

CATHODE-RAY OSCILLOSCOPE TYPE 315

INSTRUCTION MANUAL



TEKTRONIX, INC.

MANUFACTURERS OF CATHODE-RAY AND VIDEO TEST INSTRUMENTS

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TYPE 315 SERIAL NUMBER _____

IMPORTANT

Include the INSTRUMENT TYPE and SERIAL NUMBER in any correspondence regarding your instrument. Your help in this will enable us to answer your questions or fill your order with the least delay possible.

NOTE

This instruction manual has been prepared to cover TEKTRONIX Type 315 Oscilloscopes of all serial number ranges. Text, diagrams, and parts lists have been expanded to incorporate all circuit modifications adopted during the course of manufacture. The serial ranges of instruments to which various modifications were applied before shipping from the factory have been noted wherever necessary.

However, because many instruments have been modified in the field and out of serial sequence, component values and circuitry of a given instrument may differ considerably from those indicated in this manual for its serial number. The user is urged, therefore, to enter whatever changes may be necessary to bring this manual into agreement with the present circuitry of his oscilloscope.

When ordering parts, always include the following information: 1. Instrument Type (315). 2. Instrument Serial Number (as, SN 9999). 3. Part Circuit Number (as, R999). 4. Part Description (value, type, rating, tolerance, etc.). 5. The 6-digit TEKTRONIX part number (as, 999-999).

Replacement parts will be billed at current net prices and shipped prepaid by air to any point within the continental United States or Canada.

All price revision and design modification privileges reserved.



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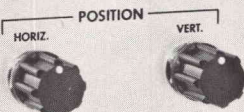
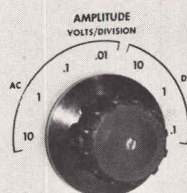
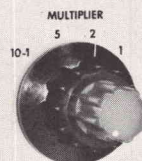
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TYPE 315 D CATHODE-RAY OSCILLOSCOPE

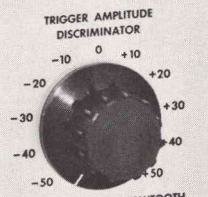
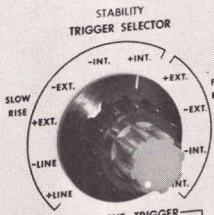
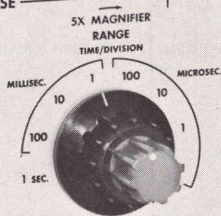


INPUT
1 MEG. 35 MMFD.
600 V. MAX.

VERTICAL
AMPLIFIER



TIME BASE



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

SECTION 1 DESCRIPTION

The Tektronix Type 315D cathode-ray oscilloscope is a small compact and portable high-performance laboratory instrument particularly designed to occupy minimum space. The vertical bandwidth extends to five megacycles from dc. Time-base ranges extending from one microsecond per sweep to fifty seconds per sweep are provided. An amplitude calibrator and a time-base magnifier are also included.

SPECIFICATIONS

Sensitivity

Twelve calibrated fixed sensitivities: ac only, 0.01, 0.02 and 0.05 volts per division, 5 cycles to 5 megacycles: dc and ac 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, and 50 volts per division. These sensitivities fit graticule divisions for direct reading of voltages. Continuously variable 10 to 1 sensitivity multiplier control also available.

Calibrator

Square wave at approximately one kilocycle available at front-panel UHF connector at four fixed peak-to-peak voltages of 0.1, 1, 10, and 100 volts with accuracy within 3 per cent.

Signal Delay

Quarter-microsecond signal delay line permits all of the triggering waveform to be viewed.

Trigger Amplitude Discriminator

Permits time base to be triggered at any desired amplitude point on the triggering waveform.

Time Base

Twenty-four fixed times per division between 0.1 microsecond and 5 seconds per division fit graticule divisions for direct reading of time. Continuously variable 10 to 1 sweep-time control also available.

Time Base Magnifier

Magnifies time base to right and left of center by factor of five times. Portion of trace appearing at center is made five times as wide.

Direct-Coupled Unblanking

Accommodates slowest sweeps.

Cathode-Ray Tube

Flat-faced high definition three-inch tube.

Graticule

Quarter-inch divisions, 8 lines vertically, 10 lines horizontally. Variable intensity edge lighting.

Power Supply

Four electronically regulated plate-voltage supplies. Power transformer will operate on either 117 or 234 volts, 50 to 800 cycles. (Special ventilating fan required for other than 50-to 60-cycle operation).

CRT Accelerating Voltage

1850 volts (for serial numbers below 350) or 1500 volts (for serial numbers above 350) from electronically regulated rf oscillator high-voltage supply.

Ventilating Fan

The Type 315D is normally supplied with a 50- to 60-cycle induction-motor fan. For frequencies much above 60 cycles a dc commutator motor and selenium rectifier are available at extra cost to extend the range to 800 cycles.



Dimensions

12 3/8" high, 8 5/8" wide and 18 1/4" long.

Weight

36 pounds.

Construction

Welded aluminum alloy.

Finish

Anodized photo-etched aluminum panel, blue wrinkle enamel case.

FUNCTIONS OF CONTROLS AND CONNECTORS

MULTIPLIER	Four-position switch to multiply VOLTS/DIVISION by factors of 1, 2, or 5. Fourth position marked 10-1 in red permits red coaxial knob to adjust multiplier continuously over 10 to 1 range.
INPUT	Coaxial UHF connector for connecting signal to vertical-deflection system.
AMPLITUDE	Seven-position control provides four fixed ac sensitivities and three fixed dc sensitivities.
FOCUS	Adjusts voltage of focusing anode to provide focusing.
INTENSITY	Adjusts control-grid voltage to control brightness of trace.
SCALE ILLUM	Adjustable series resistor in graticule lighting circuit to control amount of scale illumination.
POSITION HORIZ.	Adjusts voltages between horizontal deflection plates to position trace horizontally.
VERT.	Adjusts voltages between vertical deflection plates to position trace vertically.
TIME BASE MULTIPLIER	Four-position switch to multiply time-base TIME/DIVISION by factors of 1, 2, or 5. Fourth position marked 10-1 in red permits red coaxial knob to adjust multiplier continuously over 10 to 1 range.
RANGE	Eight-position switch provides eight fixed time base times per division in decade ratio between 0.1 microsecond per division to 1 second per division.
5X MAGNIFIER (Red label, red knob)	Two-position switch turns time-base magnifier on in clockwise position, returns time base to normal in counterclockwise position.
CALIBRATOR	Five-position switch selects four fixed peak-to-peak squarewave voltages of 0.1, 1, 10, or 100 volts. Turns calibrator oscillator off in fifth position.
TRIGGER SELECTOR	Ten-position switch selects trigger source and accommodates trigger circuits to rising or falling trigger waveforms. Accommodates trigger circuits to fast-rising or slow-rising triggering waveforms.



STABILITY
(Red label, red knob)

Adjusts voltages of gating multivibrator so that it can be set for recurrent operation or at the threshold of recurrent operation for triggered sweeps.

TRIGGER
AMPLITUDE
DISCRIMINATOR

Continuously variable voltage control determines point of operation of trigger inverter stage to select point on triggering waveform at which time-base circuit is tripped.

POWER ON

AC supply off-on toggle switch.

CAL OUT

Coaxial UHF connector for output of calibrator oscillator.

EXT TRIGGER
AC Binding Post

Connects to EXT. positions of TRIGGER SELECTOR switch through capacitor.

DC Binding Post

Connects directly to EXT. positions of TRIGGER SELECTOR switch.

+GATE

Binding post provides 25-volt positive gating pulse coincident with time base.

SAWTOOTH

Binding post provides positive-going sawtooth voltage coincident with time base.

GND.

Binding post connected to frame of instrument.



SECTION 2 OPERATING INSTRUCTIONS

PRELIMINARY INSTRUCTIONS

The Tektronix Type 315D Oscilloscope may be operated in any indoor location or in the open if it is protected from moisture.

Ventilation

Forced-air cooling is required so that care must be taken to avoid obstructing the air intake to the circulating fan.

WARNING: The Type 315D Oscilloscope should not be operated unless the fan is running. The interior will reach dangerous temperatures within five to ten minutes of such operation.

Introduction

The operation of the calibrator and the trigger circuits of the Type 315D oscilloscope is different enough that it is especially important for users familiar with previous Tektronix oscilloscopes to understand the difference.

The vertical amplifier is sufficiently stable that once the gain has been standardized, voltages can be read directly from the graticule just as you would read a voltmeter. For this reason, the calibrator in the Type 315D is not continuously variable in amplitude as are the calibrators in previous Tektronix oscilloscopes. The calibrator is intended to be used as a source of squarewave voltage, operating in the vicinity of one kilocycle, available at four accurate fixed voltage levels, 0.1, 1, 10, and 100 volts, peak-to-peak. It is useful to supply a signal for aligning the vertical amplifier, and the attenuator and probe, as well as for standardizing the gain of the vertical amplifier to the graticule calibrations.

To check the calibration of the vertical amplifier, make a connection between the CAL OUT terminal and the INPUT terminal. Then, for example, set the VERTICAL AMPLIFIER MULTIPLIER selector to 2, the AMPLITUDE selector to DC, 0.1, and the CALIBRATOR to 1 volt, peak-to-peak. With these settings, there should be exactly five graticule divisions deflection of the trace. The amplifier gain can be corrected for any difference by means of a screwdriver adjustment in the center of the AMPLITUDE selector switch.

Amplitude Measurements

To use the Type 315D for making an amplitude measurement, place the AMPLITUDE selector in the approximate range of sensitivity desired, and the MULTIPLIER selector on any one of the three steps, 1, 2, or 5. Each division of the graticule then corresponds to a voltage which can be determined directly by multiplying the AMPLITUDE and the MULTIPLIER scale readings.

In the most counterclockwise position of the MULTIPLIER selector, a continuously-variable gain is provided over a range of 10 to 1, marked in red. In this selector position, varying the red knob mounted coaxially with the AMPLITUDE selector knob varies the gain over the 10 to 1 range.

In addition to the coaxial red knob on the AMPLITUDE selector switch, there are three other red knobs mounted in a like manner on the TIME BASE and TRIGGER controls. In each case, a red scale on the panel pertains to the position or to the function of the red knob.



Trigger Amplitude Discriminator

In the operation of the time base of the Type 315D oscilloscope, the TRIGGER AMPLITUDE DISCRIMINATOR control is likely to be somewhat confusing to users familiar with previous Tektronix instruments. This control is not in any sense a trigger amplitude adjustment. The triggering circuit is direct coupled to the vertical amplifier in the INT positions of the TRIGGER SELECTOR switch, both for the AC and DC connections of the vertical amplifier and is direct coupled to one of the EXT TRIGGER panel connectors. The TRIGGER AMPLITUDE DISCRIMINATOR control determines by amplitude the portion of the triggering waveform at which triggering occurs. At settings of the DISCRIMINATOR control near zero, triggering will occur at a point on the trace above the center of the screen. Regardless of the amplitude of the waveform, triggering will occur at a point on the trace the same distance above the center of the screen, provided that the wave reaches that amplitude. The negative trigger positions of the TRIGGER SELECTOR control refer to the direction of slope of the triggering waveform at which triggering occurs. For example, to trigger the sweep from a sine wave at a point beyond the peak but above zero, the TRIGGER SELECTOR should be placed in one of the negative trigger positions and the TRIGGER AMPLITUDE DISCRIMINATOR should be turned to a positive position.

For slow rise signals whose rise time is longer than one microsecond, the TRIGGER SELECTOR should be placed in one of the SLOW RISE positions of the scale. In these positions of the control, a regenerative trigger generator produces sharp triggers suitable for initiating the sweep regardless of the rise time of the input wave. For the FAST RISE positions, the trigger generator is not regenerative and is capable of producing faster triggers so that for high frequency or fast rise time signals, the TRIGGER SELECTOR switch should be in one of these positions. The best way to determine which position is proper for a marginal type of signal is to try both positions. There is appreciable overlap.

Generally speaking, there is no difference in trigger sensitivity in the different control positions. A change in voltage which will produce a quarter of a division deflection, will easily initiate a trigger at any speed or in any part

of the wave. For a small amplitude wave, the TRIGGER DISCRIMINATOR control will need to be set near zero. With settings near maximum either clockwise or counterclockwise, a large trace will be required to initiate a sweep and the point of initiation will be near the top or bottom of the waveform.

Calibrations on the DISCRIMINATOR dial are approximately in volts for externally connected trigger voltages. For internally derived triggers, approximately seven divisions on the DISCRIMINATOR scale correspond to about ten graticule divisions of deflection.

The magnifier circuit expands to right and left the portion of the trace that is centered on the screen. Horizontal positioning precedes the magnifier circuits so that this control is used for both the normal and magnified trace.

First Time Operation

The following procedure is suggested when you put the instrument into service for the first time:

1. Set the panel controls as follows:

POWER OFF

VERTICAL AMPLIFIER MULTIPLIER. . . 2

VERTICAL AMPLIFIER AMPLITUDE.....
DC, 0.1 VOLTS/DIVISION

FOCUS. CENTER

INTENSITY COUNTERCLOCK-
WISE

SCALE ILLUM CENTER

HORIZ. POSITION. CENTER

VERT. POSITION CENTER

TIME BASE MULTIPLIER 1

TIME BASE RANGE 1 MILLISEC.

CALIBRATOR 1 VOLT

TRIGGER SELECTOR SLOW
RISE, + INT.



STABILITY COUNTERCLOCK-
WISE

TRIGGER AMPLITUDE
DISCRIMINATOR --50

2. Connect the power cord to a source of ac power capable of supplying 4 amperes at 117 volts at 60 cps. (240 volts if power transformer is so connected, and 50 to 800 cps for the universal-frequency model.)
3. Make a connection between the CAL OUT terminal and the INPUT terminal. Turn the POWER switch to ON, and permit the instrument to warm up for about a minute.
4. Advance the INTENSITY control clockwise a little past center.
5. Advance the STABILITY control until a trace appears on the screen.
6. Adjust the FOCUS and INTENSITY controls for a sharp trace and satisfactory brightness.
7. Adjust the two POSITION controls until the trace is centered on the screen as desired.
8. Return the STABILITY control clockwise until the trace just disappears and return the TRIGGER AMPLITUDE DISCRIMINATOR control clockwise toward 0 until the calibrator waveform appears on the screen.

The stability control determines whether the multivibrator retriggers itself or whether it returns to a stable condition after executing a

single sweep for each trigger received.

In the SLOW RISE positions of the TRIGGER SELECTOR switch the regenerative trigger generator produces triggers of the same amplitude when tripped regardless of the amplitude or speed of the triggering waveform. The STABILITY control should therefore be set at such a level that a trigger output of this amplitude will trigger the sweep and thereafter no change in the STABILITY control setting will be needed. The trigger sensitivity is the voltage difference needed to trip the regenerative trigger generator, which is determined by the gain between halves of this generator. There is no front-panel control of this gain, but there is an internal screwdriver adjustment which should not be changed, however, except possibly after replacing the generator tube.

In the FAST RISE positions of the TRIGGER SELECTOR switch regeneration between the halves of the trigger-generator tube is effectively removed by shorting out the plate-load resistor of the input pentode section. Since the circuit thus becomes a cathode-coupled amplifier, the amplitude of the output triggers is dependent on the differentiated rise of the triggering waveform. For slow-rising waveforms, therefore, the output trigger will be too small to trip the time-base generator. The point of transition at which better triggering will result from one or the other of the switch positions is not critical. For risetimes near one microsecond it will be well to try both types of operation. Triggering from the calibrator waveform will be more satisfactory with the TRIGGER SELECTOR switch in the SLOW RISE positions.

TRIGGERING INSTRUCTIONS

Trigger Amplitude Discriminator

1. The proper setting of this control is rather critical on trigger signals with fast rise or fall, such as square waves. Turn the control slowly and carefully. You will find the triggering unusually stable once this adjustment is made properly.
2. Set the control near zero for small signals.
3. This control is not an adjustment of trigger

sensitivity. It selects the level on the triggering signal at which triggering will take place. A control setting to the right or left of zero center will require a larger trigger signal than a setting near zero.

4. The + signs to the right and - signs to the left indicate relative voltage levels, above or below zero for dc positions of the TRIGGER SELECTOR, above and below the average for ac settings of the TRIGGER SELECTOR.



Trigger Selector

1. The + and - signs on this switch indicate the direction of slope of the triggering voltage at which triggering will occur, + for triggering during the rising part, or positive slope of the signal, and - for the falling part, or negative slope of the signal.
2. SLOW RISE positions of the selector provide a sharp trigger signal to trigger the time base when the trigger voltage passes the level set by the discriminator in the direction selected by the selector, no matter how slowly it passes this level.
3. FAST RISE positions of the selector require a fast rise (or fall) of the triggering signal to trigger the time base.

Stability

This control sets the time-base circuit so that it will run either recurrently or triggered. For triggered operation this control should be set just left of the point of recurrent operation.

Once it is set for a given time-base speed, it does not need to be reset for a wide range of trigger signals. It is not a trigger sensitivity control. Trigger sensitivity is determined by the gain of the trigger amplifier tube, which is essentially constant. The trigger amplifier gain is adjustable only by an internal screwdriver control, and will rarely need readjustment.

How to Trigger the Time Base

For a triggered sweep, first select the speed of time-base and set the TRIGGER AMPLITUDE DISCRIMINATOR clockwise.

Then adjust the STABILITY control just left of setting that gives recurrent sweeps.

Then set the TRIGGER SELECTOR for the desired source and slope of trigger voltage.

Finally, adjust the DISCRIMINATOR carefully near the expected voltage of triggering (very frequently near zero) until a triggered sweep occurs.



SECTION 3

CIRCUIT DESCRIPTION

SWEEP CIRCUIT

The time base of the TYPE 315 CATHODE-RAY OSCILLOSCOPE is generated by means of a Miller runup generator. New circuitry eliminates the usual distortion of the early part of the sawtooth. A constant current charging source to the timing capacitor improves the sawtooth linearity.

The triggering signal is selected by means of the TRIGGER SELECTOR switch connected to the B section of the cathode-coupled phase inverter, V201, with a gain of about six at each plate. The A section grid is connected to the arm of a potentiometer so that its bias can be varied over a wide range. By adjusting the bias properly you can select the portion of the triggering waveform that triggers the sweep.

A second section of the trigger selector switch connects the output of B-section plate to the trigger generator, V202, for negative-going triggering waveforms and the A section plate for positive-going triggering waveforms.

The trigger generator consists of V202, as a bistable multivibrator for slow-risetime trigger signals, and as a cathode-coupled amplifier for fast-risetime trigger signals. For signals with a risetime slower than one microsecond, the multivibrator circuit will provide the best trigger signal. In the SLOW RISE positions of the TRIGGER SELECTOR switch, SW201, C227 connected between the triode-section grid and pentode-section plate of V202 provide the regeneration. For faster rising trigger signals, the FAST RISE positions of the switch effectively removes the regeneration by shorting out plate-load resistor R220 in the pentode section of V202. V202 thus becomes a cathode-coupled amplifier.

Trigger output voltage is taken from the plate of the triode section of V202. The plate load is inductor-resistor differentiating circuit, L221, R221, so that a reasonably fast transition is required to develop large enough triggers to operate the sweep circuit. The multivibrator performs this fast transition for triggering waves otherwise too flat. It will perform a regenerative transition in either direction for slowest rise-time signals.

The sharp trigger signal is capacitance coupled into V203, a cathode-coupled stage whose output is direct coupled through cathode follower V204A to the junction of the plate of V211A and the cathode of V211B of the cascode Eccles-Jordan multivibrator. A positive signal on the B section grid of V203 is required to trigger the multivibrator. The B section of V203 is also connected to a bias-control potentiometer called STABILITY which sets the dc level.

V204B, and V205A and B surrounding V204A comprise a hold-off circuit. The function of the hold-off circuit is to reduce the voltage on the grid of the triggering cathode follower, V204A, during the sweep and for a short period after the multivibrator has recovered. V205B performs this function. During the sweep, V205B conducts so that its plate drops. At the termination of the sweep, V205B is cut off and its plate rises toward 225 volts positive. A switched capacitor between plate and ground delays this rise toward + 225 volts during the charge period, depending on the size of the capacitor. When the plate of V205B reaches 100 volts positive it is clamped to this voltage by diode-connected V205A. The trigger amplifier is so designed that it will trigger the multivibrator only when its plate is in the vicinity of 100 volts, so that triggering is held off during the rise period of the plate of V205B.



V211 and V212 comprise the cascode Eccles-Jordan multivibrator. The left-hand side of this multivibrator, V211A and B are normally conducting. Triggering is accomplished when a positive trigger through V203 to cathode follower V204A causes it to divert current from the upper half of V211, so that the plate rises. The positive step at V211B plate is coupled through cathode follower V210B to the grid of the opposite lower side of the multivibrator, V212B, and the multivibrator flops over with conduction on the right-hand side. Cathode follower V210B acts as a buffer between the plate of V211B and all other external loads so that the only additional capacitance is that added by the input capacitance of the cathode follower. This permits the plate to execute a much more rapid rise. The cathode follower drives the opposite side of the multivibrator, the unblanking cathode follower, the hold-off tube, V205B, and the gate output cathode follower, V214A.

The sweep is gated by the negative-going portion of the multivibrator, V212A and B. The plate of V212A is connected to the grid of the cathode-follower-connected pentode section of V214 through a speed-up capacitor. The cathode of this cathode follower holds the grid of V220 at about -3 volts through diode V215 during the quiescent state of the multivibrator. The negative step from the multivibrator cuts off the cathode follower and the cathode falls, disconnecting the grid of V220 through diode V215. V220 is the Miller tube time base generator. When the grid is freed from V214B cathode, it immediately begins to drop and the plate begins to rise. The plate of V220 is coupled back to the grid through a cathode follower (V221A before S/N 351, V212A after S/N 351) and the timing capacitor, and a Miller runup commences. When the plate has risen to the vicinity of 200 volts, the grid of cathode follower V213B has risen to about 100 volts so that current begins to flow in this tube which diverts current from the upper right section of the multivibrator, V212A, and the multivibrator reverts to the initial state with the left-hand side conducting. When V212A plate rises, it carries the grid of V214B with it causing diode V215B to conduct and the Miller grid to rise to -3 volts so that the plate drops again to the starting position.

The additional circuitry around the Miller tube and direct-coupled Eccles-Jordan multivibrator is provided to raise the maximum sweep speed and to eliminate the usual distortion of the saw-

tooth at the beginning of the Miller runup action.

Since the multivibrator has no timing-circuit components its recovery time of about 1 microsecond is dependent largely on tube and wiring capacitance, and is therefore more or less constant over the entire range of time bases. For the longer time bases, as much as a millisecond is required to discharge the timing capacitor, so that circuitry is needed to prevent the multivibrator from being triggered before the Miller tube has returned to its quiescent state. The required hold-off function is produced by lowering the plate return voltage of the trigger amplifier V203A for an adequate period after the time base termination. Furthermore, a sharp differentiated pulse must be derived from a triggering waveform to trigger the multivibrator so as to prevent the multivibrator from retriggering after the hold-off circuit has reached quiescence, in the presence of a sustained triggering waveform.

The circuit complication around the Miller tube removes the step from the start of the Miller runup. This is accomplished by means of a dc feedback to its grid, which causes an equilibrium point to be established where the plate of the Miller tube is resting at about 50 volts positive whenever the grid of the gating cathode follower, V214B, is held in a positive direction by the right-hand multivibrator, and the grid is at -3 volts. This is well within the class A region of the Miller tube, V220, where the plate voltage is directly proportional to the grid voltage. The relationship of 50 volts plate to -3 volts grid voltage is therefore determined by the grid to plate relationship of the Miller tube itself in the class A region of its operation. The actual grid voltage set by the voltage-divider cathode follower arrangement with V214B through disconnecting diode V215B and constant-current tube V213A, determines the starting voltage of the sawtooth. When diode V215B disconnects the Miller tube grid from the divider, constant-current tube V213A attempts to sustain the current, which it does by reducing its plate resistance, thereby pulling the Miller tube grid downward. During the period of the runup, the timing-capacitor charging current is kept essentially constant by action of the constant-current tube. The charging current remains constant within about a tenth of a per cent, but the time base is not this linear because of the variation of capacitance with voltage of the timing capacitors.



The sawtooth voltage is fed to the output amplifier through cathode follower V221A by means of a voltage divider so that horizontal positioning can be accomplished. Cathode follower V221B prevents grid current from flowing in the positioning circuit, and cathode follower V222A prevents grid current from flowing in the MAG-NORM feedback network. This network reduces the net gain of the horizontal amplifier by a factor of five in the NORM position, and permits the full gain to be realized when it is in the MAG position.

The horizontal-output amplifier stage is a cathode-coupled phase inverter with a cathode-follower coupler to each deflection plate. Use of the cathode followers to drive the deflection plates increases the horizontal bandwidth by a factor of about three times.

Magnifier

A degenerative network between the plate of V224B of the output amplifier to the grid of cathode follower V222A reduces the loop gain by a factor of five in the NORM position of the MAG-NORM switch. In the MAG position, the network is opened to permit the amplifier to operate at full gain. The MAG POSITION screwdriver control permits the dc level of the cathode follower to be set at the same value for both positions. Another screwdriver adjustment labeled MAG GAIN ADJ on the chassis permits the magnified time base to be made exactly five times the normal time base. The HORIZ POSITION control precedes the magnifier circuits and therefore positions for both the magnified and the normal time bases.

Vertical Amplifier

V1 is a twin-triode with the two sections operated in parallel. The signal is taken from the common cathode connection of V1 and applied to the cathode of V2A. V2A is operated as a grounded-grid amplifier. V2B is a cathode-follower output coupler between V2A plate and V3 grid. The preamplifier is used only on the AC, .01 VOLTS/DIVISION position of the AMPLITUDE selector switch. In this switch position, switch section SW1B connects the input terminal through C1 to the grid of V1A and B, and SW1C connects the cathode of cathode-follower V2B to the grid of V3 through a protective network. R15 is a screwdriver adjustable resistor to permit the preamplifier gain to be adjusted accu-

ately to ten times. L1 and L2 are peaking coils to improve high-frequency response.

V3 and V4 form a cathode-coupled gain-control stage. The signal is applied to the grid of V3 and coupled through the common unbypassed cathode connection to V4 which operates as a grounded-grid amplifier. The MULTIPLIER switch, SW2, connects any one of three resistor networks or a short circuit between the two cathodes to control the stage gain. In the X1 position, the cathodes are connected together and the gain is at a maximum. In the 10-1 position, an adjustable resistor is connected between cathodes to permit continuous adjustment of gain. R51 and R53 connected into the circuit in the other two positions of the switch are screwdriver adjustable to permit the gain to be adjusted to one-half or to one-fifth accurately so as to accommodate the gain to the calibrations of the graticule. R34 is a protective resistor which limits the positive excursion of V3 grid in case a high dc voltage is connected to the input connector in the dc position of SW1. C14 bypasses R34 at higher frequencies.

Plate output from V4 feeds through the delay network to the grid of V8B, a cathode-follower output-coupling tube. R521 terminates the delay network through C21 to ground. (C21 is physically located on a bracket underneath the delay-network assembly.) The delay network delays the vertical-deflection signal long enough to permit the portion of the waveform that has triggered the sweep to be displayed on the crt screen.

The output amplifier consists of V10 and V11 in parallel, in a cathode-coupled grounded-grid phase-inversion circuit with V12 and V13 in parallel. The dc grid voltage of V12 and V13 is used for vertical positioning. This voltage is controlled by V8A, a cathode-follower voltage regulator whose grid voltage is obtained from potentiometer R70, labeled VERT POSITION, connected between ground and +100 volts. R65 and R66 limit the positioning range.

R90, a part of the coupling between cathodes of V10, V11 and V12, V13, is a screwdriver adjustable resistor whose shaft is mounted coaxially with the AMPLITUDE control knob. This adjustment permits the gain of the amplifier to be accommodated to the calibrations of the graticule.



L3 in the grid circuit and L4, L5, L6, and L7 in the plate circuit provide frequency compensation.

An internal triggering signal connection from the plate of V3 to the trigger-selector circuits permits the sweep circuit to be triggered by the observed signal.

In all other positions of the AMPLITUDE control SW1, than the previously-described AC, .01 VOLTS/DIVISION position, the preamplifier is removed from the circuit, and the INPUT connector is connected to the grid of V3, either through attenuators, or unattenuated. In the AC portion of the control, C1 is connected in series with the INPUT connector. The grid of V4 is grounded, and V3 and V4 comprise a cathode-coupled grounded-grid amplifier.

The compensated input attenuators to the grid of V3 are voltage dividers in which parallel capacitor and resistor voltage dividers have the same division ratio. C3 in the 10-to-1 divider and C6 in the 100-to-1 divider permit adjustment to be made of the capacitive voltage division so that the high-frequency division ratio is the same as the low-frequency division ratio.

C2, C5, and C10 are adjustable so that the same input capacitance will exist at all AMPLITUDE switch positions. This is necessary when the probe is used because the probe is compensated for the input capacitance, and would otherwise need to be readjusted for each switch setting. C15 connected between grid of V3 and screen of V4 is a neutralizing capacitor that reduces the change in input capacitance that occurs when the MULTIPLIER switch inserts the various coupling resistors between cathodes of V3 and V4.

The MULTIPLIER switch, SW2, selects the amount of coupling between cathodes of V3 and V4 to determine the gain of the amplifier when the preamplifier is switched out. The VERT AMP DC BAL is a chassis-mounted screwdriver adjustable potentiometer connecting the cathodes of V3 and V4 to -150 volts. This control operates differentially. When it increases the resistance to the cathode of V3 it simultaneously decreases the resistance to the cathode of V4. When it is properly adjusted, the dc voltage at the two cathodes is the same and no change in vertical positioning occurs when the multiplier switch connects larger or smaller resistors between them.

CALIBRATOR

The calibrator provides four squarewave voltages of 100 volts, 10 volts, 1 volt and .01 volt, available at a UHF coaxial fitting on the front panel but not connected internally to the vertical amplifier. The source of squarewave voltage is a self-excited symmetrical ac-coupled multivibrator operating at a repetition frequency of about one kilocycle. The cathode and grids of this multivibrator are returned to -150 volts.

During the conducting period of V601B, the grid of V601A is below -150 volts and the A-section plate is cut off. V602B grid is directly connected to V601A grid and V602B plate is therefore also cut off during this period.

During the conducting period of the A section of V601, grids of V601A and V602B are both high and the plate of V602B is down below ground potential. The grid of cathode-follower V602A is directly connected to V602B plate, and it therefore varies between cutoff in the negative direction and a point near 100 volts in the posi-

tive direction, determined by voltage divider R610, R611, R612.

The cathode resistor of cathode-follower V602A is made up of a voltage-divider string, R620, R621, R622, R623, which are of such values that voltages of 10 volts, 1 volt and 0.1 volt, peak-to-peak, are produced at the taps when the cathode voltage is set at 100 volts, peak-to-peak.

R612, a screwdriver adjustment labeled CAL ADJ on the chassis, permits the grid of V602A to be set at such a level that the cathode will be at 100 volts when V602B is cut off. Since this portion of the circuit remains connected to the +225-volt supply when the CALIBRATOR switch is turned to the OFF position, the voltage calibration of the calibrator circuit can be checked with a dc voltmeter.

C603 in the grid circuit and C604 in the cathode circuit of the cathode follower reduce a small transient waveform distortion.



POWER SUPPLY

The power-supply transformer, T401, is capable of operating satisfactorily over the range of frequencies between 50 cps and 800 cps. The primary of this transformer is wound in two 117-volt sections, normally paralleled for 117-volt operation, but they are arranged to be easily reconnected in series for 234-volt operation.

Four selenium full-wave bridge rectifiers, each supplied with ac from a separate section of the transformer secondary, provide dc to four electronic voltage regulators from which are obtained the regulated voltages of -150 volts, +100 volts, +225 volts and +350 volts. In addition to these four regulated voltages, two unregulated voltage sources are provided, one at a nominal +330 volts from a tap taken ahead of the +225-volt regulator, the other at a nominal +420 volts taken from a tap ahead of the +350-volt regulator.

The regulator will regulate satisfactorily over a primary input-voltage range between 105 and 125 volts, or between 210 volts and 250 volts.

Five 6.3-volt secondary windings furnish heater power for the various parts of the instrument, and for the pilot light and graticule illumination.

Forced-air cooling is provided by a blower fan. Two fan types are available. If the Type 315D oscilloscope is to be used only on 50- to 60-cycle supply voltage, a 60-cycle fan is recommended, and is ordinarily supplied with the instrument. If higher frequencies of input voltage are to be used, however, a dc fan and rectifier are available at extra cost which will operate over the same range of frequencies that the transformer will.

Negative 150-Volt Regulator

The basic source of reference voltage is a type 5651 voltage-regulator gas diode, V401, in the cathode circuit of V402, a voltage-comparator tube. Voltage-divider string, R409, R410, R411, connected between regulated -150 volts and ground, is tapped at a voltage above -150 volts approximately equal to the voltage across the reference tube, V401, and connected to the

grid of V402. This sets the cathode and grid of V402 at approximately the same voltage, and any change in voltage at the -150-volt bus becomes a change in grid-to-cathode voltage at V402. This change is amplified in V402 and applied directly to the grids of V403 and V404, two series-regulator tubes connected together in parallel in the ground lead of the power supply. If the -150-volt bus tends to go negative below this voltage, for example, the cathode of V402 will drop thereby increasing V402 plate current. Increased plate current will lower V402 plate, which will pull down the grids of V403 and V404, thereby increasing their plate resistance, so that they insert a higher drop in the ground lead, and the -150-volt bus will rise in the direction to correct the original negative tendency. C404, bypassing R407, R409, and part of R410, improves the ac gain of the comparator circuit and reduces ripple. R410 is adjustable by a screw-driver adjustment labeled 150 V ADJ on the chassis, so that this voltage can be set accurately.

+ 100-Volt Regulator

The +100-volt supply is regulated by comparing to ground in comparator-tube V421, a voltage near ground on voltage-divider R424, R425, connected between -150 volts and the regulated +100-volt bus. The difference voltage is amplified in V421 and applied to the grid of series-regulator tube, V422, connected in series with the positive lead. C421 improves the ac gain and reduces ripple. C420 filters the unregulated dc input to the regulator, and C422A, one of three capacitors in one can, filters the regulated portion.

+ 225-Volt Regulator

The +225-volt supply is regulated by comparing to ground potential in comparator tube V441, the voltage near ground potential on voltage divider R444, R445, connected between -150 volts and the regulated +225-volt bus. The difference voltage is amplified in V441 and applied to the grid of series-regulator tube V442A, connected in series with the +225-volt bus. Dc input to this regulator is supplied from a second rectified and filtered but unregulated



source connected in series with the previous source. C440 filters the unregulated input to the regulator. A tap ahead of the regulator provides a nominal +330 volts, unregulated. C442B, the second of three capacitors in one can, filters the regulated supply at +225 volts. R443, bypassing the series-regulator tube, increases the available current at the regulated bus. C441 increases the regulator ac gain to reduce ripple.

+ 350-Volt Regulator

The +350-volt supply is regulated by comparing to ground potential the voltage near ground potential on voltage-divider R467, R468, connected between -150 volts and the regulated +350-volt bus, in comparator tube V461. The difference voltage is amplified in V461 and applied to series-regulator tube V442B in series

with the +350-volt bus. Dc input to this regulator is supplied from a third rectified and filtered, but unregulated source connected in series with the previous two sources. C460, in series with C440 of the previous supply, filters the unregulated input to the regulator. A tap is taken off ahead of the regulator at a nominal +420 volts, unregulated. C422C, the third of three capacitors in one can, filters the regulated +350-volt bus. R465, bypassing the series-regulator tube increases the current available at the regulated bus. C461 increases the regulator ac gain to reduce ripple.

R412, a front-panel control labeled SCALE ILLUM, is a variable resistor in series with the graticule illuminating lights which permits the brightness of the graticule illumination to be varied.

HIGH VOLTAGE AND CATHODE-RAY TUBE CIRCUITS

Accelerating voltage is applied to the cathode of the cathode-ray tube. The high voltage is obtained by rectifying a 50- to 60-kilocycle high-voltage alternating current supplied by an oxide-core transformer whose primary forms the inductor of an inductance-capacitance oscillator. The primary inductance is center-tapped so that it can be used in a Hartley oscillator. C804 is the tank capacitor and V803 is the oscillator tube. Plate power is fed by way of the center tap on the inductor at a nominal +350 volts from the unregulated side of the regulated +225-volt supply. V804 in the negative lead of the high-voltage winding is the rectifier supplying dc to the crt cathode. The rectifier filaments are supplied from additional windings on the same transformer. The positive end of the transformer winding is connected to regulated +225 volts. Filtering is provided by C815 connected to ground from V804 plate, and by C816 and C817 in series, also between V804 and ground.

A voltage-divider string of resistors, R902, R903, R904, R817, and R816 connected between the rectifier plate and regulated +350 volts provides voltage taps for the focusing grid and for a sample of the high voltage for use in the high-voltage regulator system. R903 of the resistor string is a front-panel control potentiometer labeled FOCUS which permits the voltage of the focusing grid to be adjusted for best focus.

R817 in the resistor string is a screwdriver-adjustable potentiometer, the arm of which is at about -150 volts. The voltage from the arm is compared to -150 volts in comparator tube V801A. The plate of V801A is connected to +350 volts through a very high resistance load, R802, and sits near ground potential. The grid of V801B is connected directly to the plate of V801A, and the plate of V801B is connected directly to the screen of oscillator-tube V803 and through plate-load resistor R803, to regulated +350 volts. Any departure of the voltage tap on R817 of the high-voltage resistor string is therefore first amplified in comparator tube V801A and again in V801B so as to change the screen voltage of V803. For example, if the oscillator voltage becomes too high, the grid voltage of V801A will drop, its plate will rise carrying V801B grid up with it. Plate current in V801B will increase, its plate will drop carrying the screen of oscillator V803 down with it, thereby reducing the gain of this tube so that the oscillation amplitude will drop.

Unblanking

A second high-voltage winding and rectifier supply high voltage to the control grid of the cathode-ray tube at about -1750 volts. V805 is the rectifier and C818 is the filter capacitor. R910, in a voltage-divider resistor string across the high voltage is adjustable by means of a



front-panel control labeled INTENSITY to permit adjustment of the spot intensity.

The positive end of this supply is connected to the unblanking-output tube, V210A, through R914. Thus the whole control-grid voltage supply including the transformer winding is raised and lowered in voltage by the unblanking pulse. This arrangement provides dc coupling of the unblanking waveform to the control grid, thereby making it possible to use as slow a sweep as desired. R914 and C902 improve the risetime of the pulse appearing at the control grid.

The ASTIGMATISM control is a potentiometer, R920, connected between regulated +225 volts

and regulated +100 volts.

An external cathode connection is provided via C901 for introducing external z-axis signals to provide beam-intensity modulation if desired. R905 prevents dc, which might leak through the dielectric of C901, from developing high voltage at the connector.

Components shown on the right of the broken line in the diagram are located on a horizontal bakelite mounting board above the end of the cathode-ray tube. The transformer, rectifier tubes, and filter capacitors shown on the diagram to the left of the broken line, are mounted inside a shield at the left lower rear corner to the left of the power transformer.

L.V. POWER SUPPLY
T.B. ON
BOTTOM OF
SCOPE



SECTION 4 MAINTENANCE

GENERAL INFORMATION

Replacement of Components

Tektronix will supply replacement components at current net prices. However, since most of the components are standard electronic and radio parts we suggest that you get them from your local dealer if you can. Be sure to consult your instruction manual first to see what tolerances are required.

We specially select some of the components, whose values must fall within prescribed limits, by sorting through our regular stocks. The components so selected will have standard RETMA color-code marks showing the values and tolerances of the stock from which they were selected, but they will not in general be replaceable from dealers stocks.

Such selected parts, as well as the parts we manufacture at Tektronix, are identified in the parts lists either by notes or by our own stock numbers. Order these parts from the Tektronix factory in Portland, Oregon.

Parts-Ordering Information

You will find a serial number on the frontispiece of this manual. This is the serial number for which this manual was prepared. Be sure that the manual number matches the number of the instrument when you order parts.

A Tektronix instruction manual usually contains hand-made changes to diagrams and parts lists, and sometimes, text. These changes are in general, only appropriate to the instrument whose serial number appears on the manual frontispiece. The hand-made changes show changes that have been made to the instrument after the printing of the manual.

We make some of the instrument changes during the factory test procedure. Our technicians hand-tailor the circuits, if it seems

appropriate, to provide the widest possible latitude of operation. Other changes are made to include the latest circuit improvements as they are developed in our engineering department, or when improved components become available. In any event, the changes are to your benefit. We have tried to give you the best instrument we can.

Soldering Precaution

The solder used on the ceramic terminals in this instrument must contain a small percentage of silver. If for any reason you resolder, be sure that the solder you use contains silver. Silver-bearing solder is used in printed-circuit techniques, and is therefore available from all solder manufacturers. Repeated use of ordinary tin-lead solder will dissolve the fused bond of silver that makes the solder adhere to the porcelain, especially if the soldering iron is quite hot.

Cooling

The Type 315D Oscilloscope is cooled by filtered forced air. The air filter is washable aluminum wool coated with adhesive. If it gets too dirty it will restrict the flow of cooling air and may cause the instrument to overheat.

To clean the filter, run hot water through it from the side that was inside. Or slosh it around in hot soapy water and rinse it in clean water. Then dry it thoroughly and coat it with new adhesive. When new, the filter is coated with "Filter Coat", a product of the Research Products Corporation. Pint cans are available under the name "Handi-Koter" from some air-conditioner suppliers. Other adhesive materials are no doubt satisfactory.

The fan motor bearings will require oiling every few months or every thousand hours of operation. Use a good grade of light machine oil, and apply only a drop or two.



Removal of the Case

Set the oscilloscope face downward on a padded flat surface, turn the two fasteners on the back approximately 1/4 turn to the left, and lift off the case. The power cord is not removable so it must be fed through the hole as the cabinet is removed.

CAUTION: Voltages high enough to be dangerous are present in this instrument. Since much maintenance must necessarily be performed with the case removed, great care should be taken to avoid contact with bare leads. Use only insulated tools, stand on a dry floor, and if possible, keep one hand in your pocket.

POWER SUPPLY

Line Voltage

The power supply of the Type 315D Oscilloscope will operate satisfactorily over the voltage ranges 105 to 125 volts and 210 to 250 volts.

The power transformer is wound with two 117-volt primaries. When the instrument leaves the factory, the primaries are ordinarily connected in parallel for 117-volt operation. If operation from 234-volt lines is desired, remove the jumpers on the power transformer between terminal 1 and terminal 2, and between terminal 3 and terminal 4. Now connect terminal 2 and 3 together. With the line still connected to terminals 1 and 4, the instrument is ready for 234-volt operation.

The fuse normally supplied when the Type 315D is wired for 117-volt operation is 5-amp, 250-volt "Slo-Blo". For proper protection on 234-volt operation, this fuse should be changed to 2 1/2-amp, 250-volt "Slo-Blo".

Line Frequency

The Type 315D is supplied in two different models, for universal line frequency 50 to 800 cycles, or for 50- to 60-cycle operation. The only difference between these models is in the fan motor supplied. The universal 50-800-cycle model uses a dc series-wound motor with a full-wave selenium bridge rectifier. A 37 1/2-volt winding on the power transformer supplies the power to the rectifier. (NOTE: A few of the early instruments did not have this winding but rather used a half-wave rectifier and a series resistor connected directly to the 117-volt line.)

Change of Fan Motor

The 60-cycle model uses a standard 60-cycle shaded-pole 117-volt motor. This motor, having

no brushes, will run quieter and the life should be longer than the dc model. This motor is recommended where the universal feature is not needed. The mounting plates are identical on the two motors so it is possible to change from one to the other if the need should arise. If wired for the 60-cycle motor, the motor wires (grey) should go to terminals 1 and 3. If wired for universal line frequency, the wires should go to terminals 14 and 17. A name plate on the back of the instrument indicates the line frequency. This plate should be changed if the motor is changed.

DC Voltages

All dc voltages are regulated and are referred to the -150-volt supply. In order for the instrument to perform properly, it is necessary for the minus 150-volt supply to be within plus or minus 2% of this value. The voltage should be checked with an accurate voltmeter and corrected if necessary by adjusting potentiometer R410 marked ADJUST -150 V (screwdriver adjust), located on the center bulkhead. This check should always be made if the 5651 tube V401 is changed.

High Voltage

The calibration of the TIME BASE and VERTICAL AMPLITUDE controls are dependent on the acceleration voltage applied to the cathode-ray tube. If it is suspected that the calibrations are off, the high-voltage supply should be checked with an accurate meter of at least 20,000 ohms-per-volt sensitivity. The supply voltage should be adjusted to -1800 volts (for serial numbers before 350) or -1650 (for serial numbers above 350) from the cathode (pin 3) of the crt to ground by means of the potentiometer R817 marked H.V. ADJUST. If more convenient, this reading may be made from the plate of V804 (heavy green

lead) to ground. V804 is the lower rectifier tube located under the shield.

Calibrator

Before adjustments are made on the vertical amplifier, it is well to check the output adjustment of the calibrator. Inasmuch as the clipper, cathode-follower V602A, remains conducting even with the CALIBRATOR switch in the OFF position, it is possible to adjust the voltage

accurately with a dc voltmeter.

An accurate voltmeter of at least 1000 ohms-per-volt sensitivity should be connected to the cathode (pin 3) of V602A. (This is the yellow lead going to the back of the CALIBRATOR switch.) The switch should be turned to the OFF position and R612 (screwdriver potentiometer marked CAL ADJ on the main bulkhead) adjusted to a reading of +100 volts. The calibration voltage will then be accurate on all settings.

VERTICAL AMPLIFIER

NOTE: A warm-up period of approximately 15 minutes to stabilize the characteristics should precede adjustments of the vertical amplifier. Also best results will be obtained if the adjustments are made in the following order:

Amplifier Gain Adjustment

Set the AMPLITUDE selector switch to the dc position, .1 VOLT/DIV. Set the MULTIPLIER to 1; set the CALIBRATOR TO 1. Connect a lead between CAL OUTPUT and INPUT, with the STABILITY control advanced so the time base is free running. Adjust the VERT POSITION control until the bottom of the display coincides with the lowest small mark on the graticule. Then adjust R90 (screwdriver adjustment in center of AMPLITUDE knob) until the top of the display coincides with the top small mark on the graticule (10 division). The CALIBRATOR voltage should be set to .1 and the display should occupy one scale division at any setting of the VERT POSITION control.

2X MULTIPLIER Adjustment

The CALIBRATOR should again be set to 1 volt and the MULTIPLIER set to 2. R51 (located on the outside of the bracket supporting the MULTIPLIER switch) is adjusted to give a display of 5 divisions.

5X MULTIPLIER Adjustment

Next set the MULTIPLIER switch to 5, adjust R53 (located on the inside of the bracket) to give a display of 2 divisions. With the

MULTIPLIER switch in the 10-1 (red) position, a full rotation of the center (red) knob will now give a display of 10 divisions in the full-clockwise position and approximately 1 division in the counterclockwise position.

Attenuator DC Balance

Now turn the CALIBRATOR to OFF and position the trace to the center of the screen. As the red knob (10-1) on the MULTIPLIER is rotated, there should be no change in position. If there is a change in position, R55, VERT AMP DC BAL (located on side of vertical amplifier chassis) should be adjusted until there is no change in position as the red knob is rotated.

NOTE: This adjustment as well as the PRE AMP GAIN ADJ may require an occasional touching up as the tubes age. Therefore holes have been provided in the sides of the cabinet to allow access to these controls.

PREAMP GAIN Adjustment

Set the CALIBRATOR to .1 volt, set the AMPLITUDE to .01 VOLTS/DIVISION, MULTIPLIER to 1. Adjust R15, labeled PRE AMP GAIN ADJ, located on side of vertical amplifier chassis, to give a display of 10 scale divisions.

Input Attenuator and Probe

The various input attenuators in the Type 315D are of the resistor-capacitor type. The resistor divider ratio is equal to the capacitor



divider ratio, and therefore the voltage division is constant for any frequency from dc to well above the requirements of the instrument. Adjustments of these attenuators is readily made while observing their square-wave response. The self-contained calibrator in the Type 315D is a suitable square-wave source, and thus a check of the attenuators is always available. When the variable capacitors in the attenuators are properly adjusted, a square wave will be correctly reproduced by the oscilloscope. If the capacitive divider has a lower attenuation than the resistive divider, a spike will appear on the leading edge of the square wave. If the capacitive divider has a higher attenuation, the corner of the leading edge will be rounded. The following adjustment procedure is recommended:

Shield

1. Lay a sheet of metal on the top of the instrument to simulate the presence of the case.

C3 Adjust

2. Set the CALIBRATOR to 10 volts. Set the AMPLITUDE to AC, 1 VOLT/DIV and the MULTIPLIER to 2. With the TRIGGER SELECTOR set to +INT, SLOW RISE, adjust the TIME BASE to display 8 to 10 cycles of the CAL waveform across the screen. Adjust C3, the rear trimmer, on the side of the switch.

C15 Adjust

3. Turn the MULTIPLIER to the 10-1 position (red), set the center knob full counterclockwise, and set the CALIBRATOR to 100 volts. Adjust C15, located on the chassis just in the rear of the MULTIPLIER switch, until no overshoot is observed. (NOTE: It may be necessary to repeat

step 2 after this adjustment as there is some interaction.)

C6 Adjust

4. Set the AMPLITUDE to 10, AC, set the MULTIPLIER to 2, set the CALIBRATOR to 100. Adjust C6 (located on the rear of the switch, and adjusted through the hole in the chassis).

Probe Adjust (C101)

5. Remove the wire connecting CAL OUT and INPUT, and connect the probe; place the tip of the probe in CAL OUT. Set AMPLITUDE to .1 VOLT/DIV, MULTIPLIER on 2, and set the CALIBRATOR on 10. Adjust C101, located on the probe body.

C2 Adjust

6. Set AMPLITUDE to 1 VOLT/DIV, MULTIPLIER on 2. Set CALIBRATOR to 100 volts. Adjust C2, located on the side of AMPLITUDE switch.

C5 Adjust

7. Set AMPLITUDE to 10 VOLTS/DIV, MULTIPLIER on 1, with the CALIBRATOR at 100 volts. Adjust C5, located on the front of the AMPLITUDE switch, through the hole on the chassis.

C10 Adjust

8. Set AMPLITUDE to .01 VOLTS/DIV, MULTIPLIER on 2, with the CALIBRATOR on 1 volt. Adjust C10, located near V1 on the front of the vertical amplifier chassis.

HIGH-FREQUENCY COMPENSATION

The following describes the adjustment procedure for high-frequency compensation in the Type 315D. The adjustments are not extremely critical. However, they do require considerable care to obtain optimum results. Also since once adjusted, they are fairly stable, readjustment should not be attempted without first eliminating other possible sources of wave-form distortion, including defective tubes or a deficient signal source. A

suitable squarewave generator or pulser is necessary in making any high-frequency adjustments of the Type 315D. The square-wave generator risetime must not exceed .04 microseconds. A Tektronix Type 104A or Type 105 Square-wave Generator will provide a suitable signal. All connections between the generator and the oscilloscope should be coaxial type and MUST be properly terminated, preferably at both ends of the cable.



Disconnect Delay Network

1. In the Type 315D, the DELAY NETWORK must be disconnected before any adjustments are made on the vertical amplifier. This can be done as follows:

Disconnect the red lead (delay line input) from pin 6 (plate) of V4.

Disconnect the purple lead (delay line output) from pin 7 (grid) of V8B.

Connect a jumper from pin 6 of V4 to pin 7 of V8B. This lead should be no longer than necessary and should be kept well away from the chassis.

Connect a 1000-ohm, 1-watt, resistor from pin 7 of V8B to the +100-volt bus. The +100-volt bus is located on the terminal of C21, which is on the bracket below the delay network.

Amplitude of Test Signal

2. Apply a square wave of 750 kc to 1 mc to the input of the Type 315 oscilloscope. Adjust the amplitude of the square wave so that it causes a deflection of 5 to 6 divisions with the MULTIPLIER on 1 or 2.

3. Adjust the TIME BASE to display 3 or 4 cycles of the square wave.

Compensating Coil Adjustments

4. Observe the leading edge of the square wave. Adjust L3, L4, L5, L6, and L7, if necessary, for the best waveform with the least over-

shoot on the leading edge of the wave. All of these adjustments interact to some extent so only a small adjustment should be made to any one coil at a time. NOTE: If the above steps are properly made, the waveform should look very good at this point. However, there may be a few remaining small wrinkles. This should not cause concern as they will disappear when the delay line is re-installed.

Preamp Adjust

5. Insert a 10-to-1 pad in the signal lead from the generator, or reduce its output sufficiently that it will not overload the preamplifier. Set the AMPLITUDE to .01 VOLT/DIV, adjust L1 and L2 for best waveform. NOTE: These adjustments are not very critical and it may require a large change in inductance to show any change in waveform. The two coils should be adjusted so that the slugs are both in about the same position.

6. The delay network should be reconnected.

DC Shift Comp

(For instruments having S/N 357 or higher)

Set the AMPLITUDE control to the DC .1 VOLTS/DIVISION position and the MULTIPLIER to 2. Advance the STABILITY control until the time base is free running and center the trace vertically. Connect a lead from CAL OUT to INPUT and switch the CALIBRATOR control alternately from the OFF position to the 1-volt position. Adjust the DC SHIFT COMP control, R87, until the base line of the display does not shift position as the calibrator is switched off and on.

DELAY NETWORK

The delay network is a 9-section, M-derived artificial transmission line providing a signal delay of .25 microsecond. An accurate impedance match between sections must be maintained to prevent reflections. Each section is adjusted by means of a variable capacitor (C501 to C522). The effects of these adjustments are distributed over the first .5 microsecond of the signal.

CAUTION: Adjustment of the delay net-

work should not be attempted without first verifying normal transient response of the output amplifier as explained under "HIGH-FREQUENCY COMPENSATION". Otherwise the delay network adjustments may be set to compensate for deficiencies in the output stage. This will cause a loss in overall bandwidth of the instrument. The following methods of adjustment will give satisfactory results:



Delay Network Test Signal

1. Apply a 100-kc square wave to the input of the oscilloscope with the AMPLITUDE set on .1 VOLT/DIV. Set the TIME BASE to 1 MICROSECOND/DIVISION.

2. Adjust the DELAY NETWORK trimmers (C501 to C522) for the smallest ripple or irregularity on the first .5 microsecond of the square wave. The position of the irregularity determines which capacitor needs to be adjusted. Try adjusting one of the center capacitors to see where it produces its effect.

Leading Edge

3. Change the TIME BASE to 5 or 10 MICROSECONDS/DIVISION and observe the squareness of the leading corner. If the corner (first .5 microsecond) is higher in amplitude than the

remainder of the square wave, repeat step 2, but setting all the capacitors at a higher capacitance. If lower, repeat using lower capacitor settings. It may be found that only part of the corner will slope up or down. In this case, only part of the capacitors will need to be increased or decreased.

Delay Network Terminating Resistor

If a square corner cannot thus be obtained, an incorrect termination resistor, R521 is indicated. To check this termination, turn off the 315D and allow the tubes to cool. Then measure R521 between pin 7 of V8B and the +100-volt bus (located on terminal of capacitor C21) with an accurate bridge. If it is outside the range of 1100 ohms \pm 1%, replace with a composition resistor selected to be within these limits. (R521 is located in the delay-network chassis, which must be removed to replace the resistor.)

ASTIGMATISM

For best focus of both horizontal and vertical lines, the final anode of the cathode-ray tube must be returned to a voltage approximately equal to the dc voltage on the deflection plates. A preliminary setting of the ASTIGMATISM control (R920), located on the back plate of the instrument, may be made by connecting a voltmeter between ground and the center arm of

this control, and adjusting to +190 volts. Because of variations in individual cathode-ray tubes, the best setting may differ slightly from this value, so final adjustment should be made while a signal is being observed. This setting should be made simultaneously with the front-panel FOCUS control because these controls interact to some extent.

TIME BASE

A complete procedure for the adjustment and calibration of the time base is outlined here. However, in normal servicing, only necessary adjustments should be made.

Timing Capacitors

We manufacture our own timing capacitors with the characteristics needed to maintain sweep-time accuracy and linearity. The capacitance ratio between capacitors used is accurate within half of one per cent so that the time-base calibrations will be right at all speeds. Most capacitors change value with voltage, temperature, and age. Variation of capacitance with voltage is particularly undesirable because it

causes nonlinearity of the time-base sawtooth. Our timing capacitors are especially free from this voltage effect. They also have minimum temperature and aging variations.

Timing capacitors C280A, C280B, and C280C are enclosed as a unit in a sealed can. If you need to replace any one of them, you must replace all three. C280-D may be composed of two capacitors, chosen to have the right characteristics and capacitance value when connected in parallel. We therefore recommend that you obtain replacements for this capacitor from Tektronix. Be sure to include the instrument serial number with your order.



Multivibrator Stability

1. Set STABILITY control (red coaxial knob) full clockwise. Adjust MULTISTABILITY (R254, screwdriver potentiometer on side of sweep deck) about half way between the points where the sweep stops on the left of the screen and where it stops on the right of the screen. NOTE: It may not be possible to make it stop on both sides. If not, adjust it to where it stops on one side or the other, then back it off approximately 1/4 turn.

Sweep Length

2. With the sweep free running at 1 MILLI-SEC/DIVISION adjust SWEEP LENGTH (R261, screwdriver adjustment on side of sweep deck) until the sweep just covers the ruled portion of the graticule (approximately 10 1/2 divisions).

Trigger Sensitivity

3. Set the TRIGGER SELECTOR to +LINE or -LINE. Set the time base RANGE to 10 MICROSECONDS/DIVISION. Set the TIME BASE MULTIPLIER to 1. Set the VERTICAL AMPLIFIER AMPLITUDE to .1 VOLT/DIVISION, MULTIPLIER on 1. Advance the STABILITY control (red knob) until a trace appears. Now turn the STABILITY control back (counterclockwise) until the trace disappears, or drops suddenly in intensity. If the trace disappears, adjust the TRIGGER AMPLITUDE DISCRIMINATOR until a dim trace is displayed. The time base is now triggered by the ac line frequency. Connect the 10X probe cable to the INPUT and touch the probe to the cathode of V203 (pin 3 and 8). This lead appears at the terminal board just back of the TRIGGER SELECTOR switch on the underside of the sweep chassis. Adjust TRIG SENS (R223, screwdriver control, located on side of the sweep chassis) until a series of oscillations are observed on the trace, then back off the control to the point where the oscillations just disappear.

V201 Balance

4. Set the TRIGGER AMPLITUDE DISCRIMINATOR to 0 (center), and set the STABILITY control full counterclockwise. Connect a dc voltmeter between ground and the grid of the pentode section of V202, pin 2, and rotate the TRIGGER SELECTOR switch from the +EXT to the -EXT positions. The voltages in the two

switch positions should be nearly equal at 190 volts. If there is a difference of over five volts it indicates either that the phase-inverter tube, V201, is not balanced, or that the plate resistors for this tube are not equal. V201 should be exchanged if necessary for a tube which gives as nearly equal voltage as obtainable with the switch in the two positions, and the resistors, R208 and R209, should be checked.

Internal -Trigger DC Level

5. With the controls set as in step 4, rotate the TRIGGER SELECTOR switch from the -INT to +INT, and if necessary, adjust R202 (a screwdriver adjustment on side of TRIGGER SELECTOR switch) until the average of the two voltages is the same as the average voltage measured in step 4.

A. Set the AMPLITUDE selector to one of the AC positions. Connect a wire between INPUT and CAL OUTPUT. Set the CALIBRATOR and the AMPLITUDE control so that a vertical deflection of approximately 0.2 division is displayed. Set TRIGGER SELECTOR to +INT or -INT, SLOW RISE. Set the STABILITY control just below the point where the sweep free runs. Set the TRIGGER AMPLITUDE DISCRIMINATOR to 0 (center). Adjust INT TRIG DC LEVEL (R202, screwdriver adjustment on side of TRIGGER SELECTOR switch) until the point of triggering occurs as close as possible to the zero setting of the TRIGGER SELECTOR DISCRIMINATOR. This point should be checked on both +INT and -INT settings of the TRIGGER SELECTOR. When a proper adjustment is made, the point of triggering will be at about the same rotation from zero with either positive or negative settings.

NOTE: For the following step and for all time-base calibration adjustments, either a suitable time-mark generator or an accurately calibrated oscillator is required. A suitable instrument is the Tektronix Type 180 Time-Mark Generator.

V213 Check (Constant-Current Tube)

6. Set the marker generator for one-micro-second marks. Set the TIME BASE to 1 MICRO-SEC/DIVISION, and the MULTIPLIER to 1. Display a stable trace of the time marks, and watch the trace as you short out R279 (15-ohm resistor in heater lead to V213A, located on bakelite



board on back of sweep chassis). Keep R279 shorted for at least 30 seconds. If any change occurs in the time base replace the constant-current tube, V213. A tube should be selected for this position which shows no change as the heater voltage is changed. A tube with low emission or with high heater-to-cathode leakage in this tube will cause an error in the timing of the 5 SEC/DIVISION range. If this trouble is suspected, switch to 1 SEC/DIVISION and MULTIPLIER to 5, and advance the STABILITY control to get a recurrent sweep. Time the full 10-centimeter transit time first with the line voltage near 105 volts and second with the line voltage increase to the vicinity of 125 volts. Any difference in the timing with a change in line voltage indicates cathode-to-heater leakage in the constant-current tube.

Time Base Calibration

7. Set the TIME BASE RANGE on 1 MILLI-SECOND/DIVISION. Connect the time-mark generator to the vertical INPUT and select time marks of 1 millisecond. Adjust SWEEP CAL (R286, screwdriver adjust on side of sweep chassis) until 10 marks correspond with 10 scale divisions.

Magnifier Gain

8. With the time marks and TIME BASE set as in step 7, turn the 5X MAGNIFIER (red knob center of RANGE switch) to the ON position (clockwise rotation). The HORIZ POSITION should be set so that the center 20 per cent of the display is on the screen of the tube. Adjust MAG GAIN (R314, screwdriver adjustment on side of sweep chassis) until 2 time marks correspond with 10 scale divisions. A more accurate adjustment may be obtained if the generator is set to 100 MICROSECONDS. Then 20 time marks will occupy 10 divisions. The linearity of the sweep should be carefully checked by noting if each time mark corresponds with a graticule division. If there is any indication that the sweep is not linear, the horizontal output tubes (V224 and V223) should be changed.

Mag. Centering

9. With the same setup as in step 7, position the trace to the right with the HORIZ POSITION control, until the second time mark as displayed on the screen is centered over the center line of the graticule (magnified sweep).

Now turn the 5X MAGNIFIER switch to OFF (counterclockwise) and reposition the trace with MAG CENTERING (R306, screwdriver adjust, on side of sweep chassis) until the second time mark is centered on the screen. When this adjustment has been properly made, there will be no movement of the display in the center of the screen as the 5X MAGNIFIER is switched on or off. In other words, the trace will be magnified equally in both directions from center.

NOTE: At this point it is recommended that all time-base ranges slower than 1 MILLI-SEC/DIVISION be checked in each of the three MULTIPLIER positions. There should be no error greater than two per cent except at 1, 2, and 5 SEC/DIVISION settings, where the error should not exceed four per cent. Any greater error indicates defective timing resistors or capacitors, or, in the case of the slowest time bases, heater-to-cathode leakage in V213A excessive.

Trace Linearity

10. If the linearity of the time base has deteriorated proceed as follows to adjust C290, C260, C276, and C303, as well as the timing circuits. These capacitors are located on the under side of the sweep deck.

C280E Adjust (Preliminary)

11. Set the TIME BASE RANGE to 10 MICROSEC/DIVISION, MULTIPLIER to 1, and display 10-microsecond time marks. Adjust C280E so that the last eight markers correspond with the last eight graticule divisions.

C290 Adjust

12. Turn 5X MAGNIFIER clockwise (on). Adjust C290 so that the first two markers occupy the same number of graticule divisions as the last two markers.

C280E Adjust

13. Turn 5X MAGNIFIER counterclockwise (off). Readjust C280E so that all 10 markers correspond with the 10 graticule divisions.

C303 Adjust (Preliminary)

14. Set TIME BASE RANGE to 1 MICRO-



SECOND/DIVISION and display one-microsecond time marks. Adjust C303 for best linearity at start of sweep.

NOTE: With the RANGE set to 1 MICRO-SEC/DIVISION the timing accuracy should be checked at the X2 and the X5 MULTIPLIER settings. Any error greater than 2% indicates resistors R282A or R2828B are defective. If there is any discrepancy it should be averaged between the settings by a compromise setting of C280E. Do not confuse timing error with non-linearity of the sweep.

C280G Adjust

15. Set TIME BASE RANGE to .1 MICRO-SECOND/DIVISION, set MULTIPLIER to 5, and display one-microsecond time marks. Ad-

just C280G so that the last four markers correspond with the last eight graticule divisions.

C260 Adjust

16. Set MULTIPLIER to 1 and display a 10-mc sine wave. Adjust C260, if necessary, so that no foldover occurs at end of sweep at normal intensity setting. C260 setting should be as near minimum capacitance as possible.

C303 Adjust

17. Readjust C303 so that 10 cycles occupy 10 graticule divisions. Repeat 15 and 17 as there is a slight interaction between their adjustments.

C276 Adjust

18. Set MULTIPLIER to 2. Adjust C276 for best linearity at start of sweep.

TIME BASE TROUBLE SHOOTING

First, check the power-supply voltages, and if necessary adjust the -150-volt supply which is the reference voltage for the other regulated supplies. Also if necessary adjust the -1650-volt accelerating voltage.

Second, check the 47-ohm, 1/2-watt resistors on the vertical terminal strip on the bottom of the sweep chassis for evidence of overheating and for open circuits.

Third, check the heaters of the tubes on the sweep chassis. Each tube, except the 6AK6, has two separate cathodes. Examine them to make sure both cathodes are hot.

Fourth, set the front-panel STABILITY control full counterclockwise, and the 5X MAGNIFIER control clockwise (on). Set the SWEEP LENGTH and MAGNIFIER GAIN screwdriver-adjustable controls full counterclockwise. The SWEEP LENGTH control, R271, and the MAGNIFIER GAIN control, R315, are accessible from the right side in the row of controls near the bottom of the instrument.

Fifth, read test-point voltages at the points shown in the following list, as the MULTI STABILITY pot is alternately turned first full clockwise, and then full counterclockwise. The MUL-

TI STABILITY pot, R254, is also mounted on the control strip at the bottom of the instrument, accessible from the right side.

Turning the MULTI STABILITY pot clockwise sets the time-base circuit in the stable state that is present at the start of the sweep. Turning it counterclockwise sets the circuit in the stable state present at the end of the sweep.

Take the readings on a sensitive voltmeter with a resistance of 10,000 ohms per volt or higher. The voltages given are nominal in most cases.

VOLTAGE TO GROUND

Test Point	Multi Stab. CW	Multi Stab. CCW	Probable Cause of Trouble
pin 8 V210B	150v \pm 10v	225v	V211
pin 7 V205B	-17v \pm 4v	0v	V205, V213
pin 7 V204B	100v	15v	V205, V204
pin 8 V204B	105v	20v	V204
pin 2 V204A	85v	10v	V203, V204
pin 1 V212A	215v	175v	V212, V213



V205 may be gassy without disturbing the foregoing voltages.

pin 2 V214	-11v	-12v V214, V215
pin 1 V215A	-11v	28v V214, V215
pin 2 V215B	-5v	-6v V214, V215
pin 1 V220	-5v	-6v V214, V215
pin 5 V220	35v	100v V220
pin 3 V221A	40v	100v V221

Set Multi. Stab. CCW

V221B, between pins 7 and 8	6v V221
V222A, between pins 2 and 3	6v V222
pin 7 V224B	0v (Adjusted by varying HORIZ. POSITION)

pin 6 V224B	190v V224, V223
pin 3 V223B	196v V224, V223
pin 6 V223B	190v V224, V223
pin 3 V223A	196v V224, V223

Feed a 10-volt signal from the CAL terminal through a blocking capacitor to pin 7 of V221. This should give a horizontal trace at least 10 cm long.

Because of the interdependence of the various parts of the time base circuits, failure of one tube may interrupt the whole time-base operation so that comparison of waveforms may not be possible. The foregoing procedure will help especially in these cases when the time base will not operate at all.

ALTERNATE PROCEDURE FOR ALIGNING INPUT ATTENUATOR AND PROBE

Preliminary Steps

1. Set C15 to half capacitance and lay a sheet of metal on the top of the instrument to simulate the presence of the case.

C3 Adjust

2. Set the CALIBRATOR to 10 volts. Set the amplitude to AC, 1 V/DIV and the MULTIPLIER to 1. With the TRIGGER SELECTOR set to +INT, SLOW RISE, adjust the time base to 200 MICROSEC/DIV. Adjust C3, the rear trimmer on the side of the switch.

C6 Adjust

3. Set the AMPLITUDE control to AC, 10 VOLTS/DIV, set the MULTIPLIER to 1, set the calibrator to 100. Adjust C6 (located on the rear of the switch, and adjusted through the hole in

the chassis).

Probe Adjust C101

4. Remove the wire connecting CAL OUT and INPUT, and connect the probe, place the tip of the probe in CAL OUT. Set AMPLITUDE to .1 VOLT/DIVISION, MULTIPLIER on 1, and set the calibrator on 10. Set TIME BASE to 2 MILLI-SEC/DIV. Adjust C101, located on the probe body.

C15 Adjust

5. Turn the multiplier to the 10-1 position (red), set the center knob full counterclockwise, and set the CALIBRATOR to 100 volts. Adjust C15, located on the chassis just in the rear of the multiplier switch, until a flat top is observed.

Adjust C2, C5, and C10 according to previous instructions.



SECTION 5

PARTS LIST

Abbreviations

Cer.	ceramic	m	milli or 10
Comp.	composition	Ω	ohm
EMC	electrolytic, metal cased	PMC	paper, metal-cased
f	farad	Poly.	polystyrene
GMV	guaranteed minimum value	Prec.	precision
h	henry	PT	paper tubular
k	kilohm or 10 ohms	v	working volts dc
meg	megohm or 10 ohms	Var.	variable
μ	micro or 10	w	watt
$\mu\mu$	micromicro or 10	WW	wire wound

Special Notes and Symbols

X000	Part first added at this serial number
000X	Part removed at this serial number
(Mod. w/)	Simple replacement not recommended. Modify for later instruments and change other listed parts to match.

Bulbs

Ckt. No.	S/N Range	Description	Part Number
B280		Neon Type NE2	150-009
B310		Neon Type NE2	150-009
B319		Neon Type NE2	150-009
B401		Incandescent, #47	150-001
B402		Incandescent, #47	150-001
B403		Incandescent, #47	150-001

Capacitors

C1		.1 μ f	PT	Fixed	600 v	20%	285-528
C2	101-643	5-20 $\mu\mu$ f	Cer.	Var.	500 v		281-032
	644 - up	4.5-25 $\mu\mu$ f	Cer.	Var.	500 v		281-010
C3		1.5-7 $\mu\mu$ f	Cer.	Var.	500 v		281-005



C4		27 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-513
C5	101-643 644 - up	5-20 $\mu\mu f$ 4.5-25 $\mu\mu f$	Cer. Cer.	Var. Var.	500 v 500 v		281-032 281-010
C6		1.5-7 $\mu\mu f$	Cer.	Var.	500 v		281-005
C7		330 $\mu\mu f$	Mica	Fixed	500 v	20%	283-518
C9		6.25 μf	EMC	Fixed	300 v	-20+50%	290-000
C10	101-643 644 - up	5-20 $\mu\mu f$ 4.5-25 $\mu\mu f$	Cer. Cer.	Var. Var.	500 v 500 v		281-032 281-010
C11		6.25 μf	EMC	Fixed	300 v	-20+50%	290-000
C12		.22 μf	PT	Fixed	400 v	20%	285-533
C13	X268 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C14		.01 μf	Cer.	Fixed	500 v	GMV	283-002
C15		1.5-7 $\mu\mu f$	Cer.	Var.	500 v		281-005
C16	X268-299 300 - up	.02 μf .01 μf	Cer. Cer.	Fixed Fixed	500 v 500 v	GMV GMV	283-004 283-002
C17	X300 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C18	X300 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C20		.01 μf	PT	Fixed	400 v	20%	285-510
C21		6.25 μf	EMC	Fixed	300 v	-20+50%	290-000
C22		.01 μf	PT	Fixed	400 v	20%	285-510
C23	X363 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C25		.01 μf	Cer.	Fixed	500 v	GMV	283-002
C26	X300 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C27	X300 - up	.01 μf	Cer.	Fixed	500 v	GMV	283-002
C86	X357 - up	20 μf	EMC	Fixed	150 v	-20+50%	290-008
C88	X357 - up	20 μf	EMC	Fixed	150 v	-20+50%	290-008
C101	101-643X	3-12 $\mu\mu f$	Cer.	Var.	500 v		281-007
C200		.047 μf	PT	Fixed	400 v	20%	285-519
C201		.001 μf	Cer.	Fixed	500 v	GMV	283-000
C202		12 $\mu\mu f$	Cer.	Fixed	500 v	10%	281-506



C212		.001 μf	Cer.	Fixed	500 v	GMV	283-000
C221		.001 μf	Cer.	Fixed	500 v	GMV	283-000
C223		470 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-525
C227		22 $\mu\mu f$	Cer.	Fixed	400 v	20%	281-510
C241A	101-643X	.1 μf	PT	Fixed	400 v	20%	285-526
C241B	101-643X	.01 μf	PT	Fixed	400 v	20%	285-510
C241C	101-643X	.001 μf	PT	Fixed	600 v	20%	285-501
C241D	101-643X	100 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-523
C241E	101-643X	22 $\mu\mu f$	Cer.	Fixed	400 v	20%	281-510
C241F	101-643X	12 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-506
C244		4.7 $\mu\mu f$	Cer.	Fixed	500 v	+ or - 1 $\mu\mu f$	281-501
C250		47 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-518
C251		12 $\mu\mu f$	Cer.	Fixed	500 v	10%	281-506
C260	101-643 644 - up	5-20 $\mu\mu f$ 4.5-25 $\mu\mu f$	Cer. Cer.	Var. Var.	500 v 500 v		281-032 281-010
C261		47 $\mu\mu f$	Cer.	Fixed	500 v	20%	281-518
C262		8 $\mu\mu f$	Cer.	Fixed	400 v	+ or - .5 $\mu\mu f$	281-503
C263		.001 μf	Cer.	Fixed	500 v	GMV	283-000
C272	101-174 175 - up	22 $\mu\mu f$ 47 $\mu\mu f$	Cer. Cer.	Fixed Fixed	400 v 500 v	20% 20%	281-510 281-518
C276	101-174 175 - up	3-12 $\mu\mu f$ 1.5-7 $\mu\mu f$	Cer. Cer.	Var. Var.	500 v 500 v		281-007 281-006
C280A		1 μf	PMC	Fixed	400 v	Selected)	
C280B		.1 μf	PT	Fixed	400 v	Selected)	Timing Series See Text
C280C	101-356 357-394 395 - up	.01 μf .01 μf .01 μf	PT Mica PT	Fixed Fixed Fixed	400 v 300 v 600 v	Selected) Selected) Selected)	291-001
C280D		.001 μf	PT	Fixed	600 v	Selected	Timing Series See Text 291-014
C280E		7-45 $\mu\mu f$	Cer.	Var.	500 v		281-012
C280F	101-643 644 - up	82 $\mu\mu f$ 82 $\mu\mu f$	Cer. Cer.	Fixed Fixed	500 v 500 v	20% 10%	Use 281-528 281-528



C280G		3-12 $\mu\mu f$	Cer.	Var.	500 v		281-007
C282		.01 μf	PT	Fixed	400 v	20%	285-510
C290		1.5-7 $\mu\mu f$	Cer.	Var.	500 v		281-005
C291		4.7 $\mu\mu f$	Cer.	Fixed	500 v	+ or -1 $\mu\mu f$	281-501
C300	101-174X	5-25 $\mu\mu f$	Cer.	Var.	500 v		281-010
C303	101-174 175 - up	4.7 $\mu\mu f$.5-5 $\mu\mu f$	Cer. Poly.	Fixed Var.	500 v 500 v	+ or -1 $\mu\mu f$	281-501 281-001
C325		.01 μf	PT	Fixed	600 v	20%	285-511
C326		.01 μf	PT	Fixed	400 v	20%	285-510
C327		.01 μf	PT	Fixed	400 v	20%	285-510
C328		.01 μf	PT	Fixed	400 v	20%	285-510
C401		2x40 μf	EMC	Fixed	250 v	-20+50%	290-040
C402		125 μf	EMC	Fixed	350 v	-20+50%	290-044
C403		.01 μf	PT	Fixed	400 v	20%	285-510
C404		.01 μf	PT	Fixed	400 v	20%	285-510
C420		2x40 μf	EMC	Fixed	250 v	-20+50%	290-041
C421		.01 μf	PT	Fixed	400 v	20%	285-510
C422A		1/3 3x10 μf	EMC	Fixed	450 v	-20+50%)	
C422B		1/3 3x10 μf	EMC	Fixed	450 v	-20+50%)	290-033
C422C		1/3 3x10 μf	EMC	Fixed	450 v	-20+50%)	
C440		2x40 μf	EMC	Fixed	450 v	-20+50%	290-043
C441		.01 μf	PT	Fixed	400 v	20%	285-510
C460		2x40 μf	EMC	Fixed	250 v	-20+50%	290-040
C461	101-347 348 - up	.01 μf .01 μf	PT PT	Fixed Fixed	400 v 600 v	20% 20%	285-511 285-511
C501	101-2687 2688 - up	1.5-7 $\mu\mu f$ 3-12 $\mu\mu f$	Cer. Cer.	Var. Var.	500 v 500 v		281-006 281-009
C502A-E	101-590	5-25 $\mu\mu f$	Cer.	Var.	500 v		281-010
C502A-B	591 - up	3-12 $\mu\mu f$	Cer.	Var.	500 v		281-009



C502C-E	591 - up	5-25 μuf	Cer.	Var.	500 v		281-011
C511A-F		5-25 μuf	Cer.	Var.	500 v		281-011
C521A-F		5-25 μuf	Cer.	Var.	500 v		281-011
C522		1.5-7 μuf	Cer.	Var.	500 v		281-006
C601		220 μuf	Mica	Fixed	500 v	20%	283-514
C602		220 μuf	Mica	Fixed	500 v	20%	283-514
C603		8 μuf	Cer.	Fixed	500 v	25%	281-503
C604		47 μuf	Cer.	Fixed	500 v	20%	281-518
C802		.001 μf	Cer.	Fixed	500 v	GMV	283-000
C804		.001 μf	PT	Fixed	600 v	20%	285-501
C805		.001 μf	PT	Fixed	600 v	20%	285-501
C815		.0068 μf	PT	Fixed	3000 v	20%	285-508
C816		.0068 μf	PT	Fixed	3000 v	20%	285-508
C817		.022 μf	PT	Fixed	400 v	20%	285-515
C818		.0068 μf	PT	Fixed	3000 v	20%	285-508
C901		.015 μf	PT	Fixed	3000 v	20%	285-513
C902		.015 μf	PT	Fixed	3000 v	20%	285-513

Fuses

Fuse	5 amp	3AG	Slo-Blo for 117V Operation	159-006
Fuse	2 amp	3AG	Slo-Blo for 234V Operation	159-023

Inductors

L1	101-643 644 - up	2.2-3.9 μh 19-35 μh Var.	Var. CV193	CV222	114-007 114-005
L2	101-643 644 - up	19-35 μh Var. 2.2-3.9 μh	CV193 Var.	CV222	114-005 114-007
L3		4.8-8.5 μh	Var.	CV482	114-020
L4		28-50 μh Var.	CV283		114-013
L5		28-50 μh Var.	CV283		114-013



L6	101-643 644 - up	53-96 μ h 53-96 μ h	Var. Var.	CV513 CV513	114-021 114-021
L7	101-643 644 - up	53-96 μ h 53-96 μ h	Var. Var.	CV513 CV513	114-021 114-021
L221	101-449X	150 μ h	Fixed	Wound on R221	108-026
L246	101-449X	70 μ h	190 turns of #39 wire, on 4.7 k, 2 w resistor 108-027		
LR2	X450 - up	150 μ h	Fixed	Wound on 1.5 k, 1 w res.	108-026
LR3	X450 - up	70 μ h	190 turns of #39 wire on 4.7 k, 2 w resistor 108-027		

Resistors

R1		900 k	1 w	Fixed	Prec.	1%	310-097
R2		111 k	1/2 w	Fixed	Prec.	1%	309-046
R3		990 k	1 w	Fixed	Prec.	1%	310-098
R4		10.1 k	1/2 w	Fixed	Prec.	1%	309-034
R5		1 meg	1/2 w	Fixed	Prec.	1%	309-014
R7		1 meg	1/2 w	Fixed	Prec.	1%	309-014
R8	X363 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R10		100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R11		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R12		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R13		22 k	2 w	Fixed	Comp.	10%	306-223
R14		27 k	2 w	Fixed	Comp.	10%	306-273
R15		200 Ω	2 w	Var.	Comp.	20%	311-004
R16	X268-350 351 - up	12 Ω 10 Ω	1/2 w 1/2 w	Fixed Fixed	Comp. Comp.	10% 10%	302-120 302-100
R19	X300 - up	6.8 k	1/2 w	Fixed	Comp.	10%	302-682
R20		600 k	1/2 w	Fixed	Prec.	1%	309-004
R21		610 k	1/2 w	Fixed	Prec.	1%	309-006
R23		4.3 k	2 w	Fixed	Comp.	5%	305-432
R24		5.6 k	2 w	Fixed	Comp.	10%	306-562
R25		5.6 k	2 w	Fixed	Comp.	10%	306-562



R26	X764 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R30		1 k	2 w	Fixed	Comp.	10%	306-102
R31		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R32		27 k	2 w	Fixed	Comp.	10%	306-273
R33		33 k	2 w	Fixed	Comp.	10%	306-333
R34		100 k	1/2 w	Fixed	Comp.	10%	302-104
R35		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R36	101-267	220 Ω	1/2 w	Fixed	Comp.	10%	302-221
	268 - up	150 Ω	1/2 w	Fixed	Comp.	10%	302-151
R39	X582 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R40		2.2 k	1 w	Fixed	Comp.	10%	304-222
R41		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R42		1 k	1/2 w	Fixed	Comp.	10%	302-102
R44		8 k	5 w	Fixed	WW	5%	308-007
R45		8 k	5 w	Fixed	WW	5%	308-007
R46		27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R50		470 Ω	1/2 w	Fixed	Comp.	10%	302-471
R51		2.5 k	1/10 w	Var.	Comp.	20%	311-010
R52	101-350	1 k	1/2 w	Fixed	Comp.	10%	302-102
	351 - up	1.2 k	1/2 w	Fixed	Comp.	10%	302-122
R53		10 k	1/10 w	Var.	Comp.	20%	311-017
R54		2250 Ω	2 w	Var.	Comp.	20%	311-071
R55		5 k	2 w	Var.	Comp.	20%	311-011
R59	101-350	12 Ω	1/2 w	Fixed	Comp.	10%	302-120
	351 - up	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R60		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R61		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R62		12 k	2 w	Fixed	Comp.	10%	306-123
R63		470 k	1/2 w	Fixed	Comp.	10%	302-474
R64		12 k	2 w	Fixed	Comp.	10%	306-123



R65		220 k	1/2 w	Fixed	Prec.	1%	309-052
R66	101-350	18 k	1/2 w	Fixed	Comp.	10%	302-183
	351 - up	22 k	1/2 w	Fixed	Comp.	5%	301-223
R69	X351-643	22 k	1/2 w	Fixed	Comp.	5%	301-223
	644 - up	22 k	1/2 w	Fixed	Comp.	10%	302-223
R70	101-350	20 k	2 w	Var.	Comp.	20%	311-018
	351 - up	250 k	2 w	Var.	Comp.	20%	311-032
R71		27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R72	101-350X	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R73		27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R74	101-350X	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R75		2 k	5 w	Fixed	WW	5%	308-003
R76		2 k	5 w	Fixed	WW	5%	308-003
R80	101-356	2.5 k	10 w	Fixed	WW	5% (non-induct.) Use Mod Kit	040-007
	357 - up	2.7 k	10 w	Fixed	WW	5% (non-induct.) Use Mod Kit	308-019
R81		6.8 k	1/2 w	Fixed	Comp.	10%	302-682
R82		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R83		750 Ω	10 w	Fixed	WW	5%	308-016
R84	101-356	2.5 k	10 w	Fixed	WW	5% (non-induct.) Use Mod Kit	040-007
	357 - up	2.7 k	10 w	Fixed	WW	5% (non-induct.) Use	308-019
R85		6.8 k	1/2 w	Fixed	Comp.	10%	302-682
R86	X357-1691	39 k	1/2 w	Fixed	Comp.	10%	302-393
	1692 - up	33 k	1/2 w	Fixed	Comp.	10%	302-333
R87	X357 - up	1 meg	2 w	Var.	Comp.	20%	311-040
R88	X357-1691	39 k	1/2 w	Fixed	Comp.	10%	302-393
	1692 - up	33 k	1/2 w	Fixed	Comp.	10%	302-333
R90		100 Ω	2 w	Var.	Comp.	20%	311-003
R91	101-350X	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R92		27 Ω	1/2 w	Fixed	Comp.	10%	302-270



R93		27 Ω	1/2 w	Fixed	Comp.	10%	302-270
R94	101-350X	10 Ω	1/2 w	Fixed	Comp.	10%	302-100
R95		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R97		100 Ω	1/2 w	Fixed	Comp.	10%	302-101
R98		100 Ω	2 w	Var.	Comp.	20%	311-003
R101	101-643X	9 meg	1/2 w	Fixed	Comp.	10%	Use 301-915
R200		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R201		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R202		10 k	1/10 w	Var.	Comp.	20%	311-017
R203		50 k	1/2 w	Fixed	Prec.	1%	309-090
R204		100 k	1/2 w	Fixed	Prec.	1%	309-045
R207	X764 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R208		4.7 k	1 w	Fixed	Comp.	10%	304-472
R209		4.7 k	1 w	Fixed	Comp.	10%	304-472
R210		18 k	2 w	Fixed	Comp.	10%	306-183
R211		47 k	1/2 w	Fixed	Comp.	10%	302-473
R212		100 k	2 w	Var.	Comp.	20%	311-025
R215		100 k	1/2 w	Fixed	Comp.	10%	302-104
R216		560 k	1/2 w	Fixed	Comp.	10%	302-564
R217		390 k	1/2 w	Fixed	Comp.	10%	302-394
R220		2.2 k	1/2 w	Fixed	Comp.	10%	302-222
R221		1.5 k	1 w	Fixed	Comp.	10%(with L221)	304-152
R222		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R223		500 Ω	2 w	Var.	Comp.	20%	311-005
R224		22 k	1 w	Fixed	Comp.	10%	304-223
R225		22 k	1 w	Fixed	Comp.	10%	304-223
R226		150 k	1/2 w	Fixed	Prec.	1%	309-049
R227		95 k	1/2 w	Fixed	Prec.	1%	309-044



R230		39 k	1/2 w	Fixed	Comp.	10%	302-393
R231		100 k	2 w	Var.	Comp.	20%	311-026
R232		18 k	2 w	Fixed	Comp.	10%	306-183
R233		2.2 k	1/2 w	Fixed	Comp.	10%	302-222
R234		470 k	1/2 w	Fixed	Comp.	10%	302-474
R235		680 k	1/2 w	Fixed	Comp.	10%	302-684
R236		470 Ω	1/2 w	Fixed	Comp.	10%	302-471
R239	X175 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R240		22 k	2 w	Fixed	Comp.	10%	306-223
R241		22 k	1/2 w	Fixed	Comp.	10%	302-223
R242		10 k	1 w	Fixed	Comp.	10%	304-103
R243		390 k	1/2 w	Fixed	Comp.	10%	302-394
R244		470 k	1/2 w	Fixed	Comp.	10%	302-474
R245		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R246		4.7 k	2 w	Fixed	Comp.	10%(with L246)	306-472
R247		4.7 k	2 w	Fixed	Comp.	10%	306-472
R248		100 k	1 w	Fixed	Comp.	10%	304-104
R250		150 k	1/2 w	Fixed	Prec.	1%	309-049
R251	101-489	150 k	1/2 w	Fixed	Comp.	10%	302-154
	490 - up	150 k	1/2 w	Fixed	Prec.	1%	309-049
R252		4.7 k	2 w	Fixed	Comp.	10%	306-472
R253	101-489	100 k	1/2 w	Fixed	Comp.	10%	302-104
	490 - up	95 k	1/2 w	Fixed	Prec.	1%	309-044
R254	101-489	50 k	2 w	Var.	Comp.	20%	311-023
	490 - up	100 k	2 w	Var.	Comp.	20%	311-026
R255		120 k	1/2 w	Fixed	Prec.	1%	309-091
R260		700 k	1/2 w	Fixed	Prec.	1%	309-008
R261		50 k	2 w	Var.	Comp.	20%	311-023
R262		47 k	1 w	Fixed	Comp.	10%	304-473
R263		1 meg	1/2 w	Fixed	Comp.	10%	302-105



R264		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R265	X175 - up	47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R270		500 k	1/2 w	Fixed	Prec.	1%	309-003
R271		100 k	1 w	Fixed	Comp.	10%	304-104
R272	101-643	18 k	1 w	Fixed	Comp.	10%	304-183
	644 - up	18 k	1 w	Fixed	Comp.	-8+0%	312-537
R273	101-643	47 k	2 w	Fixed	Comp.	10%	306-473
	644 - up	47 k	2 w	Fixed	Comp.	-5+5%	312-537
R274		22 k	2 w	Fixed	Comp.	10%	306-223
R275		4.7 k	1/2 w	Fixed	Comp.	10%	302-472
R276		3.9 k	1/2 w	Fixed	Comp.	10%	302-392
R279		15 Ω	1 w	Fixed	Comp.	10%	304-150
R280		22 k	2 w	Fixed	Comp.	10%	306-223
R281		22 k	2 w	Fixed	Comp.	10%	306-223
R282A		183 k	1/2 w	Fixed	Prec.	1%	309-050
R282B		60 k	1/2 w	Fixed	Prec.	1%	309-041
R282C	101-174	60 Ω	1/2 w	Fixed	Prec.	1%	309-067
	175 - up	56.5 k	1/2 w	Fixed	Prec.	1%	309-040
R282D		1.84 meg	1/2 w	Fixed	Prec.	1%	309-021
R282E		608 k	1/2 w	Fixed	Prec.	1%	309-005
R282F		608 k	1/2 w	Fixed	Prec.	1%	309-005
R282G	101-789	18.6 meg	2 w	Fixed	Prec.	1%	Use 310-109
	790 - up	18.6 meg	1 w	Fixed	Prec.	1%	310-109
R282H		6.12 meg	1/2 w	Fixed	Prec.	1%	309-088
R282J		6.12 meg	1/2 w	Fixed	Prec.	1%	309-088
R283		500 k	2 w	Var.	Comp.	20%	311-072
R284		18 k	2 w	Fixed	Comp.	10%	306-183
R285		10 k	1 w	Fixed	Comp.	10%	304-103
R286		10 k	2 w	Var.	WW	20%	311-015
R287	101-362	8.2 k	1/2 w	Fixed	Comp.	10%	302-822
	363 - up	4.7 k	1/2 w	Fixed	Comp.	10%	302-472



R288		20 k	2 w	Var.	Comp.	20%	311-018
R289		1.75 meg	1/2 w	Fixed	Prec.	1%	309-019
R290		2.44 meg	1/2 w	Fixed	Prec.	1%	309-024
R291		3.3 k	1/2 w	Fixed	Comp.	10%	302-332
R292	X782 - up	1 meg	1/2 w	Fixed	Comp.	10%	302-105
R293	X782 - up	2.7 meg	1/2 w	Fixed	Comp.	10%	302-275
R300	101-643	200 k	1/2 w	Fixed	Prec.	1%	309-051
	644 - up	220 k	1/2 w	Fixed	Prec.	1%	309-052
R301		47 k	1 w	Fixed	Comp.	10%	304-473
R302		47 k	1 w	Fixed	Comp.	10%	304-473
R303		700 k	1/2 w	Fixed	Prec.	1%	309-008
R304		433 k	1/2 w	Fixed	Prec.	1%	309-001
R305	101-362	68 k	1 w	Fixed	Comp.	10%	304-683
	363 - up	22 k	1 w	Fixed	Comp.	10%	304-223
R306	101-643	10 k	2 w	Var.	WW	20%	311-015
	644 - up	10 k	2 w	Var.	Comp.	20%	311-016
R308		22 k	2 w	Fixed	Comp.	10%	306-223
R310	101-1809	20 k	10 w	Fixed	WW	10%	308-025
	1810 - up	20 k	8 w	Fixed	WW	5%	308-011
R311		30 k	10 w	Fixed	WW	10%	308-027
R315		500 Ω	2 w	Var.	Comp.	20%	311-005
R316		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R317		18 k	2 w	Fixed	Comp.	10%	306-183
R318	101-1809	20 k	10 w	Fixed	WW	10%	308-025
	1810 - up	20 k	8 w	Fixed	WW	5%	308-011
R319		68 k	2 w	Fixed	Comp.	10%	306-683
R325		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R326		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R327		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R328		47 Ω	1/2 w	Fixed	Comp.	10%	302-470
R401		39 k	1/2 w	Fixed	Comp.	10%	302-393



R402		47 k	1/2 w	Fixed	Comp.	10%	302-473
R403		12 k	1/2 w	Fixed	Comp.	10%	302-123
R404		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R405		1 k	1/2 w	Fixed	Comp.	10%	302-102
R406		33 k	1/2 w	Fixed	Comp.	10%	302-333
R407		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R408		2 k	20 w	Fixed	WW	5%	308-031
R409		220 k	1/2 w	Fixed	Comp.	10%	302-224
R410		100 k	2 w	Var.	Comp.	20%	311-026
R411		270 k	1/2 w	Fixed	Comp.	10%	302-274
R412		50 Ω	2 w	Var.	WW	20%	311-055
R420		39 k	1/2 w	Fixed	Comp.	10%	302-393
R421		270 k	1/2 w	Fixed	Comp.	10%	302-274
R422		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R423		100 k	1/2 w	Fixed	Comp.	10%	302-104
R424	101-2380	143 k	1/2 w	Fixed	Prec.	1%	309-048
	2381-2558	150 k	1/2 w	Fixed	Prec.	1%	309-049
	2559 - up	220 k	1/2 w	Fixed	Prec.	1%	309-052
R425	101-2558	100 k	1/2 w	Fixed	Prec.	1%	309-045
	2559 - up	150 k	1/2 w	Fixed	Prec.	1%	309-049
R440		1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R441		270 k	1/2 w	Fixed	Comp.	10%	302-274
R442		56 k	1/2 w	Fixed	Comp.	10%	302-563
R443		3.5 k	20 w	Fixed	WW	5%	308-032
R444		220 k	1/2 w	Fixed	Prec.	1%	309-052
R445		143 k	1/2 w	Fixed	Prec.	1%	309-092
R446	X348 - up	2.2 meg	1/2 w	Fixed	Comp.	10%	302-225
R461		27 k	1/2 w	Fixed	Comp.	10%	302-273
R462		150 k	2 w	Fixed	Comp.	10%	306-154
R463		1.8 meg	1/2 w	Fixed	Comp.	10%	302-185



R464		1.8 meg	1/2 w	Fixed	Comp.	10%	302-185
R465		1.5 k	25 w	Fixed	WW	5%	308-040
R467	101-380 381 - up	1.8 meg 800 k	1/2 w 1/2 w	Fixed Fixed	Prec. Prec.	1% 1%	309-020 309-110
R468	101-380 381 - up	750 k 333 k	1/2 w 1/2 w	Fixed Fixed	Prec. Prec.	1% 1%	309-010 309-053
R469	X348-643 644 - up	2.2 meg 2.2 meg	1/2 w 1/2 w	Fixed Fixed	Prec. Comp.	1% 10%	Use 302-225 302-225
R521		1.1 k	1 w	Fixed	Prec.	1%	310-092
R601		100 k	1/2 w	Fixed	Comp.	10%	302-104
R603		820 k	1/2 w	Fixed	Comp.	10%	302-824
R604		100 k	1/2 w	Fixed	Comp.	10%	302-104
R605		820 k	1/2 w	Fixed	Comp.	10%	302-824
R610		100 k	1 w	Fixed	Comp.	10%	304-104
R611		56 k	1/2 w	Fixed	Comp.	10%	302-563
R612		50 k	2 w	Var.	Comp.	20%	311-023
R620		18 k	1/2 w	Fixed	Prec.	1%	309-036
R621		1.8 k	1/2 w	Fixed	Prec.	1%	309-030
R622		180 Ω	1/2 w	Fixed	Prec.	1%	309-072
R623		20 Ω	1/2 w	Fixed	Prec.	1%	309-064
R802		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R803		47 k	2 w	Fixed	Comp.	10%	306-473
R804		1.5 k	1/2 w	Fixed	Comp.	10%	302-152
R805		47 k	1/2 w	Fixed	Comp.	10%	302-473
R816		1.2 meg	1/2 w	Fixed	Comp.	10%	302-125
R817		2 meg	2 w	Var.	Comp.	20%	311-042
R901		27 k	1/2 w	Fixed	Comp.	10%	302-273
R902		1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R903		2 meg	1/2 w	Var.	Comp.	20%	311-043



R904		3.9 meg	2 w	Fixed	Comp.	10%	306-395
R905		1 meg	1/2 w	Fixed	Comp.	10%	302-105
R910		1 meg	1/2 w	Var.	Comp.	20%	311-041
R911		1.5 meg	1/2 w	Fixed	Comp.	10%	302-155
R912	101-752 753 - up	5.6 meg	2 w	Fixed	Comp.	10%	306-565
		6.8 meg	2 w	Fixed	Comp.	10%	306-685
R913	101-752 753 - up	5.6 meg	2 w	Fixed	Comp.	10%	306-565
		6.8 meg	2 w	Fixed	Comp.	10%	306-685
R914		100 k	1/2 w	Fixed	Comp.	10%	302-104
R920		20 k	2 w	Var.	Comp.	20%	311-018

Switches

			unwired	wired
SW1	2 wafer, 7 position, rotary	AMPLITUDE	260-045	262-016
SW2	1 wafer, 4 position, rotary	MULTIPLIER	260-141	
SW201	3 wafer, 10 position, rotary	TRIG. SELECTOR	260-140	262-018
SW202	4 wafer, 4 position, rotary	SW. MULTIPLIER	260-139	262-019
SW203	4 wafer, 8 position, rotary	SW. RANGE	260-054	262-020
SW204	1 wafer, 2 position, rotary	5X Magnifier	(part of SW203)	
SW401	single pole, single throw, toggle	POWER	260-066	
SW601	1 wafer, 5 position	CALIBRATOR	260-033	262-021

Transformers

T401	Plate and Heater Supply	T315PA2	120-012
	Primary	117/234 vac, 50/800 cycle	
	Secondaries:	130 vac 150 ma	
		130 vac 300 ma	
		140 vac 375 ma	
		220 vac 150 ma	
		6.3 vac 1.2 amp	
		6.3 vac 4 amp	
		6.3 vac 6 amp	
		6.3 vac 3.5 amp	
		6.3 vac 2.5 amp	
T801	CRT Supply	T3150A2	120-011



Thermal Cut-Outs

TK401	X175-2485	Thermal Cut-Out	155 [°]	+or-5 [°]	F.	260-071
	2468 - up	Thermal Cut-Out	160 [°]	+or-5 [°]	F.	260-157

Vacuum Tubes

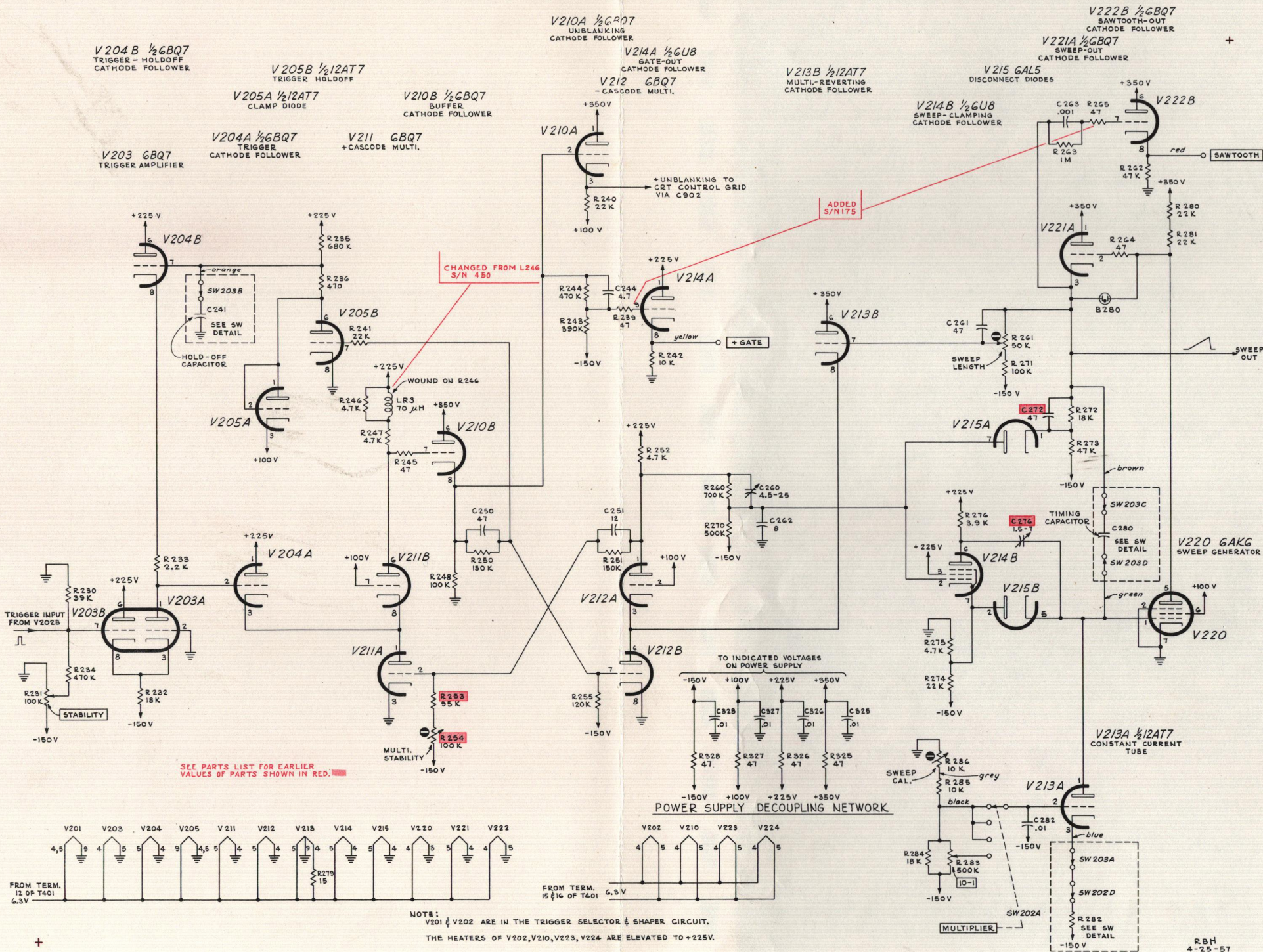
V1	6BQ7A		154-028
V2	6BQ7A		154-028
V3	6CL6		157-007
V4	6CL6		157-007
V8	6BQ7A		154-028
V10	12BY7		154-047
V11	12BY7		154-047
V12	12BY7		154-047
V13	12BY7		154-047
V201	12AT7		157-009
V202	6U8		154-033
V203	6BQ7A		154-028
V204	6BQ7A		154-028
V205	12AT7		154-039
V210	6BQ7A		154-028
V211	6BQ7A		154-028
V212	6BQ7A		154-028
V213	12AT7	Selected	157-010
V214	6U8		154-033
V215	6AL5		154-016
V220	6AK6		154-015
V221	6BQ7A		154-028
V222	6BQ7A		154-028



V223		6BQ7A		154-028
V224		6BQ7A		154-028
V401		5651		154-052
V402		6AU6		154-022
V403		12B4		154-044
V404		12B4		154-044
V421		6AU6		154-022
V422		6AS5		154-018
V441		6AU6		154-022
V442		6080		154-056
V461		6AU6		154-022
V601	101-643 644 - up	12AT7 12AU7		154-039 154-039
V602		12AT7		154-039
V801		12AT7		154-039
V803		6AQ5		154-017
V804		5642		154-051
V805		5642		154-051
V806	101-279 280 - up	3WP1 3WP2	CRT CRT	154-058 154-059





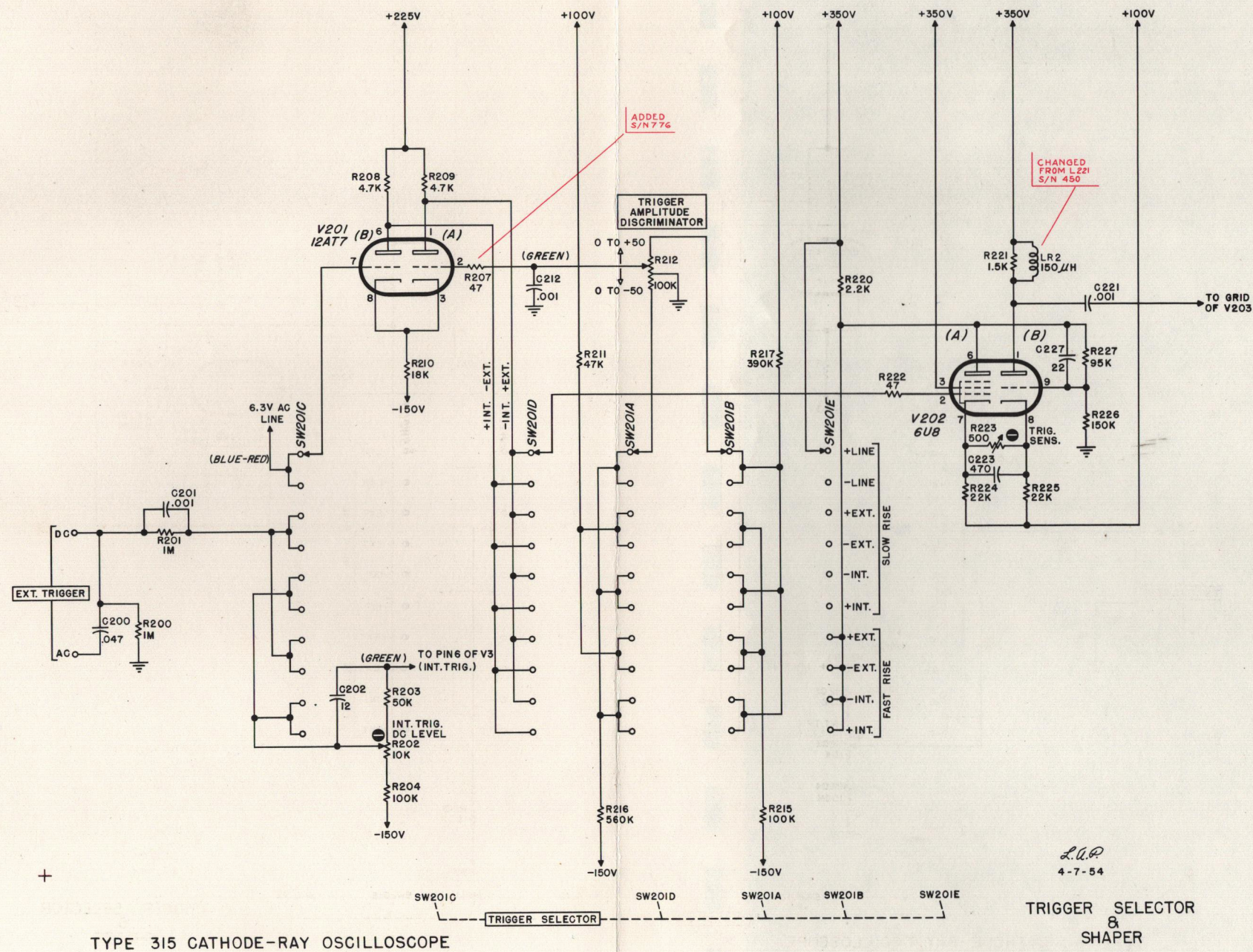


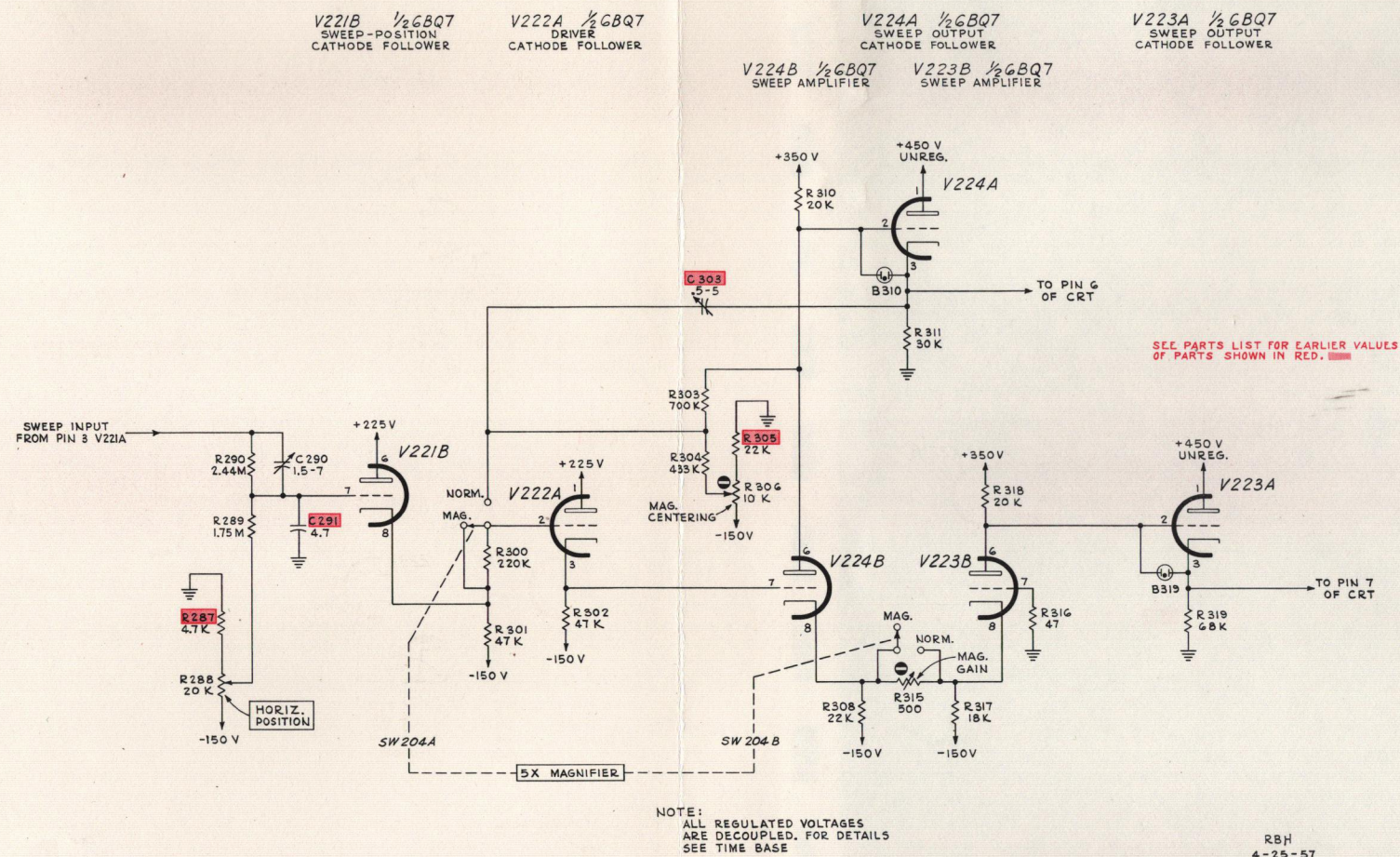


TIME BASE
RANGE & MULTIPLIER SWITCH DETAIL

A A

TIME BASE

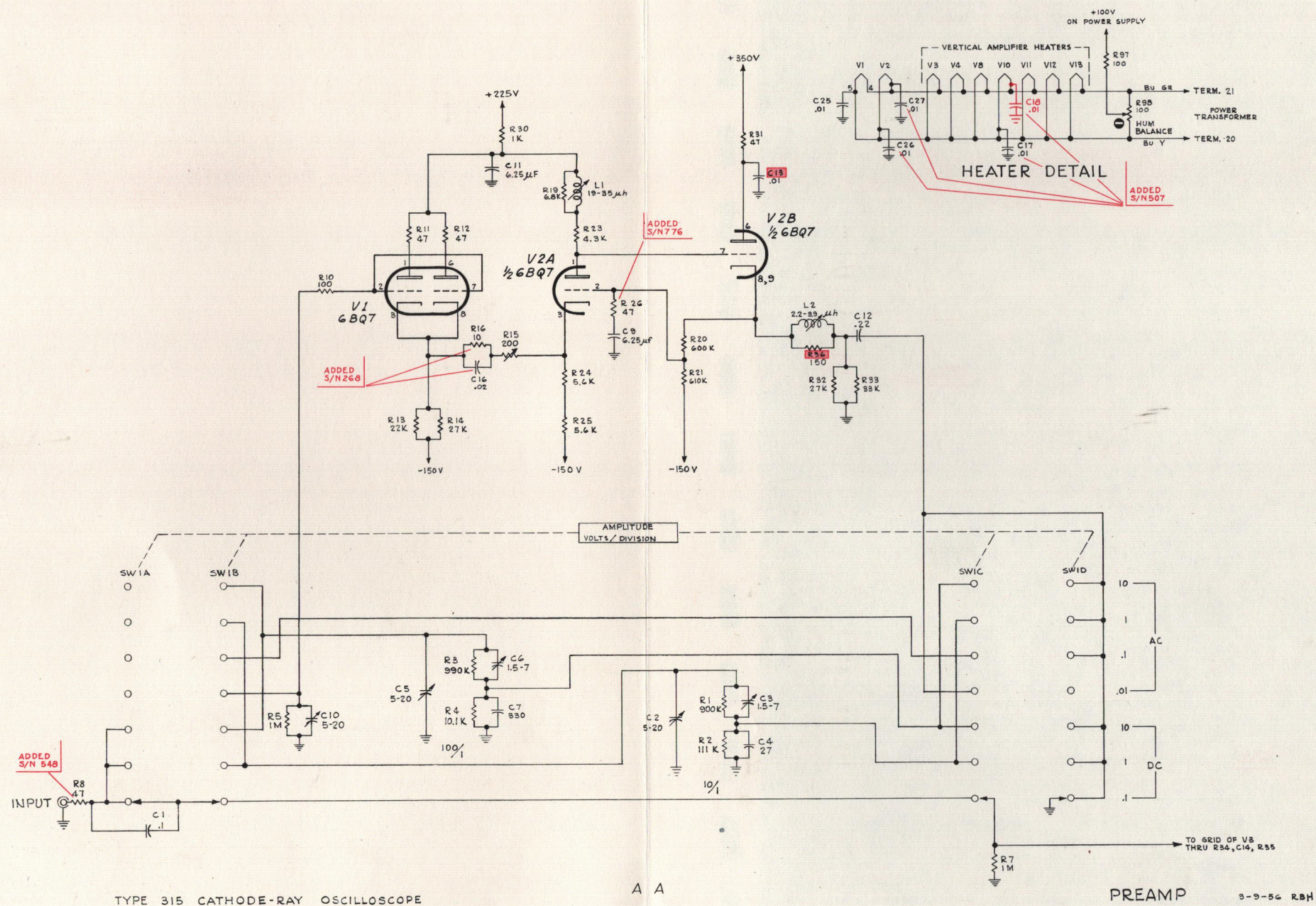


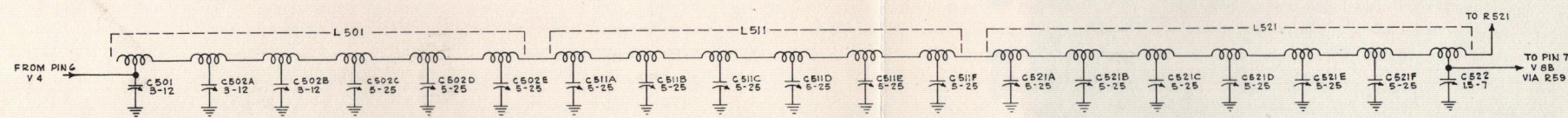


TYPE 315 CATHODE-RAY OSCILLOSCOPE

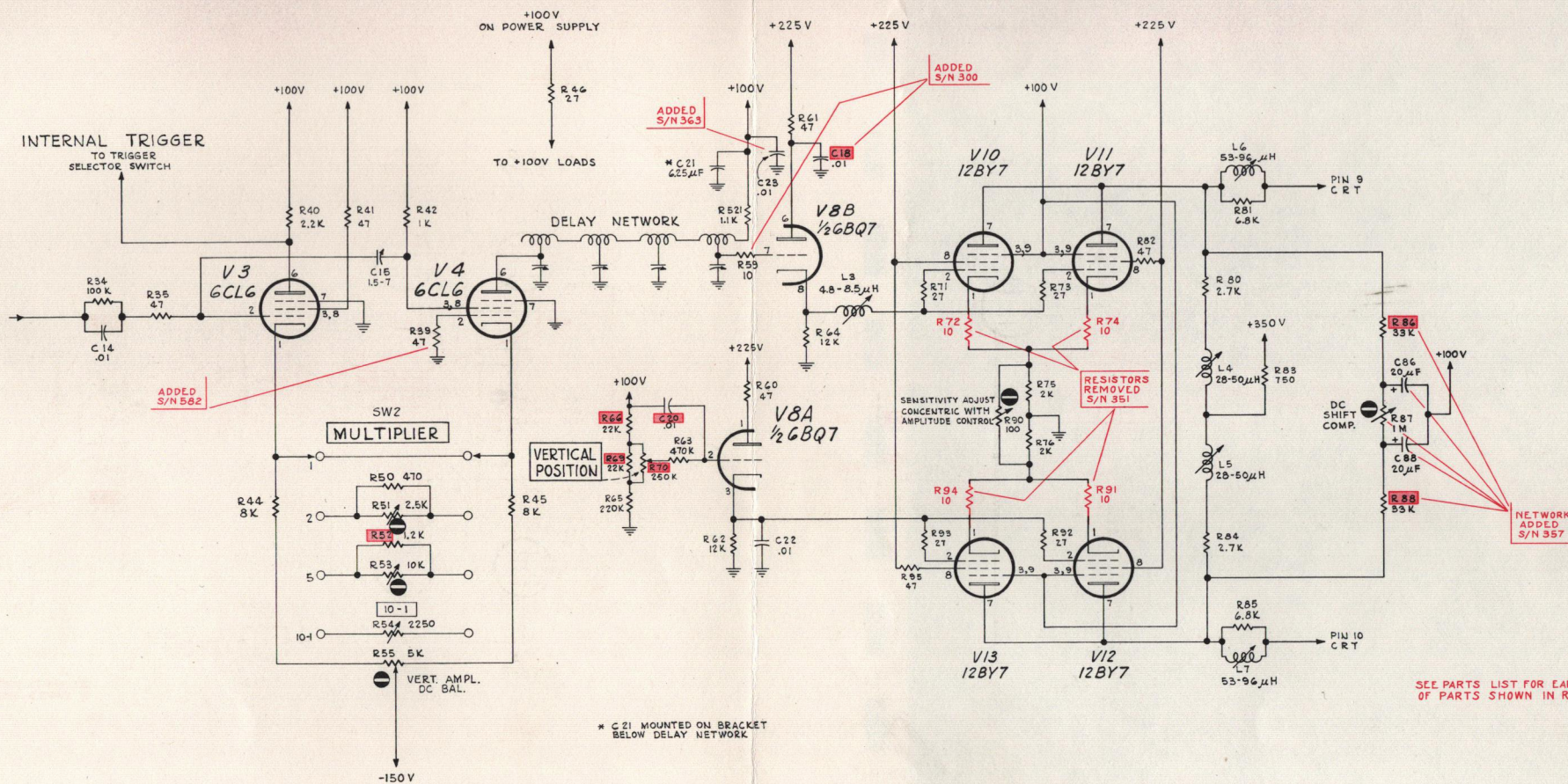
TIME BASE AMPLIFIER

A A

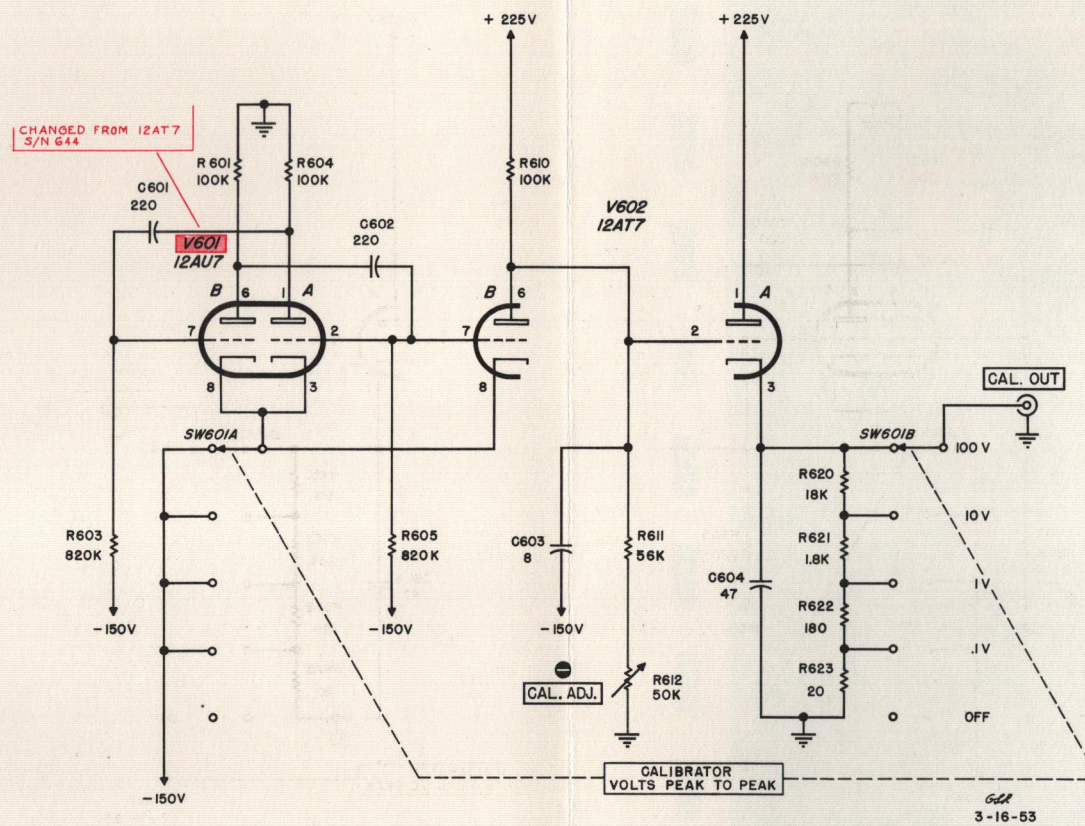




DELAY NETWORK



SEE PARTS LIST FOR EARLIER VALUES OF PARTS SHOWN IN RED.



TYPE 315 CATHODE-RAY OSCILLOSCOPE

CALIBRATOR

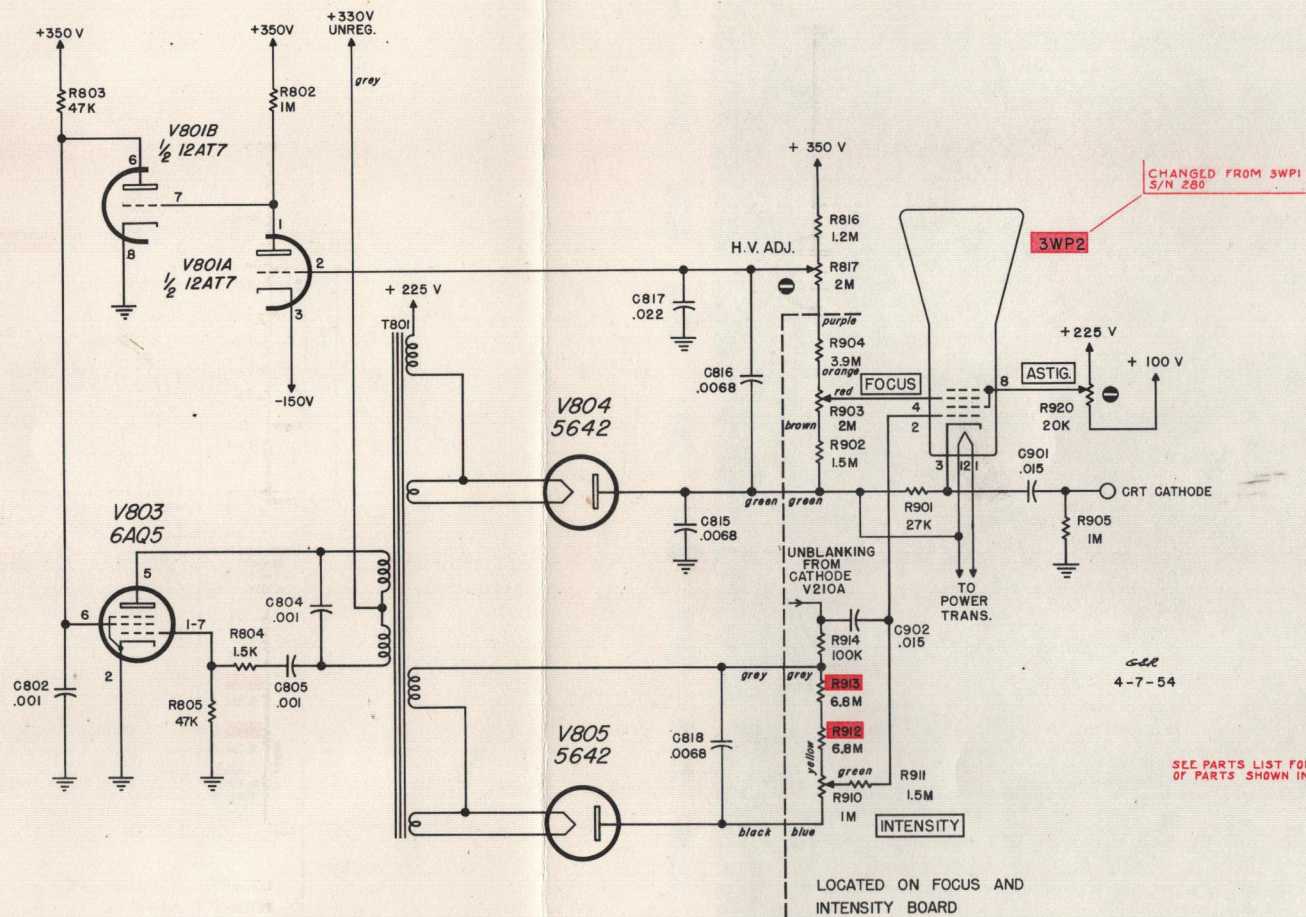
A A



A A

POWER SUPPLY

LV POWER SUPPLY



TYPE 315 CATHODE-RAY OSCILLOSCOPE

HIGH VOLTAGE AND CRT CIRCUITS