INSTRUCTION MANUAL

Serial Number__________

TYPE... 502A

DUAL-BEAM OSCILLOSCOPE

Tektronix, Inc.

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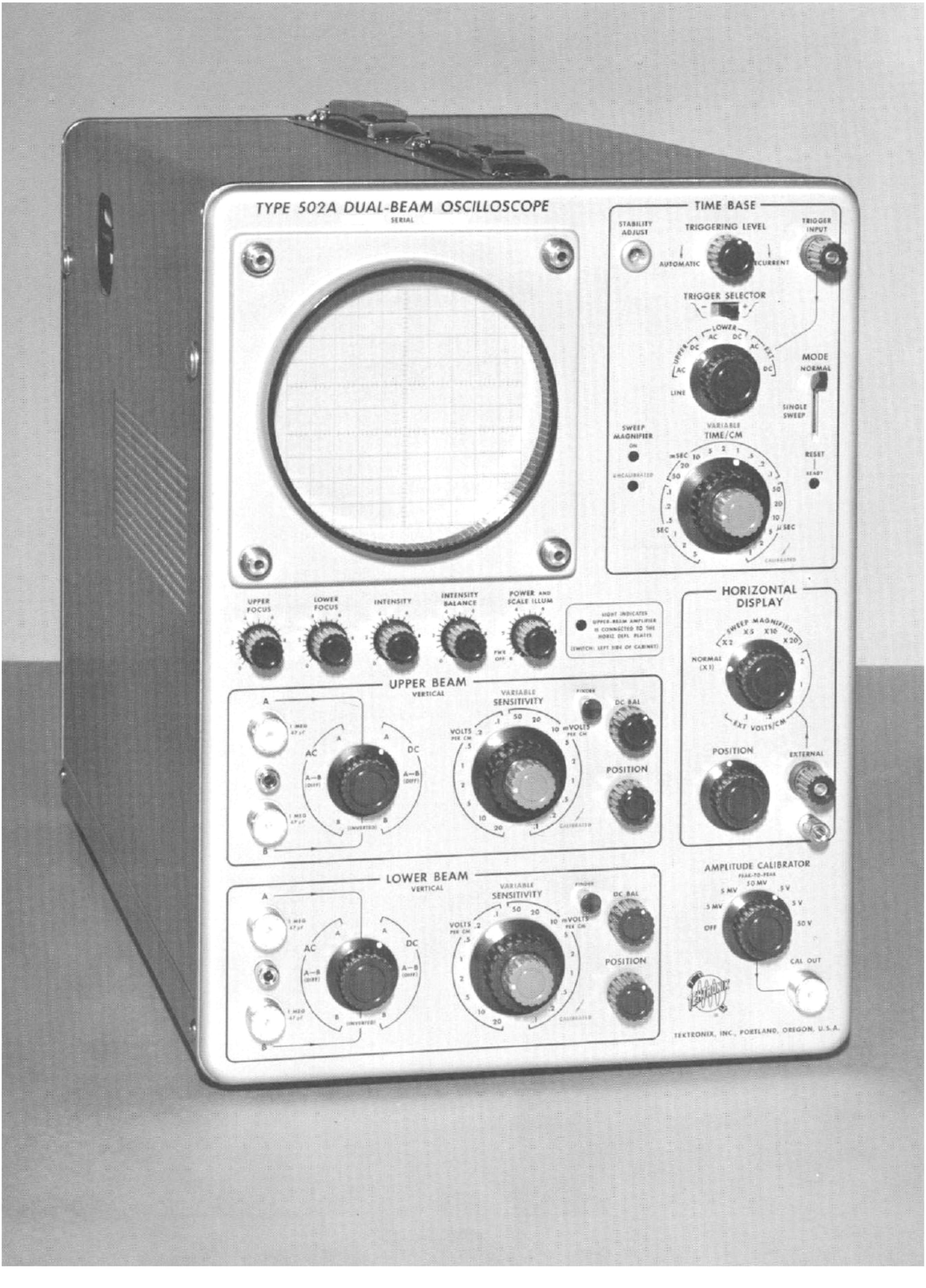
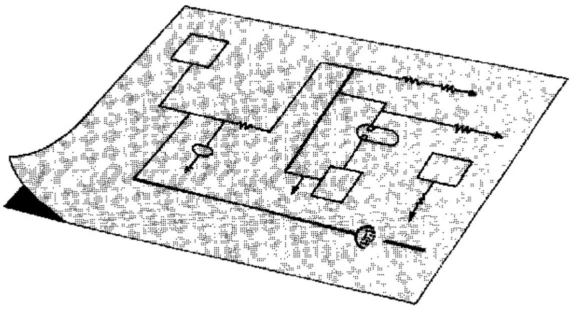

TYPE 502A DUAL-BEAM OSCILLOSCOPE
SERIAL
TIME BASE
STABILITY ADJUST
TRIGGERING LEVEL
AUTOMATIC
RECURRENT
TRIGGER INPUT
TRIGGER SELECTOR
LOWER
UPPER
AC
DC
EXT
LINE
MODE
NORMAL
SINGLE SWEEP
RESET
READY
SWEEP MAGNIFIER
ON
UNCALIBRATED
VARIABLE
TIME/CM
mSEC
μSEC
SEC
CALIBRATED
UPPER FOCUS
LOWER FOCUS
INTENSITY
INTENSITY BALANCE
POWER AND SCALE ILLUM
PWR OFF
LIGHT INDICATES UPPER-BEAM AMPLIFIER IS CONNECTED TO THE HORIZ DEFL PLATES
(SWITCH: LEFT SIDE OF CABINET)
HORIZONTAL DISPLAY
SWEEP MAGNIFIED
X2
X5
X10
X20
NORMAL (X1)
EXT VOLTS/CM
POSITION
EXTERNAL
UPPER BEAM
VERTICAL
VARIABLE
SENSITIVITY
VOLTS PER CM
mVOLTS PER CM
FINDER
DC BAL
POSITION
AC
DC
A—B (DIFF)
(INVERTED)
1 MEG 47 pF
CALIBRATED
LOWER BEAM
VERTICAL
AMPLITUDE CALIBRATOR
PEAK-TO-PEAK
OFF
.5 MV
5 MV
50 MV
.5 V
5 V
50 V
CAL OUT
TEKTRONIX
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 0.1 mv/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 μsec/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 μsec/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 μsec/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.

Input characteristics at TRIGGER INPUT connector

AC coupled—1 megohm in series with 0.01 μf.

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 ±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—23½" long, 11¼" wide, 15" high.

Weight—52 pounds.

Accessories included

2—Type P6006 attenuator probes, 010-125.

2—Binding post adapters, 013-004.

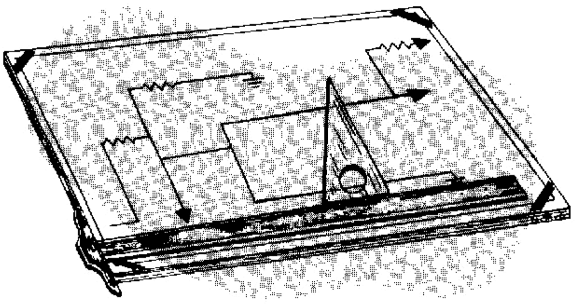
1—Light filter.

2—Instruction manuals.

1—Test lead, 012-031.

1—3 to 2-wire adapter, 103-013.

1—3-conductor power cord, 161-010.



SECTION 3

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 is 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

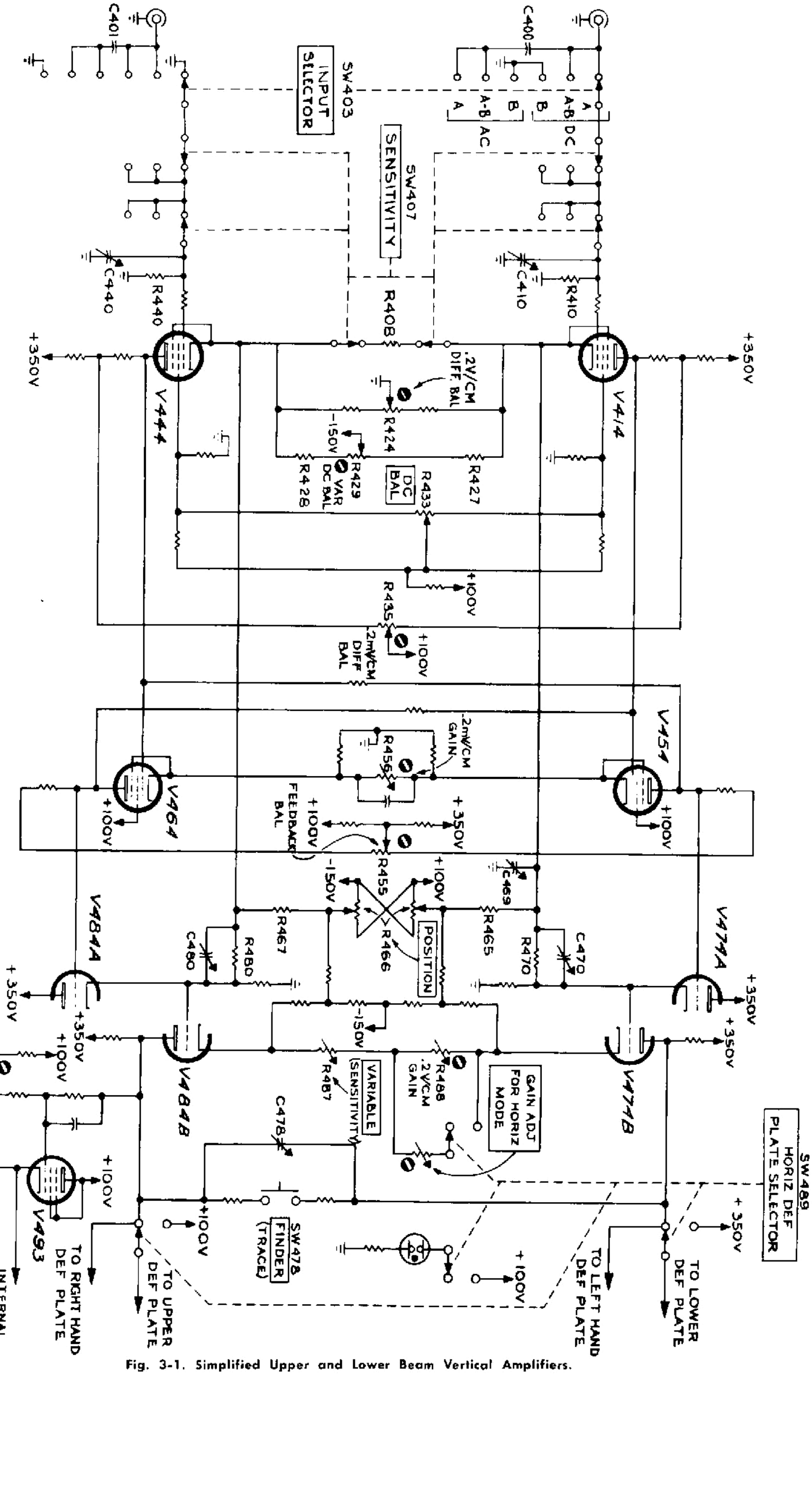


Fig. 3-1. Simplified Upper and Lower Beam Vertical Amplifiers.

(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.

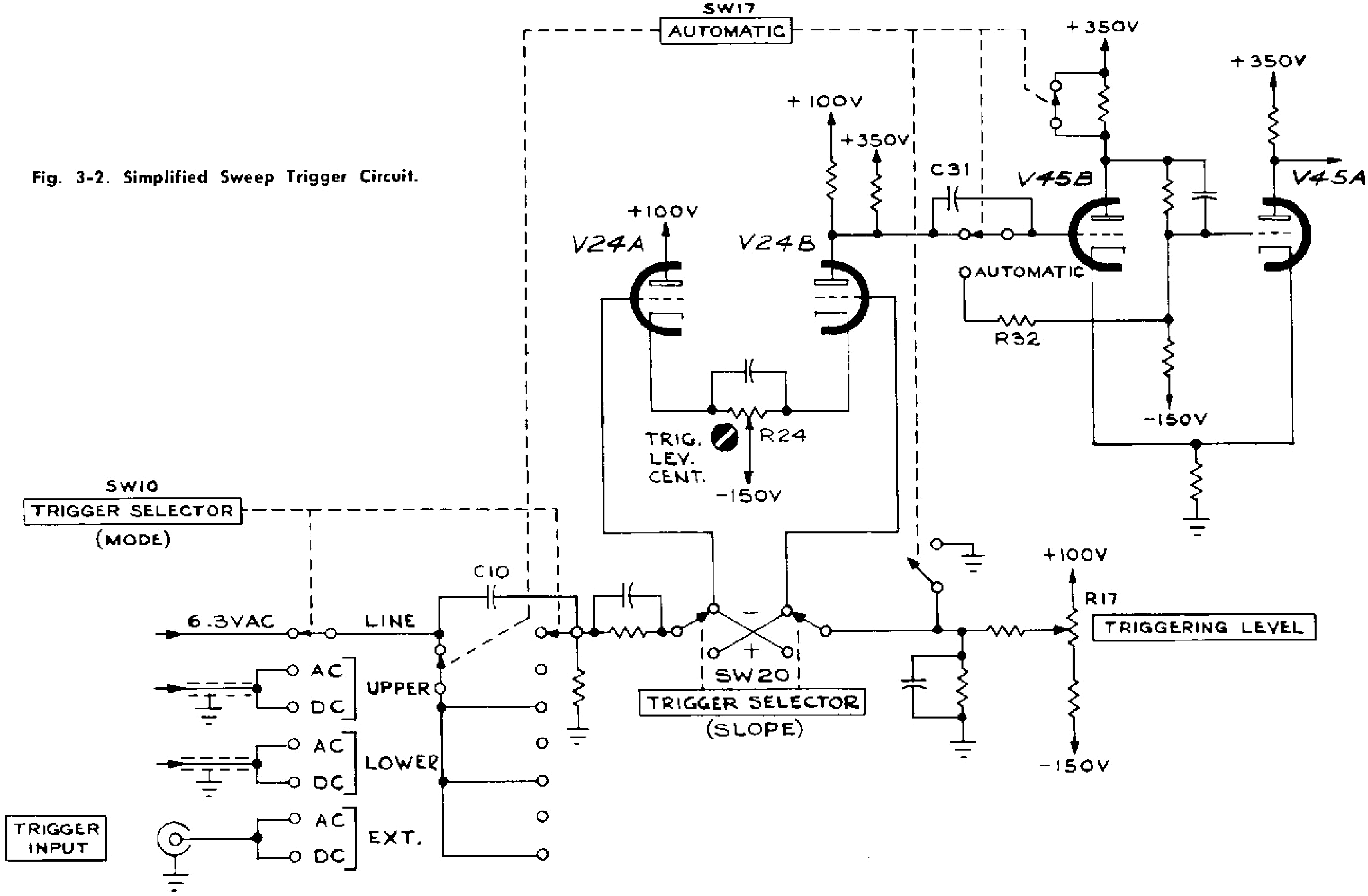
Along with the DC BAL Control, the DC unbalance in the Input Amplifier tubes is also removed by R429. Adjustment of this control will remove any vôltage change which might be seen as a positioning change by the Output Amplifier.

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 .2 MV/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 .2 mVOLTS 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 .2 mVOLTS 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 .2 V/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

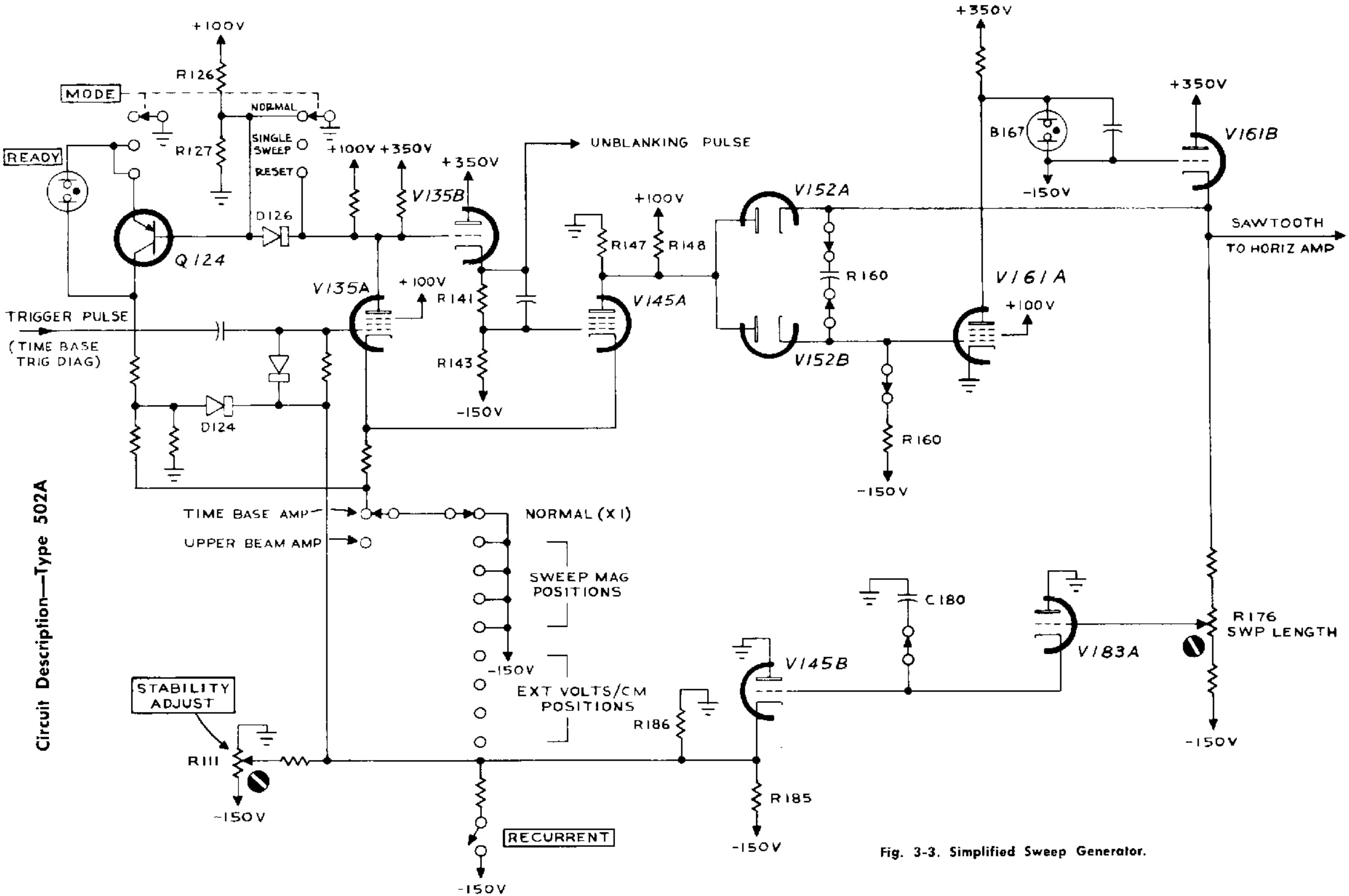


Fig. 3-3. Simplified Sweep Generator.

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) configuraton. This is accomplish 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 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 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 reversed 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.

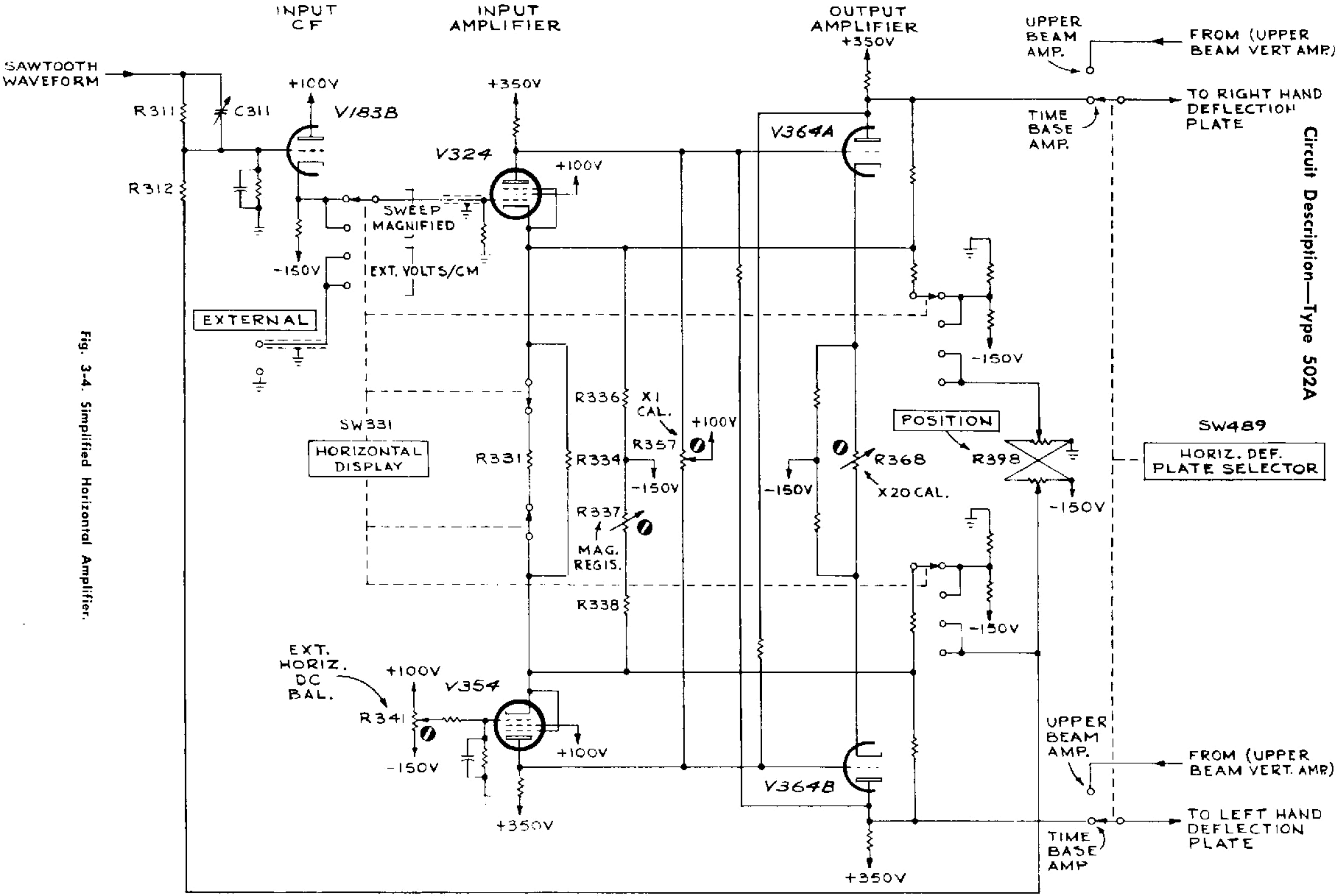


Fig. 3-4. Simplified Horizontal Amplifier.

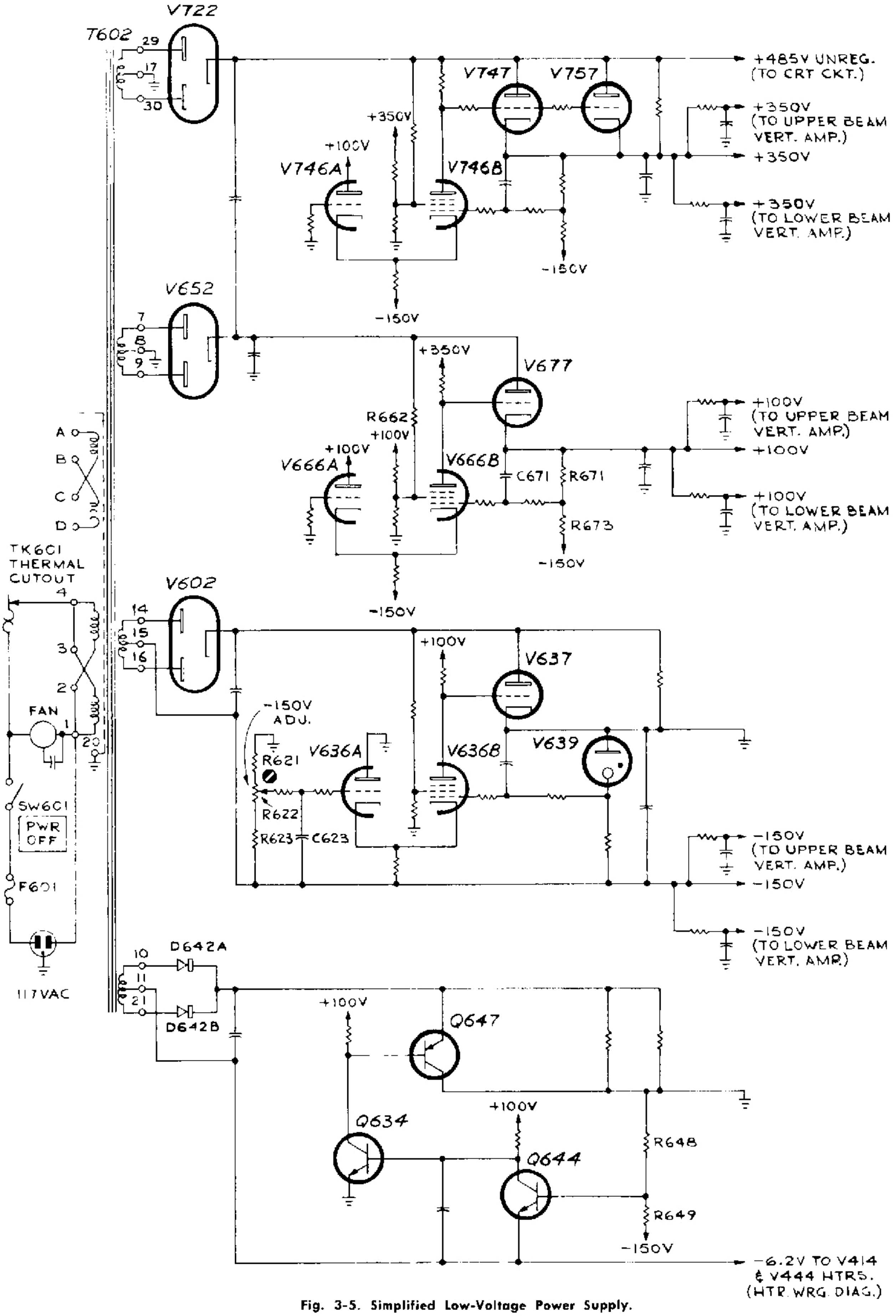


Fig. 3-5. Simplified Low-Voltage Power Supply.

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

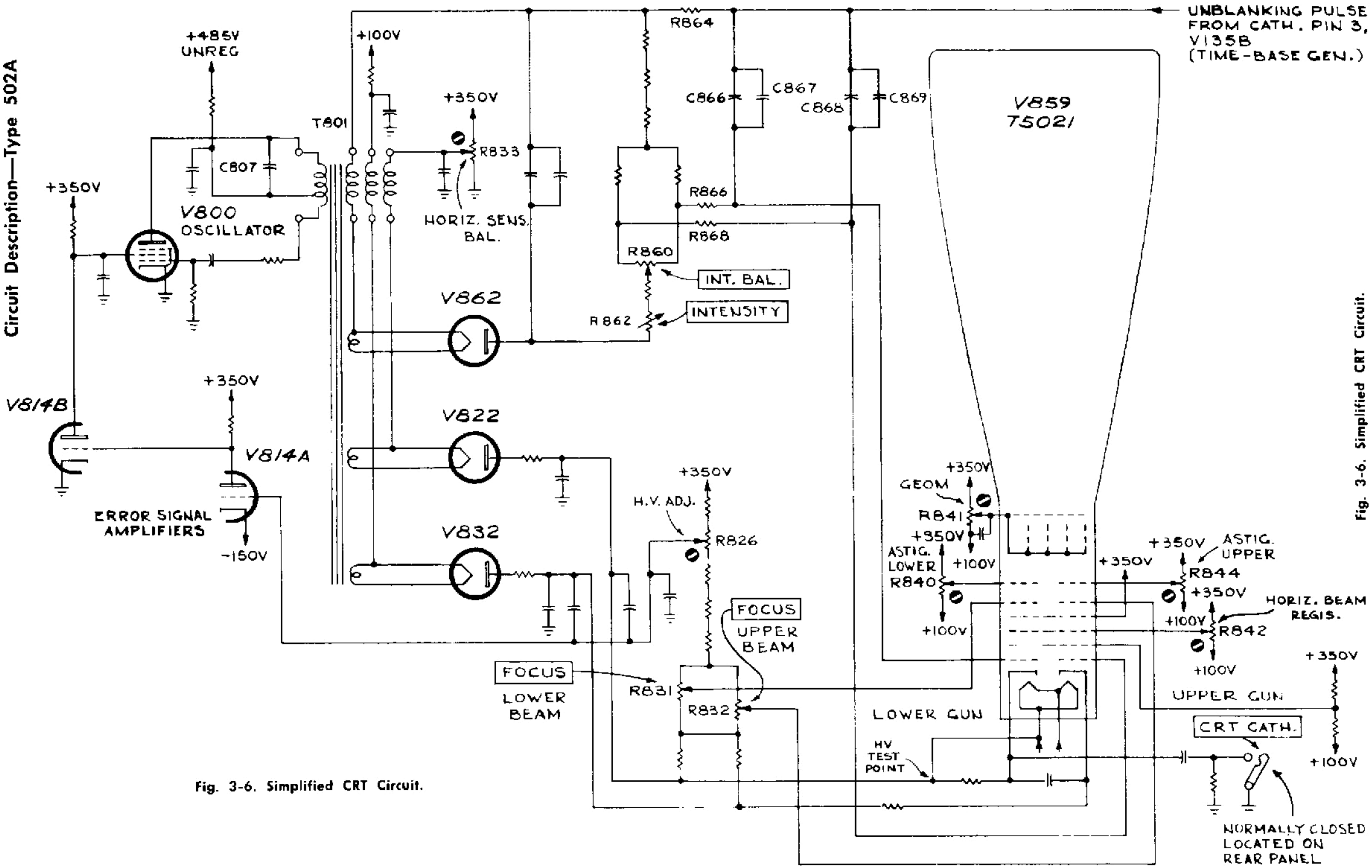


Fig. 3-6. Simplified CRT Circuit.

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

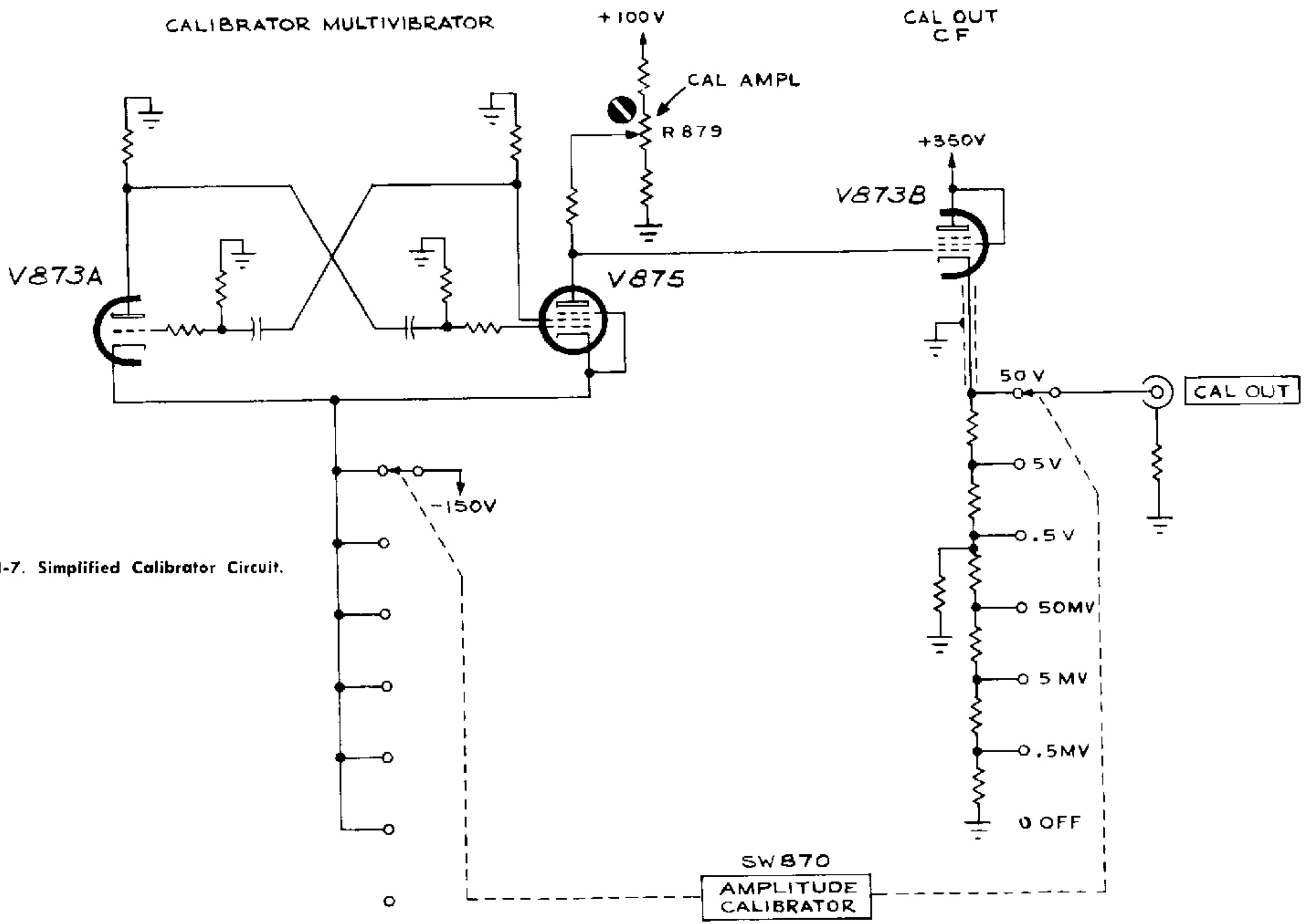


Fig. 3-7. Simplified Calibrator Circuit.

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.

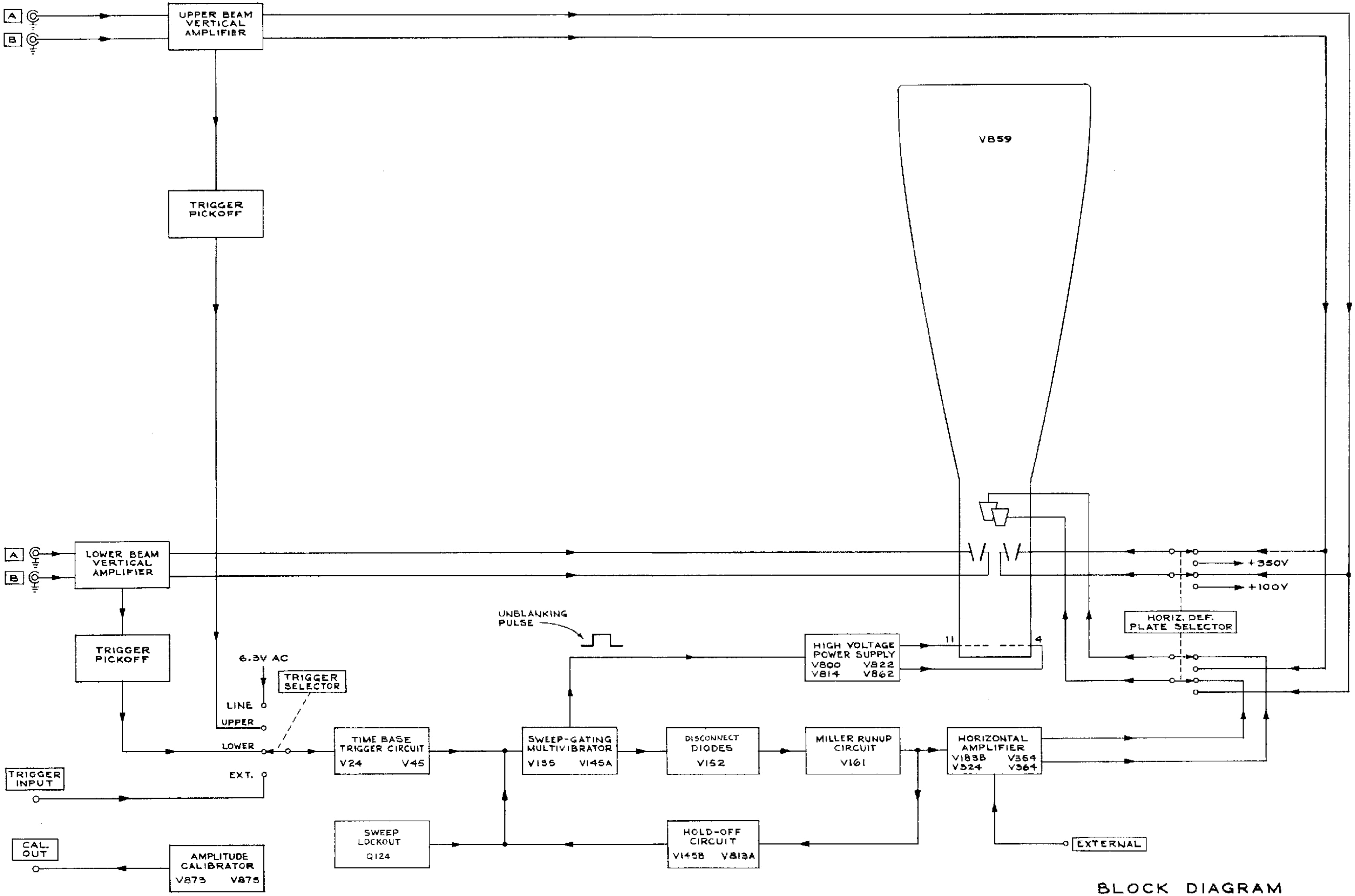
Each gun of the crt has its own FOCUS and ASTIGMATISM Controls. A single control R841 adjusts the geometry of the display, and a single INTENSITY Control controls the brilliance of both beams. An INTENSITY BALANCE Control R860 balances one grid voltage against the other so that the INTENSITY Control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

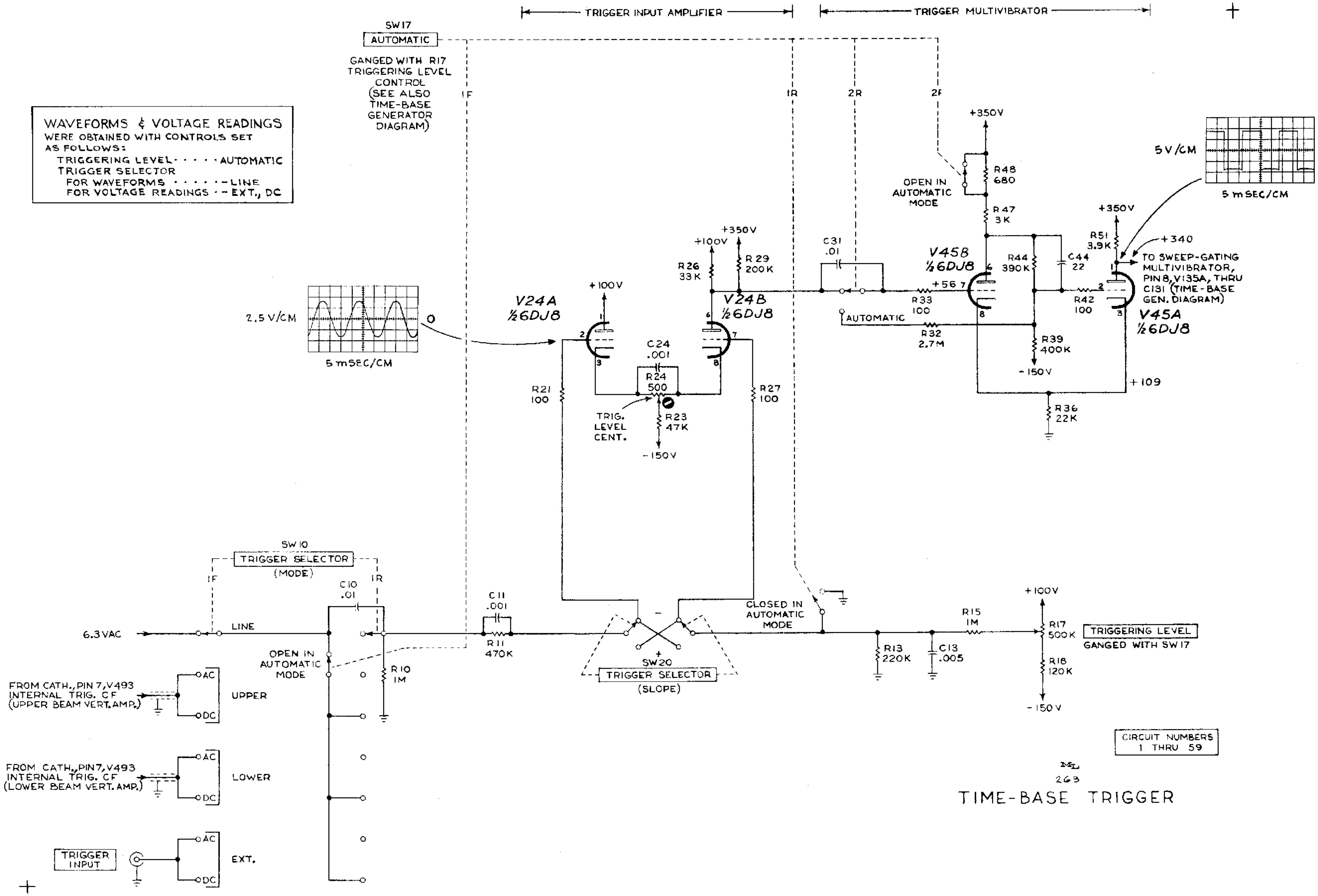
The Cal Out CF has a precision voltage divider for its cathode resistor. By means of the AMPLITUDE CALIBRATOR switch six calibrated peak-to-peak voltages, from .5 millivolt to 50 volts, are available.



BLOCK DIAGRAM

MRH
263

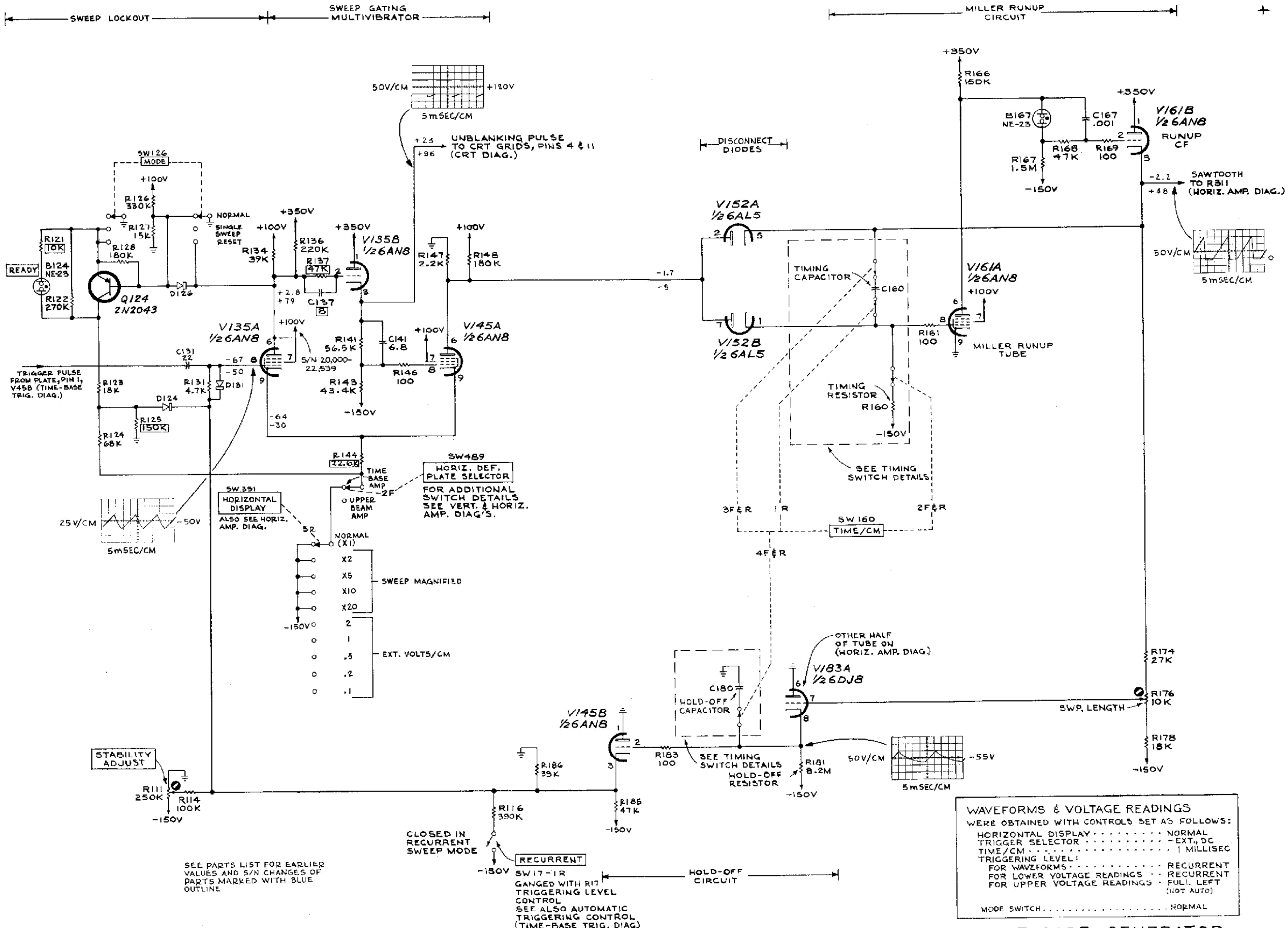
TYPE 502A OSCILLOSCOPE



TIME-BASE TRIGGER

TYPE 502A OSCILLOSCOPE

A

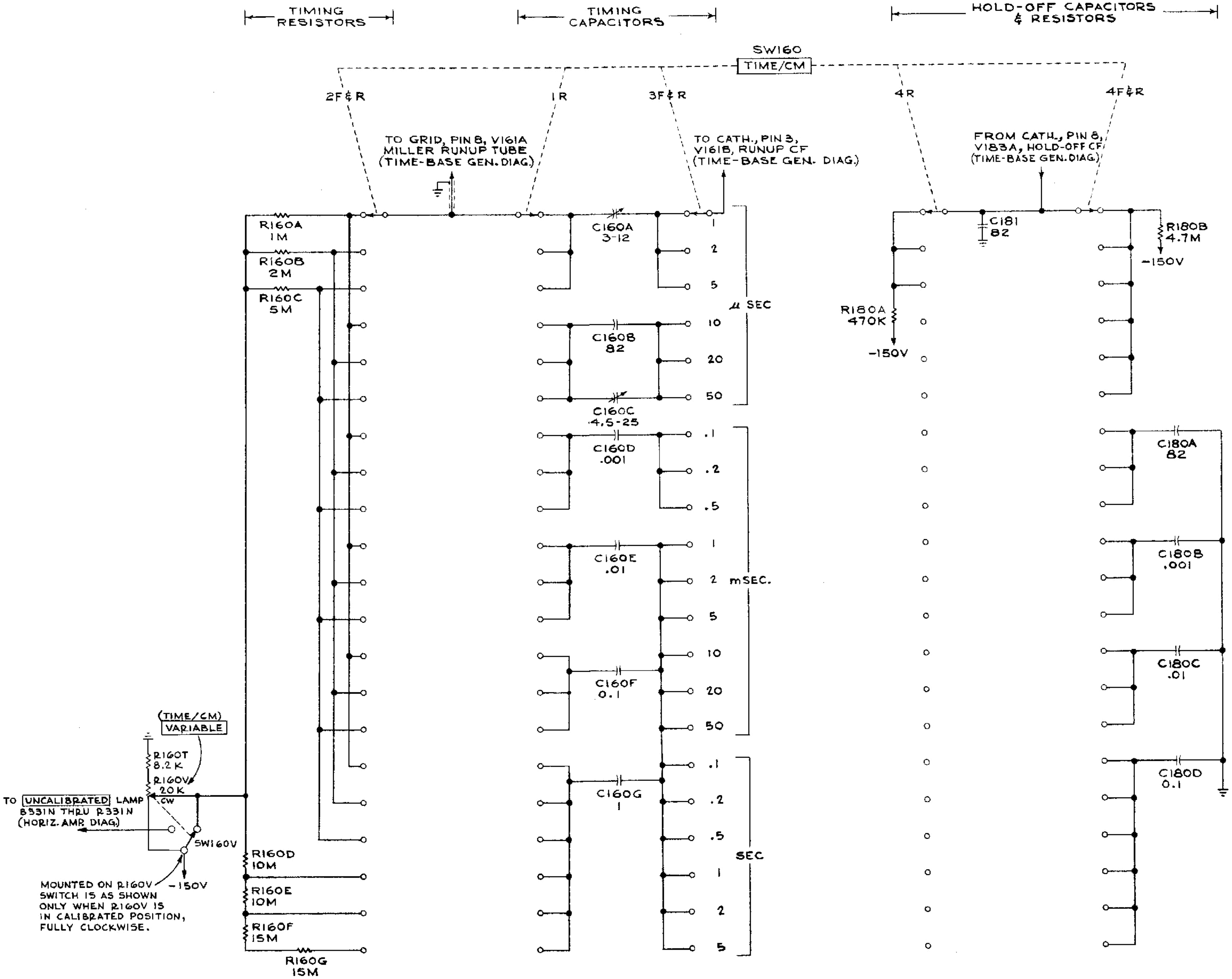


TYPE 502A OSCILLOSCOPE

TIME-BASE GENERATOR

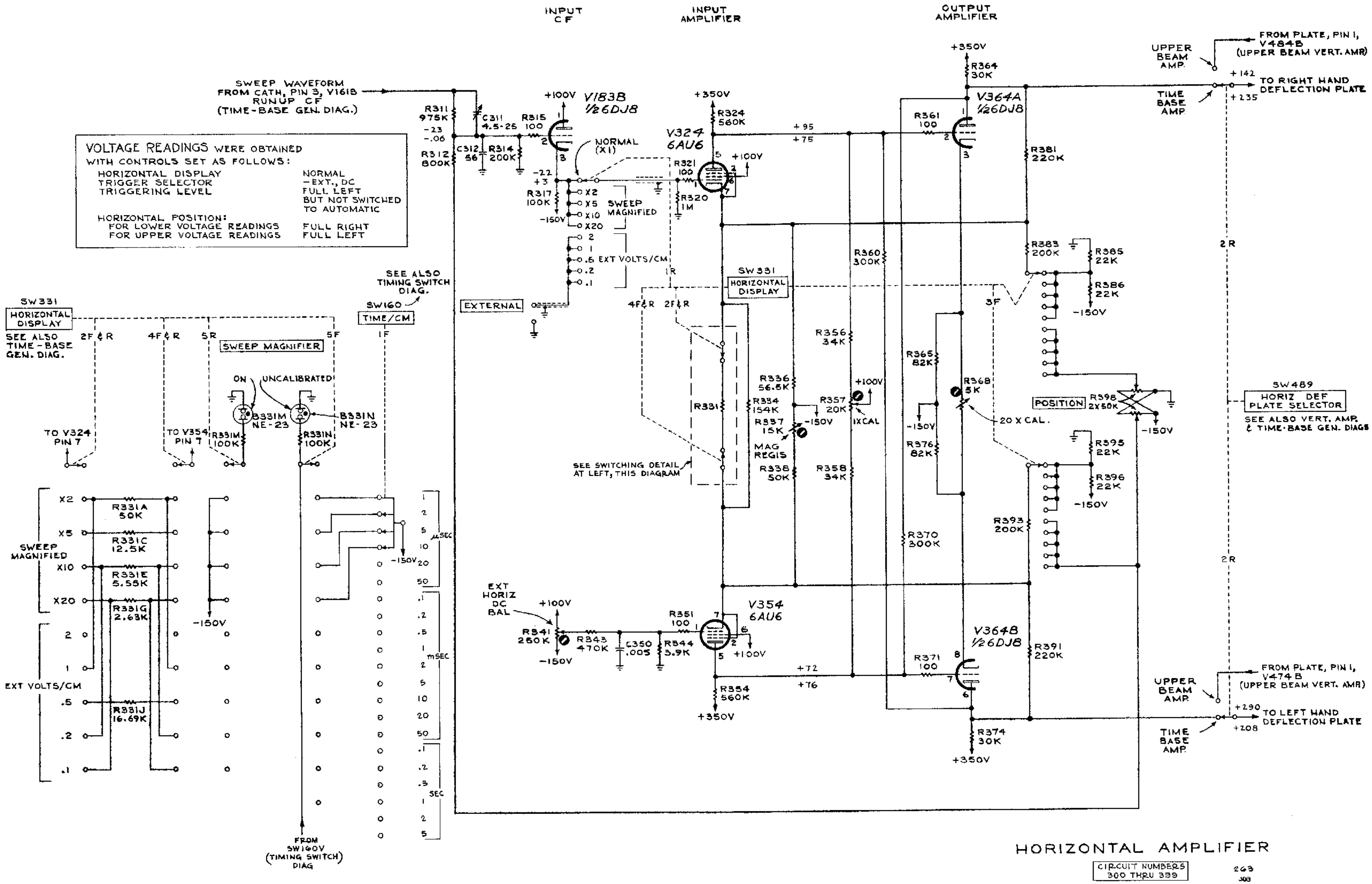
CIRCUIT NUMBERS 100 THRU 199

864



A

TIMING SWITCH

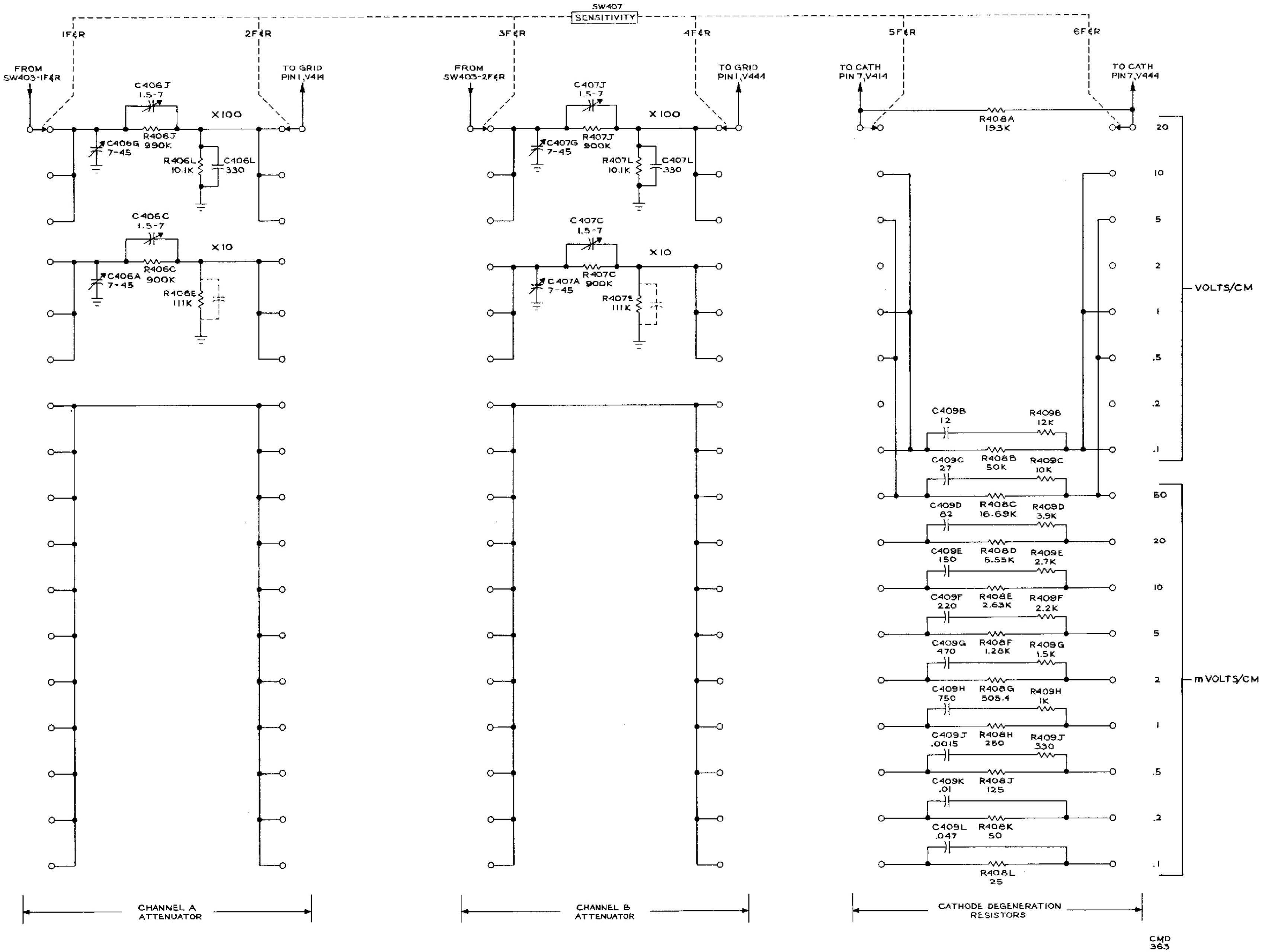


HORIZONTAL AMPLIFIER

CIRCUIT NUMBERS 300 THRU 399

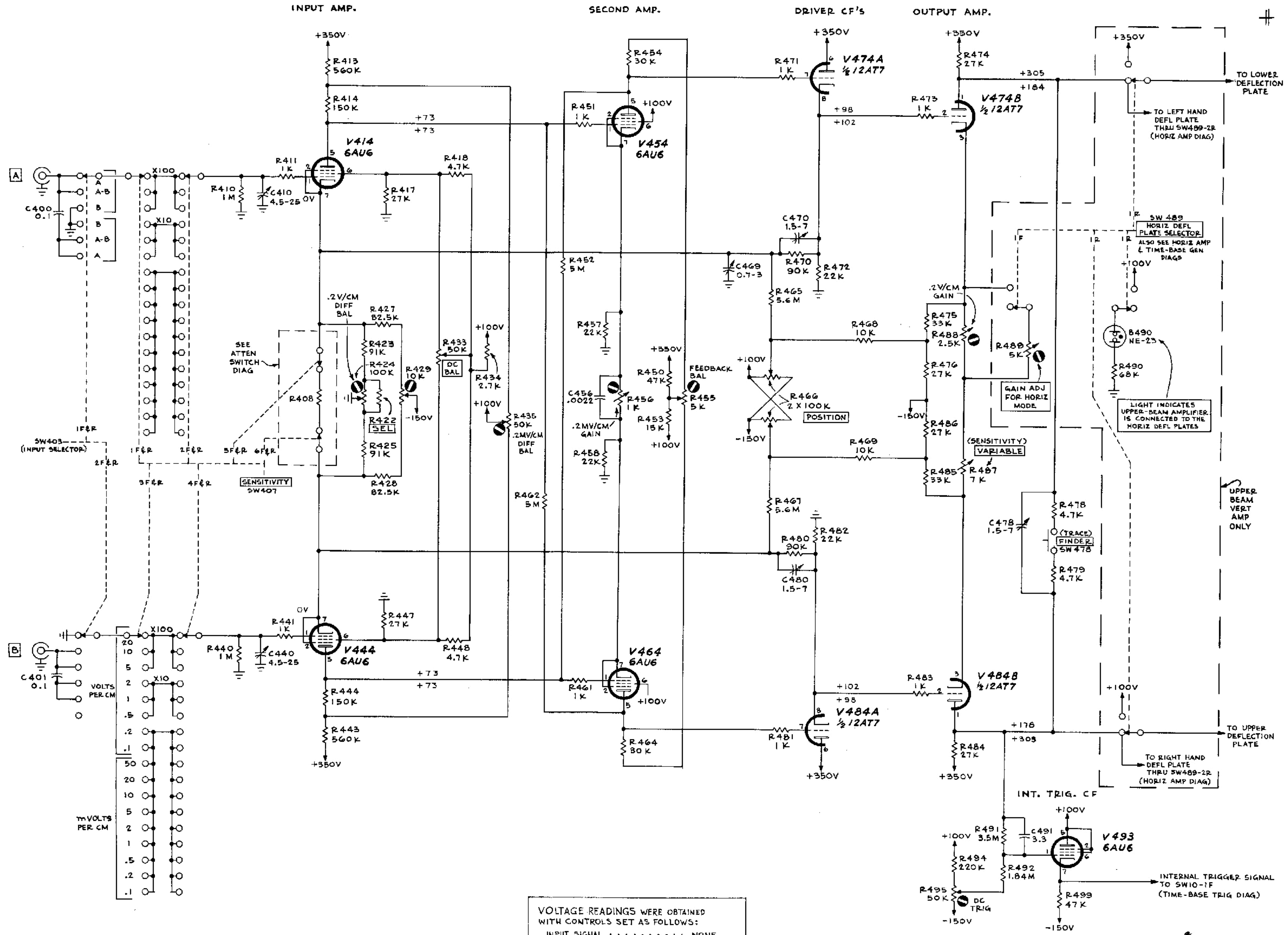
263
303

TYPE 502A OSCILLOSCOPE



VERTICAL ATTENUATOR SWITCH

TYPE 502A OSCILLOSCOPE



VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

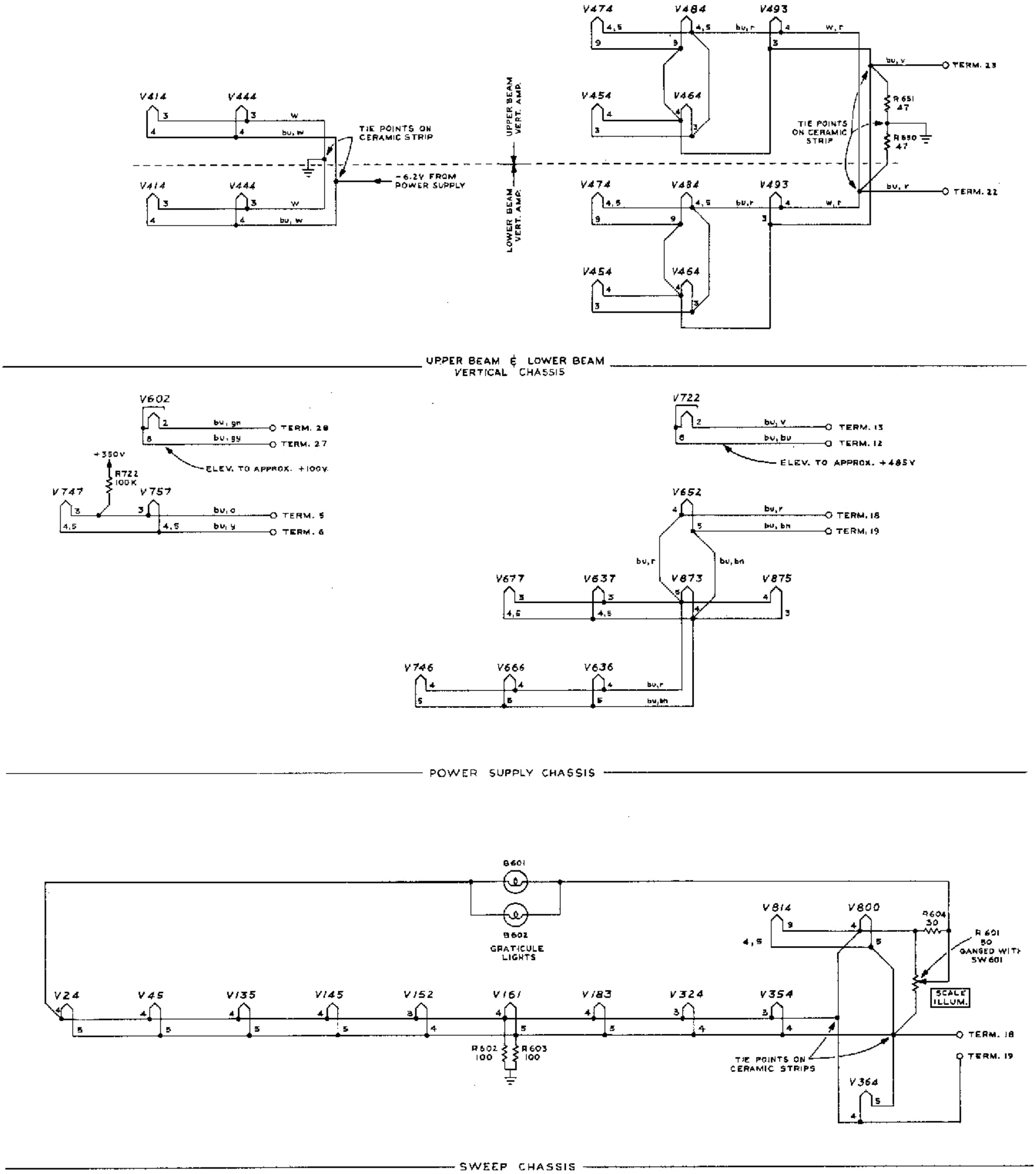
INPUT SIGNAL	NONE
SENSITIVITY	20V/CM
VERTICAL POSITION:	
FOR LOWER VOLTAGE READINGS	FULL RIGHT
FOR UPPER VOLTAGE READINGS	FULL LEFT

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

963

UPPER BEAM VERTICAL AMPLIFIER
LOWER BEAM VERTICAL AMPLIFIER

CIRCUIT NUMBERS 400 THRU 499



DON

TYPE 502A OSCILLOSCOPE

HEATER WIRING DIAGRAM

B