

**TECHNICAL
INSTRUCTION and
TRAINING for the**

**TYPE 647
NOTES**

TYPE 647
NOTES

TYPE 647

I. INTRODUCTION

A. The Type 647 is an oscilloscope main frame, designed to accommodate a 10 series vertical plug-in and a 11 series horizontal plug-in.

B. Specifications

1. Vertical Amplifier

- a. Sensitivity, 150 mv/cm (75mv/cm each side).
- b. Risetime, 5.5 nsec $\pm 7\%$ (6.4 nsec with a Type 10A2).
- c. Bandwidth, DC to -3 db down at 64 mc, $\pm 7\%$ (DC to 50 mc with a 10A2).
- d. Inputs, pins 5 and 7, blue ribbon connectors.
- e. Input impedance, 93 Ω each side.
- f. Input signal current, 1.66 ma/cm from 93 Ω source to 93 Ω input.
- g. Overall gain about 33.

2. Horizontal Amplifier

- a. Sensitivity, 347 μ a/cm.
- b. Maximum calibrated deflection rate, 10 nsec/cm.
- c. Bandwidth, DC to -3 db down at 3 mc.

3. CRT (Type T6470-31)

- a. Accelerating potential, 14 kv.
- b. Graticule area, 6 x 10 cm.
- c. Internal edge lighted graticule.
- d. Vertical deflection sensitivity, 5 v/cm, $\pm 7.5\%$.
- e. Horizontal deflection sensitivity, 15 v/cm, $\pm 7.5\%$.

Type 647

4. Unblanking
 - a. DC coupled sweep unblanking.
 - b. Multi trace chop blanking.
 - c. Unblanking for EXT HORIZ INPUT.
 5. CALIBRATOR
 - a. 1 kc, $\pm 0.1\%$.
 - b. 0.2 mv to 100v peak-to-peak square waves and 100v DC.
 - c. 5 ma peak-to-peak square wave through a current loop.
 - d. Duty factor 0.5, $\pm 0.1\%$.
 - e. Output impedance, 50Ω to $.2v$, varying to $4k\Omega$ above $.2v$.
 6. Power Supply
 - a. About 185 watts (with 10A2 and 11B2) at 117v.
 - b. Voltage ranges (regulation ranges):

95 to 122v AC	190 to 244v AC
100 to 130v AC	200 to 260v AC
106 to 137v AC	212 to 296v AC
 - c. Power line distortion requirement, 1% or less.
 - d. Regulated outputs: +100v, +15v, -15v, 175v.
 - e. Unregulated supply, +300v.
- C. A Trace Finder compresses the display, both vertically and horizontally, by about 50%.
- D. A power output connector (J101) provides regulated supply voltages for operating external devices and provides external Single Sweep reset.

Type 647

E. Environmental Characteristics (Operating)

1. Temperature

- a. -30°C to $+65^{\circ}\text{C}$ continuous when not tipped more than 20° .
- b. If operating at -30°C , allow 30 minutes for stabilization.
- c. At maximum altitude, maximum temperature is limited to 55°C .

2. Altitude, 15,000 feet.

3. Vibration, 0.025 inch peak-to-peak, 10-50-10 cps (4 G's) for 15 minutes on each axis.

F. Environmental Characteristics (Non-Operating)

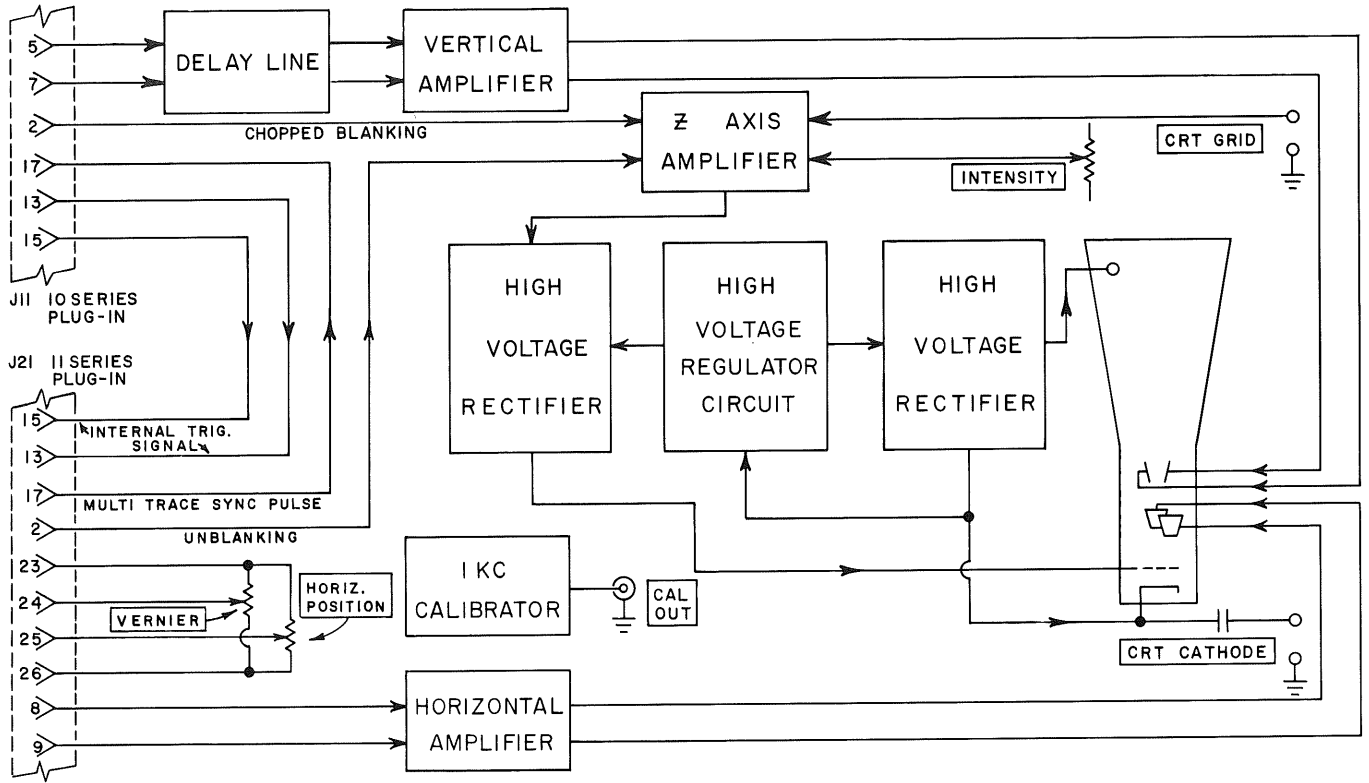
1. Temperature, -65° to 75°C .

2. Altitude, 50,000 feet.

3. Shock, 20 G's, one-half sine, for 11 msec. Two shocks each direction along each of three major axes (total of 12 shocks).

Type 647

G. Block Diagram



TYPE 647 BLOCK DIAGRAM

B-647-0075
3-3-64 dl

Type 647

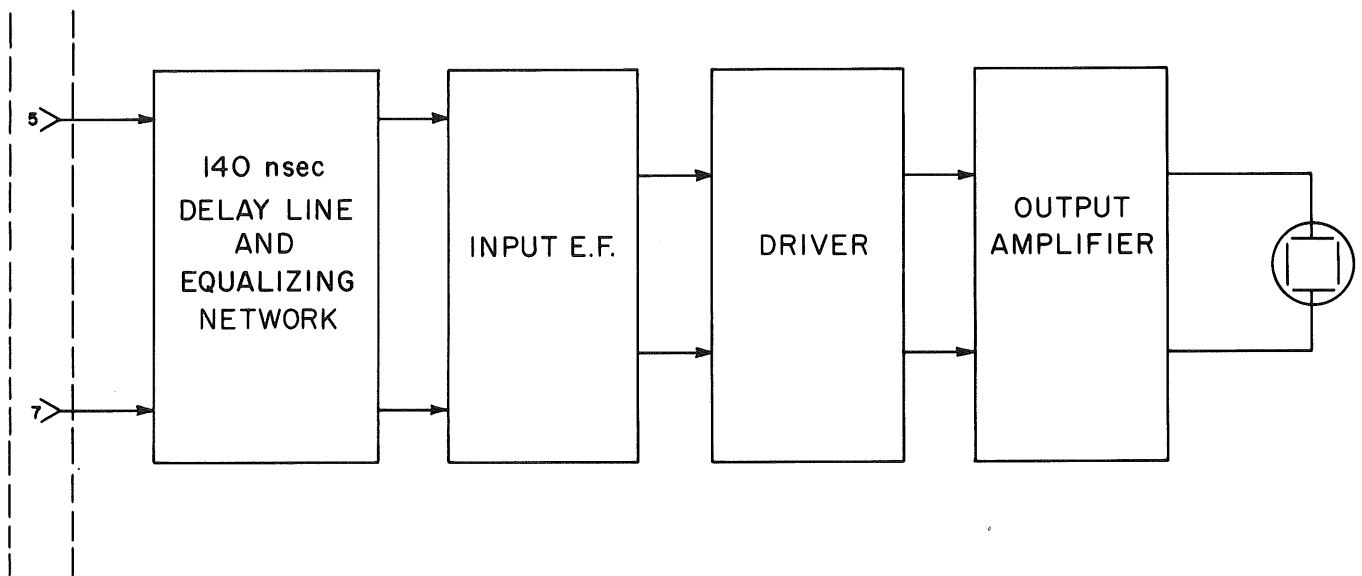
II. VERTICAL AMPLIFIER

A. The vertical amplifier provides the driving voltage for the vertical deflection plates.

1. Input (pins 5 and 7, blue ribbon connector), 150 mv/cm, push-pull.
2. Output (CRT deflection sensitivity), 5 v/cm.
3. Voltage gain nominally set at 33 (maximum gain, 42).

B. Block Diagram

1. The vertical amp is a DC coupled push-pull amplifier.



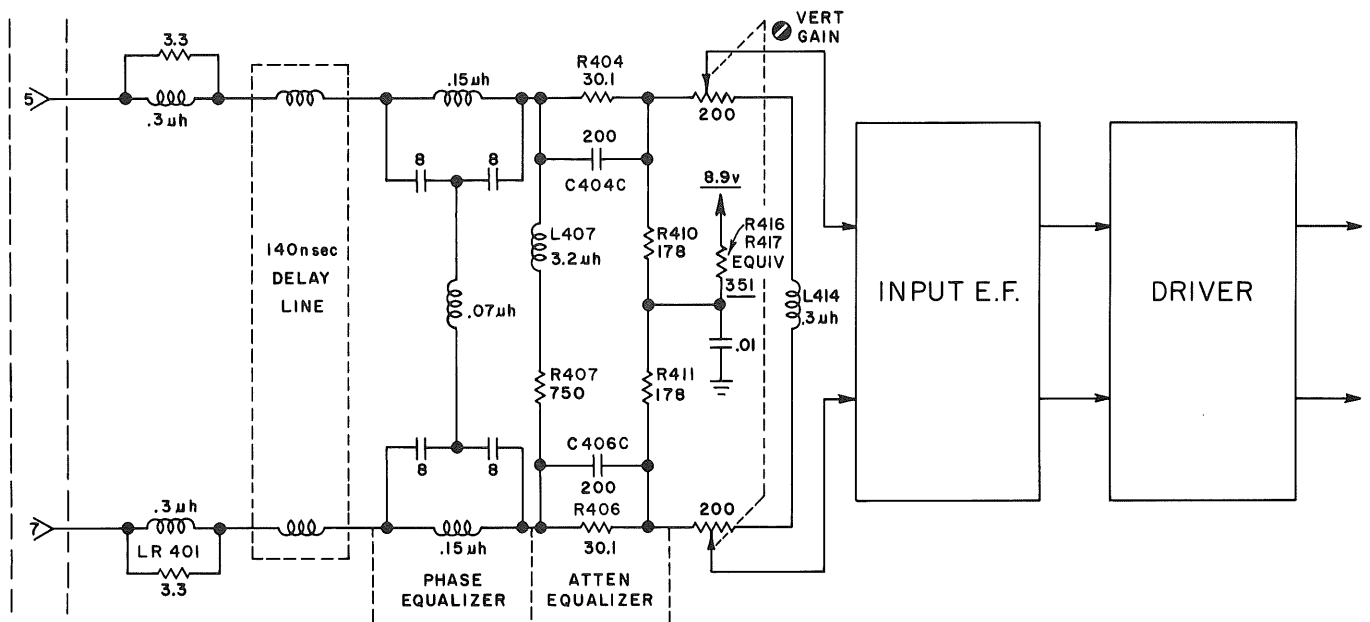
TYPE 647 VERTICAL AMPLIFIER
BLOCK DIAGRAM

B-647-0050
2-17-'64 dl

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C. Basic Circuits

1. Delay line and equalizer network.
2. Input EF.
3. Driver amplifier.
4. Output amplifier.



TYPE 647 VERTICAL AMPLIFIER
DELAY LINE AND EQUALIZING NETWORK

B-647-0051x
2-18-'64 dl

1. The Delay Line is a counter spiral wound 140 nsec cable.
 - a. It provides a delay so the signal that triggers the display can be displayed at the beginning of sweep.
 - b. The line delays both sides of the push-pull signal.
 - c. Total characteristic impedance is 186Ω (93Ω each side).
 - d. The line is terminated in the Type 10A2 in 186Ω and in the equalizer circuit in 186Ω .

Type 647

- e. There are no delay line adjustments.
 - f. Delay line cable and container are Tek made.
 - g. 0.01 inch wire is used with a DC resistance of 3Ω per side.
 - h. A shield allows the line to be wound into a smaller container without input-to-output coupling.
2. LR400, LR401 compensates for a termination mismatch at low frequencies introduced by the 3Ω wire resistance.
3. The delay line responds to a step with a preshoot (anticipation bump) and a risetime characteristic (dribble up*).
- a. The preshoot consists of two or three cycles of near 200 mc information.
 - b. The dribble-up has a time constant of about 6 nsec.
 - c. The Phase Equalizer compensates for the preshoot.
 - d. The Atten Equalizer takes care of the dribble-up.
4. Phase Equalizer
- a. The Phase Equalizer network** compensates for non-linear phase shift in the delay line that results in the preshoot.
 - b. The network provides a linear bandpass with a non-linear phase shift.
 - c. It corrects for phase shift without frequency attenuation.
 - d. The 200 mc signal that comprised the preshoot is delayed the same amount in the Phase Equalizer as the rest of the step is delayed in the delay line.

* See Nanosecond Pulse Measurements by C. N. Winningstad

** Pages 244, 247 - Radio Engineers Handbook, Terman.

Type 647

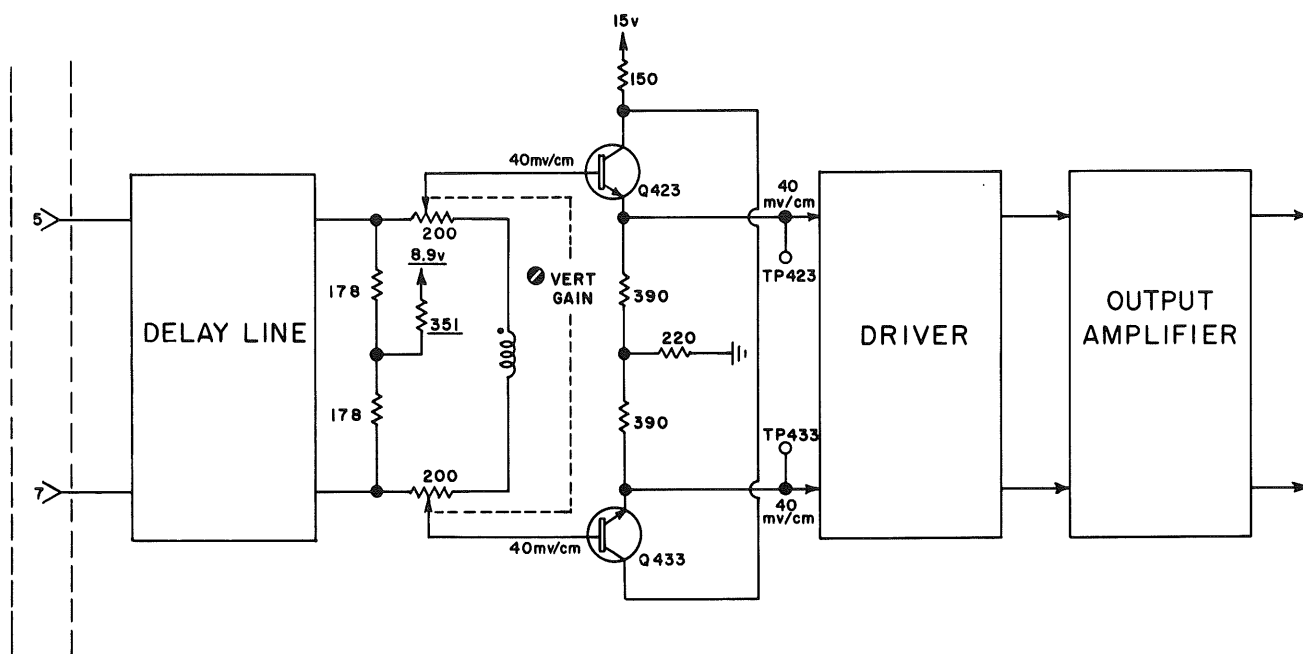
5. Attenuation Equalizer
 - a. The Attenuation Equalizer network** provides an overcompensated voltage divider to compensate for the dribble-up.
 - b. R404, R410 (and R406, R411) form the divider with C404C (and C406C) providing the compensation.
 - (1) C404C and C406C reduce the termination impedance at high frequencies.
 - (2) L407, R407 compensates for high frequency under-termination.
6. R416, R417 (and the vertical plug-in output) set quiescent levels for Q423, Q433 and the rest of the amplifier.
 - a. R416, R417 equivalent circuit is 351Ω to 8.9v.
7. Dual 200Ω VERT GAIN adj pots vary the amplifier gain from 0 to 42 (33 is optimum).
 - a. L414 compensates for transistor input C.
8. The attenuator network and VERT GAIN pots become the 186Ω output termination for the delay line.

** See previous page .

Type 647

E. Input Emitter Follower

1. The EF stage provides isolation between the delay network and the Driver Amplifier.



TYPE 647 VERTICAL AMPLIFIER
INPUT E.F.

B-647-0052x
2-18-'64 dl

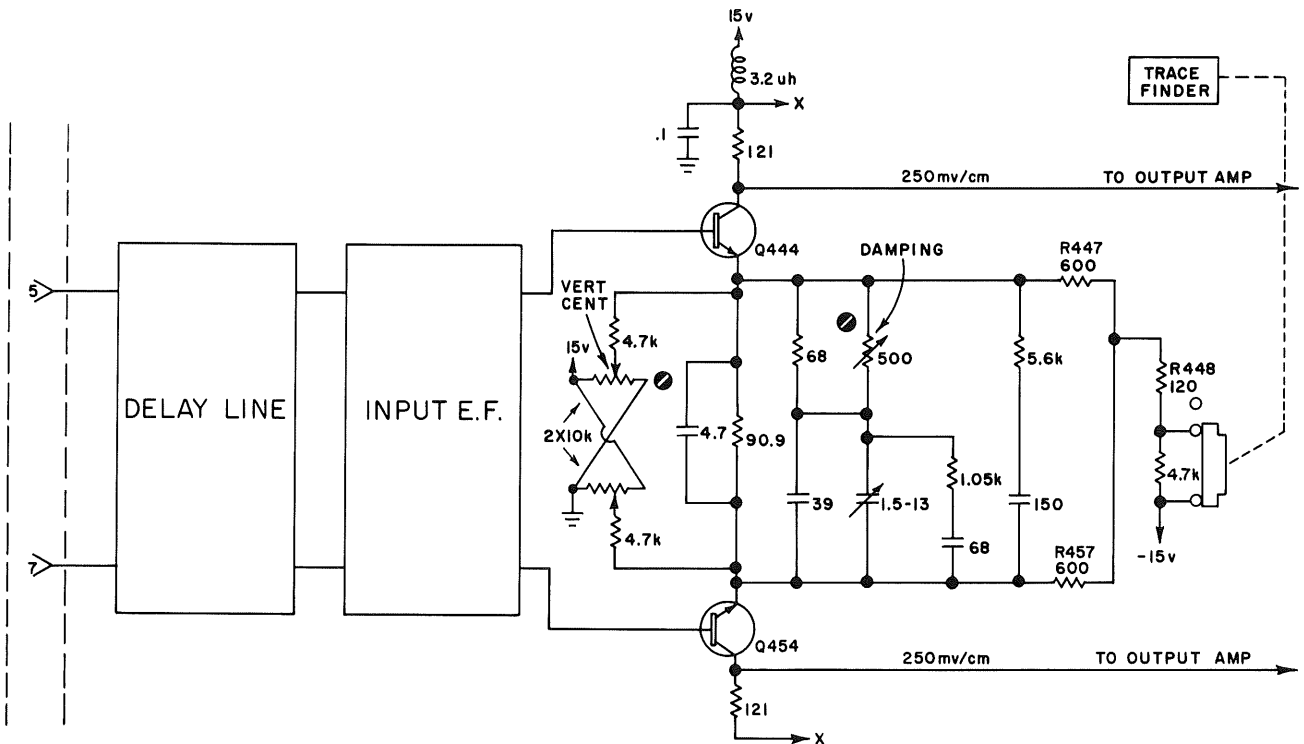
2. Q423 and Q433 are 151-127, selected Fairchild 2N2367 (or S6075) NPN silicon transistors.
3. Stage voltage gain is .98.

Type 647

- 4. Quiescent DC voltages (beam centered vertically):
 - a. Q423, Q433 bases, 8.8v.
 - b. Q423, Q433 emitters, 8.2v (TP423, TP433).
 - c. Q423, Q433 collector, 12v.
- 5. Signal voltage at the delay line is 150 mv/cm push-pull.
- 6. Signal voltage at the EF bases and emitters is about 100 mv/cm push-pull.

F. DRIVER AMPLIFIER

- 1. The Driver Amplifier is a conventional emitter coupled push-pull amplifier.



TYPE 647 VERTICAL AMPLIFIER
DRIVER AMPLIFIER

B-647-0053*
2-19-'64 dl

Type 647

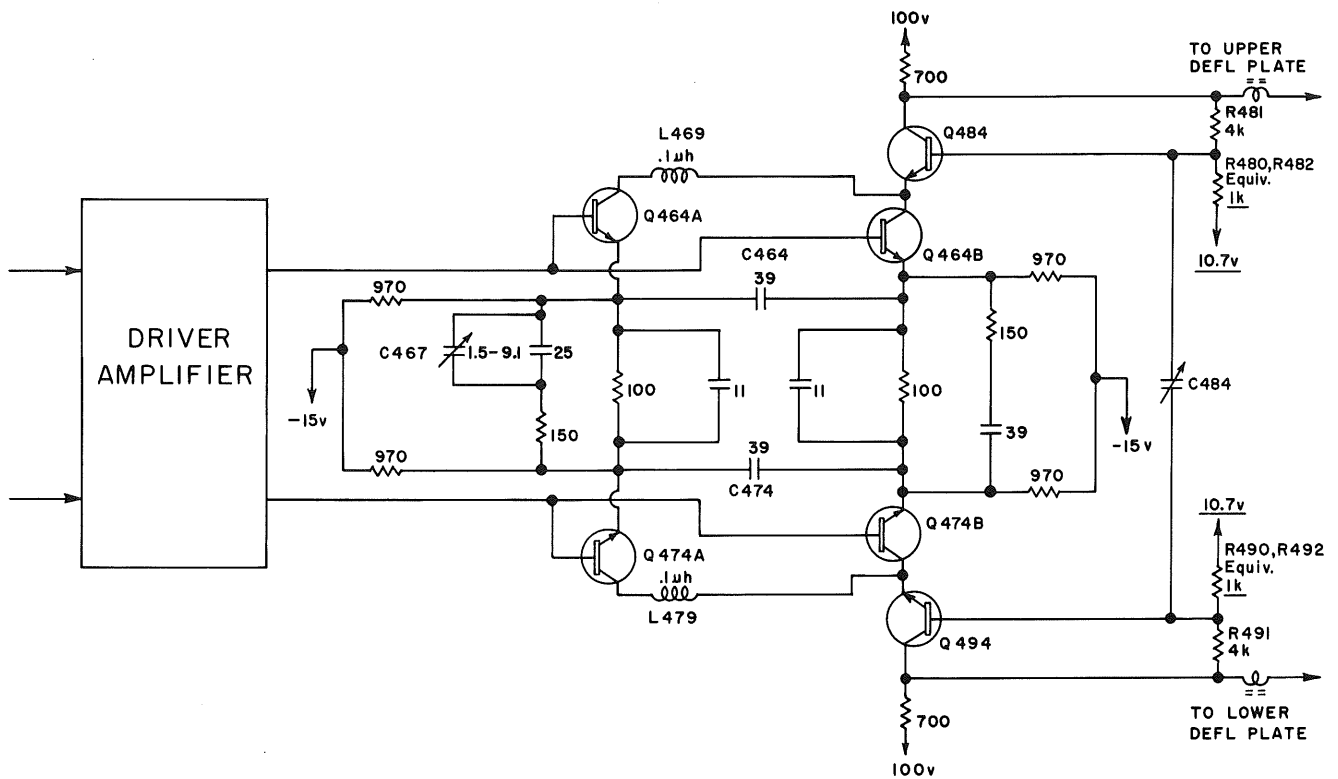
2. Q444 and Q454 are 151-127 transistors.
3. Stage voltage gain is about X2.5.
 - a. Signal voltage at the collectors is 250 mv/cm push-pull.
4. Quiescent DC levels (beams centered vertically).
 - a. Q444 and Q454 bases, 8.2v.
 - b. Q444 and Q454 emitters, 7.45v.
 - c. Q444 and Q454 collectors, 11.8v.
5. Five RC networks help retain transient response (provide HF peaking).
 - a. Each of the networks have a different time constant.
 - b. The DAMPING adjustment can set the RC time of three of the networks to prevent ringing.
 - c. R447, R457, and R448 set the quiescent current.
6. As the TRACE FINDER is pushed, current to each transistor is reduced to 2.2 ma limiting the gain of the stage.
 - a. Regardless of vertical positioning or signal amplitude, the trace is contained within the 6 cm vertical display area.
 - b. The control is a spring return push button.
7. The VERT CENT adj feeds push-pull current to the emitters allowing the calibrator to center the trace on the graticule.

G. Output Amplifier

1. The amplifier provides voltage drive for the CRT vertical deflection plates.

Type 647

2. The circuit is an emitter coupled push-pull cascode amplifier.



TYPE 647 VERTICAL AMPLIFIER
OUTPUT AMPLIFIER

B-647-0054x
2-20-64 dl

3. Q464A, Q464B, Q474A and Q474B are 151-127 transistors.
4. Voltage gain for the stage is about 20.
 - a. Signal voltage output is 5 v/cm.
5. Q484 and Q494 are 151-121, selected RCA TA1938 silicon NPN transistors.*

* Matched pairs.

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6. Quiescent DC levels (beam centered):
 - a. Q464, Q474 bases, 11.8v.
 - b. Q464, Q474 emitters, 11.2v.
 - c. Q464, Q474 collectors, 19v.
 - d. Q484, Q494 emitters, 19v.
 - e. Q484, Q494 bases, 19.5v.
 - f. Q484, Q494 collectors, 56v.
7. The parallel transistor pairs provide current drive to Q484 and Q494.
8. Q464 and Q494 provide the 5 v/cm* voltage swing required to drive the CRT deflection plates.
9. Feedback resistors R481, R491 apply 20% of the output signal voltage to Q484, Q494 bases.
 - a. R480, R482 and R490, R492 form equivalent 1k to +10.7v.
 - b. 20% of the output signal voltage forms across Q464 and Q474.
 - c. 80% of the output voltage appears across Q484, Q494.
 - d. Of the full output signal, taken across the collector loads, the voltage swing is distributed (20% - 80%) across the cascoded transistors.
10. Separate emitter current returns and emitter coupling resistors for each push-pull pair of transistors (Q464A, Q474A and Q464B, Q474B) allow the transistors to seek their own operating points.
 - a. Transistors need not be matched.
 - b. About 26 ma static current flows through each transistor.
 - c. C464 and C474 tie the emitters together at high frequencies, preventing an oscillation at about 500 mc.

* Will vary $\pm 7.5\%$ with CRT deflection sensitivity.

Type 647

11. High frequency peaking is provided in both emitter coupling circuits.
 - a. C467 provides variable peaking.
12. L469, L479 provide signal delay to match a delay present in base coupling.
13. C484 provides variable high frequency peaking by reducing negative feedback at high frequencies.

Type 647

III. HORIZONTAL AMPLIFIER

A. The Horizontal Amplifier consists of two operational amplifiers that drive the Horizontal deflection plates.

1. Output requirement is a push-pull voltage ramp 150v* peak-to-peak for 10 cm.
 - a. 75v* per side.
 - b. CRT sensitivity is 15v/cm* push-pull or 7.5 v/cm* each plate.
2. Input sensitivity is 347 $\mu\text{a}/\text{cm}$ per side.
 - a. Standardized in all horizontal plug-ins.
 - b. Inputs at pins 8 and 9 of the blue ribbon connector.
3. Transimpedance gain is 216 $\text{mv}/\mu\text{a}$.

a.
$$A_z = \frac{\Delta e_o}{\Delta i_i}$$

Where: A_z is transimpedance gain.

Δe_o is output signal voltage.

Δi_i is input signal current.

b.
$$A_z = \frac{7.5 \text{ v/cm}^*}{347 \mu\text{a/cm}}$$

$$A_z = 21.6 \text{ v/ma}$$

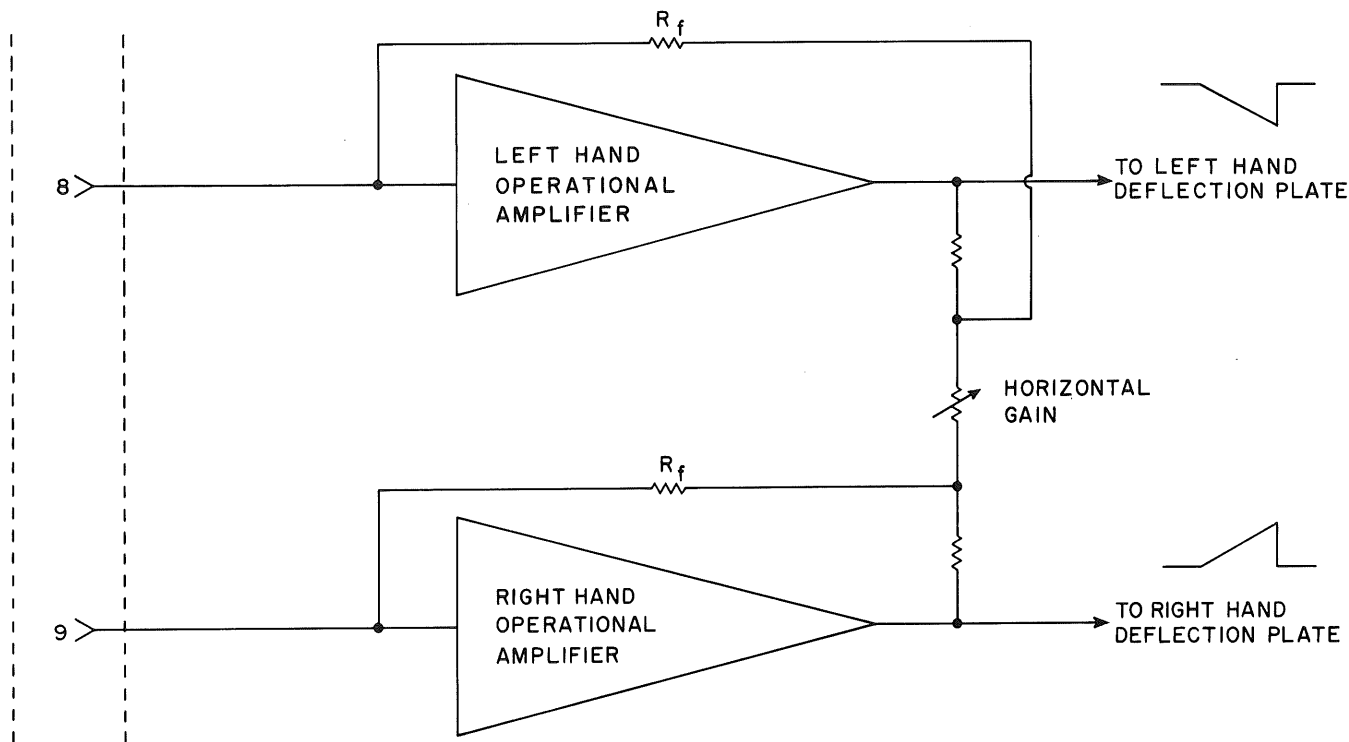
4. Total voltage gain of 11B2 Horizontal preamp and 647 Horizontal amplifier is about 7.8.
 - a.
$$A_v = \frac{7.5 \text{ v/cm}^*}{.96 \text{ v/cm}}$$

$$A_v = 7.8$$
5. A TRACE FINDER switch provides the operator with a method of reducing the sweep by about one-half.

* Will vary $\pm 7.5\%$ with CRT's.

Type 647

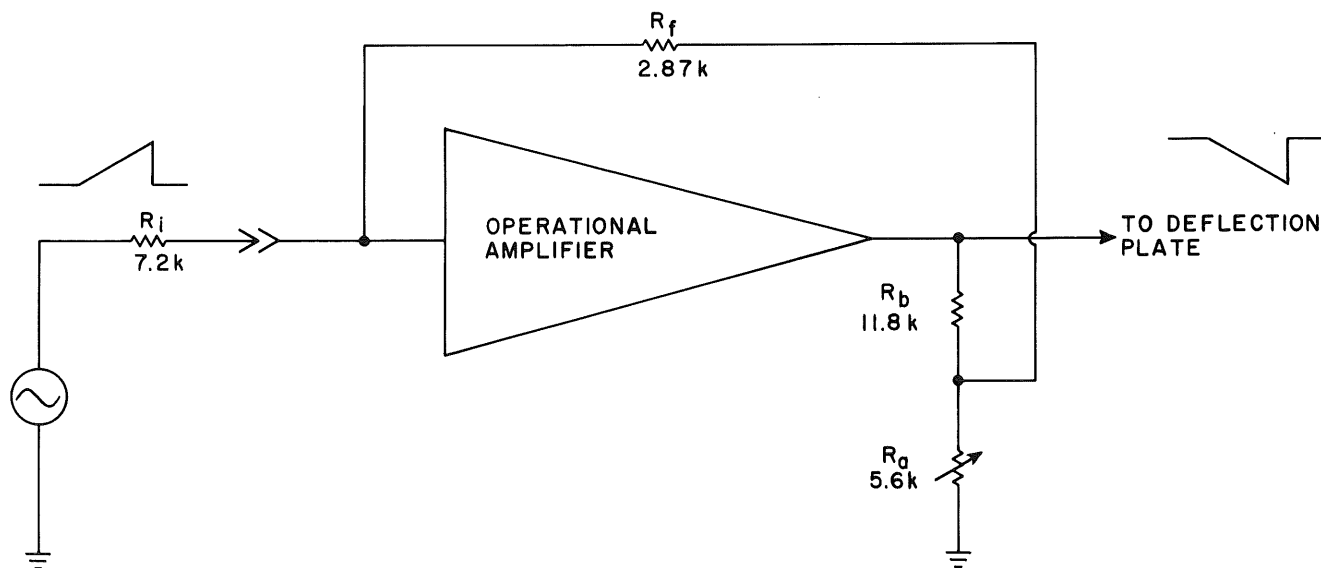
B. Block Diagram



TYPE 647 HORIZONTAL AMPLIFIER
BLOCK DIAGRAM

B-647-0068
2-22-64 ms

C. Basic Operational Amplifier



Type 647

1. Each operational amplifier has a current drive of $347 \mu\text{a}/\text{cm}$.
 - a. $R_{i\text{in}}$ with a value of 7.2k is the equivalent collector load of the Horizontal Preamp.
 - b. The hypothetical generator voltage is $2.5 \text{ v}/\text{cm}$.
 - (1) $7.2\text{k} \times 347 \mu\text{a}/\text{cm} = 2.5 \text{ v}/\text{cm}$.
2. The HORIZONTAL GAIN adj (R377) tied between the two amplifiers can be considered a divider from which the feedback is taken.
 - a. Measurements made with an instrument with a CRT deflection sensitivity of $7.2 \text{ v}/\text{cm}$ had R377 set at 3.2k .
 - b. Half R377 plus R378 forms R_a in the basic amplifier illustration (4.5k).
3. R_b is the 11.8k R376 and R_f is the 2.87k feedback resistor R371.
4. Signal voltage at the junction of R_a and R_b is $1 \text{ v}/\text{cm}$.
 - a. $2.87\text{k} \times 347 \mu\text{a}/\text{cm} = 1 \text{ v}/\text{cm}$.
5. Signal voltage at the amplifier output is $7.3 \text{ v}/\text{cm}$.
 - a. Find the value of R_a and R_f in parallel.
 - (1) $\frac{5.6\text{k} \times 2.83\text{k}}{8.43\text{k}} = 1.87\text{k}$
 - b. $e_{\text{out}} = \frac{13.67\text{k}}{1.87\text{k}} \times 1 \text{ v}/\text{cm} = 7.3 \text{ v}/\text{cm}$.
6. The gain of the operational amplifier is 2.87 .
 - a. The usual gain formula $A_v = \frac{R_f}{R_i}$ must be modified to consider the output divider.
 - b. $A_v = \frac{2.87\text{k}}{7.2\text{k}} \times \frac{13.67}{1.87} = 2.87$.

Type 647

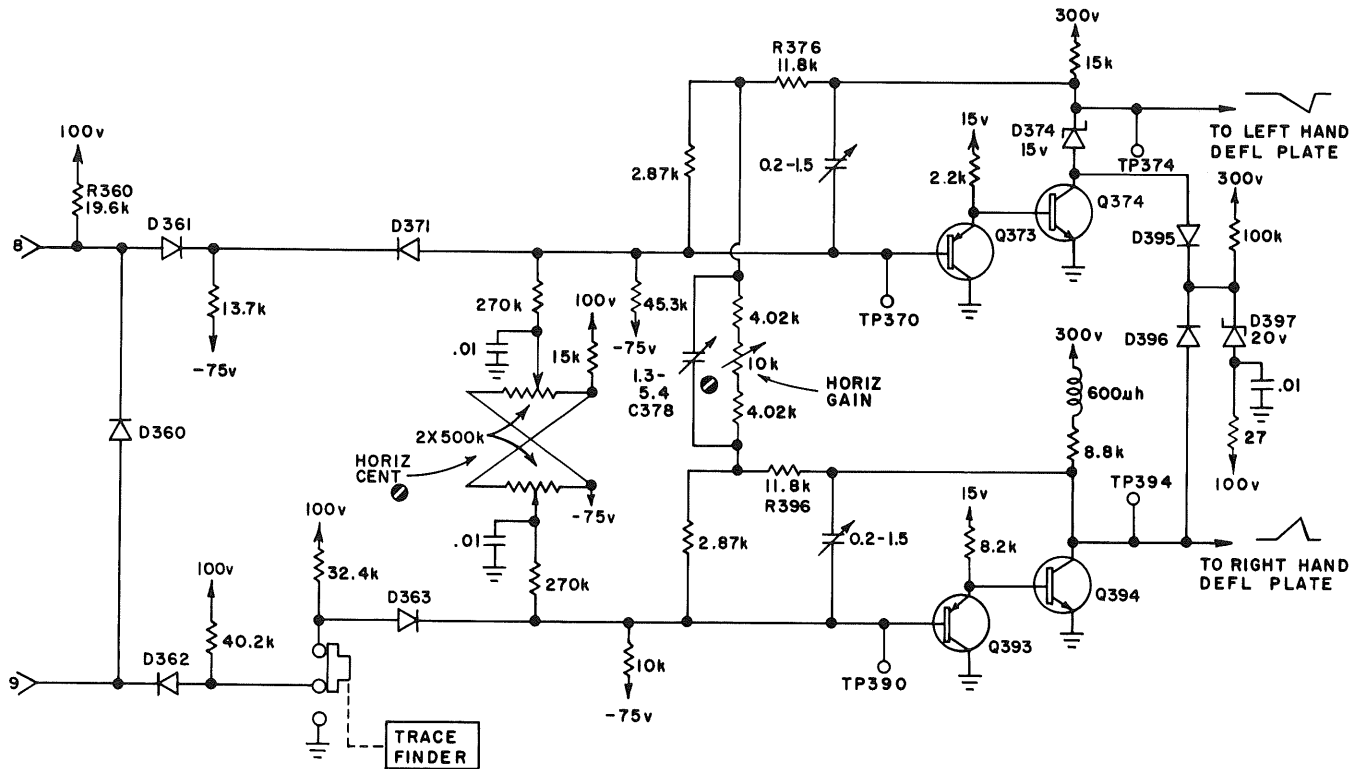
7. A check on the above calculations could be made by using the formula:

$$e_{out} = I_i R_i \times A_v$$

$$e_{out} = 347 \mu\text{a/cm} \times 7.2\text{k} \times 2.87$$

$$e_{out} = 7.2 \text{ v/cm}$$

D. Horizontal Amplifier



TYPE 647 HORIZONTAL AMPLIFIER
SIMPLIFIED SCHEMATIC

C-647-0031x
2-25-64 dl

Type 647

1. Each amplifier has two transistors and three diodes plus a tying diode and two zeners.
 - a. Q373 and Q393 are 151-122 selected Fairchild S5909 silicon PNP transistors.
 - b. Q374 and Q394 are 151-124 selected RCA TA1938 silicon NPN transistors.
 - (1) Selected for 120v BV_{CBD} .
 - (2) Mounted on beryllium oxide heat sinks.
 - c. D361, D371, D360, D362 and D363 are GE 1N3605 silicon diodes.
 - d. D395 and D396 are Raytheon 6061 silicon diodes.
 - e. D374 is a Motorola 1N3024B 15v 5% zener.
 - f. D397 is a Motorola 1M20Z10 20v zener.
2. The input to each amplifier at pins 8 and 9 of the blue ribbon connector is a current ramp, 3.47 ma peak-to-peak (for 10 cm).
3. The output is a push-pull voltage ramp, 150v peak-to-peak.
 - a. The output to the left hand CRT deflection plate is a negative going 75v sawtooth from 100v to 25v.
 - b. The right hand CRT deflection plate is a positive going 75v sawtooth from 31v to 106v.
 - c. With MAG ON, the excursion on both deflection plates is about 15v to 120v.
4. Quiescent DC levels, Q373, Q393, Q374, Q394 (trace at the center of the screen).
 - a. Q373, Q393 Bases, .15v.
 - b. Q373, Q393 Emitters, .65v.
 - c. Q374 Collector, 50v.
 - d. Q394 Collector, 70v.

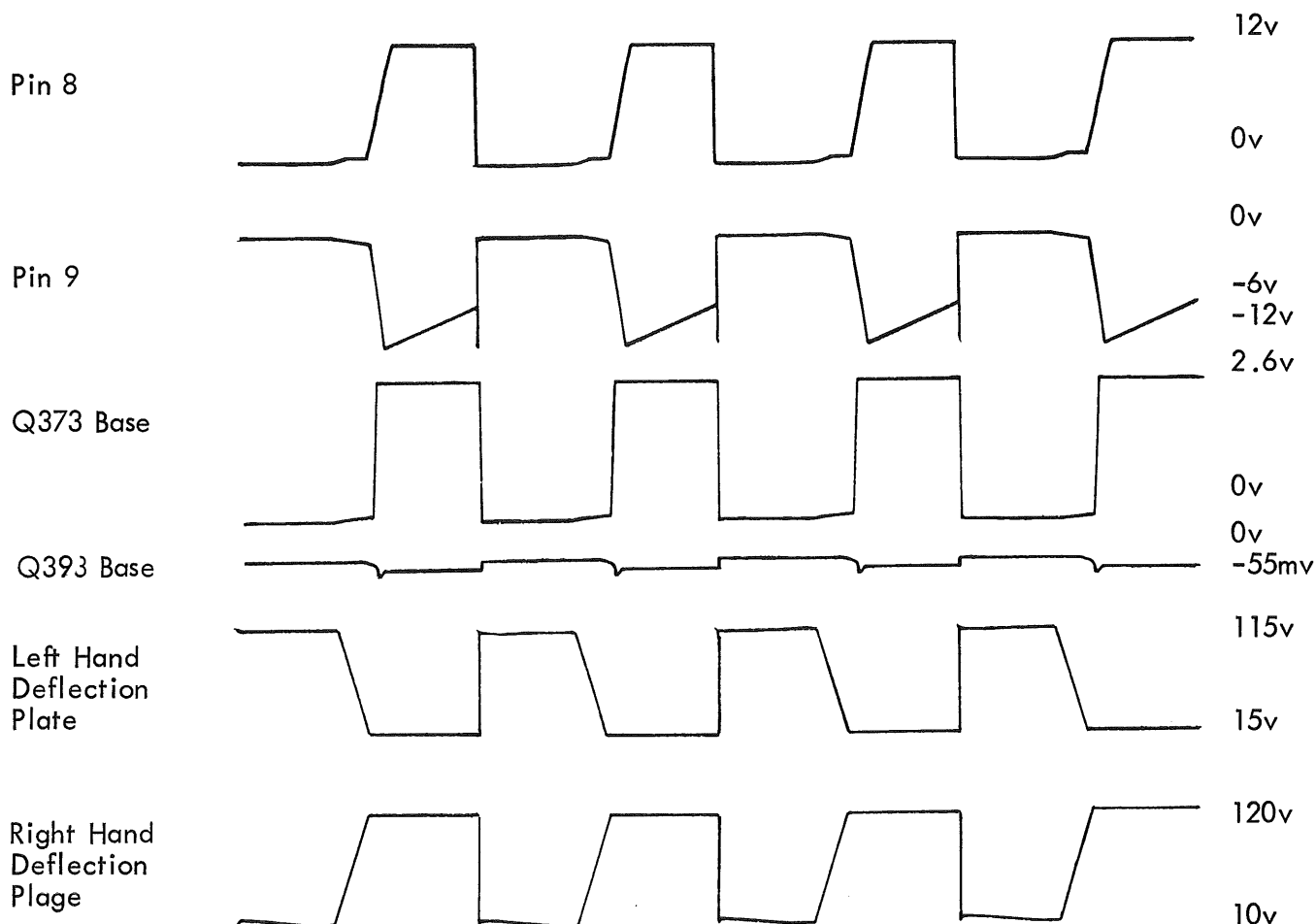
Type 647

5. Prior to sweep, D360, D361 and D362 are conducting slightly.
6. Q373 and Q393 are saturated with their bases at .15v.
7. Driving current requirements differ for Q374 and Q394.
 - a. Q374 requires more driving current during sweep at fast sweep speeds.
 - b. A 2.2k resistor is used in Q373 emitter return to satisfy the current requirements.
 - c. Q393 emitter is pulling Q394 base down during sweep so a larger emitter resistor can be used.
8. During sweep, Q394 collector moves up as its base receives a negative going ramp.
 - a. A fast rise capability is essential to assure linear sweep at fast sweep speeds.
 - b. Q394 must not be allowed to cut off as the feedback loop would be broken.
 - c. The high current requirements to charge CRT deflection plate C is provided by the lower value (8.8k) collector load resistor and the 600 uh inductor.
9. Q374 is conducting heavily during sweep so a larger collector load resistor can be used.
10. C377 and C397 are speedup caps to prevent delay to fast portions of the feedback signal.
11. As described under Basic Operational Amplifier, the HORIZ GAIN adj controls how much signal will be available for feedback.
 - a. C378 provides high frequency peaking by reducing feedback at fast sweep speeds.
12. The HORIZ CENTERING adj varies quiescent base current at Q373 and Q393 to center the trace.

Type 647

13. Operation with MAG ON.

- a. In this condition, the signal current ramp slope is increased by a factor of 10.
- b. Prior to sweep D360 is conducting and D361 and D362 are cut off.
- c. As sweep starts, D361 and D362 conduct and the current ramp is applied to Q373 and Q393 bases.
- d. As Q373 becomes less forward biased and Q374 becomes more forward biased, the output ramp is formed.
- e. As the negative going ramp to the left hand deflection plate reaches 15v, Q373 cuts off and Q374 saturates.



Type 647

- f. The feedback loop is now broken.
- g. The low impedance load on the Preamplifier (in the horizontal plug-in) is removed.
- h. The Preamp collector raises to its no load potential of 12v.
- i. D371 cuts off.
- j. Current through the feedback resistor (R376) and the HORIZ GAIN adj lift Q373 base to 5v.
- k. The left hand deflection amplifier remains in this condition until the end of sweep.
- l. As retrace begins and the voltage on pin 8 drops to 0v, D371 and Q373 conduct.
- m. With the feedback loop again functioning, Q373 base returns to .15v, and the output voltage rises to 110v.
- n. During the same cycle, a positive going current ramp is applied to Q393 base.
- o. Q393 becomes more forward biased as Q394 becomes less forward biased.
- p. As the right hand deflection plate output reaches 120v, D396 conducts clamping the output at 120v.
- q. At this point, Q393 has reached saturation and Q394 cuts off.
- r. The feedback loop is broken.
- s. The preamp collector (and pin 9 of the blue ribbon connector) drops to its no-load potential of -12v cutting off D363.
- t. The preamp output transistor saturates.
- u. Driven by its EF driver, all elements of the saturated transistor rise along the balance of the sweep ramp to about -6v.

Type 647

- v. Q393 is clamped at ground by its base-collector junction.
 - w. At retrace the preamp transistor collector begins to fall, but as it reaches -12v, the transistor comes out of saturation.
 - x. The collector reverses direction and raises rapidly to 0v.
 - y. As the voltage on pin 9 returns to 0 volts, D363 conducts, Q393 comes out of saturation, Q394 collector drops to 10v and the feedback loop is again complete.
 - Z. The sweep cycle is complete.
14. D395 does not conduct during normal (or MAG ON) operation.
- a. D395 would conduct should a circuit failure cut off Q374.
 - b. Q374 collector would clamp at 120v.
 - c. BV_{CBO} for 151-124 is 120v.
15. D374 allows the left hand deflection plate output to reach 115v (in MAG ON) without allowing Q374 to cut off.
- a. With Q374 conducting and the feedback loop complete, the magnified ramp can get a fast start.
16. It is important that both feedback loops be complete just prior to the start of magnified sweep.
- a. Opening the feedback loops after magnified sweep and prior to retrace does not affect the used portion of the output waveform.
17. D397 sets the catching level for D395 and D396 at 120v.
18. The TRACE FINDER switch can disconnect the input current from Q373 base and connect it through D360 to ground.
- a. The amplifier receives no signal.
 - b. The Right Deflection Plate Amplifier operates normally.
 - c. The sweep is reduced by 50%.
 - d. Current through R360 places the proper voltage on the left deflection plate to center the trace.

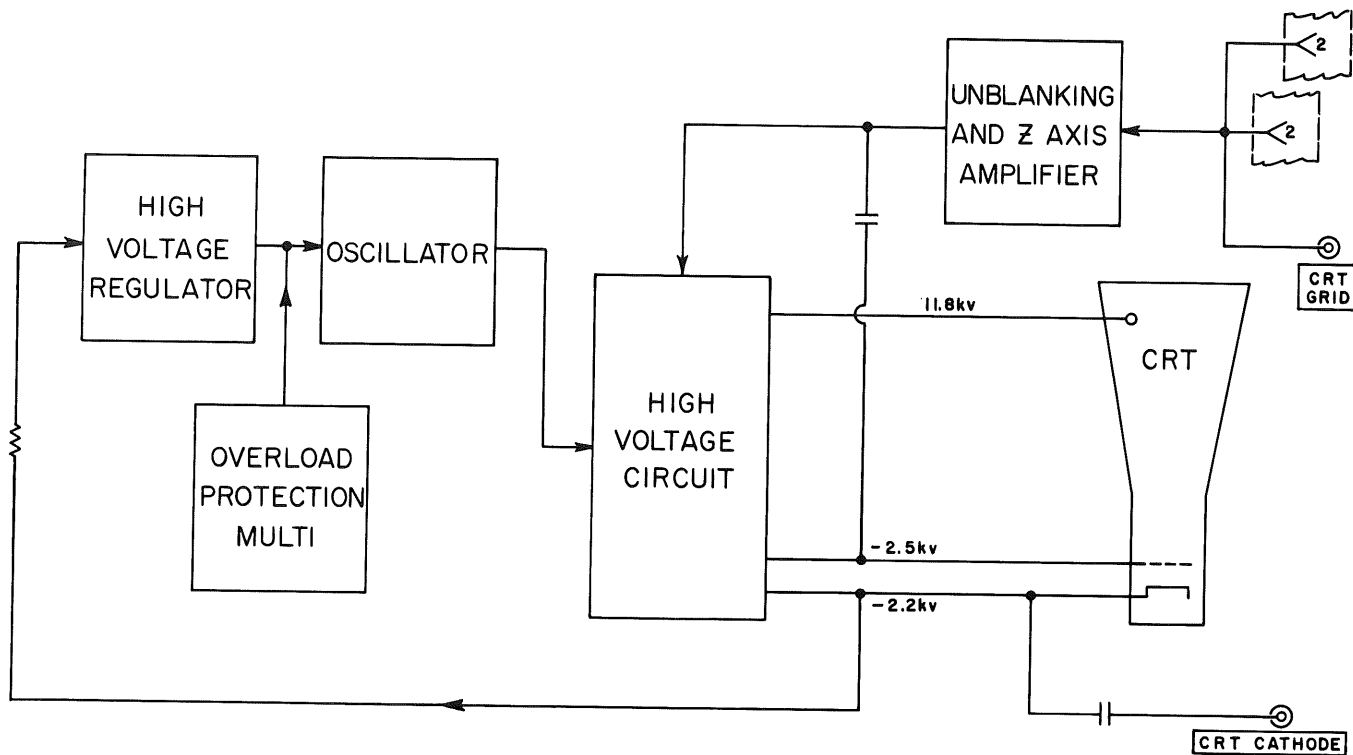
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IV. CRT AND HIGH VOLTAGE

- A. The CRT and High Voltage circuit consists of a CRT, its regulated power supply, and an unblanking and Z axis modulation amplifier.
- B. Outputs from the regulated supply.
 - 1. 11.8 kv for the CRT post accelerator anode.
 - 2. -2.2 kv for the CRT cathode.
 - 3. -2.5 kv (variable) for the CRT grid.
- C. Z Axis Modulation
 - 1. DC coupled through an amplifier to the CRT grid.
 - 2. AC coupled to the CRT cathode.
- D. Controls, Front Panel
 - 1. FOCUS
 - 2. INTENSITY
 - 3. ASTIGMATISM
 - 4. TRACE ROTATION
- E. Adjustments
 - 1. CRT GRID BIAS
 - 2. GEOMETRY
 - 3. HIGH VOLTAGE

Type 647

F. Block Diagram



TYPE 647 CRT AND HIGH VOLTAGE
BLOCK DIAGRAM NO. 1

B-647-0041
1-24-64 dl

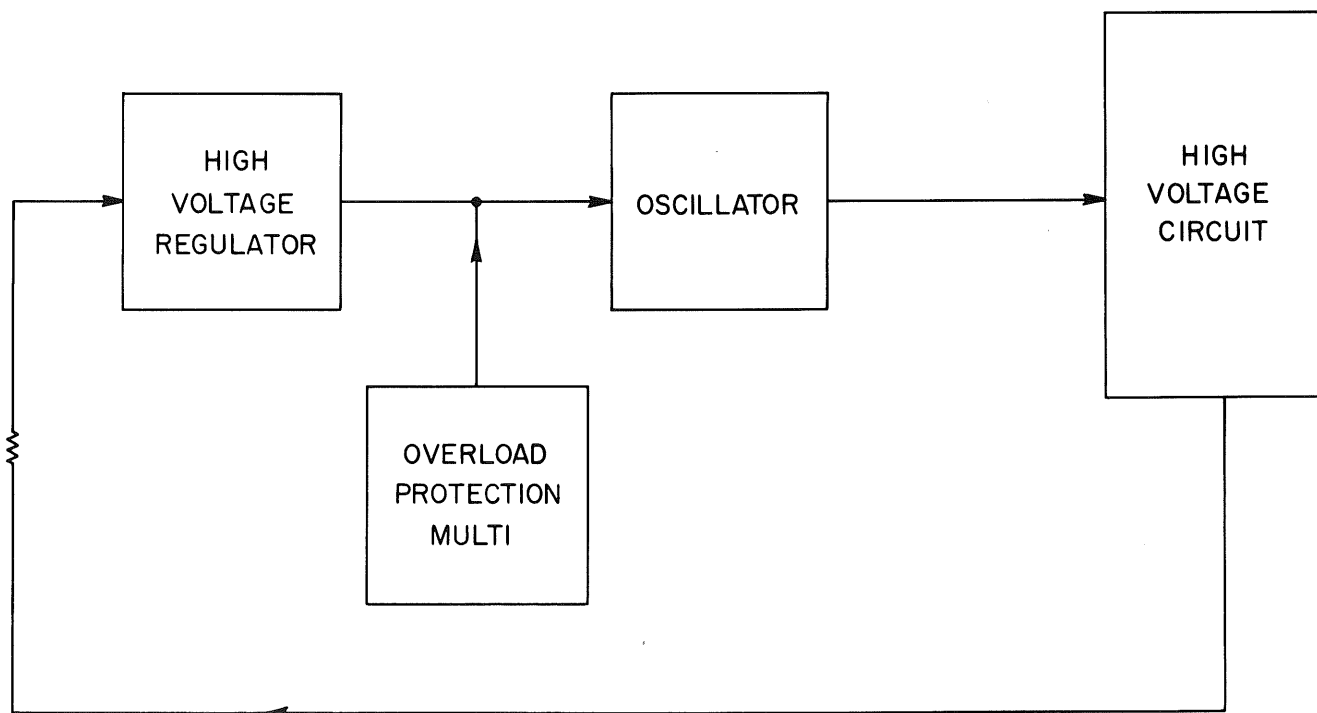
G. Basic Circuits

1. Oscillator
2. HV Regulator
3. Overload Protection Multi
4. High Voltage Circuits
5. CRT
6. Unblanking and Z Axis Amplifier

Type 647

H. Block Logic

1. The free running oscillator develops a 40 kc sine wave.
2. The sine wave voltage is stepped up in the HV transformer and rectified in three supplies.
3. +11.8 kv supplies the CRT post acceleration, -2.2 kv supplies the cathode and -2.5 kv supplies the grid.
4. The supply that feeds the CRT cathode is fed back to the regulator circuit.
5. The regulator controls the oscillator output.
6. Should an overload occur, the overload protection Multi flips, turns off the oscillator, protecting the transistor.
7. Sweep unblanking, chopped blanking and Z axis information is amplified (DC coupled) in an operational amplifier and fed to the CRT grid.
8. Z axis modulation may also be applied (AC coupled to the CRT cathode).

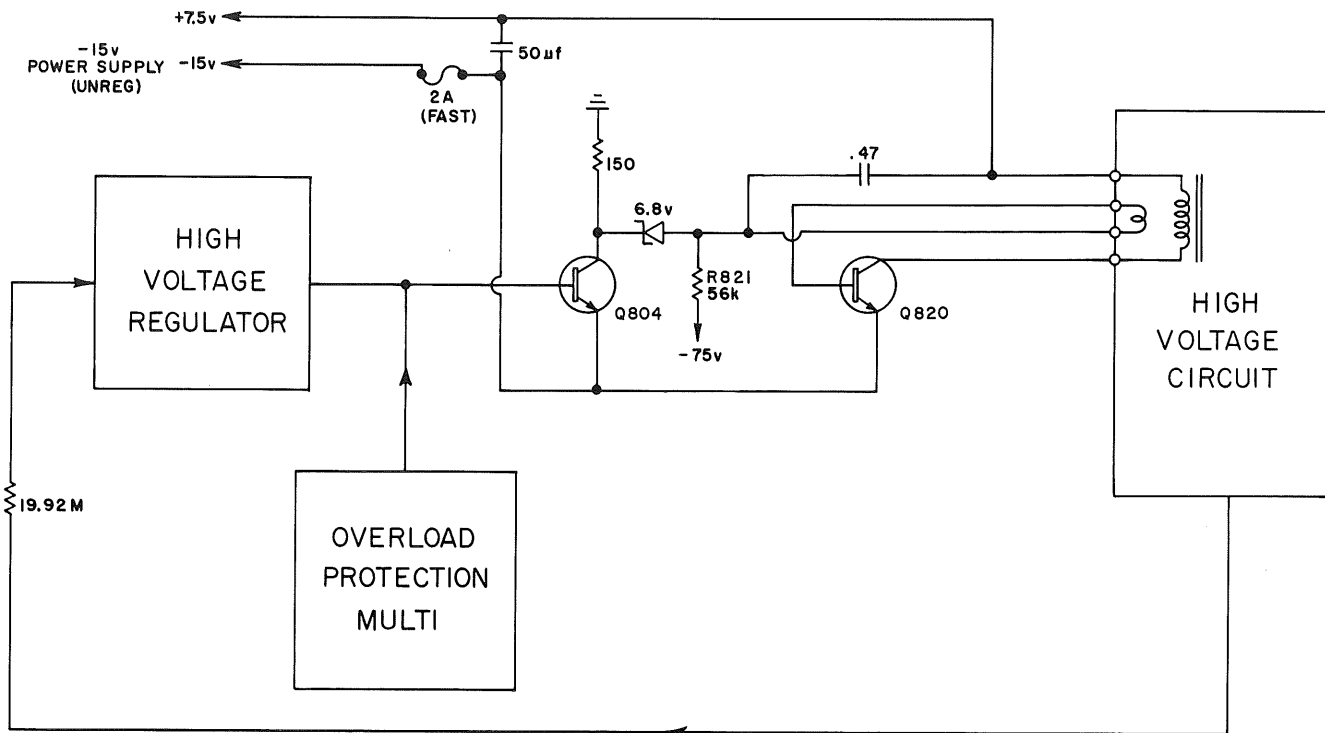


TYPE 647 CRT AND HIGH VOLTAGE
BLOCK DIAGRAM NO. 2

Type 647

I. Oscillator

1. The oscillator is a transistorized 40 kc sine wave Hartley oscillator.



TYPE 647 CRT AND HIGH VOLTAGE OSCILLATOR

B-647-0043x
2-10-'64 dl

2. Q820 is a RCA 2N1489 silicon power transistor (a 151-112 will substitute).
3. Q804 is a 151-103 selected Motorola 2N2219 silicon NPN transistor.
4. D820 is a 1N3016A Motorola 10% 6.8v zener.

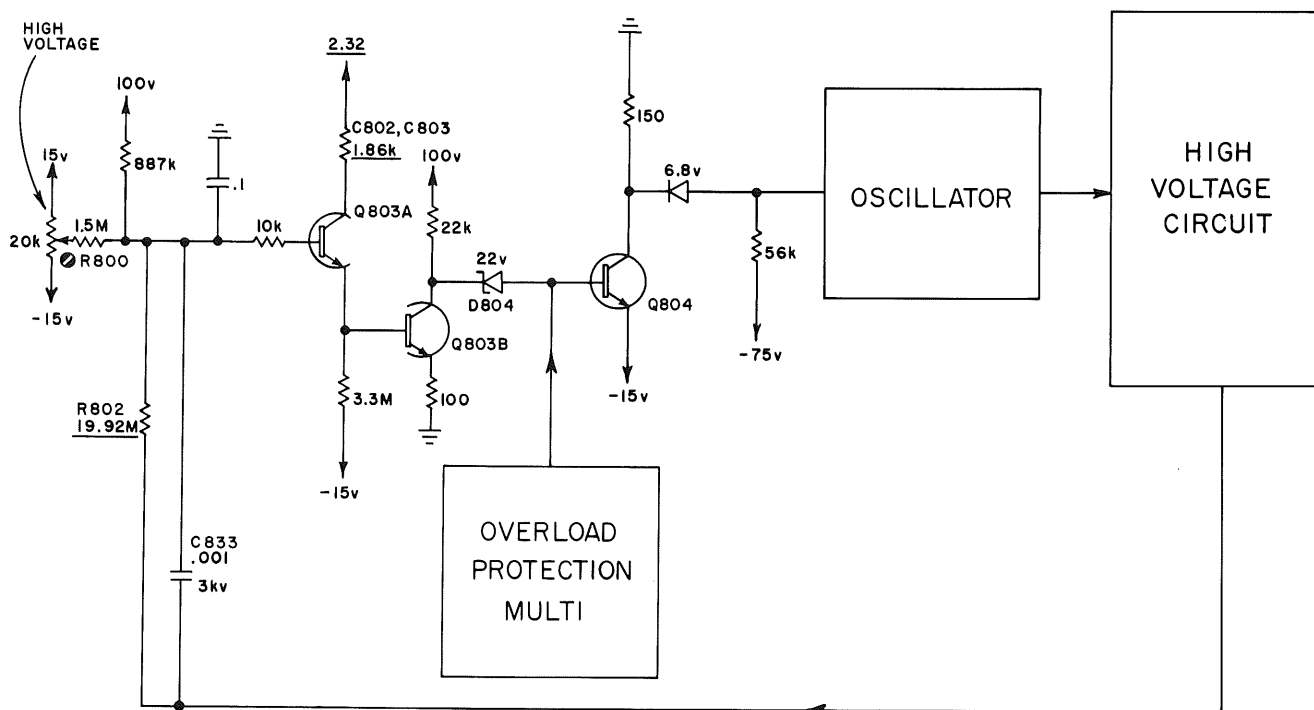
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5. Quiescent DC levels.
 - a. Q820, Q804 Emitter, -15v.
 - b. Q820 Base, -20v (oscillator running).
 - c. Q820 Collector, +8v (oscillator running).
 - d. Q804 Base, -14.2v.
 - e. Q804 Collector, -14.5v.
6. Q820 and Q804 are supplied unregulated from the -15v supply -- right off the rectifier.
 - a. The positive side is +7.5v.
 - b. The negative side is -15v.
 - c. The -15v emitter supply is fused at 2a to protect the supply if Q804 or Q820 shorts.
 - d. Since this voltage source does not have the protection of a regulated supply, a fuse is required.
7. Q820 is the oscillator transistor and Q804 is a shunt regulator.
8. High voltage transformer primary windings and secondary distributed capacitance determine the frequency.
9. The oscillator waveforms are pretty clean sine waves.
 - a. Q820 base swings from -14v to -32v.
 - b. Q820 collector swings from -8v to +26v.
10. Q804 controls the oscillator base drive.
 - a. If Q804 conducts heavily, Q820 base current decreases.
 - b. Q820 collector current decreases.
 - c. The amplitude of oscillation decreases.

Type 647

- 11. Q804 base is controlled by an amplified sample of the High Voltage output .
- 12. At the instant of turn-on with no HV output and no error voltage, Q804 biases Q820 to conduction to begin the first cycle of oscillation .
- 13. D820 drops the DC level from Q804 collector level to that required at Q820 base .
 - a. R821 provides keep-alive current for D821 .

J. High Voltage Regulator



TYPE 647 CRT AND HIGH VOLTAGE
HIGH VOLTAGE REGULATOR

B-647-0044x
2-11-'64 dl

Type 647

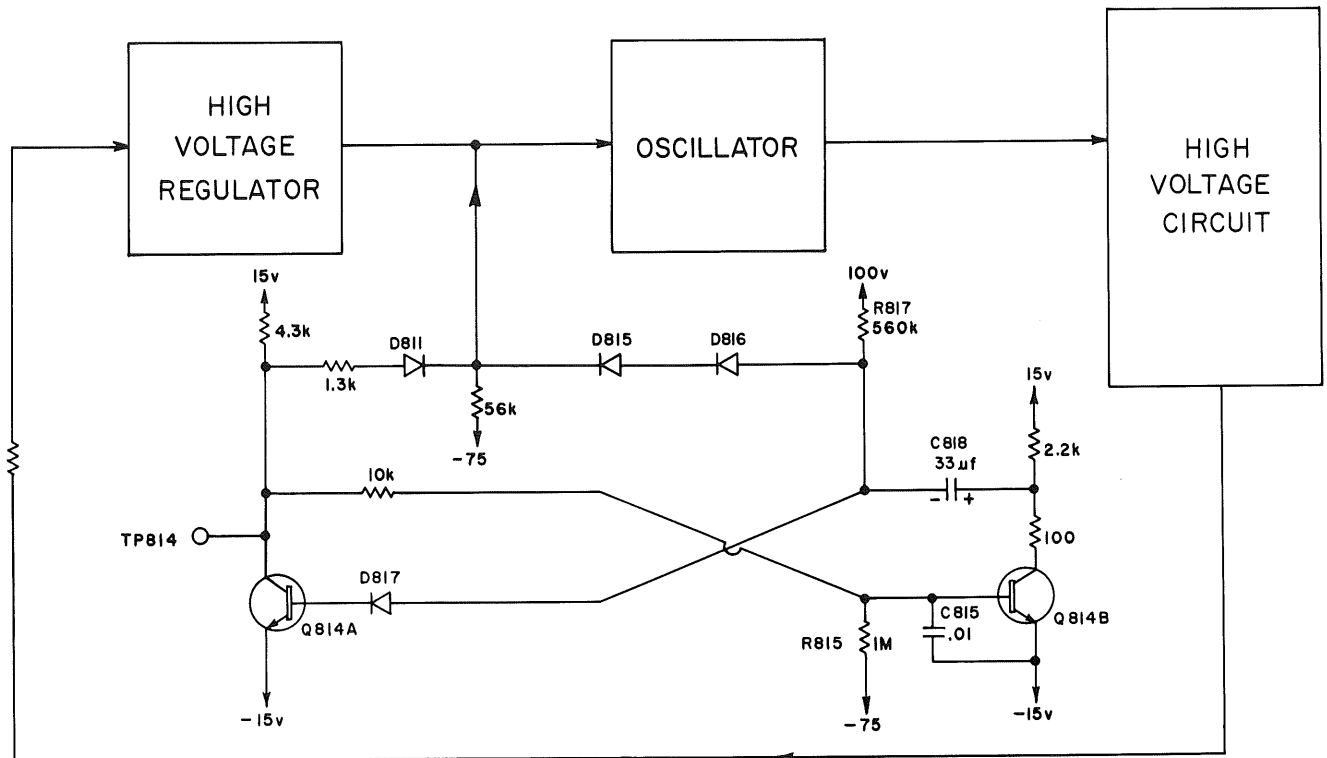
1. The circuit amplifies and inverts the HV error voltage for control of the HV oscillator.
2. Q803A, Q803B is a dual NPN silicon transistor made by Fairchild; a selected type SP8481.
3. Quiescent voltage levels, Q803.
 - a. Q803A Base, 1.25v.
 - b. Q803A Collector, 2.25v.
 - c. Q803A Emitter, .8v.
 - d. Q803B Emitter, .2v.
 - e. Q803B Collector, 7.5v.
4. A sample voltage from the CRT cathode supply is dropped by six 3.32M resistors (total 19.92M) and applied to Q803A base.
 - a. Fast error voltage changes pass through C833.
 - b. A divider is formed by the series dropping resistors and R803, R801.
 - c. C802, C803 compensate the divider (C833, and C802, C803 form a capacitive divider).
5. Q803A provides driving current for Q803B.
6. Q803B amplifies and inverts the error voltage to drive the base of control transistor, Q804.
7. If the CRT cathode supply is too low (-2.2 kv goes toward -2 kv), Q803A becomes more forward biased.
 - a. Q803B becomes more forward biased.
 - b. Q804 becomes less forward biased.
 - c. Q820 base will rise, increasing the amplitude of oscillation.
 - d. The HV supply voltages will increase.

Type 647

8. The oscillator, HV supplies and the regulator circuit form an operational amplifier with R802 as R_f and R800 as R_{in} .
 - a. The voltage source is the HIGH VOLTAGE adjustment pot R801.
 - b. A change in the HIGH VOLTAGE adjustment will change the output HIGH VOLTAGE.
 - c. The voltage at Q83A base will remain virtually unchanged.
 - d. The operational amplifier will maintain the output voltage selected by the HIGH VOLTAGE adj.
 9. D804 drops the DC level on Q803B collector (7.5v) to the -14.2v required at Q804 base.
 - a. D804 is a Motorola 1N969A, 10%, 22v zener.
 10. During normal operation (the Overload Protection Multi in its quiescent state) about 1.1 ma flows from the Protection Multi.
- K. Overload Protection Multi
1. The Overload Protection Multi protects the oscillator transistor from momentary overloads (shorts).
 - a. Without this protection, an accidental short (a test lead for example) could damage Q820.
 2. The circuit is a monostable multi with an unstable-state time of about 4 sec.
 3. Q814A and Q814B are selected Motorola 2N2219 silicon transistors.
 4. The four diodes used in the circuit are GE silicon 1N3605's.

Type 647

5. When an overload drops Q804 base below -15v (toward -16v), the multi flips, biasing Q804 to saturation.



TYPE 647 CRT AND HIGH VOLTAGE OVERLOAD PROTECTION MULTI

B-647-0045x
2-11-'64 dl

6. Q804 collector pulls Q820 base to cut off stopping the oscillator.
7. Quiescent DC levels (Q814A conducting, Q814B cut off).
 - a. Q814A Base, -14.4v.
 - b. Q814A Collector, -14.6v.
 - c. Q814A, Q814B Emitter, -15v.
 - d. Q814B Base, -15.2v.
 - e. Q814B Collector, +15v.

Type 647

8. In the quiescent state with Q814A conducting, D811 is cut off.
9. Q814A base current flows through D817 and R817 to maintain transistor saturation.
10. D815 and D816 are cut off.
 - a. When conducting, D815 and D816 provide voltage drops to match the drop of D817 and the base-emitter junction of Q814A.
 - b. A DC loop is formed through Q804 emitter-base junction, the -15 supply, Q814A emitter-base junction, D817, D816, D815 back to Q804 base.
 - c. As long as Q804 emitter-base junction is maintained, D815 and D816 will remain off.
 - d. When conducting, D815 and D816 voltage drops will change with a change in temperature to match a change with temperature at Q814A and D817.
11. If an overload occurs and Q804 base drops below -15v, D815 and D816 conduct.
 - a. D817 anode is pulled down to cut off.
 - b. With base current removed, Q814A cuts off.
 - c. Q814A collector rises toward 15v forward biasing D811.
 - d. Conducting D811 lifts Q804 base into saturation turning off the oscillator.
 - e. D815 and D816 cut off.
 - f. As Q814A collector rises, it lifts Q814B base, forward biasing it to saturation.

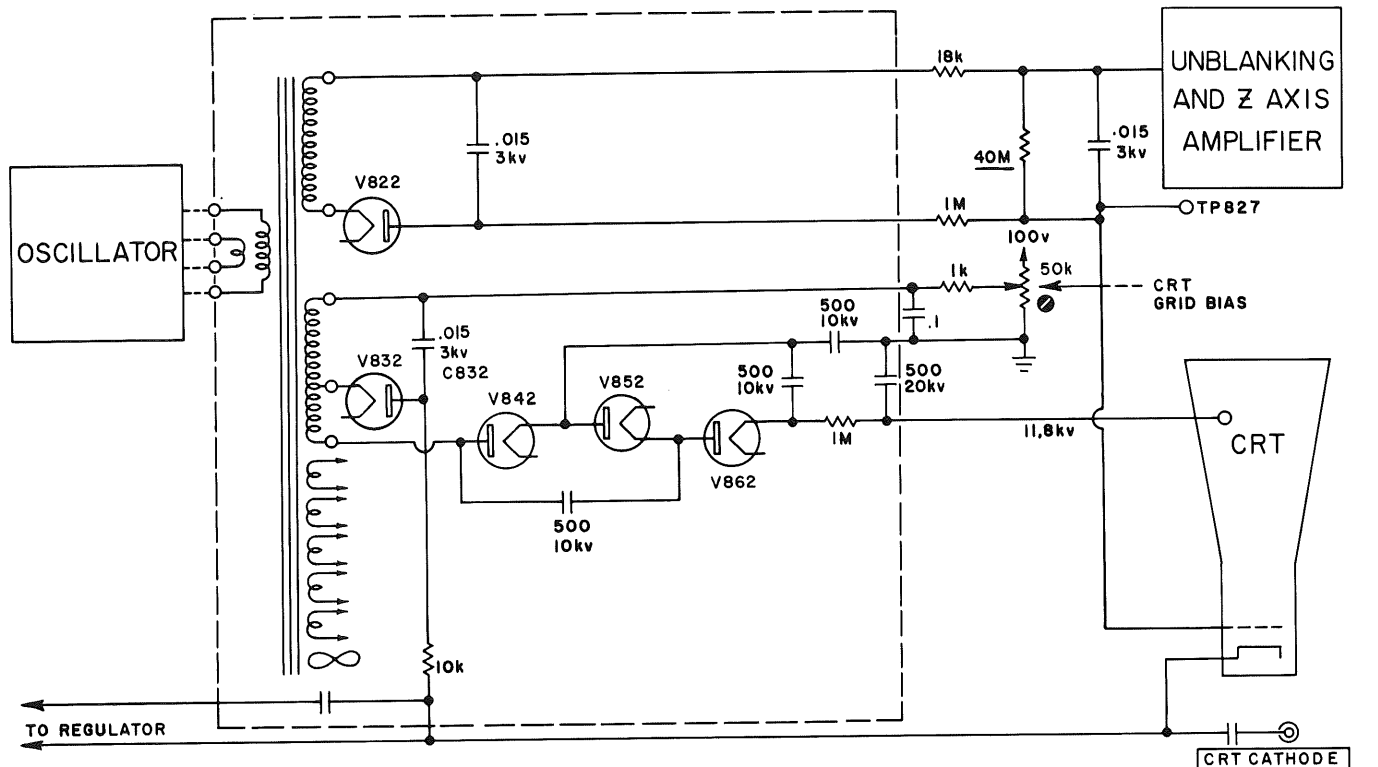
Type 647

- g. Q814B collector drops from +15v to -15v.
 - h. C818 drops keeping D816 and D817 reverse biased.
 - (1) The junction of C818 and R817 drops to -45v.
 - i. The multi is in its unstable state and the oscillator is disabled.
12. C818 charges through R817 toward 100v with a TC of 4 sec.
- a. When C818 reaches -15v, D817 becomes forward biased.
 - b. Current through D817 forward biases Q814A to conduction.
 - c. Through conventional multi action, the multi flips to its stable state as Q814B cuts off.
 - d. D811 cuts off, Q804 returns to its quiescent state and the oscillator can again function.
13. If the overload is still present, the multi will flip again in 250 msec.
- a. 250 msec is considered adequate reaction time to prevent damage to the oscillator transistor and the HV rectifier diodes.
 - b. R815, C815 set the 250 msec TC.

Type 647

L. High Voltage Rectifier

1. The circuit consists of the high voltage transformer, five vacuum tube diodes and the filter circuits.



TYPE 647 CRT AND HIGH VOLTAGE HIGH VOLTAGE CIRCUIT

B-647-0047x
2-14-'64 dl

2. There are three HV supplies.
 - a. 11.8 kv for the CRT post accelerator anode.
 - b. -2.2 kv for the CRT cathode.
 - c. -2.5 kv for the CRT grid.

Type 647

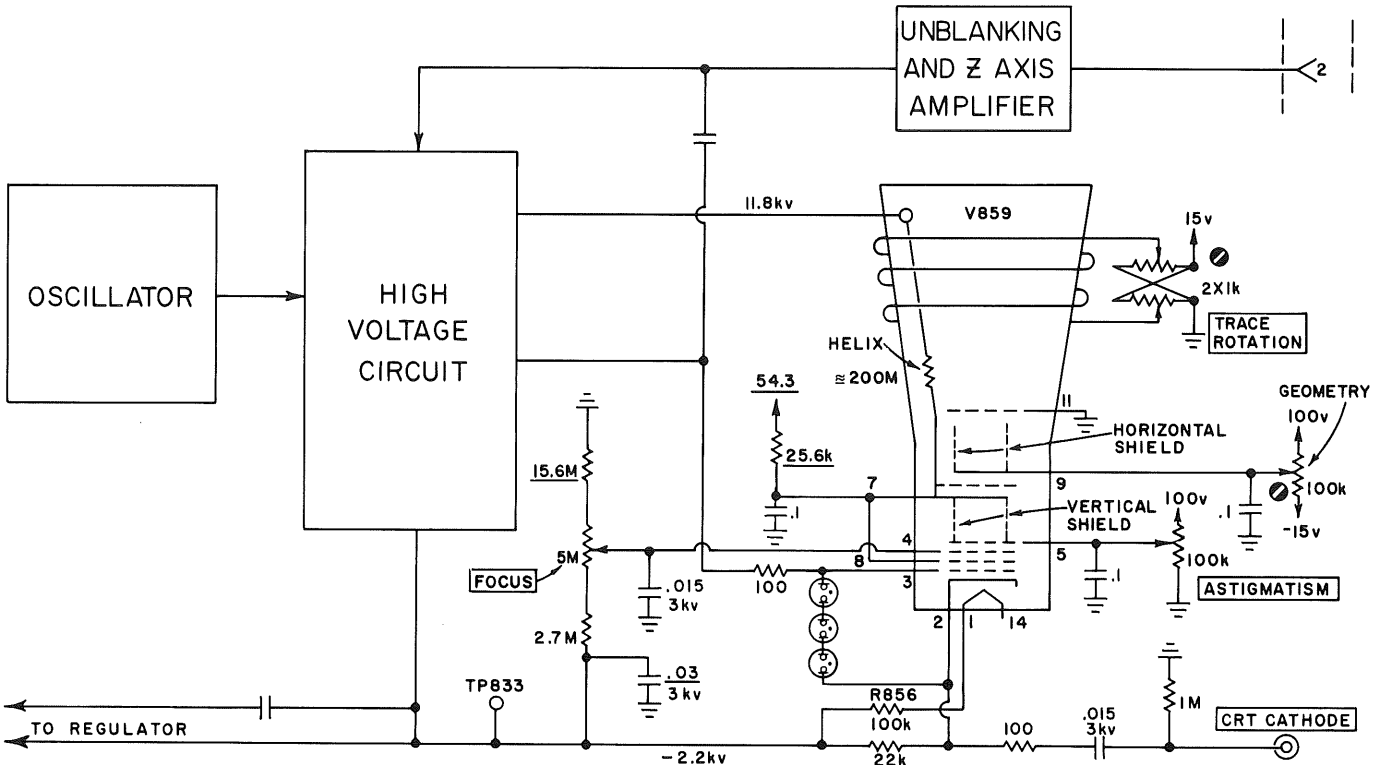
3. A CRT GRID BIAS adjustment is provided in the CRT cathode supply.
 - a. As the adjustment is made, the regulator keeps the CRT cathode and anode supplies constant.
 - b. The CRT grid supply will be adjusted.
 - c. As the control is adjusted to increase the CRT cathode supply output, the regulator circuit will decrease the CRT grid supply output.
4. The HV transformer is Tek made.
 - a. The entire winding is epoxy encapsulated.
 - b. Part of the encapsulation forms an insulated barrier between the HV windings and the core.
 - c. Since there are five filament windings, a flux unbalanced is present (two windings on one side of the core and three on the other).
 - d. A flux equalizer composed of two reverse-wound windings on each side of the core equalizes the flux.
5. The CRT grid supply uses a single 5642 as a half wave rectifier.
 - a. The rectifier supplies -2.5 kv to the CRT control grid.
 - b. The entire supply is a floating supply to which a maximum of 54v unblanking waveform (or Z axis modulation) is added providing DC unblanking to the CRT grid.
 - c. The positive side of the supply receives the unblanking waveform (from +10v to +45v).
 - d. The fast portions of the unblanking waveform are coupled through C827.
 - (1) The C of the HV transformer, the tube socket, wiring, etc., would prevent fast unblanking changes from driving the CRT grid.
 - (2) C827 bypasses the rectifier circuit and drives the CRT grid directly.

Type 647

- e. Four 10M resistors comprise the 40M bleeder resistor across the supply.
 - f. C822 filters the output.
6. The CRT cathode supply uses a tap on the anode supply winding of the HV transformer.
- a. The supply uses a single 5642 as a half wave rectifier supplying -2.2 kv to the CRT cathode.
 - b. The positive side of the supply is tied to the CRT GRID BIAS adj.
 - (1) The control has a range from 0 to 100v.
 - (2) The regulator circuit holds the output constant, however, only the CRT grid supply is affected.
 - c. Feedback for the regulator circuit is taken from this supply.
 - d. A total of 23.3M (including the FOCUS control) bleeds the CRT cathode supply.
 - e. C832 filters the output.
7. The post accelerator anode supply uses three 5642 diodes as a half wave voltage tripler to supply the CRT anode with +11.8 kv.
- a. The CRT helix (about 200M) bleeds the supply to ground.
8. The CRT cathode supply is used as the HV test point (TP833, -2.2 kv).
- a. This voltage is adjusted by the HIGH VOLTAGE adj. in the Regulator Circuit.

Type 647

M. CRT Circuit



TYPE 647 CRT HIGH VOLTAGE
CRT CIRCUIT

B-647-0048 x
2-15-64 dl

1. The CRT is a T6470* aluminized 3 x 5 inch rectangular flat-faced CRT with electrostatic focus and deflection. It has a 200 megohm helix that provides post-deflection acceleration without compression. It is ruggedized for shock and vibration. It features a lighted internal graticule.
 - a. A P31 phosphor is supplied with the production 647.

* See CRT IRB.

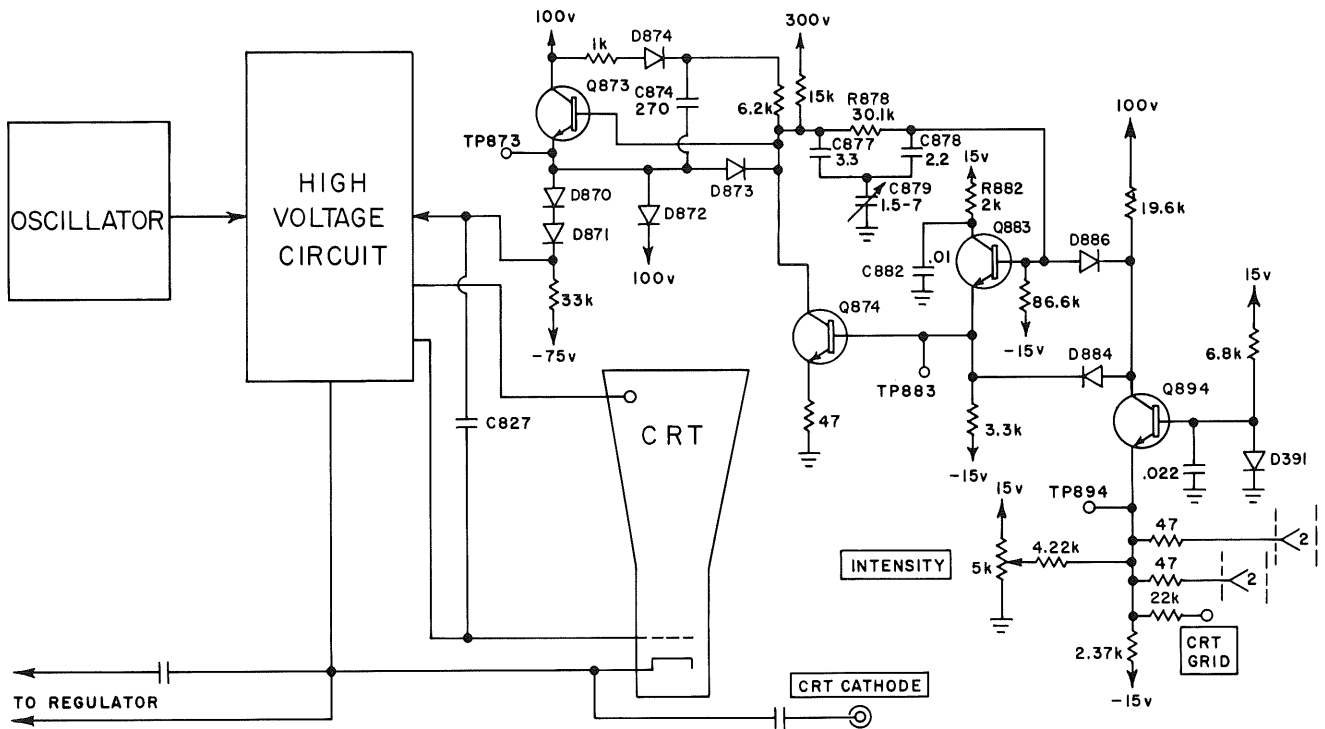
Type 647

2. Total accelerating potential is 14 kv (CRT rating is 19.5 kv maximum).
3. INTENSITY is controlled through the Unblanking Amplifier by changing CRT grid bias.
4. The FOCUS control is part of the CRT cathode supply bleeder.
 - a. The control is a 5M pot with a range of -1.6 kv to -2 kv (200v to 600v relative to the cathode).
5. The ASTIGMATISM control is a 100k pot with a range of 0v to 100v (2.2 kv to 2.3 kv relative to the cathode).
6. TRACE ROTATION control is a dual 1k pot cross connected across +15v.
 - a. The Trace Rotation coil consists of 1500 turns of No. 39 wire wrapped around the center of the CRT under the mu-metal shield.
7. GEOMETRY ADJ is a 100k pot with a range from -15v to +100v (2.2 kv to 2.3 kv relative to the cathode).
8. The vertical deflection plate shields and the first anode tie to a divider with an equivalent circuit of 25.6k to 54.3v (2.254 kv relative to the cathode).
9. The post accelerator grid is grounded (2.2 kv relative to the cathode).
10. The control grid is supplied by its own -2.5 kv HV supply.
 - a. It may be adjusted by the CRT GRID BIAS adj.
 - b. A DC coupled unblanking waveform of up to 54v peak-to-peak (depending on the INTENSITY control setting) is added to the grid bias during sweep.
 - c. DC coupled Z axis modulation drives the grid through the Unblanking Amplifier.
 - d. Three neons in series protect the CRT if the grid supply should fail.

Type 647

- 11. The cathode has its own -2.2 kv supply.
 - a. The cathode can be Z axis modulated.
 - b. Cathode Z axis modulation is DC coupled.
 - c. The Z axis input looks through a .015 μ f cap to the low cathode impedance of the CRT (about 150 Ω).
- 12. The CRT heater is elevated to cathode potential (-2.5 kv) to prevent cathode heater breakdown.
 - a. R856 isolates cathode Z axis drive from heater transformer capacitance.
- 13. A rectangular mu-metal shield protects the CRT from outside electro-magnetic fields.

N. Unblanking and Z Axis Amplifier



TYPE 647 CRT HIGH VOLTAGE UNBLANKING AND Z AXIS AMPLIFIER

B-647-0049x
2-17-'64 dl

Type 647

1. The Unblanking and Z Axis Amplifier amplifies and inverts a DC coupled Z axis signal from four sources.
 - a. INTENSITY CONTROL.
 - b. Sweep unblanking waveform from an 11 series Time Base plug-in.
 - c. Chopped blanking from a 10 series multi-trace plug-in.
 - d. An input from CRT GRID jack on the Type 647 rear panel.
2. The circuit consist of an emitter driven stage as a current drive for an operational amplifier. An output EF in turn drives the CRT grid.
3. The circuit uses four transistors and eight diodes.
 - a. Q984 and Q883 are 151-108 selected Motorola 2N2501 silicon NPN transistors.
 - b. Q874 and Q873 are 151-124 selected RCA TA1938 silicon NPN transistors.
 - (1) Q874 is mounted on a beryllium oxide heat sync.
 - c. D891, D886, D884 and D873 are GE 1N3605 silicon diodes (152-141 will substitute).
 - d. D874 and D872 are Raytheon 6061 silicon diodes (162-061 will substitute).
 - e. D870 and D871 are 152-001 silicon rectifier diodes.
 - (1) 152-002 are TI 1N1329, Motorola 1N3283 or Semtich SC15's.

Type 647

4. Voltage levels during A Sweep (free run at slow sweep).

Test Point	Transistor	INTENS CONTROL CCW		INTENS CONTROL CW	
		No Sweep	UNBLANK	UNBLANK	No Sweep
894	Q894 Base	.6v	.6v	.6v	.6v
	Q894 Emitter	-.025v	-.055v	-.9v	-.07v
	Q894 Collector	2.6v	2.4v	.2v	*1.8v
883	Q883 Base	2.55v	2.55v	.8v	2.2v
	Q883 Emitter	2v	2v	.15v	**1.5v
	Q883 Collector	8v	4v	.5v	3.8v
874	Q874 Base	2v	2v	.15v	**1.5v
	Q874 Emitter	1.3v	1.3v	0v	***1v
	Q874 Collector	10v	12v	94v	40v
873	Q873 Base	10v	12v	94v	40v
	Q873 Collector	96v	96v	96v	96v
	Q873 Emitter	9.5v	10v	94v	40v

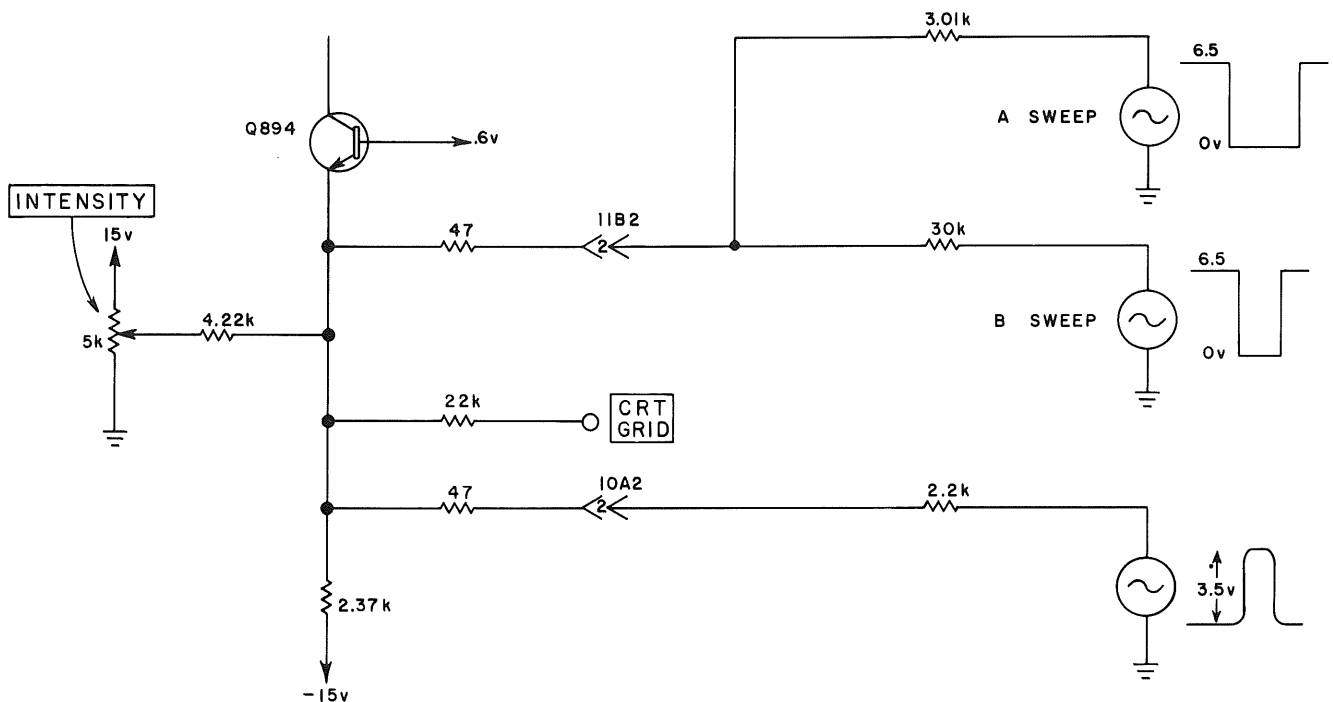
* Overshoot to 4.6v

** Overshoot to 5.8v

*** Overshoot to 5v

Type 647

5. The input circuit includes the equivalent source impedance in the vertical and horizontal plug-ins.
 - a. The illustration below shows equivalent generator and source impedance found in the 10A2 and 11B2 plug-ins.



- b. Since Q894 emitter offers a low impedance, there is little chance of kickback at the CRT GRID jack (no chopped blanking discernible at CRT GRID jack when checked with a Type 581A/82).
- c. The signals comprise a current drive to Q894.
 - (1) Signal voltage at Q894 emitter is in the millivolt range.
- d. Q894 base is clamped by D891 to .6v.
- e. Q894 provides a current drive for the operational amplifier
- f. D884 clamps Q894 collector at about 2v if Q894 is driven to cut off preventing reverse breakdown of Q894.

Type 647

6. Since Q883 base serves as the operational amplifier input, it reflects a low impedance.
 - a. Unblanking voltage at this point is 1.4v peak-to-peak (.8v to 2.2v) with INTENSITY control CW.
7. Q883 is an emitter follower driving Q874 as the gain stage.
8. R878 is R_{in} for the operational amplifier.
 - a. C877, C879, C878 help maintain constant gain at higher frequencies.
9. When Q894 collector drops D886 will pull down Q883 base.
 - a. If Q894 collector rises fast, D886 can disconnect.
 - b. The drive on a fast rise step is through D884 to Q883 emitter.
10. When the INTENSITY CONTROL is CCW, a waveform on Q883 collector will be inverted (negative going during slow sweeps).
 - a. D886 is cut off in this condition.
 - b. D884 passes a current signal that biases Q883 to greater conduction and its collector drops.
 - c. The RC circuit (R882, C882) is a decoupling circuit and the signal voltage present has no effect on the amplifier.
11. At all settings of the INTENSITY control, Q874 receives a negative going unblanking signal.
12. Q874 collector load equivalent is 4.86 k to 165v.
13. The collector signal is a positive going unblanking voltage which drives emitter follower, Q873.
 - a. A fast positive step on Q873 emitter will couple through C874, the bootstrap capacitor, disconnect D874 and bootstrap R874 to a more positive voltage increasing the drive to Q873 base.

Type 647

- b. A fast negative going step on Q873 base can cut off Q873.
 - c. D873 will then become forward biased and conduct the negative going step to Q873 emitter.
14. D870 and D871 protect the amplifier from high voltage across C827 should the CRT grid become shorted to ground.
- a. Should D870 and D871 disconnect, D872 prevents Q874 from rising above 100v.
 - b. D870 and D871 are high capacitance diodes.
 - c. The diode capacitance drives the CRT GRID supply capacitance preventing the diodes from disconnecting on fast negative steps.
15. As the leading edge of the unblanking waveform drops Q874 base, the collector rises with a slower risetime.
- a. The step, therefore, suffers a delay of about 100 nsec as it is fed back through R878.
 - b. The result is an overshoot that appears at Q883 base and emitter and Q874 base.

V. CALIBRATOR

- A. The calibrator supplies a 1 kc square wave to a front panel jack (BNC).
 - 1. 18 steps from .2 mv to 100v.
 - 2. 100v DC $\pm 1.5\%$.
 - 3. 5 ma through a current loop $\pm 1.5\%$.
- B. Specifications
 - 1. Frequency 1 kc $\pm .1\%$.
 - 2. DUTY FACTOR 50% $\pm .1\%$.

Type 647

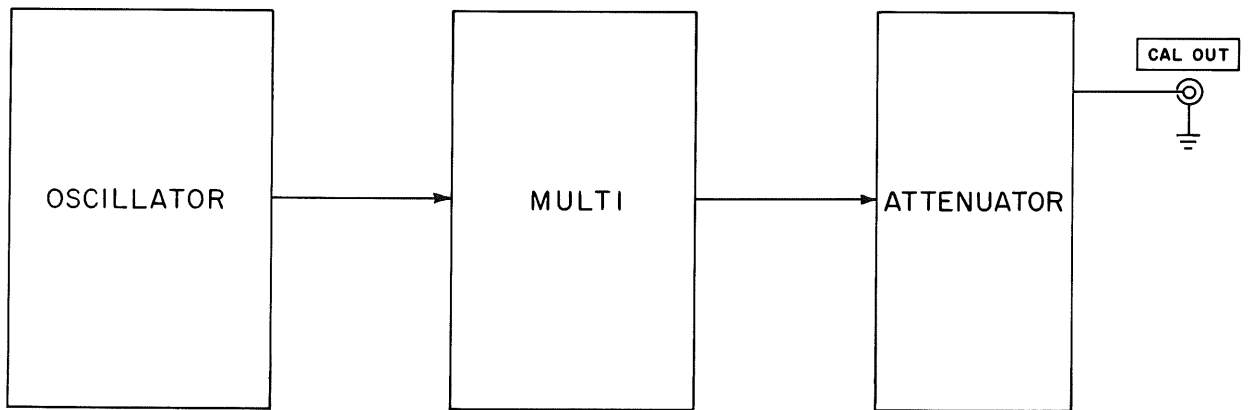
3. Output voltage

- a. .1v, $\pm 1\%$.
- b. 100v, $\pm 1.5\%$.
- c. All other mv ranges $\pm 2\%$.
- d. All other voltage ranges $\pm 3\%$.

C. Output Impedance

- 1. .2 mv to .1 volt, 50Ω , $\pm .25\%$.
- 2. .2v, 50Ω , $\pm 1\%$.
- 3. .5v to 100v varies to 4k with switch setting.

D. Block Diagram



TYPE 647 CALIBRATOR
BLOCK DIAGRAM

B-647-0055
2-20-'64 dl

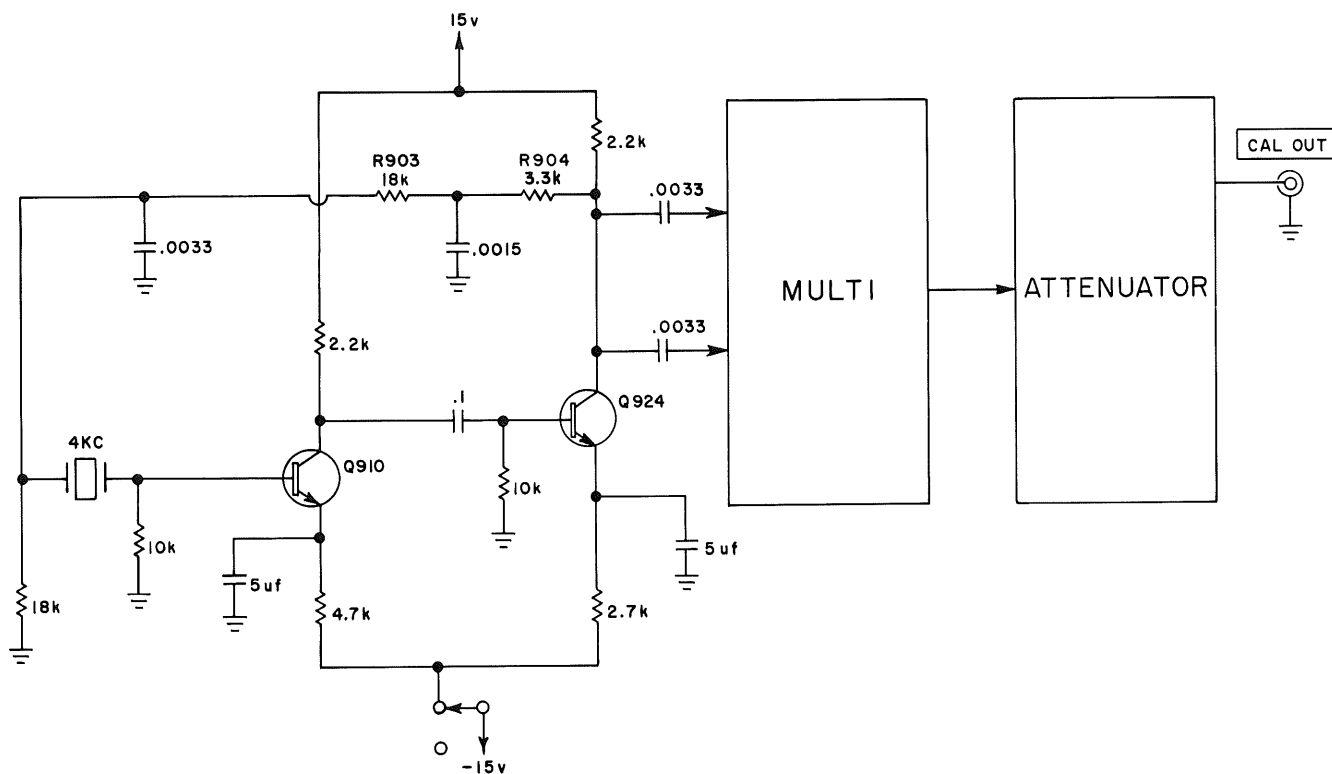
Type 647

E. Block Logic

1. The calibrator circuit consists of a 4 kc crystal controlled oscillator driving a bistable Eccles-Jordan multi.
2. The multi is designed to operate at 1 kc.
3. Its output is clamped at 100v and ground to provide a symmetrical, precise 100v peak-to-peak square wave.

F. Oscillator

1. The oscillator operates as a crystal controlled free running oscillator.

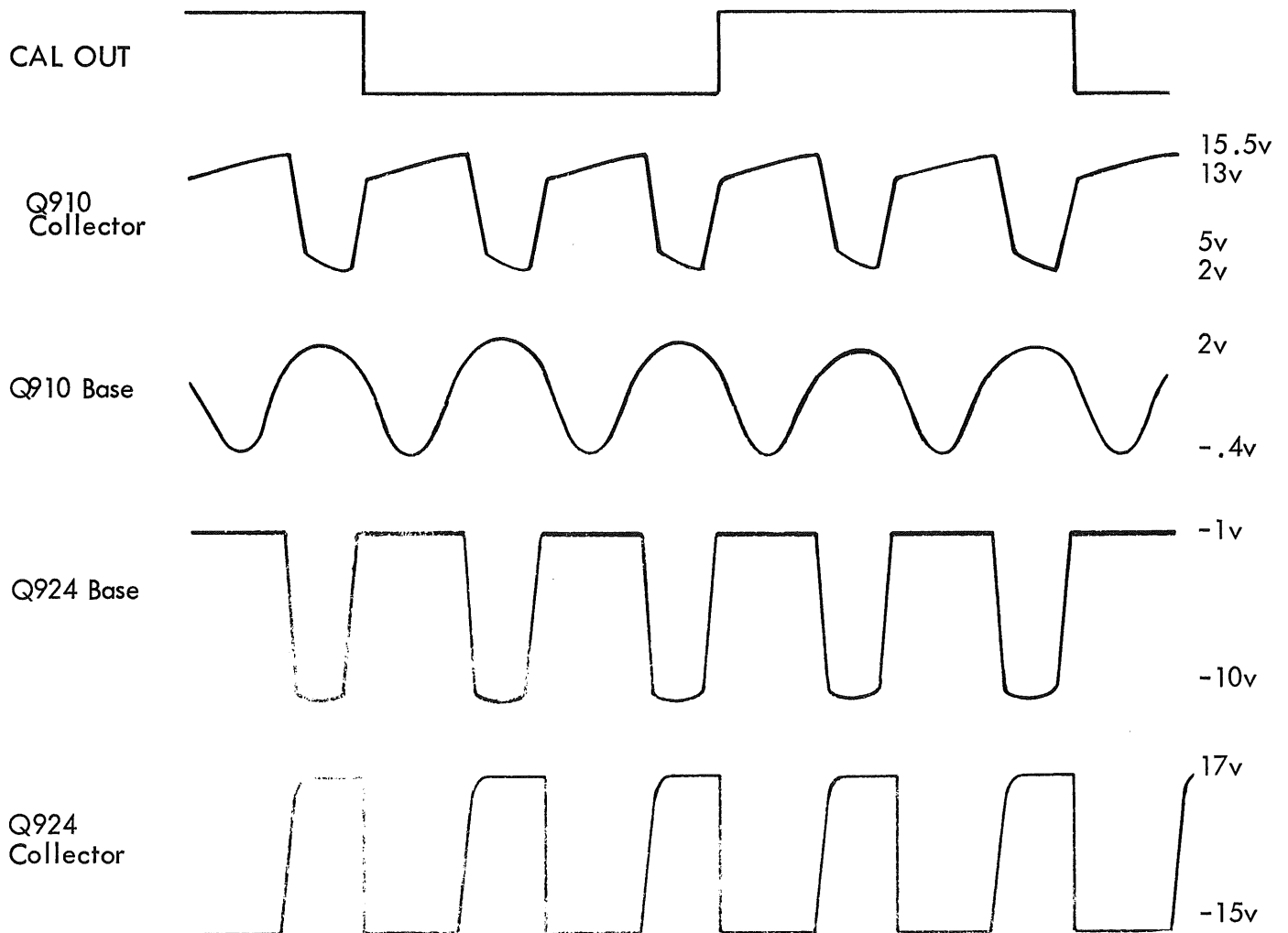


TYPE 647 CALIBRATOR
OSCILLATOR

B-647-0056x
2-21-64 dl

Type 647

2. Two transistors are used in the oscillator.
 - a. Q910 is a 151-126 selected Fairchild S5684 silicon NPN transistor.
 - b. Q924 is a 151-103 selected Motorola 2N2219 silicon NPN transistor.
3. The crystal is a James Knights hermetically sealed 4 kc crystal.
4. Two feedback loops are provided.
 - a. The feedback loop through R903, R904 is a low pass filter that prevents switching transients from reaching the crystal.
 - b. The second feedback is through C914 to Q924 base.
5. Q910 emitter is held by a 5 μ f cap at -.6v while Q924 emitter sets at -1.6v decoupled from the -15v supply by a 5 μ f cap.
6. The output waveform (at Q924 collector) is a 4 kc square wave.
 - a. Duty cycle will differ with different transistors.

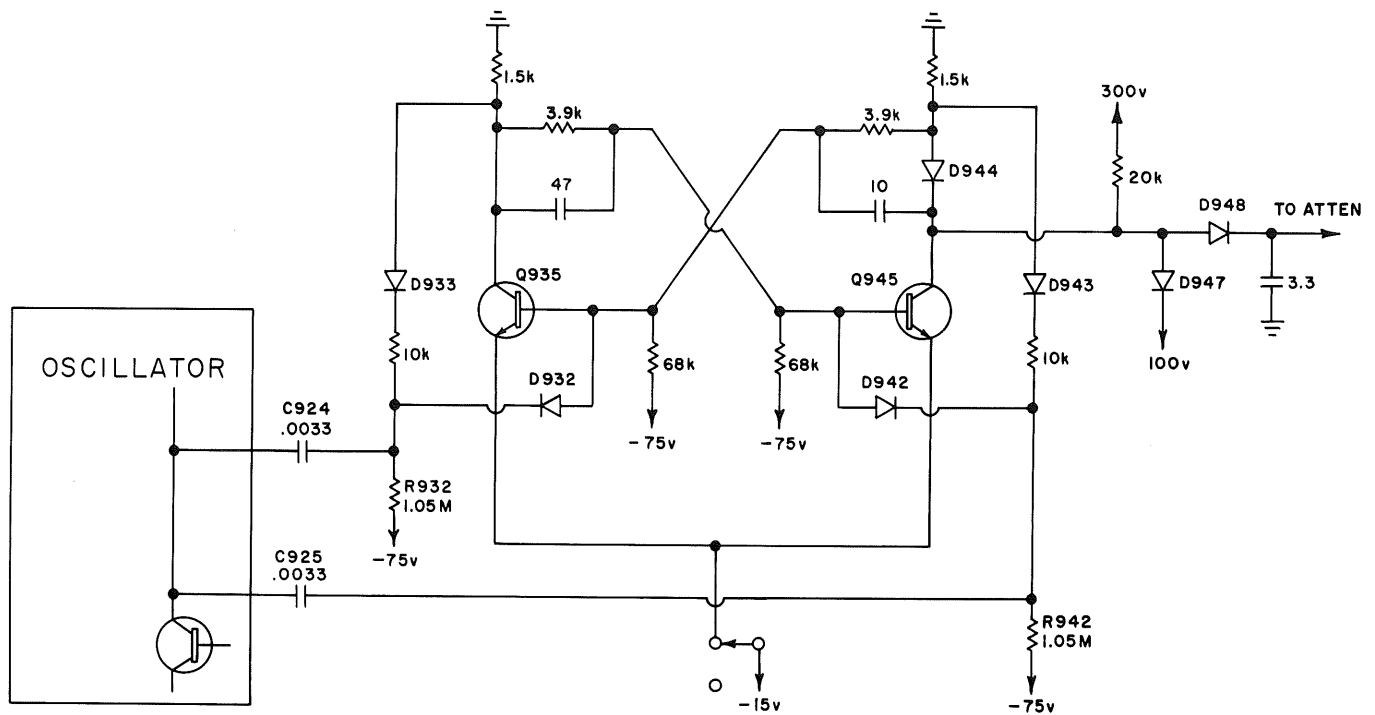


Type 647

- 7. In the 100v DC and OFF position of the AMPLITUDE CALIBRATOR control, the emitter supply is opened, stopping the oscillator.

G. Multivibrator

- 1. The multi is a bistable Eccles-Jordan which counts down from 4 kc to 1 kc and shapes the output square wave.



TYPE 647 CALIBRATOR
MULTIVIBRATOR

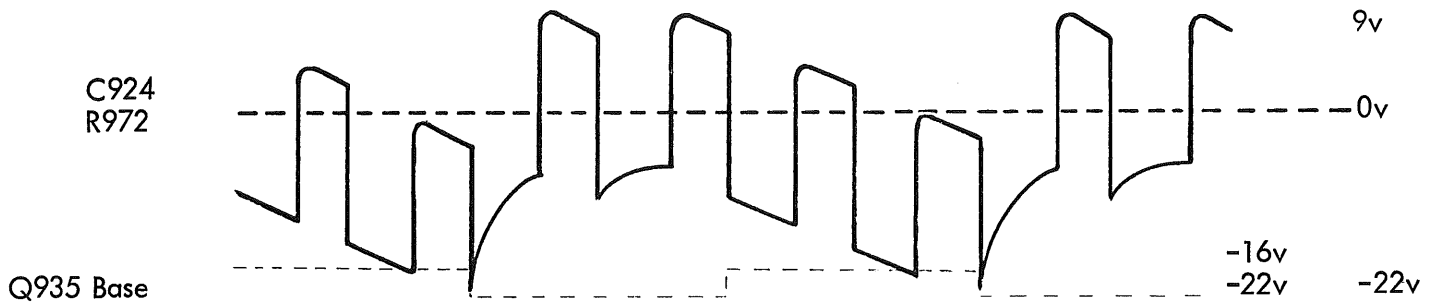
B-647-0057x
2-22-'64 dl

Type 647

2. The circuit consists of two transistors and seven diodes.
 - a. Q935 is a 151-103 Motorola.
 - b. Q945 is a 151-124 selected RCA TA1938 silicon NPN transistor.
 - c. D932, D933, D942, D943 and D948 are GE 1N3605 silicon diodes.
 - d. D944 and D947 are Raytheon silicon diodes.
3. Input coupling capacitors C924, C925 are both tied to Q924 collector. They couple the 4 kc square wave to the multi.
4. The square wave output is taken from Q945 collector and clamped at 100v by D947.
 - a. Amplitude accuracy depends on the accuracy of the 100v regulated supply.
 - b. Although a .6v rise occurs across D947, the rise is compensated for in D948.
5. An Eccles-Jordan multi that is triggered from both sides is a binary divider.
 - a. An RC circuit composed of C924, R932 and C925, R942 allows this multi to divide by 4.
6. Sequence of operation: Assume Q935 has just cut off and a Q945 is conducting.
 - a. As Q935 cuts off and its collector rises, D933 becomes forward biased.
 - b. Current through R932 charges C924 as the junction of C924 and R932 raise toward ground.
 - c. When Q945 begins conduction and its collector drops, the negative step drops Q935 base and the multi flips.

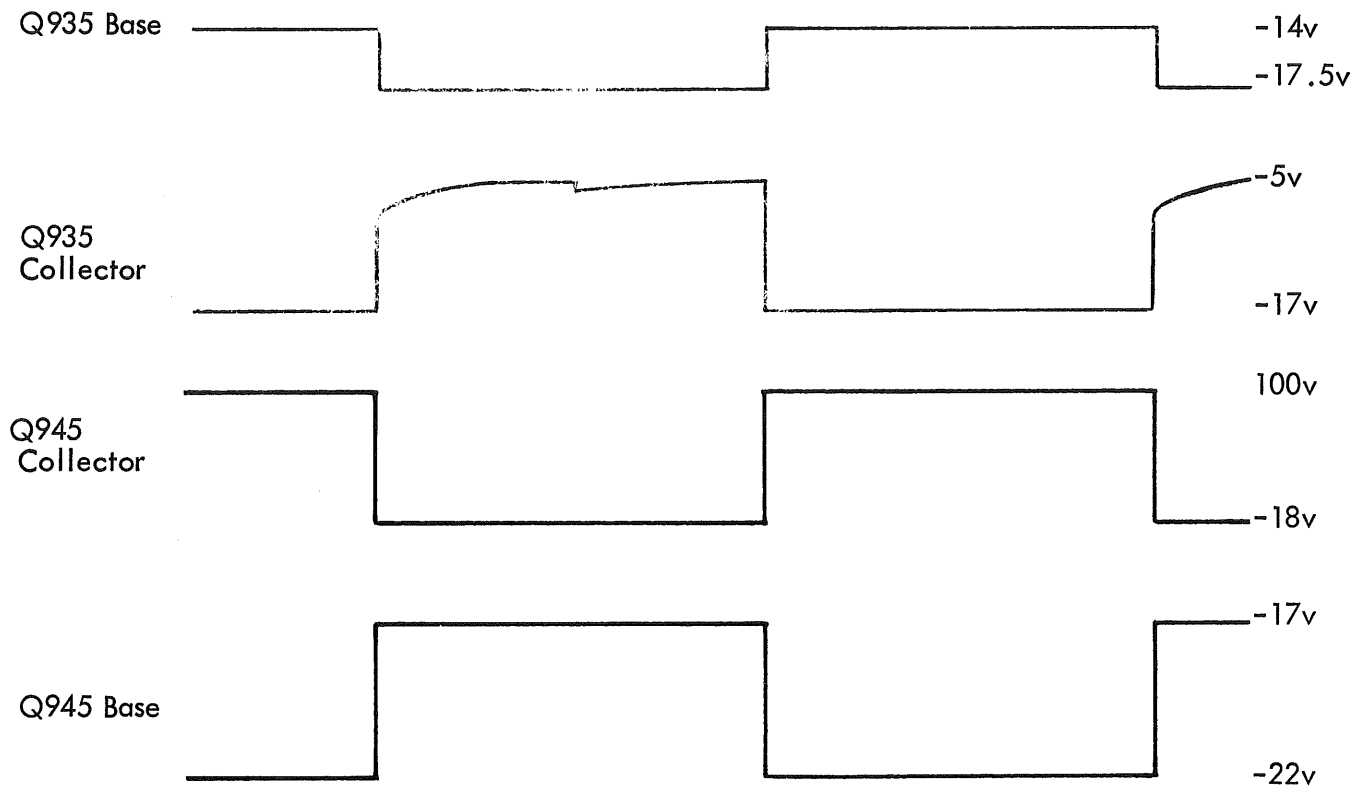
Type 647

- d. As Q935 cuts off and its collector drops, D933 cuts off.
- e. The junction of C924, R932 drops exponentially as C924 discharges toward -75v.
- f. During the operation, the 4 kc square wave (10v peak-to-peak) is present at the junction of C924, R932.
- g. Q935 will be cut off when D932 becomes forward biased.
- h. D932 will conduct when the junction of C924 and R932 reaches -16v.
- i. C924, R932 time constant is such that this junction will not reach -16v until the second full cycle of 4 kc square wave.



- j. As D932 begins conduction, Q935 base is pulled down and the multi flips.
- k. The next half cycle begins.
- l. When the coincidence of the second half cycle of 4 kc square wave and the discharge of C925 has dropped the junction of C925, R942 to -16v, D942 will become forward biased, pull down on Q945 base and the multi will flip.
- m. The 1 kc cycle is complete.

Type 647

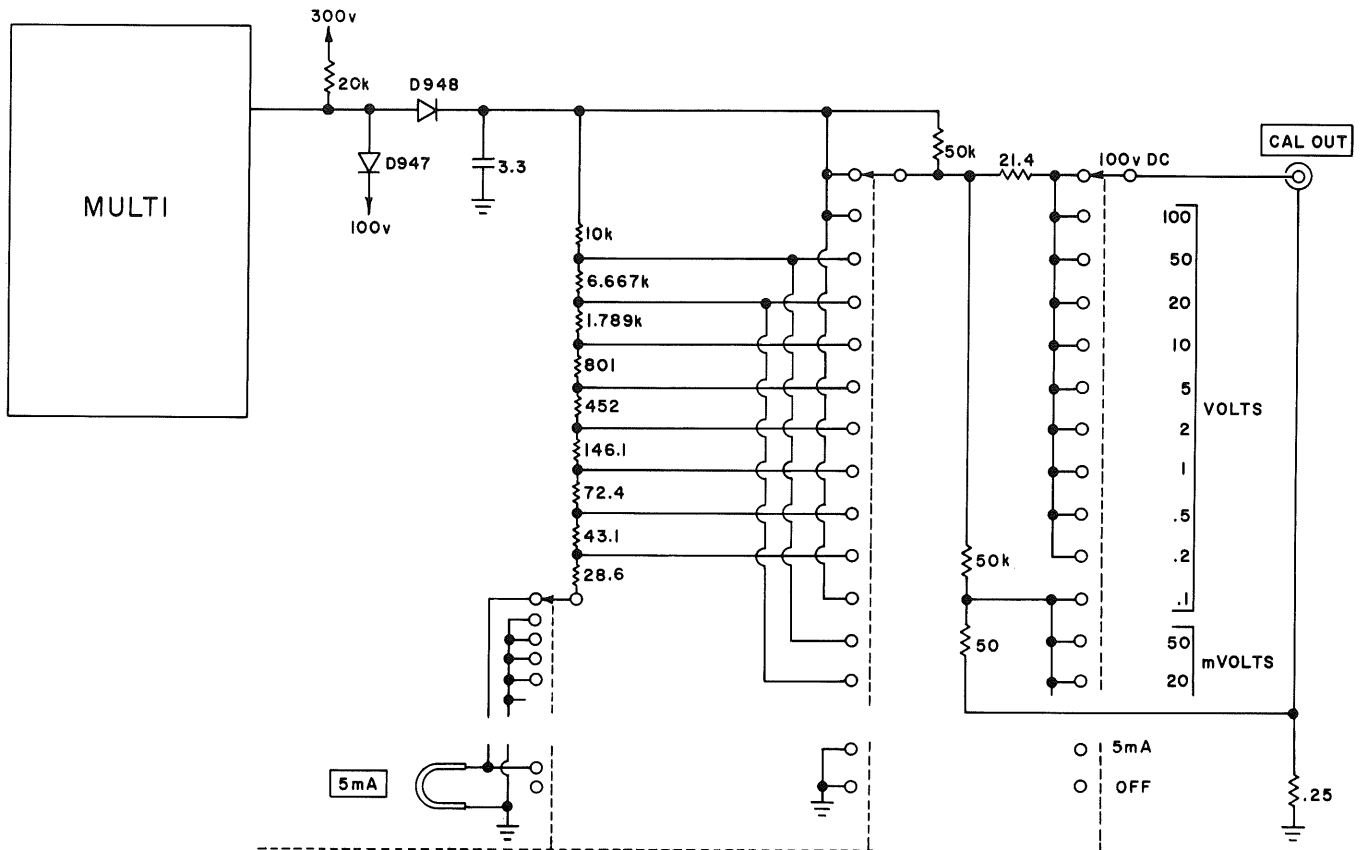


7. When Q945 cuts off, its collector raises toward 300v and is clamped at 100v.
 - a. This step is too great to drive Q935 base.
 - b. D944 disconnects when its anode passes ground, allowing Q945 collector to rise to 100v with only the first 3.5v of the step appearing on Q935 base.

Type 647

H. Attenuator

1. The attenuator drops the 100v square wave to the 1 current and 18 voltage positions.

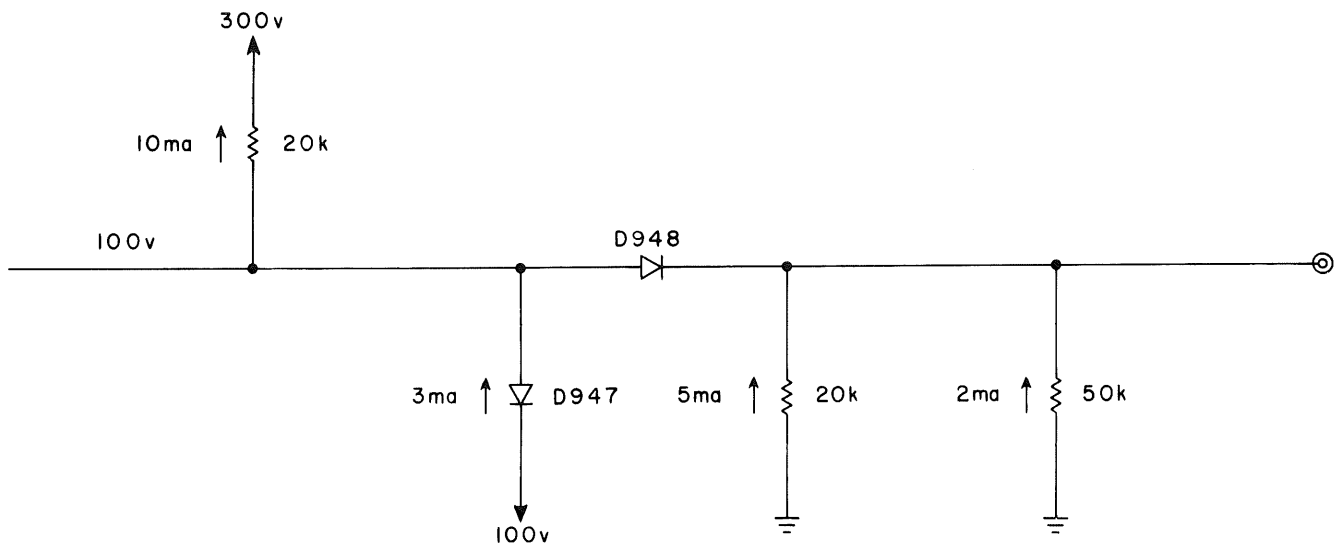


2. 100v DC Position

- a. The emitter supply to the oscillator and multi is opened.
- b. The output is clamped at 100v.

Type 647

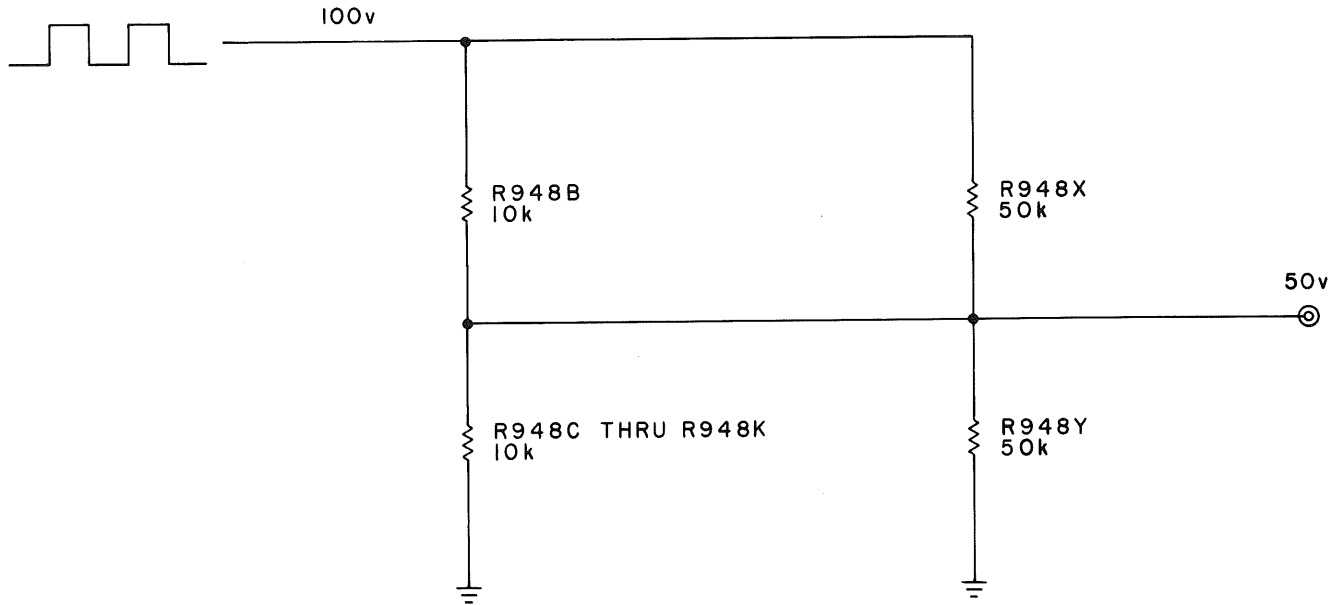
- c. The 20k divider composed of R948D through R948K returns to ground through the current loop to provide 5 ma DC.
- 3. 100v square wave position:
 - a. The 100v peak-to-peak square wave is connected directly to the CAL OUT jack.
 - b. R948X is shorted out.
- 4. In both 100v positions of the CAL switch, 3 ma flows through D947.



- a. Since 3 ma flows through D947, any load that will draw 3 ma or more will disconnect D947.
- b. A load resistance of 33k or less will disconnect the diode.
- c. With D947 open, the source impedance will rise.

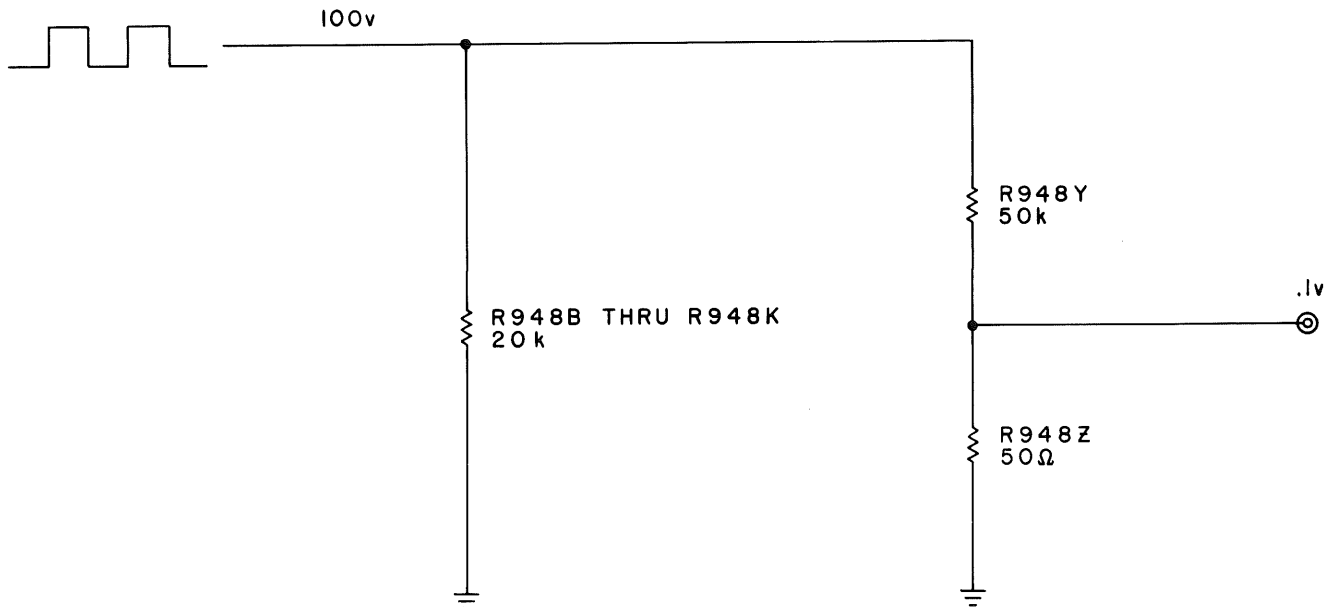
Type 647

5. .2v to 50v positions:



- a. Taps on R948B through R948C provide the voltage divisions .
- b. In the .2v position, R948L adds to R948K to provide 50Ω output impedance .
- c. C948K compensates this low impedance tap to prevent overshoot .
- d. Impedance at switch positions .5v through 50v increase in impedance to about 4k at 50v .

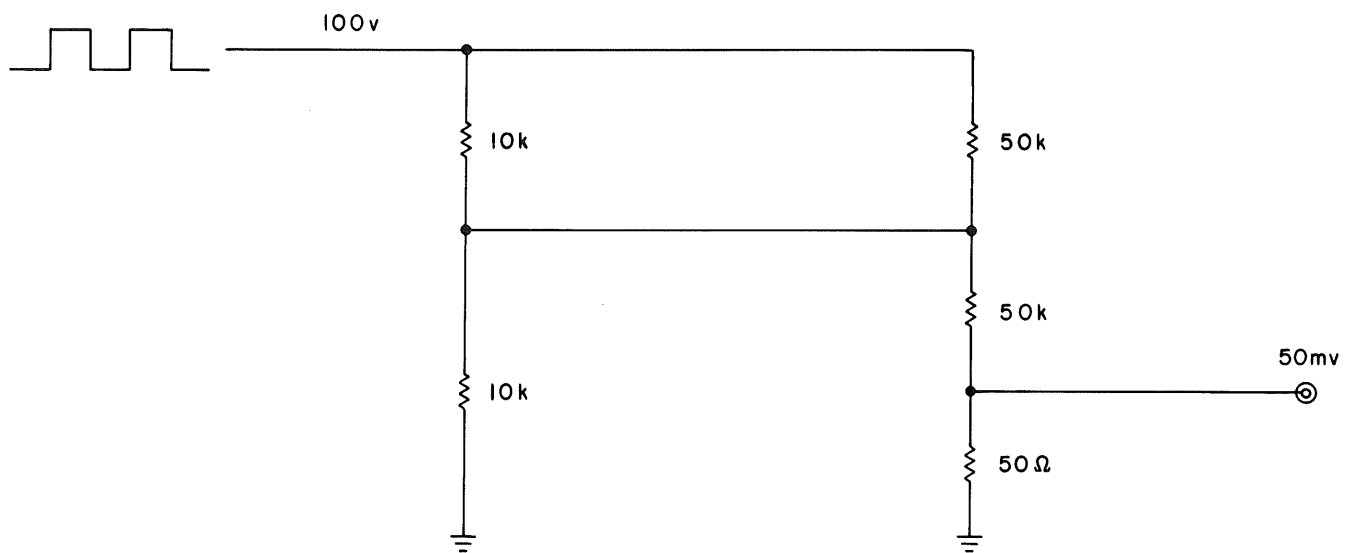
6. .1v position:



Type 647

- a. R948X is shorted out.
- b. R948Y and 948Z form a 1000 to 1 divider.
- c. R948Z provides 50Ω output impedance.
- d. C948Z compensates the low impedance portion of the divider to prevent overshoot.

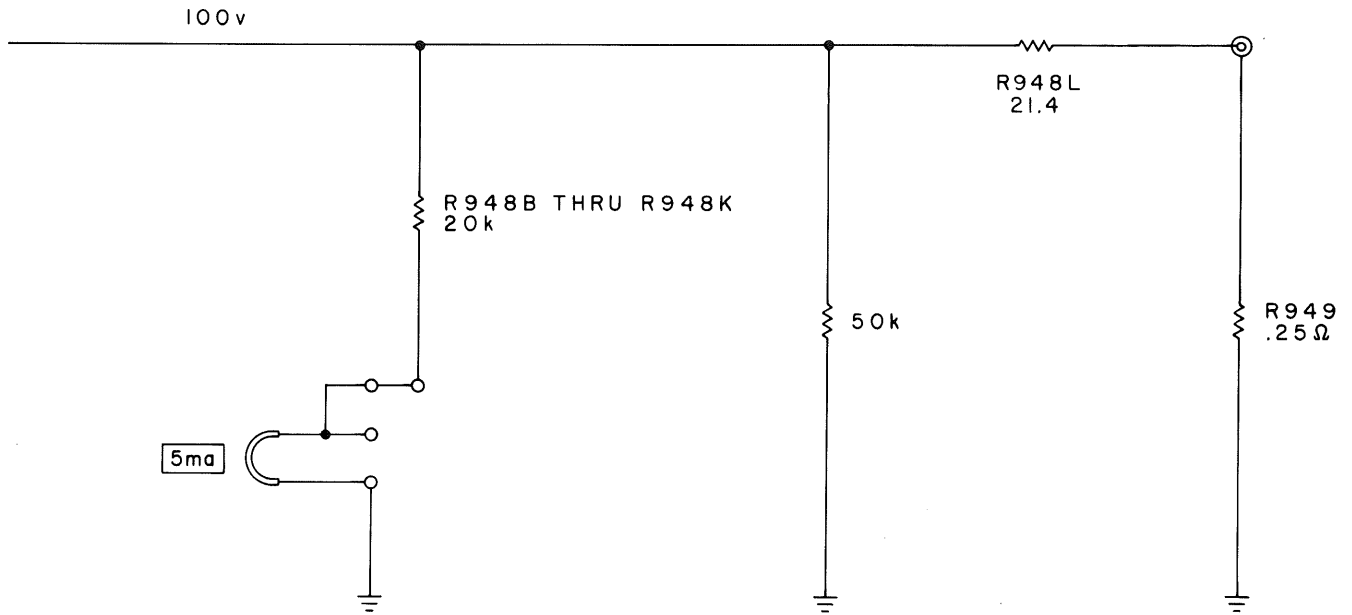
7. .2 mv to 50 mv positions:



- a. These millivolt positions use the same taps on R948B through R948K as the voltage positions.
- b. The voltage is then divided by 1000 by R948Y and R948Z.
- c. Output impedance is 50Ω .
- d. C948Z compensates the low end of the divider.

Type 647

8. 5 ma position .
 - a. Current through R948B through R948K provides a 5 ma square wave through the current loop.
 - b. The current loop is provided primarily to calibrate a current probe.
 - c. The CAL OUT is disconnected in this position preventing accidental loading of the current square wave.
9. R949, placed between CAL OUT jack ground return and ground, breaks up ground loops in the system when a coax is used.



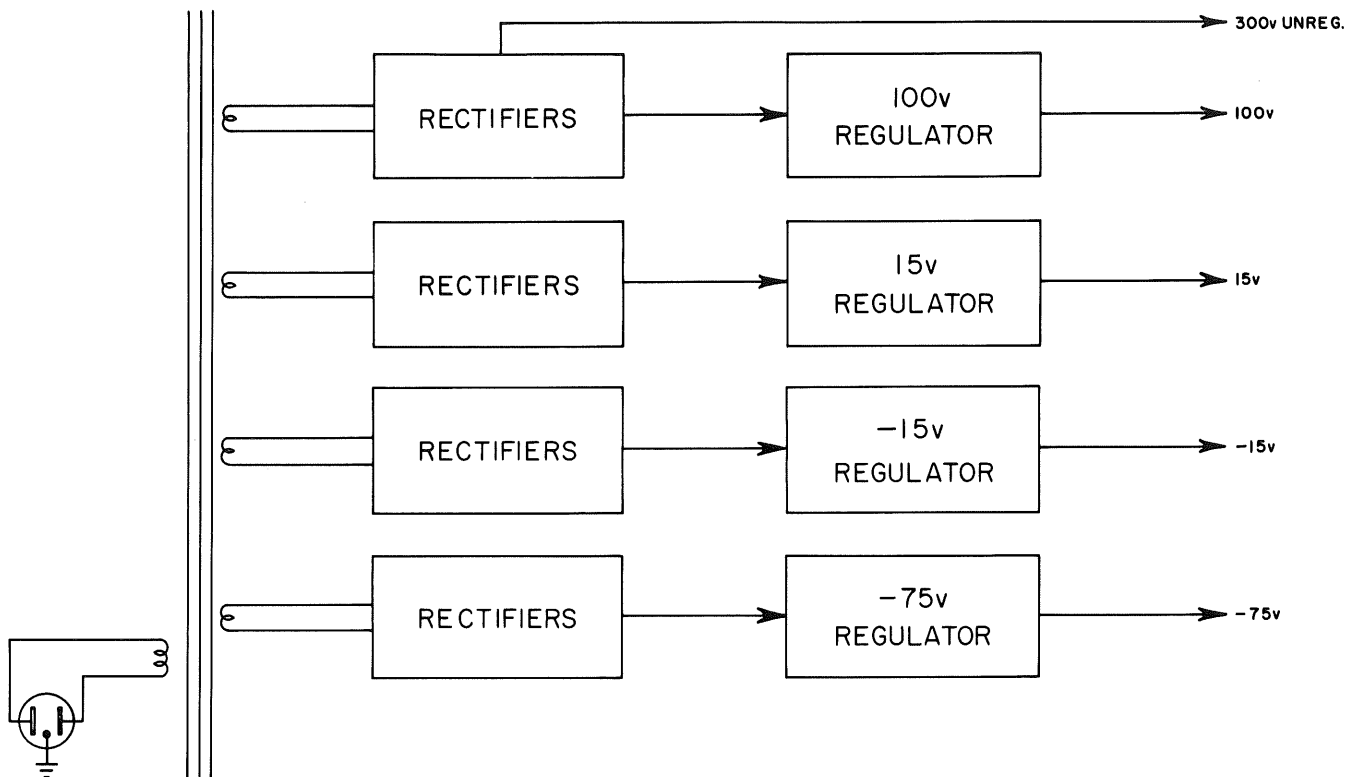
Type 647

VI. LOW VOLTAGE POWER SUPPLY

A. The Low Voltage Power Supply provides four regulated voltage sources for use in the scope main frame and plug-ins, and a 300v unregulated source for use in the main frame and plug-ins.

1. All supplies will regulate with the plug-ins removed.

B. Block Diagram



TYPE 647 POWER SUPPLY
BLOCK DIAGRAM

B-647-0062
2-17-'64 jg

Type 647

C. Block Logic

1. Regulated Supplies

- a. +100v
- b. +15v
- c. -15v
- d. -75v

2. Unregulated Supply

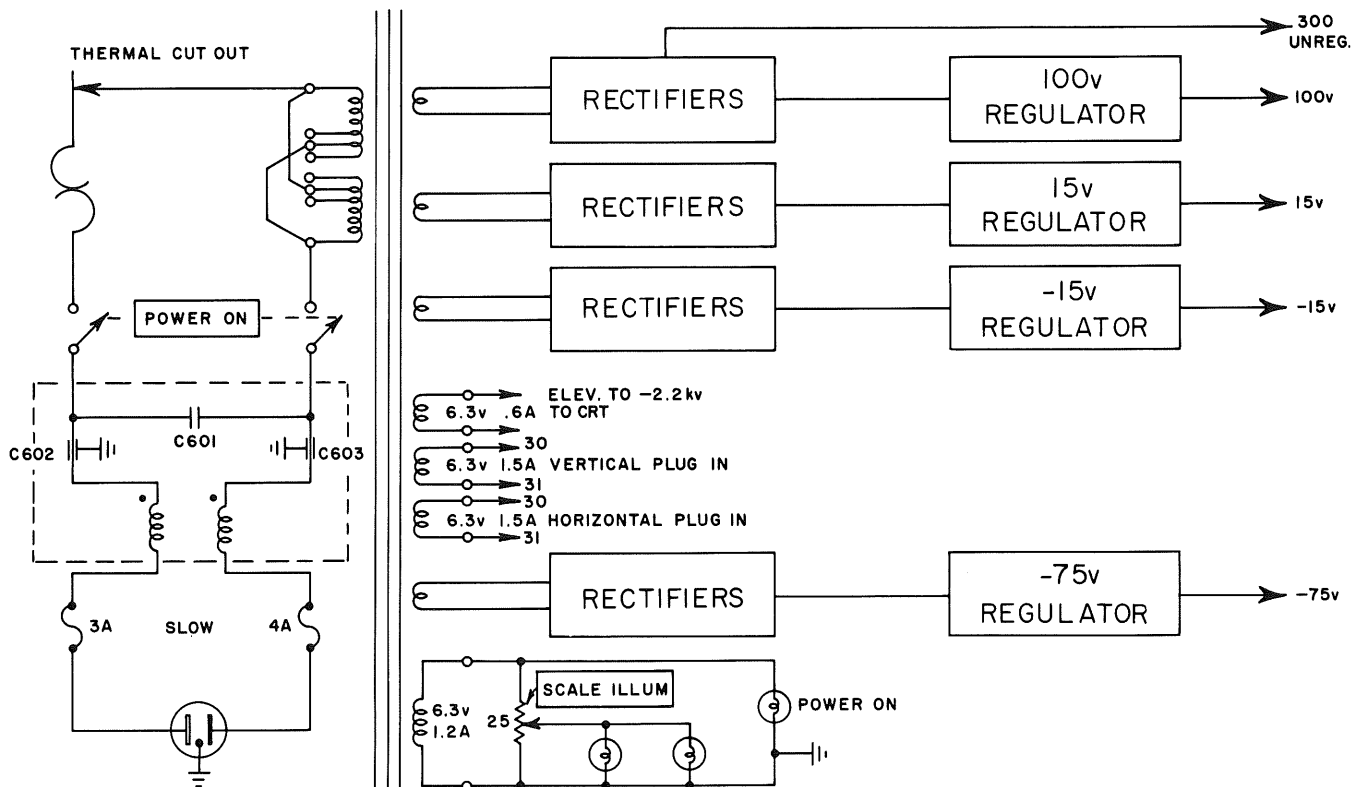
- a. +300v

3. The -75v supply has a zener reference.

4. The -15v, +15v and 100v supplies use the -75v supply as reference.

5. The +300v unregulated supply is stacked on the +100v supply.

D. Transformer Circuit.



TYPE 647 POWER SUPPLY
TRANSFORMER CIRCUIT

B-647-0063
2-18-64 jg

Type 647

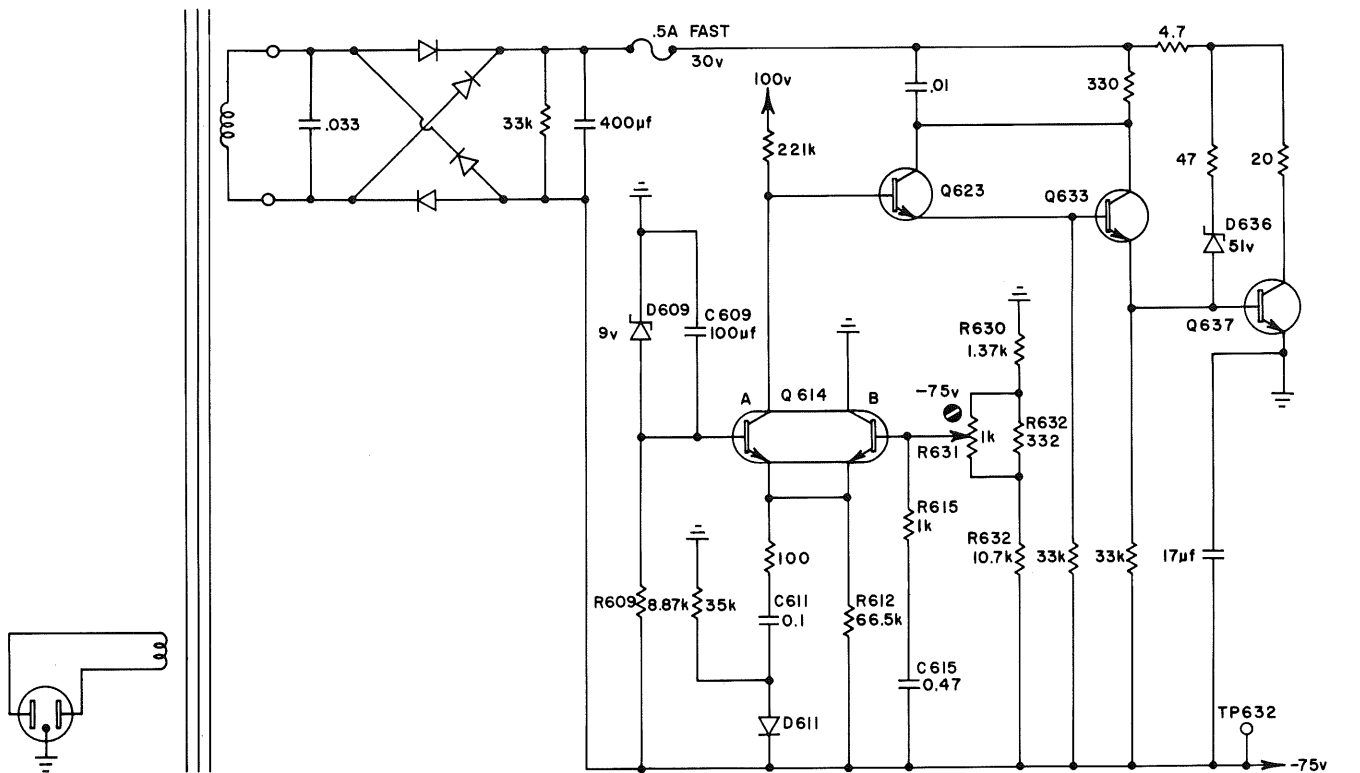
1. Besides the five DC supplies, four heater windings are provided.
 - a. 6.3v, .6a to the CRT heater.
 - (1) Elevated to -2.2 kv.
 - b. 6.3v, 1.5a to the vertical plug-in for nuvistor heaters.
 - c. 6.3v, 1.5a to the horizontal plug-in for nuvistor heaters.
 - d. 6.3v, 1.2a for POWER ON pilot light and SCALE ILLUM lights.
2. A detachable 3 wire power cord is supplied.
3. Both sides of the power line are fused.
 - a. A 3a slow blow fuse is used on one side and a 4a slow blow is used on the other.
 - b. Two fuses satisfy a military spec requirement.
 - c. By having two fuse sizes, one can predict which one will blow.
 - d. The rack mount scope has the 3a on front and the 4a on the rear panel.
4. T601, C602, C603 and C601 constitute an RF filter to reduce high frequency kick-back into the line.
 - a. There is a high 100 kc component.
 - b. Most of the kick-back comes from the silicon rectifiers firing at one point on the cycle.
5. The POWER ON switch opens both sides of the line to satisfy a military spec.
6. A thermal cut out opens one side of the line if the ambient temperature exceeds 187° f.

Type 647

7. Six primary voltage taps are available:
 - a. 95 to 122v AC.
 - b. 100 to 130v AC.
 - c. 106 to 137v AC.
 - d. 190 to 244v AC.
 - e. 200 to 260v AC.
 - f. 212 to 296v AC.
8. Power consumption at 117v line with a 10A2 and 11B2 is 185 watts.
9. Line frequency is 50 to 400 cps, $\pm 10\%$.
10. Line voltage distortion should not exceed 1%.

E. -75v Regulated Supply

1. The -75v supply is a transistorized series regulated supply fed by a full wave silicon bridge rectifier.



TYPE 647 POWER SUPPLY
-75v SUPPLY

B-647-0064x
2-19-64 jg

Type 647

2. The supply can deliver 250 ma.
 - a. Tied to pin 1 of both vertical and horizontal blue ribbon connectors.
 - b. 52 ma are used in the main frame.
 - c. The Type 11B2 uses 140 ma.
 - d. The 10A2 uses no -75v.
 - e. The output is adjusted to $-75v \pm .1\%$ with a John Fluke meter.
3. The circuit consists of four transistors, two zener diodes, and one signal diode.
 - a. Q623 and Q633 are 151-096 selected RCA or Fairchild 2N1938 silicon NPN transistors.
 - b. Q637 is a 151-113 RCA 2N1488 silicon NPN power transistor.
 - c. Q614 is a 151-104 selected Fairchild SP8481 dual silicon transistor.
 - d. D636 is a Motorola 10M5125, a 51v zener.
 - e. D609 is a 152-124 Motorola 1N938A, a 9v 5% zener with a temperature compensation of $.001\%/^{\circ}c$.
 - f. D611 is a 152-061 Raytheon 6061 silicon diode.
4. Quiescent DC levels, Q614, Q623, Q633, Q637.
 - a. Q614 Base, -9v.
 - b. Q614 Emitter, -9.6v.
 - c. Q614A Collector, 1.9v.
 - d. Q623 Base, 1.9v.
 - e. Q623 Collector, 23.8v.
 - f. Q523 Emitter, 1.3v.
 - g. Q633 Base, 1.3v.
 - h. Q633 Collector, 23.8v.
 - i. Q633 Emitter, .7v.
 - j. Q637 Base, .7v.
 - k. Q637 Collector, 22.5v.

Type 647

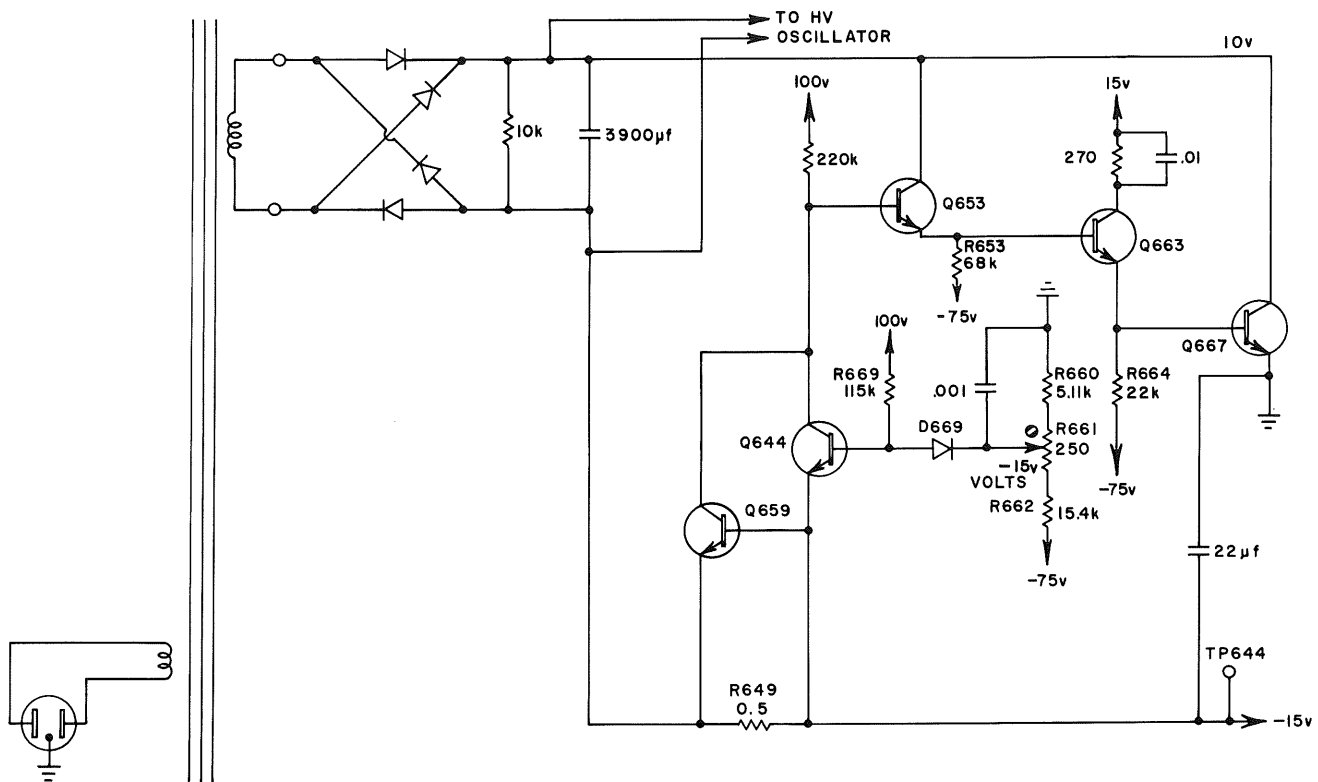
5. The full wave silicon bridge supplies 105v DC.
 - a. The bottom is at -75v; the top +30v.
 - b. C610 reduces silicon switching transients.
 - c. The supply is protected by a .5A fast-blow fuse.
 - d. The rectifier diodes are 152-066 selected RCA 1N3194 silicon 750 ma diodes with a PIV of 400v.
6. D609 provides a 9v reference signal at the base of Q614A.
 - a. C609, a 100 μ f cap, bypasses zener noise.
 - b. R609 (a metal film resistor with zero temp coefficient) limits zener current to a temperature stable range.
7. Q614B base is supplied a signal from a divider composed of R630, R631 and R632.
 - a. The divider resistors are 1% wire wound.
 - b. The signal is proportional to the -75v output.
 - c. R631 is the -75v adj.
 - d. C615 couples fast voltage changes across R632.
 - e. Q614B base sets at about -9v.
8. Q614 is connected as a comparator, comparing the reference voltage with the error voltage.
 - a. About 1 ma flows through R612, supplying both emitters.
 - (1) The side with the more positive base conducts the most current.
 - b. Q614B collector is tied to ground.
 - c. Q614A collector load resistor is 221k, providing the high voltage gain for the stage.
 - d. The output taken across 614A collector load drives Q623 base.
9. Q623 and Q633 are current amplifiers driving output power transistor, Q637.

Type 647

10. Assume the load current is increased (-75v tends to move toward -70v).
 - a. The error voltage at Q614B base moves up, biasing it to more conduction.
 - b. Q614A conducts less current and its collector moves up.
 - (1) More of the current through R612 flows through Q614B.
 - (2) Q614 beta is 150 or more.
 - c. Q623 becomes more forward biased and its emitter rises.
 - d. Q633 becomes more forward biased and its emitter rises.
 - e. Q637 becomes more forward biased satisfying the requirement for more current in the load.
 - f. As the output moves back toward -75v , Q614B base returns its original potential.
 - g. Because the loop gain of the system works to keep Q614 bases at equal potentials, there is virtually no change in the voltage at Q614B base.
11. Overload or short protection should the -75v output short to ground.
 - a. Short current through Q637 is about 1a .
 - b. Positive going surge cuts off D611.
 - (1) The charge on C611 holds D611 anode at -75v until the surge has passed.
 - (2) Without the diode, the surge would couple through C611, damaging Q614.
 - c. A fast surge coupled through C615 is limited by R615 before reaching Q614 base.

Type 647

F. -15v Regulated Supply



TYPE 647 POWER SUPPLY
-15v SUPPLY

B-647-0065x
2-20-64 jg

Type 647

1. The supply is a transistorized series regulated supply fed by a full wave silicon bridge rectifier.
 - a. An overload and short protection circuit is provided.
2. The supply delivers about 800 ma with a Type 10A2 and 11B2.
 - a. The output is adjusted to -15v , $\pm 0.1\text{v}$ with a John Fluke meter.
 - b. -15v is tied to pin 18 of both plug-in blue ribbon connectors.
3. The circuit uses five transistors and one diode.
 - a. Q653, Q659 and Q663 are 151-103 selected Motorola 2N2219 silicon NPN transistors.
 - b. Q644 is a 151-126 selected Fairchild S5684 silicon NPN transistor.
 - c. Q667 is an RCA 2N1489 silicon NPN power transistor (151-112 will substitute).
 - d. D669 is a 152-141 GE 1N3605 diode.
4. Quiescent DC levels; Q659, Q644, Q653, Q663 and Q667.
 - a. Q659 Base, -15v .
 - b. Q659 Emitter, -15.5v .
 - c. Q659 Collector, 2v .
 - d. Q644 Base, -14.5v .
 - e. Q644 Emitter, -15v .
 - f. Q644 Collector, 2v .
 - g. Q653 Base, 2v .
 - h. Q653 Emitter, 1.4v .
 - i. Q653 Collector, 8.5v .
 - j. Q663 Base, 1.4v .

Type 647

- k. Q663 Emitter, .8v.
 - l. Q663 Collector, 8.4v.
 - m. Q667 Base, .8v.
 - n. Q667 Collector, 8.5v.
5. The full wave silicon bridge supplies 24v DC.
- a. The bottom is at -15.5v and the top, 8.5v.
 - b. The rectifier diodes are 152-113, RCA 40108 silicon 10a diodes with a PIV of 50v.
 - c. Unregulated output is supplied to the HV oscillator.
6. Q644 is a voltage amplifier driving current amplifiers Q653 and Q663.
- a. Q663 provides control current for the series regulator power transistor, Q667.
7. The -75v supply used as reference, appears across the divider composed of R660, R661 and R662.
- a. A sample of the -75v reference voltage is tapped by the -15v adj and applied to Q644 base.
8. Q644 emitter, tied to -15v output compares the -15v output with the -75v reference.
9. D669 has the same voltage drop as Q644 emitter base junction.
- a. Both change equally with temperature change.
 - b. The voltage relationship between Q644 emitter and the -15v adj cannot change with temperature.
 - c. Current through R669 provides forward bias current for D669 and Q644.

Type 647

10. The theory of operation is the same as the -75v supply.
 - a. An increase in load current causes Q644 emitter to raise, biasing the transistor to less conduction.
 - b. Q644 collector raises gain times as far as the emitter.
 - c. Q653 is more forward biased and its emitter raises.
 - d. Q663 is more forward biased and its emitter raises.
 - e. Increased forward base current increases the current through series power transistor, Q667.
 - f. The requirement for more load current is satisfied and the output returns to -15v.
 - g. With a line voltage change or change in load, the -15v makes no appreciable change.

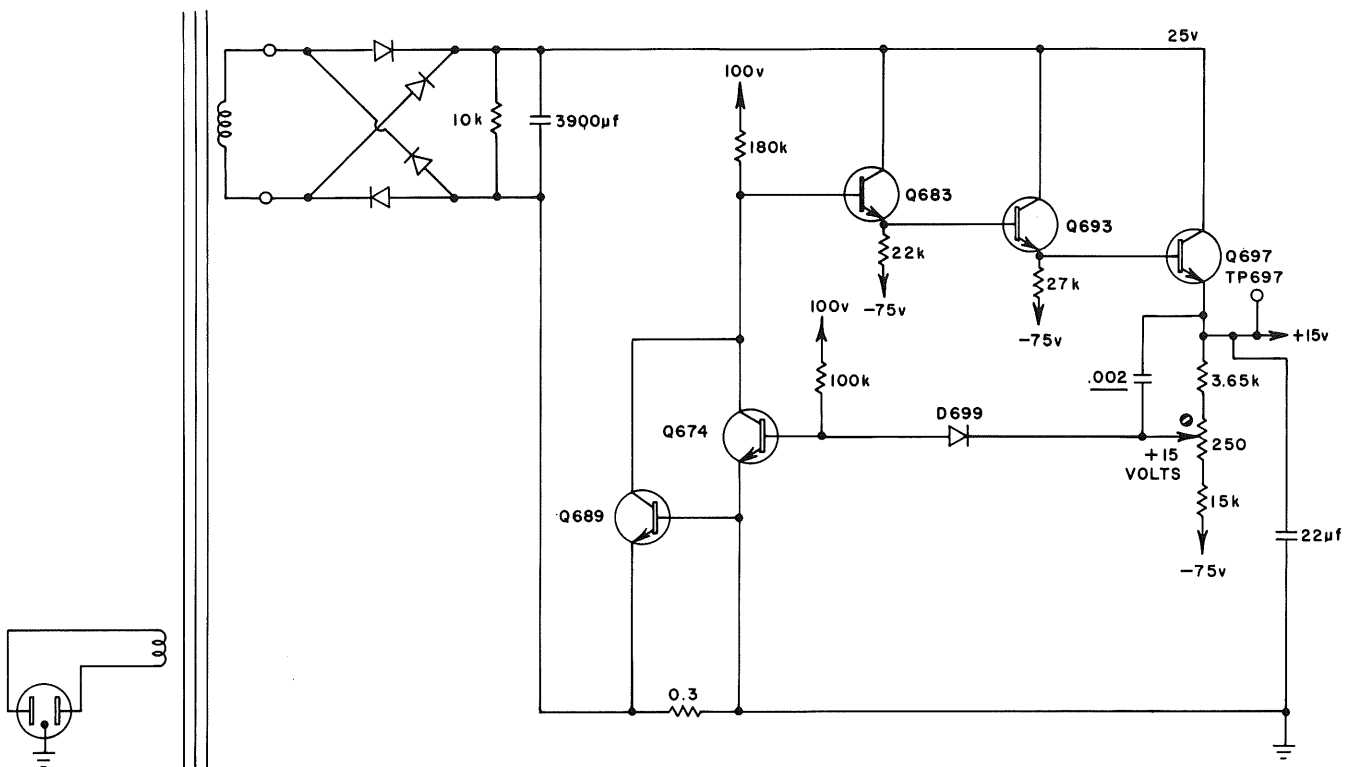
11. Overload short protection should the -15v output become shorted to ground.
 - a. A short to ground would raise the -15v output, forward biasing Q659 to saturation as the voltage drop across R649 increases.
 - b. Q659 collector pulls down on Q653 base.
 - c. Q653 and Q663 are long-tailed to -75v so bases and emitters will drop together.
 - d. As Q667 base drops, biasing Q667 to bias conduction, the voltage drop across R649 will decrease.
 - e. The voltage drop across R649 controls Q659 bias. Q659 conduction controls Q667 bias. Q667 conduction controls the voltage drop across R649.
 - f. Currents will equalize at a safe operating condition for Q667.
 - g. Since .5v base-emitter voltage will bring Q659 into conduction, a 1 amp overload will actuate the short protection circuit by providing .5v across R649.

Type 647

- 12. R653 provides a path for I_{CBO} current in Q663. R664 bleeds off I_{CBO} current in Q667.

G. +15v Regulated Supply

- 1. The supply is a transistorized series regulated supply almost identical to the -15v supply.



TYPE 647 POWER SUPPLY
+15v SUPPLY

B-647-0066 x
2-21-64 jg

Type 647

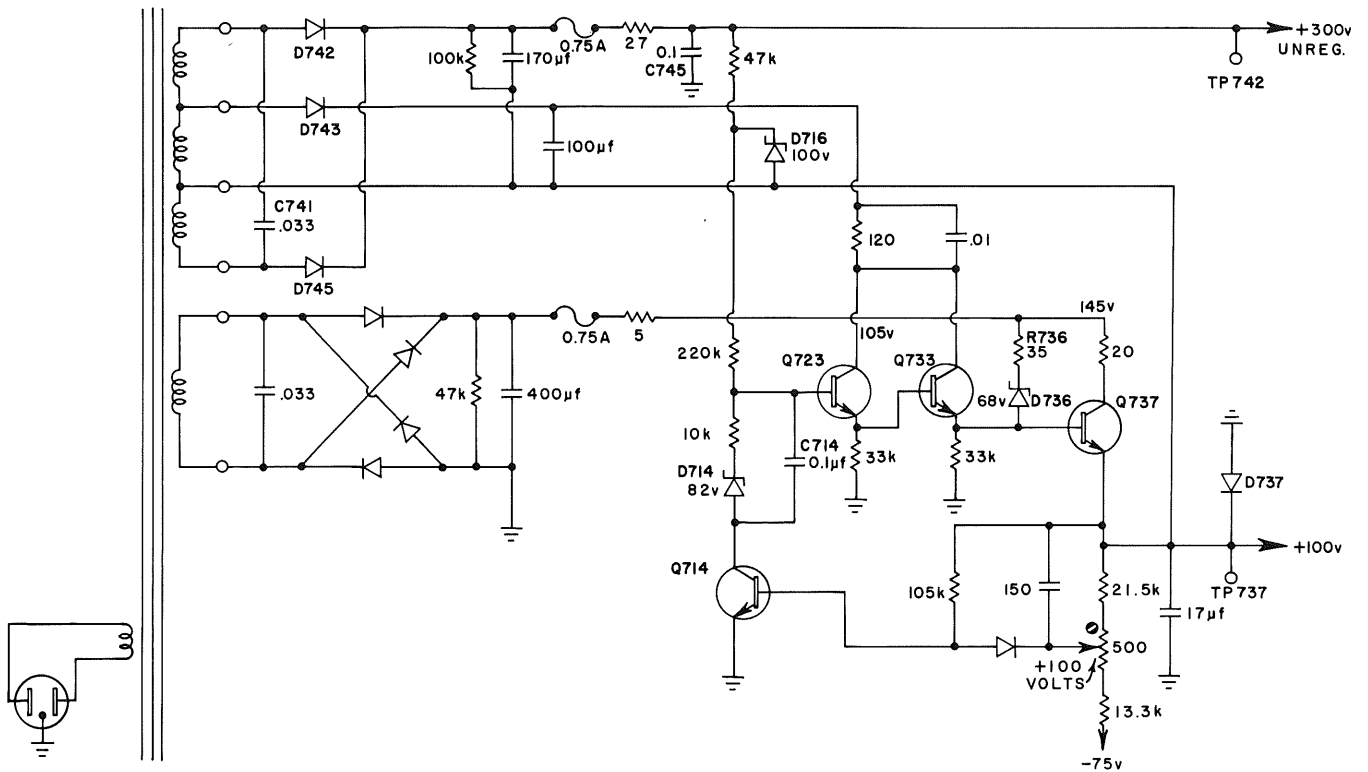
2. The supply delivers about 1300 ma with a Type 11B2 and 10A2.
 - a. Set at $15v \pm .1\%$ with a John Fluke meter.
 - b. +15v output is tied to pin 3 of both blue ribbon connectors and pin 22 of the horizontal plug-in connector.
3. The transistors differ from the -15v supply in the use of heavier duty transistors as output and driver transistors.
 - a. Q693 is a RCA 2N1701 silicon NPN power transistor (151-125 will substitute).
 - b. Q697 is a Westinghouse 152-04 silicon NPN 100w power transistor (151-110 will substitute).
4. Quiescent DC levels, Q689, Q674, Q683, Q693 and Q697.
 - a. Q689 Emitter, $-.4v$.
 - b. Q689 Collector, $16.8v$.
 - c. Q674 Base, $.58v$.
 - d. Q674 Collector, $16.8v$.
 - e. Q683 Base, $16.8v$.
 - f. Q683 Emitter, $11.2v$.
 - g. Q683 Collector, $22.2v$.
 - h. Q693 Base, $16.2v$.
 - i. Q693 Emitter, $15.6v$.
 - j. Q697 Base, $15.6v$.
 - k. Q697 Emitter, $15v$.
5. The full wave silicon bridge supplies 22.6 volts.
 - a. The bottom sets at $-.4v$ and the top at $22.2v$.
 - b. The diodes are 152-113 10a diodes like those in the -15v supply.

Type 647

- 6. Circuit operation is the same as the -15v supply except that the error voltage is applied to the feedback amplifier base instead of the emitter.
 - a. The error signal is amplified and inverted in Q674 for control of Q697 current.
- 7. Two amps of overload current is required to actuate the overload protection circuit.

H. +100v Supply

- 1. The supply is a transistorized series regulated supply similar in operation to the -15v and +15v supplies.
 - a. No overload protective circuit is provided.



TYPE 647 POWER SUPPLY
+100v SUPPLY

B-647-0067x
2-22-64 jg

Type 647

2. It delivers about 395 ma with a Type 10A2 and 11B2.
 - a. Set at +100v \pm .1% with a Fluke meter.
 - b. 100v output is tied to pin 20 of both blue ribbon connectors.
3. Transistor compliment is the same as the -15v supply except for Q737.
 - a. Q737 is a Westinghouse 151-07 (this is a Westinghouse number, not Tek) Silicon 100 watt NPN power transistor with 140v BV_{cbo} (151-111 will substitute).
 - b. D714 is a 152-135 Motorola 1N3042A 82v 10% 1 watt zener diode.
 - c. D736 is a 152-133 Motorola 1N3001B 68v 5% 10 watt zener diode.
 - d. D739 is a 152-141 GE 1N3605 silicon diode.
 - e. D737 is a 152-066 RCA 1N3194 silicon 750 ma power diode with a PIV of 400v.
 - f. D716 is a 152-134 Motorola 1N3044A 10% 100v zener.
4. Quiescent DC levels, Q714, Q723, Q733, Q737.
 - a. Q714 Base, .6v.
 - b. Q714 Collector, 19.2v.
 - c. Q723 Base, 100.2v.
 - d. Q723 Emitter, 100.14v.
 - e. Q723 Collector, 104v.
 - f. Q733 Base, 100.14v.
 - g. Q733 Emitter, 100.7v.
 - h. Q737 Base, 100.7v.
 - i. Q737 Emitter, 100v.
 - j. Q737 Collector, 125v.

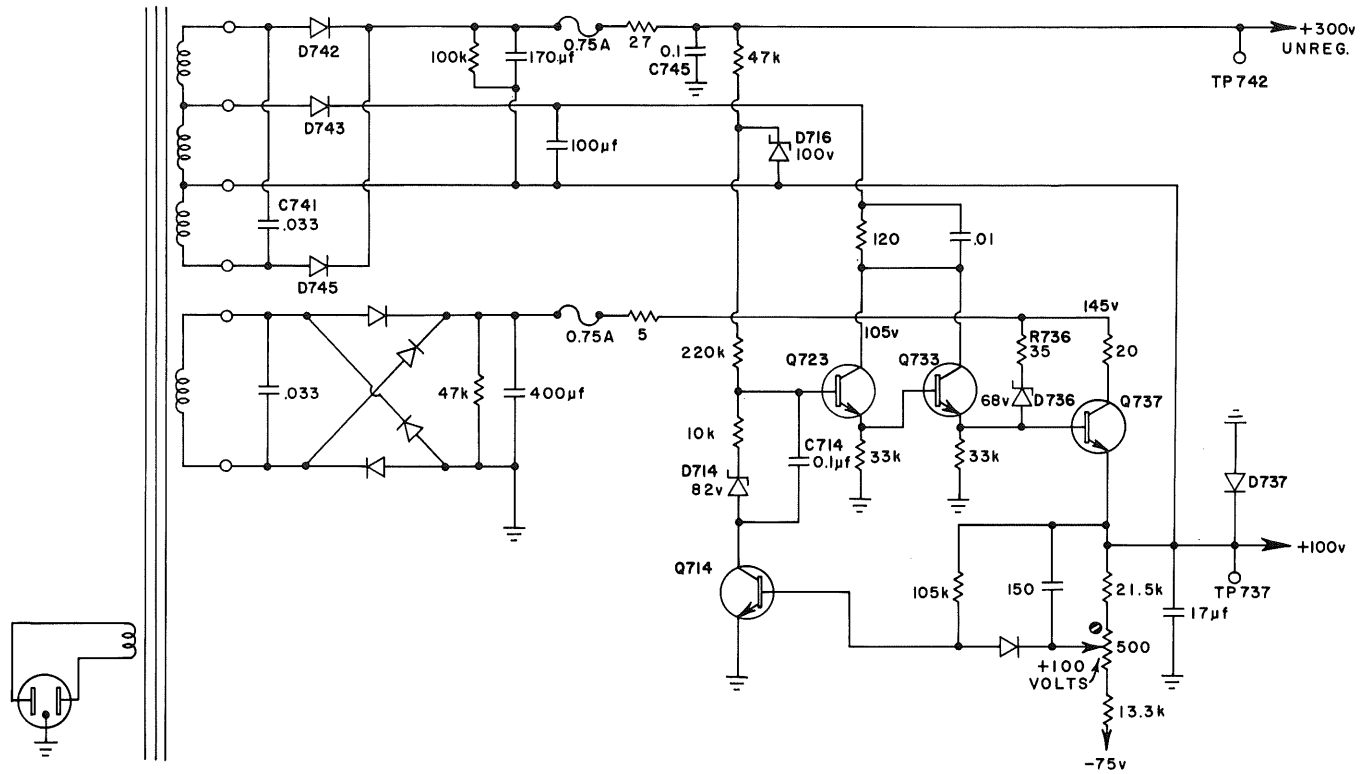
Type 647

5. The 100v supply uses a full wave silicon bridge supply delivering 136v.
 - a. The bottom of the supply is grounded.
 - b. A .75a fast-flow fuse protects the rectifier.
 - c. The rectifiers are 152-066 RCA 1N3194 silicon 750 ma power diodes with a PIV of 400v.
6. Circuit operation is the same as the 15v supply.
 - a. Q714 is the feedback amplifier.
 - b. Q723 and Q733 are current amplifiers driving the series regulator transistor, Q737.
7. Collector voltage for the amplifiers comes from the 300v unregulated supply.
 - a. Q714 collector supply is tied to the 300v supply, but zener referenced (by D716) to 100v above the 100v regulated output.
 - b. D716 then provides a 200v regulated supply for Q714.
 - c. Q723 and Q733 are supplied by a 105v tap on the 300v supply.
 - d. This is a half wave rectifier unregulated filtered supply.
8. D714 allows Q714 collector to operate within its BV_{cbo} range of 45v while allowing the Q723 base to operate near 100v.
 - a. C714 filters out zener noise.
9. D736 protects Q737 from base-collector breakdown should base to collector voltage reach 68 volts.
 - a. R736 limits zener dissipation current.
10. D737 prevents the 100v output from being driven negative by the 300v supply if the 100v fuse blows.

Type 647

I. 300v Unregulated Supply

1. The 300v supply is an unregulated supply fed by a full wave silicon rectifier.



2. The supply is stacked on the 100v regulated supply.

3. About 88 ma is drawn from the supply.

a. 300v unregulated is tied to pin 20 of both blue ribbon connectors.

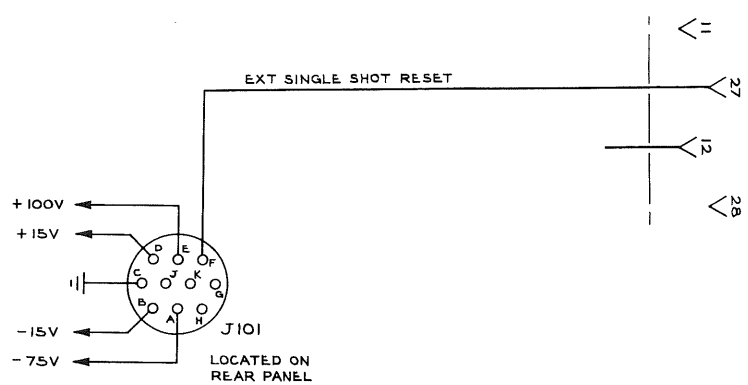
b. 300v is not used in the 10A2.

Type 647

4. The supply is fused by a .75a fast-blow fuse .
5. The rectifiers are 182066 diodes like those used in the -75 and 100v supplies .
6. C741 reduces silicon switching transients .
7. C745 bypasses D716 zener noise .

J. Rear Panel Power Jack

1. All regulated supplies are available at a rear panel jack, J101 .



2. A source of EXT SINGLE SHOT RESET voltage can be connected to pin F of J101 where it is connected to pin 27 of the horizontal plug-in blue ribbon connector .

TYPE 647
SLIDE LIST

B-647-0075	
B-647-0050	B-647-0059
B-647-0051	B-647-0062
B-647-0052	B-647-0063
B-647-0053	B-647-0064
B-647-0054	B-647-0065
B-647-0068	B-647-0066
B-647-0069	B-647-0067
C-647-0031	
B-647-0070	
B-647-0071	
B-647-0041	
B-647-0042	
B-647-0043	
B-647-0044	
B-647-0045	
B-647-0046	
B-647-0047	
B-647-0048	
B-647-0049	
C-647-0030	
B-647-0055	
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B-647-0072	
B-647-0057	
B-647-0073	
B-647-0074	
B-647-0058	
B-647-0060	
B-647-0061	
B-647-0061.1	
B-647-0061.2	