# INSTRUCTION MANUAL

## TYPE 316 OSCILLOSCOPE

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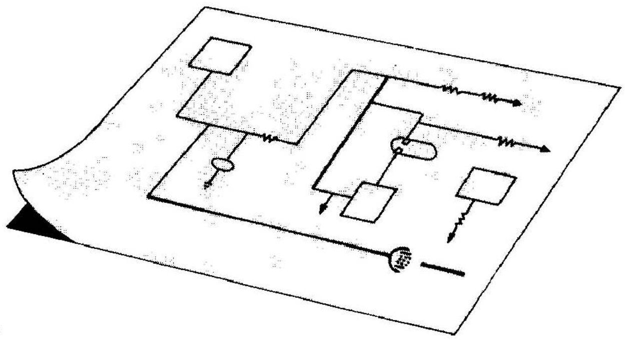
**070-316**


TYPE 316 OSCILLOSCOPE
SERIAL
TIME BASE
TRIGGER SELECTOR
AUTO.
INT
AC
LINE
EXT.
HF SYNC
DC
TRIGGER INPUT
STABILITY
TRIGGERING LEVEL
PRESET
HORIZ. INPUT
DISPLAY
NORM.
+ GATE OUT
VARIABLE
TIME/DIV.
MILLISEC
μSEC
SEC
SAWTOOTH OUT
UNCALIBRATED
CALIBRATED
FOCUS
INTENSITY
SCALE ILLUM.
VERTICAL
VARIABLE ATTEN. BAL.
VARIABLE
VOLTS/DIV.
UNCALIBRATED
AC ONLY
CALIBRATED
INPUT
DC
AC
POSITIONING
VERTICAL
HORIZONTAL
CALIBRATOR
VOLTS
PEAK TO PEAK
OFF
CAL. OUT
POWER ON
TEKTRONIX, INC.
PORTLAND, OREGON, U. S. A.



# SECTION 1

# CHARACTERISTICS

## General

The Type 316 Oscilloscope is a compact, general-purpose oscilloscope. The dc-coupled amplifier and wide range of sweep rates, combined with the size, make the Type 316 a versatile field or laboratory instrument.

## VERTICAL-DEFLECTION SYSTEM

### Input Characteristics

Direct connection-1 megohm, 38 pf.

With P510A Probe-10 megohm, 13 pf.

With P6017 Probe-10 megohm, 14 pf.

### Deflection factor

Twelve-position switch provides calibrated deflection factors from .1 v/div to 50 v/div, dc coupled, and from .01 v/div to 50 v/div, ac coupled accurate within 3%.

Continuously variable deflection factors are available from .01 v/div to approximately 125 v/div.

### Frequency response

.1 v/div to 50 v/div:

DC coupled-dc to 10 mc.

AC coupled-2 cps to 10 mc (.2 cps to 10 mc when a Type P510A or P6017 Attenuator Probe is used.)

.01 v/div to .05 v/div:

2 cps to 9 mc (1.3 cps to 9 mc when a Type P510A or P6017 Attenuator Probe is used.)

### Risetime

.035 microseconds.

## HORIZONTAL-DEFLECTION SYSTEM

### Sweep rates

Twenty-two-position switch provides calibrated sweep rates from 2 sec/div to .2 $\mu$sec/div.

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

Continuously variable sweep rates are available which will show the calibrated sweep rates down by a factor of approximately 2.5 X.

### Magnifier

Expands sweep 5 times to the right and left of the crt-screen center. Extends the fastest sweep rate to .04 $\mu$sec/div.

Accuracy: within 5%.

### Unblanking

DC coupled.

### Triggering signal requirements

Internal-.2 major graticule division.

External-.2 v to 20 v, peak-to-peak.

Frequency range-dc to 15 mc.

### Synchronizing frequency range

5 mc to 15 mc.

### Horizontal input

Deflection factor-approx. 1.3 v/div.

Frequency response-dc to 500 kc.

## OTHER CHARACTERISTICS

### Cathode-ray tube

Type T316P2-P1, P7 and P11 phosphors optional.

Accelerating potential-1,850 volts.

Deflection factor at plates:

Vertical-approximately 8 v/div (32 v/in).

Horizontal-approx. 16.5 v/div (66 v/in).

## Voltage calibrator

Square-wave output at approximately 1 kc.

Eleven fixed voltages from .05 volts to 100 volts, peak-to-peak.

Accuracy: ±3%.

## Output waveforms available

Positive gate of same duration as sweep, approximately 20 volts.

Positive-going sweep sawtooth, approximately 150 volts.

## Power requirements

Line voltage-100 to 130 or 200 to 260 v, 50-60 cycles.

Power-260 w at 117 v line voltage.

## Mechanical Characteristics

Ventilation-filtered, forced-air.

Finish-photoetched, anodized panel. Blue, perforated cabinet.

Dimensions—8½" wide, 12" high, 19½" deep.

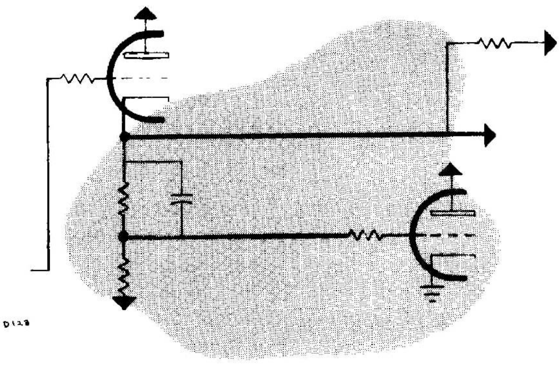
Weight-38 pounds.

## Accessories included

1-P6017 Probe.

2-A510 binding-post adapters.

1-F510-5 green filter.



# SECTION 3

# CIRCUIT DESCRIPTION

## VERTICAL-DEFLECTION SYSTEM

### Preamplifier

The Vertical Amplifier in the Type 316 Oscilloscope requires an input signal voltage of 0.1 v, peak-to-peak, to produce one division of calibrated deflection on the crt. In order to satisfy this condition, and to make the instrument applicable to a wide range of input voltages, a calibrated attenuation network and a Preamplifier are incorporated into the vertical-deflection system. When the VOLTS/DIV. switch (shown on the preamplifier circuit diagram) is in the .1 position, the signal is coupled through the X1 network—in which the attenuation is negligible—to the main Vertical Amplifier. The X1 network compensates for lead inductance in the input circuit. For settings of the VOLTS/DIV. switch between .2 and 50, the Attenuators are switched into the circuit, either singly or in tandem pairs, so that the input voltage to the main Vertical Amplifier is always .1 v for each division of the crt deflection when the VARIABLE knob is in the CALIBRATED position.

The Attenuators are frequency-compensated voltage dividers. For low-frequency signals they are resistive dividers, and the degree of attenuation is proportional to the ratio of the resistances. The reason for this is that the impedance of the capacitors, at low frequencies, is so high that their effect in the circuit is negligible. As the frequency of the input signals increases, however, the impedance of the capacitances decreases and their effect in the circuit becomes pronounced. For high-frequency signals the impedance of the capacitances is so low, compared to the resistance of the circuit, that the Attenuators become capacitive voltage dividers. For these frequencies, the degree of attenuation is inversely proportional to the ratio of the capacitances.

The variable capacitor at the input to each Attenuator (except for the X1 network) provides a means for adjusting the input capacity of the Attenuator to equal that of the main Vertical Amplifier. Similarily, C141 provides a method of adjusting the input capacity of the Preamplifier. In this manner the probe, connected to the INPUT connector, works into the same input capacity regardless of the setting of the VOLTS/DIV. switch. In the "straight through" (X1) position, the probe works directly into the main Vertical Amplifier, so no adjustment is required for this network.

By means of the AC-DC switch (SW101) the signal may be either ac-coupled or dc-coupled to the Vertical Amplifier. In the AC position the signal is coupled through C101; in the DC position, C101 is bypassed with a direct connection. When the VOLTS/DIV. switch is in any of the three positions marked AC ONLY, the AC-DC switch is electrically removed from the circuit and the signal is coupled through C101.

When working with very small voltages, greater sensitivity than furnished by the main Vertical Amplifier may be required or desired. To provide this, the Preamplifier can be switched into the circuit by turning the VOLTS/DIV. switch to any of the positions marked AC ONLY. The Preamplifier is used in conjunction, with either the X1, the X2 or the X5 Attenuator, depending on the setting of the switch, and provides three additional ranges of vertical sensitivity.

The Preamplifier, which has a calibrated signal gain of 10, consists of a single amplifier stage V154, a cathode follower output stage V163B, and a voltage-setting cathode follower V163A. The Voltage-Setting C.F. provides a +175-volt source for the plate and screen circuits of V154, and for the plate of V163B.

The gain of the Preamplifier is regulated by the setting of the PREAMP GAIN ADJ. R154. This control regulates the gain of V154 over an approximate range of 7 to 17 by varying the degeneration in its cathode circuit. For calibrated operation, however, this control must be set so that the gain is exactly 10. (See Calibration Procedure.)

High-frequency compensation for the Preamplifier is provided by a series-shunt peaking coil L150, and by series peaking coils L157 and L177. L150 and L177 provide a means for adjusting the circuit for optimum high-frequency response. R157 is included in the grid circuit of V163B to prevent parasitic oscillations that might occur.

Low-frequency accentuation for the Preamplifier is provided mainly by C146A in the plate circuit of V154. Together with R146 and R150, this circuit forms a low-frequency "boost" network to compensate for the attenuation in the cathode circuit, the screen circuit, and the rc coupling network between the Output C.F. and the Vertical Amplifier. The amount of compensation added to the circuit can however, be varied with the LOW FREQ. ADJ. control R175. (On some instruments this control is called LOW. FREQ. COMP.) By adjusting the amount of attenuation to equal that of the compensation, low frequency distortion in the amplifier is eliminated.

There are two protective devices incorporated in the design of the Preamplifier. One is the diode V142, which protects the electrolytic capacitor C154 from inverse voltage in the event the cathode circuit of V154 should go negative. This would occur, for example, if V154 were removed from its socket when the power was turned on. The other protective device is the neon lamp B163. This prevents the potential between the grid and cathode of V163B from exceeding the break-down rating of the tube in the interval from the time the instrument is first turned on and the time that V163B is warmed up to its operating condition.

## Vertical Amplifier

The Vertical Amplifier consists of two stages of direct-coupled, push-pull amplification, each preceded by a cathode follower. V183 is the signal-input cathode follower when the VOLTS/DIV. switch is in any position other than those marked AC ONLY (in other words, when the Preamplifier is not connected into the circuit). R184, bypassed by C184, prevents the grid from drawing excessive current in the event the stage should be overdriven. R187 is a suppressor for parasitic oscillations.

The Input Amplifier stage, composed of V214 and V224, is a cathode-coupled phase inverter. That is, it converts a single-ended input signal to a push-pull output signal. The VARIABLE control, located between the two cathodes, regulates the gain of the stage over a $2\frac{1}{2}$ to 1 range by varying the amount of degeneration in the cathode circuit.

When the Preamplifier is not connected into the circuit, as mentioned previously, the Input Amplifier stage receives its signal voltage from V183. The opposite cathode follower, V203, couples a fixed dc voltage from the VAR. ATTEN BAL. control to the grid of V224. When this control is properly set, the cathode voltages at the two Input Amplifier tubes will be equal and no change in vertical trace positioning will occur as a result of any change in the setting of the VARIABLE gain control.

When the Preamplifier is connected into the circuit, by turning the VOLTS/DIV. switch to any of the positions marked AC ONLY, V203 becomes the signal-input cathode follower. This action removes V183 from the signal path by returning its grid circuit to ac ground through C182. The switching of Input C.F. tubes compensates for the 180-degree shift of signal polarity introduced by the Preamplifier. With this arrangement, positive-going portions of the input signal always produce an upward deflection of the crt beam.

Vertical positioning of the crt beam is accomplished through the action of the VERTICAL POSITIONING control R231. This is a dual control, connected between +300 volts and ground. It is connected electrically so that as the voltage between ground and the arm in one increases, the voltage between ground and the arm in the other decreases. When the potential at the arms of the controls is different than at the plate of the tubes to which they are connected, current will flow through the limiting resistors R230 and R232, and through the plate-load resistors R213 and R227. This current, flowing through the plate-load resistors, will change the voltage at the plate of the tubes. Rotation of the control will therefore cause the plate voltage at one tube to increase and the plate voltage at the other to decrease. Any change in plate voltage occuring in this stage, due to rotation of the VERTICAL POSITIONING control, will be reflected as a change in vertical deflection-plate voltage at the crt, since direct coupling is used between these two points.

The Input Amplifier stage, as well as all succeeding stages, contains high-frequency peaking coils to improve the high-frequency response of the amplifier. However, since direct-coupling is employed throughout, there is no low-frequency loss in the circuit and no low-frequency compensation is required.

The Input Amplifier is coupled to the Output Amplifier by the Driver C.F. V233. The GAIN ADJ. control, R244, sets the gain of the Output Amplifier to correspond with the front panel calibration when the VARIABLE control is turned full right to the CALIBRATED position.

## Delay Line

The output signal from the Vertical Amplifier is coupled through the balanced Delay Line to the vertical-deflection plates of the crt. The function of the Delay Line is to retard the arrival of the waveform at the deflection plates until the crt has been unblanked and the horizontal sweep has been started. This delay insures that the very "front" of fast vertical signals can be observed. Because of the delay time and certain other characteristics, irregularities are introduced in the crt display when the delay line is misadjusted. And it is through analyzing the shape and position of these irregularities that we are able to effect the necessary adjustments.

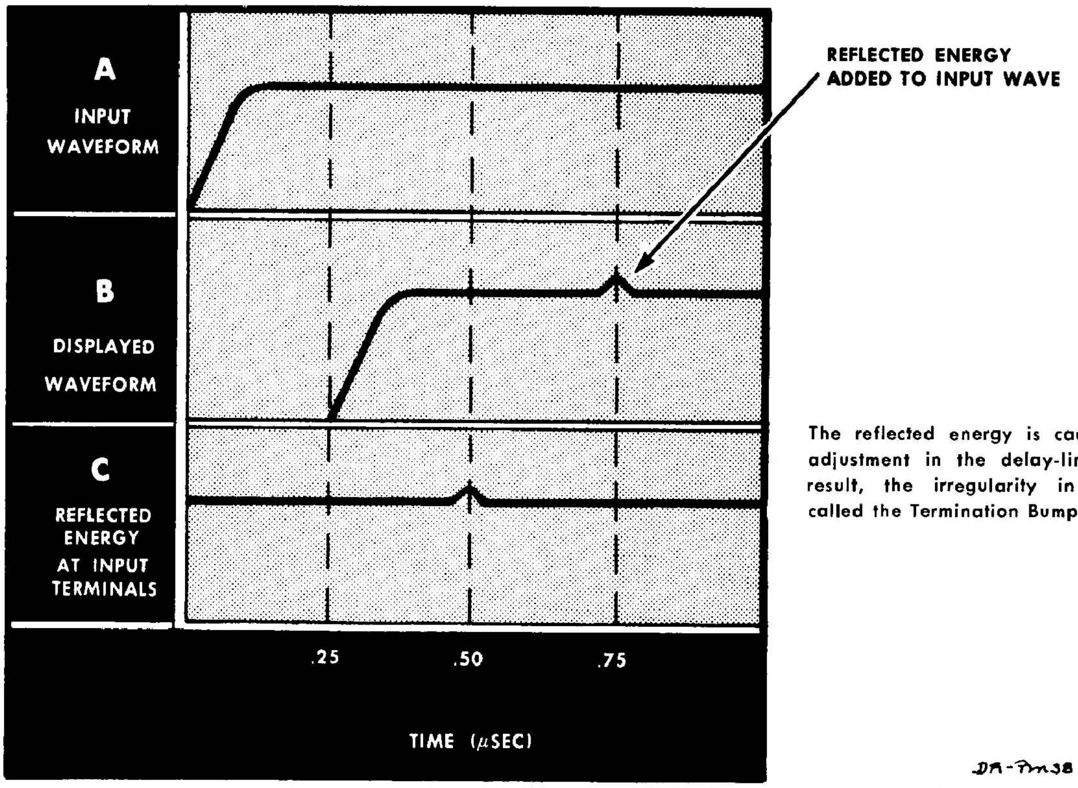
So that you will better understand the adjustment procedure (described in the Calibration Procedure, Section 5, we have outlined in the paragraphs that follow a brief description of the delay line operation and how it affects the crt display.

Consider the sequence of events when a step function is applied to the delay-line input terminals (waveforms A in Fig. 3-1). We'll assume for the moment that the delay line is in good adjustment except for two variable capacitors adjacent to the crt deflection plates.

Oen quarter microsecond after the application of the step function, the leading edge of the waveform will arrive at the crt deflection plates. The crt end of the delay line is terminated, and in normal operation the signal energy would be dissipated in the terminating resistors. However, the misadjustment of the two capacitors creates a slight impedance mismatch, resulting in the reflection of a small amount of signal energy. This reflected energy travels down the delay line toward the input terminals, while, at the same time, the original step function is being traced on the crt screen.

The reflected energy reaches the delay-line input terminals in 0.25 microseconds (the delay time of the delay line) and is once again reflected since there are no terminating resistors to absorb the energy (waveform C in Fig. 3-1). As a result, the reflected energy is present at the crt deflection plates 0.5 microseconds (twice the delay-line delay time) after it was initially reflected. This energy is manifest in the crt display as an irregularity occuring 0.5 microseconds after the leading edge of the step function (waveform B in Fig. 3-1). Because the reflected energy is the result of a misadjustment in the delay-line terminating network, we call the irregularity on the displayed waveform the Termination Bump. For ease of discussion in the following paragraphs, we shall refer to the lapsed time from leading edge to Termination Bump as time T.

Consider next the affect of a misadjustment located $\frac{1}{4}$ of the delay-line length from the input terminals. Because the velocity of propagation is uniform over the length of the




The reflected energy is caused initially by a slight misadjustment in the delay-line termination network. As a result, the irregularity in the displayed waveform is called the Termination Bump.

Fig. 3-1. Time relationship of delay-line signals.

delay line, the step function will reach the point of misadjustment ¼ of the delay-line delay time after application. This is equivalent to 1/8T. At this point, a small amount of energy is reflected back to the input terminals due to the impedance mismatch caused by the misadjustment. The reflected energy will reach the input terminals 1/8T after being reflected or ¼T after application of the step-function. This means, then, that the reflected energy will reach the crt deflection plates ¼T after the leading edge of the step function and will result in a bump located ¼ of the distance from the leading edge to the Termination Bump on the displayed waveform (see Fig. 3-2).

If the misadjustment of the previous paragraph were located elsewhere on the delay-line, it could be shown that its relative position between input terminals and termination network would correspond to the position of the resulting bump on the displayed waveform. It is this characteristic of the delay-line that allows us to locate and remedy a misadjustment.

Since the Delay Line is the load for the Vertical Output stage, it is elevated above ground by an amount equal to the plate voltage of the Output Amplifier stage. R293 and R294, in addition to terminating the line, are the plate-load resistors for the output stage.

When internal triggering of the Time Base Generator is desired (black TRIGGER SELECTOR knob is in either the + or —INT. position), a "sample" of the vertical output signal

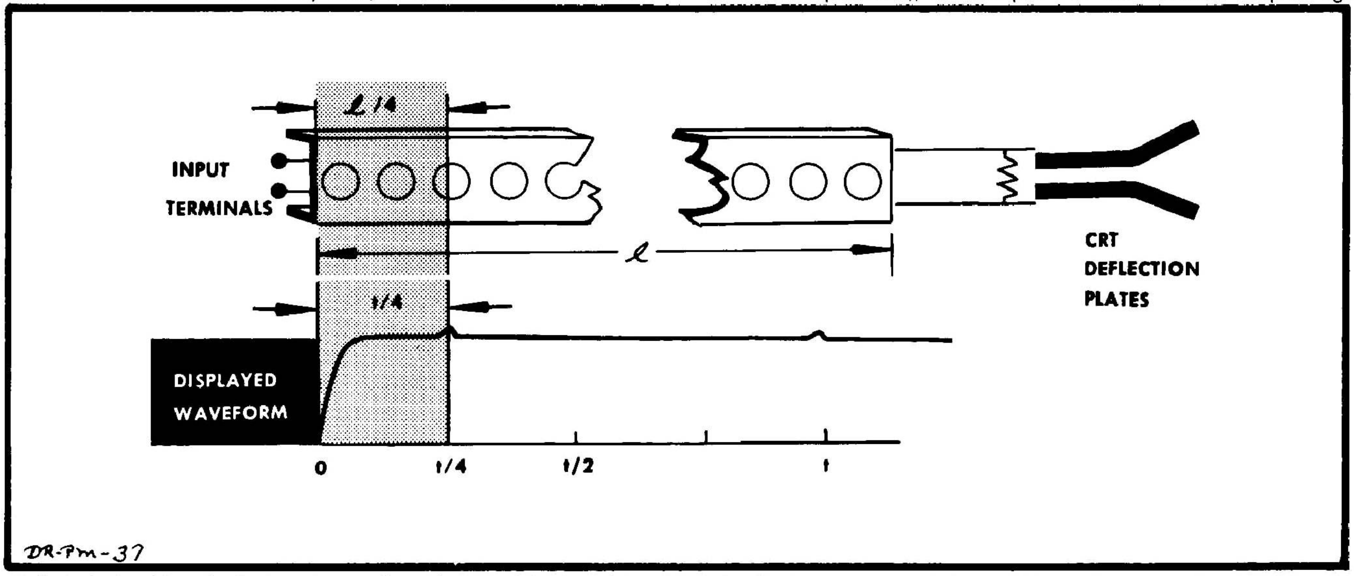



Fig. 3-2. Relationship of displayed waveform irregularities to delay-line misadjustment. The relative position of an irregularity between the start of the display and the Termination Bump corresponds to the relative position of the delay-line misadjustment between the input terminals and the terminating resistors.

is used to develop the triggering pulse. The "sample" is obtained from a tap on a coil at the input to the Delay Line. This point provides a signal suitable for good triggering action, yet presents minimum loading to the Output Stage and the Delay Line. The "triggering" signal is coupled to the Time-Base Trigger circuit by the Trigger C.F. V263, shown on the Vertical Amplifier circuit diagram.

## HORIZONTAL-DEFLECTION SYSTEM

### Time-Base Trigger

The function of the Time-Base Trigger circuitry is to develop a negative-going triggering pulse to trigger the Time-Base Generator in the proper time sequence. The signal from which the negative going triggering pulse is produced may emanate from one of three sources, as determined by the setting of the TRIGGER SELECTOR switch (black knob) SW420. When the switch is in the + or —EXT. position, an external signal is employed in the development of the triggering pulse. When the switch is in the + or —INT. position, the vertical signal itself is used to develop the triggering pulse. This was explained at the conclusion of the previous section. In the + or —LINE position of the switch, a voltage at the power line frequency is used to develop the triggering pulse.

In addition to selecting the source of the triggering voltage, switch SW420 (TRIGGER SELECTOR, black knob) also arranges the input circuit of the Trigger-Input Amplifier so that a negative-going pulse is always produced at the plate of V435B regardless of whether the switch is in a + or — position.

The Trigger-Input Amplifier V414 is a polarity-inverting, cathode-coupled amplifier. The output is always taken from the V414B plate, but the grid of either stage may be connected to the input-signal source. When the black TRIGGER SELECTOR knob is in the — position (EXT., INT. or LINE range), the V414A grid is connected to the input-signal source. The grid of V414B is connected to a dc bias source, adjustable by means of the TRIGGERING LEVEL control. This bias voltage establishes the quiescent voltage at the V414B plate. When the TRIGGER SELECTOR knob is in the + position (for any of the three ranges), the grid of V414B is connected to the input-signal source and V414A is connected to the bias source.

The voltage at the grid of V414A and the voltage at the plate of V414B are in phase with each other; that is, they both go through ac zero in the same direction at the same time. Therefore, when the switch is in any of the — positions (the signal applied to the V414A grid), the voltage at the plate of V414B is in phase with the input-signal voltage. By this arrangement, V414A acts as a cathode follower, having a gain of approximately unity, and the signal voltage developed across the cathode resistor becomes the input signal to the V414B section.

When the switch is moved to any of the + positions, the V414B grid is connected to the input-signal source. With this configuration, the voltage at the plate of V414B will be 180 degrees out of phase with the input-signal voltage. Thus, depending on the setting of the switch (+ or —), the V414B plate signal swing may be in phase, or 180 degrees out of phase, with the input signal voltage.

The Schmitt Trigger consists of V435, A and B, connected as a dc-coupled multivibrator. In the quiescent state. i.e., ready to receive a signal, V435A is conducting and its plate voltage is down. This holds the V435B grid below cutoff, since the two circuits are dc-coupled by the voltage divider R435, R436 and R437. With V435B in a state of cutoff, its plate voltage is up; hence no output is being developed.

A negative-going signal is required at the grid of V435A to drive the Schmitt Trigger into its other state in which the triggering pulse can be produced. However, the signal coupled to the V435A grid is a component of the vertical input signal, and therefore contains both negative- and positive-going voltages.

The negative-going portion will drive the V435A grid in the negative direction, and the cathodes of both tubes will follow the grid down. At the same time the V435A plate voltage starts rising, which causes the V435B grid voltage to rise. With the grid of V435B going up and its cathode going down, V435B starts conducting. The cathodes will no longer follow the V435A grid; hence the cathode voltages start going up. With the V435A grid down and its cathode up, it cuts off. As V435B conducts its plate voltage drops, creating a negative step at the output. This transition occurs very rapidly, regardless of how slowly the V435A grid signal falls.

When the signal at the grid of V435A starts in the positive direction, just the opposite will occur. That is, V435A will start conducting again, V435B will be cutoff, and the circuit will revert to its original state with the V435B plate voltage up. This completes the negative step voltage output from the Schmitt Trigger circuit.

The operation of the Schmitt Trigger circuit is exactly the same for both + and — positions of the black TRIGGER SELECTOR knob. However, since there is a reversal in signal polarity—between these two settings—triggering will occur at different points with respect to the signal being observed. For example, when the switch is in the + position, triggering will occur during the positive slope of the waveform. Conversely, when the switch is in the — position, the trace will start when the waveform is going in the negative direction.

The TRIGGER SELECTOR switch with the red knob, SW140, selects the type, or mode of triggering. In the DC position, the vertical-input signal is dc-coupled from the Trigger C.F. to the Trigger-Input Amplifier, which in turn is dc-coupled to the grid of V435A. R422 isolates the output circuit of V414B from the capacitance of the switch; R424 isolates the grid circuit of V435A from the switch.

In the AC position of the switch, capacitor C407 is connected into the input circuit; this, of course, removes any dc component of the input waveform. The Trigger-Input Amplifier, however, is still dc-coupled to the Schmitt Trigger stage.

In the AUTO. position of the switch, the Schmitt Trigger is converted from a bistable configuration to a recurrent configuration. This is accomplished by coupling the grid circuit of V435B to the grid circuit of V435A via R431. In addition, the dc-coupling between the Trigger-Input Amplifier and the Schmitt Trigger is removed when the switch is in this position.

The addition of R431 to the circuit causes the Schmitt Trigger to free-run in the absence of a vertical-input signal. For example, assume the grid of the V435A section is just being driven into cutoff. The voltage at the plate of V435A starts to rise, carrying with it the grid voltage of V435B. The grid of V435B is coupled to the grid of V435A through R431 and R424. This causes the grid voltage of V435A to start rising. The time constant of the rc network R431, R424 and C423 is such that it takes about .01 second for the V435A grid voltage to rise exponentially from its starting point, below cutoff, to a value where plate current can flow.

As V435A starts to conduct, its plate voltage drops, which in turn lowers the voltage at the V435B grid. The voltage at the V435A grid then starts dropping exponentially toward cutoff. When the grid of V435A reaches cutoff again, the circuit has completed one cycle of its approximately 50-cycle triangular waveform.

The range of voltage at the grid of V435A, between V435A cutoff and V435B cutoff, is about 3 volts when the circuit is used in the AUTO. mode (this is increased from about 0.5 volt, for the AC or DC mode, by the addition or R431 to the circuit). Since the V435A grid is never more than 3 volts from cutoff, a triggering signal with a peak-to peak amplitude of 3 volts or more can drive the grid to cutoff at any time and produce a trigger output. Smaller signals can also produce a trigger output, but only if they occur at a time when the sum of the signal voltage and the triangular grid voltage is sufficient to drive the V435A grid to cutoff. However, the duty cycle of operation is somewhat reduced when smaller triggering signals are being received.

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 a 50-cycle rate. Thus, in the absence of any vertical signal, the sweep generates a base line which indicates that the oscilloscope is adjusted to display any signal that might be connected to the vertical-deflection system.

When switch SW410 is in the HF SYNC position, the Time-Base Trigger circuits are bypassed and the input "triggering" signal is applied directly to the Time-Base Generator. This signal now acts as a synchronizing signal, superimposed on the holdoff waveform (to be discussed in the section that follows). This synchronizes the Time-Base Generator at a submultiple of the triggering-signal frequency. This mode is useful for input signals in the range from 5 megacycles to 15 megacycles.

## Time-Base Generator

The Time-Base Trigger produces a negative-going waveform which is coupled to the Time-Base Generator. This waveform is differentiated in the grid circuit of V25A to produce a sharp negative-going triggering pulse to trigger the Time-Base Generator. Positive-going pulses are also produced in the differentiation process, but they are not used in the operation of the Time-Base Generator.

The Time-Base Generator consists of three main circuits: a Bistable Multivibrator, a Miller Runup Circuit, and a Hold-Off Circuit. The Bistable Multivibrator consists of V25A, V35B and the cathode follower V25B. The essential components in the Miller Runup circuit are the Miller Tube V61B, the Runup C.F. V61A, the On-Off Diodes V52, the Timing Capacitor C160 and the Timing Resistor R160. The Hold-Off Circuit consists of the Hold-Off Divider V83A, the Hold-Off C.F. V83B, the Hold-Off capacitor C180 and the Hold-Off Resistor R181.

In the quiescent state, V25A is conducting and its plate voltage is down. This cuts off V35B through the cathode follower V25B, the voltage divider R26-R27, and the cathode resistors, R28 and R29.

The quiescent state of the Miller Tube is determined by a dc network between plate and grid. This network consists of the neon lamp B75, the Runup C.F. V61A, and the On-Off Diodes V52. The purpose of the dc network is to establish a voltage at the plate of the Miller 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 Tube rests at about —2 volts. There is about a 1½-volt drop in the Runup On-Off Diodes, about 18.5 volts bias on the Runup C.F., and about a 55-volt drop across the neon lamp. This establishes a quiescent voltage of about +33 volts at the plate of the Miller Tube.

If the STABILITY control is now advanced, making the grid of V25A more negative, a point will be reached where a negative-going triggering pulse from the Schmitt Trigger stage will cause the Bistable Multivibrator to switch rapidly to its other state. That is, V25A will be cutoff and V35B will start to conduct. As V35B conducts, its plate voltage, and the voltage at the diode plates, drops. As a result the diodes are cutoff, which permits the grid of the Miller Tube and the cathode of the Runup C.F. to seek their own voltages. Any spiking that may occur, during this transition period, is attenuated by the R52-C52 network.

As there is no diode conduction at this time, the grid of the Miller Tube starts negative, since it is connected to —150 volts through the Timing Resistor R160. The plate of the Miller Tube then starts positive, carrying with it the grid and cathode of the cathode follower V61A. This raises the voltage at the top of the Timing Capacitor C160, which in turn raises the voltage at the grid of the Miller Tube and prevents it from going over ¾ of a volt negative. The gain of the Miller Tube, as a Class A amplifier, is approximately 200. This means that a 150-volt change in plate voltage will maintain the grid voltage constant within three-quarters of a volt.

The Timing Capacitor C160 starts charging with current from the —150-volt bus. Since the voltage at the grid of the Miller Tube remains essentially constant, the voltage drop across the Timing Resistor, and hence the charging current through it, remains essentially constant. Thus, C160 charges linearly, and the voltage at the cathode of the Runup C.F. V61A rises linearly. Any departure from a linear rise in the voltage at this point will produce a change in the voltage at the grid of the Miller Tube in such a direction as to correct for the error.

The linear rise of voltage at the cathode of V61A is used as the sweep time base. Timing Capacitor C160 and Timing Resistor R160 are selected by means of the TIME/DIV. switch (SW160). The Timing Resistor determines the current that charges the Timing Capacitor. By means of the TIME/DIV. switch, both the size of the capacitor being charged and the current charging the capacitor can be selected to cover a wide range of sawtooth slopes (sweep rates). For high-speed sweeps the bootstrap capacitor C72 helps supply current to charge the stray capacitance at the plate of the Miller Tube, which permits the plate voltage to rise at the required rate.

If uncalibrated sweep speeds are desired, the VARIABLE TIME/DIV. (red knob) control varies the sweep rate over a $2\frac{1}{2}$ to 1 range. Switch SW65 is ganged with the VARIABLE control in such a way that the UNCALIBRATED light comes on when the control is turned away from the CALIBRATED position.

As explained previously, the sweep rate is determined by the timing circuit C160 and R160. The length of the sweep is determined by the setting of the SWEEP LENGTH control R82. As the sweep voltage rises linearly at the cathode of V61A, there will be a linear rise in voltage at the arm of the SWEEP LENGTH control R82. This will increase the voltage at the grid and cathode of V83A, and at the grid and cathode of V83B. As the voltage at the cathode of V83B rises, the voltage at the grid of V25A will rise. When the voltage at this point is sufficient to bring V25A out of cutoff, the multivibrator circuit will rapidly revert to its original state with V25A conducting and V35B cutoff. The voltage at the plate of V35B rises, carrying with it the voltage at the diode plates. The diode then conducts and provides a discharge path for C160 through R37 and R38, and through the resistance in the cathode circuit of V61A. 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 of the Timing Resistor (through which it charges). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller 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.

During the trace portion of the sweep sawtooth the Hold-Off Capacitor C180 charges through V83A, as a result of the rise in voltage at the cathode of V83A. At the same time, the grid of V25A is being pulled up, through the Hold-Off C.F. V83B, until V25A 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, so that during the retrace interval (and for a short period of time after the completion of the retrace) V180 holds the grid of V25A high enough so that it cannot be triggered. However, when C180 discharges to the point that V83B is cut off, it releases control of the grid of V25A and the grid returns to the level established by the STABILITY control. The hold-off time required is determined by the size of the Timing Capacitor. For this reason the TIME/DIV. switch changes the time constant of the Hold-Off Circuit simultaneously with the change of Timing Capacitors.

The STABILITY control R10 regulates the dc level at the grid of V25A. In use, this control is adjusted so that the grid voltage is just high enough to prevent the circuit from free-running. Adjusted in this manner, a sweep will only be produced when a negative-going triggering pulse from the Schmitt Trigger can drive the stage into cutoff. For convenience, a PRESET Stability control can be connected into the circuit via switch SW10. When in this position a fixed negative dc voltage is obtained from R11 and applied to the grid of V25A. Where triggering may be critical, however, the variable STABILITY control should be used.

The positive rectangular pulse appearing at the cathode of V25B is coupled through the Unblanking C.F. to the grid circuit of the crt. This pulse, whose start and duration are coincident with that of the sweep portion of the sawtooth, unblanks the crt and permits the trace to be observed.

The unblanking pulse is also coupled through another cathode follower, V43B, to a jack on the front panel labeled +GATE OUT. This is a positive pulse, which starts at ground and rises to approximately +20 volts.

The sweep sawtooth voltage at the cathode of V61A, in addition to being coupled to the Horizontal Amplifier, is also coupled through the cathode follower V43A to a jack on the front panel labeled SAWTOOTH OUT. This provides a 150-volt linear rise in voltage, starting at zero volts with respect to ground.

## Horizontal Amplifier

The Horizontal Amplifier consists of an input cathode follower, a driver cathode follower, a push-pull amplifier and an output cathode follower stage.

The sweep waveform is coupled to the grid of the Input C.F. V313B via the frequency-compensated voltage divider R310-R311. The HORIZONTAL POSITIONING control R314A supplies a manually adjustable dc voltage to the grid of V313B for horizontal positioning of the crt beam. The R315-C315 network produces a small step at the start of the waveform at the faster sweep speeds. This step is necessary to compensate for the bandpass-limiting effect of the stray capacitance in the amplifier. By its application the waveform will start linearly at the faster sweep speeds. The Input C.F. V313B provides the necessary low impedance to drive the switch capacitances and the Driver C.F. V313A; the Driver C.F. isolates the Output Amplifier from the DISPLAY switch.

In the MAG. position of the DISPLAY switch, the waveform is coupled by cathode follower V313A to the Output Amplifier stage. This stage, V354A and V374A, a cathode-coupled phase inverter, converts the single-ended input to a push-pull output. The waveform is then coupled by the Output C.F. stage, V354B and V374B, to the horizontal-deflection plates. The MAG. GAIN ADJ. varies the degeneration in the cathode circuit of the Output Amplifier and thus sets the gain of the stage. C358 reduces the degeneration at higher frequencies and thus compensates the amplifier for faster sweep rates. Bootstrap capacitors C350 and C372 also improve the response at the faster sweep rates by supplying current from the output cathode followers to charge the stray capacitance at the plates of the Output Amplifier. Neon lamp B300 is connected in the circuit when the DISPLAY switch is in the MAG. position to indicate that the magnifier circuits are in operation.

In the NORM. position of the DISPLAY switch the gain of the amplifier is reduced by a factor of five by a feedback loop between the cathode circuit of V354B and the grid circuit of V313A. This loop consists of R333 shunted by C333, and R324 and R325 shunted by C324. The amount of feedback, and hence the gain of the amplifier, is adjusted by means of R325, the HORIZ. GAIN ADJ. In the normal position of the DISPLAY switch (NORM.) both the MAG. GAIN ADJ. and the HORIZ. GAIN ADJ. will vary the gain; for this reason the MAG. GAIN ADJ. must only be set when the DISPLAY switch is in the MAG. position.

The MAG. REGIS. control R335 adjusts the voltage at the grid of V313A to equal the voltage at the cathode of V313B when the spot is in the center of the screen and the DISPLAY switch is in the NORM. position. This insures that the portion of the waveform within the center two graticule divisions, will be expanded the full length of the graticule when the DISPLAY switch is set to the MAG. position.

In the EXT. position of the DISPLAY switch the Driver C.F. is connected to an external binding post on the front panel marked HORIZ. INPUT. With this arrangement the horizontal waveform is obtained from an external source rather than from the Time-Base Generator. The HORIZ. INPUT ATTEN. control R330 varies the input voltage so that the waveform may be adjusted for the desired amplitude. In the EXT. position, horizontal beam positioning is provided by R314B rather than by R314A.

## POWER SUPPLY

Plate and filament power for the tubes in the Type 316 Oscilloscope is furnished by a single power transformer T600. The primary has two equal tapped windings; these may be connected in parallel for 100- to 130-volt operation, or in series for 200- to 260-volt operation. Silicon rectifiers are employed for the three separate full-wave, bridge-type, power supplies. The three supplies furnish regulated dc voltages of —150 volts, +100 volts and +300 volts. The +300-volt supply also has an unregulated output of about +420 volts for the oscillator tube in the high-voltage supply for the crt. It is unnecessary to regulate this supply as the high-voltage power supplies have their own regulation circuits.

Reference voltage for the —150-volt supply is established by a gas diode Voltage-Reference tube V609. This tube which has a constant voltage drop, establishes a fixed potential of about —84 volts at the grid of V606B, one-half of a Difference Amplifier. The grid potential for the other half of the Difference Amplifier, V606A, is obtained from a voltage divider consisting of R616, R617 and R618. R617, the —150 ADJ., determines the percentage of total voltage that appears at the grid of V606A and thus determines the total voltage across the divider. When this control is properly adjusted the output voltage is exactly —150 volts.

Should the loading on the supply tend to change the output voltage, the potential at the grid of V606A will change in proportion, and an error voltage will exist between the two grids of the Difference Amplifier. The error signal is amplified by V606B, whose plate is dc-coupled to the grid of the Series Tube V617B. The error voltage appearing at the grid of the Series Tube will change the voltage drop across the tube, and hence change the voltage at the plate of the tube. This change in voltage at the plate of the Series tube, which will be in a direction to compensate for the change in the output voltage, is coupled through the rectifiers and C601A to the output and thus pulls the output voltage back to its established value of —150 volts. C614 improves the ac gain of the feedback loop, and thus increases the response of the circuit to sudden changes in output voltage.

The —150-volt supply serves as a reference for the +100-volt supply. The voltage divider R641-R642 establishes a voltage of essentially zero at the grid of the Amplifier V636. If the loading should tend to change the output voltage, an error voltage will appear at the grid of the Amplifier. The error voltage will be amplified and will appear at the grid of the Series Tube V637. The cathode of V637 will follow the grid, and thus the output voltage will be returned to its established value of +100 volts. C638 improves the response of the regulator circuit to sudden changes in output voltage.

A small sample of the unregulated-bus ripple will appear at the screen of V636 through R635. This ripple signal appearing at the screen (which acts as an injector grid) will produce a ripple component at the grid of V637 which will be opposite in polarity to the ripple appearing at the plate of V637. This tends to cancel the ripple at the cathode of V637, and hence reduces the ripple on the +100-volt bus. This same circuit also improves the regulation of the circuit in the presence of line voltage variation.

The +300-volt supply functions in the same manner as the +100-volt supply. Rectified voltage from terminals 18 and 19 of the power transformer is added to the voltage supplying the +100-volt regulator to supply power for the +300-volt regulator. As mentioned previously, the +300-volt supply also provides an unregulated +420-volt output or the crt high-voltage supply.

## CRT CIRCUIT

### High Voltage Supply

A single 60-kilocycle Oscillator circuit furnishes energy for the two power supplies that provide accelerating voltages for the crt. The Oscillator is the Hartley type, whose main components are V810 and the Primary of T800 tuned by C811.

The rectifier circuits are of the half-wave type, with capacitor-input filter networks. Separate supplies are required for the grid and cathode circuits in order to provide dc-coupled unblanking to the grid supply. V822 supplies about —1850 volts for the grid of the crt (the actual voltage depends on the setting of the INTENSITY control). V832 supplies —1675 volts for the cathode. With the mean potential in the deflection area +175 volts and the cathode at —1675 volts, the accelerating potential for the crt beam is 1850 volts.

In order to provide a constant deflection sensitivity in the oscilloscope, and thereby maintain its calibration, it is necessary that the accelerating potentials in the crt remain constant. This is accomplished by regulating the grid and cathode supplies by comparing a sample of the high voltage to the regulated —150-volt supply. The "sample" voltage obtained from the arm of R841 (H.V. ADJ.), is applied to the grid of V806B; the cathode of this tube is connected to the regulated —150-volt supply. The error signal is amplified by V806B and V806A. The output of V806A varies the screen voltage of the Oscillator tube, thus controlling its output.

## Unblanking

As mentioned previously, dc-coupled unblanking is accomplished by employing separate high-voltage supplies for the grid and cathode. The cathode supply is tied to the +100-volt supply via the decoupling network R832 and C832. 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 grid of the crt via the floating grid supply.

At the faster sweep speeds the stray capacitance in the circuit would make it difficult to move the floating supply fast enough to unblank the crt in the required time. To overcome this, an isolation network composed of C822, C826, R822 and R826 is employed. The fast leading edge of the unblanking pulse, at the faster sweep speeds, is coupled directly to the grid of the crt via C826 and C822; the power supply itself is not appreciably moved during this time due to the isolating resistors R822 and R826.

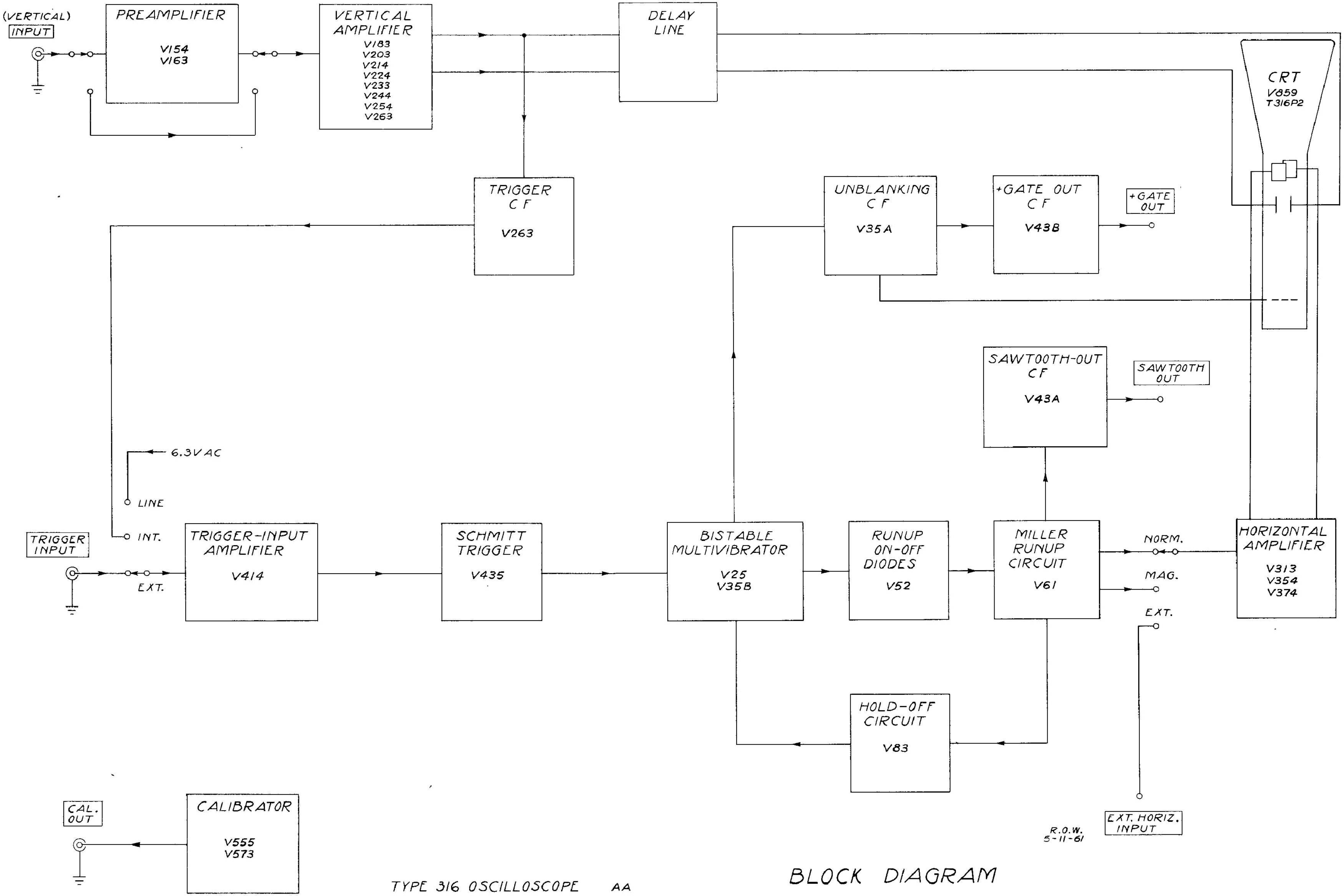
For longer unblanking pulses (at slower sweep speeds) the stray capacitance of the circuit is charged through R822; this holds the grid at the unblanked potential for the duration of the pulse.

## CALIBRATOR

The Calibrator is a square-wave generator whose approximately 1-kilocycle output is available at a front-panel jack labeled CAL. OUT. It consists of a Multivibrator, V555A-V573, connected so as to switch the Cathode Follower V555B between two operating states—cutoff and conduction.

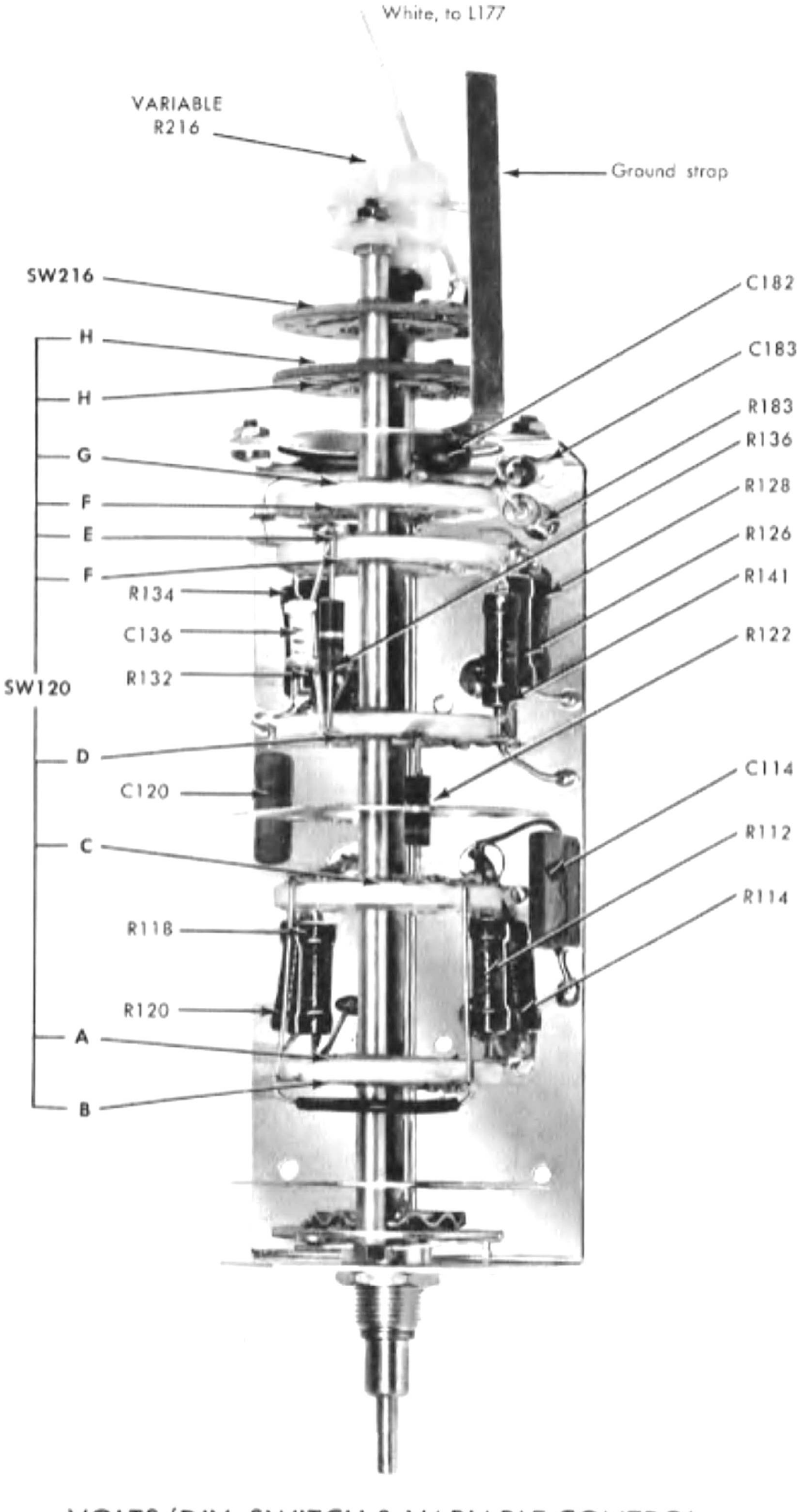
During the negative portion of the Multivibrator waveform the grid of V555B is driven well below cutoff and the cathode rests at ground potential. During the positive portion of the waveform the grid of V555B rises to slightly less than 100 volts. By means of the CAL. ADJ. R566, the grid voltage can be adjusted so that the voltage at the CAL. VOLT. CHECK jack (cathode) can be set to exactly 100 volts.

The Calibrator C.F. has a precision tapped voltage divider for its cathode resistor. By means of the VOLTS, PEAK TO PEAK switch, eleven calibrated voltages from .05 v to 100 v are available.

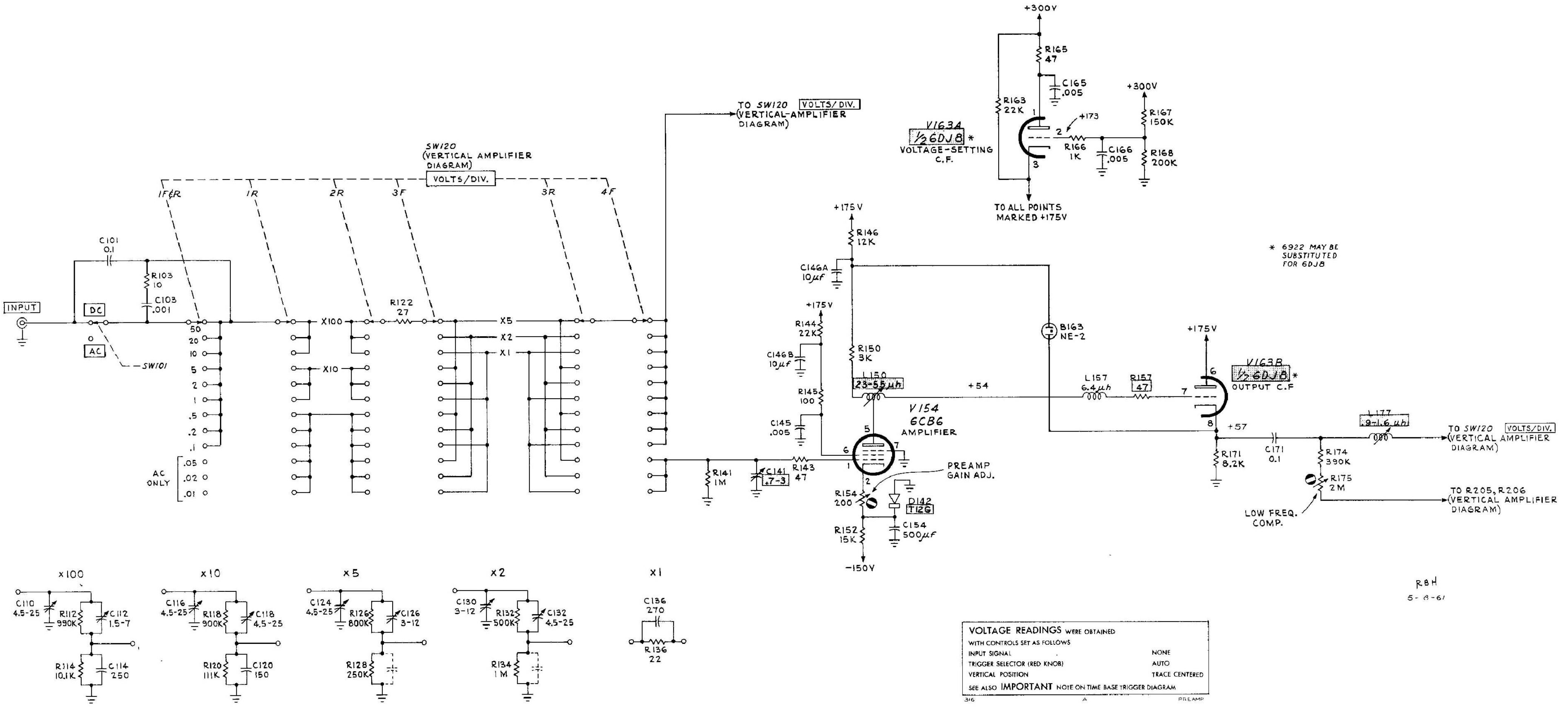



TYPE 316 OSCILLOSCOPE AA

# BLOCK DIAGRAM



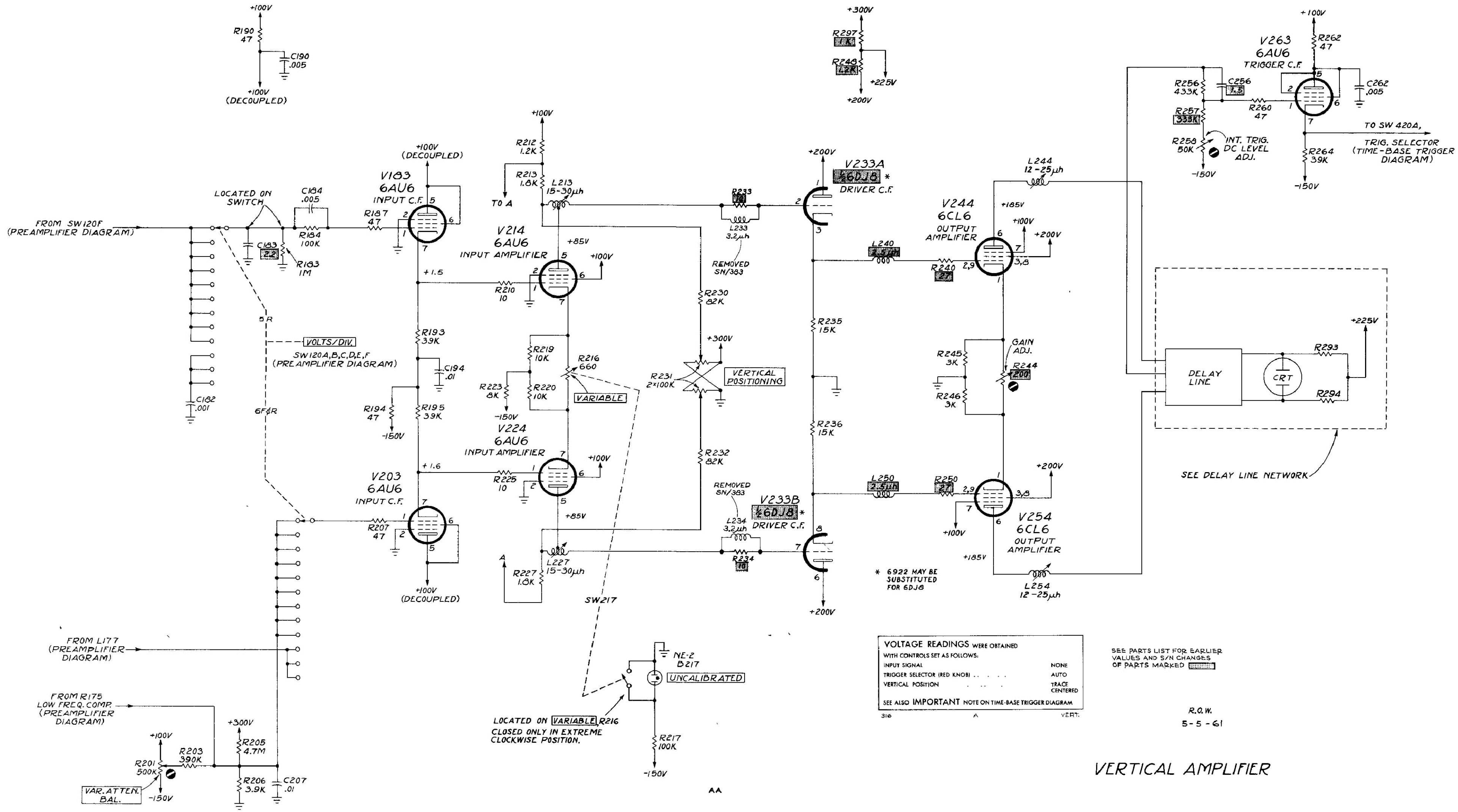

VOLTS/DIV. SWITCH & VARIABLE CONTROL




ATTENUATOR DETAILS

AA

TYPE 316 OSCILLOSCOPE




| VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS: | |
|---|---|
| INPUT SIGNAL | NONE |
| TRIGGER SELECTOR (RED KNOB) . . . . | AUTO |
| VERTICAL POSITION . . . . | TRACE CENTERED |

SEE ALSO **IMPORTANT** NOTE ON TIME-BASE TRIGGER DIAGRAM

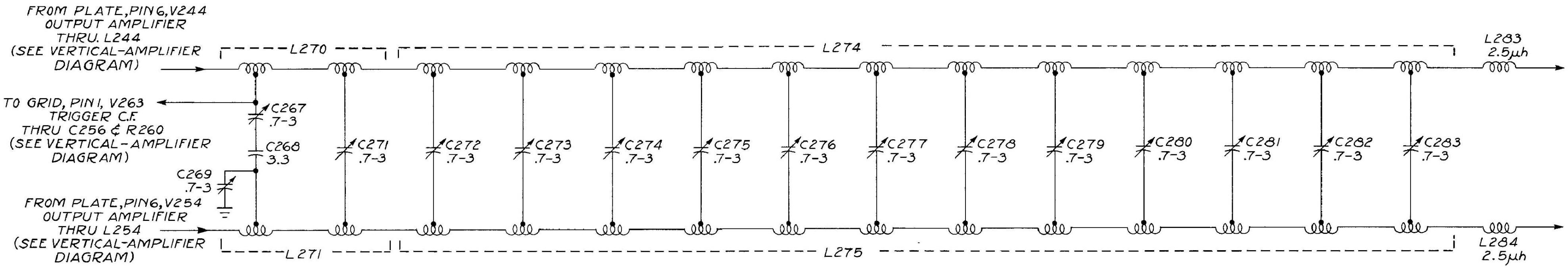
316 A VERT.

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

R.O.W.
5-5-61

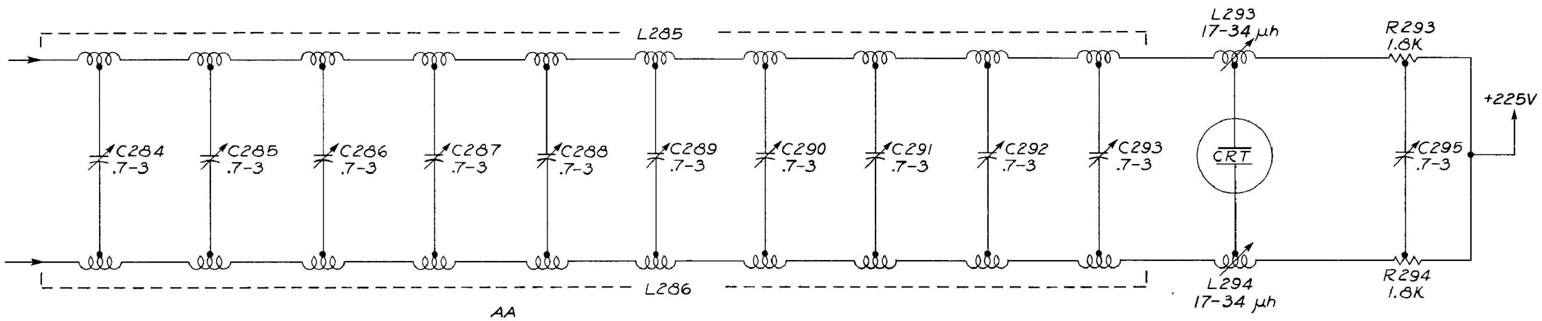
# VERTICAL AMPLIFIER

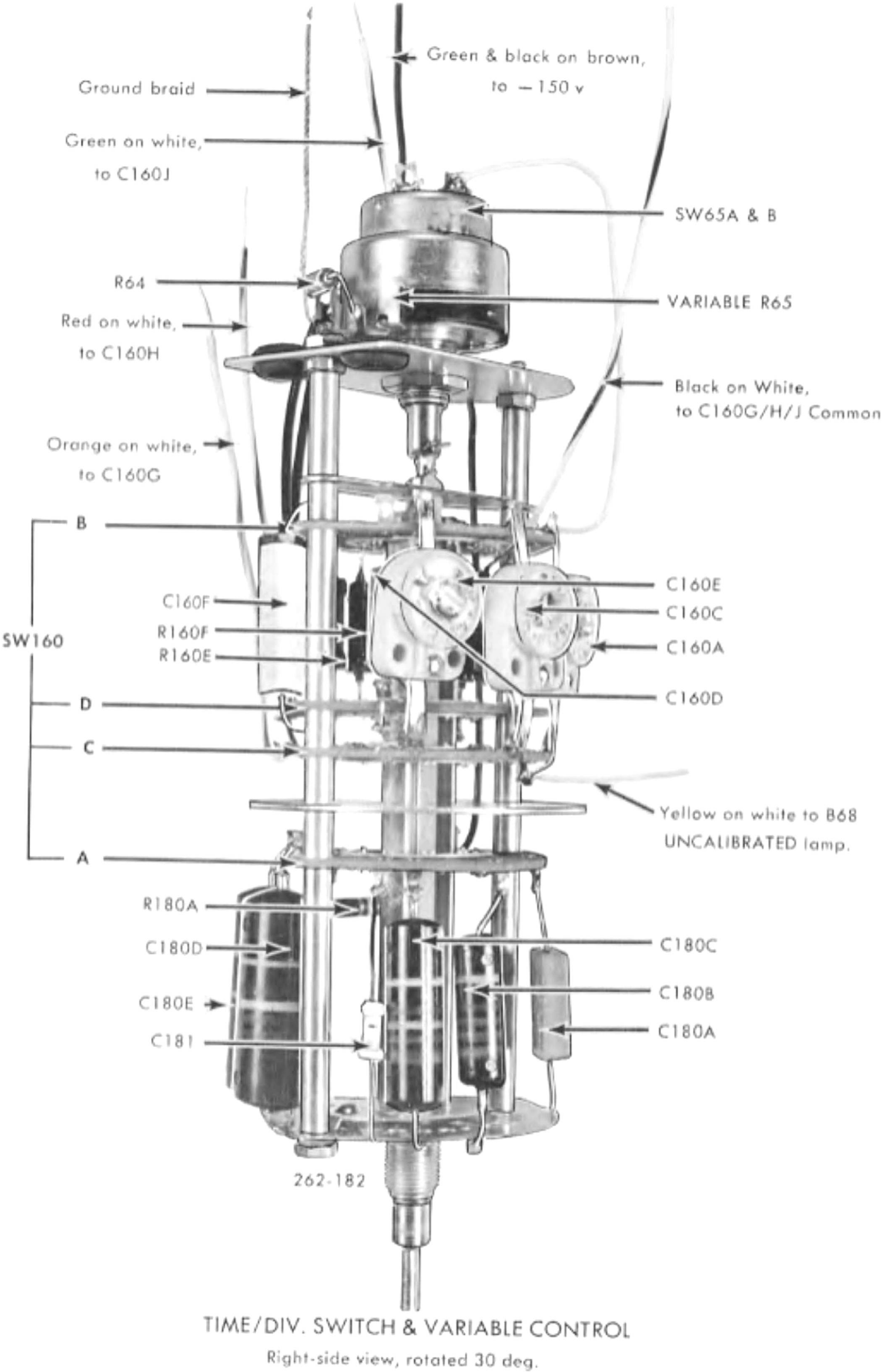
TYPE 316 OSCILLOSCOPE




DELAY LINE

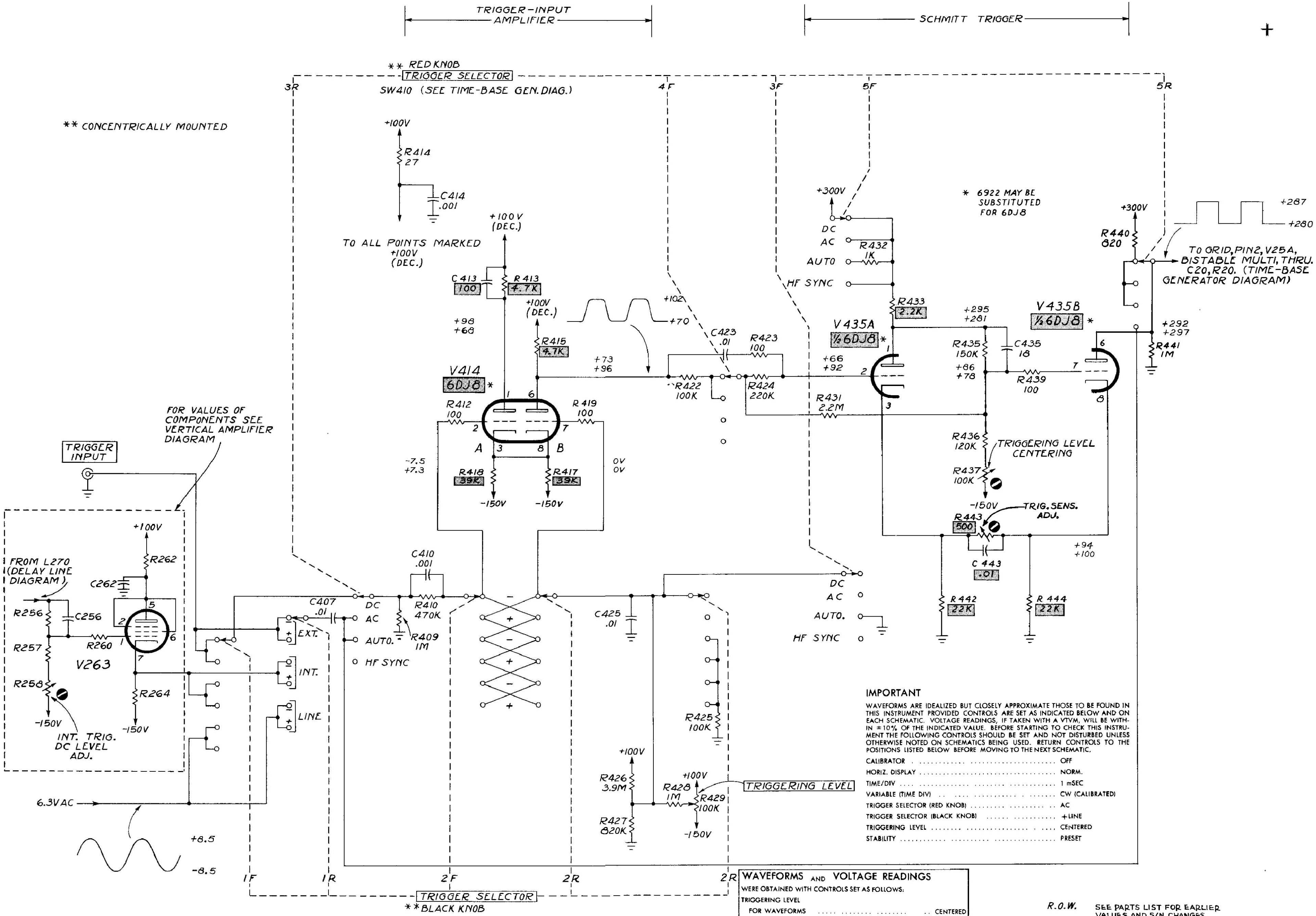
R.O.W.
5-8-61






TIME/DIV. SWITCH & VARIABLE CONTROL

Right-side view, rotated 30 deg.




## IMPORTANT

WAVEFORMS ARE IDEALIZED BUT CLOSELY APPROXIMATE THOSE TO BE FOUND IN THIS INSTRUMENT PROVIDED CONTROLS ARE SET AS INDICATED BELOW AND ON EACH SCHEMATIC. VOLTAGE READINGS, IF TAKEN WITH A VTVM, WILL BE WITHIN ±10% OF THE INDICATED VALUE. BEFORE STARTING TO CHECK THIS INSTRUMENT THE FOLLOWING CONTROLS SHOULD BE SET AND NOT DISTURBED UNLESS OTHERWISE NOTED ON SCHEMATICS BEING USED. RETURN CONTROLS TO THE POSITIONS LISTED BELOW BEFORE MOVING TO THE NEXT SCHEMATIC.

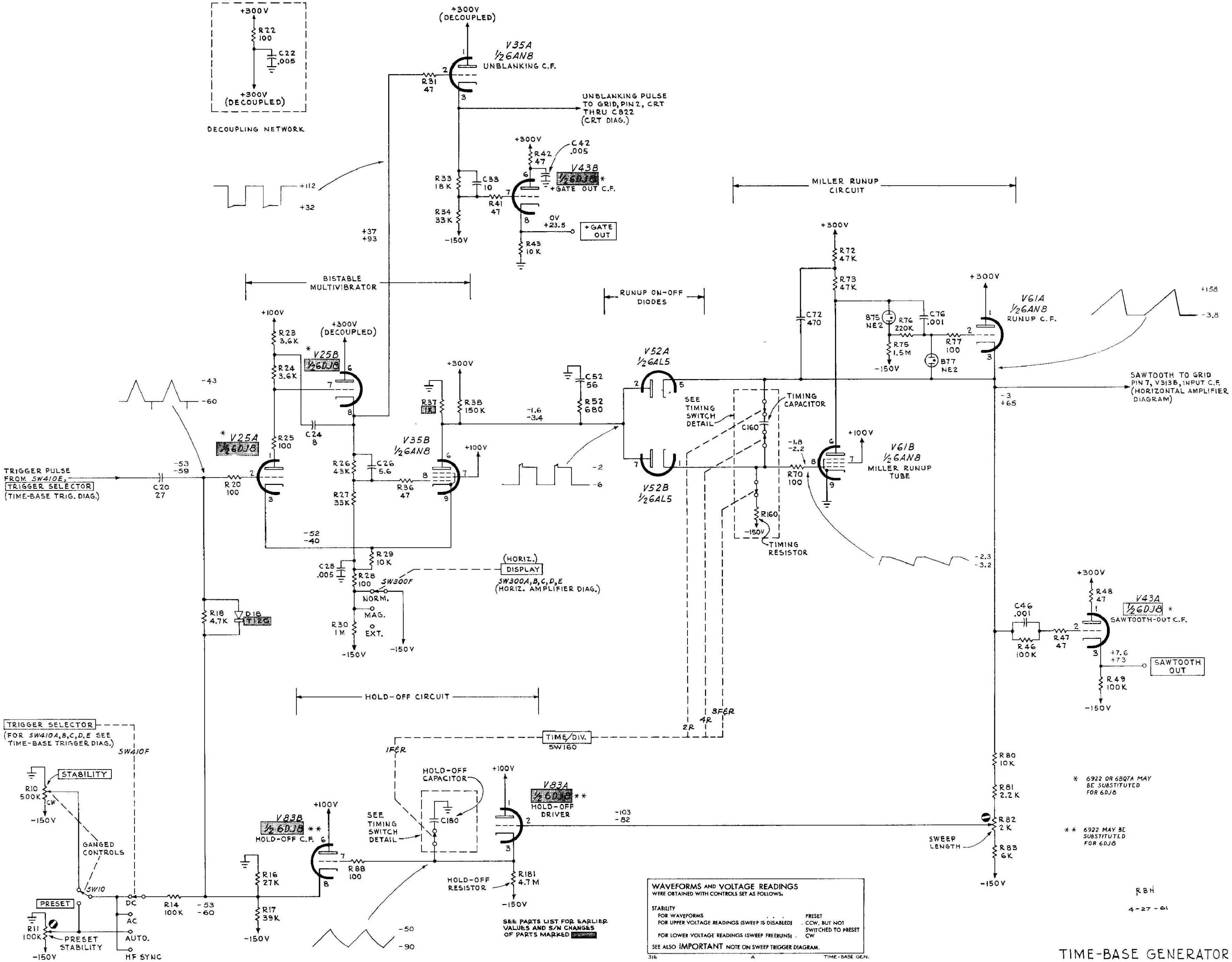
CALIBRATOR .......... OFF
HORIZ. DISPLAY .......... NORM.
TIME/DIV .......... 1 mSEC
VARIABLE (TIME DIV) .......... CW (CALIBRATED)
TRIGGER SELECTOR (RED KNOB) .......... AC
TRIGGER SELECTOR (BLACK KNOB) .......... +LINE
TRIGGERING LEVEL .......... CENTERED
STABILITY .......... PRESET

**WAVEFORMS AND VOLTAGE READINGS**
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
TRIGGERING LEVEL
FOR WAVEFORMS .......... CENTERED
FOR UPPER VOLTAGE READINGS .......... CCW
FOR LOWER VOLTAGE READINGS .......... CW
SEE ALSO **IMPORTANT** NOTE ON THIS DIAGRAM.

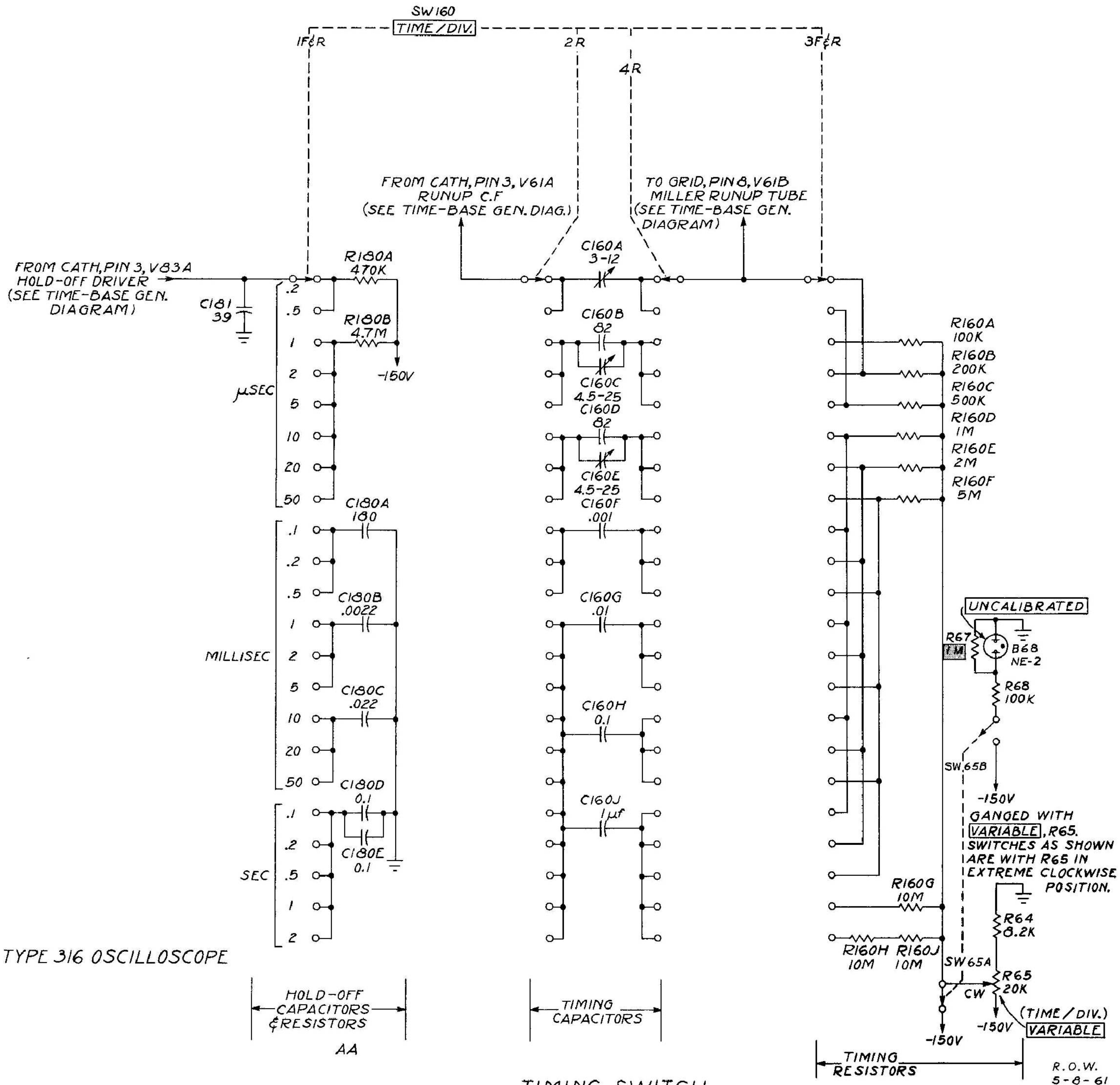
R.O.W.
5-8-61

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

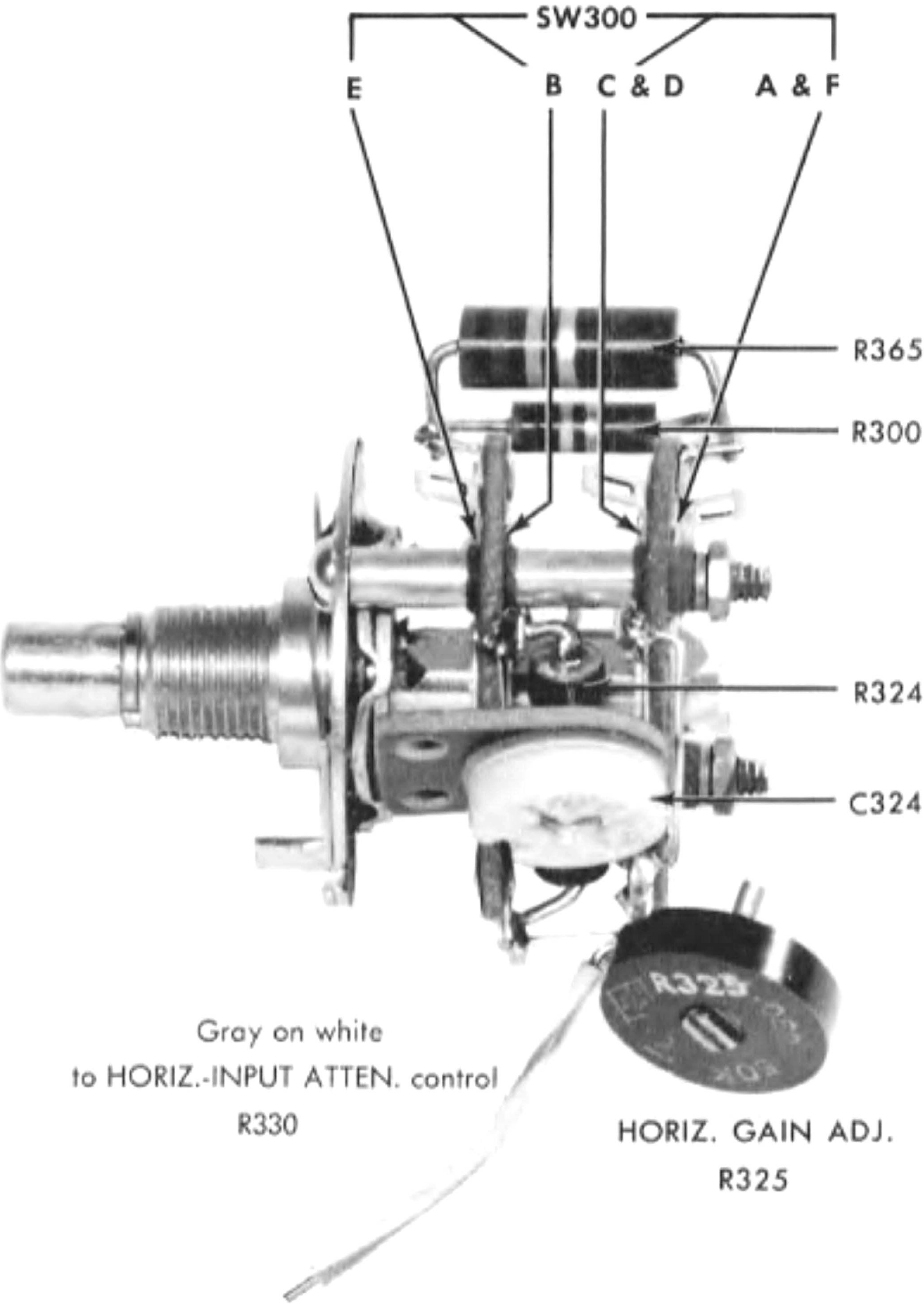
# TIME-BASE TRIGGER




# TIME-BASE GENERATOR

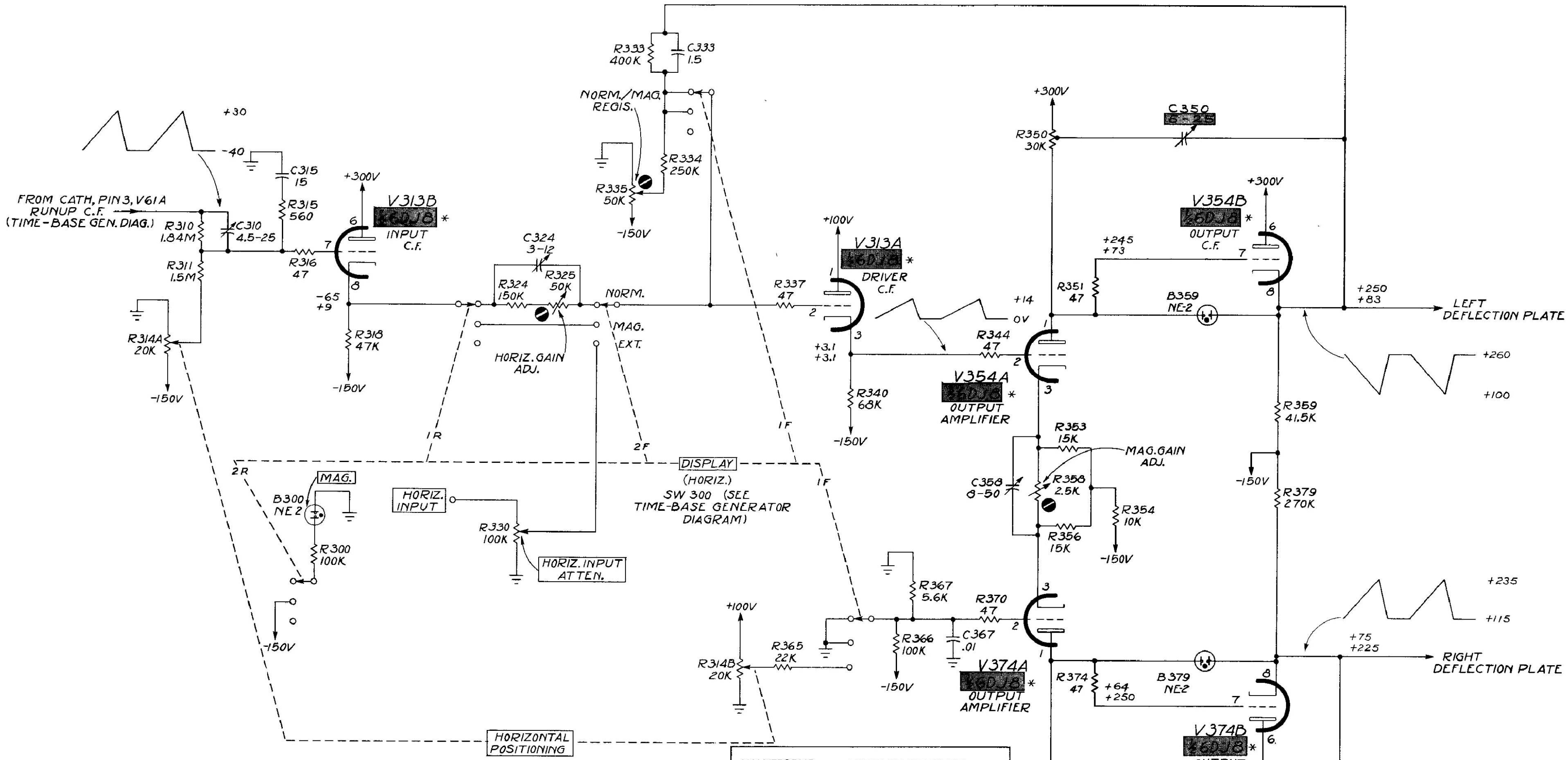



TIMING SWITCH
(TIME / DIV.)




## DISPLAY SWITCH

Right-side view, rotated 45 deg.




TYPE 316 OSCILLOSCOPE

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

**WAVEFORMS** AND **VOLTAGE READINGS**

WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

| | |
|---|---|
| EXT, HORIZ. INPUT | NONE |
| HORIZ. DISPLAY | |
| FOR WAVEFORMS | NORM. |
| FOR VOLTAGE READINGS | EXT. |
| HORIZONTAL POSITION | |
| FOR UPPER VOLTAGE READINGS | CCW |
| FOR LOWER VOLTAGE READINGS | CW |

SEE ALSO **IMPORTANT** NOTE ON TIME-BASE TRIGGER DIAGRAM.

316 A HORIZ AMP

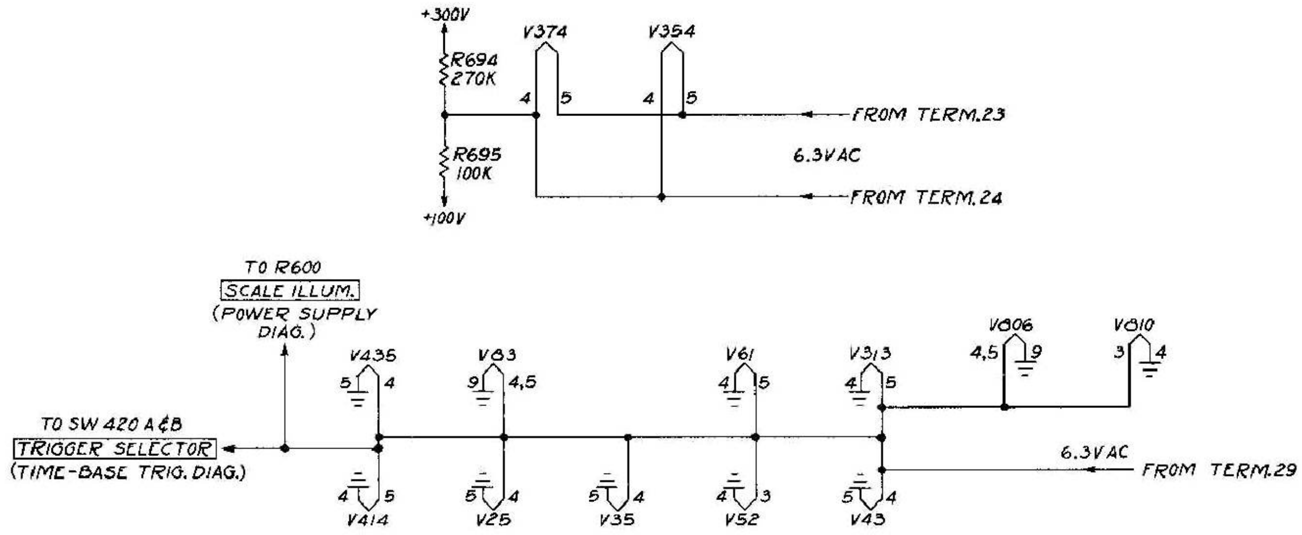
* 6922 OR 6BQ7A MAY BE SUBSTITUTED FOR 6DJ8

R. O. W.

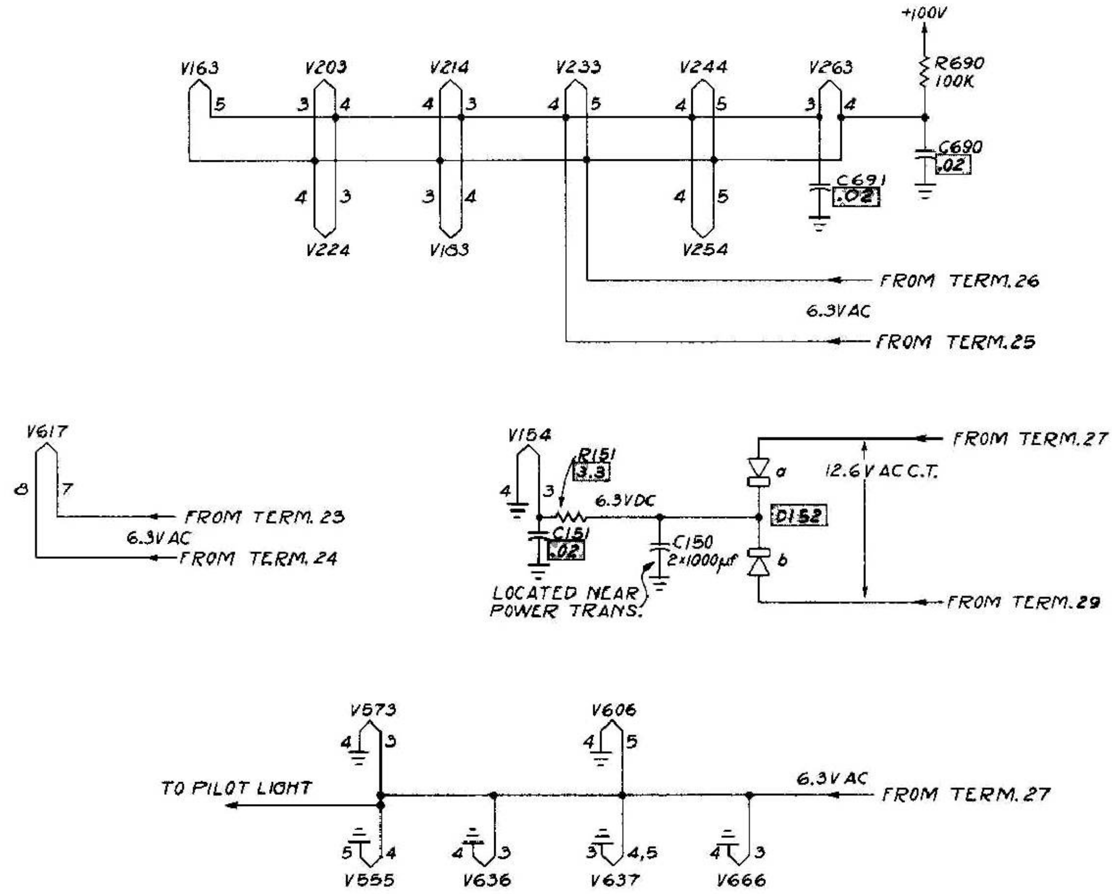
5-5-61

# HORIZONTAL AMPLIFIER

AA




TIME - BASE DECK



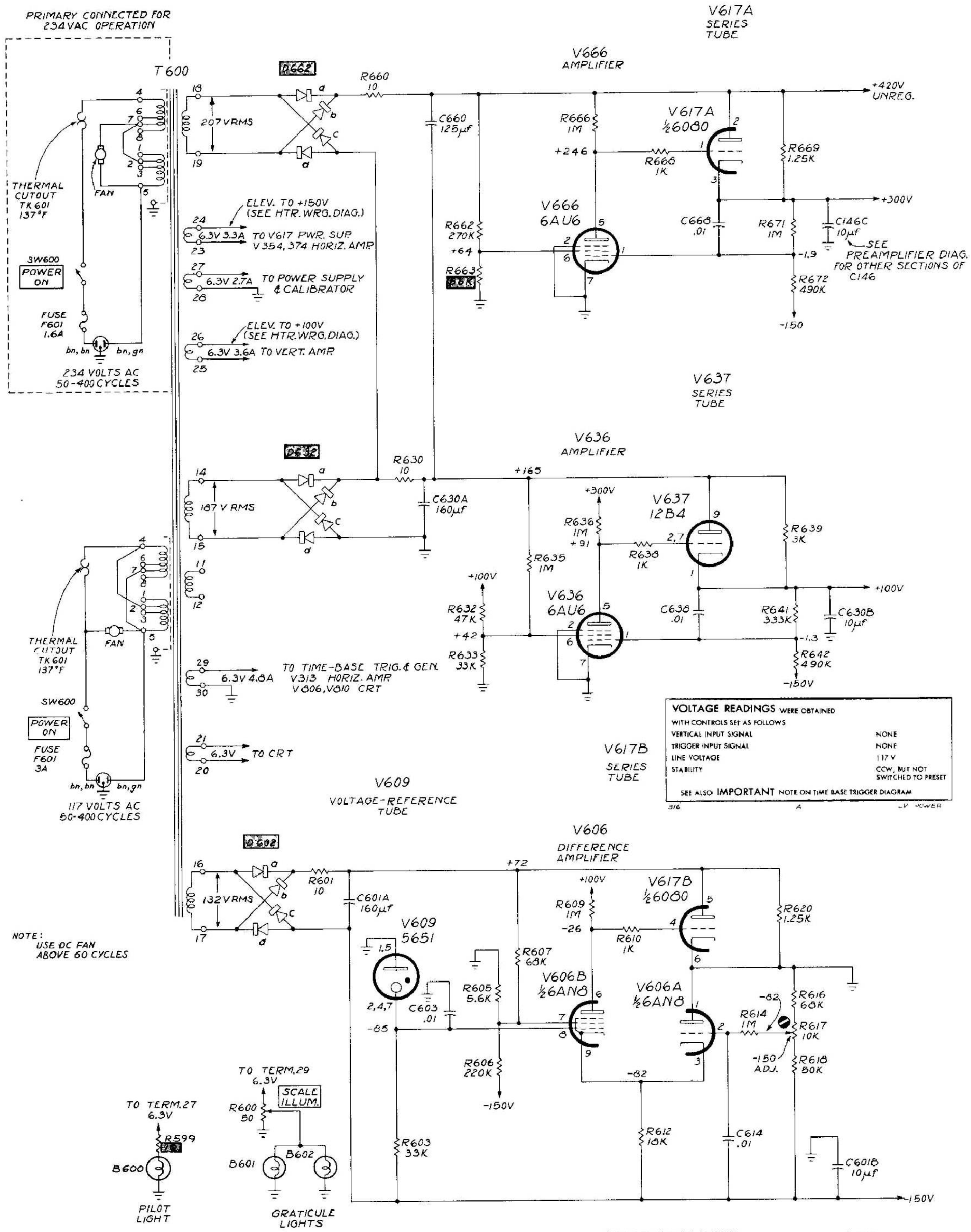

POWER DECK

R.O.W

5-5-61

TYPE 316 OSCILLOSCOPE

# HEATER WIRING DIAGRAM




SEE PARTS LIST FOR EARLIER VALUES AND S/N CHANGES OF PARTS MARKED [redacted]

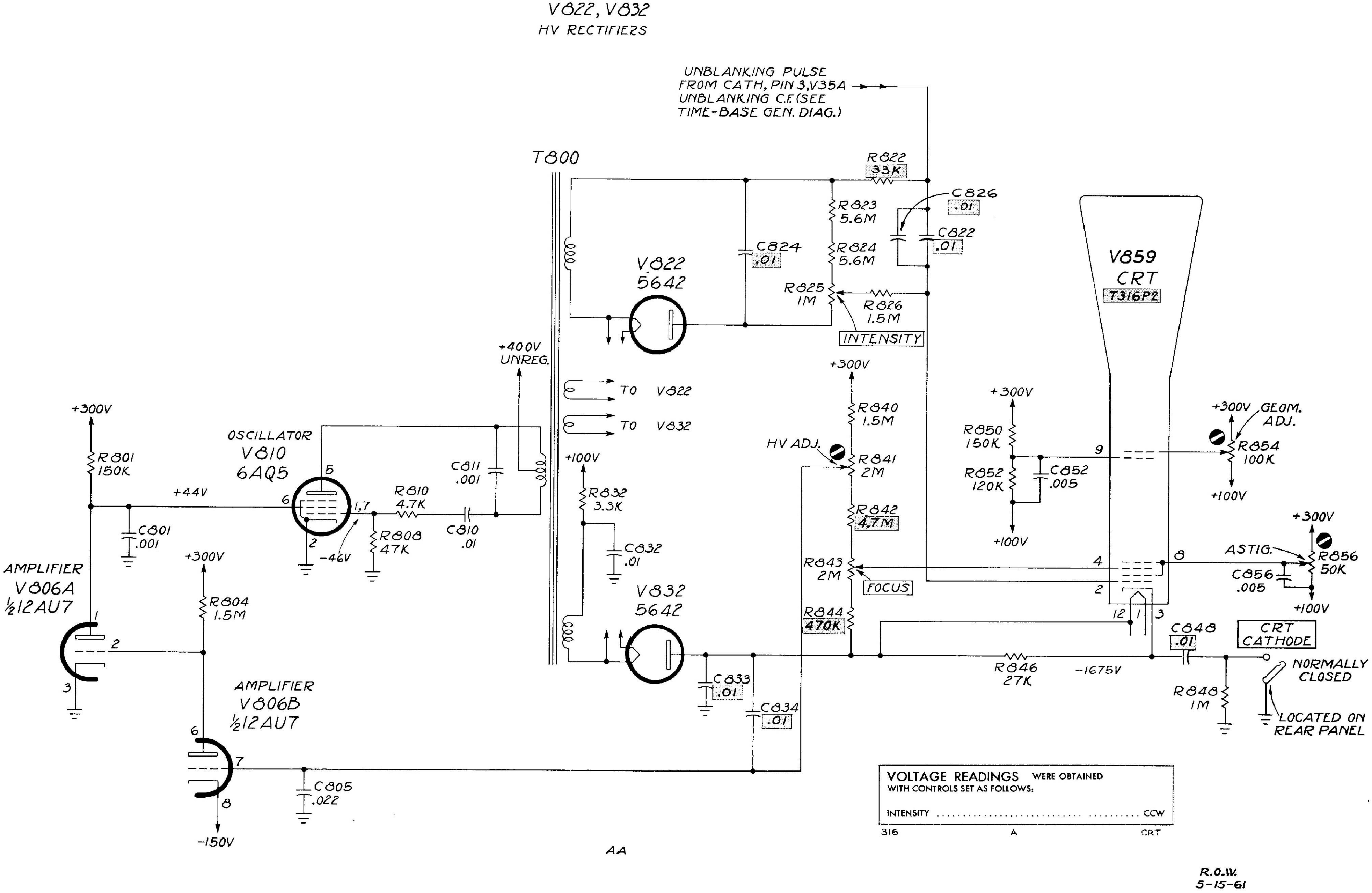
R. O. W.

5-5-61

TYPE 316 OSCILLOSCOPE

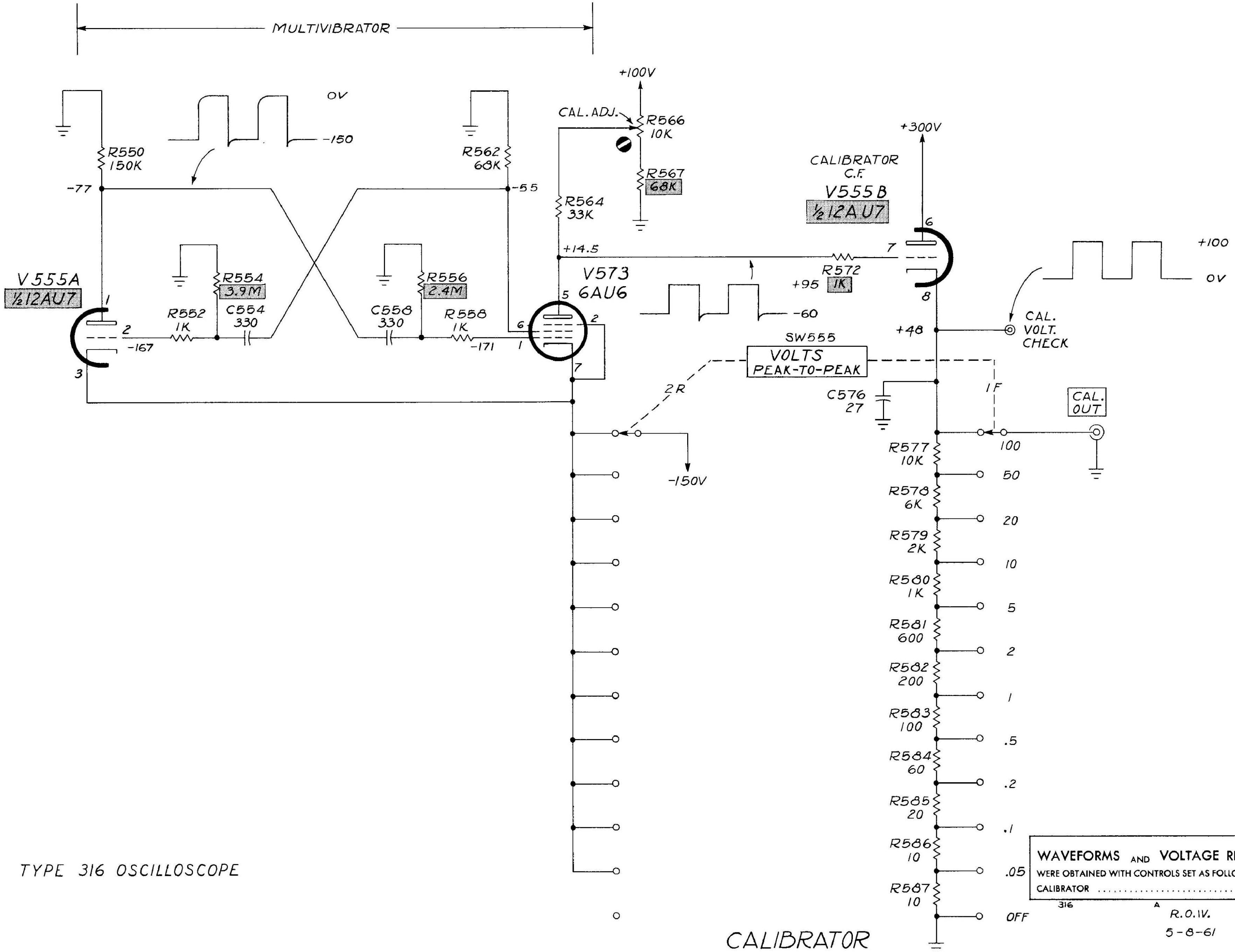
AA

LV POWER SUPPLY




TYPE 316 OSCILLOSCOPE

CRT CIRCUIT




TYPE 316 OSCILLOSCOPE

CALIBRATOR

WAVEFORMS AND VOLTAGE READINGS
WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:
CALIBRATOR .................................... ON

316 A CALIB

R.O.IV.
5-8-61

AA