

K4XL's **BAMA**

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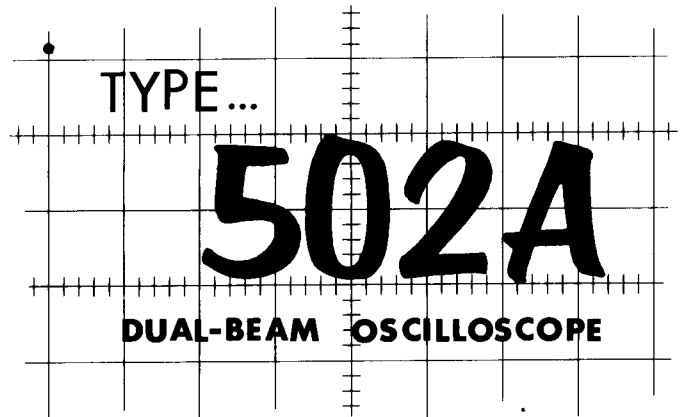
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INSTRUCTION MANUAL

Serial Number _____



Tektronix, Inc.

S.W. Millikan Way • P. O. Box 500 • Beaverton, Oregon • Phone MI 4-0161 • Cables: Tektronix
070-382



WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own 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 number with all requests for parts or service.

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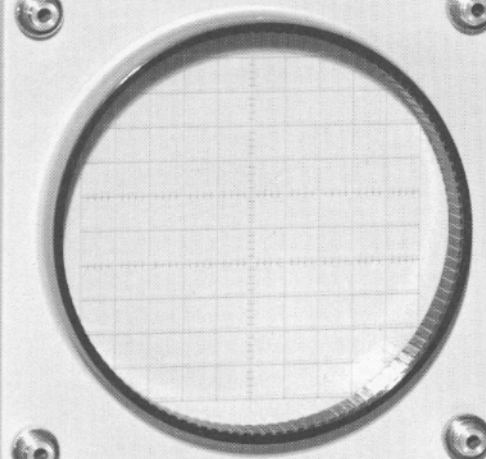


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TYPE 502A DUAL-BEAM OSCILLOSCOPE

SERIAL



TIME BASE

STABILITY ADJUST

TRIGGERING LEVEL: AUTOMATIC, RECURRENT

TRIGGER INPUT

TRIGGER SELECTOR: UPPER DC, LOWER AC, DC, EXT. DC, LINE

MODE: NORMAL, SINGLE SWEEP

RESET, READY

VARIABLE TIME/CM: mSEC (10, 5, 2, 1, .5, .2, .1), SEC (1, .5, .2, .1), μSEC (10, 5, 2, 1, .5, .2, .1)

SWEEP MAGNIFIER: ON, UNCALIBRATED, CALIBRATED

UPPER FOCUS, LOWER FOCUS, INTENSITY, INTENSITY BALANCE, POWER AND SCALE ILLUM (PWR OFF)

LIGHT INDICATES UPPER-BEAM AMPPLIFIER IS CONNECTED TO THE HORIZ DEF. PLATES (SWITCH: LEFT SIDE OF CABINET)

HORIZONTAL DISPLAY

SWEEP MAGNIFIED: X2, X5, X10, X20

NORMAL (X1)

EXT VOLTS/CM

POSITION

EXTERNAL

UPPER BEAM VERTICAL

AC, DC, A-B (DIFF), A-B (INVERTED)

VARIABLE SENSITIVITY: VOLTS PER CM (1, .5, .2, .1), mVOLTS PER CM (10, 5, 2, 1, .5, .2, .1)

DC BAL, POSITION

LOWER BEAM VERTICAL

AC, DC, A-B (DIFF), A-B (INVERTED)

VARIABLE SENSITIVITY: VOLTS PER CM (1, .5, .2, .1), mVOLTS PER CM (10, 5, 2, 1, .5, .2, .1)

DC BAL, POSITION

AMPLITUDE CALIBRATOR

PEAK-TO-PEAK

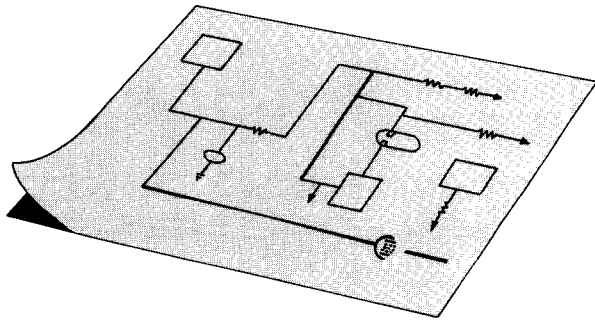
5 MV, 50 MV, 5 V, 50 V

OFF, CAL OUT

TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.

SECTION 1

CHARACTERISTICS



General

The Tektronix Type 502A Oscilloscope provides linear dual-beam displays with a wide range of sweep rates combined with high input sensitivity. In addition, the Type 502A may be used to provide dual-beam X-Y displays at medium sensitivities, and single-beam X-Y displays at high sensitivities. Vertical amplifiers for both beams may be operated with single-ended inputs for conventional operation, or with differential inputs for cancellation of common-mode signals. The wide range of operational modes available makes the Type 502A adaptable to a great many industrial and scientific applications.

VERTICAL-DEFLECTION SYSTEM

Characteristics at each input terminal

Direct connection—1 megohm paralleled by 47 pf.
 With P6006 Probe—10 megohms paralleled by approx. 9 pf.

Deflection factors

Seventeen calibrated deflection factors from 0.1 mv/cm to 20 v/cm accurate within 3%.

Continuously variable deflection factors are available from 0.1 mv/cm to approximately 50 v/cm. However, when the variable is used the frequency response in each range of the SENSITIVITY control will be slightly reduced.

Frequency response

Frequency response characteristics of the Type 502A vary with settings of the SENSITIVITY controls. Typical readings are as follows:

.1 mv/cm	50 kc
.2 mv/cm	100 kc
1 mv/cm	200 kc
50 mv/cm	400 kc
.2 v/cm	1 mc

Differential input rejection ratio

The rejection ratios specified below apply if the signal voltage at the Input connector does not exceed specified limits. The signal limits for dc coupling are, + or - 2 volts with respect to ground for settings of the SENSITIVITY control from 0.1 mv/cm to .2 v/cm, + or - 20 volts with respect to ground for settings from .5 v/cm to 2 v/cm, and + or - 200 volts with respect to ground for settings from 5 v/cm to

20 v/cm. For ac-coupling, the signal limits are 2 volts peak-to-peak from 0.1mv/cm, to .2 v/cm, 20 volts peak-to-peak from .5 v/cm to 2 v/cm, and 200 volts peak-to-peak from 5 v/cm to 20 v/cm.

The DC common mode rejection ratios are measured with a common sine-wave signal which is applied to both inputs of one vertical amplifier simultaneously. The sine-wave signal has a constant amplitude of 2 volts and a frequency as stated in the table below.

DC Common Mode Rejection Ratio

Sensitivity Setting	Sine-Wave Frequency	Rejection Ratio	(Sine-wave output held at a constant amplitude of 2 volts)
.2 VOLTS PER CM	1 kc	100:1	
.2 mVOLTS PER CM	1 kc	20,000:1	
† .1 mVOLTS PER CM	1 kc	40,000:1	
.2 VOLTS PER CM	400 kc	50:1	
.2 mVOLTS PER CM	100 kc	1000:1	
.1 mVOLTS PER CM	50 kc	2000:1	

† A rejection ratio of 40,000:1 can only be obtained if the DC BAL control has been properly adjusted.

HORIZONTAL-DEFLECTION SYSTEM

Sweep rates

Twenty-one calibrated sweep rates from 1 μ sec/cm to 5 sec/cm.

Accuracy typically within 1% of full scale; in all cases, within 3% of full scale.

Continuously variable sweep rates are available from 1 μ sec/cm to approximately 2.5 sec/cm.

Magnifier

Expands sweep 2, 5, 10, or 20 times. Calibration of magnified sweep rates accurate within 3% for sweep rates which do not exceed the maximum calibrated rate of 1 μ sec/cm.

Unblanking

DC coupled.

Triggering signal requirements

Internal—a signal producing 2 mm vertical deflection on either the UPPER or LOWER BEAM.

External—0.2 volts to 10 volts on either polarity.

Triggering signal sources

UPPER BEAM, LOWER BEAM, external, or line.

Characteristics—Type 502A

Input characteristics at TRIGGER INPUT connector

AC coupled—1 megohm in series with 0.01 μ f.

DC coupled—1 megohm.

Horizontal input

With UPPER BEAM amplifier connected to crt horizontal deflection plates:

Deflection factors of 0.1 mv/cm to 20 v/cm in 17 steps.

With external input connected to horizontal amplifier:

Deflection factors of 0.1 v/cm to 2 v/cm in 5 steps which are within $\pm 5\%$.

Input characteristics at EXTERNAL connector

1 megohm shunted by approximately 70 pf.

OTHER CHARACTERISTICS

Cathode-ray tube

Type T5021P2—P1, P7, and P11 phosphors optional.

Each vertical beam covers a minimum of 8 cm of vertical scan.

Voltage calibrator

Square wave output at approximately 1 kc.

Six calibrated voltage steps from 0.5 mv to

50 volts peak-to-peak. Accuracy—within 3%.

Graticule

Edge lighted—marked in 10 vertical and 10 horizontal 1 cm divisions with 2 mm markings on the baselines.

Power requirements

Line voltage—105 to 125 volts, or 210 to 250 volts, 50-60 cycles.

Power—Approximately 300 watts.

Mechanical characteristics

Ventilation—filtered, forced-air.

Construction—aluminum-alloy chassis and three-piece cabinet.

Dimensions—23 $\frac{1}{2}$ " long, 11 $\frac{1}{4}$ " wide, 15" high.

Weight—52 pounds.

Accessories included

2—Type P6006 attenuator probes, 010-125.

2—Binding post adapters, 013-004.

1—Light filter.

2—Instruction manuals.

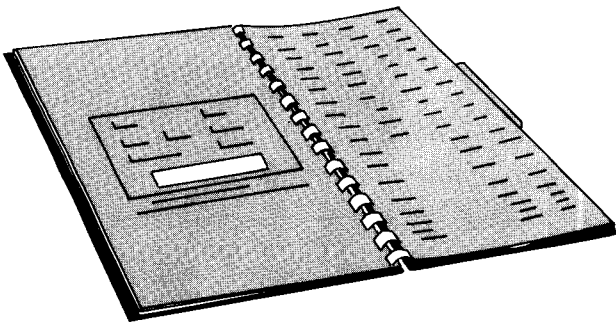
1—Test lead, 012-031.

1—3 to 2-wire adapter, 103-013.

1—3-conductor power cord, 161-010.

SECTION 2

OPERATING INSTRUCTIONS



Shipping Blocks

It is very important to remove the shipping blocks from the vertical amplifier prior to using the oscilloscope. The shipping blocks are narrow inserts, which are used to hold the vertical amplifiers firmly in place during shipment. A small tug with a pair of plier towards the outside of the instrument will remove each of the two shipping blocks used on each vertical amplifier. See figure 2-1 for the shipping block positions.

The shipping blocks should be kept for future use.

Cooling

A fan maintains safe operating temperature in the Type 502A Oscilloscope by circulating air through a filter and over the components. Therefore, the instrument must be placed so that the air intake is not blocked. The air filter must be kept clean to permit adequate air circulation. If the interior temperature should rise too high for some reason,

a thermal cutout switch will disconnect the power and keep it disconnected until the temperature drops to a safe value.

For proper air circulation, the bottom and side panels must be in place. Be sure the bottom panel is installed according to directions.

Power Requirements

The regulated power supplies in the Type 502A will operate with line voltages from 105 to 125 volts, at 117 nominal line volts, or from 210 to 250 volts at 234 nominal line volts. Proportionate line voltage variations apply when other nominal line voltage primary connections are made. For maximum dependability and long life the voltage should be near the center of this range. Fig. 2-2 shows the connections for the various line voltages.

Voltages outside of these limits, or poor line-voltage waveforms, may cause hum or jitter on the trace and may cause unstable operation. Be sure to check for proper line voltage if indications such as these are present.

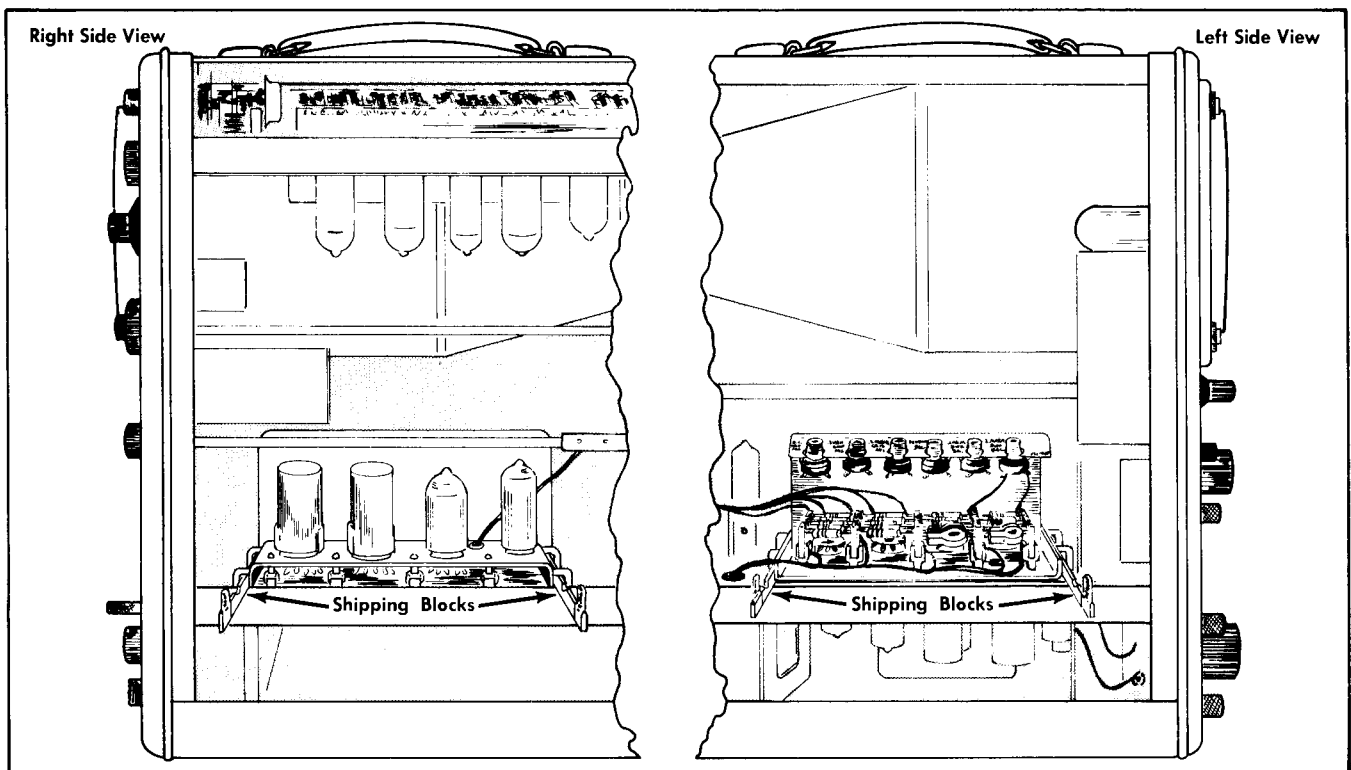


Fig. 2-1. The position of the shipping blocks for each vertical amplifier.

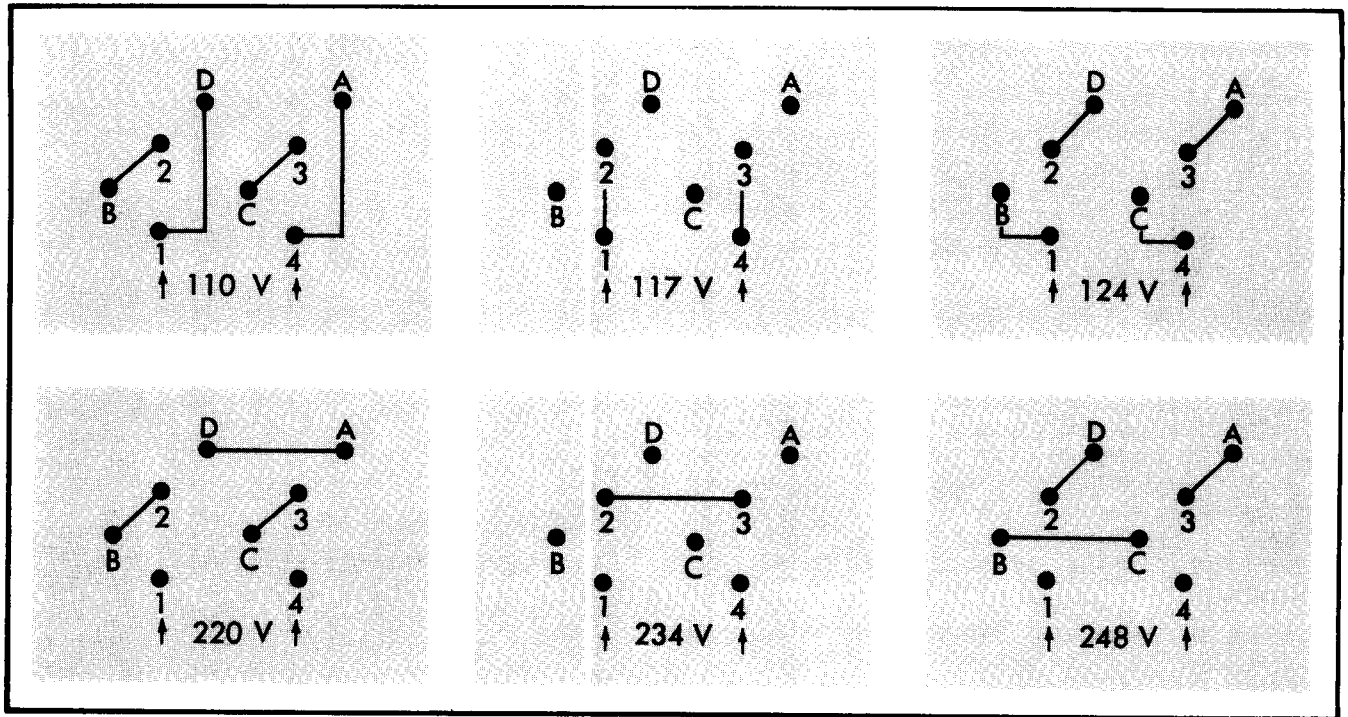


Fig. 2-2. The power transformer has two extra windings permitting nominal primary voltages of 110, 117, 124, 220, 234 or 248 volts, 50 or 60 cycle operation.

Fan Connections

The manner in which the fan is wired depends on the line voltage. For 110-124 or 220-248 volt operation, the fan is connected as shown in Fig. 2-3.

Fuse Requirements

Use a 4 amp., 3AG, Fast-Blo fuse for 110, 117 or 124 volt 60 cycle operation; for 50 cycles use a 3.2 amp., 3AG, Slo-Blo fuse. For 220, 234 or 248 volt, 60 cycle operation, use a 2 amp., 3AG, Fast-Blo fuse; for 50 cycles use a 1.6 amp., 3AG, Slo-Blo fuse.

Input Selection

On the Type 502A oscilloscope, you can connect single-ended inputs to either the A or B input connectors of the LOWER or UPPER BEAM amplifiers by rotating the Input Selector switches to the corresponding position. The choice of input connections will depend upon the display desired. Waveforms applied to input B are displayed in an inverted position on the face of the crt while waveforms applied to input A are displayed in the normal upright position. If you are not aware of this difference in the input connectors, it is probable that you will improperly evaluate the results obtained from an input to the B connector.

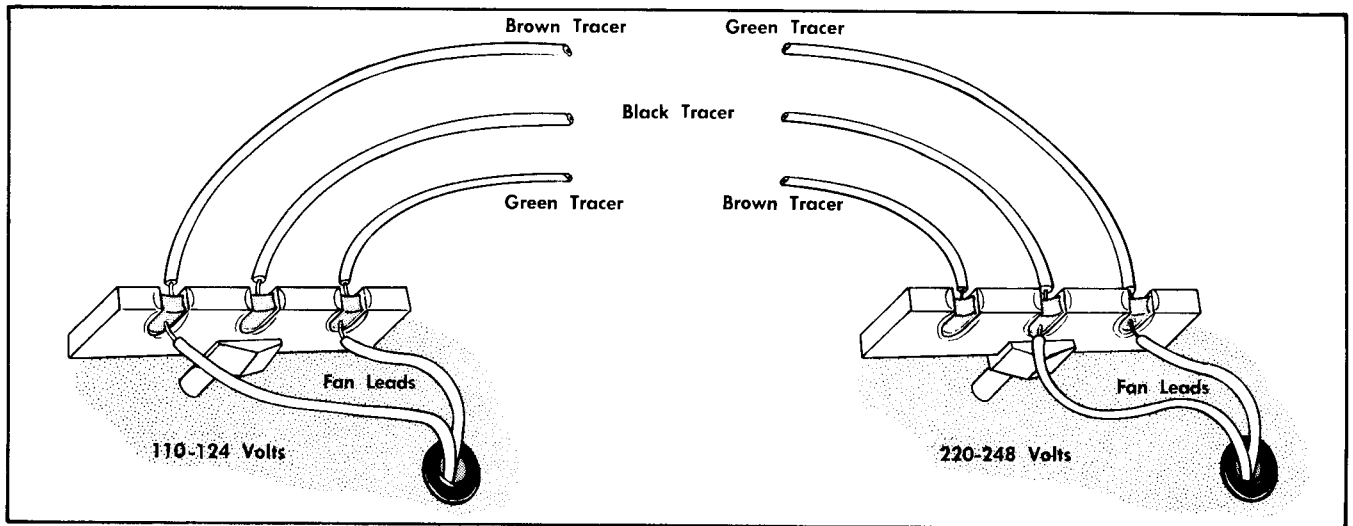


Fig. 2-3. Fan connections for the various line voltage connections.

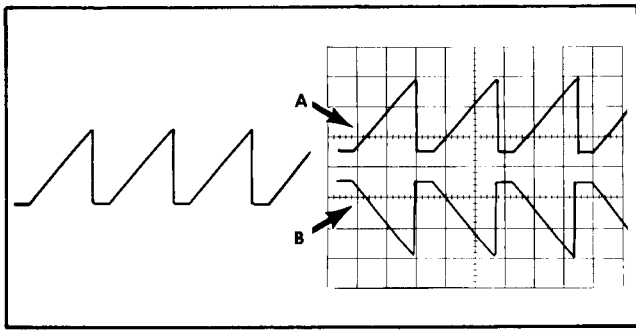


Fig. 2-4. Inputs to the vertical amplifiers. Waveforms applied to input connector A are displayed in the upright position, while waveforms applied to input connector B are inverted.

Differential inputs must be connected to both the A and B input connectors of one amplifier. In the A and B positions of the input selector switch, the corresponding waveforms are displayed on the crt. In the A-B (DIFF) position, the B input is algebraically added to the A input and the difference is displayed. This feature permits you to eliminate common mode signals within specified limits.

Input Coupling

Input signals to the vertical amplifiers can be either ac or dc coupled by placing the Input Selector switch in the corresponding positions. DC coupling applies both the ac and dc components of the input signal to the vertical amplifier circuits. This permits you to measure the dc voltage level as well as the amplitude of the ac component. It is sometimes neither necessary nor desirable to display the dc component. In such cases ac coupling should be used. With ac coupling, a capacitor is placed in series with the input connector to block the dc component while at the same time allowing the ac component to be displayed.

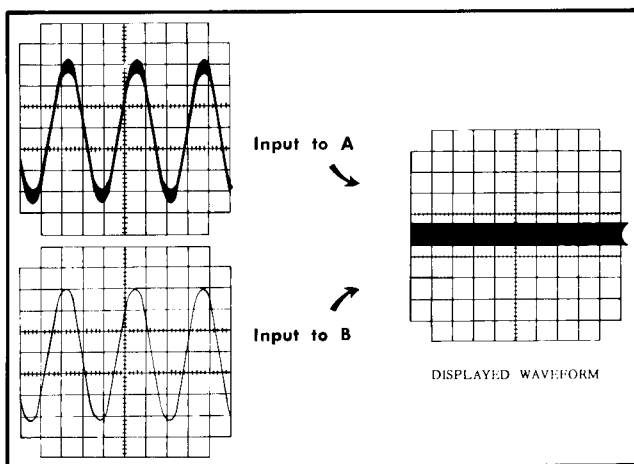


Fig. 2-5. Rejection of a common mode signal by the differential amplifier. The waveform applied to input connector B is algebraically added to the waveform applied to input connector A and the resultant waveform is displayed on the screen of the crt.

Input Connections

Here are some precautions you should observe in connecting your oscilloscope to the signal source:

1. Avoid errors in readings due to stray electric or magnetic coupling between circuits, particularly in the leads connected to the input connector. In general, unshielded leads of appreciable length are unsuited for this use. When shielded leads are used, the shields should be grounded to the input connector shield and to the chassis of the equipment being tested. Coaxial cables are recommended for many purposes. Special care must be taken in the high sensitivity ranges of the oscilloscope due to the low signal level and high amplifier gain.
2. As nearly as possible, simulate actual operating conditions in the equipment being tested. The equipment should have a load on it which is approximately equal to the load encountered in normal operation.
3. Consider the effect of loading upon the signal source due to the input circuit of the oscilloscope. The circuit at the input connectors can be represented by a resistance of 1 megohm shunted by a capacitance of 47 pf. With a few feet of shielded cable, the capacitance may well be 100 pf or more. In many cases, the effects of these resistive and capacitive loads are not negligible, and to minimize them, you might want to use a probe in the manner described in the next section.

Use of Probes

An attenuator probe lessens both capacitive and resistive loading, at the same time reducing sensitivity. When making amplitude measurements with an attenuator probe, be sure to multiply the observed amplitude by the attenuation of the probe.

A Type P6006 Probe is furnished as an accessory to the Type 502A Oscilloscope. Connected to the Input connector of the Type 502A, the probe presents an input characteristic of 10 megohms shunted by approximately 9 picofarads and has an attenuation ratio of 10:1. The maximum voltage which may be applied to the probe is 600 volts. Exceeding this rating, either in peak ac volts or dc volts, may result in damage to the components inside the probe body.

If the waveform being displayed contains fast changing portions, it is generally necessary to clip the ground lead of the probe to the chassis of the equipment being tested. Select a ground point which is near the probe connection.

Probe Adjustment

An adjustable capacitor, which is built into the probe body, is used to compensate for slight variations in input capacitance from one instrument to another. To insure the accuracy of pulse and transient measurements, this adjustment should be checked frequently.

To make this adjustment, set the AMPLITUDE CALIBRATOR and SENSITIVITY Controls on the Type 502A to display a signal of suitable amplitude. Touch the probe tip to the CAL OUT Connector and adjust the TIME/CM Control to display several cycles of the waveform.

Loosen the locking sleeve several turns. (See figure 2-6.) Now while holding onto the knurled part near the cable, turn

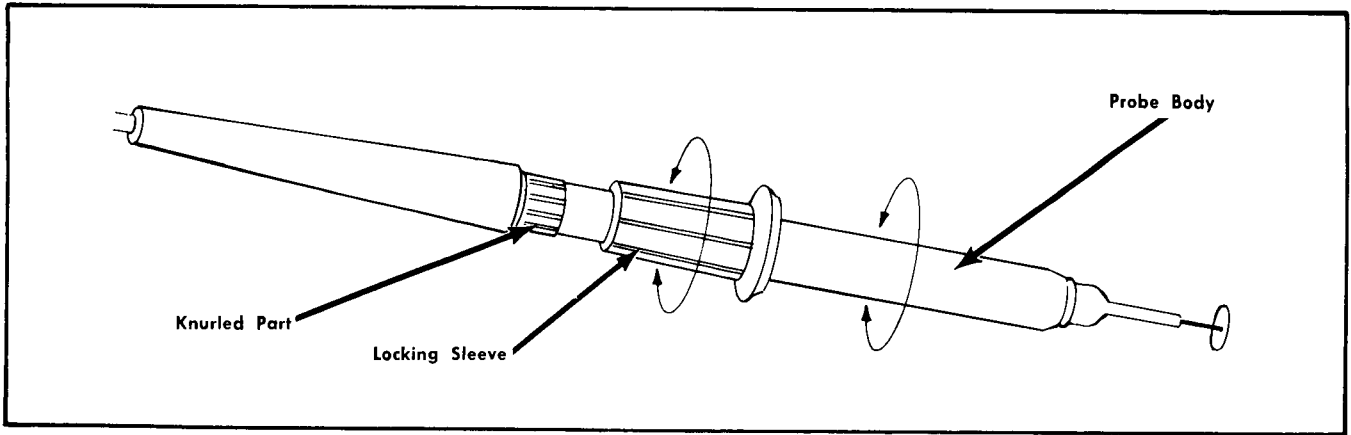


Fig. 2-6. Location of locking sleeve and knurled parts on the Type P6006 Probe.

the probe body until a flat top is obtained on the square-wave waveform. The locking sleeve should now be tightened. After the locking sleeve has been tightened, the probe compensation should be checked once more to insure that the compensation did not change when the locking sleeve was tightened.

Triggered Operation

In order to obtain a stable display of some recurrent waveform, it will be necessary for you to trigger the horizontal sweep at the correct instant of time. This will insure that the sweep will start at the same point on the observed waveform for each cycle of operation. The sweep should be triggered either by some waveform bearing a fixed time relationship to the observed waveform or by the observed waveform itself. Either method will produce the desired stable display. If the waveform which is applied to the UPPER BEAM and the waveform which is applied to the LOWER BEAM have a definite time relationship to each other it is possible to trigger from either beam and obtain simultaneously a stable display of both waveforms.

The following instructions tell you how to select the proper triggering signal for various applications of your oscilloscope. These instructions also provide information about the advantages and limitations of each triggering configuration. You should attempt to become thoroughly familiar with all of the various triggering configurations in order that you may obtain maximum use from your instrument. A thorough knowledge of the triggering configurations will allow you a greater selection of triggering methods when you are confronted with a definite triggering problem.

How to select the triggering signal source

1. To trigger the sweep from the waveform displayed on the UPPER BEAM, set the TRIGGER SELECTOR switch at UPPER AC or UPPER DC.
2. To trigger the sweep from the waveform displayed on the LOWER BEAM, set the TRIGGER SELECTOR switch at LOWER AC or LOWER DC.
3. To trigger the sweep at the power line frequency, set the TRIGGER SELECTOR switch at LINE. This mode of trig-

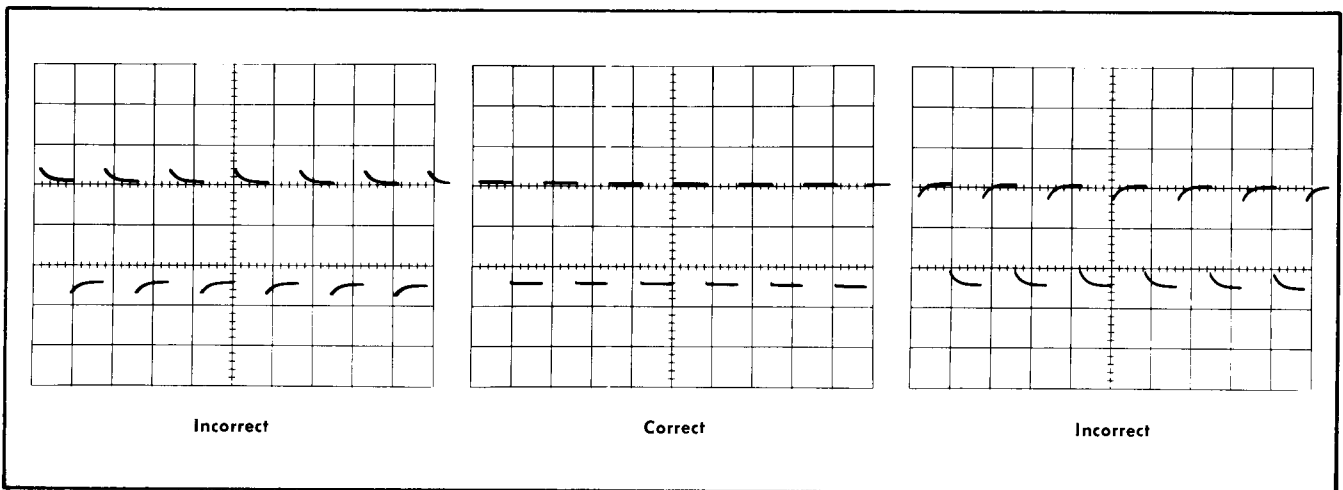


Fig. 2-7. The Type P6006 Probe is adjusted for a flat-topped square-wave display of the Calibrator waveform.

gering will normally be used when you are observing a waveform which bears a fixed time relationship to the power-line frequency.

4. To trigger the sweep from some external waveform bearing a definite time relationship to the observed waveform, connect the external waveform to the TRIGGER INPUT connector and set the TRIGGER SELECTOR switch at EXT AC or EXT DC.

External triggering provide definite advantages over other configurations of triggering in certain cases. With external triggering, the triggering signal generally remains essentially constant in amplitude and shape. It is thereby possible to observe the shaping and amplification of a signal by each stage of a circuit without resetting the triggering controls for each observation. Also time and phase relationships between the waveforms at different points in the circuit can be seen. If, for example, the external triggering signal is derived from the waveform at the input to a circuit, the time relationship and phase of the waveforms at each point in the circuit are automatically compared to the input signal by the display presented on the face of the crt.

Automatic Mode

Automatic triggering is obtained by rotating the TRIGGERING LEVEL control fully counterclockwise to the AUTOMATIC position. This provides a preset triggering level which is set to allow triggering at the average voltage point of the applied waveform. The sweep runs at approximately a 50 cycle rate when no triggering signals are applied. Automatic triggering can be used with triggering signals obtained from the LINE, UPPER, LOWER, or EXT positions of the TRIGGER SELECTOR switch, but for most waveforms, it is useful only for triggering at frequencies above approximately 50 cycles. Automatic triggering saves considerable time in observing a series of waveforms since it is not necessary to reset the triggering level for each observation.

DC Coupling

DC coupling is selected in the UPPER DC, LOWER DC, and EXT DC positions of the TRIGGER SELECTOR switch. This coupling of the triggering signal is particularly useful in triggering from waveforms which are not adaptable to ac coupling, such as random pulse trains or very low frequency waveforms. Random pulse trains pose a special problem in ac coupling since the random occurrence of the input waveforms causes the average voltage level to shift. This in turn may cause the triggering level to shift to an unstable point. This problem is not encountered with dc coupling since the triggering point is determined only by instantaneous voltages.

With dc coupling the triggering signal is obtained from either the LOWER or the UPPER BEAM amplifiers, hence varying the respective vertical position controls will change the triggering point. For this reason, you may find it necessary to readjust the TRIGGERING LEVEL controls when you change the vertical position of the trace. If you desire to eliminate this effect, you can use ac coupling provided the triggering signal is otherwise suitable for this type of coupling. With dc coupling, the dc level of external triggering signals will also affect the triggering point. Generally, when the triggering signal is small compared to its dc level, ac coupling should be used.

AC Coupling

AC coupling is selected in the LINE, LOWER AC, UPPER AC, and EXT AC positions of the TRIGGER SELECTOR switch. This coupling provides stable triggering on virtually all types of waveforms. As a general rule, however, ac coupling is unsatisfactory for triggering with low amplitude waveforms at frequencies below approximately 15 cycles. This figure will vary depending upon the amplitude and shape of the triggering waveform and should not therefore be set as an absolute standard. Triggering at frequencies below 15 cycles can be accomplished when higher amplitude triggering signals are used.

With ac coupling, the triggering point depends on the average voltage level of the triggering signals. If the triggering signals occur at random, the average voltage level will vary, causing the triggering point to also vary. This shift of the triggering point may be enough so that it is impossible to maintain a stable display. In such cases you should use dc coupling.

Trigger Slope

If you wish to trigger the sweep on the rising (positive slope) portion of the triggering waveform, place the TRIGGER SELECTOR switch at +. If you wish to trigger on the falling (negative slope) portion of the triggering waveform, place the TRIGGER SELECTOR switch at —.

Using the TRIGGERING LEVEL Control

In all positions except AUTOMATIC and RECURRENT, the TRIGGERING LEVEL Control determines at which point on the triggering signal the sweep is triggered. Using this control, the sweep can be triggered at any point on the waveform so long as the slope of the waveform is great enough to provide stable triggering. With dc coupling, the sweep cannot be triggered with any degree of stability at the top of a square wave, for example, the time that the voltage remains constant is comparatively long. As a result, the sweep triggers at random points along the top of the square wave producing considerable trace jitter.

You can use the same method to set the TRIGGERING LEVEL control for either type of coupling. After selecting the triggering slope, rotate the TRIGGERING LEVEL control fully counterclockwise to the AUTOMATIC position. Then rotate the TRIGGERING LEVEL control clockwise until the sweep no longer triggers. Continue to rotate the control in the clockwise direction until the sweep again triggers and a stable display is obtained. Further rotation of the control in the clockwise direction causes the sweep to trigger at more positive points on the triggering waveform. See Figure 2-8.

Free-Running Operation

With the Type 502A, you can get a periodic, free-running sweep, independent of any external triggering or synchronizing signal by rotating the TRIGGERING LEVEL control fully clockwise to the RECURRENT position. This permits you to observe the UPPER and LOWER BEAM traces without an input signal.

Operating Instructions—Type 502A

Note: In this illustration of the TRIGGERING LEVEL control, the AUTOMATIC and RECURRENT positions are not shown. The "Higher Region" and "Lower Region" shown do not actually appear on the front panel, but refer to the relative graticule position at which triggering occurs.

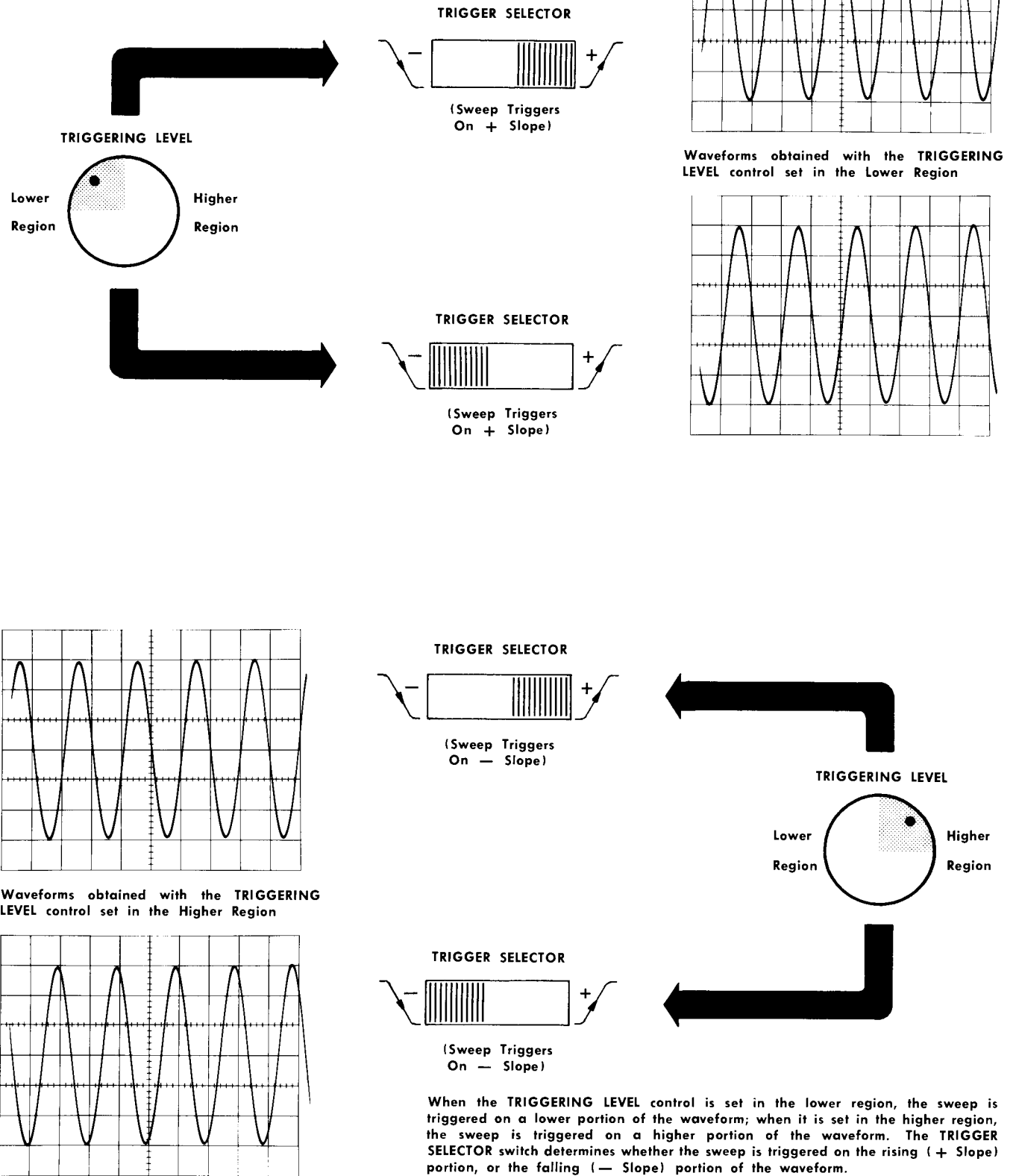


Fig. 2-8. Effects of TRIGGERING LEVEL and TRIGGER SELECTOR control settings.

Magnifier

To expand a particular part of the display horizontally, first use the Horizontal POSITION Control to position the desired part of the display to the center of the graticule. Then turn the HORIZONTAL DISPLAY switch to the magnification desired. The portion of the display at the center of the graticule will then be expanded 2, 5, 10, or 20 times depending on the setting of the HORIZONTAL DISPLAY switch. At the same time, the SWEEP MAGNIFIER ON indicator lamp will light, indicating that the display has been expanded. Any portion of the original unmagnified display can then be shown by rotating the Horizontal POSITION Control.

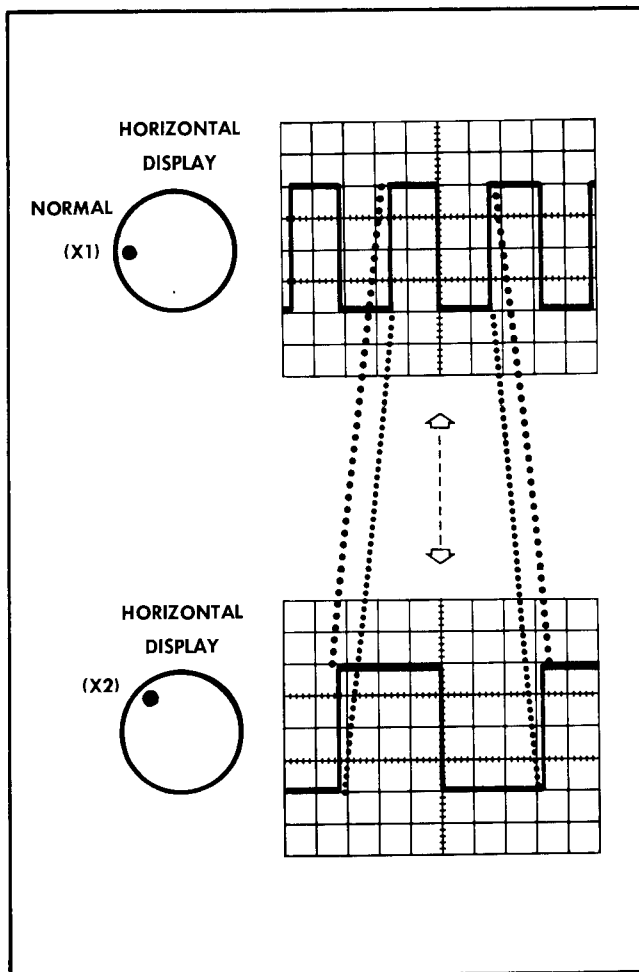


Fig. 2-9. Magnified sweep. The portion of the waveform at the vertical centerline remains stationary as the sweep is magnified. The displayed waveform is expanded left and right from the centerline. The lower waveform is a two times magnification of the upper waveform.

In magnified sweep operation, the sweep rate is multiplied by the magnification. This means that the time per centimeter indicated by the TIME/CM switch must actually be divided by the magnification to obtain the correct time required for the sweep to move one centimeter. For example, if the TIME/CM switch is set at 5 mSEC, and the magnifier is set at X5, the true time per centimeter is 5 milliseconds divided by 5, or 1 millisecond per centimeter.

Magnified sweep rates are all calibrated within 3% accuracy so long as their true time per centimeter is 1 microsecond or more. Sweep rates faster than this are uncalibrated and may be nonlinear. The SWEEP MAGNIFIER UNCALIBRATED indicator lamp lights whenever the maximum calibrated sweep rate is exceeded, to indicate that the sweep is uncalibrated.

X-Y Operation

On the Type 502A, it is possible to horizontally deflect one or both of the spots across the screen by means of some externally derived waveform, rather than by means of the internal sweep circuits. This permits the oscilloscope to be used for either single or dual-beam X-Y curve tracing.

For single-beam applications where equal horizontal and vertical-deflection factors are desirable, the UPPER BEAM amplifier can be switched to the crt horizontal deflection plates by placing the HORIZ DEF PLATE SELECTOR switch at the UPPER BEAM AMP position. This type of operation provides .1 mVOLTS PER CM to 20 VOLTS PER CM sensitivity and differential input for both horizontal and vertical deflection. The LOWER BEAM is used for vertical deflection while the UPPER BEAM is automatically positioned off the screen while waiting for an input signal. A panel light indicates when the UPPER BEAM amplifier is connected to the horizontal deflection plates.

For dual-beam X-Y applications, an external waveform can be applied to the horizontal amplifier by connecting the waveform to the EXTERNAL Horizontal Input Connector. The horizontal deflection sensitivity is controlled by the setting of the HORIZONTAL DISPLAY switch, which has a maximum sensitivity of .1 v/cm. The HORIZ DEF PLATE SELECTOR switch must be in TIME BASE AMP position for dual-beam X-Y applications.

Voltage Measurements

Accurate voltage measurements of inputs to the vertical amplifiers can be made using the calibrated deflection factor feature of the Type 502A. The following instructions tell you how to use the oscilloscope for this purpose and how to obtain the greatest possible accuracy in your measurements. It is important that proper techniques be used in order that errors are not introduced in the results.

During voltage measurements, you should always display the waveform across as much of the crt face as is possible since, as a general rule, the accuracy of your measurements will increase as the vertical size of the displayed waveform is increased. In measuring voltages, it is important to remember that the width of the trace may be an appreciable part of the overall measurement and care should be used that the trace width is not included in the vertical deflection readings you obtain. You should consistently make all readings from one side of the trace. If the bottom side of the trace is used for one reading, it should be used for all succeeding readings.

NOTE

Make sure the VARIABLE SENSITIVITY Control is in the CALIBRATED position prior to any vertical measurements, unless you have calibrated the instrument with the VARIABLE SENSITIVITY control.

How to measure the ac component of a waveform

For measuring the ac component of a waveform, ac coupling is normally used since it is usually not advantageous to display the dc component of the waveform being measured. AC component voltage measurements can usually be made with dc coupling also, but there is normally no particular advantage in doing so. To obtain peak-to-peak voltage measurement, perform the following steps.

1. To use the graticule, measure the vertical distance in centimeters from the level of the positive peak to the level of the negative peak.
2. Multiply the setting of the SENSITIVITY Control by the distance measured to obtain the indicated voltage.
3. Multiply the indicated voltage by the attenuation factor of the probe you are using to obtain the true peak-to-peak voltage.

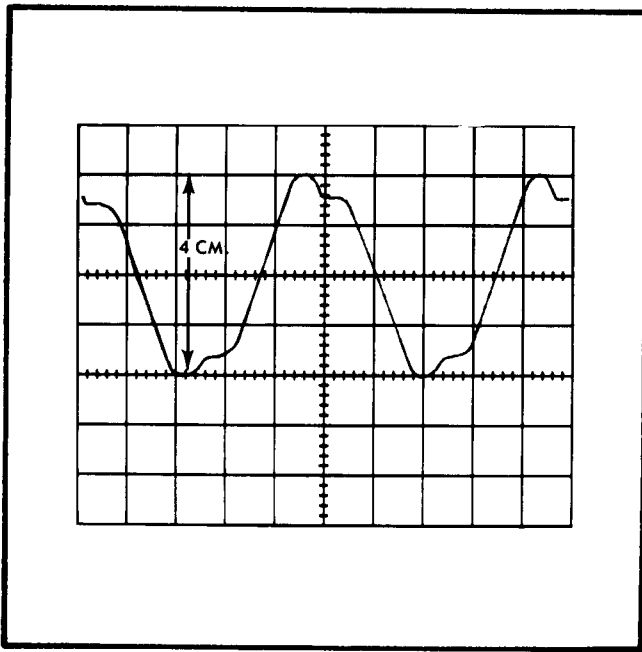


Fig. 2-10. Voltage measurement of the ac component of a waveform. The vertical distance between peaks is multiplied by the setting of the SENSITIVITY control and by the probe attenuation factor to obtain the voltage measurement.

As an example of this method, assume that using a 10X probe and a sensitivity of 1 volt per centimeter, you measure a total vertical distance between peaks of 4 centimeters. In this case then, 4 centimeters times 1 volt per centimeter gives you an indicated voltage of 4 volts peak-to-peak of sine wave. The indicated voltage times the probe attenuation factor of 10 then gives you the true peak-to-peak amplitude of 40 volts. The peak-to-peak sinusoidal voltage can then be converted to peak, rms, or average voltage through use of standard conversion factors.

How to measure instantaneous voltages

The method used to measure instantaneous voltages is very similar to the method described previously for ac com-

ponent voltage measurements. A reference line must be established on the crt screen. The actual voltage measurement is taken with respect to this reference line. If for example, the voltage measurement is to be made with respect to +100 volts, the reference line would correspond to +100 volts. In the following procedure the method is given for establishing this reference line as ground since measurements with respect to ground are by far the most common type made. The same general method may be used to measure voltage with respect to any other potential, so long as that potential is used to establish the reference line.

CAUTION

To prevent saturation of the vertical amplifiers, the peak voltage to ground at any amplifier input connector must not exceed 200 volts on 5, 10, and 20 VOLTS PER CM ranges; 20 volts on the .5, 1, and 2 VOLTS PER CM ranges; and 2 volts on all other ranges.

To obtain a voltage measurement with respect to ground, perform the following steps:

1. To establish the reference line, DC couple the oscilloscope input, then touch the probe tip to the oscilloscope ground terminal and rotate the TRIGGERING LEVEL Control fully clockwise to the RECURRENT position.

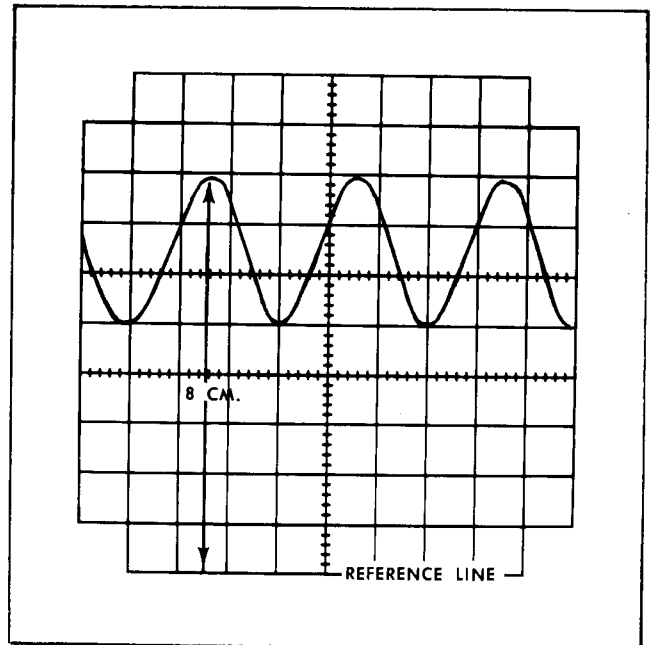


Fig. 2-11. Measuring the instantaneous voltage. The vertical distance from the point of measurement to a pre-established reference line is multiplied by the setting of the SENSITIVITY control and by the attenuation factor of the probe to obtain the voltage measurement.

2. Vertically position the trace to a convenient point on the face of the crt. (This point will depend upon the polarity and amplitude of the input signal, but it should always be chosen so that the trace lies along one of the major divisions of the graticule. The graticule division corresponding to the position of the sweep is known as the ground reference line.

Operating Instructions—Type 502A

(Do not adjust the vertical positioning control after this reference point has been established.)

3. Remove the probe tip from ground and connect the probe to the signal source. Adjust the TRIGGERING LEVEL Control for a stable display.

4. Measure the vertical distance in centimeters from the point to be measured to the ground reference line by use of the graticule.

5. Multiply the setting of the SENSITIVITY Control by the distance measured to obtain the indicated voltage.

6. Multiply the indicated voltage by the attenuation factor of the probe you are using to obtain the true voltage with respect to ground.

As an example of this method, assume that you are using a 10X probe and a sensitivity of .2 volts per centimeter and that after setting the reference line at the bottom of the graticule, you measure a distance of 8 centimeters to the point you wish to measure. In this case then, 8 centimeters times .2 volts per centimeter gives you an indicated voltage of 1.6 volts. Since the voltage point is above the ground reference line, the polarity is indicated to be positive. The indicated voltage times the probe attenuation factor of 10 then gives you the true voltage of positive 16 volts.

You should remember in determining the polarity of voltages measured in this fashion that inputs applied to the B input connectors are inverted on the face of the crt. Consequently, the apparent polarity of these inputs is opposite the true polarity. To prevent possible confusion as to polarity it is usually best to use the A input connectors for voltage measurements with respect to ground.

Time Measurement

Accurate elapsed time or time interval measurements can be made by utilizing the calibrated timebase feature of the Type 502A Oscilloscope. The sweeps are calibrated so that the beams are deflected across the screen at known rates. Since the beam travels completely across the screen in a known period of time, the time required for the beam to travel any portion of the distance can be determined. By measuring the horizontal distance between points on the displayed waveform, and by knowing the sweep rates, you can determine the time interval between the two points. For accurate measurements be sure the same reference point is used on both pulses and the VARIABLE TIME/CM Control is in the CALIBRATED position. The method for measuring a time interval is as follows:

1. Using the graticule, measure the horizontal distance in centimeters between two points whose time interval you wish to find.
2. Multiply the distance measured by the setting of the TIME/CM control to obtain the apparent time interval.
3. Divide the apparent time interval by the magnification indicated by the setting of the HORIZONTAL DISPLAY switch to obtain the correct time interval.

Frequency Measurement

The frequency of a periodically recurrent waveform can be determined if the time interval (period) of one complete

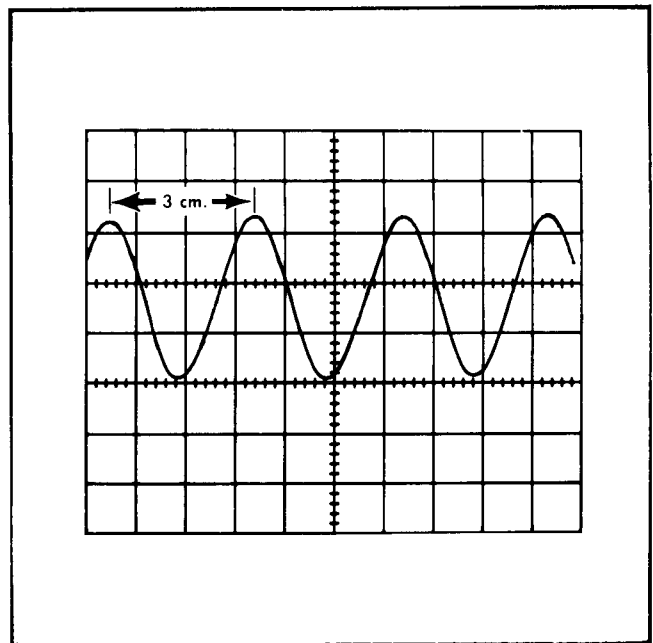


Fig. 2-12. Measuring the time interval (period) of one complete cycle of a periodically recurrent waveform. The horizontal distance in centimeters of one complete cycle (in this case 3 centimeters) is multiplied by the setting of the TIME/CM control and is divided by the sweep magnification to obtain the time interval. The frequency of the waveform is the reciprocal of its time interval.

cycle of the waveform is known. This time interval can be measured by means of the procedure described in the preceding paragraph. The frequency of a waveform is the reciprocal of its time interval

Using DC BAL and FINDER Controls

It is best to disconnect the input signal, unless the approximate amplitude of it is known. If the amplitude of the input signal is known then set the SENSITIVITY Control for a crt display of two or three centimeters and follow the instructions for no input signal.

With no input signal, turn the TRIGGERING LEVEL to RECURRENT, the single sweep MODE switch to NORMAL and the INTENSITY Control to a reasonable level. The above control settings are to insure that a trace can be seen, when it is found.

Set the vertical POSITION Control of the proper beam to its midrange position. With the SENSITIVITY Control in the .2 VOLTS PER CM position. If no input signal is connected to the Type 502A, change the SENSITIVITY Control to the .1 m VOLTS PER CM position and depress the FINDER Button. The trace should now be seen on the crt. Now turn DC BAL Control in either direction until a "fast area" is seen. A "fast area" is an area of the DC BAL Control where the trace will move a large distance for a very small movement of the DC BAL Control.

When the "fast area" of the DC BAL Control is found, the trace should be positioned in the center of this area with the DC BAL Control. The FINDER Button may now be released and the trace positioned to the proper place on the graticule.

Operating Instructions—Type 502A

If the trace shifts slightly between the different ranges of the SENSITIVITY Control this may be cured by a very slight readjustment of the DC BAL Control. The following procedure may be used to correct for this slight trace shift.

Set the free-running trace to a convenient horizontal graticule line with the SENSITIVITY Control in the .2 VOLTS PER CM position. Rotate the SENSITIVITY Control to the .1 mVOLTS PER CM position and bring the trace back to the original horizontal graticule line with the DC BAL Control.

NOTE

The "fast area" with the FINDER Button depressed can only be easily seen on the higher sensitivity settings of the SENSITIVITY Control.

Single Sweep

Single sweep is used to record waveforms which are not repetitive or waveforms which jitter too much for normal triggered-display photography.

To use the single sweep feature of the Type 502A, set the MODE switch to NORMAL. If the waveform is repetitive it should be connected to the input of the oscilloscope. If the waveform is not repetitive then an AMPLITUDE CALIBRATOR signal of the same amplitude as that of the expected signal should be used.

Adjust the trigger control to obtain a stable display of the input signal. In the case of a waveform that jitters, adjust the control to obtain the most stable display.

If a calibrator waveform was used to adjust the trigger control, disconnect the calibrator waveform from the input to the oscilloscope and connect the non-repetitive waveform source to the oscilloscope. Push the MODE switch to the RESET position. The READY light should now be lit. The Type 502A will now sweep once, on the first trigger received after the MODE switch is released; further signals will not cause the instrument to sweep.

If the waveform is repetitive leave the signal connected to the input connector of the oscilloscope. When a sweep is desired, push the MODE switch to RESET and let it return to the SINGLE SWEEP position. Upon the return of the MODE switch to the SINGLE SWEEP position, the sweep will sweep once. If another sweep is desired the MODE switch must again be pushed to the RESET position and returned to the SINGLE SWEEP position.

It may be quite convenient to use the READY light of the Single Sweep circuit as an indicator for photography. The READY light will light when the circuit is awaiting a trigger and will stay lit until the sweep has been completed. At the end of the sweep the READY light will go out and stay out until the circuit is reset for another sweep with the MODE switch.

INTENSITY BALANCE Control

The INTENSITY BALANCE Control is used to adjust the intensity of both vertical amplifiers to the same level. With both traces adjusted to the same level, each will have the same relative writing rate, hence each trace will show the same amount on a photograph.

It may be necessary to readjust the INTENSITY BALANCE Control each time the setting of the INTENSITY Control is changed. This is due to the characteristics of a mono-accelerator crt in which the triode characteristics for each crt gun are slightly different.

AUXILIARY FUNCTION

AMPLITUDE CALIBRATOR

The AMPLITUDE CALIBRATOR is a source of accurately calibrated square waves at a frequency of approximately 1 kilocycle (+ or - 30%). The output amplitude is accurate within 3% of the AMPLITUDE CALIBRATOR switch settings for no load conditions. The primary function of the calibrator is to provide a convenient method for checking the calibration of the vertical-deflection system and for adjusting the probes. It can be used for other purposes, however, if it is kept in mind that the output impedance of the calibrator varies with the output-voltage setting.

Trace-brightness (intensity) modulation

To couple markers or other signals into the crt cathodes for trace-brightness modulation, disconnect the ground strap at the rear of the instrument and apply the signal between the CRT CATHODE binding post and GND. This will simultaneously apply the signals to the upper and lower beam cathodes. At normal brightness, positive signals of about 25 volts will cut the beams off. Always replace the ground strap when you are not intensity modulating the beams.

Graticule illumination

The graticule lighting control, labeled POWER AND SCALE ILLUM, can be adjusted to suit the lighting conditions of the room. A light filter is supplied with the instrument which can be used for increased contrast. This filter should be mounted next to the crt face so it does not block the light from the graticule lines.

The graticule of the Type 502A Oscilloscope can be illuminated so that it appears to have either red or white graticule markings. The markings can be quickly changed from white to red or from red to white by removing the graticule cover and inverting the graticule. As a general rule, white graticule lines are superior to red for photographic purposes.

Direct connection to crt plates

In some applications, it may be desirable to connect a signal directly to one or more sets of crt deflection plates—bypassing the internal oscilloscope amplifiers. This can be done in the Type 502A if certain precautions are observed. One of these precautions is to maintain the average dc voltage on the deflection plates at approximately +225 volts. If the average voltage is not maintained at approximately +225 volts, the crt display may be defocused.

For many applications, ac coupling of the signal to the deflection plates is permissible. It has the advantage of allowing the use of front panel controls to position the display and permits the use of signals not having the required average voltage level. A diagram of this method of

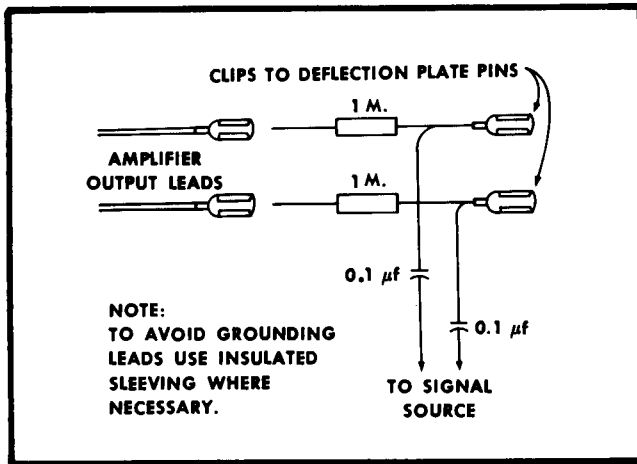


Fig. 2-13. Typical circuit for ac coupling to the crt deflection plates.

coupling is shown in Figure 2-13. Here, the leads from the oscilloscope amplifier are removed and a resistor is connected between each lead and its respective crt pin. A good value for this resistor in most cases is 1 megohm. The vertical deflection plate pins are located on the sides of the crt neck and the horizontal deflection plate pins are located on the top of the neck.

A convenient method for connecting the resistors to the crt pins is to use clips removed from standard miniature

tube sockets. Before connecting the resistors to the leads from the amplifier, slip a piece of insulated sleeving (spaghetti) over the wire. Then, after making the connections, draw the sleeving back over the insulated resistor pigtail. This will prevent the leads from accidentally shorting to the chassis. The crt pins are easily bent and you must exercise care when making these connections to avoid breaking the glass seal.

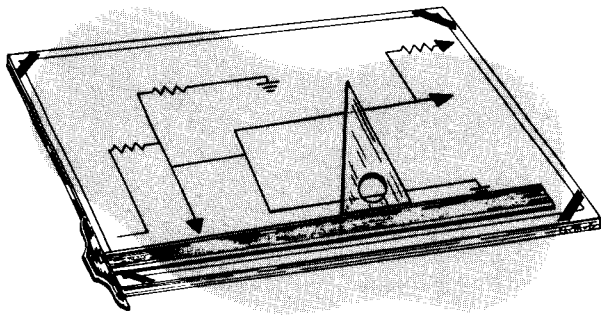
CAUTION

Do not allow the leads from the oscilloscope amplifiers to touch the chassis when the power is on. A short circuit of this type can damage the amplifier circuits.

If it is desired to couple the signal directly to the crt plates (dc coupling), it will be necessary to supply positioning voltages from the signal source. These voltages must also satisfy the requirement of an average level of +225 volts, mentioned previously. To dc couple the signal to the deflection plates, remove the leads from the crt pins and fold them back, out of the way. Taping the ends of the wires will prevent accidental shorting to the chassis. Connect the external signal source to the pins of the crt.

The vertical deflection factor of the crt is approximately 13 volts per centimeter. The horizontal deflection factor is approximately 17 volts per centimeter.

CIRCUIT DESCRIPTION



Introduction

The Type 502A is a dual-beam, high-gain, low frequency oscilloscope employing a T5021 type dual-gun cathode-ray tube. The instrument has identical Vertical Deflection Amplifiers, one for the UPPER BEAM and one for the LOWER BEAM. Simultaneous horizontal deflection of both beams is provided by a single Time-Base Generator and Horizontal Sweep Amplifier circuit.

The Type 502A circuitry is arranged so that the instrument can be used in any of several configurations. It may be used as a conventional single-beam oscilloscope by applying an input signal to either of the Vertical Deflection Amplifiers. It may be used to examine two waveforms simultaneously by applying input signals to both Vertical Amplifiers. Both deflection amplifiers may be used in a differential mode, to examine the difference between, or the algebraic sum of, two signals. The UPPER BEAM Deflection Amplifier can be connected to the horizontal deflection plates, so that the instrument may be employed as a single-beam X-Y oscilloscope. And, by means of the EXTERNAL horizontal-input connector, the instrument may be used as a dual-beam X-Y oscilloscope, with both traces plotted on the same X scale.

The UPPER BEAM Vertical and the LOWER BEAM Vertical Deflection Amplifiers are identical, so the description that follows applies to both.

The push-pull Vertical Amplifier consists of three stages of amplification, the Input Amplifier, the Second Amplifier and the Output Amplifier. A cathode-follower stage drives the Output Amplifier. The overall gain of the Amplifier is controlled by three feedback networks, two providing negative feedback and the third positive feedback (see Fig. 3-1). The Input Amplifier is a cathode-coupled paraphase amplifier (it may also be operated differentially) whose gain is controlled by negative feedback from the cathodes of the Driver C.F. stage and the Output Amplifier stage. The Second Amplifier has a positive feedback network that extends from the plate circuit on one side to the grid circuit on the other; this configuration makes this stage an almost "infinite-gain" amplifier. The result of both feedback networks is an amplifier having a sensitivity of 100 microvolts per centimeter.

The Input Circuit

The Input Selector switch SW403 determines the mode of operation for the Amplifier. When in any of the three positions marked AC the signal is ac-coupled through C400 (for Input A) and/or C401 (for Input B). When in any of the three positions marked DC the input capacitor (C400 and C401) is shorted and the signal is dc-coupled to the Input stages.

The sensitivity of the Vertical Amplifier, as mentioned previously, is 100 microvolts per centimeter. However, by means of attenuation and degeneration networks, the vertical deflection factor can be increased to 20 volts per centimeter.

It is possible, through the use of the VARIABLE SENSITIVITY Control, to introduce enough cathode degeneration into the cathodes of the Output Stage to increase the deflection factor to approximately 50 volts per centimeter.

Either of two attenuation networks can be connected in series with the Input connectors of the Vertical Amplifiers. One attenuates the signal by a factor of 10, the other by 100. For dc and low frequency signals, these networks are resistance dividers, and the degree of attenuation is proportional to the ratio of the resistance values. The reason for this is that the impedance of the capacitors, in this range of frequencies, is so high that their effect in the circuit is negligible. For higher-frequency signals, however, the impedance of the capacitors is less and their effect in the circuit is more pronounced. Near the upper-frequency range of the Amplifier the impedance of the capacitors becomes so low, compared to the resistance of the circuit, that the attenuators become capacitance dividers. For these frequencies the degree of attenuation is inversely proportional to the capacitance ratio.

In addition to providing the proper degree of attenuation, the resistance values of the attenuators are chosen so as to provide the same input resistance, regardless of the setting of the SENSITIVITY switch. For example, in the "straight through" positions of the SENSITIVITY switch (.1 mVOLTS PER CM to .2 VOLTS PER CM), the 1-megohm grid resistors . . . R410 for Input A and R440 for Input B . . . constitute the input resistance of the Vertical Amplifiers. In the range from .5 VOLTS PER CM to 2 VOLTS PER CM, the X10 Attenuator is connected into the input circuit. The resistor in the low end of the divider . . . R406E for Input A and R407E for Input B . . . shunts the grid resistor to create an equivalent resistance of 100 K ohms. This 100 K equivalent resistance is then in series with the resistor in the high side of the divider (900 K ohms) to produce a total input resistance of 1 megohm. The X100 attenuator works in the same manner. The 10.1 K resistor at the lower end of the divider shunts the 1 meg grid resistor to form an equivalent resistance of 10 K ohms. This equivalent resistance is then in series with the 990 K resistor in the upper side of the divider to create a total input resistance of 1 megohm.

The capacitance values in the attenuators are also selected to provide a constant input capacitance . . . 47 pf . . . regardless of the setting of the SENSITIVITY control. In the "straight through" positions of the switch, the total input capacitance is equal to the capacitance of C410

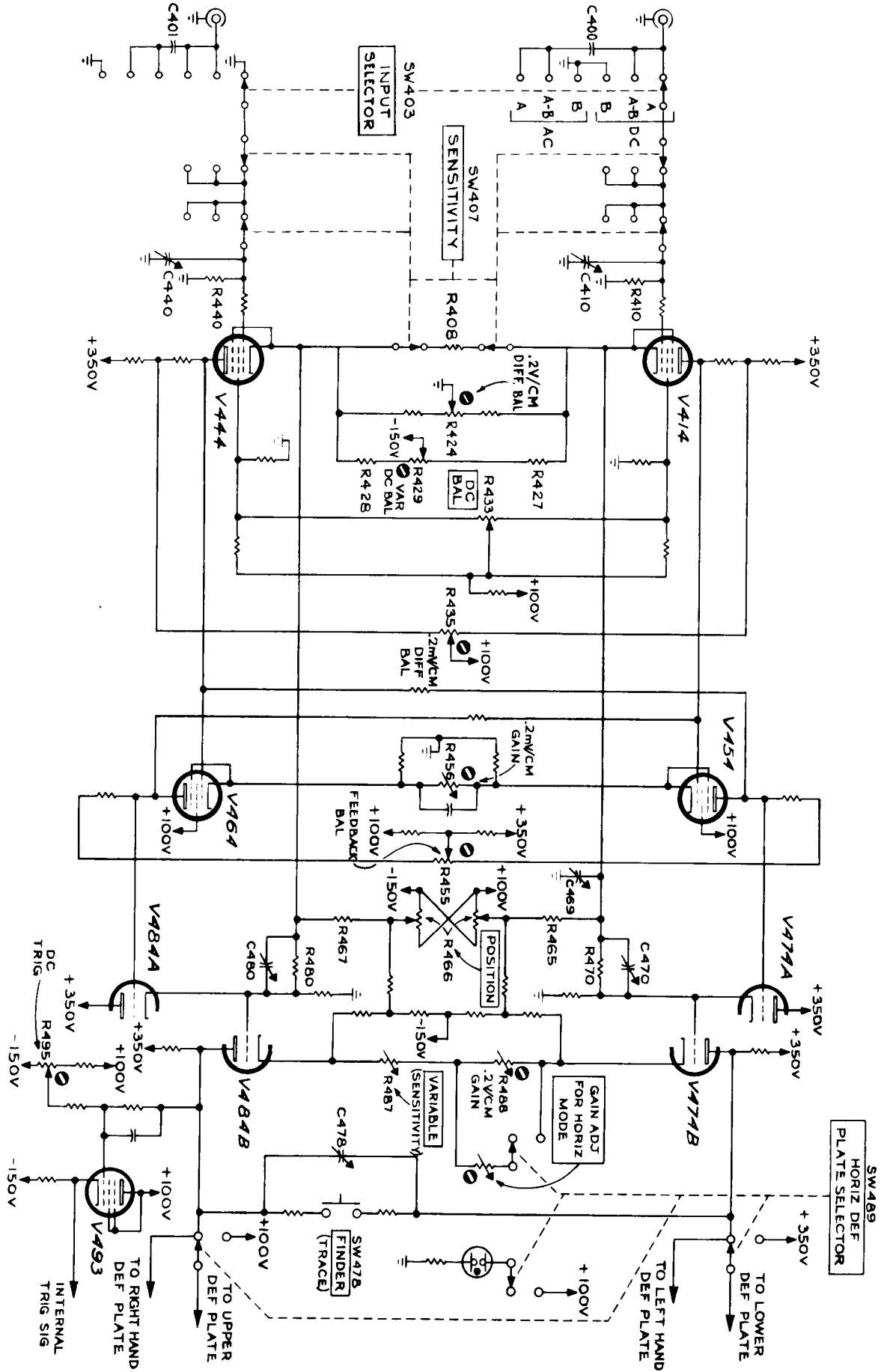


Fig. 3-1. Simplified Upper and Lower Beam Vertical Amplifiers.

(or C440 for Input B) plus the tube and stray capacitance. C410 is then adjusted so that the total input capacitance is 47 pf.

When the X100 attenuator is connected into the circuit, C406L (or C407L for Input B) shunts the 47 pf capacitance. This value of capacitance is then reduced to a very small value by series capacitor C406J (or C407J). The capacitor at the input to the attenuator then shunts this small capacitance, and is adjusted to make the total capacitance 47 pf. The X10 attenuator is designed in the same manner, except that stray capacity forms the lower branch of the divider.

Since the attenuator networks are frequency-compensated voltage dividers, a constant attenuation ratio is maintained from DC to the upper-frequency limits of the Vertical Amplifiers.

The Input Amplifier

When the Input Selector switch is in the A position (either AC- or DC-coupled) the grid of V414 is connected to the input circuit and the grid of V444 is returned to ground either through the switch or through one of the series attenuator networks. When in position B (AC or DC), V444 is the input tube and V414 is the grounded-grid tube. With either of these configurations, the Input Amplifier is a cathode coupled, paraphase amplifier; it converts a single-ended input signal to a push-pull output signal.

The cathode resistor R408 plays an important role in determining the amount of negative feedback applied to the Input Amplifier stage. As mentioned previously, this feedback voltage comes from the cathodes of the Driver C.F. stage and the Output Amplifier stage. The feedback from the Driver C.F. stage is applied through a divider consisting of R470 on one side and R408, and R480 on the other side of R408. To this compensated feedback network is added a small amount of feedback from the uncompensated network of R465 and R467. This feedback from the Output Amplifier stage helps in positioning the trace.

The smaller the value of R408 the greater the drop across the series resistor (R470, R480, R465, and R467) and the less the negative feedback applied to the Input Amplifier stage. Conversely, the greater the value of R408 the greater the drop across it and the greater the negative feedback. Thus, for very small input voltages, when the SENSITIVITY switch is set so that the resistance of R408 is quite small, there is very little negative feedback and the Input Amplifier stage operates with high gain. When the SENSITIVITY switch is set to accommodate larger input voltages the resistance of R408 is increased. This means that there is a greater amount of negative feedback and the gain of the Input Amplifier stage is decreased.

The switch diagram shows the makeup of R408. R408A is in the circuit for all positions of the SENSITIVITY switch. In the .2, 2, and 20 VOLTS/CM positions of the switch, R408A alone makes up the resistance of R408. In all other positions of the switch R408A is shunted by at least one other resistor. In the .1 mVOLTS/CM position R408A is shunted by both R408L and C409L; in the .5 mVOLTS/CM through .1 mVOLTS/CM positions, and in the .5, 1, 5 and 10 VOLTS/CM positions, it is shunted by both a resistor and an R-C network. The total value of R408 is determined by the degree to which R408A is shunted. The greater the shunting of R408A the smaller the value of R408 and the greater the gain of the Input

Amplifier stage. Conversely, the less the shunting of R408A the greater the values of R408 and the smaller the gain of the stage.

The cathodes of the Input Amplifier stage are "long-tailed" to the -150 volt supply through 82.5K resistors and R429 (VAR DC BAL).

With the grids of the Input Amplifier at ground potential, the cathodes will operate very close to ground (actually, a couple of volts positive to bias the stage). The approximately 150 volt drop across the 82.5K cathode resistors (R427 and R428) and R429 provides a constant supply of cathode current to stabilize the performance of the 6AU6 Input Amplifier tubes.

In order for the Input Amplifier stage to remain in a state of DC balance, there must be no dc voltage drop across R408 when there is no input signal. This means that the difference in potential between the two cathodes must always be zero, regardless of the value of R408. In order to provide for equal cathode voltages under this condition, the screen voltage of the two tubes can be varied with respect to each other with the DC BAL Control. Any change in the voltage at the screens will be reflected to the cathode by a factor of $1/\mu$ (the screen grid μ) and thus the cathode voltages can be equalized.

Along with the DC BAL Control, the DC unbalance in the Input Amplifier tubes is also removed by R429. Adjustment of this control will remove any voltage change which might be seen as a positioning change by the Output Amplifier.

Vertical positioning of the crt beam is accomplished through the action of the POSITION control. This is a dual control, connected between -150 volts and $+100$ volts. It is wired so that as the voltage between -150 volts and the movable arm in one side increases, the voltage between -150 volts and the movable arm in the other decreases. A change in the setting of the POSITION Control will produce a large change in the cathode voltage of the Output Amplifier stage and at the same time produce a small voltage change at the cathodes of the Input Amplifier stage. However, the compensated negative feedback circuit of the Driver C.F. stage reacts quickly to prevent any change in the cathode voltage of the Input Amplifier stage, and as a result a change in the voltage at the cathodes of the Driver C.F. stage is produced. This change in voltage at the cathodes of the Driver C.F. stage along with the voltage change at the Output Amplifier cathode, is amplified by the Output Amplifier and appears as a change in the positioning voltage at the vertical-deflection plates.

When the Input Selector switch is set to the A-B DIFF position both grids of the Input Amplifier stage are connected to the Input circuit. With this configuration the Input Amplifier stage is connected for differential operation. Two input voltages are required, and the push-pull output voltage is proportional to the difference between the two input voltages.

The .2 MV/CM DIFF BAL Control R435 adjusts the plates of the Input Amplifier stage for equal voltages when common mode signals are applied to the grids. This control is equally effective in all positions of the SENSITIVITY switch, but is primarily adjusted in the high-sensitivity position (.2 mVOLTS/CM). The .2 V/CM DIFF BAL control

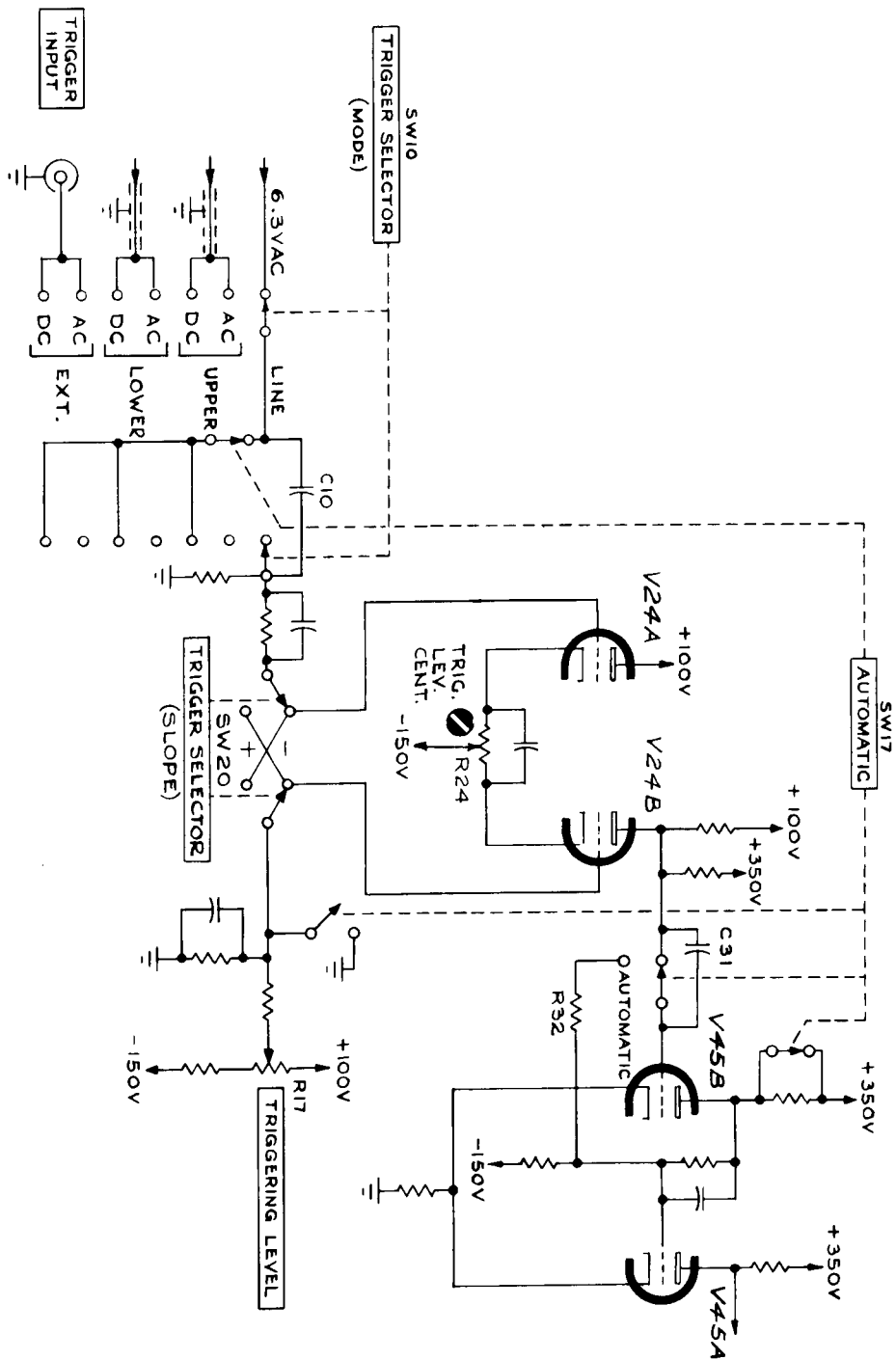


Fig. 3-2. Simplified Sweep Trigger Circuit.

R424 provides additional differential balance for the low-sensitivity ranges, and is most effective when the SENSITIVITY switch is in the .2 VOLTS PER CM position.

The Second Amplifier and Driver C.F. Stages

The push-pull output from the Input Amplifier stage is amplified in the Second Amplifier and coupled through the Driver C.F. stage to the Output Amplifier stage. As mentioned previously, the positive feedback from the plate circuit on one side of the amplifier to the grid circuit on the other makes this stage an infinite gain amplifier. However, the amplifier does not oscillate due to the overall negative feedback.

The .2MV/CM GAIN Control R456, located between the two cathodes, sets the small-signal gain of the Vertical Amplifier. This control is most effective when the SENSITIVITY switch is in the .2mVOLTS PER CM position. The FEEDBACK BAL control R455 balances the negative feedback from both sides of the Driver C.F. stage; this control is also most effective when the SENSITIVITY switch is in the .2mVOLTS PER CM position.

The Driver C.F. stage is the load for the Second Amplifier stage. Its grid circuit provides the necessary high impedance with low capacitance to maintain the gain of the Second Amplifier stage, its cathode circuit provides a very low impedance to drive the input capacitance of the Output Amplifier stage. The low output impedance of the cathode circuit also provides an excellent point from which to obtain most of the compensated negative feedback for the Input Amplifier stage.

The Output Amplifier

The Output Amplifier stage is the stage that drives the vertical-deflection plates in the crt. The gain of this stage can be adjusted by means of the .2V/CM GAIN Control R488. This control is most effective when the SENSITIVITY switch is in the .2 VOLTS PER CM position. The variable capacitor C478 adjusts the high-frequency response of the amplifier, and is used principally to provide a constant output capacitance.

The FINDER switch reduces the swing of the Output Amplifier, enough to bring the trace onto the crt.

By means of the HORIZ. DEF. PLATE SELECTOR switch SW489 the UPPER BEAM Vertical Amplifier can be connected to the horizontal-deflection plates in the crt. With this configuration the instrument can be used as a single-beam X-Y oscilloscope. The GAIN ADJ FOR HORIZ MODE Control R489 is used to increase the gain of the Amplifier slightly for this application.

Trigger Pickoff

When internal triggering of the Time-Base Generator is desired (TRIGGER SELECTOR in either of the UPPER or LOWER positions) a sample of the vertical-output signal is used to develop the triggering pulse. This sample, obtained from the plate circuit of V484B, is coupled through a frequency-compensated voltage divider to V493, a cathode-follower which drives the Time-Base Trigger circuitry. The

DC TRIG Control R495 is adjusted to set the cathode voltage to zero when triggering with DC coupling and with the beam positioned at its respective zero-center graticule line.

TIME-BASE TRIGGER

The Time-Base Trigger circuit consists of a triggering-signal amplifier V24 and a multivibrator (Schmitt Trigger) circuit V45. The function of the trigger circuitry is to produce a negative-going rectangular pulse at the plate of V45A whose repetition rate is the same as that of the triggering signal. This negative step is then differentiated to produce a very sharp negative spike (trigger) to trigger the Time-Base Generator in the proper time sequence. A positive spike is also produced by the differentiation process, but this spike is not used.

The signal from which the rectangular output is produced may emanate from one of four sources. When the TRIGGER SELECTOR switch is in the LINE position, a 6.3-volt signal at the power line frequency is used for this application. When the switch is in the UPPER or LOWER position (AC or DC), the signal is obtained from the UPPER or LOWER Beam Vertical Amplifier, respectively. In the EXT position (AC or DC), the signal is obtained from an external source through a front-panel connector (TRIGGER INPUT). In any of the DC positions of the TRIGGER SELECTOR switch the signal is coupled directly from its source to the Slope switch SW20. In any of the AC positions, the signal is coupled through C10 and then to SW20.

Although the output of the Trigger Multivibrator is always a negative rectangular pulse, the start of the pulse may be initiated by either the rising (positive-going) or falling (negative-going) portion of the triggering signal. To see how this is accomplished the operation of the Trigger Multivibrator will be described first.

In the quiescent state, that is, ready to receive a signal, V45B is conducting and its plate voltage is down. This holds the grid of V45A below cutoff, since the two circuits are dc-coupled. With V45A in a state of cutoff its plate voltage is up, hence no output is being produced.

A negative-going signal is required at the grid of V45B to force the Trigger Multivibrator into its other state in which a trigger pulse can be produced. However, since the signal at the grid of V45B is an amplification of the triggering signal, it contains both negative- and positive-going portions.

The negative-going portion of the signal will drive the grid of V45B in the negative direction, and the cathodes of both tubes will follow the grid down. At the same time the plate voltage of V45B starts to rise, which causes the grid voltage of V45A to rise. With the grid of V45A going up and its cathode going down, V45A starts to conduct. As V45A starts conducting its cathode starts going up; hence the cathode of V45B starts going up. With the grid of V45B down and its cathode up, V45B cuts off. And since V45A is conducting its plate voltage drops, creating a negative step in the output. This transition occurs very rapidly, regardless of how slowly the grid signal of V45B falls.

When the signal at the grid of V45B starts in the positive direction, just the opposite chain of events will occur. V45B will start conducting again, which in turn will drive the grid of V45A below cutoff. This will cause the voltage

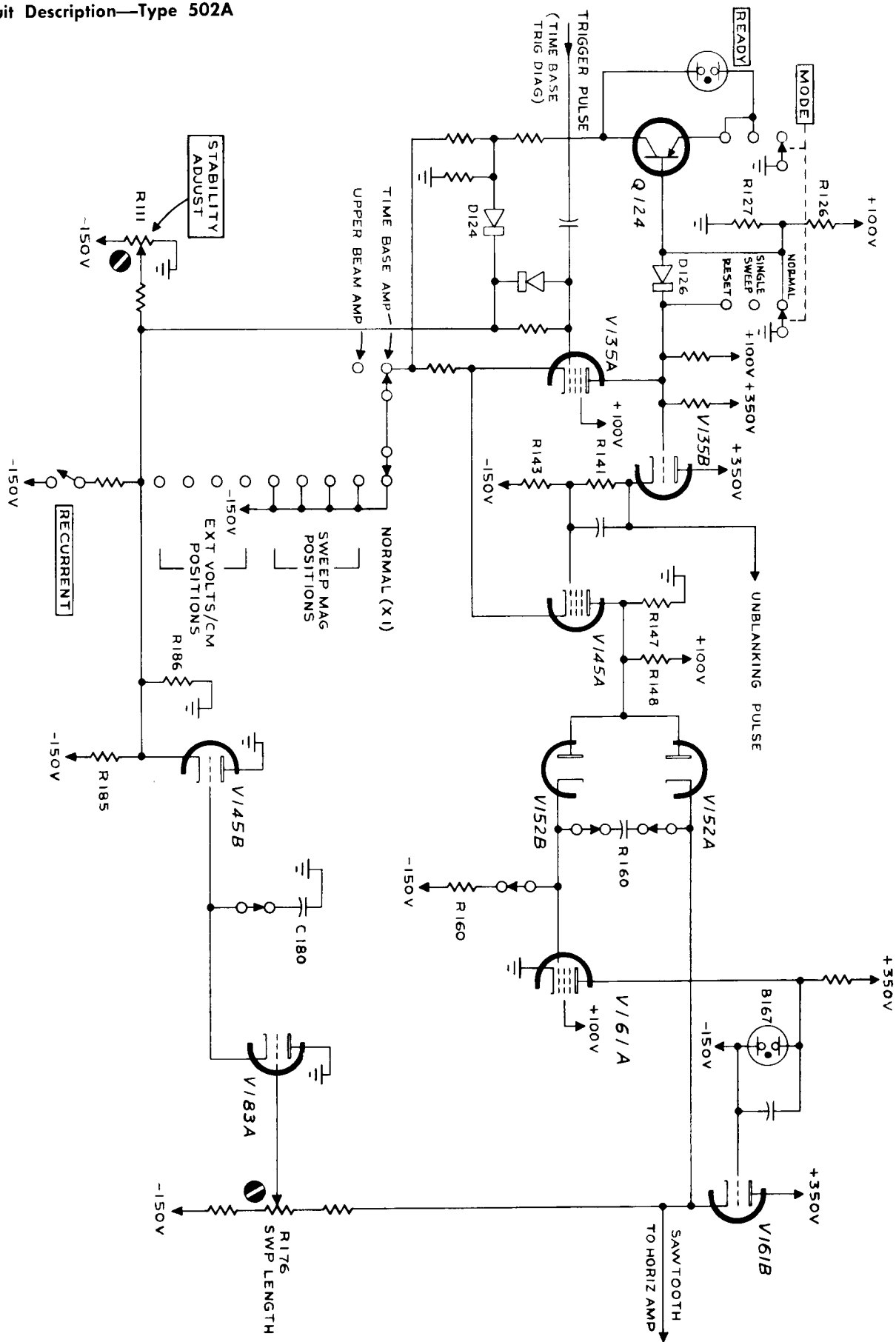


Fig. 3-3. Simplified Sweep Generator.

at the plate of V45A to rise, which in turn will complete the negative step-voltage output from the Trigger Multivibrator circuit.

The Trigger Input Amplifier V24 amplifies the triggering signal that in turn is used to drive the Trigger Multivibrator. The amplified signal is always taken from the plate of V24B, but the grid of either tube (V24A or V24B) can be connected to the input circuit. When the Slope switch SW 20 is in the — position the grid of V24A is connected to the input circuit and the grid of V24B is connected to a bias source adjustable by means of the TRIGGERING LEVEL Control R17. With this configuration V24 is a cathode-coupled amplifier, and the signal at the output plate is in phase with the signal at the input grid. The circuit operation is then as follows: With the Slope switch in the — position, triggering of the Time-Base Generator will occur on the falling (negative-going) portion of the triggering signal. Recalling that a negative-going signal is required at the grid of V45B to drive the Trigger Multivibrator into the other state of its bistable operation, this signal must be of the same polarity as the original signal at the input circuit.

However, when it is desired to trigger the Time-Base Generator on the rising or positive-going portion of the triggering signal the signal at the grid of V45B must be opposite in polarity to that at the input circuit. This is accomplished by placing the Slope switch in the + position. With this arrangement the grid of V24B is connected to the input circuit and the grid of V24A is connected to the bias source. This eliminates V24A from the amplifier circuit and V24B becomes a plate-loaded amplifier. The output waveform will therefore be opposite in polarity to the grid waveform.

The TRIG LEVEL CENT Control R24 determines the division of current through both tubes, and is adjusted so that the quiescent voltage at the plate of V24B lies in the center of the hysteresis of the Trigger Multivibrator. The TRIGGERING LEVEL Control R17 is adjusted to vary the bias on the tube to which it is connected. This in turn varies the quiescent voltage at the plate of V24B about the level established by the TRIG LEVEL CENT Control. The operator can select the point on the waveform at which he wishes to trigger the Time-Base Generator.

When the Time-Base Trigger circuit is switched into the automatic mode of triggering, (TRIGGERING LEVEL) control turned counterclockwise the AUTOMATIC switch SW17 converts the Trigger Multivibrator from a bistable configuration to a recurrent (free-running) configuration. This is accomplished by coupling the grid circuit of V45A to the grid circuit of V45B via R32. In addition, the dc-coupling between the Trigger Input Amplifier and the Triggering Multivibrator is removed when the switch is in this position. The automatic free-running mode is not to be confused with action of the Recurrent switch, shown on the Time-Base Generator diagram, which causes the Sweep-Gating Multivibrator to free-run.

The addition of R32 to the circuit causes the Triggering Multivibrator to free-run in the absence of a triggering signal. For example, assume the grid of V45B is just being driven into cutoff. The voltage at the plate of V45B starts to rise, carrying with it the voltage at the grid of V45A. Since the two grids are coupled through R32, this causes the voltage at the grid of V45B to start rising. The time-constant of the R32-C31 network is such that it takes about .01 second

for the voltage at the grid of V45B to rise exponentially from its starting point, below cutoff, to a point where plate current can start.

As V45B starts to conduct its plate voltage drops, which in turn lowers the voltage at the grid of V45A. The voltage at the grid of V45B then starts dropping exponentially. When this grid drops below cutoff again, the circuit has completed one cycle of its approximately 50-cycle triangular waveform.

With the circuit configuration just described, the horizontal sweep can be triggered with repetitive signals, over a wide range of frequencies, without readjustment. When not receiving triggers, the sweep continues at approximately a 50-cycle rate. Thus, in the absence of any triggering signal the sweep generates a base line which indicates that the instrument is adjusted to display any signal that might be connected to the vertical deflection system.

TIME-BASE GENERATOR

The Time-Base Trigger produces a negative-going rectangular waveform which is coupled to the Time-Base Generator circuit. This waveform is differentiated in the grid circuit of V135A to produce sharp negative-going triggering pulses to trigger the Time-Base Generator in the proper time sequence. Positive-going pulses are also produced in the differentiation process, but these are not used in the operation of the circuit.

The Time-Base Generator consists of four main circuits: A Lockout circuit, a bistable Sweep-Gating Multivibrator, a Miller Runup circuit, and a Hold-Off circuit. The main components in the Lockout circuit are the transistor Q124 and MODE switch SW126. The Multivibrator circuit consists of V135A, V145A and the cathode-follower V135B. The essential components in the Miller Runup circuit are the Miller Runup Tube V161A, the Runup C.F. V161B, the Disconnect Diodes V152, the Timing Capacitor C160 and the Timing Resistor R160. The Hold-Off circuit consists of the Hold-Off C.F.'s V183A and V145B, the Hold-Off capacitors C180 and C181 and the Hold-Off Resistors R181 and R180, A or B (shown on the Timing Switch diagram).

With the MODE switch in NORMAL, the quiescent state of V135A is conducting and its plate voltage is down. This cuts off V145A through the cathode-follower V135B, the voltage divider R141-143 and the cathode resistor R144.

The quiescent state of the Miller Runup Tube is determined by a dc network between plate and grid. This network consists of the neon lamp B167, the grid-cathode impedance of the Runup C.F., and the Disconnect Diodes. The purpose of this dc network is to establish a voltage at the plate of the Miller Runup Tube of such a value that the tube will operate above the knee, and thus over the linear region, of its characteristic curve.

In the quiescent state the grid of the Miller Runup Tube rests at about -2 volts. There is about 25-volts bias on the Runup C.F., and about a 60-volt drop across the neon lamp. This establishes a quiescent voltage of about $+32$ volts at the plate of the Miller Runup Tube.

A negative trigger pulse, arriving at the grid of V135A, will then cause the Sweep-Gating Multivibrator to switch rapidly to its other state. That is, V135A will be cutoff and V145A will start to conduct. As V145A conducts its plate

Circuit Description—Type 502A

voltage, and the voltage at the plates of the Disconnect Diodes, moves negative. This cuts off the diodes.

The current available through the Timing Resistor (R160) is diverted into the Timing Capacitor (C160). This tends to force the grid of the Miller Runup Tube negative. As the grid of the Miller Runup Tube starts negative the plate starts positive. This raises the voltage at the grid and cathode of the Runup C.F. As the voltage at the cathode of the Runup C.F. rises it causes the voltage at the upper end of C160 to increase, which in turn prevents the grid of the Miller Runup Tube from going negative.

The Miller Runup Tube has a gain of about 200, so that a grid voltage change of only .75 volt produces a plate voltage change of 150 volts. Due to the feedback, as explained, the small negative change in grid voltage will provide a nearly linear runup of voltage at the cathode of the Runup C.F.

Maintaining the voltage across the Timing Resistor (R160) nearly constant provides a nearly constant current into the Timing Capacitor (C160), which in turn causes a linear sawtooth output voltage to be generated.

The linear rise in voltage at the cathode of the Runup C.F. V161B is used as the sweep time base. Timing Capacitor C160 and Timing Resistor R160 are selected by means of the TIME/CM switch SW160. The Timing Resistor determines the current that charges the Timing Capacitor. By means of the Timing Switch, both the size of the capacitor being charged and the current charging the capacitor can be selected to cover a wide range of sweep rates. Thus, the timing circuit determines the rate at which the spot moves across the crt.

The length of the sweep, that is, the distance the spot moves across the crt, is determined by the setting of the SWP LENGTH Control R176. As the sweep voltage rises linearly at the cathode of V161B, there will be a linear rise in the voltage at the arm of the SWP LENGTH Control. This will increase the voltage at the grid and cathode of V183A and at the grid and cathode of V145B. As the voltage at the cathode of V145B rises the voltage at the grid of V135A will rise. When the voltage at this point rises to a point where V135A comes out of cutoff, the Sweep-Gating Multivibrator will rapidly revert to its original state with V135A conducting and V145A cutoff. The voltage at the plate of V145A will then rise, carrying with it the voltage at the plates of the Disconnect Diodes V152. The diodes then conduct and the lower-half (V152B) provides a discharge path for the Timing Capacitor through R147 and R148, and through the resistance in the cathode circuit of V161B. The plate voltage of the Miller Tube now falls linearly, under feedback conditions essentially the same as when it generated the sweep portion of the waveform, except for a reversal of direction.

The resistance through which C160 discharges is much less than that through which it charges (the Timing Resistor). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller Runup Tube will return rapidly to its quiescent voltage. This produces the retrace portion of the sweep sawtooth, during which time the crt beam returns rapidly to its starting point.

The Hold-Off Circuit prevents the Time-Base Generator from being triggered during the retrace interval. In addition,

the Hold-Off allows a finite time for the Time-Base circuits to regain a state of equilibrium after the completion of a sweep.

During the trace portion of the sweep sawtooth the Hold-Off Capacitor C180 charges through V183A as a result of the rise in voltage at the cathode of V183A. At the same time the grid of V135A is being pulled up, through the cathode-follower V145B, until V135A comes out of cutoff and starts conducting. As mentioned previously, this is the action that initiates the retrace. At the start of the retrace interval C180 starts discharging through the Hold-Off Resistor. The time-constant of this circuit is long enough, however, so that during the retrace interval, and for a short period of time after the completion of the retrace, C180 holds the grid of V135A high enough so that it cannot be triggered. However, when C180 discharges to the point that the cathode-follower V145B is cutoff, it loses control over the grid of V135A and the grid returns to the level established by the STABILITY ADJUST R111. The amount of hold-off time required is determined by the sweep rate, i.e., by the size of the Timing Capacitor. For this reason the TIME/CM switch changes the time-constant of the Hold-Off Circuit simultaneously with that of the Timing Circuit.

The STABILITY ADJUST R111 regulates the dc level at the grid of V135A. This control should be adjusted so that the voltage at the grid of V135A is just high enough to prevent the circuit from free-running. Adjusted in this manner, a sweep can only be produced when a negative trigger pulse, from the Time-Base Trigger circuit, can drive the grid of V135A below cutoff. However, should a free-running sweep be desired, the TRIGGERING LEVEL control can be turned full right; this closes the RECURRENT switch and connects the grid circuit of V135A to the -150 volt supply through R116. This permits the grid of V135A to fall to cutoff immediately upon removal of the hold-off voltage, at which point the next sweep is initiated.

When the MODE switch is in the NORMAL position, as above, the emitter of Q124 is open, making it inoperative. Also the anode of D126 is grounded, preventing any effect upon the sweep generator circuit.

When the MODE switch is thrown to the SINGLE SWEEP position, the emitter of Q124 is connected to ground and the anode of D126 is connected to a small positive voltage. To consider the action of the circuit, assume that the MODE switch is in the RESET position and then allowed to return to SINGLE SWEEP.

In the RESET position, SW126 grounds the plate of V135A. This places the same potential on both the cathode of D126 and the emitter of Q124, which reverse biases Q124. As Q124 is reverse biased, the voltage at the collector goes negative and the READY light B124 will light when the collector voltage reaches about -60 volts. D124 is also reverse biased as its anode voltage goes negative. The reverse biasing of D124 prevents the collector voltage of Q124 from affecting the grid voltage of V135A until after the sweep.

The grid voltage of V135A will rest during this time at a level which will be determined by R111, R185 and R186. This voltage will be at a value which will allow an incoming trigger pulse to switch the Multivibrator and produce a sweep.

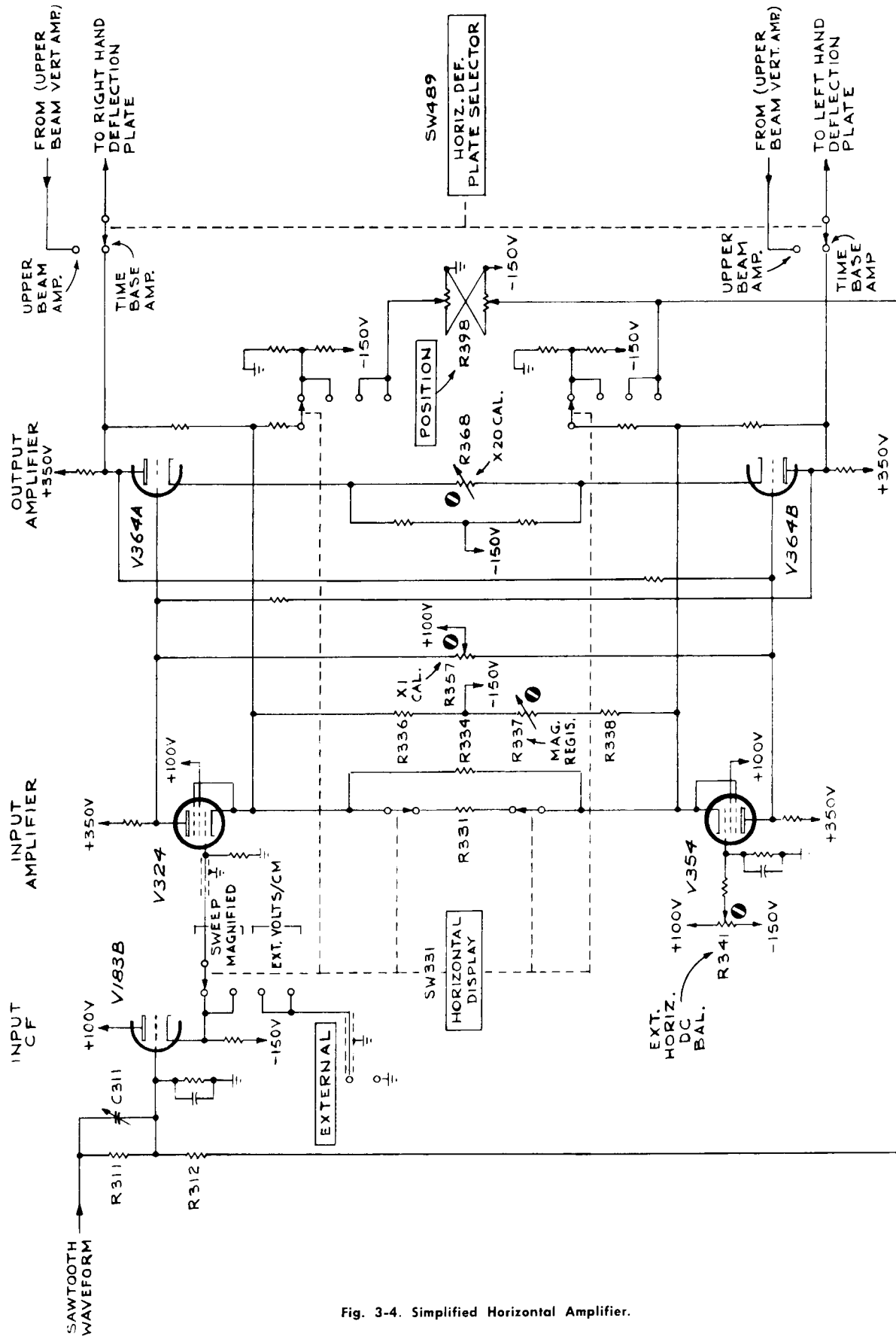


Fig. 3-4. Simplified Horizontal Amplifier.

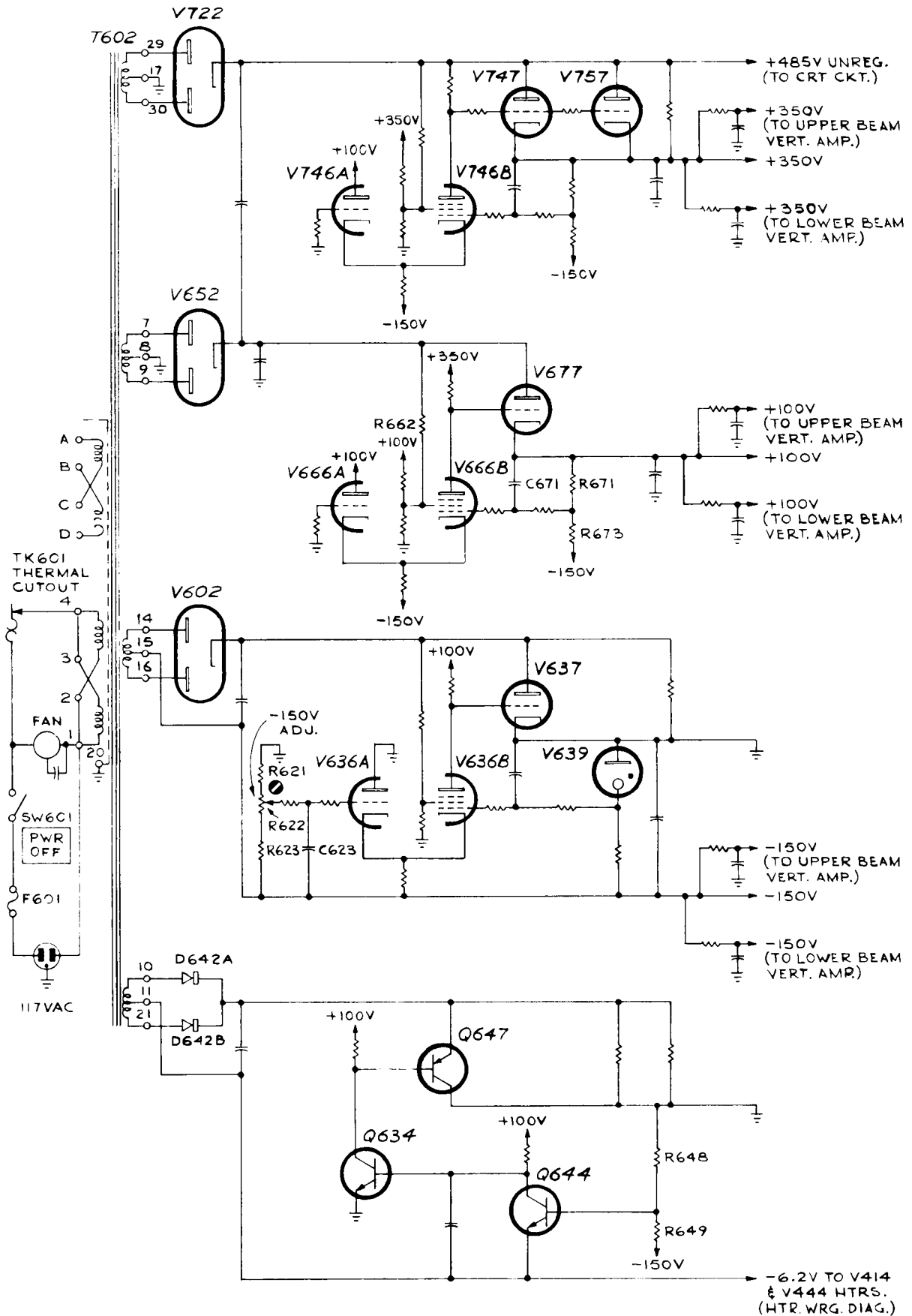


Fig. 3-5. Simplified Low-Voltage Power Supply.

The negative going trigger pulse when it arrives will cause V135A to go into cutoff and V145A to come into conduction. The action of the Sweep Generator circuit as explained still applies.

As the sweep ends, the waveform through V145B turns V135A on and turns V145A off. When V135A comes into conduction, its plate will go slightly negative and forward bias D126. The current flow through D126, R126 and R127 will drop the voltage at the base of Q124 far enough negative, in relation to ground, to turn the transistor on. The voltage on the collector will now go positive towards ground and the READY light will go out. As the collector voltage of Q124 goes positive, D24 becomes forward biased and will control the voltage level on the grid of V135A. This voltage level will be held positive enough to prevent further triggers from switching the Sweep Gating Multivibrator. The circuit will remain in this condition until the MODE switch is either thrown to the RESET position again or put in the NORMAL position.

The positive rectangular pulse appearing at the cathode of V135B is coupled to the grid circuits of the crt. This pulse, whose start and duration are coincident with the trace portion of the sweep sawtooth, unblanks the crt and permits the trace to be observed.

The Time-Base Generator is inoperative when the UPPER BEAM Vertical Amplifier is connected to the horizontal-deflection plates. One section of the HORIZ DEF PLATE SELECTOR switch SW489 is located in the cathode circuit of the Multivibrator, and immobilizes this circuit for the application just described. The same circuit is immobilized, and in the same manner, when the HORIZONTAL DISPLAY switch is set to any of the EXT ranges. With this arrangement the horizontal sweep voltage is obtained through a front-panel EXTERNAL connector rather than from the Time-Base circuits.

HORIZONTAL AMPLIFIER

The Horizontal Amplifier consists of an Input Cathode-Follower, a cathode-coupled Input-Amplifier stage, and a plate-loaded Output Amplifier to drive the horizontal deflection plates in the crt.

The HORIZONTAL DISPLAY switch SW331 determines whether the input waveform is received from the Time-Base Generator or from an external source. When this switch is in either the NORMAL or the SWEEP MAGNIFIED position, the waveform is received from the Time-Base Generator. With this configuration the sweep sawtooth is coupled to the Input C.F. via the frequency-compensated voltage divider R311-R312. The Horizontal POSITION control R398 supplies a manually adjustable dc voltage to the grid of the Input C.F. V183B for horizontal positioning of the crt beam. The Input C.F. isolates the Miller circuit from the Horizontal Amplifier and provides a low-impedance source to drive the switch capacitances and the Input Amplifier.

The Horizontal Amplifier is controlled by feedback networks much the same as the Vertical Amplifiers. This is illustrated in Fig. 3-4. A negative feedback loop extends from the plate circuit of the Output Amplifier to the cathode circuit of the Input Amplifier. The Output Amplifier, on the other hand, has a positive feedback loop between the plate circuit on one side and the grid circuit on the other.

The Input Amplifier is a cathode-coupled paraphase amplifier, and converts the positive-going sawtooth voltage, obtained from the Time-Base Generator, to a push-pull output sawtooth voltage. The gain of the Input Amplifier is determined by the amount of resistance connected between the two cathodes, which in turn determines the degree of negative feedback applied to the stage. In the NORMAL position of the HORIZONTAL DISPLAY switch, R331 is not in the circuit and the cathode resistance is composed of R334 in parallel with the series combination of R336, R337, and R338. In any of the SWEEP MAGNIFIED positions, one of the R331 resistors is switched into the cathode circuit and shunts the total cathode resistance to a lower value. This decreases the amount of negative feedback applied to the stage and consequently increases the gain of the stage.

The function of the MAG REGIS Control R337 is to insure that the waveform will be expanded symmetrically about the center of the crt when the HORIZONTAL DISPLAY switch is changed from NORMAL to any of the SWEEP MAGNIFIED positions. This control dc-balances the amplifier so that the horizontal positioning of the beam will not be affected when the beam is positioned in the center of the crt, as the value of R331 is changed. The X1 CAL Control R357 adjusts the plate-to-plate gain of the stage slightly to compensate for any circuit nonsymmetry. This control is most effective when the HORIZONTAL DISPLAY switch is in the NORMAL position.

The Output Amplifier, by virtue of its positive feedback network, is an extremely high-gain stage. The gain of the stage can be varied over a limited range with the X20 CAL Control R368 which varies the amount of cathode degeneration. This control is most effective when the HORIZONTAL DISPLAY switch is in the X20 SWEEP MAGNIFIED position.

When the HORIZONTAL DISPLAY switch is in any of the EXT VOLTS/CM positions, the horizontal signal is coupled directly from the front-panel EXTERNAL connector to the grid circuit of the Input Amplifier. This action changes the configuration of the amplifier slightly. The Input C.F. is disconnected from the circuit, which changes the dc level at the cathodes of the Input Amplifier slightly. To compensate for this change an EXT HORIZ DC BAL control R341 is adjusted to equalize the cathode voltages.

In the external positions of the HORIZONTAL DISPLAY switch, the Horizontal POSITION control is disconnected from the input circuit and connected between the plates of the Output Amplifier.

POWER SUPPLY

Plate and filament power for the tubes in the 502A Oscilloscope is furnished by a single power transformer T602. The primary has two equal tapped windings; these may be connected in parallel for 117 volt operation, or in series for 234 volt operation. The primary of T602 also has two more windings which may be used as voltage bucking or aiding windings. These windings along with the two main primary windings may be used to allow the instrument to run on line voltages of 110, 117, 124, 220, 234 and 248, depending upon how all the windings are connected. The three main full-wave power supplies furnish regulated voltages of -150, +100 and +350 volts. The +350 volt supply also has an unregulated output of about +485 volts for the high-voltage power supply for the crt. It is unnecessary to regulate this supply as the high-voltage power

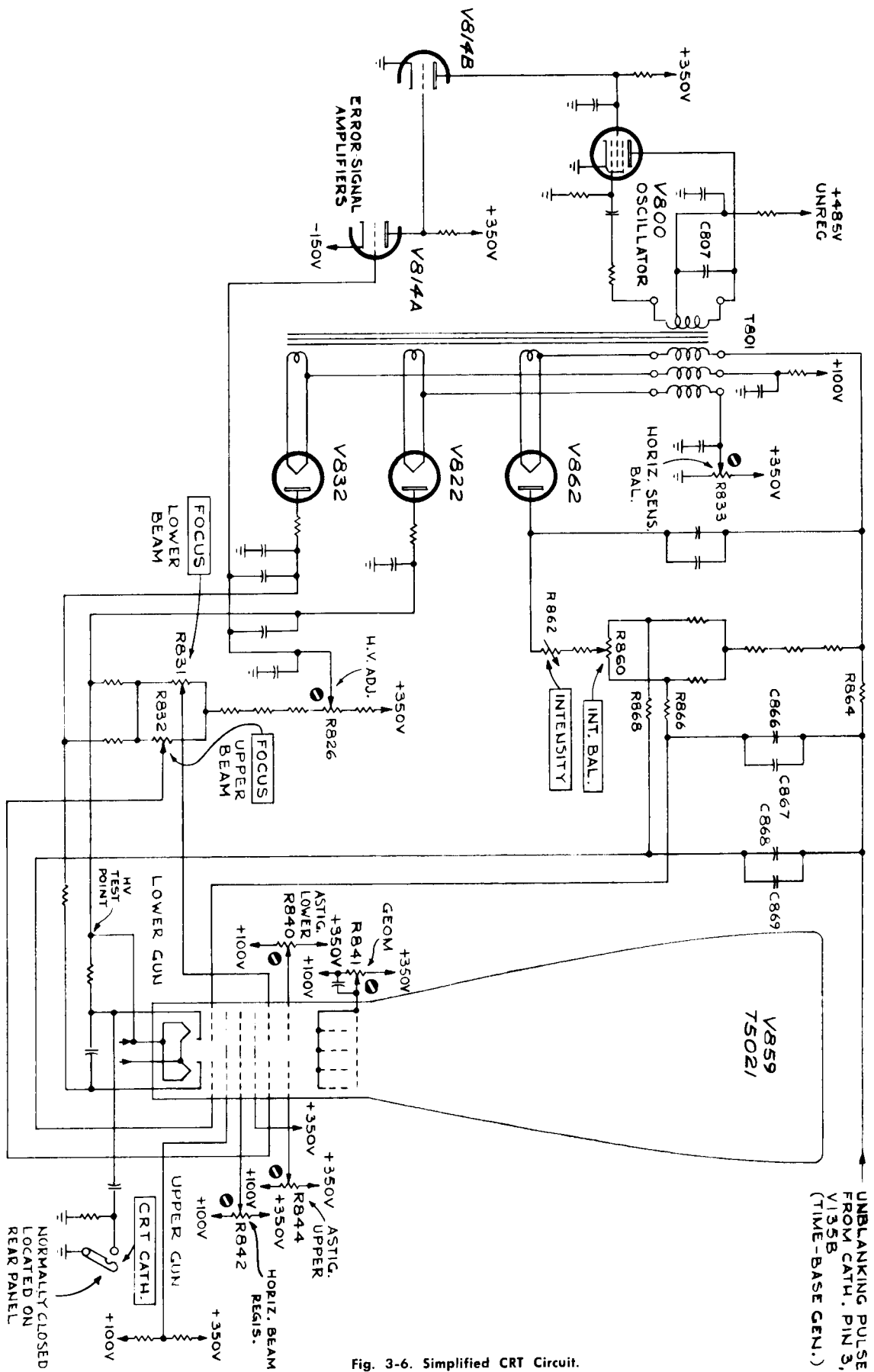


Fig. 3-6. Simplified CRT Circuit.

supplies have their own regulation circuits. In addition to the three main power supplies, a transistorized full-wave supply furnishes a regulated -6.2 volt output for the heaters in the Input Amplifier tubes in the Upper and Lower Beam Vertical Amplifiers.

Reference voltage for the -150 volt supply is furnished by a gas diode voltage-reference tube V639. This tube, which has a constant voltage drop, establishes a fixed potential of about -70 volts at the grid of V636B, one-half of a difference amplifier. The grid potential for the other half of the difference amplifier, V636A, is obtained from a divider consisting of R621, R622 and R623. R622, the -150 Control determines the percentage of total voltage that appears at the grid of V636A and thus determines the total voltage across the divider. When this control is properly adjusted the output is exactly -150 volts.

Should the loading on the supply tend to change the output voltage, the voltage at the grid of V636A will change in proportion, and an error voltage will exist between the two grids of the difference amplifier. The error signal is amplified by V636B, whose plate is dc-coupled to the grid of the series tube V637. The error voltage appearing at the grid of V637 will change the drop across the tube and hence change the voltage at the plate of the tube. The change in voltage at the plate of V637, which will be in a direction to compensate for the change in output voltage, is coupled by the impedance of the rectifier V602 back to the output and thus pulls the output voltage back to its established -150 volts. C623 improves the gain of the feedback loop and thus increases the response of the circuit to sudden change in the output voltage.

The -150 volt supply serves as a reference for the $+100$ volt supply. The divider R671-R673 establishes a voltage of essentially zero at the grid of the amplifier V666B. The actual voltage at this grid will be equal to the bias voltage required by the stage. If the loading should tend to change the output voltage an error voltage will appear at the grid of V666B. This error voltage will be amplified and will appear at the grid of the series tube V677. The cathode of V677 will follow the grid and hence the output voltage will be returned to its established value of $+100$ volts. C671 improves the response of the circuit to sudden changes in the output voltage.

A small sample of the unregulated bus ripple appears at the screen of V666B through R662. The ripple signal which appears at the screen, which acts as an injector grid, will produce a ripple component at the grid of V677 which will be opposite in polarity to the ripple appearing at the plate of V677. This tends to cancel the ripple at the cathode of the tube, and hence reduces the ripple on the $+100$ volt bus. This same circuit also improves the regulation of the supply in the presence of line voltage variations.

The $+350$ volt supply functions in the same manner as the $+100$ volt supply. Rectified voltage from the cathode of V722 is added to the voltage supplying the $+100$ volt regulator, to supply voltage for the $+350$ volt regulator. As mentioned previously, the $+350$ volt supply also furnishes an unregulated output of about $+485$ volts for the crt high-voltage supply.

The -6.2 volt supply works in essentially the same manner as the vacuum-tube supplies. The divider R648-R649 establishes a reference voltage at the base of Q644. If we now assume that the output tends to go more negative, the

emitter of Q644 will also go more negative since it is strapped directly to the output. The collector of Q644 will then go more negative, carrying with it the base of Q634. The collector of Q634 will then go up, carrying with it the base of Q647. The series-regulator transistor Q647 is essentially an emitter-follower, so the emitter will follow the base. Hence, the emitter of Q647 also goes up. This increase in the voltage at the emitter of Q647 will be coupled through the rectifiers, D642A and B, back to the output and will thus pull the output back up to its specified value.

CRT CIRCUIT

A single 40-Kc Hartley oscillator circuit furnishes energy for the three power supplies that provide voltages for the crt. The main components of the Oscillator circuit are V800 and a portion of the primary T801 tuned by C807.

The three half-wave rectifier circuits employ capacitor-input filters. Separate supplies are required for the grid and each of the cathode circuits of the crt in order to provide dc-coupled unblanking to the crt grids.

V822 and V832 supply about -2900 volts for the cathodes of the crt. V862 supplies about -3100 for the grids (the actual voltage depends on the setting of the INTENSITY control.)

In order to maintain a constant deflection sensitivity in the crt, and thereby maintain the calibration of the instrument, it is necessary that the accelerating potentials in the crt remain constant. This is accomplished by regulating the three supplies by comparing a sample of the cathode voltage to the regulated -150 volt supply. This sample voltage, obtained from the arm of the HV Control R826, is applied to the grid of V814A; the cathode of this tube is connected to the -150 volt regulated supply. The error voltage is amplified by V814A and V814B; the output of V814B varies the screen voltage of the Oscillator tube and thus controls its output.

The HORIZ SENS BAL Control R833 allows a more perfect balance of the sensitivity of the two horizontal beams. Varying this control can change the crt cathode potentials by approximately 100 volts with respect to each other. This allows for a corresponding change in horizontal sensitivities of approximately $+ or - 3\%$.

The HORIZ BEAM REGIS will allow the beams to be brought into register; i.e., the sweep for each vertical amplifier will start at the same place on the crt screen.

Unblanking

As mentioned previously, dc-coupled unblanking is accomplished by employing separate high-voltage supplies for the grids and cathodes. The cathode supplies are tied to the LV power supply. The grid supply, on the other hand, is not tied to any other supply and is therefore floating. The unblanking pulses from the Time-Base Generator are transmitted to the grids of the crt via the floating grid supply.

The stray capacitance in the circuit makes it difficult to move the floating supply fast enough to unblank the crt in the required time. To overcome this, an isolation

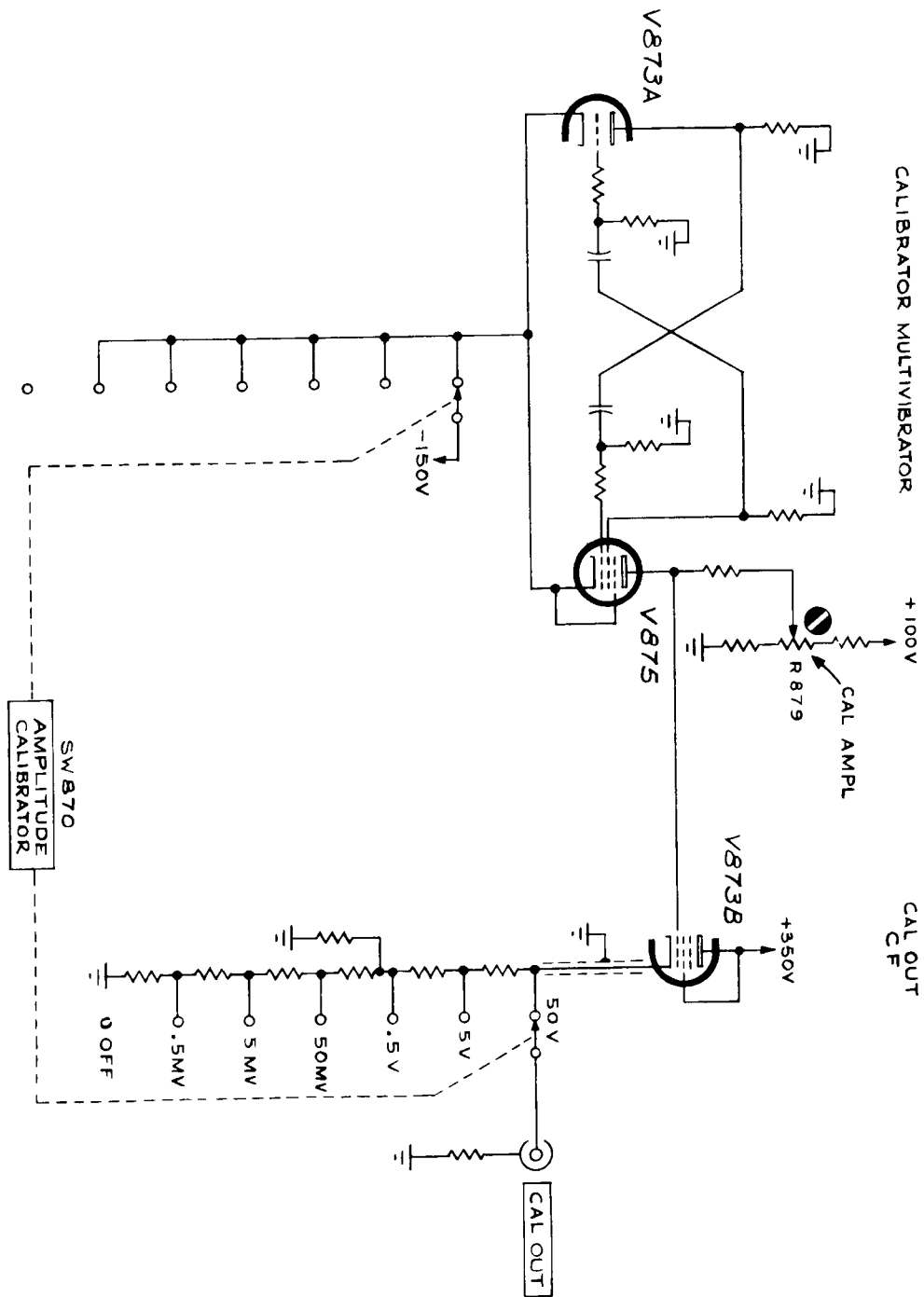


Fig. 3-7. Simplified Calibrator Circuit.

network composed of R864, C868, C869 and R868 for one grid circuit, and R864, C866, C867 and R866 for the other, is employed. By this arrangement, the fast leading edge of the unblanking pulse is coupled directly to the grids of the crt via (C866, C867) and (C868, C869). For short-duration unblanking pulses (at the faster sweep rates) the power supply itself is not appreciably moved. For longer unblanking pulses, at the slower sweep-rates, however, the stray capacitance of the circuit is charged through R864. This holds the grids at the unblanked potential for the duration of the unblanking pulse.

Each gun of the crt has its own FOCUS and ASTIGMATISM Controls. A single control R841 adjusts the geometry of the display, and a single INTENSITY Control controls the brilliance of both beams. An INTENSITY BALANCE Control R860 balances one grid voltage against the other so that the INTENSITY Control will have an equal effect on both beams.

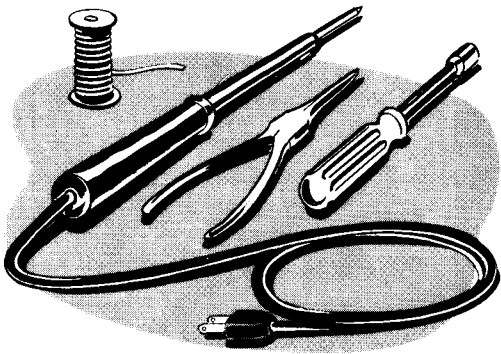
AMPLITUDE CALIBRATOR

The AMPLITUDE CALIBRATOR is a square-wave generator whose approximately 1-Kc output is available at a front-panel connector labeled CAL OUT. It consists of a Multivibrator V873A-V875 connected so as to switch the cathode-follower V873B between two operating states, cutoff and conduction.

During the negative portion of the multivibrator waveform the grid of V873B is driven well below cutoff and the cathode rests at ground potential. During the positive portion of the waveform the grid rises to slightly less than +50 volts. By means of the CAL AMPL (R879) Control, the grid voltage can be adjusted so that the cathode voltage is exactly +50 volts when the AMPLITUDE CALIBRATOR knob is turned to the OFF position.

The Cal Out CF has a precision voltage divider for its cathode resistor. By means of the AMPLITUDE CALIBRATOR switch six calibrated peak-to-peak voltages, from .5 millivolt to 50 volts, are available.

MAINTENANCE



PREVENTIVE MAINTENANCE

Air Filter

Care must be taken to assure free ventilation of the Type 502A inasmuch as some of the components are operated at dissipation levels such that excessive interior temperatures will result without adequate air circulation. To assure free passage of air the instrument must be placed so that the air intake is not blocked and the filter must be kept clean. Moreover, the side panels and bottom cover must be in place for proper air circulation. Do not remove the covers except during maintenance.

A washable filter is used at the air intake part of the instrument. Under normal operating conditions the filter should be inspected and cleaned if necessary every three to four months. More frequent inspection is required when the operating conditions are more severe.

The following cleaning procedure is suggested:

1. Flush loose dirt out of filter with a stream of hot water.
2. Prepare a hot water and mild soap or detergent solution. Wash the filter as you would wash a sponge so that the adhesive and dirt is loosened and floated off.
3. Rinse the filter and let it dry.
4. Dip or spray filter with fresh Filter Coat or Handi Coater. These products are available from the local representative of the Research Products Corporation and from most air conditioner suppliers.

Fan Motor

The fan motor bearings are sealed and should not require lubrication for the life of the motor.

Visual Inspection

You should visually inspect the entire oscilloscope every few months for possible circuit defects. These defects may include such things as loose or broken connections, damaged binding posts, improperly seated tubes, scorched wires or resistors, missing tube shields, or broken terminal strips. For most visual troubles the remedy is apparent; however, particular care must be taken when heat-damaged components are detected. Overheating of parts is often the result of other, less apparent, defects in the circuit. It is essential that you determine the cause of overheating before replacing heat-damaged parts in order to prevent further damage.

Soldering and Ceramic Strips

Many of the components in your Tektronix instruments are mounted on ceramic terminal strips. The notches in these strips are lined with a silver alloy. Repeated use of excessive heat, or use of ordinary tin-lead solder will break the silver-to-ceramic bond. Occasional use of tin-lead solder will not break the bond if excessive heat is not applied.

If you are responsible for the maintenance of a large number of Tektronix instruments, or if you contemplate frequent parts changes, we recommend that you keep on hand a stock of solder containing about 3% silver. This type of solder is used frequently in printed circuitry and should be readily available from radio-supply houses. If you prefer, you can order the solder directly from Tektronix in one pound rolls. Order by Tektronix part number 251-514.

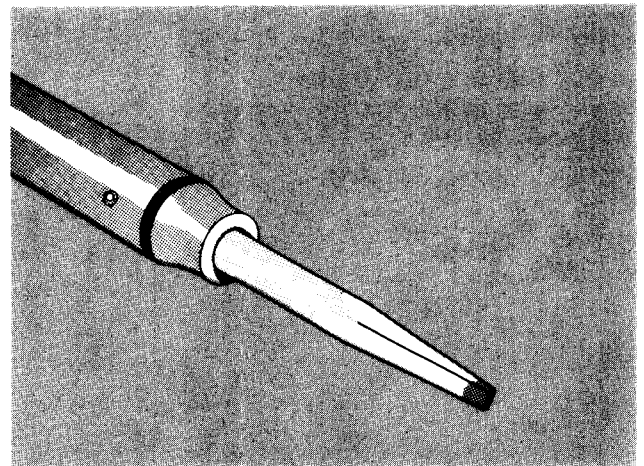


Fig. 4-1. Soldering iron tip properly shaped and tinned.

Because of the shape of the terminals on the ceramic strips it is advisable to use a wedge-shaped tip on your soldering iron when you are installing or removing parts from the strips. Fig. 4-1 will show you the correct shape for the tip of the soldering iron. Be sure to file smooth all surfaces of the iron which will be tinned. This prevents solder from building up on rough spots where it will quickly oxidize.

When removing or replacing components mounted on the ceramic strips you will find that satisfactory results are obtained if you proceed in the manner outlined below.

Maintenance—Type 502A

1. Use a soldering iron of about 75-watt rating.
2. Prepare the tip of the iron as shown in Fig. 4-1.
3. Tin only the first 1/16 to 1/8 inch of the tip. For soldering to ceramic terminal strips tin the iron with solder containing about 3% silver.

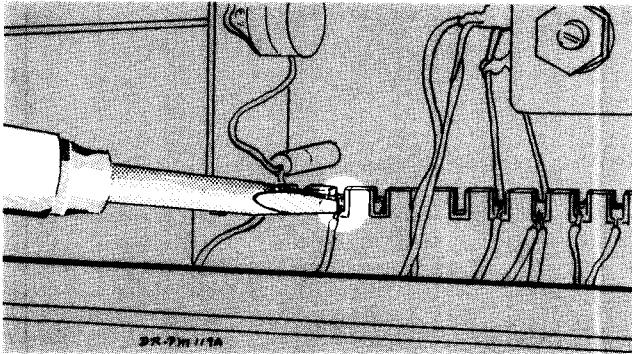


Fig. 4-2. Correct method of applying heat in soldering to a ceramic strip.

4. Apply one corner of the tip to the notch where you wish to solder (see Fig. 4-2).
5. Apply only enough heat to make the solder flow freely.
6. Do not attempt to fill the notch on the strip with solder; instead, apply only enough solder to cover the wires adequately, and to form a slight fillet on the wire as shown in Fig. 4-3.

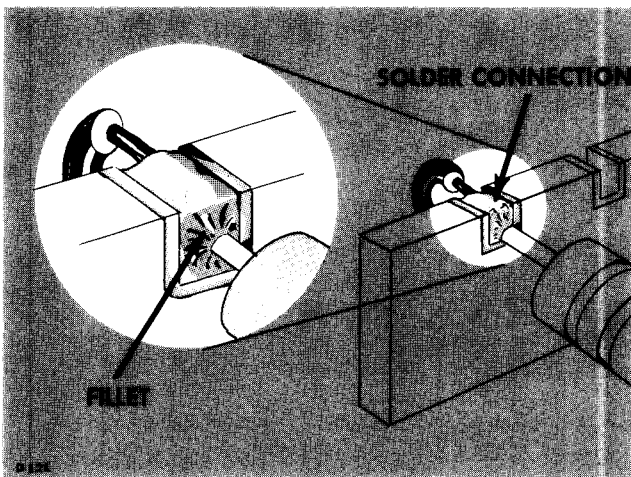


Fig. 4-3. A slight fillet of solder is formed around the wire when heat is applied correctly.

In soldering to metal terminals (for example, pins on a tube socket) a slightly different technique should be employed. Prepare the iron as outlined above, but tin with ordinary tin-lead solder. Apply the iron to the part to be soldered as shown in Fig. 4-4. Use only enough heat to allow the solder to flow freely along the wire so that a slight fillet will be formed.

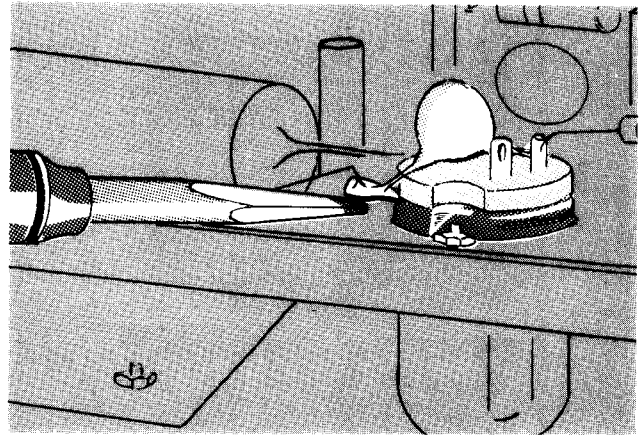


Fig. 4-4. Soldering to a terminal. Note the slight fillet of solder—exaggerated for clarity—formed around the wire.

General Soldering Considerations

When replacing wires in terminal slots clip the ends neatly as close to the solder joint as possible. In clipping the ends of wires take care the end removed does not fly across the room as it is clipped.

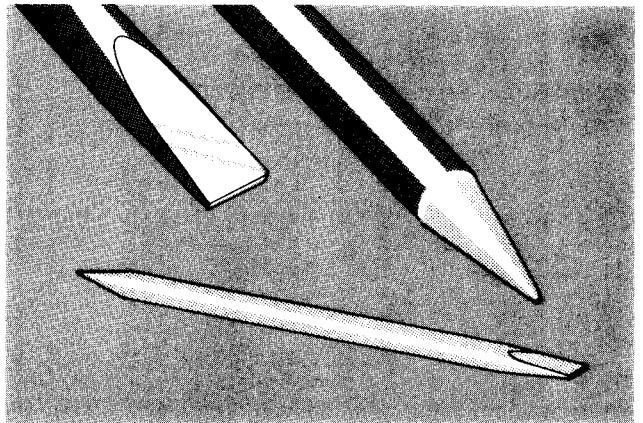


Fig. 4-5. A soldering aid constructed from a 1/4 inch wooden dowel.

Occasionally you will wish to hold a bare wire in place as it is being soldered. A handy device for this purpose is a short length of wooden dowel, with ends shaped as shown in Fig. 4-5. In soldering to terminal pins mounted in plastic rods it is necessary to use some form of "heat sink" to avoid melting the plastic. A pair of long-nosed pliers (see Fig. 4-6) makes a convenient tool for this purpose.

Ceramic Strips

To replace strips which mount with snap-in plastic fittings, first remove the original fittings from the chassis. Assemble the mounting posts on the ceramic strip. Insert the nylon collar into the mounting holes in the chassis. Carefully force the mounting post into the nylon collars. Snip off the portion of the mounting post which protrudes below the nylon collar on the reverse side of the chassis.

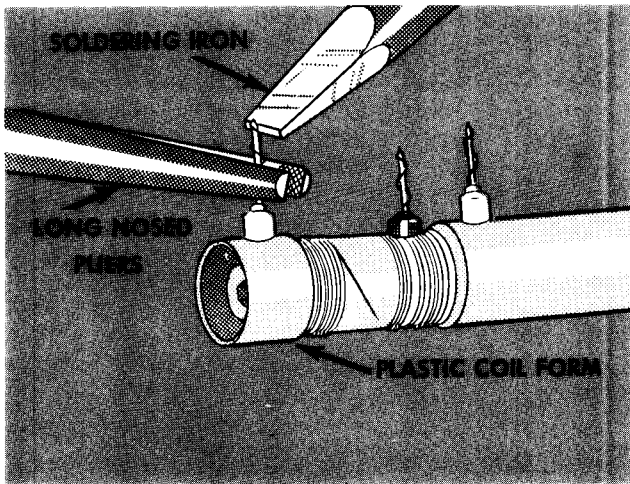


Fig. 4-6. Soldering to a terminal mounted in plastic. Note the use of the long-nosed pliers between the iron and the coil form to absorb the heat.

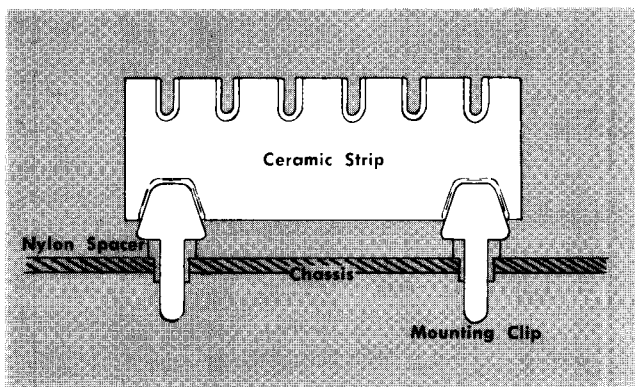


Fig. 4-7. The ceramic strip and its parts.

NOTE

Considerable force may be necessary to push the mounting posts into the nylon collars. Be sure that you apply this force to that area of the ceramic strip directly above the mounting posts.

TROUBLESHOOTING PROCEDURE

This section of the manual contains information for troubleshooting your oscilloscope. Before attempting to troubleshoot the instrument, however, make sure that any apparent trouble is actually due to a malfunction within the instrument and not to improper control settings. Instructions for the operation of the oscilloscope are contained in the Operating Instructions section of this manual.

Tube failure is the most prevalent cause of circuit failure. For this reason, the first step in troubleshooting any circuit in the instrument is to check for defective tubes, preferably by direct substitution. Do not depend on tube testers to adequately indicate the suitability of a tube for certain positions within the instrument. The criterion for usability of a tube is whether or not it works satisfactorily in the instrument. Be sure to return all good tubes to their original

sockets; if this procedure is followed less recalibration of the instrument will be required upon completion of the servicing.

When replacing any tube in the instrument, check first to see that components through which the tube draws current have not been damaged. Shorted tubes will sometimes overload and damage plate-load and cathode resistors. These damaged components can generally be located by a visual inspection of the wiring. If no damaged components are apparent, and if tube replacement does not restore operation, it will be necessary to make measurements or other checks within the circuit to locate the trouble.

The component number of each resistor, inductor, capacitor, vacuum tube, control and switch is shown on the circuit diagrams. The following chart lists the component numbers associated with each circuit:

All numbers	
less than 100	Time-Base Trigger
100 series	Time-Base Generator
300 series	Horizontal Amplifier
400 series	Upper and Lower Beam Vertical Amplifiers
700 series	Low-Voltage Power Supply
800 series	CRT Circuits, High Voltage and Amplitude Calibrator.

Switch wafers shown on the schematic diagrams are coded to indicate the position of the wafer on the actual switches. The number position of the code refers to the wafer number on the switch assembly. Wafers are numbered from the front of the switch to the rear. The letters F and R indicate whether the front or the rear of the wafer is used to perform the particular switching function.

CIRCUIT TROUBLESHOOTING

Although the Type 502A is a complex instrument, it can be thought of as consisting of six main circuits, in addition to the Calibrator circuit. These are the:

1. Low-Voltage Power Supply
2. CRT Circuit and High-Voltage Power Supply.
3. Vertical Amplifiers.
4. Time-Base Trigger Circuit.
5. Time-Base Generator.
6. Horizontal Amplifier.

The first circuit to check, for practically any type of trouble, is the Low-Voltage Power Supply. Because of the circuit configuration employed, it is possible for an improper power supply voltage to affect one circuit more than the others. For example, if the gain of the Vertical Amplifier should decrease slightly, while the other circuits appear to be functioning normally, this could be due to an improper supply voltage and not to any condition originating in the Vertical Amplifier. In cases of this type, valuable can be saved by checking the power supply first.

On the other hand, the crt display can often be used to isolate trouble to one particular circuit when trouble obviously exists in that circuit. If there is no vertical deflection, for example, when the intensity and horizontal deflection appear to be normal, it is apparent that an open condition exists in the Vertical Amplifier and this circuit should be investigated first.

TROUBLESHOOTING THE LOW-VOLTAGE POWER SUPPLY

Proper operation of every circuit in the Type 502A Oscilloscope depends on proper operation of the Low-Voltage Power Supply. The regulated voltages must remain within their specified tolerances for the instrument to maintain its calibration.

For no output voltage

If the graticule lamps and the fan do not operate when the power switch is turned on, check the power switch, the fuse, and the line voltage. If your instrument is wired for 220, 234 or 248 volt operation, also check the thermal cutout switch. (If your instrument is wired for 110, 117 or 124 volt operation, the fan will run even though the thermal cutout switch may be open.) If the fuse is not blown and the line voltage is correct, next check the primary windings of the power transformer.

If both the graticule lamps and the fan operate correctly, the primary circuit of the power transformer is operating normally and the trouble lies somewhere in the secondary circuits.

If only one of the outputs of the Low-Voltage Power Supply is zero, the trouble is probably due to a defective rectifier, series regulator, or power transformer secondary winding, although this trouble can also be caused by a short across the output. To determine which circuit element is defective, measure the secondary voltage of the transformer and the voltage at the output of the rectifier. The cause of the trouble can be determined by voltage readings obtained.

For failure of the regulated power supplies to regulate at the correct voltages.

If any or all of the supplies fail to regulate at the proper voltages, first check the line voltage. The supplies are designed to regulate between 105 and 125 volts (or 210 and 250 volts), with the design center at 117 volts (or 234 volts), rms. (There are similar line voltage ranges for the other nominal line voltages). Improper line voltage may cause one or all of the supply voltages to be off.

All the low voltage power supplies are dependent upon the -150 volt supply for regulation, and consequently, a change in the regulation point of all the supplies is indicative of a defective -150 volt supply. If the output voltage of the -150 volt supply is off by only a small amount, it may be possible to readjust the -150 Control for the proper voltage. In any event it will be necessary to recalibrate the instrument according to the procedures given in the Calibration Procedure section of this manual.

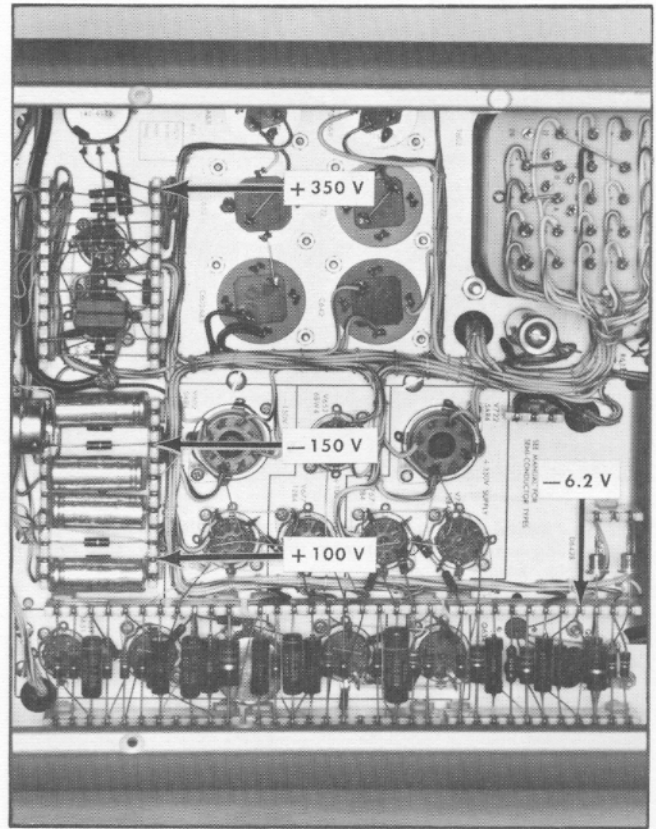


Fig. 4-8. Low voltage power supply test points.

In case of the failure of a single power supply to regulate properly, check the following:

1. Line voltage
2. Transformer voltage
3. Output voltage of the rectifier
4. Tubes or transistors
5. Loading

Important power supply voltages are marked on the power supply schematic diagram. These voltages may be used to perform checks on the power supply operation. One cause of improper regulation by a power supply is incorrect loading of the supply. To check power supply loading, shut off the power and check the resistance of the power supply output bus to ground. The -150 volts bus should read approximately 3,500 ohms, the $+100$ volt bus approximately 4,000 ohms, and the $+350$ volt bus approximately 10,000 ohms.

If none of the preceding checks determine the cause of the trouble, the cause of the improper regulation is probably a change in value of one or more of the resistors or capacitors composing the voltage divider networks. The resistance networks in the grid circuits of V746B, V666B and V636A and the base circuits of Q644 are particularly critical since they determine the output voltage of their respective power supplies. Use resistance checks to isolate the defective part or parts. The following information may be used as a quick index to troubleshooting the Low-Voltage Power Supply.

If the output voltage is high with excessive ripple, check:

1. For high line voltage
2. The amplifier tubes and transistors (V746, V666, V636, Q644, and Q634)
3. For insufficient loading

If the output voltage is high with normal ripple, check:

1. For proper resistance values in the dividers (R751 and R753; R671 and R673; R621, R622, and R623; and R648 and R649)

If the output voltage is low with excessive ripple, check:

1. For low line voltage
2. The series regulator tubes and transistor (V747, V757, V677, V637, or Q647)
3. For excessive loading
4. Open or leaky filter capacitors
5. Rectifiers (V722, V652, V602, or D642A,B)

If the output voltage is low with normal ripple, check:

1. The resistance values in the dividers
2. The capacitors across the dividers

If the output voltage is normal with excessive ripple, check:

1. Filter capacitors at the output of the rectifiers and at the regulated output
2. AC bypass capacitors in the grid circuits of the regulator amplifiers
3. Regulator amplifiers (screen grid circuits)

TROUBLESHOOTING THE CRT CIRCUIT

For troubles which affect both beams

The intensity, calibration, focus, and geometry of the crt display depend on the proper operation of the high-voltage power supply in the CRT Circuit. In general, troubles occurring in the high-voltage power supply will produce similar effects on both beams.

If no high voltage (or insufficient high voltage) is available from either the grid or cathode supplies, a defective oscillator circuit or excessive loading is probably the cause. The oscillator can be quickly checked by placing a neon bulb against V800, the oscillator tube. If the bulb glows, the oscillator is operating and the trouble is likely to be in the secondary windings of T801 if there is no high voltage, or in the regulator circuit (V814), if the high voltage is abnormally low. It is unlikely that all three rectifier tubes would simultaneously be defective.

If the neon bulb does not glow, the oscillator is not operating. If replacement of the oscillator tube V800 and the regulator tube V814 does not clear up the trouble, check

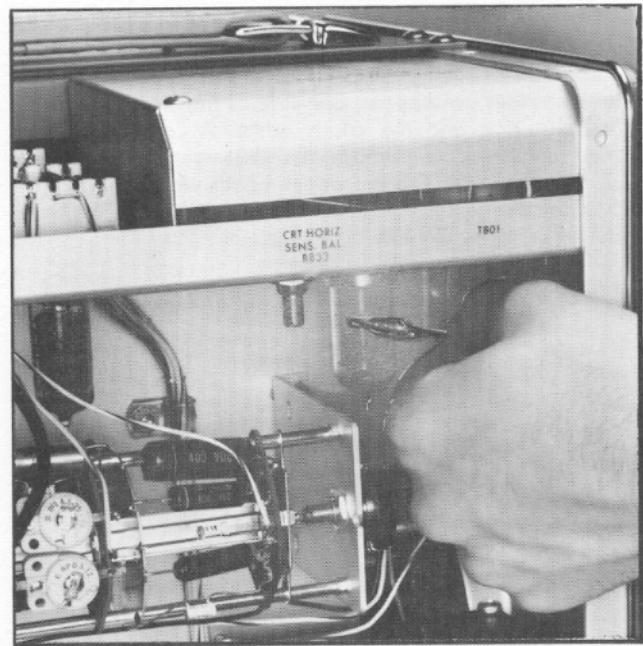


Fig. 4-9. Checking operation of the high voltage oscillator circuit by means of a neon bulb.

the components of the oscillator circuit including the primary and secondary windings of transformer T801.

If the proper output voltage is obtained from at least one of the high voltage supplies, the oscillator circuit need not be checked. In this case, you can check the rectifier and components associated with the inoperative supply. If the proper output voltages are obtained from all the H.V. supplies and the circuit is still not operating correctly, check the voltage dividers which control the intensity and focus of the beams. If these are also normal, the trouble will likely be the crt itself or its cathode circuitry. Badly misfocused and distorted displays can be caused by an open Geom Control or a loose connection at the neck of the crt.

If the high voltage appears to be abnormal, as evidenced by decreased or increased horizontal and vertical deflection sensitivity, the regulator circuit (V814) should be checked. If this tube or any component of this circuit is changed, the setting of the HV Control (R826) should be checked and adjusted if necessary according to the procedure given in the Calibration Procedure section of this manual.

For troubles which affect only one beam

Troubles which affect only one beam will generally be caused by defects in the intensity and focus voltage dividers, by the Astigmatism Controls, or by the crt. These parts (except for the crt) can be checked by voltage and resistance measurements. If the circuit checks out satisfactorily, replace the crt.

TROUBLESHOOTING THE VERTICAL AMPLIFIERS

For no spot or trace

If a trace (or spot) is visible when the vertical deflection plates are externally shorted together, but disappears when

the short is removed, the vertical amplifier is in a state of dc unbalance. To determine the cause of this condition, short the plates of the output stage (V474B and V484B) together. If the trace does not appear, one side of the circuit, between the output stage and the crt, is open. A continuity check with an ohmmeter is perhaps the best way to determine which side is open. On the upper beam vertical amplifier, check particularly the connections at the HORIZ DEF PLATE SELECTOR switch, SW489.

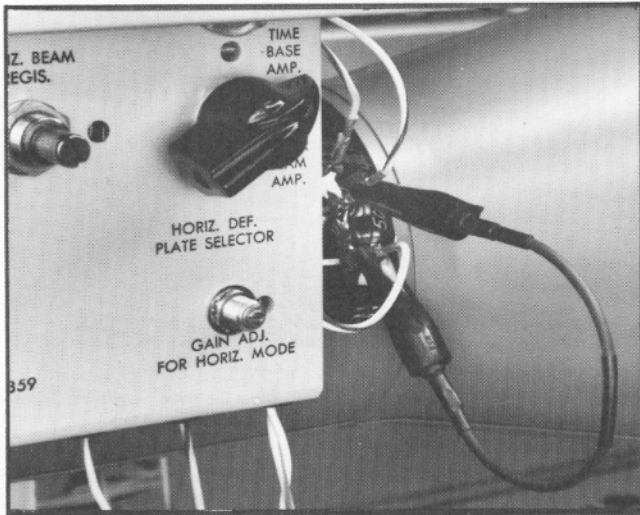


Fig. 4-10. Checking for unbalance in the upper beam vertical amplifier by shorting the vertical deflection plates together.

If the trace does appear when the plates of the output stage are shorted together, the circuit between this point and the crt pin connections is normal. The trouble then lies somewhere in the vertical amplifier ahead of the plate circuit of the output stage. To locate the defective stage, move the shorting strap back, point by point, between corresponding points on opposite sides of the circuit. As you short between the points, in turn, the spot should return on the screen as each connection is made. You may have to readjust the DC BAL controls when shorting between grids of

the input stage. When you reach a point where the spot does not return to the screen, the stage immediately following this point is at fault. The trouble may be caused by a defective tube, resistor, or capacitor.

For insufficient or no vertical deflection.

Insufficient vertical deflection indicates a change in the gain characteristics of the Vertical Amplifier. If the change is small, the Vertical Amplifier can usually be recalibrated for gain. Refer to the Calibration Procedure for this.

If the change in gain is more pronounced, or if there is no vertical deflection at all, the tubes should be checked first. Then check for components which will affect the gain of both sides of the amplifier without unbalancing the amplifier. Such parts are common cathode resistors in the amplifier stages, or plate dropping resistors which are common to both sides of the amplifier.

Insufficient vertical deflection will also be caused if the upper or lower frequency limit of the amplifier is exceeded.

For waveform distortion

Waveform distortion can be divided into two categories . . . low frequency and high frequency. If a square wave is applied to an input of the oscilloscope, the type of distortion can be determined by the shape of the displayed waveform. High frequency distortion will primarily affect the leading edge and trailing edge of the applied square wave while low frequency distortion will primarily affect the mid-portion of the waveform.

Waveforms showing low frequency distortion and two types of high frequency distortion are shown in figure 4-11. The shape of these waveforms will vary widely however, with the cause of the distortion and the frequency of the applied wave. A nominal amount of low frequency distortion is normal for very low input frequencies when ac coupling is used, and a nominal amount of high frequency distortion is normal at the upper frequency limits of the instrument. It is only when this distortion is excessive in the normal frequency range of the instrument that it constitutes a trouble.

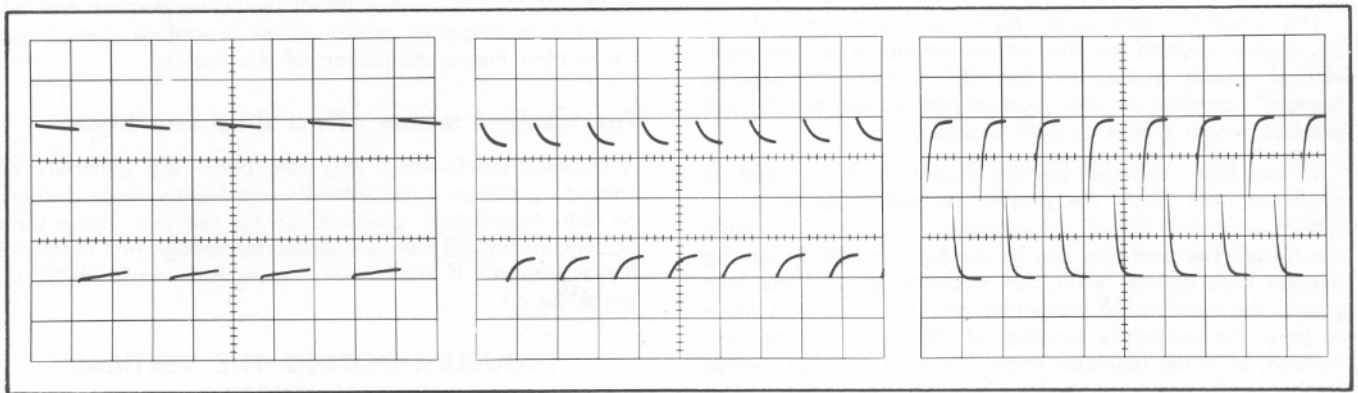


Fig. 4-11. Frequency distortion. (a) Low frequency distortion of a 20 cycle square wave due to attenuation of the low frequency components of the waveform. (b) High frequency distortion of a 1200 cycle square wave due to excessive boost of the high frequency components of the waveform. (c) High frequency distortion of a 1200 cycle square wave due to attenuation of the high frequency components of the waveform.

Low frequency distortion is usually caused by a change in the time constant of the input coupling circuit. If tubes become gassy, their resultant grid current will establish a time constant network which will affect the low frequency response of the circuit.

High frequency response can be affected considerably by an improperly adjusted probe. Consequently, in any case of high frequency distortion you should first check the probe adjustment. Refer to the Operating Instructions for the compensation procedure. Other factors which can affect the high frequency response of the vertical amplifier are mainly related to the high frequency compensation networks.

An overshoot waveform shown accentuated in Fig. 4-11 is the result of excessive high frequency compensation. This can be caused by a tube condition known as cathode interface. If this type of distortion is detected, you should check the tubes in the amplifier. If tube replacement does not completely correct the trouble, you should then check the adjustment and operation of the high frequency compensation circuits.

For improper triggering

Improper triggering can be caused by a defective trigger pickoff circuit. The trouble may be caused either by a faulty cathode follower, V493 or by a defective component in the circuit.

TROUBLESHOOTING THE TIME-BASE TRIGGER

If the trouble occurs in some but not all positions of the TRIGGER SELECTOR switch, the trouble is likely due to a defective TRIGGER SELECTOR switch or input coupling circuit. If the trouble occurs in all positions of the TRIGGER SELECTOR switch, either the trigger input amplifier or the trigger multivibrator will be at fault. You should check tubes V24 and V45.

NOTE

All voltages in this section are measured with a 20,000 ohms-per-volt voltmeter.

To determine which stage is defective, rotate the TRIGGERING LEVEL Control fully counter-clockwise to the AUTOMATIC position. With no triggering signal, the sweep should appear on the crt. If the sweep does not appear, the trigger multivibrator is defective. If the sweep does appear, either the trigger input amplifier or the trigger multivibrator may be at fault.

A check on the trigger input amplifier circuit may be made as follows: With the TRIGGERING LEVEL Control still in the AUTOMATIC position, measure the voltage at the plate, pin 6, of V24B. This voltage should be approximately +96 volts. If the voltage is incorrect, the trigger input amplifier circuit is defective. The trouble will probably exist in the resistors or switches of the circuit.

If the voltage measured is correct, rotate the TRIGGERING LEVEL Control completely through its range while monitoring the voltage at pin 6 of V24B. The voltage should

vary between approximately 34 and 135 volts. An incorrect voltage range indicates a defective trigger input amplifier or TRIGGERING LEVEL Control. If the voltage range is correct, the trouble will be in the trigger multivibrator. A trouble in the multivibrator will probably be due to defective resistors. The voltage divider network between the plate of V45A and the grid of V45B is particularly critical.

TROUBLESHOOTING THE TIME-BASE GENERATOR

For free-running operation

If the Time-Base Generator free runs when the TRIGGERING LEVEL Control is not in the RECURRENT or AUTOMATIC positions this is due to astable operation of the sweep gating multivibrator. This trouble will probably be due to defective resistors in the grid circuit of V135A (resistors R185, R186, or R111) or in the grid circuit of V145A (resistors R141 or R143).

For no horizontal sweep

If the Time-Base Generator is not producing a sawtooth waveform when the TRIGGERING LEVEL Control is in the RECURRENT position, some defect in the circuit is causing the output to remain at some fixed voltage. A clue to the cause of this trouble can be obtained by measuring the plate voltage of the Miller tube, V161A. The voltage reading obtained will probably be either approximately +300 volts or approximately +30 volts. A reading of +300 volts indicates that the Miller stage has run up and has not been reset, while a reading of +30 volts indicates that the Miller stage is not being allowed to run up. The condition that actually exists will depend on the type of trouble occurring in the circuit. The two conditions of plate voltage will be handled separately in the following paragraphs.

Miller Stage is Run-up

If the voltage at the plate of the Miller tube, V161A, is high, the tube is cutoff. This can result from any one of the following conditions: (1) Disconnect Diodes do not conduct, (2) Sweep-Gating Multivibrator does not reset, (3) Hold-Off Cathode Followers do not reset the Sweep-Gating Multivibrator and (4) Runup Cathode Follower does not drive the Hold-Off Cathode Follower. The defective stage can be detected by a series of systematic voltage measurements. When an improper voltage reading is obtained, this will indicate the defective stage.

Check the voltage at the grid of the Miller tube. If the reading is only a few volts negative, the Disconnect Diodes are probably conducting normally and can be eliminated as a possible cause of the trouble. If the voltage is more negative than -50 volts, however, the diodes are not conducting. Check V152 and resistors R147 and R148.

Measure the voltage at the output of the Time-Base Generator (pin 3 of V161B). If this voltage is approximately +250 volts, the Runup Cathode Follower stage may be assumed to be operating correctly. If this voltage is low, however, the stage is defective and its grid and cathode circuits should be checked.

Next, measure the grid to cathode voltage of the Hold-Off Cathode Follower, V183A and V145B. Both of these readings should be approximately -4 volts if the cathode followers are operating correctly. If either or both of these voltages are incorrect, check the hold-off capacitor and the resistors in the cathode circuits of the two stages.

If the previous checks gave correct results, the voltage at the grid of V135A should be sufficient to reset the multivibrator (more positive than -35 volts). If this is so, and the multivibrator still does not reset, the trouble must lie in that stage. Check the voltages at the plates of V135A, V135B, and V145A, and the resistors in the cathode circuit of V135B.

Miller Stage will not Run-up

Low voltage at the plate of the Miller tube indicates that the tube is conducting quite heavily and is not being allowed to perform its normal runup operation. If this trouble exists on only a few ranges of the TIME/CM switch the trouble is likely to be an open timing resistor. If the trouble exists on all ranges of the TIME/CM switch, the trouble is probably due to a defective Sweep-Gating Multivibrator stage.

To check the Sweep-Gating Multivibrator, monitor the voltage at the junction of R114 and R116 and adjust the STABILITY ADJUST Control for a reading of -70 volts on the voltmeter. With this voltage, the Sweep-Gating Multivibrator and the sweep should free run. If the multivibrator does not switch, check the resistances which make up the stage.

If the voltage at the junction of resistors R114 and R116 remains relatively constant as the STABILITY ADJUST Control is rotated, a defect in cathode follower V145B may be causing the stage to effectively regulate the voltage at this point. If such is the case, the probable cause of this condition is a shorted holdoff capacitor. If the voltage does not adjust to the proper level, check the resistors in the grid circuit of V135A.

For nonlinear sweep

A nonlinear sweep voltage will be generated if the current charging the Timing Capacitor does not remain constant. If the nonlinearity exists at all sweep rates, a defective Miller tube is the probable cause of the trouble. If the nonlinearity occurs only at certain sweep rates, the Miller tube or a leaky Timing Capacitor is the probable cause.

For insufficient horizontal deflection

If the horizontal trace starts at the left-hand side of the screen, but does not extend to the right-hand side, the Hold-Off circuit is resetting the Sweep-Gating Multivibrator before the sweep is complete. If the sweep cannot be adjusted to normal length with the SWP LENGTH Control R176, the resistance in the cathode circuit of V161B should be checked.

Single Sweep will not perform properly

If D126 opens, the Time-Base Generator will still operate normally when the MODE switch is in the NORMAL position. However, when the instrument is set up for Single Sweep operation, the circuit will not lockout at the end of the sweep. This of course means that each incoming trigger will produce another sweep across the crt.

If on the other hand D126 becomes shorted or leaky, then the Time-Base Generator will not produce a sweep even though the Single sweep circuit seems to be resetting all right. If this condition exists the plate voltage of V135A should be checked. It should normally be approximately $+138$ volts when the Time-Base Generator is producing a sweep, however when the Time-Base Generator is not producing a sweep the plate voltage of V135A will normally be approximately $+4$ volts.

D124 being opened will also cause the Single Sweep circuit not to lockout, even though the READY light seems to operate normally.

When D124 is shorted or leaky it will cause the Time-Base Generator to free-run since the grid of V135A is pulled negative. The TRIGGERING LEVEL Control will have little or no effect upon the free-running Time-Base Generator.

TROUBLESHOOTING THE HORIZONTAL AMPLIFIER

For no spot or trace

If both beams are visible when the horizontal deflection plates are externally shorted together, but disappear when the short is removed, the horizontal amplifier is in a state of unbalance. The procedure for troubleshooting the Horizontal Amplifier is somewhat the same as that explained previously for troubleshooting the Vertical Amplifiers for unbalance. Corresponding points on opposite sides of the Horizontal Amplifier circuit should be progressively shorted together until a point is reached where the beams do not return to the face of the crt. The stage immediately following this point is the one which is defective. Check for open resistors in the cathode and plate circuits.

For insufficient or no horizontal deflection

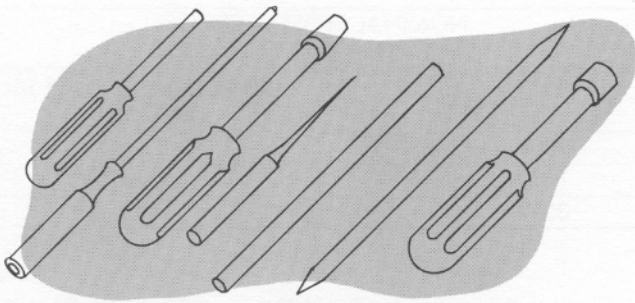
If the gain of the Horizontal Amplifier decreases, the trace will not extend to the left and right sides of the crt screen. In addition, the sweep timing will no longer be calibrated on any range of the TIME/CM switch. If the change in sweep timing and sweep length is slight, it may be possible to correct this trouble by adjusting the high voltage and the X1 CAL and X20 CAL Controls according to the instructions contained in the Calibration Procedure.

If the decrease in gain of the Horizontal Amplifier is more pronounced, or if there is no sweep at all, check for components which will affect the gain but not the balance of the amplifier. The input cathode follower, V183B, should be checked as one of the first steps. Also, the common resistances in the cathodes of the amplifier stages should be checked.

SECTION 5

CALIBRATION

PROCEDURE



General Information

The instrument should not require frequent recalibration, but occasional adjustments will be necessary when tubes and other components are changed. Also, a periodic calibration is desirable from the standpoint of preventive maintenance.

Apparent troubles occurring in the instrument are often actually the result of improper calibration of one or more circuits. Consequently this section of the manual should be used in conjunction with the Maintenance section during troubleshooting work.

In the instructions that follow, the steps are arranged in the proper sequence for a complete calibration of the instrument. Each numbered step contains the information required to make one adjustment or a series of related adjustments.

In each calibration step only the required information is given. Controls are assumed to be set at the positions they were in during the previous step unless specific instructions are given to change their settings. All test equipment, except for input signal sources, and all jumpers are disconnected at the end of each step unless instructions are given to the contrary. Input signal voltages should remain connected to the instrument until specific instructions are given to disconnect them or until another input signal is applied to the same input connector.

It will be necessary for you to refer to the calibration steps immediately preceding the adjustment you wish to make to determine the proper settings for the controls not mentioned in that step. Due to the interaction between adjustments in the horizontal and vertical amplifiers, single adjustments in these circuits usually cannot be made. When amplifier adjustments are required, the entire amplifier should be calibrated. In addition, if either the -150 volt supply or the high voltage power supply is adjusted, the entire instrument must be calibrated.

If you find that a circuit is out of calibration, but you are not aware of which particular adjustment will correct the difficulty, it is usually best to calibrate the entire circuit.

Equipment Required

The following equipment or its equivalent is necessary for a complete calibration of the Type 502A Oscilloscope.

1. DC voltmeter (sensitivity of at least 5000 ohms per volt) with corrected readings within 1% for 100, 150 and 350 volts and within 3% for 2900 volts. Be sure your meter is accurate; few portable test meters have the required accuracy, particularly after a period of use.

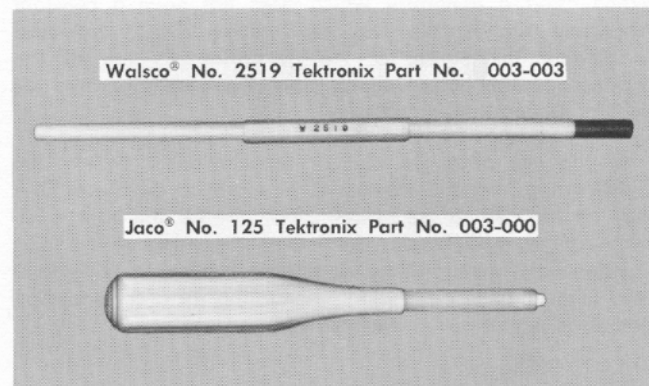


Fig. 5-1. Tools required for calibrating the Type 502A Oscilloscope.

2. Accurate rms-reading ac voltmeter, 0-150 volts (0-250 or 0-300 volts for 210- to 250-volt operation).
3. Variable autotransformer, having a rating of at least 500 watts.
4. Time-mark generator, Tektronix Type 180A or 181. If neither of these instruments is available, it will be necessary to substitute a time-mark generator having markers at 1 microsecond, 5 microsecond, 10 microsecond, 50 microsecond, 100 microsecond, and 1 millisecond intervals.
5. Square-wave generator, Tektronix Type 105. If a Type 105 Square-Wave Generator is not available, it will be necessary to substitute a square-wave generator with the following specifications: (1) output frequencies of 200 cycles, 1 kilocycle, and 10 kilocycles, (2) rise-time no more than 20 nanoseconds, and (3) output amplitude variable between approximately 40 millivolts and approximately 100 volts.
6. Oscilloscope, Tektronix Type 316 or 317. If a Type 316 or 317 Oscilloscope is not available, it will be necessary to substitute an oscilloscope with the following specifications: (1) calibrated vertical deflection factors from .01 to 10 volts per division and (2) bandpass of dc to 10 megacycles.
7. 50-ohm, 42 inch Coaxial Cable (1)
8. Tektronix 50-ohm Termination Resistor. (2)
9. Tektronix Type 5XT, 50-ohm T-Pad. (2)
10. Tektronix 47 pf Input Time Constant Standardizer, Tektronix part number 011-030 (1).
11. Tektronix Type 10XT, 50-ohm T-Pad. (1)
12. Coaxial "T" Connector. (1)

Calibration Procedure—Type 502A

13. Coaxial "Straight" Connector. (1)

14. Jumpers, 6 inch with banana plugs. (3)

15. A constant amplitude sine-wave generator having output frequencies of 1 kilocycle, 50 kilocycles, 100 kilocycles, 200 kilocycles, 400 kilocycles and 1 megacycle. The generator should also have a variable output amplitude from 500 μ volts to 2 volts.

If a constant amplitude generator is not available to cover the above ranges, any generator which has the proper frequencies and output amplitudes may be used. When using a generator which does not have a constant amplitude feature the test oscilloscope should be used to monitor the output of the generator. By use of the oscilloscope the output signal from the generator may be kept at a constant amplitude.

By the use of a DB box or an attenuator system, the signal going from the sine-wave generator to the Type 502A may be reduced to the proper amplitude for the high sensitivity ranges, while at the same time the signal going from the sine-wave generator to the test oscilloscope may be kept at a high amplitude to enable monitoring for a constant amplitude of signal out of the sine-wave generator.

Preliminary

Preset the front-panel controls of the Type 502A as follows:

POWER AND SCALE ILLUM	PWR OFF
INTENSITY	full counterclockwise
INTENSITY BALANCE	midrange
FOCUS (both beams)	midrange
TRIGGERING LEVEL	midrange
TRIGGER SELECTOR	+ LOWER AC
MODE Switch	NORMAL
TIME/CM	1 mSEC
VARIABLE	CALIBRATED
HORIZONTAL DISPLAY	2 EXT VOLTS/CM
HORIZONTAL POSITION	midrange
AMPLITUDE CALIBRATOR	OFF
HORIZ DEF PLATE SELECTOR	TIME BASE AMP

The following applies to both vertical amplifiers:

Input Selector	A-DC
SENSITIVITY	.2 VOLTS PER CM
VARIABLE	CALIBRATED
DC BAL.	control will be set later.
VERTICAL POSITION	midrange

Before applying power to the instrument the resistances of the power supplies should be checked. The typical resistances of the supplies may be found in the chart below.

NOMINAL RESISTANCES OF POWER SUPPLIES	
SUPPLY	APPROX. RESISTANCE TO GROUND
-150V	3.5 k
100V	4 k
350V	10 k

Connect the power cord and the ac voltmeter to the output of the autotransformer. Rotate the POWER AND SCALE ILLUM control clockwise to the ON position and adjust the autotransformer for an output of 117 volts (or 234 volts). Allow the instrument to warm up for several minutes before proceeding with the calibration adjustments. During calibration, periodically check the input voltage to the instrument and adjust the autotransformer as necessary to maintain the voltage at 117 or 234 volts except when the power supply regulation is being checked.

CAUTION

Do not reset the -150 control unless the power supply voltages are actually out of tolerance or you are planning to perform a complete calibration of the instrument.

1. Low-Voltage Power Supply

Connect the dc voltmeter to the output of the -150 volt power supply. Power supply output test points are shown in Fig. 5-2. Set the -150 Control for a reading of -150 volts. Check that the outputs of the -6.2, +100 and +350 volt supplies are within the specified + or - 3% tolerances. If either the +100 or +350 volt supplies are out of tolerance, reset the -150 control slightly until all power supply voltages are within tolerances.

Vary the output of the autotransformer between 105 and 125 volts (or between 210 and 250 volts) to check the regulation of the low voltage power supplies. The power supplies must regulate within + or - 3% of their correct voltages.

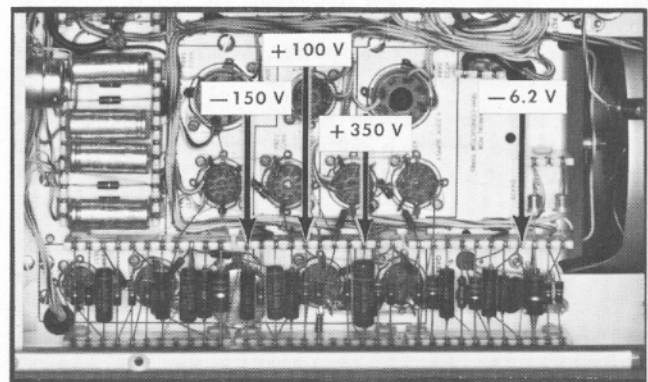


Fig. 5-2. Power Supply voltage test points.

Using the test oscilloscope, check the ripple voltage at the output of each power supply when the autotransformer is adjusted for 117 volts. Swing the autotransformer output voltage from 105 volts to 125 volts while observing the amount of ripple on the test scope. The power supply ripple should remain about the same amplitude from low line to high line voltage. Return the line voltage to 117 volts.

TYPICAL RIPPLE AMPLITUDES	
Supply	Typical Ripple
-6.2V	8mv at 105 and 115V
-150V	8mv + 50% at 105 and 125V
+100V	8mv + 50% at 105 and 125V
+350V	25mv + 50% at 105 and 125V

2. R879, CAL AMPL

Connect the dc voltmeter to the junction of R885 and the cathode of V873B. See Fig. 5-3. Adjust R879, for a reading of +50 volts on the dc voltmeter. Turn the AMPLITUDE CALIBRATOR switch to 5 MV and check for a reading of 22.5 to 27.5 volts on the dc voltmeter.

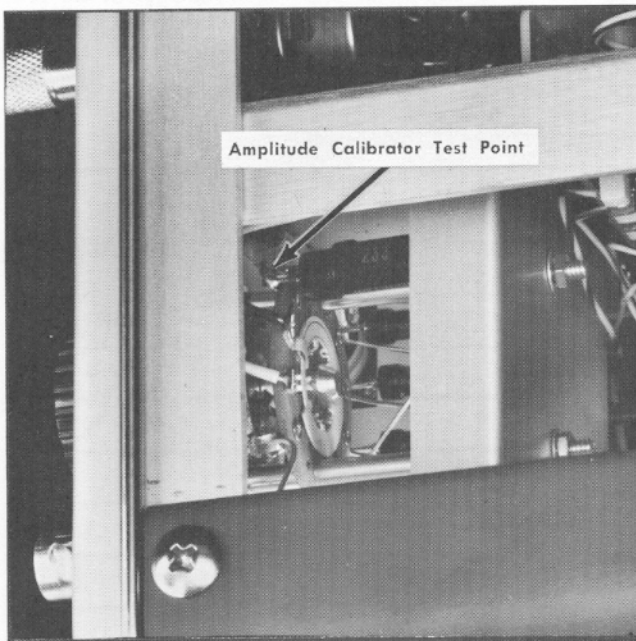


Fig. 5-3. Location of the Amplitude Calibrator test point.

3. CRT Alignment

Turn the TRIGGERING LEVEL to RECURRENT, HORIZONTAL DISPLAY switch to NORMAL and turn up the INTENSITY Control until a trace is visible (it may be necessary to adjust the Vertical Positioning control). Adjust FOCUS and ASTIGMATISM for sharpest trace (narrowest trace width). Position one of the traces under a horizontal division of the graticule near the vertical center of the crt. Loosen the clamp at the base of the crt and push the crt against the

graticule, then tighten the clamp. Now with the red knob, near the bottom of the clamp, rotate the crt until the trace runs parallel to the horizontal lines of the graticule.

4. HV

Remove the right side H V shield and with a dc voltmeter connected to the center arm of R833 (HORIZ SENS BAL). Adjust R833 until a reading of +100 volts is obtained from the center arm to ground.

Now connect the voltmeter from the H V TEST POINT to ground. Adjust the HV Control for a reading of -2900 volts. Replace HV shield.

To check HV regulation place the HORIZONTAL DISPLAY switch to 2 EXT VOLTS/CM. Position the focused spots onto the screen. Now while observing the focused spot, decrease the line voltage with the autotransformer to 105 volts. The spots should not have shown any blooming as the line voltage was decreased. Return the line voltage to 117 volts and the HORIZONTAL DISPLAY switch to the NORMAL position.

5. INTENSITY BALANCE Control

Increase the INTENSITY Control to the point where the traces have a halo forming around them. While observing the halo around each trace adjust the INTENSITY BALANCE Control until the brightness of the halos is the same.

Turn the INTENSITY down to the normal level and observe the two traces. The intensities should still be about the same.

6. ASTIG UPPER, ASTIG LOWER

Adjustment

Place the HORIZONTAL DISPLAY switch in the 2 EXT VOLTS/CM position and rotate both the UPPER and LOWER BEAM FOCUS Controls fully clockwise. Position both beams onto the screen, and adjust the ASTIG UPPER and ASTIG LOWER Controls so that both defocused spots are as nearly circular as possible. Adjust the UPPER BEAM and LOWER BEAM FOCUS Controls so that both spots are in sharp focus. Return the HORIZONTAL DISPLAY switch to NORMAL.

NOTE

If a line appears instead of a spot, the high-voltage shields are not in place.

CAUTION

It is quite easy to damage the crt phosphor when the spots are in sharp focus. The INTENSITY Control should also be kept as low as possible when doing the above adjustment.

7. GEOM

Connect 1 MILLISECONDS time marker from a Type 180A to both A inputs. Position the two traces so that only the

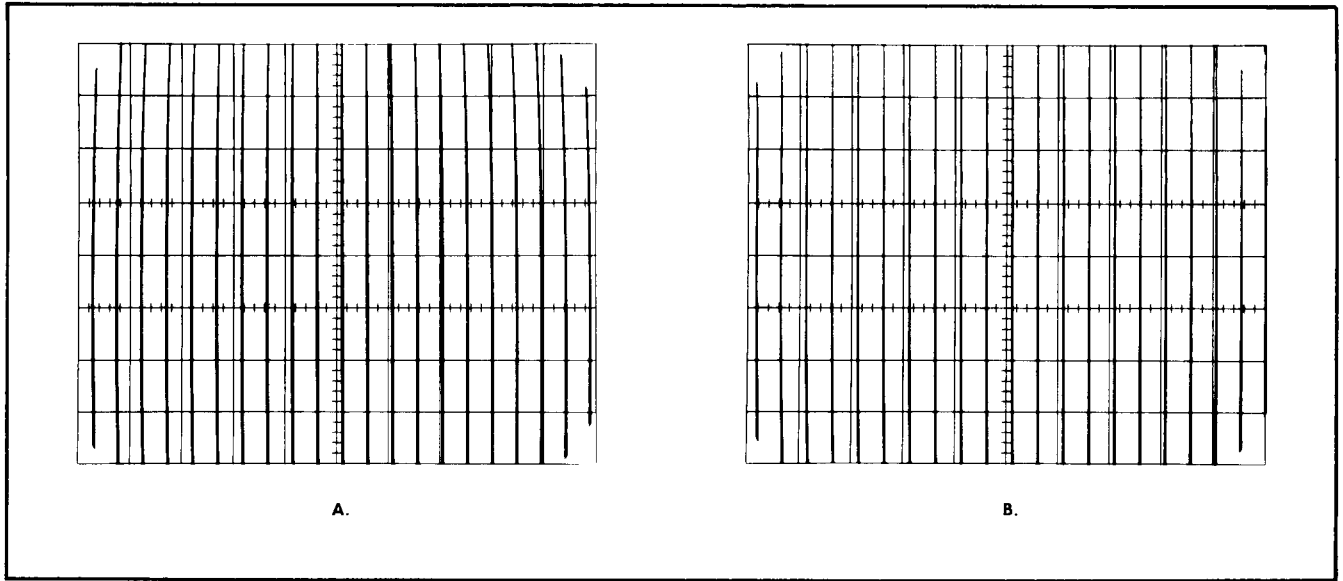


Fig. 5-4. Adjustment of the GEOM control. In waveform A the GEOM control is improperly set causing bowing of the vertical lines. In waveform B the bowing of the vertical lines has been reduced to a minimum by the proper adjustment of the GEOM control.

vertical portions of the markers are displayed on the face of the crt and adjust the TRIGGERING LEVEL Control to obtain a stable display. Set the GEOM control for minimum curvature of the vertical lines at the sides of the crt.

X20 CAL for a display of one 100 MICROSECONDS time marker per 2 cm. Now turn the HORIZONTAL DISPLAY Switch to X1 and adjust the X1 CAL for one 1 MILLI-SECONDS time marker every cm.

8. Adjusting CRT HORIZ SENS BAL and HORIZ BEAM REGIS

From the Type 180A apply 100 MICROSECONDS and 1 MILLISECONDS markers to the A input of the LOWER BEAM and the B input of the UPPER BEAM. Switch the UPPER BEAM Input Selector to B-DC and the SENSITIVITY switches of both beams to 5 VOLTS PER CM. With the Vertical POSITION Controls, position the traces until the markers of the LOWER BEAM are just touching the markers of the UPPER BEAM.

Adjust the HORIZ BEAM REGIS until the first and ninth time markers are as near being above one another as possible. Now adjust the CRT HORIZ SENS BAL until the sensitivity of the two beams is the same. At this point in the calibration the two beams are being matched to each other and the time markers may not coincide with the graticule marks.

NOTE

Every time the CRT HORIZ SENS BAL is adjusted the INT BAL must be checked. The HORIZ BEAM REGIS may also have to be readjusted at this time. The above three controls interact with each other.

9. X1 CAL and X20 CAL Adjustments

Set the UPPER BEAM Input Selector to the A-DC position. With 1 MILLISECONDS and 100 MICROSECONDS time markers applied to the A input of each beam reset the HORIZONTAL DISPLAY switch to X20 position. Adjust the

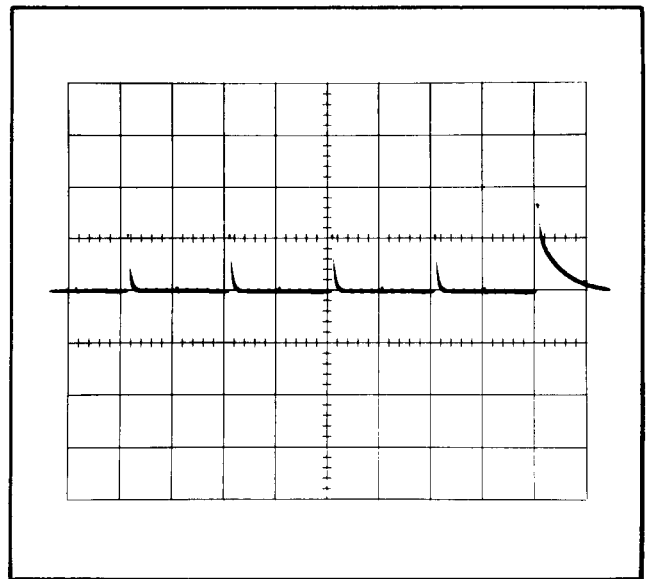


Fig. 5-5. Adjustment of the X20 control. The X20 CAL control is adjusted in the calibration procedure for the correct magnified sweep rate. The control should be set so that markers occur at 2 centimeter intervals.

There will be interaction between the X1 and X20 adjustments. After this interaction has been removed the X2 and X5 and X10 positions of the HORIZONTAL DISPLAY switch should be checked. Disconnect the time markers.

10. NORM MAG REGIS

Turn the TRIGGERING LEVEL to RECURRENT and place the HORIZONTAL DISPLAY switch in the X20 position. Position the start of the upper trace under the vertical centerline of the graticule. Rotate the HORIZONTAL DISPLAY switch to NORMAL and adjust the NORM MAG REGIS Control so that the start of the sweep again lies under the vertical centerline of the graticule. Repeat adjustments 9 and 10 until both are set correctly.

11. Check Timing from .1 millisecond through 5 seconds

From the Type 180A apply time markers to the A input of both beams as indicated below. Adjust for a stable display and check for proper display.

TIME/CM	TIME MARKERS	DISPLAY
1 mSEC	1 MILLISECONDS	1 marker/cm
2 mSEC	1 MILLISECONDS	2 markers/cm
5 mSEC	5 MILLISECONDS	1 marker/cm
10 mSEC	10 MILLISECONDS	1 marker/cm
20 mSEC	10 MILLISECONDS	2 markers/cm
50 mSEC	50 MILLISECONDS	1 marker/cm
100 mSEC	100 MILLISECONDS	1 marker/cm
200 mSEC	100 MILLISECONDS	2 markers/cm
500 mSEC	500 MILLISECONDS	1 marker/cm
1 SEC	1 SECONDS	1 marker/cm
2 SEC	1 SECONDS	2 markers/cm
5 SEC	5 SECONDS	1 marker/cm
.1 mSEC	100 MICROSECONDS	1 marker/cm

Disconnect Time Markers.

12. Fast Sweep Rate Adjustments

Turn the TIME/CM Control to 10 μ SEC and the TRIGGERING LEVEL to RECURRENT. Set the input switch of the test oscilloscope to DC.

Connect a probe from the test oscilloscope to pin 3 of V183 and adjust C311 for a flat base on the holdoff waveform. This is just a preliminary adjustment of C311.

Adjustment of the faster sweep rates is indicated in the chart below. The 1 μ SEC and the 5 μ SEC timing adjustments will interact and therefore will have to be rechecked several times. Apply time markers to both A inputs and trigger the display.

TIME/CM	TIME MARKERS FROM TYPE 180A	ADJUST OR CHECK
10 μ SEC	10 MICROSECONDS	Adjust C160C for 1 marker/cm
20 μ SEC	10 MICROSECONDS	Check for 2 markers/cm
50 μ SEC	50 MICROSECONDS	Check for 1 marker/cm
1 μ SEC	1 MICROSECONDS	Adjust C311 for 1 marker/cm
2 μ SEC	1 MICROSECONDS	Check for 2 markers/cm
5 μ SEC	5 MICROSECONDS	Adjust C160A for 1 marker/cm

Disconnect Time Markers.

13. EXT HORIZ AMP DC BAL

Rotate the HORIZONTAL DISPLAY switch through the EXT VOLTS/CM positions and adjust the EXT HORIZ AMP DC BAL Control so that there is no horizontal shift of the spots as the HORIZONTAL DISPLAY switch is rotated.

14. Checking External Gain and Attenuator

Apply 5 volts to the EXTERNAL connector from the AMPLITUDE CALIBRATOR. With the HORIZONTAL DISPLAY switch set in the 2 EXT. VOLTS/CM position check for a deflection of 2.5 cm. Check the other positions of the display switch for the proper deflection. Return the HORIZONTAL DISPLAY switch to the NORMAL position and disconnect the jumper.

NOTE

The following adjustments apply to both of the vertical amplifiers. Complete the calibration of one amplifier before proceeding to the other.

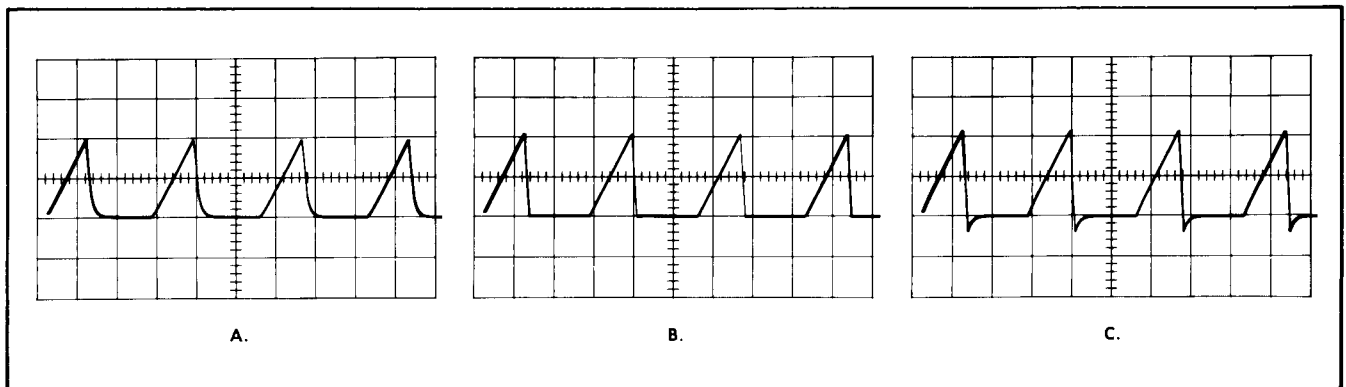


Fig. 5-6. Adjustment of C311. Waveforms A and C result from improper settings of C311. Capacitor C311 should be adjusted so that waveform B is obtained on the test oscilloscope.

15. Gas and Hum Check

With jumpers, ground both the inputs and set the SENSITIVITY switch at .2 mVOLTS PER CM. Turn TRIGGERING LEVEL to RECURRENT and using the POSITION and DC BAL Controls, position the trace onto the crt. The use of the DC BAL Control may be found in Section Two.

Now turn the Input Selector switch from A-DC to A-AC and B-DC to B-AC. The trace should not have shifted more than 2 cm during the switching from DC to AC.

To check for hum, observe the amount of hum on the free running trace. It should not be more than about 3 mm.

16. .2V/CM DIFF BAL

Set the AMPLITUDE CALIBRATOR switch at .5V and apply the calibrator output to both A and B input connectors of the vertical amplifier. Place the SENSITIVITY Control in the .2 VOLTS PER CM position and the Input Selector switch in the A-B (DIFF) DC position. Set the TIME/CM switch at 1 mSEC. Position the trace so that it lies behind the appropriate horizontal centerline. Adjust the .2V/CM DIFF BAL Control for minimum vertical deflection.

17. .2MV/CM DIFF BAL

Place the SENSITIVITY switch in the .2 mVOLTS PER CM position and position the trace so that it lies behind the appropriate horizontal centerline. Adjust the .2MV/CM DIFF BAL Control for minimum vertical deflection. Repeat steps 16 and 17 until both adjustments are correct.

18. .2V/CM GAIN

Apply a .5 volt signal from the calibrator to input A of the vertical amplifier. Set the Input Selector switch in the

A-DC position and the SENSITIVITY switch in the .2 VOLTS PER CM position. Set the .2V/CM GAIN for 2.5 centimeters of vertical deflection.

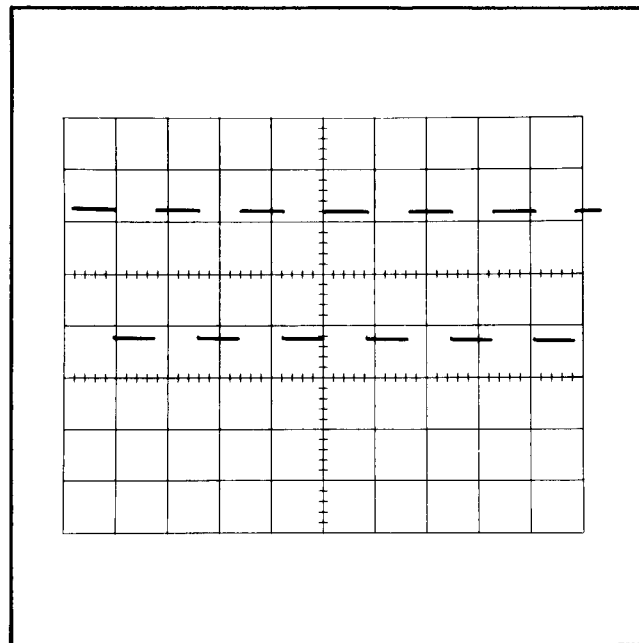


Fig. 5-8. Setting the .2 V/CM GAIN control. In the calibration procedure, the .2 V/CM GAIN control is adjusted for 2.5 centimeters of vertical deflection.

NOTE

To trigger the display properly set the TRIGGER SELECTOR to the +AC position for the beam which is being calibrated.

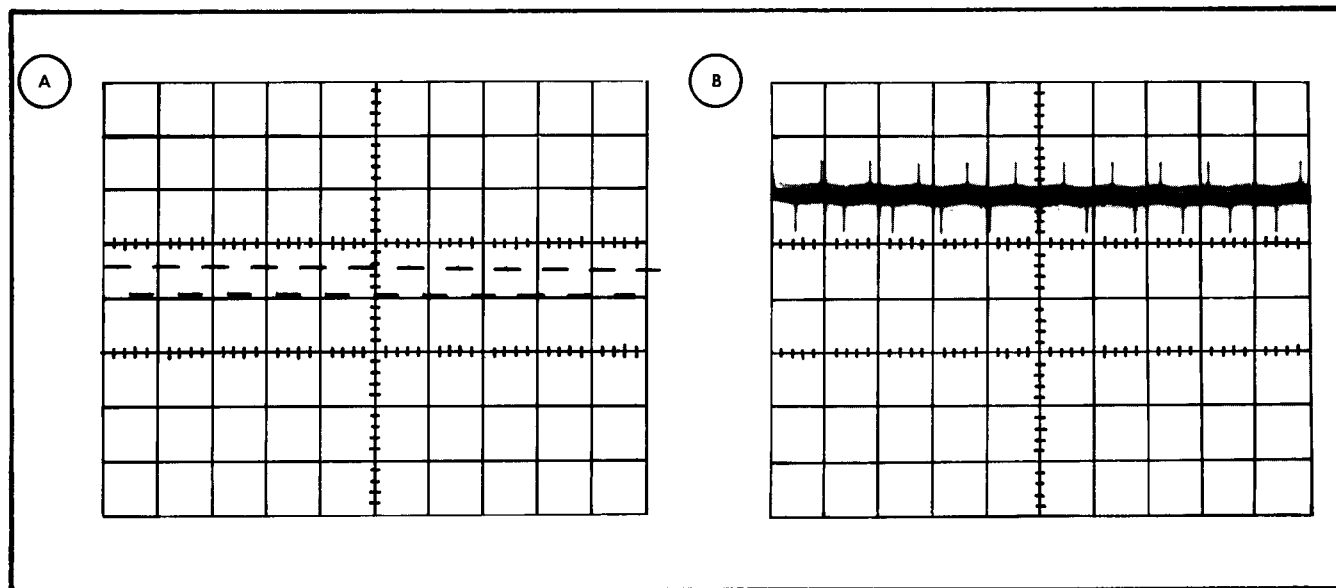


Fig. 5-7. Adjustment of the .2 MV/CM DIFF. BAL. control. If the .2MV/CM DIFF. BAL. control is slightly misadjusted, a waveform similar to waveform A will be obtained. Waveform B shows a typical display obtained when the control is adjusted properly.

19. .2MV/CM GAIN

Apply a .5 millivolt signal from the calibrator to input A of the vertical amplifier. Place the SENSITIVITY switch in the .2 mVOLTS PER CM position. Set the .2MV/CM GAIN control for 2.5 centimeters of vertical deflection. Repeat steps 18 and 19 until both adjustments are correct.

Both of the above gain adjustments should also be checked in the B-DC position of the Input Selector switch. At this time the other positions of the SENSITIVITY switch should be checked for proper attenuation. Disconnect jumpers.

20. Adjusting R429, VAR DC BAL

Set the SENSITIVITY switch to .2 VOLTS PER CM and the TRIGGERING LEVEL to RECURRENT. With the vertical POSITION Control, position the trace to the appropriate graticule center line.

While rotating the VARIABLE SENSITIVITY Control through its range, adjust R429 until the trace no longer moves as the VARIABLE SENSITIVITY Control is rotated. The trace should now show no movement when it is sitting on the appropriate graticule center line and the VARIABLE SENSITIVITY Control is rotated. Refer to figure 5-15 or 5-17 for the location of R429.

21. Vertical DC Shift

Turn the Input Selector to A-DC and the SENSITIVITY switch to .2 VOLTS PER CM. Now vertically deflect the trace with enough dc voltage to move it about 8 cm. A V.O.M. is a convenient source of voltage.

After deflecting the trace observe the drift, if any. The drift should not be more than about 1 mm.

22. High Frequency Compensations

Reset the following controls.

Input Selector	B-DC
SENSITIVITY	.2 VOLTS PER CM
TIME/CM	50 μ SEC

From a Type 105 apply 10 kc square-waves to the B input of the vertical. The cable should have a 50 Ω termination connected at each end. Adjust the oscilloscope for a stable display. Adjust the amplitude of the Type 105 until a display of 3 cm is observed on the screen. The bottom of the square wave should rest on the graticule center line for the amplifier you are calibrating.

Now adjust C470, C480 and C478 for the best possible square-wave bottom. After adjusting for a square bottom reset the Input Selector to A-DC and connect the cable and termination to the A input. Line up the top of the square wave with the proper graticule center line and adjust C469. C469 is adjusted for an optimum square top on the square-wave.

It will be necessary to recheck the adjustment of C470, C480, C478 and C469 as the adjustment of one of these capacitors may affect the adjustment of the others.

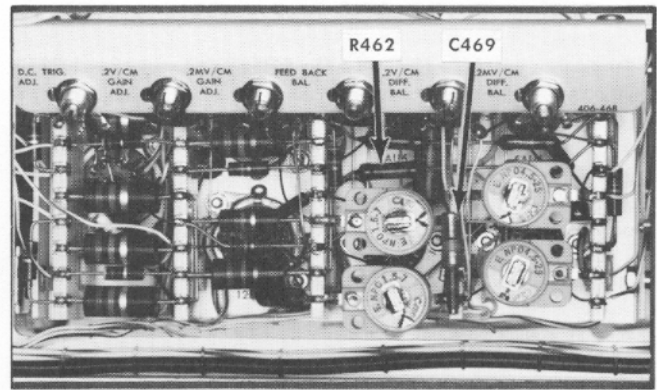


Fig. 5-9. Location of C469 and R462 in Vertical Amplifier.

23. Adjusting Common Mode Rejection Ratio

From the sine-wave generator, whose qualifications are described in the Equipment Required list, apply 1 volt of 200kc sine-wave. The waveform will be applied to both the A and B inputs of the vertical amplifier. Also apply the waveform to the horizontal amplifier EXTERNAL connector.

The one volt of signal may be measured by setting the Input Selector switch in A-DC and the SENSITIVITY switch to .2 VOLTS PER CM. The cable which leads from the generator to the oscilloscope should be terminated at both ends with 50 Ω terminations. With the properly terminated cable connected to the oscilloscope adjust the output amplitude of the sine-wave generator until a deflection of 5cm is obtained on the crt.

Set the Input Selector switch to A-B (DIFF)-DC, the vertical SENSITIVITY switch to 1 mVOLT PER CM and the HORIZONTAL DISPLAY switch to .1 EXT VOLT/CM. A lissajous waveform should now be displayed. While observing this waveform adjust the lead dress of the covered lead running from the end of R462 (5meg) to pin 5 of V414 for minimum opening of the loop.

Elimination of the eye of the loop, a straight line would result in a rejection ratio of 10,000 to 1. The opening of the loop must be less than 2 cm to give an acceptable rejection ratio.

To check the adjustment change the generator frequency to 100 kc. Now change the SENSITIVITY switch to .2 mVOLTS PER CM and check to see that the opening in the loop does not exceed 5cm.

It should be noted that there may be some interaction between the High Frequency Compensations and the Common Mode Rejection Ratio. Disconnect the input signal and all cables to oscilloscope.

NOTE

At this time the vertical which has not been calibrated up to now must be done, up to this point, before proceeding with the calibration procedure.

24. Setting GAIN ADJ FOR HORIZ MODE

Turn the HORIZ DEF PLATE SELECTOR to the UPPER BEAM AMP position and both of the vertical SENSITIVITY switches to .2 VOLTS PER CM. Connect a 50kc sine-wave signal from the generator to the A and B connectors of each vertical amplifier. This may be done with jumpers. The cable used to connect the generator to the oscilloscope should be terminated on each end with a 50Ω termination. Set the Input Selector switch of the LOWER BEAM to A-DC and the switch of the UPPER BEAM to A-B (DIFF)-DC.

Adjust the length of the vertical line with the amplitude control on the sine-wave generator until the line is 8cm high. After adjusting the vertical line for 8cm, turn the UPPER BEAM Input Selector to A-DC and the Input Selector switch of the LOWER BEAM to A-B (DIFF)-DC.

The display should now be one horizontal line. Now set the GAIN ADJ FOR HORIZ MODE (R489) until the horizontal line is 8cm long.

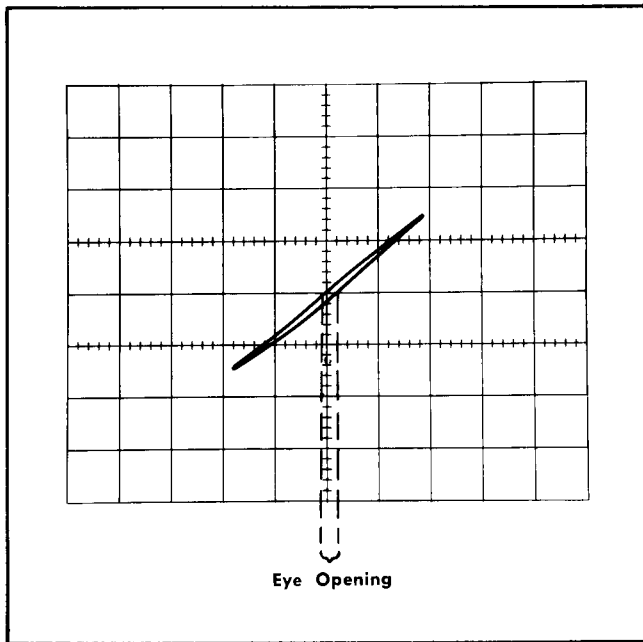


Fig. 5-10. Method of determining eye opening for X-Y phasing check.

25. X-Y Phasing Check

With the HORIZ. DEF. PLATE SELECTOR still in the UPPER BEAM AMP position insert sine-wave frequencies of the amplitude and cps as indicated below.

A convenient way of measuring the proper amplitude of the input signal is outlined below.

With the SENSITIVITY switches of each amplifier in the proper range and the input signal coupled to both the A and B input connectors of each amplifier, place the LOWER BEAM Input Selector to A-DC and the UPPER BEAM Input Selector to A-B (DIFF)-DC.

The vertical line may be used to determine the amplitude of the input signal.

Once the proper amplitude has been determined, turn the UPPER BEAM Input Selector switch to A-DC. Check to see that the eye opening of the lissajous waveform is about the same as that listed below.

The eye opening measurement of the lissajous waveform should be made near the center of the crt screen.

NOTE

When placing attenuators in the line to achieve proper amplitude, be sure to place them between the 50Ω terminator from the oscilloscope and the coax cable.

SENSITIVITY Range	Input Freq.	Amplitude	Typical Eye Opening
.2 VOLTS PER CM	1 mc	3 cm	2.5 mm
100 mVOLTS PER CM	400 kc	6 cm	5 mm
50 mVOLTS PER CM	400 kc	6 cm	5 mm
20 mVOLTS PER CM	200 kc	6 cm	5 mm
10 mVOLTS PER CM	200 kc	6 cm	5 mm
5 mVOLTS PER CM	200 kc	6 cm	5 mm
2 mVOLTS PER CM	200 kc	6 cm	5 mm
1 mVOLTS PER CM	200 kc	6 cm	5 mm
.5 mVOLTS PER CM	100 kc	6 cm	5 mm
.2 mVOLTS PER CM	100 kc	6 cm	5 mm
.1 mVOLTS PER CM	50 kc	6 cm	5 mm

Disconnect all cables used above.

NOTE

The verticals will now be done one at a time until the calibration of the verticals has been completed.

26. Measuring Vertical Response

Switch the HORIZ. DEF PLATE SELECTOR to TIME BASE AMP, the HORIZONTAL DISPLAY switch to NORMAL, Input Selector to A-DC and the SENSITIVITY switch to the .2 VOLTS PER CM position.

Apply the input sine-wave to the A input connector of the vertical amplifier. The cable should be terminated into 50 ohms on each end.

On each position of the SENSITIVITY switch first insert 4cm of 1kc sine-wave from a constant amplitude generator and then switch the generator to the higher frequency as called out in the table below.

Each vertical position should be checked for the proper response.

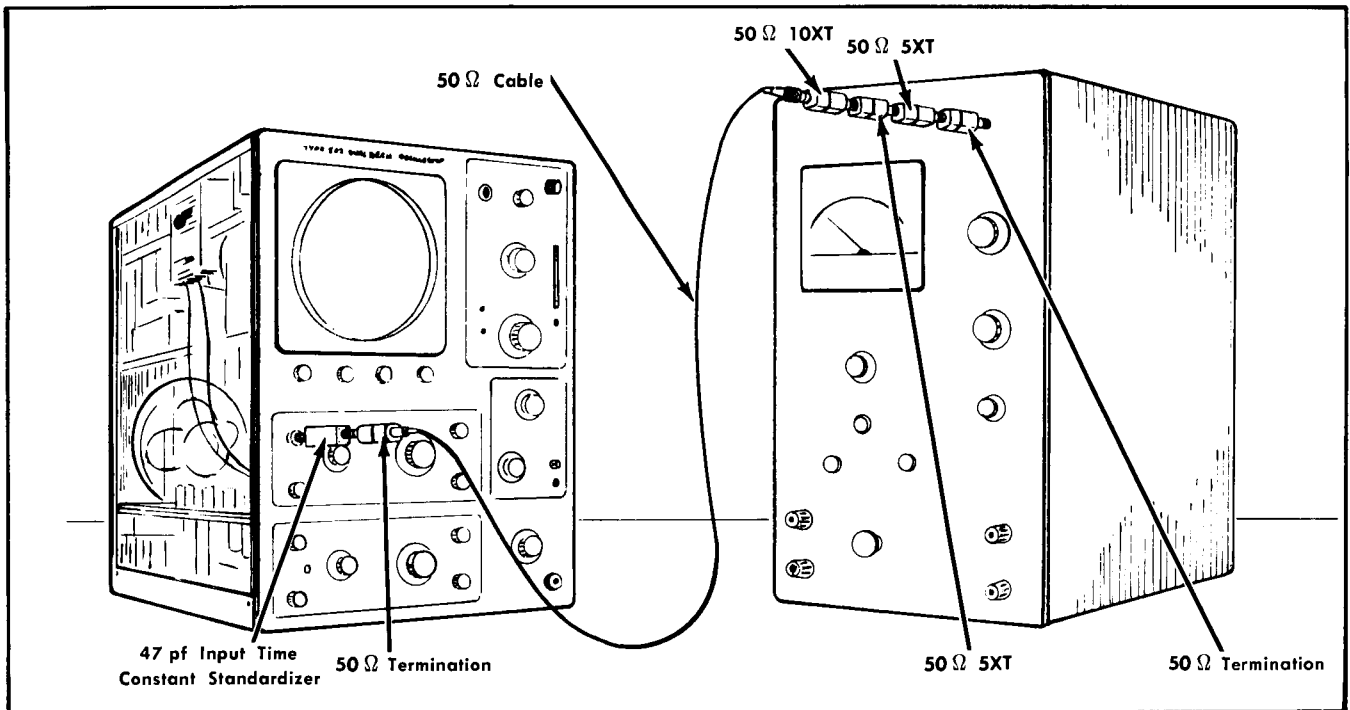


Fig. 5-11. Proper placing of the various attenuators and the Input Time Constant Standardizer.

SENSITIVITY Setting	Initial Freq. and Amplitude	Checking Freq.	Min. Amp. for Proper Response
.2 VOLTS PER CM	4 cm at 1 kc	1 mc	2.8 cm
100 mVOLTS PER CM	4 cm at 1 kc	400 kc	2.8 cm
50 mVOLTS PER CM	4 cm at 1 kc	400 kc	2.8 cm
20 mVOLTS PER CM	4 cm at 1 kc	200 kc	2.8 cm
10 mVOLTS PER CM	4 cm at 1 kc	200 kc	2.8 cm
5 mVOLTS PER CM	4 cm at 1 kc	200 kc	2.8 cm
2 mVOLTS PER CM	4 cm at 1 kc	200 kc	2.8 cm
1 mVOLTS PER CM	4 cm at 1 kc	200 kc	2.8 cm
.5 mVOLTS PER CM	4 cm at 1 kc	100 kc	2.8 cm
.2 mVOLTS PER CM	4 cm at 1 kc	100 kc	2.8 cm
.1 mVOLTS PER CM	4 cm at 1 kc	50 kc	2.8 cm

Remove input signal from oscilloscope.

27. Adjusting A Input Attenuator Compensations

Apply 1-kc square waves from the Type 105 to input connector A of the vertical amplifier through the Input Time Constant Standardizer. The cable used should be terminated into the proper resistance on each end.

Place the Input Selector switch in the A-DC position and the SENSITIVITY switch in the .2 VOLTS PER CM position. Adjust the output of the Type 105 for approximately 3 cm of vertical deflection.

Set the TRIGGER SELECTOR to trigger off the proper beam, the TIME/CM to .5mSEC and the TRIGGERING LEVEL to trigger the signal. Adjust C410 for an undistorted square wave.

Place the SENSITIVITY switch in the 2 VOLTS PER CM position and adjust the Type 105 output for approximately 3 cm of vertical deflection. Adjust C406A and C406C for an undistorted square wave.

Place the SENSITIVITY switch in the 5 VOLTS PER CM position and adjust the Type 105 output for approximately 3 cm of vertical deflection. Adjust C406G and C406J for an undistorted square wave.

28. Adjusting B Input Attenuator Compensations

Connect 1-kc square waves from the Type 105 to input connector B of the vertical amplifier through the input Time Constant Standardizer. Place the Input Selector switch in the B-DC position and the SENSITIVITY switch in the .2 VOLTS PER CM position. Set the Type 105 output amplitude for approximately 3 centimeters of vertical deflection. Adjust C440 for an undistorted square wave.

Place the SENSITIVITY switch in the 2 VOLTS PER CM position and adjust the Type 105 output for approximately 3 cm of vertical deflection. Adjust C407A and C407C for an undistorted square wave.

Place the SENSITIVITY switch in the 5 VOLTS PER CM position and adjust the Type 105 output for approximately 3 cm of vertical deflection. Adjust C407G and C407J for an undistorted square wave.

29. FEEDBACK BAL

Set the TIME/CM switch of the Type 502A to 2 mSEC; the Input Selector to B-DC and the SENSITIVITY switch to .2 mVOLTS PER CM. From the Type 105 apply 3 cm of 200 cycle square waves to the oscilloscope. Refer to figure 5-11 for the proper placing of attenuators and the capacitance standardizer. Adjust for a stable display.

While observing the display adjust the FEEDBACK BAL Control for an optimum square wave. Now apply the signal to the A input connector and change the Input Selector switch to A-DC. Check for a good square wave.

The final setting of the FEEDBACK BAL Control should be made for an optimum square wave with the input applied to either input channel. Disconnect the Type 105 from the Type 502A.

30. TRIG. LEVEL CENT.

Place the HORIZ DEF PLATE SELECTOR Switch in the TIME BASE AMP position, the UPPER BEAM SENSITIVITY switch in the .5 VOLTS PER CM position, and the TRIGGERING LEVEL Control at midrange. Connect 50 millivolts of Calibrator signal to input A of the UPPER BEAM vertical amplifier and place the TRIGGER SELECTOR switch in the UPPER AC position. Ground the junction of R15 and C13 by placing a jumper between that point and the chassis. Adjust the TRIG. LEVEL CENT Control so that the sweep will trigger correctly with the TRIGGER SELECTOR Slope Switch in either the + or - positions.

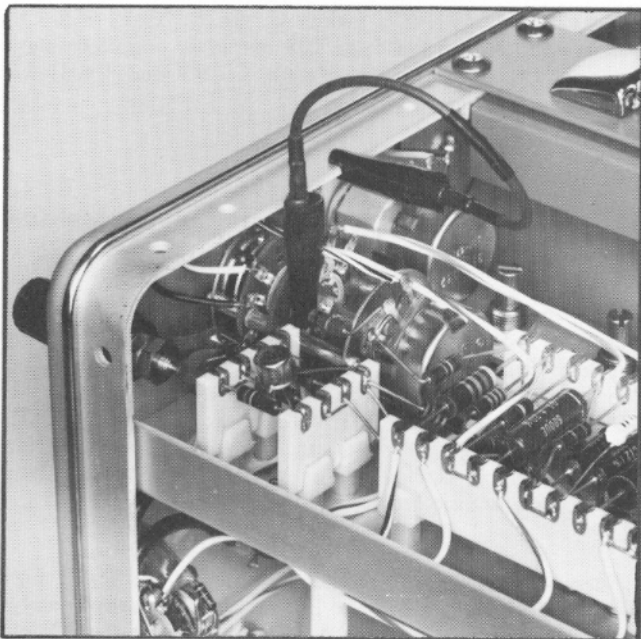


Fig. 5-12. Grounding the junction of R15 and C13. For adjustment of the TRIG LEVEL CENT and DC TRIG controls, the junction of R15 and C13 is grounded as shown.

31. STABILITY ADJUST

Disconnect the Calibrator signal, remove the jumper from the junction of R15 and C13 to ground, place the TRIGGERING LEVEL Control in the AUTOMATIC position and set the TIME/CM control to .1mSEC. Connect a meter from the wiper arm of the STABILITY ADJUST Potentiometer to ground. Rotate the STABILITY ADJUST Control clockwise from the fully counterclockwise position. Note the voltage when the trace first appears on the face of the crt. Continue to rotate the STABILITY ADJUST Control clockwise until the trace brightens and again note the voltage. Set the STABILITY ADJUST Control so that the voltage reading is midway between the two voltages previously noted.

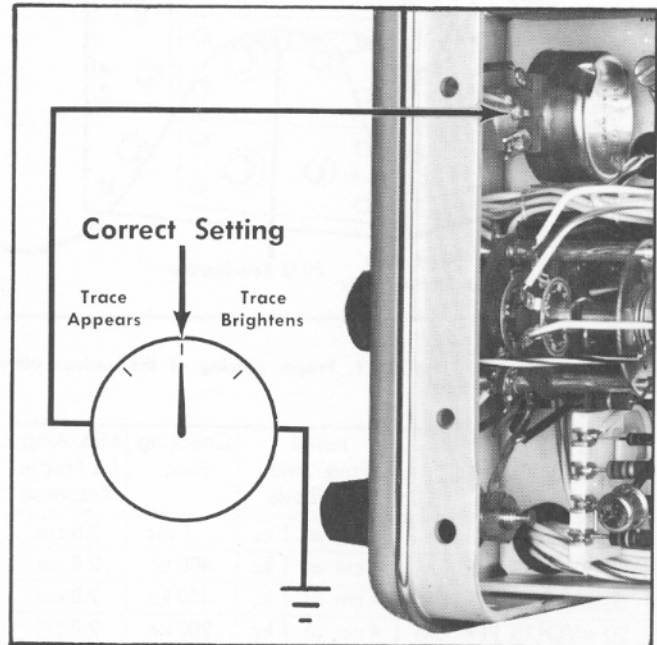


Fig. 5-13. Adjustment of the STABILITY ADJUST control.

32. UPPER BEAM DC TRIG

Position the TRIGGERING LEVEL Control to midrange and place a jumper from the junction of R15 and C13 to ground. Place the UPPER BEAM SENSITIVITY switch in the .2 VOLTS PER CM position and apply 50 MV of Calibrator signal to input A of the UPPER BEAM vertical amplifier. Position the UPPER BEAM trace under the upper horizontal centerline. Place the TRIGGER SELECTOR switch in the UPPER DC position and set the DC TRIG Control so that the sweep will trigger on either the + or - positions of the TRIGGER SELECTOR Slope Switch.

33. LOWER BEAM DC TRIG

Leave the jumper connected as in step 32. Place the LOWER BEAM Input Selector switch in the A-DC position and the LOWER BEAM SENSITIVITY switch in the .2 VOLTS PER CM position. Connect 50 MV of Calibrator signal to input A of the LOWER BEAM vertical amplifier. Place the TRIGGER SELECTOR switch in the LOWER DC position and

position the lower trace under the lower horizontal centerline. Set the DC TRIG Control so that the sweep triggers properly on both the + and — settings of the TRIGGER SELECTOR Slope Switch. Disconnect the jumper and the Calibrator signal.

34. SWP LENGTH

Place the TIME/CM switch in the 1mSEC position and the TRIGGERING LEVEL Control in RECURRENT position. Adjust the SWP LENGTH control for a total sweep length of 10.6 centimeters.

35. Single Sweep Check

Reset the following controls:

TRIGGER SELECTOR	To trigger +AC off the proper beam
MODE	NORMAL
TIME/CM	1 mSEC
HORIZONTAL DISPLAY	NORMAL (×1)
Input Selector (of beam being used)	A-AC
SENSITIVITY (of beam being used)	5 VOLTS PER CM
AMPLITUDE CALIBRATOR	5 v

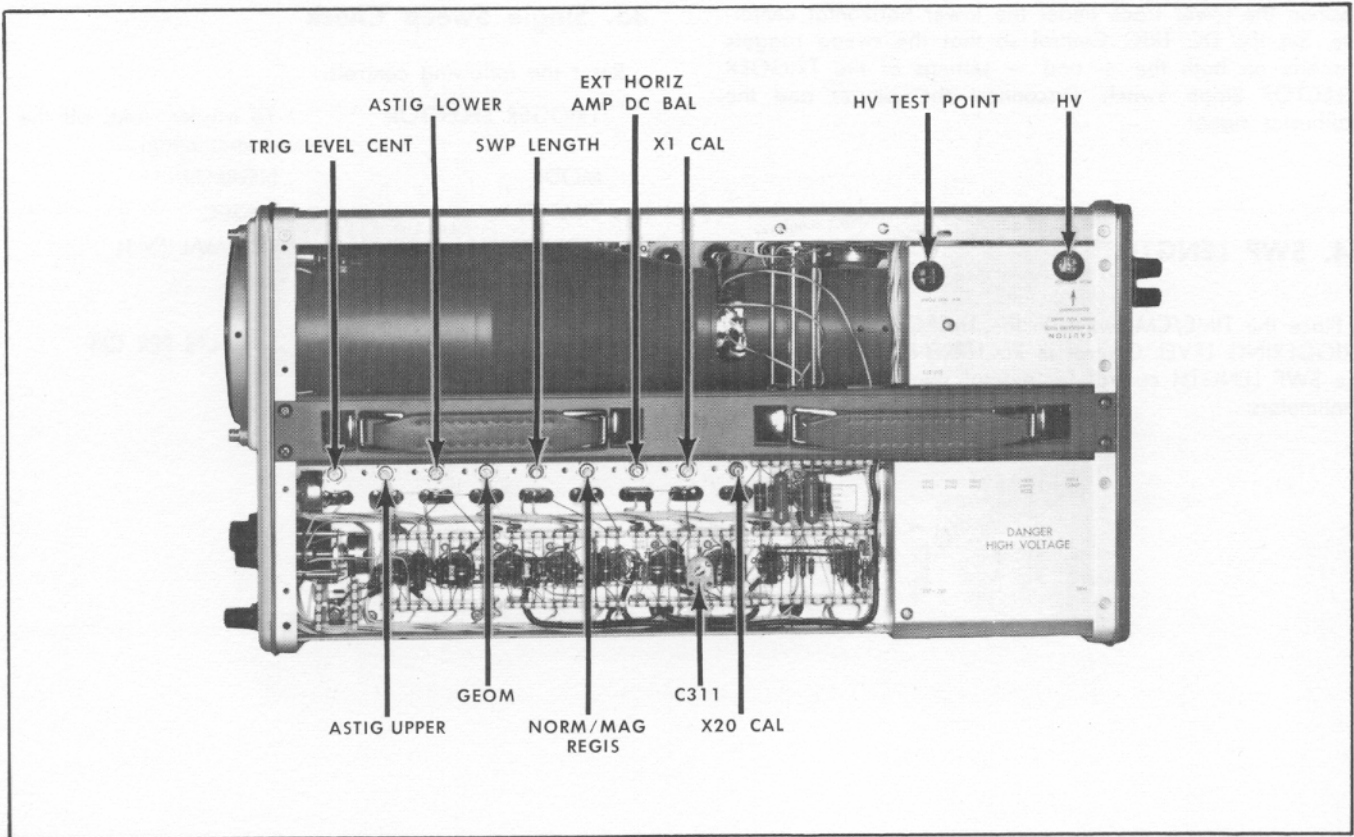


Fig. 5-14. Top view, Type 502A.

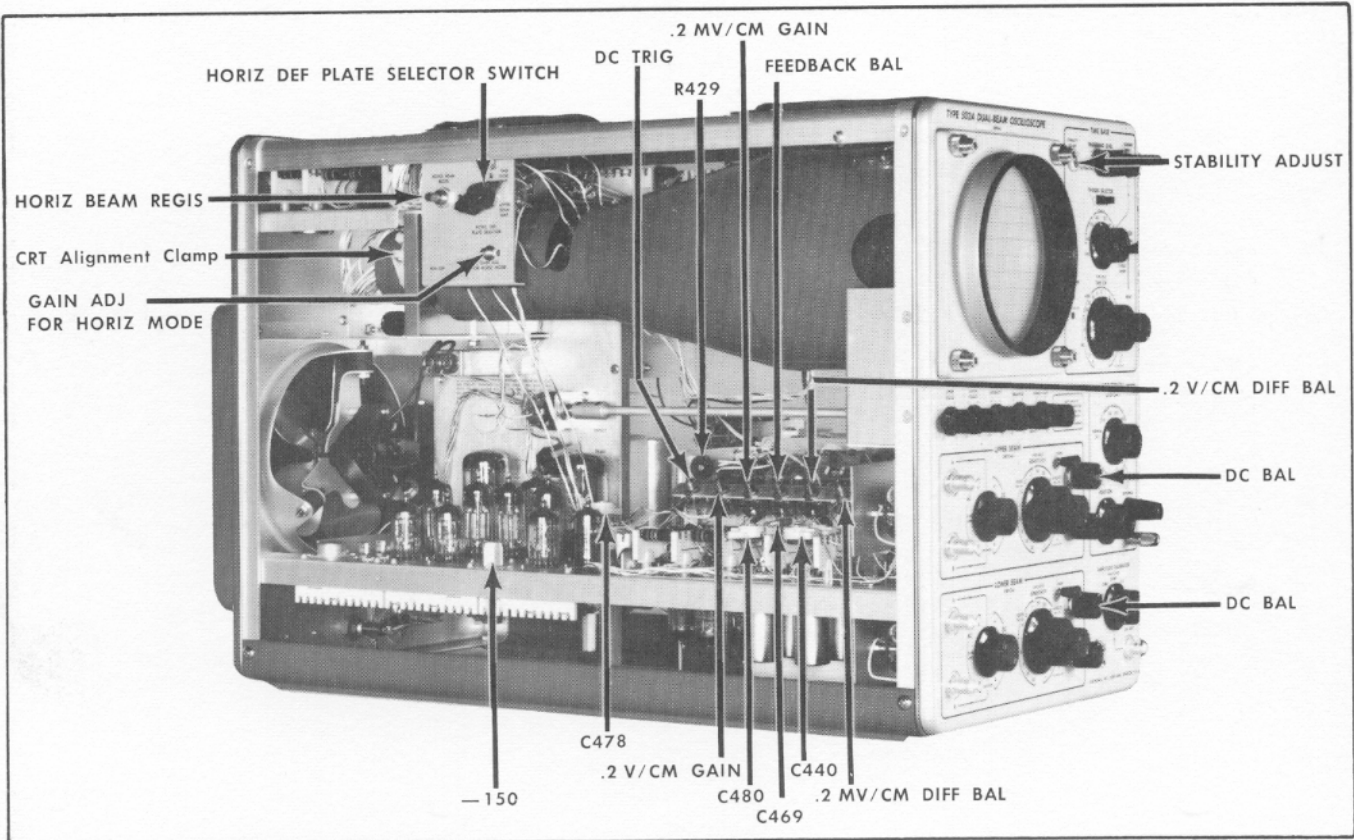


Fig. 5-15. Left side view, Type 502A.

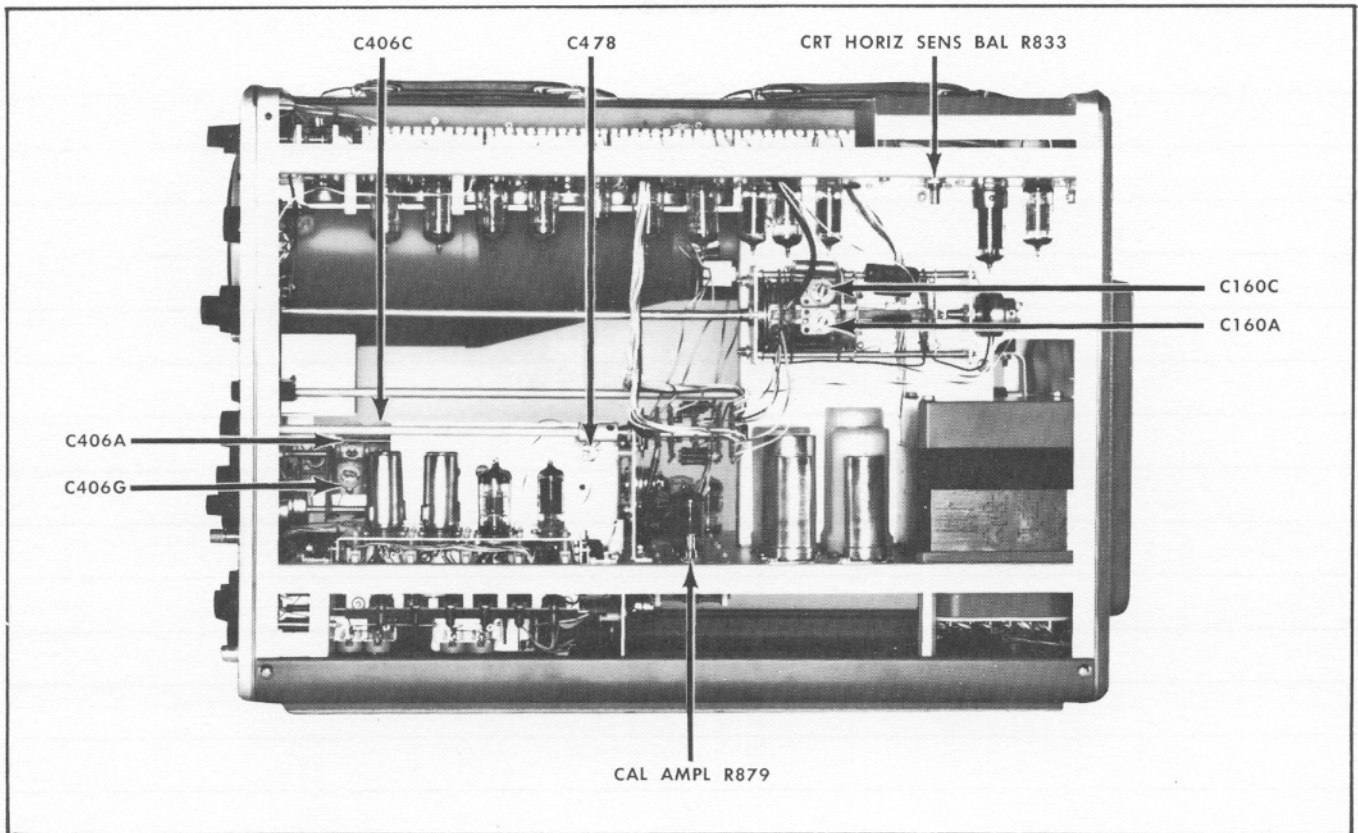


Fig. 5-16. Right side view, Type 502A.

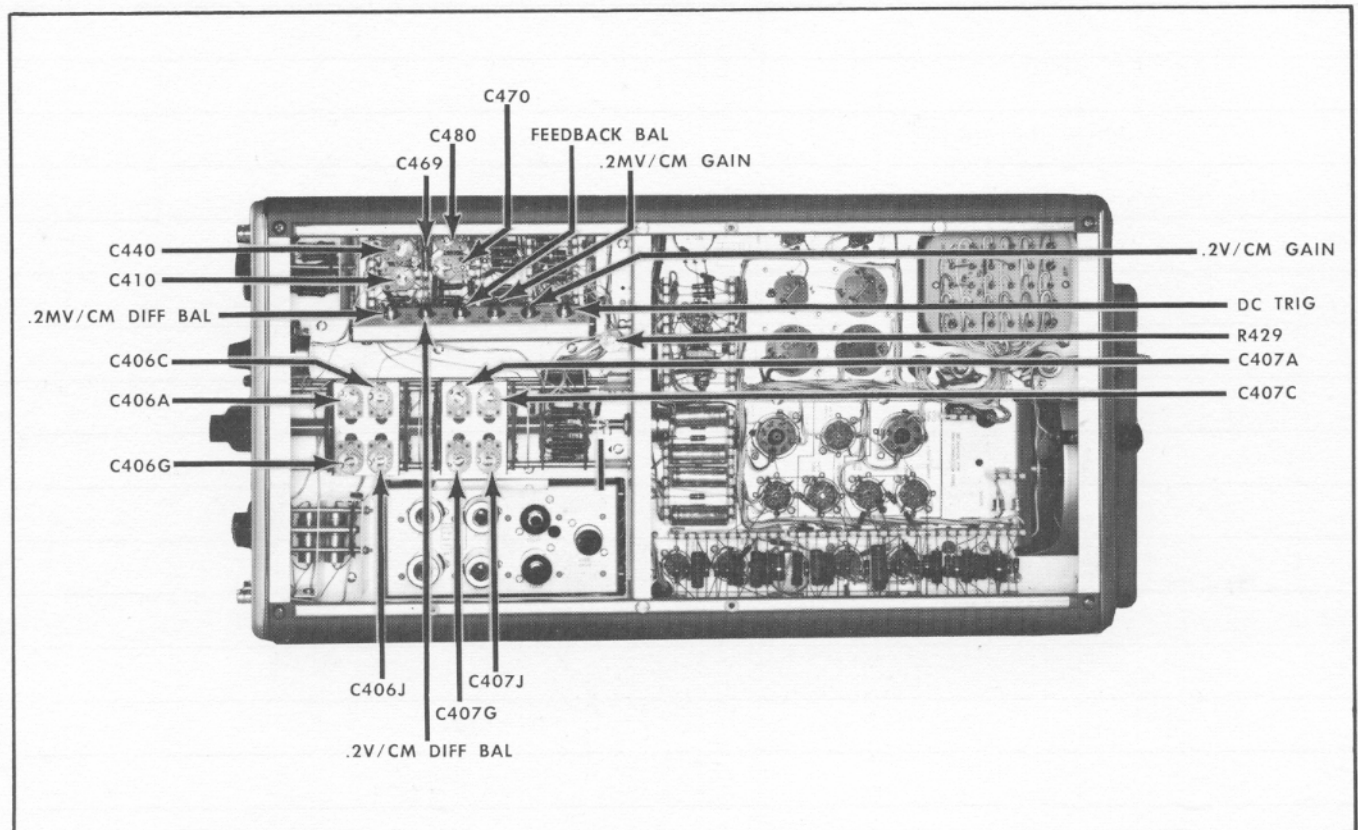


Fig. 5-17. Bottom view, Type 502A.

SECTION 6

PARTS LIST AND SCHEMATICS

PARTS ORDERING INFORMATION

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



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

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

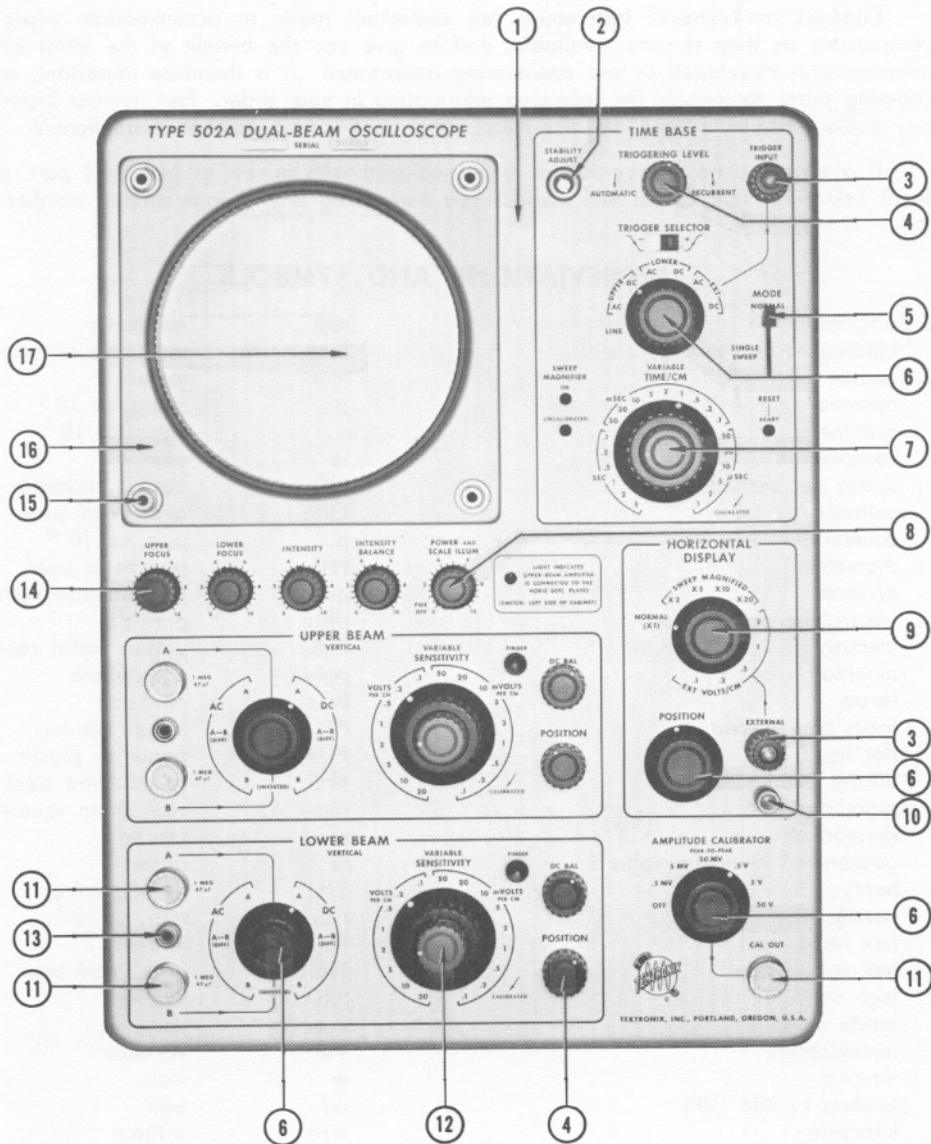
ABBREVIATIONS AND SYMBOLS

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

SPECIAL NOTES AND SYMBOLS

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

FRONT

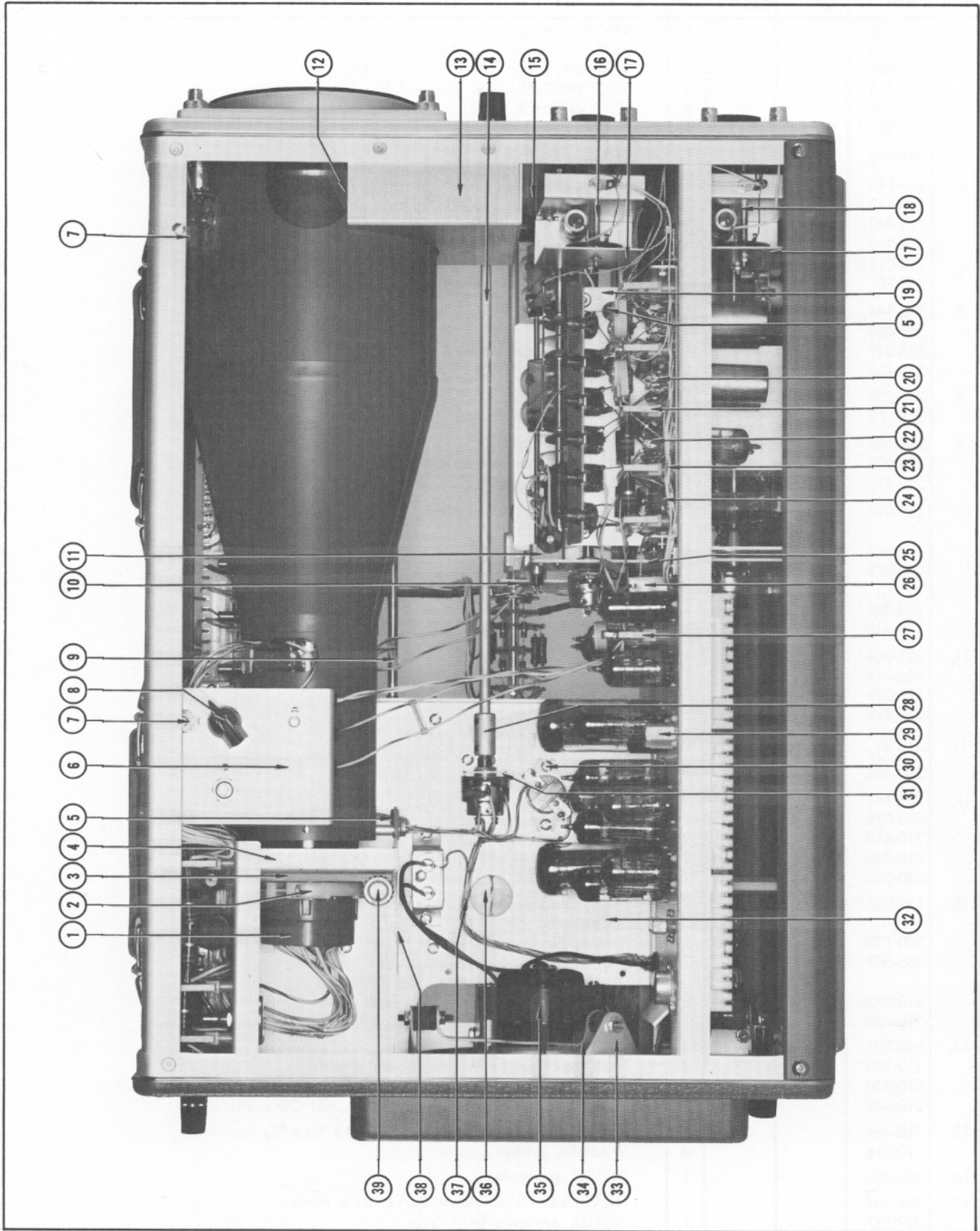


REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	333-748			1	PANEL, front
	004-174			1	COVER, panel, plastic
2.	387-785			1	PLATE, subpanel, front, alum.
	358-010			1	BUSHING, alum. 3/8-32 x 9/16 in. anodized
	210-013			1	LOCKWASHER, steel, internal 3/8 x 11/16 in.
	210-494			1	NUT, hex, alum. 3/8-32 x 1/2 x 11/16 in.
	210-012			1	LOCKWASHER, steel, pot internal 3/8 x 1/2 in.
	210-207			1	LUG, solder, pot plain, 3/8 in.
3.	129-063			2	POST, binding, 5 way, charcoal
	358-169			2	BUSHING, binding post, charcoal
	210-010			2	LOCKWASHER, steel, internal #10
	210-206			2	LUG, solder, SE10, long
	210-445			4	NUT, hex, steel, 10-32 x 3/8 in.

FRONT

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
4.	366-148			5	KNOB, charcoal
	210-413			5	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.
	210-840			5	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD
	210-013			3	LOCKWASHER, steel, internal $\frac{3}{8}$ x $1\frac{1}{16}$ in.
	210-012			3	LOCKWASHER, steel, pot internal $\frac{3}{8}$ x $\frac{1}{2}$ in.
	210-207			2	LUG, solder, pot plain $\frac{3}{8}$ in.
5.	366-215			1	KNOB, charcoal
6.	366-145			5	KNOB, charcoal
	210-413			2	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.
	210-840			2	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD
	210-013			4	LOCKWASHER, steel, internal $\frac{3}{8}$ x $1\frac{1}{16}$ in.
	210-012			1	LOCKWASHER, steel, pot internal $\frac{3}{8}$ x $\frac{1}{2}$ in.
	210-207			1	LUG, solder, pot plain $\frac{3}{8}$ in.
7.	366-144			1	KNOB, charcoal
	366-038			1	KNOB, small, red
	358-029			1	BUSHING, hex, brass, $\frac{3}{8}$ -32 x $1\frac{13}{32}$ in.
	210-413			1	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.
8.	366-220			1	KNOB, charcoal
	358-178			1	BUSHING, front panel, charcoal
9.	366-145			1	KNOB, charcoal
	358-029			1	BUSHING, hex, brass, $\frac{3}{8}$ -32 x $1\frac{13}{32}$ in.
	210-413			1	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.
10.	129-020			1	POST, binding, assembly
					Consisting of:
	355-503			1	STEM, plated
	200-072			1	CAP, plated
					Mounting Hardware: (not included)
	210-206			1	LUG, solder, SE10 long
210-445			1	NUT, hex, steel, 10-32 x $\frac{3}{8}$ in.	
11.	131-064			5	CONNECTOR, chassis mount, coaxial
	406-244			5	BRACKET, nylon molded, .160 x $\frac{3}{4}$ x $1-\frac{3}{4}$ in.
	211-025			10	SCREW, 4-40 x $\frac{3}{8}$ in. FHS
	210-812			10	WASHER, fiber, #10
	210-004			10	LOCKWASHER, steel, internal #4
	210-224			5	LUG, solder #10 non-locking, $\frac{7}{8}$ in. long
	210-406			10	NUT, hex, brass, 4-40 x $\frac{3}{16}$ in.
12.	366-144			2	KNOB, charcoal
	366-038			2	KNOB, small, red
	210-413			2	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.
	210-840			2	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD
	210-013			2	LOCKWASHER, steel, internal $\frac{3}{8}$ x $1\frac{1}{16}$ in.
13.	129-053			2	POST, binding, assembly
					Consisting of:
	200-103			2	CAP, binding post, brass, $\frac{3}{8}$ x $1\frac{1}{32}$ x $\frac{1}{4}$ -28 in. thread
	355-507			2	STEM, binding post, brass, $\frac{3}{8}$ x $1\frac{3}{16}$ in.
					Mounting Hardware: (not included)
	210-223			2	LUG, solder, $\frac{1}{4}$ in. hole lock round perimeter
210-455			2	NUT, hex, steel, $\frac{1}{4}$ -28 x $\frac{3}{8}$ x $\frac{3}{32}$ in.	
14.	366-225			4	KNOB, charcoal
	210-583			4	NUT, hex, $\frac{1}{4}$ -32 x $\frac{5}{16}$ in. double chamfer
	210-940			4	WASHER, steel, $\frac{1}{4}$ ID x $\frac{3}{8}$ in. OD
	210-046			4	LOCKWASHER, steel, internal tooth .400 OD x .261 in. ID
15.	210-424			4	NUT, knurled, brass, graticule $\frac{3}{8}$ -24 x $\frac{9}{16}$ x $\frac{3}{16}$ in.
	210-816			4	WASHER, rubber
16.	200-382			1	COVER, graticule
17.	331-047			1	GRATICULE, 5 in. 10 cm Vert x 10 cm Horiz.
	337-187			1	SHIELD, graticule light, 5 in.

LEFT SIDE



LEFT SIDE

REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	136-019			1	SOCKET, 14 pin
2.	354-103			1	RING, clamping assembly
	354-178			1	RING, CRT securing (not shown)
	211-560			1	SCREW, 6-32 x 1 in. RHS
	210-407			1	NUT, hex, brass, 6-32 x 1/4 in.
3.	432-022			1	BASE, CRT rotator, alum. 2-3/4 x 3-3/16 x 9/16 in.
	211-561			2	SCREW, 6-32 x 3/8 in. hex soc FH cap
	210-503			1	NUT, CRT rotator, securing
4.	406-537			1	BRACKET, CRT support, alum. 3-7/16 x 4-5/8 x 7/16 x 1-1/2 in.
5.	348-003			3	GROMMET, rubber, 5/16 in.
6.	262-180			1	SWITCH, HORIZONTAL DEFLECTION PLATE SELECTOR, wired
	406-359			1	Includes: BRACKET, alum. 1-1/2 x 5-1/4 x 1/2 in.
	348-002			3	GROMMET, rubber, 1/4 in.
	210-413			2	NUT, hex, brass, 3/8-32 x 1/2 in.
	210-840			2	WASHER, steel, .390 ID x 7/16 in. OD
	386-784			1	PLATE, alum. 1-3/8 x 1-1/4 in.
	210-406			2	NUT, hex, brass, 4-40 x 3/16 in.
	210-004			2	LOCKWASHER, steel, internal #4
	385-080			1	ROD, alum. hex, 1/4 x 7/16 in.
	211-503			1	SCREW, 6-32 x 3/16 in. BHS
	211-507			3	Mounting Hardware: (not included) SCREW, 6-32 x 5/16 in. BHS
	210-457			2	NUT, keps, steel, 6-32 x 5/16 in.
7.	343-004			2	CLAMP, cable, 5/16 in. plastic
	211-510			1	SCREW, 6-32 x 3/8 in. BHS
	211-511			1	SCREW, 6-32 x 1/2 in. BHS
	210-803			2	WASHER, steel, 6L x 3/8 in.
	210-457			2	NUT, keps, steel, 6-32 x 5/16 in.
8.	366-068			1	KNOB, small, black
9.	344-047			5	CLIP, deflection plate, poly.
10.	348-002			1	GROMMET, rubber, 1/4 in.
11.	406-635			1	BRACKET, low capacity, pot mounting, delrin, 1/2 in.
	213-035			2	SCREW, thread cutting, 4-40 x 1/4 in. PHS, phillips
	210-438			2	NUT, hex, brass 1-72 x 5/32 in. with pot
12.	124-068			1	STRIP, felt, gray, 1/8 x 1 x 5-3/4 in. (not shown)
13.	337-238	20000	21069	1	SHIELD, F & I, alum.
	337-606	21070		1	SHIELD, F & I, alum.
	211-541			2	SCREW, 6-32 x 1/4 in. FHS, 100° CSK, phillips
14.	384-547			1	ROD, spacing, alum. 1/4 x 13-13/16 in.
15.	200-263			1	COVER, dust, pot, vernier, poly, 17/32 x 1 in.
16.	262-179			1	SWITCH, INPUT SELECTOR, wired
	348-002			1	Includes: GROMMET, rubber, 1/4 in.
	343-006			2	CLAMP, cable, 1/2 in. plastic
	211-511			1	SCREW, 6-32 x 1/2 in. BHS
	210-803			2	WASHER, steel, 6L x 3/8 in.
	210-006			1	LOCKWASHER, steel, internal #6
	210-407			1	NUT, hex, brass, 6-32 x 1/4 in.
	210-202			1	LUG, solder, SE6 with 2 wire holes
	211-503			1	NUT, CRT rotator, securing, alum.
	210-407			1	NUT, hex, brass, 6-32 x 1/4 in.
17.	386-845			2	PLATE, AC/DC Switch, alum. 2-3/16 x 2-29/64 in.
	210-406			4	NUT, hex, brass, 4-40 x 3/16 in.
	210-004			4	LOCKWASHER, steel, internal #4

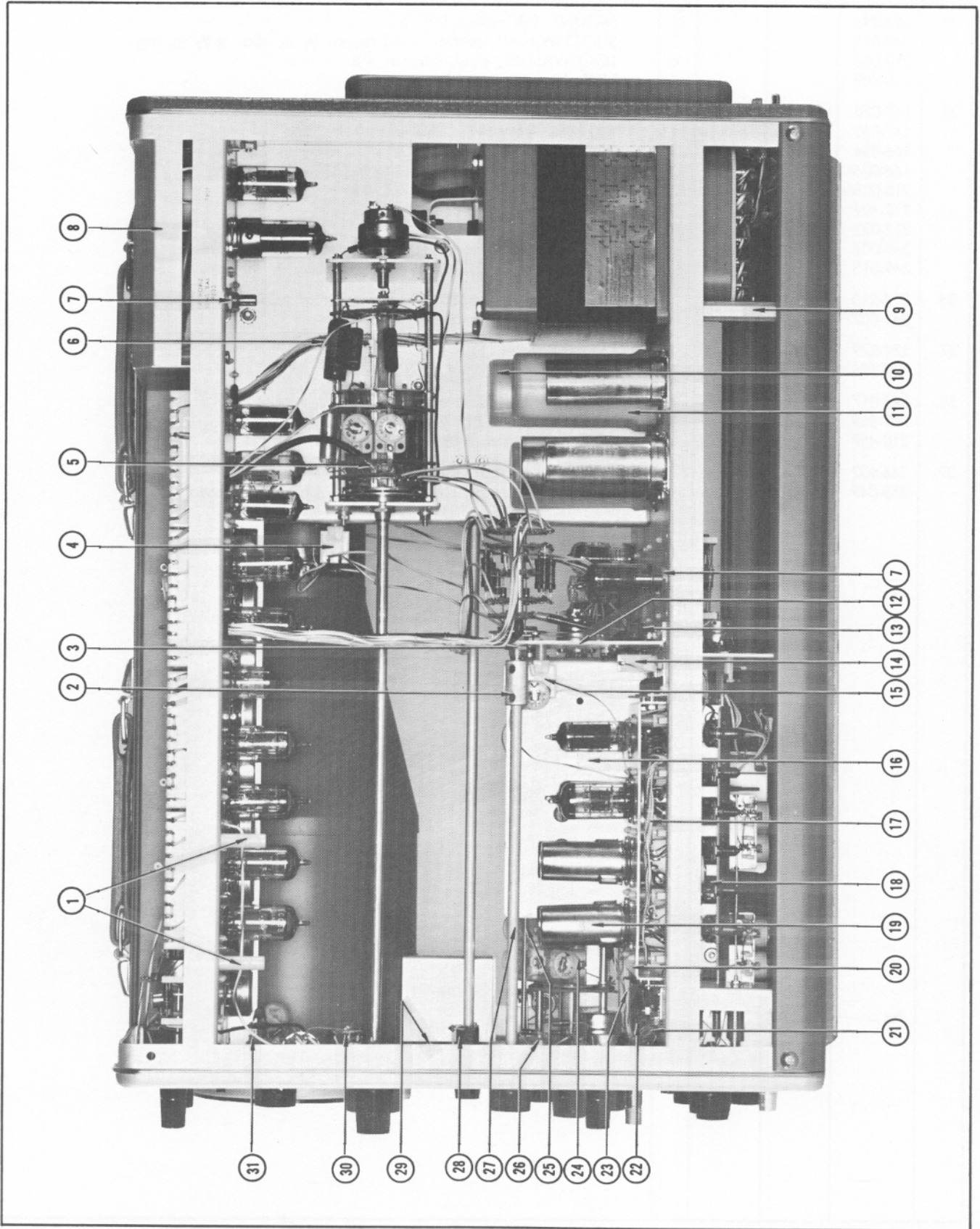
LEFT SIDE

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
18.	262-190			1	SWITCH, INPUT SELECTOR "B", wired Includes:
	343-006			2	CLAMP, cable, 1/2 in. plastic
	211-511			1	SCREW, 6-32 x 1/2 in. BHS
	210-803			2	WASHER, steel, 6L x 3/8 in.
	210-006			1	LOCKWASHER, steel, internal #6
	210-407			2	NUT, hex, brass 6-32 x 1/4 in.
	210-202			1	LUG, solder, SE6 with 2 wire holes
	211-503			1	SCREW, 6-32 x 3/16 in. BHS
	348-002			1	GROMMET, rubber, 1/4 in.
19.	406-468			1	BRACKET, V.A. pot, alum. 5/8 x 5 1/16 in.
	211-504			2	SCREW, 6-32 x 1/4 in. BHS
20.	136-010			4	SOCKET, 7 pin, without center pin
	211-033			8	SCREW, 4-40 x 5/16 in. Pan HS, with lockwasher
	210-004			7	LOCKWASHER, steel, internal #4
	210-201			1	LUG, solder, SE4
	210-406			8	NUT, hex, brass, 4-40 x 3/16 in.
21.	124-090			5	STRIP, ceramic, 3/4 in. x 9 notches, clip mounted
	361-009			10	SPACER, nylon, molded
22.	136-015			2	SOCKET
	211-033			4	SCREW, 4-40 x 3/16 in. Pan HS, with lockwasher
	210-004			4	LOCKWASHER, steel, internal #4
	210-406			4	NUT, hex, brass, 4-40 x 3/16 in.
23.	179-396			1	CABLE harness, V.A. left
24.	136-044			1	SOCKET, 7 pin tube, bakelite with ground lugs
	211-033			2	SCREW, 4-40 x 5/16 in. Pan HS with lockwasher
	210-004			2	LOCKWASHER, steel, internal #4
	210-406			2	NUT, hex, brass, 4-40 x 3/16 in.
25.	406-925			1	BRACKET switch, alum. 1 x 2-7/8 x 3 in.
	211-510			3	SCREW, 6-32 x 3/8 in. BHS
	210-803			3	WASHER, steel, 6L x 3/8 in.
	210-457			3	NUT, keps, steel, 6-32 x 5/16 in.
26.	124-100			1	STRIP, ceramic, 3/4 in. x 1 notch, clip mounted
	361-007			1	SPACER, nylon, molded
27.	124-089			1	STRIP, ceramic, 3/4 in. x 7 notches, clip mounted
	361-009			2	SPACER, nylon, molded
28.	376-007			1	COUPLING, 1 in. long with 2 tapped holes Includes:
	213-005			2	SCREW, set, 8-32 x 1/8 in. HSS
29.	210-444			1	NUT, hex, alum. 1/2 x 5/8 in. long, 3/8-32 in. int. thread
	210-840			1	WASHER, steel, .390 ID x 9/16 in. OD
30.	211-504			2	SCREW, 6-32 x 1/4 in. BHS
	210-006			2	LOCKWASHER, steel, internal #6
	210-407			2	NUT, hex, brass, 6-32 x 1/4 in.
31.	406-926			1	BRACKET, pot, alum. 1/2 x 1 x 1 in.
	211-507			2	SCREW, 6-32 x 5/16 in. BHS
	210-006			2	LOCKWASHER, steel, internal #6
	210-407			2	NUT, hex, brass, 6-32 x 1/4 in.
	210-413			1	NUT, hex, brass, 3/8-32 x 1/2 in.
	210-840			1	WASHER, steel, .390 ID x 9/16 in. OD
	210-012			1	LOCKWASHER, steel, pot, internal 3/8 x 1/2 in.
32.	386-837			1	PLATE, bulkhead
	212-023			6	SCREW, 8-32 x 3/8 in. BHS
	210-804			3	WASHER, steel, 8S x 3/8 in.
	210-458			6	NUT, keps, steel, 8-32 x 1 1/32 in.
33.	354-051			1	RING, fan, alum. 5-3/4 in. ID with mounting ears
	213-104			6	SCREW, thread forming #6 x 3/8 THS, phillips

LEFT SIDE

REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
34.	426-046			1	MOUNT, fan motor, 5-1/2 in.
	348-008			3	SHOCKMOUNT, rubber, solid round, 1/2 in. dia. x 1/2 in. high
	210-008			6	LOCKWASHER, steel, internal #8
	210-409			6	NUT, hex, brass, 8-32 x 5/16 in.
35.	147-020	20000	20685	1	MOTOR, 115 V AC, .1567 shaft 1 in. long
	147-022	20686		1	MOTOR, 115 V AC, .1567 shaft 1 in. long
	166-084	20000	20685	2	TUBE, spacing, alum. .196 ID x 5/16 OD x 1/8 in. long
	166-006	20686		2	TUBE, spacing, alum. .196 ID x 5/16 OD x 1/8 in. long
	210-008			2	LOCKWASHER, steel, internal #8
	210-409			2	NUT, hex, brass, 8-32 x 5/16 in.
	212-022	X20686		2	SCREW, 8-32 x 1 1/2 in. RHS
	369-001	20000	20685	1	FAN, alum. 5 1/2 in. blade clock rotation, 1/4 in. bore
	369-015	20686		1	FAN, alum. 5 1/2 in. blade clock rotation, 1/4 in. bore
36.	214-210			1	SPOOL, solder, assembly, with 3 feet of solder
	361-007			1	SPACER, nylon, molded
37.	179-279	20000	20685	1	CABLE harness, 110V
	179-696	20686		1	CABLE harness, 110 V
38.	387-017			1	PLATE, air deflector, alum. 5-9/16 x 6-1/8 x 1/2 in.
	211-559			2	SCREW, steel, 6-32 x 3/8 in. FHS, phillips
	210-457			2	NUT, keps, steel, 6-32 x 5/16 in.
39.	366-032			1	KNOB, small red, with 3/16 in. insert holes
	355-049			1	STUD, CRT rotator, steel, 3/16 x 3-1/4 x 10-32 in. thread

RIGHT SIDE



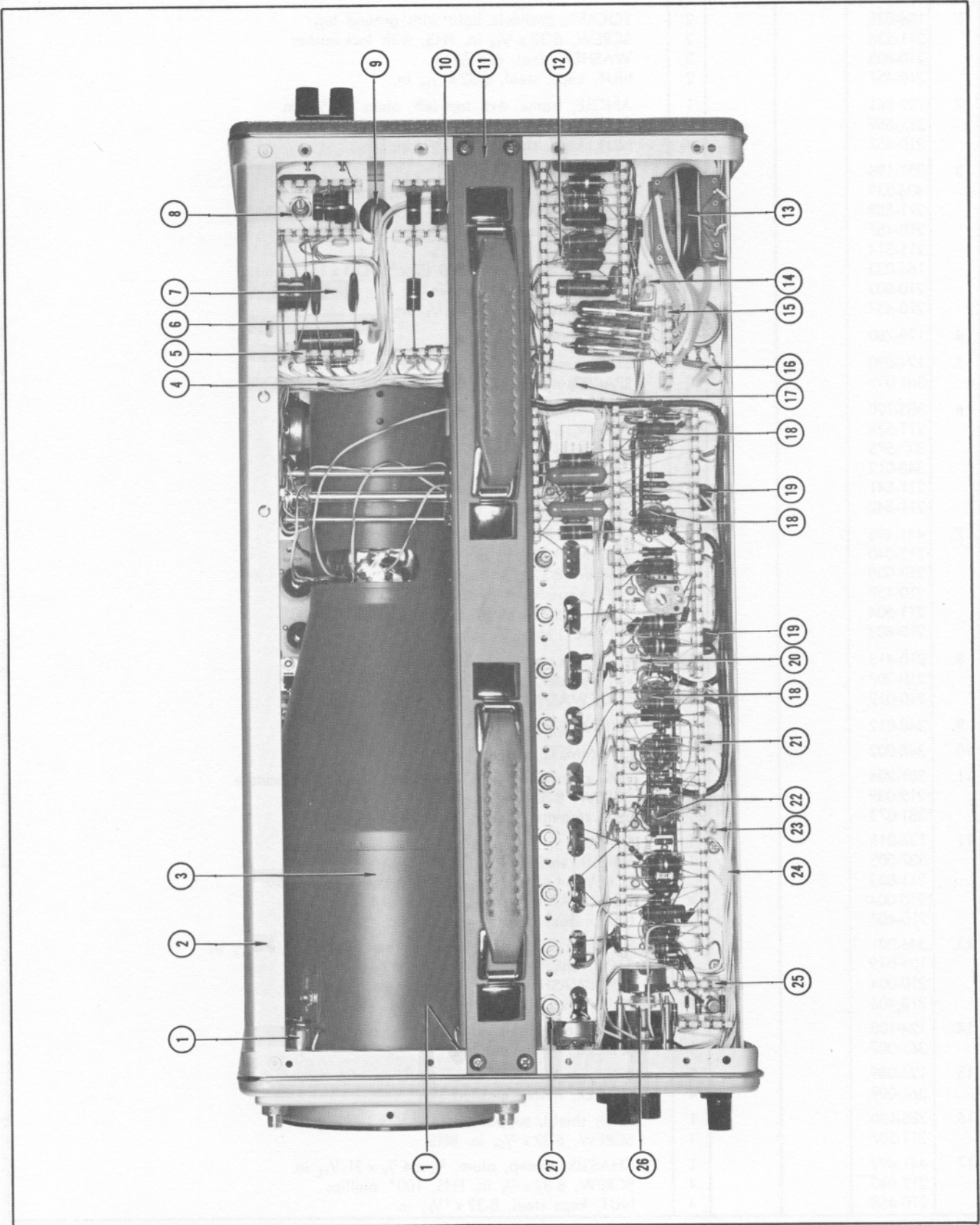
RIGHT SIDE

REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION	
		EFF.	DISC.			
1.	385-135			2	SCREW, thread cutting, 6-32 x $\frac{3}{8}$ in. truss HS, phillips	
	213-041			2	SCREW, thread cutting, 6-32 x $\frac{3}{8}$ in. truss HS, phillips	
2.	376-007			1	COUPLING, 1 in. long with 2 tapped holes Includes:	
	213-005			2	SCREW, set, 8-32 x $\frac{1}{8}$ in. HSS	
3.	210-413			1	NUT, hex, brass $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.	
	210-840			1	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD	
	210-012			1	LOCKWASHER steel, pot, internal $\frac{3}{8}$ x $\frac{1}{2}$ in.	
4.	124-086			1	STRIP, ceramic, $\frac{3}{4}$ in. x 2 notches, clip mounted	
	361-007			1	SPACER, nylon, molded	
5.	262-556			1	SWITCH, TIME/CM, wired Includes:	
	406-361			2	BRACKET, switch, alum. 2- $\frac{1}{2}$ x 3- $\frac{1}{4}$ x $\frac{1}{2}$ in.	
	384-277			1	ROD, steel, shaft $\frac{1}{8}$ in. dia. x 18- $\frac{31}{64}$ in. long	
	376-014			1	COUPLING, pot, wire steel, .041 in. dia.	
	210-449			2	NUT, hex, brass, 5-40 x $\frac{1}{4}$ in.	
	210-006			1	LOCKWASHER, steel, internal #6	
	210-202			1	LUG, solder, SE6 with 2 wire holes	
	210-413			3	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.	
	210-012			2	LOCKWASHER, steel, pot internal $\frac{3}{8}$ x $\frac{1}{2}$ in.	
	210-840			1	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD	
	210-407			2	NUT, hex, brass, 6-32 x $\frac{1}{4}$ in.	
	210-803			2	WASHER, steel, 6L x $\frac{3}{8}$ in.	
	210-006			2	LOCKWASHER, steel, internal #6 Mounting Hardware: (not included)	
	211-510			4	SCREW, 6-32 x $\frac{3}{8}$ in. BHS	
	210-803			4	WASHER, steel, 6L x $\frac{3}{8}$ in.	
	210-457			4	NUT, keps, steel, 6-32 x $\frac{5}{16}$ in.	
	6.	343-004			1	CLAMP, cable, $\frac{5}{16}$ in. plastic
		211-511			1	SCREW, 6-32 x $\frac{1}{2}$ in. BHS
		210-803			1	WASHER, steel, 6L x $\frac{3}{8}$ in.
		210-457			1	NUT, keps, steel, 6-32 x $\frac{5}{16}$ in.
7.	210-413			2	NUT, hex, brass, $\frac{3}{8}$ -32 x $\frac{1}{2}$ in.	
	210-840			2	WASHER, steel, .390 ID x $\frac{9}{16}$ in. OD	
	210-012			1	LOCKWASHER, steel, pot, internal $\frac{3}{8}$ x $\frac{1}{2}$ in.	
	210-207			1	LUG, solder, pot plain, $\frac{3}{8}$ in.	
8.	337-330			1	SHIELD, H.V., alum. 4 x 5- $\frac{13}{32}$ x 1- $\frac{3}{8}$ in.	
	211-541			2	SCREW, 6-32 x $\frac{1}{4}$ in. FHS, 100° CSK, phillips	
	211-542			1	SCREW, 6-32 x $\frac{5}{16}$ in. truss HS, phillips	
9.	385-141			1	ROD, transformer support, alum. hex, $\frac{3}{8}$ x 3- $\frac{15}{64}$ in.	
	211-522			1	SCREW, 6-32 x $\frac{5}{8}$ in. FHS, 100° phillips	
10.	200-259			1	COVER, capacitor, polyethylene, 3- $\frac{9}{16}$ x 1.365 in. dia.	
11.	200-293			2	COVER, capacitor, polyethylene, 3- $\frac{1}{32}$ x 1.365 in. dia.	
12.	406-372			1	BRACKET, Horiz. Display Switch, alum. 3 x 3- $\frac{5}{8}$ x $\frac{1}{2}$ in.	
	211-507			2	SCREW, 6-32 x $\frac{5}{16}$ in. BHS	
	210-006			2	LOCKWASHER, steel, internal #6	
	210-407			2	NUT, hex, brass, 6-32 x $\frac{1}{4}$ in.	
13.	343-002			1	CLAMP, cable, $\frac{3}{16}$ in. plastic	
	211-510			1	SCREW, 6-32 x $\frac{3}{8}$ in. BHS	
	210-863			1	WASHER, steel, for #10 screw	
	210-006			1	LOCKWASHER, steel, internal #6	
	210-407			1	NUT, hex, brass, 6-32 x $\frac{1}{4}$ in.	
14.	124-100			1	STRIP, ceramic, $\frac{3}{4}$ in. x 1 notch, clip mounted	
	361-007			2	SPACER, nylon, molded	
15.	124-088			1	STRIP, ceramic, $\frac{3}{4}$ in. x 4 notches, clip mounted	
	361-009			2	SPACER, nylon, molded	

RIGHT SIDE

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION	
		EFF.	DISC.			
16.	337-256			1	SHIELD, V.A. chassis, alum. 3-1/4 x 5-7/16 x 1/2 in.	
	211-507			2	SCREW, 6-32 x 5/16 in. BHS	
	210-457			2	NUT, keps, steel, 6-32 x 5/16 in.	
17.	179-395			1	CABLE harness, V.A. right	
18.	348-003			2	GROMMET rubber, 5/16 in.	
19.	337-007			4	SHIELD, tube, 7/8 in. ID x 1-3/4 in. high, with spring	
20.	441-494			1	CHASSIS, V.A. alum. 5/8 x 2-1/8 x 2-7/8 x 6-1/16 in.	
	348-039			4	SHOCKMOUNT, assembly	
	406-399			4	BRACKET, shockmount, steel, 1/2 x .875 x .531 in.	
	210-407			4	NUT, hex, brass, 6-32 x 1/4 in.	
	210-006			4	LOCKWASHER, steel, internal #6	
	211-507			4	SCREW, 6-32 x 5/16 in. BHS	
	210-457			4	NUT, keps, steel, 6-32 x 5/16 in.	
	21.	343-042			2	CLAMP, cable, 5/16 in. (half) plastic
211-507				2	SCREW, 6-32 x 5/16 in. BHS	
210-803				2	WASHER, steel, 6L x 3/8 in.	
210-006				2	LOCKWASHER, steel, internal #6	
210-407				2	NUT, hex, brass, 6-32 x 1/4 in.	
22.		179-262			1	CABLE harness, Trigger
23.	179-782			1	CABLE harness, Position and Balance	
24.	262-555			1	SWITCH, SENSITIVITY, wired	
					Includes:	
	406-401			1	BRACKET, front	
	406-402			1	BRACKET, rear	
	214-153			8	FASTENER, snap, double prong delrin	
	384-271			1	ROD, shaft 1/8 in. dia. x 9-5/8 in. long	
	376-014			1	COUPLING, pot, wire steel, .041 in. dia.	
	385-111			2	ROD, nylon, 1/4 x 5/8 in. tapped 5-40 in. thru	
					Mounting Hardware: (not included)	
	211-507			2	SCREW, 6-32 x 3/16 in. BHS	
	210-803			4	WASHER, steel, 6L x 3/8 in.	
	25.	384-279			1	ROD, extension, switch assembly
		354-201			1	RING, retaining
210-595				1	NUT, hex, alum. 1/4-32 x 1/2 in.	
210-011				1	LOCKWASHER, steel, internal 1/4 in.	
26.	200-263			1	COVER, dust, pot, vernier, poly, 17/32 x 1 in.	
27.	384-545			1	ROD, spacing, alum. 1/4 x 9-1/4 in.	
28.	352-008			2	HOLDER, melamine, neon bulb, single, black molded	
	211-031			2	SCREW, 4-40 x 1 in. FHS	
	210-406			4	NUT, hex, brass, 4-40 x 3/16 in.	
29.	210-202			1	LUG, solder, SE6 with 2 wire holes	
	211-538			1	SCREW, 6-32 x 5/16 in. FHS, 100° CSK, phillips	
	210-407			1	NUT, hex, brass, 6-32 x 1/4 in.	
30.	352-006			1	HOLDER, melamine, neon, double, molded	
	211-031			1	SCREW, 4-40 x 1 in. FHS	
	210-406			2	NUT, hex, brass, 4-40 x 3/16 in.	
31.	211-023			2	SCREW, 4-40 x 1/4 in. FHS	
	210-406			4	NUT, hex, brass, 4-40 x 3/16 in.	

TOP



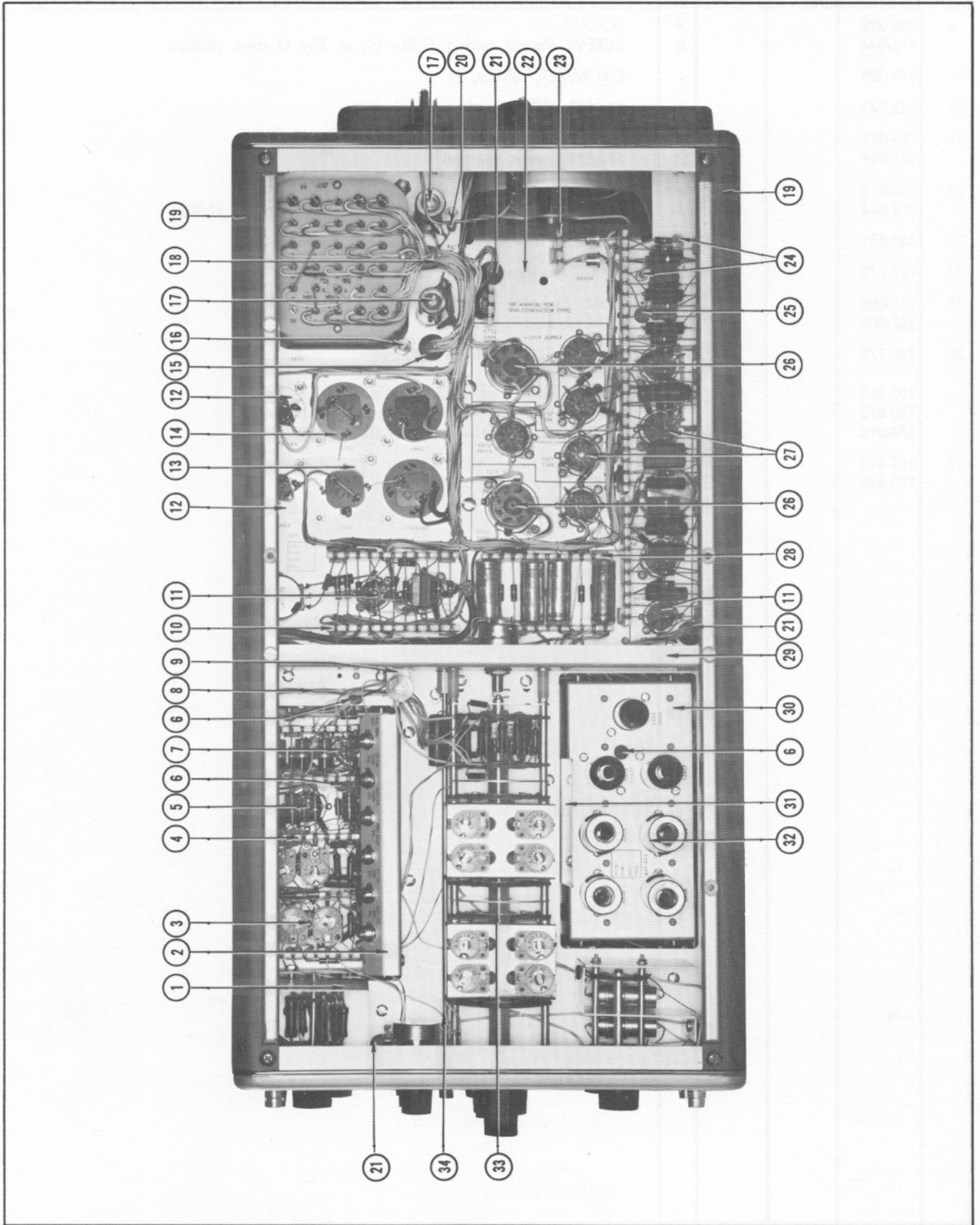
TOP

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	136-035			2	SOCKET, graticule light with ground lug
	211-534			2	SCREW, 6-32 x 5/16 in. PHS, with lockwasher
	210-803			2	WASHER, steel, 6L x 3/8 in.
	210-457			2	NUT, keps, steel, 6-32 x 5/16 in.
2.	122-061			1	ANGLE, frame, ext. top left, alum. 20-7/16 in.
	211-559			4	SCREW, steel, 6-32 x 3/8 in. 100° CSK, phillips
	210-457			4	NUT, keps, steel, 6-32 x 5/16 in.
3.	337-196			1	SHIELD, CRT 5 in.
	406-239			1	BRACKET, CRT spring, sp. phosphor bronze
	211-559			6	SCREW, 6-32 x 3/8 in. 100° CSK, phillips
	210-457			6	NUT, keps, steel, 6-32 x 5/16 in.
	211-514			1	SCREW, 6-32 x 3/4 in. BHS
	166-033			1	TUBE, spacer, alum. .180 ID x 1/4 OD x 3/8 in. long
	210-803			2	WASHER, steel, 6L x 3/8 in.
	210-457			1	NUT, keps, steel, 6-32 x 5/16 in.
4.	179-780			1	CABLE harness, F & I
5.	124-090			6	STRIP, ceramic, 3/4 in. x 9 notches, clip mounted
	361-009			12	SPACER, nylon, molded
6.	385-120			1	ROD, shield support, nylon, 1/4 x 1-27/32 in.
	211-538			1	SCREW, 6-32 x 5/16 in. FHS, 100° CSK
	337-575			1	SHIELD, H.V. alum. 5-1/16 x 3-17/32 x 1-3/4 in.
	348-012			2	GROMMET, rubber, 5/8 in.
	211-541			2	SCREW, 6-32 x 1/4 in. FHS, 100° CSK
	211-542			1	SCREW, 6-32 x 5/16 in. THS, phillips
7.	441-495			1	CHASSIS, F & I, alum. 9/16 x 5-11/16 x 5-3/8 in.
	212-040			3	SCREW, 8-32 x 3/8 in. 100° FHS
	212-008			2	SCREW, 8-32 x 1/2 in. BHS
	210-458			5	NUT, keps, steel, 8-32 x 11/32 in.
	211-504			2	SCREW, 6-32 x 1/4 in. BHS
	210-803			2	WASHER, steel, 6L x 3/8 in.
8.	210-413			1	NUT, hex, brass, 3/8-32 x 1/2 in.
	210-207			1	LUG, solder, pot plain, 3/8 in.
	210-012			1	LOCKWASHER, steel, pot, internal 3/8 x 1/2 in.
9.	348-012			1	GROMMET, rubber, 5/8 in.
10.	348-002			2	GROMMET, rubber, 1/4 in.
11.	381-204			1	BAR, alum. 20-7/16 in. long, blue vinyl, with handle
	212-039			4	SCREW, 8-32 x 3/8 in. THS
	381-073			2	BAR, retaining, alum. 3/16 x 1/2 x 1-3/4 in.
12.	136-015			1	SOCKET
	337-005			1	SHIELD, socket, 29/32 in. ID
	211-033			2	SCREW, 4-40 x 5/16 in. Pan HS, with lockwasher
	210-004			4	LOCKWASHER, steel, internal #4
	210-406			2	NUT, hex, brass, 4-40 x 3/16 in.
13.	346-001			1	STRAP, mounting, H.V. transformer, alum. 5/16 x 4-1/4 in.
	124-045			1	STRIP, bakelite, insulating, 1/2 x 2-1/2 in.
	210-004			2	LOCKWASHER, steel, internal #4
	210-406			2	NUT, hex, brass, 4-40 x 3/16 in.
14.	124-100			1	STRIP, ceramic, 3/4 in. x 1 notch, clip mounted
	361-007			1	SPACER, nylon, molded
15.	124-089			2	STRIP, ceramic, 3/4 in. x 7 notches, clip mounted
	361-009			4	SPACER, nylon, molded
16.	385-120			1	ROD, shield, support, nylon, 1/4 x 1-27/32 in.
	211-507			1	SCREW, 6-32 x 5/16 in. BHS
17.	441-492			1	CHASSIS, sweep, alum. 3/4 x 4-7/8 x 21-1/16 in.
	212-040			4	SCREW, 8-32 x 3/8 in. FHS, 100° phillips
	210-458			4	NUT, keps steel, 8-32 x 11/32 in.

TOP

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
18.	136-008			3	SOCKET
	213-044			6	SCREW, thread cutting, 5-32 x 3/16 in. Pan H steel, phillips
19.	348-005			4	GROMMET, rubber, 1/2 in.
20.	343-043			1	CLAMP, #20 wire for neon bulbs
21.	124-091			11	STRIP, ceramic, 3/4 in. x 11 notches, clip mounted
	361-009			22	SPACER, nylon, molded
22.	136-015			8	SOCKET
	213-044			16	SCREW, thread cutting, 5-32 x 3/16 in. Pan H steel, phillips
23.	348-031			1	GROMMET, snap-in, polypropylene, 1/4 in. dia.
24.	179-778			1	CABLE, harness, sweep
25.	124-088			2	STRIP, ceramic, 3/4 in. x 4 notches, clip mounted
	361-009			4	SPACER, nylon, molded
26.	262-178			1	SWITCH, TRIGGER LEVEL, wired
					Includes:
	210-413			2	NUT, hex, brass, 3/8-32 x 1/2 in.
	210-012			1	LOCKWASHER steel, pot internal 3/8 x 1/2 in.
	376-014			1	COUPLING, pot wire steel, .041 in. dia.
27.	210-413			9	NUT, hex, brass, 3/8-32 x 1/2 in.
	210-840			9	WASHER, steel, .390 ID x 9/16 in. OD

BOTTOM



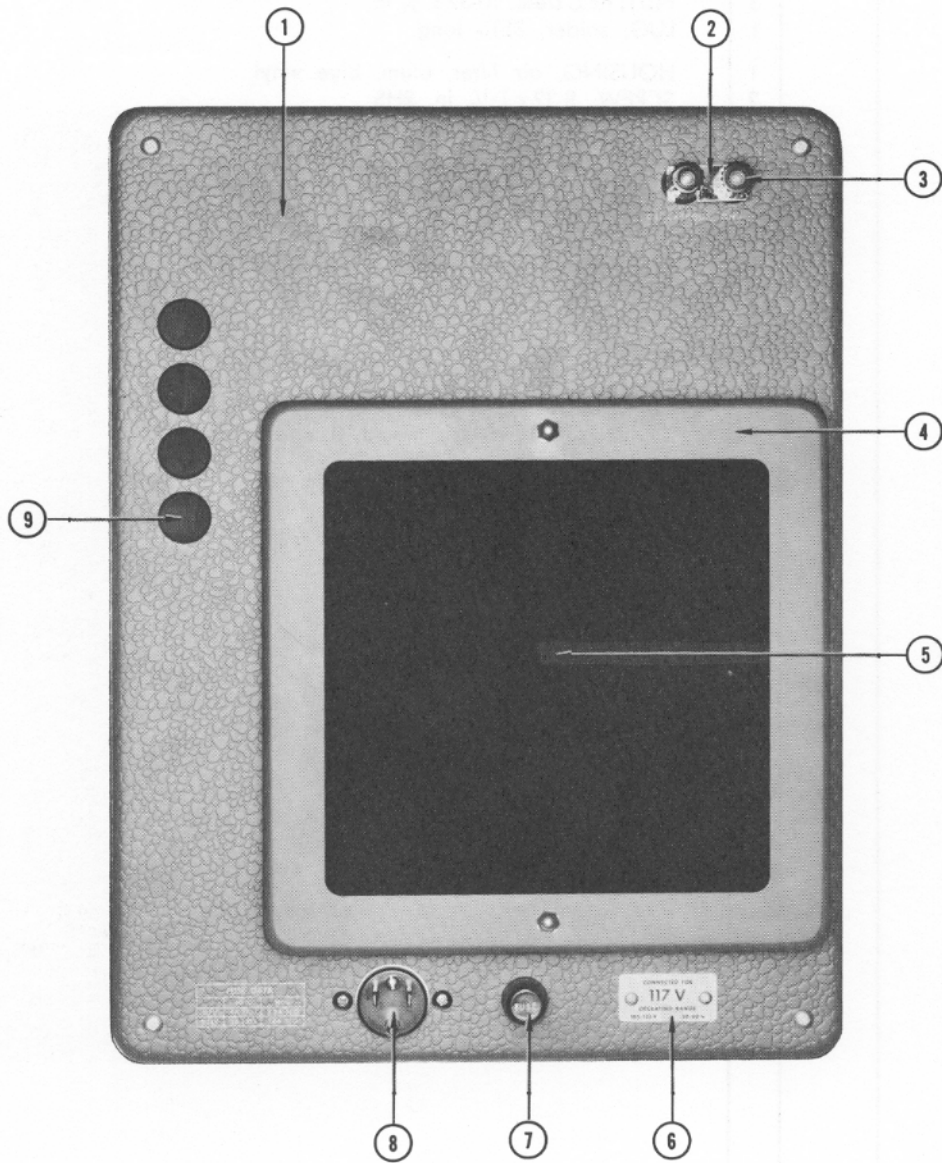
BOTTOM

REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	337-237			1	SHIELD, alum. 1- ³ / ₄ x ¹ / ₂ in.
	210-004			2	LOCKWASHER, steel, internal #4
	210-406			2	NUT, hex, brass, 4-40 x ³ / ₁₆ in.
2.	406-468			1	BRACKET, V.A. pot, alum. ⁵ / ₈ x 5- ¹⁵ / ₁₆ in.
	211-504			2	SCREW, 6-32 x ¹ / ₄ in. BHS
3.	136-010			4	SOCKET, 7 pin without center pin
	211-033			8	SCREW, 4-40 x ⁵ / ₁₆ in. Pan HS, with lockwasher
	210-004			7	LOCKWASHER, steel, internal #4
	210-201			1	LUG, solder, SE4
	210-406			8	NUT, hex, brass, 4-40 x ³ / ₁₆ in.
4.	124-090			5	STRIP, ceramic, ³ / ₄ in. x 9 notches, clip mounted
	361-009			10	SPACER, nylon, molded
5.	136-015			2	SOCKET
	211-033			4	SCREW, 4-40 x ⁵ / ₁₆ in. Pan HS, with lockwasher
	210-004			4	LOCKWASHER, steel, internal #4
	210-406			4	NUT, hex, brass, 4-40 x ³ / ₁₆ in.
6.	348-002			3	GROMMET, rubber, ¹ / ₄ in.
7.	136-044			1	SOCKET, 7 pin tube, bakelite, with ground lugs
	211-033			2	SCREW, 4-40 x ⁵ / ₁₆ in. Pan HS, with lockwasher
	210-004			2	LOCKWASHER, steel, internal #4
	210-406			2	NUT, hex, brass, 4-40 x ³ / ₁₆ in.
8.	179-263			1	CABLE harness, Calibrator Switch
9.	406-635			1	BRACKET, low capacity pot mounting, delrin
	213-035			2	SCREW, thread cutting, 4-40 x ¹ / ₄ in. PHS, phillips
	210-438			2	NUTS, hex, brass, 1-72 x ⁵ / ₃₂ in.
10.	124-091			8	STRIP, ceramic, ³ / ₄ in. x 11 notches, clip mounted
	361-009			16	SPACER, nylon, molded
11.	136-008			2	SOCKET
	213-044			4	SCREW, thread cutting, 5-32 x ³ / ₁₆ in. Pan H steel
12.	386-253			2	PLATE, metal, small, capacitor mounting
	211-534			4	SCREW, 6-32 x ⁵ / ₁₆ in. PHS, with lockwasher
	210-006			4	LOCKWASHER, steel, internal #6
	210-407			4	NUT, hex, brass, 6-32 x ¹ / ₄ in.
13.	386-255			1	PLATE, metal, large, capacitor mounting
	211-534			2	SCREW, 6-32 x ⁵ / ₁₆ in. PHS, with lockwasher
	210-006			2	LOCKWASHER, steel, internal #6
	210-407			2	NUT, hex, brass, 6-32 x ¹ / ₄ in.
14.	386-254			3	PLATE, fiber, large, capacitor mounting
	211-543			6	SCREW, 6-32 x ⁵ / ₁₆ in. RHS
	210-006			6	LOCKWASHER steel, internal #6
	210-407			6	NUT, hex, brass, 6-32 x ¹ / ₄ in.
15.	348-005			1	GROMMET, rubber, ¹ / ₂ in.
16.	212-546			4	SCREW, 10-32 x 4- ¹ / ₂ in. hex HS
	210-812			4	WASHER, fiber #10
	210-010			4	LOCKWASHER, steel, internal #10
	210-564			3	NUT, hex, stainless, 10-32 x ³ / ₈ in. double chamfered
17.	212-037			2	SCREW, 8-32 x 1- ³ / ₄ in. Fil HS
	210-808			1	WASHER, brass, centering, resistor, 20 w.
	210-809			1	WASHER, brass centering resistor, 25 w.
	210-008			1	LOCKWASHER, steel, internal #8
	210-462			2	NUT, hex, alum. 8-32 x ¹ / ₂ x ²³ / ₆₄ thick body, 25 w res. mtg.
	212-004			2	SCREW, 8-32 x ⁵ / ₁₆ in. BHS
18.	179-779			1	CABLE, harness, power
19.	122-065			2	ANGLE, frame, ext. bottom, alum. 20- ⁷ / ₁₆ in. blue vinyl
	212-039			8	SCREW, 8-32 x ³ / ₈ in. THS
	210-458			8	NUT, keps, steel 8-32 x ¹¹ / ₃₂ in.

BOTTOM

REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION	
		EFF.	DISC.			
20.	210-202			1	LUG, solder, SE6 with 2 wire holes	
	211-504			1	SCREW, 6-32 x 1/4 in. BHS	
	210-407			1	NUT, hex, brass, 6-32 x 1/4 in.	
21.	348-004			3	GROMMET, rubber, 3/8 in.	
22.	441-493			1	CHASSIS, power, alum. 23/32 x 10-13/16 x 21-1/16 in.	
	212-040			6	SCREW, 8-32 x 3/8 in. 100° FHS	
	210-458			6	NUT, keps, steel, 8-32 x 1 1/32 in.	
23.	124-087			2	STRIP, ceramic, 3/4 in. x 3 notches, clip mounted	
	361-009			2	SPACER, nylon, molded	
24.	211-510			2	SCREW, 6-32 x 3/8 in. BHS	
	210-202			1	LUG, solder, SE6 with 2 wire holes	
	210-006			1	LOCKWASHER, steel, internal #6	
	210-407			2	NUT, hex, brass, 6-32 x 1/4 in.	
25.	136-050			2	SOCKET, transistor, 4 pin with flat saddle	
	213-055			4	SCREW, thread cutting, 2-56 x 3/16 in. PHS	
26.	136-011			2	SOCKET, ground	
	213-044			4	SCREW, thread cutting, 5-32 x 3/16 in. Pan H steel	
27.	136-015			9	SOCKET	
	213-044			18	SCREW, thread cutting, 2-56 x 3/16 in. PHS	
28.	124-106			2	STRIP, ceramic, 7/16 in. x 11 notches, clip mounted	
	361-007			4	SPACER, nylon, molded	
29.	406-927			1	BRACKET, Sensitivity switch, shield, alum.	
	211-510			2	SCREW, 6-32 x 3/8 in. BHS	
	211-522			2	SCREW, 6-32 x 5/8 in. FHS	
	210-803			6	WASHER, steel, 6L x 3/8 in.	
	210-457			4	NUT, keps, steel, 6-32 x 5/16 in.	
30.	441-494			1	CHASSIS, V.A. alum. 5/8 x 2-1/8 x 2-7/8 x 6-1/16 in.	
	348-039			4	SHOCKMOUNT, assembly	
	406-399			4	BRACKET, shockmount, steel, 1/2 x .875 x .531 in.	
	210-407			4	NUT, hex, 6-32 x 1/4 in.	
	210-006			4	LOCKWASHER, steel, internal #6	
	211-507			4	SCREW, 6-32 x 5/16 in. BHS	
	210-457			4	NUT, keps, steel, 6-32 x 5/16 in.	
31.	337-259			1	SHIELD, V.A. lower, alum. 2-7/8 x 2-7/8 x 1/2 in.	
	211-507			2	SCREW, 6-32 x 5/16 in. BHS	
32.	337-007			4	SHIELD, tube, 7/8 ID x 1-3/4 in. high, with spring	
33.	262-555			1	SWITCH, SENSITIVITY, wired	
					Includes:	
	406-401			1	BRACKET, front	
	406-402			1	BRACKET, rear	
	214-153			8	FASTENER, snap, double pronged, delrin	
	384-271			1	ROD, shaft, 1/8 in. dia. x 9-5/8 in. long	
	376-014			1	COUPLING, pot, wire steel, .041 in. dia.	
	385-111			2	ROD, nylon	
					Mounting Hardware: (not included)	
	211-507			2	SCREW, 6-32 x 5/16 in. BHS	
	210-803			4	WASHER, steel, 6L x 3/8 in.	
	34.	384-301			1	ROD, extension, switch assembly
		354-201			1	RING, retaining
210-595				1	NUT, hex, alum. 1/4-32 x 1/2 in.	
210-011				1	LOCKWASHER, steel, internal 1/4 in.	

REAR

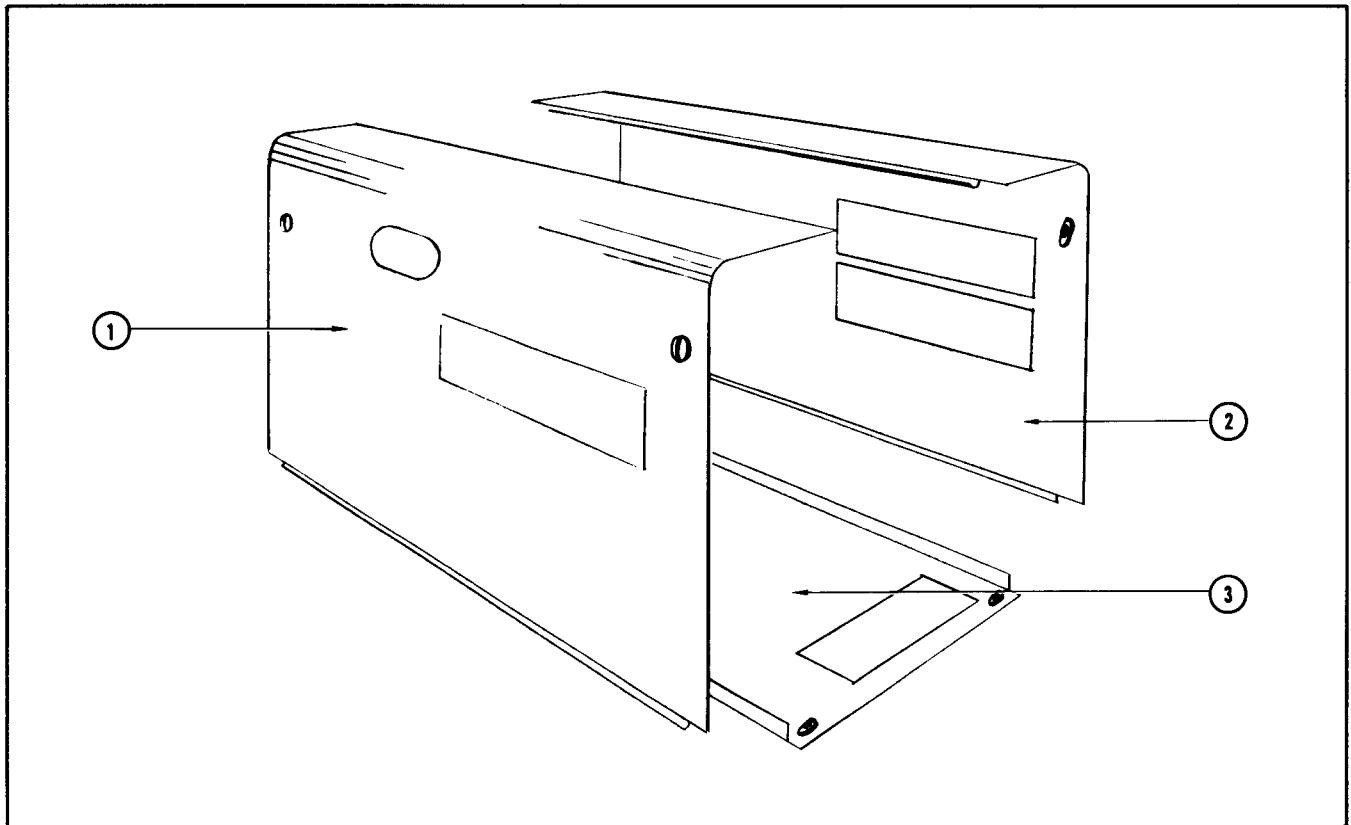


Parts List — Type 502A

REAR

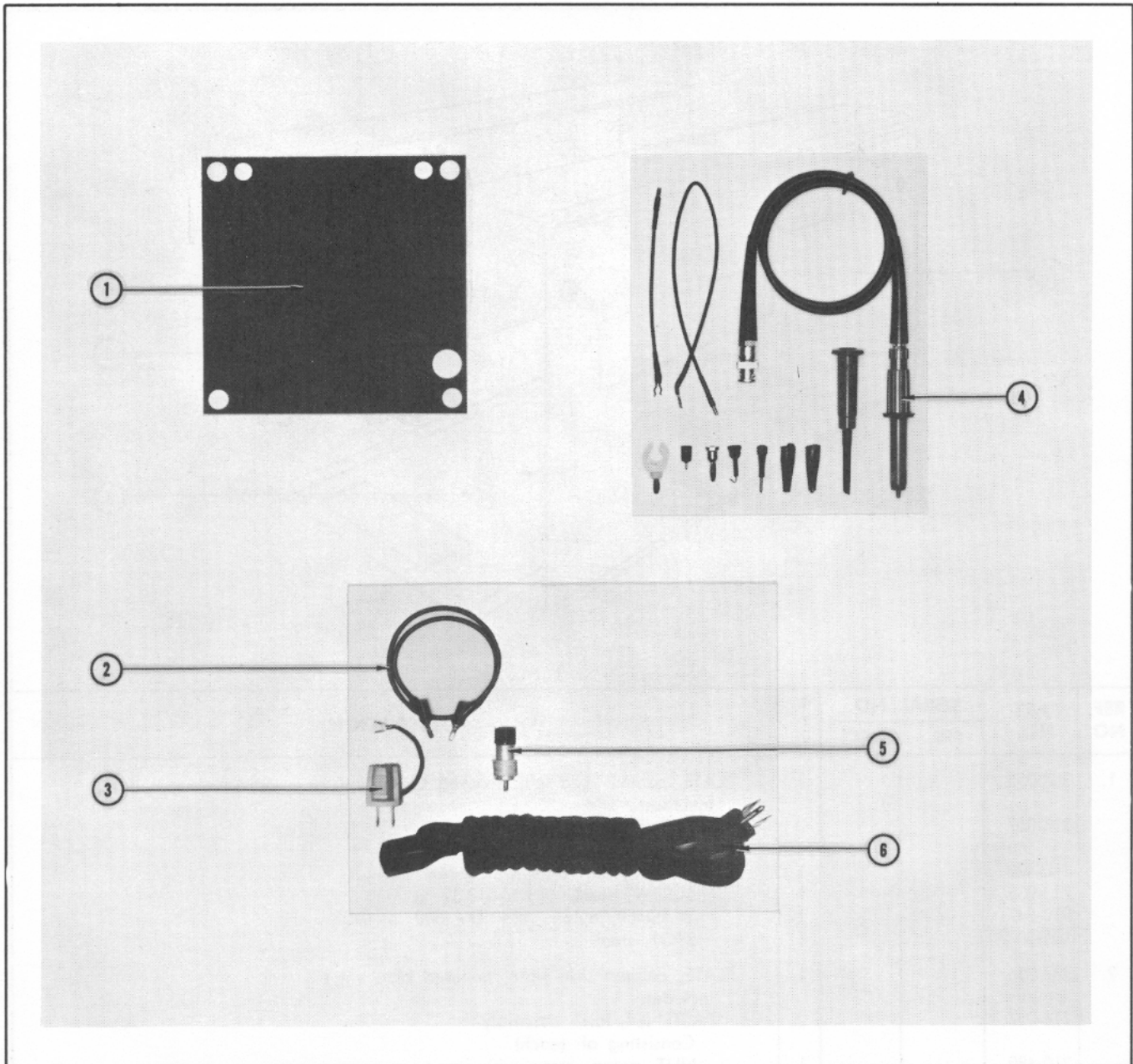
REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	387-786			1	PLATE, rear overlay, alum.
	387-787			1	PLATE, subpanel, rear, alum.
	213-104			4	SCREW, thread forming #6 x 3/8 in. THS, phillips
2.	386-427			1	PLATE, brass, 9/16 x 1-9/32 in. ground plated, open end
3.	129-063			2	POST, binding, 5 way, charcoal
	358-169			1	BUSHING, binding post, charcoal
	210-010			2	LOCKWASHER, steel, internal #10
	210-445			3	NUT, hex, steel, 10-32 x 3/8 in.
	210-206			1	LUG, solder, SE10 long
4.	380-017			1	HOUSING, air filter, alum. blue vinyl
	212-031			2	SCREW, 8-32 x 1-1/4 in. RHS
	210-458			2	NUT, keps, steel, 8-32 x 1 1/32 in.
	210-402			2	NUT, cap, hex, brass, 8-32 x 5/16 in.
5.	378-022			1	FILTER, air, Scott foam, charcoal, 3/4 x 8-1/4 x 8-1/4 in.
	378-763			1	FILTER, screen, alum. 6 1/2 x 6 1/2 x 3/16 in.
6.	334-679			1	TAG, metal serial number insert
	213-088			2	SCREW, thread forming #4 x 1/4 in. PHS, phillips
7.	352-010			1	HOLDER, fuse, 3AG
	210-873			1	WASHER, rubber, 1/2 ID x 1 1/16 OD x 3/64 in.
	200-015			1	CAP, fuse, 3AG, raw
8.	131-102			1	CONNECTOR, chassis mount, 3 wire, male
					Consisting of:
	129-041			1	POST, ground, steel
	200-185			1	COVER, 3 wire motor base
	210-003			2	LOCKWASHER, steel, external #4
	210-551			2	NUT, hex, steel, 4-40 x 1/4 in.
	211-015			1	SCREW, 4-40 x 1/2 in. RHS
	214-078			2	PIN, connecting, brass
	377-041			1	INSERT, black urea
	386-933			1	PLATE, brass, 2-1/8 in. motor base mounting
					Mounting Hardware: (not included)
					SCREW, 6-32 x 3/8 in. THS, phillips
				NUT, keps, steel, 6-32 x 5/16 in.	
9.	134-067			4	PLUG, "D" hole, nylon, gray

CABINET



REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	387-055			1	PLATE, cabinet side left, textured blue vinyl Includes:
	214-057			2	FASTENER, latch assembly Consisting of: (each)
	210-480			1	NUT, nylon, large with insert
	213-033			1	SCREW, steel, 1/2 x 1/2 x 8-32 in.
	210-847			1	WASHER, nylon, .164 ID x .500 in. OD
	105-007			1	STOP, steel
2.	387-056			1	PLATE, cabinet side right, textured blue vinyl Includes:
	214-057			2	FASTENER, latch assembly Consisting of: (each)
	210-480			1	NUT, nylon, large with insert
	213-033			1	SCREW, steel, 1/2 x 1/2 x 8-32 in.
	210-847			1	WASHER, nylon, .164 ID x .500 in. OD
	105-007			1	STOP, steel
3.	387-057			1	PLATE, cabinet bottom, textured blue vinyl Includes:
	214-057			4	FASTENER, latch assembly Consisting of: (each)
	210-480			1	NUT, nylon, large with insert
	213-033			1	SCREW, steel, 1/2 x 1/2 x 8-32 in.
	210-847			1	WASHER, nylon, .164 ID x .500 in. OD
	105-007			1	STOP, steel

ACCESSORIES



REF. NO.	PART NO.	SERIAL/MODEL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1.	378-539			1	FILTER, polarized light, 5-11/16 x 5-11/16 in.
2.	012-031			1	CORD, patch, banana plug both ends, 18 in. red
3.	103-013			1	ADAPTER, power cord, 3 wire to 2 wire
4.	010-125			2	PROBES, P6006, 42 in.
5.	013-004			2	ADAPTER, binding post
6.	161-010			1	CORD, power, 16 gauge, 8 ft., 3 wire

ELECTRICAL PARTS LIST

Values are fixed unless marked Variable.

Ckt. No.	Tektronix Part Number	Description	S/N Range
Bulbs			
B124	150-027	Neon, Type NE-23	READY
B167	150-027	Neon, Type NE-23	
B331 M	150-027	Neon, Type NE-23	ON
B331 N	150-027	Neon, Type NE-23	UNCALIBRATED
B490	150-027	Neon, Type NE-23	
B601	150-001	Incandescent, Type #47	Graticule Light
B602	150-001	Incandescent, Type #47	Graticule Light

Capacitors

Tolerance $\pm 20\%$ unless otherwise indicated.

Tolerance of all electrolytic capacitors are as follows (with exceptions):

3 V — 50 V = -10% , $+250\%$

51 V — 350 V = -10% , $+100\%$

351 V — 450 V = -10% , $+50\%$

C10	283-002	.01 μf	Disc Type	500 v		
C11	283-000	.001 μf	Disc Type	500 v		
C13	283-001	.005 μf	Disc Type	500 v		
C24	283-000	.001 μf	Disc Type	500 v		
C31	285-510	.01 μf	MT	400 v		
C44	281-510	22 pf	Cer.	500 v		
C131	281-510	22 pf	Cer.	500 v		
C137	281-503	8 pf	Cer.	500 v	$\pm .5$ pf	X21070-up
C141	281-541	6.8 pf	Cer.	500 v	10%	
C160A	281-007	3-12 pf	Cer.	Var.		
C160B	283-534	82 pf	Mica	500 v	5%	
C160C	281-010	4.5-25 pf	Cer.	Var.		
C160D	*291-008	.001 μf			$\pm 1/2\%$	
C160E	*291-007	.01 μf	} Timing Series		$\pm 1/2\%$	
C160F		.1 μf				
C160G		1 μf				
C167	283-000	.001 μf	Disc Type	500 v		
C180A	281-528	82 pf	Cer.	500 v	10%	
C180B	285-501	.001 μf	MT	600 v		
C180C	285-510	.01 μf	MT	400 v		
C180D	285-526	.1 μf	MT	400 v		
C181	281-528	82 pf	Cer.	500 v	10%	
C311	281-010	4.5-25 pf	Cer.	Var.		
C312	281-521	56 pf	Cer.	500 v	10%	
C350	283-001	.005 μf	Disc Type	500 v		

Parts List — Type 502A

Capacitors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range				
C400†	*295-066	.1 μ f	PTM	600 v	matched within 1% of each other				
C401†									
C406A†						281-012	7-45 pf	Cer.	Var.
C406C†						281-005	1.5-7 pf	Cer.	Var.
C406G†						281-012	7-45 pf	Cer.	Var.
C406J†	281-005	1.5-7 pf	Cer.	Var.					
C406L†	281-546	330 pf	Cer.	500 v	10%				
C407A†	281-012	7-45 pf	Cer.	Var.					
C407C†	281-005	1.5-7 pf	Cer.	Var.					
C407G†	281-012	7-45 pf	Cer.	Var.					
C407J†	281-005	1.5-7 pf	Cer.	Var.					
C407L†	281-546	330 pf	Cer.	500 v	10%				
C409B†	281-506	12 pf	Cer.	500 v	10%				
C409C†	281-513	27 pf	Cer.	500 v					
C409D†	281-528	82 pf	Cer.	500 v	10%				
C409E†	281-524	150 pf	Cer.	500 v					
C409F†	283-513	220 pf	Mica	500 v	5%				
C409G†	283-522	470 pf	Mica	500 v	10%				
C409H†	283-524	750 pf	Mica	500 v	5%				
C409J†	283-035	.0015 μ f	Disc Type	500 v					
C409K†	285-510	.01 μ f	MT	400 v					
C409L†	285-519	.047 μ f	MT	400 v					
C410†	281-010	4.5-25 pf	Cer.	Var.					
C440†	281-010	4.5-25 pf	Cer.	Var.					
C456†	285-543	.0022 μ f	MT	400 v					
C469†	281-027	.7-3 pf	Tub.	Var.					
C470†	281-005	1.5-7 pf	Cer.	Var.					
C478†	281-005	1.5-7 pf	Cer.	Var.					
C480†	281-005	1.5-7 pf	Cer.	Var.					
C491†	281-534	3.3 pf	Cer.	500 v	$\pm .25$ pf				
C601	285-612	1.5 μ f	PMC	236 v	X20686-up				
C602A,B	*290-092	10 x 80 μ f	EMC	450 v					
C623	285-510	.01 μ f	MT	400 v					
C633	285-510	.01 μ f	MT	400 v					
C635	Use 283-057	.1 μ f	Disc Type	200 v					
C642	*290-091	4000 μ f	EMC	15 v					
C644	290-025	6.25 μ f	EMT	300 v					
C645	290-025	6.25 μ f	EMT	300 v					
C652	*290-043	2 x 40 μ f	EMC	450 v					
C671	285-510	.01 μ f	MT	400 v					
C685	290-025	6.25 μ f	EMT	300 v					
C686	290-025	6.25 μ f	EMT	300 v					
C722	*290-042	2 x 40 μ f	EMC	450 v					
C751	285-511	.01 μ f	PTM	600 v					
C757A,B	*290-037	2 x 20 μ f	EMC	450 v					
C765A,B	*290-037	2 x 20 μ f	EMC	450 v					

† There are two parts of this description in your instrument, one in each of the Vertical Amplifiers.

Capacitors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
C800	285-501	.001 μ f	MT	600 v	
C805	285-510	.01 μ f	MT	400 v	
C807	283-538	.003 μ f	Mica	500 v	10%
C808	use 283-022	.02 μ f	Disc Type	1400 v	
C820	285-519	.047 μ f	MT	400 v	
C822	283-034	.005 μ f	Disc Type	4000 v	
C824	use 285-510	.01 μ f	MT	400 v	
C828	283-034	.005 μ f	Disc Type	4000 v	
C830	283-034	.005 μ f	Disc Type	4000 v	
C833	283-006	.02 μ f	Disc Type	600 v	
C836	283-034	.005 μ f	Disc Type	4000 v	
C838	285-526	.1 μ f	MT	400 v	
C839	283-034	.005 μ f	Disc Type	4000 v	
C841	283-001	.005 μ f	Disc Type	500 v	
C847	use 283-057	.1 μ f	Disc Type	200 v	
C850	283-034	.005 μ f	Disc Type	4000 v	
C851	283-034	.005 μ f	Disc Type	4000 v	
C866	use 283-082	.01 μ f	Disc Type	4000 v	
C867	use 283-082	.01 μ f	Disc Type	4000 v	
C868	use 283-082	.01 μ f	Disc Type	4000 v	
C869	use 283-082	.01 μ f	Disc Type	4000 v	
C871	283-518	330 pf	Mica	500 v	10%
C876	283-518	330 pf	Mica	500 v	10%

Diodes

D124	*152-061	Silicon	Tek Spec		20000-22539
D124	*152-107	Silicon	Replaceable by 1N647		22540-up
D126	*152-061	Silicon	Tek Spec		20000-22539
D126	*152-107	Silicon	Replaceable by 1N647		22540-up
D131	152-008	Germanium	T12G		
D642A	*152-047	Silicon	Replaceable by 1N2862		
D642B	*152-047	Silicon	Replaceable by 1N2862		

Fuses

F601	159-017	4 Amp 3AG Fast-Blo	117 v oper. 60 cycle		
	159-026	3.2 Amp 3AG Slo-Blo	117 v oper. 50 cycle		
	159-021	2 Amp 3AG Fast-Blo	234 v oper. 60 cycle		
	159-003	1.6 Amp 3AG Slo-Blo	234 v oper. 50 cycle		

Resistors

Resistors are fixed, composition, $\pm 10\%$ unless otherwise indicated.

R10	302-105	1 meg	$\frac{1}{2}$ w		
R11	302-474	470 k	$\frac{1}{2}$ w		
R13	302-224	220 k	$\frac{1}{2}$ w		
R15	302-105	1 meg	$\frac{1}{2}$ w		
R17†	311-034	500 k	2 w	Var.	TRIGGERING LEVEL

† Ganged with SW17. Furnished as a unit.

Parts List — Type 502A

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
R18	302-124	120 k	1/2 w		
R21	302-101	100 Ω	1/2 w		
R23	304-473	47 k	1 w		
R24	311-005	500 Ω	2 w	Var.	TRIG. LEVEL CENT.
R26	302-333	33 k	1/2 w		
R27	302-101	100 Ω	1/2 w		
R29	301-204	200 k	1/2 w		5%
R32	302-275	2.7 meg	1/2 w		
R33	302-101	100 Ω	1/2 w		
R36	306-223	22 k	2 w		
R39	309-126	400 k	1/2 w	Prec.	1%
R42	302-101	100 Ω	1/2 w		
R44	309-056	390 k	1/2 w	Prec.	1%
R47	301-302	3 k	1/2 w		5%
R48	302-681	680 Ω	1/2 w		
R51	302-392	3.9 k	1/2 w		
R111	311-032	250 k	2 w	Var.	STABILITY ADJUST
R114	302-104	100 k	1/2 w		
R116	use 302-394	390 k	1/2 w		
R121	316-103	10 k	1/4 w		X21070-up
R122	301-274	270 k	1/2 w		5%
R123	302-183	18 k	1/2 w		
R124	302-683	68 k	1/2 w		
R125	use 302-154	150 k	1/2 w		
R126	302-334	330 k	1/2 w		
R127	302-153	15 k	1/2 w		
R128	302-184	180 k	1/2 w		
R131	302-472	4.7 k	1/2 w		
R134	301-393	39 k	1/2 w		5%
R136	303-224	220 k	1 w		5%
R137	302-101	100 Ω	1/2 w		20000-21069
R137	302-473	47 k	1/2 w		21070-up
R141	309-040	56.5 k	1/2 w	Prec.	1%
R143	309-176	43.4 k	1/2 w	Prec.	1%
R144	324-309	16.2 k	1 w	Prec.	1%
R144	324-323	22.6 k	1 w	Prec.	1%
R146	302-101	100 Ω	1/2 w		20000-22539
R147	302-222	2.2 k	1/2 w		22540-up
R148	302-184	180 k	1/2 w		
R160A	309-014	1 meg	1/2 w	Prec.	1%
R160B	309-023	2 meg	1/2 w	Prec.	1%
R160C	309-087	5 meg	1/2 w	Prec.	1%
R160D	309-095	10 meg	1/2 w	Prec.	1%
R160E	309-095	10 meg	1/2 w	Prec.	1%
R160F	310-061	15 meg	1 w	Prec.	2%
R160G	310-061	15 meg	1 w	Prec.	2%
R160T	302-822	8.2 k	1/2 w		
R160V†	311-108	20 k		Var.	WW VARIABLE (Time/CM)
R161	302-101	100 Ω	1/2 w		

† Concentric with SW160V. Furnished as a unit.

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
R166	306-154	150 k	2 w		
R167	302-155	1.5 meg	1/2 w		
R168	302-473	47 k	1/2 w		
R169	302-101	100 Ω	1/2 w		
R174	306-273	27 k	2 w		
R176	311-016	10 k	2 w	Var.	SWP. LENGTH
R178	304-183	18 k	1 w		
R180A	302-474	470 k	1/2 w		
R180B	302-475	4.7 meg	1/2 w		
R181	301-825	8.2 meg	1/2 w		5%
R183	302-101	100 Ω	1/2 w		
R185	302-473	47 k	1/2 w		
R186	301-393	39 k	1/2 w		5%
R311	309-144	975 k	1/2 w	Prec.	1%
R312	309-110	800 k	1/2 w	Prec.	1%
R314	309-051	200 k	1/2 w	Prec.	1%
R315	302-101	100 Ω	1/2 w		
R317	302-104	100 k	1/2 w		
R320	309-014	1 meg	1/2 w	Prec.	1%
R321	302-101	100 Ω	1/2 w		
R324	301-564	560 k	1/2 w		5%
R331A	309-090	50 k	1/2 w	Prec.	1%
R331C	309-228	12.5 k	1/2 w	Prec.	1%
R331E	309-229	5.55 k	1/2 w	Prec.	1%
R331G	309-230	2.63 k	1/2 w	Prec.	1%
R331J	309-231	16.69 k	1/2 w	Prec.	1%
R331M	302-104	100 k	1/2 w		
R331N	302-104	100 k	1/2 w		
R334	309-234	154 k	1/2 w	Prec.	1%
R336	310-065	56.5 k	1 w	Prec.	1%
R337	311-045	15 k	2 w	Var.	MAG. REGIS.
R338	310-086	50 k	1 w		Prec. 1%
R341	311-032	250 k	2 w	Var.	EXT. HORIZ. DC BAL.
R343	302-474	470 k	1/2 w		
R344	302-392	3.9 k	1/2 w		
R351	302-101	100 Ω	1/2 w		
R354	301-564	560 k	1/2 w		5%
R356	309-129	34 k	1/2 w	Prec.	1%
R357	311-018	20 k	2 w	Var.	1X CAL.
R358	309-129	34 k	1/2 w	Prec.	1%
R360	301-304	300 k	1/2 w		5%
R361	302-101	100 Ω	1/2 w		
R364	308-105	30 k	8 w		WW 5%
R365	305-823	82 k	2 w		5%
R368	311-011	5 k	2 w	Var.	20X CAL.
R370	301-304	300 k	1/2 w		5%
R371	302-101	100 Ω	1/2 w		
R374	308-105	30 k	8 w		WW 5%
R376	305-823	82 k	2 w		5%
R381	309-052	220 k	1/2 w	Prec.	1%

Parts List — Type 502A

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
R383	301-204	200 k	1/2 w		5%
R385	302-223	22 k	1/2 w		
R386	302-223	22 k	1/2 w		
R391	309-052	220 k	1/2 w	Prec.	1%
R393	301-204	200 k	1/2 w		5%
R395	302-223	22 k	1/2 w		
R396	302-223	22 k	1/2 w		
R398	311-416	2 x 50 k		Var.	POSITION
R406C†	309-111	900 k	1/2 w	Prec.	1%
R406E†	309-046	111 k	1/2 w	Prec.	1%
R406J†	309-013	990 k	1/2 w	Prec.	1%
R406L†	309-034	10.1 k	1/2 w	Prec.	1%
R407C†	309-111	900 k	1/2 w	Prec.	1%
R407E†	309-046	111 k	1/2 w	Prec.	1%
R407J†	309-013	990 k	1/2 w	Prec.	1%
R407L†	309-034	10.1 k	1/2 w	Prec.	1%
R408A†	309-243	193 k	1/2 w	Prec.	1%
R408B†	309-090	50 k	1/2 w	Prec.	1%
R408C†	309-231	16.69 k	1/2 w	Prec.	1%
R408D†	309-229	5.55 k	1/2 w	Prec.	1%
R408E†	309-230	2.63 k	1/2 w	Prec.	1%
R408F†	309-241	1.28 k	1/2 w	Prec.	1%
R408G†	309-203	505.4 Ω	1/2 w	Prec.	1/4 %
R408H†	309-178	250 Ω	1/2 w	Prec.	1%
R408J†	309-240	125 Ω	1/2 w	Prec.	1%
R408K†	309-128	50 Ω	1/2 w	Prec.	1%
R408L†	309-177	25 Ω	1/2 w	Prec.	1%
R409B†	316-123	12 k	1/4 w		
R409C†	315-103	10 k	1/4 w		5%
R409D†	316-392	3.9 k	1/4 w		
R409E†	315-272	2.7 k	1/4 w		5%
R409F†	315-222	2.2 k	1/4 w		5%
R409G†	316-152	1.5 k	1/4 w		
R409H†	315-102	1 k	1/4 w		5%
R409J†	315-331	330 Ω	1/4 w		5%
R410†	*312-583††	1 meg	1/2 w	Prec.	1%
R411†	302-102	1 k	1/2 w		
R413†	301-564	560 k	1/2 w		5%
R414†	309-049	150 k	1/2 w	Prec.	1%
R417†	301-273	27 k	1/2 w		5%
R418†	301-472	4.7 k	1/2 w		5%
R422†††	316-105	1 meg	1/4 w		X21070-up
R423†	301-913	91 k	1/2 w		5%
R424†	Use 311-347	100 k	.2 w	Var.	.2 V/CM DIFF. BAL.
R425†	301-913	91 k	1/2 w		5%
R427†	309-432	82.5 k	1/2 w	Prec.	1%

† There are two parts of this description in your instrument; one in each of the Vertical Amplifiers.

†† R410 and R440 are a matched pair. Furnished as a unit.

††† Selected part; may not appear in your instrument.

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description			S/N Range
R428†	309-432	82.5 k	1/2 w		Prec.	1%
R429†	311-017	10 k	.1 w	Var.		VAR. DC BAL.
R433†	311-243	50 k		Var.		DC BAL.
R434†	301-272	2.7 k	1/2 w			5%
R435†	311-125	50 k	.2 w	Var.		.2 MV/CM DIFF. BAL.
R440†	*312-583††	1 meg	1/2 w		Prec.	1%
R441†	302-102	1 k	1/2 w			
R443†	301-564	560 k	1/2 w			5%
R444†	309-049	150 k	1/2 w		Prec.	1%
R447†	301-273	27 k	1/2 w			5%
R448†	301-472	4.7 k	1/2 w			5%
R450†	306-473	47 k	2 w			
R451†	302-102	1 k	1/2 w			
R452†	309-414	5 meg	1/2 w		Prec.	1%
R453†	306-153	15 k	2 w			
R454†	301-303	30 k	1/2 w			5%
R455†	311-067	5 k	.2 w	Var.		FEEDBACK BAL.
R456†	311-084	1 k	.2 w	Var.		.2 MV/CM GAIN
R457†	301-223	22 k	1/2 w			5%
R458†	301-223	22 k	1/2 w			5%
R461†	302-102	1 k	1/2 w			
R462†	309-414	5 meg	1/2 w		Prec.	1%
R464†	301-303	30 k	1/2 w			5%
R465†	Use 301-565	5.6 meg	1/2 w			5%
R466†	311-028	2 x 100 k	2 w	Var.		POSITION
R467†	Use 301-565	5.6 meg	1/2 w			5%
R468†	302-103	10 k	1/2 w			
R469†	302-103	10 k	1/2 w			
R470†	309-195	90 k	1/2 w		Prec.	1%
R471†	302-102	1 k	1/2 w			
R472†	304-223	22 k	1 w			
R473†	302-102	1 k	1/2 w			
R474†	305-273	27 k	2 w			5%
R475†	Use 306-333	33 k	2 w			
R476†	306-273	27 k	2 w			
R478†	302-472	4.7 k	1/2 w			
R479†	302-472	4.7 k	1/2 w			
R480†	309-195	90 k	1/2 w		Prec.	1%
R481†	302-102	1 k	1/2 w			
R482†	304-223	22 k	1 w			
R483†	302-102	1 k	1/2 w			
R484†	305-273	27 k	2 w			5%
R485†	Use 306-333	33 k	2 w			
R486†	306-273	27 k	2 w			
R487†	311-399	7 k		Var.		VARIABLE (Sensitivity)

† There are two parts of this description in your instrument; one in each of the Vertical Amplifiers.

†† R410 and R440 are a matched pair. Furnished as a unit.

Parts List — Type 502A

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description			S/N Range
R488†	311-120	2.5 k	.2 w	Var.		.2 V/CM GAIN GAIN ADJ. FOR HORIZ. MODE
R489	311-067	5 k	.2 w	Var.		
R490	302-683	68 k	1/2 w			
R491†	309-086	3.5 meg	1/2 w		Prec. 1%	
R492†	309-021	1.84 meg	1/2 w		Prec. 1%	
R494†	302-224	220 k	1/2 w			DC TRIG. SCALE ILLUM.
R495†	311-125	50 k	.2 w	Var.		
R499†	304-473	47 k	1 w			
R601††	311-057	50 Ω		Var.	WW	
R602	302-101	100 Ω	1/2 w			
R603	302-101	100 Ω	1/2 w			5%
R604	308-142	30 Ω	3 w		WW	
R618	302-102	1 k	1/2 w			
R619	302-105	1 meg	1/2 w			
R621	310-054	68 k	1 w		Prec. 1%	
R622	311-015	10 k		Var.	WW	—150 VOLTS 1%
R623	310-086	50 k	1 w		Prec.	
R630	302-333	33 k	1/2 w			
R631	302-105	1 meg	1/2 w			
R632	302-102	1 k	1/2 w			
R633	302-105	1 meg	1/2 w			5%
R635	302-183	18 k	1/2 w			
R636	302-105	1 meg	1/2 w			
R637	308-040	1.5 k	25 w		WW	
R639	302-333	33 k	1/2 w			
R642	302-104	100 k	1/2 w			
R643	302-104	100 k	1/2 w			
R644	302-101	100 Ω	1/2 w			
R645	302-101	100 Ω	1/2 w			
R646	306-150	15 Ω	2 w			
R647	306-150	15 Ω	2 w			
R648	309-030	1.8 k	1/2 w		Prec. 1%	1%
R649	310-068	42.226 k	1 w		Prec.	
R650	302-470	47 Ω	1/2 w			
R651	302-470	47 Ω	1/2 w			
R659	302-102	1 k	1/2 w			
R660	302-473	47 k	1/2 w			
R661	302-473	47 k	1/2 w			
R662	302-185	1.8 meg	1/2 w			
R665	306-273	27 k	2 w			
R666	302-105	1 meg	1/2 w			
R668	302-102	1 k	1/2 w			1%
R669	302-105	1 meg	1/2 w			
R671	310-088	143 k	1 w		Prec.	
R673	310-055	220 k	1 w		Prec.	

† There are two parts of this description in your instrument; one in each of the Vertical Amplifiers.

†† Ganged with SW601. Furnished as a unit.

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
R685	302-101	100 Ω	$\frac{1}{2}$ w		
R686	302-101	100 Ω	$\frac{1}{2}$ w		
R722	302-104	100 k	$\frac{1}{2}$ w		
R739	302-102	1 k	$\frac{1}{2}$ w		
R740	302-273	27 k	$\frac{1}{2}$ w		
R741	302-474	470 k	$\frac{1}{2}$ w		
R742	304-274	270 k	1 w		
R745	304-563	56 k	1 w		
R746	302-225	2.2 meg	$\frac{1}{2}$ w		
R747	302-102	1 k	$\frac{1}{2}$ w		
R748	302-102	1 k	$\frac{1}{2}$ w		
R749	302-225	2.2 meg	$\frac{1}{2}$ w		
R751	310-094	400 k	1 w	Prec.	1%
R753	309-151	174 k	$\frac{1}{2}$ w	Prec.	1%
R756	302-102	1 k	$\frac{1}{2}$ w		
R757	308-064	2.25 k	20 w	WW	5%
R765	302-101	100 Ω	$\frac{1}{2}$ w		
R766	302-101	100 Ω	$\frac{1}{2}$ w		
R800	306-563	56 k	2 w		
R805	302-333	33 k	$\frac{1}{2}$ w		
R806	302-392	3.9 k	$\frac{1}{2}$ w		
R808	306-122	1.2 k	2 w		
R809	302-474	470 k	$\frac{1}{2}$ w		
R820	302-102	1 k	$\frac{1}{2}$ w		
R824	316-472	4.7 k	$\frac{1}{4}$ w		
R825	306-225	2.2 meg	2 w		
R826	311-039	1 meg	2 w	Var.	HIGH VOLTAGE
R827	306-275	2.7 meg	2 w		
R828	306-335	3.3 meg	2 w		
R829	306-335	3.3 meg	2 w		
R830	306-395	3.9 meg	2 w		
R831	311-254	5 meg	.2 w	Var.	FOCUS Lower Beam
R832	311-254	5 meg	.2 w	Var.	FOCUS Upper Beam
R833	311-026	100 k	2 w	Var.	HORIZ. SENS. BAL.
R834	316-472	4.7 k	$\frac{1}{4}$ w		
R836	306-395	3.9 meg	2 w		
R837	302-103	10 k	$\frac{1}{2}$ w		
R838	302-103	10 k	$\frac{1}{2}$ w		
R839	302-105	1 meg	$\frac{1}{2}$ w		
R840	311-026	100 k	2 w	Var.	ASTIG. LOWER
R841	311-026	100 k	2 w	Var.	GEOM.
R842	311-023	50 k	2 w	Var.	HORIZ. BEAM REGIS.
R843	304-273	27 k	1 w		
R844	311-026	100 k	2 w	Var.	ASTIG. UPPER
R845	304-273	27 k	1 w		
R846	302-155	1.5 meg	$\frac{1}{2}$ w		
R847	302-225	2.2 meg	$\frac{1}{2}$ w		
R852	306-825	8.2 meg	2 w		
R853	306-825	8.2 meg	2 w		
R854	306-825	8.2 meg	2 w		

Parts List — Type 502A

Resistors (continued)

Ckt. No.	Tektronix Part Number		Description		S/N Range
R858	306-156	15 meg	2 w		
R859	306-156	15 meg	2 w		
R860	311-397	2 meg		Var.	INTENSITY BAL.
R861	304-105	1 meg	1 w		
R862	311-397	2 meg		Var.	INTENSITY
R863	302-226	22 meg	1/2 w		
R864	302-563	56 k	1/2 w		
R865	302-226	22 meg	1/2 w		
R866	302-105	1 meg	1/2 w		
R868	302-105	1 meg	1/2 w		
R870	302-154	150 k	1/2 w		
R871	302-335	3.3 meg	1/2 w		
R872	302-102	1 k	1/2 w		
R874	302-683	68 k	1/2 w		
R875	302-225	2.2 meg	1/2 w		
R876	302-102	1 k	1/2 w		
R878	302-473	47 k	1/2 w		
R879	311-016	10 k	2 w	Var.	CAL. AMPL.
R880	304-333	33 k	1 w		
R883	302-101	100 Ω	1 w		
R884	309-237	204 Ω	1 w		Prec. 1%
R885	310-066	18 k	1 w		Prec. 1%
R886	309-030	1.8 k	1/2 w		Prec. 1%
R887	309-235	9 k	1/2 w		Prec. 1%
R888	309-236	900 Ω	1/2 w		Prec. 1%
R889	309-238	90 Ω	1/2 w		Prec. 1%
R890	309-096	10 Ω	1/2 w		Prec. 1%
R899	*308-090	.25 Ω	1 w		WW

Switches

	Unwired	Wired		
SW10	260-233	*262-177	Rotary	TRIGGER SELECTOR
SW17†	260-235	*262-178	Rotary	TRIGGERING LEVEL
SW20	260-447		Slide	TRIGGER SELECTOR (Slope)
SW126	260-501		Lever	MODE
SW160	260-529	*262-556	Rotary	TIME/CM
SW160V†	311-108			
SW331	260-236	*262-172	Rotary	HORIZONTAL DISPLAY
SW403A††	260-238	*262-179	Rotary	INPUT SELECTOR (Upper)
SW403B††	260-238	*262-190	Rotary	INPUT SELECTOR (Lower)
SW407††	260-525	*262-555	Rotary	SENSITIVITY
SW478††	260-247		Push-button	FINDER (Trace)
SW489	260-237	*262-180	Rotary	HORIZ. DEFL. PLATE SELECTOR
SW601†††	311-057			POWER OFF
SW870	260-234	*262-176	Rotary	AMPLITUDE CALIBRATOR
TK601 Use	260-208		Thermal Cutout	133° F ± 5° F

† Ganged with R17. Furnished as a unit.

† Concentric with R160V. Furnished as a unit.

†† There are two parts of this description in your instrument; one in each of the Vertical Amplifiers.

††† Ganged with R601. Furnished as a unit.

Transformers

Ckt. No.	Tektronix Part Number	Description	S/N Range
T602	*120-117	L. V. Power	
T801	*120-150	H. V. Power	

Transistors

Q124	151-093	2N2043
Q634	151-004	2N214
Q644	151-004	2N214
Q647	Use 151-137	2N2148

Electron Tubes

V24	154-187	6DJ8/ECC88
V45	154-187	6DJ8/ECC88
V135	154-078	6AN8
V145	154-078	6AN8
V152	154-016	6AL5
V161	154-078	6AN8
V183	154-187	6DJ8/ECC88
V324	154-022	6AU6
V354	154-022	6AU6
V364	154-187	6DJ8/ECC88
V414†	} *157-073††	6AU6
V444†		6AU6
V454†		6AU6
V464†		6AU6
V474†		12AT7
V484†	154-039	12AT7
V493†	154-022	6AU6
V602	154-168	5AR4/GZ34
V636	154-078	6AN8
V637	154-044	12B4
V639	154-052	5651
V652	154-119	6BW4
V666	154-078	6AN8
V677	154-044	12B4
V722	154-168	5AR4/GZ34
V746	154-078	6AN8
V747	154-044	12B4
V757	154-044	12B4
V800	154-302	6DT5
V814	154-041	12AU7

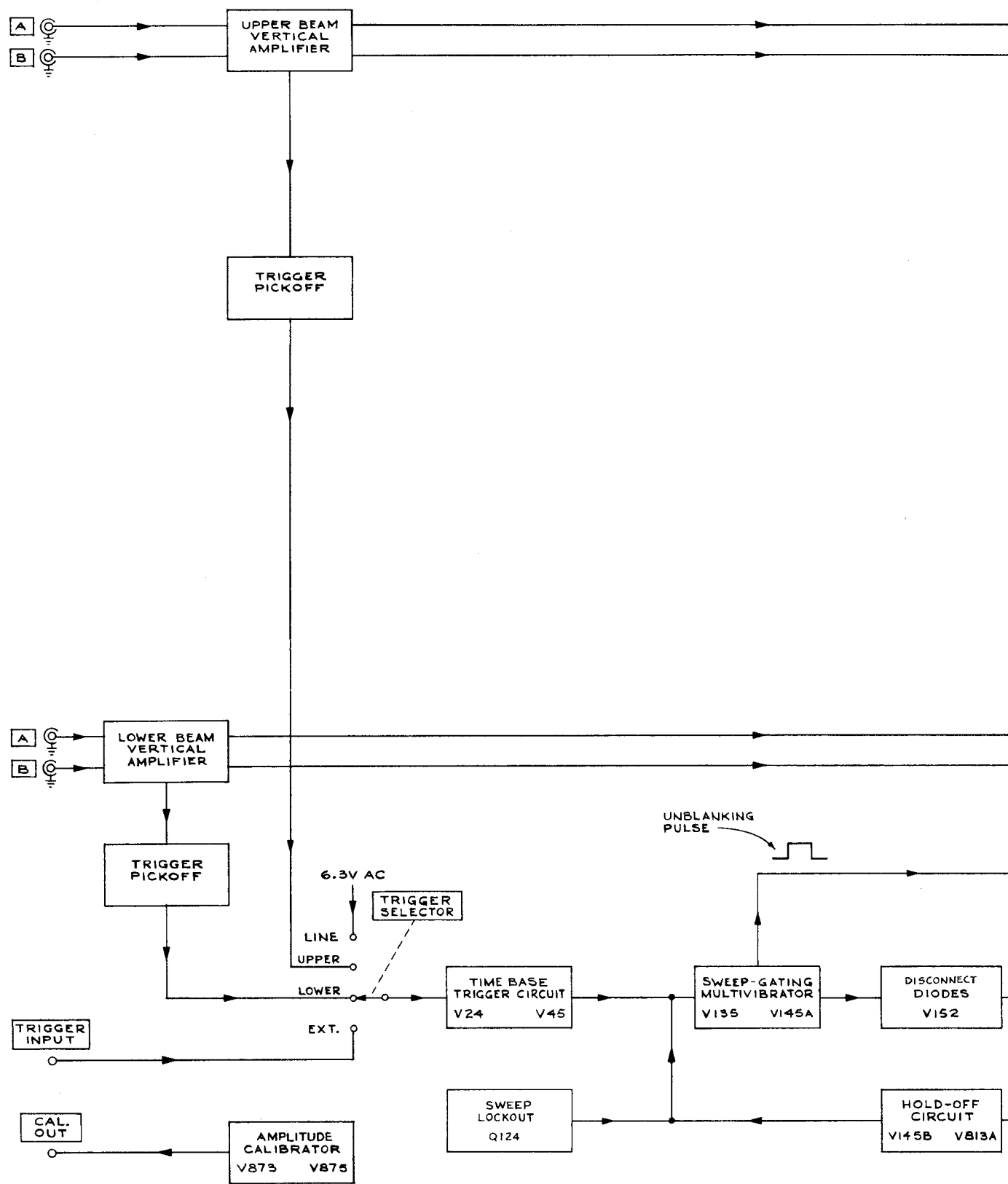
† There are two parts of this description in your instrument; one in each of the Vertical Amplifiers.

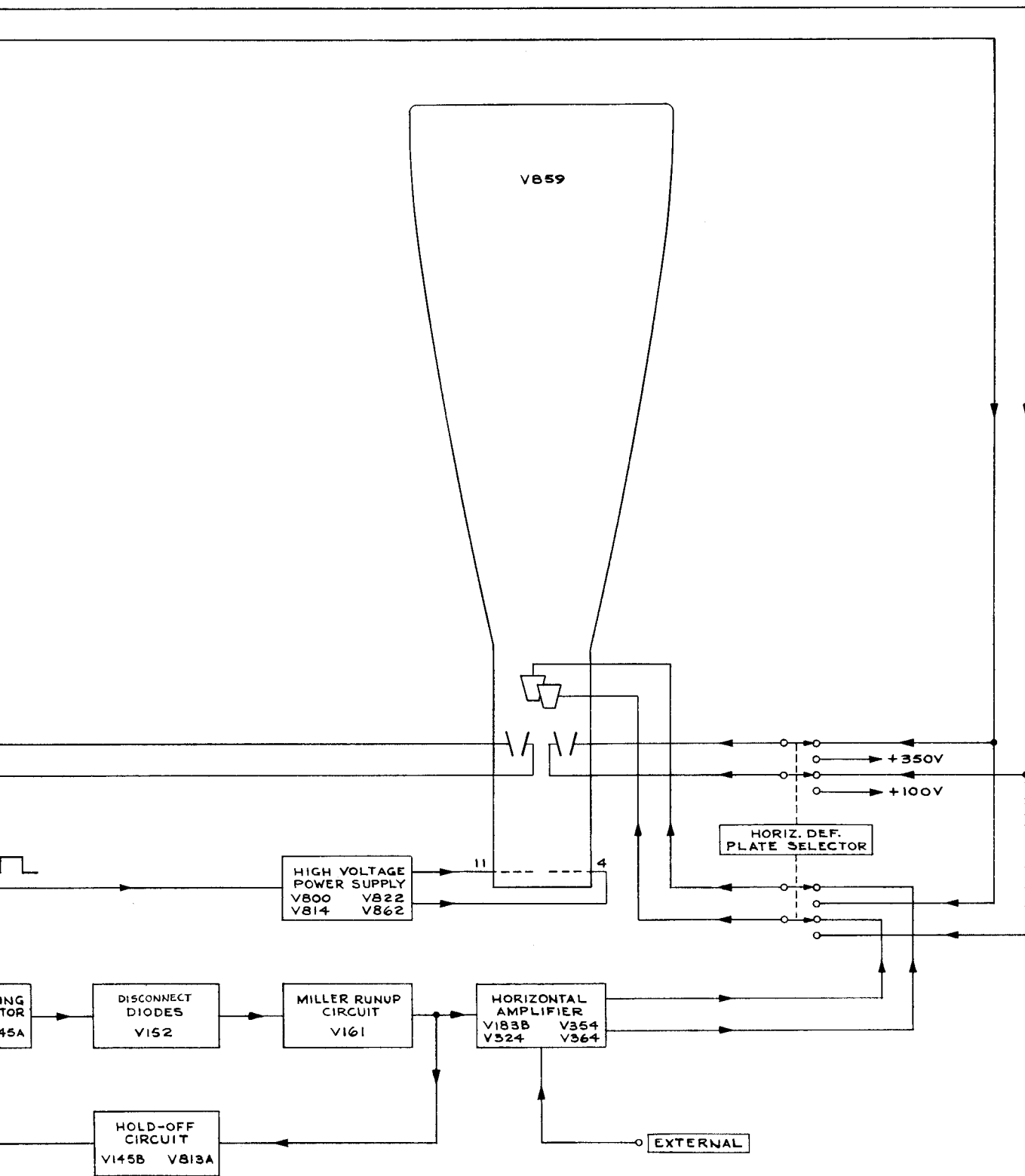
†† V414 and V444 furnished as a unit.

Parts List — Type 502A

Electron Tubes *(continued)*

Ckt. No.	Tektronix Part Number	Description	S/N Range
V822	154-051	5642	
V832	154-051	5642	
V859	*154-246	T5021-2 CRT Standard Phosphor	
V862	154-051	5642	
V873	154-078	6AN8	
V875	154-022	6AU6	

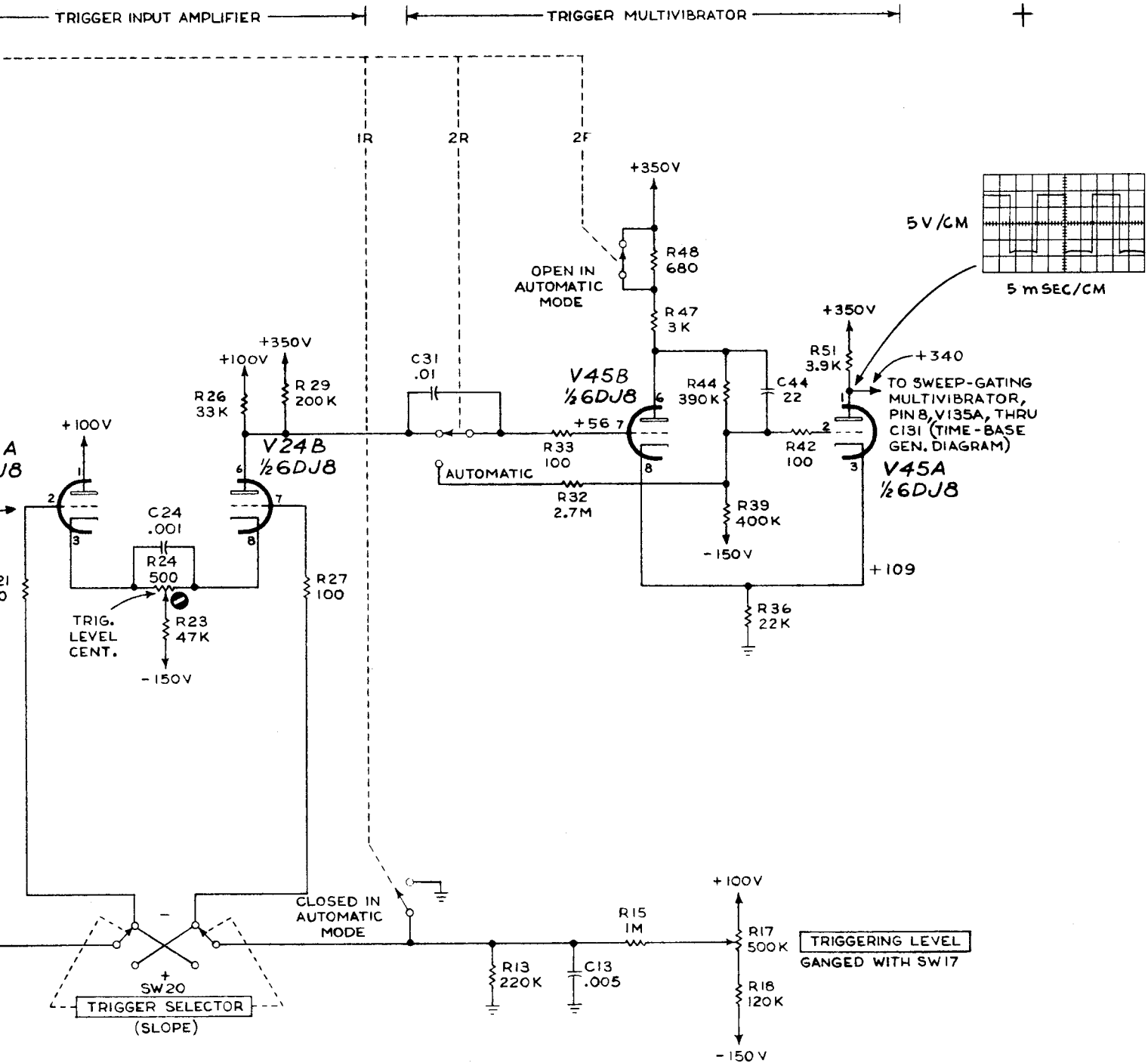




A

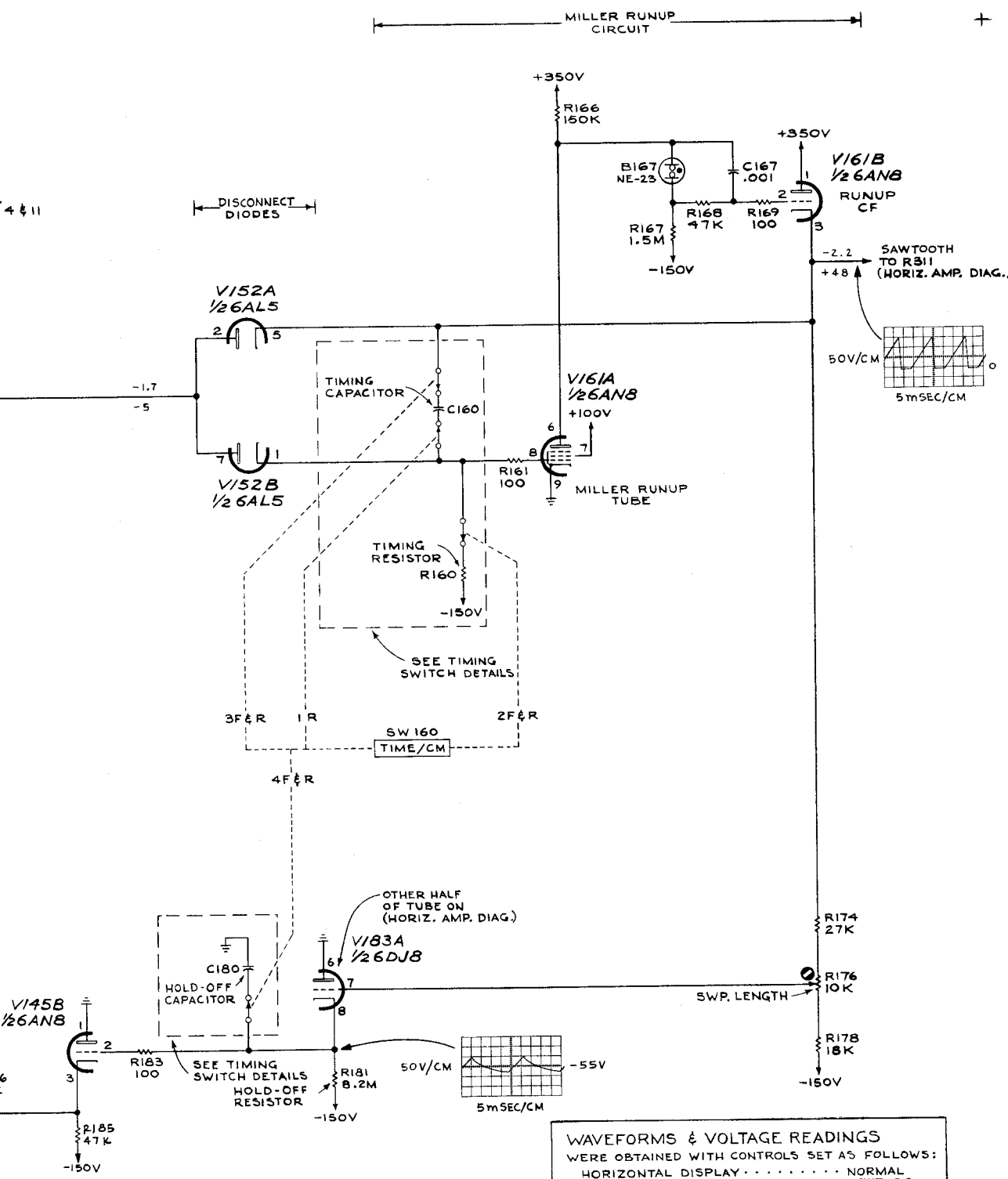
BLOCK DIAGRAM

MRH
263



CIRCUIT NUMBERS
1 THRU 59

TIME-BASE TRIGGER



WAVEFORMS & VOLTAGE READINGS
 WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
 HORIZONTAL DISPLAY NORMAL
 TRIGGER SELECTOR -EXT., DC
 TIME/CM 1 MILLISEC
 TRIGGERING LEVEL:
 FOR WAVEFORMS RECURRENT
 FOR LOWER VOLTAGE READINGS . . . RECURRENT
 FOR UPPER VOLTAGE READINGS . . . FULL LEFT (NOT AUTO)
 MODE SWITCH NORMAL

TIME-BASE GENERATOR

CIRCUIT NUMBERS
 100 THRU 189

864
 308

4 & 11

DISCONNECT DIODES

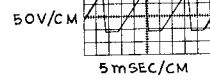
-1.7
 -5

+350V

+350V

-150V

-2.2
 +4.8



+100V

MILLER RUNUP TUBE

TIMING CAPACITOR

TIMING RESISTOR

SEE TIMING SWITCH DETAILS

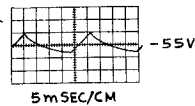
3F & R 1 R 2F & R
 SW 160
 TIME/CM
 4F & R

OTHER HALF OF TUBE ON (HORIZ. AMP. DIAG.)

V163A
 1/2 6DJ8

HOLD-OFF CAPACITOR

SEE TIMING SWITCH DETAILS HOLD-OFF RESISTOR



-150V

V145B
 1/2 6AN8

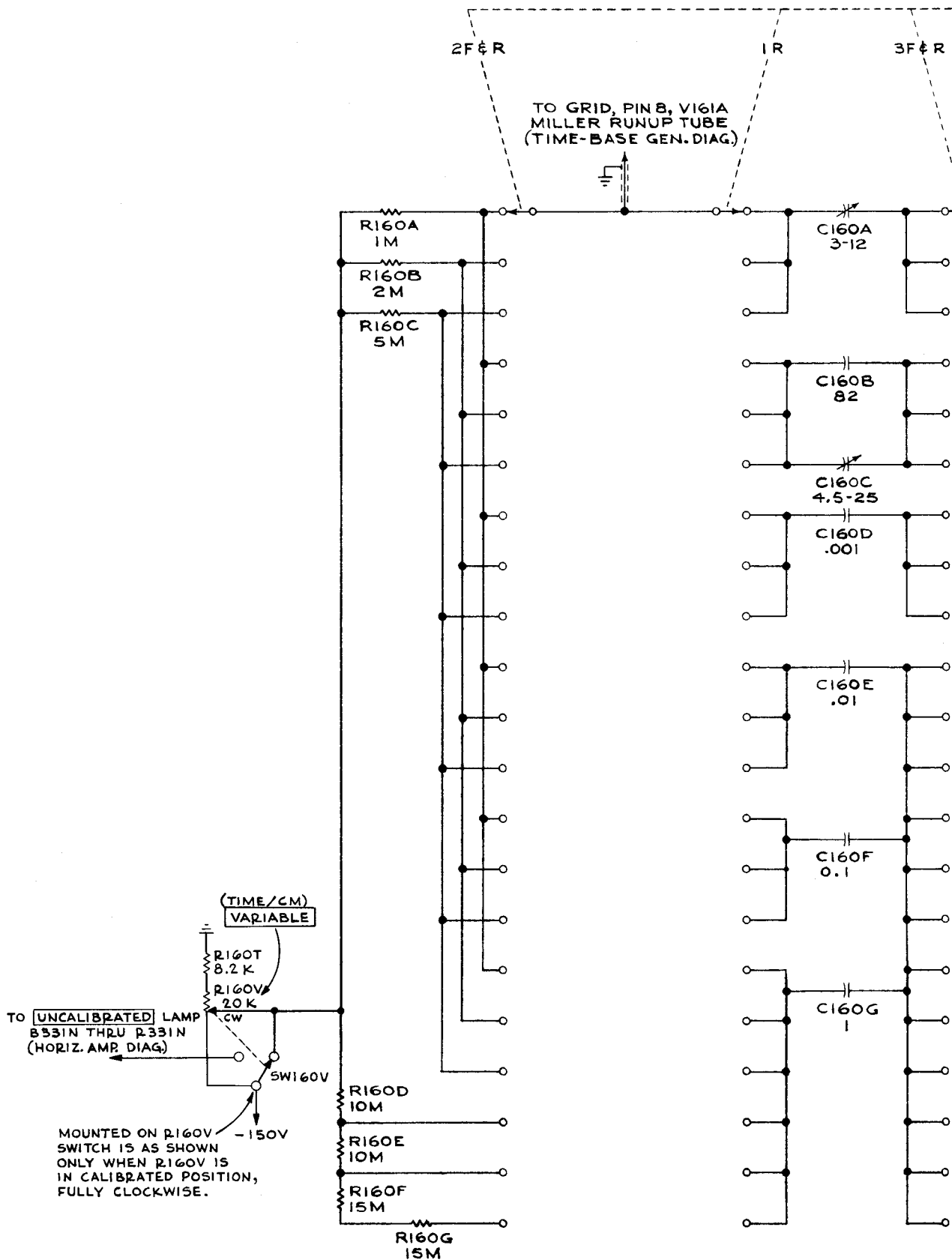
HOLD-OFF CIRCUIT

NO AUTOMATIC TRIGGERING CONTROL (BASE TRIG. DIAG.)

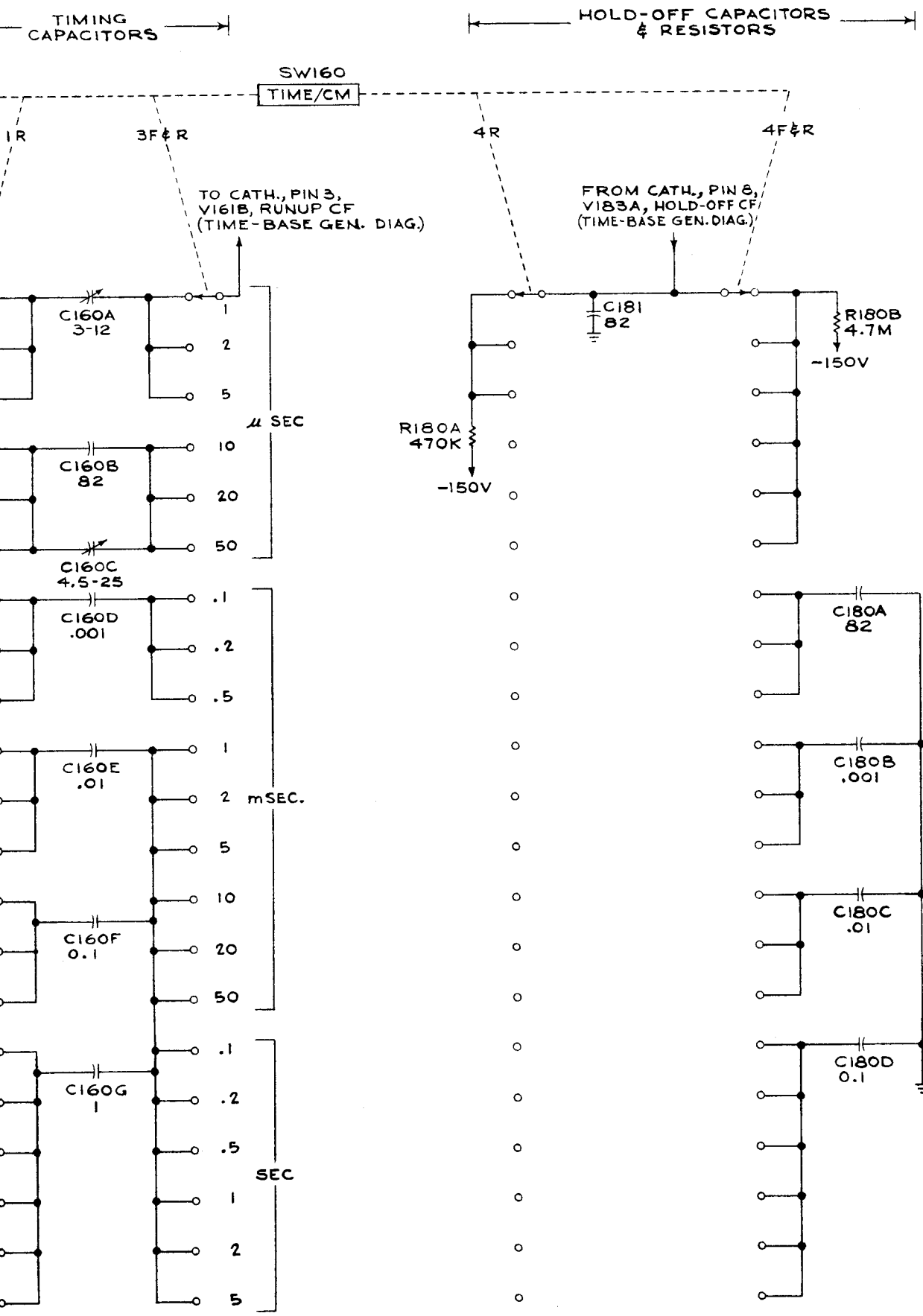
D

← TIMING RESISTORS →

← TIMING CAPACITORS →



TYPE 502A OSCILLOSCOPE



A

TIMING SWITCH

INPUT
CF

INPUT
AMPLIFIER

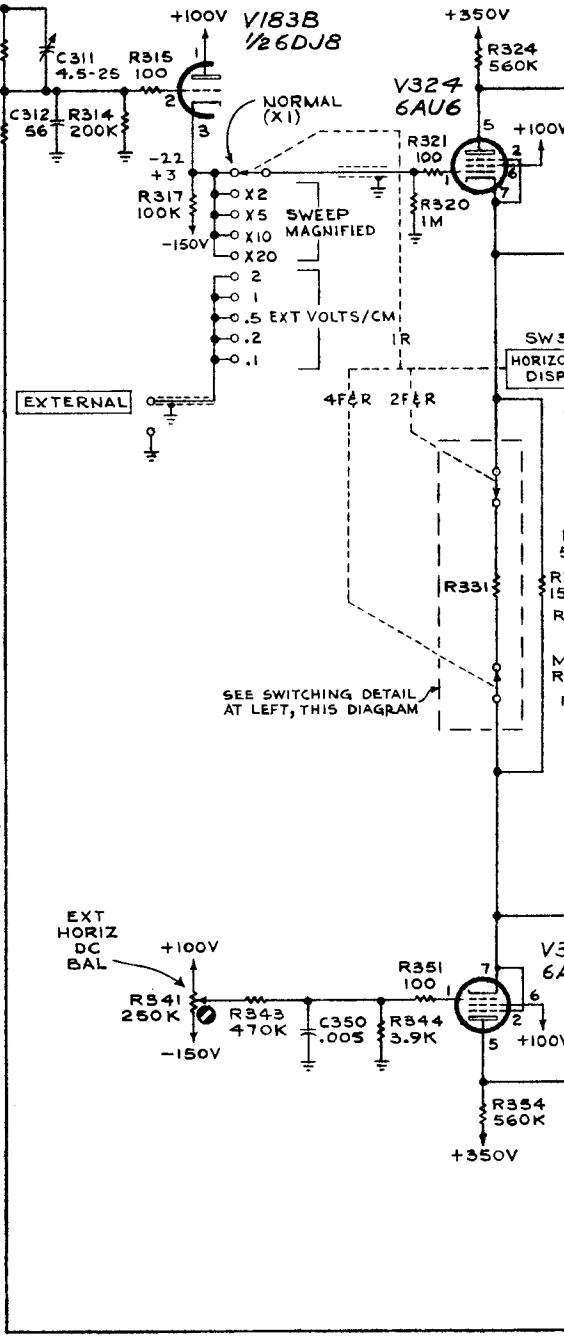
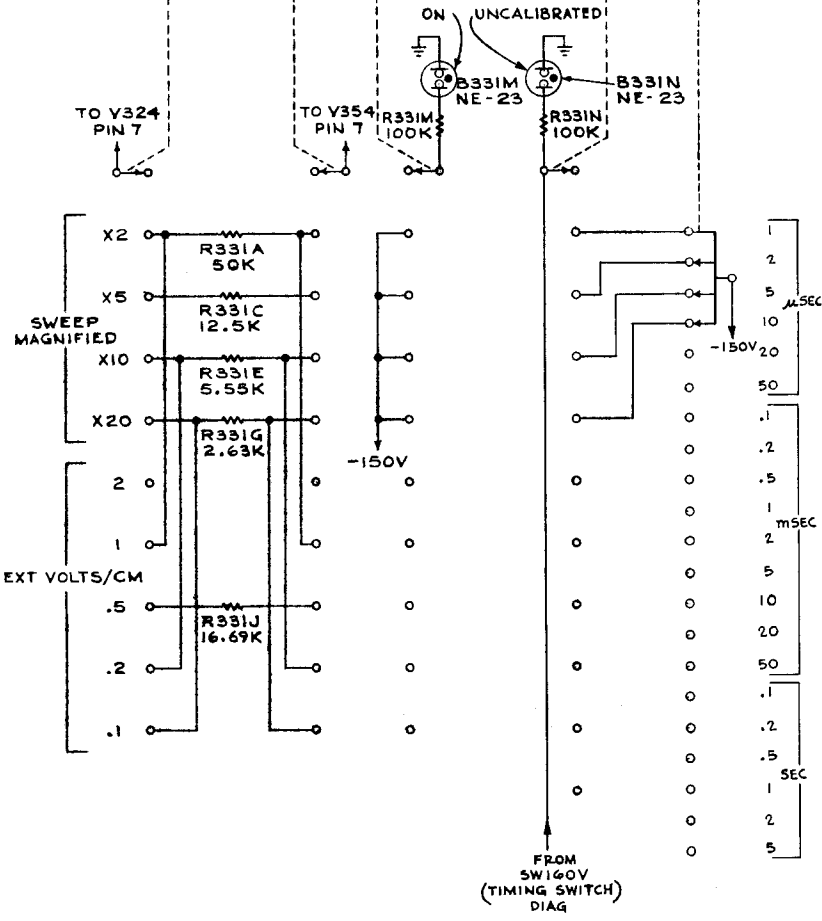
SWEEP WAVEFORM
FROM CATH, PIN 3, V161B
RUNUP CF
(TIME-BASE GEN. DIAG.)

VOLTAGE READINGS WERE OBTAINED
WITH CONTROLS SET AS FOLLOWS:

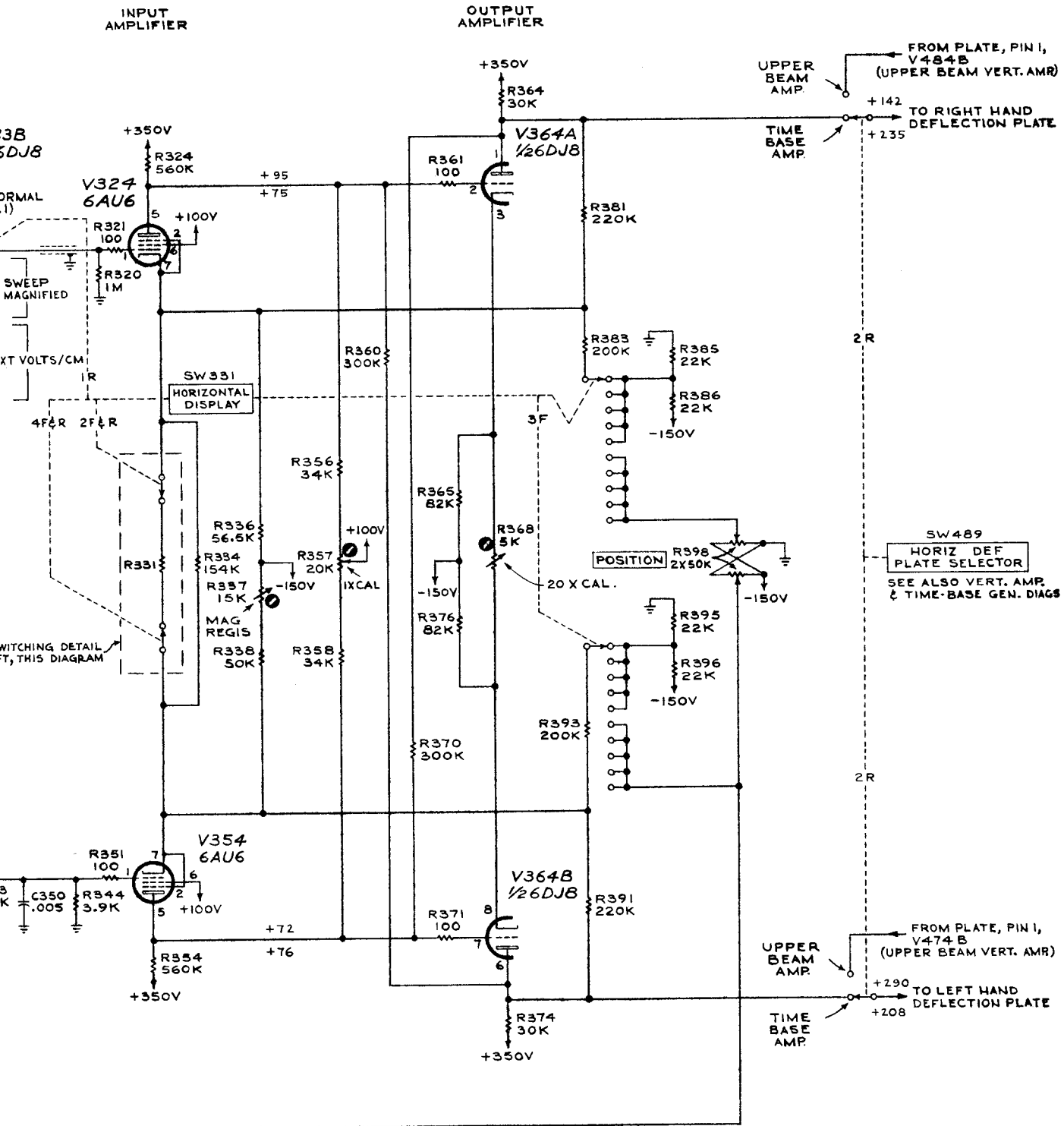
HORIZONTAL DISPLAY	NORMAL
TRIGGER SELECTOR	-EXT., DC
TRIGGERING LEVEL	FULL LEFT
	BUT NOT SWITCHED
	TO AUTOMATIC
HORIZONTAL POSITION:	FULL RIGHT
FOR LOWER VOLTAGE READINGS	FULL LEFT
FOR UPPER VOLTAGE READINGS	FULL LEFT

SW331
HORIZONTAL
DISPLAY
SEE ALSO
TIME-BASE
GEN. DIAG.

SEE ALSO
TIMING SWITCH
DIAG.



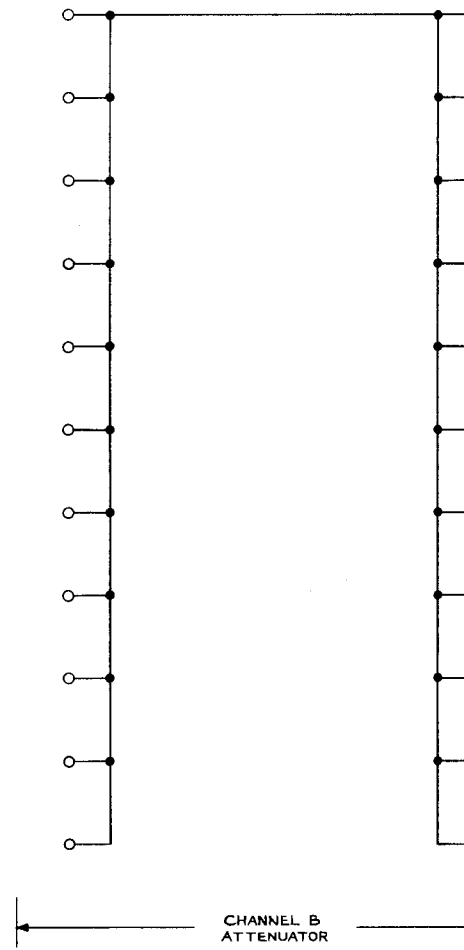
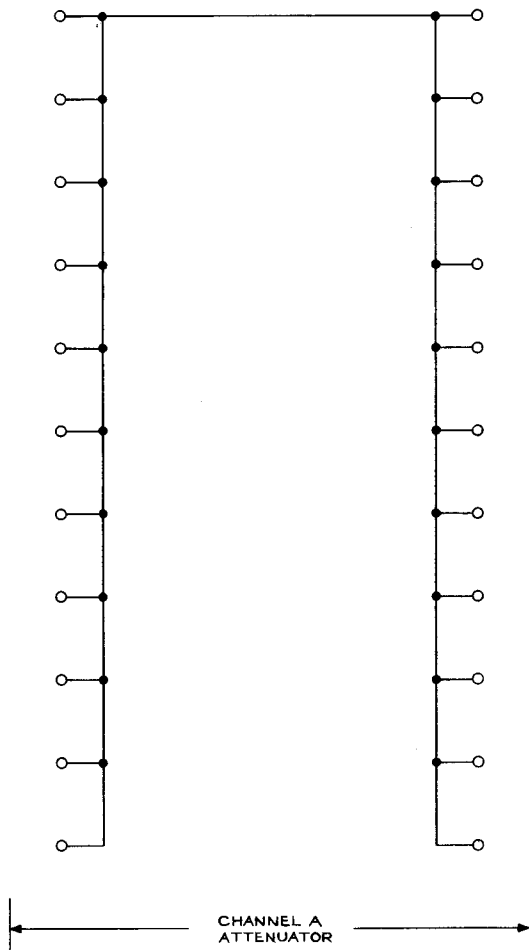
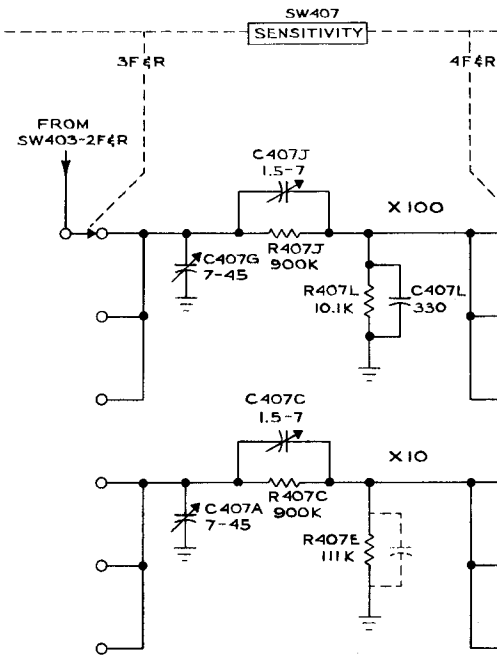
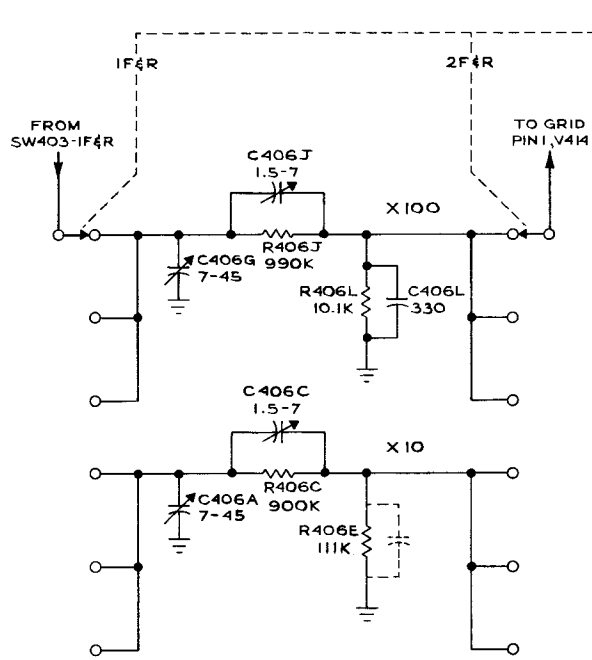
TYPE 502A OSCILLOSCOPE



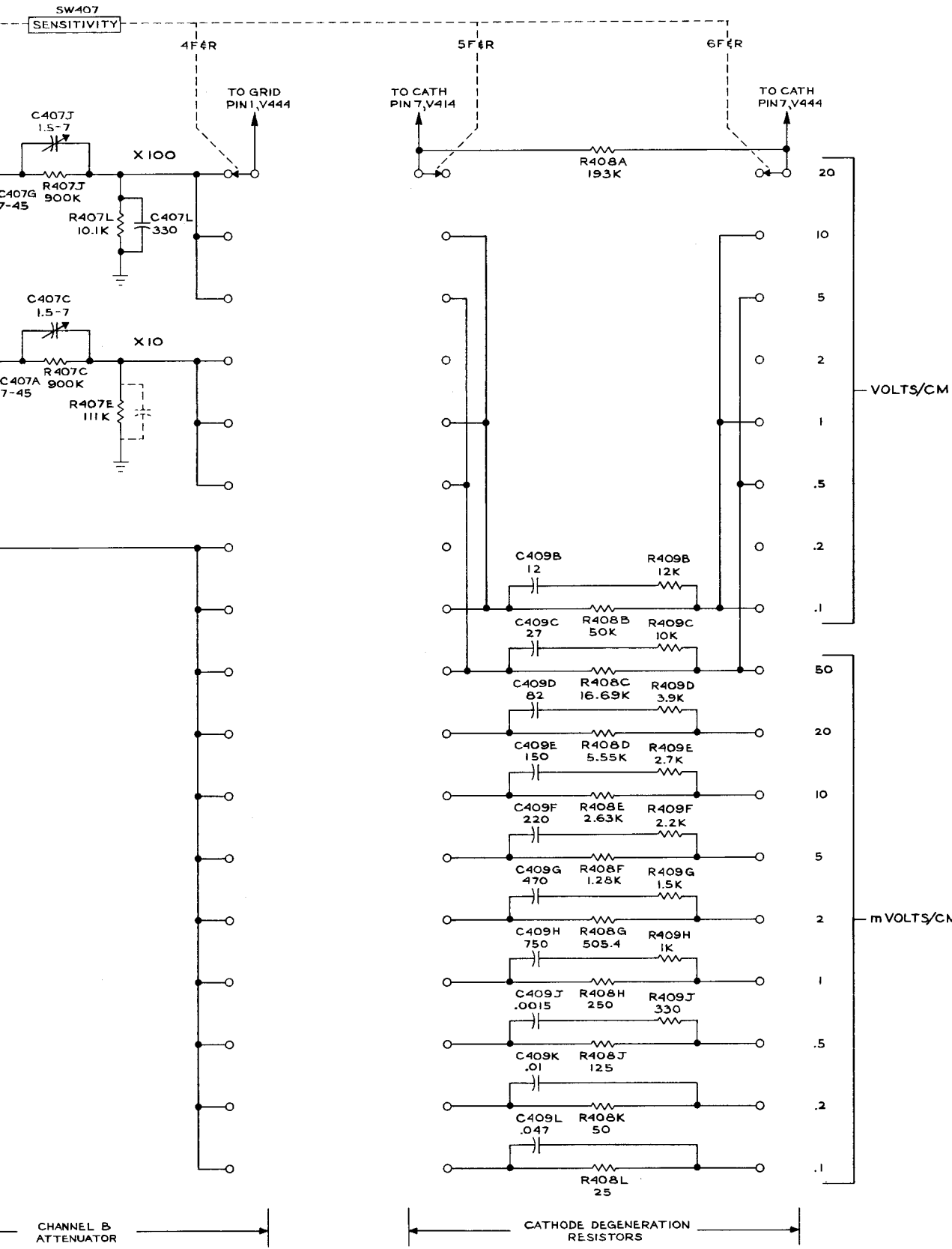
HORIZONTAL AMPLIFIER

CIRCUIT NUMBERS
300 THRU 399

263
308



TYPE 502A OSCILLOSCOPE

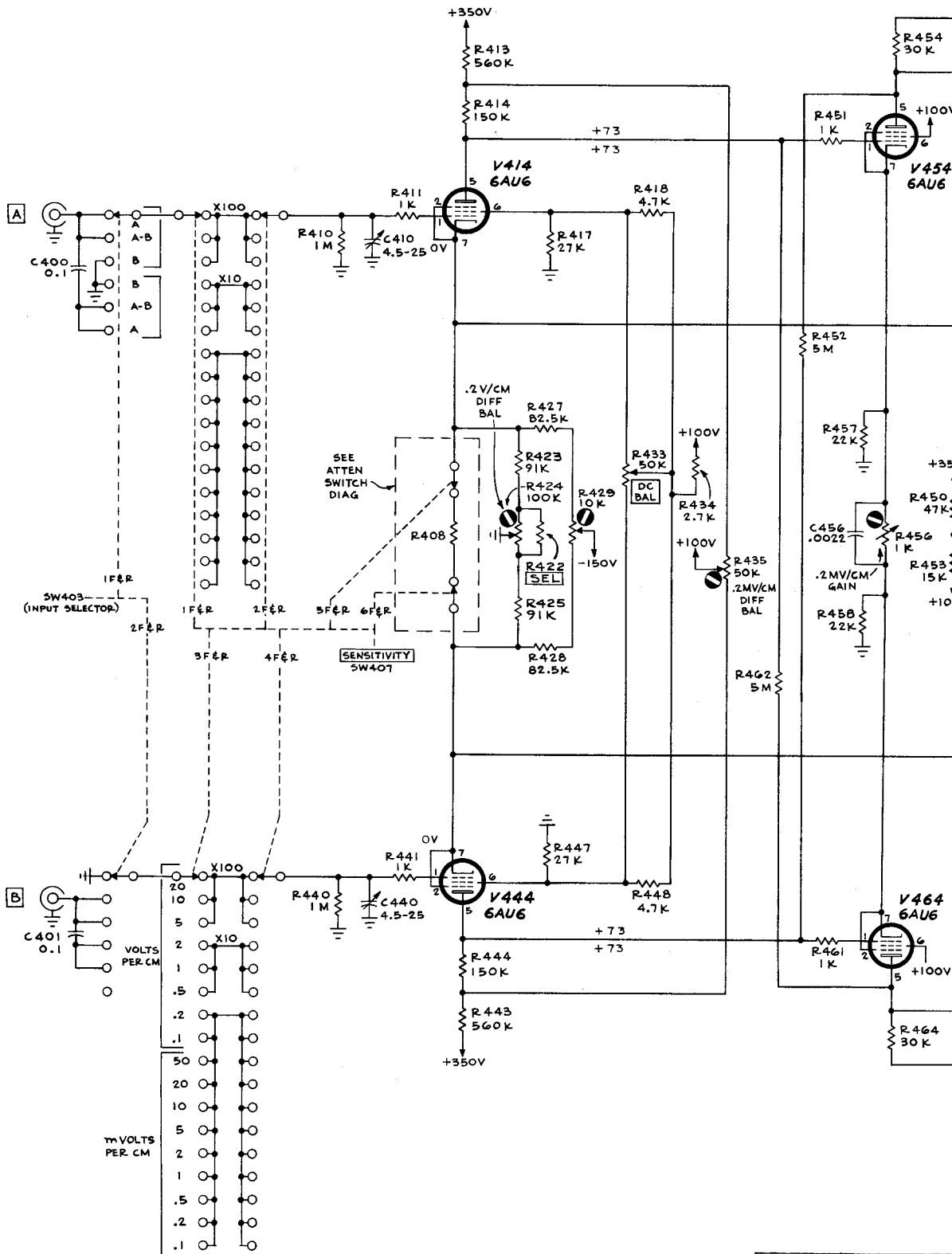


CMD
363

VERTICAL ATTENUATOR SWITCH

INPUT AMP.

SECOND AMP.



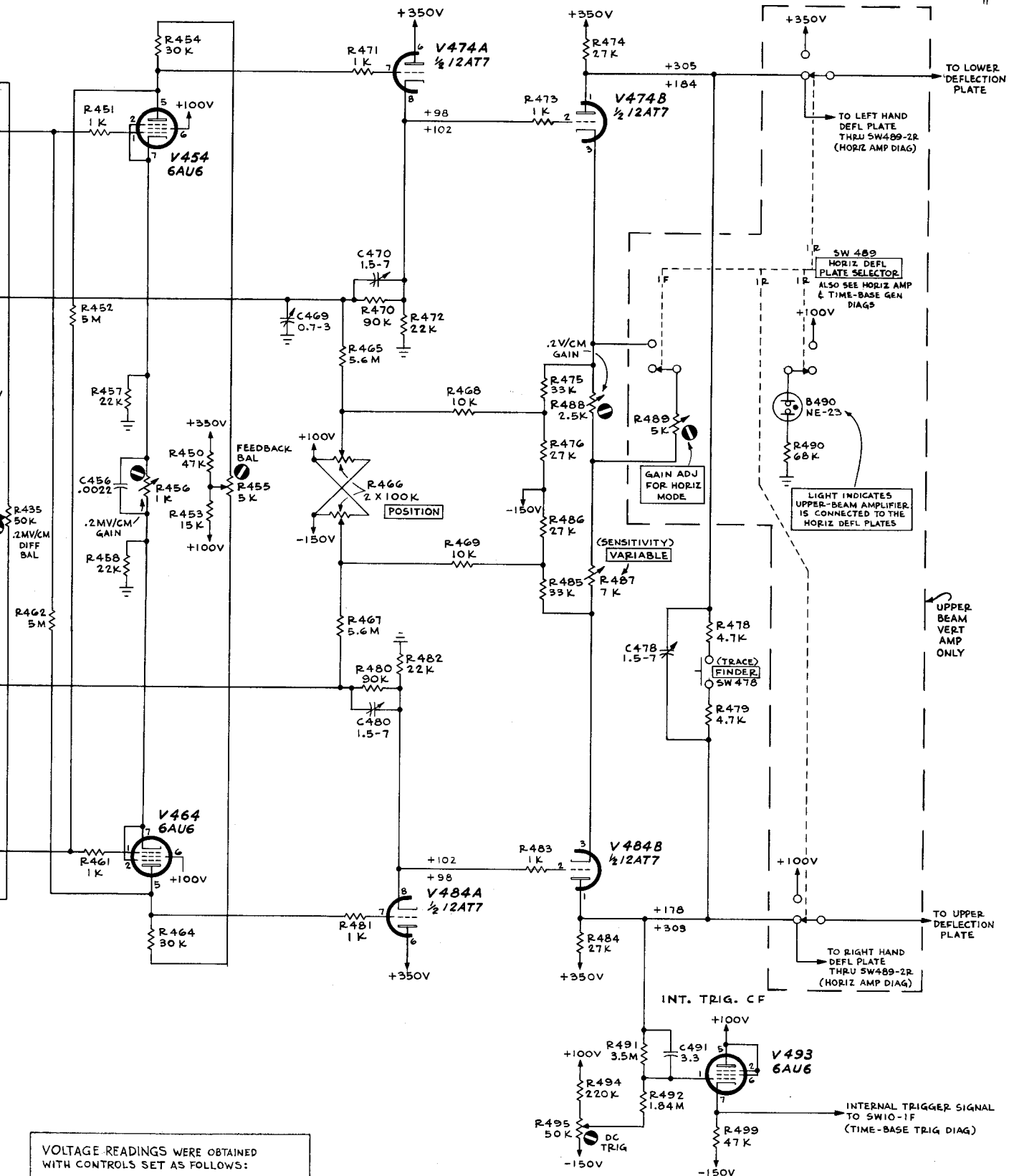
VOLTAGE READINGS WERE
WITH CONTROLS SET AS FOL
INPUT SIGNAL
SENSITIVITY
VERTICAL POSITION:
FOR LOWER VOLTAGE READING
FOR UPPER VOLTAGE READING

+ TYPE 502A OSCILLOSCOPE

SECOND AMP.

DRIVER CF'S

OUTPUT AMP.

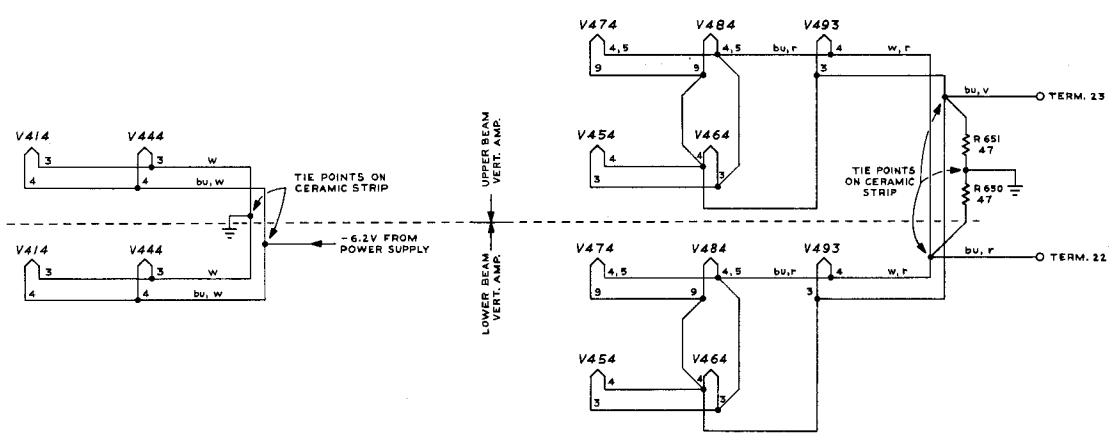


VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
 INPUT SIGNAL NONE
 SENSITIVITY 20V/CM
 VERTICAL POSITION:
 FOR LOWER VOLTAGE READINGS . . FULL RIGHT
 FOR UPPER VOLTAGE READINGS . . FULL LEFT

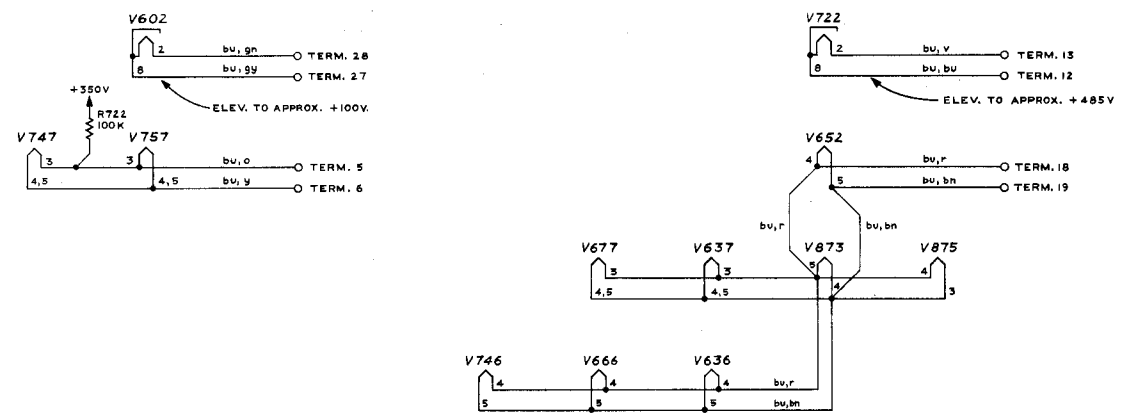
SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH BLUE OUTLINE

UPPER BEAM VERTICAL AMPLIFIER
 LOWER BEAM VERTICAL AMPLIFIER

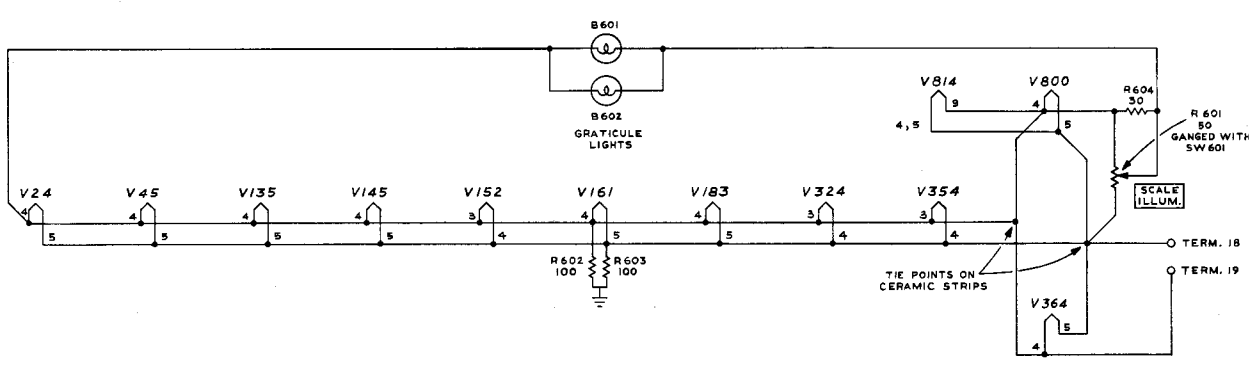
CIRCUIT NUMBERS
 400 THRU 499



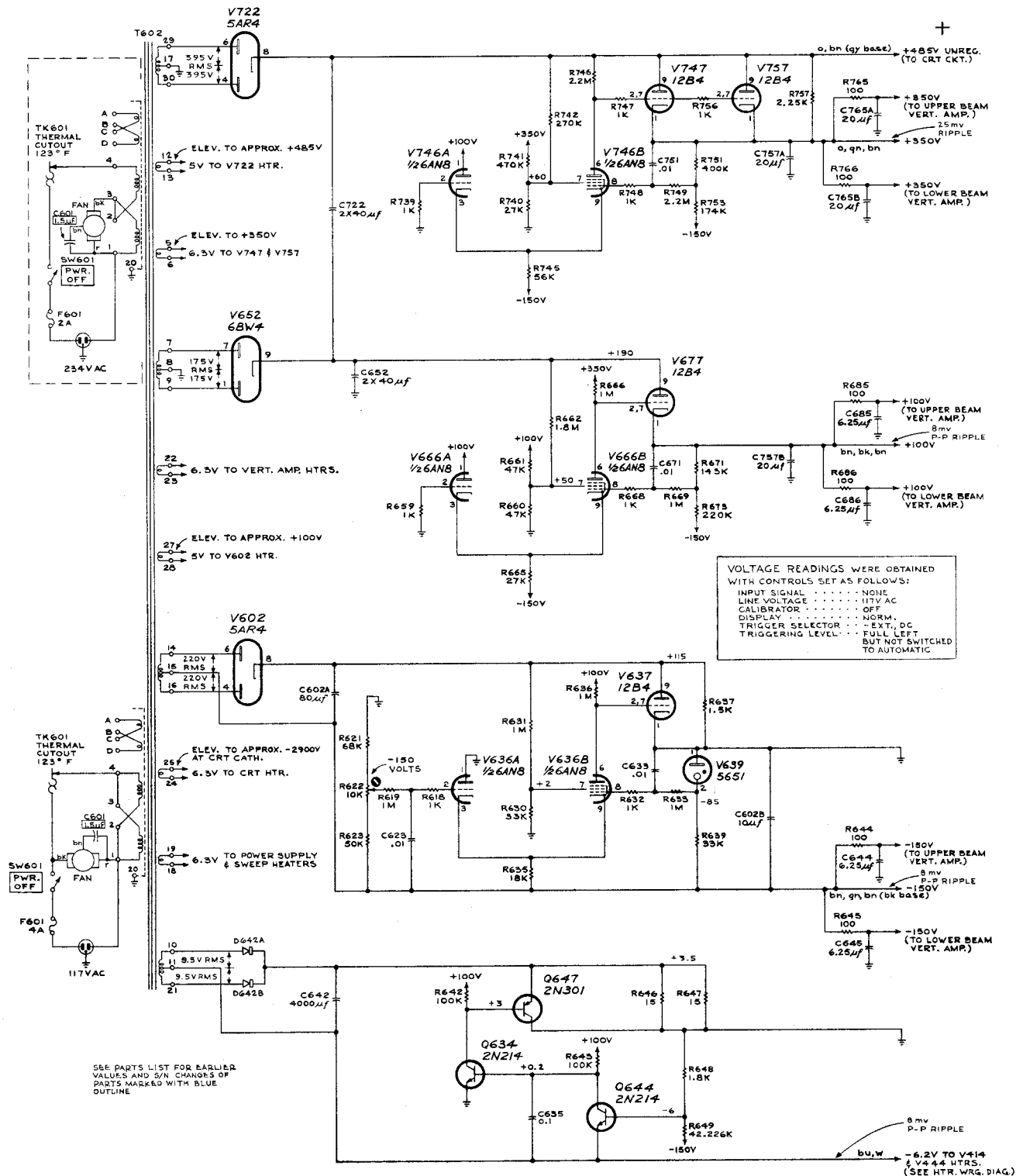
UPPER BEAM & LOWER BEAM
VERTICAL CHASSIS



POWER SUPPLY CHASSIS



SWEEP CHASSIS



VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
 INPUT SIGNAL NONE
 LINE VOLTAGE 117V AC
 CALIBRATOR OFF
 DISPLAY NORM.
 TRIGGER SELECTOR EXT. DC FULL LEFT
 TRIGGERING LEVEL BUT NOT SWITCHED TO AUTOMATIC

SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED WITH BLUE OUTLINE

POWER SUPPLY
 CIRCUIT NUMBERS 600 THRU 789

TDB 863

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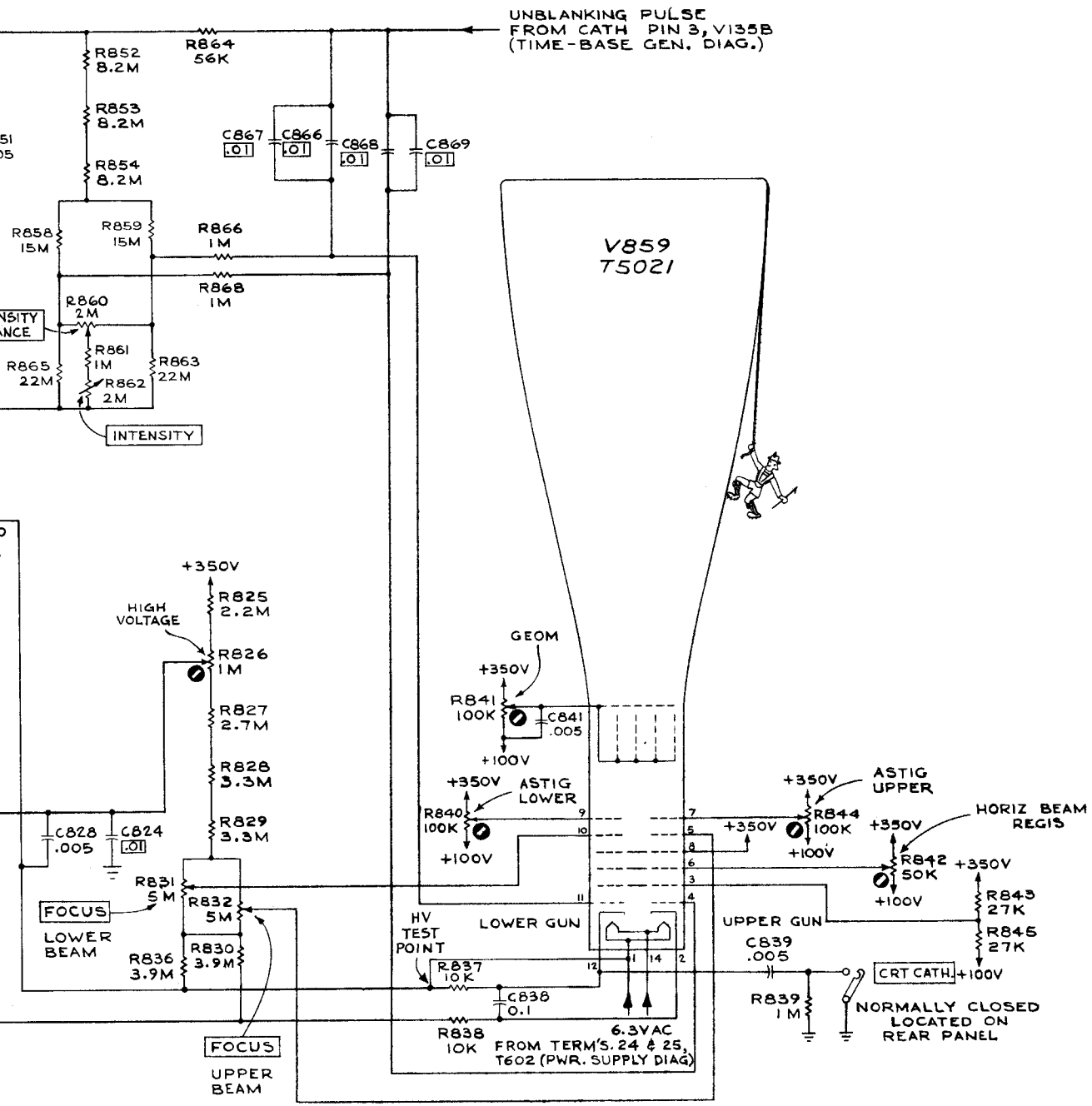
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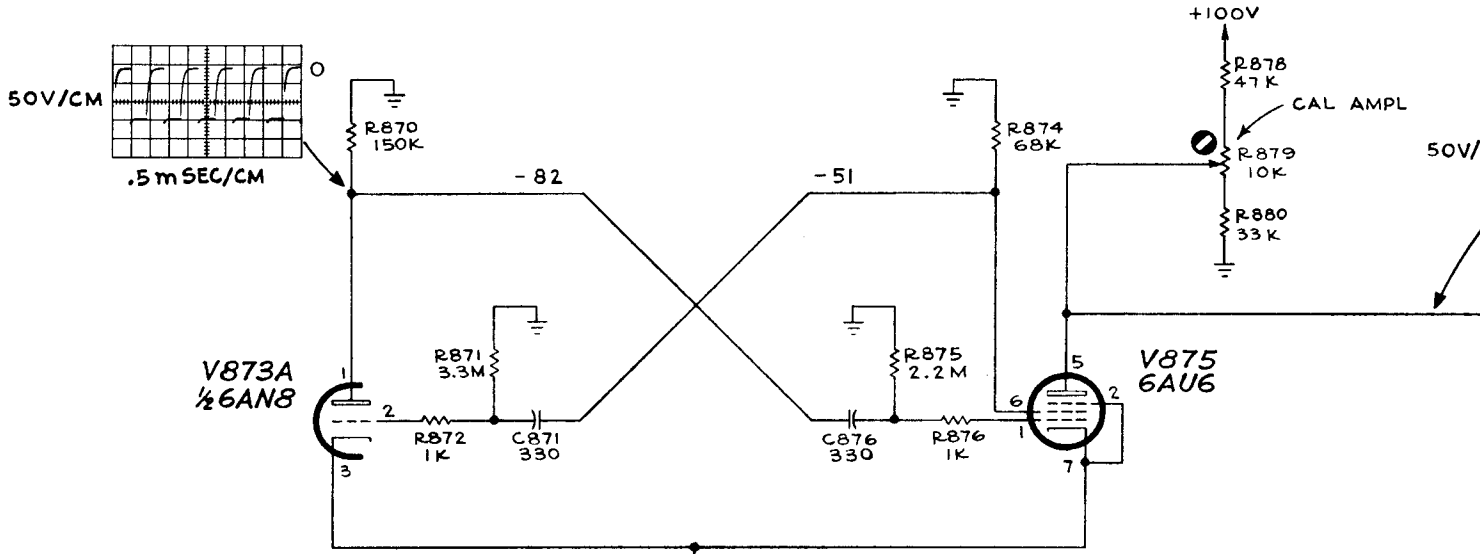


CIRCUIT NUMBERS
800 THRU 869

CRT CIRCUIT

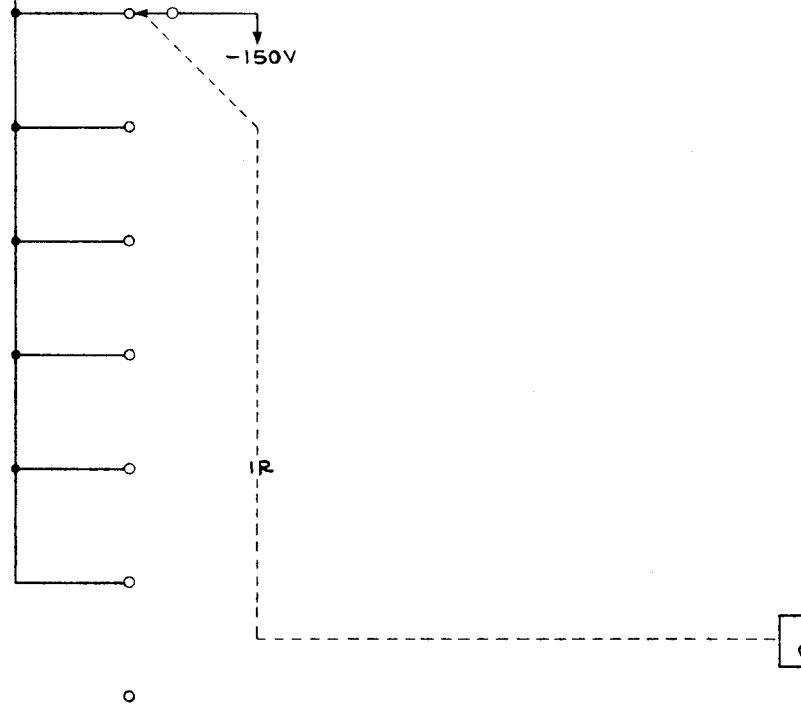
964
JDB

← CALIBRATOR MULTIVIBRATOR →



WAVEFORMS & VOLTAGE READINGS
 WERE OBTAINED WITH CONTROLS SET AS
 FOLLOWS:
 AMPLITUDE CALIBRATOR..... 50V

VOLTAGE READINGS MAY VARY WITH CALIBRATOR
 DUTY CYCLE.

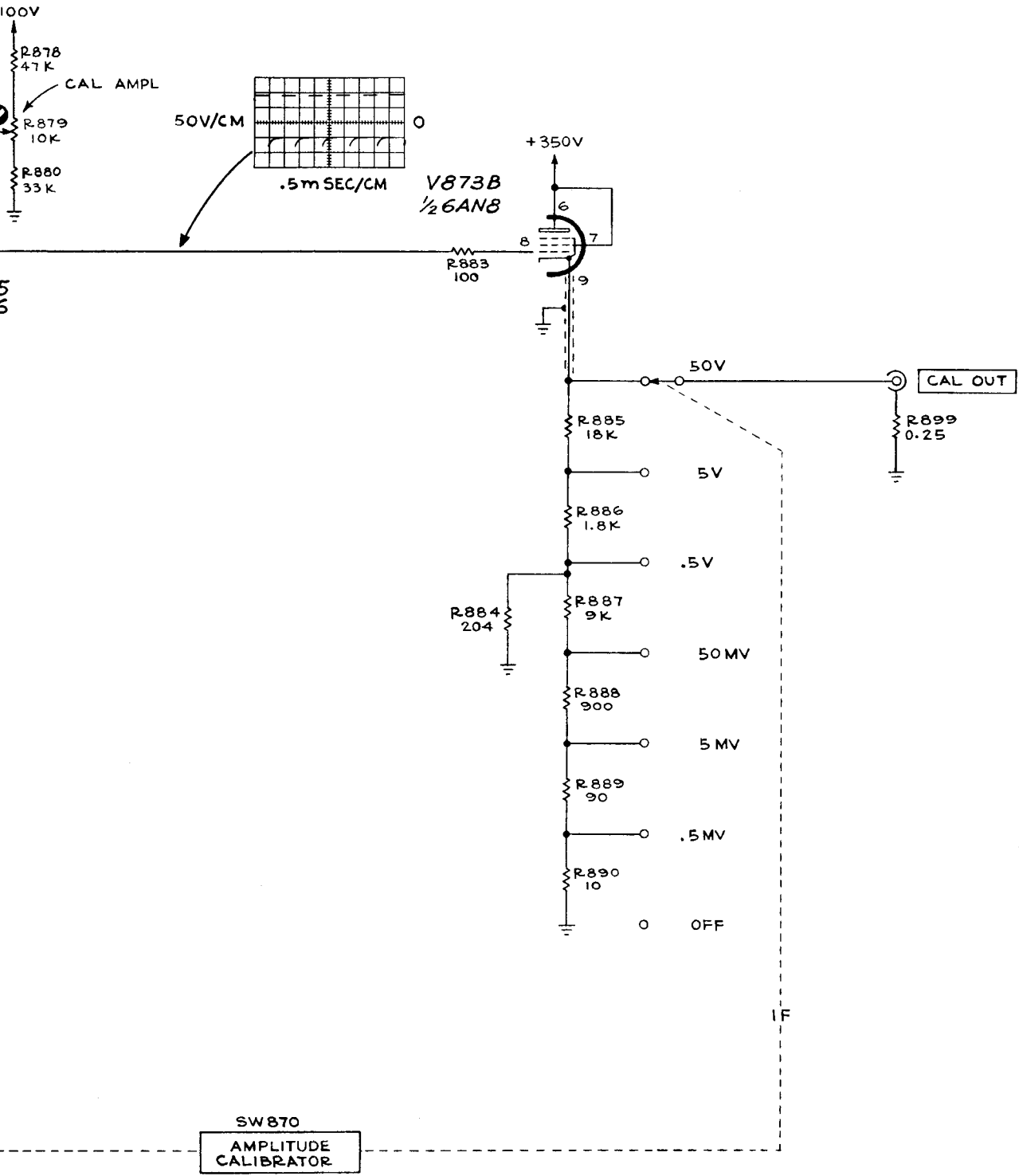


TYPE 502A OSCILLOSCOPE

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CAL. OUT CF



CALIBRATOR

CIRCUIT NUMBERS
870 THRU 899

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. If it does not, your manual is correct as printed.

TYPE 502A -- TENT. S/N 23430

PARTS LIST CORRECTION

CHANGE TO:

V152

157-0104-01

Selected 6AL5