INSTRUCTION MANUAL

Serial Number ___________

TYPE 647A OSCILLOSCOPE

Tektronix, Inc.

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070-0614-00 1266

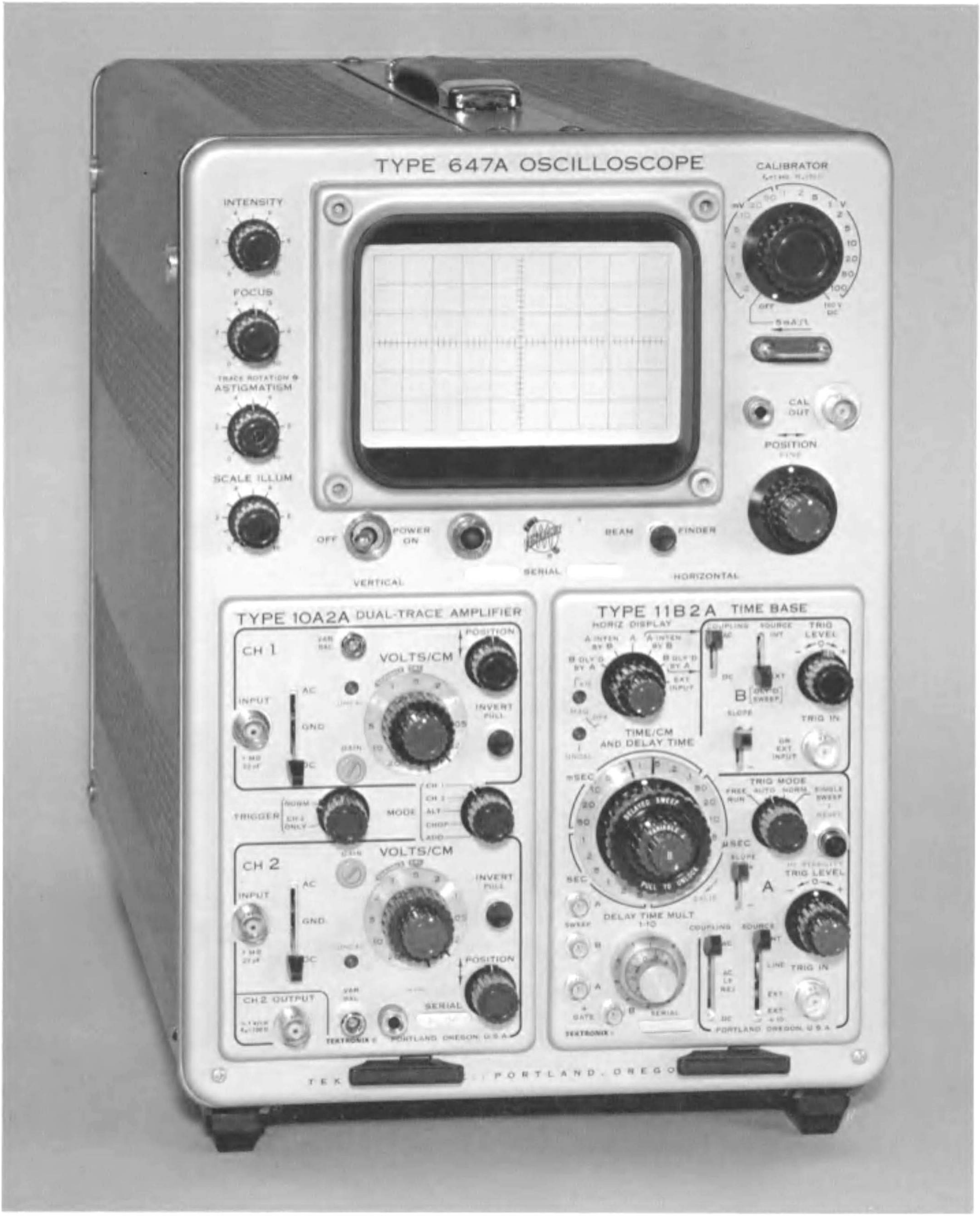


Fig. 1-1. The Type 647A Oscilloscope (shown with Type 10A2A and Type 11B2A plug-in units).

SECTION 1
CHARACTERISTICS

Introduction

The Tektronix Type 647A Oscilloscope is a general purpose, high-performance oscilloscope designed to operate in a wide range of environmental conditions. A Tektronix 10-series vertical plug-in unit is required in the left compartment and a Tektronix 11-series horizontal plug-in unit in the right compartment to form a complete measurement system. The following characteristics apply to the Type 647A only. Refer to the plug-in unit Instruction Manuals for characteristics of the complete system.

The electrical characteristics which follow are divided into two categories. Characteristics listed in the Performance Requirement column are checked in the Performance Check and Calibration sections of this manual. Items listed in the Supplemental Information column are provided for reference use and do not directly reflect the measurement capabilities of this instrument. The Performance Check procedure given in Section 5 of this manual provides a convenient method of checking the Performance Requirements listed in this section. The following electrical characteristics apply over a calibration interval of 1000 hours at an ambient temperature range of —30° C to +65° C, except as otherwise indicated. Warm-up time for given accuracy is 20 minutes.

ELECTRICAL CHARACTERISTICS

VERTICAL AMPLIFIER

Characteristics	Performance Requirement	Supplemental Information
Deflection Factor	300 millivolts/centimeter of CRT deflection	Open circuit voltage of 186-ohm source generator
Deflection Accuracy	Within ±1% at 25° C when driven from a 186 ohm push-pull source	
Bandwidth (at —3 dB point)	DC to 120 MHz or greater	Measured with Tektronix calibration fixture 067-0544-00
Risetime (calculated)	2.9 nanoseconds or less	
Low-Frequency Linearity	0.15 centimeter or less total amplitude variation of two-centimeter display when positioned over entire vertical display area.	Includes CRT linearity. Measured at center screen horizontally.
Delay Line		Approximately 140 nanoseconds

HORIZONTAL AMPLIFIER

Characteristics	Performance Requirement	Supplemental Information
Deflection Factor	0.347 milliampere/centimeter of CRT deflection, per side, push-pull	Short circuit current of source generator
Deflection Accuracy	Within ±1% at 25° C when driven from a 20-kilohm push-pull source	Measured over middle eight centimeters of graticule
Calibrated Sweep Deflection Rate	See 11-series time-base instruction manual	Type 647A capable of DC to 10 nanosecond/centimeter sweep deflection rate
Bandwidth	See 11-series time-base instruction manual for combined bandwidth of Type 647A and time-base unit	
Remote Single-Sweep Reset		Pin F of J101 (on rear panel) provides input for remote single-sweep reset to 11-series time-base units with compatible features

Z AXIS INPUT

Characteristics	Performance Requirement	Supplemental Information
Input to CRT GRID Binding Post Sensitivity	Four volt, or less, peak-to-peak signal produces noticeable modulation at normal intensity	

Z-AXIS INPUT *(Cont)*

Characteristics	Performance Requirement		Supplemental Information
Polarity of operation	Positive-going input signal decreases trace intensity		
Usable frequency range	DC to 10MHz or greater		
Input resistance			Approximately 22 kilohms
Input to CRT CATHODE Binding Post Sensitivity	Five volt, or less, peak-to-peak signal produces noticeable modulation at normal intensity		
Polarity of operation	Positive-going input signal decreases trace intensity		
Usable frequency range	500HZ to 100MHz or greater		
Input time constant			Approximately 330 microseconds (0.015 μF and 22 kΩ)

CALIBRATOR

Characteristics	Performance Requirement		Supplemental Information
Waveshape	Square wave		
Polarity			Positive going with baseline at zero volts
Output Voltages	0.2-millivolt to 100-volt square waves in 18 steps, and 100 volts DC		Steps in 1-2-5 sequence
Output Current	Five milliamperes through current loop		
Repetition Rate	One kilohertz		
Accuracy	0° C to +40° C	—30 ° C to +65° C	
Voltage			
100 mV and 100 V	Within ±1%	Within ±1.5%	
All other voltages	Within ±2%	Within ±3%	With one megohm or greater load
Current (Calculated)	Within ±1.5%		
Repetition rate	Within ±0.1%		
Risetime	One microsecond or less		With 20 pF or less load
Duty Cycle	49.9% to 50.1%		
Output Resistance (0° C to +40° C) 0.2 mV to 100 mV			50 ohms, ±0.4%
200 mV			50 ohms, ±1.5%
0.5 V to 100 V			Varies with switch position to a maximum of approximately four kilohms

POWER SUPPLY

Characteristics	Performance Requirement	Supplemental Information
Line Voltage	115 volts nominal or 230 volts nominal	
Voltage Ranges (AC, RMS) 115-volts nominal	90 to 110 volts 104 to 126 volts 112 to 136 volts	Line voltage and range selected by Line Voltage Selector assembly on rear panel. Voltage ranges apply for waveform distortion which reduces the peak line voltage 5% or less below the true sine-wave peak values.
230-volts nominal	180 to 220 volts 208 to 252 volts 224 to 272 volts	
Line Frequency	45 to 440 hertz	
Power Consumption at 115 volts and 60 hertz		190 watts maximum. 2.0 amps maximum (includes plug-ins).

CATHODE-RAY TUBE (CRT)

Characteristics	Performance Requirement	Supplemental Information
Tube Type		Tektronix T6470-31-1 rectangular
Phosphor		P31 standard. Others available on special order

CATHODE-RAY TUBE *(Cont)*

Characteristics	Performance Requirement	Supplemental Information
Accelerating Potential		Approximately 14kv total (cathode potential —2.2 kV)
Graticule		
Type	Internal	
Area	Six divisions vertical by 10 divisions horizontal. Each division equals one centimeter	
Illumination	Variable edge lighting	
Unblanking	Bias-type, DC coupled to CRT grid	
Raster Distortion	0.1 division or less	
Beam Finder	Limits display within viewing area	

ENVIRONMENTAL CHARACTERISTICS

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical performance requirements given in this section following environmental test. Complete details on environmental test procedures, including failure criteria, etc., may be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.

Characteristics	Performance Requirement	Supplemental Information
Temperature		
Operating	—30° C to +65° C	Automatic resetting thermal cutout protects instrument from overheating. Limit applies when instrument is not tipped more than 20° in any direction from level. Maximum operating temperature when operated on rear feet is +55° C.
Non-operating	—55° C to +75° C	
Altitude		
Operating	15,000 feet maximum	Derate maximum operating temperature by 1°/1000 feet change in altitude above 5000 feet
Non-operating	50,000 feet maximum	May be tested during non-operating temperature test
Humidity		
Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B	Exclude freezing and vibration
Vibration		
Operating and Non-operating	15 minutes vibration along each of the three major axes at a total displacement of 0.025-inch peak to peak (4 g at 55 c/s) from 10-55-10 c/s in one-minute cycles. Hold at 55 c/s for three minutes on each axis.	Instrument secured to vibration plateform during test. Total vibration time, about 55 minutes.
Shock		
Operating and non-operating	Two shocks of 20 g, one-half sine, 11 millisecond duration along each major axis	Guillotine - type shocks. Total of 12 shocks
Transportation	Meets National Safe Transit type of test when packaged as shipped from Tektronix, Inc.	
Package vibration	One hour vibration slightly in excess of 1 g	Package should just leave vibration surface
Package drop	30 inch drop on any corner, edge or flat surface	

SECTION 3
CIRCUIT DESCRIPTION

Introduction

This section of the manual contains an electrical description of the circuitry used in the Type 647A. The description begins with a discussion of the instrument using the basic block diagram shown in Fig. 3-1. Then each circuit is described in detail using a detailed block diagram to show the interconnections between the stages in each major circuit, and the relationship of the front-panel controls to the individual stages.

A complete block diagram is located in the Diagrams section at the rear of this manual. This block diagram shows the overall relationship between all of the circuits in this instrument. Complete schematics of each circuit are also given in the Diagrams section. Refer to these diagrams throughout the following circuit description for electrical values and relationship.

BLOCK DIAGRAM

General

The following block diagram discussion is provided to aid in understanding the overall concept of the Type 647A before the individual circuits are discussed in detail. A basic block diagram of the Type 647A is shown in Fig. 3-1. Only the basic interconnections between the individual blocks are shown in this diagram. Each block in this block diagram represents a major circuit within the instrument. The number on each block refers to the circuit diagram at the rear of this manual which shows the complete circuit.

Input signals to be displayed on the CRT are applied to the Vertical Amplifier from the vertical plug-in unit through the interconnecting plug. The Vertical Amplifier circuit amplifies this input signal to bring it to the level necessary to drive the CRT vertical deflection plates. Likewise, the Horizontal Amplifier circuit amplifies the signal connected to it from the time-base plug-in unit. The output of the Horizontal Amplifier circuit provides the horizontal deflection for the CRT. The internal trigger signal from the vertical unit is connected through the Type 647A to the time-base unit and the alternate trace sync pulse generated by the time-base unit is connected to the vertical unit.

The CRT Circuit provides the voltages and controls necessary for the operation of the cathode-ray tube. The Z Axis Amplifier stage in the CRT circuit determines the CRT intensity and unblanking level as controlled by the INTENSITY control, chopped blanking signal from the vertical unit, unblanking gate from the time-base unit or a signal connected to the CRT CATHODE or CRT GRID connectors.

The Power Supply circuit provides the low-voltage power necessary for operation of this instrument and the associated plug-ins. The Calibrator circuit produces a square-wave output signal with accurate amplitude and frequency which can be used to check the basic calibration of the associated plug-ins and for compensation of passive probes. The current probe loop provides an accurate current source for calibration of current-probe systems.

CIRCUIT OPERATION

General

The following circuit analysis is written around the detailed block diagrams which are given for each major circuit. These detailed block diagrams give the names of the individual stages within the major circuits and shows how they are connected together to form the major circuit. The block diagrams also show the inputs and outputs for each major circuit and the relationship of the front-panel controls to the individual stages. The circuit diagrams from which the detailed block diagrams are derived are shown in the Diagrams section of this manual. The names assigned to the individual stages on the detailed block diagrams are used throughout the following discussion.

This circuit analysis attempts to describe the electrical operation and relationship of all circuits in the Type 647A. The theory of operation for circuits which are commonly used in the electronics industry is not described here. Instead, references are given to textbooks or other source material where more complete information on these circuits can be found. Circuits which are unusual or are peculiar to this instrument are described in detail.

VERTICAL AMPLIFIER

General

The Vertical Amplifier circuit provides amplification for the vertical signal from the 10-series vertical plug-in unit and connects it to the vertical deflection plates of the CRT. The BEAM FINDER switch compresses an overscanned display within the viewing area when pushed in. Fig. 3-2 shows a detailed block diagram of the Vertical Amplifier circuit. A schematic of this circuit is shown on diagram 2 at the rear of this manual.

Delay Line

The Delay Line provides approximately 140 nanoseconds delay for the vertical signal to allow the time-base unit enough time to initiate a sweep before the vertical signal reaches the vertical deflection plates. This allows the instrument to display the leading edge of the signal originating the trigger pulse when using internal triggering.

Phase Equalizer Network

The Phase Equalizer Network, L405A-L405B-L405C-L405D-L405E-L405F-C405A-C405B-C405C, L407A-L407B-L407C-L407D-L407E-L407F-C407A-C407B-C407C and C406A-C406B-C406C,

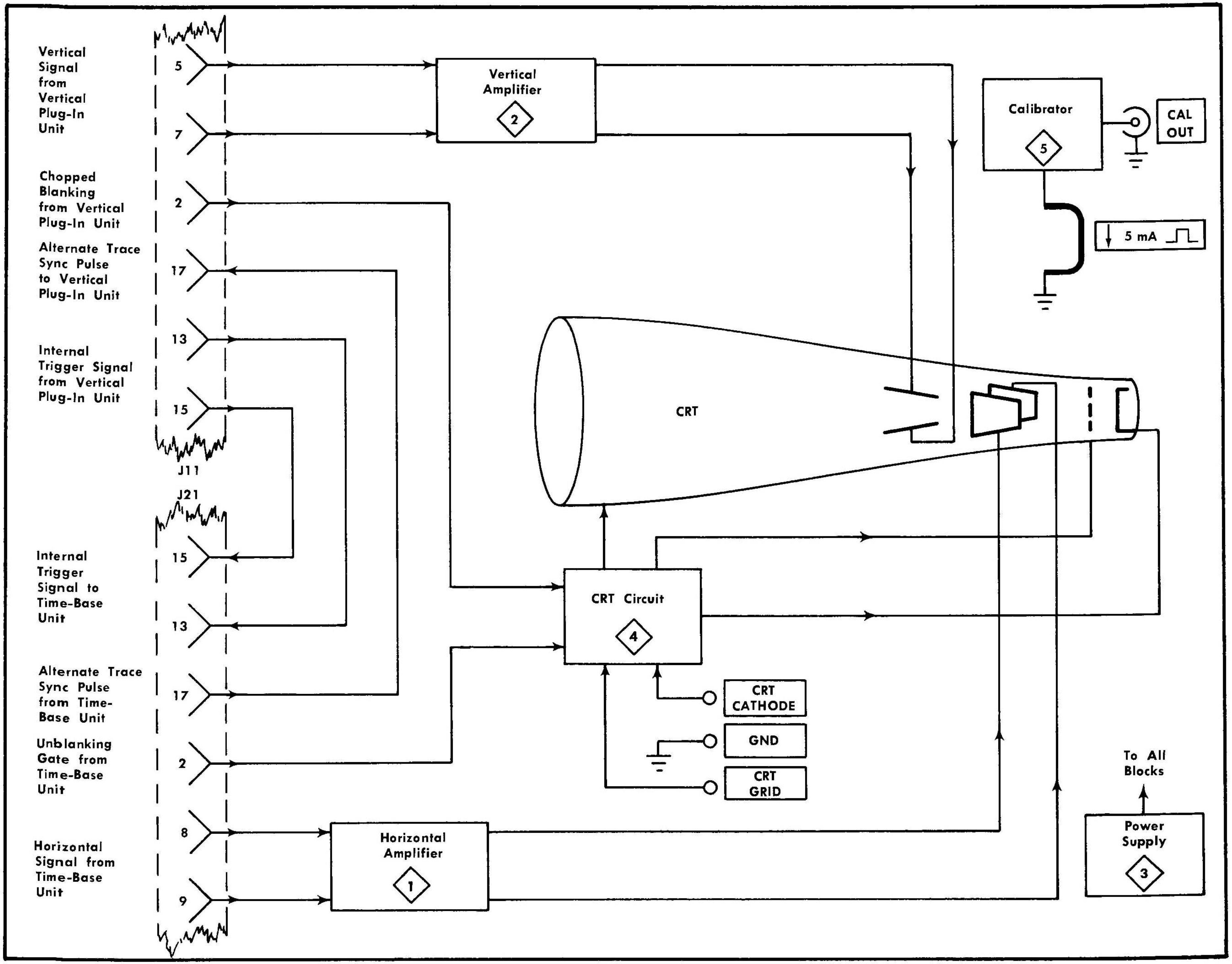


Fig. 3-1. Simplified block diagram of the Type 647A.

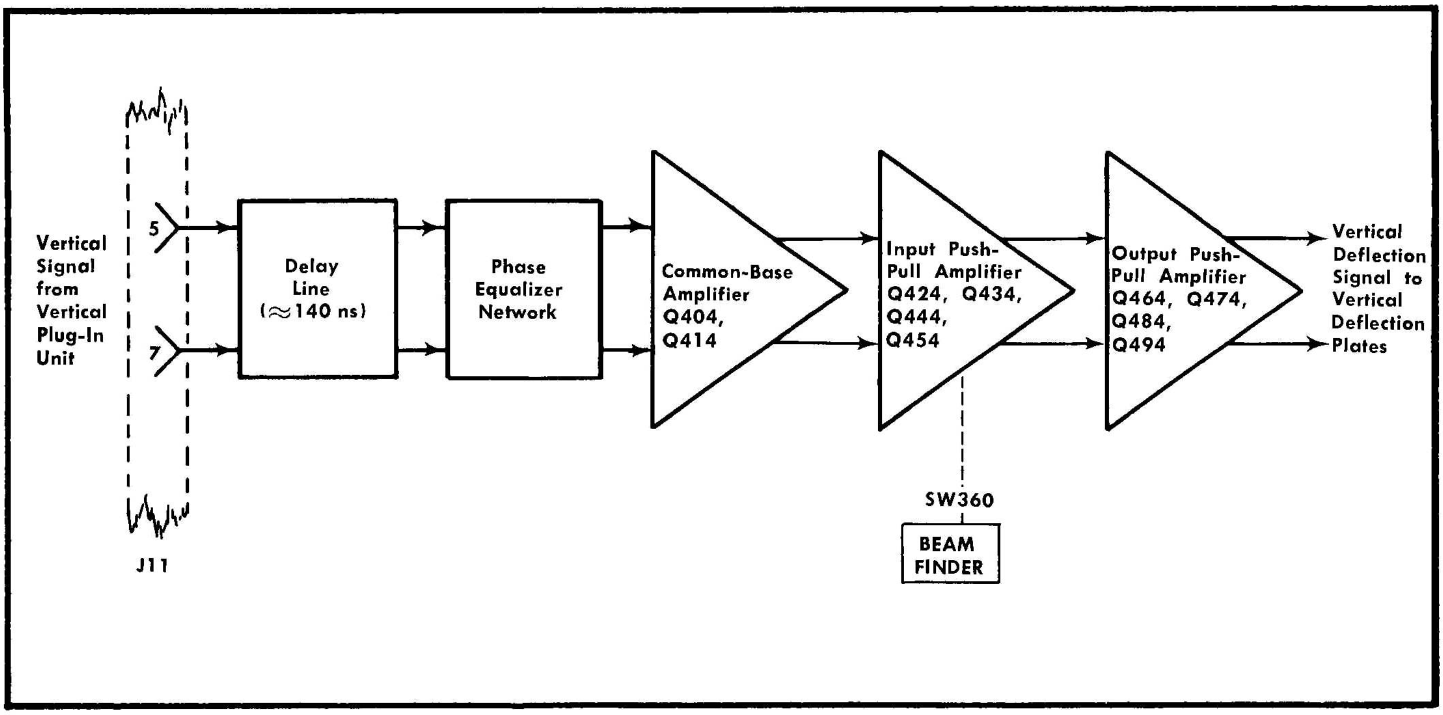


Fig. 3-2. Vertical Amplifier detailed block diagram.

corrects for the phase distortion of the delay line. R405 and R407 in series with the base-emitter resistance of Q404 and Q414 provide the forward termination for the delay line.

Common-Base Amplifier

The Common-Base Amplifier stage, Q404 and Q414, provides a low input impedance to properly terminate the Delay Line (along with the Phase Equalizer Network). It also provides isolation between the Delay Line stage and the following stages. The DC Centering adjustment, R409, is adjusted to balance the current at the output of the amplifier for a center-screen display when the associated amplifier unit position control is centered.

Input Push-Pull Amplifier

The vertical deflection signal from the Common-Base Amplifier stage is connected to the Input Push-Pull Amplifier stage, Q424-Q434-Q444-Q454. The network C435-C437-C438-C439-R428-R429-L428 provides high-frequency compensation for the vertical system. C435, C437, L428 and R429 are adjustable to provide optimum high-frequency response. The Gain adjustment, R427, varies the emitter degeneration between Q424 and Q434 to control the overall gain of the Vertical Amplifier. Zener diodes D440 and D450 limit the voltage swing across R440 and R450 to prevent Q424 and Q434 from saturating when the display is driven off the display area.

Transistors Q444 and Q454 operate in a similar manner to the Common-Base Amplifier stage. They provide a low-impedance load for Q424 and Q434 for maximum high-frequency response, and provide isolation between the Input and Output Push-Pull Amplifier stages.

When BEAM FINDER switch, SW360, in the emitter circuit of Q424-Q434 is pressed, it limits the dynamic range of this stage to compress the display within the viewing area. Normally, SW360 is closed and R423 is bypassed. When SW360 is pressed, the switch is open and R423 is connected into the circuit. This resistor limits the emitter current available to Q424-Q434 and the display is limited within the viewing area. Although the display is not linear, it provides a method of locating a signal that is overscanning the display area due to incorrect positioning or deflection factor.

Output Push-Pull Amplifier

The Output Push-Pull Amplifier stage is basically the same as the previous stage. The network C462-C463-C464-C465-C466-C468-R463-R464-R465-R466-R467-R468-R473-R474-R475 provides boosting for frequencies lower than those affected by the similar network in the preceding stage. C465, R465, R467 and R475 are adjustable to provide optimum response. Thermistor R461 provides bandwidth stabilization with temperature changes. Zener diodes D480 and D490 limit the voltage swing across R480 and R490 to prevent Q464 and Q474 from saturating when the display is driven off the display area. Diodes D483, D493 and D494 protect transistors Q484 and Q494 from damage if the +15-volt or —15-volt supplies are shorted to ground. The output of the amplifier is connected to the vertical deflection plates of the CRT. LR489 and LR499 provide damping for the leads connecting the output signal to the deflection plates.

HORIZONTAL AMPLIFIER

General

The Horizontal Amplifier circuit amplifies the push-pull horizontal deflection signal from the time-base unit and connects it to the horizontal deflection plates. Fig. 3-3 shows a detailed block diagram of the Horizontal Amplifier circuit. A schematic of this circuit is shown on diagram 1 at the rear of this manual.

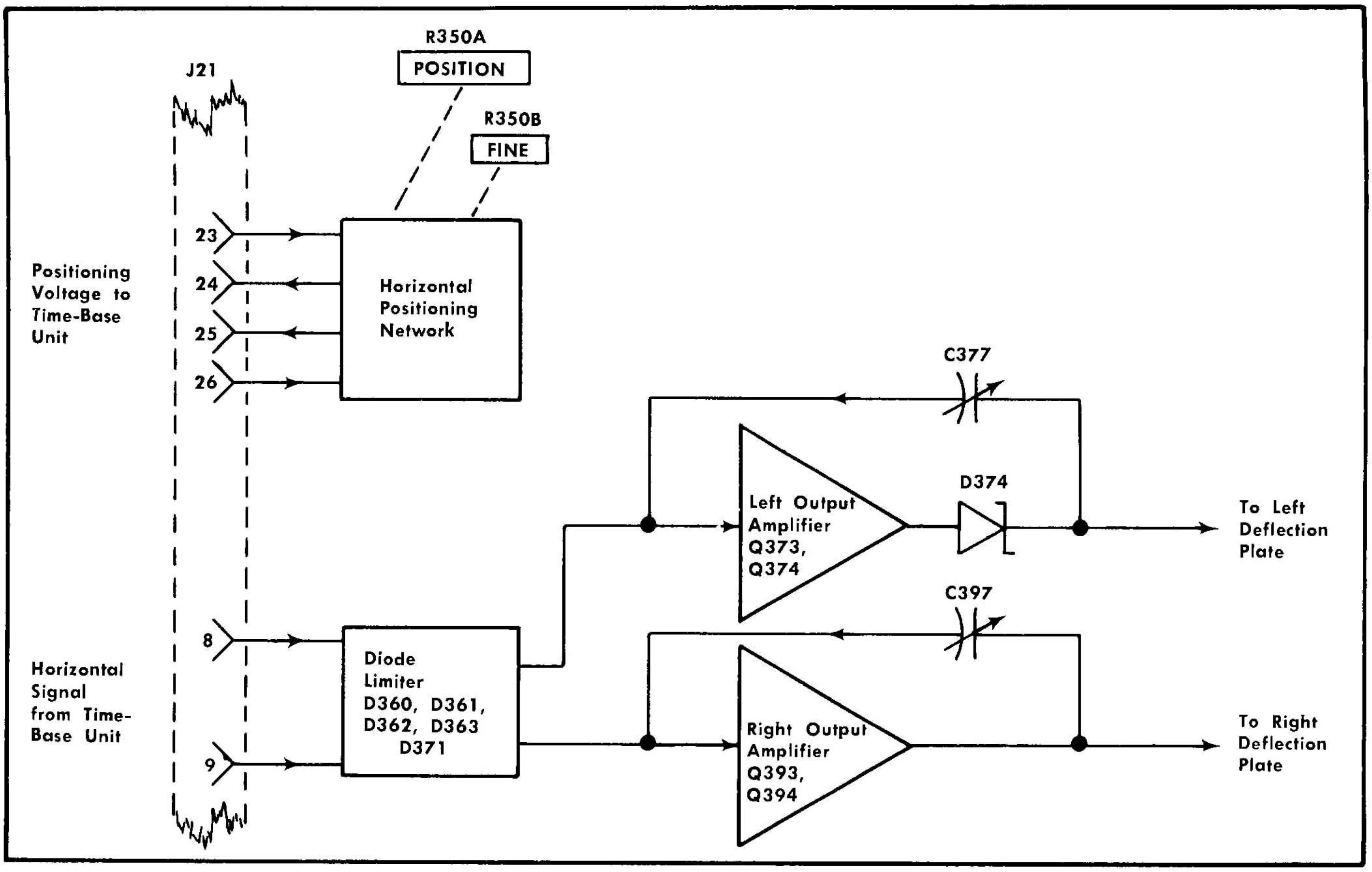


Fig. 3-3. Horizontal Amplifier detailed block diagram.

Diode Limiter

The Diode Limiter stage, D360-D361-D362-D363-D371, limits the dynamic range of the push-pull deflection signal current reaching the Horizontal Amplifier circuit so it cannot be overdriven with extreme horizontal POSITION control settings or when the sweep is magnified. This limiting network allows the Left and Right Output Amplifier stages to have a fast recovery when overdriven to provide good operation for fast sweep rates. The limiting action takes place as follows (example given for extreme positioning; operation is similar for magnified sweep): For on-screen displays, all diodes except D360 are forward biased. The forward current through diodes D361 and D362 is equal in the quiescent state. As the trace is positioned to the left side of the display area, the current through D361 and D362 decreases, and it drops to zero when the display is positioned off the left side of the screen. However, this current drops to zero before the Left Output Amplifier stage is turned off or the Right Output Amplifier stage is saturated. Further positioning current beyond the point of limiting to the left side flows through diode D360. This current holds the voltage bias of diodes D361 and D362 near zero so the diodes recover quickly (for fast, magnified sweeps). The Diode Limiter stage operates in a similar manner when the trace is positioned to the right side of the display area. Quiescent current through D363 and D371 is equal for an on-screen display and it decreases to zero as the display is positioned off the right side of the screen. This occurs before the Right Output Amplifier is cut off or the Left Output Amplifier is saturated.

Left Output Amplifier

Q373 and Q374 are connected as a current-driven feedback amplifier with a low input impedance. The Horiz Cent adjustment balances DC input current to the amplifier to produce a centered spot when a zero-deflection signal is applied to the input. Negative feedback is provided from the anode of zener diode D374 to the base of Q373 through R376 and R371 at DC and low sweep rates, and through C377 at fast sweep rates. C377 adjusts the feedback for optimum linearity at fast sweep rates.

Zener diode D397 and diodes D395 and D396 limit the positive-going output swing of Q374 and Q394. This limiting takes place only if some condition occurs which would otherwise damage Q374 or Q394. The current flow through R398, D397 and R397 sets a level of about +120 volts at the cathodes D395 and D396. If the collector of either Q374 or Q394 exceeds this voltage, the corresponding diode is forward biased and prevents the voltage from going any further positive.

The Horiz Gain adjustment, R377, varies the resistive feedback of the Left Output Amplifier stage and the Right Output Amplifier stage to control the overall gain of the Horizontal Amplifier circuit. C378 provides medium frequency compensation for optimum sweep linearity.

Right Output Amplifier

The Right Output Amplifier stage operates in basically the same manner as just described for the Left Output Amplifier stage. The deflection signal for the right deflection plate of the CRT is obtained directly from the collector of Q394. The high-frequency linearity is controlled by feedback capacitor C397.

The BEAM FINDER switch, SW360, limits the horizontal scan, when pressed, to present a display which is within the graticule area of the CRT. When SW360 is pressed, the horizontal deflection signal to the Right Output Amplifier stage is disconnected. The horizontal deflection of the CRT is now produced only by the Left Output Amplifier stage and this deflection is not sufficient to deflect the beam beyond the graticule limits.

Horizontal Positioning Network

The Horizontal Positioning Network (shown in Interconnecting Sockets diagram 6) provides the control voltages necessary to determine the horizontal position of the trace. These voltage levels are connected to the time-base unit through terminals 23, 24, 25 and 26 of the interconnecting plug, J21. The POSITION control, R350A, and FINE control, R350B, are connected in parallel. The POSITION control provides rapid positioning and the FINE control provides more precise positioning.

LOW-VOLTAGE POWER SUPPLY

General

The low-voltage Power Supply circuit provides the operating power for this instrument from four regulated supplies and one unregulated supply. Electronic regulation[1] is used to provide stable, low-ripple output voltages. Each regulated supply contains a short-protection circuit to prevent instrument damage if a supply is inadvertently shorted to ground. The Power Input block includes the power transformer and the Voltage Selector Assembly. The Voltage Selector Assembly allows selection of the nominal operating voltage and regulating range for the instrument. Fig. 3-4 shows a detailed block diagram of the Power Supply circuit. A schematic of this circuit is shown on diagram 3 at the rear of this manual.

Power Input

Power is applied to the primary of transformer T601 through the EMI (electro-magnetic interference) filter, 115-volt line fuse F601, POWER switch SW601, thermal cutout TK601, Voltage Selector switch SW602 and Range Selector Switch SW603. The Voltage Selector switch SW602 connects the split primaries of T601 in parallel for 115-volt nominal operation, or in series for 230-volt nominal operation. A second line fuse, F602, is connected into the circuit when the Voltage Selector switch is set to the 230 V position to provide the correct protection for 230-volt operation (F602 current rating is one-half of F601 rating). Each half of the primary winding has taps above and below the 115-volt (230) nominal point. The Range Selector switch, SW603, uses these taps to allow the instrument to regulate correctly on higher or lower than normal line voltages. As the Range Selector switch is switched from LO to M to HI, more turns are effectively added to the primary winding and the turns ratio is decreased. This provides a fairly constant voltage in the secondary of T601 even though the applied line voltage has increased.

[1]Phillip Cutler, "Semiconductor Circuit Analysis", McGraw-Hill, New York, 1964. pp. 559-625.

Thermal cutout TK601 provides thermal protection for this instrument. If the internal temperature of the instrument exceeds a safe operating level, TK601 opens to interrupt the applied power. When the temperature returns below a safe level, TK601 automatically closes to reapply the power.

—75-Volt Supply

The —75-Volt Supply provides the reference voltage for the other regulated supplies. The output from the secondary of T601 is rectified by bridge rectifier D612A-D. The unregulated voltage across filter capacitor C612 is applied to the —75-Volt Series Regulator stage. The current through the Series Regulator stage is controlled by the Error Amplifier to provide the correct regulated output voltage.

The Error Amplifier is connected as a difference amplifier[2] (comparator). Reference voltage for the comparator is provided by zener diode D609 which sets the base of Q614A at about —9 volts. The base level of Q614B is determined by divider R630-R631-R632-R634 between the output of this supply and ground. R631 is adjustable to set the output voltage of this supply to —75 volts. R612 is the emitter resistor for both halves of the comparator and the current through it divides between Q614A and Q614B. The output current of the Error Amplifier stage controls the conduction of the Series Regulator stage (through Q623 and Q633). This output current changes to maintain nearly equal voltages at the bases of Q614A and Q614B to hold the output voltage constant. The output voltage is adjusted as follows: If the —75 Volts adjustment, R631, is turned clockwise, the current through Q614B increases (Q614B base voltage tends to go more positive than the base of Q614A) and the current through Q614A decreases. Decreased current through Q614A produces less voltage drop which results in increased base current to Q623. The emitter of Q623 rises positive and pulls the base and emitter of Q633 positive also to increase the conduction of the Series Regulator transistor, Q637. The increased current through the Series Regulator stage increases the current to the load and the output voltage increases. This places more voltage across divider R630-R631-R632-R634 and the divider action returns the base of Q614B to about —9 volts. A similar, but opposite, action takes place when R631 is turned counterclockwise.

The output voltage is regulated to provide a constant voltage to the load by feeding a portion of the output voltage back to the Series Regulator, Q637. For example, assume that the output voltage increases (more negative) because of a decrease in load or an increase in line voltage. This negative-going level at the output is applied across the voltage divider R630-R631-R632-R634 and causes the base of Q614B to go negative. The current flow through Q614B is reduced which makes Q614A conduct more, bringing its collector negative. When the collector of Q614A goes negative, it

[2]Ibid., pp. 365-372.

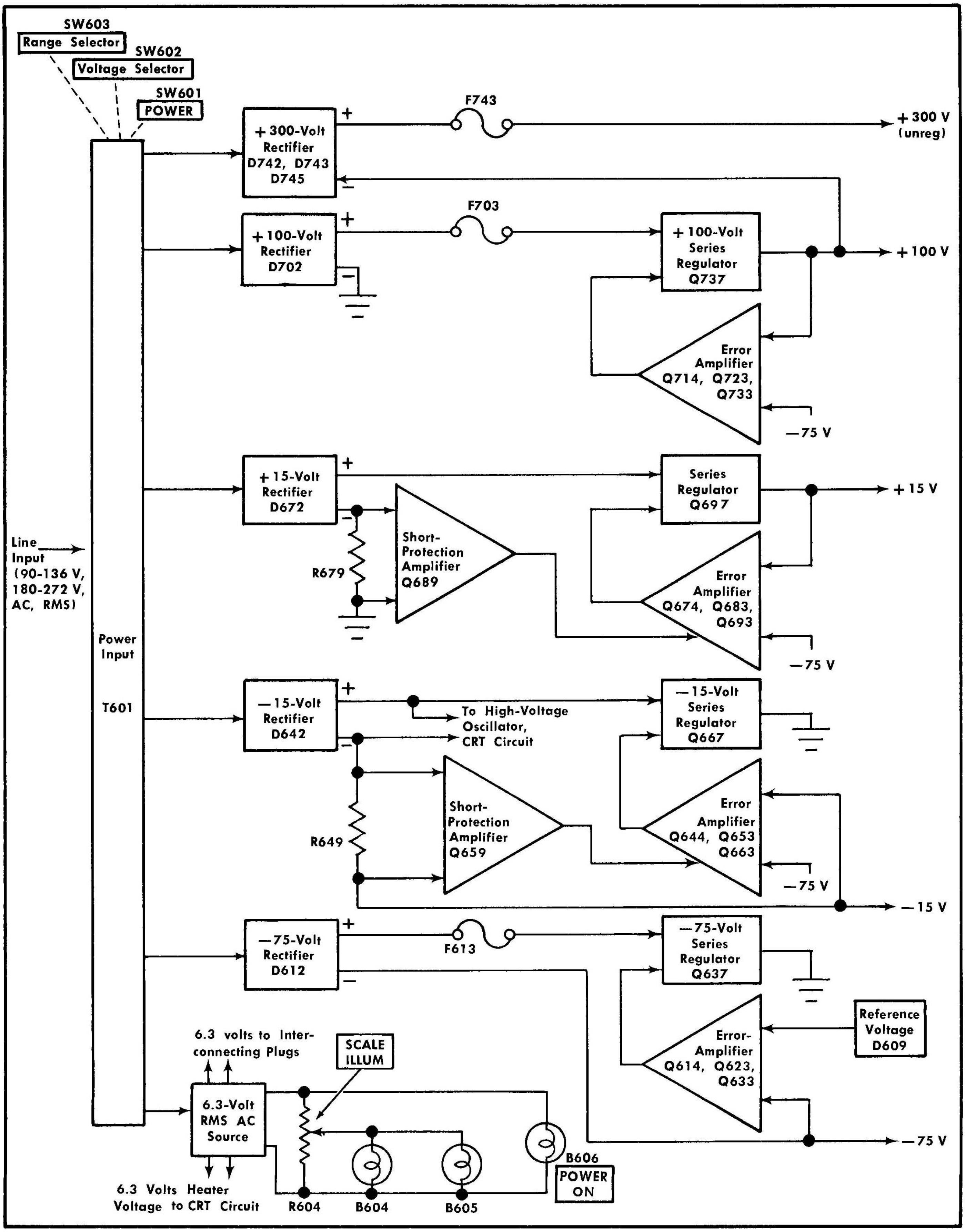


Fig. 3-4. Power Supply detailed block diagram.

results in reduced current through Q623, Q633 and Q637. Reduced current through Q637 means that there is less current through the load and the output voltage decreases (less negative) to correct the original voltage change. In a similar manner the Series Regulator and Error Amplifier stages compensate for output changes due to ripple.

Zener diode D636 and fuse F613 protect this supply if the —75-Volt output is shorted. For normal operation, D636 is not conducting and does not affect the circuit. However, when the output is shorted, the voltage across Q637 increases. D636 and R636 connect this increase in voltage back to the base of Q637, forcing it to conduct heavily. This arrangement turns Q637 on very quickly when the output is shorted to greatly increase its collector current. The increased current through Q637 causes fuse F613 to open and interrupt the unregulated voltage to this supply before the shorted condition can cause damage. The operating current for Q614A is supplied by the +100-Volt Supply. The +100-Volt Supply has a similar protection circuit which interrupts its output when it is shorted. Therefore, the —75-Volt Supply shuts off when the +100-Volt Supply is shorted. Since the —75-Volt Supply provides the reference voltage for the remaining supplies, all regulated outputs are reduced when the —75-Volt Supply or the +100-Volt Supply are shorted. Diode D611 protects Q614A and Q623 when the —75-Volt Supply is shorted to ground.

—15-Volt Supply

Rectified voltage for operation of the —15-Volt Supply is provided by D624A-D. The unregulated voltage across the filter capacitor C642 is connected to the —15-Volt Series Regulator and to the High-Voltage Oscillator in the CRT Circuit. Reference voltage for the —15-Volt Supply is provided by voltage divider R660-R661-R662 between the regulated —75 volts and ground. The —15-Volts adjustment, R661, varies the voltage at the base of Q644 to set the output level of this supply. The —75-volt level is held stable by the —75-Volt Supply as discussed previously. If the —15-volt output changes, this change appears at the emitter of Q644 as an error signal. Regulation of the output voltage is controlled by the —15-Volt Series Regulator stage, Q667, in a similar manner to that described for the —75-Volt Supply. Diode D669 provides thermal compensation for the base-emitter junction of Q644.

Shorting protection for this supply is provided by current limitation. For normal operation, the emitter-base voltage of the Short Protection Amplifier stage, Q659, is not enough to bias it on. However, when the output is shorted, high current is demanded from the Series Regulator, Q667, and this current flows through R649. The voltage drop across R649 becomes sufficient to forward bias Q659 and its collector current produces a control level which limits the conduction of the Series Regulator to protect it from exceeding its current rating. Diode D650 protects Q653 if the +15-Volt Supply is shorted to ground.

+15-Volt Supply

Diodes D672A-D provide the rectified voltage for the +15-Volt Supply. This supply operates in a similar manner to the —15-Volt Supply except that the negative side of the supply is connected to ground to provide a positive output voltage. Output level of this supply is set by the +15 Volts adjustment, R691.

+100-Volt Supply

Rectified voltage for operation of the +100-Volt Supply is provided by D702A-D. The unregulated voltage across C702 is connected to the +100-Volt Series Regulator. Reference voltage for this supply is provided by voltage-divider R730-R731-R732 between the regulated —75 volts and the output of this supply. Since the —75-volt level is held stable by the —75-Volt Regulator circuit, any change at the base of Error Amplifier Q714 is due to a change at the output of the +100-Volt Supply. Regulation of the output voltage is controlled by Error Amplifier Q714-Q723-Q733 and Series Regulator Q737 in a manner similar to that described for the —75-Volt Supply. The +100-Volts adjustment, R731, sets the quiescent conduction level of the Error Amplifier stage to provide an output level of +100 volts. R719 and zener diode D716 are connected between the +300-volt and +100-volt supplies to establish a stable +200 volts at the cathode of D716. This +200 volts is the collector supply voltage for Q714. R714, R716 and zener diode D714 set the DC operating level of Q714. Diode D712 protects Q714 if the output of the +100-Volt Supply is shorted. D743 and C743 provide the collector supply voltage for Q723 and Q733. Shorting protection for this supply is provided by zener diode D736 and R736 as in the —75-Volt Supply. D736 increases the conduction of the Series Regulator, Q737, when the output is shorted, to quickly open fuse F703 to interrupt the current flow. Diode D737 protects the +100-Volt Supply from damage if it is shorted to one of the negative supplies.

+300-Volt Unregulated Supply

Diodes D742 and D745 are connected as a full-wave center-tapped rectifier and the output is filtered by C742. The unregulated voltage across C742 (about +200 volts) is connected in series with the +100-Volt Supply to obtain the +300-volts unregulated output. Fuse F743 protects this supply if the output is shorted. R745 and C745 provide high-frequency filtering for the entire supply.

6.3-Volt RMS AC Sources

The four 6.3-volt RMS secondary windings of T601 provide power for the POWER ON light B606 and scale illumination lights B604 and B605, heater voltage for the CRT and 6.3 volts for the plug-in units. The 6.3-volt winding for the CRT is elevated to —2.2 kV. The SCALE ILLUM control, R604, controls the current through B604 and B605 to control the illumination of the graticule lines.

CRT CIRCUIT

General

The CRT Circuit provides the high voltage and control circuits necessary for operation of the cathode-ray tube (CRT). This circuit also contains the Z Axis Amplifier which determines the trace intensity. Fig. 3-5 shows a detailed block diagram of the CRT Circuit. A schematic of this circuit is shown on diagram 4 at the rear of this manual.

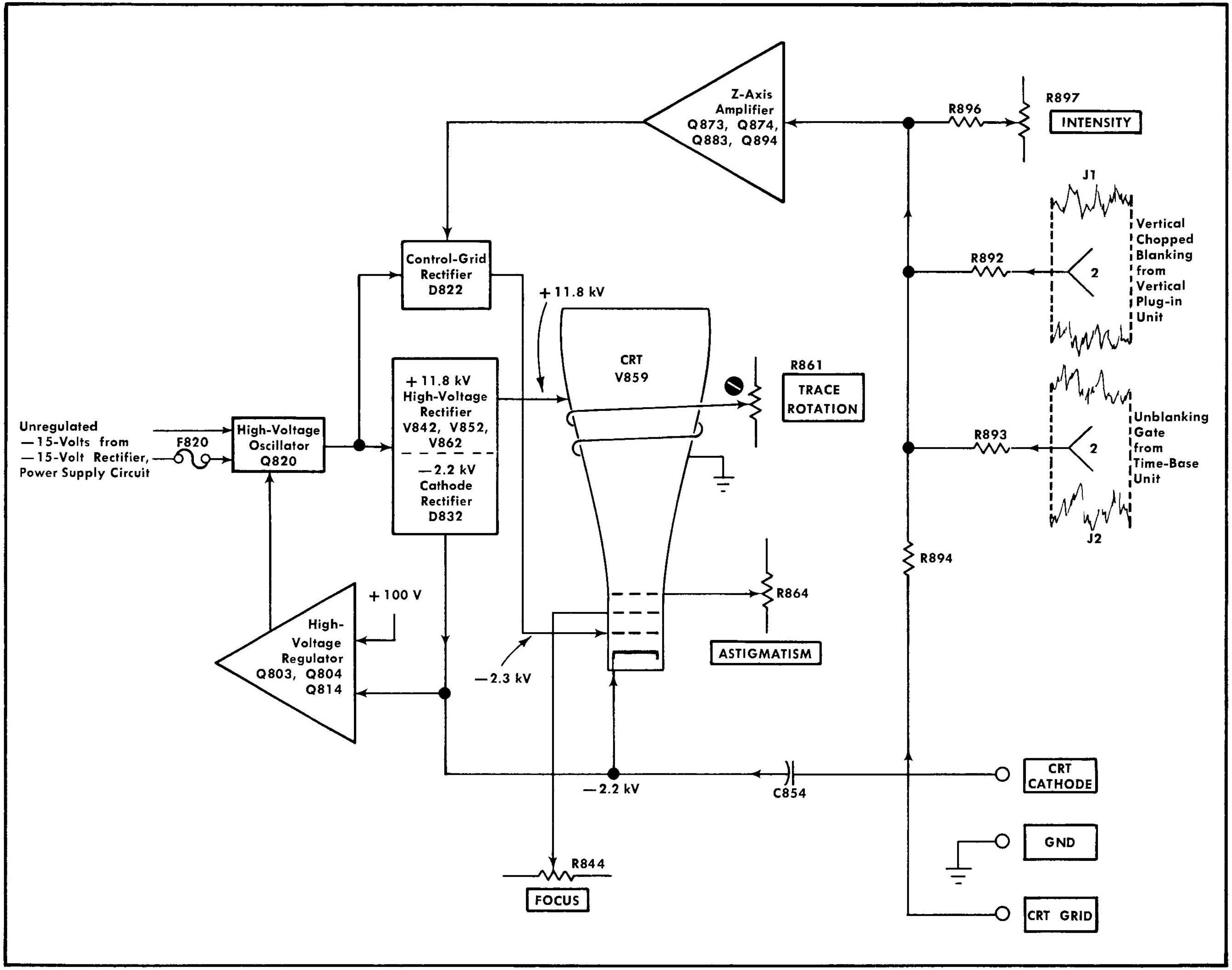


Fig. 3-5. CRT Circuit detailed block diagram.

High-Voltage Oscillator

Q820 with its associated circuitry comprises a class C oscillator[3] to produce the drive for the high-voltage transformer, T820. When the instrument is turned on, the current through R817 charges C821 positive and Q820 is forward biased. The collector current of Q820 increases and a voltage is developed across the collector winding of T820. This produces a corresponding voltage increase in the feedback winding of T820 which is connected to the base of Q820, and it conducts even harder. While Q820 is on, its base current exceeds the current through R817 and C821 charges negatively. Eventually the rate of collector current increase in Q820 becomes less than that required to maintain the voltage across the collector winding and the output voltage drops. This turns off Q820 by way of the feedback voltage to the base. The voltage waveform at the collector of Q820 is a sine wave at the resonant frequency of T820. Q820 remains off until a little less than one cycle later when C820 discharges sufficiently to raise the voltage at the base of Q820 positive enough to bias Q820 into conduction again. The cycle repeats at a frequency of 40 to 50 kilohertz. The amplitude of sustained oscillation depends upon the average current delivered to the base of Q820.

Fuse F820 protects the —15-Volt Supply if the High-Voltage Oscillator stage is shorted or the feedback path opens. The filter network, C820-L820, prevents the 50-kilohertz current changes in the High-Voltage Oscillator stage from affecting the —15-volt regulator circuit.

High-Voltage Regulator

The +100-volt supply is the reference voltage for the High-Voltage Regulator circuit. Feedback from the secondary of T820 is connected to the base of Q803 through the voltage dropping network R802A, B, C, D, E, F. This portion of the —2.2 kV Cathode Rectifier output voltage is amplified by Q803, Q804 and Q814 and becomes a controlling current into the base of Q820. This determines the amplitude of the oscillations at the collector of Q820.

Regulation takes place as follows: If the output voltage at the HV Test Point starts to go positive (less negative), a portion of this positive-going voltage is applied to the base of Q803. The current through Q803 increases and it, in turn, increases the current through Q804 and Q814. An increase in current through Q814 means that more average current is applied to the base of Q820. More base current in Q820 increases the collector current which produces a larger induced voltage in the secondary of T820. This increased voltage appears as a more negative voltage at the HV Test Point to correct the original positive-going change. This feedback regulates the output of the —2.2 kV Cathode Rectifier.

Output voltage level of the high-voltage supply is controlled by the High Voltage adjustment, R801, in the base circuit of Q803. This control permits a "fine" adjustment of the +100-volt reference voltage for the regulator applied through R803 and it sets the output level to which the circuit regulates.

[3]Lloyd P. Hunter (ed.), "Handbook of Semiconductor Electronics", second edition, McGraw-Hill, New York, 1962. pp. 14-19 — 14-21.

High-Voltage Rectifiers

The high-voltage transformer, T820, has two high-voltage output windings and three low-voltage windings. The low-voltage windings provide filament voltage for V842, V852 and V862. The two high-voltage windings provide the negative and positive accelerating voltage, and the CRT grid bias voltage. All of these outputs are controlled by the High-Voltage Regulator stage.

Positive accelerating potential for the CRT anode is supplied by voltage tripler V842-V852-V862. This rectified voltage is filtered by the network C838-R838 to provide an output of about +11.8 kilovolts. The load return for this supply is through the resistive helix inside the CRT to pin 7 of the CRT, and then to ground through R850-R851 and the +100-volt supply.

The negative accelerating potential for the CRT cathode is supplied by the half-wave rectifier D832. Voltage output is about —2.2 kilovolts. A portion of this output voltage is connected to the High-Voltage Regulator stage to provide a regulated high-voltage output.

The half-wave rectifier D822 provides a negative voltage for the control grid of the CRT. The output level of this supply is adjustable to determine the control-grid to cathode bias. This adjustment determines the positive reference voltage of the —2.2 kV Cathode Rectifier which in turn controls the output of the Control-Grid Rectifier stage. This occurs as follows: The High Voltage adjustment, R801, is adjusted to provide —2.2 kV at the HV Test Point (referenced to ground) and the High-Voltage Regulator stage is designed to hold the output voltage constant at this level. When the setting of the CRT Grid Bias adjustment R832 is changed, the positive voltage of the supply (at the junction of C831-R831) is changed. For example if R832 is rotated counterclockwise, the voltage at the junction of C831-R831 rises more positive. This tends to shift the voltage level at the HV Test Point slightly positive. This error is sensed by the High-Voltage Regulator stage and a correcting signal is connected to the High-Voltage Oscillator stage to make it produce more current in the secondary of T820 to return the HV Test Point to —2.2 kV. The increased secondary voltage also increases the output of the Control-Grid Rectifier stage making the CRT grid bias more negative (cathode level regulated at —2.2 kV). The positive accelerating potential of the CRT anode changes also, although the change is insignificant in relation to the overall voltage output from the supply. Action is similar but opposite when the CRT Grid Bias control is rotated clockwise.

The neon bulbs B852-B853-B854 provide protection for the CRT if the voltage difference between the control grid and the cathode exceeds about 180 volts. The unblanking pulse from the Z-Axis Amplifier is connected to the positive side of the Control Grid Rectifier to change the control grid level and determine CRT intensity, trace unblanking, dual-trace blanking and intensity modulation level.

CRT Control Circuits

Focus of the CRT display is controlled by the FOCUS control, R844. The divider R840-R841-R842-R843-R844-R845 is connected between the CRT cathode supply and ground. The voltage applied to the focus grid is more positive (less negative) than the voltage on either the control grid or the

CRT cathode. The ASTIGMATISM control, R864, which is used in conjunction with the FOCUS control to provide a well-defined display, varies the positive level on the astigmatism grid.

The Geometry adjustment, R863, varies the level on the horizontal deflection plate shields to control the overall geometry of the display. Two adjustments control the trace alignment by varying the magnetic field within the CRT. The Y Axis Alignment adjustment, R865, controls the current through L865 which affects the beam after vertical deflection but before horizontal deflection. The TRACE ROTATION adjustment, R861, controls the current through L861 and affects both vertical and horizontal rotation of the beam.

An external signal applied to the CRT CATHODE connector is connected to the cathode of the CRT through R855 and C854. C854 couples all but the low-frequency signals to the CRT cathode. This signal increases or decreases the display intensity, depending on polarity, to produce an intensity modulated display.

Z-Axis Amplifier

The input transistor, Q894, in the Z-Axis Amplifier circuit is a current-driven, low-impedance amplifier. It provides termination for the input signals as well as isolation between the input signals and the following stages. The current signals from the various control sources are connected to the emitter of Q894 and the sum of the signals determines the collector level. D884 and D886 in the collector provide overdrive limiting for the amplifier at minimum intensity. When the INTENSITY control is set fully counterclockwise (minimum), the collector current of Q894 is reduced and its collector rises positive. D886 is reverse biased and D884 is forward biased to limit the current to the base of Q883 and clamp the collector of Q894 about 0.6 volts more positive than the emitter level of Q883. At normal intensity levels, D884 is reverse biased and the signal from Q894 is coupled to the base of Q883 through D886.

The input signals vary the current drive to the emitter of Q894 which produces a collector current to determine the brilliance of the display. The INTENSITY control sets the quiescent level at the emitter of Q894. When R897 is turned in the clockwise direction, more current is added to the emitter of Q894, which increases the overall output from this circuit to provide a brighter display. However, the vertical chopped blanking, unblanking gate and the CRT GRID input signals determine whether the trace is visible. The vertical chopped blanking signal from the vertical plug-in unit blanks the trace during dual-trace switching. This positive pulse decreases the current through Q894 during trace switching time to blank the CRT display. The unblanking gate from the time-base unit blanks the CRT during sweep retrace and recovery time so there is no display on the screen. When the time-base unit is triggered to produce a sweep, a negative-going unblanking gate current is connected to the emitter of Q894 to allow the emitter current to reach the level established by the INTENSITY control and the other blanking inputs. An external blanking signal can be connected to the CRT GRID binding post to change the trace intensity. A positive-going signal connected to the CRT GRID connector decreases trace intensity and a negative-going signal increases trace intensity.

Q883 and Q874 are connected as a feedback amplifier with DC feedback provided by R878. Capacitors C877, C878 and C879 provide high-frequency feedback. Variable capacitor C879 is adjusted for optimum step response to provide an even unblanking level at fast sweep rates. For fast, positive-going changes (unblanking) C874-R874-D874-R871 serve as a bootstrapping circuit which provides extra current to charge the stray capacitance at the base of Q873 more rapidly. For negative-going changes, diode D873 is forward biased to pull the output rapidly negative in spite of the fact that Q873 is driven into cutoff. Diode D872 prevents the emitter level of Q873 from rising above +100 volts. The output unblanking pulse at the emitter of Q873 is connected to the CRT circuit through D870 and D871. These diodes protect the Z-Axis Amplifier stage if the Control-Grid Rectifier stage is shorted.

CALIBRATOR

General

The Calibrator circuit produces a square-wave output with accurate amplitude and frequency. This output is available as a square-wave voltage at the CAL OUT connector or as a square-wave current through the 5 mA probe current loop. An accurate +100 volts DC level is also available. The CALIBRATOR switch selects the attenuation of the output signal to provide square-wave voltage outputs between 100 volts and 0.2 millivolts peak to peak. Fig. 3-6 shows a detailed block diagram of the Calibrator circuit. A schematic of this circuit is shown on diagram 5 at the rear of this manual.

Calibrator Oscillator

The Calibrator Oscillator stage is a crystal-controlled oscillator with an oscillating frequency of four kilohertz as determined by crystal Y900. The signal at the collector of Q900 is connected to the base of Q924 through C914. Feedback from the collector of Q924 to crystal Y910 through R903 and R904 sustain the oscillation of the circuit. The collector signal of Q924 is connected to the Calibrator Multivibrator stage through C924 and C925. The CALIBRATOR switch, SW948, connects the emitter circuits of Q910 and Q924 to —15 volts in all positions except OFF and 100 V DC. In these two positions, the Calibrator Oscillator stage is inoperative.

Calibrator Multivibrator

The Calibrator Multivibrator stage is a bistable multivibrator[1]. The state of this multivibrator is switched with every other cycle from the Calibrator Oscillator stage to provide an output frequency of one kilohertz from a four kilohertz switching signal. This occurs as follows: For purposes of explanation, assume that Q935 has just switched off and Q945 has just switched on. When Q935 turns off, its collector goes positive and D933 is forward biased. C924 charges positive through R933 and D933, and this positive-going voltage across C924 holds D932 reverse biased. When Q945 turns on, its negative-going collector level reverse biases D943 and the charge path of C925 through R943 is interrupted. C925 begins to discharge

[1]Jacob Millman and Herbert Taub, "Pulse, Digital and Switching Waveforms", McGraw-Hill, New York, 1965. pp. 362-389.

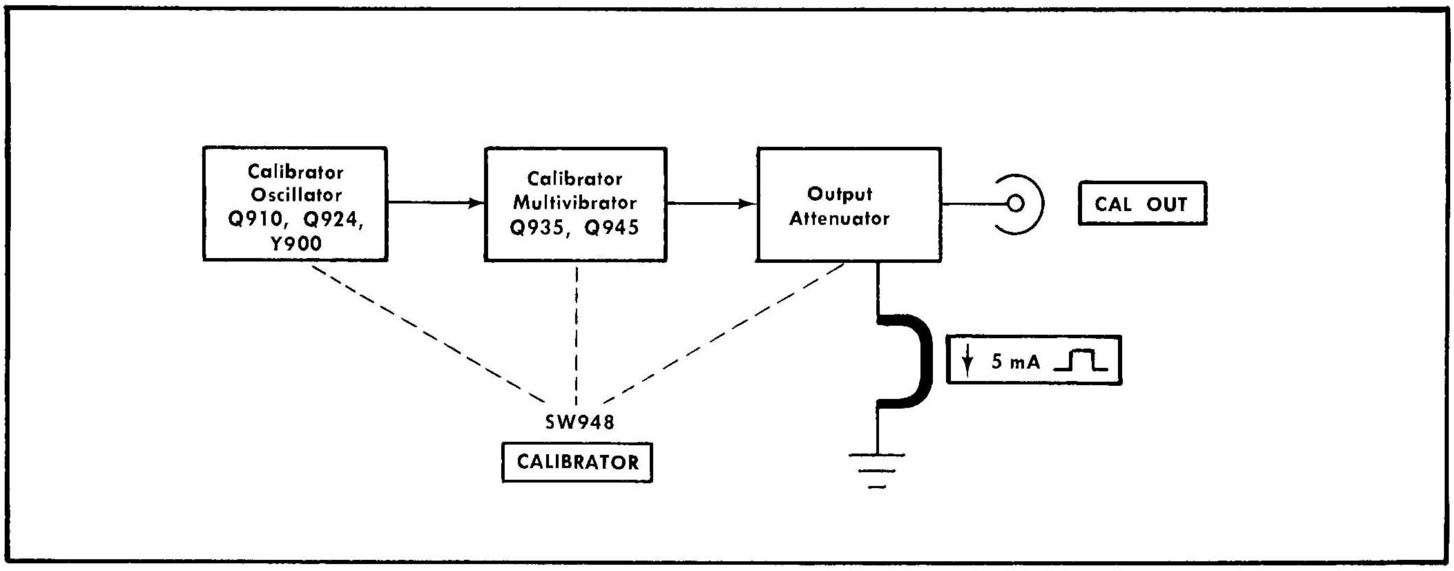


Fig. 3-6. Calibrator detailed block diagram.

through R942 and it holds D942 reverse biased. The steering diodes in this circuit, D932 and D942, accept negative-going trigger pulses. With the circuit conditions as described, both steering diodes are reverse biased to prevent any trigger signals from reaching the multivibrator. The discharge time of C925 determines when Q945 can be switched off and Q935 switched on. This discharge time is such that the first negative-going portion of the oscillator signal applied through C925 is blocked by D942. However, when the oscillator signal goes negative again, C925 has discharged enough to allow D942 to conduct. The negative signal is connected to the base of Q945 through D942 and Q945 is reverse biased. Its collector rises positive and C945-R945 couple this positive change to the base of Q935 to turn it on. The collector of Q935 goes negative and the coupling through C935-R935 to the base of Q945 aids the multivibrator in rapidly switching states.

Now conditions are reversed. D943 is forward biased and C925 is charged positive to hold D942 reverse biased. D932 is held reverse biased as C924 discharges through R932 and it cannot switch with the first negative-going signal from the Calibrator Oscillator stage. When the second negative-going signal arrives, C924 is discharged enough so D932 conducts and the multivibrator is switched to complete the cycle. Notice that the Calibrator Multivibrator stage completes one complete cycle with each four negative-going signals from the Calibrator Oscillator stage (four complete cycles). The −15-volt emitter voltage for Q935 and Q945 is disconnected by the CALIBRATOR switch in the OFF and 100 V DC positions to make the Calibrator Multivibrator inoperative.

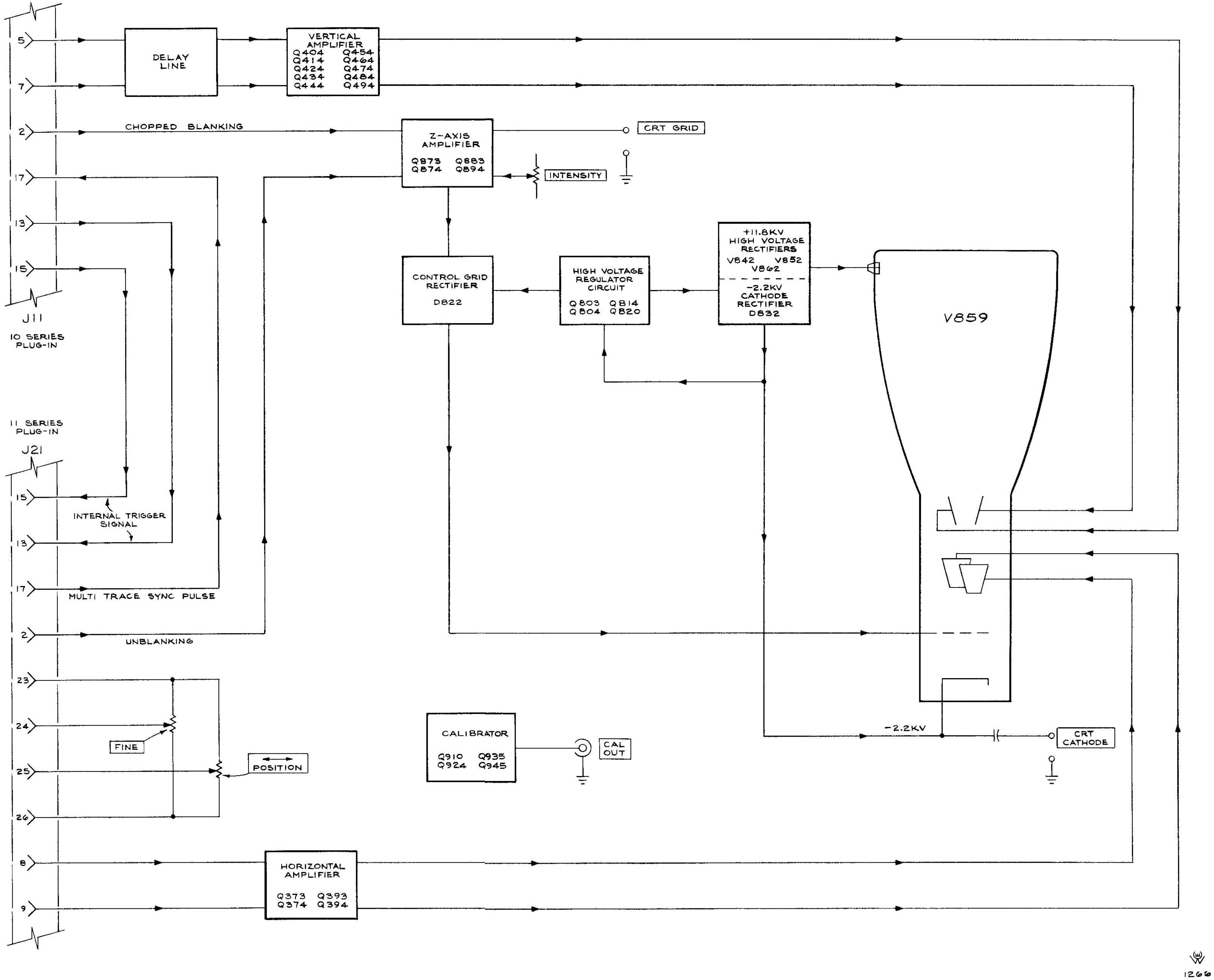
Output Attenuator

When Q945 in the Calibrator Multivibrator stage is on, its collector drops to about −14 volts which reverse biases D948. Since there is no current through the divider resistors to the load, the output level drops to zero volts. When Q945 turns off, its collector rises positive to about +100.5 volts as set by R946-D947-R947 between +100 and +300 volts. D944 is reverse biased to disconnect this positive level from the base of Q935 and from ground through R944. D948 is forward biased and its junction voltage drop equals that of D947 to return the level at its cathode to +100 volts. The signal voltage available at the CAL OUT connector is determined by divider R948B-Z (made up of 13 precision resistors) and the setting of the CALIBRATOR switch. In the 100 V DC position, the Calibrator Oscillator and Calibrator Multivibrator stages are inoperative to produce a +100-volt DC output level. In the 100 VOLTS to .2 mV positions, precision divider resistors are switched into the circuit to provide the correct output square-wave voltage. The positions of .2 VOLTS and below have an accurate 50-ohm output resistance. In the 5 mA square-wave position, the square-wave voltage to the CAL OUT connector is disconnected. The +100-volt square-wave at the cathode of D948 is connected to the current probe loop through resistors R948B-K. These resistors provide an accurate 20 kilohm series resistance to set the current through the current probe loop to an accurate five-milliampere square wave.

INTERCONNECTING SOCKETS

General

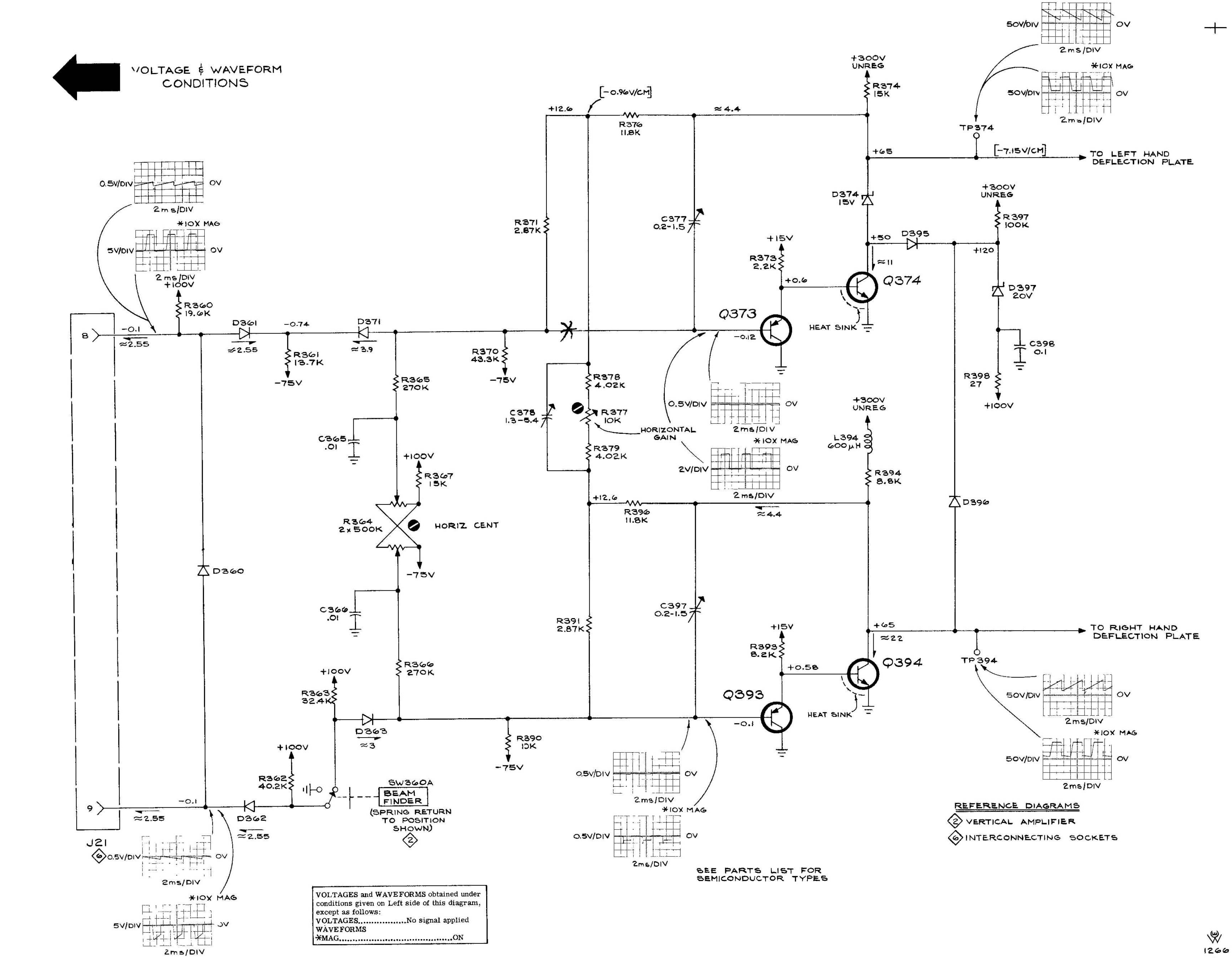
Diagram 6 shows the interconnections between the Power Supply outputs and the vertical interconnecting plug, J11, and the horizontal interconnecting plug, J21. This diagram also shows the connection to rear-panel connector J101.



TYPE 647A OSCILLOSCOPE

A

BLOCK DIAGRAM



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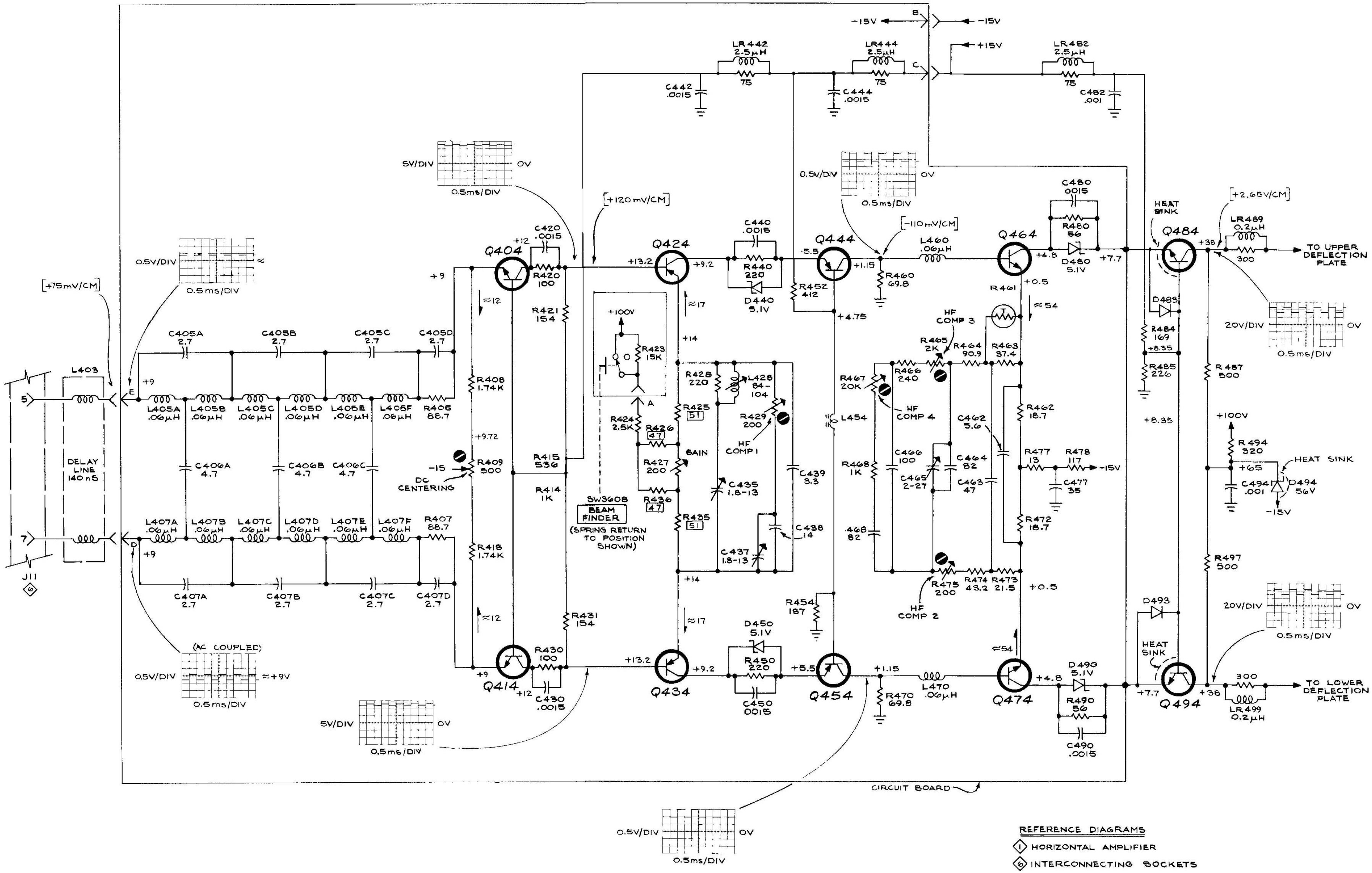
TYPE 647A OSCILLOSCOPE

A1

HORIZONTAL AMPLIFIER ①



REFERENCE DIAGRAMS

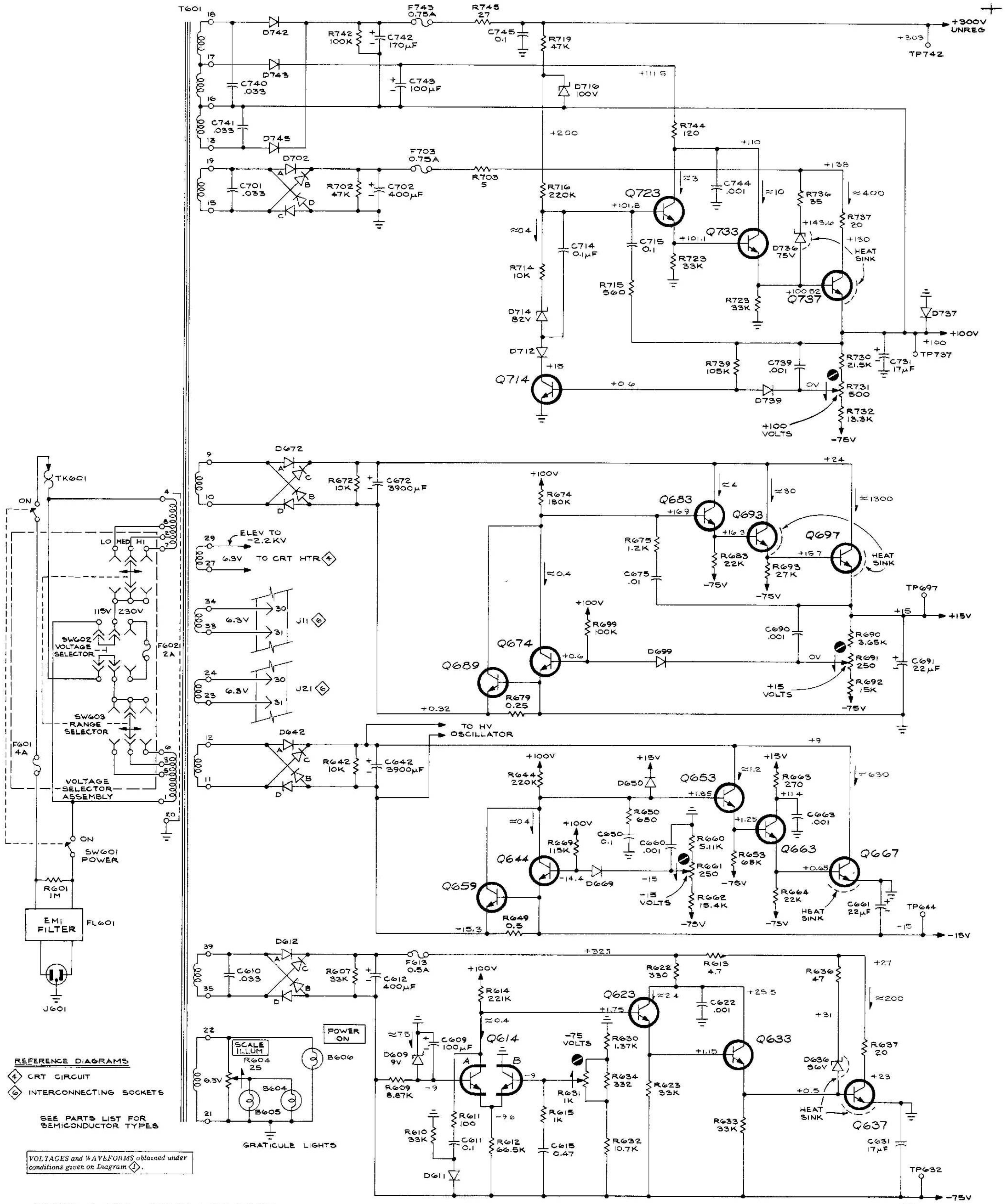
◇1 HORIZONTAL AMPLIFIER

◇6 INTERCONNECTING SOCKETS

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES and WAVEFORMS obtained under conditions given on Diagram ◇1, except as follows:
VOLTAGES..................No signal applied

868



REFERENCE DIAGRAMS

4 CRT CIRCUIT

6 INTERCONNECTING SOCKETS

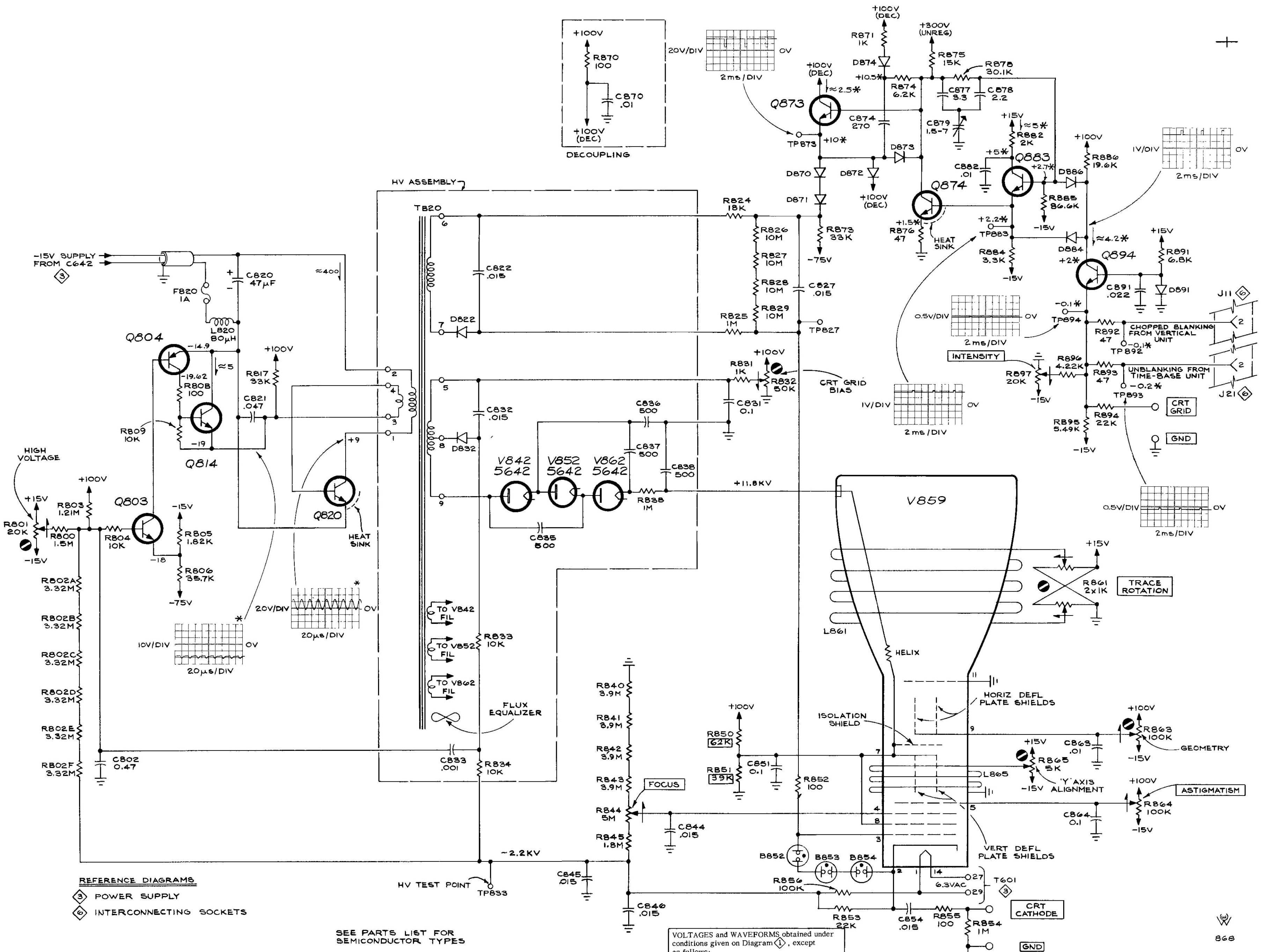
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1.

TYPE 647A OSCILLOSCOPE

A4

POWER SUPPLY 3

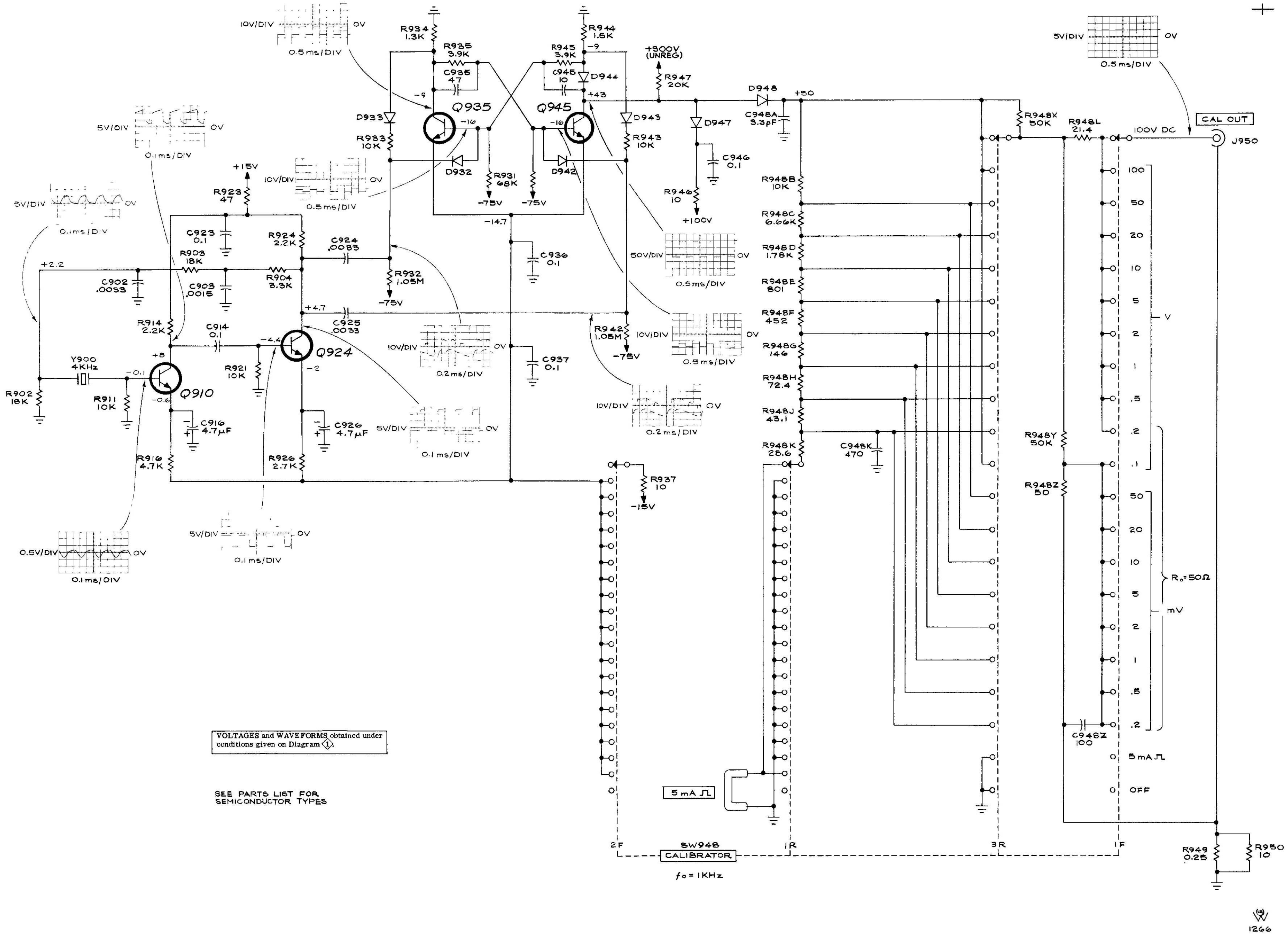


VOLTAGES and WAVEFORMS obtained under conditions given on Diagram 1, except as follows:
VOLTAGES..........................No signal applied
*Time-Base plug-in set to external input and INTENSITY control set fully CCW.
WAVEFORMS
*Test oscilloscope triggered internally.

TYPE 647A OSCILLOSCOPE

B

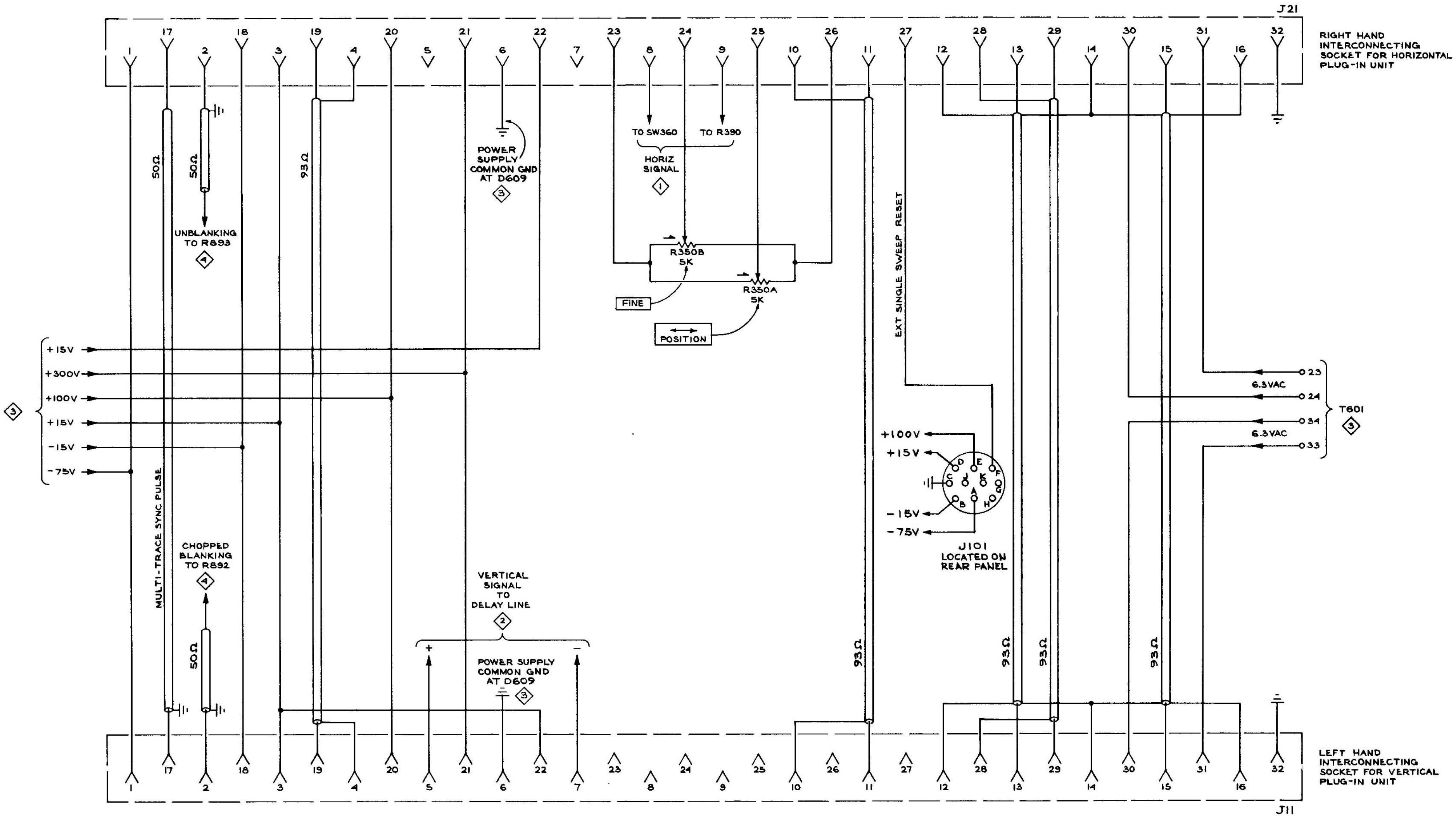
CRT CIRCUIT 4



TYPE 647A OSCILLOSCOPE

A

CALIBRATOR 5



REFERENCE DRAWINGS

1. HORIZONTAL AMPLIFIER
2. VERTICAL AMPLIFIER
3. POWER SUPPLY
4. CRT CIRCUIT

1266