Shop

INSTRUCTION MANUAL

Serial Number 32628

TYPE 422 OSCILLOSCOPE

With AC-DC Power Supply
SN 20,000 and up

Tektronix, Inc.
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070-0895-00 1268

WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial or Model Number with all requests for parts or service.

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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.

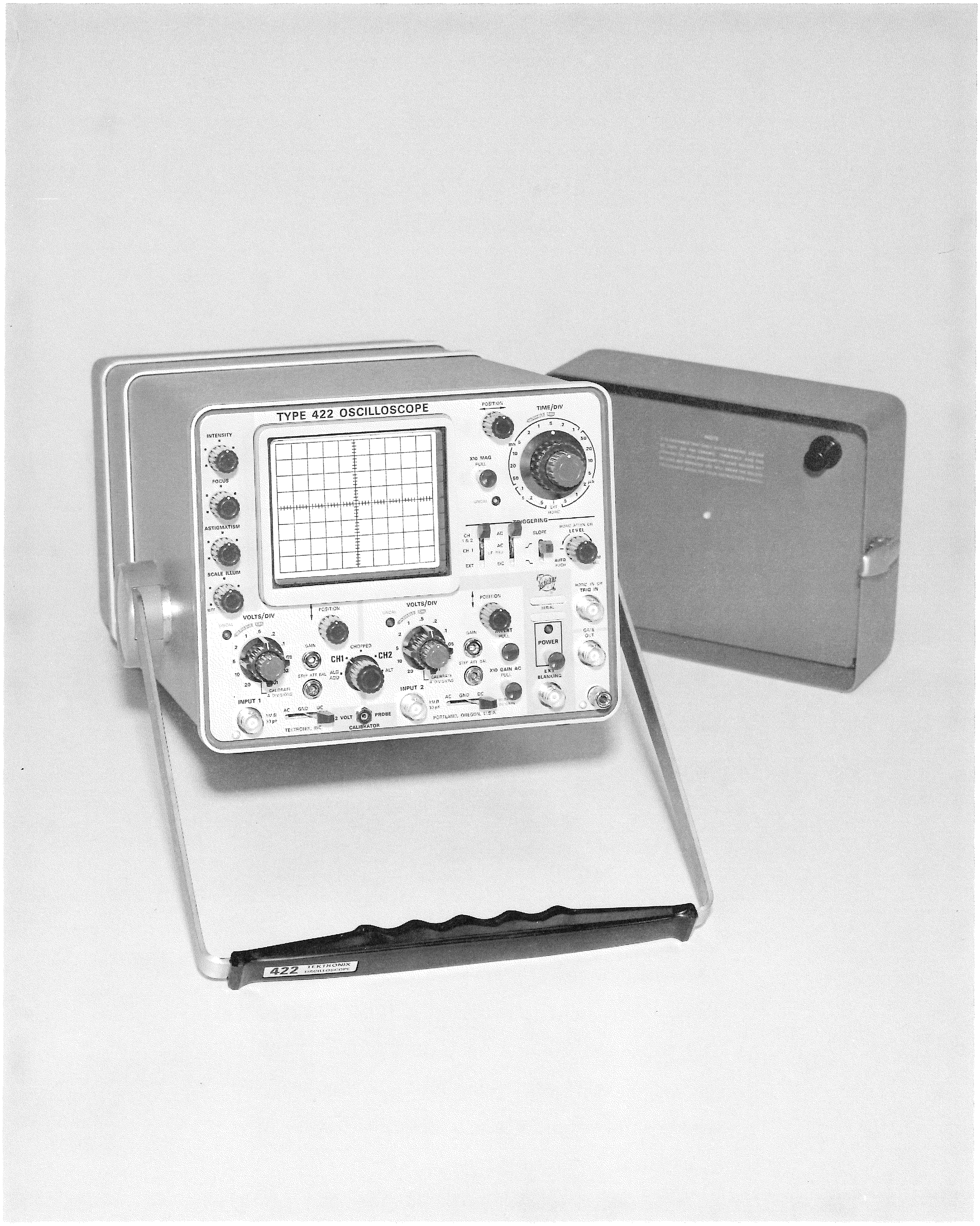


Fig. 1-1. Type 422 Oscilloscope with the AC-DC Power Supply.

SECTION 1
TYPE 422 SPECIFICATION
With AC-DC Power Supply

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

Introduction

The Tektronix Type 422 Oscilloscope is a solid-state portable instrument that combines small size and light weight with the ability to make precision waveform measurements. The instrument is mechanically designed to withstand the shock, vibration and other extremes of environment associated with portability. The dual-channel DC-to-15 megahertz vertical system provides calibrated deflection factors from 0.01 to 20 volts/division. A X10 gain feature in Channel 2 allows each Channel 2 deflection factor to be increased 10 times and provides a minimum deflection factor for Channel 2 of 0.001 volt/division in the 0.01 position (AC-coupled with reduced frequency response). The trigger circuits provide stable triggering over the full range of vertical frequency response. The horizontal deflection system provides calibrated sweep rates from 0.5 second to 0.5 microsecond/division. A X10 horizontal magnifier allows each sweep rate to be increased 10 times and provides a maximum sweep rate of 0.05 microsecond/division in the 0.5 μs position. X-Y measurements can be made by applying the vertical (Y) signal to either the INPUT 1 or INPUT 2 connector and the horizontal (X) signal to the HORIZ IN OR TRIG IN connector (TIME/DIV switch set to EXT HORIZ).

The Type 422 with AC-DC Power Supply can be operated from any one of three power sources; AC line, external DC, or internal rechargeable batteries. The regulated low-voltage power supply assures that instrument performance is not affected by variations in internal battery charge level, applied DC voltage, or AC line voltage and frequency. Maximum total power consumption is 26 watts for external DC operation and 30 watts for AC operation. The instrument will operate about four hours from the internal batteries when fully charged.

This instrument will meet the electrical characteristics listed in Table 1-1 following complete calibration as given in Section 5. The performance check procedure given in Section 5 provides a convenient method of checking instrument performance without making internal checks or adjustments. The following electrical characteristics apply over a calibration interval of 1000 hours and an ambient temperature range of −15° C to +55° C, except as otherwise indicated. Warmup time for given accuracy is 20 minutes.

TABLE 1-1

ELECTRICAL

Characteristic	Performance	
VERTICAL DEFLECTION SYSTEM		
Deflection Factor		
Channel 1 or 2 calibrated range, X1 gain		
Without probe	10 millivolts/division to 20 volts/division in 11 steps. Steps in 1-2-5 sequence.	
With P6012 Probe	100 millivolts/division to 200 volts/division in 11 steps. Steps in 1-2-5 sequence.	
Channel 2 only calibrated range, X10 gain		
Without probe	One millivolt/division to two volts/division in 11 steps. Steps in 1-2-5 sequence.	
With P6012 Probe	10 millivolts/division to 20 volts/division in 11 steps. Steps in 1-2-5 sequence.	
Channel 1 or 2 accuracy, X1 gain		
With or without probe	Within 3% of indicated deflection.	
Channel 2 only accuracy, X10 gain	+20° C to +30° C	−15° C to +55° C
With or without probe	Within 4% of indicated deflection.	Within 7.5% of indicated deflection.
Uncalibrated (variable) range	Continuously variable between calibrated deflection factor settings. Extends maximum uncalibrated deflection factor to at least 50 volts/division.	

Characteristic	Performance
Low-Frequency Linearity	0.15 division or less compression or expansion of a center-screen two-division signal when positioned to the top and bottom of the graticule area.
Bandwidth with Four-Division Reference	
DC input coupling	
Channel 1 or 2, X1 gain	DC to 15 megahertz or greater (—3 dB points).
Channel 2 only, X10 gain	DC to five megahertz or greater (—3 dB points).
AC input coupling	
Channel 1 or 2, X1 gain	
Without probe	Two hertz or less to 15 megahertz or greater (—3 dB points).
With P6012 Probe	0.2 hertz or less to 15 megahertz or greater (—3 dB points).
Channel 2 only, X10 gain	
With or without probe	Five hertz or less to five megahertz or greater (—3 dB points).
Step Response	
Risetime	
Channel 1 or 2, X1 gain	24 nanoseconds or less.
Channel 2 only, X10 gain	70 nanoseconds or less.
Aberrations	
With four-division pulse centered vertically	Peak aberrations not to exceed +3% or —3%; total peak-to-peak aberrations not to exceed 3%.
With eight-division pulse centered vertically	Peak aberrations not to exceed +5% or —5%; total peak-to-peak aberrations not to exceed 5%.
Vertical Display Modes (selected by front-panel vertical Mode switch)	Channel 1 only. Channel 2 only. Dual-trace, alternate between channels. Dual-trace, chopped between channels. Added algebraically.
Input Coupling Modes (selected by front-panel Input Coupling switch)	AC (capacitive) coupled or DC (direct) coupled.

Characteristic	Performance
Maximum Input Voltage	
AC and DC input coupling	300 volts (DC + peak AC). Peak-to-peak AC less than 300 volts (one kilohertz or less).
Input RC Characteristics	
Resistance	One Megohm ±2%.
Capacitance	33 picofarads ±1 pF.
Time constant	33 microseconds ±1%.
Input Current at +20° C to +30° C	Negligible.
Step Attenuator Balance	0.1 division or less trace shift between calibrated VOLTS/DIV switch positions.
DC Drift	
Drift with time	
Short term (with temperature and line voltage constant)	0.1 division or less during any minute within first hour after 20-minute warmup.
Long term (temperature between +20° C and +30° C and line voltage constant)	0.2 division or less total during first hour after 20-minute warm-up.
Drift with line voltage change (temperature held constant)	0.1 division or less with line voltage varied from low line to high line.
Drift with temperature (line voltage constant)	0.2 division or less for each 10° C change in temperature.
Common Mode Rejection Ratio	100:1 or greater at 50 kilohertz with optimized setting of Channel 1 and 2 GAIN adjustments at one kilohertz.
Channel Isolation (at 15 megahertz)	
Equal deflection factors	At least 100:1.
Unequal deflection factors	At least 10,000:1.
Chopped Mode	
Repetition rate	150 kilohertz ±20%.
Time segment from each channel	2.0 to 4.7 microseconds.
Polarity Inversion (selected by Channel 2 INVERT switch)	Displayed signal from Channel 2 can be inverted.

Characteristic	Performance
Delay Line	Permits viewing of leading edge of triggering signal (internal triggering only).
TRIGGERING	
Trigger Source (selected by front-panel TRIGGERING Source switch)	Internal from both Channel 1 and 2. Internal from Channel 1 only. External from signal applied to TRIG IN connector.
Trigger Coupling (selected by front-panel TRIGGERING Coupling switch)	AC (capacitive)coupled. AC (capacitive) coupled with attenuation of low-frequency signals. DC (direct) coupled.
Trigger Slope (selected by front-panel SLOPE switch)	Sweep can be triggered from the positive-going or negative-going portion of trigger signal.
Trigger Level	LEVEL control allows selection of the triggering point on the selected slope of the trigger signal.
Trigger Mode (selected by front-panel TRIGGERING Mode switch)	AUTO Mode for triggered sweep at point selected by LEVEL control when adequate trigger signal is applied (see Trigger Sensitivity); sweep free runs at sweep rate selected by TIME/DIV switch when trigger signal is inadequate or below 20 hertz. NORM Mode for triggered sweep at point selected by LEVEL control when adequate trigger signal is applied (see Trigger Sensitivity); no trace when trigger signal is inadequate.
Trigger Sensitivity (AUTO and NORM Mode)	
Internal	
AC	0.2 division of deflection minimum, 50 hertz to five megahertz; increasing to one division at 15 megahertz.
AC LF REJ	0.2 division of deflection minimum, 50 kilohertz to five megahertz; increasing to one division at 15 megahertz. Will not trigger on two-division or less sine wave at 120 hertz or less.
DC	0.2 division of deflection minimum, DC to five megahertz; increasing to one division at 15 megahertz.
External	
AC	125 millivolts minimum, 50 hertz to five megahertz; increasing to 0.6 volt at 15 megahertz.
AC LF REJ	125 millivolts minimum, 50 kilohertz to five megahertz; increasing to 0.6 volt at 15 megahertz. Will not trigger on 1.25 volt or less sine wave at 120 hertz or less.
DC	125 millivolts minimum, DC to five megahertz; increasing to 0.6 volt at 15 megahertz.
External Trigger Input	
RC characteristics	100 kilohms ±3% paralleled by 33 picofarads ±5 pF.
Maximum Input voltage	250 volts DC + peak AC.
LEVEL control range	At least +10 to −10 volts.
TIME BASE	
Sweep Rate	
Calibrated range	
Unmagnified	0.5 second to 0.5 microsecond/division in 19 steps. Steps in 1-2-5 sequence.
Magnified	50 milliseconds to 0.05 microsecond/division in 19 steps. Steps in 1-2-5 sequence.
Uncalibrated (variable) range	Continuously variable between calibrated sweep rate settings. Extends slowest uncalibrated sweep rate to at least 1.25 seconds/division.
Accuracy	
Unmagnified	
Over center eight divisions	Within 3% of indicated sweep rate.
Over any two division portion within center eight divisions	Within 4% of indicated sweep rate.
Magnified	
Over center eight divisions	Within 5% of equivalent sweep rate.

Characteristic	Performance
Over any two division portion within center eight divisions	Within 7.5% of equivalent sweep rate.
Sweep Length	10.4 to 12.1 divisions.

EXTERNAL HORIZONTAL INPUT

Deflection Factor	
X10 MAG switch pushed in	10 volts/division.
X10 MAG switch pulled out	One volt/division.
Accuracy	Within 25%.
HORIZ ATTEN Range	At least 10:1.
Bandwidth	DC to 500 kilohertz or greater (−3 dB points).
Input RC Characteristics	300 kilohms ±10% paralleled by 35 picofarads ±3 pF.

CALIBRATOR

Waveshape	Square wave.	
Polarity	Negative-going with baseline at zero volts.	
Output Voltage		
CALIBRATOR jack	Two volts peak to peak.	
Internal	0.2 volts. Internally connected to Input Amplifiers in CALIBRATE 4 DIVISIONS positions of Channel 1 and 2 VOLTS/DIV switches.	
Repetition Rate	One kilohertz.	
Accuracy		
Voltage	+20° C to +30° C	−15° C to +50° C
CALIBRATOR jack	Within 0.5%.	Within 1.5%.
Internal	Within 1.5%.	Within 2.5%.
Repetition rate	Within 20%.	
Duty Cycle	45% to 55%.	
Output Resistance	1.95 kilohms ±3%.	

Z AXIS INPUT

Sensitivity	Two volt signal blanks trace.
Polarity of Operation	Positive-going signal required.
Input Resistance	250 ohms ±10%.

Characteristic	Performance
SIGNAL OUTPUTS	
Gate	
Waveshape	Rectangular.
Polarity	Negative-going with baseline near zero volts.
Output voltage	0.5 volt or greater.
Duration	Same duration as sweep.
Output Resistance	620 ohms ±10%.

CATHODE—RAY TUBE (CRT)

Graticule	
Type	Internal with variable edge lighting.
Area	Eight divisions vertical by 10 divisions horizontal. Each division equals 0.8 centimeter.
Horizontal Resolution	140 lines in 10 divisions.

POWER SUPPLY

AC	
Line voltage range (selected by rear-panel Power Mode switch)	
115-volts nominal	
Operating	92 to 137 volts AC RMS.
Battery charging	92 to 126.5 volts AC RMS.
230-volts nominal	
Operating	184 to 274 volts AC RMS.
Battery charging	184 to 253 volts AC RMS.
Line frequency	45 to 440 hertz. Derate upper line voltage limit linearly to a maximum of 10% between 50 and 45 hertz.
Maximum power consumption 95 to 137 volts line, operating or charging	30 watts, 0.4 ampere.
DC	
Voltage range	11.5 to 35 volts DC with supplied DC power cord.
Chassis to external source potential	+200 volts measured from chassis to power source.
Maximum Power consumption	26 watts. Maximum current (amperes) = 26 ÷ applied DC voltage.

Characteristic	Performance
Battery	
Batteries	20 size D nickel-cadmium cells supplied in battery pack, Tektronix Part No. 016-0066-02 (optional accessory).
Charge time (Power Mode switch set to CHARGE BATT 115V AC or 230V AC)	At least 16 hours to reach full capacity.
Operating time[1] (batteries charged and operated at +20°C to +30°C)	
SCALE ILLUM off (full counterclockwise)	At least five hours
SCALE ILLUM at maximum (fully clockwise)	At least 4.5 hours.

TABLE 1-2

ENVIRONMENTAL

NOTE

This instrument will meet the electrical characteristics given in Table 1-1 over the following environmental limits. Complete details on environmental test procedures, including failure criteria, etc., can be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.

Characteristic	Performance
Temperature	
Without batteries	
Operating	−15° C to +55° C
Non-operating	−55° C to +75° C.
With batteries	
Operating	−15° C to +40° C.
Non-operating	−40° C to +60° C.
Altitude	
Operating	15,000 feet maximum.
Non-operating	Test limit 50,000 feet.
Humidity	
Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B. Omit freezing and vibration. Allow 24 hour post-test drying period at +25°C ±5°C and 30% to 80% relative humidity. Limit maximum temperature to +60° C if tested with batteries.
Vibration	
Operating and non-operating	15 minutes along each of the three major axes at a total displacement of 0.025-inch peak to peak (3.9 g at 55 c/s) with frequency varied from 10-55-10 in one minute cycles. Hold at any resonant point, or if none, at 55 c/s for three minutes on each axis.
Shock	
Operating	Two guillotine-type shocks of 30 g, one-half sine, 11-millisecond duration each direction along each major axis. Total of 12 shocks.
Non-operating	One guillotine-type shock of 60 g, one-half sine, 11-millisecond duration in each direction along each major axis. Total of six shocks.
Electromagnetic Interference (EMI) As Tested in Mil-I-6181D	
Radiated interference	Interference radiated from the instrument under test within the given limits from 150 kilohertz to 1000 megahertz (with mesh CRT filter installed).
Conducted interference	Interference conducted out of the instrument under test through the power cord within the given limits from 150 kilohertz to 25 megahertz.
Transportation	
Packaged instrument	Qualifies under National Safe Transit Commitee test procedure 1A, Category II.

[1]Operating time applies to new batteries. Ampere-hour capacity may be reduced by as much as 20% after one year.

TABLE 1-3

PHYSICAL

Characteristic	Performance
Ventilation	Safe operating temperature is maintained by radiant cooling. Automatic resetting thermal cutouts in the power supply protect instrument from overheating.
Warm-up Time	20 minutes for rated accuracy.
Finish	Anodized front panel with blue-vinyl painted aluminum cabinet.
Overall Dimensions (measured at maximum points)	
Height	6 15/16 inches (17.7 centimeters).
Width	10 5/16 inches (26.2 centimeters).
Depth (including front cover)	18 9/16 inches (47.2 centimeters).
Depth (handle positioned for carrying)	20 5/8 inches (52.4 centimeters).
Weight	
Without battery pack	
Without front cover	20 1/2 pounds (9.3 kilograms).
With front cover and standard accessories	23 pounds (10.5 kilograms).
With battery pack	
Without front cover	27 1/2 pounds (12.5 kilograms).
With front cover and standard accessories	30 pounds (13.7 kilograms).

STANDARD ACCESSORIES

Standard accessories supplied with the Type 422 are listed on the last pullout page of the Mechanical Parts List illustrations. For optional accessories available for use with this instrument, see the Tektronix, Inc. catalog.

SECTION 2
OPERATING INSTRUCTIONS

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

General

To effectively use the Type 422, the operation and capabilities of the instrument must be known. This section describes the operation of the front-panel controls, gives first-time and general operating information and lists some basic applications for this instrument.

Front Cover

The front cover furnished with the Type 422 provides a dust-tight seal around the front panel. Use the cover to protect the front panel when storing or transporting this instrument. The cover also provides storage for the power cord, probes and other accessories (see Fig. 2-1).

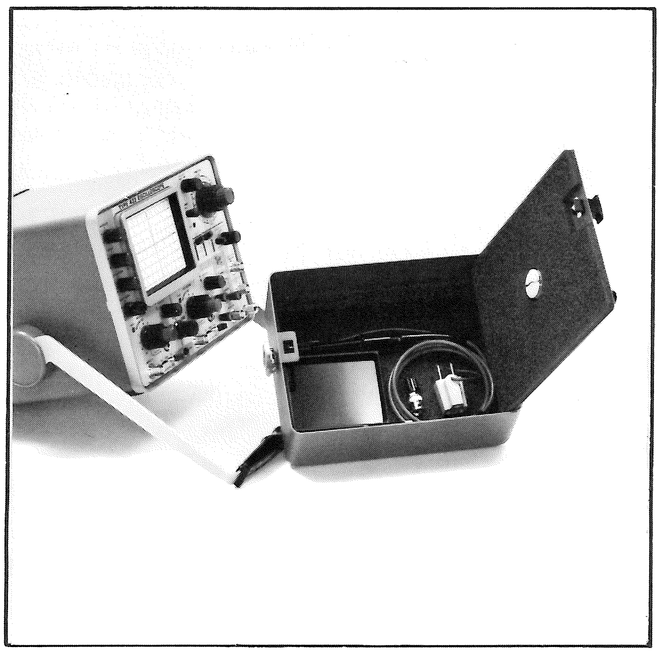


Fig. 2-1. Accessory storage provided in front cover.

OPERATING VOLTAGE

General

The Type 422 Oscilloscope with AC-DC Power Supply features a detachable power supply section which can be removed for convenience of operation or maintenance. A rechargeable battery pack is also available for use with the AC-DC Power Supply to make this instrument completely portable. The following information provides removal instructions, battery pack installation and information necessary for operation in each power mode as well as information on rechargeable nickel-cadmium batteries.

Removing the Power Supply

The power supply can be removed from the indicator for maintenance, calibration, remote operation, installation of batteries, or to gain access to the interior of the indicator. Loosen the four securing screws located in the rear feet of the power supply (see Fig. 2-2) and then separate the two units by sliding the power supply to the rear, off the support rods. To re-attach the power supply to the indicator, reverse the above procedure.

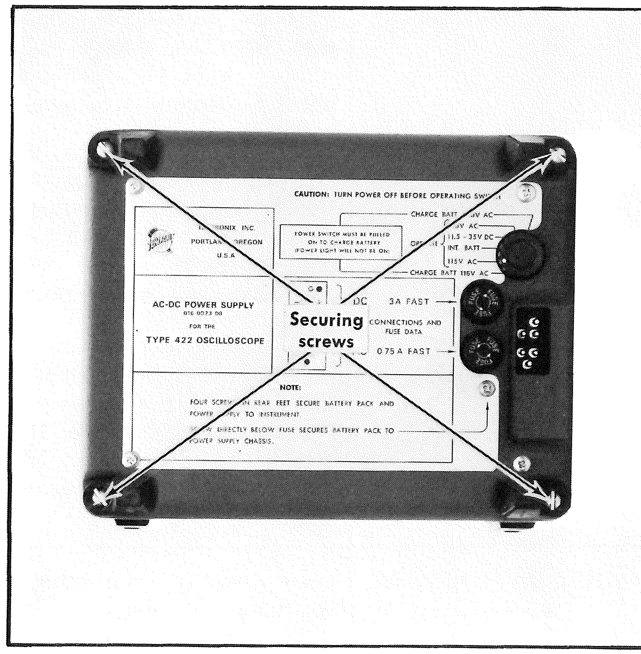


Fig. 2-2. Location of screws on rear of power supply which attach power supply to indicator.

Power Selection

The Type 422 with AC-DC Power Supply can be operated from either a 115-volt or 230-volt (nominal) AC line voltage source, from an 11.5 to 35 volt external DC source, or from internal batteries (battery pack must be purchased separately). The power supply also contains a battery charger circuit to recharge the internal batteries when operated from an AC line voltage source. The Power Mode switch on the rear panel of the power supply selects the operating power mode. Table 2-1 describes the operation in each position of the Power Mode switch.

TABLE 2-1

Power Mode Switch Functions

Switch Position	Function
CHARGE BATT 230V AC	Used when AC line voltage applied to instrument is 230 volts nominal. Charges internal battery pack at a 400 milliampere rate when POWER switch is on. Indicator does not operate in this switch position.
230V AC	Provides instrument operation from a 230-volt nominal AC line voltage source. Indicator operable and a 30 milliampere trickle charge is applied to battery pack.
11.5–35V DC	Provides instrument operation from an external DC source. Indicator operable but no charging is provided for battery pack.
INT BATT	Provides instrument operation from an internal battery pack. Indicator operable but battery pack cannot be charged in this switch position.
115V AC	Provides instrument operation from a 115-volt nominal AC line voltage source. Indicator operable and a 30 milliampere trickle charge is applied to battery pack.
CHARGE BATT 115V AC	Used when AC line voltage applied to instrument is 115 volts nominal. Charges internal battery pack at a 400 milliampere rate when POWER switch is on. Indicator does not operate in this switch position.

CAUTION

Turn the POWER switch off (pushed in) before operating the Power Mode switch.

AC Operation

The Type 422 with AC-DC Power Supply can be operated from either a 115-volt or a 230-volt (nominal) AC line voltage source. The Power Mode switch on the rear of the power supply converts the instrument from one operating range to the other and also selects the other power modes (see Table 2-1 for description of the Power Mode switch). In the OPERATE 115V AC position of the Power Mode switch, this instrument provides stable operation over a line voltage range of 95 to 137 volts (without batteries). When in the OPERATE 230V AC position, stable operation is provided with line voltage variations between 190 and 274 volts. Stable operation is also provided for line frequencies between 45 and 440 hertz. However for line frequencies below 50 hertz, derate the upper line voltage limit linearly to a maximum of 10% at 45 hertz.

To convert this instrument from 115-volt to 230-volt nominal AC operation, use the following procedure:

1. Disconnect the instrument from the power source.

2. Set the Power Mode switch for the desired line voltage.

3. Change the line-cord power plug to match the power-source receptacle or use a suitable adapter.

This instrument is designed to be used with a three-wire AC power system. If a three- to two-wire adapter is used to connect this instrument to a two-wire AC power system, be sure to connect the ground lead of the adapter to earth (ground). Failure to complete the ground system may allow the chassis to be elevated above ground potential and pose a shock hazard.

For AC operation, connect the AC power cord to the AC portion of the power receptacle (see Fig. 2-3). Select the nominal operating voltage and the power mode with the Power Mode switch. More information on operation in the CHARGE BATT 230V AC and CHARGE BATT 115V AC positions is given under Battery Operation in this section.

DC Operation

This instrument can be operated from an external DC source by connecting the DC power cord to the DC portion of the power receptacle (see Fig. 2-3) and by setting the

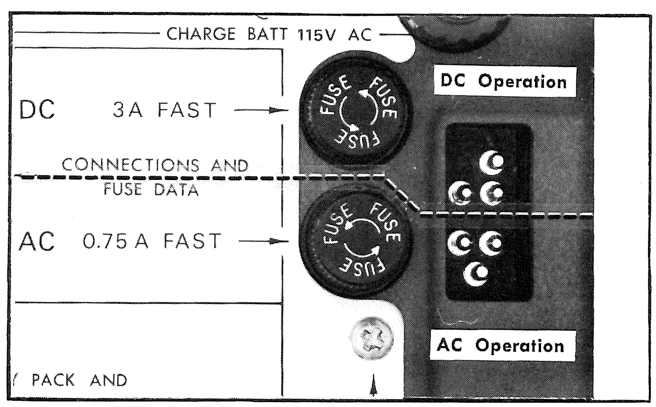


Fig. 2-3. Portion of power receptacle used for AC and external DC operation.

Power Mode switch to the OPERATE 11.5 - 35V DC position. The DC power cord is supplied without an input connector. A suitable connector can be added to match the power source, or the pigtail leads can be used as supplied. Correct connections for the leads are as follows:

Green	Earth (Ground)
White	Negative DC
Black	Positive DC

WARNING

If this instrument is operated without the green lead of the DC power cord connected to earth (ground), the chassis is floating with respect to earth. Operation with the green lead disconnected is not recommended due to the potential shock hazard produced if the chassis becomes elevated with respect to earth.

The power input stage of the AC-DC Power Supply features a ground system which is isolated from chassis ground for external DC operation in the OPERATE 11.5 - 35V DC position. This feature allows the instrument to be operated from DC voltages which are elevated up to 200 volts maximum from chassis ground. Be sure the chassis remains connected to earth (ground) with the green lead of the DC power cord for safety reasons.

When operated from an external DC source, stable operation is provided over an input voltage range of 11.5 to 35 volts DC. Stable operation is provided with external DC source voltage variations as long as the minimum instantaneous DC voltage level does not go below 11.5 volts DC. The internal battery charger circuit is inoperative for DC operation.

Battery Operation

Battery-Pack Installation. This instrument can be operated from the internal batteries for completely portable operation through the use of the battery pack. Order the battery pack from your local Tektronix Field Engineer or representative by Tektronix Part No. 016-0066-02. Use the following procedure to install the battery pack:

1. For easy removal of the power supply, position the instrument as shown in Fig. 2-4A.

2. Loosen and remove the four securing screws located in the rear feet of the power supply (see Fig. 2-4B).

3. Separate the AC-DC Power Supply from the indicator by sliding the power supply to the rear, off the support rods.

4. Loosen and remove the battery box attaching screw located below the fuse holders (see Fig. 2-4B).

5. Remove the battery box from the power supply.

6. Remove the four short bolts located in the battery-pack securing holes (see Fig. 2-4B).

NOTE

The bolts removed in step 6 allow the Type 422 with AC-DC Power Supply to meet the EMI specifications given in Section 1 when the battery pack is not installed. These bolts are replaced with the screws to be removed from the battery pack in step 8. If the instrument is operated without the battery pack, replace the bolts for minimum EMI radiation.

7. Lay the battery pack on a flat, non-conducting surface so it is resting on the interconnecting banana jacks and the spring bracket. The cutout in the battery pack should be positioned on the right side as shown in Fig. 2-4C.

8. Loosen and remove the four screws from the battery pack (located near each corner; see Fig. 2-4C).

9. Slide the battery box over the battery pack (see Fig. 2-4D). The switch, connector and fuse holes in the battery box should be located directly above the cutout in the battery pack.

10. Install the four battery-pack screws removed from the battery pack in step 8 into the battery-pack securing holes located near the rear feet. Fig. 2-4B shows the location of these screws. Tighten the screws evenly and securely.

11. Install the complete battery box/battery pack assembly onto the rear of the power supply so the switch, connector and fuses fit through the cutouts in the battery pack and battery box (see Fig. 2-4E). Also guide the interconnecting banana jacks so they mate with the banana plugs on the power supply.

12. Replace the battery-box attaching screw removed in step 4.

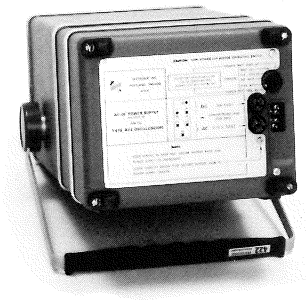
CAUTION

This screw is designed to hold the battery box and power supply together during assembly. The securing screws to be installed in step 14 hold the complete power supply assembly to the indicator to produce a rugged instrument. When handling the AC-DC Power Supply when it is not installed on the instrument, be careful to avoid placing too much strain on the switch bracket by the weight of the battery pack.

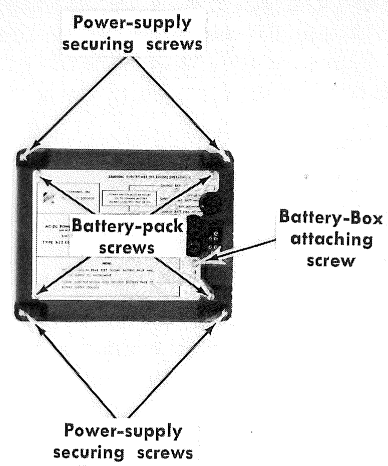
13. Slide the power supply onto the four support rods of the indicator (see Fig. 2-4F). The CRT of the indicator must fit into the cutout in the AC-DC Power Supply.

14. Replace the four securing screws located in the feet of the power supply. Tighten these screws evenly and securely.

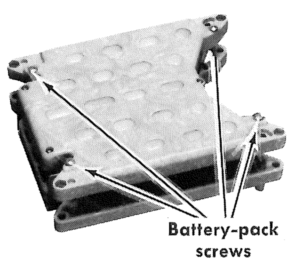
15. Before operating the instrument from the batteries, charge the batteries for at least 16 hours. Complete charging information is given under Battery Charging.



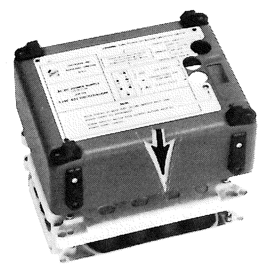
A. Correct position for easy removal of the AC-DC Power Supply.



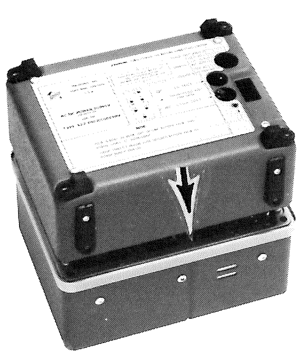
B. Location of securing screws on rear of power supply.



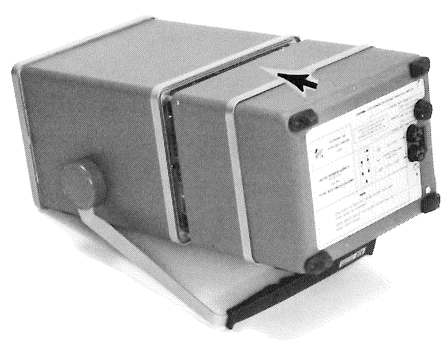
C. Location of screws in battery pack.



D. Installing the battery box on the battery pack.



E. Installing battery assembly on the AC-DC Power Supply.



F. Installing the AC-DC Power Supply on the indicator.

Fig. 2-4. Installing the battery pack in the AC-DC Power Supply.

Battery Precautions. The nickel-cadmium battery cells used in the AC-DC Power Supply have been selected as a result of extensive evaluation. Each battery cell in the battery pack has received an ampere-hour test, has met or exceeded the minimum ampere-hour storage requirement and has been rigidly inspected. The battery cells used in the battery pack should provide a useful operating life extending over several hundred charge-discharge cycles.

To extend the useful operating life of the nickel-cadmium battery cells used in this instrument, observe the following precautions.

1. Do not exceed the recommended charge rate as provided by the AC-DC Power Supply.

2. Do not charge the battery pack at the full rate for extended periods beyond the recommended charge time.

3. Excessive discharge of the battery pack after the POWER light begins to blink may cause one or more of the cells to reverse polarity. Although the cells are protected against immediate damage, repeated polarity reversal will shorten the useful life of the batteries.

4. Observe the temperature limits given in this manual for battery charging, operation and storage.

Battery Operation. This instrument can be operated on the internal batteries over an ambient temperature range of −15° C to +40° C. However, the maximum operating time and useful battery life is provided at about +25° C. Table 2-2 lists typical battery charge capacity with variations in charge and discharge temperatures. For operation from the internal batteries, set the Power Mode switch on the rear of the AC-DC Power Supply to the OPERATE INT BATT position (be sure battery pack is charged). The POWER switch on the front panel of the Type 422 controls the power to the circuits in the instrument in the same manner as for AC or DC operation.

TABLE 2-2
Typical Battery Charge Capacity
(referenced to charge-discharge at +20°C to +30°C)

Charge temperature	Operating temperature		
	−15°C	+20°C to +30°C	+55°C
0°C	40%	60%	50%
+20°C to +30°C	65%	100%	85%
+40°C	40%	65%	55%

When this instrument is connected to an AC line-voltage source, the internal batteries can be recharged when the Power Mode switch is set to the applicable CHARGE BATT position (see Battery Charging). The battery charger circuit is disconnected in the OPERATE INT BATT position so the instrument cannot be operated from the batteries while the batteries are being charged. To simultaneously charge the batteries and operate the instrument, use the OPERATE 230V AC or OPERATE 115V AC position (30 milliampere trickle charge applied to batteries).

WARNING

When this instrument is operated from the internal batteries, the chassis is floating with respect to earth (ground). Connect the instrument to earth with a jumper lead from the front-panel ground post. Operation without this ground lead is not recommended due to the potential shock hazard produced if the chassis becomes elevated with respect to earth.

When operating from the internal batteries, the POWER light on the front panel of the indicator provides an indication of the charge level on the internal batteries. When the batteries have been discharged to near the minimum level necessary for correct power supply regulation, the POWER light begins to blink. Further discharge of the batteries beyond this level not only provides inaccurate measurements, but may also damage the batteries.

The following suggestions will aid in obtaining the maximum operating time from the batteries:

1. Set the INTENSITY control only as far clockwise as is necessary to obtain a visible display. Due to the type of CRT blanking used in this instrument, the CRT emits electrons even though the sweep is not operating (also see discussion on Intensity Control in this section).

2. Whenever the instrument is not to be used for periods longer than about 1/2 hour, turn the POWER switch off (pushed in). Since this instrument is completely solid-state except for the CRT, it requires only about 30 seconds warmup before it is operable and about five minutes warmup to reach the specified accuracy.

3. Set the SCALE ILLUM control fully counterclockwise unless the graticule is not visible when making a measurement. When scale illumination must be used, return the SCALE ILLUM control to the fully counterclockwise position after the measurement.

Battery Charging. The battery pack of the AC-DC Power Supply can be charged from either a 115-volt or 230-volt (nominal) AC line-voltage source. In the CHARGE BATT 230V AC or CHARGE BATT 115V AC positions of the Power Mode switch, the battery pack is charged at a 400 milliampere rate. In the OPERATE 230V AC or OPERATE 115V AC positions, the battery pack is trickle-charged at about a 30 milliampere rate. A 16-hour charge period in either of the CHARGE BATT positions should be sufficient to charge the battery pack to its full potential. Although the batteries may not be damaged immediately by longer charge periods, repeated over-charging will shorten the useful life of the batteries. A full charge level can be maintained on the battery pack by the 30 milliampere trickle charge available in the OPERATE 230V AC or OPERATE 115V AC positions (POWER switch must be pulled out).

The battery pack can be charged even when the AC-DC Power supply is removed from the indicator if the Power Mode switch is in the correct position and the POWER switch is turned on at the power supply. This feature provides a means of continuous operation from batteries if more than one supply is available. It also provides a method of trickle charging the battery pack without the instrument in operation if the batteries must be stored for long periods of time (Power Mode switch set to OPERATE 230V AC or OPERATE 115V AC).

The battery pack can be charged over an ambient temperature range of −15° C to +40° C. However, the maximum operating time and useful battery life is provided when the batteries are charged and discharged at about +25° C (see Table 2-2). Thermal cutouts in the AC-DC Power Supply protect the battery pack from overheating during charge time. The battery pack normally becomes warmer as it reaches full charge potential. If the temperature surrounding the battery pack exceeds the safe operating level, a thermal cutout switches the charge rate from the 400 milliampere full-charge to the 30 milliampere trickle-charge rate. When the temperature returns to a safe operating level, the thermal cutout returns the charge rate to the 400 milliampere level. If the charge rate is reduced for an extended period during a charge cycle, the battery pack will not reach full charge in the recommended 16-hour charge time. Therefore, do not assume battery pack failure because of reduced operating time. Instead, recharge the battery pack for 16 hours at a reduced ambient temperature and then check the operating time. If insufficient operating time is still obtained, the battery pack is probably defective (see Battery Pack Maintenance in Section 4 for more information).

During normal usage or storage, the individual battery cells in the battery pack acquire slightly different charge characteristics. To provide the best overall operation and maximum operating life, the charge on the individual battery cells should be equalized periodically. This can be done without damage to the battery cells by charging the batteries at the full charge rate for 24 hours (be sure ambient temperature is low enough to prevent opening of the thermal cutout). This should be done after every 15 charge-discharge cycles or every 30 days, whichever occurs first.

Battery-Pack Maintenance and Troubleshooting. Complete information on maintenance and troubleshooting of the battery pack is given in Section 4.

Battery Pack Storage. The battery pack used in the AC-DC Power Supply can be stored in a charged or a partially charged condition. For best shelf life when storing the battery pack for long periods of time, fully recharge the battery pack about every three months. Although the battery pack is fully charged when shipped from Tektronix, Inc., recharge the battery pack completely before operating the instrument.

Charge retention characteristics of nickel-cadmium batteries vary with the storage temperature and humidity. The battery pack may be stored at ambient temperatures between −40°C and +60°C without damage, either in the instrument or as a separate unit. However, the self-discharge rate increases with ambinet temperature. For example, cells stored at +20°C will lose about 50% of their stored charge in three months but when stored at +50°C, they will be almost completely self-discharged in only one month. High humidity also increases the rate of self-discharge. If this instrument must be stored at either high ambient temperature or high humidity for an extended period of time, it is recommended that the battery pack be continuously trickle charged (charge battery pack completely at full-charge rate before extended trickle charge).

Low-Batteries Indicator

The POWER light blinks to indicate when the battery pack voltage is too low for continued measurement accuracy. The batteries used in this instrument may be damaged by excessive discharge. Therefore, the instrument should not be operated from the battery pack after the POWER light begins to blink, since such operation not only may provide inaccurate measurements, but may also shorten the useful life of the battery pack.

Operating the Power Supply Remotely.

The indicator can be operated with the power supply removed for maintenance, calibration or special applications. The interconnecting plug on the rear of the indicator can be detached and used as an extension cable. To remove the interconnecting plug, loosen the three secrews holding it to the indicator and slide it up slightly; then move it away from the rear of the indicator. Unwrap the power cable from the rear of the indicator.

The two spring clips on the power supply circuit board are provided to secure the power cable to the power supply for remote operation. To use the clips, first be sure the POWER switch is set to OFF at the power supply. Then, hook one spring clip into the hole provided in the interconnecting plug (see Fig. 2-5). Slide the plug into place while depressing the other spring clip. To remove the plug, reverse the order in which it was attached.

CAUTION

Do not bend the spring clips so they latch without using the procedure described here. Otherwise, they will latch when the power supply is remounted on the indicator and will be difficult to remove without damage to the instrument.

When operating the power supply remotely, the POWER switch on the front of the indicator is inoperative. The POWER switch can be actuated at the power supply. The ON and OFF positions of the switch are noted on the circuit board.

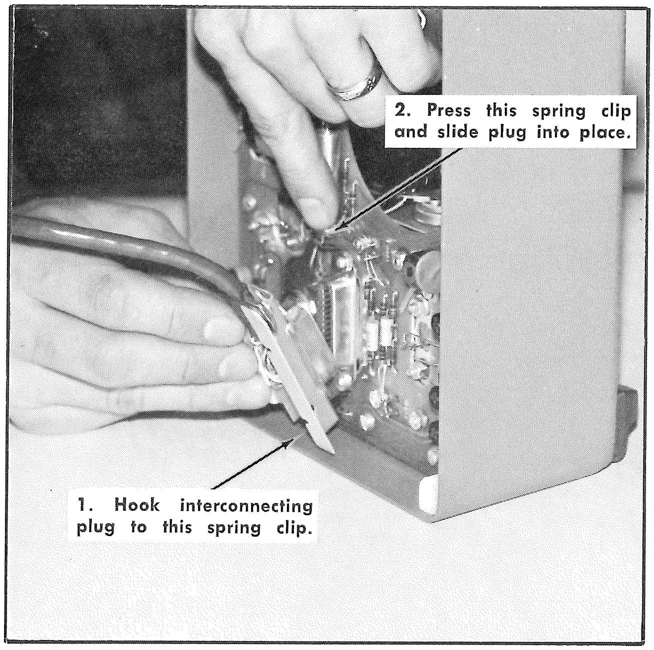


Fig. 2-5. Securing the power cable to the power supply for remote operation.

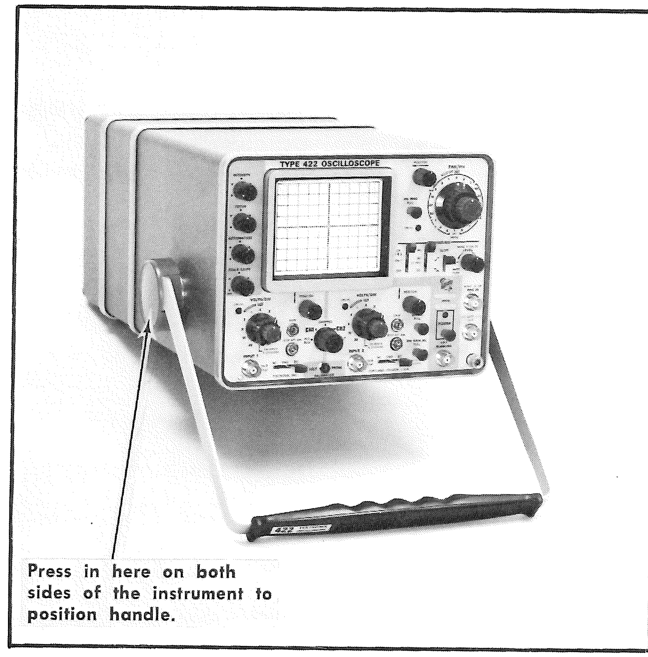


Fig. 2-6. Handle positioned to provide a stand for the instrument.

OPERATING TEMPERATURE

General

The Type 422 with AC-DC Power Supply requires very little air circulation for proper operation. Thermal cutouts in the indicator and the power supply provide thermal protection and disconnect the instrument power if the internal temperature exceeds a safe operating level. Power is automatically restored when the temperature returns to a safe level. The Type 422 with AC-DC Power Supply can be operated where the ambient air temperature is between −15°C and +55°C (+40°C maximum with battery pack installed). This instrument can be stored in ambient temperatures between −55°C and +75°C (−40°C to +60°C with batteries). After storage at temperatures beyond the operating limits, allow the chassis to come within the operating limits before power is applied.

Operating Position

The handle of the Type 422 can be positioned for carrying or as a tilt-stand for the instrument. To position the handle, press in at both pivot points (see Fig. 2-6) and turn the handle to the desired position. Several positions are provided for convenient carrying or viewing. The instrument can also be set on the rear-panel feet either for operation or storage.

CONTROLS AND CONNECTORS

General

A brief description of the function and operation of the controls and connectors of the Type 422 follows. Fig. 2-7 shows the front panel of this instrument More detailed information is given in this section under General Operating Information.

Cathode-Ray Tube (CRT)

INTENSITY	Controls brightness of display.
FOCUS	Provides adjustment for optimum display definition.
ASTIGMATISM	Used in conjunction with the FOCUS control to obtain a well-defined display.
SCALE ILLUM	Controls graticule illumination.

Vertical (both channels if applicable)

VOLTS/DIV	Selects vertical deflection factor in 1-2-5 sequence (VARIABLE control must be in CAL position for indicated deflection).
VARIABLE	Provides variable uncalibrated deflection factors between the calibrated settings of the VOLTS/DIV switch.
UNCAL	Light indicates that VARIABLE VOLTS/DIV control is not in the CAL position.
POSITION	Controls vertical position of the trace.
GAIN	Screwdriver adjustment to set gain of the vertical input amplifier.

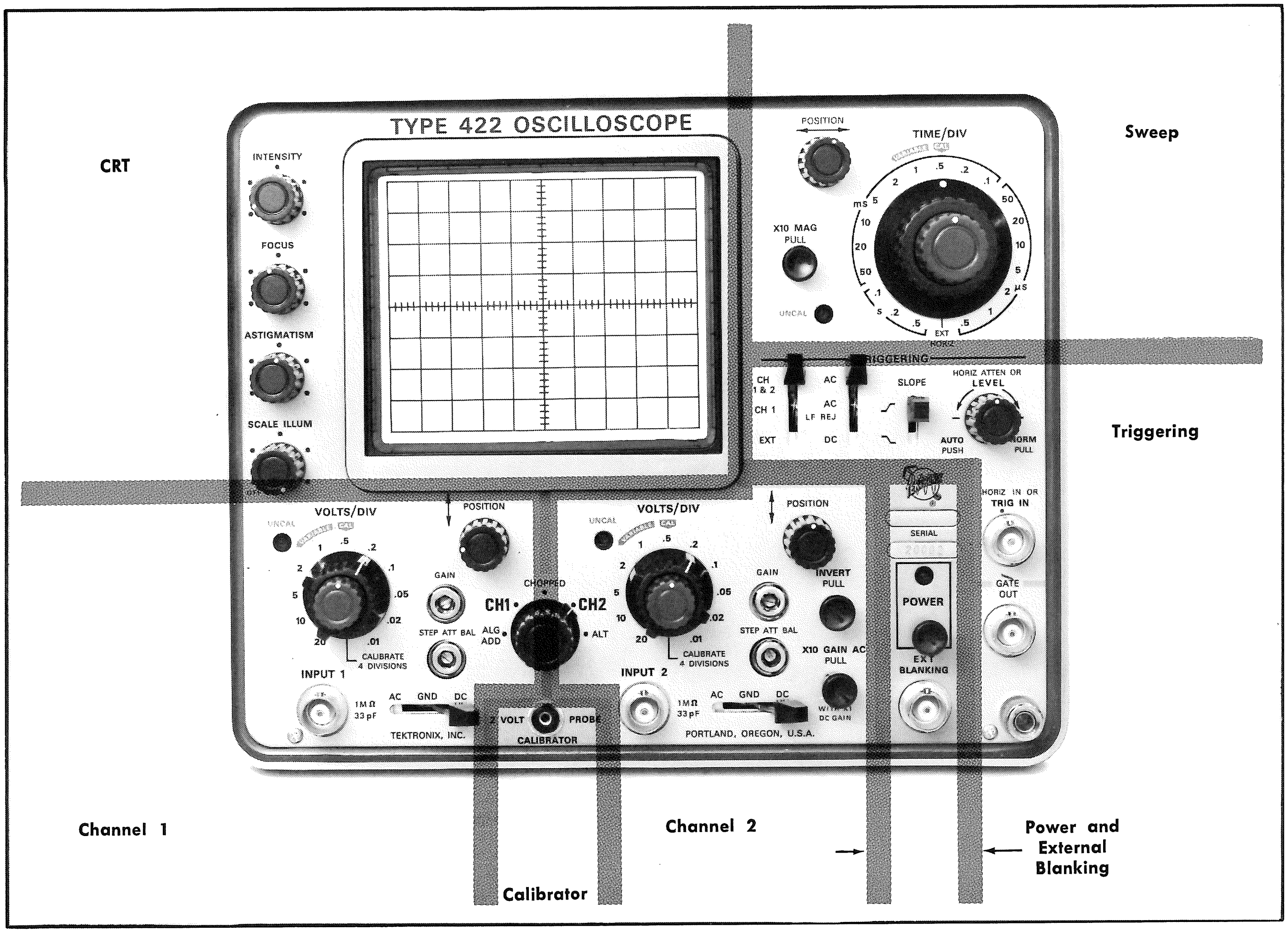


Fig. 2-7. Front-panel controls and connectors.

STEP ATT BAL — Screwdriver adjustment to balance the input amplifier in the .02, .05 and .1 positions of the VOLTS/DIV switch.

INPUT — Input connector for vertical deflection signals.

Input Coupling (AC GND DC) — Selects method of coupling input signal to input amplifier.

AC: DC component of input signal is blocked. Low frequency −3 dB point is about two hertz.

GND: Input circuit is grounded (does not ground applied signal).

DC: Provides coupling for all signals from DC to 15 megahertz or greater.

Mode (not labeled) — Selects mode of operation of vertical input amplifiers.

ALG ADD: Signals applied to INPUT 1 and INPUT 2 connectors are algebraically added and the algebraic sum is displayed on the CRT. The INVERT switch in Channel 2 allows the display to be CH 1 + CH 2 or CH 1 − CH 2.

CH 1: The signal applied to the INPUT 1 connector is displayed.

CHOPPED: Dual-trace display of signals on both channels. Display switched at a repetition rate of about 150 kilohertz.

CH 2: The signal applied to the INPUT 2 connector is displayed.

ALT: Dual-trace display of signals on both channels. Display switched between channels at end of each sweep.

INVERT (CH 2 only)
: Push-pull switch to invert the Channel 2 display.

X10 GAIN AC (CH 2 only)
: Push pull switch to increase AC gain of Channel 2 amplifier 10 times (decreases deflection factor 10 times).

Calibrator

CALIBRATOR
: Output jack providing two-volt square-wave signal for compensating probes.

Triggering

Source (not labeled)
: Selects source of trigger signal.

CH 1 & 2: Internal trigger signal obtained from displayed channel(s).

CH 1: Internal trigger signal obtained only from Channel 1.

EXT: Trigger signal obtained from an external signal applied to TRIG IN connector.

Coupling (not labeled)
: Determines method of coupling trigger signal to trigger circuit.

AC: Rejects DC and attenuates signals below about 50 hertz. Accepts signals between about 50 hertz and 15 megahertz.

AC LF REJ: Rejects DC and attenuates signals below about 50 kilohertz. Accepts signals between about 50 kilohertz and 15 megahertz.

DC: Accepts all trigger signals from DC to 15 megahertz or greater.

SLOPE
: Selects slope of trigger signal which starts the sweep.

_/‾ : Sweep can be triggered from positive-going portion of trigger signal.

‾_ : Sweep can be triggered from negative-going portion of trigger signal.

LEVEL
: Selects amplitude point on trigger signal at which sweep is triggered.

TRIGGERING Mode (not labeled)
: Push-pull switch, actuated by the LEVEL control, which determines the triggering mode.

AUTO (pushed in): Sweep initiated by the applied trigger signal at point selected by the LEVEL control when the trigger signal repetition rate is above about 20 hertz (or above lower limit of frequency range selected by TRIGGERING Coupling switch). Triggered sweep can be obtained only throughout amplitude range of applied trigger signal. When the LEVEL control is outside the amplitude range, when the trigger repetition rate is below the lower frequency limit or when the trigger signal is inadequate, the sweep free runs at the sweep rate selected by the TIME/DIV switch to produce a reference trace.

NORM (pulled out): Sweep initiated by the applied trigger signal at point selected by the LEVEL control throughout the frequency range selected by the TRIGGERING Coupling switch. Triggered sweep can be obtained only throughout amplitude range of applied trigger signal. When the LEVEL control is outside the amplitude range, when the trigger repetition rate is outside the frequency range selected by the TRIGGERING Coupling switch or when the trigger signal is inadequate, there is no trace.

TRIG IN
: Input connector for external trigger signal.

GATE OUT
: Output connector providing a negative-going rectangular pulse which is coincident with the sweep.

Ground (not labeled)
: Binding post to establish common ground between the Type 422 and the associated equipment.

Sweep

POSITION
: Controls horizontal position of display.

X10 MAG
: Push-pull switch to increase sweep rate to 10 times setting of TIME/DIV switch by horizontally expanding the center division of the display.

TIME/DIV
: Selects sweep rate of the sweep generator (VARIABLE control must be in CAL position and X10 MAG switch pushed in for indicated sweep rate). In the EXT HORIZ position, horizontal deflection is provided by a signal connected to the HORIZ IN connector.

VARIABLE	Provides uncalibrated sweep rates between the calibrated settings selected by the TIME/DIV switch. The sweep rate in each TIME/DIV switch position can be reduced to at least the sweep rate of the next adjacent position to provide continuously variable sweep rates from 0.05 microsecond/division (X10 MAG switch pulled out) to 1.25 seconds/division.
UNCAL	Light indicates that VARIABLE TIME/DIV control is not in the CAL position.
HORIZ ATTEN (LEVEL)	Provides approximately 10:1 attenuation for external horizontal signals connected to the HORIZ IN connector when the TIME/DIV switch is set to EXT HORIZ.
HORIZ IN (TRIG IN)	Input connector for external horizontal signal when TIME/DIV switch is set to EXT HORIZ.

Power and External Blanking

POWER	Light: Indicates that POWER switch is on and power is available. For the OPERATE INT BATT position of the Power Mode switch, the POWER light blinks to indicate that the batteries are discharged too far for continued operation. Switch: Push-pull switch to control power to the instrument.
EXT BLANKING	Input connector for external blanking signals.

Rear-Panel

Power Mode (see Fig. 2-2)	Selects the operating power mode. CHARGE BATT 230 V AC: Used when AC line voltage applied to instrument is 230 volts nominal. Charges internal battery pack at a 400 milliampere rate when POWER switch is on. Indicator does not operate in this switch position. OPERATE 230V AC: Provides instrument operation from a 230-volt nominal AC line voltage source. Indicator operable and a 30 milliampere trickle charge is applied to battery pack. OPERATE 11.5–35 V DC: Provides instrument operating from an external DC source. Indicator operable but no charging is provided for battery pack. OPERATE INT BATT: Provides instrument operation from internal battery pack. Indicator operable but battery pack cannot be charged in this switch position. OPERATE 115V AC: Provides instrument operation from a 115-volt nominal AC line voltage source. Indicator operable and a 30 milliampere trickle charge is applied to battery pack. CHARGE BATT 115V AC: Used when AC line voltage applied to instrument is 115 volts nominal. Charges internal battery pack at a 400 milliampere rate when POWER switch is on. Indicator does not operate in this switch position.

FIRST-TIME OPERATION

General

The following steps demonstrate the use of the controls and connectors of the Type 422. It is recommended that this procedure be followed completely for familiarization with this instrument.

Setup Information

1. Set the front-panel controls as follows:

Vertical controls (both channels where applicable)

VOLTS/DIV	CALIBRATE 4 DIV
VARIABLE	CAL
Input Coupling	GND
POSITION	Midrange
Mode	CH 1
INVERT	Pushed in
X10 GAIN AC	Pushed in

Triggering Controls

Source	CH 1 and 2
Coupling	AC
SLOPE	Positive going (⨍)
Mode	AUTO
LEVEL	Midrange

Horizontal controls

POSITION	Midrange
TIME/DIV	.5 mSEC
VARIABLE	CAL
X10 MAG	Pushed in

Other controls

INTENSITY	Counterclockwise
FOCUS	Centered
ASTIGMATISM	Centered
SCALE ILLUM	Any position
POWER	Pushed in

2. Connect the Type 422 to an AC power source that meets the voltage and frequency requirements of the instrument. If external DC or internal batteries must be used for this procedure, see Operating Voltage in this section.

3. Pull the POWER switch out to turn on the instrument. Allow several minutes warmup so the instrument reaches a normal operating temperature before proceeding.

CRT Controls

4. Advance the INTENSITY control until the trace is at the desired viewing level (about midrange).

5. Adjust the FOCUS and ASTIGMATISM controls for a sharp, well-defined display over the entire trace length.

6. Set the Channel 1 VOLTS/DIV switch to .01.

7. Position the trace with the Channel 1 POSITION control so it coincides with the center horizontal graticule line. If the trace is not parallel with this graticule line, see Trace Alignment Adjustment in this section.

8. Rotate the SCALE ILLUM control throughout its range and notice that the graticule lines are illuminated as the control is turned clockwise (most obvious with mesh or tinted filter installed). Set control so graticule lines are illuminated as desired.

Vertical Controls

9. Set the Channel 1 VOLTS/DIV switch to the CALIBRATE 4 DIVISIONS position.

10. Center the display with the Channel 1 POSITION control. The display is a square wave, four divisions in amplitude with about five cycles displayed on the screen. If the display is not four divisions in amplitude, see Vertical Gain Adjustment in this section.

11. Turn the Channel 1 VARIABLE control throughout its range. Notice that the UNCAL light comes on when the VARIABLE control is moved from the CAL position (fully clockwise). The deflection should be reduced to about two divisions in the fully counterclockwise position. Return the Channel 1 VARIABLE control to CAL.

12. Change the Channel 1 VOLTS/DIV switch between .05 and .01. If the vertical position of the trace shifts, see Step Attenuator Balance in this section.

13. Set the Channel 1 VOLTS/DIV switch to 1 and position the trace to the center horizontal line with the Channel 1 POSITION control. This provides a ground reference at the center horizontal line.

14. Connect the 10X probe (supplied accessory) to the INPUT 1 connector. Position the probe tip so it is in contact with the CALIBRATOR jack.

15. Set the Channel 1 Input Coupling switch to DC. Notice that the baseline of the waveform remains at the center horizontal line (ground reference).

16. Set the Channel 1 Input Coupling switch to AC. Notice that the waveform is centered about the center horizontal line (ground reference).

17. Set the vertical Mode switch to CH 2 and the Channel 2 VOLTS/DIV switch to the CALIBRATE 4 DIVISIONS position. Connect the 10X probe to the INPUT 2 connector.

18. Turn the CH 2 POSITION control to center the display. The display will be similar to the previous display for Channel 1. Check the Channel 2 gain as described in step 10. The Channel 2 VARIABLE control operates as described in step 11 and the Channel 2 Input Coupling switch operates as given in steps 13 through 16.

19. Check the Channel 2 step attenuator balance as described in step 12.

20. Set the Channel 2 VOLTS/DIV switch to .5 and the Channel 2 Input Coupling switch to AC. Position the probe tip so it is in contact with the CALIBRATOR jack. The CRT display should be about 0.4 division in amplitude.

21. Pull the X10 GAIN AC switch. The display should be increased to four divisions. Push in the X10 GAIN AC switch.

22. Set the MODE switch to ALT and return both VOLTS/DIV switches to CALIBRATE 4 DIVISIONS. Position the Channel 1 waveform to the top of the graticule area and the Channel 2 waveform to the bottom of the graticule area. Turn the TIME/DIV switch throughout its range. Notice that the display alternates between channels at all sweep rates.

23. Set the vertical Mode switch to CHOP and the TIME/DIV switch to 10 μs. Notice the switching between channels as shown by the segmented traces. Set the TRIGGERING Source switch to CH 1; the traces should appear more solid, since the instrument is no longer triggered on the between-channel switching transients. Turn the TIME/DIV switch throughout its range. A dual-trace display is presented at all sweep rates but, unlike ALT, both channels are displayed on each sweep on a time-sharing basis. Return the TIME/DIV switch to .5 ms.

24. Set the vertical Mode switch to ALG ADD. The display should be eight divisions in amplitude. Notice that either vertical POSITION control moves the display.

25. Pull the INVERT switch to invert the Channel 2 signal The display is a straight line (if the Channel 1 and 2 gain is set correctly) indicating that the algebraic sum of the two signals is zero. Set either VOLTS/DIV switch to .01. The square wave display indicates that the algebraic sum of the two signals is no longer zero. Return the vertical Mode switch to CH 1 and both VOLTS/DIV switches to CALIBRATE 4 DIVISIONS. Push in the INVERT switch.

Triggering Controls

26. Rotate the LEVEL control throughout its range. The display free runs at the extremes of rotation.

27. Pull the LEVEL control to set the TRIGGERING Mode switch to NORM. Again rotate the LEVEL control throughout its range. Notice that a display is presented only when correctly triggered. Push in the LEVEL control to return the TRIGGERING Mode switch to AUTO.

28. Set the SLOPE switch to the negative-going position. The trace starts on the negative part of the square wave. Return this switch to the position-going position; the trace starts with the positive part of the square wave.

29. Set the TRIGGERING Coupling switch to DC. Turn the Channel 1 POSITION control until the display becomes unstable (only part of square wave visible). Return the TRIGGERING Coupling switch to AC; the display is again stable. Since changing vertical position of the trace changes the DC level of the internal trigger signal, this demonstration shows how changes in the DC level affect DC trigger coupling. Return the display to the center of the display area.

30. Set the vertical Mode switch to CH 2; the display should remain stable. Set the Channel 1 VOLTS/DIV switch to .01; the display free runs. Set the TRIGGERING Source switch to CH 1 & 2; the display is again stable. Return the Channel 1 VOLTS/DIV switch to CALIBRATE 4 DIVISIONS.

31. Connect the 10X probe to the TRIG IN connector. Position the probe tip so it is in contact with the CALIBRATOR jack. Set the TRIGGERING Source switch to EXT. Operation of the TRIGGERING Coupling, SLOPE, Mode and LEVEL controls for external triggering is the same as described in steps 26 through 30. Set the TRIGGERING Source switch to CH 1.

Normal and Magnified Sweep

32. Note the CRT display. Then, set the TIME/DIV switch to 5 ms. Pull the X10 MAG switch. The display should be similar to that obtained with the TIME/DIV switch at .5 ms and the X10 MAG switch pushed in.

33. Turn the horizontal POSITION control so the display starts at about the center of the graticule. Now turn the horizontal POSITION control in the opposite direction. Notice that for about five divisions the trace moves slowly to the left and the control turns easily. Then, the drag on the control increases slightly and the trace begins to move much faster to the left. This control provides a combination of course and fine adjustment. To use the control effectively, turn it slightly past the desired point of adjustment (coarse adjust). Then reverse the direction of rotation and use the fine adjustment to establish more precise positioning. Set the TIME/DIV switch to .5 ms and push in the X10 MAG switch. Return the start of the trace to the left edge of the graticule.

34. Turn the VARIABLE TIME/DIV control throughout its range. Notice that the UNCAL light comes on when the VARIABLE TIME/DIV control is moved from the CAL position (fully clockwise). The sweep rate is reduced as the VARIABLE control is turned counterclockwise as indicated by more cycles displayed on the CRT. Return the VARIABLE TIME/DIV control to CAL.

35. If an external signal is available (one to 10 volts peak to peak), the function of the external horizontal amplifier can be demonstrated. Turn the INTENSITY control to a lower setting to protect the CRT phosphor. Then set the TIME/DIV switch to EXT HORIZ and turn the HORIZ ATTEN control (LEVEL) fully clockwise. Connect the external horizontal signal to the HORIZ IN connector (TRIG IN).

36. Set the INTENSITY control to provide an adequate display. The display should be rectangular, four divisions vertically with the horizontal length of the display variable with the HORIZ ATTEN control (vertical deflection provided by internal Calibrator signal).

37. Set the HORIZ ATTEN control so the display is less than one division horizontally. Pull the X10 MAG switch. Re-position the display onto the viewing area if necessary and notice that the display is about 10 times larger horizontally. Push in the X10 MAG switch.

External Blanking

38. If an external signal is available (positive two volts peak, minimum), the function of the External Blanking circuit can be demonstrated. Connect the external signal to the INPUT 1 connector. Set the Channel 1 Input Coupling switch to DC and set the Channel 1 VOLTS/DIV switch to display about five divisions of the signal. Now, connect the external signal to the EXT BLANKING connector also. Notice that the positive peaks of the display are blanked out.

39. Disconnect all test equipment.

This completes a description of the basic operating procedure for the Type 422. Instrument operations not explained here, or operations which need further explanation are discussed under General Operating Information.

TYPE 422 TEST SETUP CHART

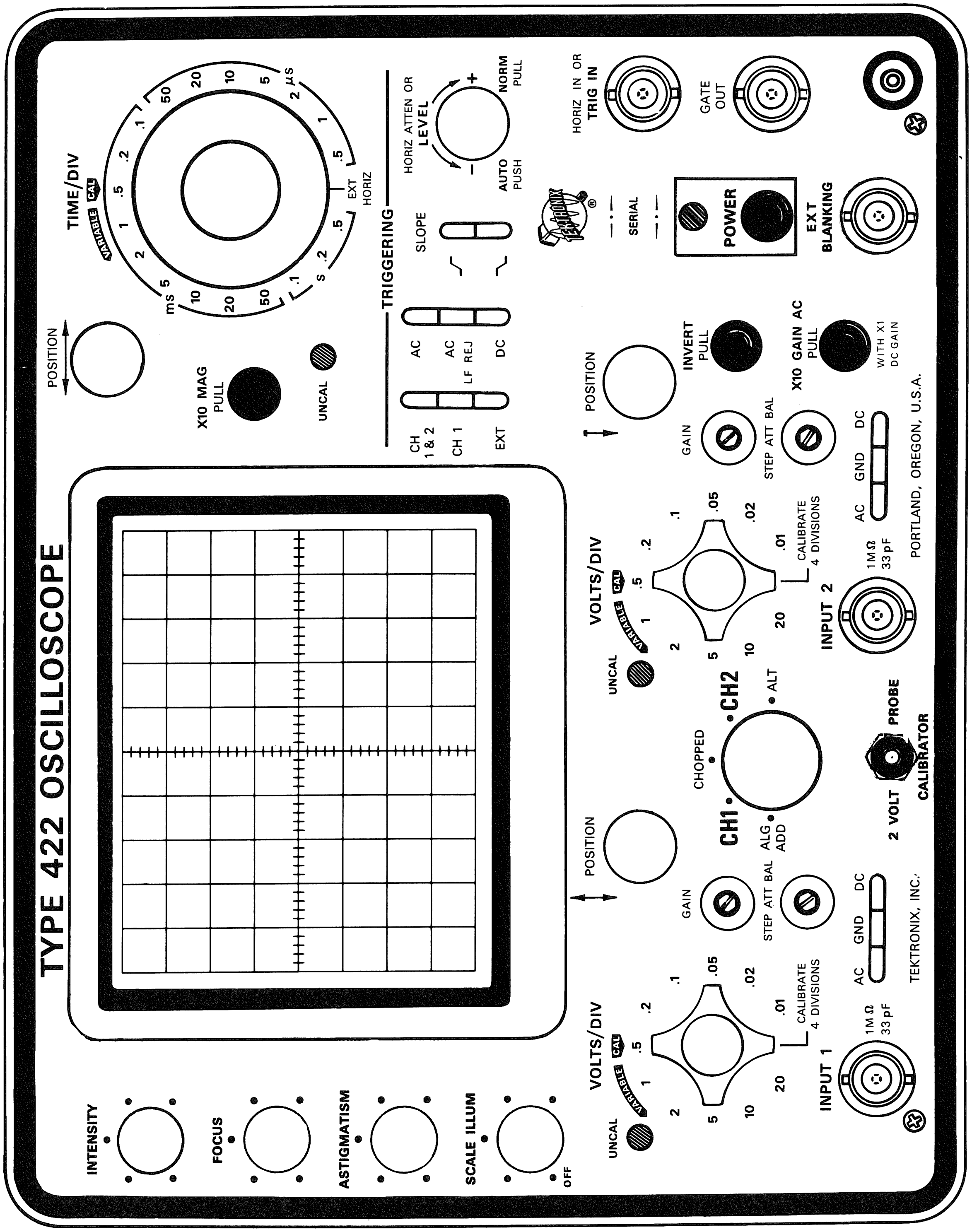


Fig. 2-8.

TEST SETUP CHART

General

Fig. 2-8 shows the front panel of the Type 422. This chart may be reproduced and used as a test-setup record for special measurements, applications or procedures, or it may be used as a training aid for familiarization with this instrument.

GENERAL OPERATING INFORMATION

Intensity Control

The setting of the INTENSITY control may affect the correct focus of the display. Slight readjustment of the FOCUS and ASTIGMATISM controls may be necessary when the intensity level is changed. To protect the CRT phosphor, do not turn the INTENSITY control higher than necessary to provide a satisfactory display. The light filters reduce the observed light output from the CRT. When using these filters, avoid advancing the INTENSITY control to a setting that may burn the phosphor. When the highest intensity display is desired, remove the filters and use the clear graticule only. Apparent trace intensity can also be improved in such cases by reducing the ambinet light or using a viewing hood. Also be careful that the INTENSITY control is not set too high when changing the TIME/DIV switch from a fast to a slow sweep rate, or when switching to the external horizontal mode of operation.

The Type 422 CRT uses deflection-plate blanking to deflect the CRT beam off the viewing area during retrace time and when the sweep is not operating. With this type of blanking system, the CRT cathode is emitting electrons at the same rate whether a display is produced or not. The cathode current is determined entirely by the setting of the INTENSITY control. For this reason, the CRT may fail prematurely even though a display has not been presented if the INTENSITY control is left at a high setting for extended periods of time. Therefore, to obtain maximum CRT life, always set the INTENSITY control fully counterclockwise except when viewing the CRT.

Focus and Astigmatism Adjustment

The following procedure provides a convenient method of establishing optimum setting of the FOCUS and ASTIGMATISM controls.

1. Set the VOLTS/DIV switch to CALIBRATE 4 DIVISIONS.

2. Set the TIME/DIV switch to .5 ms and the LEVEL control for a stable display.

3. With the FOCUS AND ASTIGMATISM controls set to midrange, adjust the INTENSITY control so the rising portion of the display can just be seen.

4. Set the ASTIGMATISM control so the vertical and horizontal portions of the display are equally focused (not necessarily well focused).

5. Set the FOCUS control so the vertical portion of the trace is as thin as possible.

6. Repeat steps 4 and 5 for best overall focus. Make final check at normal intensity.

Trace Alignment Adjustment

If a free running trace is not parallel with the horizontal graticule lines, set the Trace Rotation adjustment as follows: Position the trace to the center horizontal line. Adjust the Trace Rotation adjustment (the power supply must be operated remotely for access to this adjustment) so the trace is parallel with the horizontal graticule lines.

Graticule

The graticule of the Type 422 is internally marked on the faceplate of the CRT to provide accurate, no-parallax measurements. The graticule is marked with eight vertical and 10 horizontal divisions. Each division is 0.8 centimeter square. In addition, each major division is divided into five minor divisions at the center vertical and horizontal lines. The vertical gain and horizontal timing are calibrated to the graticule so accurate measurements can be made from the CRT. The illumination of the graticule lines can be varied with the SCALE ILLUM control.

Fig. 2-9 shows the graticule of the Type 422 and defines the various measurement lines. The terminology defined here will be used in all discussions involving graticule measurements.

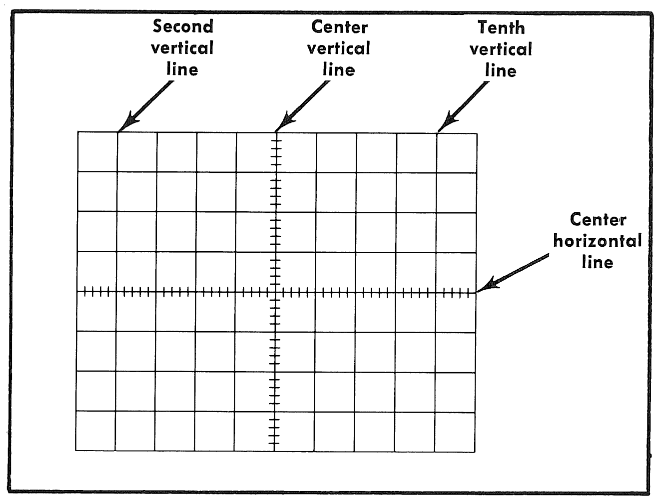


Fig. 2-9. Definition of measurement lines on Type 422 graticule.

Light Filter

The mesh filter provided with the Type 422 provides shielding against radiated EMI (electro-magnetic interference) from the face of the CRT. It also serves as a light filter to make the trace more visible under high ambient light conditions. To remove the filter, press down at the bottom of the frame and pull the top of the filter away from the CRT faceplate (see Fig. 2-10).

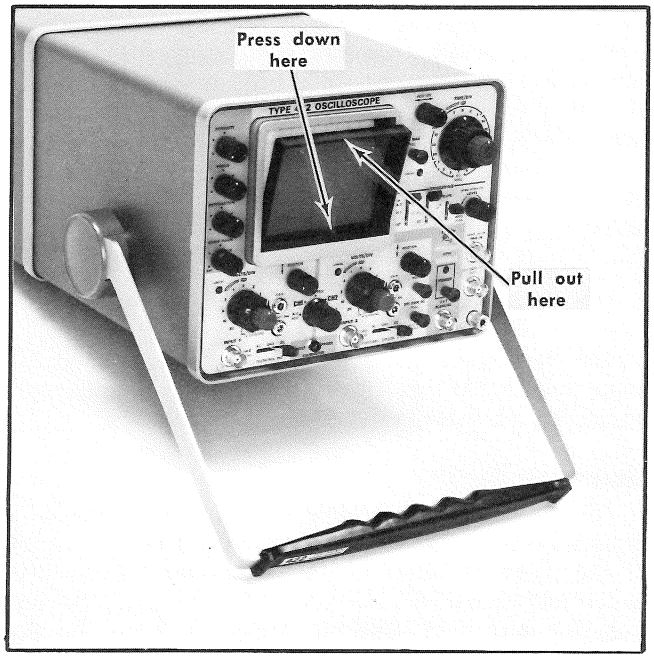


Fig. 2-10. Removing the light filter or faceplate protector.

The tinted light filter minimizes light reflections from the face of the CRT to improve contrast when viewing the display under high ambient light conditions. A clear plastic faceplate protector is also provided for use when neither the mesh nor the tinted filter is used. The clear faceplate protector provides the best display for waveform photographs. It is also preferable for viewing high writing rate displays.

A filter or faceplate protector should be used at all times to protect the CRT faceplate from scratches. The faceplate protector and the tinted light filter mount in the same holder. To remove the light filter or faceplate protector from the holder, press it out to the rear. Both can be replaced by snapping them back into the holder.

Vertical Channel Selection

Either of the input channels can be used for single-trace displays. Apply the signal to the desired INPUT connector and set the vertical Mode switch to display the channel used. Since channel 1 only triggering is provided only in Channel 1, and the invert and X10 AC gain features are provided only for Channel 2, the correct channel must be selected to take advantage of these features. For dual-trace displays, connect the signals to both INPUT connectors and set the vertical Mode switch to one of the dual-trace positions.

Vertical Gain Adjustment

To check the gain of either channel, set the VOLTS/DIV switch to the CALIBRATE 4 DIVISIONS position and the VARIABLE control to CAL. The vertical deflection should be exactly four divisions. If not, adjust the front-panel GAIN adjustment for exactly four divisions of deflection.

NOTE

If the gain of the two channels must be closely matched (such as for ALG ADD operation), use the adjustment procedure given in the Calibration Procedure

The best measurement accuracy when using probes is provided if the GAIN adjustment is made with the probes installed. This compensates for any inaccuracies of the probes. Set the VOLTS/DIV switch to .05 and apply an accurate square wave to the probe tips. Also, to provide the best measurement accuracy, calibrate the vertical gain of the Type 422 at the temperature at which the measurement is to be made.

Step Attenuator Balance Adjustment

To check the step attenuator balance of either channel, set the Input Coupling switch to GND and the TRIGGERING mode switch to AUTO. Change the VOLTS/DIV switch from .05 to .01. If the trace moves vertically, adjust the front-panel STEP ATT BAL adjustment as follows:

1. With the Input Coupling switch set to GND and the VOLTS/DIV switch set to .05, move the trace to the center horizontal line of the graticule with the vertical POSITION control.

2. Set the VOLTS/DIV switch to .01 and adjust the STEP ATT BAL adjustment to return the trace to the center horizontal line.

3. Repeat steps 1 and 2 for minimum trace shift as the VOLTS/DIV switch is changed from .05 to .01.

Signal Connections

In general, probes offer the most convenient means of connecting a signal to the input of the Type 422. Tektronix probes are shielded to prevent pickup of electrostatic interference. A 10X attenuator probe offers a high input impedance and allows the ciruict under test to perform very close to normal operating conditions. However, a 10X probe also attenuates the input signal 10 times. A Tektronix field effect transistor probe offers the same high-input impedance as the 10X probes. However, it is particularly useful since it provides wide-band operation while presenting no attenuation (1X gain) and a low input capacitance. A standard 1X probe can be used for signal connection, although it does not provide as high an input impedance and may result in a lower overall bandwidth. Specialized probes are also available from Tektronix, Inc. for high-voltage measurement, current measurement, etc. See the Tektronix, Inc. catalog for characteristics and compatability of probes for use with this system.

In high-frequency applications requiring maximum over all bandwidth, use coaxial cables terminated in their characteristic impedances at the Type 422 INPUT connectors. High-level, low-frequency signals can be connected directly to the Type 422 INPUT connectors using short unshielded leads and the BNC to binding post adapter (supplied accessory). This coupling method works best for signals below about one kilohertz and deflection factors above one volt/division. When this coupling method is used, establish a common ground between the Type 422 and the equipment under test. Attempt to position the leads away from any source of interference to avoid errors in the display. If interference is excessive with unshielded leads, use a coaxial cable or a probe.

Loading Effect of Type 422

As nearly as possible, simulate actual operating conditions in the equipment under test. Otherwise, the equipment under test may not produce a normal signal. The 10X attenuator and field effect transistor probes mentioned previously offer the least circuit loading. See the probe instruction manual for loading characteristics of the probes.

When the signal is coupled directly to the input of the Type 422, the input impedance is about one megohm paralleled by about 30 pF. When the signal is coupled to the input through a coaxial cable, the effective input capacitance is increased. The actual input capacitance depends upon the type and length of cable used and the frequency of the signal.

Ground Considerations

Reliable signal measurements cannot be made unless both the oscilloscope and the unit under test are connected together by a common reference (ground) lead in addition to the signal lead or probe. Although the three-wire AC power cord provides a common connection when used with equipment with similar power cords, the ground loop produced may make accurate measurements impossible. The ground straps supplied with the probes provide an adequate ground. The shield of a coaxial cable provides a common ground when connected between two coaxial connectors (or with suitable adapters to provide a common ground). When using unshielded signal leads, a common ground lead should be connected from the Type 422 chassis to the chassis of the equipment under test. Additional ground considerations must be made for safety reasons to provide an earth (ground) connection to this instrument at all times when operating from external DC or internal batteries (see Operating Voltage in this section for details).

Input Coupling

The Channel 1 and 2 Input Coupling switches allow a choice of input coupling methods. The type of display desired and the applied signal will determine the coupling to use.

The DC Coupling position can be used for most applications. This position allows measurement of the DC component of a signal. It must also be used to display signals below about 20 hertz (two hertz with a 10X probe) as they will be attenuated in the AC position.

In the AC Coupling position, the DC component of the signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about two hertz (−3 dB point). Therefore, some low-frequency attenuation can be expected near this frequency limit. Attenuation in the form of waveform tilt will also appear in square waves which have low-frequency components. The AC coupling position provides the best display of signals with a DC component which is much larger than the AC components.

The GND position provides a ground reference at the input of the Type 422 without the need to externally ground the INPUT connectors. The signal applied to the input connector is internally disconnected, but not grounded, and the input circuit is held at ground potential.

Deflection Factor

The amount of vertical deflection produced by a signal is determined by the signal amplitude, the attenuation factor of the probe (if used), the setting of the VOLTS/DIV switch and the setting of the VARIABLE VOLTS/DIV control. The calibrated deflection factors indicated by the VOLTS/DIV switches apply only when the VARIABLE VOLTS/DIV control is set to the CAL position.

The VARIABLE VOLTS/DIV controls provide continuously variable (uncalibrated) vertical deflection factors between the calibrated settings of the VOLTS/DIV switches. The VARIABLE control extends the maximum vertical deflection factor of the Type 422 to at least 50 volts/division (20 volts position).

When the X10 GAIN AC switch in Channel 2 is pulled out, the deflection factor indicated by the VOLTS/DIV switch must be divided by 10 to obtain the actual deflection factor.

Channel 2 X10 Gain

The X10 GAIN AC switch provides 10 times gain for the Channel 2 amplifier to extend the minimum deflection factor to 0.001 volt/division in the .01 position of the Channel 2 VOLTS/DIV switch. The DC component of the applied signal is not amplified. For best results when using the X10 GAIN AC switch, the Channel 2 Input Coupling switch should be set to the AC position.

Dual-Trace Operation

Alternate Mode. The ALT position of the vertical Mode switch produces a display which alternates between Channel 1 and 2 with each sweep of the CRT. Although the ALT mode can be used at all sweep rates, the CHOPPED mode provides a more satisfactory display at sweep rates below about 0.5 millisecond/division. At these slow sweep rates, alternate mode switching becomes visually perceptible.

Proper internal triggering in the ALT mode can be obtained in either the CH 1 & 2 or the CH 1 position of the TRIGGERING Source switch. When in the CH 1 & 2 position, the sweep is triggered from the signal on each channel. This provides a stable display of two unrelated signals, but does not indicate the time relationship between the signals. In the CH 1 position, the two signals are displayed showing true time relationship. If the signals are not time related, the Channel 2 waveform will be unstable in the CH 1 Source switch position.

Chopped Mode. The CHOPPED position of the vertical Mode switch produces a display which is electronically switched between channels. In general, the CHOPPED mode provides the best display at sweep rates slower than about 0.2 millisecond/division or whenever dual-trace, non-repetitive phenomena is to be displayed. At faster sweep rates the chopped switching becomes apparent and may interfere with the display.

Proper internal triggering for the CHOPPED mode is provided with the TRIGGERING Source switch set to CH 1. If the CH 1 & 2 position is used, the sweep circuits are triggered from the between-channel switching signal and both waveforms will be unstable. External triggering from a signal which is time-related to either signal provides the same result as CH 1 triggering.

Two signals which are time-related can be displayed in the chopped mode showing true time relationship. However, if the signals are not time-related, the Channel 2 display will appear unstable.

Two non-repetitive transient or random signals occurring within the time interval determined by the TIME/DIV switch (10 times sweep rate) can be compared using the CHOPPED mode. To trigger the sweep correctly, the Channel 1 signal must precede the Channel 2 signal. Since the display shows true time relationship, time-difference measurements can be made.

Algebraic Addition

General. The ALG ADD position of the vertical Mode switch can be used to display the sum or difference of two signals, for common-mode rejection to remove an undesired signal, or for DC offset (applying a DC voltage to one channel to offset the DC component of a signal on the other channel). The common-mode rejection ratio of the Type 422 is greater than 100:1 at 50 kilohertz.

Deflection Factor. The overall deflection in the ALG ADD position of the vertical Mode switch with both VOLTS/DIV switches set to the same position is the same as the deflection factor indicated by either VOLTS/DIV switch. The amplitude of an added mode display can be determined directly from the resultant CRT deflection multiplied by the deflection factor indicated by either VOLTS/DIV switch. However, if the Channel 1 and 2 VOLTS/DIV switches are set to different deflection factors, the resultant voltage is difficult to determine from the CRT display. In this case, the voltage amplitude of the resultant display can be determined accurately only if the amplitude of the signal applied to either channel is known.

Precautions. The following general precautions should be observed when using the ALG ADD mode:

1. Do not exceed the input voltage rating of the Type 422.

2. Do not apply signals that exceed an equivalent of about eight times the VOLTS/DIV switch setting. For example, with a VOLTS/DIV switch setting of .5, the voltage applied to that channel should not exceed about four volts. Larger voltages may distort the display.

3. Use Channel 1 and 2 POSITION control settings which most nearly position the signal of each channel to mid-screen when viewed in either the CH 1 or CH 2 positions of the vertical Mode switch. This insures the greatest dynamic range for ALG ADD mode operation.

4. For similar response from each channel, set the Channel 1 and 2 Input Coupling switches to the same position.

Trigger Source

CH 1 & 2. In the CH 1 & 2 position of the TRIGGERING Source switch, the trigger signal is obtained from the displayed signal. This position provides the most convenient operation when displaying single channel displays. However, for dual-trace displays, special considerations must be made to provide the correct display. See Dual-Trace Operation in this section for dual-trace triggering information.

CH 1. The CH 1 position of the TRIGGERING Source switch provides a trigger signal from only the signal appled to the INPUT 1 connector. This position provides a stable display of the Channel 1 signal and is useful for certain dual-trace applications (see Dual-Trace Operation).

EXT. An external signal connected to the TRIG IN connector can be used to trigger the sweep in the EXT position of the TRIGGERING Source switch. The external signal must be time-related to the displayed signal to produce a stable display. An external trigger signal can be used to provide a triggered display when the internal signal is too low in amplitude for correct triggering, or contains signal components on which it is not desired to trigger. It is also useful when signal tracing in amplifiers, phase-shift networks, wave-shaping circuits, etc. The signal from a single point in the circuit can be connected to the TRIG IN connector through a signal probe or cable. The sweep is then triggered by the same signal at all times and allows examination of amplitude, time relationship or wave-shape changes of signals at various points in the circuit without resetting the TRIGGERING controls.

Trigger Coupling

Three methods of coupling the trigger signal to the trigger circuits can be selected with the TRIGGERING Coupling switch. Each position permits selection or rejection of the frequency components of the trigger signal which trigger the sweep.

AC. In the AC position of the TRIGGERING Coupling switch, the DC component of the trigger signal is blocked. Signals with low-frequency components below about 50

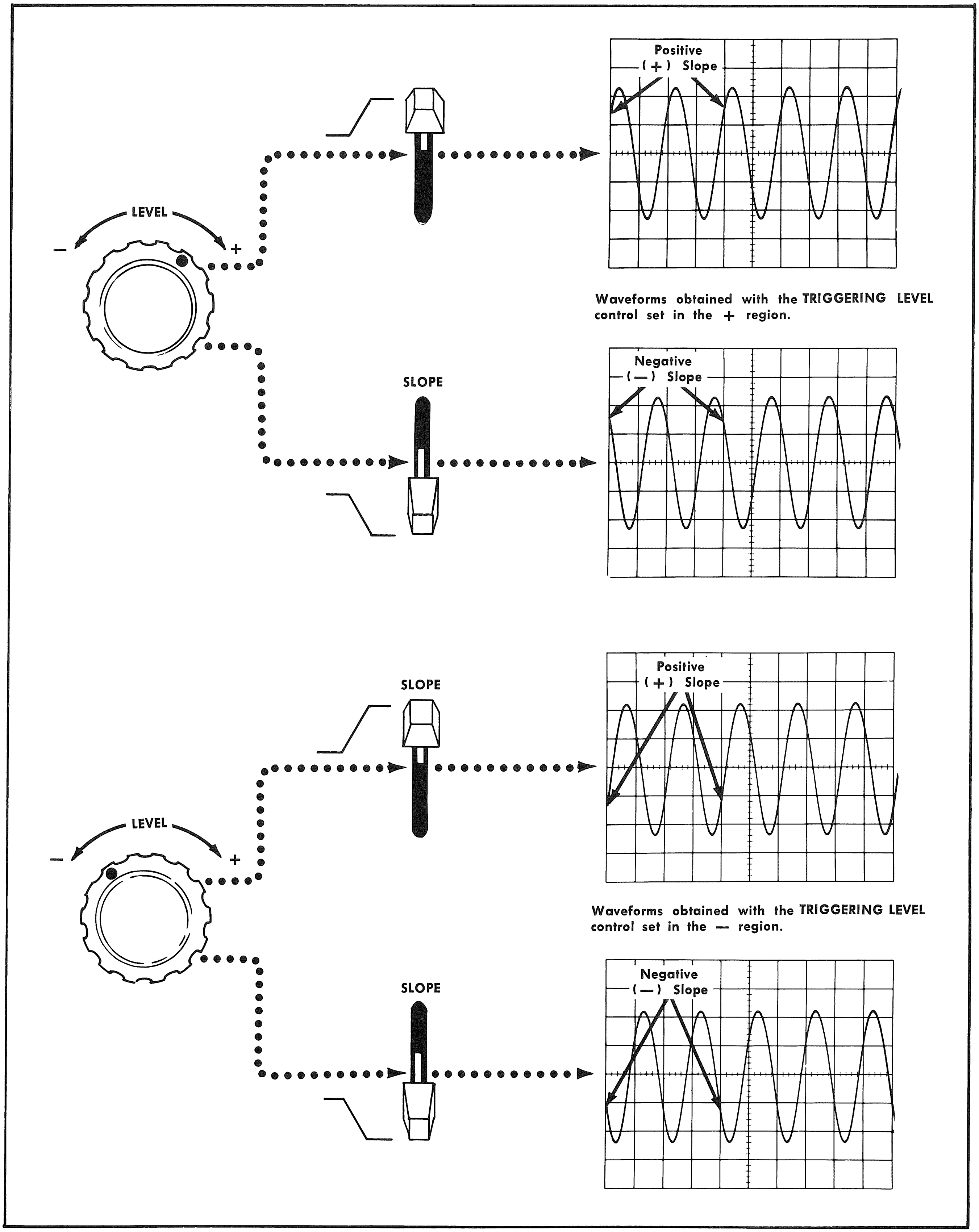


Fig. 2-11. Effect of the TRIGGERING LEVEL control and SLOPE switch on the CRT display.

hertz are attenuated. In general, AC coupling can be used for most applications. However, if the signal contains unwanted low-frequency signals or if the sweep is to be triggered at a low-repetition rate or DC level, one of the remaining TRIGGERING Coupling switch positions will provide a better display.

The triggering point in the AC position depends upon the average voltage level of the trigger signals. If the trigger signals occur at random, the average voltage level will vary, causing the triggering point to vary also. This shift of the triggering point may be enough so it is impossible to maintain a stable display. In such cases, use DC coupling.

AC LF REJ. In the AC LF REJ position, DC is rejected and low-frequency signals below about 50 kilohertz are attenuated. Therefore, the sweep is triggered only by the higher-frequency components of the trigger signal. This position is particularly useful for providing stable triggering if the trigger signal contains line-frequency components. Also, in the ALT position of the vertical Mode switch the AC LF REJ position provides the best display at fast sweep rates when comparing two unrelated signals (TRIGGERING Coupling switch set to CH 1 & 2).

DC. DC coupling can be used to provide stable triggering with low-frequency signals which would be attenuated in the AC position, or with low repetition rate signals. It can also be used to trigger the sweep when the trigger signal reaches a DC level selected by the setting of the LEVEL control. When using internal triggering, the setting of the Channel 1 and 2 POSITION controls affects the DC triggering point (CH 1 & 2 position only).

DC trigger coupling should not be used in the ALT dual-trace mode if the TRIGGERING Source switch is set to CH 1 & 2. If used, the sweep will trigger on the DC level of one trace and then either lock out completely or free run on the other trace. Correct DC triggering for this mode can be obtained with the TRIGGERING Source switch set to CH 1.

Trigger Slope

The TRIGGERING SLOPE switch determines whether the trigger circuit responds to the positive-going or negative-going portion of the trigger signal. When the SLOPE switch is in the positive-going (⎍) position, the display starts with the positive-going portion of the waveform; in the negative-going (⎍̅) position, the display starts with the negative-going portion of the waveform (see Fig. 2-11). When several cycles of a signal appear in the display, the setting of the SLOPE switch is often unimportant. However, if only a certain portion of a cycle is to be displayed, the setting of the SLOPE switch is important to provide a display which starts on the desired slope of the input signal.

Trigger Level

The TRIGGERING LEVEL control determines the voltage level on the triggering waveform at which the sweep is triggered. When the LEVEL control is set in the + region, the trigger circuit responds at a more positive point on the trigger signal. In the — region, the trigger circuit responds at a more negative point on the trigger signal. Fig. 2-11 illustrates this effect with different settings of the SLOPE switch.

To set the LEVEL control, first select the TRIGGERING source, coupling and slope. Then, set the LEVEL control fully counterclockwise and rotate it clockwise until the display starts at the desired point.

Trigger Mode

General. The TRIGGERING MODE switch is actuated by the LEVEL control. When the LEVEL control is pushed in, the TRIGGERING Mode switch is in the AUTO position and when the LEVEL control is pulled out, the TRIGGERING Mode switch is in the NORM position.

AUTO. The AUTO position of the TRIGGERING Mode switch provides a stable display when the LEVEL control is correctly set (see Trigger Level in this section) and an adequate trigger signal is available.

When the trigger repetition rate is less than about 20 hertz, or in the absence of an adequate trigger signal, the Sweep Generator free runs at the sweep rate selected by the TIME/DIV switch to produce a reference trace. When an adequate trigger signal is again applied, the free-running condition ends and the Sweep Generator is triggered to produce a stable display (with correct LEVEL control setting).

NORM. Operation in the NORM position of the TRIGGERING Mode switch is the same as in the AUTO position when a trigger signal is applied. However, when no trigger signal is present, the Sweep Generator remains off and there is no display.

Use the NORM mode to display signals with repetition rates below about 20 hertz. This mode provides an indication of an adequate trigger signal as well as the correctness of trigger control settings, since there is no display without proper triggering.

Horizontal Sweep Rate

The TIME/DIV switch provides 19 calibrated sweep rates ranging from 0.5 microsecond to 0.5 second/division. The VARIABLE control provides continuously variable sweep rates between the settings of the TIME/DIV switch. Whenever the UNCAL light is on, the sweep rate is uncalibrated. The light is off when the VARIABLE control is set to the CAL position.

When making time measurements from the graticule, the area between the second and tenth vertical lines of the graticule provides the most linear time measurement (see Fig. 2-12). Therefore, the first and last divisions of the display should not be used when making accurate time measurements. Position the start of the timing area to the second vertical line and adjust the TIME/DIV switch so the

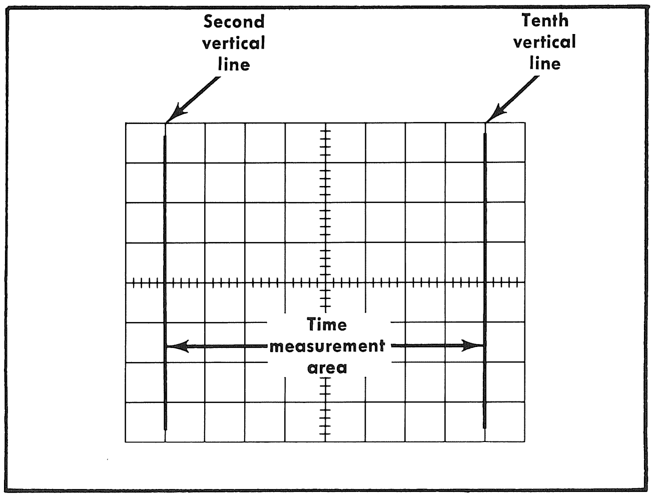


Fig. 2-12. Area of graticule used for accurate time measurements.

end of the timing area falls between the second and tenth vertical lines.

Sweep Magnification

The sweep magnifier expands the sweep ten times. The center division of the unmagnified display is the portion visible on the screen in magnified form (see Fig. 2-13). Equivalent length of the magnified sweep is more than 100 divisions; any 10-division portion can be viewed by adjusting the horizontal POSITION control to bring the desired portion onto the viewing area. The dual-range feature of the horizontal POSITION control (see Horizontal Position Control discussion which follows) is particularly useful when the magnifier is on.

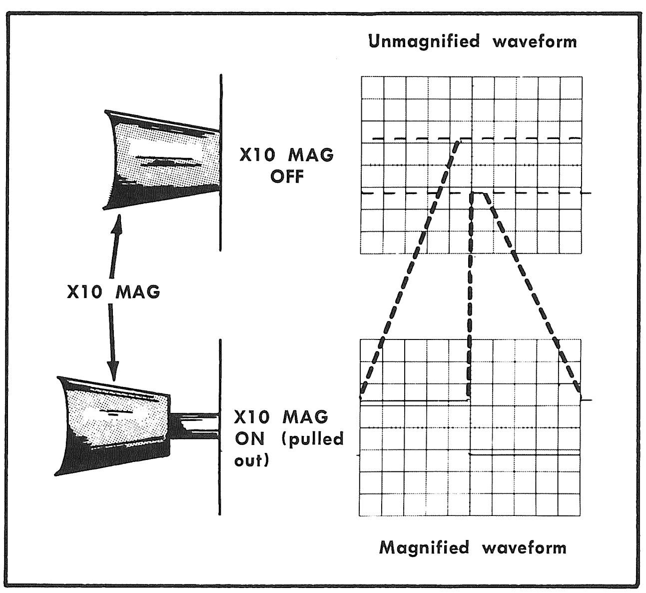


Fig. 2-13. Operation of the sweep magnifier.

To use the magnified sweep, first move the portion of the display to be expanded to the center of the graticule. Then pull the X10 MAG switch. The light located below the X10 MAG switch is on whenever the magnifier is on.

When the X10 MAG switch is pulled out, the sweep rate is determined by dividing the TIME/DIV switch setting by 10. For example, if the TIME/DIV switch is set to .5 μs, the magnified sweep rate is 0.05 microsecond/division. The magnified sweep rate must be used for all time measurements when the X10 MAG switch is pulled out. The magnified sweep rate is calibrated when the UNCAL light is off.

Horizontal Position Control

The dual-range horizontal POSITION control used in the Type 422 provides a combination of coarse and fine adjustments in a single control. When this control is rotated, fine positioning is provided for a range of about 0.5 division for normal sweep, or five divisions for magnified operation and the trace can be positioned precisely. Then, after the fine range is exceeded, the coarse adjustment comes into effect to provide rapid positioning of the trace. To use this control effectively for precise positioning, first turn the control to move the trace slightly beyond the desired position (coarse range). Then reverse the direction of rotation to use the fine range to establish the precise trace position desired.

External Horizontal Input

In some applications it is desirable to display one signal versus another signal rather than against time (internal sweep). The EXT HORIZ position of the TIME/DIV switch provides a means for applying an external signal to the horizontal amplifier for this type of display.

Connect the external horizontal signal to the HORIZ IN connector (TRIG IN). With the HORIZ ATTEN control TRIGGERING LEVEL) fully clockwise and the X10 MAG switch pushed in, the horizontal deflection factor is about 10 volts/division. Deflection factor with the X10 MAG switch pulled out is about one volt/division. The HORIZ ATTEN control provides at least 10:1 variable attenuation within the above ranges. The X and Y channels of this instrument are not time matched and some inherent phase shift is apparent. Take this inherent phase shift into account when making measurements. For aid in interpreting lissajous displays, refer to the reference books listed under Applications.

External Blanking

The CRT display of the Type 422 can be externally blanked by a signal connected to the EXT BLANKING connector. External blanking signals are direct-coupled to the blanking deflection plates. A two-volt positive signal connected to the EXT BLANKING connector on the front panel will completely blank the display at any INTENSITY control setting. For external blanking, the CRT display cannot be satisfactorily intensity-modulated, but is either turned on or off. Deflection blanking systems (as used in the Type 422) do not provide a "gray scale".

Calibrator

The internal calibrator of the Type 422 provides a convenient signal for checking vertical gain. This signal is internally connected to the Input Amplifiers when the VOLTS/DIV switches are set to the CALIBRATE 4 DIVISIONS position. The calibrator output signal available at the front-panel CALIBRATOR jack is also very useful for checking and adjusting probe compensation as described in the probe instruction manual. In addition, the calibrator can be used as a convenient signal source for application to external equipment.

APPLICATIONS

General

The following information describes the procedures and techniques for making basic measurements with a Type 422 Oscilloscope. These applications are not described in detail since each application must be adapted to the requirements of the individual measurements. This instrument can also be used for many applications which are not described in this manual. Contact your local Tektronix Field Office or representative for assistance in making specific measurements with this instrument. Also, the following books describe oscilloscope measurement techniques which can be adapted for use with this instrument.

Harley Carter, "An Introduction to the Cathode Ray Oscilloscope", Phillips Technical Library, Cleaver-Hume Press Ltd., London, 1960.

J. Czech, "Oscilloscope Measuring Technique", Phillips Technical Library, Springer-Verlag, New York, 1965.

Robert G. Middleton and L. Donald Payne, "Using the Oscilloscope in Industrial Electronics", Howard W. Sams & Co. Inc., The Bobbs-Merrill Company Inc., Indianapolis, 1961.

John F. Rider and Seymour D. Uslan, "Encyclopedia of Cathode-Ray Oscilloscopes and Their Uses", John F. Rider Publisher Inc., New York, 1959.

John F. Rider, "Obtaining and Interpreting Test Scope Traces", John F. Rider Publisher Inc., New York, 1959.

Rufus P. Turner, "Practical Oscilloscope Handbook", Volumes 1 and 2, John F. Rider Publisher Inc., New York, 1964.

Peak-to-Peak Voltage Measurements--AC

To make peak-to-peak voltage measurements, use the following procedure:

1. Apply the signal to either INPUT connector.

2. Set the vertical Mode switch to display the channel used.

3. Set the VOLTS/DIV switch to display about six divisions of the waveform.

4. Set the Input Coupling switch to AC.

NOTE

For low-frequency signals below about 20 hertz use the DC position to prevent attenuation.

5. Set the TRIGGERING controls to obtain a stable display. Set the TIME/DIV switch to a position that displays several cycles of the waveform.

6. Turn the vertical POSITION control so the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line, and the top of the waveform is on the viewing area. With the horizontal POSITION control, move the display so one of the upper peaks lies near the center vertical line (see Fig. 2-14).

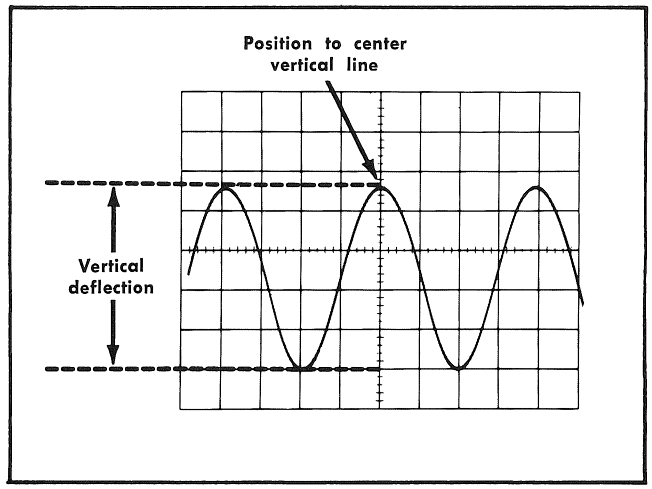


Fig. 2-14. Measuring peak-to-peak voltage of a waveform.

7. Measure the divisions of vertical deflection peak to peak. Make sure the VARIABLE VOLTS/DIV control is in the CAL position.

NOTE

This technique can also be used to make measurements between two points on the waveform, rather than peak to peak.

8. Muliply the distance measured in step 7 by the VOLTS/DIV switch setting. Also include the attenuation factor of the probe if used.

EXAMPLE. Assume that the peak-to-peak vertical deflection is 4.6 divisions (see Fig. 2-14) using a 10X attenuator probe and a VOLTS/DIV switch setting of .5.

$$\text{Volts Peak to Peak} = \text{vertical deflection (divisions)} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

Volts Peak to Peak = 4.6 X 0.5 V X 10

The peak-to-peak voltage is 23 volts.

Instantaneous Voltage Measurements--DC

To measure the DC level at a given point on a waveform, use the following procedure:

1. Connect the signal to either INPUT connector.

2. Set the vertical Mode switch to display the channel used.

3. Set the VOLTS/DIV switch to display about six divisions of the waveform.

4. Set the Input Coupling switch to GND.

5. Set the TRIGGERING Mode switch to AUTO.

6. Position the trace to the bottom line of the graticule or other reference line. If the voltage is negative with respect to ground, position the trace to the top line of the graticule. Do not move the vertical POSITION control after this reference line has been established.

NOTE

To measure a voltage level with respect to a voltage other than ground, make the following changes in step 6. Set the Input Coupling switch to DC and apply the reference voltage to the INPUT connector. Then position the trace to the reference line.

7. Set the Input Coupling switch to DC. The ground reference line can be checked at any time by switching to the GND position.

8. Set the TRIGGERING control to obtain a stable display. Set the TIME/DIV switch to a setting that displays several cycles of the signal.

9. Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured. For example, in Fig. 2-15 the measurement is made between the reference line and point A.

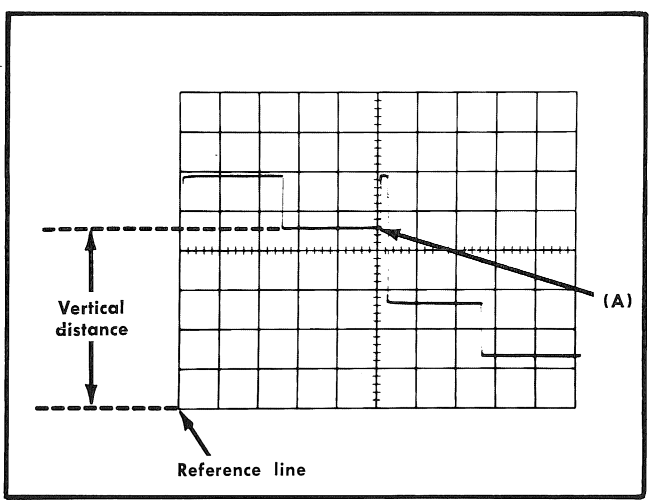


Fig. 2-15. Measuring instantaneous DC voltage with respect to a reference voltage.

10. Establish the polarity of the signal. If the waveform is above the reference line the voltage is positive; below the line, negative (with the INVERT switch pushed in for Channel 2).

11. Multiply the distance measured in step 9 by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if used.

EXAMPLE: Assume that the vertical distance measured is 4.6 divisions (see Fig. 2-15) and the waveform is above the reference line using a 10X attenuator probe and a VOLTS/DIV switch setting of 2.

Using the formula:

$$\text{Instantaneous Voltage} = \text{vertical distance (divisions)} \times \text{polarity} \times \text{VOLTS/DIV setting} \times \text{probe attenuation factor}$$

Substituting the given values:

$$\text{Instantaneous Voltage} = 4.6 \times +1 \times 2\,V \times 10$$

The instantaneous voltage is +92 volts.

Comparison Measurements

In some applications it may be desirable to establish arbitrary units of measurement other than those indicated by the VOLTS/DIV switch or TIME/DIV switch. This is particularly useful when comparing unknown signals to a reference amplitude or repetition rate. One use for the comparison-measurement technique is to facilitate calibration of equipment (e.g., on an assembly-line test) where the desired amplitude or repetition rate does not produce an exact number of divisions of deflection. The adjustment will be easier and more accurate if arbitrary units of measurement are established so that correct adjustment is indicated by an exact number of divisions of deflection. Arbitrary sweep rates can be useful for comparing harmonic signals to a fundamental frequency, or for comparing the repetition rate of the input and output pulses in a digital count-down circuit. The following procedure describes how to establish arbitrary units of measure for comparison measurements. Although the procedure for establishing vertical and horizontal arbitrary units of measurement is much the same, both processes are described in detail.

Vertical Deflection Factor. To establish an arbitrary vertical deflection factor based upon a specific reference amplitude, proceed as follows:

1. Connect the reference signal to the INPUT connector. Set the TIME/DIV switch to display several cycles of the signal.

2. Set the VOLTS/DIV switch and the VARIABLE VOLTS/DIV control to produce a display an exact number of graticule divisions in amplitude. Do not change the VARIABLE VOLTS/DIV control after obtaining the desired deflection. This display can be used as a reference for amplitude comparison measurements.

3. To establish an arbitrary vertical defelction factor so the amplitude of an unknown signal can be measured accurately at any setting of the VOLTS/DIV switch, the amplitude of the reference signal must be known. If it is not known, it can be measured before the VARIABLE VOLTS/DIV control is set in step 2.

4. Divide the amplitude of the reference signal (volts) by the product of the vertical deflection established in step 2 (divisions) and the setting of the VOLTS/DIV switch. This is the vertical conversion factor.

$$\text{Vertical Conversion Factor} = \frac{\text{reference signal amplitude (volts)}}{\text{vertical deflection (divisions)} \times \text{VOLTS/DIV switch setting}}$$

5. To measure the amplitude of an unknown signal, disconnect the reference signal and connect the unknown signal to the INPUT connector. Set the VOLTS/DIV switch to a setting that provides sufficient vertical deflection to make an accurate measurement. Do not readjust the VARIABLE VOLTS/DIV control.

6. Measure the vertical deflection in divisions and calculate the amplitude of the unknown signal using the following formula.

$$\text{Signal Amplitude} = \text{VOLTS/DIV switch setting} \times \text{vertical conversion factor} \times \text{vertical deflection (divisions)}$$

EXAMPLE. Assume a reference signal amplitude of 30 volts, a VOLTS/DIV switch setting of 5 and the VARIABLE VOLTS/DIV control is adjusted to provide a vertical deflection of four divisions.

Substituting these values in the vertical conversion factor formula (step 4):

$$\text{Vertical Conversion Factor} = \frac{30\text{ V}}{4 \times 5\text{ V}} = 1.5$$

Then with a VOLTS/DIV switch setting of 10, the peak-to-peak amplitude of an unknown signal which produces a vertical deflection of five divisions can be determined by using the signal amplitude formula (step 6):

$$\text{Signal Amplitude} = 10\text{ V} \times 1.5 \times 5 = 75\text{ volts}$$

Sweep Rates. To establish an arbitary horizontal sweep rate based upon a specific reference frequency, proceed as follows:

1. Connect the reference signal to the INPUT connector. Set the VOLTS/DIV switch for four or five divisions of vertical deflection.

2. Set the TIME/DIV switch and the VARIABLE TIME/DIV control so one cycle of the signal covers an exact number of horizontal divisions. Do not change the VARIABLE TIME/DIV control after obtaining the desired deflection. This display can be used as a reference for frequency comparison measurements.

3. To establish an arbitrary sweep rate so the repetition rate of an unknown signal can be measured accurately at any setting of the TIME/DIV switch, the repetition rate of the reference signal must be known. If it is not known, it can be measured before the VARIABLE TIME/DIV switch is set in step 2.

4. Divide the repetition rate of the reference signal (seconds) by the product of the horizontal deflection established in step 2 (divisions) and the setting of the TIME/DIV switch. This is the horizontal conversion factor

$$\text{Horizontal Conversion Factor} = \frac{\text{reference signal repetition rate (seconds)}}{\text{horizontal deflection (divisions)} \times \text{TIME/DIV switch setting}}$$

5. To measure the repetition rate of an unknown signal, disconnect the reference signal and connect the unknown signal to the INPUT connector. Set the TIME/DIV switch to a setting that provides sufficient horizontal deflection to make an accurate measurement. Do not readjust the VARIABLE TIME/DIV control.

6. Measure the horizontal deflection in divisions and calculate the repetition rate of the unknown signal using the following formula:

$$\text{Repetition Rate} = \text{TIME/DIV switch setting} \times \text{horizontal conversion factor} \times \text{horizontal deflection (divisions)}$$

NOTE

If the horizontal magnifier is used be sure to use the magnified sweep rate in place of the TIME/DIV switch setting.

EXAMPLE. Assume a reference signal frequency of 455 hertz (repetition rate 2.19 milliseconds), and a TIME/DIV switch setting of .2 ms, with the VARIABLE TIME/DIV control adjusted to provide a horizontal deflection of eight divisions. Substituting these values in the horizontal conversion factor formula (step 4):

$$\text{Horizontal Conversion Factor} = \frac{2.19\text{ milliseconds}}{.2 \times 8} = 1.37$$

Then, with a TIME/DIV switch setting of 50 μs the repetition rate of an unknown signal which completes one cycle in seven horizontal divisions can be determined by using the repetition rate formula (step 6):

$$\text{Repetition Rate} = 50\ \mu s \times 1.37 \times 7 = 480\ \mu s$$

This answer can by converted to frequency by taking the reciprocal of the repetition rate (see applications on Determining Frequency).

Time Duration Measurements

To measure time between two points on a waveform, use the following procedure:

1. Connect the signal to one of the INPUT connectors.

2 Set the vertical Mode switch to display the channel used.

3. Set the VOLTS/DIV switch to display about four divisions of the waveform.

4. Set the TRIGGERING controls to obtain a stable display.

5. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the time measurement points (see Fig. 2-16). See Horizontal Sweep Rate in this section concerning nonlinearity of first and last divisions of display.

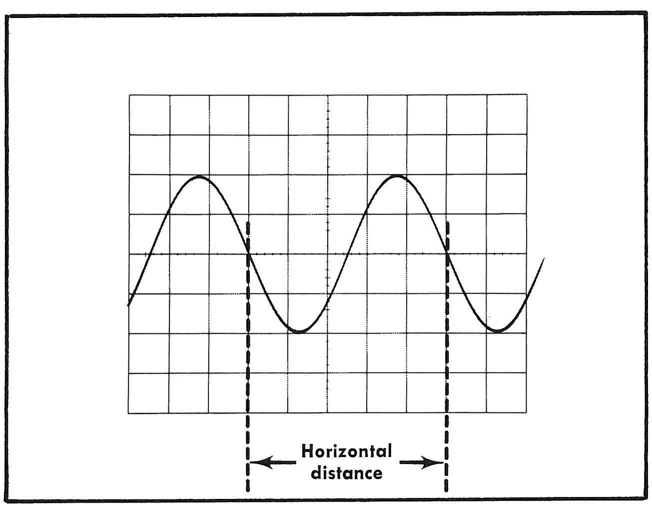


Fig. 2-16. Measuring time duration between points on a waveform.

6. Adjust the vertical POSITION control to move the points between which the time measurement is made to the center horizontal line.

7. Adjust the horizontal POSITION control to center the time-measurement points within the center eight divisions of the graticule.

8. Measure the horizontal distance between the time measurement points. Be sure the VARIABLE TIME/DIV control is set to CAL.

9. Multiply the distance measured in step 8 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

EXAMPLE. Assume that the horizontal distance between the time measurement points is five divisions (see Fig. 2 16) and the TIME/DIV switch is set to .1 ms with the magnifier off.

Using the formula:

$$\text{Time duration} = \frac{\text{horizontal distance (divisions)} \times \text{TIME/DIV setting}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time duration} = \frac{5 \times 0.1\ \text{ms}}{1}$$

The time duration is 0.5 milliseconds.

Determining Frequency

The time measurement technique can also be used to determine the frequency of a signal. The frequency of a periodically recurrent signal is the reciprocal of the time duration (period) of one cycle.

Use the following procedure:

1. Measure the time duration of one cycle of the waveform as described in the previous application.

2. Take the reciprocal of the time duration to determine the frequency.

EXAMPLE. The frequency of the signal shown in Fig. 2-16, which has a time duration of 0.5 milliseconds, is:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{0.5\ \text{ms}} = 2\ \text{kHz}$$

Risetime Measurements

Risetime measurements employ basically the same techniques as time-duration measurements. The main difference is the points between which the measurement is made. The following procedure gives the basic method of measuring risetime between the 10% and 90% points of the waveform.

1. Connect the signal to either INPUT connector.

2. Set the vertical Mode switch to display the channel used.

3. Set the VOLTS/DIV switch and VARIABLE control to produce a display an exact number of divisions in amplitude.

4. Center the display about the center horizontal line with the vertical POSITION control.

5. Set the TRIGGERING controls to obtain a stable display.

6. Set the TIME/DIV switch to the fastest sweep rate that will display less than eight divisions between the 10% and 90% points on the waveform.

7. Determine the 10% and 90% points on the rising portion of the waveform. The figures given in Table 2-3 are for the points 10% up from the start of the rising portion and 10% down from the top of the rising portion (90% point).

TABLE 2-3

Divisions of display	10% and 90% points	Divisions vertically between 10% and 90% points
4	0.4 and 3.6 divisions	3.2
5	0.5 and 4.5 divisions	4.0
6	0.6 and 5.4 divisions	4.8
7	0.7 and 6.3 divisions	5.6
8	0.8 and 7.2 divisions	6.4

8. Adjust the horizontal POSITION control to move the 10% point of the waveform to the second vertical line of the graticule. For example with a six division display, the 10% point would be 0 6 division up from the start of the rising portion (see Fig. 2-17).

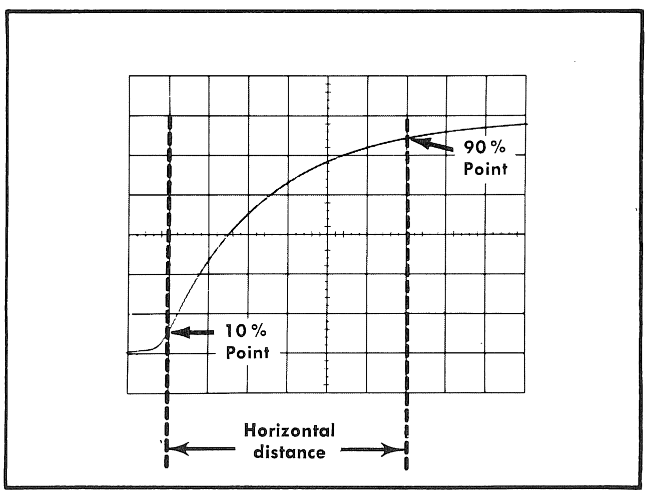


Fig. 2-17. Measuring risetime.

9. Measure the horizontal distance between the 10% and 90% points. Be sure the VARIABLE TIME/DIV control is set to CAL.

10. Multiply the distance measured in step 9 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

EXAMPLE. Assume that the horizontal distance between the 10% and 90% points is six divisions (see Fig. 2-17) and the TIME/DIV switch is set to 1 μs with the magnifier on.

Using the time duration formula to find risetime:

$$\text{Time Duration (Risetime)} = \frac{\text{horizontal distance (divisions)} \times \text{TIME/DIV setting}}{\text{magnification}}$$

Substituting the given values:

$$\text{Risetime} = \frac{6 \times 1\ \mu s}{10}$$

The risetime if 0.6 microseconds.

Time Difference Measurements

The calibrated sweep rate and dual-trace features of the Type 422 allow measurement of time difference between two separate events. To measure time difference use the following procedure:

1. Set the Input Coupling switches to the same position, depending on the type of coupling desired.

2. Set the vertical Mode switch to either CHOPPED or ALT. In general, CHOPPED is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals. More information on determining the mode is given under Dual-Trace Operation in this section.

3. Set the TRIGGERING Source switch to CH 1.

4. Connect the reference signal to the INPUT 1 connector and the comparison signal to the INPUT 2 connector. The reference signal should precede the comparison signal in time. Use coaxial cables or probes which have equal time delay to connect the signals to the INPUT connectors.

5. If the signals are of opposite polarity, pull out the INVERT switch to invert the Channel 2 display (signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation).

6. Set the VOLTS/DIV switches to produce four or five division displays.

7. Set the TRIGGERING LEVEL control for a stable display.

8. If possible, set the TIME/DIV switch for a sweep rate which shows three or more divisions between the two waveforms.

9. Adjust the vertical POSITION controls to center each waveform (or the points on the display between which the

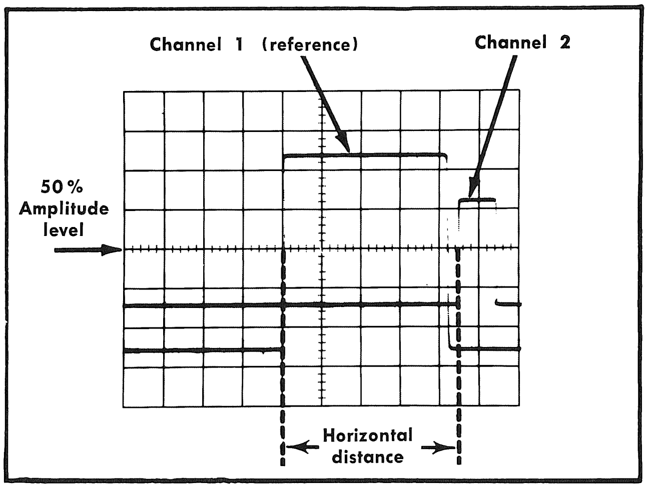


Fig. 2-18. Measuring time difference between two pulses.

measurement is being made) in relation to the center horizontal line.

10. Adjust the horizontal POSITION control so the Channel 1 (reference) waveform crosses the center horizontal line at a vertical graticule line.

11. Measure the horizontal distance between the Channel 1 waveform and the Channel 2 waveform (see Fig. 2-18).

12. Multiply the measured distance by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

EXAMPLE. Assume that the TIME/DIV switch is set to 50 μs, the magnifier is on and the horizontal distance between waveforms is 4.5 divisions (see Fig. 2-18).

Using the formula:

$$\text{Time Delay} = \frac{\text{TIME/DIV setting} \times \text{horizontal distance (divisions)}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time Delay} = \frac{50\,\mu s \times 4.5}{10}$$

The time delay is 22.5 microseconds.

Normal Trigger Generator

Ordinarily, the signal to be displayed also provides the trigger signal for the oscilloscope. In some instances, it may be desirable to reverse this situation and have the oscilloscope trigger the signal source This can be done by connecting the signal at the GATE OUT connector to the input of the signal source. Set the LEVEL control fully clockwise, TRIGGERING Mode switch to AUTO and adjust the TIME/DIV switch for the desired display. Since the signal source is triggered by a signal that has a fixed time relationship to the sweep, the output of the signal source can be displayed on the CRT as though the Type 422 were triggered in the normal manner.

Multi-Trace Phase Difference Measurements

Phase comparison between two signals of the same frequency can be made using the dual-trace feature of the Type 422. This method of phase difference measurement can be used up to the frequency limit of the vertical system. To make the comparison, use the following procedure.

1. Set the Input Coupling switches to the same position, depending on the type of coupling desired.

2. Set the vertical Mode switch to either CHOPPED or ALT. In general, CHOPPED is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals. More information on determining the mode is given under Dual-Trace Operation in this section.

3. Set the TRIGGERING Coupling switch to CH 1.

4. Connect the reference signal to the INPUT 1 connector and the comparison signal to the INPUT 2 connector. The reference signal should precede the comparison signal in time. Use coaxial cables or probes which have similar time delay characteristics to connect the signals to the INPUT connectors.

5. If the signals are of opposite polarity, pull the INVERT switch out to invert the Channel 2 display. (Signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation.)

6. Set the VOLTS/DIV switches and the VARIABLE VOLTS/DIV controls so the displays are equal and about five divisions in amplitude.

7. Set the TRIGGERING controls to obtain a stable display.

8. Set the TIME/DIV switch to a sweep rate which displays about one cycle of the waveform.

9. Move the waveforms to the center of the graticule with the vertical POSITION controls.

10. Turn the VARIABLE TIME/DIV control until one cycle of the reference signal (Channel 1) occupies exactly eight divisions between the second and tenth vertical lines

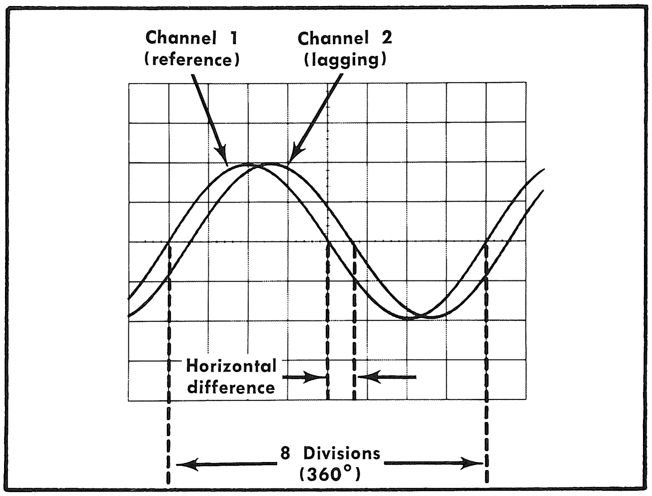


Fig. 2-19. Measuring phase difference.

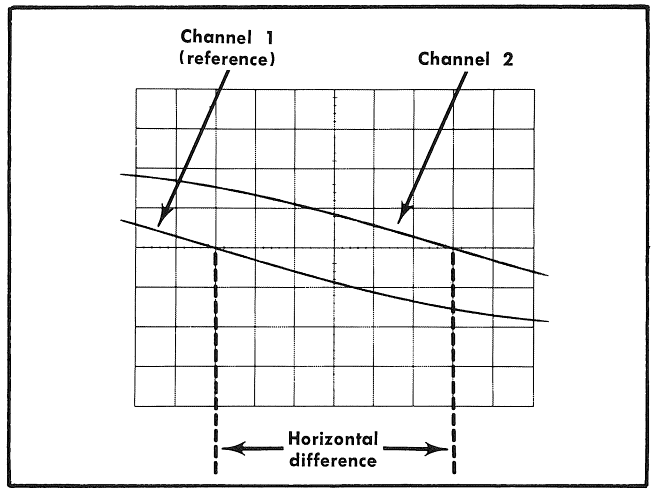


Fig. 2-20. High resolution phase-difference measurement with increased sweep rate.

of the graticule (see Fig. 2-19). Each division of the graticule represents 45° of the cycle (360° ÷ 8 divisions = 45°/division). The sweep rate can be stated in terms of degrees as 45°/division.

11. Measure the horizontal difference between corresponding points on the waveforms.

12. Multiply the measured distance (in divisions) by 45°/division (sweep rate) to obtain the exact amount of phase difference.

EXAMPLE. Assume a horizontal difference of 0.6 divisions with a sweep rate of 45°/division as shown in Fig. 2-19.

Using the formula:

$$\text{Phase Difference} = \begin{matrix}\text{horizontal}\\ \text{difference}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{sweep rate}\\ \text{(degrees/div)}\end{matrix}$$

Substituting the given values:

Phase Difference = 0.6 X 45°

The phase difference is 27°.

High Resolution Phase Measurements

More accurate dual-trace phase measurements can be made by increasing the sweep rate (without changing the VARIABLE TIME/DIV control setting). One of the easiest ways to increase the sweep rate is with the X10 MAG switch. The magnified sweep rate is determined by dividing the sweep rate obtained previously by the amount of sweep magnification.

EXAMPLE. If the sweep rate were increased 10 times with the magnifier, the magnified sweep rate would be 45°/division ÷ 10 = 4.5°/division. Fig. 2-20 shows the same signals as used in Fig. 2-19 but with the X10 MAG switch pulled out. With a horizontal difference of six divisions, the phase difference is:

$$\text{Phase Difference} = \begin{matrix}\text{horizontal}\\ \text{difference}\\ \text{(division)}\end{matrix} \times \begin{matrix}\text{magnified sweep rate}\\ \text{(degrees/div)}\end{matrix}$$

Substituting the given values:

Phase Difference = 6 X 4.5°.

The phase difference is 27°.

Common-Mode Rejection

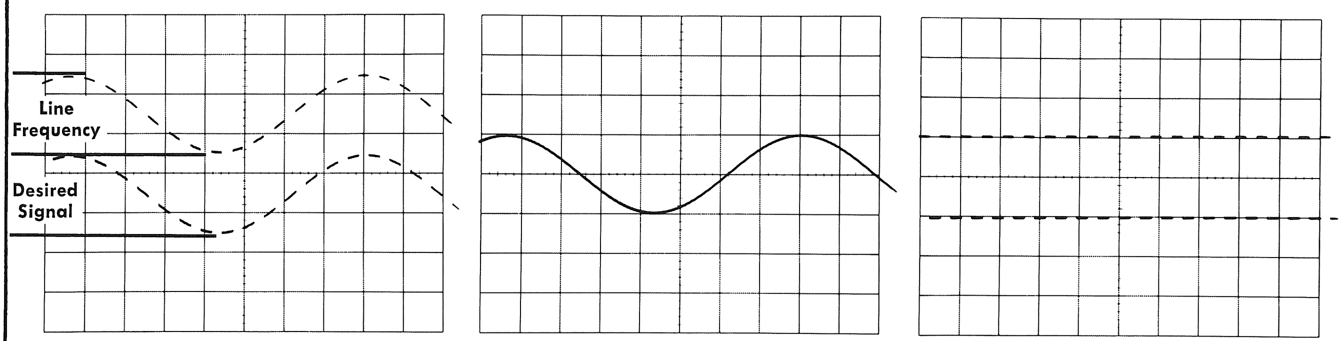
The ALG ADD feature of the Type 422 can be used to display signals which contain undesirable components. These undesirable components can be eliminated through common-mode rejection. The precautions given under Algebraic Addition should be observed.

1. Connect the signal containing both the desired and undesired information to the INPUT 1 connector.

2. Connect a signal similar to the unwanted portion of the Channel 1 signal to the INPUT 2 connector. For example, in Fig. 2-21 a line-frequency signal is connected to Channel 2 to cancel out the line-frequency component of the Channel 1 signal.

3. Set both Input Coupling switches to DC (AC if DC component on input signal is too large).

4. Set the vertical Mode switch to ALT. Set the VOLTS/DIV switches so the signals are about equal in amplitude.



(A) Channel 1 signal. (B) Channel 2 signal. (C) Resultant display.

Fig. 2-21. Using the ALG ADD feature for common-mode rejection: (A) Channel 2 signal contains desired information along with line-frequency component, (B) Channel 2 signal contains line-frequency only, (C) resultant CRT display using common mode rejection.

5. Set the TRIGGERING Source switch to CH 1 & 2.

6. Set the vertical Mode switch to ALG ADD. Pull the INVERT switch so the common-mode signals are of opposite polarity.

7. Adjust the Channel 2 VOLTS/DIV switch and VARIABLE VOLTS/DIV control for maximum cancellation of the common-mode signal.

8. The signal which remains should be only the desired portion of the Channel 1 signal. The undesired signal is cancelled out.

EXAMPLE. An example of this mode of operation is shown in Fig. 2-21. The signal applied to Channel 1 contains unwanted line-frequency components (Fig. 2-21A). A corresponding line-frequency signal is connected to Channel 2 (Fig. 2-21B). Fig. 2-21C shows the desired portion of the signal as displayed when common-mode rejection is used.

SECTION 3
CIRCUIT DESCRIPTION

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

Introduction

This section of the manual contains a description of the circuitry used in the Type 422 Oscilloscope with AC-DC Power Supply. 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 back of this manual. This block diagram shows the overall relationship between all of the circuits. 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 discussion is provided to aid in understanding the overall concept of the Type 422 before the individual circuits are discussed in detail. A basic block diagram of the Type 422 is shown in Fig. 3-1. Only the basic interconnections between the individual blocks are shown on this diagram. Each block represents a major circuit within the instrument. The number in each block refers to the complete circuit diagram located at the back of the manual.

Signals to be displayed on the CRT are applied to the INPUT 1 and/or the INPUT 2 connector. The input signals are amplified by the Channel 1 Input Amplifier and/or the Channel 2 Input Amplifier circuit. Each Input Amplifier circuit includes separate vertical deflection factor, input coupling, position, gain, variable attenuation and balance controls. A trigger-pickoff stage in the Channel 1 Input Amplifier circuit supplies a sample of the Channel 1 input signal to the Sweep Trigger circuit to provide triggering from the Channel 1 signal only. The Channel 2 Input Circuit contains a X10 gain stage to allow the Channel 2 deflection factors to be increased 10 times and an invert feature to invert the Channel 2 signal as displayed on the CRT. The output of both Input Amplifier circuits is connected to the Vertical Switching and Output Amplifier circuit. This circuit selects the channel(s) to be displayed on the CRT and provides the final amplification for the vertical signal before it is applied to the vertical deflection plates of the CRT. A delay line is included in the Vertical Switching and Output Amplifier circuit to delay the vertical signal slightly so the horizontal circuits have enough time to start the sweep before the input signal arrives at the vertical deflection plates. An output signal from this circuit is connected to the CRT Circuit to blank out the between-channel switching transients when in the chopped mode of operation. A trigger-pickoff network in this circuit provides a sample of the displayed signal(s) to the Sweep Trigger circuit.

The Sweep Trigger circuit produces an output pulse which initiates the sweep signal produced by the Sweep Generator circuit. The input signal to the Sweep Trigger circuit can be selected from either the Channel 1 Input Amplifier circuit, the Vertical Switching and Output Amplifier circuit, or an external signal connected to the HORIZ IN OR TRIG IN connector. This circuit contains level, slope, coupling, source and mode controls to select the desired triggering. The Sweep Generator circuit produces a linear sawtooth output signal when initiated by the Sweep Trigger circuit. The slope (sweep rate) of the sawtooth produced by the Sweep Generator circuit is controlled by the TIME/DIV switch. The Sweep Generator circuit also produces an unblanking gate signal to unblank the CRT so the display can be presented. This gate signal is coincident with the sawtooth produced by the Sweep Generator. An external signal can be connected to this circuit through the EXT BLANKING connector to blank portions of the CRT display. A gate signal which is also coincident with the sawtooth is available at the GATE OUT connector. The Sweep Generator circuit also provides an alternate trace sync pulse which is connected to the Vertical Switching and Output Amplifier circuit. This pulse switches the display between channels at the end of each sweep when in the alternate mode of operation.

The sawtooth output signal from the Sweep Generator circuit is connected to the Horizontal Amplifier circuit in all positions of the TIME/DIV switch except the EXT HORIZ position. In the EXT HORIZ position, external signals connected to the HORIZ IN OR TRIG IN connector can be applied to the Horizontal Amplifier circuit to produce horizontal deflection on the CRT. The Horizontal Amplifier circuit amplifies the applied sawtooth or external horizontal deflection signal and produces a push-pull output signal to drive the horizontal deflection plates of the

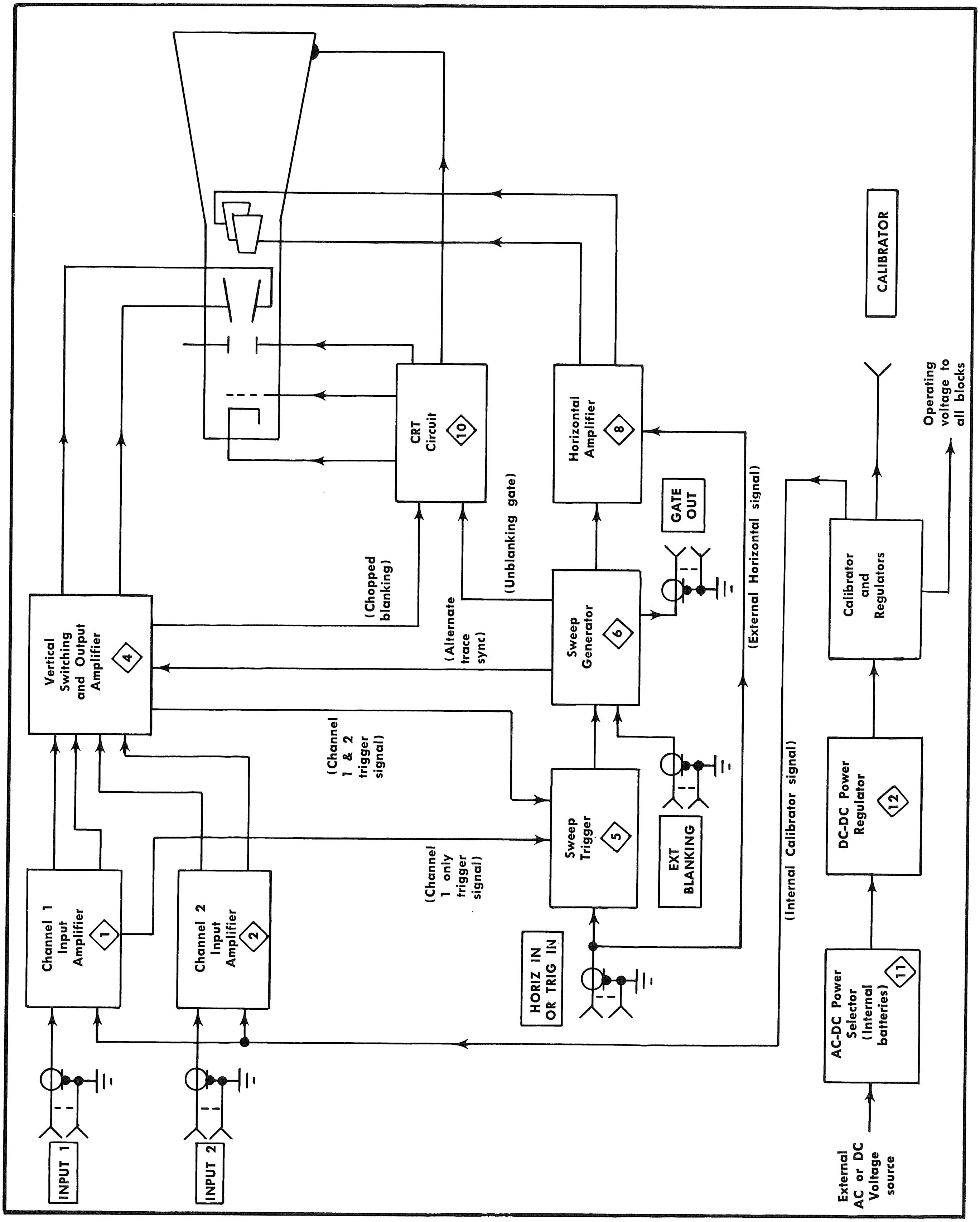


Fig. 3-1. Basic block diagram of Type 422 with AC-DC Power Supply.

CRT. This circuit also contains a 10X magnifier to increase the sweep rate ten times in any TIME/DIV switch position or to provide a ten times reduction in external horizontal deflection factor for external horizontal operation.

The CRT Circuit provides the voltages and contains the controls necessary for the operation of the cathode-ray tube (CRT). The AC-DC Power Selector circuit provides power to the DC-DC Regulator circuit. This power is selected from an external AC or DC voltage connected to this instrument or from internal rechargeable batteries. This circuit also contains a battery charging circuit to recharge the internal batteries. The DC-DC Regulator circuit provides the low-voltage power necessary for the operation of this instrument. The voltages produced by the DC-DC Regulator circuit are connected to the Calibrator and Regulators circuit through the interconnecting plug between the indicator and power supply. The Calibrator and Regulators circuit distributes the voltage to all of the circuits in this instrument and also produces several stable voltages from the unregulated supplies. The Calibrator and Regulators circuit also produces a square wave output with accurate amplitude which can be used to check the gain of the vertical system or to compensate attenuator probes. In the CALIBRATE 4 DIVISIONS position of the Channel 1 and Channel 2 VOLTS/DIV switches, the square wave signal is internally connected to the Input Amplifier circuits. If the gain of the Input Amplifier circuits is correctly set, a display exactly four divisions in amplitude is presented. The square wave signal is also available at the front-panel CALIBRATOR jack.

CIRCUIT OPERATION

General

This section provides a detailed description of the electrical operation and relationship of the circuits in the Type 422 with AC-DC Power Supply. The theory of operation for circuits unique to this instrument are described in detail in this discussion. Circuits which are commonly used in the electronics industry are not described in detail. Instead, references are given to textbooks or other source material which describe the complete operation of these circuits.

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 show how they are connected together to form the major circuit. The block diagrams also show the inputs and outputs for each circuit and the relationship of the front-panel controls to the individual stages. The names assigned to the individual stages of these block diagrams are used throughout the following discussion. The circuit diagrams from which the detailed block diagrams are derived are shown in the Diagrams section.

CHANNEL 1 INPUT AMPLIFIER

General

Input signals for vertical deflection on the CRT can be connected to the INPUT 1 connector. The Channel 1 Input Amplifier circuit provides control of vertical deflection factor, input coupling, vertical position, vertical gain, balance and variable deflection factor. It also contains a stage to provide a sample of the Channel 1 input signal to the Sweep Trigger circuit for internal triggering from the Channel 1 signal only. Fig. 3-2 shows a detailed block diagram of the Channel 1 Input Amplifier circuit. A schematic of this circuit is shown on diagram 1 at the back of the manual.

Input Coupling

Input signals applied to the INPUT 1 connector can be AC-coupled, DC-coupled or internally disconnected. When Input Coupling switch SW1 is in the DC position, the input signal is directly coupled to the Input Attenuator stage. In the AC position, the input signal passes through blocking capacitor C1. This capacitor prevents the DC component of the signal from passing to the amplifier. The GND position opens the signal path and the input to the amplifier is connected to ground. This provides a ground reference without the need to disconnect the applied signal from the INPUT 1 connector.

Input Attenuator

The effective overall Channel 1 deflection factor of the Type 422 is controlled by the Channel 1 VOLTS/DIV switch. In all positions of the Channel 1 VOLTS/DIV switch except .01 and .02, the basic deflection factor of the vertical deflection system is 0.05 volt per division of CRT deflection. To increase this basic deflection factor to the values indicated on the front panel, precision attenuators are switched into the circuit. In the .01 and .02 positions, input attenuation is not used. Instead, the gain of the Feedback Amplifier stage is changed to decrease the deflection factor.

For Channel 1 VOLTS/DIV switch positions above .05, the attenuators are switched into the circuit singly or in pairs to produce the vertical deflection factor indicated on the front panel. These attenuators are frequency-compensated voltage dividers. For DC and low-frequency signals they are primarily resistance dividers and the voltage attenuation is determined by the resistance ratio in the circuit. The reactance of the capacitors in the circuit is so high at low frequencies that their effect in the circuit is negligible. However at higher frequencies, the reactance of the capacitors decreases and the attenuator becomes primarily a capacitance voltage divider.

In addition to providing constant attenuation at all frequencies within the bandwidth of the instrument, the Input Attenuators are designed to maintain the same input RC characteristics (one megohm X 33 picofarads) for each set-

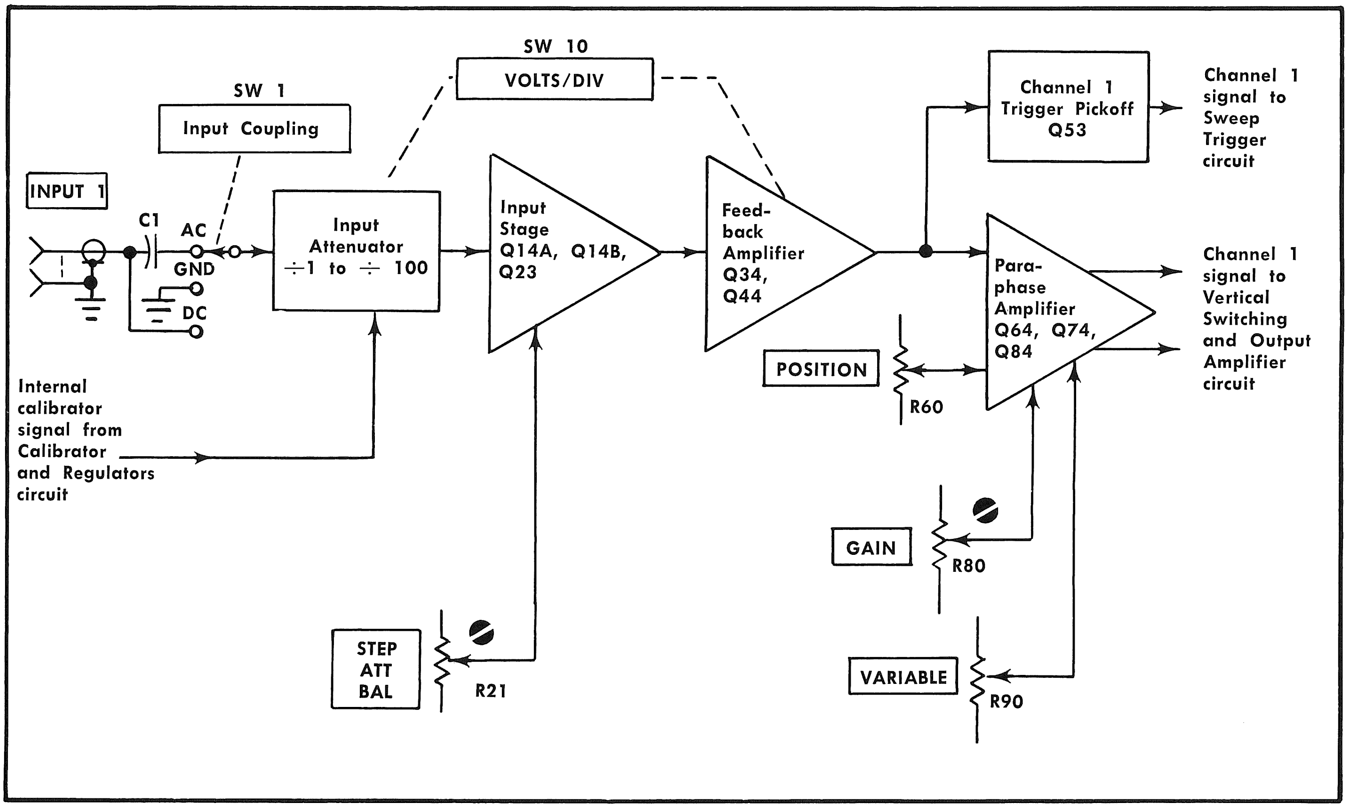


Fig. 3-2. Channel 1 Input Amplifier detailed block diagram.

ting of the Channel 1 VOLTS/DIV switch. Each attenuator contains an adjustable series capacitor to provide correct attenuation at high frequencies and an adjustable shunt capacitor to provide correct input capacitance.

In the CALIBRATE 4 DIVISIONS position of the Channel 1 VOLTS/DIV switch, the INPUT 1 connector and Input Attenuator are disconnected. Instead, a 0.2-volt square-wave signal from the Calibrator and Regulators circuit is connected to the Input Stage. The basic 0.05 volt per division deflection factor of the vertical deflection system provides a four-division display when the Channel 1 GAIN control is set correctly. This position of the Channel 1 VOLTS/DIV switch allows the calibration of the Channel 1 Input Amplifier to be checked without additional equipment.

Input Stage

The Channel 1 signal from the Input Attenuator stage is connected to the Input Stage through the network C11-C12-R10-R11-R12. Resistor R10 establishes the input resistance of this stage and is a part of the attenuation network at all Channel 1 VOLTS/DIV switch positions. Variable capacitor C12 adjusts the basic input time constant for a nominal value of one megohm X 33 picofarads. FET (field-effect transistor) Q14A is connected as a source follower to provide a high input impedance for the applied signal with a low-impedance drive to the following stage. Diodes D14 and D15 protect the input circuit by clamping the gate of Q14A if the signal at the gate exceeds either +12.5 volts or −12.5 volts.

FET Q14B is a constant current source for Q14A and also provides temperature compensation for Q14A. STEP ATT BAL adjustment R21 varies the gate level of Q14B to provide a zero-volt level at the emitter of Q34 with no signal applied. With a zero-volt level at the emitter of Q34, the trace position will not change when switching between the .01, .02 and .05 positions of the Channel 1 VOLTS/DIV switch. The signal at the source of Q14A is connected to the Feedback Amplifier stage through C14-R14 and emitter follower Q23. Q23 serves to isolate the Input Stage and the Feedback Amplifier stage.

Feedback Amplifier

Feedback Amplifier[1] Q34 and Q44 changes the overall gain of the Channel 1 Input Amplifier in the .01 and .02 positions of the Channel 1 VOLTS/DIV switch. Gain of this stage is determined by the ratio of R39 and the resistance (R_E) between the emitter of Q34 and ground (R30, R32 or open circuit). These resistors alter the negative feedback and thus change the gain of this stage. This can be represented by the formula:

$$\text{Gain} = \frac{R_E + R39}{R_E}$$

[1]**Jacob Millman and Herbert Taub, "Pulse, Digital and Switching Waveforms", McGraw-Hill, New York, 1965, pp 15-18.**

In the .01 position, R30 provides the emitter resistance for Q34 and the gain of the stage is five. In the .02 position, R32 provides the emitter resistance for Q34 to result in a stage gain of 2.5. In the .05 and higher Channel 1 VOLTS/DIV switch positions, the emitter resistance is infinity (open circuit) to produce a gain for this stage of one. As mentioned in the Input Stage discussion, the STEP ATT BAL adjustment is set to provide a zero-volt level at the emitter of Q34 under quiescent conditions. Since there is no voltage difference across the emitter resistance of Q34, changing the emitter resistance does not change the current in the circuit. Therefore, the trace position does not change when switching between the .01, .02 and .05 positions of the Channel 1 VOLTS/DIV switch.

Zener diode D41 along with the network C41-R41 provides a stable, low-impedance voltage source for the emitter of Q44. Diode D30 protects the base-emitter junction of Q44 against reverse breakdown from high negative input voltages. Capacitor C40 provides high-frequency regenerative feedback from the collector to base of Q44 to stabilize this stage. Variable Balance adjustment R35 sets the output DC level of the Feedback Amplifier stage so there is no current flow between the emitters of Q84 and Q94 in the Paraphase Amplifier stage under quiescent conditions. With this configuration, the position of the zero-volt reference trace will not shift as the Channel 1 VARIABLE control is rotated.

Channel 1 Trigger Pickoff

The signal at the collector of Q44 in the Feedback Amplifier stage is connected to the Channel 1 Trigger Pickoff stage through R51. This sample of the Channel 1 input signal provides internal triggering from the Channel 1 signal only. Q53 is connected as an emitter follower to provide isolation between the Channel 1 Input Amplifier and the Sweep Trigger circuits. It also provides a minimum load for the Feedback Amplifier stage and a low output impedance to the Sweep Trigger circuit. The CH 1 Trigger DC Level adjustment R57 provides a zero-volt DC output level to the Sweep Trigger circuit with no signal applied to Channel 1. Output from the Channel 1 Trigger Pickoff stage is connected to the Sweep Trigger circuit through the TRIGGERING Source switch.

Paraphase Amplifier

The output signal from the Feedback Amplifier stage is connected to the Paraphase Amplifier stage. Q84 and Q94 are connected as a common-emitter phase inverter (paraphase amplifer)[2] to convert the single-ended input signal to a push-pull output signal. Gain of this stage is determined by emitter degeneration. As the resistance between the emitters of Q84 and Q94 increases, emitter degeneration increases also, to result in less gain through the stage. GAIN adjustment R80 varies the resistance between the emitters of Q84 and Q94 to set the overall gain of the Channel 1 Input Amplifier. This control is set to provide calibrated vertical deflection factors. Channel 1 VARIABLE control R90 provides variable gain to provide continuously variable deflection factors between the calibrated settings of the Channel 1 VOLTS/DIV switch. The network C78-D78-R77-R78-R79 connected to the base of Q94 provides the same DC level and circuit response in the Channel 1 Input Amplifier as the X9 Gain Stage provides in the Channel 2 Input Amplifier circuit. Vertical position of the trace is determined by Channel 1 POSITION control R60. This control sets the conduction of Q64 and Q74, which controls the quiescent emitter current of Q84 and Q94. The output signal at the collectors of Q84 and Q94 is connected to the Diode Gate stage in the Vertical Switching and Output Amplifier circuit through C84-R84-R85 and C94-R94-R95.

CHANNEL 2 INPUT AMPLIFIER

General

The Channel 2 Input Amplifier circuit is basically the same as the Channel 1 Input Amplifier circuit. Only the differences between the two circuits are described here. Portions of this circuit not described in the following discussion operate in the same manner as for the Channel 1 Input Amplifier circuit (corresponding circuit numbers assigned in the 100 - 199 range). Fig. 3-3 shows a detailed block diagram of the Channel 2 Input Amplifier circuit. A schematic of this circuit is shown on diagram 2 at the back of the manual.

Feedback Amplifier

Basically, the Channel 2 Feedback Amplifier stage operates as described for Channel 1. However, there are several differences. Channel 2 does not have a trigger pickoff circuit. C143 and R143 provide a similar load at the collector of Q144 to that provided by the Channel 1 Trigger Pickoff stage at the collector of Q44. This RC network assures similar response in each channel. Also, Channel 2 has a X10 gain feature which is not contained in Channel 1. Complete operation of this feature is described under X9 Gain Stage.

X9 Gain Stage

The Channel 2 Input Amplifier circuit contains an additional amplifier stage comprised of Q154 and its associated components. The signal at the collector of Q144 in the Channel 2 Feedback Amplifier stage is connected to the X10 GAIN AC switch SW150. When this switch is in the X1 position (pushed in), the X9 Gain Stage establishes the DC level at the base of Q194. The Channel 2 Paraphase Amplifier stage operates in the same manner as described for Channel 1. When the X10 GAIN AC switch is pulled out to the X10 position, the signal from the Channel 2 Feedback Amplifier stage is capacitively coupled to the X9 Gain Stage as well as to the Channel 2 Paraphase Amplifier stage. Amplifier Q154 provides nine times gain for the signal which is connected to its base through R151 and C151. This amplified signal is connected to the base of Q194 in the Channel 2 Paraphase Amplifier stage through R156. Normal gain of the Paraphase Amplifier is one times. The amplified signal

[2] **Lloyd P. Hunter (ed.), "Handbook of Semiconductor Electronics", second edition, McGraw-Hill, New York, pp. 11-94.**

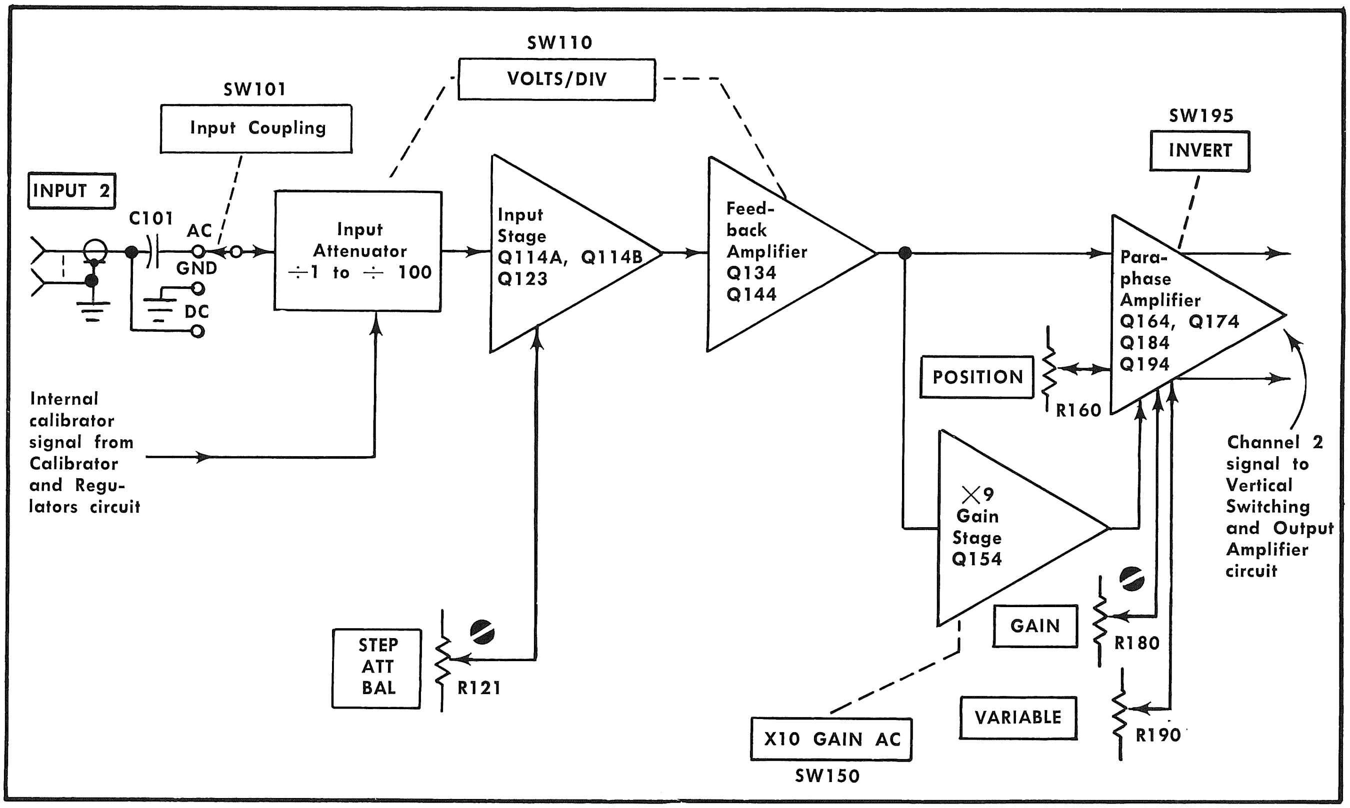


Fig. 3-3. Channel 2 Input Amplifier detailed block diagram.

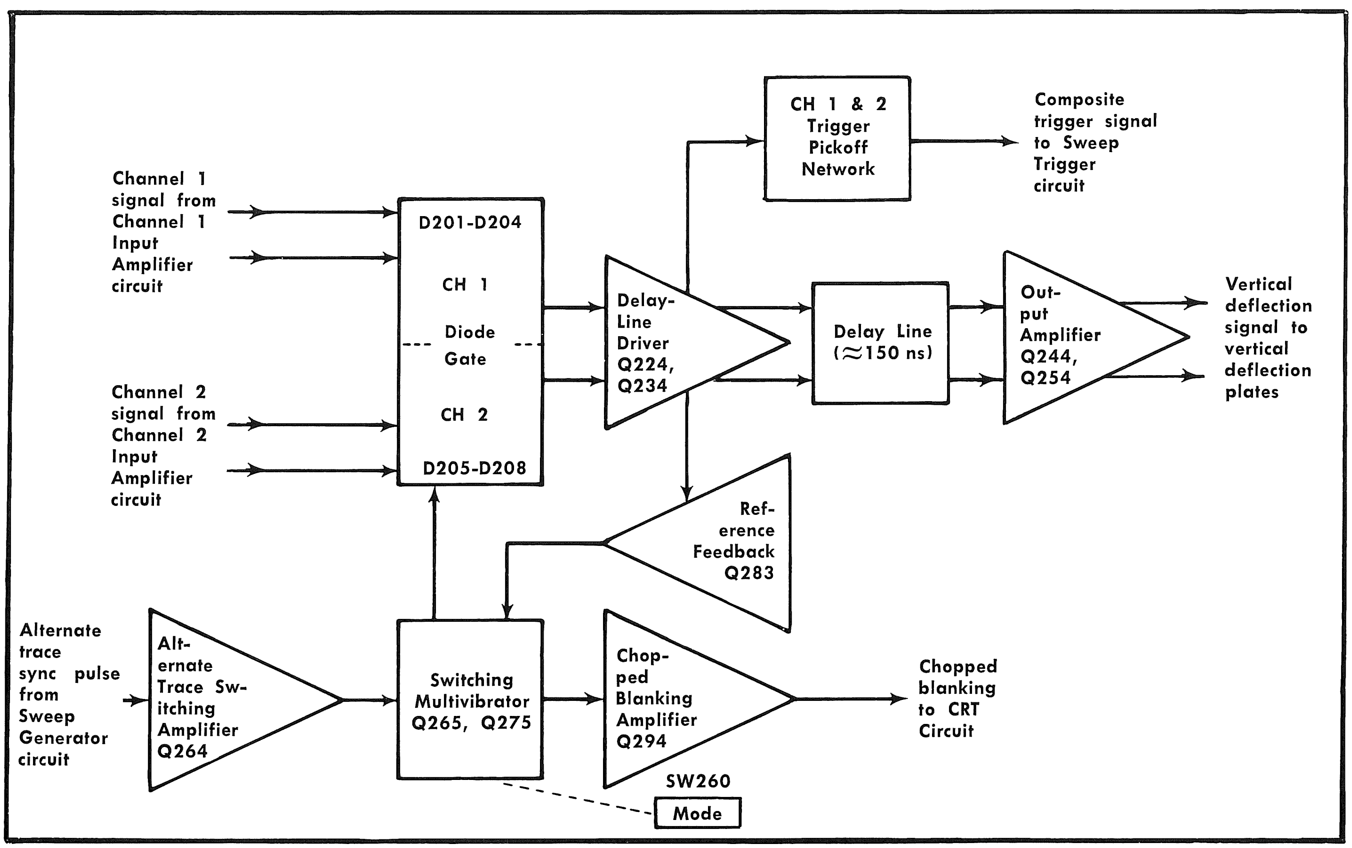


Fig. 3-4. Vertical Switching and Output Amplifier detailed block diagram.

from the X9 Gain Stage (nine times amplification) is algebraically added to the normal signal through the Paraphase Amplifier stage (one times amplification) to provide an output signal at the collectors of Q184 and Q194 which is amplified 10 times. Since the signal connected to the X9 Gain Stage is AC coupled through C151, the DC level of the applied signal is not preserved. Therefore, DC level measurements cannot be made from the CRT display when using this feature.

Paraphase Amplifier

The basic Channel 2 Paraphase Amplifier configuration and operation is the same as for Channel 1 when the X10 GAIN AC switch is pushed in. However, the INVERT switch SW195 is a feature of the Channel 2 circuit. This switch allows the displayed signal from Channel 2 to be inverted when displayed on the CRT.

VERTICAL SWITCHING AND OUTPUT AMPLIFIER

General

The Vertical Switching and Output Amplifier circuit determines whether the Channel 1 and/or Channel 2 signal is displayed on the CRT. This circuit also provides the final amplification for the vertical deflection signal before it is applied to the CRT. Fig. 3-4 shows a detailed block diagram of the Vertical Switching and Output Amplifier circuit. A schematic of this circuit is shown on diagram 4 at the back of the manual.

Diode Gate

The Diode Gates, consisting of four diodes each, can be thought of as switches which allow either of the Input Amplifier output signals to be connected to the vertical Output Amplifier. D201 through D204 control the Channel 1 output and D205 through D208 control the Channel 2 output. These diodes are in turn controlled by the Switching Multivibrator stage for dual-trace displays, or by Mode switch SW260 for single trace displays.

CH 1. In the CH 1 position of the Mode switch, +12 volts is applied to the junction of D206-D207 in the Channel 2 Diode Gate through R273 (see simplified diagram in Fig. 3-5). This forward biases D206-D207 and reverse biases D205-D208 to block the Channel 2 signal so it cannot pass to the Delay-Line Driver stage. At the same time in the Channel 1 Diode Gate, D202-D203 are connected to −12 volts through R265. This voltage holds D202-D203 reverse biased while D201-D204 are forward biased. Therefore, the Channel 1 signal can pass to the Delay-Line Driver stage.

CH 2. In the CH 2 position of the Mode switch, the above conditions are reversed. D202-D203 are connected to +12 volts through R263 and D206-D207 are connected to −12 volts through R275. The Channel 1 Diode Gate blocks the signal and the Channel 2 Diode Gate allows the signal to pass.

Switching Multivibrator

ALT. In this mode of operation the Switching Multivibrator operates as a bistable multivibrator[3]. In the ALT position of the Mode switch, +12 volts is connected to the collector of Alternate Trace Switching Amplifier stage Q264, through R260. Q264 is normally off and the current through R260 passes to the "on" Switching Multivibrator transistor through either D264 or D274. For example, if Q265 is conducting, current is supplied to Q265 through D264. The current flow through collector resistor R265 produces a more positive voltage at the collector of Q265 which is connected to D202-D203 in the Channel 1 Diode Gate. This forward biases D202-D203, and the Channel 1 Diode Gate is blocked as it is for Channel 2 only operation. At the same time, Q275 is reverse biased and its collector drops negative to the voltage set by divider R267-R279-R275. This negative voltage reverse biases D206-D207 in the Channel 2 Diode Gate and allows the Channel 2 signal to pass through the Diode Gate to the Delay-Line Driver stage.

The alternate trace sync pulse is applied to Q264 through R261 and C261. The positive-going sync pulse at the base of Q264 momentarily turns Q264 on to conduct the R260 current away from the Switching Multivibrator stage. This turns off both Q265 and Q275. When Q264 turns off again after the alternate-sync pulse, the charge on C269 and C279 determines whether Q265 or Q275 conducts. For example, with Q265 conducting, the collector of Q275 drops more negative than the collector of Q265. This produces a greater charge on C279 than on C269. This charge is stored by C269 and C279 while Q264 is on. When the current is again applied to the Switching Multivibrator stage after the alternate-sync pulse ends, the greater charge on C279 holds the base of Q265 more positive than the base of Q275. Therefore, Q275 conducts first and its collector rises positive to hold Q265 reverse biased. The multivibrator has switched and the conditions described previously are reversed; now the Channel 2 Diode Gate is reverse biased and the Channel 1 signal passes through the Channel 1 Diode Gate.

The Reference Feedback stage, Q283, provides common-mode voltage feedback from the Delay-Line Driver stage to allow the diode gates to be switched with a minimum amplitude switching signal. The emitter level of Q283 is connected to the collectors of the Switching Multivibrator transistors through D281-R281 and D282-R282. The collector level of the "on" Switching Multivibrator transistor is more positive than the "off" transistor and either D281 or D282 is forward biased. This clamps the anodes of the forward-biased shunt diodes of the applicable Diode Gate about 0.5 volts more negative than the emitter level of Q283. The level at the emitter of Q283 follows the average voltage level at the emitters of the Delay-Line Driver transistors. This configuration clamps the forward-biased shunt diodes near their switching level so they can be switched quickly with a minimum amplitude switching signal. It also maintains about the same current through the Diode Gate shunt diodes so they can be switched with a minimum amplitude switching signal, regardless of the deflection signal at the cathodes of the shunt diodes.

[3]Millman and Taub, pp. 362-389.

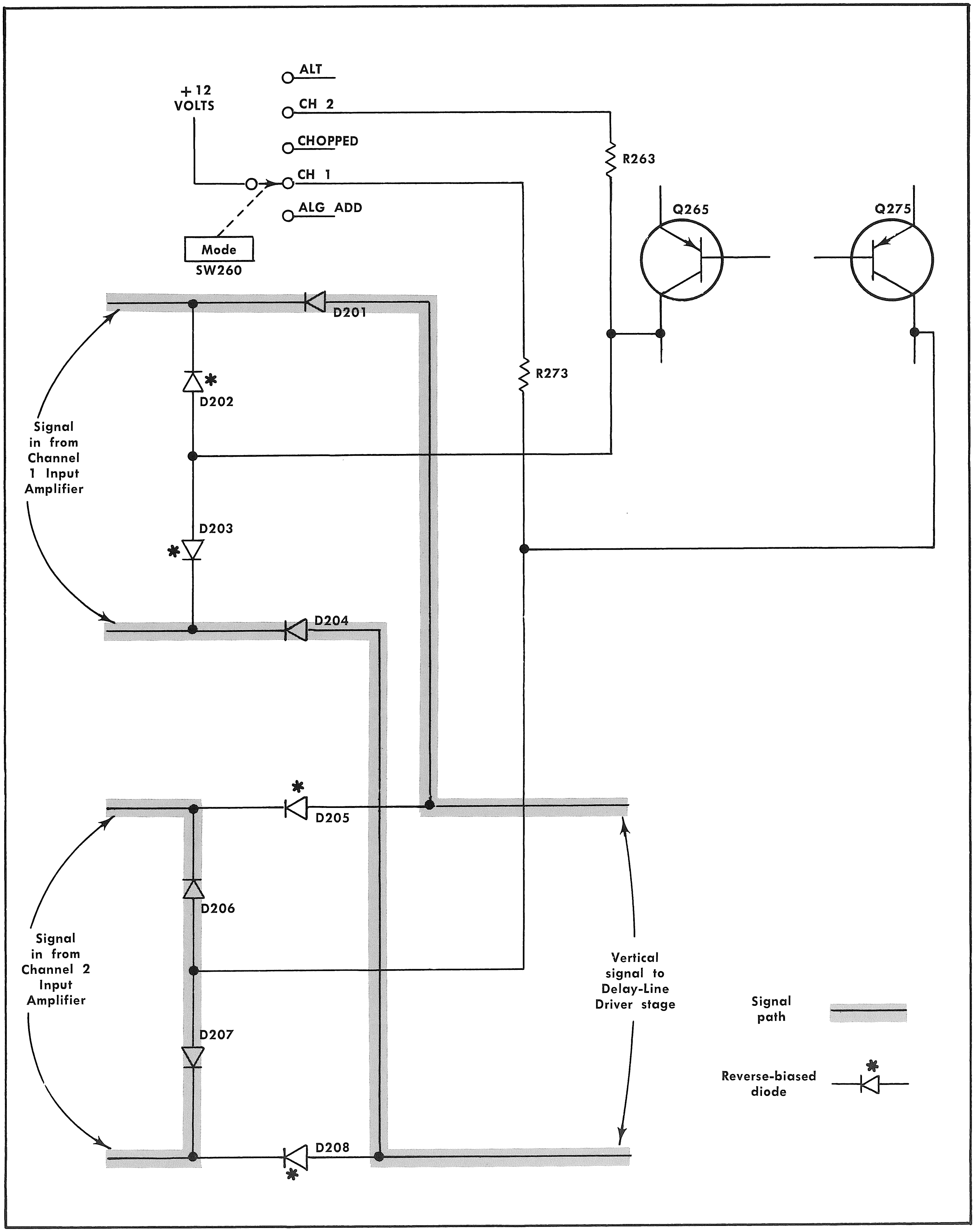


Fig. 3-5. Effect of Diode Gate on signal path (simplified Vertical Switching and Output Amplifier diagram). Conditions shown for CH 1 position of Mode switch.

CHOPPED. In the CHOPPED position of the Mode switch, the Switching Multivibrator stage free runs as an astable multivibrator[4] at about a 150-kilohertz rate. In this mode, the emitters of Q265 and Q275 are connected to +12 volts through R264 or R274. At the time of turn-on, one of the transistors begins to conduct; for example, Q265. Q265 forward biases the Channel 1 shunt diodes to prevent the Channel 1 signal from reaching the Delay-Line Driver stage. At the same time, the Channel 2 Diode Gate passes the Channel 2 signal to the Delay-Line Driver stage.

The frequency-determining components in the CHOPPED mode are C267-R264-R274. Switching action occurs as follows: When Q265 is on, C267 begins to charge toward +12 volts on the Q275 side through R274. The emitter of Q275 also goes toward +12 volts as C267 charges. The base level of Q275 is fixed at a positive point determined by divider R269-R277 between +12 volts and the collector level of Q265. When the emitter voltage of Q275 reaches a level slightly more positive than its base, Q275 conducts. The collector of Q275 goes positive as it conducts, and pulls the base of Q265 positive through divider R279-R267 to turn Q265 off. When Q265 turns off, its collector goes negative to reverse bias the Channel 1 Diode Gate shunt diodes and allow the Channel 1 signal to pass to the Delay-Line Driver stage. Simultaneously, the collector of Q275 goes positive as it turns on to forward-bias the Channel 2 Diode Gate shunt diodes, blocking the Channel 2 signal. C267 begins to charge towards +12 volts again, but this time through R264. The emitter of Q265 goes positive as C267 charges until Q265 turns on. Q275 is turned off as described above to switch the Diode Gate and the cycle begins again.

The Chopped Blanking Amplifier stage Q294 provides an output pulse to the CRT Circuit which blanks out the transition between the Channel 1 trace and the Channel 2 trace. As the Switching Multivibrator changes states, the negative-going step at the emitter of either Q265 or Q275 is connected to Q294 through C266 or C276. The pulse at the base of Q294 turns it off momentarily to produce a positive-going pulse at its collector. The positive-going pulse at the collector of Q294, which is coincident with trace switching, is connected to the CRT Circuit through R295.

ALG ADD. In the ALG ADD position of the Mode switch, the Diode Gate stage allows both signals to pass to the Delay-Line Driver stage. The Channel 1 and Channel 2 Diode Gates are both held on by +12 volts connected to the anodes of the series diodes through R210 and R211. Since both signals are connected to the Delay-Line Driver stage, the output signal is the algebraic sum of the signals on Channel 1 and 2.

Delay-Line Driver

Output signal from the Diode Gate stage is connected to Delay Line Driver stage Q224 and Q234. Q224 and Q234 are connected as feedback amplifiers with R221-R224 and R231-R234 providing feedback from the collector to the base. The delay-line compensation network C227-C228-C237-R227-R228-R237, provides high-frequency compensation for the Delay Line. C237 and R237 are adjustable to provide optimum response. R226 and R236 along with the output impedance of the Delay-Line Driver stage comprise the reverse termination for the Delay Line.

Diodes D210 and D211 clamp the input of the Delay-Line Driver stage if it goes more negative than about 0.5 volts. This clamping action prevents the output transistors of the Channel 1 and Channel 2 Input amplifier circuits from going into saturation during alternate trace switching time. Diodes D213 and D214 connected between the bases of Q224 and Q234 protect the Delay-Line Driver stage from high-amplitude signals by limiting the peak-to-peak voltage difference at the bases of Q224 and Q234 to about one volt. The Common Mode Current adjustment R215 provides a means of adjusting the Q224-Q234 emitter voltage to zero volts. This centers the voltage and current levels in the Delay-Line Driver stage.

CH 1 & 2 Trigger Pickoff Network

The trigger signal for CH 1 & 2 trigger operation is obtained from the collector of Q224. C217-R217-R218-R219 comprise the CH 1 & 2 Trigger Pickoff Network. C217 is adjustable to allow the high-frequency response of the Ch 1 & 2 trigger signal to be matched to the Ch 1 only response. C235 and R235 connected to the collector of Q234 balance the Delay-Line Driver stage by providing the same load at the collector of Q234 as the CH 1 & 2 Trigger Pickoff Network provides at the collector of Q224.

Delay Line

The Delay Line provides approximately 150 nanoseconds delay for the vertical signal to allow the Sweep Generator circuit time to initiate a sweep before the vertical signal reaches the vertical deflection plates of the CRT. This allows the instrument to display the leading edge of the signal originating the trigger pulse when using internal trigger .

Output Amplifier

The vertical signal at the output of the Delay Line is applied to the Output Amplifier through the networks C242-R242 and C252-R252. R242 and R252 along with the input impedance of this stage provide the forward termination for the Delay Line. The Output Amplifier stage provides the final voltage amplification for the vertical deflection signal before it is applied to the vertical deflection plates of the CRT. The signal at the collector of Q244 is connected to the upper vertical deflection plate through L245, and the signal at the collector of Q254 is connected to the lower vertical deflection plate through L255. These inductors are adjustable to provide correct high-frequency response.

SWEEP TRIGGER

General

The Sweep Trigger circuit produces trigger pulses to start

[4] **Millman and Taub, pp. 438-451.**

the Sweep Generator circuit. These trigger pulses are derived either from the internal trigger signal from the vertical deflection system or an external signal connected to the TRIG IN connector. Controls are provided in this circuit to select trigger source, coupling, slope, level and mode. Fig. 3-6 shows a detailed block diagram of the Sweep Trigger circuit. A schematic of this circuit is shown on diagram 5 at the back of the manual.

Trigger Source

The TRIGGERING Source switch SW305 selects the source of the trigger signal. Three trigger sources are available; internal from both channel 1 and 2, internal from channel 1 only, and external. The internal trigger signal is obtained from the vertical deflection system. In the CH 1 & 2 position of the TRIGGERING Source switch, the trigger signal is obtained from the CH 1 & 2 Trigger Pickoff Network in the Vertical Switching and Output Amplifier circuit. This signal is a sample of the displayed channel (or channels for dual-trace operation). Since this trigger signal source follows the Diode Gate stage, the trigger signal in this position also includes the chopped switching transients when operating in the CHOPPED vertical mode. The trigger pickoff for CH 1 & 2 triggering also follows the POSITION control. Therefore, the DC level of the trigger signal in this Source switch position changes as the vertical position of the display is changed.

When the TRIGGERING Source switch is in the CH 1 position, the internal trigger signal is obtained from the Channel 1 Trigger Pickoff stage in the Channel 1 Input Amplifier circuit. This signal is a sample of only the signal applied to the INPUT 1 connector. Since this trigger pickoff precedes the POSITION control, the trigger signal is not affected by changes in vertical position of the display.

External trigger signals applied to the TRIG IN connector can be used to trigger the sweep in the EXT position of the TRIGGERING Source switch. Input resistance at DC is about 100 kilohms paralleled by about 35 picofarads. Variable capacitor C302 provides high-frequency compensation for the external triggering circuit.

Trigger Coupling

The TRIGGERING Coupling switch SW310 offers a means of accepting or rejecting certain frequency components of the trigger signal. In the AC position of the Coupling switch, the DC component of the trigger signal is blocked by coupling capacitors C306 and C309. Frequency components below about 50 hertz are attenuated. In the AC LF REJ position, additional capacitors C305 and C308 are connected in series with C306 and C309 to block DC and attenuate frequency components below about 50 kilohertz. The DC position passes all signals from DC to at least 15 megahertz.

Nonlinear Feedback Amplifier

The trigger signal at the output of the TRIGGERING Coupling switch is connected to the Nonlinear Feedback Amplifier stage through R321. Diodes D320 and D321 limit the input voltage swing to about ±0.5 volts to protect this stage if a high-amplitude signal is inadvertently connected to the TRIG IN connector. Transistors Q323 and Q324 are connected as a feedback amplifier with two parallel feedback paths. When the output voltage swing of this stage is less than about ±0.3 volts, the feedback path is through C353-R353. For higher output voltages, the feedback is through the limiting network C332-C333-D331-D332-D333-D334-R331-R332-R333-R334. The effect of this configuration is a higher gain for low-amplitude signals than for high-amplitude signals. To

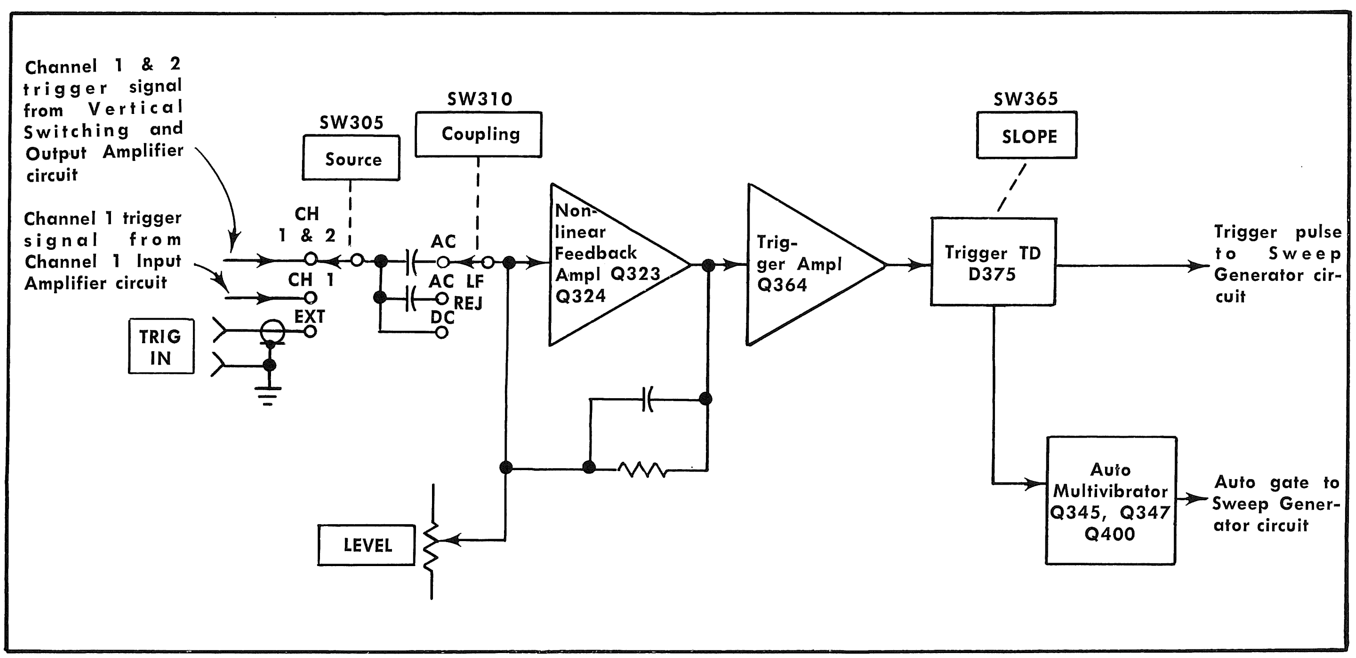


Fig. 3-6. Sweep Trigger detailed block diagram.

understand the action, assume that the trigger signal at the base of Q323 is positive-going. This produces a positive-going signal at the emitter of Q323 which forward-biases Q324, and its collector goes negative. The signal at the collector of Q324 is connected to the Trigger Amplifier stage and the feedback networks through C325-D325. Zener diode D325 reduces the DC level of the output signal without appreciable attenuation of the trigger signal. If the signal is less (lower in amplitude) than about −0.3 volt, negative feedback is provided to the base of Q323 through feedback network C353-R353 to establish a stage gain of about 1.4. Variable capacitor C353 provides high-frequency compensation for this stage.

As long as the output signal is less than about −0.3 volt, the limiting network is effectively disconnected. Diode D331 is reverse biased, since its anode is held at about +0.3 volt by the forward voltage drop of germanium diode D332. Likewise, D334 is reverse biased since its cathode is held at about −0.3 volt by the forward voltage drop of germanium diode D333. When the output signal exceeds about −0.3 volt, silicon diode D331 is forward biased since its anode is held at about +0.3 volt. Negative feedback is now provided to the base of Q323 through C332-R332. Since R332 has a lower resistance than R353, more feedback voltage reaches the base of Q323 to limit the stage gain to about 0.14. This limiting for higher amplitude signals provides about the same output signal from this stage for small input signals as for large input signals. Action is similar for negative-going signals with D334 being forward biased to provide limiting feedback through C333-R333 at about +0.3 volt.

LEVEL control R355A determines the point on the trigger signal where triggering occurs. When the LEVEL control is set near midrange, the output level from this stage is at about zero volts. This results in a CRT display which starts near the zero-volt level of the displayed waveform (near the average DC level for AC trigger coupling). As the LEVEL control is turned clockwise toward + (variable arm of R355A moves toward −12 volts), a more positive voltage level is produced at the output of this stage. This results in a CRT display which starts at a more positive point on the displayed waveform. The action is similar but opposite when the LEVEL control is turned counterclockwise toward −. See the Trigger TD discussion for more detail on how the output level from this stage changes the trigger point on the displayed waveform.

Trigger Amplifier

The output signal from the Non-linear Feedback Ampli fier stage is connected to the base of Trigger Amplifier Q364. Diode D363 provides a reference at the emitter of Q364 of about −0.6 volts. Therefore, as the signal at the base of Q364 goes more negative than about zero volts, the collector current of Q364 is reduced, and vice versa. This output current at the collector of Q364 is in phase with the trigger input signal current at the base of Q323. The output signal from the Trigger Amplifier stage is connected to the Trigger TD stage through the SLOPE switch.

Trigger TD

The Trigger TD stage shapes the output signal from the Trigger Amplifier stage to provide a trigger pulse with a fast leading edge. For positive-slope triggering, the Trigger Amplifier stage operates as a current shunt for tunnel diode[5] D375 (see Fig. 3-7A). The cathode level of tunnel diode D375 is set at about +6.2 volts by zener diode D364. When a positive-going trigger signal is applied to the Sweep Trigger circuit, the output current of the Trigger Amplifier stage decreases. This allows the current through tunnel diode D375 to increase and it switches to its high-voltage state. The reactance of L373 is high as D375 switches, and therefore L373, R373 and T377 do not load D375. This allows a majority of the D375 switching current to reach the Sweep Gate circuit (through T401). R373 establishes the DC bias on tunnel diode D375 and C377 blocks this DC current from flowing in the primary of T401. The tunnel-diode switching signal is connected to the Sweep Generator circuit through transformer T401. Resistor R378 lowers the "Q" of T401 to reduce ringing. Diode D401 in the secondary of T401 allows only the positive-going trigger pulses to pass to the Sweep Generator circuit.

The circuit remains in this condition until the output current of the Trigger Amplifier stage increases due to the applied trigger signal. Then, the Trigger Amplifier stage shunts the current from D375 so that it returns to its low-voltage state. Notice that D375 switches to its high-voltage state in phase with the applied trigger signal. This action results in a CRT display which starts on the positive-going slope of the displayed waveform.

When SLOPE switch SW365 is set to the negative-going position, D375 is effectively inverted in the circuit (see Fig. 3-7B). Now the Trigger Amplifier stage acts as a series current source for tunnel diode D375. The anode of D375 is held at about +6.2 volts by zener diode D364. As the trigger signal applied to the Sweep Trigger circuit goes positive, the output current of the Trigger Amplifier stage decreases and the current through D375 decreases also. Tunnel diode D375 reverts to its low-voltage state, where it remains until the applied trigger signal goes negative. When this occurs, the Trigger Amplifier provides more current through D375 and it switches to its high-voltage state. Notice that for negative-slope triggering, D375 switches to its high-voltage state 180° out of phase with the applied trigger signal. Therefore, the CRT display starts on the negative-going portion of the displayed waveform.

The LEVEL control determines the exact point on the selected slope at which tunnel diode D375 switches to its high-voltage state, and therefore determines the point on the signal where the CRT display begins. The LEVEL control varies the quiescent DC level at the base of Q364 (see Nonlinear Feedback Amplifier discussion), and thus also sets the quiescent current level at the output of the Trigger Amplifier stage. This action occurs as follows (example given for positive-slope triggering): Assume that the LEVEL

[5] **Millman and Taub, pp. 452-455.**

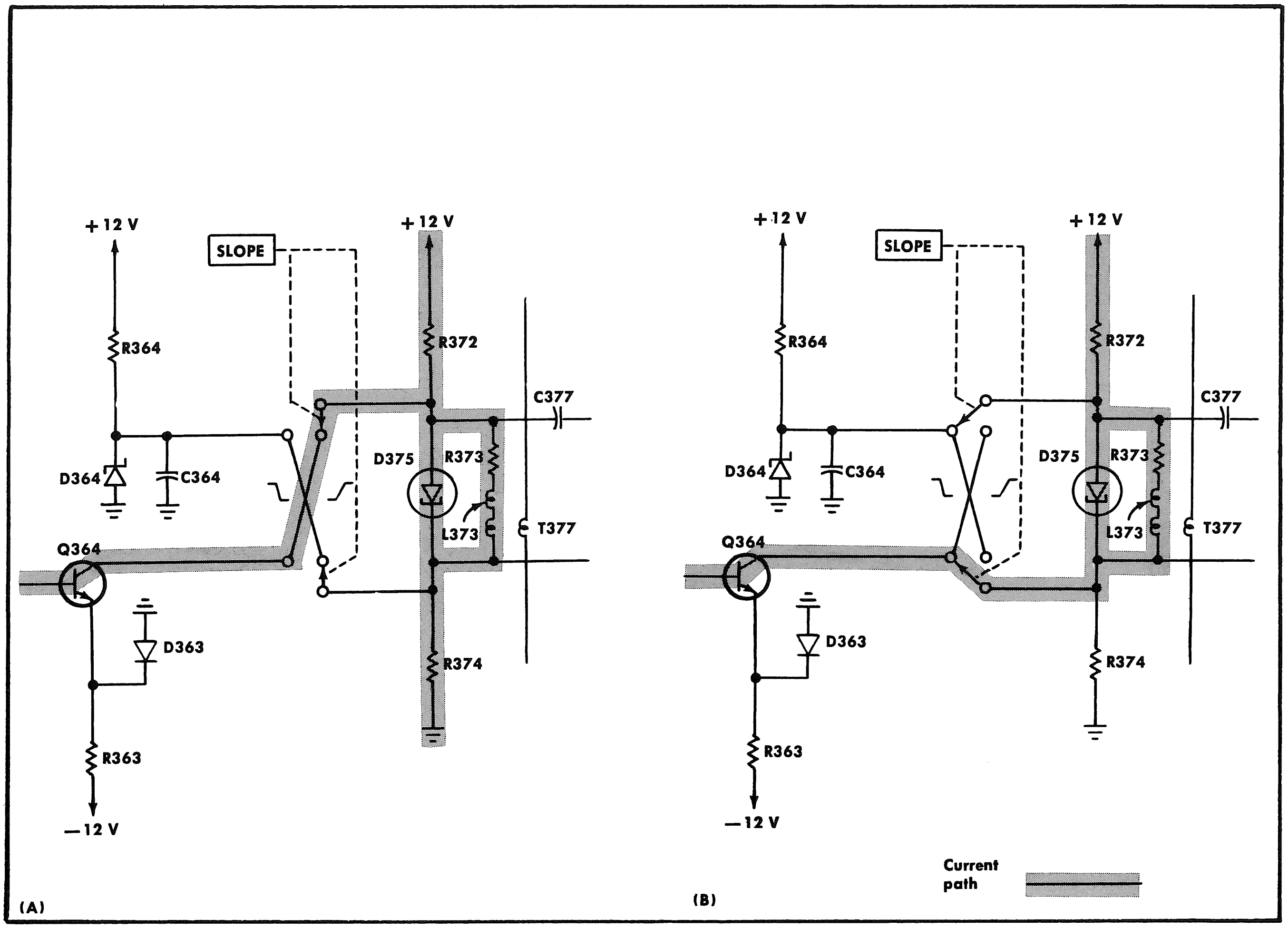


Fig. 3-7. Current path for (A) positive-slope triggering, (B) negative-slope triggering.

control is turned clockwise from midrange to produce a display which starts at a more positive level on the selected slope. When the LEVEL control is turned clockwise toward +, a more positive quiescent DC level is established at the base of Q364 which results in more output current from the Trigger Amplifier stage. Since the Trigger Amplifier stage is operating as a current shunt for positive-slope triggering, the signal at the base of Q364 must go farther negative before enough current returns to the Trigger TD and it can switch to its high-voltage state. Therefore, the resultant CRT display starts at a more positive point on the displayed waveform. When the LEVEL control is turned toward −, the DC level at the base of Q364 goes negative to reduce the quiescent current at the output of the Trigger Amplifier stage. Now, the trigger signal does not have to rise as far positive before D375 switches to its high-voltage state and the resultant CRT display starts at a more negative level on the displayed waveform.

Auto Multivibrators

The basic configuration of the Auto Multivibrator stage is a monostable multivibrator[6] comprised of transistors Q345 and Q347. This stage produces the control gate to the Sweep Generator circuit for auto-trigger operation. Under quiescent conditions (no trigger signal) Q345 is biased on by the positive voltage applied to its base from C342-R340-R342 through T377 and R341. The base of Q347 is referenced to ground through R344, and both diode D344 and transistor Q347 are reverse biased. The collector level of Q347 depends upon the setting of TRIGGERING Mode switch SW355. When this switch is in the AUTO position (pushed in), the level at the collector of Q347, and therefore the output level to the Sweep Generator circuit, is determined by the absence or presence of trigger pulses at the input of this stage. For the quiescent condition, Q347 is off and its collector rises positive to the level determined by voltage divider R348-R402-R407. The base level of Q400 as determined by divider R348-R402-R407 is about +1.5 volts and Q400 is forward biased. The voltage drops across the base-emitter junction of Q400 and across D408 balance out to provide an auto gate output level to the Sweep Generator circuit of about +1.5 volts (this level corresponds to the free running condition of the Sweep Generator; see the discussion on Auto Trigger Mode Operation).

[6]**Millman and Taub, pp. 405-438.**

When a trigger signal is present, a negative-going pulse is connected to the base of Q345 through T377 and R341 as Tunnel Diode D375 switches to its high-voltage state. This negative-going pulse momentarily interrupts the conduction of Q345 and its emitter goes negative. The emitter of Q347 goes negative also. At the same time, the positive-going change at the collector of Q345 is connected to the base of Q347 through RC network C343-R344. Q347 is forward biased and its emitter level rises, forward biasing D346 to provide more emitter current for Q347. The collector of Q347 drops negative to charge capacitor C400 (through R400) to the level at the collector of Q347. The voltage at the base of Q400 as determined by divider R402-R407 between the collector level of Q347 and −12 volts is negative enough to reverse bias Q400, since its emitter is clamped at about −0.3 volt by D407. The 0.6-volt forward drop across D408 sets an output level to the Sweep Generator circuit of about +0.3 volt. This level allows a triggered sweep to be produced. As C343 charges, the base current of Q347 is reduced and its emitter voltage level goes negative. Diode D346 is reverse biased and Q345 turns on as the emitter level of Q347 drops to about zero volts. As Q345 turns on, its collector goes negative and this negative-going change is connected to the base of Q347 through C343. Q347 is turned off completely and its collector goes positive to allow C400 to charge. Diode D344 clamps the base of Q347 at about −0.6 volt to prevent base-emitter breakdown as C343 discharges. When C343 is discharged, D344 is reverse biased and the base of Q347 returns to about zero volts.

If the Auto Multivibrator does not receive another trigger pulse, C400 charges to a level which allows Q400 to return to conduction in about 50 to 100 milliseconds. Then, Q400 is biased on again to produce a positive auto gate level for a free-running sweep. This also occurs if the trigger signal repetition rate is less than the recharge time of C400. However, if a repetitive trigger signal is received before C400 is recharged to the level that allows Q400 to turn on, Q347 turns on and discharges C400 completely so it starts its recharge cycle again. Since Q400 remains reverse biased, the auto gate level remains negative to allow a triggered sweep to be produced as long as a trigger signal is available to the Sweep Generator circuit. More information on AUTO Mode triggering is given under Auto Trigger Mode Operation in the Sweep Generator discussion.

When TRIGGERING Mode switch SW355 is in the NORM position, the collector of Q347 is held at ground potential regardless of the trigger signal or the condition of the Auto Multivibrator stage. This places a bias level of about −3 volts on the base of Q400. Since its emitter is clamped at about −0.3 volt by D407, Q400 is reverse biased. The 0.6 volt drop across D408 when it is forward biased after sweep holdoff time sets an output level to the Sweep Generator circuit of about +0.3 volt.

SWEEP GENERATOR

General

The Sweep Generator circuit produces a sawtooth voltage which is amplified by the Horizontal Amplifier circuit to provide horizontal sweep deflection on the CRT. This output signal is generated on command (trigger pulse) from the Sweep Trigger circuit. The Sweep Generator circuit also produces an unblanking gate to unblank the CRT during sweep time. In addition, this circuit produces an alternate sync pulse for the vertical deflection system and a gate out signal at the front panel. Fig. 3-8 shows a detailed block diagram of the Sweep Generator circuit. A schematic of this circuit is shown on diagram 5 at the back of the manual.

The TRIGGERING Mode switch allows two modes of operation. In the NORM position (LEVEL control pulled out), a sweep is produced only when a trigger pulse is received from the Sweep Trigger circuit. Operation in the AUTO position (LEVEL control pushed in) is much the same as for NORM except that a free-running trace is displayed when a trigger signal is not present, when the trigger repetition rate is too low or when the amplitude of the trigger signal is not adequate. The following circuit description is given for operation in the NORM mode. Differences in operation for the AUTO mode are discussed later.

Normal Trigger Mode Operation

Sweep Gate. The positive-going trigger pulse generated by the Sweep Trigger circuit is applied to the Sweep Gate stage. Tunnel diode D405 is quiescently biased in its low-voltage state. When the positive-going trigger pulse is applied to its anode, the current through D405 increases and it rapidly switches to its high-voltage state, where it remains until reset at the end of the sweep. The positive-going change at the anode of D405 is connected to the base of Q414 through C405-R405 and Q414 goes into saturation (collector drops to ground). Collector current for Q414 is supplied from R415 (through R414), which also supplies emitter current for Q424 and Q434. Capacitor C418 couples the fast changes at the collector of Q414 directly to the collector circuit of Q424 to insure that the sweep starts quickly when triggered. The negative-going voltage at the collector of Q414 is also connected to the Unblanking Circuit.

Unblanking Circuit. The negative-going gate pulse from the Sweep Gate stage is connected to the base of Q473 through divider R471-R472. Capacitor C471 provides frequency compensation for the divider so the signal applied to the base of Q473 maintains a fast rise. The collector level of Q473 is set at about −6.2 volts by zener diode D474. The negative-going gate pulse forward biases Q473 and its emitter goes negative. This signal is connected to the CRT Circuit through C477-R477 as an unblanking gate signal to unblank the CRT during sweep time so a sweep can be displayed. It is also connected to the GATE OUT connector on the front panel through D479, R479 and R478 to provide a gate signal coincident with the sweep. External signals can be connected to the front-panel EXT BLANKING connector to blank portions of the displayed waveform. Diode D476 allows only the positive signals to pass to the CRT Circuit. Diode D479 blocks the EXT BLANKING signal from the GATE OUT connector.

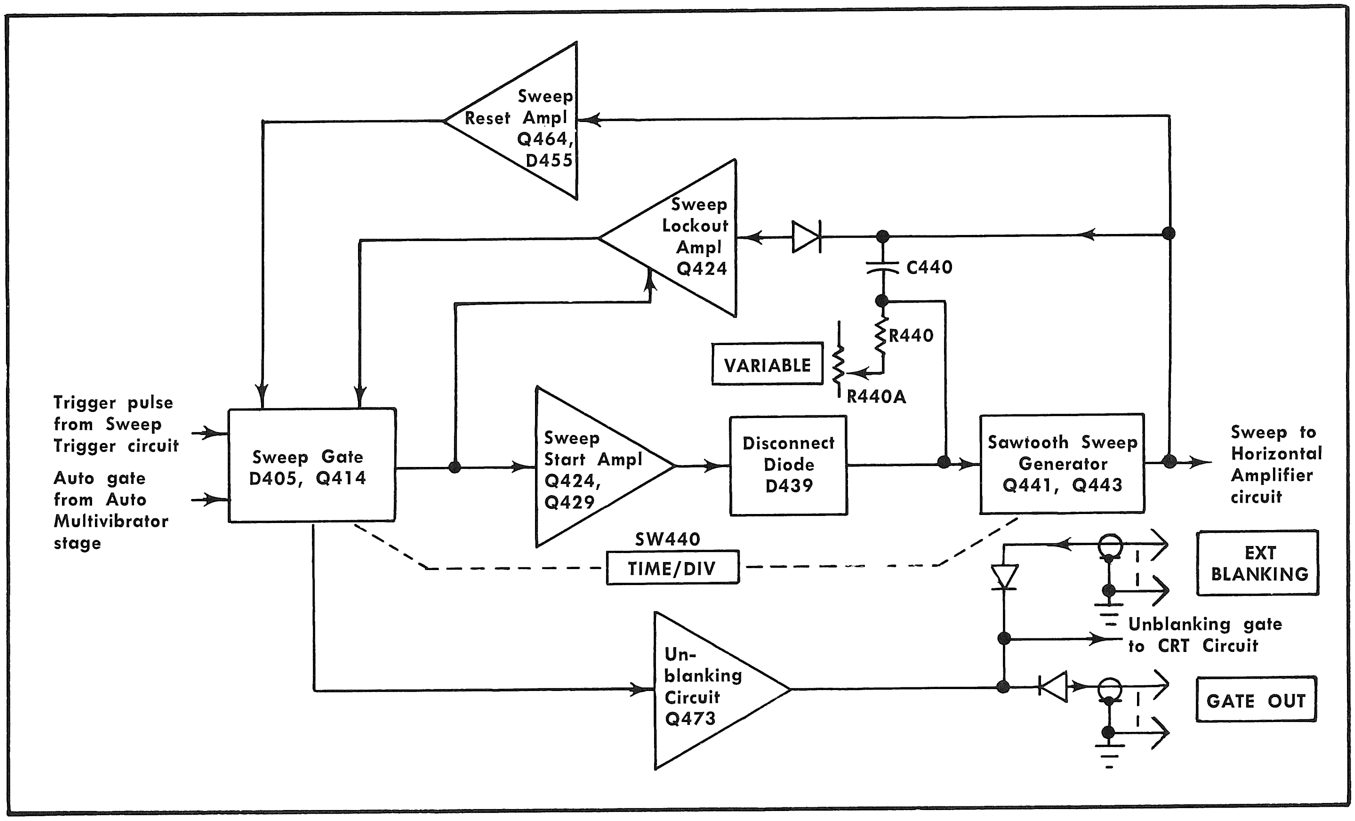


Fig. 3-8. Sweep Generator detailed block diagram.

The sweep gate signal from the collector of Q414 is also connected to the Vertical Switching and Output Amplifier circuit through R470. This signal provides an alternate sweep pulse to switch the vertical channels at the end of each sweep.

Sweep Start Amplifier. Before this circuit is triggered, Sweep Start Amplifier Q424 is quiescently conducting through R415, R423 and L423. The current through R424 raises the collector level of Q424 positive to forward bias Disconnect Diode D439. Transistor Q429 sets a constant voltage at the base of Q424 to establish the quiescent levels in the Sweep Start Amplifier, Disconnect Diode, Sawtooth Sweep Generator, Sweep Reset Amplifier and Sweep Lockout Amplifier stages. This constant voltage insures that the sweep starts at the same point each time (see Sweep Reset Amplifier discussion for further details). When the sweep gate signal from Q414 turns Q424 (and Q434) off upon receipt of a trigger, the collector of Q424 goes negative toward the −12-volt supply through R424. However, when the collector level of Q424 reaches about −2.2 volts, D438 is forward biased to clamp the circuit at this level.

Disconnect Diode. The Disconnect Diode D439 is quiescently conducting current through timing resistor R440 and R442. This prevents timing current from timing resistor R440 from charging timing capacitor C440. The sweep gate signal from the Sweep Start Amplifier reverse biases D439 and interrupts the quiescent current flow. Now the timing current through the timing resistor begins to charge timing capacitor C440 so the Sawtooth Sweep Generator stage can produce a sawtooth output signal. The fast rising portion of the sweep gate signal produced by the action of C418 reduces the switching time of D439, which improves the timing linearity at the start of the sweep.

Sawtooth Sweep Generator. The basic sweep generator circuit is a Miller Integrator circuit[7]. When the current flow through the Disconnect Diode is interrupted by the gate signal, timing capacitor C440 begins to charge negatively on the R440-R442 side through timing resistor R440. As the timing capacitor charges toward the voltage applied to the timing resistor, the gate of FET Q443 goes negative also. This produces a negative-going output voltage at the source of Q443 which is connected to the base of Q441. Q441 amplifies and inverts the voltage change at its base to produce an amplified positive-going sawtooth output. To provide a linear charging rate for the timing capacitor, the sweep output signal is connected to the positive side of C440. This feedback opposes any tendency for a voltage at the gate of Q443 to change, so the resultant change at the gate of Q443 is actually very small. Therefore, the charging current through R440 to C440 remains constant to produce a linear sawtooth output signal. The output voltage continues to rise in a positive direction until the circuit is reset through the Sweep Reset Amplifier stage. The output signal from the collector of Q441 is connected to the Horizontal Amplifier circuit.

[7]**Millman and Taub, 540-548.**

Time/Div Switch. The timing capacitor and resistor are selected by the TIME/DIV switch to provide the various sweep rates listed on the front panel. Diagram 7 shows a complete diagram of the TIME/DIV switch. VARIABLE TIME/DIV control R440A (see Timing Switch diagram) provides continuously variable, uncalibrated sweep rates between the calibrated settings by varying the charge rate of the timing capacitor.

Sweep Reset Amplifier. The positive-going sawtooth signal at the collector of Q441 is connected to tunnel diode D455 through voltage divider R451-R452. D455 is quiescently biased in its low-voltage state. As the sawtooth output level reaches about +30 volts, the voltage level connected to the anode of D455 rises positive enough to switch D455 to its high-voltage state. The positive voltage change at the anode of D455 as it switches is connected to Q464 through R456 and Q464 goes into saturation (collector drops to ground). This results in less current to tunnel diode D405 and it reverts to its low-voltage state. The base of Q414 also goes negative and it turns off to allow Q424 to return to conduction. When Q424 turns on, its collector rises positive and Disconnect Diode D439 is forward biased to quickly discharge timing capacitor C440 through R442. This produces the retrace portion of the sawtooth signal. Transistor Q464 turns off as tunnel diode D455 reverts to its low-voltage state along with the negative-going retrace. The Sawtooth Sweep Generator stage is now ready to produce another sweep as soon as tunnel diode D405 is enabled after the hold-off period and a trigger pulse is received. The positive-going change at the collector of Q414 is also connected to the Unblanking Circuit so the CRT is blanked during retrace time.

Sweep Lockout Amplifier. Quiescently before the sweep is triggered, Q424 and Q434 are both conducting and their emitter current is supplied through R415. The collector of Q434 is held at about +0.3 volt as determined by the auto gate level from the Sweep Trigger circuit (see Auto Multivibrator discussion). The sweep gate from Q414 diverts the current from R415 at the start of the sweep and both Q424 and Q434 turn off. In addition, the positive-going sawtooth output reverse biases D430 to interrupt the base-current path for Q434. The collector of Q434 goes negative toward −12 volts through R454 and this negative level at the collector of Q434 holds D401 reverse biased through R401 and T401 (see Sweep Trigger circuit) to prevent incoming trigger pulses from reaching tunnel diode D405. The circuit remains in this condition until the sweep gate from Q414 goes positive at the end of the sweep. Then, the current from R415 is again available to Q424 and Q434. Q424 is forward biased, but Q434 remains off since D430 is held reverse biased by the positive sawtooth level at the output of this circuit. Therefore, most of the current available from R415 flows through Q424, producing the retrace portion of the sawtooth. As the sawtooth at the output of this circuit drops negative to its quiescent level, D430 is forward biased as its cathode drops about 1.2 volt more negative than the level at the emitter of Q434. Then, Q434 is forward biased and its collector attempts to rise positive. However, the RC networks C432-R432 and C434-R434 along with capacitor C401 delay the voltage change at the collector of Q434 to allow a hold off period for all circuits to return to their original conditions before the next sweep is produced. As these capacitors charge, the anode level of D401 rises along with the collector of Q434 until it again can allow the positive-going trigger pulses to pass.

Auto Trigger Mode Operation

Operation of the Sweep Generator circuit in the AUTO position of the TRIGGERING Mode switch (LEVEL control pushed in) is the same as for NORM when a trigger pulse is present. However when a trigger pulse is not present, a free-running reference trace is produced in the AUTO mode. This occurs as follows (refer to the Sweep Trigger diagram for reference to the Auto Multivibrator, C401, R401 and D402):

The auto gate level from the Auto Multivibrator stage is connected to the collector of Q434. When the instrument is triggered, the auto gate level from the Auto Multivibrator stage is held at about zero volts and the sweep is produced and reset as just described for NORM operation. However, when a trigger pulse is not available, the auto gate level rises positive to about +1.5 volts. Now, when the sweep is reset and Q434 turns on, its collector attempts to rise positive toward +1.5 volts as the holdoff network charges. Diode D402 bypasses C401-D401-R401-T401 and connects the collector level of Q434 directly to the anode of D405. The more positive collector level for Q434 set by the auto gate allows more current to flow through Sweep Gate tunnel diode D405, so that it switches to its high-voltage state and automatically retriggers the sweep. Therefore, the Sweep Generator circuit is automatically retriggered at the end of each holdoff period and a free-running sweep is produced. Since the sweep free runs at the sweep rate of the Sweep Generator as selected by the TIME/DIV switch, a bright reference trace is produced even at fast sweep rates.

External Horizontal Operation

When the TIME/DIV switch is in the EXT HORIZ position, the Sweep Generator circuit is disabled so it cannot produce a sweep. In the EXT HORIZ position, the TIME/DIV switch connects −12 volts to tunnel diode D405 through D403 and R403. This holds D405 reverse biased so it cannot accept the applied trigger pulses. At the same time, a negative unblanking level is connected to the CRT circuit through diode D404 so the external horizontal display can be presented. In all other positions of the TIME/DIV switch, both D403 and D404 are held reverse biased by the positive voltage applied to their cathodes through R404.

HORIZONTAL AMPLIFIER

General

The Horizontal Amplifier circuit provides the output signal to the horizontal deflection plates of the CRT. In all positions of the TIME/DIV switch except EXT HORIZ, the horizontal deflection signal is a sawtooth from the Sweep Generator circuit. In the EXT HORIZ position, the hori-

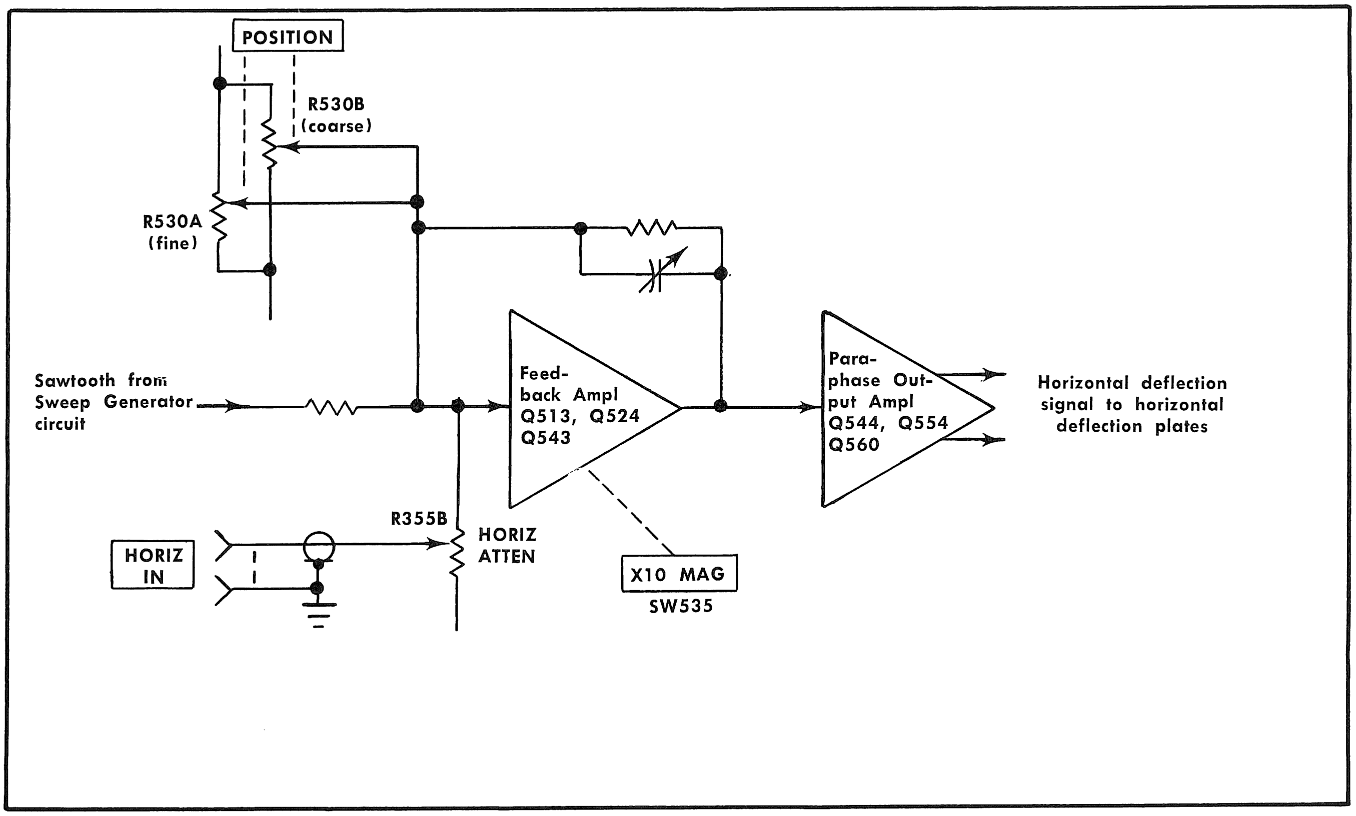


Fig. 3-9. Horizontal Amplifier detailed block diagram.

zontal deflection signal is an external signal applied to the HORIZ IN connector. In addition, this circuit contains the horizontal magnifier circuit and the horizontal positioning network. Fig. 3-9 shows a detailed block diagram of the Horizontal Amplifier circuit. A schematic of this circuit is shown on diagram 8 at the back of this manual.

Feedback Amplifier

The input sigr or the Horizontal Amplifier circuit is selected by the TIME/DIV switch SW440. In all positions of the TIME/DIV switch except EXT HORIZ, the sawtooth from the Sweep Generator circuit is connected to the base of Q513 through C511-R511 and R512. C511 provides high-frequency compensation to improve sweep linearity at fast sweep rates. Sweep Cal adjustment R512 is part of a current divider which determines the sawtooth current applied to the base of Q513. R512 is adjusted to provide calibrated horizontal sweep rates.

Horizontal POSITION control R530A and R530B sets the quiescent DC output level at the emitter of Q543 to determine the horizontal position of the CRT display. This control is a dual-range control to provide a combination of coarse and fine adjustment in a single control. When the control is rotated, fine control R530A provides positioning for a range of about 0.5 division for normal sweep or five divisions for magnified operation. Then after the fine range is exceeded, the coarse control R530B provides rapid positioning of the trace.

For EXT HORIZ operation, an external signal connected to the HORIZ IN (TRIG IN) connector is applied to the base of Q513 through R501, R355B and R510-R512. The HORIZ ATTEN control R355B (TRIGGERING LEVEL) provides about 10:1 variable attenuation for the external horizontal signal. For external horizontal operation, the Sweep Generator circuit is disabled so there is no sawtooth input. The TIME/DIV switch connects a positioning voltage to the base of Q513 through R516 and R515 in the EXT HORIZ position. This voltage positions the external horizontal display near the center of the display area horizontally when the horizontal POSITION control is centered.

Transistors Q513, Q524 and Q543 are connected as a feedback amplifier with capacitive feedback from the collector of Q524 and resistive feedback from the emitter of Q543. Diode D512 in the base circuit of Q513 limits the positive signal change at the base of Q513 to about +0.6 volt. Diode D513 protects Q513 from reverse-voltage damage and D524 prevents Q543 from going into saturation when overdriven (X10 magnification). For X1 magnification (X10 MAG switch pushed in) the resistive feedback through the parallel paths of R537 and R527 sets the gain of the stage so the horizontal deflection on the CRT is calibrated (with correct adjustment of Sweep Cal R512). The bias network R535-R536 determines the center-screen DC level at the emitter of Q543. Mag Register adjustment R535 in this network is set so tnis center-screen voltage is the same for X1 magnification as for X10 magnification

(X10 MAG switch pulled out). Variable capacitor C537 provides high-frequency compensation for a linear display (X1 operation) at fast sweep rates. When the X10 MAG switch is pulled out, resistive feedback is provided only through R527 and capacitive feedback through C527-C528. The feedback for X10 operation is about 1/10th that for X1 operation so the circuit gain is increased 10 times. Variable capacitor C527 provides high-frequency compensation for a linear X10 magnified display at fast sweep rates.

Paraphase Output Amplifier

The output signal from the Feedback Amplifier is connected to the base of Q544. Transistors Q544 and Q554 are connected as a paraphase amplifier to convert the single-ended input to a push-pull output signal which is necessary to drive the horizontal deflection plates of the CRT. Circuit operation is as follows: The positive-going sawtooth from the Sweep Generator (or positive-going external horizontal signal) is amplified and inverted through the Feedback Amplifier stage to provide a negative-going signal at the base of Q544. This negative-going signal at the base of Q544 reduces its conduction and its collector goes positive. This produces a positive-going sawtooth output signal at the collector of Q544 which is connected to the right deflection plate of the CRT.

Transistor Q560 is connected as a constant current source for Q544-Q554 with its output current determined by divider R564-R565 and emitter resistor R562. When the current through Q544 is reduced, more current is available to Q554 through C556-R556. This increase in current forward biases Q554, which is connected as a common-base stage. The increase in current through Q554 produces a negative-going sawtooth at its collector which is connected to the left deflection plate of the CRT. Thus the single ended input signal has been amplified and is available as a push-pull output signal.

CALIBRATOR AND REGULATORS

General

The Calibrator and Regulators circuit provides a square-wave output with accurate amplitude. This output is available at the CALIBRATOR jack on the front panel or it is internally connected to the vertical deflection system in the CALIBRATE 4 DIVISIONS positions of both VOLTS/DIV switches. This circuit also contains two regulator circuits to provide regulated outputs of +10.5 and −81 volts. In addition, this circuit provides the interconnections between the power supply unit and the indicator and includes the voltage sources for the VARIABLE control UNCAL lights. Fig. 3-10 shows a detailed block diagram of the Calibrator and Regulators circuit. A schematic of this circuit is shown on diagram 10 at the back of this manual.

Calibrator

Transistors Q765 and Q775 are connected as an astable multivibrator. Frequency of operation is about one kilohertz. Circuit operation is as follows: Assume that Q765 has just turned off and Q775 turned on. While Q765 was on, C760 charged negatively on the Q765 side to a level which is about 0.6 volt more positive than the emitter level of Q765. Now with Q765 off, C760 discharges toward +12 volts through R760. As C760 discharges, the anode of D760 follows and when it reaches a level about 1.2 volts more positive than the base level of Q765 (as established by divider R765-R773), Q765 is forward biased. As Q765 turns on, its collector rises positive and pulls the base of Q775 positive through R763. Q775 turns off and its collector drops negative to about −6.5 volts to reverse bias D780. With D780 reverse biased, the voltage across output divider R786-R787 is determined by the voltage applied to it through D782 from R780-R781 and the −81-volt supply. Calibrator Amplitude adjustment R780 is adjusted to provide an accurate two-volt peak-to-peak square-wave signal at the CALIBRATOR jack on the front panel. This also pro-

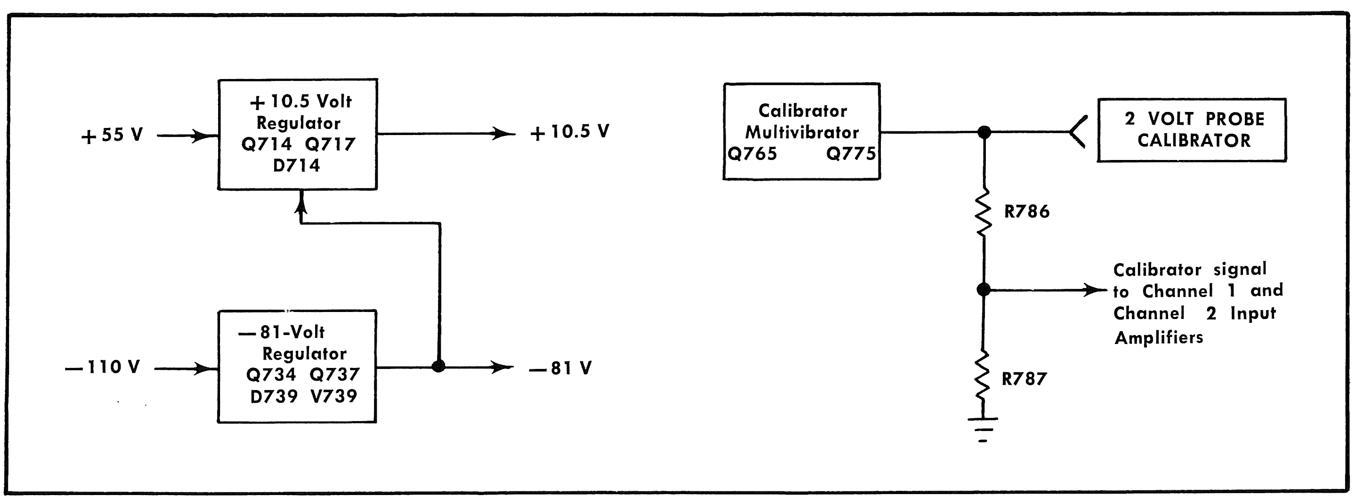


Fig. 3-10. Calibrator and Regulators detailed block diagram.

duces a 200-millivolt internal signal to the vertical deflection system.

At the time Q775 turned off, C760 was charged negatively on the Q775 side and it begins to discharge toward +12 volts through R770. When it reaches a level about 1.2 volts more positive than the base of Q775 (as determined by divider R763-R775) Q775 is forward biased and it turns Q765 off through R773. The collector of Q775 rises positive and forward biases diode D780 to shunt the R780-R781 current away from the output divider. Diode D782 is reverse biased and there is no voltage across the output divider. Therefore, the voltage level of both outputs rises to zero volts. The cycle has been completed and now C760 begins to discharge through R760 to start the next cycle.

−81-Volt Regulator

SN 28000 and up. The regulating circuit for the −81-volt power supply is basically a feedback amplifier. Zener diode D730 provides a 6.2 volt reference voltage that is applied to the amplifier input resistance comprised of R731 and R732. Variable resistor R732 adjusts the amplifier gain, thereby adjusting the output voltage level. D734 sets the level at the base of Q734 at or near zero volts. Any deviations in the −81 volt output level are coupled back to the base of amplifier Q734 by C733-R733. The amplified and inverted error signal at the collector of Q734 controls the output level of the power supply through emitter follower Q735 and zener diode D736. Emitter follower Q737 is a series regulator for the power supply output voltage. Field effect transistor Q736 acts as a relatively high-impedance current source for the Q734-Q735 circuitry.

SN 20000 thru 27999. Unregulated −110 volts from the power supply provides the negative voltage source for the −81-Volt Regulator stage. This voltage is connected to the emitter of Q734 through R733 and to the base of Q734 through zener diode D739. D739 holds the forward base-emitter voltage drop of Q734 constant so Q734 operates as a constant current source for voltage-regulator tube V739. The voltage drop of V739 is 81 volts and along with the forward drop of diode D735, it sets a level of about −81.6 volts at the base of Q737. The base-emitter drop of Q737 produces an output voltage of −81 volts at the emitter of Q737. Due to the constant-current action of transistor Q734 and zener diode D739 and the constant-voltage action of voltage regulator V739, the output voltage level is held very stable.

+10.5-Volt Regulator

Reference voltage for the +10.5-Volt Regulator stage is provided by the −81-Volt Regulator. Transistors Q714 and Q717 operate as a feedback-stabilized voltage regulator circuit to maintain a constant +10.5 volt output level. At time of turn on, circuit operation is as follows: Positive voltage from the +55-volt supply provides current to the base of Q717 through R716 and R715. Q717 is forward biased and its emitter rises positive, following the voltage at its base. The voltage at the base of Q714 also rises positive until it reaches about +0.6 volt; then Q717 is forward biased and the resulting collector current through R714-R715-R716 offsets the base current of Q717 from the +55-volt supply to stabilize the circuit voltages at this point.

The output of this supply is stabilized at +10.5 volts by the feedback through Q714 to oppose changes due to the load or due to ripple from the unregulated +55-volt supply. For example, if the output voltage at the emitter of Q717 attempts to rise further positive, more current flows through Q714 (forward bias of Q714 increases through R712-R718). This increase in collector current from Q714 reduces the base current of Q717 so that it conducts less. Thus Q717 provides less current to the load and the output voltage returns to +10.5 volts. Likewise, if the output voltage at the emitter of Q717 begins to fall below +10.5 volts, the feedback through Q714 allows more current to flow through Q717 to raise its emitter voltage to +10.5 volts. Zener diode D714 holds the junction of R715-R716 at a level about 22 volts more positive than the output level of this supply. This action provides a stable source voltage for Q714 and Q717 to reduce the ripple due to the +55-volt source. Diode D718 provides temperature conpensation for this stage.

Other Functions

The circuitry shown on the Calibrator and Regulators diagram also includes the voltage interconnections between the power supply unit and the indicator. Neon bulb B728 receives voltage from the power supply unit to indicate when the POWER switch is on. SCALE ILLUM control R725 controls the current through B725 and B726 to control the illumination of the graticule lines on the CRT. Neon bulbs B741, B743 and B745 provide indication of uncalibrated conditions in the Channel 1 Input Amplifier, Channel 2 Input Amplifier and Sweep Generator circuits respectively. SW741, SW743 and SW745 apply voltage to the respective UNCAL lights when the associated VARIABLE control is not in the CAL position.

CRT Circuit

General

The CRT Circuit provides the high-voltage and control circuits necessary for operation of the cathode-ray tube (CRT). Fig. 3-11 shows a detailed block diagram of the CRT circuit. A schematic of this circuit is shown on diagram 10 at the back of this manual.

High-Voltage Multipliers and High-Voltage Regulator

The drive signal for the primary of high-voltage transformer T801 is obtained from the associated power supply. The frequency of this drive signal is about 20 kilohertz. When connected to the AC-DC Power Supply, the drive signal is connected to the two halves of the T801 primary

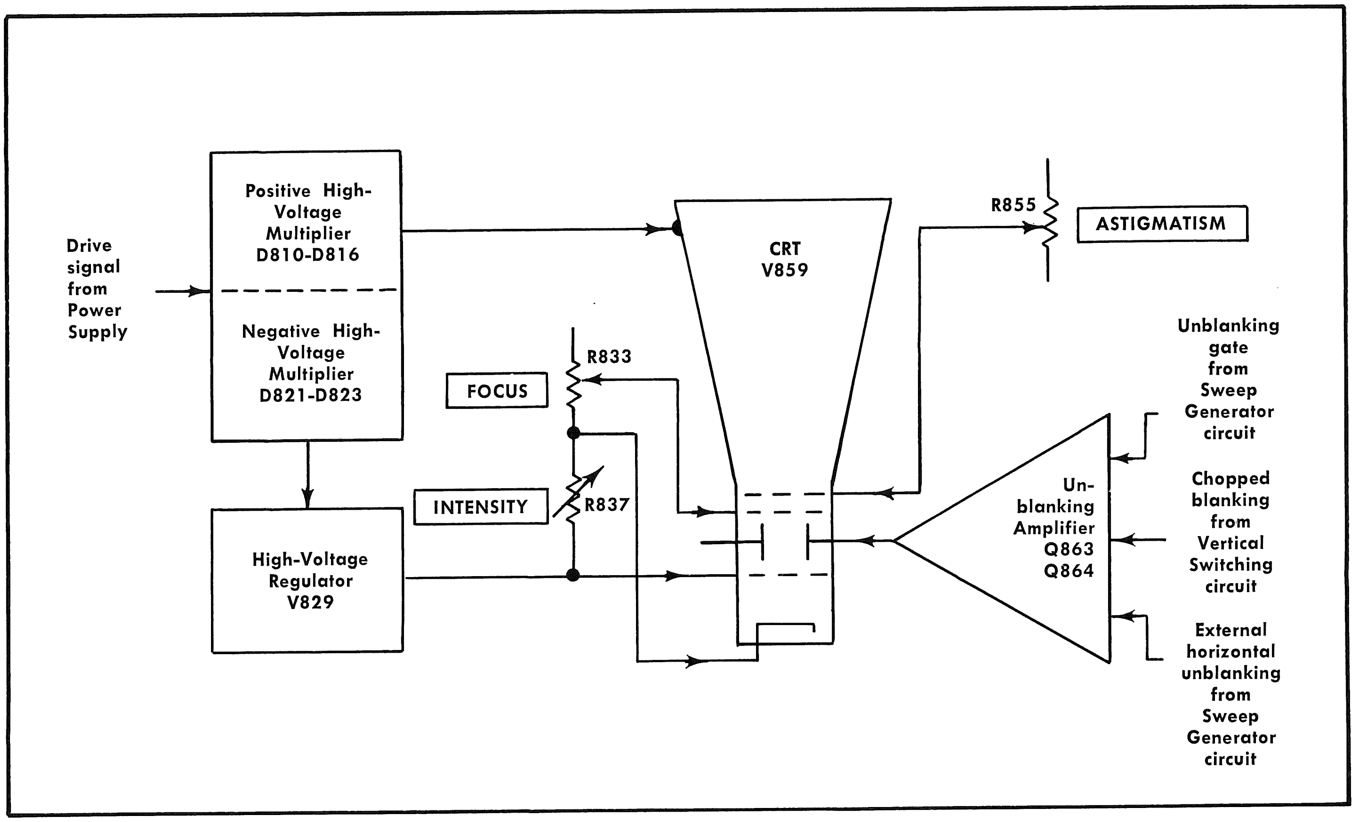


Fig. 3-11. CRT Circuit detailed block diagram.

in parallel. Terminals 1 and 4 are connected together and terminals 3 and 6 are connected together. The output across the secondary of T801 at terminals 7 and 8 is about 700 volts peak. This output becomes the source voltage for two voltage-multiplier circuits to produce the positive and negative accelerating potential for the CRT.

Diodes D810-D811-D812-D813-D814-D815-D816 along with capacitors C810-C811-C812-C813-C814-C815-C816 form a voltage pentupler multiplier[8] network to provide a positive accelerating potential of about +4900 volts at the CRT anode. Ground return for this supply is through the resistive helix inside the CRT to pin 5, and then to ground through R844. Diodes D821-D822-D823 along with capacitors C821-C822-C823 form a voltage tripler multiplier network to provide the negative accelerating potential. The output of the Negative High-Voltage Multiplier is regulated by the High-Voltage Regulator V829 and connected to the control grid of the CRT through D839-R839. The parallel network of D839-R839 compensates for the CRT cathode potential changes as the CRT cathode current is changed. This network in series with the internal impedance of V829 has a voltage-current characteristic equal and opposite to that of the CRT grid-cathode structure. Therefore, the overall accelerating potential of the CRT remains constant.

[8]Tektronix Circuit Concepts booklet, "Power Supply Circuits", Tektronix Part No. 062-0888-00, pp. 14-16.

Secondary terminals 9 and 10 of T801 provide filament voltage for the CRT. The filament voltage can be obtained from the high-voltage transformer since the CRT has a very low filament-current drain. Diodes D849 A-D provide rectified filament voltage and C849 filters the filament voltage to hold it constant at about 6.3 volts. The CRT cathode and the filament are connected together through R846. This raises the potential on the CRT filament to about the same level as the cathode to prevent cathode-to-filament breakdown. Neon bulb B846 provides further protection, since it ignites if the voltage difference between the cathode and filament exceeds about 65 volts.

CRT Control Circuits

The regulated negative accelerating potential is applied across the divider R831-R832-R833-R834-R837-R838. The INTENSITY control R837 determines the current through this divider to set the level at the cathode of the CRT. The cathode is more positive (less negative) than the control grid because of the voltage drop across R838 and the INTENSITY control R837. As the level at the CRT cathode is changed with the INTENSITY control, the beam current and therefore the display brightness is changed also. The FOCUS control R833 is also part of this divider and it sets the level on the focus grid of the CRT. The added voltage drop across R884 and the FOCUS control R833 sets the focus grid at a more positive level (less negative) than either the control grid or the cathode. The ASTIGMATISM control R855, which is used in conjunction with the FOCUS control to provide a well-defined display, varies the level on the astigmatism grid. Geometry adjustment R854 varies the level on the horizontal deflection plate shield to control the overall geometry of the display. Since the source voltage for both the ASTIGMATISM control and the Geometry adjustment is obtained from the low-voltage supply, the voltage on these elements of the CRT is about zero volts.

Two adjustments control the trace alignment by varying the magnetic field around the CRT. The Y Axis Align adjustment R856 controls the current through L856, which affects the CRT beam after vertical deflection but before horizontal deflection. Trace Rotation adjustment R851 controls the current through L859 and affects both vertical and horizontal rotation of the CRT beam.

Unblanking Amplifier

The CRT in the Type 422 uses deflection blanking to deflect the CRT beam off the viewing area during retrace time and when the sweep is not operating. The deflection-blanking plate connected to pin 7 is fixed at about +17 volts by the voltage drop of zener diode D841 from the +55-volt supply. Since the +55-volt supply is not closely regulated the exact voltage on this deflection-blanking plate varies somewhat with changes in input voltage without affecting operation of the instrument. The level on the deflection-blanking plate connected to pin 12 is determined by the unblanking gate from the Sweep Generator circuit. Quiescently, before the sweep is triggered, the unblanking gate level is about zero volts and Q864 is biased near cutoff. The base level of Q864 is fixed at about +0.6 volt by R865 and D865 connected between the +12-volt supply and ground. Very little current is flowing through Q864 as determined by R868-R869, and the collector of Q864 rises positive toward the +55-volt supply. The potential at pin 12 of the CRT rises positive to about +50 volts and, since the difference in potential between the two deflection blanking plates is significant, the electron beam is deflected off the viewing area of the CRT to blank the display. Notice that the +55-volt supply provides the operating potential for the circuits connected to both deflection-blanking plates. Therefore, the ripple and voltage variations from the +55-volt supply will appear equally on both deflection-blanking plates. Since this appears as a common-mode signal at both plates, however, it does not deflect the electron beam passing between the plates.

When the instrument is triggered, the negative-going unblanking gate supplies current to Q864 through R866 and C477-R477 (see Sweep Generator diagram). Q864 is forward biased to conduct more, and the deflection-blanking plate connected to pin 12 drops to about the same potential as on the other plate (pin 7). Now the electron beam can reach the phosphor to produce a display. The Unblanking Center adjustment R869 is adjusted to provide maximum beam current (brightest display). The circuit remains in this condition until the unblanking gate ends.

The unblanking gate can be interrupted during a trace to blank portions of the display. In the CHOPPED position of the vertical Mode switch, a positive-going signal is connected to R866 during the between-trace switching time. This signal interrupts the current supplied to Q864 and the trace is momentarily blanked so the transition between the Channel 1 and the Channel 2 trace cannot be seen. Provisions are also made in the Sweep Generator circuit for trace blanking from an external signal connected to the EXT BLANKING connector (see Unblanking Circuit discussion). When the unblanking gate ends, Q864 returns to its quiescent conduction level and Q863 pulls pin 12 of the CRT to its quiescent level of about +50 volts to blank the CRT.

When this instrument is operated in the External Horizontal mode, the CRT must be unblanked to produce a display, since the Sweep Generator is inoperative in this mode. When the TIME/DIV switch is set to the EXT HORIZ position, a negative level is connected to the emitter of Q864 through R867 (see diagram 6 for schematic). Q864 is biased on to unblank the CRT so the external horizontal display can be presented. The CRT remains unblanked until the TIME/DIV switch is changed from the EXT HORIZ position (external blanking signals connected to the EXT BLANKING connector can be used to blank portions of the display).

AC-DC Power Supply

General

The AC-DC Power Supply provides the operating power for this instrument from a variety of power sources. DC-DC regulation is used in this supply to provide stable, low-ripple output voltage and to attain high operating efficiency. This circuit also provides the drive signal for the High-Voltage Multiplier stages in the CRT circuit.

AC-DC Power Selector

General The AC-DC Power Selector circuit provides rectified, unregulated power to the DC-DC Regulator circuit from an AC line voltage source, external DC source or from the internal battery pack. This circuit also contains battery charging and low-voltage indicating stages. Fig. 3-12 shows a detailed block diagram of the AC-DC Power Selector circuit. A schematic of this circuit is shown on diagram 11 at the back of this manual.

AC Power Input. AC power is applied to the primary of T1001 through the AC line fuse F1000, filter C1000-T1000, thermal cutout TK1000, POWER switch SW1001 and Power Mode switch SW1030. The Power Mode switch SW1030 connects the split primary windings of T1001 in parallel for 115-volt nominal operation (CHARGE BATT 115V AC and OPERATE 115V AC positions) or in series for 230-volt nominal operation (CHARGE BATT 230V AC and OPERATE 230V AC positions).

Filter C1000-T1000 reduces the EMI radiation conducted out of this instrument through the AC power cord. Thermal cutout TK1000 provides thermal protection when

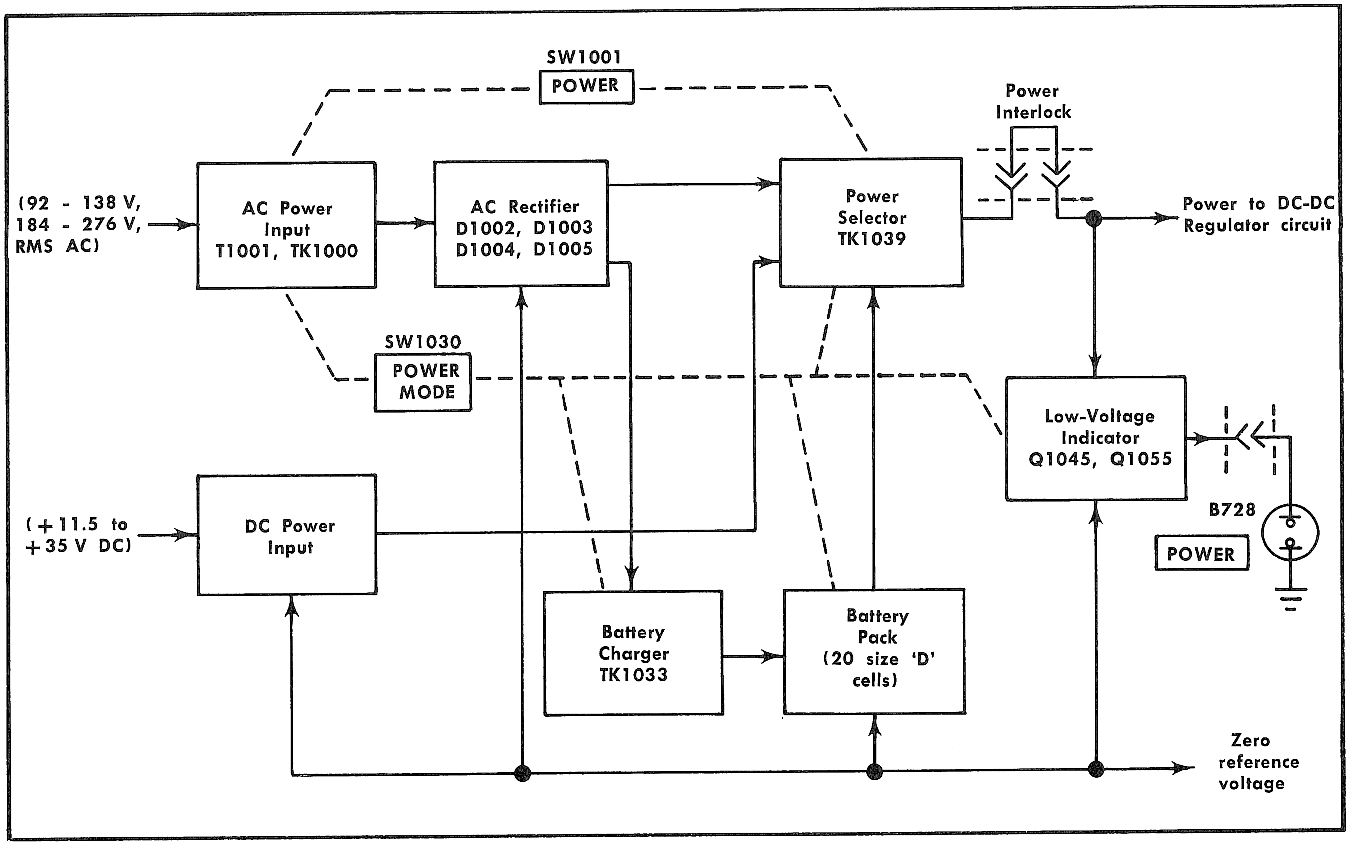


Fig. 3-12. AC-DC Power Selector detailed block diagram.

operated from an AC line. If the internal temperature of the instrument exceeds a safe operating level, TK1000 opens to interrupt the applied power. When the temperature returns to a safe level, TK1000 automatically closes to re-apply the power.

AC Rectifier. The voltage at the secondary of T1001 is rectified by the AC Rectifier D1002-D1003-D1004-D1005. Diodes D1003 and D1004 comprise a center-tapped full-wave rectifier to provide rectified AC voltage for operation from an AC line voltage source. D1002-D1003-D1004-D1005 are connected across the secondary of T1001 as a full-wave bridge rectifier to provide about twice the rectified voltage obtained from D1003-D1004 (notice that D1003 and D1004 are a part of both rectifiers). This voltage is connected to the Battery Charger stage to recharge the internal Battery Pack. Capacitors C1002-C1003-C1004 filter the output voltages of the AC Rectifier stage.

Battery Charger. The rectified voltage produced by the AC Rectifier stage (full-wave bridge portion) provides a charging voltage for the internal Battery Pack as controlled by the Power Mode switch SW1030. Transistors Q1023 and Q1033 are connected as emitter followers between the rectified voltage from the AC Rectifier and the Battery Pack. When the Power switch SW1001 is on and the Power Mode switch SW1030 is in any position except OPERATE 11.5-35V DC or OPERATE INT BATT, rectified voltage is connected across the voltage divider composed of R1022 and zener diode D1022. The anode of zener diode D1022 is connected to the positive terminal of the Battery Pack through D1016, SW1030 and F1014, and therefore maintains a level at its cathode and the base of Q1023 about eight volts more positive than the potential at the positive terminal of the Battery Pack. The base level of Q1023 sets the base level of Q1033 to determine the charging current through R1033, Q1033 and R1034. In the CHARGE BATT 115V AC and CHARGE BATT 230V AC positions of the Power Mode switch, the charging current is connected to the Battery Pack through TK1033, by-passing R1031. A charge rate of about 400 milliamperes is provided. Thermal cutout TK1033 monitors the temperature of the Battery Pack during charge time. If the temperature of the Battery Pack exceeds a safe level during charge time, TK1033 opens to interrupt the 400 milliampere charge rate. However when this occurs, charging current is still applied to the Battery Pack through R1031. This resistor limits the charge rate to a 30 milliampere trickle charge. When the Battery Pack temperature returns to a safe level, TK1033 automatically closes to return the charge current to the 400 milliampere rate. In the OPERATE 115V AC and OPERATE 230V AC positions of the Power Mode switch, the current path through TK1033 is open. The charging current is applied to the Battery Pack through R1031 to provide a 30 milliampere trickle charge.

As the Battery Pack charges, its output potential increases. This increase in voltage is reflected at the base of Q1033 through zener diode D1022 and emitter follower Q1023. Therefore, as the output potential of the Battery Pack increases, the bias on Q1033 and its charge current remain fairly constant throughout the charge cycle. For this reason, it is important to reduce the charge rate to trickle charge after the recommended period to prevent damage to the Battery Pack due to overcharging. (See Operating Instructions.)

Fuse F1014 protects the instrument from damage if excessive current is demanded by the Battery Pack during the charge cycle. Diode D1016 is reversed biased when the AC power to the instrument is shut off to disconnect the Battery Pack from the Battery Charger stage.

DC Power Input. DC power is applied to the Power Selection stage through filter C1010-C1011-C1012-T1010, Power Mode switch SW1030 and DC fuse F1014. Filter C1010-C1011-C1012-T1010 reduces the EMI radiation conducted out of the instrument through the DC power cord. The Power Mode switch SW1030 connects the external DC source to the Power Selection stage only in the OPERATE 11.5-35V DC position. Fuse F1014 protects the instrument if excess current is demanded from the external DC source. D1014 provides reverse-voltage protection for the power supply. If the external DC voltage is inadvertently connected to the AC-DC Power Supply with the wrong polarity. D1014 appears essentially as a short circuit across the input connector. The excess current flowing through D1014 under this condition causes F1014 to open to protect the instrument.

Battery Pack. The Battery Pack consists of 20 size D rechargable nickel-cadmium battery cells. When Power Mode switch SW1030 is in the OPERATE INT BATT position, the battery potential is connected to the Power Selection stage through F1014. Fuse F1014 protects the Battery Pack if excessive current is demanded during battery operation. The Battery Pack can be recharged from an AC line with the correct setting of the Power Mode switch (see Battery Charger).

Power Selection. The power source from which the Type 422 AC-DC Power Supply is operated is selected by the Power Mode switch SW1030. This switch also determines the battery charge rate as discussed under Battery Charger. The power from the source selected by SW1030 is connected to the Low-Voltage Indicator stage and the DC-DC Regulator circuit through TK1039, POWER switch SW1001 and the power interlock. Thermal cutout TK1039 provides thermal protection for this instrument, primarily for external DC or battery operation. If the internal temperature of the instrument exceeds a safe operating level, TK1039 opens to interrupt the power. When the temperature returns to a safe level, TK1039 automatically closes to re-apply the power. The power interlock disconnects the output power from the Power Selection stage when the AC-DC Power Supply is disconnected from the indicator. Since the Battery Charger stage is not affected by the power interlock, the Battery Pack can be charged even when the AC-DC Power Supply is disconnected from the indicator.

Power Mode switch SW1030 also determines the level on the zero-reference voltage line. In all positions of SW1030 except OPERATE 11.5-35V DC, this line is connected to chassis ground to provide a ground reference to all stages connected to this line. However, in the OPERATE 11.5-35V DC position, the zero-reference voltage line is disconnected from chassis ground and connected to the negative terminal of the DC input connector. This allows the instrument to be operated from DC voltages which are elevated above earth (ground).

CAUTION

See the precautions given in Section 2 for operation from elevated DC voltages.

Low-Voltage Indicator. The Low-Voltage Indicator stage monitors the unregulated power output to the DC-DC Regulator circuit when the Power Mode switch SW1030 is in the OPERATE INT BATT position. The unregulated power at the output of this circuit is connected across divider R1041-D1041 to the zero-reference voltage line. Zener diode D1041 maintains a level at the anode of D1042 which is about 11 volts more positive than the zero-reference voltage line (ground for battery operation). The voltage at the base of Q1045 is determined by voltage divider R1046-R1047-R1048 between the unregulated output of this circuit and the zero-reference voltage line. Low-Voltage Indicator adjustment R1047 sets the base level of Q1045 for correct operation of this stage. The base level of Q1055 is determined by voltage divider R1043-R1044 between the collector of Q1045 and the zero-reference line.

When the Battery Pack is fully charged, the unregulated output level of this circuit is about +24 volts. The voltage at the base of Q1045 (with correct adjustment of R1047) is held more positive than the voltage at the anode of D1042 as set by zener diode D1041. Therefore Q1045 and D1042 are both reverse biased. With no current flowing through Q1045, the base of Q1055 drops negative to about the level on the zero-reference voltage line (ground) and Q1055 is off also. The collector of Q1055 is connected to the junction of D1057-R1057 in the OPERATE INT BATT position by SW1030. However since Q1055 is off when the Battery Pack is charged, the level at its collector is set by the level at the junction of D1057-R1057 and D1054 is reverse biased to disconnect the collector circuit of Q1055 from the base circuitry of Q1045. With Q1055 off, current flows from the +95-volt supply through R1057 and D1057 to ignite the POWER neon in the indicator to indicate that power is applied.

As the Battery Pack discharges, the voltage applied to the Low-Voltage indicator stage becomes less positive. Low Voltage Indicator adjustment R1047 is set so that Q1045 is biased on when the unregulated output voltage from this circuit drops to 22 volts. When Q1045 is forward biased, it conducts through R1041, D1042, R1043 and R1044. The current through voltage divider R1043-R1044 produces a more positive voltage at the base of Q1055 to bias it into conduction. The current through Q1055 flows through R1054, D1054, R1047 and R1046 to pull the base of Q1045 even more negative. This produces negative feedback to Q1055, which makes it conduct even harder. When Q1055 conducts, its collector drops negative to pull the voltage at the junction of D1057-R1057 negative enough so the POWER neon does not have sufficient voltage applied to ignite it. However, under this condition C1057-R1059 and the POWER neon form a neon-bulb relaxation oscillator to provide a blinking-light indication of low battery potential. Current flows through R1059 from the +95-volt supply to charge C1057. As the charge on C1057 builds up to the firing potential of the POWER neon, the neon ignites and discharges C1057. Then the POWER neon extinguishes until C1057 recharges to the firing potential of the bulb.

DC-DC Regulator

General. The DC-DC Regulator circuit produces regulated DC output voltages for the indicator from the rectified (unregulated) DC power output of the AC-DC Power Selector circuit. Fig. 3-13 shows a detailed block diagram of the DC-DC Regulator circuit. A schematic of this circuit is shown on diagram 12 at the back of this manual.

Principle of Operation. Fig. 3-14A gives a simplified schematic to show the operating principle of this circuit. Switch SW1 is closed to allow the current flow through the primary of T1 (inductor) from the voltage source (battery) to build up to a given level and produce a flux-field in the primary of T1. When SW1 is opened, the field around the primary of T1 collapses to induce a voltage into the secondary. The secondary voltage is rectified by D1 to provide current to load R_L.

Notice that output current is produced by the collapsing field of inductor T1 (source voltage removed). Therefore, if this field is always the same, a constant voltage will be induced into the secondary of T1 on each cycle. The graph shown in Fig. 3-14B represents the linear rising current of a purely inductive load in response to two different source voltages. With high source voltage, current through the inductor reaches arbitrary level Y — Y' at time T_1 and with low source voltage the current reaches the same level at time T_2. However, if the applied voltage is removed at the time the current reaches level Y — Y' in each case, the collapsing fields are the same for both source voltages as shown by the shaded areas. Applying this principle to the circuit shown in Fig. 3-14A, the same current would be induced into the secondary of T1 in both cases since the collapsing fields are the same.

With a constant current level being induced into the secondary of T1 with changes in source voltages, to produce a regulated output voltage across the load R_L it is only necessary to establish a fixed cycle in which this action occurs. By use of idealized waveforms, Fig. 3-14C shows how this can be done. Notice that the pulse period is the same for both high source voltage and low source voltage. However, the pulse duration is changed so the current induced into the primary of T1 is constant with each source voltage, thereby creating the same field in the inductor (primary of T1). Since the pulse period is the same regardless of the source voltage, the voltage induced into the secondary of T1 remains constant to produce a constant voltage across load R_L. Filter capacitor C1 filters out any variations during the pulse period to maintain a constant output voltage.

This discussion gives the basic concept of the DC-DC Regulator circuit. The method in which the pulse period and pulse duration are changed to maintain a constant output voltage is given in the following circuit discussions. Fig. 3-15 shows idealized waveforms from the DC-DC Regulator circuit. These waveforms will be referred to throughout the following discussions to show the inter-relationship between the various stages in this circuit.

Start Circuit. When the AC-DC Power Supply is first turned on, there is no output from the Isolated Supply since there is no voltage being induced into transformer T1201. Therefore, a starting voltage must be supplied so this circuit can start operation. This voltage is provided by the Start Circuit D1192-Q1193-Q1194. The input voltage from the AC-DC Power Selector circuit is applied across R1191-D1191-D1192. Zener diode D1192 and diode D1191 set the base voltage of Q1193 at about +9.7 volts. Transistors Q1193 and Q1194 operate as a voltage regulator stage to provide about +9.1 volts starting voltage at the positive output of the Isolated Supply (only at turn-on time). This voltage is sufficient for the Blocking Oscillator, Multivibrator, Steering Switch, Power Control and Isolated Supply stages to begin operation. After a few cycles the Isolated Supply output raises to its normal +12-volt level. Then the emitter of Q1193 also goes positive to about +12 volts and, since its base is held at about +9.7 volts by D1191-D1192, it is reverse biased. With Q1193 reverse biased, its collector rises positive toward the level of the input voltage and pulls the base of Q1194 toward this level also. This reverse biases Q1194 to turn off the Start Circuit and isolate the input voltage from the Isolated Supply.

Blocking Oscillator. Transistor Q1120 along with its associated circuitry comprises a blocking oscillator[9]. When power is applied to Q1120 through decoupling network C1120-R1120, Q1120 conducts through the collector winding of transformer T1120. The current flow through the collector winding of T1120 induces a current into the base winding of T1120 which aids the forward bias of Q1120 and quickly drives it into saturation. When Q1120 reaches saturation, the field around T1120 begins to collapse and a negative-going pulse is coupled to the base of Q1120 through the base winding of T1120 to reverse bias Q1120. Diode D1120 by-passes the collector winding of T1120 so the collapsing field does not change the level at

[9]Millman and Taub, pp. 597-601.

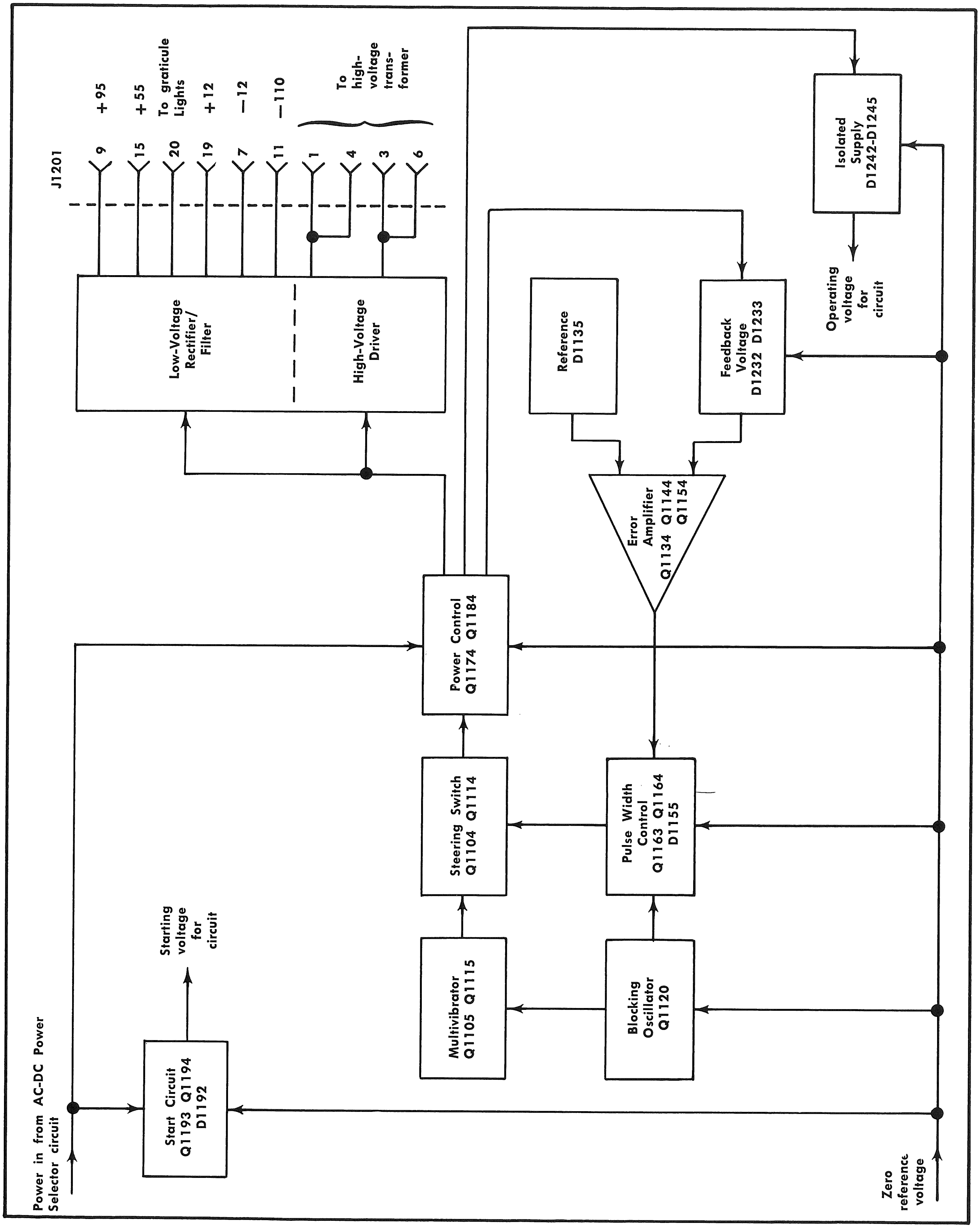


Fig. 3-13. DC-DC Regulator detailed block diagram.

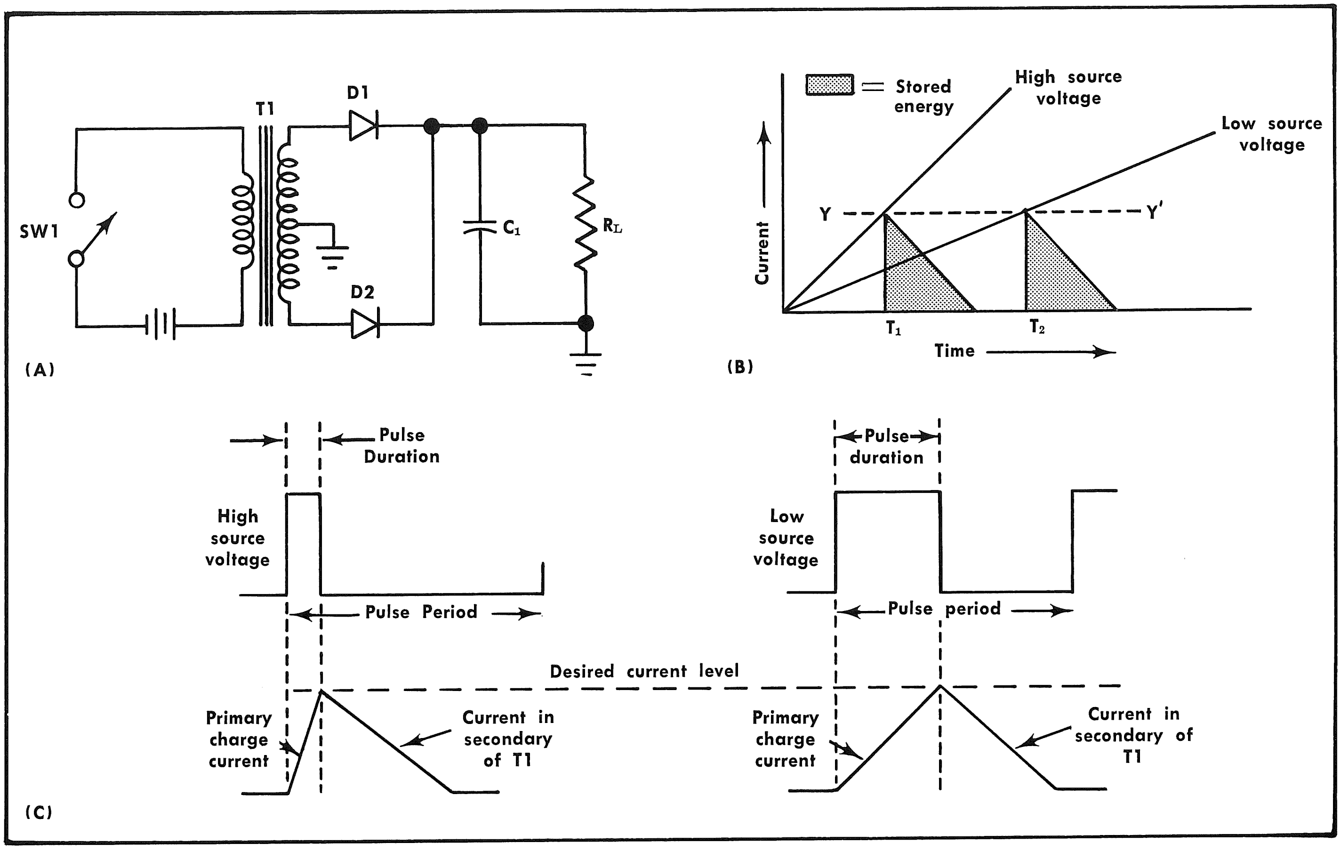


Fig. 3-14. Illustration of energy-storage principle: (A) Simplified diagram of energy-storage circuit, (B) graph of charge stored in inductor versus source voltage, (C) idealized waveforms.

the collector of Q1120. A third winding of T1120 provides a negative going output pulse to the Multivibrator stage. This pulse is of short duration due to the action of Q1120. (See waveform 1, Fig. 3-15.)

The operating frequency of the Blocking Oscillator stage is determined by C1121-R1123-R1124-R1125 in the emitter circuit of Q1120. When Q1120 conducts, its emitter quickly goes positive along with the signal applied to the base from T1120. C1121 quickly discharges to the level on the emitter of Q1120. When Q1120 shuts off, its emitter level is determined by the charge rate of C1121. The charge current for C1121 is supplied through R1124-R1125 and through R1123-D1155. As C1121 charges toward the zero-reference voltage level, the emitter level of Q1120 follows. However, when the emitter level of Q1120 drops to where it is about 0.5 volt more negative than the base level set by diodes D1117-D1118, Q1120 is forward biased to start a new cycle. Frequency of operation is about seven kilohertz. The Oscillator Frequency adjustment R1125 varies the charge time of C1121 and thus determines the frequency at which the blocking oscillator operates. The signal at the emitter of Q1120 is connected to the Pulse Width Control stage through R1123 (see waveform 2, Fig. 3-15).

Multivibrator. Transistors Q1105 and Q1115 form a bistable miltivibrator. The negative-going output pulses from the Blocking Oscillator stage are connected to the junction of D1105 and D1115 through R1118. These pulses switch the Multivibrator as follows: assume that Q1105 is conducting and Q1115 is off. The current through Q1105 raises its emitter more positive than the emitter of Q1115 and also pulls the collector of Q1105 more negative than the collector of Q1115. The negative-going pulses from the Blocking Oscillator stage are connected to the bases of both Q1105 and Q1115 through diodes D1105 and D1115. This pulse momentarily interrupts the conduction of both transistors. When the pulse ends, the stored charge on commutating capacitor C1106 determines which transistor conducts first. While Q1105 is conducting, C1106 charges positive on the Q1105 side to the level at the emitter of Q1105. This charge holds the emitter of Q1115 more negative than the emitter of Q1105 while they are momentarily off. Then as the Blocking Oscillator pulse ends, both Q1105 and Q1115 attempt to come into conduction. However, since the emitter of Q1115 is the more negative, this transistor achieves the greater base-emitter bias and conducts the more heavily. The collector of Q1115 goes negative and pulls the base of Q1105 negative also, to reverse bias Q1105. Thus, Q1115 has gained control of the stage. The action is similar but opposite when the next trigger pulse is received from the Blocking Oscillator stage. The output pulses at the collectors of Q1105 and Q1115 are connected to the Steering Switch stage. Waveform 3 (Fig. 3-15) shows the Multivibrator output from Q1105. The output from Q1115 is similar except that it is 180° out of phase with the waveform shown.

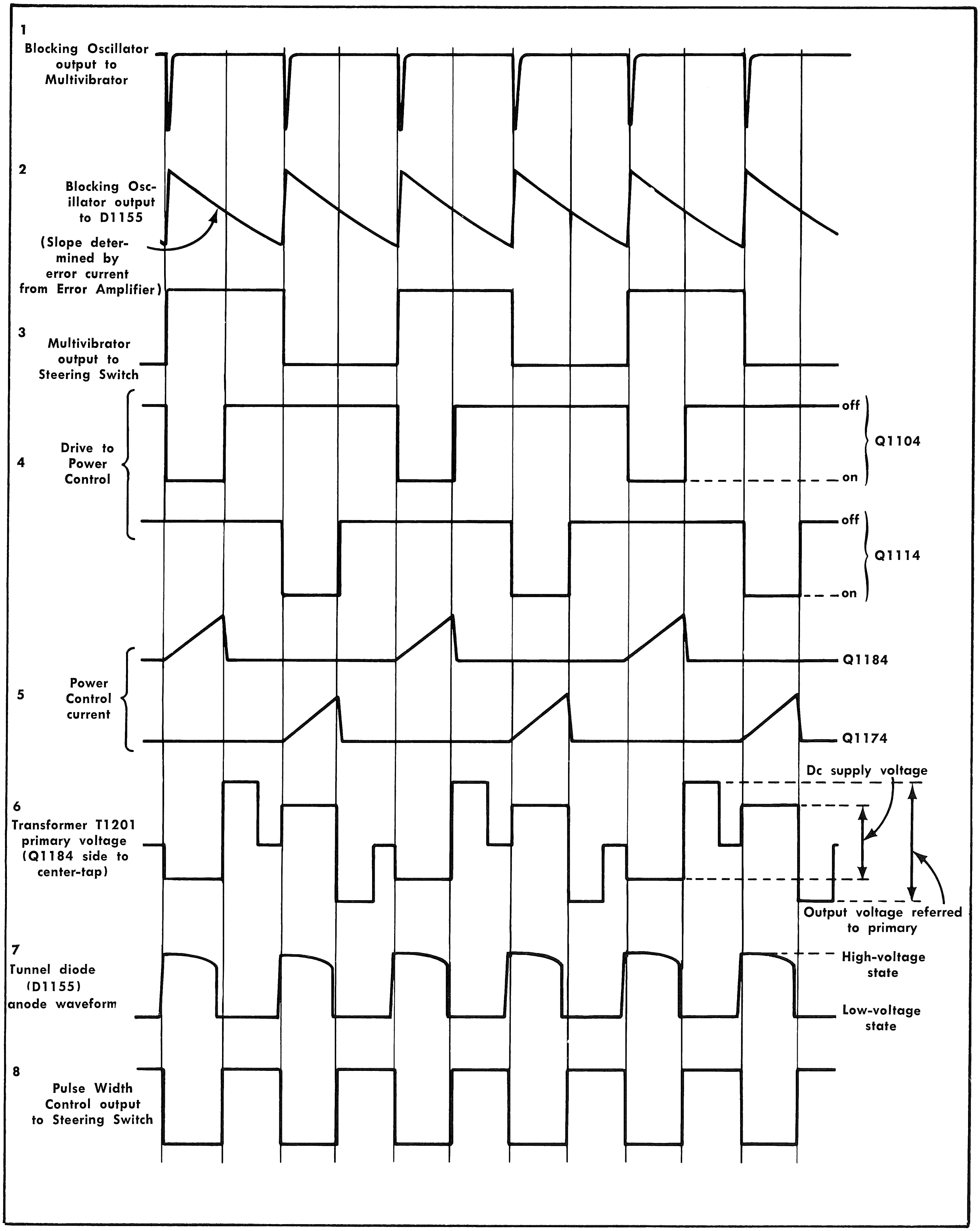


Fig. 3-15. Idealized DC-DC Regulator circuit waveforms.

Steering Switch. The Steering Switch stage is controlled by two simultaneous input signals. The positive-going pulse from the conducting Multivibrator stage transistor provides a turn-on signal to enable either Q1104 or Q1114 at a fixed rate as determined by the Blocking Oscillator and Multivibrator stages. The Steering Switch transistor which is not turned on is held reverse biased by the negative-going signal from the other side of the Multivibrator. However, the control signal from the Pulse Width Control stage determines the actual conduction time of the Steering Switch transistors. The duration of this signal from the Pulse Width Control stage is changed to compensate for variations in input voltage levels. The output voltage from T1201 is sampled to provide this control (see Pulse Width Control discussion for details).

To follow the action of the Steering Switch stage, assume that Q1105 in the Multivibrator stage has just turned on. This connects a negative-going voltage to the base of Q1104 to enable it. At the same time, a positive going voltage is connected to the base of Q1114 to reverse bias it. The control signal from the Pulse Width Control stage begins coincidentally with the switching of the Multivibrator stage (compare waveforms 3 and 7, Fig. 3-15). This negative-going signal is connected to the center tap of transformer T1171 to complete the collector current path for Q1104 through D1104 and one-half of transformer T1171. Q1104 conducts until the control signal goes positive as determined by the Pulse Width Control stage. This removes the negative collector voltage necessary for conduction of Q1104, and both Q1104 and Q1114 remain off until the Multivibrator stage switches, even though Q1104 is enabled. When the Multivibrator stage switches, conditions are reversed and Q1114 conducts as controlled by the Pulse Width Control stage. Diodes D1104 and D1114 protect transistors Q1104 and Q1114 from the high-amplitude positive spike which is generated by the collapsing field of T1171 as the transistors are turned off at the end of the control pulse from the Pulse Width Control stage.

Power Control. The Power Control stage is controlled by the pulses induced into T1171 from the Steering Switch stage (see previous discussion). The Power Control stage in turn controls the flow of current from the input voltage (from AC-DC Power Selector circuit) through the primary of transformer T1201. The current flow through the primary of T1201 is controlled so as to induce the same voltage into the secondary of T1201 regardless of the input voltage.

The conducting transistor in the Steering Switch stage determines which side of the Power Control stage conducts. For example, with Q1104 conducting, a voltage is induced into the secondary of T1171 to forward bias Q1174 and to hold Q1184 reverse biased. The collector current for Q1174 is supplied through L1182-R1182, L1189-D1189, one-half of the primary of T1201, and D1176. When either Q1174 or Q1184 in the Power Control stage turn on, a high flow of current is demanded. Capacitive network C1170-C1171-C1172 supplies this initial current demand and inductors L1172 and L1182 prevent the current surges at turn-on from affecting the AC-DC Power Selector circuit. Resistors R1172 and R1182 serve as damping resistors for L1172 and L1182 respectively to prevent oscillation of the inductors. Capacitors C1177 and C1187 are in the circuit to provide protection at turn-off time (this protection is discussed in the next paragraph). However, if these capacitors were in the circuit at turn-on, they would have to be charged before the collectors of Q1174 and Q1184 could drop negative. This would produce nonlinear current in the primary of T1201. Diodes D1177 and D1187 prevent this nonlinear current by disconnecting the capacitors when the associated transistor turns on. For example, when Q1174 turns on, D1177 is reverse biased to allow the collector of Q1174 to rapidly drop negative without having to discharge C1177 first. Resistor R1177 remains in the circuit to provide a discharge path for C1177. Before D1177 becomes fully reversed biased, it does provide a discharge path for C1177 for a very brief time. Inductor L1189 resists this sudden current change to prevent nonlinear current in the primary of T1201. Since L1189 is fairly low in inductance, it saturates while collector current is still flowing in the circuit. However, D1189 conducts to prevent the inductive feedback produced by the collapsing field of L1189 from affecting the current in the primary of T1201.

When the control pulse from the Steering Switch stage ends (as determined by the Pulse Width Control stage), the collapsing field in T1171 reverses the induced voltages to the bases of Q1174 and Q1184. A negative voltage is applied to the base of Q1174 and it is reverse biased. The collector of Q1174 rises positive and capacitor C1177 provides protection for the transistor during this time. The collapsing field in the primary of T1201 attempts to maintain current through Q1174 even though it is reverse biased and the simultaneous high current and high positive voltage would exceed the wattage rating of this transistor. However as C1177 charges, it delays the rise in voltage at the collector of Q1174 until its current has dropped to a fairly low value. Diode D1176 and zener diode D1174 also provide protection for Q1174 at this time. Diode D1176 isolates the collector of Q1174 from the large negative-going transients generated in the primary of T1201 by the collapsing field, and zener diode D1174 limits the positive collector-emitter voltage to 75 volts maximum. The collapsing field in transformer T1171 places a positive-going voltage at the base of Q1184. Q1184 is forward biased momentarily to aid the collapsing field in transformer T1201.

The length of time that the Power Control stage conducts is controlled by the Pulse Width Control stage so the same amount of magnetic flux is built up in T1201 regardless of the unregulated DC input voltage. Then, a constant voltage is induced into the secondary of T1201 to maintain a regulated output. See the Pulse Width Control discussion for details on how the regulated output is maintained.

When the Steering Switch stage switches so the opposite transistor is conducting, the opposite Power Control transistor conducts. For example, when conduction of the Steering Switch stage switches to Q1114, the voltage induced to the bases of Q1174 and Q1184 forward biases Q1184 and holds Q1174 reverse biased. Operation is the same as described for Q1174. Waveform 5 in Fig. 3-15 shows the collector currents of Q1174 and Q1184. Waveform 6 shows the voltage across the Q1184 side of transformer T1201.

Feedback Voltage. Diodes D1232 and D1233 form a center-tapped, full-wave rectifier. The rectified output of the diodes is filtered by C1232-C1233-R1232 to provide a feedback voltage of about +12 volts to the Error Amplifier stage. The exact output level depends upon the voltage induced into transformer T1201 and this feedback is used to maintain a constant output voltage level from the AC-DC Power Supply. The center-tap of this winding of T1201 is connected to chassis ground through C1231 and to the zero-reference voltage level.

Error Amplifier and Reference. Transistors Q1134, Q1144 and Q1154 are connected as an error amplifier to sense changes in the output voltage level and to provide a correction signal to the Pulse Width Control stage. Zener diode D1135 sets the emitter voltage of Q1134 at about +9 volts more positve than the zero-reference voltage level through R1136. This voltage remains constant due to the zener action of D1135. The base voltage of Q1134 is set by divider R1130-R1131-R1132 connected between the Feedback Voltage and the zero-reference voltage level. If the Feedback Voltage level changes due to a difference in voltage induced into transformer T1201, a sample of this change is applied to the base of Q1134 through temperature-compensation diode D1132. Capacitor C1133, connected between the base and emitter of Q1134, reduces the effect of ripple on the conduction of Q1134. Therefore, the conduction of Q1134 is affected only by an increase or decrease in output voltage from T1201. The change in voltage at the base of Q1134 changes the current through this transistor. The output current change is amplified by transistors Q1144 and Q1154 and applied to the Pulse Width Control stage as an error current to correct the original output voltage error. —12 Volts adjustment R1130, in the base divider of Q1134, is adjustable to set the bias level of Q1134 such that a —12-volt output level is produced by the —12-volt rectifier. The other supplies will also be within their voltage tolerance when this adjustment is set correctly.

To understand the operation of this circuit, assume that the Feedback Voltage output level increases because more voltage is being induced into the secondary of T1201. This places more voltage across divider R1130-R1131-R1132 and the base of Q1134 rises positive. Since the emitter of Q1134 is held constant by zener diode D1135, this positive-going change at the base of Q1134 results in a reduction in forward bias to reduce the current through this transistor. Less current from Q1134 results in a greater forward bias on Q1144 to produce a positive-going change at its collector. Transistor Q1154 operates as a voltage regulator to control the flow of current to the Pulse Width Control stage. The positive-going change at the collector of Q1144 forward biases Q1154 to supply more current to the Pulse Width Control stage. This increase in error current to the Pulse Width Control stage reduces the voltage induced into the secondary of T1201 to correct the original output voltage error to maintain a regulated output voltage (see Pulse Width Control discussion which follows for more details). The action of the Error Amplifier stage is similar but opposite when the Feedback Voltage level decreases.

Pulse Width Control. The Pulse Width Control stage is the final step in maintaining a regulated output voltage regardless of input voltage variations. This stage consists of tunnel diode D1155 and amplifier Q1163-Q1164. Tunnel diode D1155 is switched to its high-voltage state by the positive-going signal at the emitter of the Blocking Oscillator (compare waveforms 2 and 7, Fig. 3-15). The positive going step at the anode of D1155 when it switches to its high-voltage state is connected to the base of Q1164 through R1162. Q1164 is forward biased by this step, and it couples a negative step to the base of Q1163 to turn it on also. When Q1163 turns on, it completes the conduction path between the center tap of T1171 and the zero-reference voltage level to allow one of the Steering Switch transistors to conduct (compare time relationship between waveforms 3, 4 and 8, Fig. 3-15). The conduction of the Steering Switch stage controls the amount of energy induced into T1201 from which the output voltage is produced (see Steering Switch and Power Control discussions). Therefore, the amount of time that the Pulse Width Control stage allows the Steering Switch transistors to conduct determines the output voltage. The time that tunnel diode D1155 remains in its high-voltage state is determined by the recharge time of C1121 and the error current from the Error Amplifier stage. The recharge time of C1121 is determined by Oscillator Frequency adjustment R1125. The error current from the Error Amplifier is determined by —12 Volts adjustment R1130 and the output level of the Reference Voltage stage. When D1155 drops to its low-voltage state, both Q1163 and Q1164 are reverse biased to interrupt the collector current path for the Steering Switch stage. The —12 Volts adjustment is set so the error current supplied to tunnel diode D1155 ends the Pulse Width Control stage output signal at such a time as to provide the correct regulated output voltages from the AC-DC Supply (within input voltage range).

To maintain regulated output voltages with changes in input voltage level, the Feedback Voltage Error Amplifier, Pulse Width Control, Steering Switch and Power Control stages work together as follows: Assume that the input voltage from the AC-DC Power Selector circuit decreases (e.g., Battery Pack output level drops due to normal discharge). This results in less voltage induced into the secondary of T1201, which produces a lower output level from the Feedback Voltage stage. The Error Amplifier stage senses this decrease in output level from the Feedback Voltage stage and, as a result, produces a decrease in error current to the Pulse Width Control stage. A decrease in error current allows D1155 to remain in its high-voltage state longer. Since D1155 remains in its high-voltage state longer, the Steering Switch and Power Control stages conduct for a longer period. This allows more of the input current to flow in the primary circuit of T1201. With an increase in current in the primary of T1201, more voltage is induced into its secondary to compensate for the original decrease in output level The action is similar but opposite for an increase in input voltage level.

Isolated Supply. The Isolated Supply provides positive and negative voltage levels for the operation of the DC-DC Regulator circuit. The voltage induced into the secondary of T1201 is rectified by center-tapped, full-wave rectifiers D1242-D1243 and D1244-D1245 to produce positive and negative outputs of about 12 volts. The output at the cathodes of D1242-D1243 is filtered by C1195 and C1199 to maintain a stable +12-volt output level. Filter network C1245-C1246-L1246 maintains a stable −12-volt output level from the anodes of D1244 and D1245. The center-tap of this winding of T1201 is connected to chassis ground through C1242 and to the zero-reference voltage level.

Low-Voltage Recitifier/Filter. The output voltage from the secondary of T1201 is rectified and filtered to provide the regulated DC output voltages for the indicator. All of the output voltages are produced by center-tapped full-wave rectifiers except the −110-volt output. Capacitive filtering can be used to provide stable output voltage because of the regulation of the primary voltage applied to T1201 and also due to the frequency of operation (approximately seven kilohertz). The rectifiers for each voltage and their associated filter networks are as follows: +95 volt, D1202-D1223 and C1202-C1203; +55 volt, D1203-D1222 and C1204-C1205-L1204; graticule-light voltage, D1214-D1215 and C1214; +12 volt, D1216-D1217 and C1216-C1217-C1218-C1219-L1217-L1219; −12 volt, D1212-D1213 and C1210-C1211-C1212-C1213-L1212-L1213. Diodes D1224 and D1225 along with capacitors C1224 and C1225 form a voltage doubler network to provide a −110-volt output from the same winding that provides the unrectified voltage for the +55-volt output.

High-Voltage Driver. The unrectified secondary voltage which provides power to the −12- and +12-volt outputs is also used for high-voltage driver power. This voltage is connected to the high-voltage transformer in the indicator through terminals 1—4 and 3—6 of J1201.

Ground Connections

Capacitors C1173, C1181, C1231 and C1242 provide short high-frequency current paths between the various ground planes in this supply and the zero-reference voltage line. Although these capacitors appear schematically to be connected directly between two areas which are both at ground potential, this configuration eliminates ground loops which might otherwise result due to the method of construction necessary. Also, the component location on the circuit board requires that the collector of Q1163 be returned across the board in parallel with the +12-volt lead and connected to the zero-reference voltage level at C1199. Resistor R1165 damps ringing at the collector of Q1163 by absorbing reflections along the short-circuited transmission line formed by the above lead configuration.

NOTES

SECTION 4
MAINTENANCE

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

Introduction

This section of the manual contains maintenance information for use in preventive maintenance, corrective maintenance or troubleshooting of the Type 422.

Cabinet Removal

The cabinet can be removed from the indicator as follows:

1. First remove the power supply from the rear of the indicator as follows:

   a. Loosen the four securing screws located in the rear feet of the power supply.

   b. Separate the two units by sliding the power supply to the rear off the support rods.

2. Remove the three screws located in the trim casting which hold the cabinet to the rear of the indicator.

3. Slide the cabinet to the rear and off the support rods.

Power-Supply Cover Removal

The cover can be removed from the power supply as follows:

1. First remove the power supply from the indicator as given in step 1 above.

2. Remove the screw located directly below the fuse holder and remove the battery box and battery pack from the power supply.

3. Remove the four screws located in the trim casting and the three screws located on the bottom (see Fig. 4-1).

4. Slip the power-supply cover off the power-supply chassis.

WARNING

Dangerous potentials exist at several points throughout this instrument. When this instrument is operated with the covers removed, do not touch exposed connections or components. Some transistors may have elevated cases. Disconnect power before cleaning the instrument or replacing parts.

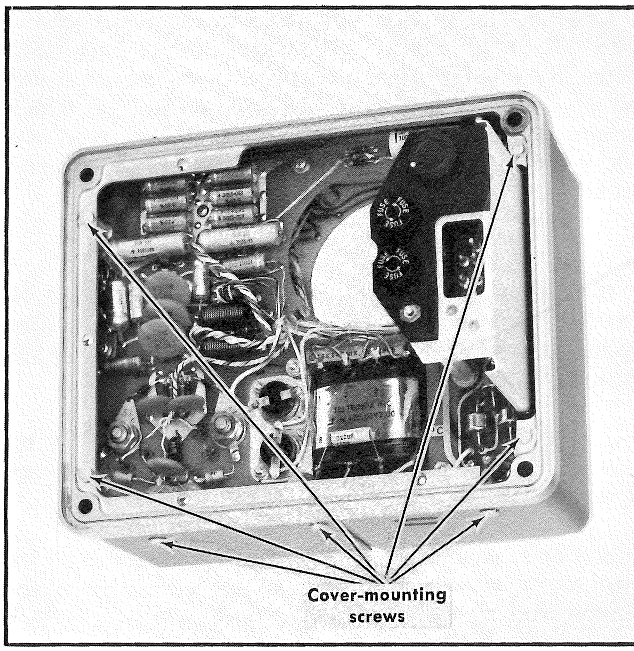


Fig. 4-1. Location of cover mounting screws on rear and bottom of AC-DC Power Supply.

PREVENTIVE MAINTENANCE

General

Preventive maintenance consists of cleaning, visual inspection, lubrication etc. Preventive maintenance performed on a regular basis may prevent instrument breakdown and will improve the reliability of this instrument. The severity of the environment to which the Type 422 is subjected determines the frequency of maintenance. A convenient time to perform preventive maintenance is preceding recalibration of the instrument.

Cleaning

General. The Type 422 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 also provides an electrical conduction path which may result in instrument failure.

The cabinet provides protection against dust in the interior of the instrument. Operation without the cabinet in place necessitates more frequent cleaning. The front cover provides dust protection for the front panel and the CRT face. The front cover should be installed for storage or transportation.

CAUTION

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

Exterior. Loose dust accumlated on the outside of the Type 422 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.

CRT. Clean the plastic light filter, faceplate protector and the CRT face with a soft, lint-free cloth dampened with denatured alcohol. The CRT mesh filter can be cleaned in the following manner:

1. Hold the filter in a vertical position and brush lightly with a soft No. 7 watercolor brush to remove light coatings of dust or lint.

2. Greasy residues or dried-on dirt can be removed with a solution of warm water and a neutral pH liquid detergent. Use the brush to lightly scrub the filter.

3. Rinse the filter thoroughly in clean water and allow to air dry.

4. If any lint or dirt remains, use clean low-pressure air to remove. Do not use tweezers or other hard cleaning tools on the filter, as the special finish may be damaged.

5. When not in use, store the mesh filter in a lint-free, dust-proof container such as a plastic bag.

Interior. Dust in the interior of the instrument should be removed occasionally due to its electrical conductivity under high-humidity conditions. The best way to clean the interior is to blow off the accumulated dust with dry, low-pressure 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.

The high-voltage circuits, particularly parts located in the high-voltage compartment and the area surrounding the post-deflection anode connector, should receive special attention. Excessive dirt in these areas may cause high-voltage arcing and result in improper instrument operation.

WARNING

The battery pack is capable of delivering a very large current if accidentally short circuited. Be careful to prevent shorting the battery terminals or associated wires with tools metal work bench etc. A severe burn can be obtained if a ring, watch band, etc. comes in contact with the battery terminals.

Battery-Pack Cleaning. When the battery pack is over-charged or when discharged to the point of polarity reversal, gas is formed within the nickel-cadmium cell. The nickel-cadmium cells used in the battery pack incorporate a vent so this internal pressure does not damage the battery. However, as the internal pressure is relieved, a small amount of the electrolyte may be expelled with the gas. Although the cells will not be damaged unless this happens repeatedly, this loss of electrolyte may result in shorter overall battery life. The battery box should be inspected occasionally for any electrolyte residue on the battery pack or in the battery compartment. Any residue which is found should be cleaned away with a 2% solution of boric acid in water. A 2% solution of boric acid can be obtained by dissolving 1 ¼ teaspoons of boric acid powder in one cup of water. After the residue has been cleaned from the battery pack and the battery compartment, dry the wetted area thoroughly with a soft cloth.

Lubrication

The reliability of potentiometers, rotary switches and other moving parts can be maintained if they ary kept properly lubricated. Use a cleaning-type lubricant (e.g., Tektronix Part No. 006-0218-00) on switch contacts. Lubricate switch detents with a heavier grease (e.g., Tektronix Part No. 006-0219-00). Potentiometers which are not permanently sealed should be lubricated with a lubricant which does not affect electrical characteristics (e.g., Tektronix Part No. 006-0220-00). The pot lubricant can also be used on shaft bushings. Do not over lubricate. A lubrication kit containing the necessary lubricants and instructions is available from Tektronix, Inc. Order Tektronix Part No. 003-0342-00.

Visual Inspection

The Type 422 should be inspected occasionally for such defects as broken connections, broken or damaged ceramic strips, improperly seated transistors, damaged circuit boards and heat-damaged parts.

The corrective procedure 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 over-heating be corrected to prevent recurrence of the damage.

Transistor Checks

Periodic checks of the transistors in the Type 422 are not recommended. The best check of transistor performance is actual operation in the instrument. More details on checking transistor operation are given under Troubleshooting.

Recalibration

To assure accurate measurements, check the calibration of this instrument after each 1000 hours of operation or every six months if used infrequently. In addition, replacement of components may necessitate recalibration of the affected circuits. Complete calibration instructions are given in the Calibration section.

The calibration procedure can 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 to facilitate troubleshooting of the Type 422. Information contained in other sections should be used along with the following information to aid in locating the defective component. An understanding of the circuit operation is very helpful in locating troubles. See the Circuit Description section for complete information.

Troubleshooting Aids

Diagrams. Complete circuit diagrams are given on foldout pages in the Diagrams section. The component number and electrical value of each component in this instrument are shown on the diagrams. Each main circuit is assigned a series of component numbers. Table 4-1 lists the main circuits in the Type 422 and the series of component numbers assigned to each. Important voltages and waveforms are also shown on the digrams. The portions of the circuit mounted on circuit boards are enclosed with a blue line.

TABLE 4-1
Component Numbers

Component numbers on diagrams	Diagram number	Circuit
1-99	1	Channel 1 Input Amplifier
100-199	2	Channel 2 Input Amplifier
200-299	4	Vertical Switching and Output Amplifier
300-399	5	Sweep Trigger
400-499	6	Sweep Generator
500-599	8	Horizontal Amplifier
700-799	9	Calibrator and Regulators
800-899	10	CRT Circuit
1000-1099	11	AC-DC Power Selector
1100-1299	12	DC-DC Regulator

Switch Wafer Identification. Switch wafers shown on the diagrams are coded to indicate the position of the wafer in the complete switch assembly. The numbered portion of the code refers to the wafer number counting from the front, or mounting end of the switch, toward the rear. The letters F and R indicate whether the front or rear of the wafer performs the particular switching function. For example, a wafer designated 2R indicates that the rear of the second wafer from the front is used for this particular switching function.

Circuit Boards. Figs. 4-8 through 4-17 show the circuit boards used in the Type 422. Fig. 4-7 shows the location of each board within the instrument. Each electrical component on the boards is identified by its circuit number. The circuit boards are also outlined on the diagrams with a blue line. These pictures, used along with the diagrams, aid in locating the components mounted on the circuit boards.

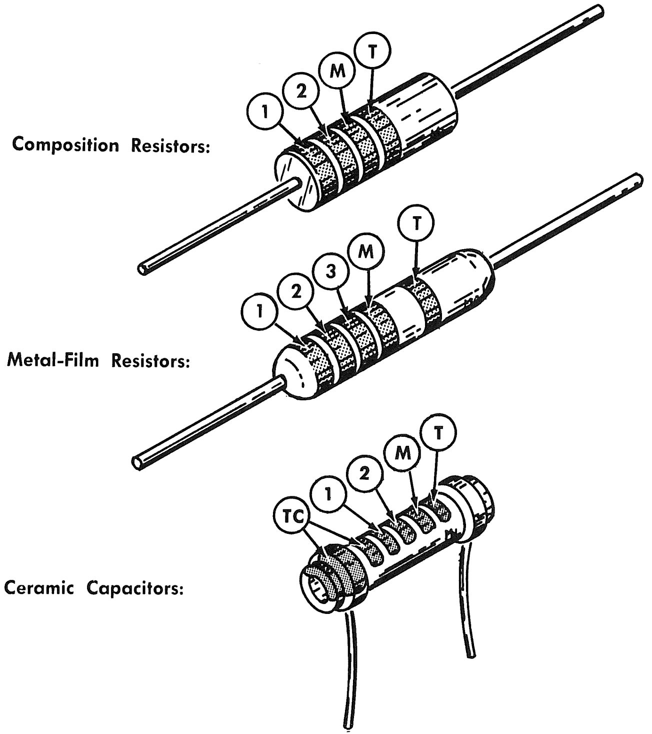
Wiring Color-Code. All insulated wire and cable used in the Type 422 is color-coded to facilitate circuit tracing. Signal carrying leads are identified with one or two colored stripes. Voltage supply leads are identified with three stripes to indicate the approximate voltage using the EIA resistor color-code. A white background color indicates a positive voltage and a tan background indicates a negative voltage. The widest color stripe identifies the first color of the code. Table 4-2 gives the wiring color-code for the power-supply voltages used in the Type 422.

TABLE 4-2
Power Supply Wiring Color Code

Supply	Background color	First stripe	Second stripe	Third stripe
−110 volt	Tan	Brown	Black	Brown
−81 volt	Tan	Gray	Black	Black
−12 volt	Tan	Brown	Red	Black
+10.5 volt	White	Violet	Green	Black
+12 volt	White	Brown	Red	Black
+55 volt	White	Green	Green	Black
+95 volt	White	Brown	Black	Brown

Resistor Color-Code. In addition to the brown composition resistors, some metal-film resistors and some wire-wound resistors are used in the Type 422. The resistance values of wire-wound resistors are printed on the body of the component. The resistance values of composition resistors and metal-film resistors are color-coded on the components 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. 4-2). Metal-film resistors have five stripes consisting of three significant figures, a multiplier and a tolerance value.

Capacitor Marking. The capacitance values of common disc capacitors and small electrolytics are marked in micro-



Ⓘ ② and ③ —1st, 2nd and 3rd significant figures;
Ⓜ —multiplier; Ⓣ —tolerance;
ⓉⒸ —temperature coefficient.

Resistor and Capacitor Color Code

Color	Significant Figures	Multiplier: Resistors	Multiplier: Capacitors	Tolerance: Resistors	Tolerance: Capacitors
Silver	---	10^{-2}	---	±10%	---
Gold	---	10^{-1}	---	±5%	---
Black	0	1	1	---	±20% or 2 pF*
Brown	1	10	10	±1%	±1% or 0.1 pF*
Red	2	10^{2}	10^{2}	±2%	±2%
Orange	3	10^{3}	10^{3}	±3%	±3%
Yellow	4	10^{4}	10^{4}	±4%	+100% −0%
Green	5	10^{5}	10^{5}	±0.5%	±5% or 0.5 pF*
Blue	6	10^{6}	10^{6}	---	---
Violet	7	---	---	---	---
Gray	8	---	10^{-2}	---	+80% −20% or 0.25 pF*
White	9	---	10^{-1}	---	±10% or 1 pF*
(none)	---	---	---	±20%	±10% or 1 pF*

*For capacitance of 10 pF or less.

NOTE: Ⓣ and/or ⓉⒸ color code for capacitors depends upon manufacturer and capacitor type. May not be present in some cases.

Fig. 4-2. Color-code for resistors and ceramic capacitors.

farads on the side of the component body. The white ceramic capacitors used in the Type 422 are color coded in picofarads using a modified EIA code (see Fig. 4-2).

Diode Color-Code. The cathode end of each glass-encased 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 three significant digits of the Tektronix Part Number using the resistor color-code system (e.g., a diode color-coded pink or blue-brown-gray-green indicates Tektronix Part Number 152-0**185**-00). The cathode and anode ends of a metal-encased diode can be identified by the diode symbol marked on the body.

Transistor Lead Configuration. Fig. 4-3 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 422.

1. Transistor Tester

Description: Tektronix Type 575 Transistor-Curve Tracer or equivalent.

Purpose: To test the semiconductors used in this instrument.

2. Multimeter

Description: VTVM, 10 megohm input impedance and 0 to 500 volts range; ohmmeter, 0 to 50 megohms. Accuracy, within 3%. Test probes must be insulated to prevent accidental shorting.

Purpose: To check voltages and for general troubleshooting in this instrument.

NOTE

A 20,000 ohms/volt VOM can be used to check the voltages in this instrument if allowances are made for the circuit loading of the VOM at high-impedance points.

3. Test Oscilloscope

Description: DC to 15 MHz frequency response, 50 millivolts to 50 volts/division deflection factor. A 10X probe should be used to reduce circuit loading.

Purpose: To check waveforms in this instrument.

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 assure proper connection, operation and calibration.

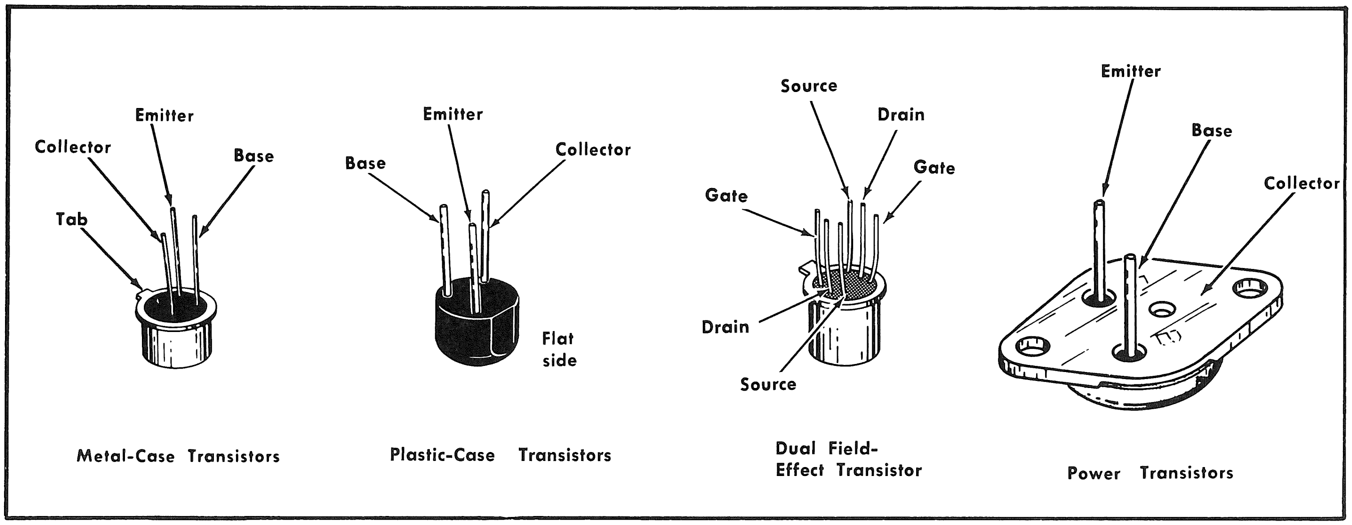


Fig. 4-3. Electrode configuration for transistors in this instrument (as viewed from bottom).

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 procedures given under Corrective Maintenance.

1. Check Control Settings. Incorrect control settings can indicate a trouble that does not exist. If there is any question about the correct function or operation of any control, see the Operating Instructions section.

2. Check Associated Equipment. Before proceeding with troubleshooting of the Type 422, check that the equipment used with this instrument is operating correctly. Check that the signal is properly connected and that the interconnecting cables are not defective. Also, check the power source.

3. 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.

4. Check Instrument Calibration. Check the calibration of this instrument, or the affected circuit if the trouble appears in one circuit. The apparent trouble may only be a result of misadjustment or may be corrected by calibration. Complete calibration instructions are given in the Calibration section.

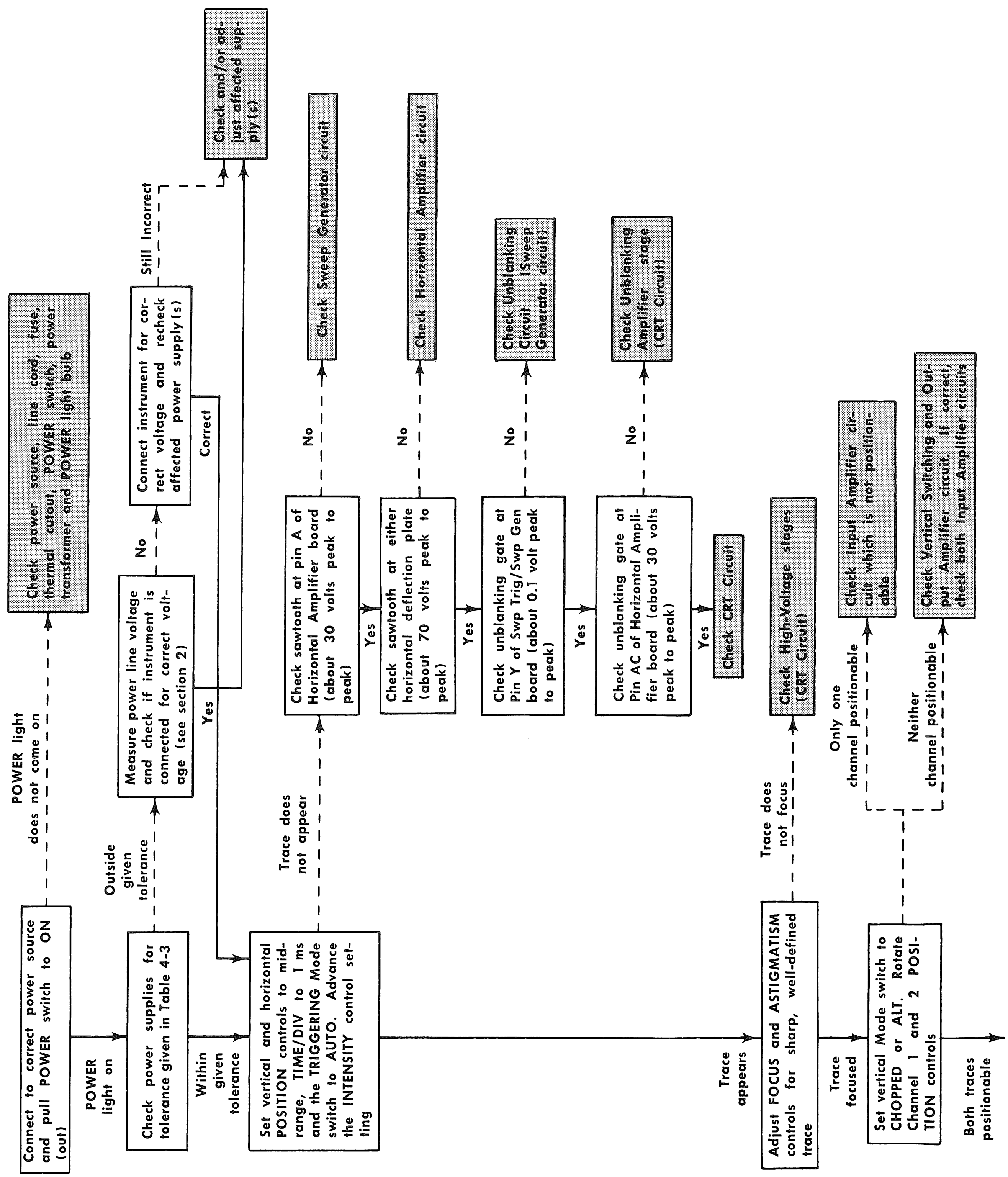
5. Isolate Trouble to a Circuit. To isolate trouble to a circuit, note the trouble symptom. The symptom often identifies the circuit in which the trouble is located. For example, poor focus indicates that the CRT circuit (includes high voltage) is probably at fault. When trouble symptoms appear in more than one circuit, check affected circuits by taking voltage and waveform readings.

Incorrect operation of all circuits often indicates trouble in the power supply. Check first for correct voltage of the individual supplies. However, a defective component elsewhere in the instrument can appear as a power-supply trouble and may also affect the operation of other circuits. Table 4-3 lists the tolerances of the power supplies in this instrument. If a power-supply voltage is within the listed tolerance, the supply can be assumed to be working correctly. If outside the tolerance, the supply may be misadjusted or operating incorrectly. Use the procedure given in the Calibration section to adjust the power supplies.

TABLE 4-3
Power Supply Tolerance and Ripple

Power supply	Tolerance	Maximum ripple (peak to peak) Line frequency	High frequency (8 kHz)
−81 volt	−80 to −82 volts	20 millivolts	8 millivolts
−12 volt	−11.9 to −12.1 volts	20 millivolts	8 millivolts
+10.5 volt	+10.3 to +10.7 volts	1 millivolt	1 millivolt
+12 volt	+11.7 to +12.3 volts	20 millivolts	8 millivolts
+55 volt	+53.9 to +56.7 volts	0.32 volt	— —
+95 volt	+93.1 to +97.9 volts	0.4 volt	— —

Fig. 4-4 provides a guide for locating a defective circuit. This chart may not include checks for all possible defects; use steps 6 through 8 in such cases. Start from the top of the chart and perform the given checks on the left side of the page until a step is found which does not produce the indicated results. Further checks and/or the circuit in which the trouble is probably located are listed to the right of this step.



Connect to correct power source and pull POWER switch to ON (out)
POWER light does not come on
Check power source, line card, fuse, thermal cutout, POWER switch, power transformer and POWER light bulb
POWER light on
Check power supplies for tolerance given in Table 4-3
Outside given tolerance
Measure power line voltage and check if instrument is connected for correct voltage (see section 2)
No
Connect instrument for correct voltage and recheck affected power supply (s)
Still Incorrect
Check and/or adjust affected supply (s)
Correct
Yes
Within given tolerance
Set vertical and horizontal POSITION controls to midrange, TIME/DIV to 1 ms and the TRIGGERING Mode switch to AUTO. Advance the INTENSITY control setting
Trace does not appear
Check sawtooth at pin A of Horizontal Amplifier board (about 30 volts peak to peak)
No
Check Sweep Generator circuit
Yes
Check sawtooth at either horizontal deflection plate (about 70 volts peak to peak)
No
Check Horizontal Amplifier circuit
Yes
Check unblanking gate at Pin Y of Swp Trig/Swp Gen board (about 0.1 volt peak to peak)
No
Check Unblanking Circuit (Sweep Generator circuit)
Yes
Check unblanking gate at Pin AC of Horizontal Amplifier board (about 30 volts peak to peak)
No
Check Unblanking Amplifier stage (CRT Circuit)
Yes
Check CRT Circuit
Trace appears
Adjust FOCUS and ASTIGMATISM controls for sharp, well-defined trace
Trace does not focus
Check High-Voltage stages (CRT Circuit)
Trace focused
Set vertical Mode switch to CHOPPED or ALT. Rotate Channel 1 and 2 POSITION controls
Only one channel positionable
Check Input Amplifier circuit which is not positionable
Neither channel positionable
Check Vertical Switching and Output Amplifier circuit. If correct, check both Input Amplifier circuits
Both traces positionable

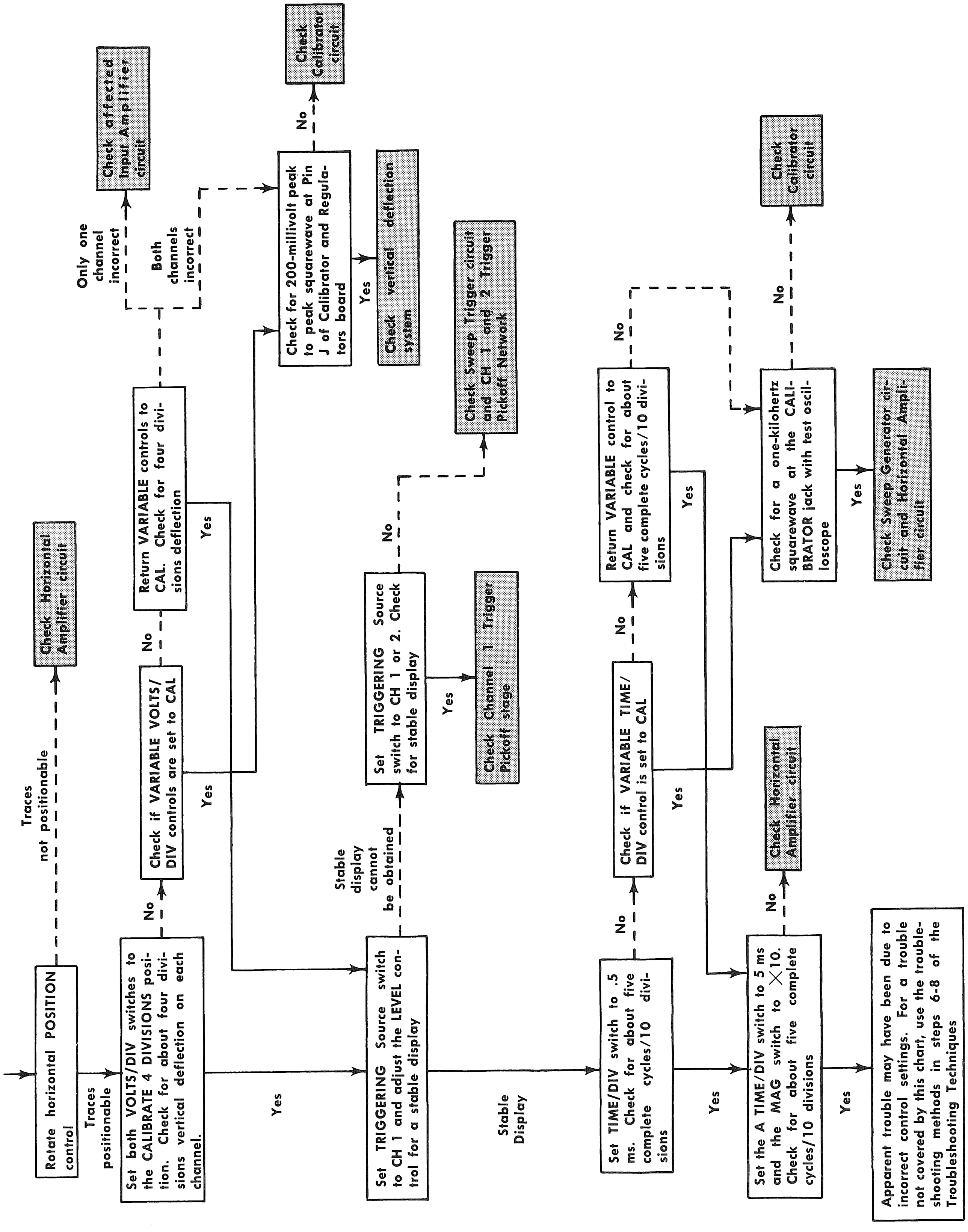


Fig. 4-4. Troubleshooting chart for Type 422 with AC-DC Power Supply.

After the defective circuit has been located, proceed with steps 6 through 8 to locate the defective component(s).

6. Check Circuit Board Interconnections. After the trouble has been isolated to a particular circuit, check the pin connectors on the circuit board for correct connection. Figs. 4-8 through 4-17 show the correct connections for each board.

The pin connectors used in this instrument also provide a convenient means of circuit isolation. For example, a short in a power supply can be isolated to the power supply itself by disconnecting the pin connectors for that voltage at the remaining boards.

7. Check Voltages and Waveforms. Often the defective component can be located by checking for the correct voltage or waveform in the circuit. Typical voltages and waveforms are given on the diagrams.

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 first diagram page.

8. Check Individual Components. The following procedures describe methods of checking individual components in the Type 422. 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 dynamic tester (such as Tektronix Type 575). Static-type testers are not recommended, since they do not check operation under simulated operating conditions.

CAUTION

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

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 meter leads are reversed.

CAUTION

Do not use an ohmmeter scale that has a high internal current. High currents may damage the diode. Do not measure tunnel diodes with an ohmmeter; use a dynamic tester (such as a Tektronix Type 575 Transistor-Curve Tracer).

C. RESISTORS. Check the resistors with an ohmmeter. See the Electrical Parts List for the tolerance of the resistors used 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 (roll-off).

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 initial charge of the capacitor. An open capacitor can best be detected with a capacitance meter or by checking whether the capacitor passes AC signals.

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.

Battery-Pack Troubleshooting. The Type 422 with AC-DC Power Supply provides about four hours of continuous operation from a fully charged battery pack. The actual operating time may vary due to the age of the batteries, number of charge-discharge cycles, signal applied, INTENSITY control setting and other factors. If the batteries do not provide the normal operating time, first completely charge the batteries for the recommended 16-hour charge period (see Battery Charging in Section 2 for complete information on charging). If possible, charge the battery pack in an ambient temperature between +15°C and +25°C. This allows the battery pack to attain its maximum charge and also will minimize the chances that the battery pack protection thermal cutout will open because of excess temperature (see Section 2 for more information). Measure the potential across the interconnecting banana jacks of the power pack. A fully charged battery pack should measure about 24 volts. If the battery pack measures below 22 volts either the battery charger circuit is inoperative or the battery pack is defective. The battery charger circuit can be checked for operation using the procedure given in step 7 of the Calibration procedure. If the battery charger is working correctly and the voltage reads low, the battery pack is probably defective.

If the battery pack measures about 24 volts but the POWER light begins to blink too soon when operating from the batteries, either the battery pack has lost its charge retaining capacity or the low-batteries indicator circuit is defective. First be sure that the batteries have been charged properly for the recommended charge period. Then, operate the instrument from the batteries until the POWER light begins to blink. Now, measure the potential across the battery pack interconnecting terminals. If it is below about 22 volts, the battery pack has lost its charge retention capacity. If the voltage is above about 22 volts, the low-batteries indicator circuit may be at fault.

If the battery pack is found to be defective, the entire battery pack should be returned to Tektronix, Inc. for maintenance. Contact your local Tektronix Field Office or representative for assistance. The battery pack should be regarded as a single power storage unit rather than as a set of individual cells. It is not designed to be disassembled for inspection or repair. Refer all maintenance on the battery pack itself to Tektronix, Inc.

CAUTION

The warranty on this instrument may be altered if the sealed case-retaining screws of the battery pack are removed.

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 422 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 lists 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 in the instrument, particularly at high frequencies. 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 components are used in the Type 422. These components are manufactured or selected by Tektronix, Inc. to meet specific performance requirements, or are manufactured for Tektronix, Inc. in accordance with our specifications. These special components are 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. A description of the part (if electrical, include circuit number).

4. Tektronix Part Number.

Soldering Techniques

WARNING

Disconnect the instrument from the power source before soldering.

Circuit Boards. Use ordinary 60/40 solder and a 35- to 40-watt pencil type soldering iron on the circuit boards. 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 wiring from the base material.

The following technique should be used to replace a component on a circuit board. Most components can be replaced without removing the boards from the instrument.

1. 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 board as it may damage the board.

2. When the solder begins to melt, pull the lead out gently. This should leave a clean hole in the board. 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.

3. Bend the leads of the new component to fit the holes in the board. If the component is replaced while the board is mounted in the instrument, cut the leads so they will just protrude through the board. Insert the leads into the holes in the board so the component is firmly seated against the board (or as positioned originally). If it does not seat properly, heat the solder and gently press the component into place.

4. Touch the iron to the connection and apply a small amount of solder to make a firm solder joint; do not apply too much solder. 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.

5. Clip the excess lead that protrudes through the board (if not clipped in step 3).

6. Clean the area around the solder connection with a flux-remover solvent. Be careful not to remove information printed on the board.

Ceramic Terminal Strips. Solder used on the ceramic terminal strips should contain about 3% silver. Use a 40- to

75-watt soldering iron with a 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.

A sample roll of solder containing about 3% silver is mounted in the front cover for this instrument. Additional solder of this 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 ceramic terminal strips.

1. Use a hot iron for a short time. Apply only enough heat to make the solder flow freely. Use a heat sink to protect heat-sensitive components.

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 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 1/8-inch wide wedge shaped tip.

Observe the following precautions when soldering metal terminals:

1. Apply only enough heat to make the solder flow freely. Use a heat sink to protect heat-sensitive components.

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.

Ceramic Terminal Strip Replacement. A complete ceramic terminal strip assembly is shown in Fig. 4-5. Replacement strips (including studs) and spacers are supplied under separate part numbers. However, the old spacers may

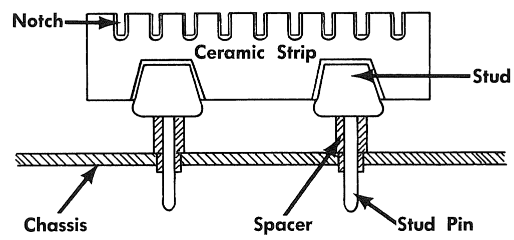


Fig. 4-5. Ceramic terminal strip assembly.

be re-used 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 to show location of the components and connections.

2. Pry or pull the damaged strip from the chassis. Be careful not to damage 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 stud extends through the spacers, cut off the excess.

4. Replace all components and connections. Observe the soldering precautions given under Soldering Techniques in this section.

Circuit Board Replacement. If a circuit board is damaged beyond repair, either the entire assembly including all soldered-on components, or the board only, can be replaced. Part numbers are given in the Mechanical Parts List for either the completely wired or the unwired board. Most of the components mounted on the circuit boards can be replaced without removing the boards from the instrument. Observe the soldering precautions given under Soldering Techniques in this section. However, if the bottom side of the board must be reached or if the board must be moved to gain access to other areas of the instrument, only the mounting screws need to be removed. The interconnecting wires on most of the boards are long enough to allow the board to be moved out of the way or turned over without disconnecting the pin connectors.

GENERAL:

Most of the connections to the circuit boards in the indicator are made with pin connectors. However, some connections are soldered to the board. Also, the connections between the Attenuator and the Input Amplifier boards are soldered. See the special removal instructions for the Input Amplifier boards.

Use the following procedure to remove a circuit board:

1. Disconnect all pin connectors from the board and unsolder any soldered connections.

2. Remove all screws holding the board to the chassis.

3. Lift the circuit board out of the instrument Do not force or bend the board.

4. To replace the board, reverse the order of removal. Correct location of the pin connectors is shown in Figs. 4-8 through 4-17. Replace the pin connectors carefully so they mate correctly with the pins. If forced into place incorrectly positioned the pin connectors may be damaged.

INPUT AMPLIFIER UNIT REMOVAL:

The Input Amplifier boards and the attenuators can be removed from the Type 422 as a unit, or the circuit boards can be removed separately. To remove the board only, follow the procedure described under GENERAL. To remove as a unit, proceed as follows:

1. Unsolder the wire from the Input Coupling switch and the ground lead from the BNC connector.

2. Remove the front-panel VOLTS/DIV and VARIABLE knobs.

3. Remove the securing nuts on the VOLTS/DIV switch and the GAIN control.

4. Remove the two screws located at the rear of the Attenuator which secure the assembly to the chassis.

5. Disconnect all pin connectors on the board. Do not unsolder the soldered connections.

6. Lift up the rear of the assembly and slide it out of the instrument. The support rod on the lower left side of the instrument must be removed to allow clearance for the Channel 1 Attenuator. A nutdriver or socket wrench should be used to remove this rod, as an open-end wrench may damage the rod and prevent the power supply from being secured to the indicator properly.

7. The Input Amplifier board can now be removed from the assembly as follows:

a. Unsolder the remaining connections between the Attenuator and the circuit board.

b. Remove the three screws which hold the circuit board to the Attenuator.

8. To replace the unit, reverse the order of removal. When replacing the Channel 2 Attenuator assembly, be sure the INVERT and X10 GAIN AC switches fit properly in the actuating assemblies.

Transistor Replacement. Transistors should not be replaced unless actually defective. If removed from their sockets during routine maintenance, return them to their original sockets. Unnecessary replacement 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. 4-3 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 a transistor 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. Transistors which have heat radiators or are mounted on the chassis use silicone grease to increase heat transfer. 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.

Cathode-Ray Tube Replacement. Use care when handling a CRT. Protective clothing and safety glasses should be worn. Avoid striking it on any object which might cause it to crack or implode. When storing a CRT, place it face down on a smooth surface with a protective cover or soft mat under the faceplate to protect it from scratches.

The CRT shield should also be handled carefully. This shield protects the CRT display from distortion due to magnetic interference. If the shield is dropped or struck sharply, it may lose its shielding ability.

The following procedure outlines the removal and replacement of the cathode- ray tube:

A. REMOVAL:

1. Remove the power supply and then remove the indicator cabinet as described previously.

2. Remove the light filter or faceplate protector.

3. Disconnect the CRT anode connector. Ground this lead and the anode connection to discharge any stored charge.

4. Disconnect the trace-rotation leads at the Horizontal Amplifier board.

5. Unsolder the −12-volt power supply lead at the Y Axis Align control.

6. Disconnect the deflection-plate connectors. Be careful not to bend the deflection-plate pins.

7. Remove the CRT socket shield.

8. Remove the CRT socket.

9. Remove the two nuts (by the graticule lights) which hold the front of the CRT shield to the subpanel.

10. Remove the graticule lights from the studs and position them away from the shield.

11. Remove the remaining two screws holding the shield bracket to the rear of the indicator.

12. Slide the CRT assembly to the rear of the instrument until the faceplate clears the mounting studs. Then lift the front of the CRT assembly up and slide it out of the instrument.

13. Loosen the CRT clamp at the rear of the CRT shield near the shield bracket.

14. Hold one hand on the CRT faceplate and push forward on the CRT base with the other. As the CRT starts out of the shield, grasp it firmly. When the CRT is free of the clamp slide the shield completely off the CRT. Be careful not to bend the neck pins.

B. REPLACEMENT:

1. Insert the CRT into the shield. Be careful not to bend the neck pins. Seat the CRT firmly against the shield.

2. Tighten the CRT clamp.

3. Place the light mask over the CRT faceplate.

4. Using a method similar to that for removal (step 12) re-insert the CRT assembly into the instrument. Be sure the CRT faceplate seats properly in the subpanel.

5. Replace the two lower screws in the shield bracket.

6. Replace the graticule lights and securing nuts.

7. Replace the CRT socket and socket shield.

8. Reconnect the anode connector. Align the plug on the CRT and the jack in the connector and press firmly on the insulated cover to snap the jack into place

9. Reconnect the trace-rotation leads and the −12-volt lead at the Y-Axis Align Control.

10. Reconnect the deflection-plate connectors. Correct location is indicated on the CRT shield.

11. Adjust the TRACE ROTATION, Y Axis Align and Geometry adjustments. Adjustment procedure is given in the Calibration section. Also check the basic vertical and horizontal gain.

NOTE

If the Trace Rotation adjustment does not have enough range to make the trace parallel with the graticule lines, reverse the connection of the leads at the Horizontal Amplifier board.

Fuse Replacement. Table 4-4 gives the rating, location and function of the fuses used in this instrument.

TABLE 4-4
Fuse Ratings

Circuit number	Rating	Location	Function
F1000	3/4 A Fast	Rear of power supply	115-230 V line
F1014	3 A Fast	Rear of power supply	11.5-35 V line

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 numbers.

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 on 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.

When removing the transformer, tag the leads with the corresponding terminal numbers to aid in connecting the new transformer. After the transformer is replaced check the performance of the complete instrument using the Performance Check procedure.

High-Voltage Compartment. The components located in the high-voltage compartment can be reached for maintenance or replacement by using the following procedure.

1. Remove the cabinet from the instrument as described earlier in this section.

2. Turn the instrument over with the bottom side up.

3. Remove the two screws which hold the high-voltage compartment to the chassis.

4. Lift the complete high-voltage compartment away from the chassis.

5. Slide the shield off the plastic high-voltage housing. The two pins on the bottom of the housing must be freed from the holes in the shield before the shield can be slid off.

6. Remove the lid of the high-voltage housing.

7. To replace the high-voltage compartment, reverse the order of removal. When placing the circuit boards back into the compartment, be sure the insulator sheet is installed in the proper place. Fig. 4-6 shows the correct location of the circuit boards and the insulator sheet.

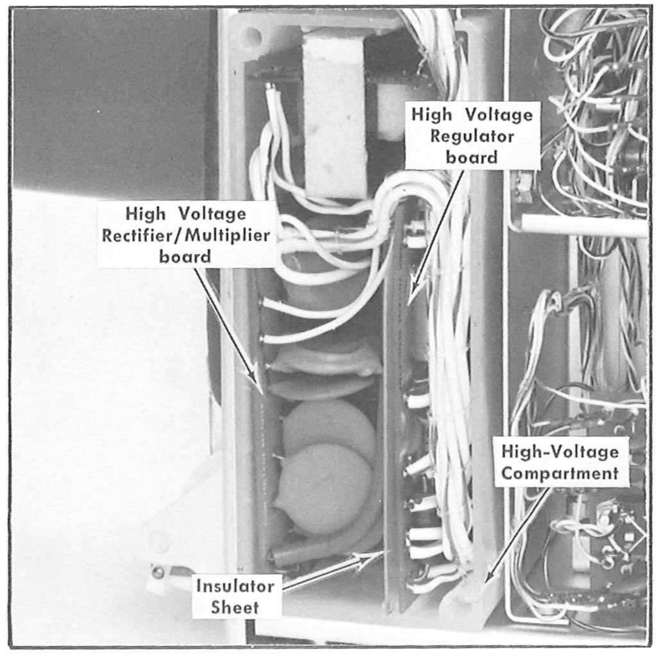


Fig. 4-6. Location of circuit boards in high-voltage compartment.

NOTE

All solder joints in the high-voltage compartment should have smooth surfaces. Any protrusions may cause high-voltage arcing at high altitudes.

Recalibration After Repair

After any electrical component has been replaced, the calibration of that particular circuit should be checked, as well as the calibration of other closely related circuits. Since the low-voltage supply affects all circuits, calibration of the entire instrument should be checked if work has been done in the low-voltage supply or if the power transformer has been replaced. The Performance Check procedure provides a quick and convenient means of checking instrument operation.

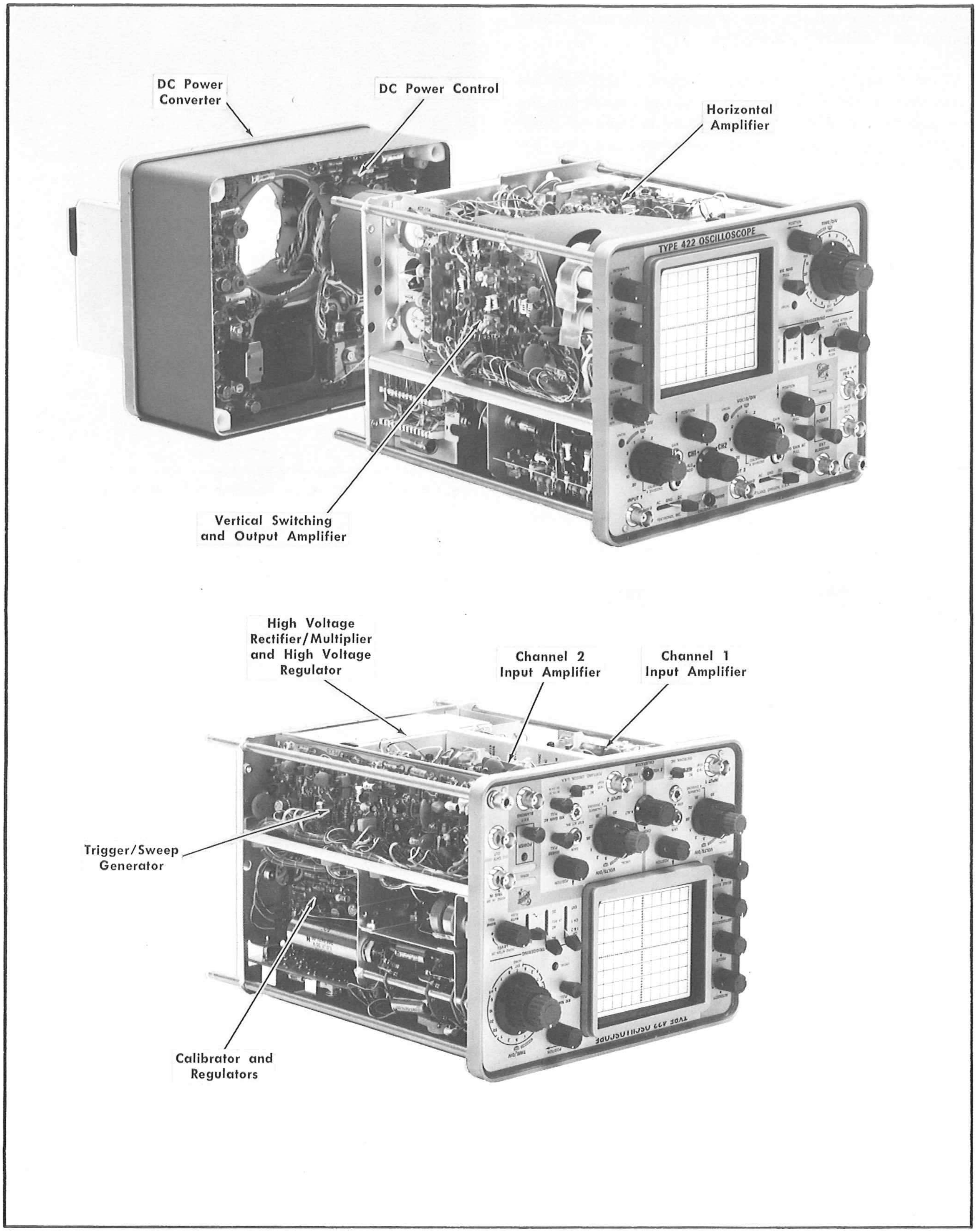


Fig. 4-7. Location of circuit boards in the Type 422 and AC-DC Power Supply.

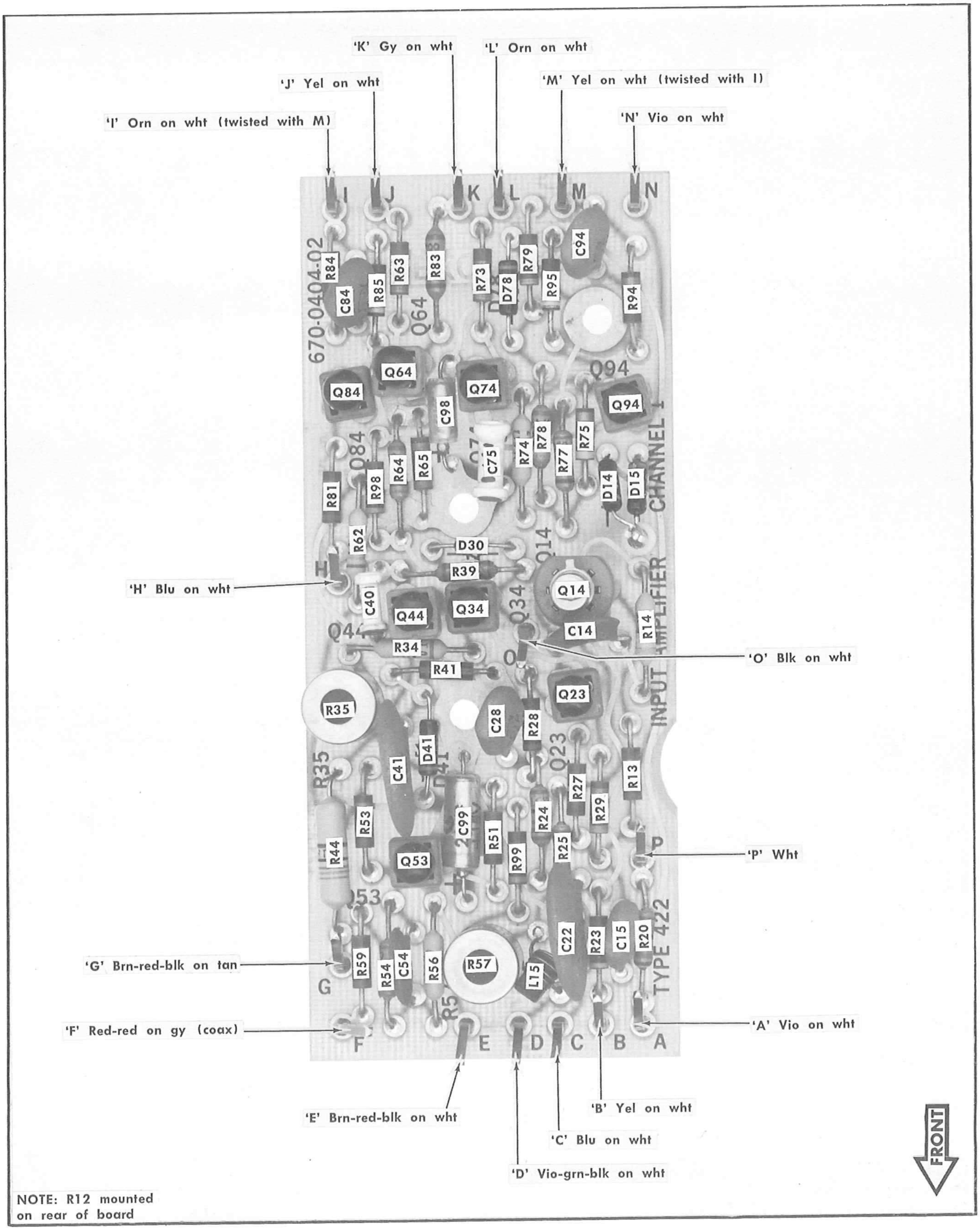


Fig. 4-8. Channel 1 Input Amplifier circuit board.

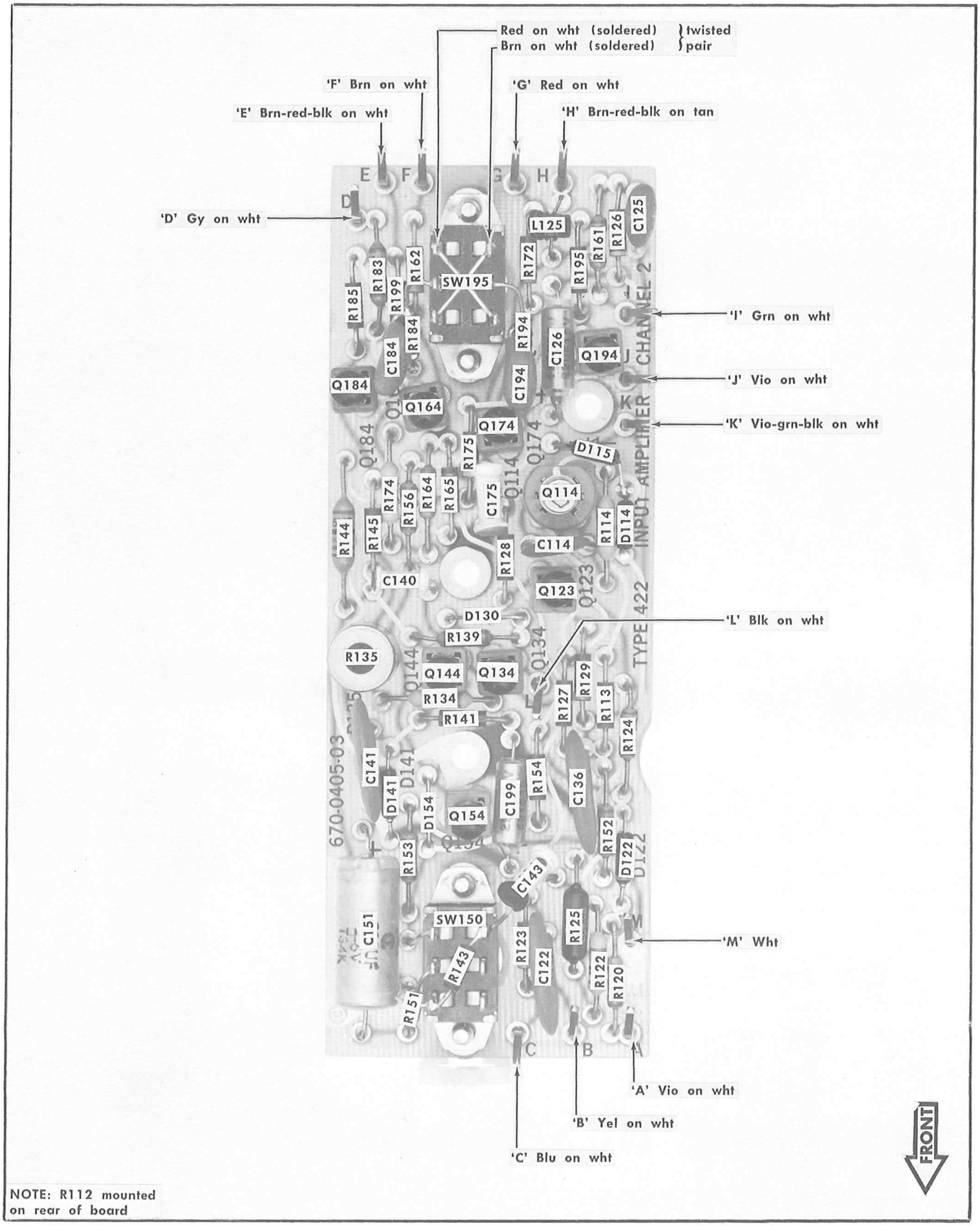


Fig. 4-9. Channel 2 Input Amplifier circuit board.

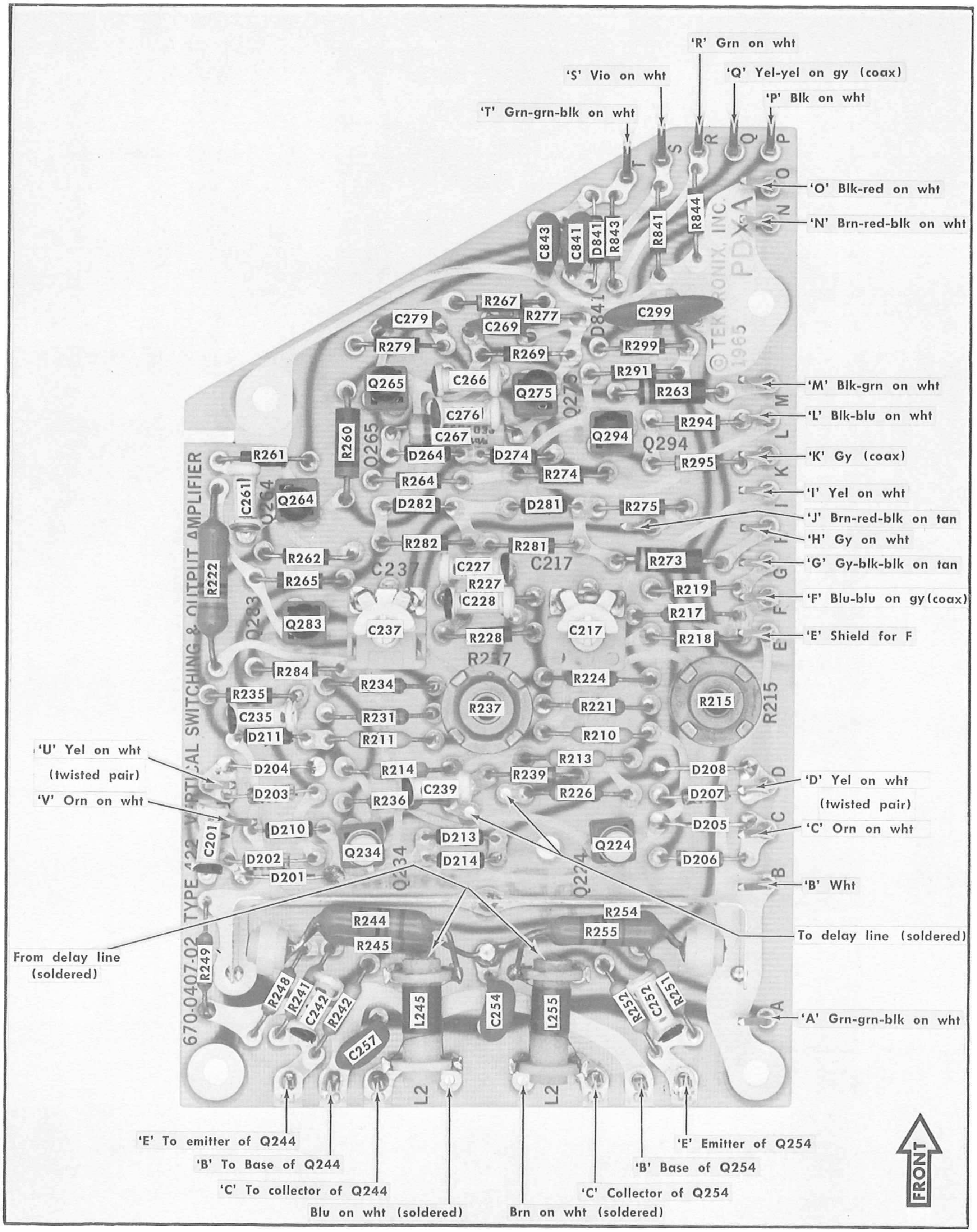


Fig. 4-10. Vertical Switching and Output Amplifier circuit board.

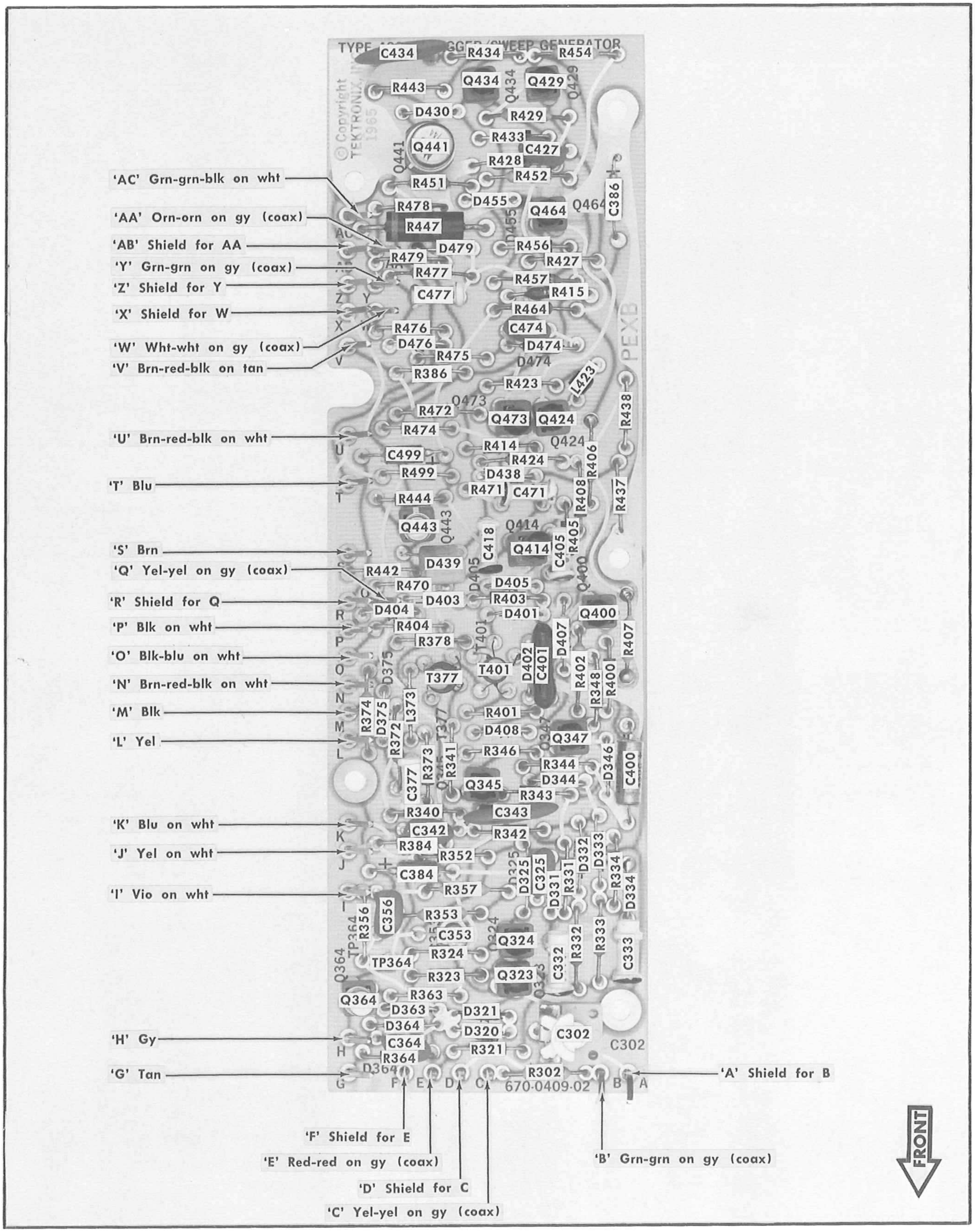


Fig. 4-11. Trigger/Sweep Generator circuit board.

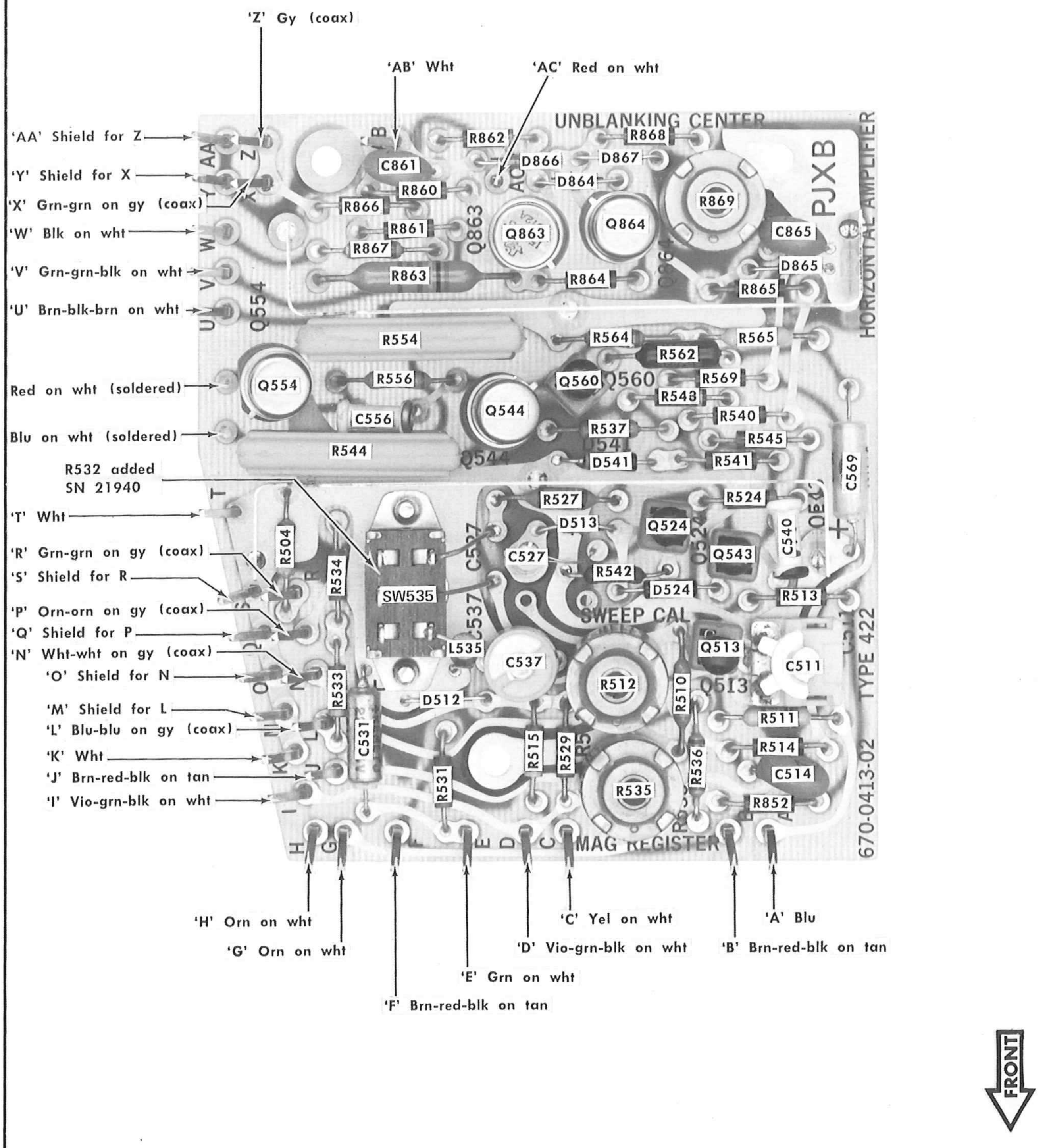


Fig. 4-12. Horizontal Amplifier circuit board.

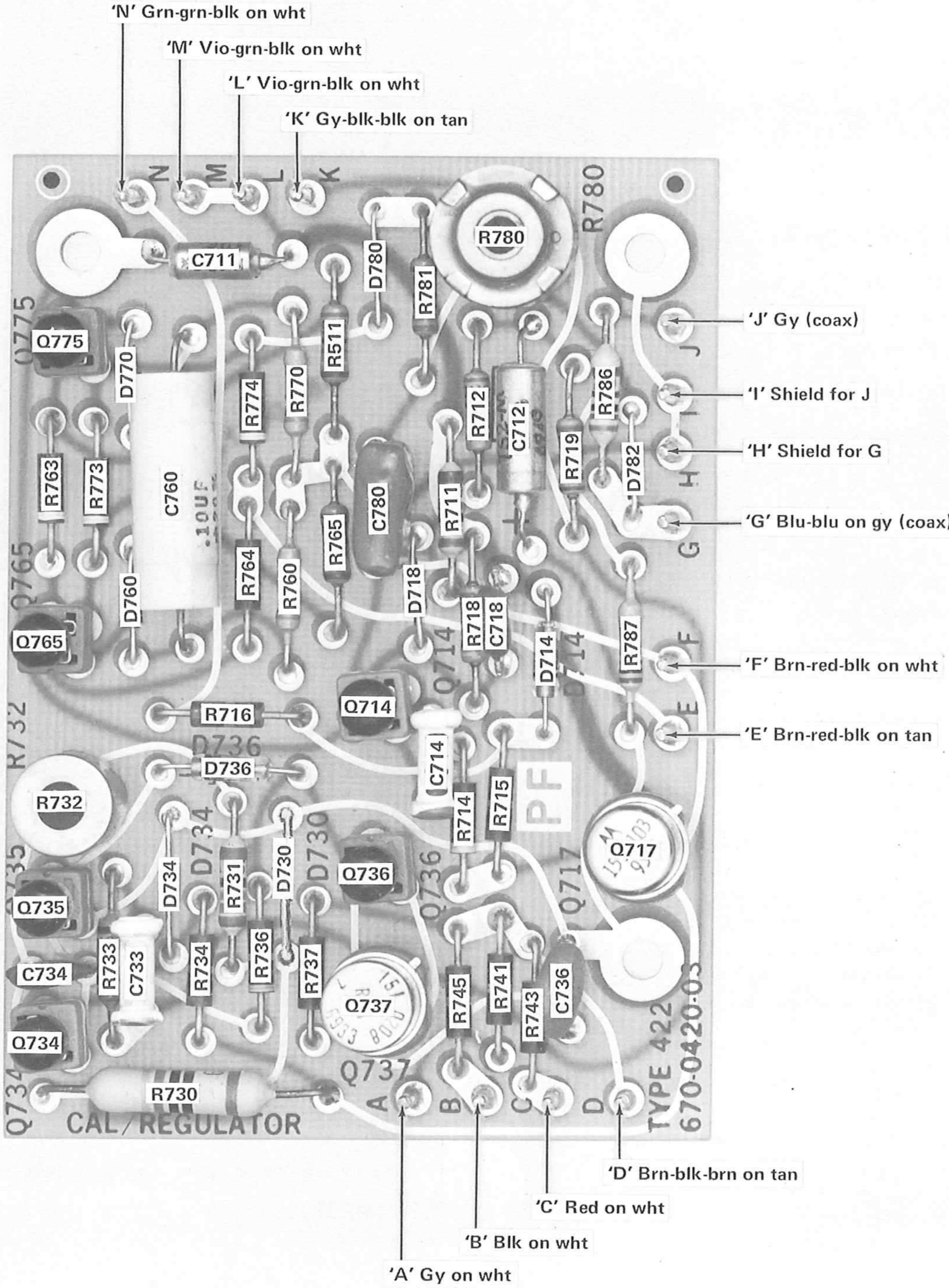


Fig. 4-13A. Calibrator and Regulators circuit board (SN 28000 and up).

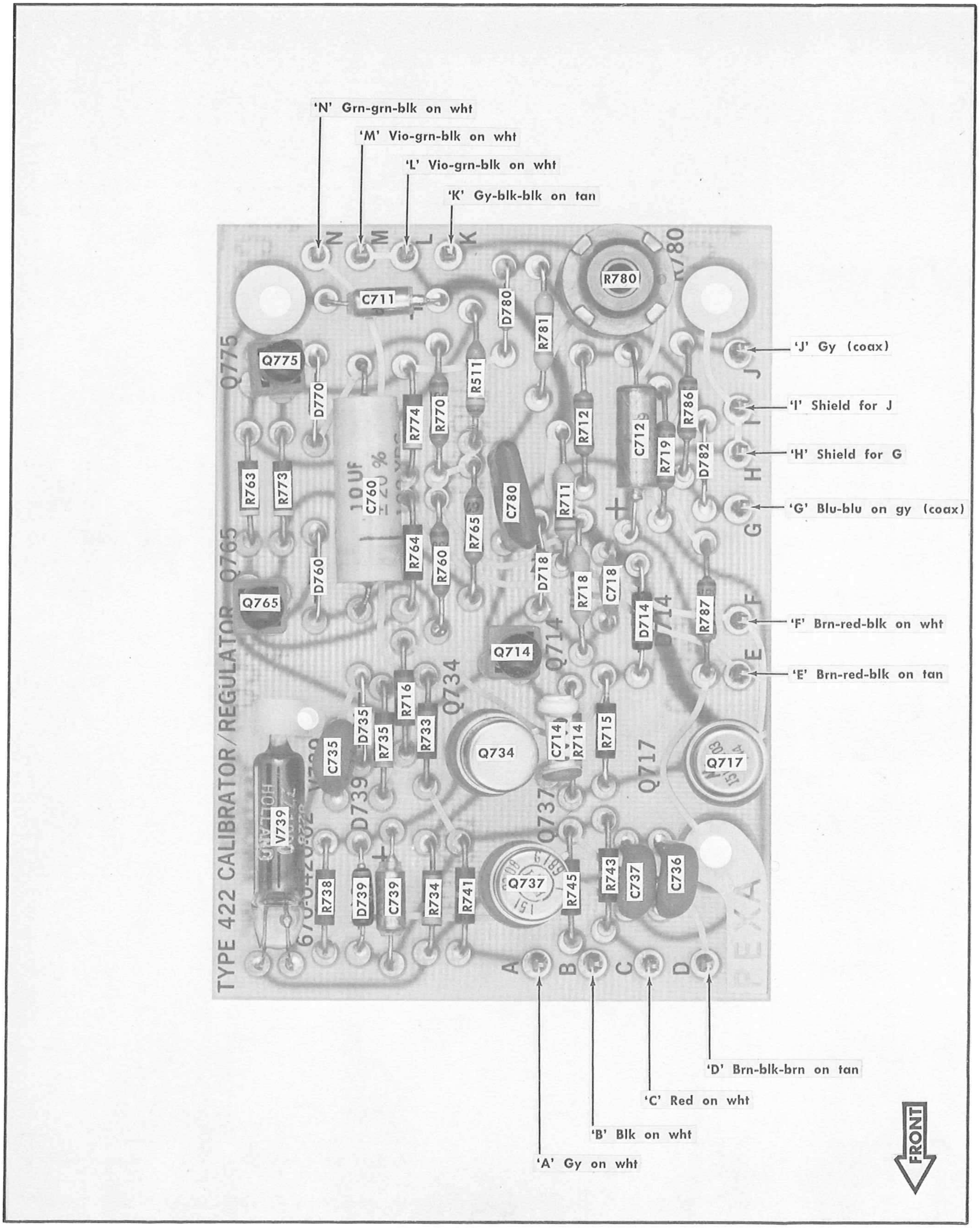


Fig. 4-13B. Calibrator and Regulators circuit board (SN 20000 thru 27999).

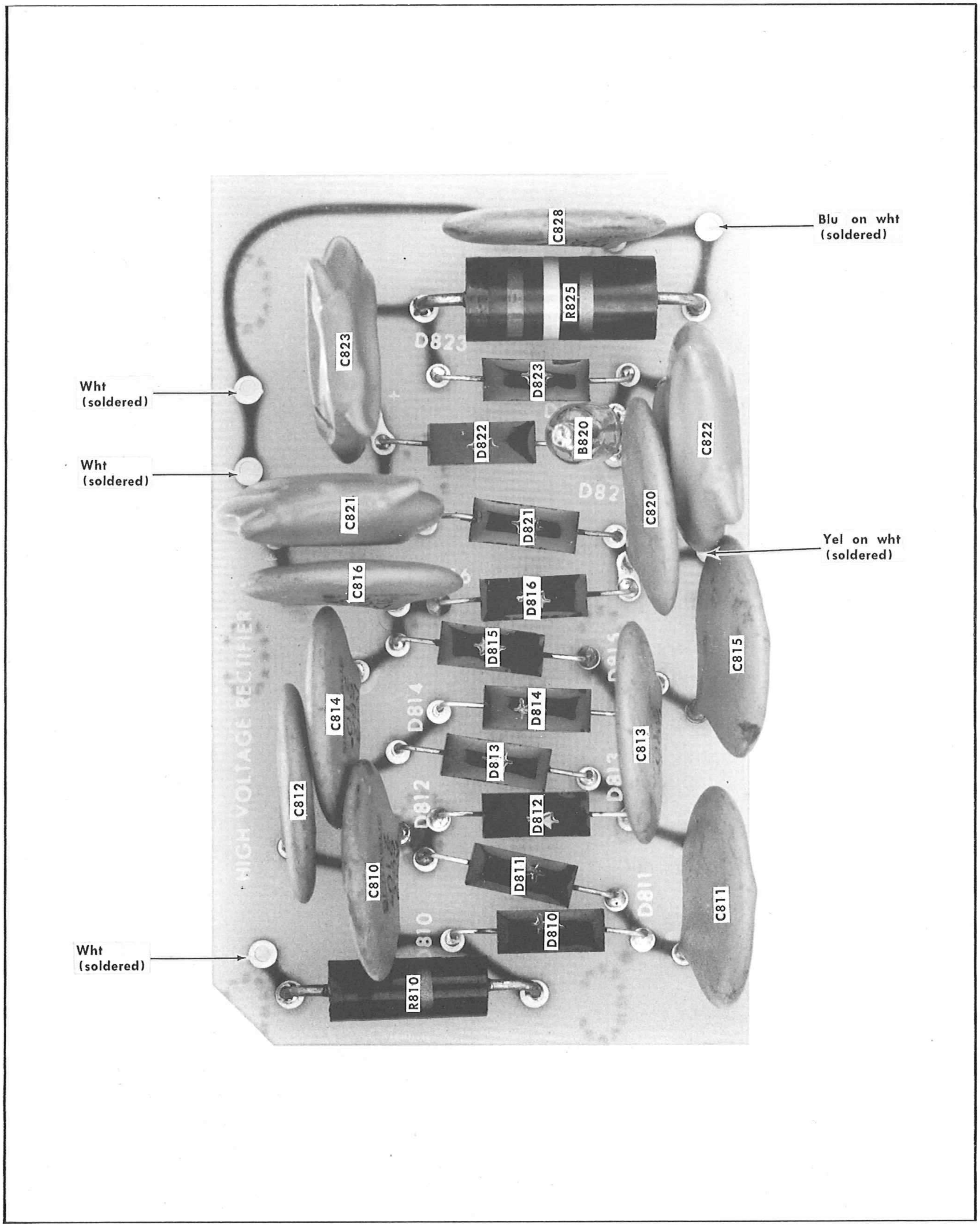


Fig. 4-14. High Voltage Rectifier/Multiplier circuit board.

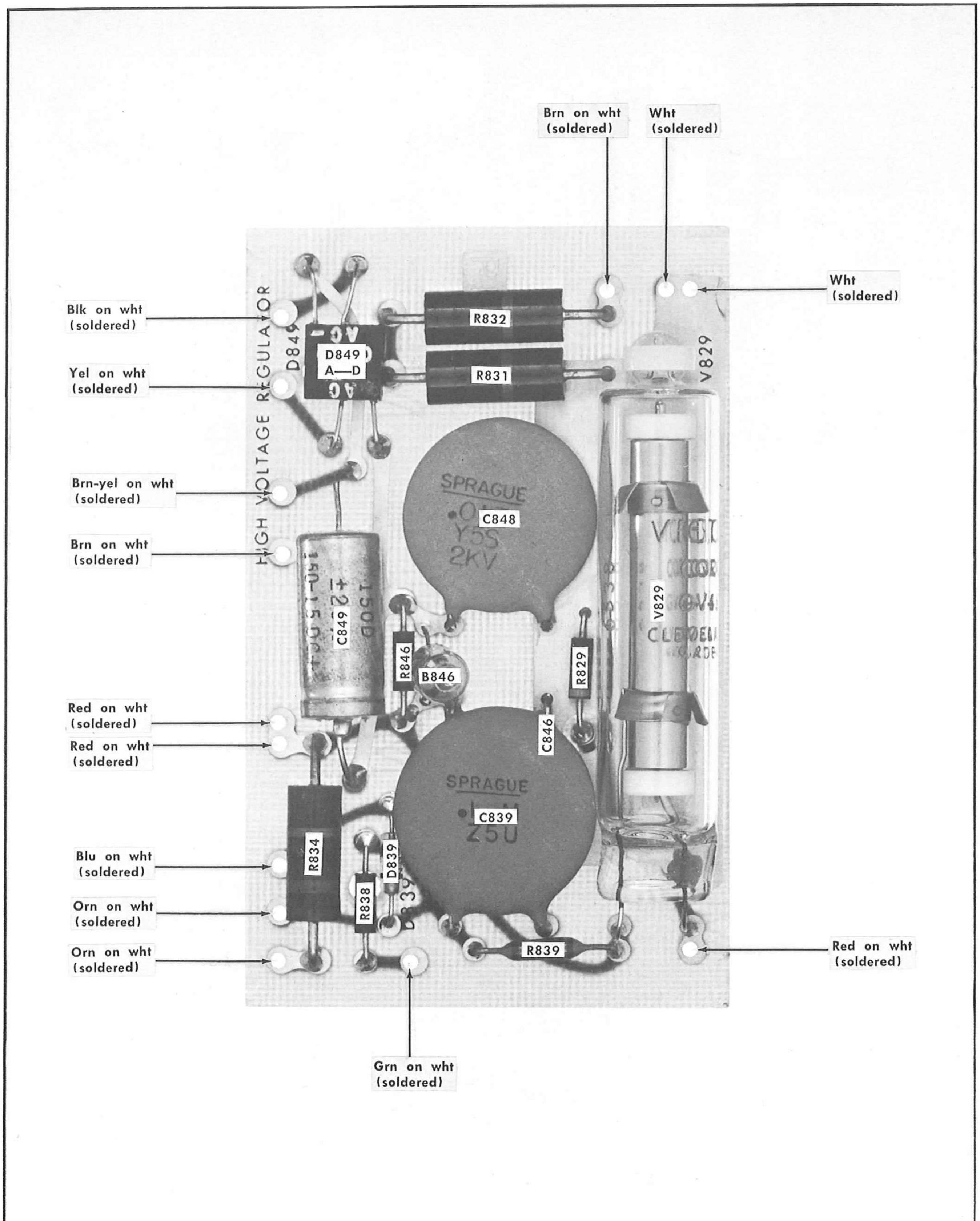


Fig. 4-15. High Voltage Regulator circuit board.

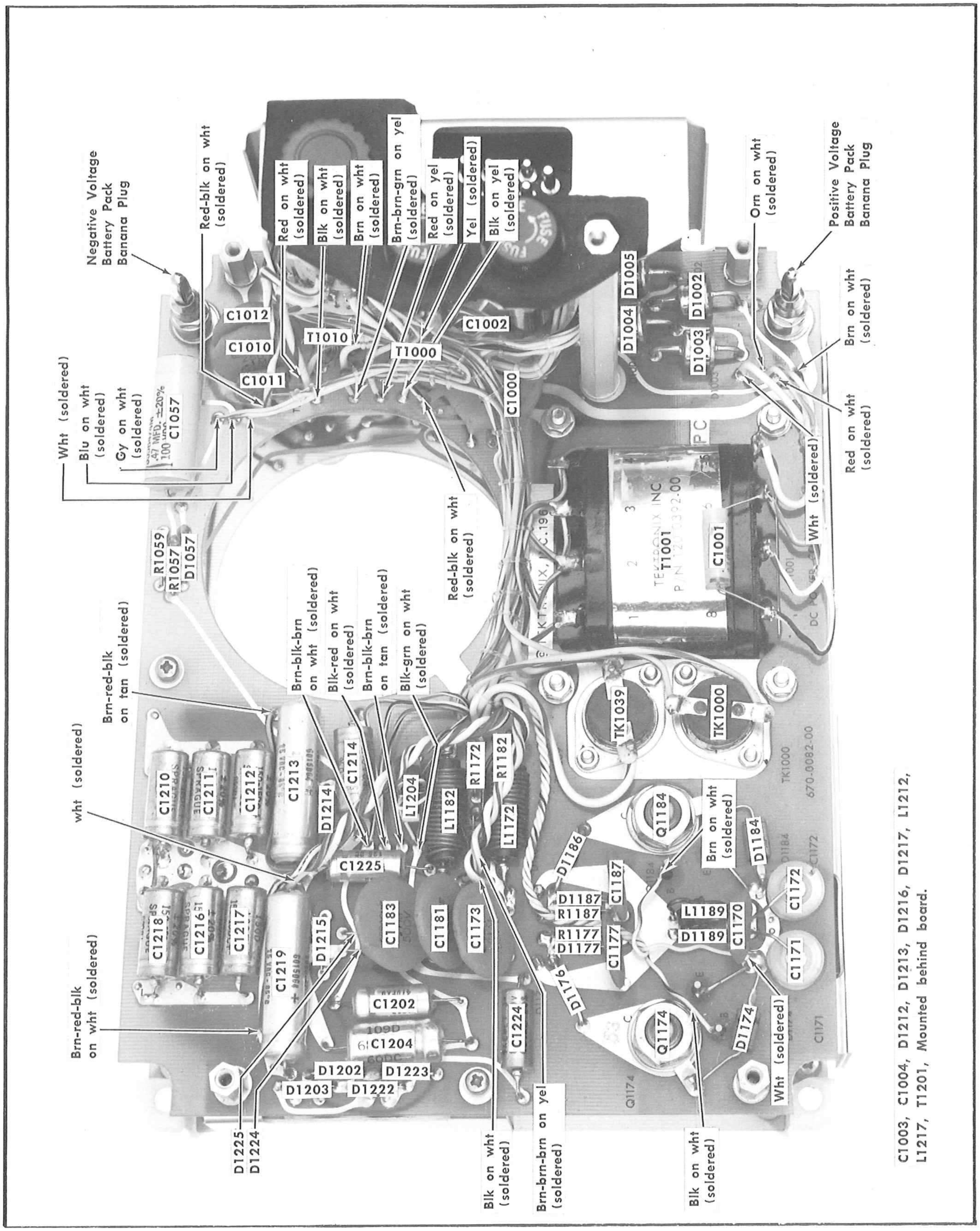


Fig. 4-16. DC Power Converter circuit board.

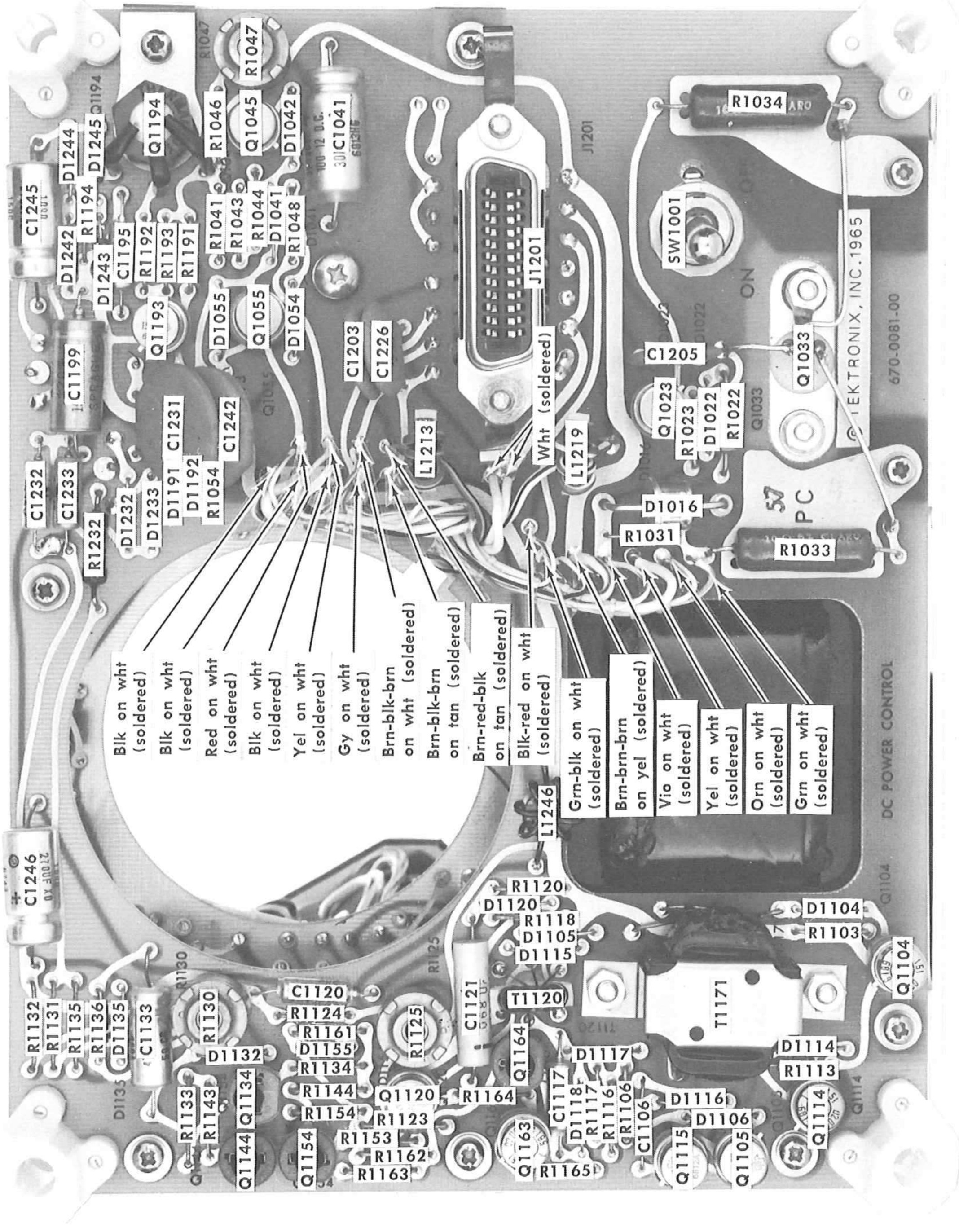


Fig. 4-17. DC Power Control circuit board.

NOTES

SECTION 5
PERFORMANCE CHECK/CALIBRATION

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

Introduction

To assure instrument accuracy, check the calibration of the Type 422 every 1000 hours of operation, or every six months if used infrequently. Before complete calibration, thoroughly clean and inspect this instrument as outlined in the Maintenance section.

As an aid to the calibration of the instrument, a Short-Form Procedure is given prior to the complete procedure. To facilitate instrument calibration for the experienced calibrator, the Short-Form Procedure lists the calibration adjustments necessary for each step and the applicable tolerances. This procedure also includes the step number and title as listed in the complete Performance Check/Calibration Procedure and the page number on which each step begins. Therefore, the Short-Form Procedure can be used as an index to locate a step in the complete procedure. Another feature of the Short-Form Procedure is the spaces provided to record performance data or to check off steps as they are completed. This procedure can be reproduced and used as a permanent record of instrument calibration.

The complete Performance Check/Calibration Procedure can be used to check instrument performance without removing the covers or making internal adjustments by performing all portions except the ADJUST- part of a step. Screwdriver adjustments which are accessible without removing the covers are adjusted as part of the performance check procedure. A note titled PERFORMANCE CHECK ONLY gives instructions which are applicable only to the performance check procedure and if necessary, lists the next applicable step for the performance check procedure.

Completion of each step in the complete Performance Check/Calibration Procedure insures that this instrument meets the electrical specifications given in Section 1. Where possible, instrument performance is checked before an adjustment is made. For best overall instrument performance when performing a complete calibration procedure, make each adjustment to the exact setting even if the CHECK— is within the allowable tolerance.

NOTE

All waveforms shown in this procedure were taken with a Tektronix Oscilloscope Camera System. Limits, tolerances and waveforms in this procedure are given as calibration guides and should not be interpreted as instrument specifications except as specified in Section 1.

A partial calibration is often desirable after replacing components, or to touch up the adjustment of a portion of the instrument between major recalibrations. To check or adjust only part of the instrument, set the controls as given under Preliminary Control Settings and start with the nearest test equipment picture preceding the desired portion. If any controls need to be changed from the preliminary settings for this portion of the calibration procedure, they are listed under the heading Partial Procedure following the equipment required picture. To prevent unnecessary recalibration of other parts of the instrument, readjust only if the tolerance given in the CHECK— part of the step is not met. If readjustment is necessary, also check the calibration of any steps listed in the INTERACTION— part of the step.

TEST EQUIPMENT REQUIRED

General

The following test equipment and accessories, or its equivalent, is required for complete calibration of the Type 422. Specifications given are the minimum necessary for accurate calibration. Therefore, some of the recommended equipment may have specifications which exceed those given. All test equipment is assumed to be correctly calibrated and operating within the given specifications. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

Special Tektronix calibration fixtures are used in this procedure only where they facilitate calibration. These special calibration fixtures are available from Tektronix, Inc. Order by part number through your local Tektronix Field Office or representative.

Test Equipment

1. Variable DC power supply[1]. Voltage range, at least +11 to +35 volts; current capability, at least 2.5 amperes; output voltage monitored within 3%. For example, Trygon Model HR40-5B.

2. Precision DC voltmeter[1]. Accuracy, within 0.1%; resolution, 50 microvolts; range, zero to 100 volts. For example, Fluke Model 825A Differential DC Voltmeter.

3. Test oscilloscope. Bandwidth, DC to five megahertz; minimum deflection factor, one millivolt/division; accuracy, within 3%. Tektronix Type 422 Oscilloscope recommended (use X10 gain feature to obtain one millivolt minimum deflection factor).

[1] **Not required for performance check only.**

4. Variable autotransformer.[1] Must be capable of supplying about 75 volt-amperes over a range of 95 to 137 volts (190 to 274 volts for 230-volt nominal line). (If autotransformer does not have an AC voltmeter to indicate output voltage, monitor the output with an AC voltmeter with range of at least 137 or 274 volts, RMS.) For example, General Radio W10MT3A Metered Variac Autotransformer (use General Radio W20HMT3A for 230-volt nominal line).

5. DC volt-ammeter (VOM).[1] Minimum sensitivity, 20,000 ohms/volt; range, 0 to 1500 volts and 0 to 500 milliamperes; accuracy, checked to within 1% at −1385 and at the currents to be measured. For example, Triplett Model 630-NA.

6. Time-mark generator. Marker outputs, 50 nanoseconds to 0.5 second; marker accuracy, within 0.1%. Tektronix Type 184 Time-Mark Generator recommended.

7. Standard amplitude calibrator. Amplitude accuracy, within 0.25%; signal amplitude, 20 millivolts to 100 volts; output signal, one-kilohertz square wave. Tektronix calibration fixture 067-0502-00 recommended.

8. Square-wave generator. Must have the following output capabilities (may be obtained from separate generators): 120 volts amplitude at one and 10 kilohertz repetition rate with a 120 nanosecond or less risetime; 500 millivolts into 50 ohms at 100 kilohertz repetition rate with a five nanosecond risetime. Tektronix Type 106 Square-Wave Generator recommended (meets both output requirements).

9. High-frequency constant-amplitude sine-wave generator. Frequency, 350 kilohertz to above 15 megahertz; reference frequency, 50 kilohertz; output amplitude, variable from five millivolts to five volts peak to peak into 50 ohms; amplitude accuracy, output amplitude constant within 3% of reference at 50 kilohertz as output frequency changes. Tektronix Type 191 Constant Amplitude Signal Generator recommended.

10. Low-frequency constant-amplitude sine-wave generator. Frequency, two hertz to one megahertz; output amplitude, variable from 40 millivolts to five volts peak to peak; amplitude accuracy, output amplitude constant within 3% of reference at one kilohertz as output frequency changes. For example, General Radio Model 1310-A Oscillator.

Accessories

11. DC power cord.[1] Fits DC portion of AC-DC Power Supply power receptacle. Tektronix Part No. 161-0016-01 (supplied accessory).

12. 1X probe. Tektronix P6011 Probe recommended.

[1] **Not required for performance check only.**

13. Patch cord (two). Length, 18 inches; connectors, dual banana plug-jack. Tektronix Part No. 012-0031-00.

14. AC power cord. Fits AC portion of AC-DC Power Supply power receptacle. Tektronix Part No. 161-0015-01.

15. 50-ohm resistor. 10 watt, 5%. Tektronix Part No. 308-0362-00.

16. 680-ohm resistor. Two watt, 5%. Tektronix Part No. 305-0681-00.

17. Jumper lead. Length, six inches; connectors, alligator clips both ends. Not available from Tektronix.

18. Cable. Impedance, 50 ohms; type, RG-58/U; length, 42 inches; connectors, BNC. Tektronix Part No. 012-0057-01.

19. 10X probe for test oscilloscope.[1] Tektronix P6012 Probe recommended.

20. Dual input coupler. Matched signal transfer to each input. Tektronix calibration fixture 067-0525-00.

21. Adapter. Adapts GR874 connector to BNC male connector. Tektronix Part No. 017-0063-00.

22. Cable. Impedance, 50 ohms; type, RG-58/U; length, 18 inches; connectors, BNC. Tektronix Part No. 012-0076-00.

23. 10X attenuator (two). Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0059-00.

24. Termination. Impedance, 50 ohms; accuracy, ±3%; connectors, BNC. Tektronix Part No. 011-0049-00.

25. Input RC normalizer. Time constant, one megohm X 33 pF; attenuation, 2X; connectors, BNC. Tektronix calibration fixture 067-0540-00.

26. Adapter. Adapts BNC male connector to dual binding post, Pomona #1269. Tektronix Part No. 103-0090-00.

Adjustment Tools

27. Screwdriver. Three-inch shaft, 3/32-inch bit for slotted screws. Tektronix Part No. 003-0192-00.

28. Low-capacitance screwdriver.[1] 1 1/2-inch shaft. Tektronix Part No. 003-0000-00.

29. Tuning tool.[1] Handle and insert for 5/64-inch (ID) hex cores. Tektronix Part Nos. 003-0307-00 and 003-0310-00.

SHORT-FORM PROCEDURE

Type 422, Serial No. ______________

Calibration Date ______________

Calibrated By ______________

1. Adjust −12-Volt Power Supply (R1130) Page 5-9

REQUIREMENT: −12 volts ±0.12 volt.

PERFORMANCE: −12 volts ± ____volt.

2. Adjust Blocking Oscillator Frequency (R1125) Page 5-9

REQUIREMENT: Correct oscillator frequency; see complete procedure.

PERFORMANCE: Correct ____; incorrect ____.

3. Check DC Regulation Page 5-10

Supply	REQUIREMENT:	PERFORMANCE:
+10.5 volt	+10.3 to +10.7 volts	________ volts
−12 volt	−11.9 to −12.1 volts	________ volts
+12 volt	+11.7 to +12.3 volts	________ volts
+55 volt	+53.9 to +56.7 volts	________ volts
+95 volt	+93.7 to +97.9 volts	________ volts
−81 volt	−80 to −82 volts	________ volts

4 Check DC Ripple Page 5-11

Supply	REQUIREMENT: (maximum)	PERFORMANCE:
−12 volt	20 millivolts	______ millivolts
+12 volt	20 millivolts	______ millivolts
+55 volt	0.32 volt	______ volt
+95 volt	0.4 volt	______ volt
+10.5 volt	1 millivolt	______ millivolt
−81 volt	20 millivolts	______ millivolts

5. Adjust Low-Voltage Indicator (R1047) Page 5-12

REQUIREMENT: Power light begins to blink with DC input voltage of 22 volts +0, −1 volt.

PERFORMANCE: Correct ____; incorrect ____.

6. Check AC Operation Page 5-12

Output voltage

Supply	REQUIREMENT:	PERFORMANCE:
−12 volt	−11.9 to −12.1 volts	________ volts
+12 volt	+11.7 to +12.3 volts	________ volts
+55 volt	+53.9 to +56.7 volts	________ volts
+95 volt	+93.7 to +97.9 volts	________ volts
+10.5 volt	+10.3 to +10.7 volts	________ volts
−81 volt	−80 to −82 volts	________ volts

Ripple

Supply	REQUIREMENT: (maximum)	PERFORMANCE:
−12 volt	8 millivolts	______ millivolts
+12 volt	8 millivolts	______ millivolts
+10.5 volt	1 millivolt	______ millivolt
−81 volt	8 millivolts	______ millivolts

7. Check Battery Charger Operation Page 5-13

REQUIREMENT:

CHARGE BATT 115V AC; 95-volt line, 325 milliamperes minimum. 126.5-volt line, 450 milliamperes maximum.

OPERATE 115V AC; 95- and 126.5 volt line, 30 to 50 milliamperes.

PERFORMANCE:

CHARGE BATT 115V AC; 95-volt line, ____ milliamperes. 126.5-volt line, ____ milliamperes.

OPERATE 115V AC; 95- and 126.5-volt line, ____ and ____ milliamperes.

8. Check High-Voltage Supply Page 5-13

REQUIREMENT: −1385 volts ±69.5 volts.

PERFORMANCE: −1385 volts ± ____volts.

9. Adjust unblanking Center (R869) Page 5-13

REQUIREMENT: Maximum trace intensity.

PERFORMANCE: Correct ____; incorrect ____.

10. Check/Adjust Trace Rotation (R851) Page 5-13

REQUIREMENT: Trace parallel to center horizontal line within 0.1 division/10 divisions.

PERFORMANCE: Within ____division.

11. Check/Adjust Y Axis Alignment (R856) Page 5-14

REQUIREMENT: Markers parallel to the center vertical line within 0.1 division.

PERFORMANCE: Within ____division.

12. Check/Adjust CRT Geometry (R854) Page 5-15

REQUIREMENT: Bowing of markers at left and right edges of graticule within 0.1 division. Trace parallel to the top and bottom horizontal lines of the graticule within 0.1 division.

PERFORMANCE: Left and right edges within division; top and bottom within ____ division.

13. Check/Adjust Channel 1 Step Attenuator and Variable Balance (R21, R35) Page 5-16

REQUIREMENT: Step attenuator balance, less than 0.1 division vertical trace shift as Channel 1 VOLTS/DIV switch is changed from .05 to .01. Variable balance, less than 0.2 division vertical trace shift as Channel 1 VARIABLE VOLTS/DIV control is rotated throughout its range.

PERFORMANCE: Step attenuator balance, ____ division shift. Variable balance, ____ division shift.

14. Check/Adjust Channel 2 Step Attenuator and Variable Balance (R121, R135) Page 5-17

REQUIREMENT: Step attenuator balance, less than 0.1 division vertical trace shift as Channel 2 VOLTS/DIV switch is changed from .05 to .01. Variable balance, less than 0.2 division vertical trace shift as Channel 2 VARIABLE VOLTS/DIV control is rotated throughout its range.

PERFORMANCE: Step attenuator balance, ____ division shift. Variable balance, ____ division shift.

15. Adjust Common-Mode Current (R215) Page 5-17

REQUIREMENT: Correct operation; see complete procedure.

PERFORMANCE: Correct ____ ; incorrect ____ .

16. Check/Adjust Channel 1 and 2 Gain (R80, R180) Page 5-18

REQUIREMENT: Four divisions ±0.12 division vertical deflection at .05 VOLTS/DIV with 0.2-volt square-wave input.

PERFORMANCE: Four divisions ± ____ division.

17. Check Added Mode Operation Page 5-19

REQUIREMENT: Correct signal addition within 3%.

PERFORMANCE: Correct ____; incorrect ____.

18. Check Channel 1 and 2 Deflection Accuracy Page 5-19

REQUIREMENT: Vertical deflection factor within 3% of Channel 1 and 2 VOLTS/DIV switch indication.

PERFORMANCE: Correct ____; incorrect (list exceptions) ________________________________ .

19. Check Channel 2 X10 Gain Page 5-19

REQUIREMENT: Four divisions ±0.16 division vertical deflection at .05 VOLTS/DIV, X10 GAIN AC pulled out with 20-millivolt square-wave input.

PERFORMANCE: Four divisions ± ____ division.

20. Check Channel 1 and 2 Variable Volts/Division Control Range Page 5-19

REQUIREMENT: Continuously variable between the calibrated settings of the VOLTS/DIV switches.

PERFORMANCE: Correct ____; incorrect ____ .

21. Check Low-Frequency Vertical Linearity Page 5-19

REQUIREMENT: 0.15 division or less compression or expansion of a center-screen two-division signal when positioned to the vertical extremes of the graticule area.

PERFORMANCE: ____ division.

22. Check Channel 1 and 2 Input Coupling Switch Operation Page 5-20

REQUIREMENT: Correct signal coupling in each position of the Channel 1 and 2 Input Coupling switches.

PERFORMANCE: Correct ____; incorrect ____ .

23. Check Trace Shift Due to Input Current Page 5-20

REQUIREMENT: Negligible at .01 VOLTS/DIV as Channel 1 and 2 Input Coupling switches are changed from GND to DC.

PERFORMANCE: Correct ____; incorrect ____ .

24. Check Alternate Operation Page 5-21

REQUIREMENT: Trace alternation at all sweep rates.

PERFORMANCE: Correct ____ ; incorrect ____ .

25. Check/Adjust Channel 1 Volts/Division Switch Compensation (C3B, C3C, C4B, C4C, C5B, C5C, C6B, C6C, C12) Page 5-21

REQUIREMENT: Optimum square corner and flat top within +3% or −3% with total peak-to-peak aberrations not to exceed 3% at each Channel 1 VOLTS/DIV switch position.

PERFORMANCE: Correct ____; incorrect (list exceptions) ________________________________ .

26. Check/Adjust Channel 2 Volts/Division Switch Compensation (C103B, C103C, C104B, C104C, C105B, C105C, C106B, C106C, C112) Page 5-21

REQUIREMENT: Optimum square corner and flat top within +3% or −3% with total peak-to-peak aberrations not to exceed 3% at each Channel 1 VOLTS/DIV switch position.

PERFORMANCE: Correct ____; incorrect (list exceptions) ____.

27. Check/Adjust High-Frequency Compensation (C237, L245, L255, R237) Page 5-22

REQUIREMENT: Optimum 100 kilohertz square-wave response at .05 VOLTS/DIV within +0.15 or −0.15 division with total peak-to-peak aberrations not to exceed 0.15 division).

PERFORMANCE: Correct ____; incorrect ____.

28. Check Upper Vertical Bandwidth Limit of Channel 1 and 2 Page 5-23

REQUIREMENT: Not more than −3 dB at 15 megahertz.

PERFORMANCE: −3 dB point, ____ megahertz.

29. Check Channel 2 X10 Gain Upper Vertical Bandwidth Page 5-24

REQUIREMENT: Not more than −3 dB at five megahertz.

PERFORMANCE: −3 dB point, ____ megahertz.

30. Check Common-Mode Rejection Ratio Page 5-24

REQUIREMENT: 100:1 or greater at 50 kilohertz.

PERFORMANCE: Correct ____; incorrect ____.

31. Check AC-Coupled Lower Vertical Bandwidth Limit Page 5-24

REQUIREMENT: Channel 1 and 2 (X1 gain), not more than −3 dB at two hertz. Channel 2 only with X10 GAIN AC switch pulled out, not more than −3 dB at five hertz.

PERFORMANCE: X1 gain: Correct ____; incorrect ____. X10 gain: Correct ____; incorrect ____.

32. Check Channel Isolation Ratio Page 5-25

REQUIREMENT: 10,000:1 or greater.

PERFORMANCE: Correct ____; incorrect ____.

33. Adjust Channel 1 Only Triggering DC Level (R57) Page 5-25

REQUIREMENT: Zero volts within 50 millivolts output from the Channel 1 Trigger Pickoff stage.

PERFORMANCE: Within ____ millivolts.

34. Adjust Internal Trigger Compensation (C217, C353) Page 5-25

REQUIREMENT: Optimum square-wave response through internal trigger pickoffs for CH 1 & 2 and CH 1 triggering.

PERFORMANCE: Correct ____; incorrect ____.

35. Adjust External Trigger Compensation (C302) Page 5-26

REQUIREMENT: Optimum square-wave response for external trigger signals from TRIG IN connector.

PERFORMANCE: Correct ____; incorrect ____.

36. Check High-Frequency Triggering Operation Page 5-27

REQUIREMENT: Internal, stable display in the AC, AC LF REJ and DC TRIGGERING Coupling switch positions for the CH 1 and CH 1 & 2 TRIGGERING Source switch positions with the TRIGGERING Mode switch set to AUTO and NORM; check with 0.2-division display at five megahertz and one-division display at 15 megahertz. External, stable display in the AC, AC LF REJ and DC TRIGGERING Coupling switch positions for the EXT TRIGGERING Source switch position with the TRIGGERING Mode switch set to AUTO and NORM; check with 0.125-volt signal at five megahertz and 0.6-volt signal at 15 megahertz.

PERFORMANCE: Correct ____; incorrect (list exceptions) ____.

37. Check Low-Frequency Triggering Operation Page 5-28

REQUIREMENT: Internal, stable display in the AC and DC TRIGGERING Coupling switch positions for the CH 1 and CH 1 & 2 TRIGGERING Source switch positions with the TRIGGERING Mode switch set to AUTO and NORM; check with 0.2-division display at 50 hertz. External, stable display in the AC and DC TRIGGERING Coupling switch positions for the EXT TRIGGERING Source switch position with the TRIGGERING Mode switch set to AUTO and NORM; check with 0.125-volt signal at 50 hertz.

PERFORMANCE: Correct ____; incorrect (list exceptions) ____.

38. Check Low-Frequency Reject Operation — Page 5-28

REQUIREMENT: Stable display with 0.2-division display at 50 kilohertz; does not trigger with two-division display at 50 hertz.

PERFORMANCE: Correct ___; incorrect ___.

39. Check Triggering Slope Operation — Page 5-29

REQUIREMENT: Stable triggering on correct slope of trigger signal.

PERFORMANCE: Correct ___; incorrect ___.

40. Check Triggering Level Control Range — Page 5-29

REQUIREMENT: At least + and −10 volts.

PERFORMANCE: Correct ___; incorrect ___.

41. Check Auto Recovery Time — Page 5-29

REQUIREMENT: Stable display with 50-millisecond markers; free-running display with 0.1-second markers.

PERFORMANCE: Correct ___; incorrect ___.

42. Check/Adjust Normal Timing (R512) — Page 5-29

REQUIREMENT: Correct timing within 0.24 division at 0.5 ms/DIV over middle eight divisions of the display; within 0.08 division over any two-division interval within center eight divisions.

PERFORMANCE: Within ___ division over center eight divisions; within ___ divisions (worst case) over two-division interval.

43. Check Sweep Length — Page 5-30

REQUIREMENT: 10.4 to 12.1 divisions.

PERFORMANCE: ___ divisions.

44. Check Magnified Timing — Page 5-30

REQUIREMENT: Correct magnified timing within 0.4 division at 0.5 ms/DIV over center eight divisions of display over total magnified sweep length; within 0.15 division over any two-division interval within center eight divisions of total magnified sweep length.

PERFORMANCE: Within ___ division (worst case) over center eight divisions; within ___ division (worst case) over two-division interval.

45. Check/Adjust Normal-Magnified Registration (R535) — Page 5-31

REQUIREMENT: Less than 0.2-division shift of marker at center vertical line when X10 MAG switch is pushed in.

PERFORMANCE: ___ division shift.

46. Check Variable Time/Division Control Range — Page 5-31

REQUIREMENT: Continuously variable between calibrated TIME/DIV switch settings.

PERFORMANCE: Correct ___; incorrect ___.

47. Adjust 5 Microsecond Timing (C440A) — Page 5-32

REQUIREMENT: Correct timing within 0.24 division at 5 μs/DIV.

PERFORMANCE: Within ___ division.

48. Adjust 0.5 Microsecond Timing (C537) — Page 5-32

REQUIREMENT: Correct timing within 0.24 division at 0.5 μs/DIV.

PERFORMANCE: Within ___ division.

49. Adjust 0.5 Microsecond X10 Magnified Timing (C511, C527) — Page 5-32

REQUIREMENT: Correct magnified timing at start and middle of total magnified sweep length with TIME/DIV switch set to 0.5 μs.

PERFORMANCE: Correct ___; incorrect ___.

50. Check Normal Sweep Timing Accuracy — Page 5-33

REQUIREMENT: Correct timing within 0.24 division over center eight divisions of display at each TIME/DIV switch setting.

PERFORMANCE: Correct ___; incorrect (list exceptions) ________________________.

51. Check Magnified Sweep Timing Accuracy — Page 5-33

REQUIREMENT: Correct magnified timing within 0.4 division over center eight divisions of total magnified sweep length at each TIME/DIV switch setting.

PERFORMANCE: Correct ___; incorrect (list exceptions) ________________________.

52. Check Gate Output Signal Page 5-33

REQUIREMENT: 0.5 volt or greater amplitude; duration at 1 ms/DIV, between 5.2 and 6.05 divisions at test oscilloscope sweep rate of two milliseconds/division.

PERFORMANCE: ____ volt amplitude; ____ division duration.

53. Check Chopped Operation Page 5-33

REQUIREMENT: Repetition rate, 150 kilohertz ±20% indicated by cycle duration of 5.6 to 8.4 divisions at 1 μs/DIV; time segment displayed from each channel, 2.0 to 4.7 microseconds; switching transients blanked out.

PERFORMANCE: ____ cycle duration; ____ microsecond time segment; blanking correct ____; incorrect ____.

54. Check External Horizontal Operation Page 5-35

REQUIREMENT: Deflection of 4.0 to 6.7 divisions with 50-volt signal (X10 MAG switch pushed in, HORIZ ATTEN clockwise); deflection of 4.0 to 6.7 divisions with five-volt signal (X10 MAG switch pulled out, HORIZ ATTEN clockwise) with a 10:1 reduction in deflection factor when HORIZ ATTEN is turned fully counterclockwise.

PERFORMANCE: Correct ____; incorrect ____.

55. Check External Horizontal Bandwidth Page 5-36

REQUIREMENT: Not more than –3 dB at 500 kilohertz.

PERFORMANCE: –3 dB point, ____ megahertz.

56. Check External Blanking Page 5-36

REQUIREMENT: Trace blanked with two-volt positive peak signal.

PERFORMANCE: Correct ____; incorrect ____.

57. Check/Adjust Calibrator Amplitude Page 5-36

REQUIREMENT: –2 volts ±10 millivolts at CALIBRATOR jack with Q775 removed and –200 millivolts ±3 millivolts internal. Check operation in CALIBRATE 4 DIVISIONS position of Channel 1 and 2 VOLTS/DIV switches.

PERFORMANCE: External, within millivolts; internal, within ____ millivolts; CALIBRATE 4 DIVISIONS Channel 1, within ____ division; Channel 2, within ____ division.

58. Check Calibrator Repetition Rate Page 5-37

REQUIREMENT: Duration of one cycle between 4.2 and 6.3 divisions at .2 ms/DIV.

PERFORMANCE: ____ divisions.

59. Check Calibrator Duty Cycle Page 5-37

REQUIREMENT: Length of positive segment of square wave between 4.5 and 5.5 divisions with one complete cycle/10 divisions.

PERFORMANCE: Positive segment, ____ divisions.

PERFORMANCE CHECK/CALIBRATION PROCEDURE

General

The following procedure is arranged so the Type 422 can be calibrated with the least interaction of adjustments and reconnection of equipment. A picture of the test equipment required for each group of steps is given to aid in identification of the necessary equipment. The control settings and test equipment setup throughout this procedure continue from the preceding step(s) unless noted otherwise. The control settings can be checked at any "test equipment required" picture by setting the controls as given at the start of the procedure under the heading Preliminary Control Settings. Then make any changes listed following the "test equipment required" picture, under the heading Partial Procedure (also applies to partial calibration procedure).

NOTE

Control titles which are printed on the front panel of the Type 422 are capitalized in this procedure (e.g.,INTENSITY). Internal adjustments are initial capitalized only (e.g., Ch 1 Gain).

The following procedure uses the equipment listed under Test Equipment Required. If other equipment is substituted, control settings or calibration setup may need to be altered to meet the requirements of the equipment used. Detailed operating instructions for the test equipment are not given in this procedure. Refer to the instruction manual for the test equipment if more information is required.

NOTE

This instrument should be calibrated at an ambient temperature of +25°C ±5°C for best overall accuracy. The performance of this instrument can be checked at any temperature within the 0°C to +40°C range. If the ambient temperature is outside the given range, see Section 1 for the applicable tolerances.

Preliminary Procedure for Performance Check Only

1. Connect the Type 422 to a power source which meets the voltage and frequency requirements of this instrument.

2. Set the controls as given under Preliminary Control Settings. Allow at least 20 minutes warmup before proceeding.

3. Begin the performance check with step 6.

Preliminary Procedure for Complete Calibration

1. Remove the power supply and cabinet from the Type 422 (see Section 4).

2. Remove the battery box from the power supply (see Section 2).

3. Connect the power supply for remote operation (see Section 2).

4. Connect the AC-DC Power Supply to the variable DC supply with the DC power cord (supplied accessory).

5. Set the controls as given under Preliminary Control Settings except as follows:

Power Mode OPERATE 11.5 - 35V DC

6. Turn the variable DC power supply on and set it for an output voltage of +24 volts. Allow at least 20 minutes warmup between proceeding.

Preliminary Control Settings

Set the Type 422 controls as follows:

CRT Controls	
INTENSITY	Midrange
FOCUS	Adjust for well defined display
ASTIGMATISM	Adjust for well defined display
SCALE ILLUM	Clockwise
Vertical controls (both channels if applicable)	
VOLTS/DIV	.05
VARIABLE	CAL
Input Coupling	DC
POSITION	Midrange
Mode	CH 1
INVERT	Pushed in
X10 GAIN AC	Pushed in
Triggering controls	
Source	CH 1 & 2
Coupling	AC
SLOPE	Positive going
Mode	AUTO
LEVEL	Midrange
Sweep controls	
POSITION	Midrange
TIME/DIV	1 ms
VARIABLE	CAL
X10 MAG	Pushed in
Power	
POWER	ON (at power supply)
Rear panel	
Power Mode	OPERATE 115V AC

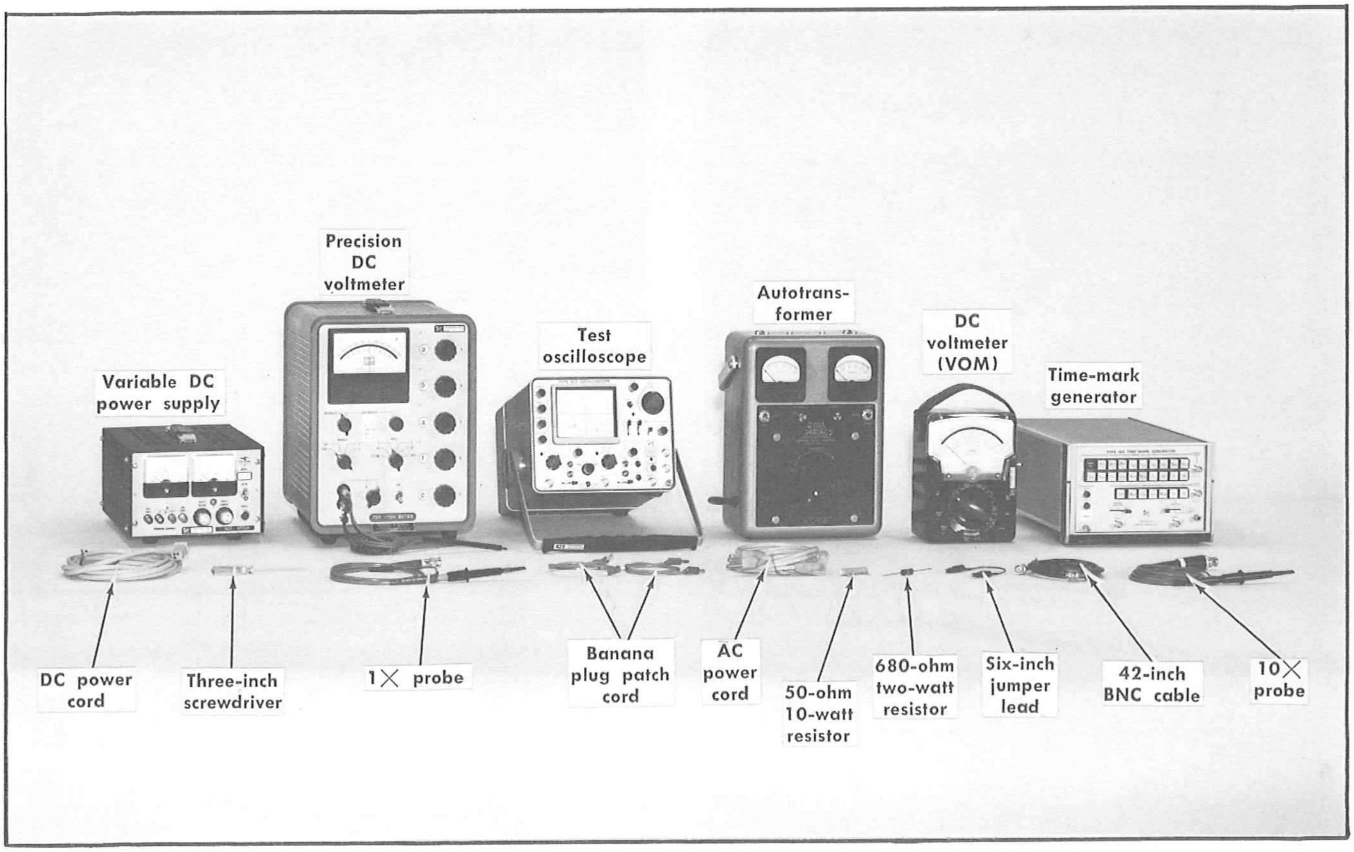


Fig. 5-1. Test equipment required for steps 1 through 15.

1. Adjust −12-Volt Supply

PERFORMANCE CHECK ONLY

Steps 1 through 9 are not applicable to a performance check. Set controls as given under Preliminary Control Settings and begin with step 10.

a. Test equipment required for steps 1 through 15 is shown in Fig. 5-1.

b. Change the following control settings:

INTENSITY	Counterclockwise
TRIGGERING Mode	NORM (pulled out)
Power Mode (rear panel)	OPERATE 11.5 - 35V DC

c. Connect the precision DC voltmeter from the −12-volt test point (in indicator, see Fig. 5-2A) to chassis ground.

NOTE

Power Supply voltage and ripple tolerances given in steps 1 through 8 are typical values provided as guides to correct instrument operation and are not instrument specifications. Actual values may exceed those listed without loss of measurement accuracy if the instrument meets the specifications given in Section 1 as tested in this procedure.

d. CHECK—Meter reading; −12 volts ±0.12 volt.

e. ADJUST— −12 Volts adjustment R1130 (see Fig. 5-2B) for −12 volts.

f. INTERACTION—May affect operation of all circuits within the Type 422.

2. Adjust Blocking Oscillator Frequency

a. Connect the precision DC voltmeter to the DC input monitoring points (see Fig. 5-3A).

b. Set the variable DC power supply for 11.2 volts as indicated on the precision DC voltmeter.

c. Connect the 1X probe to the test oscilloscope vertical input connector.

d. Set the test oscilloscope for a vertical deflection factor of 20 volts/division at a sweep rate of 20 microseconds/division.

e. Connect the probe tip to the oscillator frequency test point (junction of D1176-D1177; see Fig. 5-3B). Connect the probe ground strap to chassis ground.

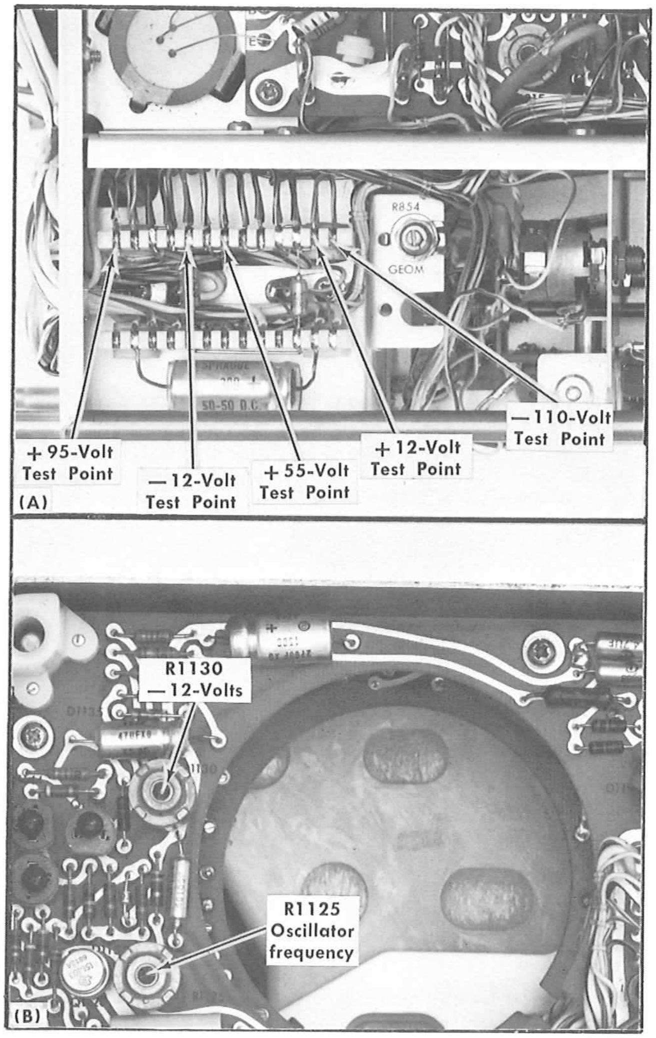


Fig. 5-2. (A) Location of –12-volt and +12-volt power supply test points (left side of indicator), (B) location of DC power supply adjustments (DC Power Control board).

f. CHECK—Test oscilloscope display similar to Fig. 5-3C. If necessary, readjust the test oscilloscope triggering control so the display starts at the correct point.

g. ADJUST—Oscillator Frequency adjustment R1125 (see Fig. 5-2B) for waveform similar to that shown in Fig. 5-3C with a minimum amount of jitter.

h. Recheck step 1. If readjustment is necessary, recheck this step also.

i. Disconnect the precision DC voltmeter and the test oscilloscope.

3. Check DC Regulation

a. Set the variable DC power supply for +11.5-volts output.

b. CHECK—Table 5-1 lists the power supplies in this instrument. Check each supply with the precision DC voltmeter for output voltage within the given range. Power supply test points are shown in Figs. 5-2 and 5-4.

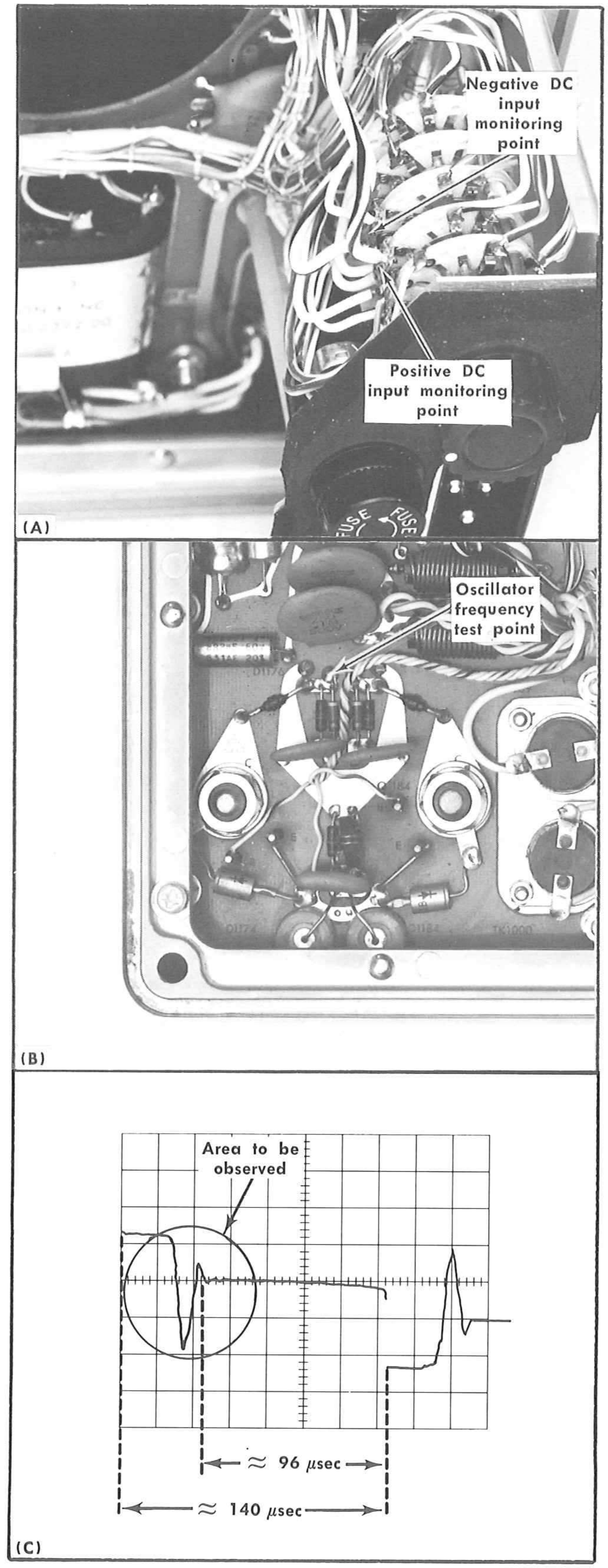


Fig. 5-3. (A) Location of external DC-input monitoring points (on Power Mode switch), (B) location of oscillator-frequency test point (DC Power Converter circuit board), (C) typical test oscilloscope display indicating correct oscillator frequency.

TABLE 5-1

Power Supply Output Voltage and Ripple

Power Supply	Output Voltage Range	Maximum Ripple[2] (peak to peak)	
		High Frequency	AC Line Frequency
−12 volt	−11.9 to −12.1 volts	20 millivolts	8 millivolts
+ 12 volt	+ 11.7 to + 12.3 volts	20 millivolts	8 millivolts
+ 55 volt	+ 53.9 to 50.3 volts	2 volt	
+ 95 volt	+ 93.1 to + 97 9 volts	0.4 volt	
+ 10.5 volt	+ 10.3 to + 10.7 volts	1 millivolt	1 millivolt
−81 volt	−80 to −82 volts	20 millivolts	8 millivolts

[2] Disregard fast spikes; see Fig. 5-5.

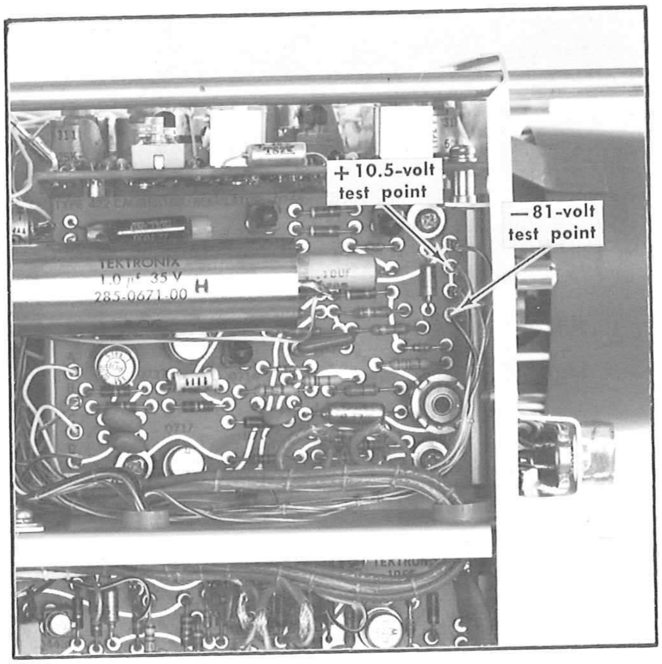


Fig. 5-4. Location of +10.5-volt and −81-volt power supply test points (Calibrator and Regulators board).

c. Set the variable DC power supply for +22-volts output.

d. CHECK—Each supply with the precision DC voltmeter for the tolerances given in Table 5-1.

e. Set the variable DC power supply for +35-volts output.

f. CHECK—Each supply with the precision DC voltmeter for the tolerances given in Table 5-1.

g. Disconnect the voltmeter.

4. Check DC Ripple

a. Set the test oscilloscope for a vertical deflection factor of 10 millivolts/division, AC coupled, at a sweep rate of 20 microseconds/division (1X probe connected to vertical input connector).

b. CHECK—Test oscilloscope display for maximum ripple of each supply as listed in Table 5-1. Fig. 5-5 shows a typical display of ripple and the levels between which the ripple measurement should be made. Power supply test points are shown in Fig. 5-2 and 5-4. Change the test oscilloscope vertical deflection factor as necessary to provide the correct display of ripple.

c. Set the variable DC power supply for +22-volts output.

d. CHECK—Ripple of each supply for tolerances given in Table 5-1.

e. Set the variable DC power supply for +11.5-volts output.

f. CHECK—Ripple of each supply for tolerances given in Table 5-1.

g. Disconnect the variable DC power supply and the test oscilloscope.

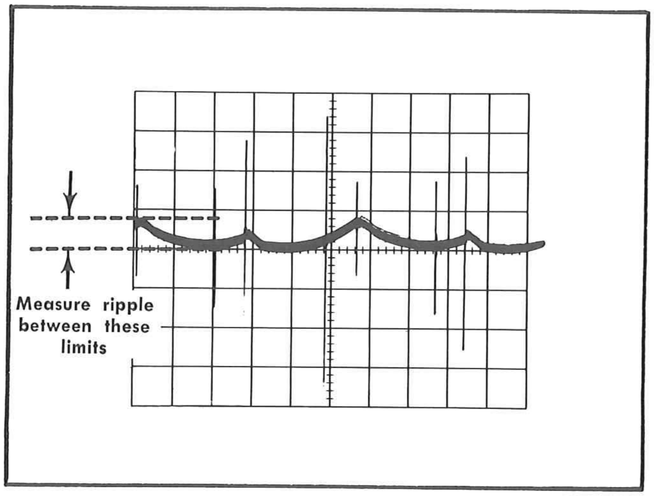


Fig. 5-5. Typical test oscilloscope display of power-supply ripple (sweep rate 20 microseconds/division).

5. Adjust Low-Voltage Indicator

a. Set the Power Mode switch (rear panel) to OPERATE INT BATT.

b. Connect the variable DC power supply positive output to the bottom battery-interconnection banana plug (see Fig. 5-6) with an 18-inch dual banana plug-jack patch cord. Connect the negative output to the top battery-interconnection banana plug with another 18-inch dual banana plug-jack patch cord.

c. Connect the precision DC voltmeter to the battery-interconnection banana plugs.

d. Set the variable DC power supply for about +35 volts output.

e. CHECK—POWER light (front panel of indicator) is on and does not blink.

f. Slowly decrease the output voltage of the variable DC power supply.

g. CHECK—POWER light begins to blink when power supply output voltage is 22 volts +0, −1 volt as indicated by the precision DC voltmeter.

h. ADJUST—With the variable DC power supply set to exactly +22 volts, set the Low-Voltage Indicator adjustment R1047 (see Fig. 5-6B) clockwise until the POWER light is on steady. Then, slowly adjust this control counterclockwise until the POWER light just begins to blink.

i. Recheck parts d through g of this step.

j. Disconnect all test equipment.

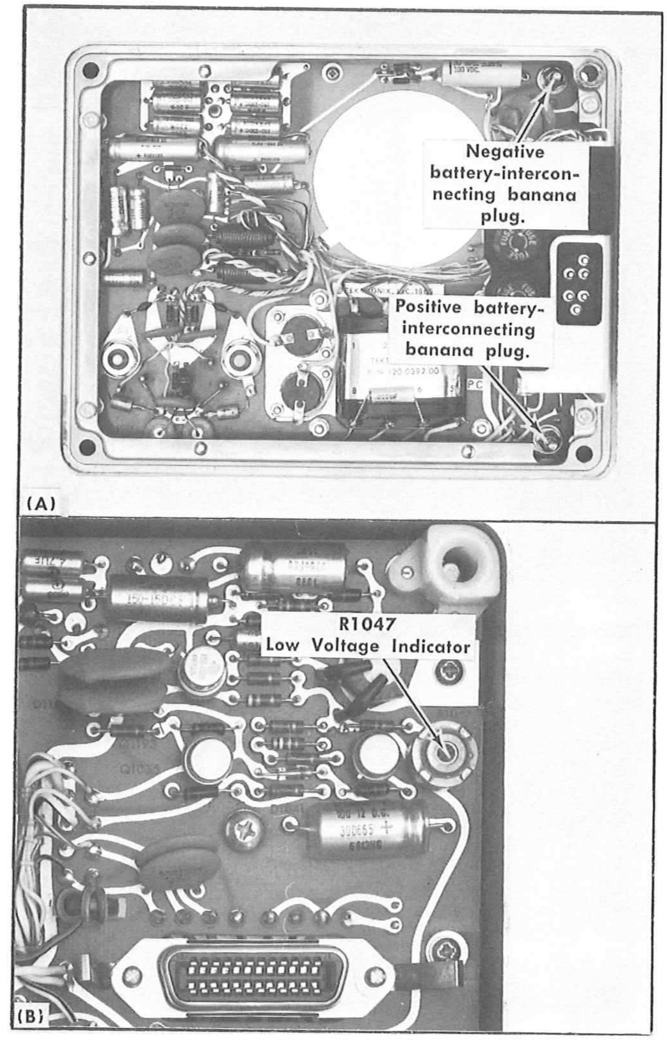


Fig. 5-6. (A) Location of battery-interconnection banana plugs (rear of power supply), (B) location of low-voltage indicator adjustment (DC Power Control board).

6. Check AC Operation

a. Set the Power Mode switch (rear panel) to OPERATE 115V AC (use OPERATE 230V AC for 230-volt nominal line).

b. Connect the autotransformer to an AC line voltage source.

c. Set the autotransformer output voltage to 115 (or 230) volts.

d. Connect the AC-DC Power Supply to the autotransformer output with the AC power cord.

e. CHECK—Output voltage of each supply with the precision DC voltmeter for tolerances given in Table 5-1.

f. Set the autotransformer output voltage to 95 or 190) volts.

g. CHECK—Output voltage of each supply with the precision DC voltmeter for the tolerances given in Table 5-1.

h. Set the autotransformer output voltage to 137 (or 274) volts.

i. CHECK—Output voltage of each supply with the precision DC voltmeter for the tolerances given in Table 5-1.

j. Disconnect the precision DC voltmeter and use the test oscilloscope with 1X probe for parts m through q.

k. CHECK—Ripple of each supply for AC ripple tolerances given in Table 5-1.

l. Set the autotransformer output voltage to 95 (or 190) volts.

m. CHECK—Ripple of each supply for AC ripple tolerances given in Table 5-1.

n. Set the autotransformer output voltage to 115 (or 230) volts.

o. CHECK—Ripple of each supply for AC ripple tolerances given in Table 5-1.

p. Disconnect the voltmeter.

7. Check Battery Charger Operation

a. Turn off the AC power to the instrument.

b. Set the Power Mode switch (rear panel) to CHARGE BATT 115V AC (use CHARGE BATT 230V AC for 230-volt nominal line).

c. Connect the 50-ohm 10-watt resistor to one of the battery terminals (see Fig. 5-6A) with the six-inch jumper lead. Connect the ammeter between the remaining battery terminal and the other side of the resistor. Position all leads so a short-circuit condition does not exist.

d. Set the autotransformer output voltage to 95 (or 190) volts and re-apply the AC power.

e. CHECK—Ammeter reading; 325 milliamperes minimum.

NOTE

Do not leave the instrument on in this condition for extended periods of time as the high current through the external resistor may cause it to overheat. If the resistor becomes overheated, turn off the power and allow it to cool before continuing.

f. Set the autotransformer output voltage to 126.5 (or 253) volts.

g. CHECK—Ammeter reading; 450 milliamperes maximum.

h. Turn off the AC power to the instrument.

i. Replace the 50-ohm resistor with a 680-ohm two-watt resistor.

j. Set the Power Mode switch to OPERATE 115V AC (use OPERATE 230V AC for 230-volt nominal line).

k. Turn on the AC power.

l. CHECK—Ammeter reading; 30 to 50 milliamperes.

m. Set the autotransformer output voltage to 95 (or 190) volts.

n. CHECK—Ammeter reading; 30 to 50 milliamperes.

o. Turn off the instrument and disconnect all test equipment. If the AC line voltage available is not about 115 (or 230) volts, leave the autotransformer connected to the instrument and set it for 115 (or 230) volts.

8. Check High-Voltage Supply

a. With the AC power off, remove the plastic cover from the CRT socket.

b. Connect the DC voltmeter (VOM) from the high-voltage test point (pin 3 of CRT socket, see Fig. 5-7) to chassis ground.

c. Return the POWER switch to ON (at power supply).

d. CHECK—Meter reading; −1385 volts ±69.5 volts.

e. Disconnect the voltmeter and replace the plastic cover.

9. Adjust Unblanking Center

a. Change the following control settings:

INTENSITY	Midrange
TRIGGERING Mode	AUTO (pushed in)

b. ADJUST—Unblanking Center adjustment R869 (see Fig. 5-8) for maximum trace intensity. This should occur near the center of adjustment range.

10. Check/Adjust Trace Rotation

a. Position the trace to the center horizontal line with the Channel 1 POSITION control.

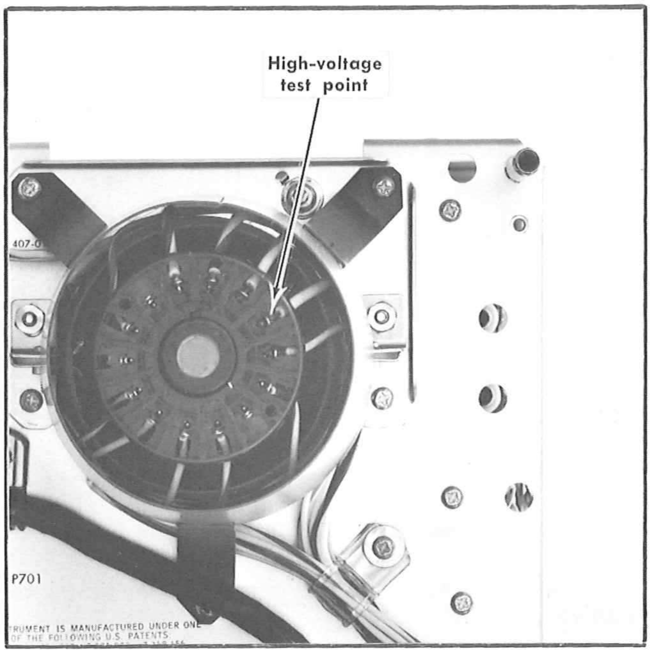


Fig. 5-7. Location of high-voltage test point (rear panel, socket cover removed).

b. Adjust the FOCUS and ASTIGMATISM controls for a well defined display.

c. CHECK—Trace should be parallel to the center horizontal line within 0.1 division/10 divisions (i.e., with trace positioned to center horizontal line at the left vertical line of the graticule, the trace must be within 0.1 division of the center horizontal line at the right vertical line).

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

d. ADJUST—Trace rotation adjustment R851 (see Fig. 5-9) so the trace is parallel to the center horizontal line.

NOTE

If the Trace Rotation adjustment does not have enough range to make the trace parallel with the horizontal graticule lines, reverse the connection of these leads at the Horizontal Amplifier board.

11. Check/Adjust Y Axis Alignment

a. Connect the time-mark generator (Type 184) to the INPUT 1 connector with the 42-inch BNC cable.

b. Set the time-mark generator for output markers of one and 0.1 millisecond.

c. Set the LEVEL control for a stable display.

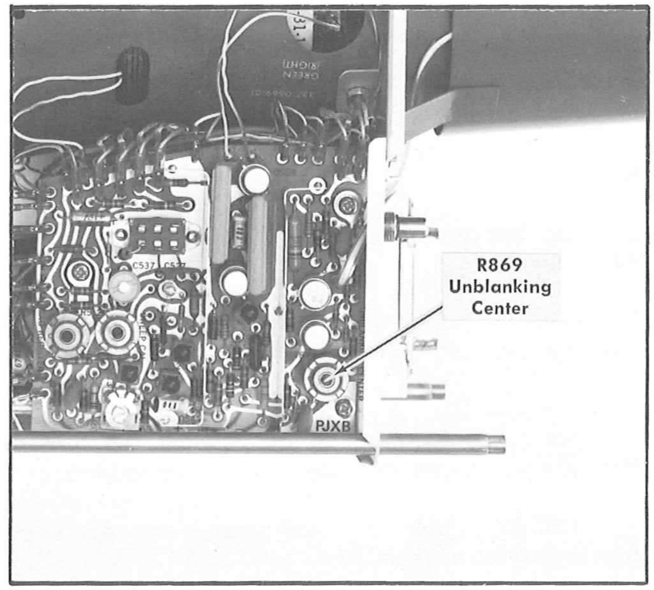


Fig. 5-8. Location of Unblanking Center adjustment (Horizontal Amplifier board).

d. Set the Channel 1 VOLTS/DIV switch so the large markers extend beyond the top and bottom of the graticule area.

e. CHECK—Markers should be parallel to the center vertical line within 0.1 division.

f. ADJUST—Y Axis Align adjustment R856 (see Fig. 5-10) so the markers are parallel to the center vertical line.

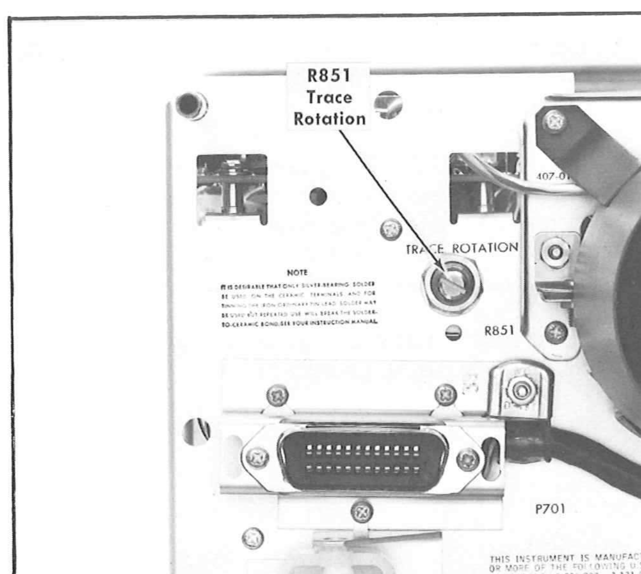


Fig. 5-9. Location of Trace Rotation adjustment (rear panel).

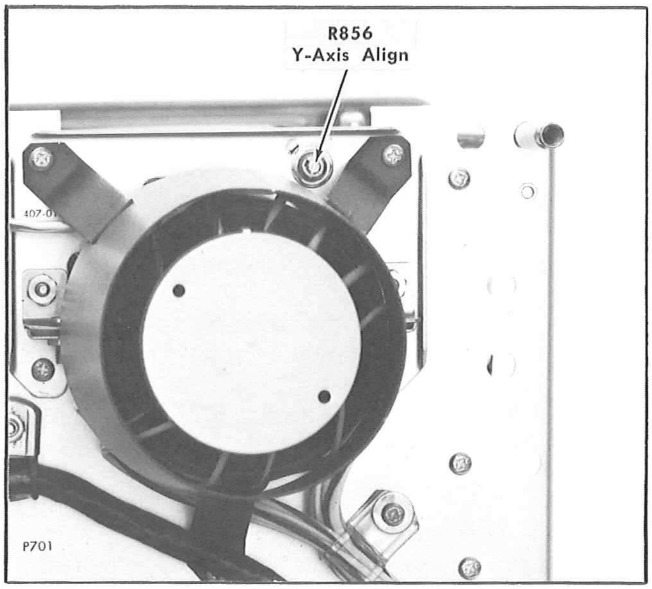


Fig. 5-10. Location of Y Axis Align adjustment (rear panel).

12. Check/Adjust CRT Geometry

a. Set the horizontal POSITION and VARIABLE TIME/DIV controls so a large marker coincides with each graticule line.

b. CHECK—CRT display for 0.1 division or less bowing of the markers at the left and right edges of the graticule. Fig. 5-11 shows a typical display with good geometry as well as examples of poor geometry.

c. ADJUST—Geom adjustment R854 (see Fig. 5-11D) for minimum curvature of the markers at the left and right edges of the graticule.

d. Recheck step 11 and readjust if necessary. If readjustment is necessary, recheck this step also.

e. Disconnect the time-mark generator.

f. Position the trace to the top horizontal line of the graticule.

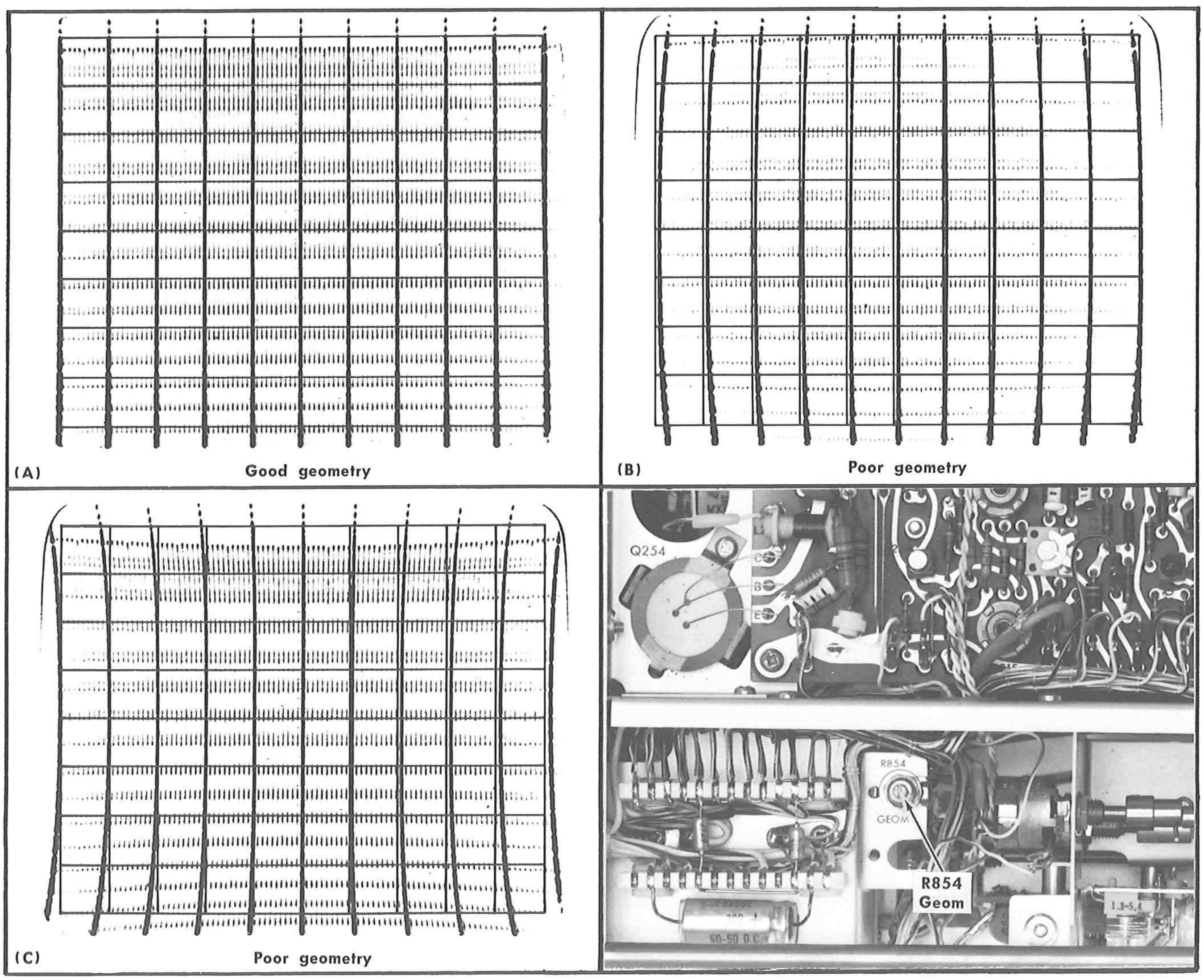


Fig. 5-11. (A)Typical CRT display of good geometry, (B) and (C) poor geometry, (D) location of Geom adjustment (left side).

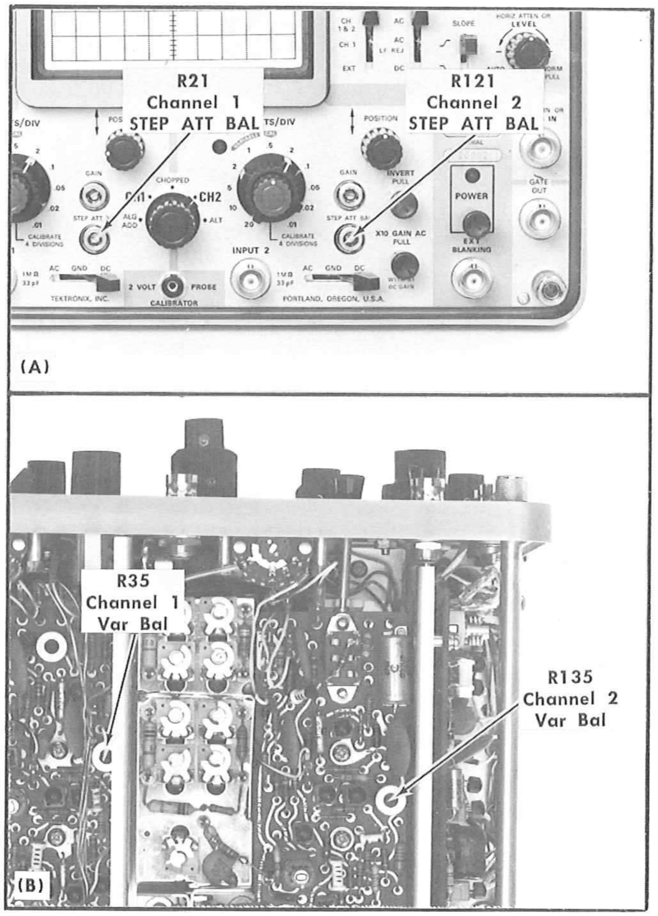


Fig. 5-12. (A) Location of step attenuator balance adjustment (front panel), (B) location of variable balance adjustment (Channel 1 and Channel 2 Input Amplifier boards).

g. CHECK—Deviation from straight line should not exceed ±0.1 division.

h. Position the trace to the bottom horizontal line of the graticule.

i. CHECK—Deviation from straight line should not exceed ±0.1 division.

j. Return the VARIABLE TIME/DIV control to CAL.

13. Check/Adjust Channel 1 Step Attenuator and Variable Balance

a. Set both Input Coupling switches to GND.

b. Position the trace to the center horizontal line with the Channel 1 POSITION control.

c. CHECK—Change the Channel 1 VOLTS/DIV switch from .05 to .01. Trace should not move more than 0.1 division vertically.

PERFORMANCE CHECK ONLY

Front-panel adjustment; can be adjusted as part of performance check.

d. ADJUST—Channel 1 STEP ATT BAL adjustment R21 (see Fig. 5-12A) for minimum trace shift as the Channel 1 VOLTS/DIV switch is changed from .05 to .01.

e. Set the Channel 1 VOLTS/DIV switch to .05.

f. CHECK—Rotate the Channel 1 VARIABLE VOLTS/DIV control throughout its range. Trace should not move more than 0.2 division vertically.

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

g. ADJUST—Channel 1 Var Bal adjustment R35 (see Fig. 5-12B) for minimum trace shift as the Channel 1 VARIABLE VOLTS/DIV control is rotated throughout its range.

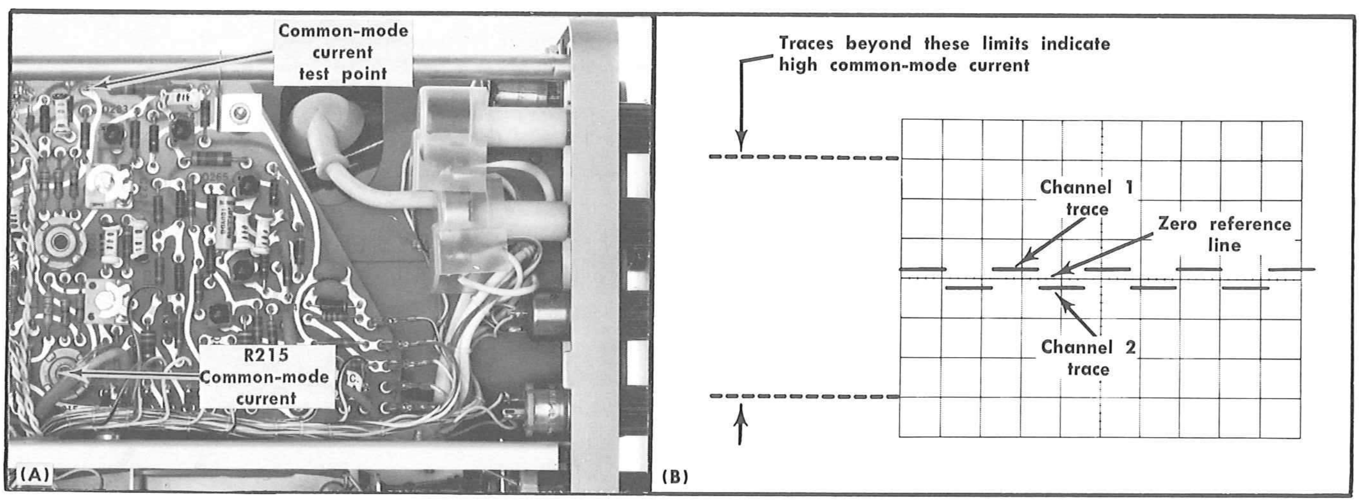


Fig. 5-13. (A) Common-mode current test point and adjustment (Vertical Switching and Output Amplifier board), (B) typical test oscilloscope display showing test limits (vertical deflection, 0.2 volt/division, sweep rate five milliseconds/division).

h. Return the Channel 1 VARIABLE VOLTS/DIV control to CAL.

i. Repeat steps b through h for minimum trace shift for check c and f.

14. Check/Adjust Channel 2 Step Attenuator and Variable Balance

a. Set the vertical MODE switch to CH 2.

b. Position the trace to the center horizontal line with the Channel 2 POSITION control.

c. CHECK—Change the Channel 2 VOLTS/DIV switch from .05 to .01. Trace should not move more than 0.1 division vertically.

PERFORMANCE CHECK ONLY

Front-panel adjustment; can be adjusted as part of performance check.

d. ADJUST—Channel 2 STEP ATT BAL adjustment R121 (see Fig. 5-12A) for minimum trace shift as the Channel 2 VOLTS/DIV switch is changed from .05 to .01.

e. Set the Channel 2 VOLTS/DIV switch to .05.

f. CHECK—Rotate the Channel 2 VARIABLE VOLTS/DIV control throughout its range. Trace should not move more than 0.2 division vertically.

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

g. ADJUST—Channel 2 Var Bal adjustment R135 (see Fig. 5-12B) for minimum trace shift as the Channel 2 VARIABLE VOLTS/DIV control is rotated throughout its range.

h. Return the Channel 2 VARIABLE VOLTS/DIV control to CAL.

i. Repeat steps b through h for minimum trace shift for check c and f.

15. Adjust Common-Mode Current

PERFORMANCE CHECK ONLY

This step is not applicable to a performance check. Change the following control settings and proceed with step 16: CH 1 and 2 VOLTS/DIV, .05; CH 1 Input Coupling, DC; vertical Mode, CH 1; TIME/DIV, .5 ms.

a. Change the following control settings:

CH 1 and 2 VOLTS/DIV	.05
Vertical Mode	ALT
TIME/DIV	.5 ms

b. Position both traces to the center horizontal line with the Channel 1 and 2 POSITION controls.

c. Connect the 10X probe to the test oscilloscope input connector.

d. Set the test oscilloscope for a vertical deflection of 0.02 volt/division (0.2 volt/division at 10X probe tip), DC coupled, at a sweep rate of five milliseconds/division.

e. Ground the input of the test oscilloscope and position the test-oscilloscope trace to the center horizontal line.

f. Connect the 10X probe tip to the common-mode current test point (common emitters of Q224 and Q234; see Fig. 5-13A). Connect the probe ground lead to chassis ground..

g. CHECK—Test oscilloscope display for three divisions or less offset from the center horizontal line (see Fig. 5-13B).

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

h. ADJUST—Common-Mode Current adjustment R215 (see Fig. 5-13A) for optimum balance of common-mode current in each channel as shown by equal spacing from the center horizontal line. Balance must occur within three divisions of the centerline.

i. Disconnect all test equipment.

j. INTERACTION—Check steps 16 - 18.

Control Setup

When performing a complete procedure, change the following control settings and proceed with step 16.

CH 1 Input Coupling	DC
Vertical Mode	CH 1

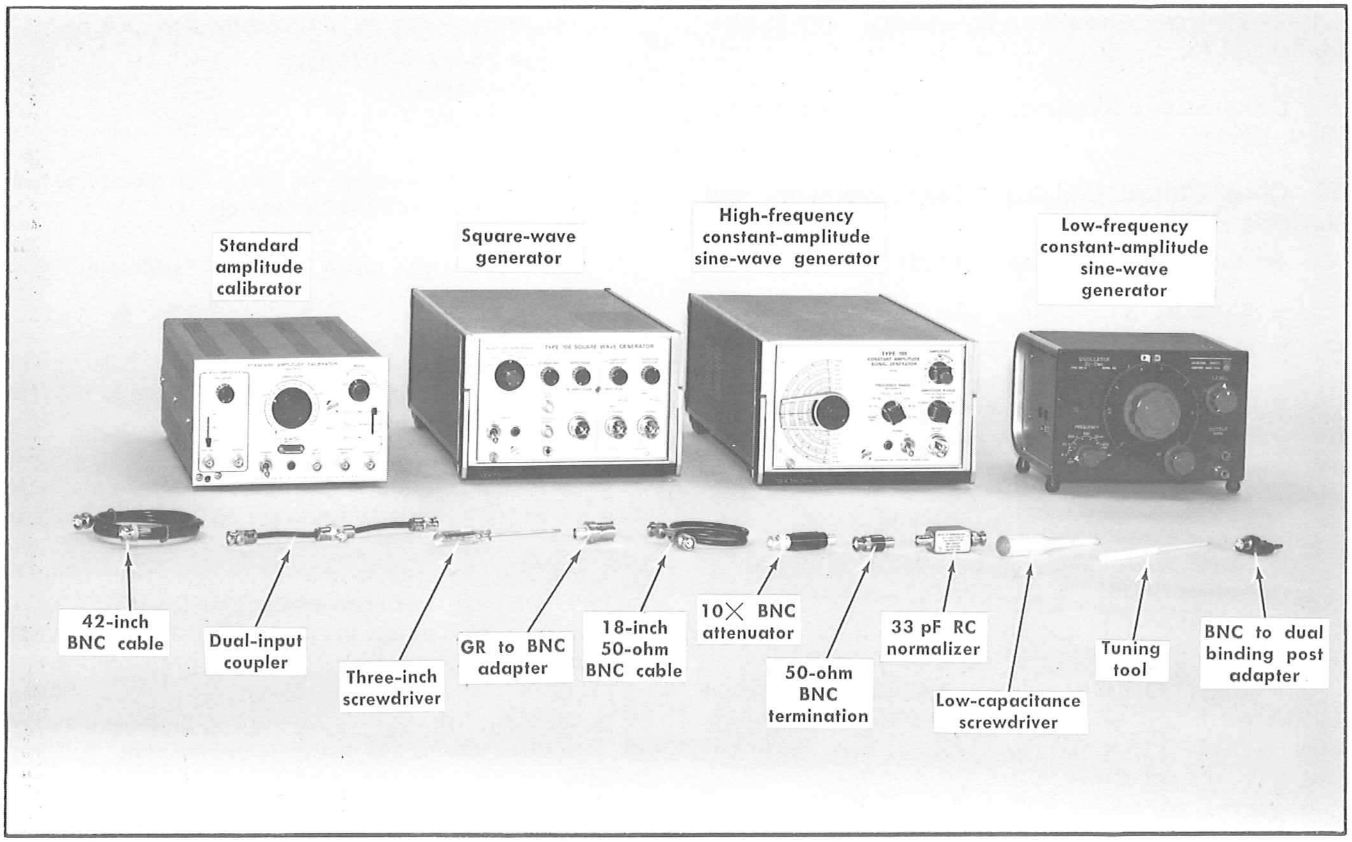


Fig. 5-14. Test equipment required for steps 16 through 32.

Partial Procedure

If beginning a partial procedure with this step, set the controls as given under Preliminary Control Settings except as follows:

CH 2 Input Coupling	GND
TIME/DIV	.5 ms

16. Check/Adjust Channel 1 and 2 Gain

a. Test equipment required for steps 16 through 32 is shown in Fig. 5-14.

b. Connect the standard amplitude calibrator (067-0502-00) output connector to the INPUT 1 and INPUT 2 connectors through a 42-inch BNC cable and the dual-input coupler.

c. Set the standard amplitude calibrator for a 0.2-volt square-wave output.

d. Position the display to the center of the graticule with the Channel 1 POSITION control.

e. CHECK—CRT display for four divisions ±0.12 division of deflection (within 3%).

PERFORMANCE CHECK ONLY

Front-panel adjustment; can be adjusted as part of performance check.

f. ADJUST—Channel 1 GAIN adjustment R80 (see Fig. 5-15) for exactly four divisions of deflection.

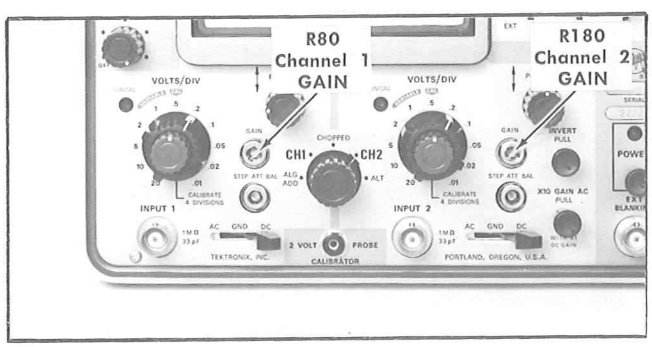


Fig. 5-15. Location of gain adjustments.

g. Change the following control settings:

CH 2 Input Coupling	DC
Vertical Mode	ALG ADD
INVERT	Pulled out

h. CHECK—CRT display for straight line.

PERFORMANCE CHECK ONLY

Front-panel adjustment; can be adjusted as part of performance check.

i. ADJUST—Channel 2 GAIN adjustment R180 (see Fig. 5-15) for straight line.

17. Check Added Mode Operation

a. Push in the INVERT switch.

b. Set the standard amplitude calibrator for a 0.12-volt square-wave output.

c. CHECK—CRT display for four divisions ±0.12 division of amplitude.

18. Check Channel 1 and 2 Deflection Accuracy

a. Change the following control settings:

CH 2 Input Coupling	GND
Vertical Mode	CH 1

b. CHECK—Using the Channel 1 VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-2, check vertical deflection within 3% at each position of the Channel 1 VOLTS/DIV switch.

TABLE 5-2

Vertical Deflection Accuracy

VOLTS/DIV switch setting	Standard amplitude calibrator output	Vertical deflection in divisions	Maximum error for ±3% accuracy (divisions)
.01	50 millivolts	5	±0.15
.02	0.1 volt	5	±0.15
.05	Checked and adjusted in step 12		
.1	0.5 volt	5	±0.15
.2	1 volt	5	±0.15
.5	2 volts	4	±0.12
1	5 volts	5	±0.15
2	10 volts	5	±0.15
2	20 volts	4	±0.12
10	50 volts	5	±0.15
20	100 volts	5	±0.15

c. Change the following control settings:

CH 1 Input Coupling	GND
CH 2 Input Coupling	DC
Vertical Mode	CH 2

d. CHECK—Using the Channel 2 VOLTS/DIV switch and standard amplitude calibrator settings given in Table 5-2, check vertical deflection within 3% at each position of the Channel 2 VOLTS/DIV switch.

19. Check Channel 2 X10 Gain

a. Change the following control settings:

CH 1 and 2 VOLTS/DIV	.05
X10 GAIN AC	Pulled out

b. Set the standard amplitude calibrator for a 20-millivolt square-wave output.

c. CHECK—CRT display for four divisions ±0.16 division of deflection (within 4%).

d. Push in the X10 GAIN AC switch.

20. Check Channel 1 and 2 Variable Volts/Division Control Range

a. Set the standard amplitude calibrator for a 0.2-volt square-wave output.

b. CHECK—Turn the Channel 2 VARIABLE VOLTS/DIV control fully counterclockwise. Display should be reduced to 1.6 divisions or less (indicates adequate range for continuously variable deflection factor between the calibrated steps). Channel 2 UNCAL light must be on when Channel 2 VARIABLE control is not in CAL position.

c. Change the following control settings:

CH 1 Input Coupling	DC
Vertical Mode	CH 1

d. CHECK—Turn the Channel 1 VARIABLE VOLTS/DIV control fully counterclockwise. Display should be reduced to 1.6 divisions or less (indicates adequate range for continuously variable deflection factor between the calibrated steps). Channel 1 UNCAL light must be on when Channel 1 VARIABLE control is not in CAL position.

21. Check Low-Frequency Vertical Linearity

a. Set the standard amplitude calibrator for a 0.2-volt square-wave output.

b. Position the display to the center of the graticule with the Channel 1 POSITION control.

c. Set the Channel 1 VARIABLE VOLTS/DIV control for exactly two divisions of deflection (see Fig. 5-16B).

d. Position the top of the display to the top horizontal line of the graticule.

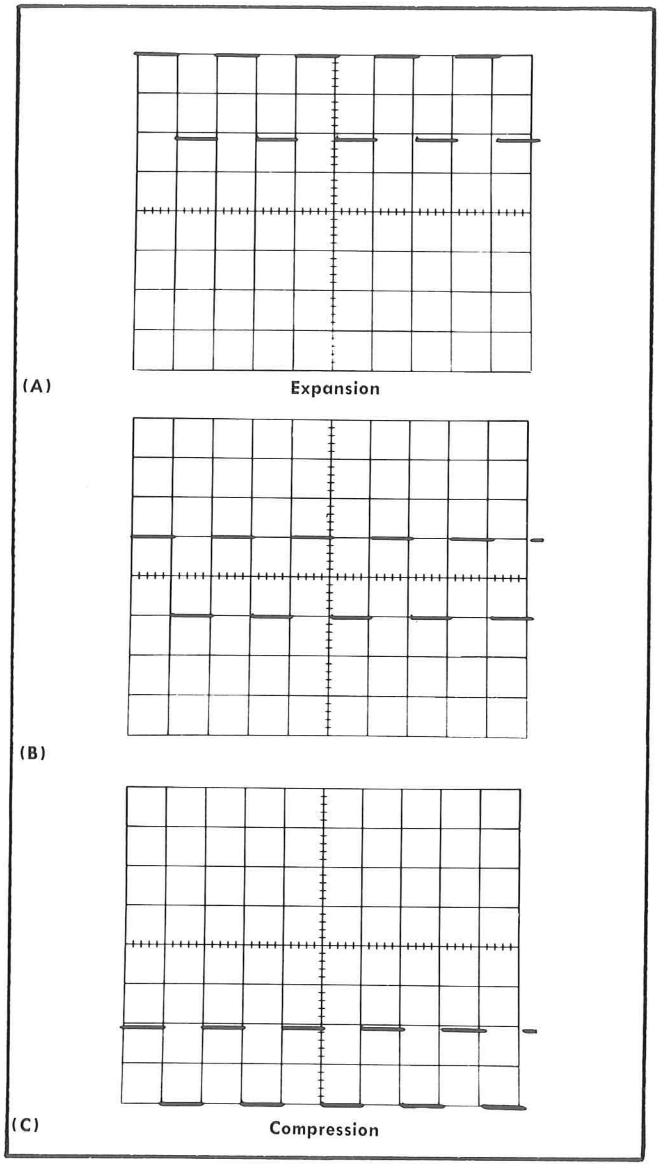


Fig. 5-16. Typical CRT display showing acceptable compression and expansion. (A) Expansion, (B) correct deflection at center of graticule, (C) expansion.

e. CHECK—Compression or expansion not to exceed 0.15 division (see Fig. 5-16).

f. Position the bottom of the display to the bottom horizontal line of the graticule.

g. CHECK—Compression or expansion not to exceed 0.15 division (see Fig. 5-16).

h. Set the vertical Mode switch to CH 2.

i. Position the display to the center of the graticule with the Channel 2 POSITION control.

j. Set the Channel 2 VARIABLE VOLTS/DIV control for exactly two divisions of deflection (see Fig. 5-16B).

k. Position the top of the display to the top horizontal line of the graticule.

l. CHECK—Compression or expansion not to exceed 0.15 division (see Fig. 5-16).

m. Position the bottom of the display to the bottom horizontal line of the graticule.

n. CHECK—Compression or expansion not to exceed 0.15 division (see Fig. 5-16).

22. Check Channel 1 and 2 Input Coupling Switch Operation

a. Return both VARIABLE VOLTS/DIV controls to CAL.

b. Position display with the Channel 2 POSITION control so the bottom of the square wave is at the center horizontal line.

c. Set the Channel 2 Input Coupling switch to AC.

d. CHECK—CRT display centered about center horizontal line.

e. Set the Channel 2 Input Coupling switch to GND.

f. CHECK—CRT display for a straight line near the center horizontal line.

g. Set the vertical Mode switch to CH 1.

h. Position display with the Channel 1 POSITION control so the bottom of the square wave is at the center horizontal line.

i. Set the Channel 1 Input Coupling switch to AC.

j. CHECK—CRT display centered about center horizontal line.

k. Set the Channel 1 Input Coupling switch to GND.

l. CHECK—CRT display for a straight line near the center horizontal line.

m. Disconnect all test equipment.

23. Check Trace Shift Due to Input Current

a. Set both VOLTS/DIV switches to .01.

b. Position the trace to the center horizontal line with the Channel 1 POSITION control.

c. CHECK—Set the Channel 1 Input Coupling switch to DC; trace shift should be negligible.

d. Set the vertical Mode switch to CH 2.

e. Position the trace to the center horizontal line with the Channel 2 POSITION control.

f. CHECK—Set the Channel 2 Input Coupling switch to DC; trace shift should be negligible.

24. Check Alternate Operation

a. Set the vertical Mode switch to ALT.

b. Position the traces about two divisions apart.

c. Turn the TIME/DIV switch throughout its range.

d. CHECK—Trace alternation between Channel 1 and 2 at all sweep rates. At faster sweep rates, alternation is not apparent; instead display appears as two traces on the screen.

25. Check/Adjust Channel 1 Volts/Division Switch Compensation

a. Change the following control settings:

CH 1 and 2 VOLTS/DIV	.05
Vertical Mode	CH 1
TIME/DIV	.2 ms

b. Connect the square-wave generator (Type 106) high-amplitude output connector to the INPUT 1 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable, 10X BNC attenuator, 50-ohm BNC termination and the 33 pF RC normalizer, in given order.

c. Set the square-wave generator for a four-division display at one kilohertz in the high-amplitude mode.

d. CHECK—CRT display at each Channel 1 VOLTS/DIV switch setting as given in Table 5-3 for optimum square corner and flat top within +3% or −3% with total peak-to-peak aberrations not to exceed 3% (see Fig. 5-17A). Remove the 10X attenuator and 50-ohm termination as given in Table 5-3. Readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum vertical deflection in the 20 position.

e. ADJUST—Channel 1 VOLTS/DIV switch compensation as given in Table 5-3 (use low-capacitance screwdriver). First adjust for optimum square corner and then for optimum flat top. Remove the 10X attenuator and 50-ohm termination as given in Table 5-3 and readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum deflection in the 20 position. Fig. 5-17B shows the location of the variable capacitors.

TABLE 5-3

Channel 1 VOLTS/DIV Switch Compensation

Channel 1 VOLTS/DIV switch setting	Attenuator compensated	Adjusted for optimum: Square corner	Adjusted for optimum: Flat top
.05	÷ 1	– –	C12
.02	Check	If out of tolerance, compromise setting at .01, .02 and .05 for best overall response.	
.01	Check		
Remove external 10X attenuator from generator			
.1	÷ 2	C3C	C3B
.2	÷ 4	C4C	C4B
.5	÷ 10	C5C	C5B
Remove 50-ohm termination			
1	Check	If out of tolerance, compromise setting at .5, 1 and 2 for best overall response.	
2	Check		
5	÷100	C6C	C6B
10	Check	If out of tolerance, compromise setting at 5, 10 and 20 for best overall response.	
20	Check		

26. Check/Adjust Channel 2 Volts/Division Switch Compensation

a. Set the vertical Mode switch to CH 2.

b. Connect the square-wave generator high-amplitude output connector to the INPUT 2 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable, 10X BNC attenuator, 50-ohm BNC termination and the 33 pF RC normalizer, in given order.

c. Set the square-wave generator for a four-division display at one kilohertz in the high-amplitude mode.

d. CHECK—CRT display at each Channel 1 VOLTS/DIV switch setting as given in Table 5-4 for optimum square corner and flat top within +3% or −3%, with total peak-to-peak aberrations not to exceed 3% (see Fig. 5-17A). Remove the 10X attenuator and 50-ohm termination as

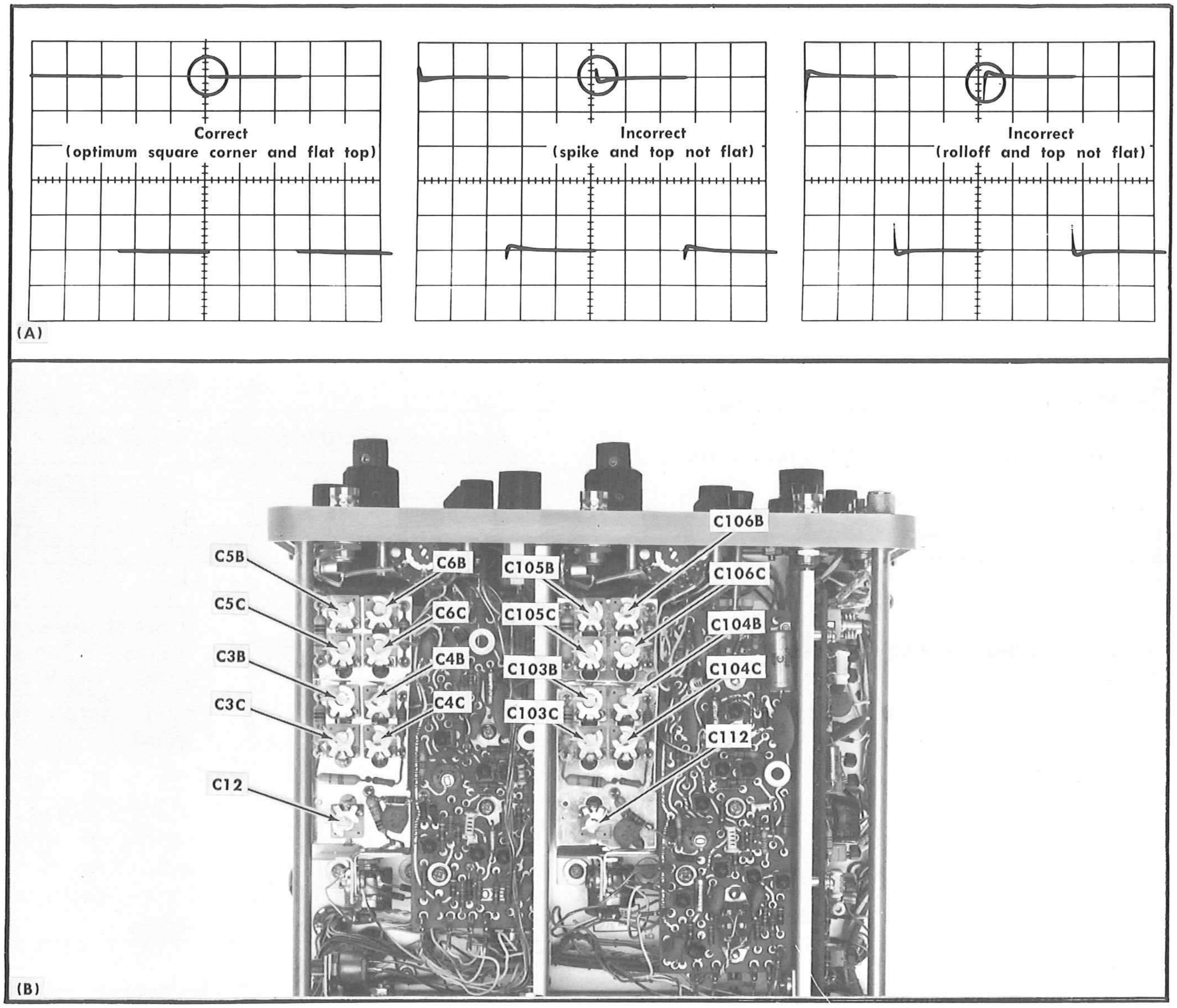


Fig. 5-17. (A) Typical CRT displays showing correct and incorrect compensation, (B) location of compensation adjustments (bottom).

given in Table 5-4. Readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum vertical deflection, in the 20 position.

e. ADJUST—Channel 2 VOLTS/DIV switch compensation as given in Table 5-4 (use low-capacitance screwdriver). First adjust for optimum square corner and then for optimum flat top. Remove the 10X attenuator and 50-ohm termination as given in Table 5-4 and readjust the generator output amplitude at each setting to maintain a four-division display, or to provide maximum deflection in the 20 position. Fig. 5-17B shows the location of the variable capacitors.

f. Disconnect all test equipment.

27. Check/Adjust High-Frequency Compensation

a. Connect the square-wave generator fast-rise + output connector to the INPUT 1 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable and the 50-ohm BNC termination.

b. Change the following control settings:

CH 1 & 2 VOLTS/DIV	.05
Vertical Mode	CH 1
TIME/DIV	.5 μs
X10 MAG	Pulled out

TABLE 5-4

Channel 2 VOLTS/DIV Switch Compensation

Channel 2 VOLTS/DIV Switch setting	Attenuator compensated	Adjusted for optimum	
		Square corner	Flat top
.05	÷ 1	– –	C112
.02	Check	If out of tolerance, compromise setting at .01, .02 and .05 for best overall response.	
.01	Check		
Remove external 10X attenuator from generator			
.1	÷ 2	C103C	C103B
.2	÷ 4	C104C	C104B
.5	÷ 10	C105C	C105B
Remove 50-ohm termination			
1	Check	If out of tolerance, compromise setting at .5, 1 and 2 for best overall response.	
2	Check		
5	÷100	C106C	C106B
10	Check	If out of tolerance, compromise setting at 5, 10 and 20 for best overall response.	
20	Check		

c. Set the square-wave generator for a five-division display at 100 kilohertz in the fast-rise mode.

d. CHECK—CRT display for optimum square-wave response with aberrations not to exceed +0.15 or –0.15 division, with total peak-to-peak aberrations not to exceed 0.15 division (within +3% or –3% with total peak-to-peak aberrations within 3%; (see Fig. 5-18A).

e. ADJUST—R237, C237, L245 and L255 in given order for optimum square-wave response (use low-capacitance screwdriver for C237 and tuning tool for L245-L255). Fig. 5-18B shows the location of these adjustments; L245 and L255 can be adjusted through the access holes in the rear panel of the indicator. Since these adjustments interact, readjust until optimum square-wave response is obtained.

f. Set the vertical Mode switch to CH 2.

g. Connect the square-wave generator fast-rise + output connector to the INPUT 2 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable and the 50-ohm BNC termination.

h. Set the square-wave generator for a five-division display at 100 kilohertz in the fast-rise mode.

i. CHECK—CRT display for optimum square-wave response similar to Channel 1 response.

j. ADJUST—If necessary, compromise the adjustment of R237, C237, L245 and L255 for best response for both checks d and i.

k. Disconnect all test equipment.

28. Check Upper Vertical Bandwidth Limit of Channel 1 and 2

a. Change the following control settings:

Vertical Mode	CH 1
TIME/DIV	.5 ms
X10 MAG	Pushed in

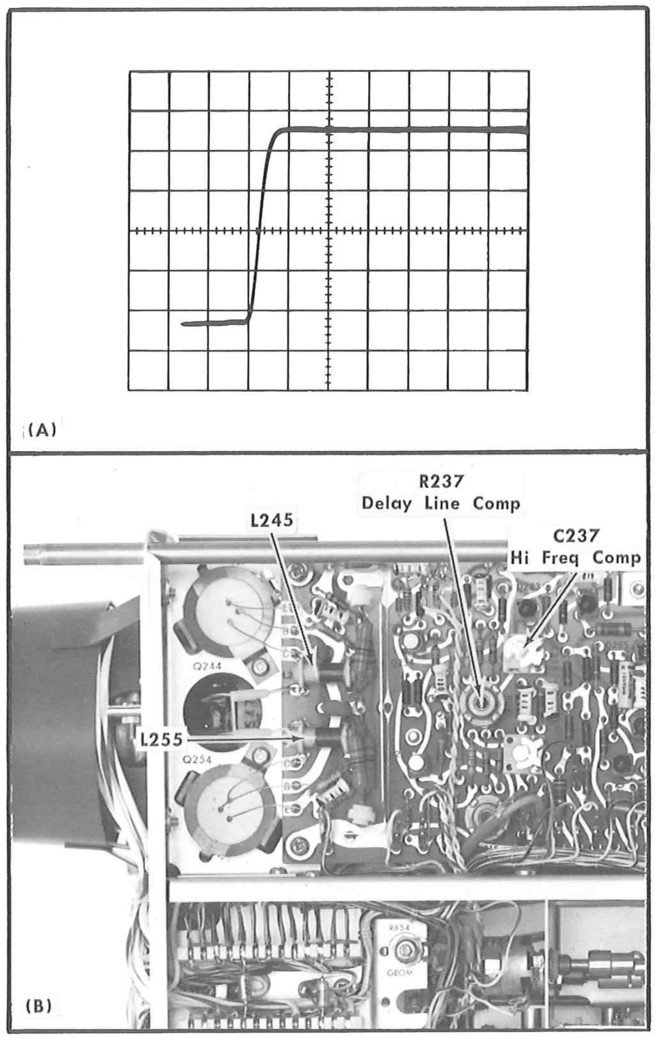


Fig. 5-18. (A) Typical CRT display showing correct high-frequency compensation, (B) location of high-frequency compensation adjustments (Vertical Switching and Output Amplifier board).

b. Connect the high-frequency constant-amplitude sine-wave generator (Type 191) to the INPUT 2 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable and the 50-ohm BNC termination.

c. Set the constant-amplitude generator for a four-division display, centered on the graticule, at its reference frequency (50 kilohertz).

d. Without changing the output amplitude, increase the output frequency of the constant-amplitude generator until the display is reduced to 2.8 divisions (—3 dB point).

e. CHECK—Output frequency of generator must be 15 megahertz or higher.

f. Set the vertical Mode switch to CH 2.

g. Disconnect the BNC termination from the INPUT 1 connector and re-connect it to the INPUT 2 connector.

h. Set the constant-amplitude generator for a four division display, centered on the graticule, at its reference frequency (50 kilohertz).

i. Without changing the output amplitude, increase the output frequency of the constant-amplitude generator until the display is reduced to 2.8 divisions (—3 dB point).

j. CHECK—Output frequency of generator must be 15 megahertz or higher.

29. Check Channel 2 X10 Gain Upper Vertical Bandwidth

a. Set the Channel 2 Input Coupling switch to AC.

b. Pull the X10 GAIN AC switch.

c. Set the constant-amplitude generator for a four-division display, centered on the graticule, at its reference frequency (50 kilohertz).

d. Without changing the output amplitude, increase the output frequency of the constant-amplitude generator until the display is reduced to 2.8 divisions (—3 dB point).

e. CHECK—Output frequency of generator must be five megahertz or higher.

30. Check Common-Mode Rejection Ratio

a. Connect the high-frequency sine-wave generator to the INPUT 1 and 2 connectors through the GR to BNC adapter, 18-inch 50-ohm BNC cable, 50-ohm BNC termination and the dual-input coupler.

b. Push in the X10 GAIN AC switch.

c. Set the sine-wave generator for an eight-division display at 50 kilohertz.

d. Change the following control settings:

Vertical Mode	ALG ADD
INVERT	Pulled out

e. CHECK—CRT display for 0.1 division deflection, or less (common-mode rejection ratio of 100:1 or greater).

f. Disconnect all test equipment.

31. Check AC-Coupled Lower Vertical Bandwidth Limit

a. Change the following control settings:

CH 1 and 2 Input Coupling	AC
Vertical Mode	CH 1
INVERT	Pushed in
TIME/DIV	.5 s

b. Connect the low-frequency constant-amplitude sine-wave generator to the INPUT 1 connector through the BNC to dual binding post adapter, 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

c. Set the low-frequency generator for a four-division display, centered on the graticule, at a reference frequency of one kilohertz.

d. Without changing the output amplitude, reduce the output frequency of the generator to two hertz.

e. CHECK—CRT display 2.8 divisions, or greater, in amplitude (not more than —3 dB).

f. Set the vertical Mode switch to CH 2.

g. Disconnect the 50-ohm termination from the INPUT 1 connector and reconnect it to the INPUT 2 connector.

h. Set the low-frequency generator for a four-division display, centered on the graticule, at a reference frequency of one kilohertz.

i. Without changing the output amplitude, reduce the output frequency of the generator to two hertz.

j. CHECK—CRT display 2.8 divisions, or greater, in amplitude (not more than —3 dB).

k. Pull the X10 GAIN AC switch.

l. Set the low-frequency generator for a four-division display, centered on the graticule, at a reference frequency of one kilohertz.

m. Without changing the output amplitude, reduce the output frequency of the generator to five hertz.

n. CHECK—CRT display 2.8 divisions or greater in amplitude (not more than —3 dB).

32. Check Channel Isolation Ratio

a. Change the following control settings:

CH 1 VOLTS/DIV	.01
CH 2 VOLTS/DIV	2
CH 1 Input Coupling	GND
CH 2 Input Coupling	DC
X10 GAIN AC	Pushed in
TIME/DIV	.5 ms

b. Connect the low-frequency sine-wave generator to the INPUT 2 connector with the BNC to dual binding post adapter and the 42-inch BNC cable.

c. Set the low-frequency generator for a five-division display at one megahertz.

d. Set the vertical Mode switch to CH 1.

e. CHECK—CRT display 0.1 division or less in amplitude (channel isolation 10,000:1 or greater).

f. Change the following control settings:

CH 1 VOLTS/DIV	2
CH 2 VOLTS/DIV	.01
CH 1 Input Coupling	DC
CH 2 Input Coupling	GND

g. Connect the low-frequency sine-wave generator to the INPUT 1 connector with the BNC to dual binding post adapter and the 42-inch BNC cable.

h. Set the low-frequency generator for a five-division display at one megahertz.

i., Set the vertical Mode switch to CH 2.

j. CHECK—CRT display 0.1 division or less in amplitude (channel isolation 10,000:1 or greater).

k. Disconnect all test equipment.

Control Setup

When performing a complete procedure, change the following control settings and proceed with step 33.

CH 1 and CH 2 VOLTS/DIV	.05
Vertical Mode	CH 1

Partial Procedure

If beginning a partial procedure with this step, set the controls as given under Preliminary Control Settings.

33. Adjust Channel 1 Only Triggering DC Level

PERFORMANCE CHECK ONLY

Steps 33 through 35 are not applicable to a performance check. Change the CH 1 Input Coupling Switch to DC and proceed with step 35.

a. Test equipment required for steps 33 through 53 is shown in Fig. 5-19.

b. Change the following control settings:

CH 1 Input Coupling	GND
TRIGGERING Coupling	DC

c. Connect the 10X probe to the vertical input connector of the test oscilloscope.

d. Set the test oscilloscope for a vertical deflection factor of 0.01 volt/division (0.1 volts/division at 10X probe tip) at a sweep rate of 20 microseconds/division with the input coupling switch set to the ground position.

e. Position the test oscilloscope trace to the center horizontal line of the graticule to establish a zero reference level. Then set the test oscilloscope input coupling switch to DC.

f. Connect the 10X probe tip to TP364 (trigger compensation test point, see Fig. 5-21A). Connect the probe ground strap to chassis ground. Be sure the probe is compensated.

g. Set the LEVEL control to return the test oscilloscope trace to the center horizontal line (zero reference level).

h. Set the TRIGGERING Source switch to CH 1.

i. CHECK—Test oscilloscope trace within 0.5 division of the center horizontal line (zero reference level).

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

j. ADJUST—CH 1 DC Level adjustment R57 (see Fig. 5-20) to position the test oscilloscope trace to the center horizontal line.

34. Adjust Internal Trigger Compensation

a. Set the Channel 1 Input Coupling switch to DC.

b. Remove transistor Q364 (see Fig. 5-21A) from its socket.

c. Connect the square-wave generator high-amplitude output connector to the INPUT 1 connector through the GR to BNC adapter, 18-inch 50-ohm BNC cable, two 10X BNC attenuators and the 50-ohm BNC termination, in given order.

d. Set the square-wave generator for a one-division display on the test oscilloscope at a frequency of 10 kilohertz in the high-amplitude mode.

e. CHECK—Test oscilloscope display for optimum square-wave response similar to Fig. 5-21B (this waveform

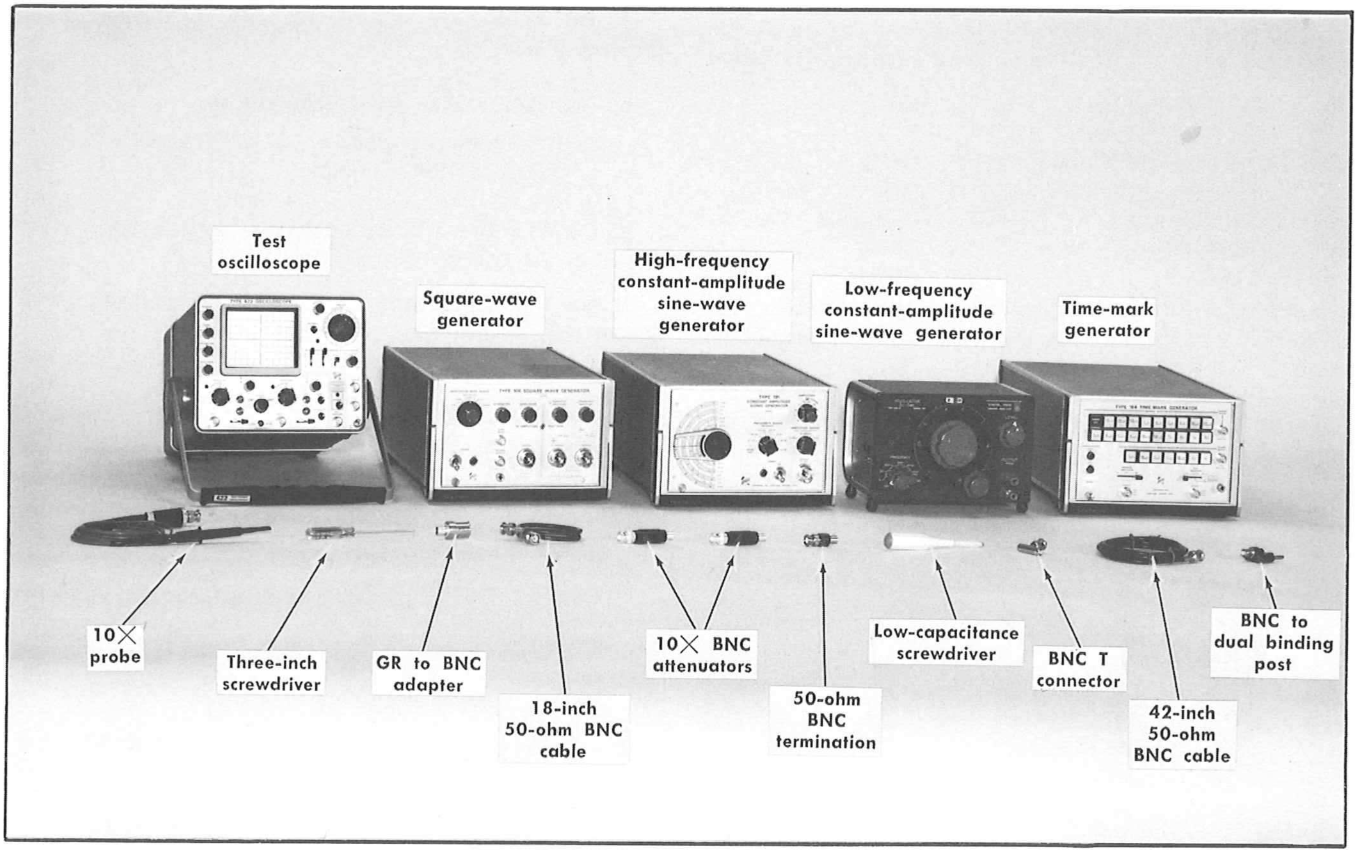


Fig. 5-19. Test equipment required for steps 33 through 53.

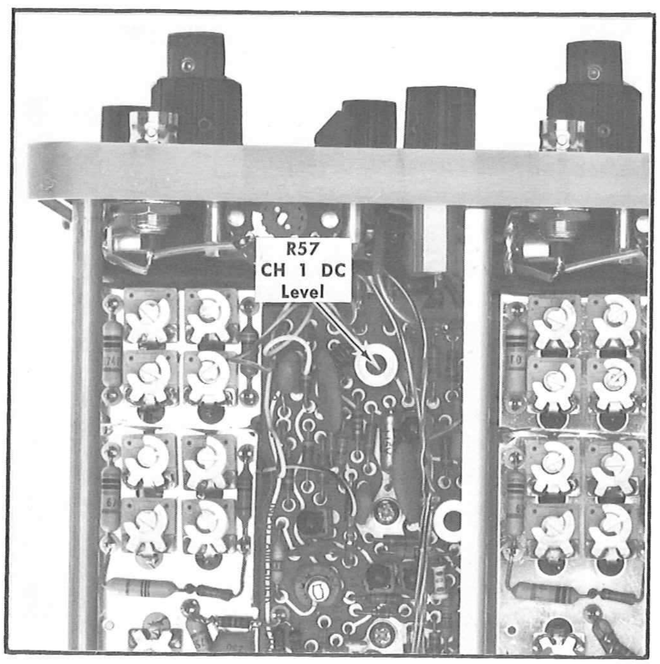


Fig. 5-20. Location of CH 1 DC Level adjustment (Channel 1 Input Amplifier board).

does not indicate optimum response but is provided for reference only). Notice that the lower corner of the square wave is the area of interest.

f. ADJUST—C353 (see Fig. 5-21A) for optimum square-corner at the lower corner of the waveform (use low-capacitance screwdriver).

g. Set the TRIGGERING Source switch to CH 1 & 2.

h. CHECK—Test oscilloscope for optimum square-wave response similar to Fig. 5-21B.

i. ADJUST—C217 (see Fig. 5-21C) for optimum square-corner on the lower corner of the waveform (use low-capacitance screwdriver).

35. Adjust External Trigger Compensation

a. Disconnect the output of the 50-ohm termination from the INPUT 1 connector and re-connect it to the TRIG IN connector.

b. Set the TRIGGERING Source switch to EXT.

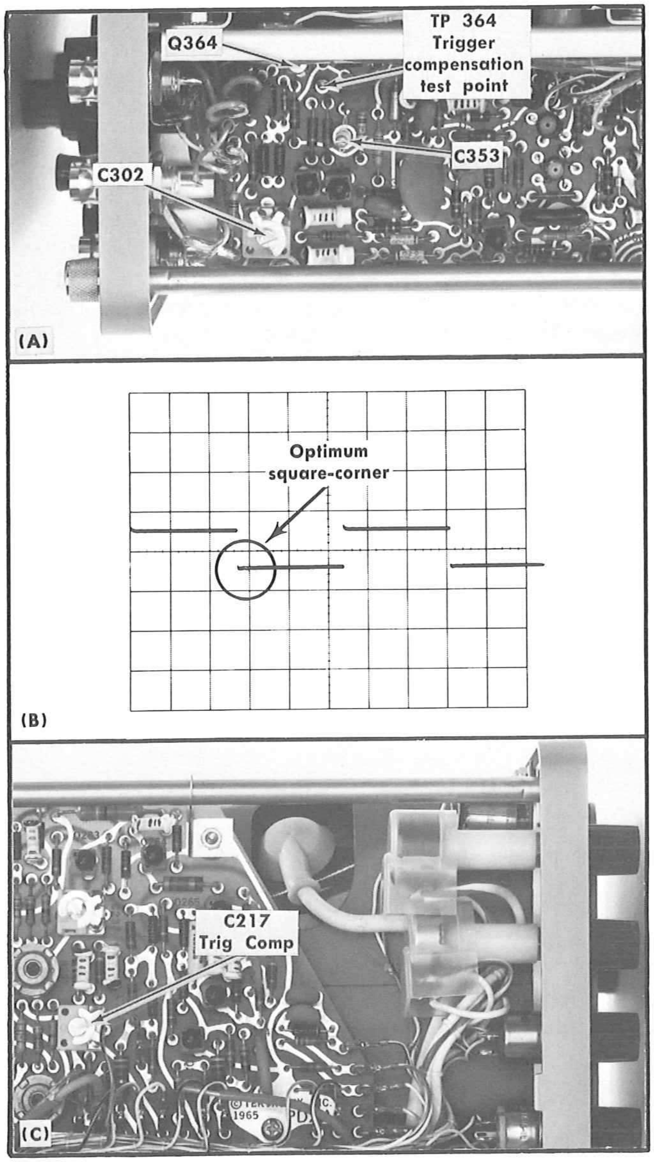


Fig. 5-21. (A) Location of trigger compensation test point and adjustment (Trigger/Sweep Generator board), (B) typical test oscilloscope display showing correct compensation, (C) location of C217 (Vertical Switching and Output Amplifier board).

c. Set the square-wave generator for a one-division display on the test oscilloscope at a frequency of 10 kilohertz in the high-amplitude mode.

d. CHECK—Test oscilloscope display for optimum square-corner at the lower corner of the waveform similar to Fig. 5-21B.

e. ADJUST—C302 (see Fig. 5-21A) for optimum square-wave response.

f. Disconnect all test equipment and replace Q364.

36. Check High-Frequency Triggering Operation

a. Change the following control settings:

CH 1 and 2 VOLTS/DIV	.2
TRIGGERING Source	CH 1 & 2
TRIGGERING Coupling	AC
TIME/DIV	.5 μs

b. Connect the high-frequency constant-amplitude sinewave generator to the INPUT 1 connector through the 18-inch 50-ohm BNC cable, 50-ohm BNC termination and the BNC T connector. Connect the output of the BNC T connector to the TRIG IN connector through a 42-inch 50-ohm BNC cable.

c. Set the constant-amplitude generator for a 0.2-division display at five megahertz.

d. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

e. Set the TRIGGERING MODE switch to NORM (pulled out).

f. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

g. Set the constant-amplitude generator for a one-division display at 15 megahertz.

h. Pull the X10 MAG switch.

i. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

j. Set the TRIGGERING Mode switch to AUTO (pushed in).

k. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

l. Change the following control settings;

Ch 1 VOLTS/DIV	.05
TRIGGERING Source	EXT
X10 MAG	Pushed in

m. Set the constant-amplitude generator for a 2.5 division display (0.125 volt) at its reference frequency (50 kilohertz).

n. Without changing the output amplitude, set the constant-amplitude generator output frequency to five megahertz.

o. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

p. Set the TRIGGERING Mode switch to NORM (pulled out).

q. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

r. Set the Channel 1 VOLTS/DIV switch to .1.

s. Set the constant-amplitude generator for a six-division display (0.6 volt) at its reference frequency (50 kilohertz).

t. Without changing the output amplitude, set the constant-amplitude generator to 15 megahertz.

u. Pull the X10 MAG switch.

v. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

w. Set the TRIGGERING Mode switch to AUTO (pushed in).

x. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC, AC LF REJ and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

y. Disconnect all test equipment.

37. Check Low-Frequency Triggering Operation

a. Change the following control settings:

Ch 1 VOLTS/DIV	.05
TIME/DIV	5 ms
X10 MAG	Pushed in

b. Connect the low-frequency constant-amplitude sine-wave generator to the INPUT 1 connector through the BNC to dual binding post adapter, 42-inch 50-ohm BNC cable, 50-ohm BNC termination and BNC T connector. Connect the output of the BNC T connector to the TRIG IN connector with an 18-inch 50-ohm BNC cable.

c. Set the low-frequency generator for a 2.5-division display (0.125 volt) at one kilohertz.

d. Without changing the output amplitude, set the constant-amplitude generator output frequency to 50 hertz.

e. CHECK—Stable CRT display can be obtained with TRIGGERING Coupling switch set to AC and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

f. Set the TRIGGERING Mode switch to NORM (pulled out).

g. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC and DC (LEVEL control may be adjusted as necessary to obtain a stable display).

h. Set the TRIGGERING Source switch to CH 1 & 2.

i. Set the low-frequency generator for a 0.2-division display at 50 hertz.

j. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

k. Set the TRIGGERING Mode switch to AUTO (pushed in).

l. CHECK—Stable CRT display can be obtained with the TRIGGERING Coupling switch set to AC and DC and the TRIGGERING Source switch set to CH 1 and CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

38. Check Low-Frequency Reject Operation

a. Change the following control settings:

TRIGGERING Coupling	AC LF REJ
TRIGGERING Mode	NORM
TIME/DIV	.1 ms

b. Set the low-frequency generator for a 0.2-division display at 50 kilohertz.

c. CHECK—Stable CRT display can be obtained with the TRIGGERING Source switch set to CH 1 & 2 (LEVEL control may be adjusted as necessary to obtain a stable display).

d. Set the low-frequency generator for a two-division display at 50 kilohertz.

e. Without changing the output amplitude, set the low-frequency generator to 50 hertz.

f. Set the TIME/DIV switch to 5 ms.

g. CHECK—Stable CRT display cannot be obtained at any setting of the LEVEL control with the TRIGGERING Source switch set to CH 1 and CH 1 & 2.

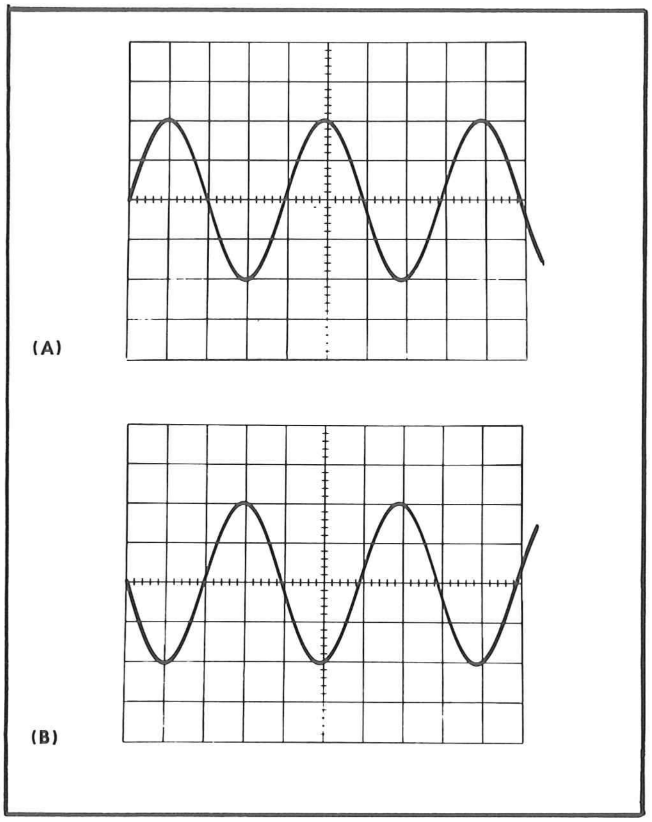


Fig. 5-22. (A) Typical CRT display when checking positive-slope triggering, (B) typical CRT display when checking negative-slope triggering.

39. Check Triggering Slope Switch Operation

a. Change the following control settings:

TRIGGERING Coupling	AC
TIME/DIV	.2 ms

b. Set the low-frequency sine-wave generator for a four-division display at one kilohertz.

c. CHECK—CRT display starts on the positive slope of the waveform (see Fig. 5-22A).

d. Set the SLOPE switch to the negative-going position.

e. CHECK—CRT display starts on the negative slope of the waveform (see Fig. 5-22B).

40. Check Triggering Level Control Range

a. Change the following control settings:

CH 1 VOLTS/DIV	5
TRIGGERING Source	EXT
TRIGGERING Coupling	DC
LEVEL	Midrange

b. Set the low-frequency sine wave generator for a four-division display (20 volts peak to peak).

c. CHECK—Rotate the LEVEL control throughout its range and check that the display can be triggered (stable display) at any point along the negative slope of the waveform (indicates LEVEL control range of at least + and − 10 volts). The display is not triggered at either extreme of rotation.

d. Set the SLOPE switch to the positive-going position.

e. CHECK—Rotate the LEVEL control throughout its range and check that the display can be triggered (stable display) at any point along the positive slope of the waveform (indicates LEVEL control range of at least + and − 10 volts). The display is not triggered at either extreme of rotation.

f. Disconnect all test equipment.

41. Check Auto Recovery Time

a. Change the following control settings:

CH 1 VOLTS/DIV	.5
TRIGGERING Source	CH 1 & 2
TRIGGERING Coupling	AC
TRIGGERING Mode	AUTO
TIME/DIV	.5 ms

b. Connect the time-mark generator to the INPUT 1 connector through the 42-inch 50-ohm BNC cable and the 50-ohm BNC termination.

c. Set the time-mark generator for 50-millisecond markers.

d. CHECK—Stable display can be obtained with the LEVEL control.

e. Set the time-mark generator for 0.1-second markers.

f. CHECK—Stable display cannot be obtained at any setting of the LEVEL control.

42. Check/Adjust Normal Timing

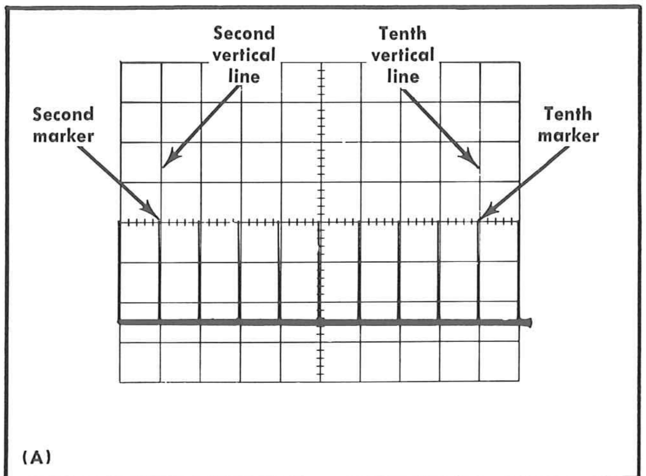
a. Set the time-mark generator for 0.5-millisecond markers.

b. Set the LEVEL control for a stable display.

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule (see Fig. 5-23A). Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

NOTE

Unless otherwise noted, use the middle eight horizontal divisions (between second and tenth vertical lines of the graticule) when checking or adjusting timing.



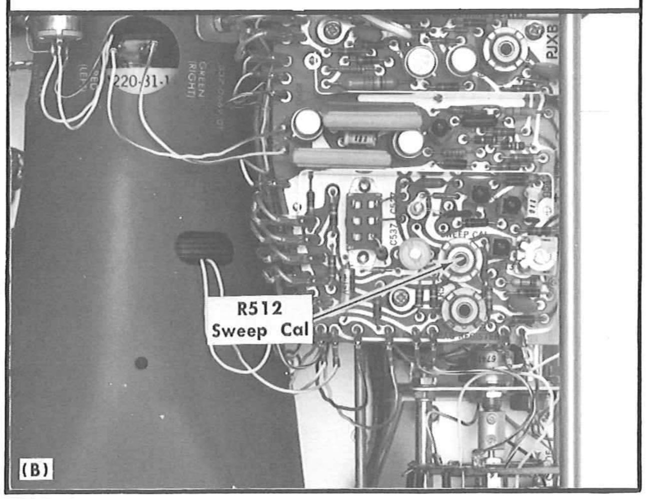


Fig. 5-23. (A) Typical CRT display showing correct sweep calibration, (B) location of Sweep Cal adjustment (Horizontal Amplifier board).

d. ADJUST—Sweep Cal adjustment R512 (see Fig. 5-23B) for one marker each division. The second and tenth markers must coincide exactly with their respective graticule lines (reposition the display slightly with the horizontal POSITION control if necessary).

e. Position the second marker to the second vertical line.

f. CHECK—Fourth marker within 0.08 division (within 4%) of the fourth vertical line.

g. Position the third marker to the third vertical line.

h. CHECK—Fifth marker within 0.08 division (within 4%) of the fourth vertical line.

i. Continue this check for each two-division portion of the sweep within the center eight divisions of the graticule.

j. INTERACTION—Check steps 43 through 53.

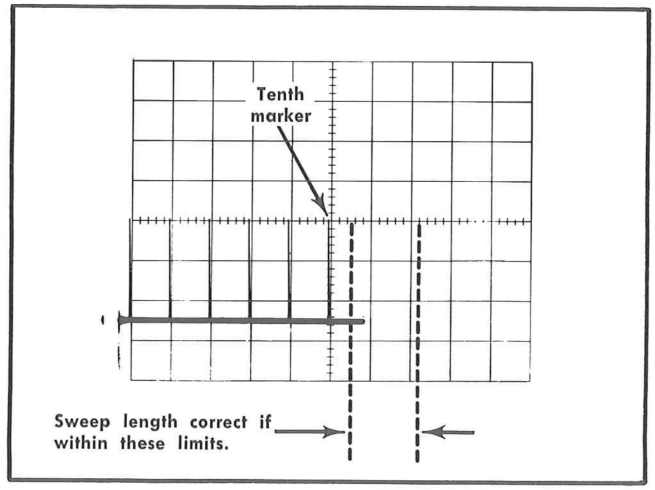


Fig. 5-24. Typical CRT display when checking sweep length.

43. Check Sweep Length

a. Position the tenth marker to the center vertical line with the horizontal POSITION control (see Fig 5-24).

b. CHECK—Sweep length between 10.4 and 12.1 divisions as shown by 0.4 to 2.1 divisions of display to the right of the center vertical line (see Fig. 5-24).

44. Check Magnified Timing

a. Set the time-mark generator for 50-microsecond markers.

b. Change the following control settings:

X10 MAG	Pulled out
Horizontal POSITION	Midrange

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines. Marker at tenth vertical line must be within 0.4 division (within 5%) of that graticule line when the marker at the second vertical line is positioned exactly.

d. Position the first 10-division portion of the total magnified sweep onto the viewing area with the horizontal POSITION control.

e. CHECK—One marker each division between the second and tenth vertical lines. Marker at the tenth vertical line must be within 0.4 division (within 5%) of that graticule line when the marker at the second vertical line is positioned exactly

f. Repeat this check for each 10-division portion of the total magnified sweep length.

g. Set the horizontal POSITION control to midrange.

h. Position a marker to the second vertical line.

i. CHECK—Marker within 0.15 division (within 7.5%) of the fourth vertical line.

j. Position the marker nearest the third vertical line exactly to that line.

k. CHECK—Marker within 0.15 division (within 7.5%) of the fifth vertical line.

l. Continue this check for each two-division portion of the displayed sweep within the center eight divisions of the graticule.

m. INTERACTION—Check steps 45, 49 and 51.

45. Check Variable Time/Division Control Range

a. Set the time-mark generator for five-millisecond markers.

b. Position the first marker to the center vertical line (see Fig. 5-25A) with the horizontal POSITION control (use the fine range of the POSITION control for precise positioning).

c. Push the X10 MAG switch in.

d. CHECK—First marker within 0.2 division of the center vertical line (see Fig. 5-25B).

NOTE

This tolerance is provided as a guide to correct instrument operation and is not an instrument specification.

e. ADJUST—Mag Register adjustment, R535 (see Fig. 5-25C) to position the first marker to the center vertical line.

f. Pull the X10 MAG switch.

g. Position the middle marker (three markers on sweep) to the center vertical line.

h. Push the X10 MAG switch in.

i. CHECK—Middle marker within 0.2 division of the center vertical line.

j. ADJUST—If middle marker is outside the given tolerance, compromise the setting of the Mag Register adjustment for best overall operation in checks d and i.

k. Pull the X10 MAG switch and repeat parts b through

46. Check Variable Time/Division Control Range

a. Push the X10 MAG switch in.

b. Set the time-mark generator for 10-millisecond markers.

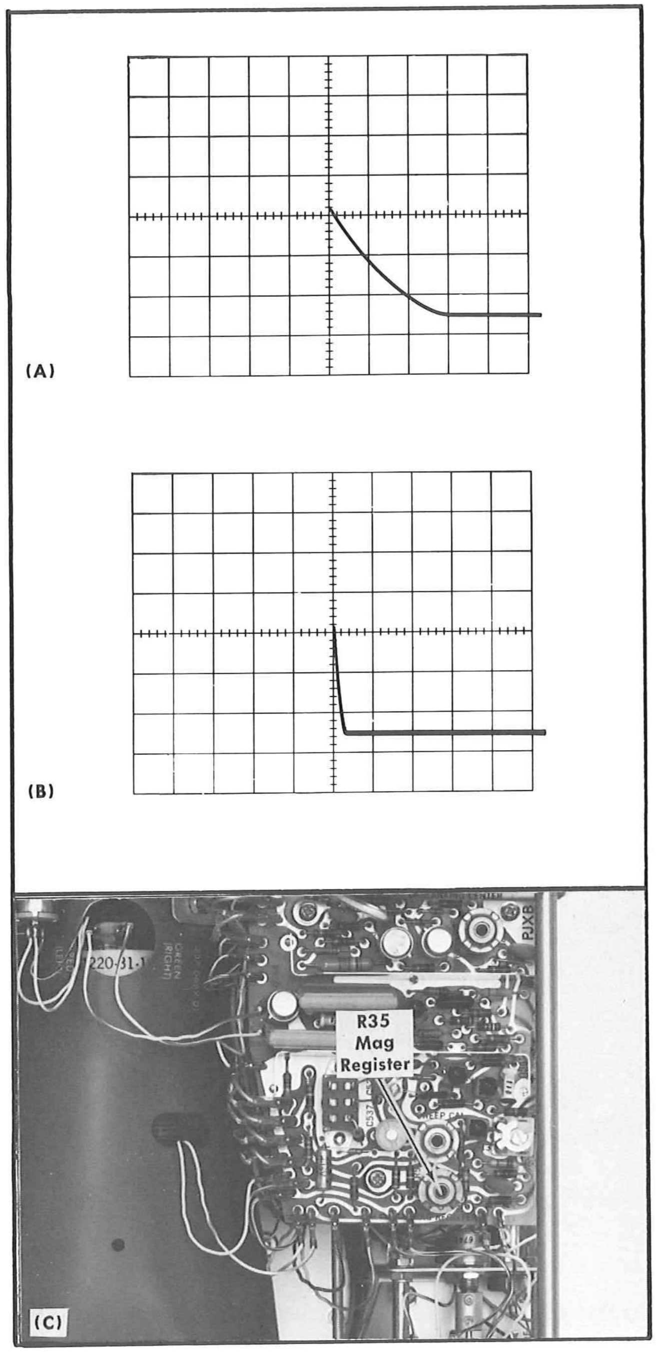


Fig. 5-25. Typical CRT display showing correct magnified registration. (A) X10 MAG switch pulled out, (B) X10 MAG switch pushed in, (C) location of Mag Register adjustment (Horizontal Amplifier board).

c. Position the markers to the far left and right vertical lines of the graticule with the horizontal POSITION control.

d. Turn the VARIABLE TIME/DIV control fully counterclockwise.

e. CHECK—CRT display for four-division maximum spacing between markers (indicates adequate range for continuously variable sweep rates between the calibrated steps).

f. Return the VARIABLE TIME/DIV control to CAL.

47. Adjust 5 Microsecond Timing

PERFORMANCE CHECK ONLY

Complete normal and magnified accuracy of the TIME/DIV switch is checked in Tables 5-5 and 5-6. Therefore delete steps 47 through 49 for a performance check only and proceed to step 50.

a. Set the time-mark generator for five-microsecond markers.

b. Set the TIME/DIV switch to 5 μs.

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule. Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

d. ADJUST—C440A (see Fig. 5-26) for one marker each division (use low-capacitance screwdriver).

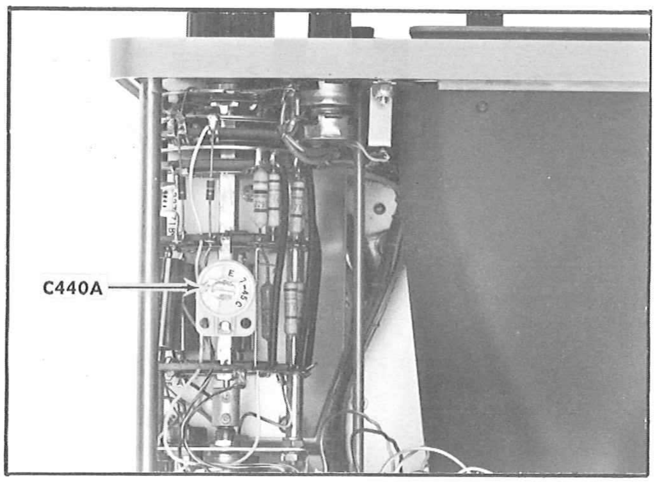


Fig. 5-26. Location of C440A (top).

48. Adjust 0.5 Microsecond Timing

a. Set the time-mark generator for 0.5 microsecond markers.

b. Set the TIME/DIV switch to .5 μs.

c. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule. Tenth marker must be within 0.24 division (within 3%) of the tenth vertical line with the second marker positioned exactly to the second vertical line.

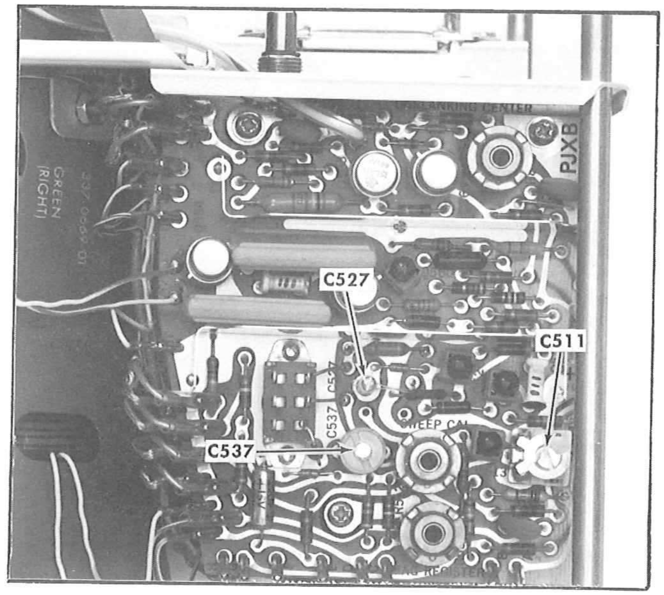


Fig. 5-27. Location of high-speed timing adjustments (Horizontal Amplifier board).

d. ADJUST—C537 (see Fig. 5-27) for one marker each division (use low-capacitance screwdriver).

e. Set the TIME/DIV switch to 1 μs.

f. CHECK—CRT display for two markers each division between the second and tenth vertical lines of the graticule. If necessary, compromise the setting of C537 for minimum timing error in the .5 μs and 1 μs positions.

49. Adjust 0.5 Microsecond X10 Magnified Timing

a. Set the time-mark generator for 50-nanosecond markers.

b. Change the following control settings:

TIME/DIV	.5 μs
X10 MAG	Pulled out

c. Position the first marker of the total magnified sweep length to the second vertical line of the graticule.

d. CHECK—CRT display for one marker each division between the second and tenth vertical lines of the graticule.

e. ADJUST—C511 (see Fig. 5-27) for one marker each division (use low-capacitance screwdriver).

f. Adjust the horizontal POSITION control so the center of the total magnified sweep is displayed. If necessary, temporarily push in the X10 MAG switch to obtain the correct position.

g. CHECK—CRT display for one marker each divison between the second and tenth vertical lines of the graticule (X10 MAG switch pulled out).

h. ADJUST—C527 (see Fig. 5-27) for one marker each division (use low-capacitance screwdriver).

i. Repeat parts c through h of this step until optimum timing is obtained.

50. Check Normal Sweep Timing Accuracy

a. Push the X10 MAG switch in.

CAUTION

To prevent permanent damage to the CRT phosphor at slow sweep rates position the baseline of the marker display below the viewing area.

b. CHECK—Using the TIME/DIV switch and time mark generator settings given in Table 5-5, check sweep timing within 0.24 division (within 3%) over the middle eight divisions of the display. Adjust the LEVEL control as necessary to obtain a stable display.

51. Check Magnified Sweep Timing Accuracy

a. Pull the X10 MAG switch.

b. CHECK—Using the TIME/DIV switch and time-mark generator settings given in Table 5-6, check magnified timing within 0.4 division (within 5%) over the middle eight divisions of the total magnified sweep length.

c. Disconnect all test equipment.

52. Check Gate Output Signal

a. Change the following control settings:

TRIGGERING Source	CH 1 & 2
TIME/DIV	1 ms
X10 MAG	Pushed in

b. Connect the GATE OUT connector to the input of the test oscilloscope with a 42-inch BNC cable.

c. Set the test oscilloscope for a vertical deflection of 0.1 volt/division and a sweep rate of two milliseconds/division.

d. CHECK—Test oscilloscope for five divisions or greater amplitude (0.5 volt or greater in amplitude; see Fig. 5-28). Gate duration should be between 5.2 and 6.05 divisions (10.4 to 12.1 times the TIME/DIV switch setting).

e. Disconnect the test oscilloscope.

53. Check Chopped Operation

a. Change the following control settings:

Vertical Mode	CHOPPED
TIME/DIV	1 μs

b. Position the traces about four divisions apart with the Channel 1 and 2 POSITION controls.

TABLE 5-5
Normal Sweep Timing

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)
.5 μs	0.5 microsecond	1
1 μs	1 microsecond	1
2 μs	1 microsecond	2
5 μs	5 microsecond	1
10 μs	10 microsecond	1
20 μs	10 microsecond	2
50 μs	50 microsecond	1
.1 ms	0.1 millisecond	1
.2 ms	0.1 millisecond	2
.5 ms	0.5 millisecond	1
1 ms	1 millisecond	1
2 ms	1 millisecond	2
5 ms	5 millisecond	1
10 ms	10 millisecond	1
20 ms	10 millisecond	2
50 ms	50 millisecond	1
.1 s	0.1 second	1
.2 s	0.1 second	2
.5 s	0.5 second	1

TABLE 5-6
Magnified Sweep Timing Accuracy

TIME/DIV switch setting	Time-mark generator output	CRT display (markers/division)
.5 μs	50 nanosecond	1
1 μs	.1 microsecond	1
2 μs	.1 microsecond	2
5 μs	.5 microsecond	1
10 μs	1 microsecond	1
20 μs	1 microsecond	2
50 μs	5 microsecond	1
.1 ms	10 microsecond	1
.2 ms	10 microsecond	2
.5 ms	50 microsecond	1
1 ms	.1 millisecond	1
2 ms	.1 millisecond	2
5 ms	.5 millisecond	1
10 ms	1 millisecond	1
20 ms	1 millisecond	2
50 ms	5 millisecond	1
.1 s	10 millisecond	1
.2 s	10 millisecond	2
.5 s	50 millisecond	1

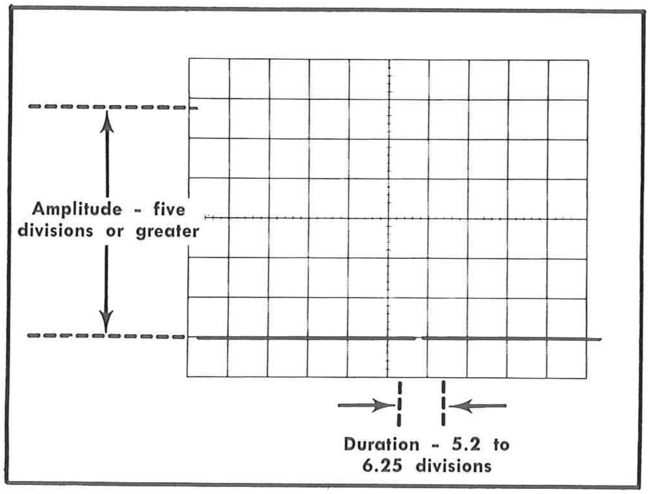


Fig. 5-28. Typical test oscilloscope display when checking GATE OUT signal (vertical deflection 0.1 volt/division; sweep rate two milliseconds/division).

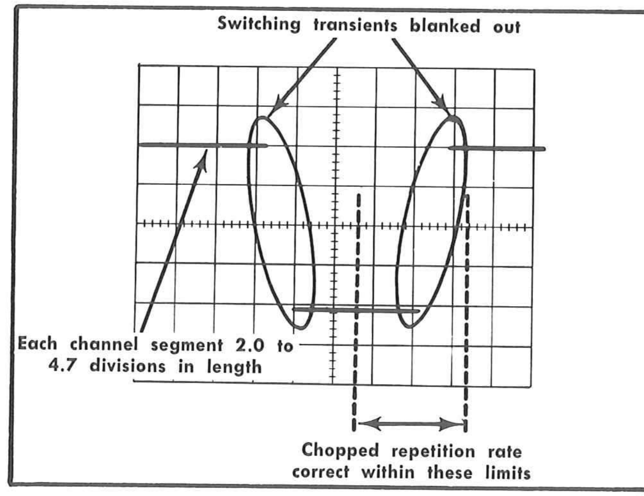


Fig. 5-29. Typical CRT display when checking chopped repetition rate and blanking.

c. CHECK—CRT display for duration of each cycle between 5.6 and 8.4 divisions (150 kilohertz ±20%; see Fig. 5-29).

d. CHECK—CRT display for total length of each channel segment between 2.0 and 4.7 divisions (2.0 to 4.7 microseconds).

e. CHECK—CRT display for complete blanking of switching transients between chopped segments (see Fig. 5-29).

Control Setup

When performing a complete procedure, change the following control settings and proceed with step 54.

Vertical Mode	CH 1

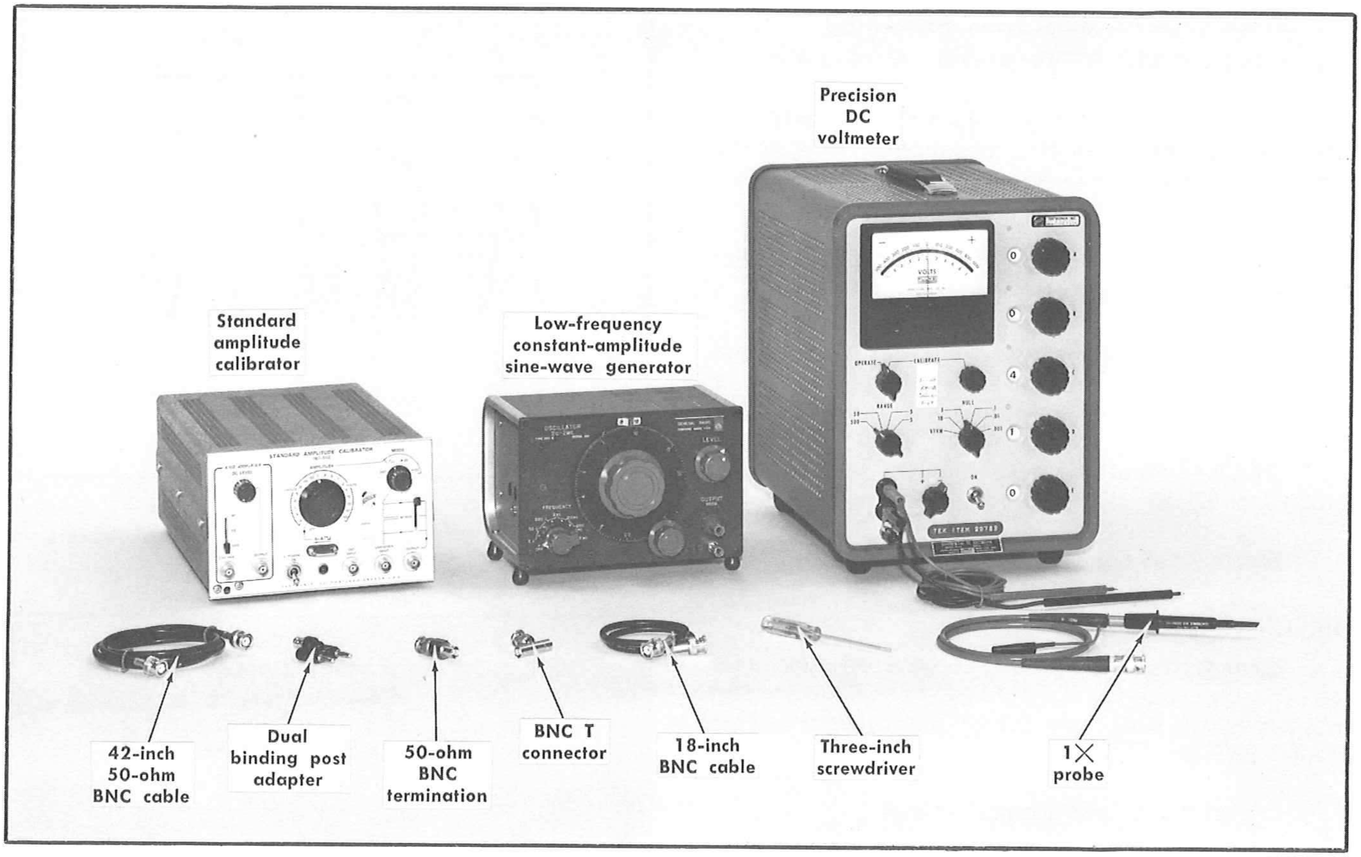


Fig. 5-30. Test equipment required for steps 54 through 59.

Partial Procedure

If beginning a partial procedure with this step, set the controls as given under Preliminary Control Settings.

54. Check External Horizontal Operation

a. Test equipment required for steps 54 through 59 is shown in Fig. 5-30.

CAUTION

To prevent permanent damage to the CRT phosphor, reduce the INTENSITY control setting if a halo forms around the external horizontal display.

b. Change the following control settings:

HORIZ ATTEN (LEVEL)	Clockwise
TIME/DIV	EXT HORIZ

c. Connect the standard amplitude calibrator output connector to the HORIZ IN (TRIG IN) connector with the 42-inch BNC cable.

d. Set the standard amplitude calibrator for a 50-volt square-wave output.

e. Center the display (two dots) on the graticule with the horizontal POSITION control.

f. CHECK—CRT display for horizontal deflection between 4.0 and 6.7 divisions (10 volts/division ±25%).

g. Pull the X10 MAG switch.

h. Set the standard amplitude calibrator for a five-volt square-wave output.

i. Center the display on the graticule with the horizontal POSITION control.

j. CHECK—CRT display for horizontal deflection between 4.0 and 6.7 divisions (one volt/division ±25%). Note the exact horizontal deflection.

k. Set the standard amplitude calibrator for a 50-volt square-wave output.

l. Turn the HORIZ ATTEN control fully counterclockwise.

m. CHECK—CRT display for horizontal deflection equal to or less than noted in part j (indicates 10:1 or greater range).

n. Disconnect all test equipment.

55. Check External Horizontal Bandwidth

a. Turn the HORIZ ATTEN control fully clockwise.

b. Connect the low-frequency constant-amplitude sine-wave generator to the HORIZ IN connector through the BNC to dual binding post adapter, 42-inch 50-ohm BNC cable and 50-ohm BNC termination.

c. Set the constant-amplitude generator for six divisions of horizontal deflection at 50 kilohertz.

d. Without changing the output amplitude, increase the output frequency of the constant-amplitude generator until the display is reduced to 4.2 divisions (—3 dB point).

e. CHECK—Output frequency of generator must be 500 kilohertz or higher.

f. Disconnect all test equipment.

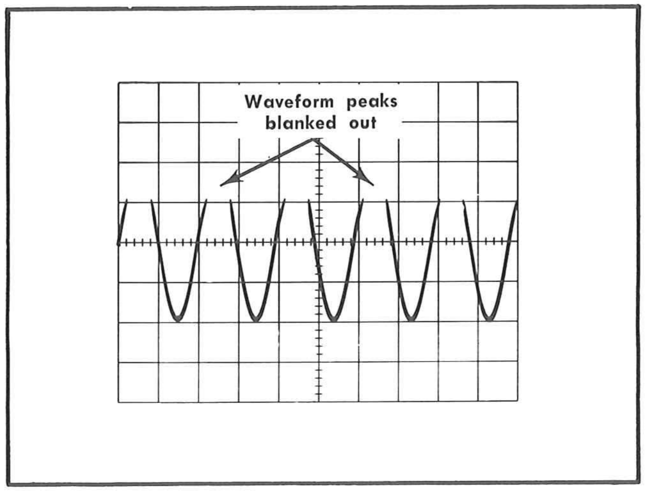


Fig. 5-31. Typical CRT display when checking external blanking.

56. Check External Blanking

a. Connect the low-frequency sine-wave generator to the INPUT 1 connector through the BNC to dual binding post adapter, 42-inch BNC cable, the BNC T connector and the 50-ohm BNC termination.

b. Change the following control settings:

TIME/DIV	10 μs
X10 MAG	Pushed in

c. Set the sine-wave generator for a four-division display (two volts positive, peak) at 50 kilohertz.

d. Adjust the LEVEL control for a stable display.

e. Connect the output of the BNC T connector the EXT BLANKING connector with an 18-inch BNC cable.

f. CHECK—The positive peaks of the displayed signal should be blanked with a normal INTENSITY control setting (see Fig. 5-31).

g. Disconnect all test equipment.

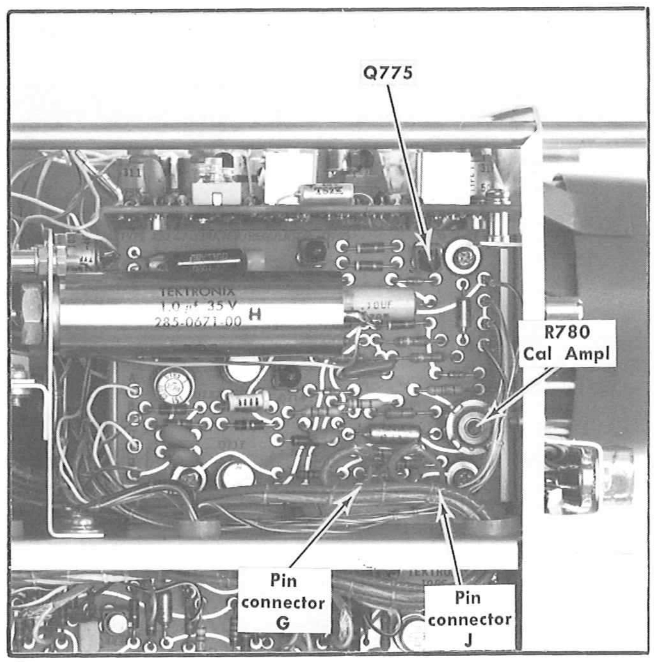


Fig. 5-32. Location of calibrator test points and amplitude adjustment (Calibrator and Regulator board).

57. Check/Adjust Calibrator Amplitude

PERFORMANCE CHECK ONLY

Parts a through g of this step are not applicable to a performance check. Proceed to part h.

a. Connect the precision DC voltmeter from pin connector G on the Calibrator and Regulators board (see Fig. 5-32) to chassis ground.

b. Remove transistor Q775 (see Fig. 5-32) from its socket.

c. CHECK—Meter reading; —2 volts ±10 millivolts (within 0.5%).

d. ADJUST—Calibrator Amplitude adjustment R780 (see Fig. 5-32) for exactly —2 volts.

e. Connect the precision DC voltmeter from pin connector J on the Calibrator and Regulators board (see Fig. 5-32) to chassis ground.

f. CHECK—Meter reading: —200 millivolts ± 3 millivolts (within 1.5%).

g. Disconnect the voltmeter and replace Q775.

h. Connect the 1X probe to the INPUT 1 connector.

i. Position the probe tip so it is in contact with the CALIBRATOR jack.

j. Set the TIME/DIV switch to .5 ms.

k. CHECK—CRT display exactly four divisions in amplitude (two volts amplitude at CALIBRATOR JACK).

NOTE

Checks in parts k, m and o are valid only if the Channel 1 and 2 GAIN were adjusted exactly in step 12 of this procedure.

l. Set both VOLTS/DIV switches to the CALIBRATE 4 DIVISIONS position.

m. CHECK—CRT display four divisions ±0.06 division in amplitude (internal calibrator accuracy within 1.5%, CALIBRATE 4 DIVISIONS position of Channel 1 VOLTS/DIV switch operating correctly).

n. Set the vertical Mode switch to CH 2.

o. CHECK—CRT display four divisions ±0.06 division in amplitude (internal calibrator accuracy within 1.5%, CALIBRATE 4 DIVISIONS position of Channel 2 VOLTS/DIV switch operating correctly).

58. Check Calibrator Repetition Rate

a. Set the TIME/DIV switch to 0.2 ms.

b. Position the start of the display to the farthest left vertical line.

c. CHECK—CRT display for length of one complete cycle between 4.2 and 6.3 divisions (repetition rate one kilohertz ±20%).

59. Check Calibrator Duty Cycle

a. Set the TIME/DIV switch to 50 μs.

b. Set the VARIABLE TIME/DIV control for one complete cycle in 10 divisions.

c. CHECK—CRT display for length of positive segment of the square wave between 4.5 and 5.5 divisons (duty cycle 45% to 55%).

This completes the checkout/calibration procedure for the Type 422 with AC-DC Power Supply. Replace the cabinet and re-attach the power supply to the indicator. If the instrument has been completely checked and adjusted to the tolerances given in this procedure it will meet or exceed the specifications given in Section 1.

NOTES

PARTS LIST ABBREVIATIONS

BHB	binding head brass
BHS	binding head steel
cap.	capacitor
cer	ceramic
comp	composition
conn	connector
CRT	cathode-ray tube
csk	countersunk
DE	double end
dia	diameter
div	division
elect.	electrolytic
EMC	electrolytic, metal cased
EMT	electrolytic, metal tubular
ext	external
F & I	focus and intensity
FHB	flat head brass
FHS	flat head steel
Fil HB	fillister head brass
Fil HS	fillister head steel
h	height or high
hex.	hexagonal
HHB	hex head brass
HHS	hex head steel
HSB	hex socket brass
HSS	hex socket steel
ID	inside diameter
inc	incandescent
int	internal
lg	length or long
met.	metal
mtg hdw	mounting hardware
OD	outside diameter
OHB	oval head brass
OHS	oval head steel
P/O	part of
PHB	pan head brass
PHS	pan head steel
plstc	plastic
PMC	paper, metal cased
poly	polystyrene
prec	precision
PT	paper, tubular
PTM	paper or plastic, tubular, molded
RHB	round head brass
RHS	round head steel
SE	single end
SN or S/N	serial number
S or SW	switch
TC	temperature compensated
THB	truss head brass
thk	thick
THS	truss head steel
tub.	tubular
var	variable
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.

SECTION 6
ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

INDICATOR

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Bulbs			
B725	150-0059-00			Incandescent #386			
B726	150-0059-00			Incandescent #386			
B728	150-0035-00			Neon, A1D T2			
B741	150-0035-00			Neon, A1D T2			
B743	150-0035-00			Neon, A1D T2			
B745	150-0035-00			Neon, A1D T2			
B820	150-0035-00			Neon, A1D T2			
B846	150-0035-00			Neon, A1D T2			
				Capacitors			
Tolerance ±20% unless otherwise indicated.							
C1	*285-0672-00			0.1 μF	MT	600 V	+5%—15%
C3B	281-0099-00			1.3-5.4 pF, Var	Air		
C3C	281-0102-00			1.7-11 pF, Var	Air		
C3D	281-0572-00			6.8 pF	Cer	500 V	±0.5 pF
C4B	281-0102-00			1.7-11 pF, Var	Air		
C4C	281-0102-00			1.7-11 pF, Var	Air		
C5A	281-0501-00			4.7 pF	Cer	500 V	±1 pF
C5B	281-0102-00			1.7-11 pF, Var	Air		
C5C	281-0099-00			1.3-5.4 pF, Var	Air		
C5E	281-0509-00			15 pF	Cer	500 V	10%
C6A	281-0504-00			10 pF	Cer	500 V	10%
C6B	281-0102-00			1.7-11 pF, Var	Air		
C6C	281-0099-00			1.3-5.4 pF, Var	Air		
C6E	283-0606-00			250 pF	Mica	500 V	10%
C10[1]	281-0529-00	X20079		1.5 pF (nominal value) Selected			
C11	283-0068-00			0.01 μF	Cer	500 V	
C12	281-0099-00			1.3-5.4 pF, Var	Air		
C14	283-0119-00			2200 pF	Cer	200 V	5%
C15	283-0068-00	20000	27999	0.01 μF	Cer	500 V	
C15	283-0059-00	28000		1 μF	Cer	25 V	+80%—20%
C22	283-0081-00	20000	24999	0.1 μF	Cer	25 V	+80%—20%
C22	283-0059-00	25000	27999	1 μF	Cer	25 V	+80%—20%
C22	283-0111-00	28000		0.1 μF	Cer	50 V	
C28	283-0068-00			0.01 μF	Cer	500 V	
C40	281-0611-00			2.7 pF	Cer	200 V	±0.25 pF
C41	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C54	283-0113-00			56 pF	Cer	500 V	1%
C60	290-0267-00			1 μF	Elect.	35 V	
C75	281-0523-00			100 pF	Cer	350 V	

[1]Added if necessary.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors *(cont)*			
C84	283-0068-00			0.01 μF	Cer	500 V	
C94	283-0068-00			0.01 μF	Cer	500 V	
C98	290-0246-00			3.3 μF	Elect.	15 V	10%
C99	290-0134-00			22 μF	Elect.	15 V	
C101	*285-0672-00			0.1 μF	MT	600 V	+5%—15%
C103B	281-0099-00			1.3-5.4 pF, Var	Air		
C103C	281-0102-00			1.7-11 pF, Var	Air		
C103D	281-0572-00			6.8 pF	Cer	500 V	±0.5 pF
C104B	281-0102-00			1.7-11 pF, Var	Air		
C104C	281-0102-00			1.7-11 pF, Var	Air		
C105A	281-0501-00			4.7 pF	Cer	500 V	±1 pF
C105B	281-0102-00			1.7-11 pF, Var	Air		
C105C	281-0099-00			1.3-5.4 pF, Var	Air		
C105E	281-0509-00			15 pF	Cer	500 V	10%
C106A	281-0504-00			10 pF	Cer	500 V	10%
C106B	281-0102-00			1.7-11 pF, Var	Air		
C106C	281-0099-00			1.3-5.4 pF, Var	Air		
C106E	283-0606-00			250 pF	Mica	500 V	10%
C110[2]	281-0529-00	X20079		1.5 pF (nominal value) Selected			
C111	283-0068-00			0.01 μF	Cer	500 V	
C112	281-0099-00			1.3-5.4 pF, Var	Air		
C114	283-0119-00			2200 pF	Cer	200 V	5%
C122	283-0081-00	20000	24999	0.1 μF	Cer	25 V	+80%—20%
C122	283-0059-00	25000	27999	1 μF	Cer	25 V	+80%—20%
C122	283-0111-00	28000		0.1 μF	Cer	50 V	
C125	283-0068-00			0.01 μF	Cer	500 V	
C126	290-0134-00			22 μF	Elect.	15 V	
C136	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C140	281-0611-00			2.7 pF	Cer	200 V	±0.25 pF
C141	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C143	281-0508-00			12 pF	Cer	500 V	
C151	290-0138-00			330 μF	Elect.	6 V	
C160	290-0267-00			1 μF	Elect.	35 V	
C175	281-0523-00			100 pF	Cer	350 V	
C184	283-0068-00			0.01 μF	Cer	500 V	
C194	283-0068-00			0.01 μF	Cer	500 V	
C199	290-0134-00			22 μF	Elect.	15 V	
C201	281-0626-00			3.3 pF	Cer	500 V	5%
C217	281-0077-00			1.3-5.4 pF, Var	Air		
C227	281-0503-00	20000	24999	8 pF	Cer	500 V	±0.5 pF
C227	281-0501-00	25000	27999	4.7 pF	Cer	500 V	±1 pF
C227	281-0592-00	28000		4.7 pF (nominal value) Selected			
C228	281-0505-00	20000	24999	12 pF	Cer	500 V	10%
C228	281-0541-00	25000		6.8 pF	Cer	500 V	10%
C235	281-0626-00			3.3 pF	Cer	500 V	5%
C237	281-0078-00			1.4-7.3 pF, Var	Air		
C239	281-0504-00	20000	24999	10 pF	Cer	500 V	10%
C239	281-0505-00	25000		12 pF	Cer	500 V	10%

[2]Added if necessary.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors *(cont)*			
C242	281-0503-00			8 pF	Cer	500 V	±0.5 pF
C252	281-0503-00			8 pF	Cer	500 V	±0.5 pF
C254	283-0068-00			0.01 μF	Cer	500 V	
C257	283-0068-00			0.01 μF	Cer	500 V	
C261	281-0525-00			470 pF	Cer	500 V	
C266	281-0518-00			47 pF	Cer	500 V	
C267	285-0598-00			0.01 μF	PTM	100 V	5%
C269	283-0028-00			0.0022 μF	Cer	50 V	
C276	281-0518-00			47 pF	Cer	500 V	
C279	283-0028-00			0.0022 μF	Cer	50 V	
C299	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C302	281-0077-00			1.3-5.4 pF, Var	Air		
C305	283-0599-00			98 pF	Mica	600 V	5%
C306	*285-0610-00			0.1 μF	MT	600 V	10%
C308	281-0536-00			0.001 μF	Cer	500 V	10%
C309	283-0059-00			1 μF	Cer	25 V	+80%—20%
C325	283-0068-00			0.01 μF	Cer	500 V	
C332	281-0632-00			35 pF	Cer	500 V	1%
C333	281-0632-00			35 pF	Cer	500 V	1%
C342	283-0068-00			0.01 μF	Cer	500 V	
C343	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C353	281-0064-00			0.25-1.5 pF, Var	Tub.		
C356	283-0068-00			0.01 μF	Cer	500 V	
C364	283-0068-00			0.01 μF	Cer	500 V	
C365	283-0068-00			0.01 μF	Cer	500 V	
C377	281-0523-00			100 pF	Cer	350 V	
C382	290-0267-00			1 μF	Elect.	35 V	
C384	290-0267-00			1 μF	Elect.	35 V	
C386	290-0267-00			1 μF	Elect.	35 V	
C400	290-0415-00			5.6 μF	Elect.	35 V	10%
C401	283-0624-00			1300 pF	Mica	500 V	2%
C405	281-0546-00			330 pF	Cer	500 V	10%
C418	281-0504-00			10 pF	Cer	500 V	10%
C427	283-0068-00			0.01 μF	Cer	500 V	
C434	283-0081-00			0.1 μF	Cer	25 V	+80%—20%
C440A	281-0012-00			7-45 pF, Var	Cer		
C440B	285-0006-00			68 pF	Glass	500 V	5%
C440C	*295-0079-00			0.001 μF	Checked assembly		
C440D	*295-0079-00			0.01 μF	Checked assembly		
C440E	*295-0079-00			0.1 μF	Checked assembly		
C440F	*295-0079-00			1 μF	Checked assembly		
C440H	283-0068-00			0.01 μF	Cer	500 V	
C440T	281-0523-00			100 pF	Cer	350 V	
C471	281-0620-00			21 pF	Cer	500 V	1%
C474	283-0068-00			0.01 μF	Cer	500 V	
C477	281-0630-00			390 pF	Cer	500 V	5%

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Capacitors *(cont)*			
C511	281-0076-00			1.2-3.5 pF, Var	Air		
C514	283-0068-00			0.01 μF	Cer	500 V	
C527	281-0064-00			0.25-1.5 pF, Var	Tub.		
C531	290-0134-00			22 μF	Elect.	15 V	
C537	281-0092-00			9-35 pF, Var	Cer		
C540	281-0504-00			10 pF	Cer	500 V	10%
C556	281-0543-00	20000	21939	270 pF	Cer	500 V	10%
C556	283-0598-00	21940		253 pF	Mica	300 V	5%
C561	281-0513-00	20000	21939X	27 pF	Cer	500 V	
C569	290-0167-00			10 μF	Elect.	15 V	
C711	290-0267-00			1 μF	Elect.	35 V	
C712	290-0187-00			4.7 μF	Elect.	35 V	
C714	281-0523-00			100 pF	Cer	350 V	
C718	283-0000-00			0.001 μF	Cer	500 V	
C723	290-0267-00			1 μF	Elect.	35 V	
C727	290-0267-00			1 μF	Elect.	35 V	
C733	281-0546-00	X28000		330 pF	Cer	500 V	10%
C734	283-0067-00	X28000		0.001 μF	Cer	200 V	10%
C735	283-0068-00	20000	27999X	0.01 μF	Cer	500 V	
C736	283-0068-00			0.01 μF	Cer	500 V	
C737	283-0068-00	20000	27999X	0.01 μF	Cer	500 V	
C739	290-0188-00	20000	27999X	0.1 μF	Elect.	35 V	10%
C741	283-0068-00			0.01 μF	Cer	500 V	
C743	283-0068-00			0.01 μF	Cer	500 V	
C760	285-0622-00			0.1 μF	PTM	100 V	
C780	283-0129-00			0.56 μF	Cer	100 V	
C810	283-0105-00			0.01 μF	Cer	2000 V	
C811	283-0105-00			0.01 μF	Cer	2000 V	
C812	283-0105-00			0.01 μF	Cer	2000 V	
C813	283-0105-00			0.01 μF	Cer	2000 V	
C814	283-0105-00			0.01 μF	Cer	2000 V	
C815	283-0105-00			0.01 μF	Cer	2000 V	
C816	283-0105-00			0.01 μF	Cer	2000 V	
C820	283-0105-00			0.01 μF	Cer	2000 V	
C821	*283-0112-00			0.01 μF	Cer	2000 V	
C822	*283-0112-00			0.01 μF	Cer	2000 V	
C823	*283-0112-00			0.01 μF	Cer	2000 V	
C828	283-0105-00			0.01 μF	Cer	2000 V	
C829	290-0117-00			50 μF	Elect.	50V	+75%—10%
C839	283-0008-00			0.1 μF	Cer	500 V	
C841	283-0068-00			0.01 μF	Cer	500 V	
C843	283-0068-00			0.01 μF	Cer	500 V	
C846	283-0105-00			0.01 μF	Cer	2000 V	
C848	283-0105-00			0.01 μF	Cer	2000 V	
C849	290-0248-01			150 μF	Elect.	15 V	
C861	283-0068-00			0.01 μF	Cer	500 V	
C865	283-0068-00			0.01 μF	Cer	500 V	

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Semiconductor Device, Diodes	
D14	*152-0323-00			Silicon	Tek Spec
D15	*152-0323-00			Silicon	Tek Spec
D30	152-0141-02			Silicon	1N4152
D41	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D78	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D114	*152-0323-00			Silicon	Tek Spec
D115	*152-0323-00			Silicon	Tek Spec
D122	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D130	152-0141-02			Silicon	1N4152
D141	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D154	*152-0185-00			Silicon	Replaceable by 1N4152
D201	152-0333-00			Silicon	High speed and conductance
D202	*152-0075-00			Germanium	Tek Spec
D203	*152-0075-00			Germanium	Tek Spec
D204	152-0333-00			Silicon	High speed and conductance
D205	152-0333-00			Silicon	High speed and conductance
D206	*152-0075-00			Germanium	Tek Spec
D207	*152-0075-00			Germanium	Tek Spec
D208	152-0333-00			Silicon	High speed and conductance
D210	*152-0185-00			Silicon	Replaceable by 1N4152
D211	*152-0185-00			Silicon	Replaceable by 1N4152
D213	*152-0185-00			Silicon	Replaceable by 1N4152
D214	*152-0185-00			Silicon	Replaceable by 1N4152
D264	*152-0185-00			Silicon	Replaceable by 1N4152
D274	*152-0185-00			Silicon	Replaceable by 1N4152
D281	*152-0185-00			Silicon	Replaceable by 1N4152
D282	*152-0185-00			Silicon	Replaceable by 1N4152
D320	*152-0323-00			Silicon	Tek Spec
D321	*152-0323-00			Silicon	Tek Spec
D325	152-0278-00			Zener	1N4372A 400 mW, 3 V, 5%
D331	152-0141-02			Silicon	1N4152
D332	*152-0075-00			Germanium	Tek Spec
D333	*152-0075-00			Germanium	Tek Spec
D334	152-0141-02			Silicon	1N4152
D344	*152-0185-00			Silicon	Replaceable by 1N4152
D346	152-0141-02			Silicon	1N4152
D363	*152-0185-00			Silicon	Replaceable by 1N4152
D364	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D375	152-0182-00			Tunnel	1N3719 10 mA, 2.5%
D401	152-0141-02			Silicon	1N4152
D402	152-0141-02			Silicon	1N4152
D403	*152-0185-00			Silicon	Replaceable by 1N4152
D404	*152-0185-00			Silicon	Replaceable by 1N4152
D405	152-0081-00	20000	21353	Tunnel	1N3714 2.2 mA, 10%
D405	152-0402-00	21354		Tunnel	2.2 mA (Note diode polarity)
D407	*152-0075-00			Germanium	Tek Spec

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Semiconductor Device, Diodes *(cont)*	
D408	152-0141-02			Silicon	1N4152
D430	152-0333-00			Silicon	High speed and conductance
D438	*152-0185-00			Silicon	Replaceable by 1N4152
D439	*152-0249-00			Silicon	Assembly
D455	152-0181-00			Tunnel	1N3713 1 mA, 2.5%
D474	152-0166-00			Zener	1N753A 400 mW, 6.2 V, 5%
D476	*152-0185-00			Silicon	Replaceable by 1N4152
D479	152-0333-00			Silicon	High speed and conductance
D512	*152-0185-00			Silicon	Repalceable by 1N4152
D513	*152-0185-00			Silicon	Replaceable by 1N4152
D524	*152-0233-00	20000	21141	Silicon	Tek Spec
D524	*152-0322-00	21142		Silicon	Tek Spec
D541	152-0149-00			Zener	1N961B 400 mW, 10 V, 5%
D714	152-0281-00			Zener	1N969B 400 mW, 22 V, 5%
D718	*152-0185-00			Silicon	Replaceable by 1N4152
D730	152-0461-00	X28000		Zener	1N821 6.2 V, 5%
D734	*152-0185-00	X28000		Silicon	Reeplaceable by 1N4152
D735	152-0333-00	20000	27999X	Silicon	High speed and conductance
D736	152-0285-00	X28000		Zener	1N980B 400 mW, 6.2 V, 5%
D739	152-0166-00	20000	27999X	Zener	1N753A 400 mW, 6.2 V, 5%
D760	*152-0185-00			Silicon	Replaceable by 1N4152
D770	*152-0185-00			Silicon	Replaceable by 1N4152
D780	*152-0185-00			Silicon	Replaceable by 1N4152
D782	*152-0185-00			Silicon	Replaceable by 1N4152
D810	152-0170-00			Silicon	1N4441
D811	152-0170-00			Silicon	1N4441
D812	152-0170-00			Silicon	1N4441
D813	152-0170-00			Silicon	1N4441
D814	152-0170-00			Silicon	1N4441
D815	152-0170-00			Silicon	1N4441
D816	152-0170-00			Silicon	1N4441
D821	152-0170-00			Silicon	1N4441
D822	152-0170-00			Silicon	1N4441
D823	152-0170-00			Silicon	1N4441
D839	152-0255-00			Zener	400 mW, 51 V, 5%
D841	152-0283-00			Zener	1N976B 400 mW, 43 V, 5%
D849 A, B, C, D	*152-0260-00			Silicon	Assembly, Tek Spec
D864	*152-0185-00			Silicon	Replaceable by 1N4152
D865	152-0333-00			Silicon	High speed and conductance
D866	*152-0185-00			Silicon	Replaceable by 1N4152
D867	*152-0185-00			Silicon	Replaceable by 1N4152
				Connectors	
J1	131-0352-00			Coaxial, 1 contact, BNC	
J101	131-0352-00			Coaxial, 1 contact, BNC	
J301	131-0352-00			Coaxial, 1 contact, BNC	
J475	131-0352-00			Coaxial, 1 contact, BNC	
J479	131-0352-00			Coaxial, 1 contact, BNC	
P701	131-0345-00			24 pin, male	

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Inductors	
L1	276-0541-00			Core, Ferrite	
L15	*120-0407-00			Toroid, 5 turns single	
L101	276-0541-00			Core, Ferrite	
L125	*120-0407-00			Toroid, 5 turns single	
L240	*119-0037-01	20000	24999	Delay Line Assembly	
L240	*119-0209-00	25000		Delay Line Assembly	
L245	*114-0284-00			10-22 μH, Var	Core 276-0506-00
L255	*114-0285-00			10-22 μH, Var	Core 276-0506-00
L363	276-0576-00	X25000		Core, Toroid Ferrite	
L373	*108-0509-00			2.5 μH	
L423	*108-0474-00			2 μH	
L535	276-0507-00			Core, Ferramic Suppressor	
L856	*108-0350-00			Coil, Y Axis Alignment	
L859	*108-0320-01			Trace Rotation	
				Transistors	
Q14A	151-1011-00			Silicon	Dual, FET
Q14B	151-1011-00			Silicon	Dual, FET
Q23	151-0220-00			Silicon	2N4122
Q34	151-0223-00			Silicon	2N4275
Q44	151-0220-00			Silicon	2N4122
Q53	151-0223-00			Silicon	2N4275
Q64	151-0224-00			Silicon	2N3692
Q74	151-0224-00			Silicon	2N3692
Q84	151-0223-00			Silicon	2N4275
Q94	151-0223-00			Silicon	2N4275
Q114A	151-1011-00			Silicon	Dual, FET
Q114B	151-1011-00			Silicon	Dual, FET
Q123	151-0220-00			Silicon	2N4122
Q134	151-0232-00			Silicon	2N4275
Q144	151-0220-00			Silicon	2N4122
Q154	151-0220-00			Silicon	2N4122
Q164	151-0224-00			Silicon	2N3692
Q174	151-0224-00			Silicon	2N3692
Q184	151-0223-00			Silicon	2N4275
Q194	151-0223-00			Silicon	2N4275
Q224	*151-0127-00			Silicon	Selected from 2N2369
Q234	*151-0127-00			Silicon	Selected from 2N2369
Q244	*151-0121-00			Silicon	Selected from 2N3118
Q254	*151-0121-00			Silicon	Selected from 2N3118
Q264	151-0223-00			Silicon	2N4275

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Transistors *(cont)*	
Q265	151-0220-00			Silicon	2N4122
Q275	151-0220-00			Silicon	2N4122
Q283	151-0220-00			Silicon	2N4122
Q294	151-0223-00			Silicon	2N4275
Q323	151-0220-00			Silicon	2N4122
Q324	151-0223-00			Silicon	2N4275
Q345	151-0223-00			Silicon	2N4275
Q347	151-0224-00			Silicon	2N3692
Q364	151-0223-00			Silicon	2N4275
Q400	151-0224-00			Silicon	2N3692
Q414	151-0223-00			Silicon	2N4275
Q424	151-0220-00			Silicon	2N4122
Q429	151-0224-00			Silicon	2N3692
Q434	151-0220-00			Silicon	2N4122
Q441	*151-0103-00			Silicon	Replaceable by 2N2219
Q443	151-1015-00			Silicon	FET
Q464	151-0223-00			Silicon	2N4275
Q473	151-0220-00			Silicon	2N4122
Q513	151-0223-00			Silicon	2N4275
Q524	151-0220-00			Silicon	2N4122
Q543	151-0220-00			Silicon	2N4122
Q544	*151-0124-00			Silicon	Selected from 2N3119
Q554	*151-0124-00			Silicon	Selected from 2N3119
Q560	151-0224-00			Silicon	2N3692
Q714	151-0224-00			Silicon	2N3692
Q717	*151-0103-00			Silicon	Replaceable by 2N2219
Q734	*151-0136-00	20000	27999	Silicon	Replaceable by 2N3053
Q734	151-0220-00	28000		Silicon	2N4122
Q735	151-0224-00	X28000		Silicon	2N3692
Q736	151-1005-00	X28000		Silicon	FET
Q737	151-0208-00			Silicon	2N4036
Q765	151-0220-00			Silicon	2N4122
Q775	151-0220-00			Silicon	2N4122
Q863	*151-0103-00			Silicon	Replaceable by 2N2219
Q864	*151-0121-00			Silicon	Selected from 2N3118

Resistors

Resistors are fixed, composition, ±10% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Description			
R3C	322-0610-01			500 kΩ	¼ W	Prec	½%
R3E	322-0481-01			1 MΩ	¼ W	Prec	½%
R4C	322-0469-01			750 kΩ	¼ W	Prec	½%
R4E	321-0628-01			333 kΩ	⅛ W	Prec	½%
R5C	322-0621-01			900 kΩ	¼ W	Prec	½%

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INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R5E	321-1389-01			111 kΩ	1/8 W	Prec	1/2%
R6C	322-0624-01			990 kΩ	1/4 W	Prec	1/2%
R6E	321-1289-01			10.1 kΩ	1/8 W	Prec	1/2%
R9	315-0820-00			82 Ω	1/4 W		5%
R10	322-0481-01			1 MΩ	1/4 W	Prec	1/2%
R11	315-0364-00			360 kΩ	1/4 W		5%
R12	315-0101-00			100 Ω	1/4 W		5%
R13	315-0101-00			100 Ω	1/4 W		5%
R14	321-0164-00			499 Ω	1/8 W	Prec	1%
R20	321-0330-00			26.7 kΩ	1/8 W	Prec	1%
R21	311-0328-00			1 kΩ, Var			
R23	315-0474-00	20000	24999	470 kΩ	1/4 W		5%
R23	315-0103-00	25000	27999	10 kΩ	1/4 W		5%
R23	315-0474-00	28000		470 kΩ	1/4 W		5%
R24	321-0165-00			511 Ω	1/8 W	Prec	1%
R25	321-0339-00			33.2 kΩ	1/8 W	Prec	1%
R27	315-0274-00			270 kΩ	1/4 W		5%
R28	315-0201-00			200 Ω	1/4 W		5%
R29	315-0302-00			3 kΩ	1/4 W		5%
R30	321-0107-01			127 Ω	1/8 W	Prec	1/2%
R32	321-0148-01			340 Ω	1/8 W	Prec	1/2%
R34	321-0182-00			768 Ω	1/8 W	Prec	1%
R35	311-0827-00	20000	27999	250 Ω, Var			
R35	311-0827-01	28000	30639	250 Ω, Var			
R35	311-0827-00	30640		250 Ω, Var			
R39	321-0165-01			511 Ω	1/8 W	Prec	1/2%
R41	315-0102-00			1 kΩ	1/4 W		5%
R44	322-0170-00			576 Ω	1/4 W	Prec	1%
R45	315-0151-00			150 Ω	1/4 W		5%
R51	315-0221-00			220 Ω	1/4 W		5%
R53	315-0182-00			1.8 kΩ	1/4 W		5%
R54	321-0273-00			6.81 kΩ	1/8 W	Prec	1%
R56	321-0300-00			13 kΩ	1/8 W	Prec	1%
R57	311-0836-00	20000	27999	5 kΩ, Var			
R57	311-0836-01	28000	30639	5 kΩ, Var			
R57	311-0836-00	30640		5 kΩ, Var			
R59	315-0101-00			100 Ω	1/4 W		5%
R60	311-0545-00			2 x 1 kΩ, Var			
R61	321-0183-00			787 Ω	1/8 W	Prec	1%
R62	321-0121-00			178 Ω	1/8 W	Prec	1%
R63	315-0331-00			330 Ω	1/4 W		5%
R64	321-0150-00			357 Ω	1/8 W	Prec	1%
R65	315-0622-00			6.2 kΩ	1/4 W		5%
R73	315-0331-00			330 Ω	1/4 W		5%
R74	321-0151-00			365 Ω	1/8 W	Prec	1%
R75	315-0432-00			4.3 kΩ	1/4 W		5%
R77	321-0167-00			536 Ω	1/8 W	Prec	1%
R78	321-0143-00			340 Ω	1/8 W	Prec	1%
R79	315-0431-00			430 Ω	1/4 W		5%
R80	311-0169-00			100 Ω, Var			
R81	315-0101-00	20000	25129	100 Ω	1/4 W		5%
R81	315-0221-00	25130		220 Ω	1/4 W		5%

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R83	321-0085-00			75 Ω	⅛ W	Prec	½%
R84	315-0271-00			270 Ω	¼ W		5%
R85	315-0470-00			47 Ω	¼ W		5%
R90[3]	311-0385-01	20000	25129	250 Ω, Var			
R90[3]	311-0385-02	25130		250 Ω, Var			
R91	315-0102-00	20000	25129X	1 kΩ	¼ W		5%
R94	315-0271-00			270 Ω	¼ W		5%
R95	315-0470-00			47 Ω	¼ W		5%
R98	315-0330-00			33 Ω	¼ W		5%
R99	307-0104-00			3.3 Ω	¼ W		5%
R103C	322-0610-01			500 kΩ	¼ W	Prec	½%
R103E	322-0481-01			1 MΩ	¼ W	Prec	½%
R104C	322-0469-01			750 kΩ	¼ W	Prec	½%
R104E	321-0628-01			333 kΩ	⅛ W	Prec	½%
R105C	322-0621-01			900 kΩ	¼ W	Prec	½%
R105E	321-1389-01			111 kΩ	⅛ W	Prec	½%
R106C	322-0624-01			990 kΩ	¼ W	Prec	½%
R106E	321-1289-01			10.1 kΩ	⅛ W	Prec	½%
R109	315-0820-00			82 Ω	¼ W		5%
R110	322-0481-01			1 MΩ	¼ W	Prec	½%
R111	315-0364-00			360 kΩ	¼ W		5%
R112	315-0101-00			100 kΩ	¼ W		5%
R113	315-0101-00			100 kΩ	¼ W		5%
R114	321-0164-00			499 Ω	⅛ W	Prec	1%
R120	321-0304-00			14.3 kΩ	⅛ W	Prec	1%
R121	311-0328-00			1 kΩ, Var			
R122	321-0178-00			698 Ω	⅛ W	Prec	1%
R123	315-0474-00	20000	24999	470 kΩ	¼ W		5%
R123	315-0103-00	25000	27999	10 kΩ	¼ W		5%
R123	315-0474-00	28000		470 kΩ	¼ W		5%
R124	321-0165-00			511 Ω	⅛ W	Prec	1%
R125	321-0307-00			15.4 kΩ	⅛ W	Prec	1%
R126	307-0106-00			4.7 Ω	¼ W		5%
R127	315-0274-00			270 kΩ	¼ W		5%
R128	315-0201-00			200 Ω	¼ W		5%
R129	315-0302-00			3 kΩ	¼ W		5%
R130	321-0107-01			127 Ω	⅛ W	Prec	½%
R132	321-0148-01			340 Ω	⅛ W	Prec	½%
R134	321-0182-00			768 Ω	⅛ W	Prec	1%
R135	311-0827-00	20000	27999	250 Ω, Var			
R135	311-0827-01	28000	30639	250 Ω, Var			
R135	311-0827-00	30640		250 Ω, Var			
R139	321-0165-01			511 Ω	⅛ W	Prec	1%
R141	315-0102-00			1 kΩ	¼ W		5%
R143	315-0221-00			220 Ω	¼ W		5%

[3]Furnished as a unit with SW741.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R144	322-0170-00			576 Ω	¼ W	Prec	1%
R145	315-0151-00			150 Ω	¼ W		5%
R151	321-0136-00			255 Ω	⅛ W	Prec	1%
R152	321-0283-00	20000	29773	8.66 kΩ	⅛ W	Prec	1%
R152	321-0282-00	29774		8.45 kΩ	⅛ W	Prec	1%
R153	321-0237-00	20000	29773	108 Ω	⅛ W	Prec	1%
R153	321-0236-00	29774		2.8 kΩ	⅛ W	Prec	1%
R154	315-0202-00			2 kΩ	¼ W		5%
R156	321-0121-00			178 Ω	⅛ W	Prec	1%
R160	311-0545-00			2 x 1 kΩ, Var			
R161	321-0183-00			787 Ω	⅛ W	Prec	1%
R162	321-0121-00			178 Ω	⅛ W	Prec	1%
R163	315-0331-00			330 Ω	¼ W		5%
R164	321-0150-00			357 Ω	⅛ W	Prec	1%
R165	315-0622-00			6.2 kΩ	¼ W		5%
R172	315-0331-00			330 Ω	¼ W		5%
R174	321-0151-00			365 Ω	⅛ W	Prec	1%
R175	315-0432-00			4.3 kΩ	¼ W		5%
R180	311-0169-00			100 Ω, Var			
R181	315-0101-00	20000	25129	100 Ω	¼ W		5%
R181	315-0221-00	25130		220 Ω	¼ W		5%
R183	321-0085-00			75 Ω	⅛ W	Prec	1%
R184	315-0271-00			270 Ω	¼ W		5%
R185	315-0470-00			47 Ω	¼ W		5%
R190[4]	311-0385-01	20000	25129	250 Ω, Var			
R190[4]	311-0385-02	25130		250 Ω, Var			
R191	315-0102-00	20000	25129X	1 kΩ	¼ W		5%
R194	315-0271-00			270 Ω	¼ W		5%
R195	315-0470-00			47 Ω	¼ W		5%
R199	307-0104-00			3.3 Ω	¼ W		5%
R210	321-0217-00			1.78 kΩ	⅛ W	Prec	1%
R211	321-0217-00			1.78 kΩ	⅛ W	Prec	1%
R213	321-0229-00			2.37 kΩ	⅛ W	Prec	1%
R214	321-0229-00			2.37 kΩ	⅛ W	Prec	1%
R215	311-0462-00			1 kΩ, Var			
R217	321-0369-00			68.1 kΩ	⅛ W	Prec	1%
R218	315-0102-00			1 kΩ	¼ W		5%
R219	315-0185-00			1.8 MΩ	¼ W		5%
R221	321-0159-00			442 Ω	⅛ W	Prec	1%
R222	323-0154-00			392 Ω	½ W	Prec	1%
R224	321-0161-00			464 Ω	⅛ W	Prec	1%
R226	321-0094-00			93.1 Ω	⅛ W	Prec	1%
R227	315-0912-00	20000	24999	9.1 kΩ	¼ W		5%
R227	315-0273-00	25000		27 kΩ	¼ W		5%
R228	315-0243-00	20000	24999	24 kΩ	¼ W		5%
R228	315-0822-00	25000		8.2 kΩ	⅛ W		5%

[4]Furnished as a unit with SW743.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R231	321-0159-00			442 Ω	1/8 W	Prec	1%
R234	321-0161-00			464 Ω	1/8 W	Prec	1%
R235	315-0102-00			1 kΩ	1/4 W		5%
R236	321-0094-00			93.1 Ω	1/8 W	Prec	1%
R237	311-0463-00			5 kΩ, Var			
R239	315-0221-00			220 Ω	1/4 W		5%
R241	321-0194-00			1.02 kΩ	1/8 W	Prec	1%
R242	321-0097-00	20000	24999	100 Ω	1/8 W	Prec	1%
R242	321-0091-00	25000		86.6 Ω	1/8 W	Prec	1%
R244	323-0186-00			845 Ω	1/2 W	Prec	1%
R245	323-0186-00			845 Ω	1/2 W	Prec	1%
R248	321-0189-00			909 Ω	1/8 W	Prec	1%
R249	321-0208-00			1.43 kΩ	1/8 W	Prec	1%
R251	321-0194-00			1.02 kΩ	1/8 W	Prec	1%
R252	321-0097-00	20000	24999	100 Ω	1/8 W	Prec	1%
R252	321-0091-00	25000		86.6 Ω	1/8 W	Prec	1%
R254	323-0186-00			845 Ω	1/2 W	Prec	1%
R255	323-0186-00			845 Ω	1/2 W	Prec	1%
R260	301-0361-00			360 Ω	1/2 W		5%
R261	315-0102-00			1 kΩ	1/4 W		5%
R262	315-0222-00			2.2 kΩ	1/4 W		5%
R263	301-0431-00			430 Ω	1/2 W		5%
R264	315-0681-00			680 Ω	1/4 W		5%
R265	315-0272-00			2.7 kΩ	1/4 W		5%
R267	315-0472-00			4.7 kΩ	1/4 W		5%
R269	315-0222-00			2.2 kΩ	1/4 W		5%
R273	301-0431-00			430 Ω	1/2 W		5%
R274	315-0681-00			680 Ω	1/4 W		5%
R275	315-0272-00			2.7 kΩ	1/4 W		5%
R277	315-0472-00			4.7 kΩ	1/4 W		5%
R279	315-0222-00			2.2 kΩ	1/4 W		5%
R281	315-0152-00			1.5 kΩ	1/4 W		5%
R282	315-0152-00			1.5 kΩ	1/4 W		5%
R284	315-0271-00			270 Ω	1/4 W		5%
R291	315-0223-00			22 kΩ	1/4 W		5%
R294	315-0122-00			1.2 kΩ	1/4 W		5%
R295	315-0471-00			470 Ω	1/4 W		5%
R299	315-0330-00			33 Ω	1/4 W		5%
R302	321-0385-00			100 kΩ	1/8 W	Prec	1%
R321	315-0151-00			150 Ω	1/4 W		5%
R323	315-0562-00			5.6 kΩ	1/4 W		5%
R324	315-0122-00			1.2 kΩ	1/4 W		5%
R331	315-0103-00			10 kΩ	1/4 W		5%
R332	321-0289-00			10 kΩ	1/8 W	Prec	1%
R333	321-0289-00			10 kΩ	1/8 W	Prec	1%
R334	315-0103-00			10 kΩ	1/4 W		5%
R340	315-0113-00			11 kΩ	1/4 W		5%

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R341	315-0201-00			200 Ω	¼ W		5%
R342	315-0301-00			300 Ω	¼ W		5%
R343	315-0103-00			10 kΩ	¼ W		5%
R344	315-0513-00			51 kΩ	¼ W		5%
R346	315-0123-00			12 kΩ	¼ W		5%
R348	315-0133-00			13 kΩ	¼ W		5%
R352	315-0622-00			6.2 kΩ	¼ W		5%
R353	321-0414-00			200 kΩ	⅛ W	Prec	1%
R355A[5] } R355B }	311-0844-00			100 kΩ 5 kΩ, Var			
R356	315-0103-00			10 kΩ	¼ W		5%
R357	321-0387-00			105 kΩ	⅛ W	Prec	1%
R363	315-0132-00			1.3 kΩ	¼ W		5%
R364	315-0621-00			620 Ω	¼ W		5%
R372	321-0154-00			392 Ω	⅛ W	Prec	1%
R373	315-0390-00			39 Ω	¼ W		5%
R374	321-0194-00			1.02 kΩ	⅛ W	Prec	1%
R378	315-0431-00			430 Ω	¼ W		5%
R382	307-0104-00			3.3 Ω	¼ W		5%
R384	307-0106-00			4.7 Ω	¼ W		5%
R386	307-0104-00			3.3 Ω	¼ W		5%
R400	315-0470-00			47 Ω	¼ W		5%
R401	315-0151-00			150 Ω	¼ W		5%
R402	321-0309-00			16.2 kΩ	⅛ W	Prec	1%
R403	315-0302-00			3 kΩ	¼ W		5%
R404	315-0104-00			100 kΩ	¼W		5%
R405	315-0271-00			270 Ω	¼ W		5%
R406	321-1249-00			3.88 kΩ	⅛ W	Prec	1%
R407	321-0351-00			44.2 kΩ	⅛ W	Prec	1%
R408	315-0512-00			5.1 kΩ	¼ W		5%
R414	315-0431-00			430 Ω	¼ W		5%
R415	321-0206-00			1.37 kΩ	⅛ W	Prec	1%
R423	315-0100-00			10 Ω	¼ W		5%
R424	321-0297-00			12.1 kΩ	⅛ W	Prec	1%
R427	315-0332-00			3.3 kΩ	¼ W		5%
R428	321-0278-00			7.68 kΩ	⅛ W	Prec	1%
R429	321-0303-00			14 kΩ	⅛ W	Prec	1%
R433	315-0103-00			10 kΩ	¼ W		5%
R434	315-0912-00			9.1 kΩ	¼ W		5%
R437	315-0152-00			1.5 kΩ	¼ W		5%

[5]Furnished as a unit with SW355.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R438	315-0103-00			10 kΩ	¼ W		5%
R440A[6]	311-0468-00			100 kΩ, Var			
R440B	315-0473-00			47 kΩ	¼ W		5%
R440C	323-0401-00			147 kΩ	½ W	Prec	1%
R440D	323-0430-00			294 kΩ	½ W	Prec	1%
R440E	323-0459-00	20000	21349	590 kΩ	½ W	Prec	1%
R440E	323-0773-01	21350		588 kΩ	½ W	Prec	½%
R440F	323-0497-07			1.47 MΩ	½ W	Prec	1/10%
R440G	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440H	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440J	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440K	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440L	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440M	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440N	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440P	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440R	323-0497-00			1.47 MΩ	½ W	Prec	1%
R440T	315-0151-00			150 Ω	¼ W		5%
R442	315-0100-00			10 Ω	¼ W		5%
R443	315-0822-00			8.2 kΩ	¼ W		5%
R444	315-0101-00			100 Ω	¼ W		5%
R447	303-0752-00			7.5 kΩ	1 W		5%
R451	321-0337-00			31.6 kΩ	⅛ W	Prec	1%
R452	321-0322-00			22.1 kΩ	⅛ W	Prec	1%
R454	321-0271-00			6.49 kΩ	⅛ W	Prec	1%
R456	315-0821-00			820 Ω	¼ W		5%
R457	321-0326-00			24.3 kΩ	⅛ W	Prec	1%
R464	321-0255-00			4.42 kΩ	⅛ W	Prec	1%
R470	315-0471-00			470 Ω	¼ W		5%
R471	321-0274-00			69.8 kΩ	⅛ W	Prec	1%
R472	321-0317-00			19.6 kΩ	⅛ W	Prec	1%
R474	315-0751-00			750 Ω	¼ W		5%
R475	315-0471-00			470 Ω	¼ W		5%
R476	315-04710-0			470 Ω	¼ W		5%
R477	321-0154-00			392 Ω	⅛ W	Prec	1%
R478	315-0102-00			1 kΩ	¼ W		5%
R479	315-0162-00			1.6 kΩ	¼ W		5%
R501	315-0304-00			300 kΩ	¼ W		5%
R504	321-0154-00			392 Ω	⅛ W	Prec	1%
R510	321-0243-00			3.32 kΩ	⅛ W	Prec	1%
R511	321-0385-00			100 kΩ	⅛ W	Prec	1%

[6]Furnished as a unit with SW745.

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R512	311-0510-00			10 kΩ, Var			
R513	315-0103-00			10 kΩ	¼ W		5%
R514	315-0100-00			10 Ω	¼ W		5%
R515	315-0473-00			47 kΩ	¼ W		5%
R516	315-0473-00			47 kΩ	¼ W		5%
R524	315-0302-00			3 kΩ	¼ W		5%
R527	321-1399-06			142 kΩ	⅛ W	Prec	¼%
R529	315-0304-00			300 kΩ	¼ W		5%
R530A } R530B }	311-0470-00			2 x 50 kΩ, Var			
R531	315-0621-00			620 Ω	¼ W		5%
R532	317-0106-00	X21940	24999	10 MΩ	⅛ W		5%
R532	317-0685-00	25000		6.8 MΩ (nominal value) Selected			
R533	315-0363-00			36 kΩ	¼ W		5%
R534	315-0104-00			100 kΩ	¼ W		5%
R535	311-0464-00			25 kΩ, Var			
R536	321-0360-00			54.9 kΩ	⅛ W	Prec	1%
R537	321-0651-00			15.8 kΩ	⅛ W	Prec	¼%
R540	315-0243-00			24 kΩ	¼ W		5%
R541	315-0510-00			51 Ω	¼ W		5%
R542	308-0417-00			5.1 Ω	½ W	WW	2%
R543	315-0821-00			820 Ω	¼ W		5%
R544	*310-0669-00	20000	21939	8.5 kΩ	4 W	Prec	1%
R544	*310-0688-00	21940		9.5 kΩ	4 W	Prec	1%
R545	315-0151-00			150 Ω	¼ W		5%
R554	*310-0668-00	20000	21939	12.4 kΩ	4 W	Prec	1%
R554	*310-0689-00	21940		10 kΩ	4 W	Prec	1%
R556	321-0181-00	20000	21939	750 Ω	⅛ W	Prec	1%
R556	*310-0168-00	21940		549 Ω	⅛ W	Prec	1%
R561	321-0208-00	20000	21939X	1.43 kΩ	⅛ W	Prec	1%
R562	321-0148-00	20000	21939	340 Ω	⅛ W	Prec	1%
R562	321-0154-00	21940		392 Ω	⅛ W	Prec	1%
R564	321-0277-00			7.5 kΩ	⅛ W	Prec	1%
R565	321-0256-00			4.53 kΩ	⅛ W	Prec	1%
R569	307-0103-00			2.7 Ω	¼ W		5%
R711	321-0267-00			5.9 kΩ	⅛ W	Prec	1%
R712	321-0301-00			13.3 kΩ	⅛ W	Prec	1%
R714	315-0472-00			4.7 kΩ	¼ W		5%
R715	315-0203-00			20 kΩ	¼ W		5%
R716	315-0153-00			15 kΩ	¼ W		5%
R718	321-0347-00			40.2 kΩ	⅛ W	Prec	1%
R719	321-0331-00			27.4 kΩ	⅛ W	Prec	1%
R725	311-0516-00			150 Ω, Var			
R730	323-0181-00	X28000		750 Ω	½ W	Prec	1%
R731	321-0325-00	X28000		23.7 kΩ	⅛ W	Prec	1%
R732	311-0836-01	X28000	30639	5 kΩ, Var			
R732	311-0836-00	30640		5 kΩ, Var			
R733	315-0182-00	20000	27999	1.8 kΩ	¼ W		5%
R733	321-0436-00	28000		340 kΩ	⅛ W	Prec	1%
R734	315-0432-00	20000	27999	4.3 kΩ	¼ W		5%
R734	315-0103-00	28000		10 kΩ	¼ W		5%
R735	315-0474-00	20000	27999X	470 kΩ	¼ W		5%

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R736	315-0474-00	X28000		470 kΩ	¼ W		5%
R737	315-0102-00	X28000		1 kΩ	¼ W		5%
R738	315-0102-00	20000	27999X	1 kΩ	¼ W		5%
R741	315-0224-00			220 kΩ	¼ W		5%
R742	315-0106-00			10 MΩ	¼ W		5%
R743	315-0224-00			220 kΩ	¼ W		5%
R744	315-0106-00			10 MΩ	¼ W		5%
R745	315-0224-00			220 kΩ	¼ W		5%
R746	315-0106-00			10 MΩ	¼ W		5%
R760	321-0269-00			6.19 kΩ	⅛ W	Prec	1%
R763	315-0912-00			9.1 kΩ	¼ W		5%
R764	315-0562-00			5.6 kΩ	¼ W		5%
R765	321-0326-00			24.3 kΩ	⅛ W	Prec	1%
R770	321-0269-00			6.19 kΩ	⅛ W	Prec	1%
R773	315-0912-00			9.1 kΩ	¼ W		5%
R774	315-0912-00			9.1 kΩ	¼ W		5%
R775	321-0326-00			24.3 kΩ	⅛ W	Prec	1%
R780	311-0510-00			10 kΩ, Var			
R781	321-0372-00			73.2 kΩ	⅛ W	Prec	1%
R786	321-0641-01			1.8 kΩ	⅛ W	Prec	½%
R787	321-0126-01			200 Ω	⅛ W	Prec	½%
R810	303-0105-00			1 MΩ	1 W		5%
R825	305-0564-00			560 kΩ	2 W		5%
R829	315-0363-00			36 kΩ	¼ W		5%
R831	303-0225-00			2.2 MΩ	1 W		5%
R832	303-0225-00			2.2 MΩ	1 W		5%
R833	311-0469-00			1 MΩ, Var			
R834	303-0185-00			1.8 MΩ	1 W		5%
R837	311-0498-00			500 kΩ, Var			
R838	315-0203-00			20 kΩ	¼ W		5%
R839	321-0418-00			221 kΩ	⅛ W	Prec	1%
R841	315-0752-00			7.5 kΩ	¼ W		5%
R843	315-0433-00			43 kΩ	¼ W		5%
R844	315-0183-00			18 kΩ	¼ W		5%
R845	315-0472-00	X25000		4.7 kΩ	¼ W		5%
R846	315-0274-00			270 kΩ	¼ W		5%
R851	311-0112-00			15 kΩ, Var			
R852	315-0622-00			6.2 kΩ	¼ W		5%
R854	311-0110-00			100 kΩ, Var			
R855	311-0467-00			100 kΩ, Var			
R856	311-0579-00			20 kΩ, Var			
R860	315-0152-00			1.5 kΩ	¼ W		5%
R861	315-0100-00			10 Ω	¼ W		5%
R862	315-0301-00			300 Ω	¼ W		5%
R863	323-0268-00			6.04 kΩ	½ W	Prec	1%
R864	315-0101-00			100 Ω	¼ W		5%
R865	315-0562-00			5.6 kΩ	¼ W		5%
R866	315-0150-00			15 Ω	¼ W		5%
R867	321-0226-00			2.21 kΩ	⅛ W	Prec	1%
R868	315-0272-00			2.7 kΩ	¼ W		5%
R869	311-0508-00			50 kΩ, Var			

INDICATOR (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Switches	
	Wired or Unwired				
SW1	260-0665-00	20000	30639	Lever	CH 1 AC GND DC
SW1	260-1168-00	30640		Lever	CH 1 AC GND DC
SW10 Wired	*262-0845-00			Rotary	CH 1 VOLTS/DIV
SW10	260-0661-02			Rotary	CH 1 VOLTS/DIV
SW101	260-0665-00	20000	30639	Lever	CH 2 AC GND DC
SW101	260-1168-00	30640		Lever	CH 2 AC GND DC
SW110 Wired	*262-0845-00			Rotary	CH 2 VOLTS/DIV
SW110	260-0661-02			Rotary	CH 2 VOLTS/DIV
SW150	260-0583-01			Slide	X10 GAIN AC
SW195	260-0583-01			Slide	INVERT
SW260	260-0660-00			Rotary	MODE
SW305	260-0662-00			Lever	TRIGGERING SOURCE
SW310	260-0663-00			Lever	TRIGGERING COUPLING
SW355[7]	311-0844-00				
SW365	260-0664-00			Lever	SLOPE
SW440 Wired	*262-0722-01	20000	21939	Rotary	TIME/DIV
SW440 Wired	*262-0722-02	21940		Rotary	TIME/DIV
SW440	260-0659-01			Rotary	TIME/DIV
SW535	260-0583-01			Slide	X10 MAG
SW741[8]	311-0385-01	20000	25129		CAL (CH 1 VAR VOLTS/DIV)
SW741[8]	311-0385-02	25130			CAL (CH 1 VAR VOLTS/DIV)
SW743[9]	311-0385-01	20000	25129		CAL (CH 2 VAR VOLTS/DIV)
SW743[9]	311-0385-02	25130			CAL (CH 2 VAR VOLTS/DIV)
SW745[10]	311-0468-00				CAL (VAR TIME/DIV)
				Transformers	
T377	*120-0604-00			Toroid, 2 windings	
T401	*120-0380-00			Toroid, 4 turns trifilar	
T801	*120-0378-02			H. V. Power	
				Test Point	
TP364	*214-0579-00			Pin, Test Point	
				Electron Tubes	
V739	154-0370-00	20000	27999X	ZZ1000	
V829	*154-0432-00			GV4, S-1400, checked	
V859	*154-0466-05			T4220-31-1 CRT Standard Phosphor	
				CRT Optional Phosphors	
	*154-0466-07			P2	
	*154-0466-08			P7	
	*154-0466-09			P11	

[7]Furnished as a unit with R355A, B.

[8]Furnished as a unit with R90.

[9]Furnished as a unit with R190.

[10]Furnished as a unit with R440A.

POWER SUPPLY
(*016-0073-00)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Battery			
BT1014	016-0066-02			Battery Pack (contains 20X size "D" Nickel-cadmium cells)			

Values are fixed unless marked Variable.

Capacitors

Tolerance ±20% unless otherwise indicated.

Ckt. No.	Tektronix Part No.	Eff	Disc	Value	Type	Voltage	Tolerance
C1000	283-0022-00			0.02 μF	Cer	1400 V	
C1001	285-0566-00			0.022 μF	PTM	200 V	10%
C1002	290-0259-00			100 μF	Elect.	50 V	
C1003	290-0300-00			1300 μF	Elect.	40 V	+75%—10%
C1004	290-0300-00			1300 μF	Elect.	40 V	+75%—10%
C1010	283-0008-00			0.1 μF	Cer	500 V	
C1011	283-0129-00			0.56 μF	Cer	100 V	
C1012	283-0008-00			0.1 μF	Cer	500 V	
C1041	290-0171-00			100 μF	Elect.	12 V	
C1057	285-0623-00			0.47 μF	PTM	100 V	
C1106	290-0267-00			1 μF	Elect.	35 V	
C1117	290-0134-00			22 μF	Elect.	15 V	
C1120	290-0134-00			22 μF	Elect.	15 V	
C1121	285-0686-00			0.068 μF	PTM	100 V	10%
C1133	290-0272-00			47 μF	Elect.	50 V	
C1170	283-0111-00			0.1 μF	Cer	50 V	
C1171	290-0274-00			80 μF	Elect.	50 V	+75%—10%
C1172	290-0274-00			80 μF	Elect.	50 V	+75%—10%
C1173	283-0008-00			0.1 μF	Cer	500 V	
C1177	283-0013-00			0.01 μF	Cer	1000 V	
C1181	283-0008-00			0.1 μF	Cer	500 V	
C1183	283-0008-00			0.1 μF	Cer	500 V	
C1187	283-0013-00			0.01 μF	Cer	1000 V	
C1195	290-0134-00			22 μF	Elect.	15 V	
C1199	290-0248-01			150 μF	Elect.	15 V	
C1202	290-0272-00			47 μF	Elect.	50 V	
C1203	283-0013-00			0.01 μF	Cer	1000 V	
C1204	290-0273-00			68 μF	Elect.	60 V	10%
C1205	283-0013-00			0.01 μF	Cer	1000 V	
C1210	290-0248-01			150 μF	Elect.	15 V	
C1211	290-0248-01			150 μF	Elect.	15 V	
C1212	290-0248-01			150 μF	Elect.	15 V	
C1213	290-0266-00			290 μF	Elect.	15 V	
C1214	290-0248-01			150 μF	Elect.	15 V	
C1216	290-0248-01			150 μF	Elect.	15 V	
C1217	290-0248-01			150 μF	Elect.	15 V	
C1218	290-0248-01			150 μF	Elect.	15 V	
C1219	290-0266-00			290 μF	Elect.	15 V	
C1224	290-0270-00			8.2 μF	Elect.	60 V	
C1225	290-0271-00			9 μF	Elect.	125 V	+20%—15%

©

POWER SUPPLY (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description		
				Capacitors *(cont)*		
C1226	283-0013-00			0.01 μF	Cer	1000 V
C1231	283-0008-00			0.1 μF	Cer	500 V
C1232	290-0187-00			4.7 μF	Elect.	35 V
C1233	290-0187-00			4.7 μF	Elect.	35 V
C1242	283-0008-00			0.1 μF	Cer	500 V
C1245	290-0323-00			270 μF	Elect.	15 V
C1246	290-0323-00			270 μF	Elect.	15 V
				Semiconductor Device, Diodes		
D1002	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1003	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1004	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1005	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1014	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1016	152-0198-00			Silicon	MR 1032A 200 V PIV, 3A	
D1022	152-0127-00			Silicon	1N7552 400 mW, 7.5 V 5%	
D1041	152-0055-00			Zener	1N962A 400 mW, 11 V 5%	
D1042	*152-0061-00			Silicon	Tek Spec	
D1054	*152-0061-00			Silicon	Tek Spec	
D1055	*152-0061-00			Silicon	Tek Spec	
D1057	*152-0061-00			Silicon	Tek Spec	
D1104	*152-0061-00			Silicon	Tek Spec	
D1105	*152-0061-00			Silicon	Tek Spec	
D1106	*152-0061-00			Silicon	Tek Spec	
D1114	*152-0061-00			Silicon	Tek Spec	
D1115	*152-0061-00			Silicon	Tek Spec	
D1116	*152-0061-00			Silicon	Tek Spec	
D1117	*152-0061-00			Silicon	Tek Spec	
D1118	*152-0061-00			Silicon	Tek Spec	
D1120	*152-0061-00			Silicon	Tek Spec	
D1132	*152-0061-00			Silicon	Tek Spec	
D1135	152-0123-00			Zener	1N935A 400 mW, 9.1 V 5% TC	
D1155	152-0169-00			Tunnel	1N3712 1 mA	
D1174	152-0101-00			Zener	1N3041B 1 W, 75 V 5%	
D1176	152-0180-00			Silicon	Fast switching UTR 1112	
D1177	*152-0061-00			Silicon	Tek Spec	
D1184	152-0101-00			Zener	1N3041B 1 W, 75 V 5%	
D1186	152-0180-00			Silicon	Fast switching UTR 1112	

POWER SUPPLY (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description	
				Semiconductor Device, Diodes *(cont)*	
D1187	*152-0061-00			Silicon	Tek Spec
D1189	*152-0061-00			Silicon	Tek Spec
D1191	*152-0061-00			Silicon	Tek Spec
D1192	152-0306-00			Zener	1N960B 400 mW, 9.1 V 5%
D1202	152-0224-00			Silicon	UTR 166
D1203	*152-0061-00			Silicon	Tek Spec
D1212	152-0179-00			Silicon	Fast switching UTR 02
D1213	152-0179-00			Silicon	Fast switching UTR 02
D1214	*152-0061-00			Silicon	Tek Spec
D1215	*152-0061-00			Silicon	Tek Spec
D1216	152-0179-00			Silicon	Fast switching UTR 02
D1217	152-0179-00			Silicon	Fast switching UTR 02
D1222	*152-0061-00			Silicon	Tek Spec
D1223	152-0224-00			Silicon	URT 166
D1224	*152-0061-00			Silicon	Tek Spec
D1225	*152-0061-00			Silicon	Tek Spec
D1232	*152-0061-00			Silicon	Tek Spec
D1233	*152-0061-00			Silicon	Tek Spec
D1242	*152-0061-00			Silicon	Tek Spec
D1243	*152-0061-00			Silicon	Tek Spec
D1244	*152-0061-00			Silicon	Tek Spec
D1245	*152-0061-00			Silicon	Tek Spec
				Fuses	
F1000	159-0042-00			3/4 A 3 AG Fast-Blo 115 V-230 V operation	
F1014	159-0015-00			3 A 3 AG Fast-Blo 11.5 V-35 V operation (internal battery)	
				Connectors	
J1201	131-0346-00			24 pin, female	
P1000	131-0384-00			AD/DC Power	
				Inductors	
L1172	*108-0337-00			25 μH	
L1182	*108-0337-00			25 μH	
L1189	*120-0395-00			Toroid, 3 turns single	
L1204	276-0525-00			Core, Ferrite	
L1212	*108-0336-00			100 μH	

POWER SUPPLY (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Inductors *(cont)*			
L1213	276-0525-00	Core, Ferrite					
L1217	*108-0336-00	100 μH					
L1219	276-0525-00	Core, Ferrite					
L1246	*120-0415-00	Toroid, 8 turns single					
				Transistors			
Q1023	*151-0136-00			Silicon	Replaceable by 2N3053		
Q1033	*151-0148-00			Silicon	Selected RCA 40250		
Q1045	*151-0087-00			Silicon	Selected from 2N1131		
Q1055	*151-0096-00			Silicon	Selected from 2N1893		
Q1104	151-0208-00			Silicon	2N4036		
Q1105	*151-0103-00			Silicon	Replaceable by 2N2219		
Q1114	151-0208-00			Silicon	2N4036		
Q1115	*151-0103-00			Silicon	Replaceable by 2N2219		
Q1120	*151-0103-00			Silicon	Replaceable by 2N2219		
Q1134	151-0220-00			Silicon	2N4122		
Q1144	151-0220-00			Silicon	2N4122		
Q1154	151-0224-00			Silicon	2N3692		
Q1163	151-0208-00			Silicon	2N4036		
Q1164	151-0224-00			Silicon	2N3692		
Q1174	*151-0163-00			Silicon	Selected from 2N1899		
Q1184	*151-0163-00			Silicon	Selected from 2N1899		
Q1193	*151-0103-00			Silicon	Replaceable by 2N2219		
Q1194	151-0208-00			Silicon	2N4036		
				Resistors			
Resistors are fixed, composition, ±10% unless otherwise indicated.							
R1022	301-0362-00			3.6 kΩ	½ W		5%
R1023	315-0302-00			3 kΩ	¼ W		5%
R1031	315-0181-00			180 Ω	¼ W		5%
R1033	308-0166-00			16 Ω	5 W	WW	5%
R1034	308-0166-00			16 Ω	5 W	WW	5%
R1041	315-0682-00			6.8 kΩ	¼ W		5%
R1043	315-0393-00			39 kΩ	¼ W		5%
R1044	315-0822-00			8.2 kΩ	¼ W		5%
R1046	315-0113-00			11 kΩ	¼ W		5%
R1047	311-0496-00			2.5 kΩ, Var			
R1048	315-0822-00			8.2 kΩ	¼ W		5%
R1054	315-0822-00			8.2 kΩ	¼ W		5%
R1057	315-0104-00			100 kΩ	¼ W		5%
R1059	315-0105-00			1 MΩ	¼ W		5%
R1103	315-0471-00			470 Ω	¼ W		5%

POWER SUPPLY (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description			
				Resistors *(cont)*			
R1106	315-0220-00			22 Ω	¼ W		5%
R1113	315-0471-00			470 Ω	¼ W		5%
R1116	315-0220-00			22 Ω	¼ W		5%
R1117	315-0182-00			1.8 kΩ	¼ W		5%
R1118	315-0821-00			820 Ω	¼ W		5%
R1120	315-0100-00			10 Ω	¼ W		5%
R1123	321-0193-00			1 kΩ	⅛ W	Prec	1%
R1124	315-0332-00			3.3 kΩ	¼ W		5%
R1125	311-0510-00			10 kΩ, Var			
R1130	311-0496-00			2.5 kΩ, Var			
R1131	321-0235-00			2.74 kΩ	⅛ W	Prec	1%
R1132	321-0314-00			18.2 kΩ	⅛ W	Prec	1%
R1133	321-0330-00			26.7 kΩ	⅛ W	Prec	1%
R1134	315-0512-00			5.1 kΩ	¼ W		5%
R1135	321-0139-00			274 Ω	⅛ W	Prec	1%
R1136	315-0390-00			39 Ω	¼ W		5%
R1143	315-0471-00			470 Ω	¼ W		5%
R1144	315-0103-00			10 kΩ	¼ W		5%
R1153	315-0470-00			47 Ω	¼ W		5%
R1154	315-0272-00			2.7 kΩ	¼ W		5%
R1161	315-0822-00			8.2 kΩ	¼ W		5%
R1162	315-0471-00			470 Ω	¼ W		5%
R1163	315-0123-00			12 kΩ	¼ W		5%
R1164	315-0223-00			22 kΩ	¼ W		5%
R1165	307-0103-00			2.7 Ω	¼ W		5%
R1172	315-0470-00			47 Ω	¼ W		5%
R1177	315-0471-00			470 Ω	¼ W		5%
R1182	315-0470-00			47 Ω	¼ W		5%
R1187	315-0471-00			470 Ω	¼ W		5%
R1191	315-0432-00			4.3 kΩ	¼ W		5%
R1192	315-0101-00			100 Ω	¼ W		5%
R1193	315-0222-00			2.2 kΩ	¼ W		5%
R1194	315-0330-00			33 Ω	¼ W		5%
R1232	309-0060-00			4 Ω	½ W	Prec	1%
				Switches			
	Wired or Unwired						
SW1001	260-0676-00			Rotary		POWER	
SW1030	260-0679-00			Toggle		POWER MODE	
				Thermal Cutouts			
TK1000	260-0677-00			158° F			
TK1033	260-0678-00			105° F			
TK1039	260-0677-00			158° F			

POWER SUPPLY (cont)

Ckt. No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Description
				Transformers
T1000	*120-0397-00			Toroid, 10 turns bifilar
T1001	*120-0392-00			Power
T1010	*120-0397-00			Toroid, 10 turns bifilar
T1120	*120-0396-00			Toroid, 6 turns trifilar
T1171	*120-0393-00			Driver
T1201	*120-0394-00			Toroid, Pre-Regulator

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 LIST ILLUSTRATIONS

(Located behind diagrams)

SECTION 7
MECHANICAL PARTS LIST

FIG. 1 FRONT

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-1	262-0845-00			1	SWITCH, wired—CH 1 VOLTS/DIV
	- - - - - -			-	switch includes:
	260-0661-01			1	SWITCH, unwired
-2	441-0789-00			1	CHASSIS, attenuator
	- - - - - -			-	mounting hardware: (not included w/chassis)
	210-0053-00			2	LOCKWASHER, #2, split
	210-0405-00			2	NUT, hex., 2-56 x $^3/_{16}$ inch
-3	407-0107-00			1	BRACKET, attenuator preamplifier
	- - - - - -			-	mounting hardware: (not included w/bracket)
	213-0055-00			2	SCREW, thread forming, 2-32 x $^3/_{16}$ inch, PHS
-4	211-0008-00			2	SCREW, 4-40 x $^1/_4$ inch, PHS
-5	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, $^1/_4$ ID x $^3/_8$ inch OD
	210-0583-00			1	NUT, hex., $^1/_4$-32 x $^5/_{16}$ inch
-6	376-0029-00			1	COUPLING, rod
	- - - - - -			-	coupling includes:
	213-0075-00			2	SCREW, set, 4-40 x $^3/_{32}$ inch, HSS
	376-0014-00			1	COUPLING, wire
-7	103-0049-04			1	ADAPTER, shaft coupling (long)
-8	103-0050-02			1	ADAPTER, shaft coupling (short)
-9	384-0398-00			1	ROD, shaft, attenuator
-10	131-0344-00			9	CONNECTOR, terminal feed-thru
	- - - - - -			-	mounting hardware for each: (not included w/connector)
	358-0241-00			1	BUSHING, plastic
-11	- - - - - -			9	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
	214-0456-00			1	FASTENER, plastic
-12	337-0716-00			1	SHIELD, attenuator
-13	384-0341-00			1	ROD, shaft, gain
	- - - - - -			-	mounting hardware: (not included w/switch)
-14	211-0008-00			2	SCREW, 4-40 x $^1/_4$ inch, PHS
	210-0054-00			2	LOCKWASHER, #4, split
	210-0851-00			2	WASHER, flat, 0.119 ID x $^3/_8$ inch OD
-15	210-0976-00			2	WASHER, flat, 0.390 ID x 0.562 inch OD
	210-0413-00			1	NUT, $^3/_8$-32 x $^1/_2$ inch

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-16	670-0404-02	20000	27999	1	ASSEMBLY, circuit board—CHANNEL 1 PREAMP
	670-0404-02	28000		1	ASSEMBLY, circuit board—CHANNEL 1 PREAMP
	- - - - - -			-	assembly includes:
	388-0613-02	20000	27999	1	BOARD, circuit
	388-0613-04	28000		1	BOARD, circuit
	- - - - - -			-	board includes:
-17	214-0507-00			6	PIN, connector, 45°, male
-18	136-0220-00			8	SOCKET, transistor, 3 pin
-19	136-0235-00	20000	27999	1	SOCKET, transistor, 6 pin
	136-0235-01	28000		1	SOCKET, transistor, 6 pin
-20	131-0344-00			1	CONNECTOR, feed thru
	- - - - - -			-	mounting hardware: (not included w/connector)
-21	358-0241-00			1	BUSHING, plastic
	- - - - - -			-	mounting hardware: (not included w/assembly)
-22	211-0116-00			3	SCREW, sems, 4-40 x 5/16 inch, PHB
-23	366-0322-00			1	KNOB, large charcoal—CH 1 VOLTS/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-24	366-0140-00			1	KNOB, small red—VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-25	366-0153-00			1	KNOB, small charcoal—SCALE ILLUM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-26	366-0153-00			1	KNOB, small charcoal—ASTIGMATISM
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-27	366-0153-00			1	KNOB, small charcoal—FOCUS
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-28	366-0153-00			1	KNOB, small charcoal—INTENSITY
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-29	333-0838-05			1	PANEL, front
	- - - - - -			-	mounting hardware: (not included w/panel)
	213-0055-00			2	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-30	366-0153-00			2	KNOB, small charcoal—POSITION
	- - - - - -			-	each knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-31	348-0031-00			7	GROMMET, plastic, 3/32 inch diameter
-32	384-0432-00			1	ROD, 10X Mag, w/plastic knob

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-33	200-0604-02			1	ASSEMBLY, front cover
	- - - - - -			-	assembly includes:
-34	348-0077-00			1	CUSHION, cover bottom
-35	214-0756-00			2	PIN, hinge
-36	214-0531-00			2	LATCH, chrome
-37	348-0013-00			4	FOOT, rubber
-38	200-0603-01			1	ASSEMBLY, accessory cover
	- - - - - -			-	assembly includes:
	214-0210-00			1	ASSEMBLY, solder spool
	- - - - - -			-	assembly includes:
	214-0209-00			1	SPOOL, solder
	- - - - - -			-	mounting hardware: (not included w/assembly)
	361-0009-00			1	SPACER, plastic, 0.188 inch long
-39	348-0071-00			1	CUSHION, accessory cover lid
-40	214-0594-00			2	PIN, actuator
-41	200-0632-00			2	CAP, actuator, black plastic
-42	204-0282-00			1	BODY, latch
-43	214-0787-00			1	STEM, latch
-44	366-0140-00			1	KNOB, small red—VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-45	366-0322-00			1	KNOB, large charcoal—CH 2 VOLTS/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-46	262-0845-00			1	SWITCH, wired—CH 2 VOLTS/DIV
	- - - - - -			-	switch includes:
	260-0661-01			1	SWITCH, unwired
-47	441-0789-00			1	CHASSIS, attenuator
	- - - - - -			-	mounting hardware: (not included w/chassis)
	210-0053-00			2	LOCKWASHER, #2, split
	210-0405-00			2	NUT, hex., 2-56 x 3/16 inch
-48	407-0107-00			1	BRACKET, attenuator preamplifier
	- - - - - -			-	mounting hardware: (not included w/bracket)
	213-0055-00			2	SCREW, thread forming, 2-32 x 3/16 inch, PHS
-49	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-50	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/16 inch OD
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-51	376-0029-00			1	COUPLING, rod
	- - - - - -			-	coupling includes:
	213-0075-00			2	SCREW, set, 4-40 x 7/32 inch, HSS
-52	376-0014-00			1	COUPLING, wire
-53	103-0049-04			1	ADAPTER, shaft coupling (long)
	103-0050-02			1	ADAPTER, shaft coupling (short)
-54	384-0393-00			1	ROD, shaft, attenuator
-55	131-0344-00			9	CONNECTOR, terminal feed-thru
	- - - - - -			-	mounting hardware for each: (not included w/connector)
	358-0241-00			1	BUSHING, plastic

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1-56	- - - - - -			9	CAPACITOR
	- - - - - -			-	mounting hardware for each: (not included w/capacitor)
	214-0456-00			1	FASTENER, plastic
-57	337-0716-00			1	SHIELD, attenuator
-58	384-0341-00			1	ROD, shaft, gain
	- - - - - -			-	mounting hardware: (not included w/switch)
-59	211-0008-00			2	SCREW, 4-40 x $^{1}/_{4}$ inch, PHS
	210-0054-00			2	LOCKWASHER, #4, split
	210-0851-00			2	WASHER, flat, 0.119 ID x $^{3}/_{8}$ inch OD
-60	210-0976-00			2	WASHER, flat, 0.390 ID x 0.562 inch OD
	210-0413-00			1	NUT, hex., $^{3}/_{8}$-32 x $^{1}/_{2}$ inch
-61	670-0405-03	20000	279999	1	ASSEMBLY, circuit board—CHANNEL 2 PREAMP
	620-0405-04	28000		1	ASSEMBLY, circuit board—CHANNEL 2 PREAMP
	- - - - - -			-	assembly includes:
	388-0614-03	20000	27999	1	BOARD, circuit
	388-0614-05	28000		1	BOARD, circuit
	- - - - - -			-	board includes:
-62	214-0507-00			12	PIN, connector, 45°, male
-63	136-0220-00			8	SOCKET, transistor, 3 pin
	136-0235-00	20000	27999	1	SOCKET, transistor, 6 pin
	136-0235-01	28000		1	SOCKET, transistor, 6 pin
-64	131-0344-00			1	CONNECTOR, feed thru
	- - - - - -			-	mounting hardware: (not included w/connector)
	358-0241-00			1	BUSHING, plastic
-65	351-0147-00			4	GUIDE, switch actuator
-66	214-1044-00			2	ACTUATOR, switch
-67	260-0583-01			2	SWITCH, slide
	- - - - - -			-	mounting hardware for each: (not included w/switch)
	213-0191-00			2	SCREW, thread forming, 5-32 x $^{5}/_{8}$ inch, PHS
	- - - - - -			-	mounting hardware: (not included w/assembly)
-68	211-0116-00			3	SCREW, sems, 4-40 x $^{5}/_{16}$ inch, PHS
-69	262-0722-01	20000	21939	1	SWITCH, wired—TIME/DIV
	262-0722-02	21940		1	SWITCH, wired—TIME/DIV
	- - - - - -			-	switch includes:
	260-0659-01			1	SWITCH, unwired
	131-0371-00			2	CONNECTOR, single contact, female
-70	384-0217-00			1	ROD, extension
-71	337-0718-00			1	SHIELD, switch
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0008-00			3	SCREW, 4-40 x $^{1}/_{4}$ inch, PHS
-72	376-0039-00			1	COUPLING
	- - - - - -			-	coupling includes:
	213-0075-00			2	SCREW, set, 4-40 x $^{3}/_{32}$ inch, HSS
-73	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0940-00			1	WASHER, flat, $^{1}/_{4}$ ID x $^{3}/_{8}$ inch OD
	210-0583-00			1	NUT, hex., $^{1}/_{4}$-32 x $^{5}/_{16}$ inch
-74	348-0056-00			1	GROMMET, plastic, $^{3}/_{8}$ inch diameter
-75	- - - - - -			1	CAPACITOR
	- - - - - -			-	mounting hardware: (not included w/capacitor)
	210-0018-00			1	LOCKWASHER, internal, $^{5}/_{16}$ inch
	210-0524-00			1	NUT, hex., $^{5}/_{16}$-24 x $^{1}/_{2}$ inch

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
1-76	407-0101-00			1	BRACKET, switch, rear
	- - - - - -			-	mounting hardware: (not included w/bracket)
	210-0055-00			2	LOCKWASHER, #6, split
	210-0449-00			2	NUT, hex., 5-40 x 1/4 inch
	- - - - - -			-	mounting hardware: (not included w/switch)
-77	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
	210-0054-00			1	LOCKWASHER, #4, split
	210-0851-00			2	WASHER, flat, 0.119 ID x 3/8 inch OD
-78	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-79	366-0031-00			1	KNOB, small red—VARIABLE CAL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-80	366-0160-00			1	KNOB, large charcoal—TIME/DIV
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-81	384-0430-00			1	ROD, Invert switch, w/knob
-82	384-0434-00			1	ROD, X10 Gain AC switch, w/knob
-83	384-0336-01			1	ROD, Power switch, w/knob
-84	366-0153-00			1	KNOB, small charcoal—LEVEL
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x 3/16 inch, HSS
-85	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-86	210-0207-00			1	LUG, solder, 3/8 ID x 5/8 inch OD, SE
-87	407-0462-00			1	BRACKET
	- - - - - -			-	mounting hardware: (not included w/bracket)
-88	211-0008-00			1	SCREW, 4-40 x 1/4 inch, PHS
	211-0007-00			1	SCREW, 4-40 x 3/16 inch, PHS
	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-89	384-0637-00			4	ROD, frame
-90	386-0121-00			1	PLATE, front casting
	- - - - - -			-	plate includes:
	129-0076-03			1	POST, binding
-91	352-0084-00			4	HOLDER, neon
	200-0609-00			4	CAP, lamp, neon holder
	378-0541-00			4	FILTER, lens, neon indicator light
-92	260-0665-00			2	SWITCH, lever—AC GND DC
	- - - - - -			-	mounting hardware for each: (not included w/switch)
	220-0413-00			2	NUT, hex., rod, 4-40 x 3/16 x 0.500 inch long
-93	344-0120-00			2	CLIP, capacitor mounting
	- - - - - -			-	mounting hardware for each: (not included w/clip)
	211-0087-00			1	SCREW, 2-56 x 3/16 inch, FHS
	210-0405-00			1	NUT, hex., 2-56 x 3/16 inch

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-94	210-0255-00			3	LUG, solder, 3/8 inch OD
-95	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
-96	358-0251-00			2	BUSHING, 1/4-32 x 0.375 x 0.424 inch long
-97	358-0054-00			2	BUSHING, banana jack
	- - - - - -			-	mounting hardware for each: (not included w/bushing)
	210-0046-00			1	LOCKWASHER, internal, 0.261 ID x 0.400 inch OD
	210-0465-00			1	NUT, hex., 1/4-32 x 3/8 inch
-98	- - - - - -			5	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/6 inch OD
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-99	200-0103-00			1	CAP, ground stem
-100	214-0996-00			1	SPRING, filter
-101	260-0662-00			1	SWITCH, lever—Triggering SOURCE
	- - - - - -			-	mounting hardware: (not included w/switch)
	220-0413-00			1	NUT, hex., rod, 4-40 x 3/16 x 0.500 inch long
-102	260-0663-00			1	SWITCH, lever—Triggering COUPLING
	- - - - - -			-	mounting hardware: (not included w/switch)
	220-0413-00			2	NUT, hex., rod, 4-40 x 3/16 x 0.500 inch long
-103	260-0664-00			1	SWITCH, lever—Trigger SLOPE
	- - - - - -			-	mounting hardware: (not included w/switch)
	220-0413-00			2	NUT, hex., rod, 4-40 x 3/16 x 0.500 inch long
-104	- - - - - -			2	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0046-00			1	LOCKWASHER, internal, 1/4 ID x 0.400 inch OD
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-105	136-0205-00			2	SOCKET, graticule light
	- - - - - -			-	mounting hardware for each: (not included w/socket)
	210-0589-00			1	NUT, locking, 4-40 x 1/4 inch
-106	200-0608-00			2	COVER, variable resistor
-107	131-0383-00			1	CONNECTOR, anode

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-108	437-0076-00			1	ASSEMBLY, cabinet
	- - - - - -			-	assembly includes:
-109	348-0069-00			2	FOOT, bottom
	- - - - - -			-	mounting hardware for each: (not included w/foot)
	211-0501-00			2	SCREW, 6-32 x 1/8 inch, PHS
	- - - - - -			-	mounting hardware: (not included w/assembly)
	211-0097-00			3	SCREW, 4-40 x 5/16 inch, PHS
-110	337-0699-00			1	SHIELD, CRT, rear
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
	210-0054-00			1	LOCKWASHER, #4, split
-111	200-0616-00			1	COVER, CRT socket
-112	136-0222-00			1	ASSEMBLY, CRT socket
	- - - - - -			-	assembly includes:
	136-0202-01			1	SOCKET, CRT
	- - - - - -			-	socket includes:
	136-0202-00			1	SOCKET, CRT
	214-0464-00			14	CONTACT, CRT socket
-113	337-0669-01			1	SHIELD, CRT
	- - - - - -			1	TUBE, cathode ray
	- - - - - -			-	tube includes:
	354-0258-00			1	RING, light reflector (not shown)
-114	348-0070-01			4	CUSHION, CRT
-115	343-0115-00			1	CLAMP, CRT, rear mount (bottom)
-116	124-0170-01			2	STRIP, liner
-117	343-0116-00			1	CLAMP, CRT, rear mount (top)
-118	211-0134-00			2	SCREW, 4-40 x 3/8 inch, PHS
-119	407-0105-01			1	BRACKET, CRT shield
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0117-00			2	SCREW, 4-40 x 5/16 inch, FHS
	210-0053-00			6	LOCKWASHER, internal, #4
	220-0438-00			4	NUT, hex., 4-40 x 1/4 inch
-120	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-121	367-0063-00			1	ASSEMBLY, carrying handle
	- - - - - -			-	assembly includes:
-122	200-0602-00			2	COVER, handle
-123	367-0046-01			1	HANDLE, carrying
	- - - - - -			-	mounting hardware: (not included w/handle)
	211-0512-00			4	SCREW, 6-32 x 1/2 inch, 100° csk, FHS
-124	214-0516-00			2	SPRING, handle index
-125	214-0515-00			2	INDEX, hub
-126	214-0513-00			2	INDEX, ring
	- - - - - -			-	mounting hardware: (not included w/assembly)
-127	213-0139-00			2	SCREW, 10-24 x 3/8 inch, HHS
	210-0805-00			2	WASHER, flat, 0.204 ID x 0.438 inch OD

FIG. 1 FRONT *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
1-128	131-0352-00			5	CONNECTOR, coaxial, 1 contact, BNC w/hardware
-129	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0223-00			1	LUG, solder, $\frac{1}{4}$ ID x $\frac{7}{16}$ inch OD, SE
	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
-130	358-0252-00			1	BUSHING, ball, swivel
-131	366-0215-01			5	KNOB, charcoal, lever
-132	136-0187-00			1	SOCKET, 1 pin
	- - - - - -			-	mounting hardware: (not included w/socket)
	210-0940-00			1	WASHER, flat, $\frac{1}{4}$ ID x $\frac{3}{8}$ inch OD
-133	210-0471-00			1	NUT, hex., $\frac{1}{4}$-32 x $\frac{5}{16}$ x $\frac{9}{32}$ inch
-134	366-0225-00			1	KNOB, charcoal—MODE
	- - - - - -			-	knob includes:
	213-0020-00			1	SCREW, set, 6-32 x $\frac{1}{8}$ inch, HSS

FIG. 2 CHASSIS

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
2-1	179-0941-02	20000	303999	1	CABLE HARNESS, vertical
	179-0941-03	304000		1	CABLE HARNESS, vertical
	- - - - - -			-	cable harness includes:
-2	131-0371-00			1	CONNECTOR, single contact, female
-3	670-0407-02	20000	24999	1	ASSEMBLY, circuit board—SWITCHING & OUTPUT AMPLIFIER
	670-0407-03	25000		1	ASSEMBLY, circuit board—SWITCHING & OUTPUT AMPLIFIER
	- - - - - -			-	assembly includes:
	388-0616-02			1	BOARD, circuit
	- - - - - -			-	board includes:
-4	214-0507-00			22	PIN, connector, 45°, male
-5	337-0717-00			1	SHIELD, horizontal amplifier
-6	129-0069-00			2	POST, tie-off
	- - - - - -			-	mounting hardware for each: (not included w/post)
	361-0008-00			1	SPACER, plastic, 0.281 inch long
-7	344-0119-00			6	CLIP, electrical
-8	136-0220-00			7	SOCKET, transistor, 3 pin
	- - - - - -			-	mounting hardware: (not included w/assembly)
-9	211-0116-00			4	SCREW, sems, 4-40 x 5/16 inch, PHB
	210-0994-00			3	WASHER, flat, 0.125 ID x 0.250 inch OD
	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-10	407-0103-00			1	BRACKET, vertical board
-11	175-0582-00			1	WIRE, CRT lead, 0.458 foot, striped brown, w/connector
	175-0583-00			1	WIRE, CRT lead, 11½ inches, striped red, w/connector
	175-0584-00			1	WIRE, CRT lead, 11½ inches, striped green, w/connector
	175-0596-00			1	WIRE, CRT lead, 0.417 foot, striped blue, w/connector
-12	214-0153-00			1	FASTENER, snap, double-pronged
-13	214-0511-00			2	SPRING, transistor mounting
	- - - - - -			-	mounting hardware for each: (not included w/spring)
	211-0007-00			1	SCREW, 4-40 x 3/16 inch, PHS
-14	214-0317-00	20000	20449	2	HEAT SINK, insulator disc
	214-1138-00	20500		2	HEAT SINK, insulator disc
-15	352-0082-00			2	HOLDER, transistor mounting
-16	407-0104-00			1	BRACKET, vertical output
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
-17	348-0063-00			5	GROMMET, plastic, ½ inch diameter
-18	343-0089-00			2	CLAMP, cable, plastic, size "D"
-19	343-0006-00			1	CLAMP, cable, plastic, ½ inch
	- - - - - -			-	mounting hardware: (not included w/clamp)
	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
	210-0851-00			1	WASHER, flat, 0.119 ID x 3/8 inch OD
-20	210-0201-00			3	LUG, solder, SE #4
	- - - - - -			-	mounting hardware for each: (not included w/lug)
	213-0044-00			1	SCREW, thread forming, 5-32 x 3/16 inch, PHS

FIG. 2 CHASSIS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Q t y	Description 1 2 3 4 5
2-21	441-0601-03	20000	24999	1	CHASSIS, main frame
	441-0601-05	25000		1	CHASSIS, main frame
	- - - - - -			-	mounting hardware: (not included w/chassis)
	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
	210-0586-00			3	NUT, keps, 4-40 x 1/4 inch
-22	337-0722-00			1	SHIELD, interchannel
	- - - -			-	mounting hardware: (not included w/shield)
	210-0586-00			5	NUT, keps, 4-40 x 1/4 inch
-23	348-0031-00			1	GROMMET, plastic, 3/32 inch diameter
-24	260-0660-00			1	SWITCH, unwired—Mode
	- - - -			-	mounting hardware: (not included w/switch)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-25	348-0056-00			6	GROMMET, plastic, 3/8 inch diameter
-26	670-0409-02			1	ASSEMBLY, circuit board—TRIGGER/SWEEP GENERATOR
	- - - - - -			-	assembly includes:
	388-0618-02			1	BOARD, circuit
	- - - - - -			-	board includes:
-27	214-0507-00			22	PIN, connector, 45°, male
-28	214-0506-00			10	PIN, connector, straight, male
-29	214-0565-00			2	FASTENER, pin press
-30	136-0220-00	20000	24999	11	SOCKET, transistor, 3 pin
	136-0220-00	25000		10	SOCKET, transistor, 3 pin
	136-0331-00	X25000		1	SOCKET, transistor, 3 pin
-31	131-0633-00			17	TERMINAL, pin
-32	214-0579-00			1	PIN, test point
	- - - - - -			-	mounting hardware: (not included w/assembly)
-33	211-0097-00			5	SCREW, 4-40 x 5/16 inch, PHS
	210-0054-00			5	LOCKWASHER, #4, split
	210-0994-00			5	WASHER, flat, 0.125 ID x 0.250 inch OD
-34	179-0940-01			1	CABLE HARNESS, sweep
	- - - - - -				cable harness includes:
-35	131-0371-00			1	CONNECTOR, single contact, female
-36	337-0720-00			1	SHIELD, trigger sweep
	- - - -			-	mounting hardware: (not included w/shield)
	211-0008-00			4	SCREW, 4-40 x 1/4 inch, PHS
	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
	210-0851-00			4	WASHER, flat, 0.119 ID x 3/8 inch OD

FIG. 2 CHASSIS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-37	214-0524-00			1	ACTUATOR, X10 Gain AC switch
-38	670-0420-02	20000	27999	1	ASSEMBLY, circuit board—CALIBRATOR
	670-0420-03	28000		1	ASSEMBLY, circuit board—CALIBRATOR
	- - - - - -			-	assembly includes:
	388-0617-03	20000	27999	1	BOARD, circuit
	388-0615-05	28000		1	BOARD, circuit
	- - - - - -			-	board includes:
-39	214-0506-00			14	PIN, connector, straight, male
-40	136-0183-00	20000	27999	3	SOCKET, transistor, 3 pin
	136-0183-00	28000		13	SOCKET, transistor, 3 pin
-41	136-0220-00	20000	27999	3	SOCKET, transistor, 3 pin
	136-0220-00	28000		6	SOCKET, transistor, 3 pin
-42	343-0088-00	20000	27999X	1	CLAMP, plastic, cable, size "C"
	- - - - - -			-	mounting hardware: (not included w/assembly)
-43	211-0116-00			3	SCREW, sems, 4-40 x 5/16 inch, PHB
-44	407-0100-00			1	BRACKET, calibrator mounting
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
-45	179-0942-00			1	CABLE HARNESS, calibrator
	- - - - - -			-	cable harness includes:
-46	131-0371-00			1	CONNECTOR, single contact, female
-47	119-0037-01			1	ASSEMBLY, delay line
	- - - - - -			-	assembly includes:
-48	352-0083-01			1	HOLDER, delay line
-49	200-0606-01			1	COVER, delay line
	- - - - - -			-	mounting hardware: (not included w/assembly)
	210-0406-00			2	NUT, hex., 4-40 x 3/16 inch
	210-0589-00			4	NUT, locking, 4-40 x 1/4 inch
	210-0851-00			4	WASHER, flat, 0.119 ID x 3/8 inch OD
	210-0601-01			2	EYELET, brass
-50	670-0413-02	20000	21939	1	ASSEMBLY, circuit board—HORIZONTAL AMPLIFIER
	670-0413-03	21940		1	ASSEMBLY, circuit board—HORIZONTAL AMPLIFIER
	- - - - - -			-	assembly includes:
	388-0615-05			1	BOARD, circuit
-51	131-0633-00			1	TERMINAL, pin, straight
-52	214-0507-00			28	PIN, connector, 45°, male

FIG. 2 CHASSIS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-53	136-0183-00			4	SOCKET, transistor, 3 pin
-54	136-0220-00			3	SOCKET, transistor, 3 pin
-55	337-0717-00			2	SHIELD, horizontal amplifier
-56	260-0583-01			1	SWITCH, slide
	- - - - - -			-	mounting hardware: (not included w/switch)
-57	213-0191-00			2	SCREW, thread forming, 5-32 x 5/8 inch, PHS
-58	351-0147-00			2	GUIDE, switch actuator
-59	214-1044-00			1	ACTUATOR, switch
	- - - - - -			-	mounting hardware: (not included w/assembly)
-60	211-0116-00			3	SCREW, sems, 4-40 x 5/16 inch, PHB
-61	179-0943-01			1	CABLE HARNESS, horizontal
	- - - - - -			-	cable harness includes:
-62	131-0371-00			1	CONNECTOR, single contact, female
-63	343-0144-00			2	CLAMP, loop, 0.125 inch ID
	- - - - - -			-	mounting hardware: (not included w/clamp)
-64	211-0014-00			1	SCREW, 4-40 x 1/2 inch, PHS
	210-0851-00			2	WASHER, flat, 0.119 ID x 3/8 inch OD
	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch
-65	- - - - - -			3	RESISTOR, variable
	- - - - - -			-	mounting hardware for each: (not included w/resistor)
	210-0940-00			1	WASHER, flat, 1/4 ID x 3/8 inch OD
	210-0583-00			1	NUT, hex., 1/4-32 x 5/16 inch
-66	124-0147-00			2	STRIP, ceramic, 7/16 inch, w/13 notches
	- - - - - -			-	each strip includes:
	355-0046-00			2	STUD, plastic
	- - - - - -			-	mounting hardware for each: (not included w/strip)
	361-0007-00			2	SPACER, plastic, 0.188 inch long
-67	337-0719-01			1	SHIELD, high-voltage
	- - - - - -			-	mounting hardware: (not included w/shield)
	211-0008-00			3	SCREW, 4-40 x 1/4 inch, PHS
	210-0586-00			3	NUT, keps, 4-40 x 1/4 inch
-68	386-0117-00			1	PLATE, rear frame
-69	343-0004-00			1	CLAMP, cable, plastic, 5/16 inch
	- - - - - -			-	mounting hardware: (not included w/clamp)
	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
	210-0851-0C			1	WASHER, flat, 0.119 ID x 3/8 inch OD

FIG. 2 CHASSIS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
2-70	358-0244-00			2	BUSHING, flange
	- - - - - -			-	mounting hardware for each: (not included w/bushing)
	211-0014-00			1	SCREW, 4-40 x 1/2 inch, PHS
	210-0851-00			1	WASHER, flat, 0.119 ID x 3/8 inch OD
-71	- - - - - -			1	RESISTOR, variable
	- - - - - -			-	mounting hardware: (not included w/resistor)
	210-0207-00			1	LUG, solder, 3/8 ID x 5/8 inch OD, SE
	210-0012-00			1	LOCKWASHER, internal, 3/8 x 1/2 inch
	210-0840-00			1	WASHER, flat, 0.390 ID x 9/16 inch OD
	210-0413-00			1	NUT, hex., 3/8-32 x 1/2 inch
-72	643-0408-00			1	ASSEMBLY, connector cable
	- - - - - -			-	assembly includes:
-73	407-0097-00			1	BRACKET, power connector
-74	343-0004-00			1	CLAMP, cable, plastic, 5/16 inch
	- - - - - -			-	mounting hardware: (not included w/clamp)
	210-0863-00			1	WASHER, D shape, 0.191 ID x 33/64 w, 33/64 inch long
	210-0586-00			1	NUT, keps, 4-40 x 1/4 inch
-75	131-0345-00			1	CONNECTOR, male, 24 pin
	- - - - - -			-	mounting hardware: (not included w/connector)
	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
	210-0586-00			2	NUT, keps, 4-40 x 1/4 inch
	- - - - - -			-	mounting hardware: (not included w/assembly)
-76	211-0008-00	20000	30009	3	SCREW, 4-40 x 1/4 inch, PHS
	211-0007-00	30010		3	SCREW, 4-40 x 3/16 inch, PHS
-77	214-0526-01			1	ACTUATOR, toggle switch
-78	214-0863-00			1	PIN, spiral spring
-79	214-0509-00			1	SPRING, switch actuator
-80	407-0106-00			1	BRACKET, power switch actuator
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0008-00			2	SCREW, 4-40 x 1/4 inch, PHS
-81	337-0721-00			1	SHIELD, high-voltage power supply

FIG. 2 CHASSIS *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
2-	621-0423-00			1	ASSEMBLY, high-voltage power
	- - - - - -			-	assembly includes:
-82	202-0135-00			1	BOX, high-voltage
-83	670-0410-00			1	ASSEMBLY, circuit board—HIGH-VOLTAGE RECTIFIER
	- - - - - -			-	assembly includes:
	388-0620-00			1	BOARD, circuit
-84	214-0523-00			1	INSULATOR, high-voltage
-85	200-0607-00			1	COVER, high-voltage box
-86	670-0411-01			1	ASSEMBLY, circuit board—HIGH-VOLTAGE REGULATOR
	- - - - - -			-	assembly includes:
	388-0619-01			1	BOARD, circuit
-87	129-0075-00			1	POST, tie-off
	- - - - - -			-	mounting hardware: (not included w/post)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-88	179-0961-01			1	CABLE HARNESS, high voltage
	- - - - - -			-	mounting hardware: (not included w/assembly)
-89	211-0594-00			2	SCREW, 6-32 x 2½ inches, THS
	210-0803-00			2	WASHER, flat, 0.150 ID x ⅜ inch OD
-90	343-0003-00			1	CLAMP, cable, plastic, ¼ inch
	- - - - - -			-	mounting hardware: (not included w/clamp)
	211-0097-00			1	SCREW, 4-40 x 5/16 inch, PHS
	210-0851-00			1	WASHER, flat, 0.119 ID x ⅜ inch OD
-91	407-0458-00			1	BRACKET
	- - - - - -			-	mounting hardware: (not included w/bracket)
	210-0586-00			2	NUT, keps, 4-40 x ¼ inch
-92	131-0344-00			1	CONNECTOR, terminal feed thru
	- - - - - -			-	mounting hardware: (not included w/connector)
-93	358-0241-00			1	BUSHING, plastic

FIG. 3 AC-DC POWER SUPPLY

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-	016-0073-00			1	AC-DC POWER SUPPLY
	- - - - - -			-	AC-DC power supply includes:
-1	670-0082-00			1	ASSEMBLY, circuit board, wired—DC POWER CONVERTER
	- - - - - -			-	assembly includes:
	388-0623-00			1	BOARD, circuit, rear
-2	134-0016-00			2	PLUG, banana, female
	- - - - - -			-	mounting hardware for each: (not included w/plug)
	212-0570-00			1	SCREW, 10-32 x 5/8 inch, PHS
	210-1003-00			2	WASHER, flat, #10
	210-0056-00			1	LOCKWASHER, #10, split
	361-0102-00			1	SPACER, tube
-3	179-0978-01			1	CABLE HARNESS, AC-DC
-4	385-0183-00			1	ROD, support
	- - - - - -			-	mounting hardware: (not included w/rod)
	211-0116-00			1	SCREW, sems, 4-40 x 5/16 inch, PHB
-5	426-0121-00			1	MOUNT, toroid
	- - - - - -			-	mounting hardware: (not included w/mount)
	361-0007-00			1	SPACER, plastic, 0.063 inch
-6	407-0125-01			1	BRACKET, side
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0116-00			1	SCREW, sems, 4-40 x 5/16 inch, PHB
-7	179-0979-00			1	CABLE HARNESS, transfer
-8	384-0519-00			2	ROD, spacing
	- - - - - -			-	mounting hardware for each: (not included w/rod)
	213-0049-00			1	SCREW, 6-32 x 5/16 inch, HHS
	210-0055-00			1	LOCKWASHER, #6, split
	210-0802-00			1	WASHER, flat, 0.150 ID x 5/16 inch OD
-9	354-0253-00			2	RING, capacitor mounting
-10	- - - - - -			2	TRANSISTOR
	- - - - - -			-	mounting hardware for each: (not included w/transistor)
	210-0996-00			1	WASHER, shouldered, 5/16 ID x 3/4 inch OD
	210-0807-01			1	WASHER, 5/16 ID x 5/8 inch OD
	210-0217-00			1	LUG, solder, 5/16 inch
	210-0057-00			1	LOCKWASHER, 5/16 inch, split
	210-0524-01			1	NUT, hex., 5/16-24 x 1/2 inch
-11	- - - - - -			1	TRANSISTOR
	- - - - - -			-	mounting hardware: (not included w/transistor)
	386-0143-00			1	PLATE, MICA INSULATOR
	211-0507-00			2	SCREW, 6-32 x 5/16 inch, PHS
	210-0811-00			2	WASHER, fiber, #6
	210-0261-00			1	LUG, solder, high voltage
	210-0802-00			1	WASHER, flat, 0.150 ID x 5/16 inch OD
	210-0055-00			2	LOCKWASHER, #6, split
	210-0407-00			2	NUT, hex., 6-32 x inch
-12	- - - - - -			2	THERMAL CUTOUT
	- - - - - -			-	mounting hardware for each: (not included w/thermal cutout)
	210-0054-00			2	LOCKWASHER, #4, split
	210-0407-00			2	NUT, hex., 4-40 x 3/16 inch
-13	407-0124-00			1	BRACKET, heat sink

FIG. 3 AC-DC POWER SUPPLY *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
3-14	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
	211-0537-00			2	SCREW, 6-32 x $^{3}/_{8}$ inch, THS
	210-0802-00			2	WASHER, flat, 0.150 ID x $^{5}/_{16}$ inch OD
	210-0055-00			2	LOCKWASHER, #6, split
-15	386-0191-00			1	PLATE, support
	- - - - - -			-	mounting hardware: (not included w/plate)
	211-0038-00			2	SCREW, 4-40 x $^{5}/_{16}$ inch, 100° csk, FHS
-16	260-0676-00			1	SWITCH, toggle—POWER
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0414-00			1	NUT, hex., $^{15}/_{32}$-32 x $^{9}/_{16}$ inch
	354-0055-00			1	RING, locking, switch
	210-0473-00			1	NUT, switch, $^{15}/_{32}$-32 x $^{5}/_{64}$ inch, 12 sided
-17	351-0090-00			4	GUIDE, corner, power supply
	- - - - - -			-	mounting hardware for each: (not included w/guide)
	213-0034-00			2	SCREW, thread cutting, 4-40 x $^{5}/_{16}$ inch, PHS
-18	214-0289-00			1	HEAT SINK, transistor
	- - - - - -			-	mounting hardware: (not included w/heat sink)
	210-0909-00			1	WASHER, mica, 0.196 ID x 0.625 inch OD
	210-0010-00			1	LOCKWASHER, internal, #10
	210-0410-00			1	NUT, hex., 10-32 x $^{5}/_{16}$ inch
-19	426-0121-00			3	MOUNT, toroid
	- - - - - -			-	mounting hardware for each: (not included w/mount)
	361-0007-00			1	SPACER, plastic, 0.188 inch long
-20	131-0346-00			1	CONNECTOR, 24 pin, female
	- - - - - -			-	mounting hardware: (not included w/connector)
	211-0034-00			2	SCREW, 2-56 x $^{1}/_{2}$ inch, RHS
	210-0864-00			2	WASHER, $^{3}/_{16}$ ID x $^{3}/_{8}$ inch OD
	210-0053-00			2	LOCKWASHER, #2, split
	210-0405-00			2	NUT, hex., 2-56 x $^{3}/_{16}$ inch
-21	214-0566-00			2	SPRING, clip
-22	407-0126-00			1	BRACKET, transformer mounting
	- - - - - -			-	mounting hardware: (not included w/bracket)
	211-0504-00			2	SCREW, 6-32 x $^{1}/_{4}$ inch, PHS
	210-0802-00			2	WASHER, flat, 0.150 ID x $^{5}/_{16}$ inch OD
	210-0055-00			2	LOCKWASHER, #6, split
	210-0407-00			2	NUT, hex., 6-32 x $^{1}/_{4}$ inch
-23	670-0081-00			1	ASSEMBLY, circuit board, wired—DC POWER CONTROL
	- - - - - -			-	assembly includes:
	388-0624-00			1	BOARD, circuit, front
-24	136-0183-00			14	SOCKET, 3 pin transistor
	- - - - - -			-	mounting hardware: (not included w/assembly)
-25	211-0116-00			9	SCREW, sems, 4-40 x $^{5}/_{16}$ inch, PHB

FIG. 3 AC-DC POWER SUPPLY *(cont)*

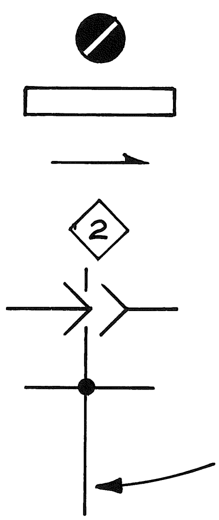
Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
3-26	- - - - - -			1	TRANSFORMER
	- - - - - -			-	mounting hardware: (not included w/transformer)
	211-0530-00			2	SCREW, 6-32 x 1 $^3/_4$ inches, PHS
	210-0802-00			4	WASHER, flat, 0.150 ID x $^5/_{16}$ inch OD
	210-0983-00			4	WASHER, shouldered, #6
	210-0055-00			4	LOCKWASHER, #6 split
	210-0407-00			4	NUT, hex., 6-32 x $^1/_4$ inch
-27	179-0977-01			1	CABLE HARNESS, chassis
-28	- - - - - -			1	THERMAL CUTOUT
	- - - - - -			-	mounting hardware: (not included w/thermal cutout)
	210-0054-00			2	LOCKWASHER, #4, split
	210-0406-00			2	NUT, hex., 4-40 x $^3/_{16}$ inch
-29	131-0384-00			1	CONNECTOR, AC-DC
	- - - - - -			-	mounting hardware: (not included w/connector)
	210-0054-00			2	LOCKWASHER, #4, split
	210-0406-00			2	NUT, hex., 4-40 x $^3/_{16}$ inch
-30	407-0123-00			1	BRACKET, support
-31	260-0679-00			1	SWITCH, unwired—POWER MODE
	- - - - - -			-	mounting hardware: (not included w/switch)
	210-0840-00			1	WASHER, flat, 0.390 ID x $^9/_{16}$ inch OD
	210-0413-00			1	NUT, hex., $^3/_8$-32 x $^1/_2$ inch
-32	385-0185-00			1	ROD, support
	- - - - - -			-	mounting hardware: (not included w/rod)
	210-0056-00			1	LOCKWASHER, #10, split
	220-0434-00			1	NUT, hex., shouldered, 0.560 inch long
-33	343-0089-00			1	CLAMP, cable, plastic, size "D"
-34	384-0519-00			2	ROD, spacing
	- - - - - -			-	mounting hardware for each: (not included w/rod)
	213-0049-00			1	SCREW, 6-32 x $^5/_{16}$ inch, HHS
	210-0055-00			1	LOCKWASHER, #6, split
	210-0802-00			1	WASHER, flat, 0.150 ID x $^5/_{16}$ inch OD
-35	214-0568-00			1	GASKET, switch bracket
-36	366-0326-00			1	KNOB, small charcoal—POWER MODE
	- - - - - -			-	knob includes:
	213-0004-00			1	SCREW, set, 6-32 x $^3/_{16}$ inch, HSS
-37	352-0002-00			2	ASSEMBLY, fuse holder
	- - - - - -			-	assembly includes:
-38	352-0010-00			1	HOLDER, fuse
	210-0873-00			1	WASHER, rubber, $^1/_2$ ID x $^{11}/_{16}$ inch OD
	- - - - - -			1	NUT, fuse holder
-39	200-0582-00			1	CAP, fuse
-40	380-0079-00			1	HOUSING, power supply
	- - - - - -			-	mounting hardware: (not included w/housing)
	211-0565-00			3	SCREW, 6-32 x $^1/_4$ inch, THS
	211-0534-00			1	SCREW, sems, 6-32 x $^5/_{16}$ inch, PHS

FIG. 3 AC-DC POWER SUPPLY *(cont)*

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Serial/Model No. Disc	Qty	Description 1 2 3 4 5
3-41	202-0138-00			1	BOX, battery, power supply
	- - - - - -			-	box includes:
-42	348-0069-00			2	FOOT, bottom
	- - - - - -			-	mounting hardware for each: (not included w/foot)
	211-0501-00			2	SCREW, 6-32 x 1/8 inch, PHS
-43	348-0068-00	20000	21832	4	FOOT, rear
	348-0068-01	21833		4	FOOT, rear
	- - - - - -			-	mounting hardware for each: (not included w/foot)
	213-0034-00	20000	30909	1	SCREW, thread cutting 4-40 x 5/16 inch, RHS
	213-0119-00			1	SCREW, thread forming, 4-24 x 3/8 inch, PHS
-44	212-0572-00			4	SCREW, 10-32 x 5 1/2 inches, RHS
-45	211-0542-00			4	SCREW, 6-32 x 5/16 inch, THS
	210-0803-00			4	WASHER, flat, 0.150 ID x 3/8 inch OD
	210-0457-00			4	NUT, keps, 6-32 x 5/16 inch
-46	334-0959-00			1	TAG, information
	- - - - - -			-	mounting hardware: (not included w/tag)
	211-0542-00			1	SCREW, 6-32 x 5/16 inch, THS
-47	210-0201-00			1	LUG, solder, SE #4
	- - - - - -			-	mounting hardware: (not included w/lug)
	210-0406-00			1	NUT, hex., 4-40 x 3/16 inch

SECTION 8
DIAGRAMS

The following symbols are used on the diagrams:



Screwdriver adjustment

Front-, side- or rear-panel control or connector

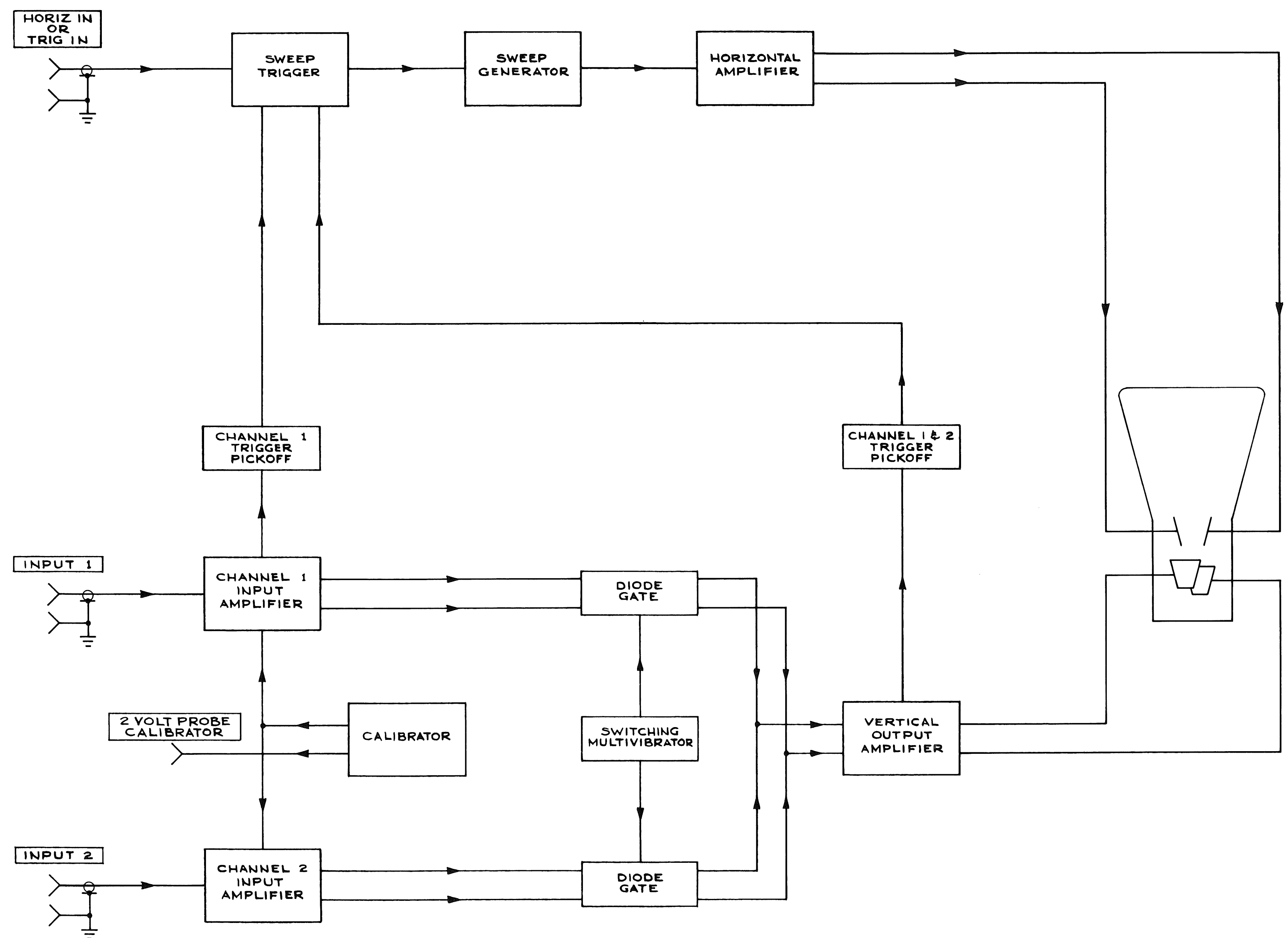
Clockwise control rotation in direction of arrow

Refer to indicated diagram

Connection to circuit board made with pin connector at indicated pin

Connection soldered to circuit board

Blue line encloses components located on circuit board


HORIZ IN OR TRIG IN
SWEEP TRIGGER
SWEEP GENERATOR
HORIZONTAL AMPLIFIER
CHANNEL 1 TRIGGER PICKOFF
CHANNEL 1 & 2 TRIGGER PICKOFF
INPUT 1
CHANNEL 1 INPUT AMPLIFIER
DIODE GATE
2 VOLT PROBE CALIBRATOR
CALIBRATOR
SWITCHING MULTIVIBRATOR
VERTICAL OUTPUT AMPLIFIER
INPUT 2
CHANNEL 2 INPUT AMPLIFIER
DIODE GATE

VOLTAGE AND WAVEFORM TEST CONDITIONS

Typical voltage measurements and waveform photographs were obtained under the following conditions unless noted otherwise on the individual diagrams:

Test Oscilloscope (with 10X probe)

Frequency response	DC to 15 megahertz
Deflection factor (with 10X probe)	0.5 volts to 50 volts/division
Input impedance (with 10X probe)	10 Megohms, 7.5 picofarads
Probe ground	Type 422 chassis ground
Trigger Source	External from Type 422 GATE OUT connector to indicate true time relationship between signals
Recommended type (as used for waveforms on diagrams)	Type 543B with Type 1A2 plug-in unit

Voltmeter

Type	Non-loading AC (RMS)-DC VTVM
Sensitivity	20,000 ohm/volt
Range	0 to 1000 volts
Reference voltage	Type 422 chassis ground

Type 422 Conditions

Line voltage	115 volts
Signal applied	
Voltages	None
Waveforms	Internal calibrator signal
Connectors	No connections (except as given above)
Trace position	Centered
Control settings	As follows except as noted otherwise on individual diagrams.

CRT Controls

INTENSITY	Midrange
FOCUS	Adjust for well-defined display
ASTIGMATISM	Adjust for well-defined display
SCALE ILLUM	As desired

Vertical Controls (both channels where applicable)

VOLTS/CM	0.5 (CALIBRATE 4 DIVISIONS for waveforms only)
VARIABLE	CAL
Input Coupling	GND
POSITION	Midrange
Mode	CH 1
INVERT	Pushed in
X10 GAIN AC	Pushed in

Triggering Controls

Source	CH 1 & 2
Coupling	AC
SLOPE	Positive-going
Mode	AUTO (pushed in)
LEVEL	Centered

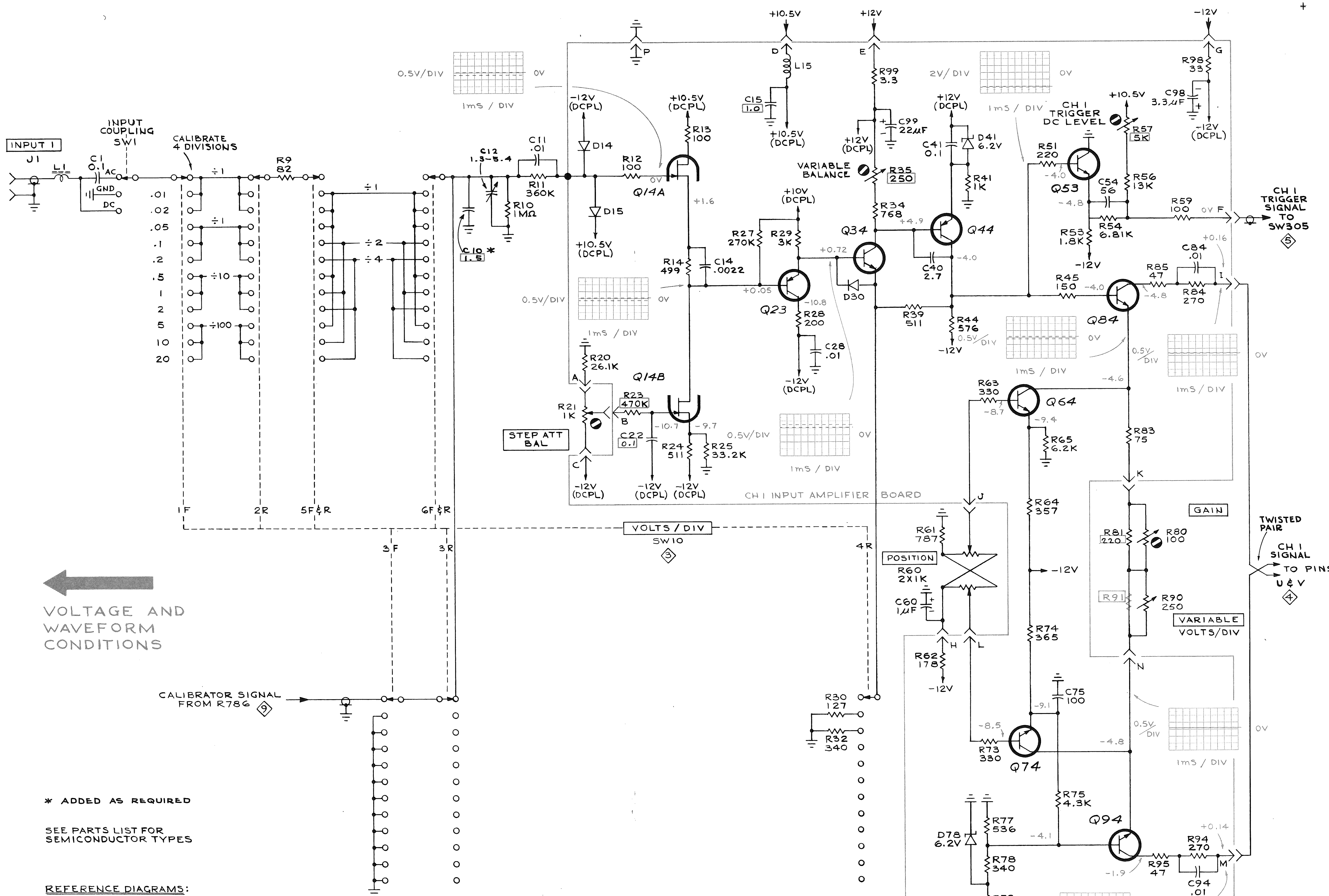
Sweep Controls

POSITION	Midrange
TIME/DIV	.5 ms
VARIABLE	CAL
X10 MAG	Pushed in

Power

POWER	ON (at power supply)

All voltages given on the diagrams are in volts. Waveforms shown are actual waveform photographs taken with a Tektronix Oscilloscope Camera System and Projected Graticule. Voltages and waveforms on the diagrams (shown in blue) are not absolute and may vary between instruments because of differing component tolerances, internal calibration, front-panel control settings or meter accuracy.



* ADDED AS REQUIRED

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

- 3 ATTENUATORS
- 4 VERTICAL SWITCHING & OUTPUT AMPLIFIER
- 5 SWEEP TRIGGER
- 9 CALIBRATOR & REGULATOR

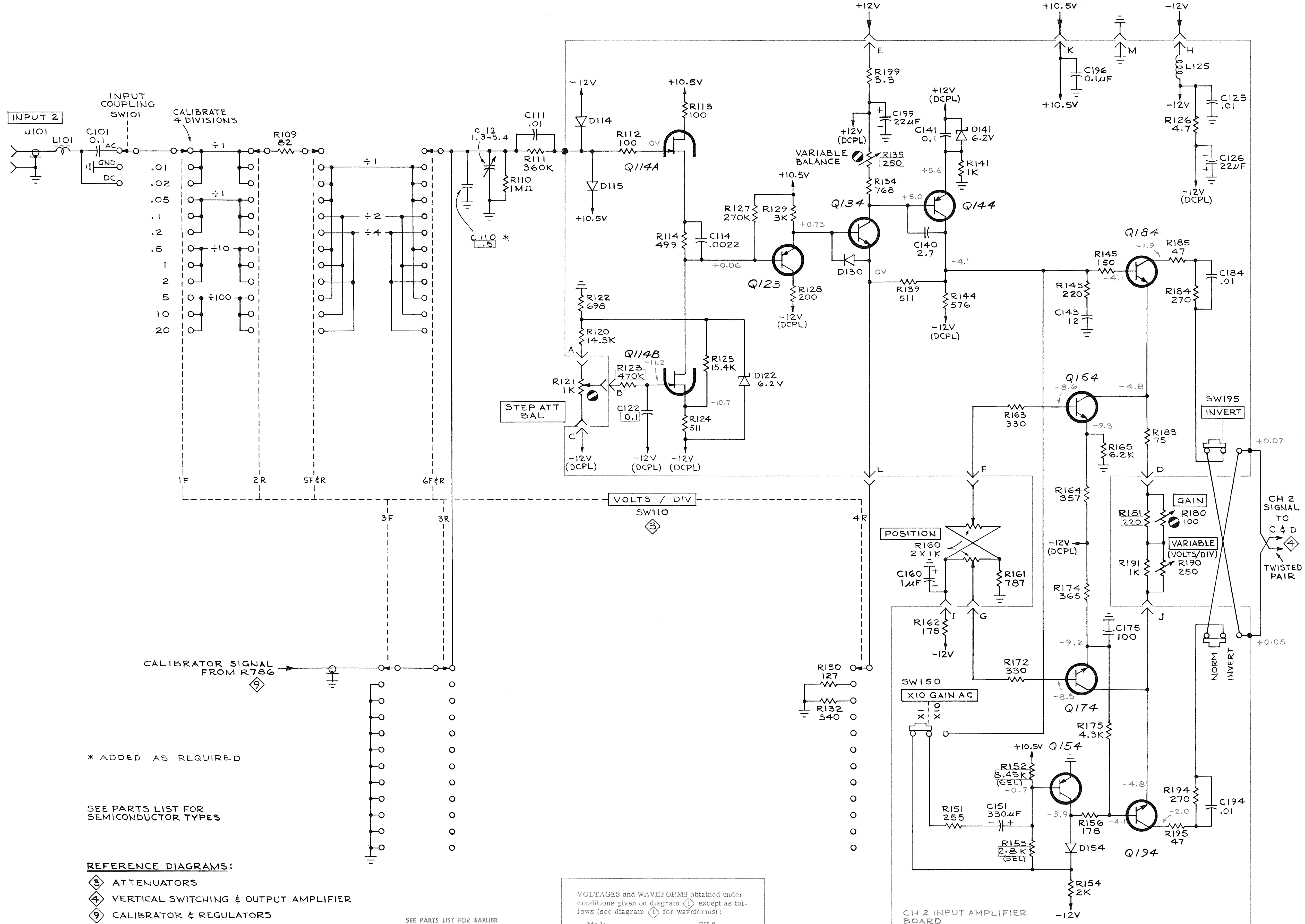
SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGES and WAVEFORMS obtained under conditions given on left side of this diagram.

TYPE 422 AC-DC

D

CHANNEL 1 INPUT AMPLIFIER 1 0870
(S/N 20,000-UP)



* ADDED AS REQUIRED

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

REFERENCE DIAGRAMS:

- ③ ATTENUATORS
- ④ VERTICAL SWITCHING & OUTPUT AMPLIFIER
- ⑨ CALIBRATOR & REGULATORS

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGES and WAVEFORMS obtained under conditions given on diagram ① except as follows (see diagram ① for waveforms):

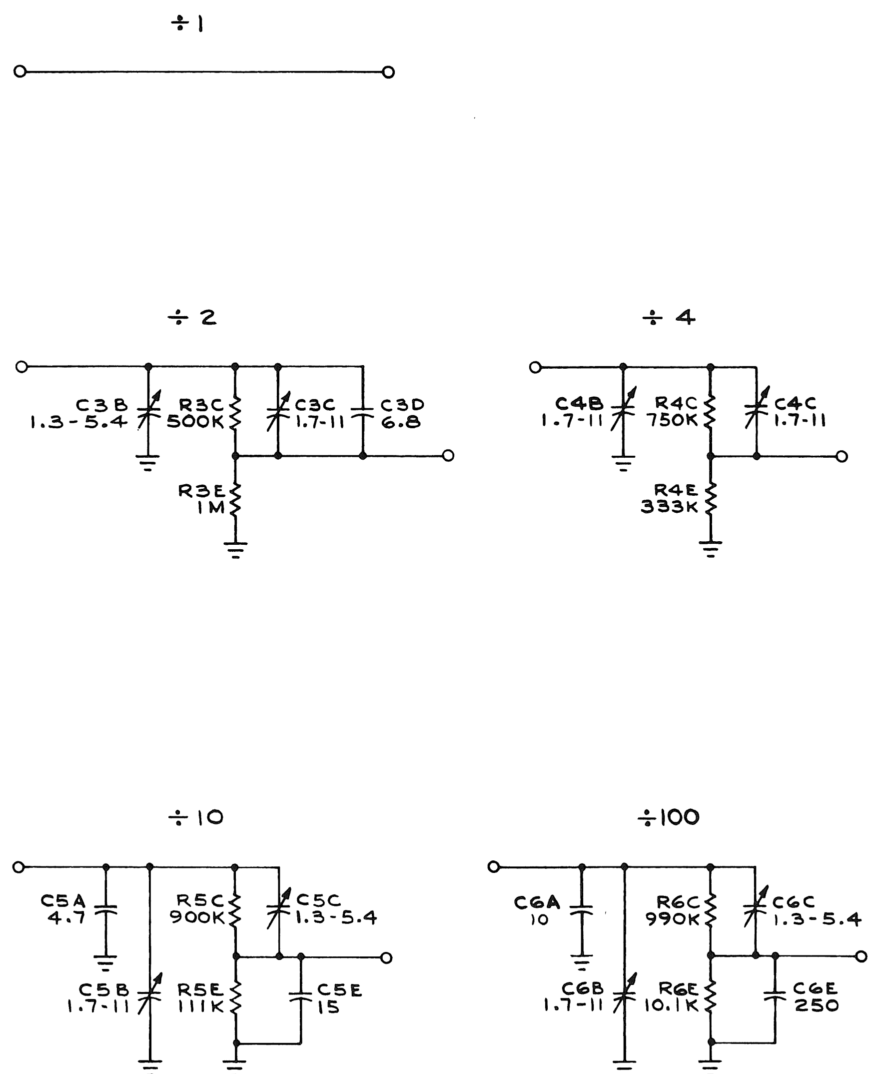
Mode	CH 2

TYPE 422 AC-DC

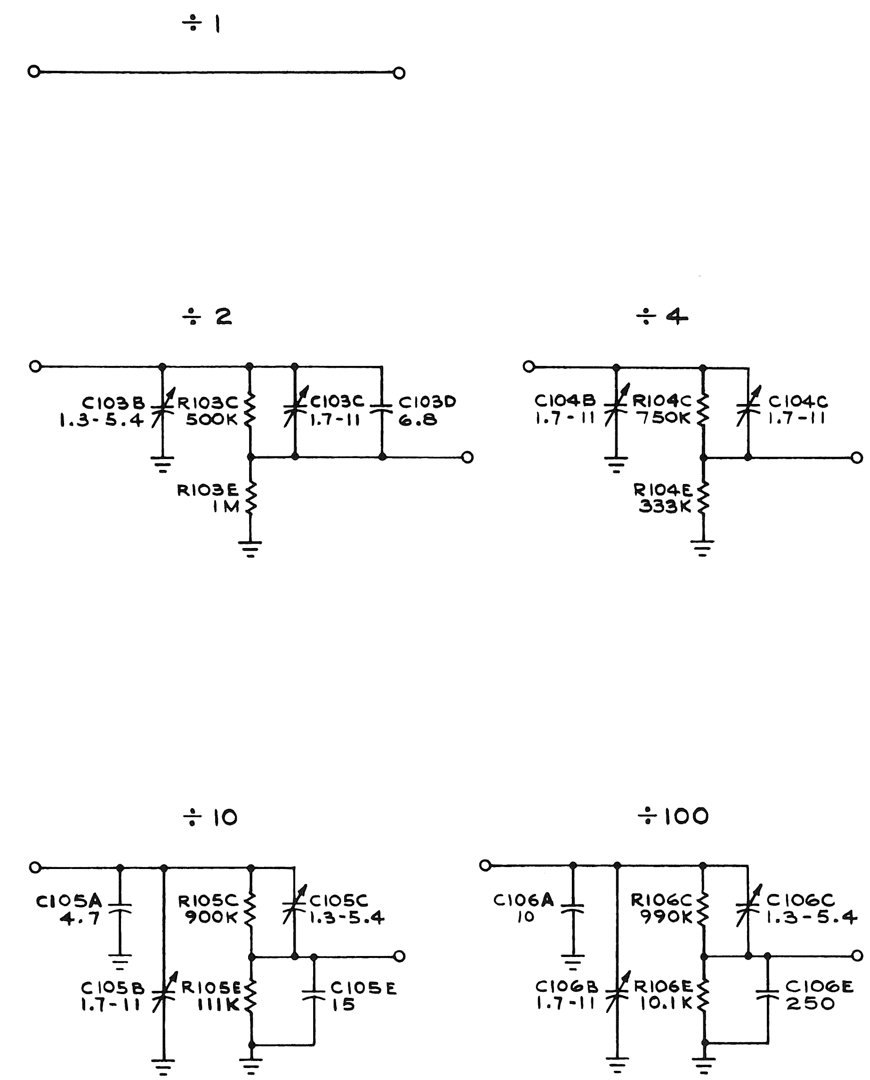
E

CHANNEL 2 INPUT AMPLIFIER ② 0271
S/N 20,000 - UP

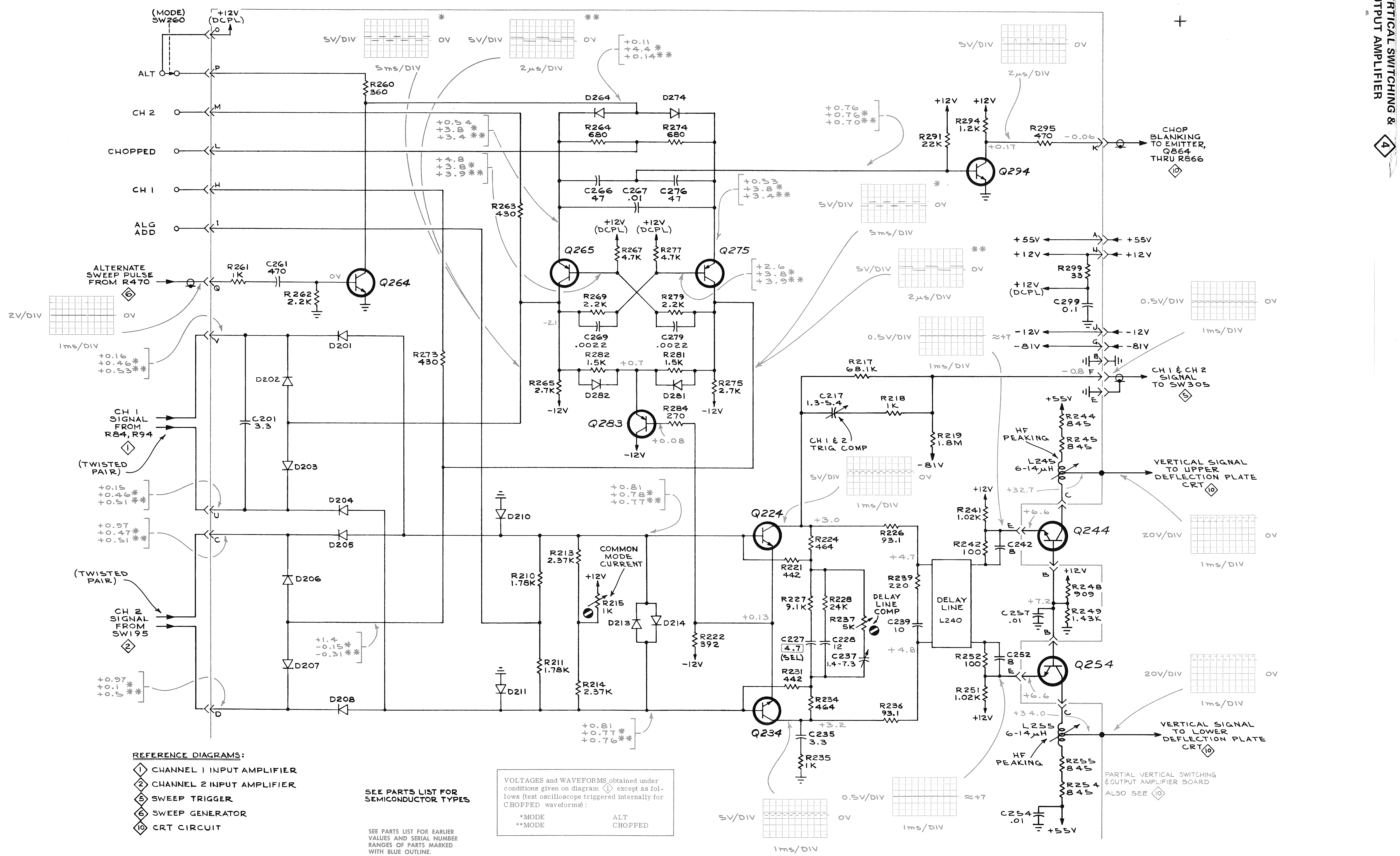
CH 2 INPUT AMPLIFIER ②



CHANNEL 1



CHANNEL 2



REFERENCE DIAGRAMS:

1. CHANNEL 1 INPUT AMPLIFIER
2. CHANNEL 2 INPUT AMPLIFIER
5. SWEEP TRIGGER
6. SWEEP GENERATOR
10. CRT CIRCUIT

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

VOLTAGES and WAVEFORMS obtained under conditions given on diagram 1 except as follows (test oscilloscope triggered internally for CHOPPED waveforms):

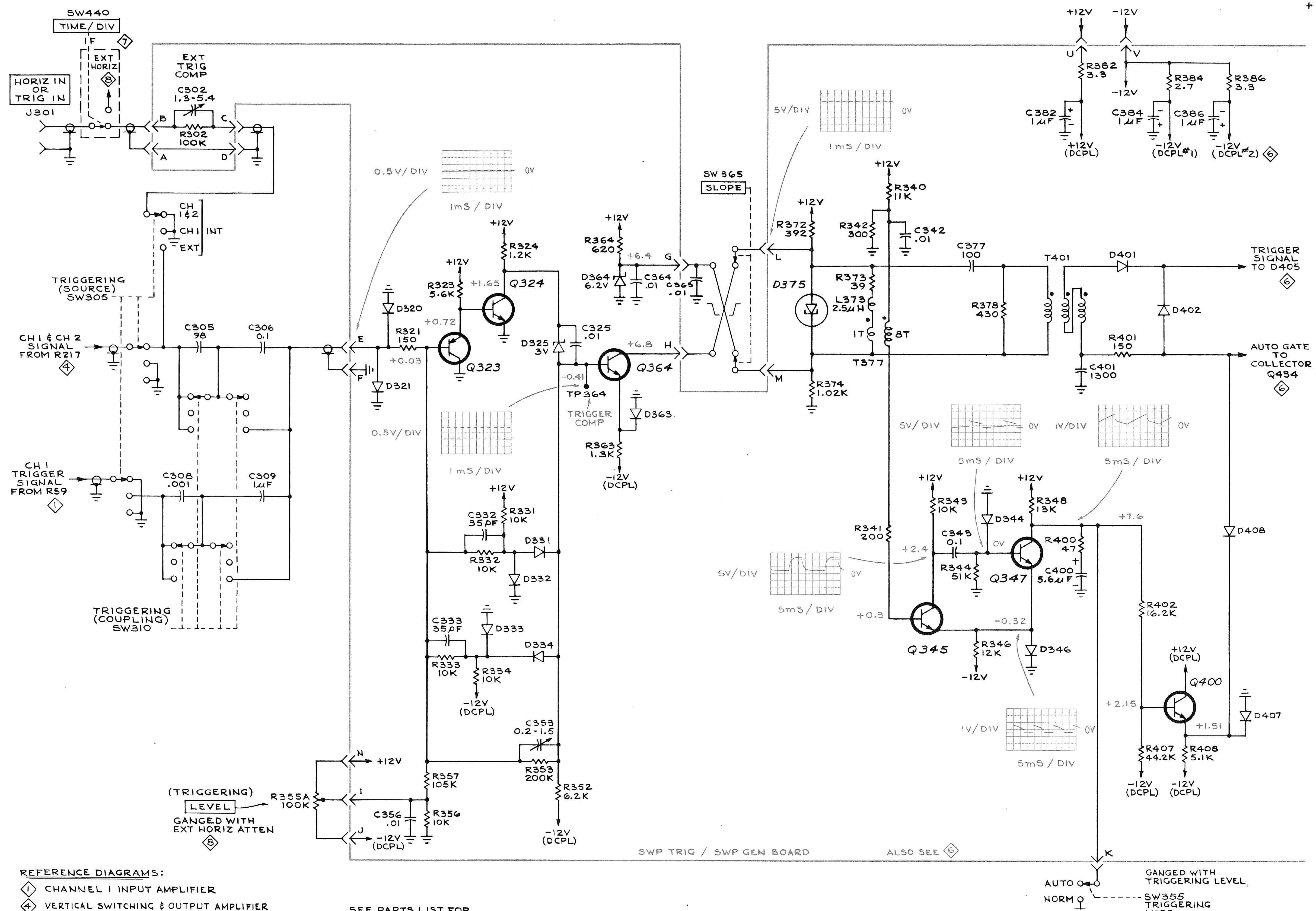
*MODE ALT
**MODE CHOPPED

TYPE 422 AC-DC

B

0870

VERTICAL SWITCHING & OUTPUT AMPLIFIER 4
(S/N 20,000-UP)



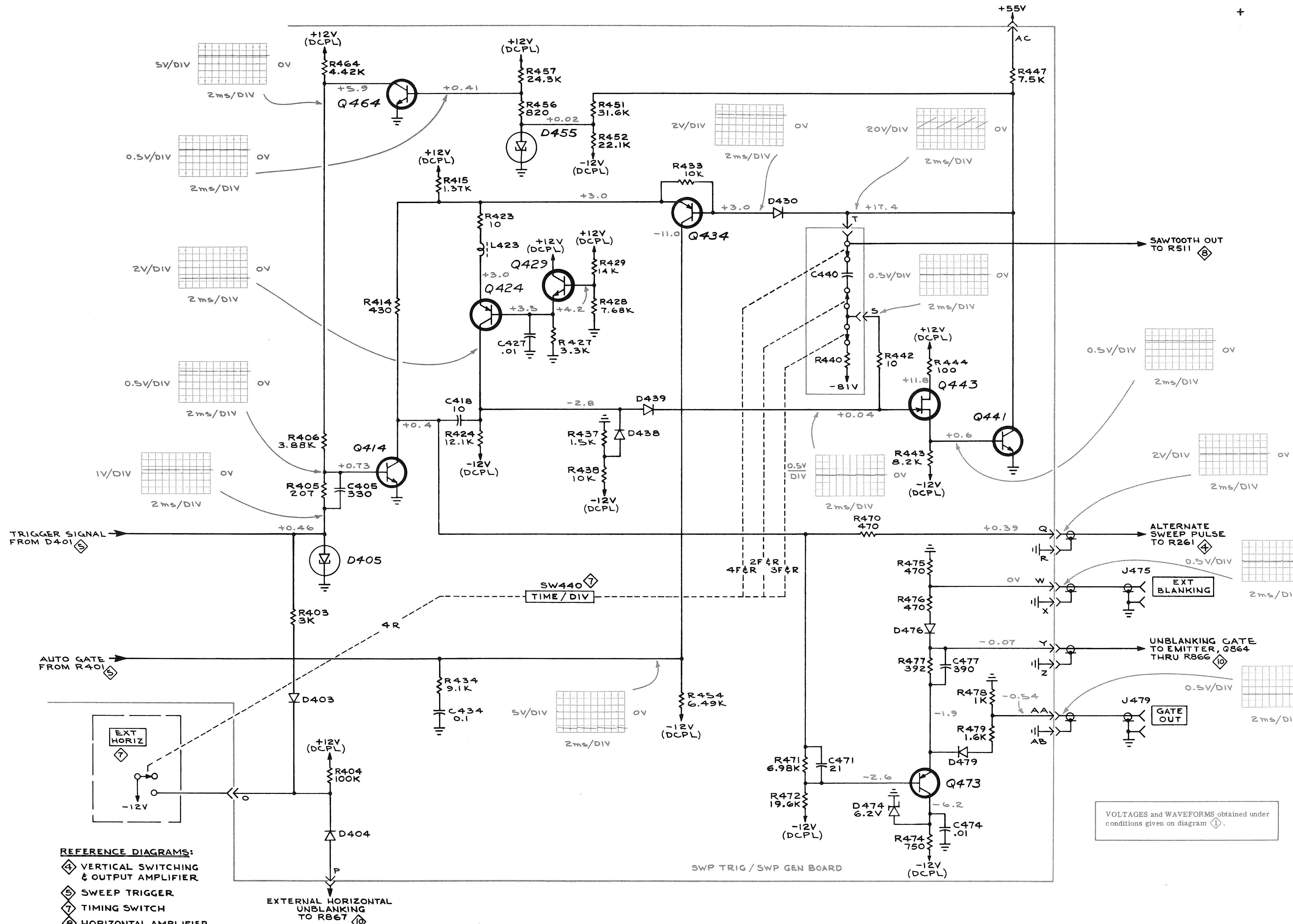
REFERENCE DIAGRAMS:

- 1 CHANNEL 1 INPUT AMPLIFIER
- 4 VERTICAL SWITCHING & OUTPUT AMPLIFIER
- 6 SWEEP GENERATOR
- 7 TIMING SWITCH
- 8 HORIZONTAL AMPLIFIER

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

VOLTAGES and WAVEFORMS obtained under conditions given on diagram 1

SWEEP TRIGGER 5



VOLTAGES and WAVEFORMS obtained under conditions given on diagram 1.

REFERENCE DIAGRAMS:
- 4 VERTICAL SWITCHING & OUTPUT AMPLIFIER
- 5 SWEEP TRIGGER
- 7 TIMING SWITCH
- 8 HORIZONTAL AMPLIFIER
- 10 CRT CIRCUIT

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

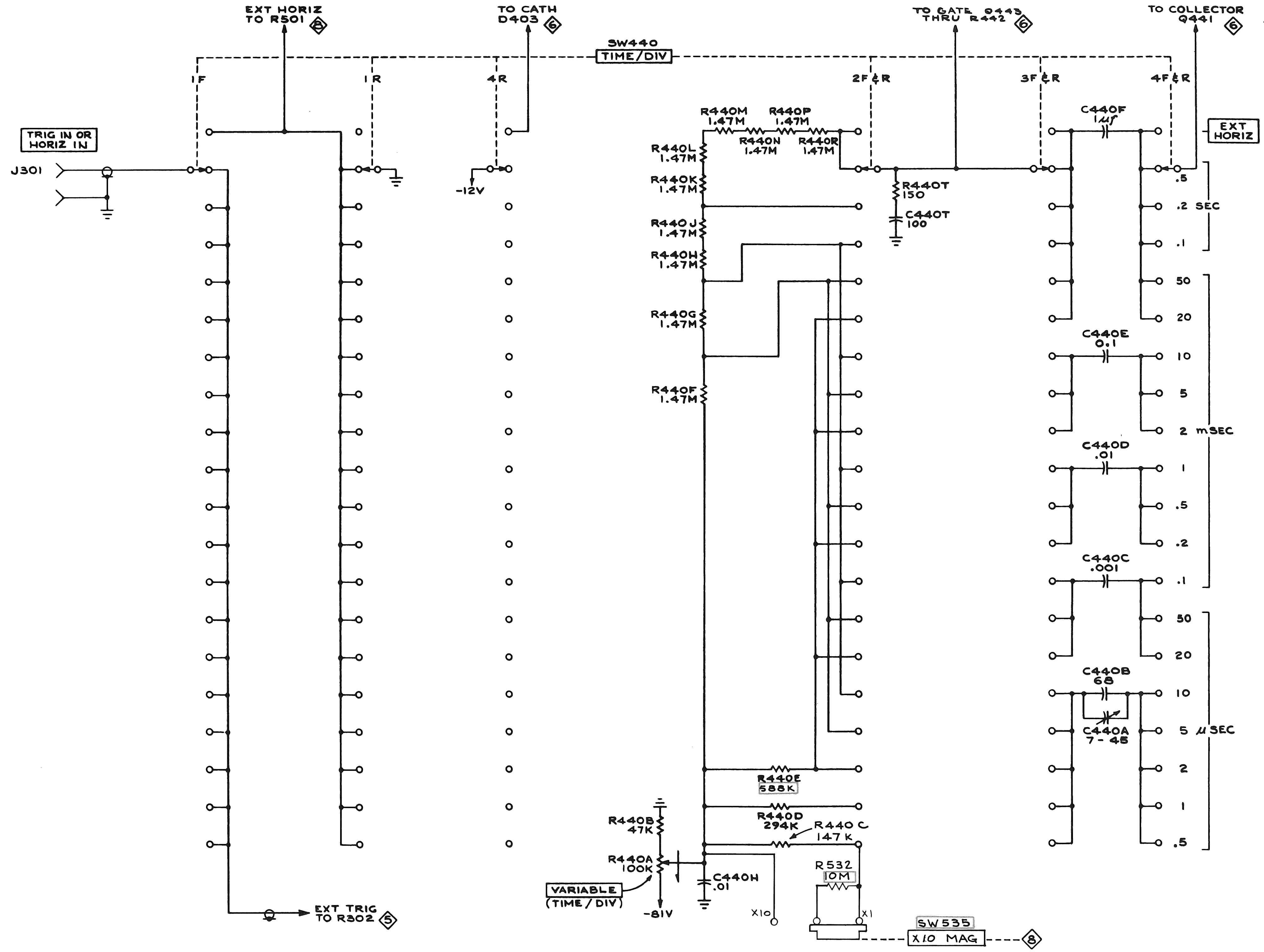
1268

TYPE 422 AC-DC

A1

SWEEP GENERATOR 6
(S/N 20,000-UP)

SWEEP GENERATOR 6



REFERENCE DIAGRAMS:

- 5 SWEEP TRIGGER
- 6 SWEEP GENERATOR
- 8 HORIZONTAL AMPLIFIER

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.

TYPE 422 AC-DC

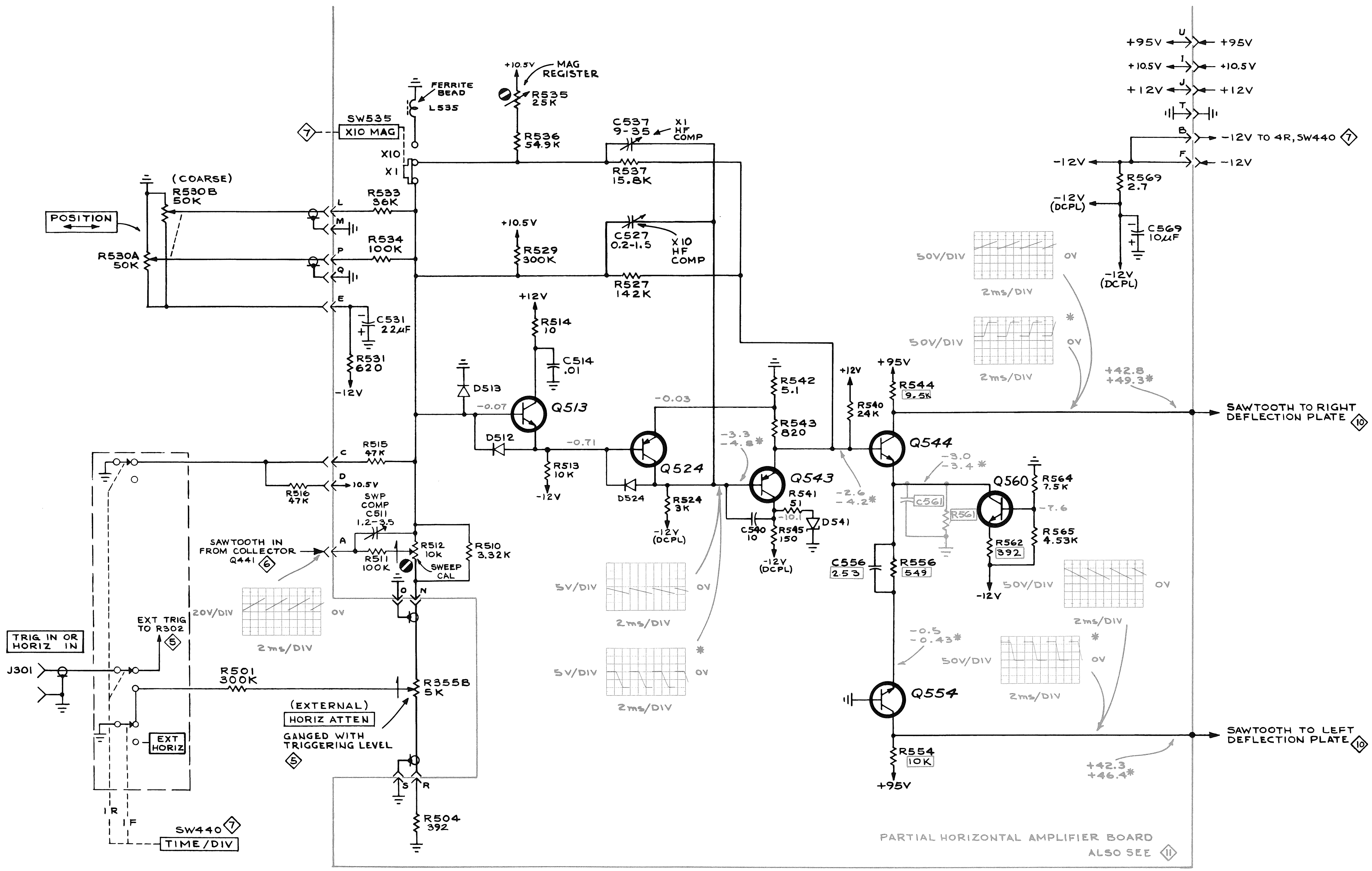
©

869

TIMING SWITCH 7

(S/N 20,000 - UP)

TIMING SWITCH 7



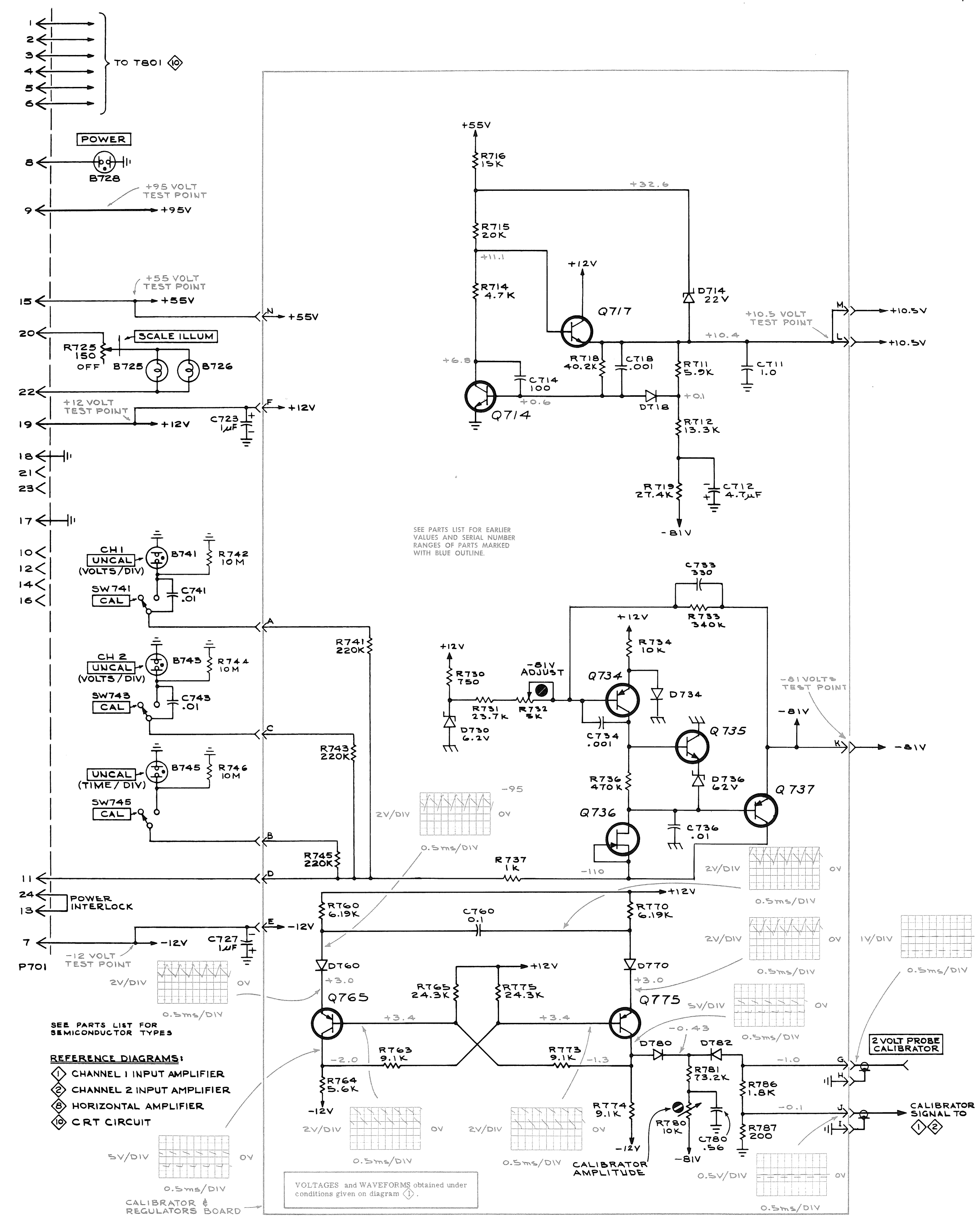
VOLTAGES and WAVEFORMS obtained under conditions given on diagram ① except as follows:

*MAG X10 (pulled out)

REFERENCE DIAGRAMS:

- ⑤ SWEEP TRIGGER
- ⑥ SWEEP GENERATOR
- ⑦ TIMING SWITCH
- ⑩ CRT CIRCUIT

SEE PARTS LIST FOR SEMICONDUCTOR TYPES



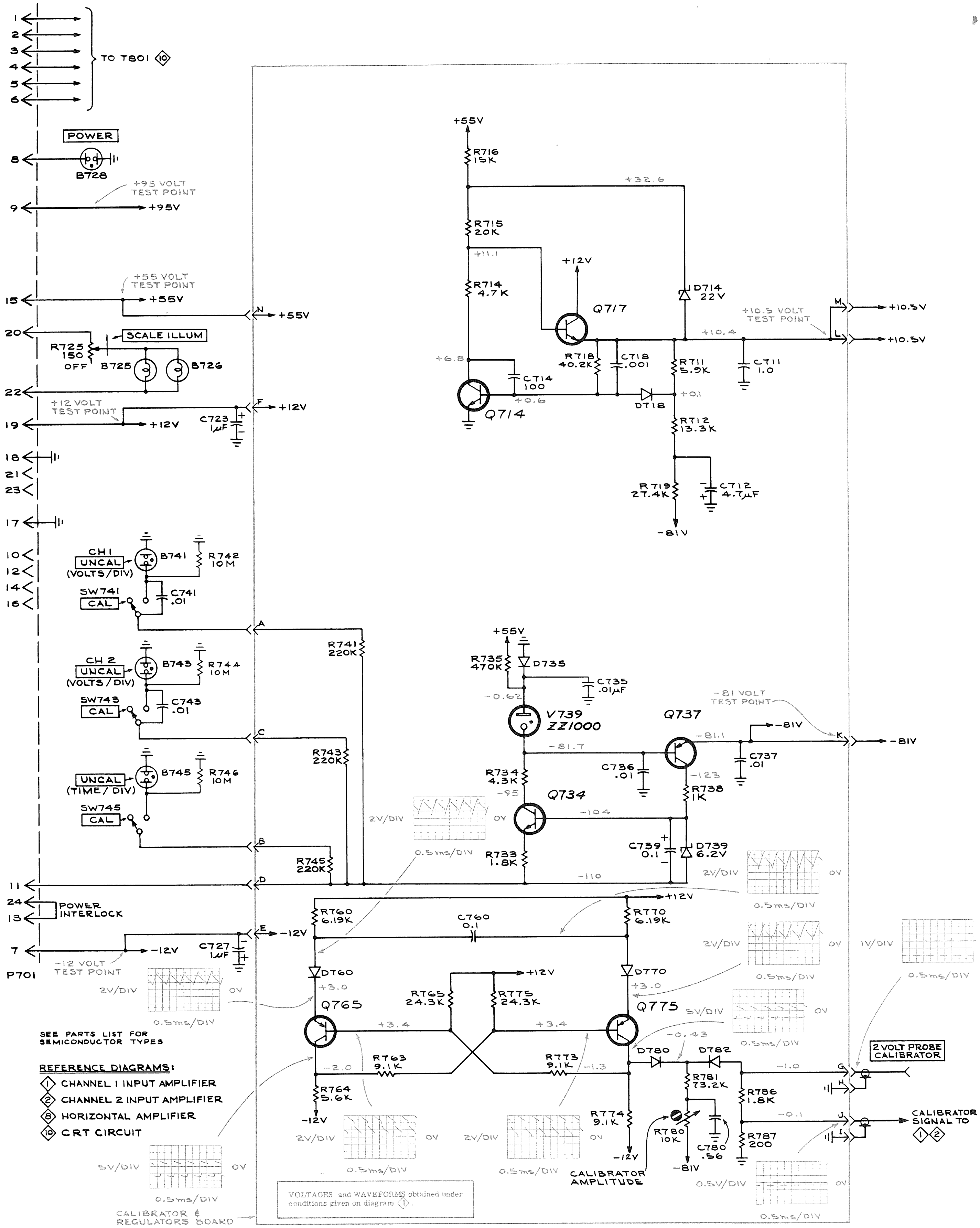
CALIBRATOR & REGULATOR 9

TYPE 422 AC-DC

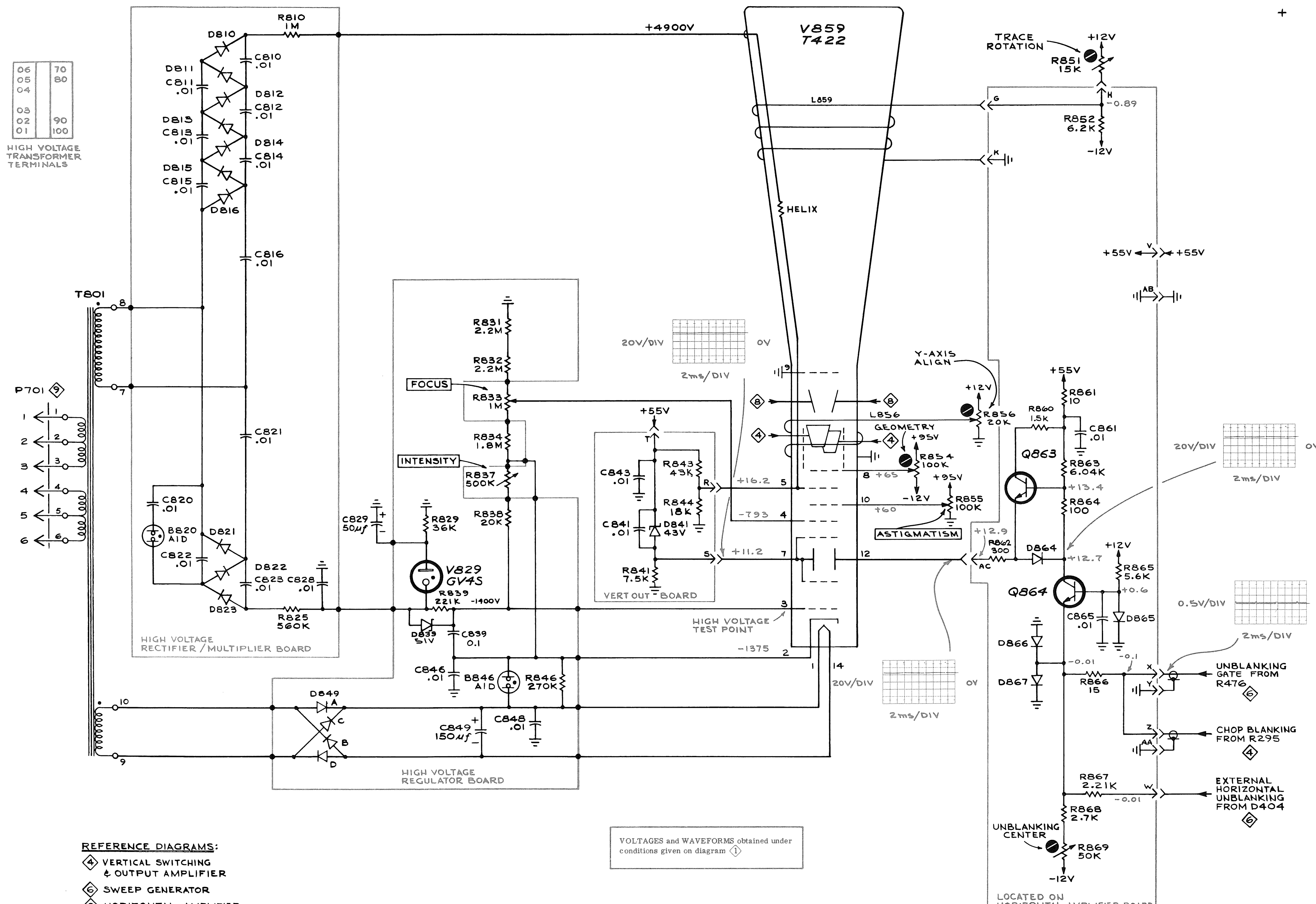
A

0870

CALIBRATOR & REGULATORS 9
(S/N 28,000-UP)



CALIBRATOR & REGULATOR 9

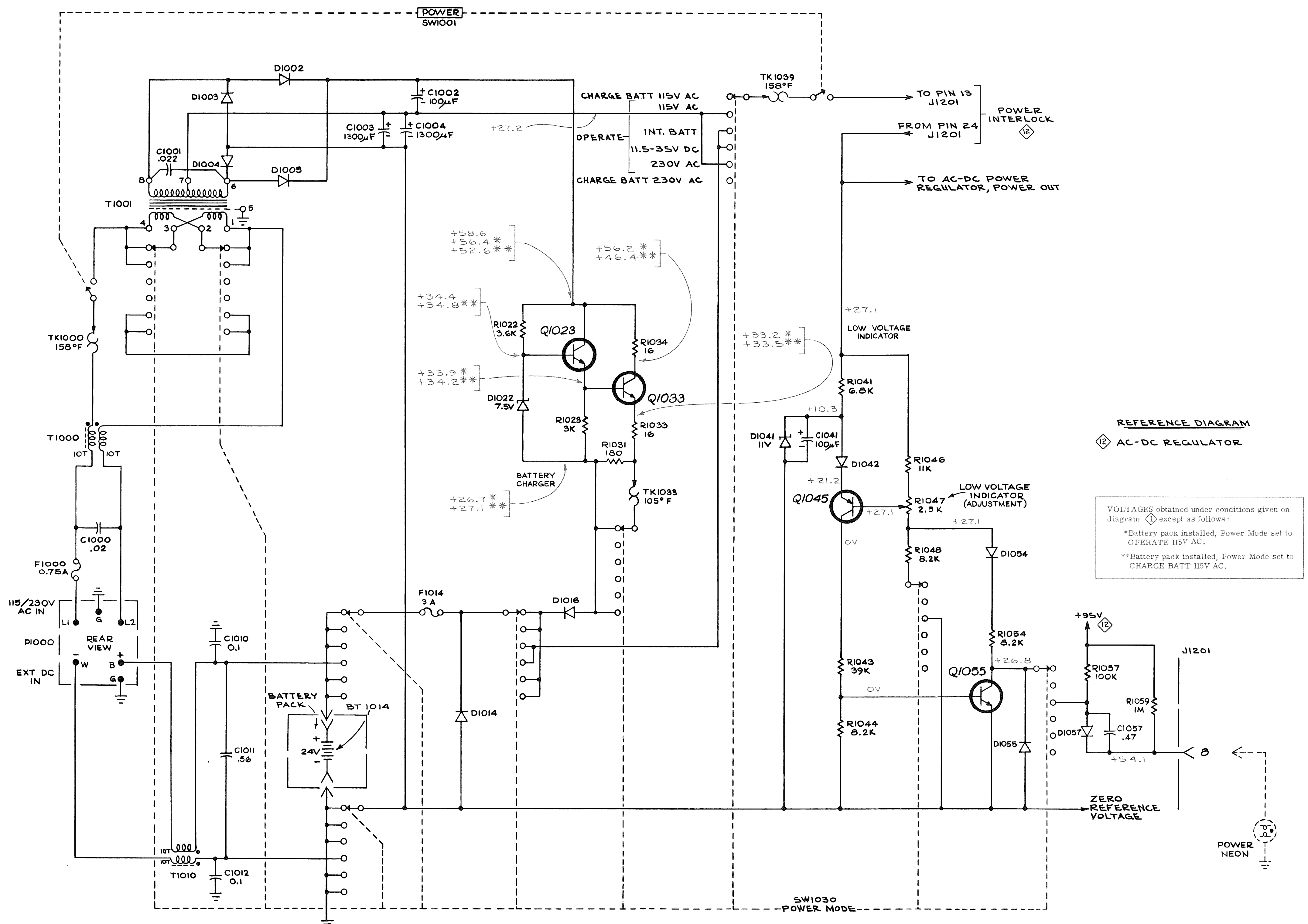


REFERENCE DIAGRAMS:

- 4 VERTICAL SWITCHING & OUTPUT AMPLIFIER
- 6 SWEEP GENERATOR
- 8 HORIZONTAL AMPLIFIER
- 9 CALIBRATOR & REGULATORS

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

1268



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

1268

TYPE 422 AC-DC

A

AC-DC POWER SELECTOR 11
(S/N 20,000-UP)

AC-DC POWER SELECTOR 11

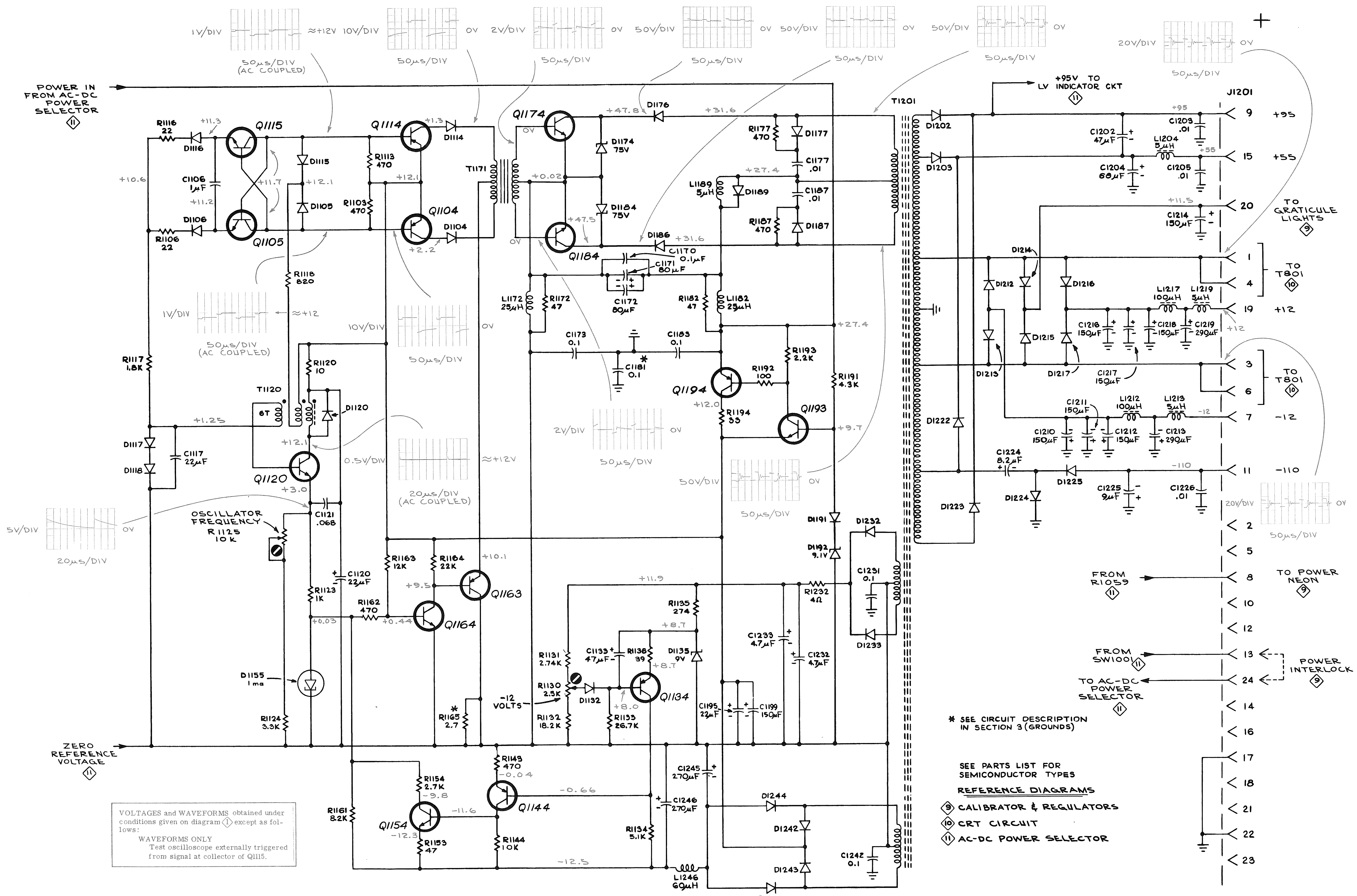
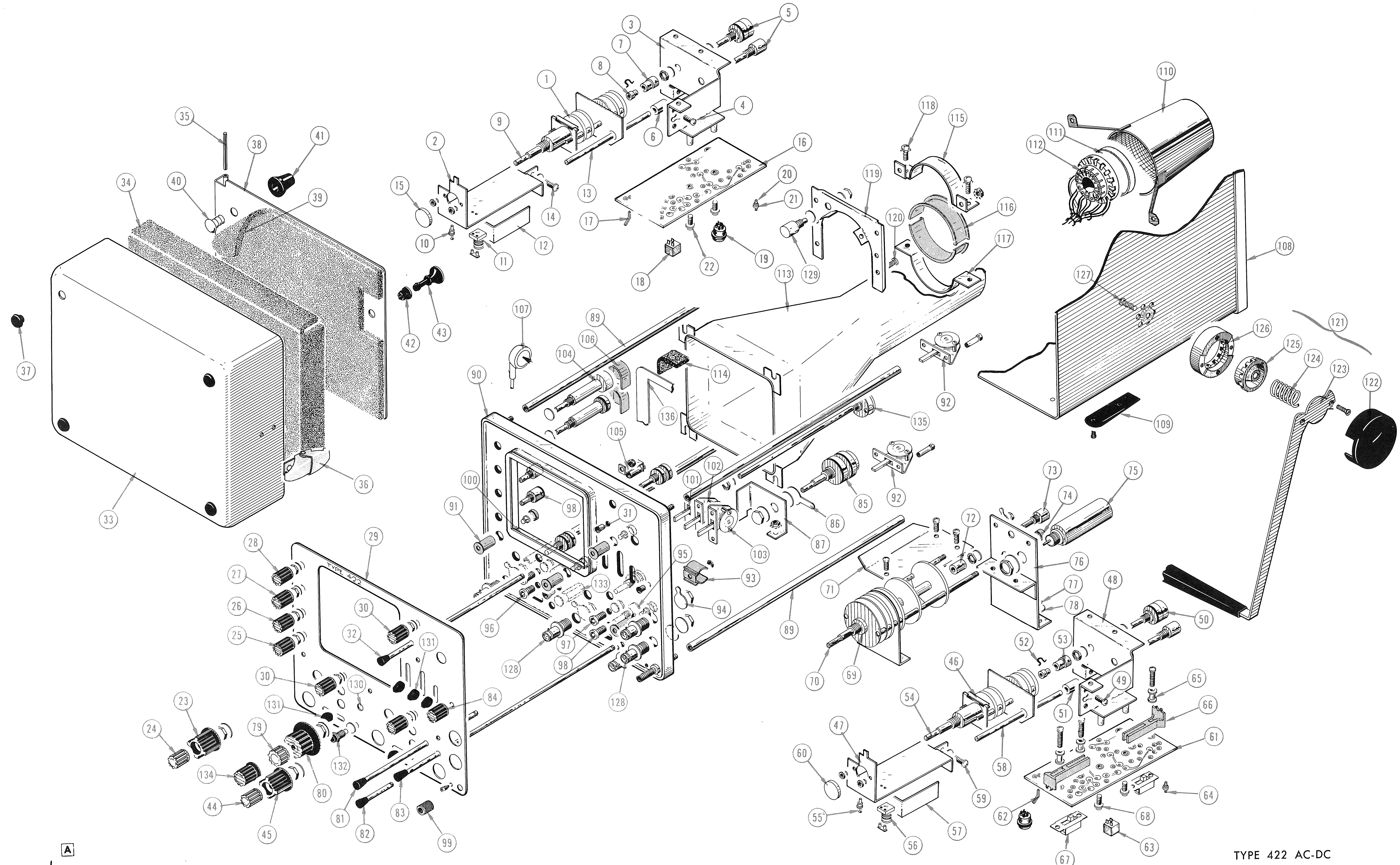
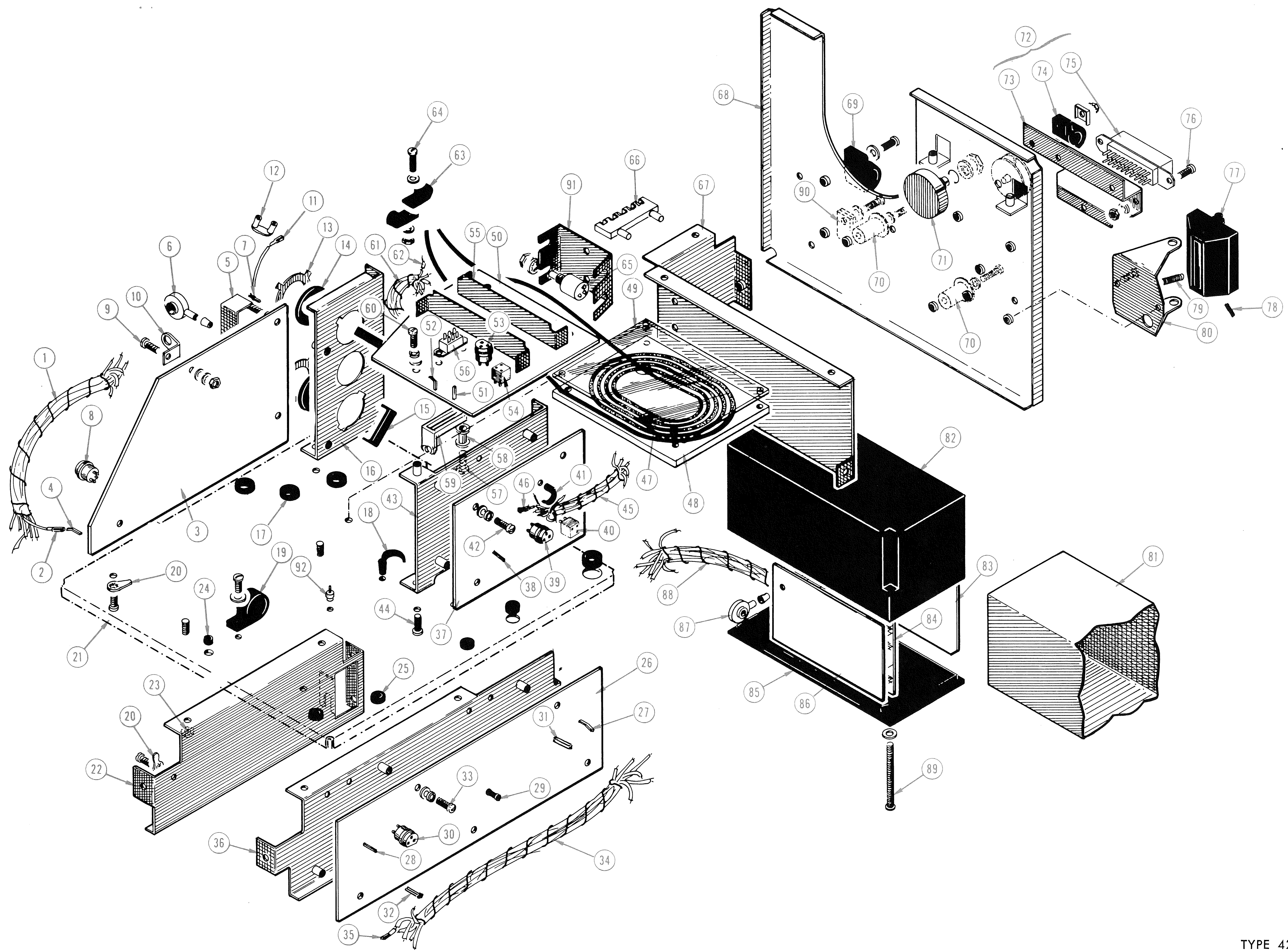

POWER IN FROM AC-DC POWER SELECTOR (11)
ZERO REFERENCE VOLTAGE (11)
Q1115
Q1105
Q1114
Q1104
Q1174
Q1184
Q1120
Q1163
Q1164
Q1194
Q1193
Q1134
Q1154
Q1144
T1171
T1120
T1201
J1201
OSCILLATOR FREQUENCY R1125 10K
D1155 1 ma
-12 VOLTS
+95V TO LV INDICATOR CKT (11)
+95
+55
TO GRATICULE LIGHTS (9)
TO T801 (10)
+12
-12
-110
FROM R1059 (11)
TO POWER NEON (9)
FROM SW1001 (11)
TO AC-DC POWER SELECTOR (11)
POWER INTERLOCK (9)
1V/DIV
10V/DIV
2V/DIV
50V/DIV
20V/DIV
5V/DIV
0.5V/DIV
50μs/DIV
50μs/DIV (AC COUPLED)
20μs/DIV
20μs/DIV (AC COUPLED)
* SEE CIRCUIT DESCRIPTION IN SECTION 3 (GROUNDS)
SEE PARTS LIST FOR SEMICONDUCTOR TYPES
REFERENCE DIAGRAMS
(9) CALIBRATOR & REGULATORS
(10) CRT CIRCUIT
(11) AC-DC POWER SELECTOR
VOLTAGES and WAVEFORMS obtained under conditions given on diagram (1) except as follows:
WAVEFORMS ONLY
Test oscilloscope externally triggered from signal at collector of Q1115.

FIG 1 FRONT



A

TYPE 422 AC-DC


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92

A

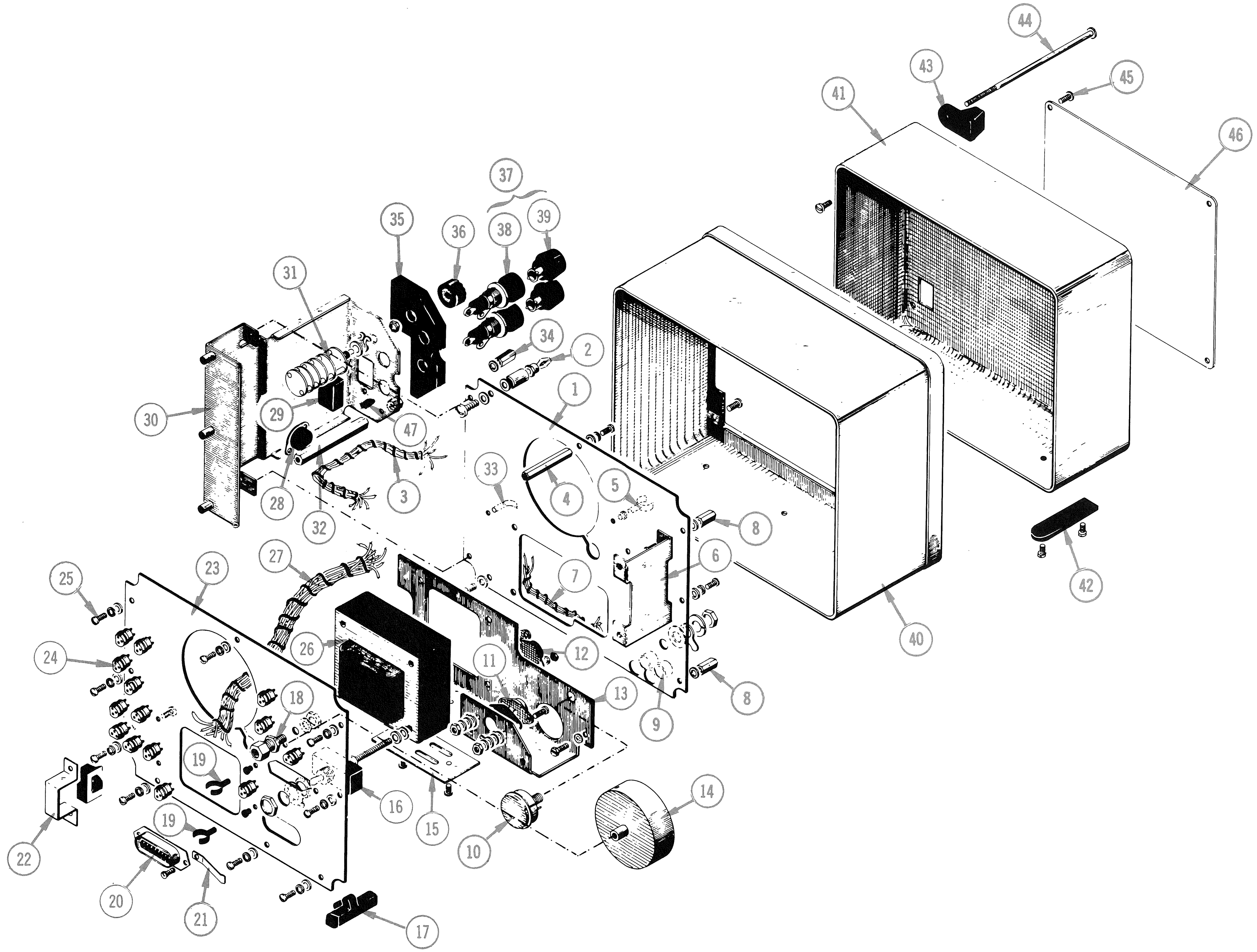

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FIG 4 ACCESSORIES

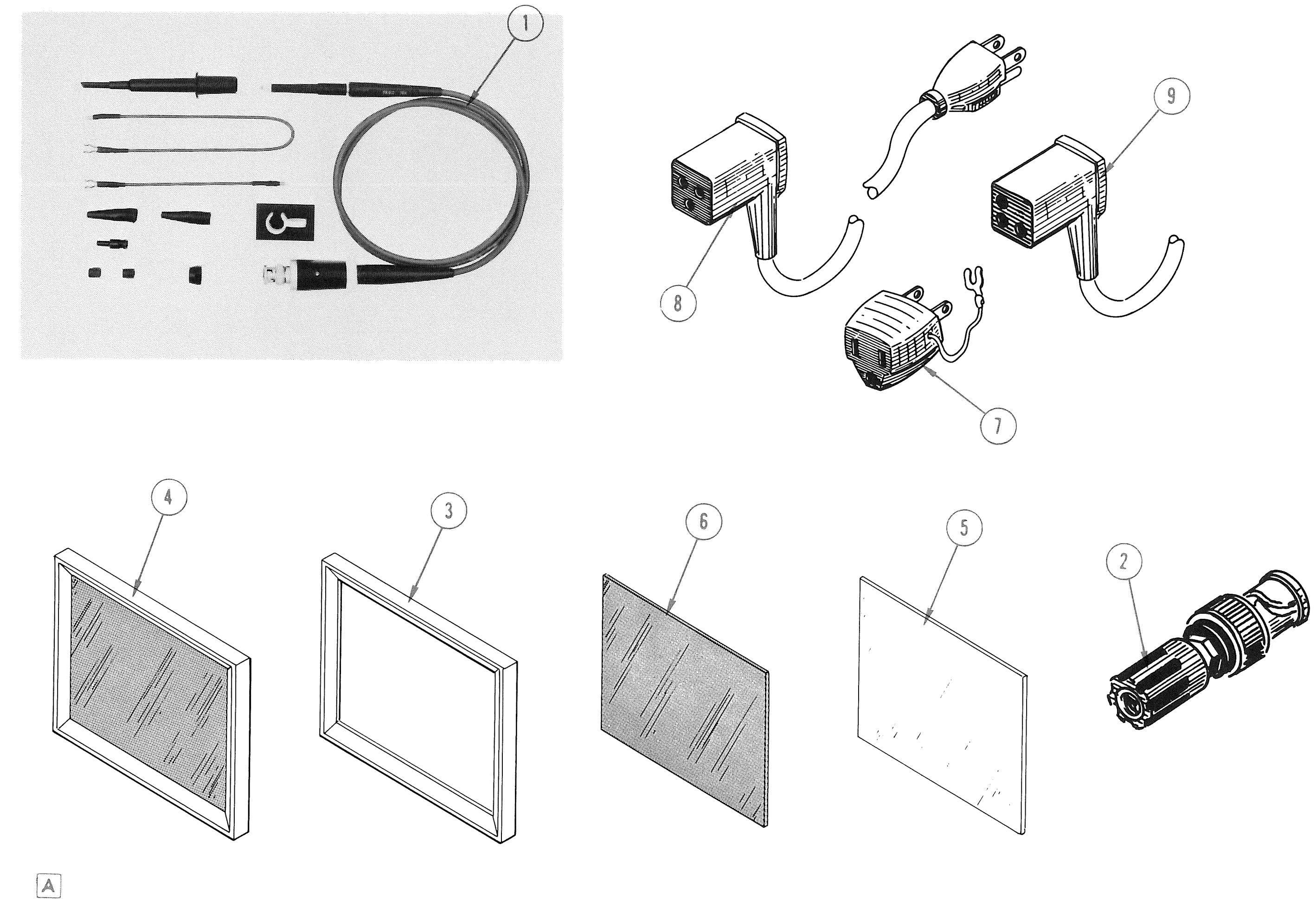


FIG. 4 ACCESSORIES

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	1 2 3 4 5 Description
4-1	010-0203-00			2	PROBE PACKAGE, P6012, 10X, 42 inches BNC
-2	103-0033-00			1	ADAPTER, BNC to binding post
-3	354-0248-00			1	RING, ornamental
-4	378-0571-00			1	FILTER, mesh (installed)
-5	386-0118-00			1	PLATE, protector, CRT, clear
-6	378-0549-00			1	FILTER, light
-7	103-0013-00[1]			1	ADAPTER, power cord, 3 to 2 wire
-8	161-0015-01[1]			1	CORD, power, 18 ga. 8 ft. 3 wire, AC
-9	161-0016-01[1]			1	CORD, power, 18 ga. 8 ft. 3 wire, DC
	070-0895-00			2	MANUAL, instruction (not shown)

[1] **All furnished with power supply when purchased separately**

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.

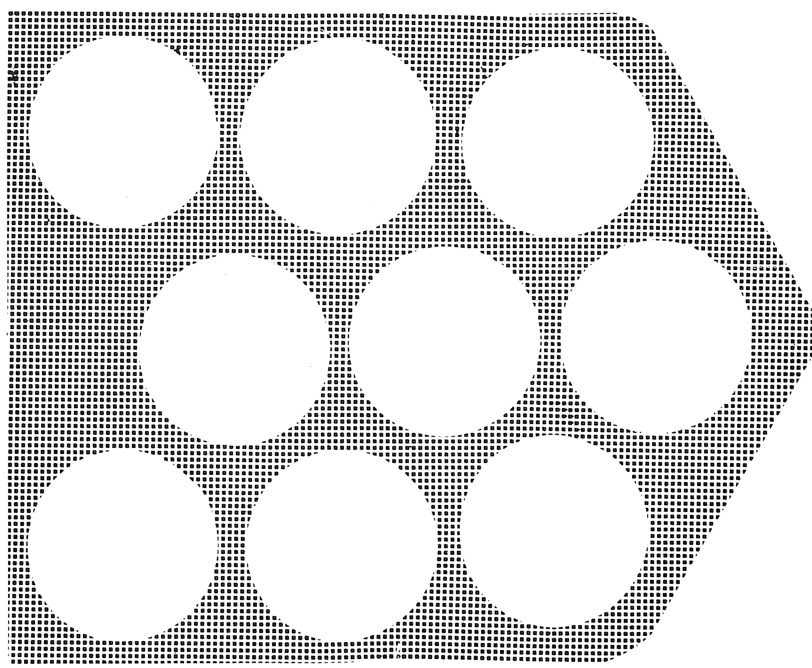
STANDARD ACCESSORIES CORRECTION

FIG. 4 ACCESSORIES

CHANGE: Fig. & Index No. 4-4 to read:

-4	378-0648-00	1 FILTER, mesh (installed)

INSTALLATION INSTRUCTIONS
422 BATTERY PACK



070-0549-00 566

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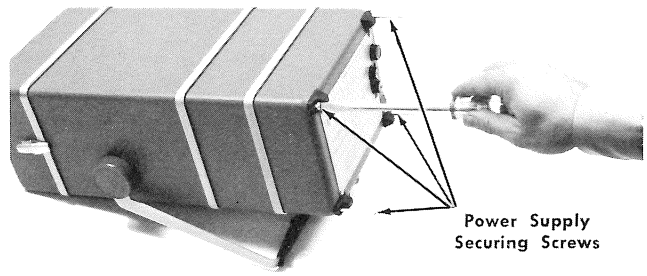
BATTERY PACK

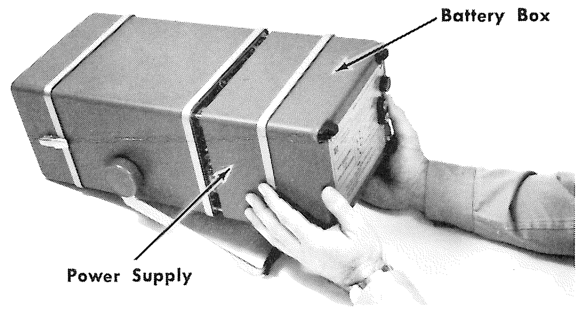
INSTALLATION INSTRUCTIONS
422 BATTERY PACK

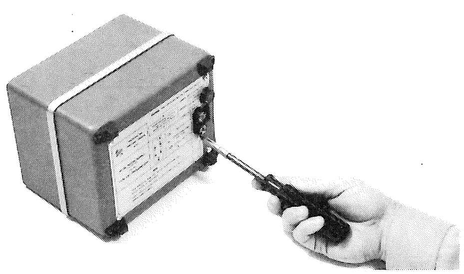
1. Removing the Power Supply and Battery Box

a. Loosen and remove the four power supply securing screws located in the rear feet of the instrument.

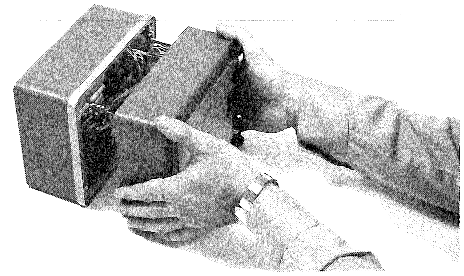


b. Separate the power supply and battery box from the indicator unit by sliding them to the rear and off the support rods.



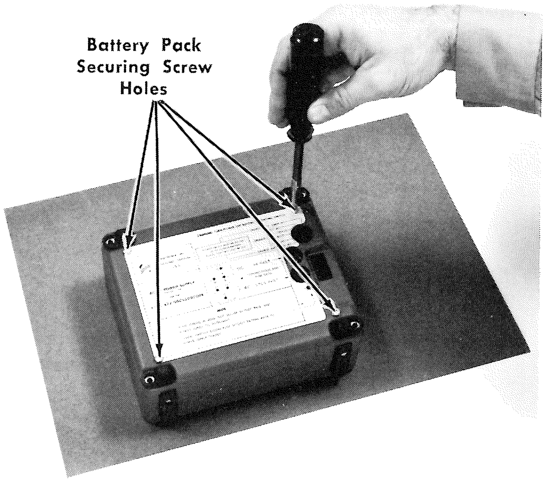


c. Loosen and remove the screw located just below the fuse holders.



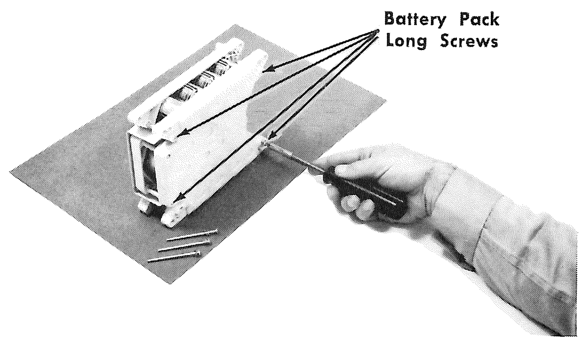
d. Detach the battery box from the power supply.

2. Attaching the Battery Pack

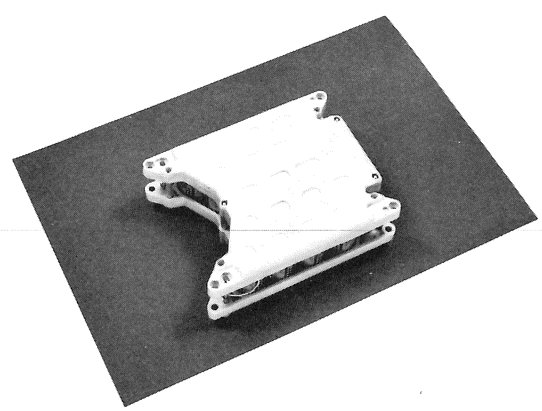


a. Remove and discard the four screws from the Battery Pack securing screw holes.

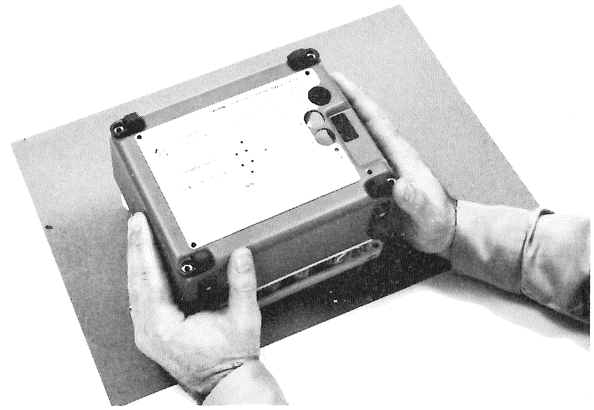
b. Loosen and remove from the Battery Pack the four long screws which go through it near its corners.

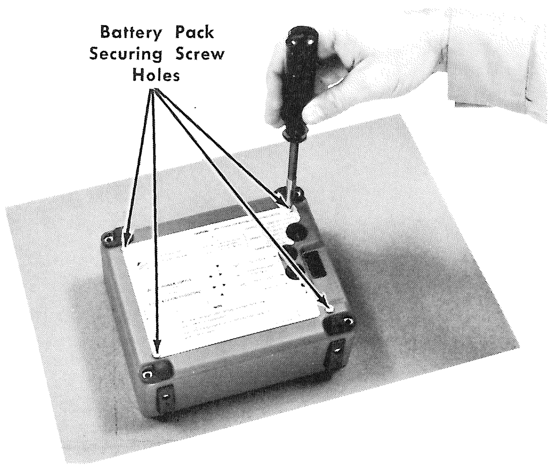


c. Set the Battery Pack on a non-conducting flat surface so it is resting on its interconnecting banana jacks and spring bracket.



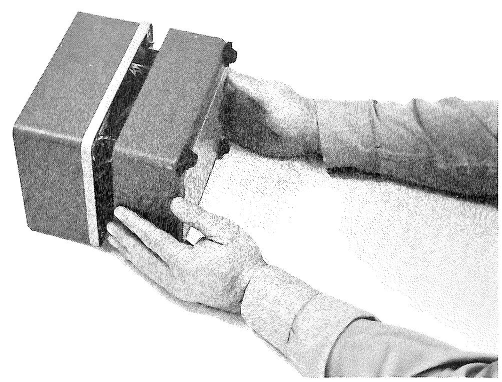
d. Place the battery box over the Battery Pack so that the cutout in the Battery Pack is directly under the knob, fuse and input connector holes in the battery box.

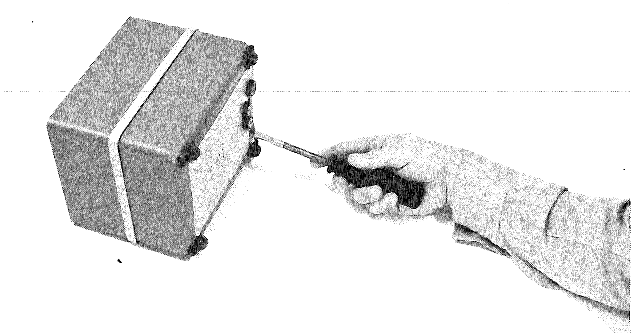




e. Start each of the four long screws, removed from the Battery Pack in step 2b into the four holes indicated, then tighten the four screws securely.

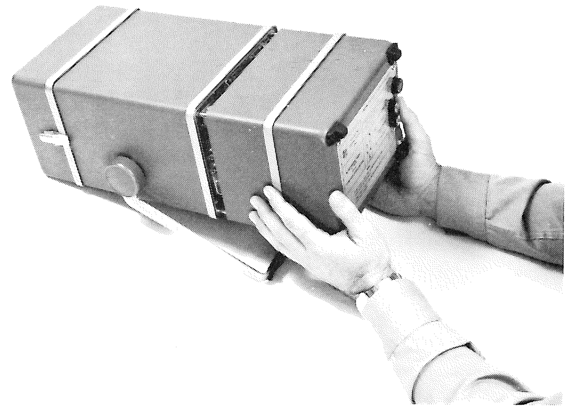
f. Install the battery box/Battery Pack onto the power supply, guiding the interconnecting banana jacks onto the banana plugs of the power supply.



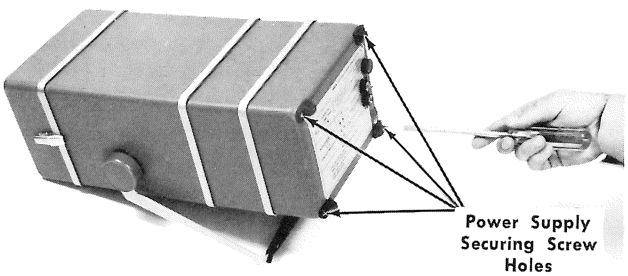


g. Re-install and securely tighten the screw removed in step 1c.

3. Attaching the Power Supply



a. Slide the power supply onto the four support rods protruding from the indicator unit.



b. Start the four screws removed in step 1a into the holes located in the four rear feet of the power supply; then tighten all four screws securely.

This completes the Battery Pack installation procedure. For more information on the Battery Pack refer to the instruction manual for the Type 422 AC-DC Power Supply.

BATTERY-PACK INFORMATION

Battery Precautions

The Nickel-Cadmium battery cells used in the AC-DC Power Supply have been selected as a result of extensive evaluation. Each battery cell in the battery pack has received on ampere-hour test, has met or exceeded the minimum ampere-hour storage requirement and has been rigidly inspected. The battery cells used in the battery pack should provide a useful operating life extending over several hundred charge-discharge cycles.

To extend the useful operating life of the Nickel-Cadmium battery cells used in this instrument, observe the following precautions.

1. Do not exceed the recommended charge rate as provided by the AC-DC Power Supply.

2. Do not charge the battery pack at the full rate for extended periods beyond the recommended charge time.

3. Excessive discharge of the battery pack after the POWER light begins to blink may cause one or more of the cells to reverse polarity. Although the cells are protected against immediate damage, repeated polarity reversal will shorten the useful life of the batteries.

4. Observe the temperature limits given in the manual for battery charging, operation and storage.

Battery Charging

The battery pack of the AC-DC Power Supply can be charged from either a 115-volt or 230-volt (nominal) AC line-voltage source. In the CHARGE BATT 230 V AC or CHARGE BATT 115 V AC positions of the Power Mode switch, the battery pack is charged at a 400 milliampere rate. In the OPERATE 230 V AC or OPERATE 115 V AC positions, the battery pack is trickle-charged at about a 30 milliampere rate. A 16-hour charge period in either of the CHARGE BATT positions should be sufficient to charge the battery pack to its full potential. Although the batteries may not be damaged immediately by longer charge periods, repeated over-charging will shorten the useful life of the batteries. A full charge level can be maintained on the battery pack by the 30 milliampere trickle charge available in the OPERATE 230 V AC or OPERATE 115 V AC positions (POWER switch must be pulled out).

The battery pack can be charged even when the AC-DC Power supply is removed from the indicator if the Power Mode switch is in the correct position and the POWER switch is turned on at the power supply. This feature provides a means of continuous operation from batteries if more than one supply is available. It also provides a method of trickle charging the battery pack without the instrument in operation if the batteries must be stored for long periods of time (Power Mode switch set to OPERATE 230 V AC or OPERATE 115 V AC).

The battery pack can be charged over an ambient temperature range of −15°C to +40°C. However, the maximum operating time and useful battery life is provided when the batteries are charged and discharged at about +25°C. Thermal cutouts in the AC-DC Power Supply protect the battery pack from overheating during charge time. The battery pack normally becomes warmer as it reaches full charge potential. If the temperature surrounding the battery pack exceeds the safe operating level, a thermal cutout switches the charge rate from the 400 milliampere full-charge to the 30 millampere trickle-charge rate. When the temperature returns to a safe operating level, the thermal cutout returns the charge rate to the 400 milliampere level. If the charge rate is reduced for an extended period during a charge cycle, the battery pack will not reach full charge in the recommended 16-hour charge time. Therefore, do not assume battery pack failure because of reduced operating time. Instead, recharge the battery pack for 16 hours at a reduced ambient temperature and check the operating time. If sufficient operating time is still obtained, the battery pack is probably defective (see Battery Pack Maintenance for more information).

During normal usage or storage, the individual battery cells in the battery pack acquire slightly different charge characteristics. To provide the best overall operation and maximum operating life, the charge on the individual battery cells should be equalized periodically. This can be done without damage to the battery cells by charging the batteries at the full charge rate for 24 hours (be sure ambient temperature is low enough to prevent opening of the thermal cutout). This should be done after every 15 charge-discharge cycles or every 30 days, whichever occurs first.

Battery-Pack Maintenance

WARNING

The battery pack is capable of delivering a very large current if accidentally short circuited. Be careful to prevent shorting the battery terminals or associated wires with tools metal work bench etc. A severe burn can be obtained if a ring, watch band, etc. comes in contact with the battery terminals.

When the battery pack is overcharged or when discharged to the point of polarity reversal, gas is formed within the Nickel-Cadmium cells. The Nickel-Cadmium cells used in the battery pack incorporate a vent so this internal pressure does not damage the battery. However, as the internal pressure is relieved, a small amount of the electrolyte may be expelled with the gas. Although the cells will not be damaged unless this happens repeatedly, this loss of electrolyte may result in shorter overall battery life. The battery box should be inspected occasionally for any electrolyte residue on the battery pack or in the battery compartment. Any residue which is found should be cleaned away with a 2% solution of boric acid in water. A 2% solution of boric acid can be obtained by dissolving 1¼ teaspoons of boric acid powder in one cup of water. After the residue has been cleaned from the battery pack and the battery compartment, dry the wetted area thoroughly with a soft cloth.

The Type 422 with AC-DC Power Supply provides about four hours of continuous operation from a fully charged battery pack. The actual operating time may vary due to the age of the batteries, number of charge-discharge cycles, signal applied, INTENSITY control setting and other factors. If the batteries do not provide the normal operating time, first completely charge the batteries for the recommended 16-hour charge period. If possible, charge the battery pack in an ambient temperature between +15° C and +25° C. This allows the battery pack to attain its maximum charge and also will minimize the chances that the battery pack protection thermal cutout will open because of excess temperature. Measure the potential across the interconnecting banana jacks of the power pack. A fully charged battery pack should measure about 24 volts. If the battery pack measures below 22 volts, either the battery charger circuit is inoperative or the battery pack is defective. The battery charger circuit can be checked for operation using the Calibration procedure in the manual. If the battery charger is working correctly and the voltage reads low, the battery pack is probably defective.

If the battery pack measures about 24 volts but the POWER light begins to blink too soon when operating from the batteries, either the battery pack has lost its charge retaining capacity or the low-batteries indicator circuit is defective. First be sure that the batteries have been charged properly for the recommended charge period. Then, operate the instrument from the batteries until the POWER light begins to blink. Now, measure the potential across the battery pack interconnecting terminals. If it is below about 22 volts, the battery pack has lost its charge retention capacity. If the voltage is above about 22 volts, the low-batteries indicator may be at fault.

If the battery pack is found to be defective, the entire battery pack should be returned to Tektronix, Inc. for maintenance. Contact your local Tektronix Field Office or representative for assistance. The battery pack should be regarded as a single power storage unit rather than as a set of individual cells. It is not designed to be disassembled for inspection or repair. Refer all maintenance on the battery pack itself to Tektronix, Inc.

CAUTION

The warranty on this instrument may be altered if the sealed case-retaining screws of the battery pack are removed.

Battery-Pack Storage

The battery pack used in the AC-DC Power Supply can be stored in a charged or a partially charged condition. For best shelf life when storing the battery pack for long periods of time, fully recharge the battery pack about every three months. Although the battery pack is fully charged when shipped from Tektronix, Inc., recharge the battery pack completely before operating the instrument.

Charge retention characteristics of Nickel-Cadmium batteries vary with the storage temperature and humidity. The battery pack may be stored at ambient temperatures between −40° C and +60° C without damage, either in the instrument or as a separate unit. However, the self-discharge rate increases with ambient temperature. For example, cells stored at +20° C will lose about 50% of their stored charge in three months but when stored at +50° C, they will be almost completely self-discharged in only one month. High humidity also increases the rate of self-discharge. If the instrument must be stored at either high ambient temperature or high humidity for an extended period of time, it is recommended that the battery pack be continuously trickle charged (charge battery pack completely at full-charge rate before extended trickle charge).

BATTERY PACK
(Part No. 016-0066-02)

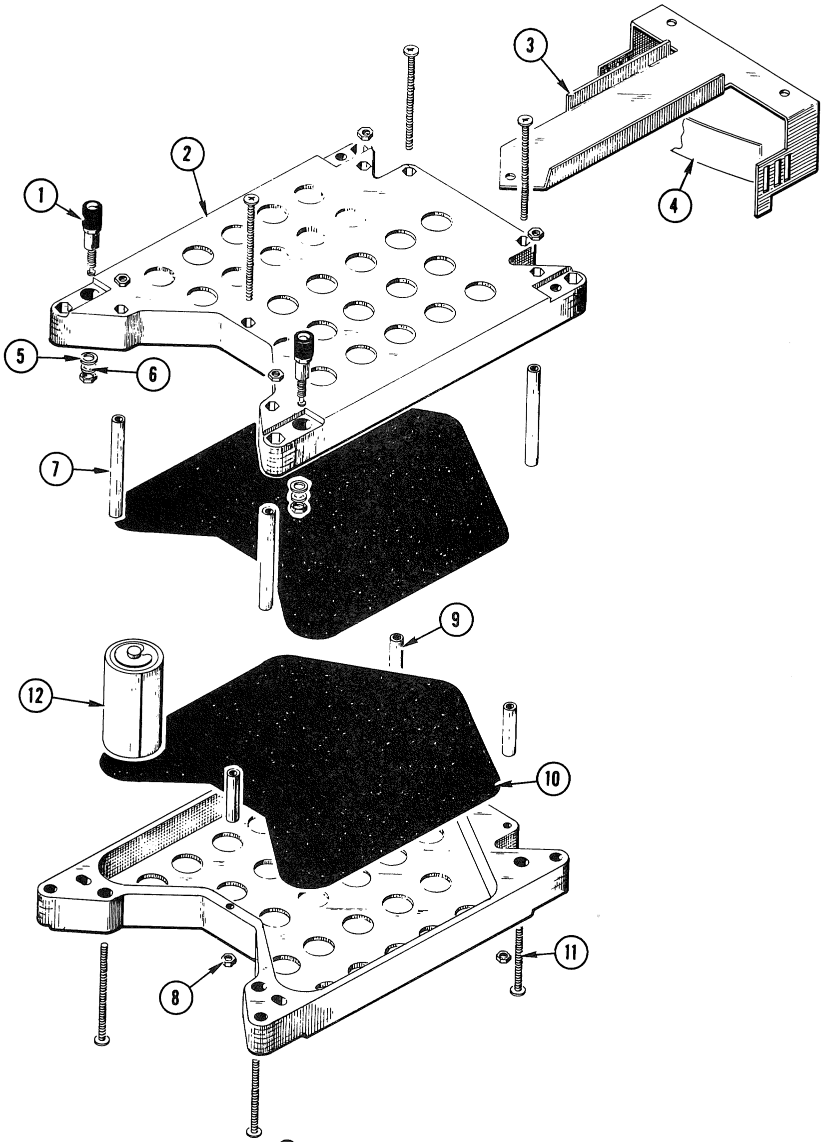


Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Disc	Qty	Description 1 2 3 4 5
1	355-0104-00			2	STUD, interconnecting
2	352-0085-00			2	HOLDER, battery, molded
3	407-0128-01			1	BRACKET, spring
4	214-0556-00			1	SPRING, 4.125 inches long
5	210-0802-00			9	WASHER, flat, 0.150 ID x 5/16 inch OD
6	210-0055-00			5	LOCKWASHER, internal, split, #6
7	166-0400-00			4	TUBE, spacer, 1.453 inches long
8	220-0456-00			9	NUT, hex., 6-32 x 1/4 inch
9	166-0039-00			3	TUBE, spacer, 1 inch long
10	348-0076-00			2	CUSHION, foam
11	211-0594-00			7	SCREW, 6-32 x 2 1/2 inches, THS
12	146-0010-00			20	BATTERY, D size, w/solder tab

DATA SHEET

NO. 062-0672-00

DATE AUG. 1969(R)

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