUTPUT AMPLIFIER                          |
| 2 | PERIOD GENERATOR      | 8  | ATTENUATOR & OFFSET CURRENT GENERATOR     |
| 3 | DELAY GENERATOR       | 9  | POWER SUPPLY                              |
| 4 | FUNCTION PROGRAM #2   | 10 | SWITCH DETAILS & REMOTE PROGRAM CONNECTOR |
| 5 | WIDTH GENERATOR       |    |   |
| 6 | PULSE SHAPE GENERATOR |    |   |

Not all diagrams in this manual apply to your instrument:

Refer to diagrams with Serial Number ranges corresponding to your instrument Serial Number.

Refer to circuit card diagrams with Series letters corresponding to those of cards in your instrument. (Series letters are located on corner of each card and on card holder support bar.)

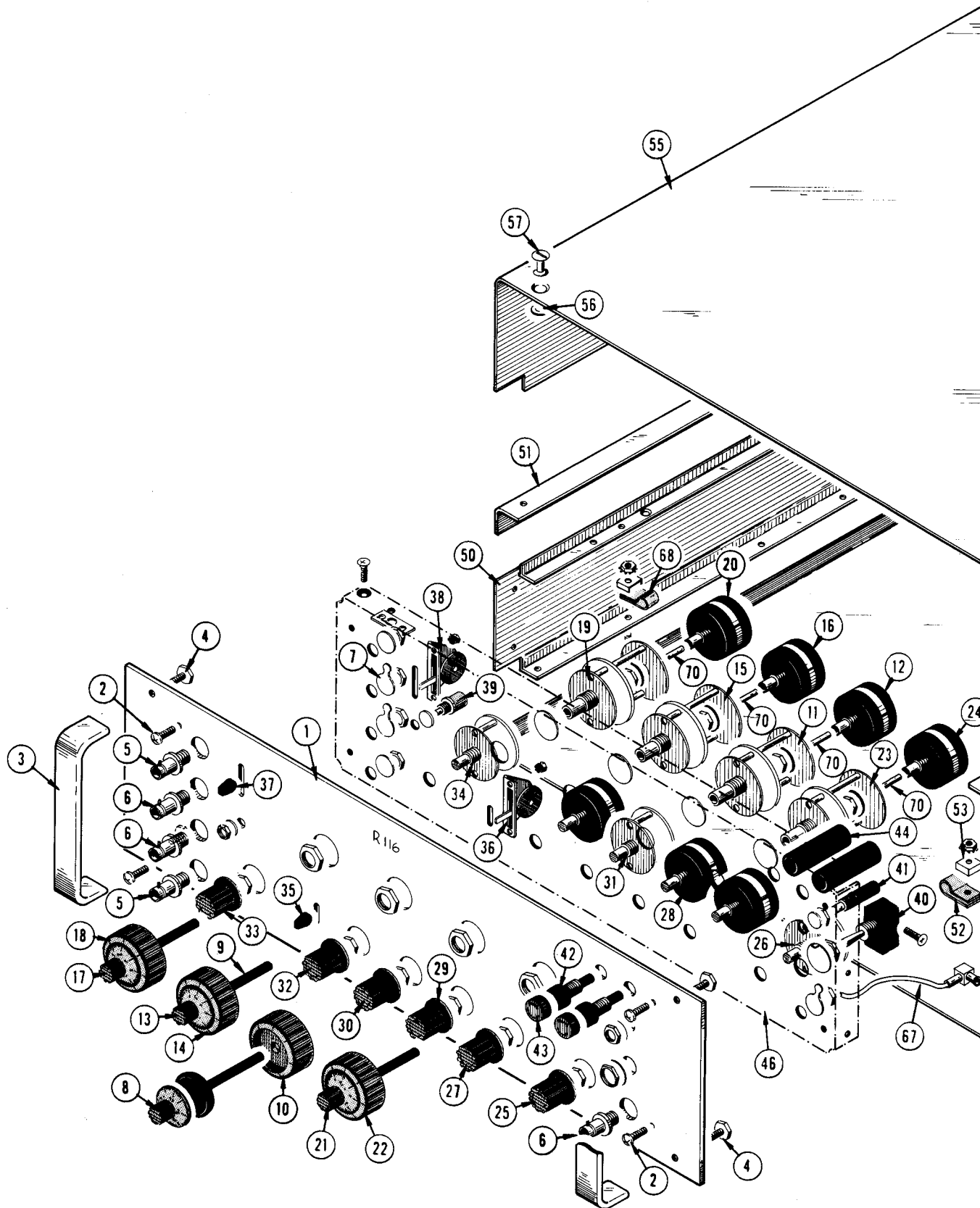
INTERCONNECTING DIAGRAM  
SN 1084-UP



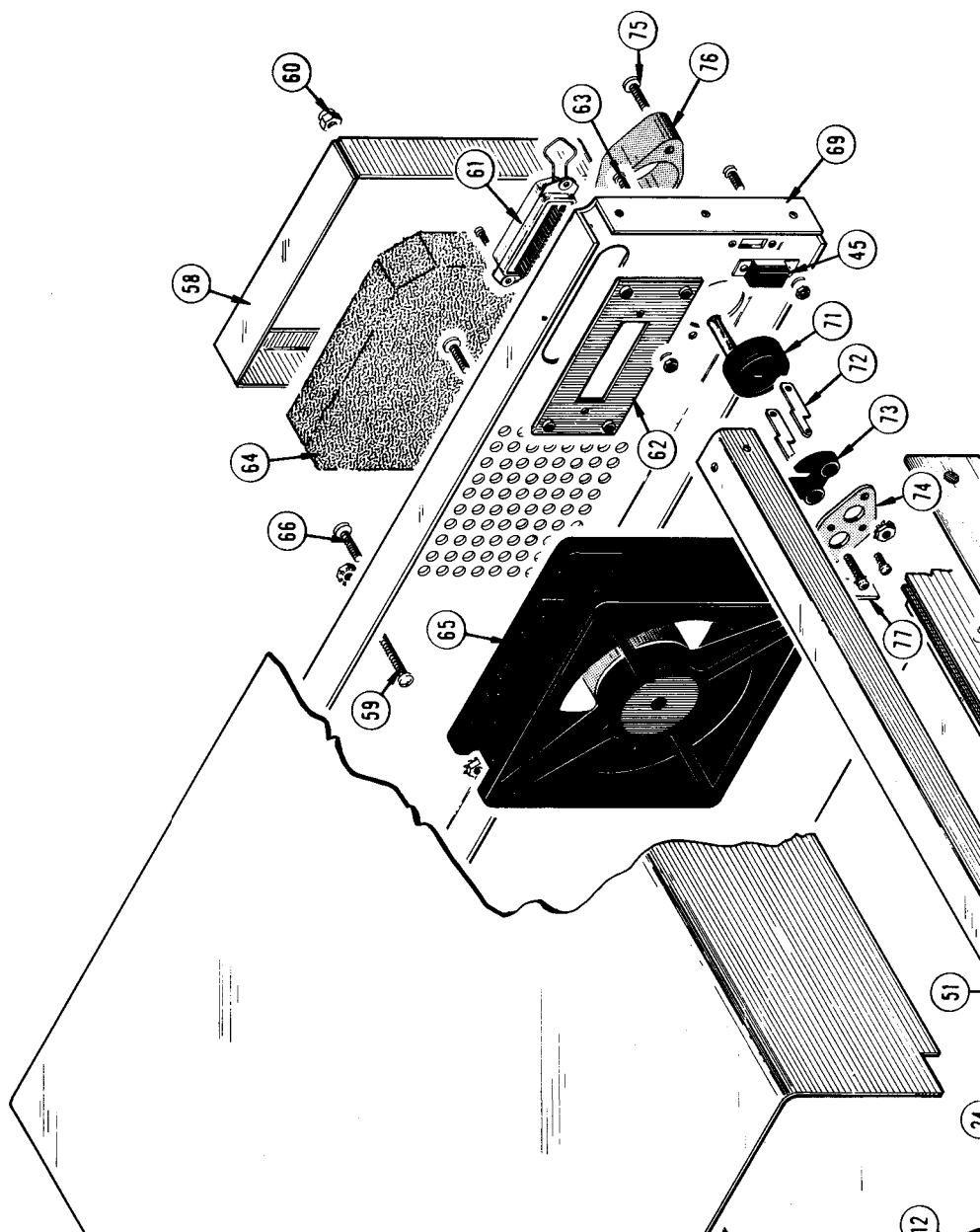
1169

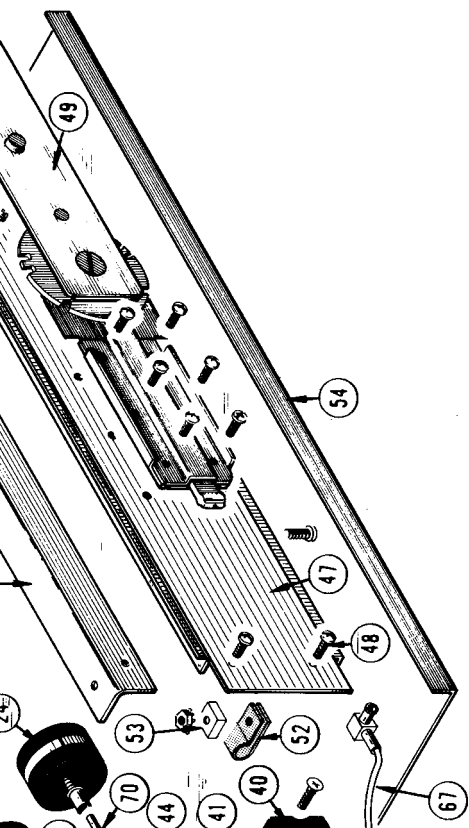


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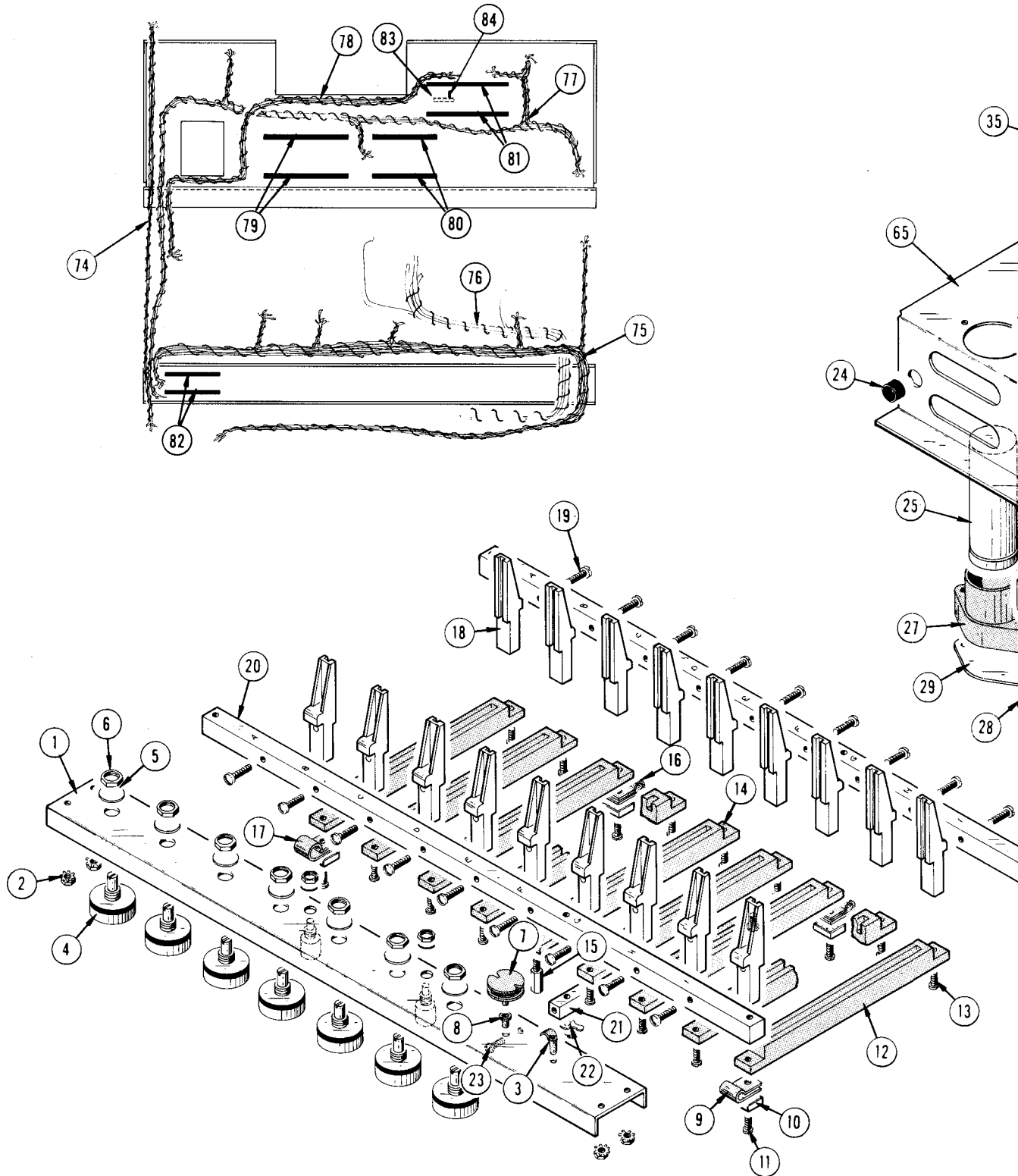
TYPE R116 PROGRAMMABLE PULSE GENERATOR—(SN 1084-up)

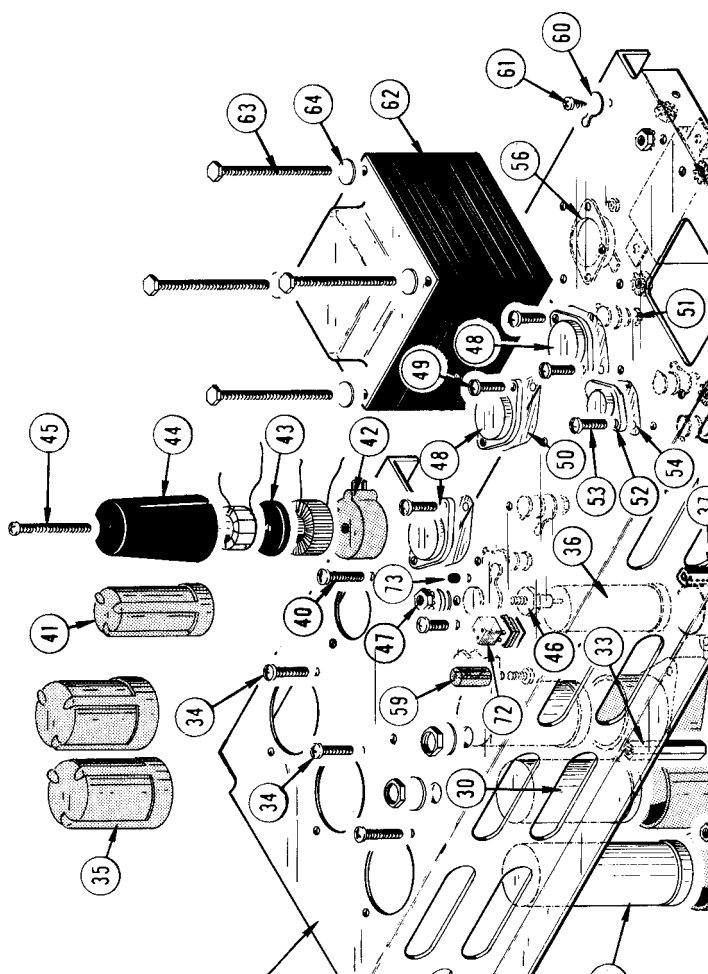


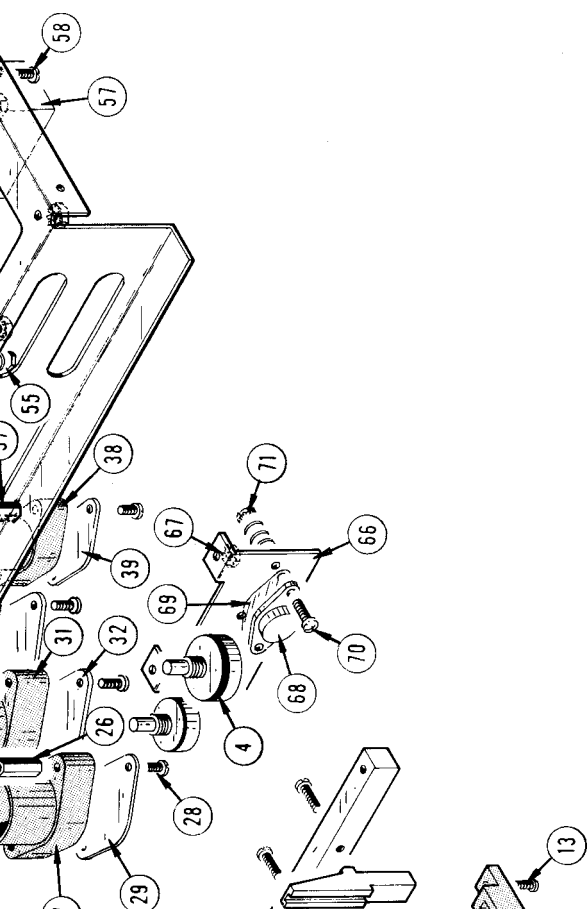


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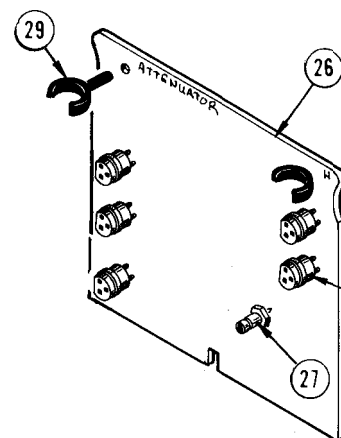
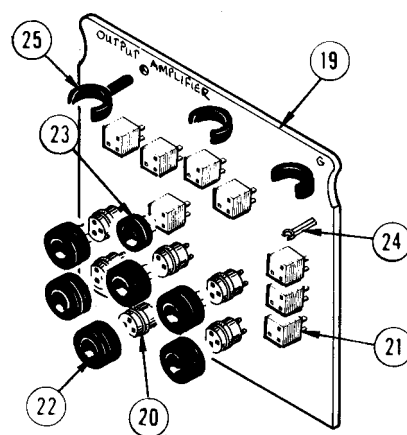
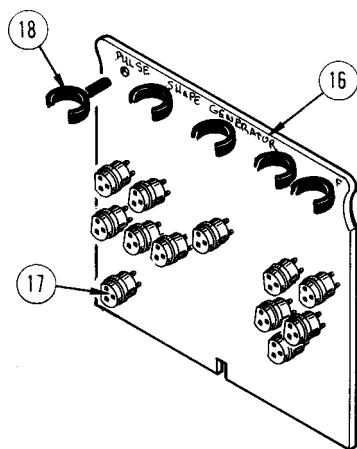
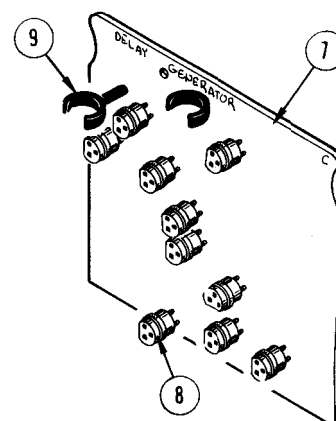
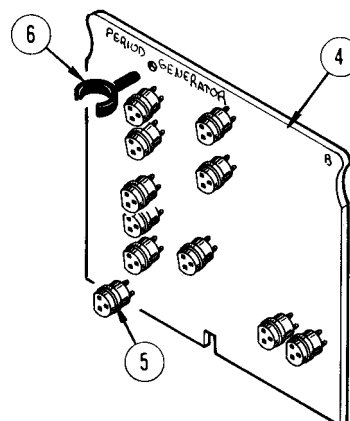
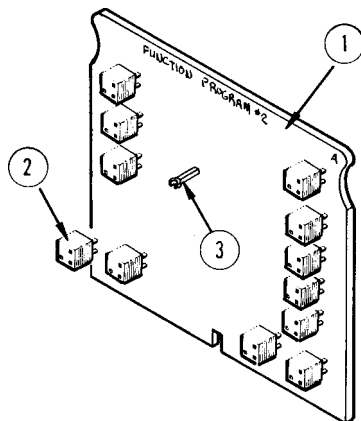
# CABLE HARNESS & CERAMIC STRIP DETAIL

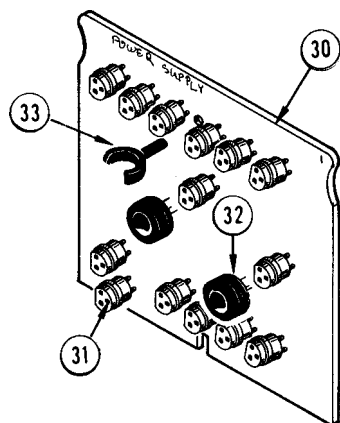
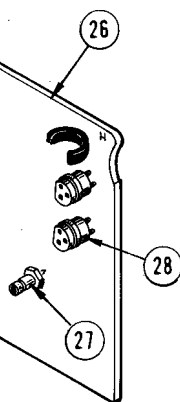
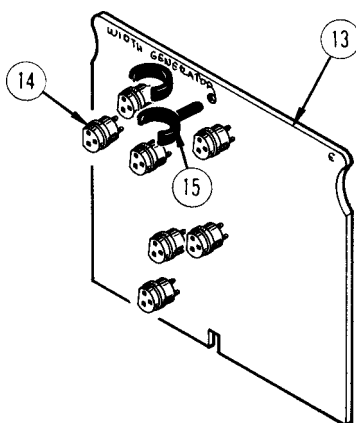
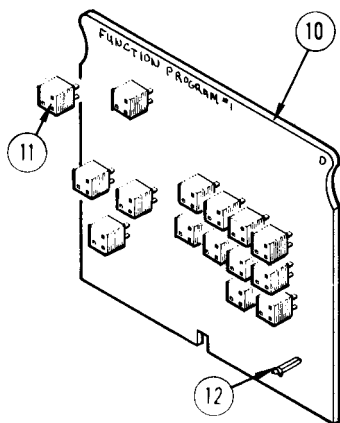






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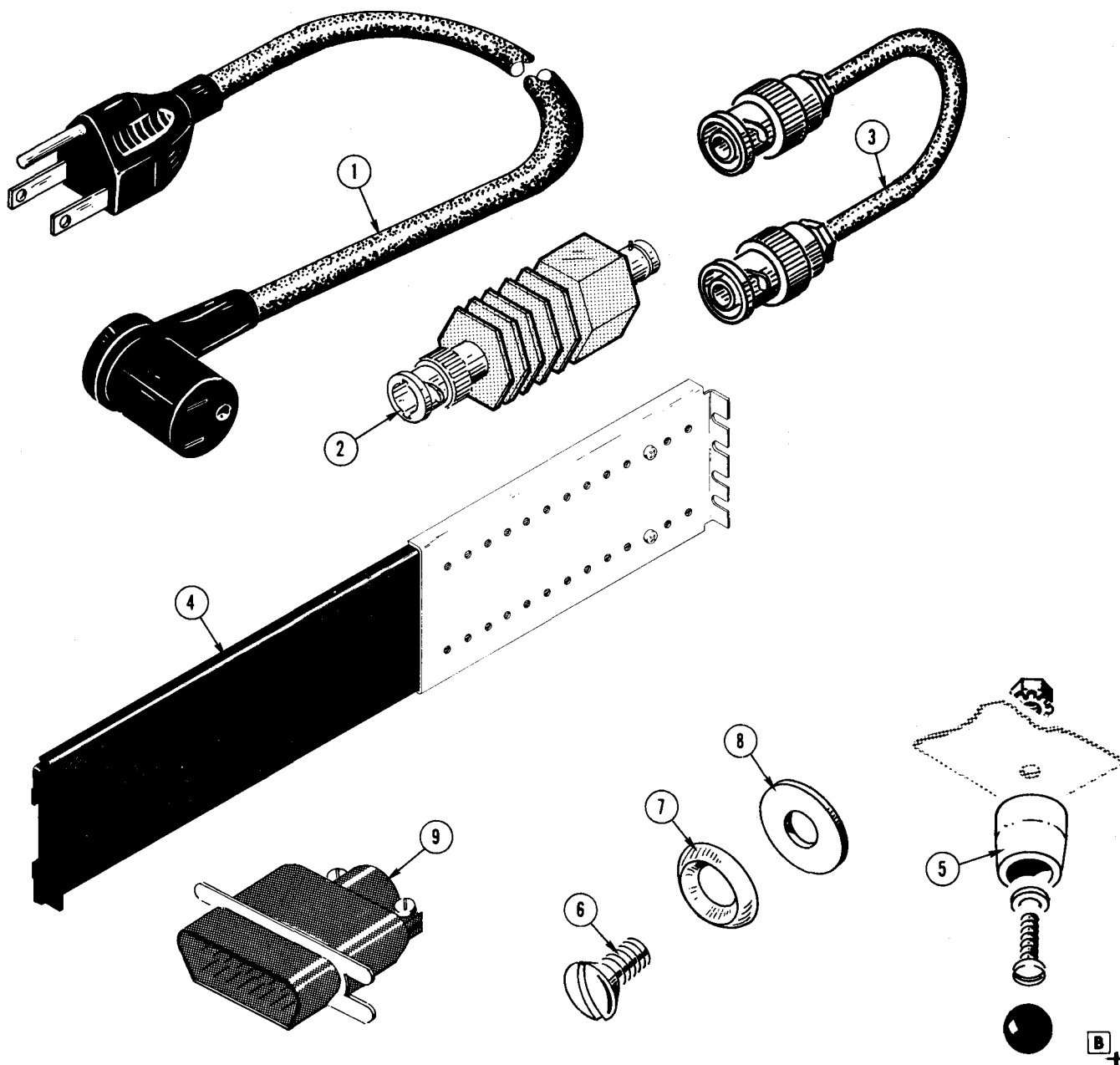


Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q t y						Description
					1	2	3	4	5	
4-1	161-0024-00	1084	1099	1						CORD, power, 3-conductor, 8-foot, right angle, female
	161-0024-01	1100	1299	1						CORD, power, 3-conductor, 8-foot, right angle, female
	161-0024-03	1300		1						CORD, power, 3-conductor, 8-foot, right angle, female
-2	011-0099-00			1						TERMINATION, 50 $\Omega$ , in-line, w/BNC connectors
-3	012-0057-01			1						ASSEMBLY, cable, 50 $\Omega$ coaxial, 42 inches, w/BNC connectors
-4	351-0084-00			1						TRACK, slide, 18 x 3 $\frac{3}{8}$ inches, left & right, w/2 brackets
-5	016-0052-00			1						KIT, cabinet feet
-6	212-0512-00			4						SCREW, 10-32 x $\frac{1}{2}$ inch, OHS
-7	210-0833-00			4						WASHER, finishing, plated, #10
-8	210-0917-00			4						WASHER, plastic, 0.191 ID x $\frac{5}{8}$ inch OD
-9	131-0293-00			1						CONNECTOR, 36 terminal, cable end, male
	070-1042-00			1						MANUAL, instruction (not shown)

## FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations which appear either on the back of the diagrams or on pullout pages immediately following the diagrams of the instruction manual.

## INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the Description column.

*Assembly and/or Component*  
*Detail Part of Assembly and/or Component*  
*mounting hardware for Detail Part*  
*Parts of Detail Part*  
*mounting hardware for Parts of Detail Part*  
*mounting hardware for Assembly and/or Component*

Mounting hardware always appears in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation.

**Mounting hardware must be purchased separately, unless otherwise specified.**

## PARTS ORDERING INFORMATION

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

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, instrument type or number, serial or model number, and modification number if applicable.

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

Change information, if any, is located at the rear of this manual.

## ABBREVIATIONS AND SYMBOLS

For an explanation of the abbreviations and symbols used in this section, please refer to the page immediately preceding the Electrical Parts List in this instruction manual.

INDEX OF MECHANICAL PARTS ILLUSTRATIONS

Title	Location (reverse side of)
FIG. 1 FRONT & FRAME . . . . ATTENUATOR SERIES H & OFFSET CURRENT GEN	
FIG. 2 BRACKETS & CHASSIS . . . . .	POWER SUPPLY & CHASSIS
FIG. 3 CIRCUIT CARDS . . . SWITCH DETAIL & REMOTE PROGRAM CONNECTOR	
FIG. 4 ACCESSORIES . . . . .	INTERCONNECTING DIAGRAM

# SECTION 10

## MECHANICAL PARTS LIST

FIG. 1 FRONT &amp; FRAME

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q					Description
				t	y	1	2	3	
1-1	333-0890-00			1					PANEL, front
-2	212-0068-00			-					mounting hardware: (not included w/panel)
				4					SCREW, 8-32 x $\frac{5}{16}$ inch, THS
-3	367-0032-00			2					HANDLE, chrome
-4	213-0090-00			-					mounting hardware for each: (not included w/handle)
	210-0010-00			2					SCREW, 10-32 x $\frac{1}{2}$ inch, HHS
				2					WASHER, lock, internal, #10
-5	131-0352-00			2					CONNECTOR, coaxial, 1 contact, BNC
-6	131-0352-00			3					CONNECTOR, coaxial, 1 contact, BNC
-7	210-0255-00			-					mounting hardware for each: (not included w/connector)
	210-1000-00			1					LUG, solder, $\frac{3}{8}$ inch
				1					WASHER, BNC connector
-8	366-0334-00			1					KNOB, charcoal—WIDTH-MULTIPLIER
	213-0075-00			-					knob includes:
				1					SETSCREW, 4-40 x $\frac{3}{32}$ inch, HSS
-9	358-0269-00			4					BUSHING, index mount, dial
-10	366-0335-00			1					KNOB, charcoal—WIDTH-RANGE
	213-0004-00			-					knob includes:
				2					SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-11	260-0706-00	1084	1429	1					SWITCH, unwired—WIDTH
	260-0706-01	1430		1					SWITCH, unwired—WIDTH
	210-0049-00			-					mounting hardware: (not included w/switch)
	210-0579-00			1					WASHER, lock, internal, $\frac{5}{8}$ ID x 0.867 inch OD
				1					NUT, hex., $\frac{5}{8}$ -24 x $\frac{3}{4}$ inch
-12	213-0022-00			1					RESISTOR, variable
	210-0012-00			-					resistor includes:
	210-0413-00	1084	1429	1					SETSCREW, 4-40 x $\frac{3}{16}$ inch, HSS
	210-0413-00	1430		-					mounting hardware: (not included w/resistor)
	210-0801-00	X1430		1					WASHER, lock, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD
	211-0008-00	X1430		2					NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
	426-0289-00	X1430		1					NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
				2					WASHER, flat, 0.14 ID x 0.281 inch OD
				2					SCREW, 4-40 x $\frac{1}{4}$ inch, PHS
				1					MOUNT, plastic
-13	366-0334-00			1					KNOB, charcoal—DELAY OR BURST TIME-MULTIPLIER
	213-0075-00			-					knob includes:
				1					SETSCREW, 4-40 x $\frac{3}{32}$ inch, HSS
-14	366-0335-00			1					KNOB, charcoal—DELAY OR BURST TIME-RANGE
	213-0004-00			-					knob includes:
				2					SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS

FIG. 1 FRONT &amp; FRAME (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q t y	Description					
						1	2	3	4	5
1-15	260-0706-00	1034	1429	1	SWITCH, unwired—DELAY OR BURST TIME					
	260-0706-01	1430		1	SWITCH, unwired—DELAY OR BURST TIME					
	- - - - -			-	mounting hardware: (not included w/switch)					
	210-0049-00			1	WASHER, lock, internal, $\frac{5}{8}$ ID x 0.867 inch OD					
	210-0579-00			1	NUT, hex., $\frac{5}{8}$ -24 x $\frac{3}{4}$ inch					
-16	- - - - -			1	RESISTOR, variable					
	- - - - -			-	resistor includes:					
	213-0022-00			1	SETSCREW, 4-40 x $\frac{3}{16}$ inch, HSS					
	- - - - -			-	mounting hardware: (not included w/resistor)					
	210-0012-00			1	WASHER, lock, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD					
	210-0413-00	1034	1429	2	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch					
	210-0413-00	1430		1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch					
	210-0801-00	X1430		2	WASHER, flat, 0.14 ID x 0.281 inch OD					
	211-0008-00	X1430		2	SCREW, 4-40 x $\frac{1}{4}$ inch, PHS					
-17	366-0334-01			1	MOUNT, plastic					
	- - - - -			1	KNOB, charcoal—PERIOD-MULTIPLIER					
	- - - - -			-	knob includes:					
	213-0075-00			1	SETSCREW, 4-40 x $\frac{3}{32}$ inch, HSS					
	-18 366-0335-02			1	KNOB, charcoal—PERIOD-RANGE					
	- - - - -			-	knob includes:					
	213-0004-00			2	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS					
	-19 260-0705-00	1034	1429	1	SWITCH, unwired—PERIOD					
	260-0705-01	1430		1	SWITCH, unwired—PERIOD					
-20	- - - - -			-	mounting hardware: (not included w/switch)					
	210-0049-00			1	WASHER, lock, internal, $\frac{5}{8}$ ID x 0.867 inch OD					
	210-0579-00			1	NUT, hex., $\frac{5}{8}$ -24 x $\frac{3}{4}$ inch					
	- - - - -			1	RESISTOR, variable					
	- - - - -			-	resistor includes:					
	213-0022-00			1	SETSCREW, 4-40 x $\frac{3}{16}$ inch, HSS					
	- - - - -			-	mounting hardware: (not included w/resistor)					
	210-0012-00			1	WASHER, lock, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD					
	210-0413-00	1034	1429	2	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch					
-21	210-0413-00	1430		1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch					
	210-0801-00	X1430		2	WASHER, flat, 0.14 ID x 0.28 inch OD					
	211-0008-00	X1430		2	SCREW, 4-40 x $\frac{1}{4}$ inch, PHS					
	426-0289-00	X1430		1	MOUNT, plastic					
	- - - - -			1	KNOB, charcoal—AMPLITUDE-MULTIPLIER					
	- - - - -			-	knob includes:					
	213-0075-00			1	SETSCREW, 4-40 x $\frac{3}{32}$ inch, HSS					
	-22 366-0335-01			1	KNOB, charcoal—AMPLITUDE-RANGE					
	- - - - -			-	knob includes:					
-23	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS					
	260-0707-00	1034	1429	1	SWITCH, unwired—AMPLITUDE					
	260-0707-01	1430		1	SWITCH, unwired—AMPLITUDE					
	- - - - -			-	mounting hardware: (not included w/switch)					
	210-0049-00			1	WASHER, lock, internal, $\frac{5}{8}$ ID x 0.867 inch OD					
	210-0579-00			1	NUT, hex., $\frac{5}{8}$ -24 x $\frac{3}{4}$ inch					

FIG. 1 FRONT &amp; FRAME (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q † y	Description
					1 2 3 4 5
1-24	- - - - -			1	RESISTOR, variable
	- - - - -			-	resistor includes:
	213-0022-00			1	SETSCREW, 4-40 x $\frac{3}{16}$ inch, HSS
	- - - - -			-	mounting hardware: (not included w/resistor)
	210-0012-00			1	WASHER, lock, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD
	210-0413-00			1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
	210-0801-00	X1430		2	WASHER, flat, 0.14 ID x 0.281 inch OD
	211-0008-00	X1430		2	SCREW, 4-40 x $\frac{1}{4}$ inch, PHS
	426-0289-00	X1430		1	MOUNT, plastic
-25	366-0173-00			1	KNOB, charcoal—POLARITY
	- - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-26	260-0709-00			1	SWITCH, unwired—POLARITY
	- - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
	210-0413-00			1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-27	366-0173-00			1	KNOB, charcoal—FALLTIME MULT
	- - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-28	- - - - -			3	RESISTOR, variable
	- - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
	210-0413-00			2	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
	210-0012-00			1	WASHER, lock, internal, $\frac{3}{8}$ ID x $\frac{1}{2}$ inch OD
-29	366-0173-00			1	KNOB, charcoal—RISETIME MULT
	- - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-30	366-0173-00			1	KNOB, charcoal—RISETIME FALLTIME RANGE
	- - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-31	260-0710-00			1	SWITCH, unwired—RISETIME FALLTIME RANGE
	- - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
	210-0413-00			1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-32	366-0173-00			1	KNOB, charcoal—DC OFFSET
	- - - - -			-	knob includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-33	366-0173-00			1	KNOB, charcoal—MODE
	- - - - -			-	knob, includes:
	213-0004-00			1	SETSCREW, 6-32 x $\frac{3}{16}$ inch, HSS
-34	260-0708-00			1	SWITCH, unwired—MODE
	- - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
	210-0413-00			1	NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-35	366-0215-01			1	KNOB, charcoal—PROGRAM
-36	260-0711-00			1	SWITCH, lever—PROGRAM
	- - - - -			-	mounting hardware: (not included w/switch)
	220-0413-00			2	NUT, hex., 4-40 x 0.187 x 0.562 inch long
-37	366-0215-01			1	KNOB, charcoal—TRIGGER SOURCE
-38	260-0490-00			1	SWITCH, lever—TRIGGER SOURCE
	- - - - -			-	mounting hardware: (not included w/switch)
	220-0413-00			2	NUT, hex., 4-40 x 0.187 x 0.562 inch long

FIG. 1 FRONT &amp; FRAME (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q					Description
				I	Y	1	2	3	
1-39	260-0247-00			1					SWITCH, unwired—TRIG
	- - - - -			-					mounting hardware: (not included w/switch)
	210-0940-00			1					WASHER, flat, $\frac{1}{4}$ ID x $\frac{3}{8}$ inch OD
	210-0583-00			1					NUT, hex., $\frac{1}{4}$ -32 x $\frac{5}{16}$ inch
	210-0046-00			1					WASHER, lock, internal, $\frac{1}{4}$ ID x 0.400 inch OD
-40	260-0199-00			1					SWITCH, toggle—POWER
	- - - - -			-					mounting hardware: (not included w/switch)
	354-0055-00			1					RING, locking switch
	210-0902-00			1					WASHER, flat, 0.470 ID x $\frac{21}{32}$ inch OD
	210-0473-00			1					NUT, 12 sided, $\frac{15}{32}$ -32 x $\frac{5}{64}$ inch
	210-0414-00			1					NUT, hex., $\frac{15}{32}$ -32 x $\frac{9}{16}$ inch
-41	- - - - -			1					LIGHT, pilot
	- - - - -			-					mounting hardware: (not included w/light)
	210-0978-00			1					WASHER, flat, $\frac{3}{16}$ ID x $\frac{1}{2}$ inch OD
	210-0590-00			1					NUT, hex., $\frac{3}{8}$ -32 x $\frac{7}{16}$ inch
	352-0002-00			2					ASSEMBLY, fuse holder
	- - - - -			-					each assembly includes:
-42	352-0010-00			1					HOLDER, fuse
	210-0873-00			1					WASHER, rubber, $\frac{1}{2}$ ID x $\frac{11}{16}$ inch OD
	- - - - -			1					NUT
-43	200-0582-00			2					CAP, fuse
-44	200-0237-00			2					COVER, insulation, fuse holder
-45	260-0675-00	1084	1249	1					SWITCH, slide
	260-0675-01	1250		1					SWITCH, slide
	- - - - -			-					switch includes:
	260-0675-00			1					SWITCH, slide
	337-1036-00			1					SHIELD, solder
	- - - - -			-					mounting hardware: (not included w/switch)
	210-0406-00			2					NUT, hex., 4-40 x $\frac{3}{16}$ inch
	211-0008-00			2					SCREW, 4-40 x $\frac{1}{4}$ inch, PHS
-46	386-0223-00			1					PLATE, subpanel, front
-47	122-0131-01			1					ANGLE, right rail
	- - - - -			-					mounting hardware: (not included w/angle)
-48	212-0023-00			4					SCREW, 8-32 x $\frac{3}{8}$ inch, PHS
-49	351-0027-00			1					TRACK, slideout, chassis (pair)
	- - - - -			-					mounting hardware: (not included w/track)
	212-0518-00			6					SCREW, 10-32 x $\frac{5}{16}$ inch, PHB
-50	122-0131-00			1					ANGLE, left rail
	- - - - -			-					mounting hardware: (not included w/angle)
	212-0023-00			4					SCREW, 8-32 x $\frac{3}{8}$ inch, PHS

FIG. 1 FRONT &amp; FRAME (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q † y	1	2	3	4	5	Description
1-51	122-0114-00			2						ANGLE, top rail
	- - - - -			-						mounting hardware for each: (not included w/angle)
	212-0040-00			4						SCREW, 8-32 x 3/8 inch, 100° csk, FHS
	210-0458-00			4						NUT, keps, 8-32 x 11/32 inch
-52	343-0005-00			1						CLAMP, cable, pastic, 7/16 inch
	- - - - -			-						mounting hardware: (not included w/clamp)
	211-0014-00			1						SCREW, 4-40 x 1/2 inch, PHS
-53	210-0863-00			1						WASHER, D shape, 0.191 ID x 33/64 x 33/64 inch long
	210-0457-00			1						NUT, keps, 6-32 x 5/16 inch
-54	200-0542-00			1						COVER, dust, bottom
	- - - - -			-						cover includes:
	214-0389-00			4						FASTENER, retainer, split ring
	214-0390-00			4						FASTENER, stud
-55	200-0540-01			1						COVER, dust, top
	- - - - -			-						cover includes:
-56	214-0389-00			4						FASTENER, retainer, split ring
-57	214-0390-00			4						FASTENER, stud
-58	200-0541-01			1						COVER, filter
	- - - - -			-						mounting hardware: (not included w/cover)
-59	211-0516-00			4						SCREW, 6-32 x 7/8 inch, PHS
	210-0407-00			4						NUT, hex., 6-32 x 1/4 inch
-60	210-0401-00			4						NUT, cap, hex., 6-32 x 5/16 inch
-61	131-0294-00			1						CONNECTOR, 36 pin
	210-0001-00			2						WASHER, lock, internal, #2
	210-0405-00			2						NUT, hex., 2-56 x 3/16 inch
	211-0001-00			2						SCREW, 2-56 x 1/4 inch, RHS
-62	386-0221-00			1						PLATE, connector
	- - - - -			-						mounting hardware: (not included w/plate)
-63	211-0504-00			4						SCREW, 6-32 x 1/4 inch, PHS
-64	378-0029-00			1						FILTER, air foam
-65	119-0031-00	1084	1419	1						FAN
	119-0331-01	1420		1						FAN
	- - - - -			-						mounting hardware: (not included w/fan)
-66	211-0511-00	1084	1419	4						SCREW, 6-32 x 1/2 inch, PHS
	211-0513-00	1420		4						SCREW, 6-32 x 5/8 inch, PHS
	210-0457-00			4						NUT, keps, 6-32 x 5/16 inch



FIG. 1 FRONT &amp; FRAME (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No.		Q t y						Description
		Eff	Disc		1	2	3	4	5	
1-67	175-0360-00			1						ASSEMBLY, 50 Ω cable
-68	343-0006-00			1						CLAMP, cable, plastic, 1/2 inch
-69	386-0222-00			1						PLATE, frame, rear
-70	384-0380-00	1084	1319	4						ROD, extension
	384-0237-00	1320		4						ROD, extension
	131-0430-01	1084	1199	1						ASSEMBLY, connector, motor base
	131-0430-02	1200		1						ASSEMBLY, connector, motor base
	- - - - -			-						assembly includes:
	213-0088-00	1084	1199	1						SCREW, thread forming, 4-40 x 1/4 inch, PHS
	213-0146-00	1200		1						SCREW, thread forming, #6 x 0.313 inch, PHS
	129-0041-01	1084	1199	1						POST, ground
	200-0185-01	1084	1199	1						COVER, motor base, black
-71	204-0335-00	1200		1						BODY-CONTACT ASSEMBLY
-72	214-0078-00			2						PIN, brass, connecting
-73	377-0051-00	1084	1199	1						INSERT, black
	214-1016-00	1200		1						INSULATOR, connector
	211-0132-00	1084	1199	1						SCREW, sems, 4-40 x 1/2 inch, PHS
	211-0534-00	1200	1369	1						SCREW, sems, 6-32 x 5/16 inch, PHS
	211-0614-00	1370		1						SCREW, sems, 6-32 x 1/4 inch, PHS
-74	386-1044-00	1084	1199	1						PLATE
	386-1357-01	1200		1						PLATE
	- - - - -			-						mounting hardware: (not included w/assembly)
-75	211-0507-00	1084	1179	2						SCREW, 6-32 x 5/16 inch, PHS
	211-0514-00	1180		2						SCREW, 6-32 x 3/4 inch, PHS
-76	337-0955-00	X1180		1						SHIELD
-77	131-0023-00	X1159		1						CONNECTOR, 2-point

FIG. 2 BRACKETS &amp; CHASSIS

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q t y 1 2 3 4 5					Description
2-1	407-0414-00			1					BRACKET
	- - - - -			-					mounting hardware: (not included w/bracket)
	211-0510-00			4					SCREW, 6-32 x $\frac{3}{8}$ inch, PHS
-2	210-0457-00			4					NUT, keps, 6-32 x $\frac{5}{16}$ inch
-3	343-0088-00			1					CLAMP, small, snap-in
-4	- - - - -			7					RESISTOR, variable
	- - - - -			-					mounting hardware for each: (not included w/resistor)
-5	210-0840-00			1					WASHER, flat, 0.390 ID x $\frac{9}{16}$ inch OD
-6	210-0413-00			1					NUT, hex., $\frac{3}{8}$ -32 x $\frac{1}{2}$ inch
-7	- - - - -			2					RESISTOR, variable
	- - - - -			-					mounting hardware for each: (not included w/resistor)
	210-0583-00			1					NUT, hex., $\frac{1}{4}$ -32 x $\frac{5}{16}$ inch
	210-0940-00			1					WASHER, flat, $\frac{1}{4}$ ID x $\frac{3}{8}$ inch OD
-8	214-0210-00			1					ASSEMBLY, solder spool
	- - - - -			-					assembly includes:
	214-0209-00			1					SPOOL, solder
	- - - - -			-					mounting hardware: (not included w/assembly)
	361-0007-00			1					SPACER, plastic, 0.188 inch long
-9	343-0001-00			1					CLAMP, cable, plastic, $\frac{1}{8}$ inch
	- - - - -			-					mounting hardware: (not included w/clamp)
-10	210-0863-00			1					WASHER, D shape, 0.191 ID x $\frac{33}{64}$ x $\frac{33}{64}$ inch long
-11	211-0014-00			1					SCREW, 4-40 x $\frac{1}{2}$ inch, PHS
-12	131-0292-00	1084	1139	6					CONNECTOR, 56 pin
	131-0292-01	1140		6					CONNECTOR, 56 pin
	- - - - -			-					mounting hardware for each: (not included w/connector)
-13	211-0014-00			2					SCREW, 4-40 x $\frac{1}{2}$ inch, PHS
-14	131-0292-00	1084	1139	3					CONNECTOR, 56 pin
	131-0292-01	1140		3					CONNECTOR, 56 pin
	- - - - -			-					mounting hardware for each: (not included w/connector)
-15	129-0079-00			2					POST, cover support
-16	343-0003-00			2					CLAMP, cable, plastic, $\frac{1}{4}$ inch
	- - - - -			-					mounting hardware for each: (not included w/clamp)
	210-0863-00			1					WASHER, D shape, 0.191 ID x $\frac{33}{64}$ x $\frac{33}{64}$ inch long
	211-0014-00			1					SCREW, 4-40 x $\frac{1}{2}$ inch, PHS
-17	343-0005-00			2					CLAMP, cable, plastic, $\frac{7}{16}$ inch
	- - - - -			-					mounting hardware for each: (not included w/clamp)
	210-0863-00			1					WASHER, D shape, 0.191 ID x $\frac{33}{64}$ x $\frac{33}{64}$ inch long
	211-0014-00			1					SCREW, 4-40 x $\frac{1}{2}$ inch, PHS

FIG. 2 BRACKETS &amp; CHASSIS (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q t y	1	2	3	4	5	Description
2-18	351-0059-00			18						GUIDE, circuit card
	- - - - -			-						mounting hardware for each: (not included w/guide)
-19	211-0511-00			1						SCREW, 6-32 x 1/2 inch, PHS
-20	381-0244-02	1084	1207	2						BAR, guide, board support
	381-0244-03	1208	1359	2						BAR, guide, board support
	381-0244-04	1360		2						BAR, guide, board support
	- - - - -			-						mounting hardware for each: (not included w/bar)
	212-0040-00			2						SCREW, 8-32 x 3/8 inch, 100° csk, FHS
-21	381-0245-00			1						BAR, support
	- - - - -			-						mounting hardware: (not included w/bar)
-22	210-0202-00			1						LUG, solder, SE #6
	211-0514-00			2						SCREW, 6-32 x 3/4 inch, PHS
-23	211-0510-00			2						SCREW, 6-32 x 3/8 inch, PHS
-24	348-0063-00			1						GROMMET, plastic, 1/2 inch diameter
-25	- - - - -			1						CAPACITOR
	- - - - -			-						mounting hardware: (not included w/capacitor)
-26	385-0146-00			2						ROD, hex., 1/4 OD x 1 1/16 inch long
-27	432-0048-00			1						BASE, large capacitor mounting
	211-0514-00			2						SCREW, 6-32 x 3/4 inch, PHS
-28	211-0507-00			2						SCREW, 6-32 x 5/16 inch, PHS
-29	386-0255-00			1						PLATE, metal, flange
-30	- - - - -			2						CAPACITOR
	- - - - -			-						mounting hardware for each: (not included w/capacitor)
-31	432-0048-01			1						BASE, large capacitor mounting
-32	386-0254-00			1						PLATE, fiber, flange
	211-0507-00			2						SCREW, 6-32 x 5/16 inch, PHS
-33	385-0168-00			2						ROD, spacer, 1/4 hex., 1.168 inch long
-34	211-0514-00			2						SCREW, 6-32 x 3/4 inch, PHS
-35	200-0538-00			2						COVER, capacitor, plastic
-36	- - - - -			1						CAPACITOR
	- - - - -			-						mounting hardware: (not included w/capacitor)
-37	385-0146-00			2						ROD, hex., 1/4 OD x 1 1/16 inch long
-38	432-0047-00			1						BASE, small capacitor mounting
-39	386-0252-00			1						PLATE, fiber, flange
-40	211-0514-00			2						SCREW, 6-32 x 3/4 inch, PHS
	211-0507-00			2						SCREW, 6-32 x 5/16 inch, PHS

FIG. 2 BRACKETS &amp; CHASSIS (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	No. Disc	Q † y						Description
					1	2	3	4	5	
2-41	200-0256-00			1						COVER, capacitor, plastic
-42	- - - - -			1						COIL
	- - - - -			-						mounting hardware: (not included w/coil)
	211-0507-00			1						SCREW, 6-32 x $\frac{5}{16}$ inch, PHS
-43	210-1007-00			1						WASHER, non-metallic
-44	200-0659-00			1						COVER, inductor
-45	211-0553-00			1						SCREW, 6-32 x $1\frac{1}{2}$ inches, RHS
-46	- - - - -			1						DIODE
	- - - - -			-						mounting hardware: (not included w/diode)
	210-0206-00			1						LUG, solder, SE #10 long
	210-0909-00			2						WASHER, mica, 0.196 ID x 0.625 inch OD
	210-0910-00			1						WASHER, plastic, $\frac{3}{16}$ ID x $\frac{5}{16}$ inch OD
-47	220-0410-00			1						NUT, keps, 10-32 x $\frac{3}{8}$ inch
	210-0805-00			2						WASHER, flat, 0.204 ID x 0.438 inch OD
-48	- - - - -			3						TRANSISTOR
	- - - - -			-						mounting hardware for each: (not included w/transistor)
-49	211-0510-00			2						SCREW, 6-32 x $\frac{3}{8}$ inch, PHS
-50	386-0978-00			1						PLATE, mica, insulator
	210-0811-00			2						WASHER, fiber, shouldered
	210-0802-00			2						WASHER, flat, 0.150 ID x $\frac{5}{16}$ inch OD
	210-0006-00			1						WASHER, lock, internal, #6
	210-0202-00			1						LUG, solder, SE #6
-51	210-0407-00			2						NUT, hex., 6-32 x $\frac{1}{4}$ inch
-52	- - - - -			2						TRANSISTOR
	- - - - -			-						mounting hardware for each: (not included w/transistor)
-53	211-0510-00			2						SCREW, 6-32 x $\frac{3}{8}$ inch, PHS
-54	386-0143-00			1						PLATE, mica, insulator
	210-0811-00			2						WASHER, fiber, shouldered
	210-0802-00			2						WASHER, flat, 0.150 ID x $\frac{5}{16}$ inch OD
	210-0006-00			2						WASHER, lock, internal, #6
	210-0202-00			1						LUG, solder, SE #6
-55	210-0407-00			2						NUT, hex., 6-32 x $\frac{1}{4}$ inch

FIG. 2 BRACKETS &amp; CHASSIS (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q † y						Description
					1	2	3	4	5	
2-56	- - - - -			1						SWITCH, thermal cutout
	- - - - -			-						mounting hardware: (not included w/switch)
	213-0044-00			2						SCREW, thread forming, 5-32 x $\frac{3}{16}$ inch, PHS
-57	- - - - -			1						FILTER, line
	- - - - -			-						mounting hardware: (not included w/filter)
-58	212-0004-00			2						SCREW, 8-32 x $\frac{5}{16}$ inch, PHS
	210-0458-00			2						NUT, keps, 8-32 x $\frac{11}{32}$ inch
-59	385-0134-00			2						ROD, plastic, $\frac{5}{16}$ OD x $\frac{5}{8}$ inch long
	- - - - -			-						mounting hardware for each: (not included w/rod)
	213-0041-00			1						SCREW, thread cutting, #6 x $\frac{3}{8}$ inch, THS
-60	210-0201-00			6						LUG, solder, SE #4
	- - - - -			-						mounting hardware for each: (not included w/lug)
-61	213-0044-00			1						SCREW, thread forming, 5-32 x $\frac{3}{16}$ inch, PHS
-62	- - - - -			1						TRANSFORMER
	- - - - -			-						mounting hardware: (not included w/transformer)
-63	212-0515-00			4						SCREW, 10-32 x $2\frac{1}{4}$ inches, HHS
	220-0812-00			4						WASHER, fiber, #10
	220-0410-00			4						NUT, keps, 10-32 x $\frac{3}{8}$ inch
-65	441-0637-00			1						CHASSIS, power
	- - - - -			-						mounting hardware: (not included w/chassis)
	211-0510-00			2						SCREW, 6-32 x $\frac{3}{8}$ inch, PHS
	212-0023-00			8						SCREW, 8-32 x $\frac{3}{8}$ inch, PHS
	210-0457-00			2						NUT, keps, 6-32 x $\frac{5}{16}$ inch
	210-0458-00			8						NUT, keps, 8-32 x $\frac{11}{32}$ inch
-66	407-0395-00			1						BRACKET, transistor
	- - - - -			-						mounting hardware: (not included w/transistor)
	212-0023-00			2						SCREW, 8-32 x $\frac{3}{8}$ , PHS
-67	210-0458-00			2						NUT, keps, 8-32 x $\frac{11}{32}$ inch
-68	- - - - -			2						TRANSISTOR
	- - - - -			-						mounting hardware for each: (not included w/transistor)
-69	386-0143-00			1						PLATE, mica, insulating
-70	211-0510-00			2						SCREW, 6-32 x $\frac{3}{8}$ inch, PHS
	210-0802-00			2						WASHER, flat, 0.150 ID x $\frac{5}{16}$ inch OD
	210-0006-00			1						WASHER, lock, internal, #6
	210-0202-00			1						LUG, solder, SE #6
	210-0811-00			2						WASHER, fiber, shouldered, #6
-71	210-0407-00			2						NUT, hex., 6-32 x $\frac{1}{4}$ inch

FIG. 2 BRACKETS &amp; CHASSIS (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q t y	1	2	3	4	5	Description
2-72	136-0218-00			1						SOCKET, 3 pin transistor
	- - - - -			-						mounting hardware: (not included w/socket)
	354-0285-00			1						RING, transistor socket mounting
-73	343-0031-00			1						GROMMET
-74	179-1013-01			1						CABLE HARNESS, connector
-75	179-1010-01	1084	1309	1						CABLE HARNESS, switch
	179-1010-02	1310		1						CABLE HARNESS, switch
-76	179-1320-01	X1310		1						CABLE HARNESS, coaxial connectors
-77	179-1011-02			1						CABLE HARNESS, power #1
-78	179-1012-01			1						CABLE HARNESS, power #2
-79	124-0091-00			2						STRIP, ceramic, $\frac{3}{4}$ inch H, w/11 notches
	- - - - -			-						each strip includes:
	355-0046-00			2						STUD, plastic
	- - - - -			-						mounting hardware for each: (not included w/strip)
	361-0009-00			2						SPACER, plastic, 0.406 inch long
-80	124-0090-00			2						STRIP, ceramic $\frac{3}{4}$ inch h, w/9 notches
	- - - - -			-						each strip includes:
	355-0046-00			2						STUD, plastic
	- - - - -			-						mounting hardware for each: (not included w/strip)
	361-0009-00			2						SPACER, plastic, 0.406 inch long
-81	124-0145-00			2						STRIP, ceramic, $\frac{7}{16}$ inch h, w/20 notches
	- - - - -			-						each strip includes:
	355-0046-00			2						STUD, plastic
	- - - - -			-						mounting hardware for each: (not included w/strip)
	361-0009-00			2						SPACER, plastic, 0.406 inch long
-82	124-0147-00			2						STRIP, ceramic, $\frac{7}{16}$ inch h, w/13 notches
	- - - - -			-						each strip includes:
	355-0046-00			2						STUD, plastic
	- - - - -			-						mounting hardware for each: (not included w/strip)
	361-0009-00			2						SPACER, plastic, 0.406 inch long
-83	124-0149-00			1						STRIP, ceramic, $\frac{7}{16}$ inch h, w/7 notches
	- - - - -			-						strip includes:
	355-0046-00			2						STUD, plastic
	- - - - -			-						mounting hardware: (not included w/strip)
	361-0009-00			2						SPACER, plastic, 0.406 inch long
-84	214-0506-00			1						PIN, connector

FIG. 3 CIRCUIT CARDS

Fig. & Index No.	Tektronix Part No.	Serial/Model No.		Q f y	Description
		Eff	Disc		
3-1	670-0213-01			1	ASSEMBLY, circuit card, FUNCTION PROGRAM #2
	388-0663-01			-	assembly includes:
				1	CARD, circuit
-2	136-0220-00			12	SOCKET, transistor, 3 pin
-3	131-0579-00			4	TERMINAL, test point
-4	670-0214-00	MODEL 1	MODEL 5	1	ASSEMBLY, circuit card—PERIOD GENERATOR (Series B)
	670-0214-01	MODEL 1		1	ASSEMBLY, circuit card—PERIOD GENERATOR (Series Q)
				-	assembly includes:
	388-0664-00	MODEL 1	MODEL 3	1	CARD, circuit
	388-0664-01	MODEL 4		1	CARD, circuit
-5	136-0183-00			11	SOCKET, transistor, 3 pin
-6	352-0086-00			1	HOLDER, toroid
-7	670-0215-00	MODEL 1	MODEL 1	1	ASSEMBLY, circuit card—DELAY GENERATOR (Series C)
	670-0215-01	MODEL 1		1	ASSEMBLY, circuit card—DELAY GENERATOR (Series O)
				-	assembly includes:
	388-0665-00			1	CARD, circuit
-8	136-0183-00			10	SOCKET, transistor, 3 pin
-9	352-0086-00			2	HOLDER, toroid
-10	670-0216-02			1	ASSEMBLY, circuit card—FUNCTION PROGRAM #1
				-	assembly includes:
	388-0666-02			1	CARD, circuit
-11	136-0220-00			15	SOCKET, transistor, 3 pin
-12	131-0579-00			10	TERMINAL, test point
-13	670-0217-01	MODEL 1	MODEL 3	1	ASSEMBLY, circuit card—WIDTH GENERATOR (Series P)
	670-0217-02	MODEL 1		1	ASSEMBLY, circuit card—WIDTH GENERATOR (Series R)
				-	assembly includes:
	388-0667-00			1	CARD, circuit
-14	136-0183-00			7	SOCKET, transistor, 3 pin
-15	352-0086-00			2	HOLDER, toroid
-16	670-0218-00			1	ASSEMBLY, circuit card—PULSE SHAPE GENERATOR
				-	assembly includes:
	388-0668-00			1	CARD, circuit
-17	136-0183-00			12	SOCKET, transistor, 3 pin
-18	352-0086-00			5	HOLDER, toroid
-19	670-0219-01			1	ASSEMBLY, circuit card—OUTPUT AMPLIFIER
				-	assembly includes:
	388-0669-02			1	CARD, circuit
-20	136-0183-00			6	SOCKET, transistor, 3 pin
-21	136-0220-00			8	SOCKET, transistor, 3 pin, square
-22	214-0668-00			6	HEAT SINK
-23	214-0667-00			1	HEAT SINK
-24	131-0579-00			1	TERMINAL, test point
-25	352-0086-00			2	HOLDER, toroid

FIG. 3 CIRCUIT CARDS (Cont)

Fig. & Index No.	Tektronix Part No.	Serial/Model Eff	No. Disc	Q					Description
				Y	1	2	3	4	
3-26	670-0220-01	-	-	1					ASSEMBLY, circuit card—ATTENUATOR
	-	-	-	-					assembly includes:
	388-0670-01	-	-	1					CARD, circuit
-27	131-0391-00	-	-	1					CONNECTOR, coaxial, 50 $\Omega$ male
-28	136-0183-00	-	-	5					SOCKET, transistor, 3 pin
-29	352-0086-00	-	-	2					HOLDER, toroid
-30	670-0221-00	-	-	1					ASSEMBLY, circuit card—POWER SUPPLY
	-	-	-	-					assembly includes:
	388-0671-01	-	-	1					CARD, circuit
-31	136-0183-00	-	-	14					SOCKET, transistor, 3 pin
-32	214-0668-00	-	-	2					HEAT SINK
-33	352-0086-00	-	-	1					HOLDER, toroid



## **MANUAL CHANGE INFORMATION**

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Sections of the manual are often printed at different times, so some of the information on the change pages may already be in your manual. Since the change information sheets are carried in the manual until ALL changes are permanently entered, some duplication may occur. If no such change pages appear in this section, your manual is correct as printed.