INSTRUCTION MANUAL

TYPE 109

PULSE GENERATOR

Tektronix, Inc.
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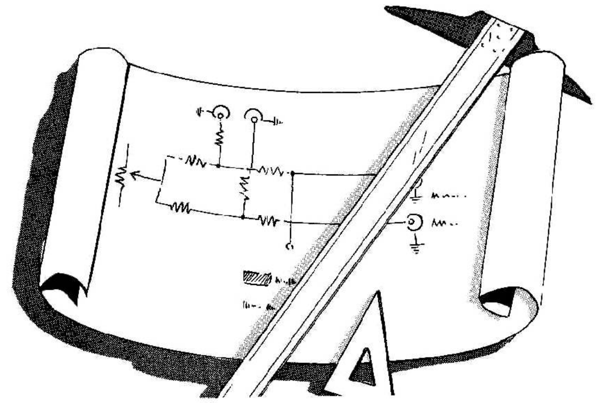
070-299 563


TYPE 109
PULSE GENERATOR
(RISETIME ≤ 0.25 NANOSEC)
AMPLITUDE
0 5 10 15 20 25 30 35 40 45 50
VOLTAGE RANGE
0.5 5.0 50 EXT. PWR.
EXT. POWER OR MONITOR
52 K 2 W
52 K 2 W
50 Ω CHG. LINE 1
50 Ω CHG. LINE 2
PULSE POLARITY
− +
POWER ON
TURN OFF TO EXTEND MERCURY SWITCH LIFE
50 Ω
OUTPUT
SERIAL
TEKTRONIX
TEKTRONIX, INC., PORTLAND, OREGON, U.S.A.



SECTION 1

CHARACTERISTICS

General Information

The Tektronix Type 109 Pulse Generator is a fast-risetime pulse generator similar to the pulse generator section of the Type 110. The Type 109 is capable of producing pulses of different widths, calibrated-amplitudes, and polarities for use in driving and testing the response of devices operating in the nanosecond region.

An external network, supplied with the Type 109, provides long duration pulses with an amplitude decay of only 10% in 400 nanoseconds. This network is useful for testing amplifier linearity or tuning delay lines.

Pulse Amplitude

Three calibrated ranges: 0 to 0.5 v, 0 to 5 v, 0 to 50 v.

Accuracy is within 3% of the front-panel full-scale marking. Each range is continuously variable.

±50 volts is the maximum calibrated amplitude using the internal power supply; ±300 volts maximum allowed using an external supply and either or both contacts.

Polarity

Positive or negative.

Risetime

Less than 0.25 nsec (nanosecond or 10^{-9} second). Pulse risetime is illustrated in Figs. 1-1 and 1-2.

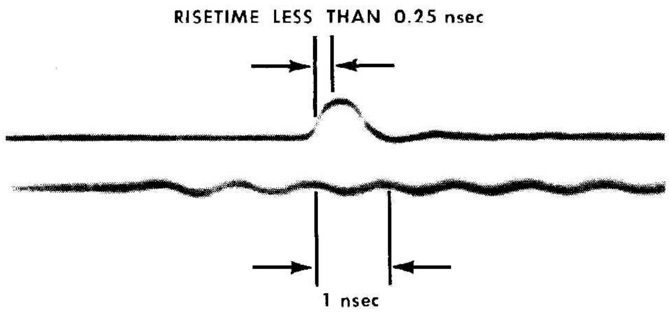


Fig. 1-1. A double exposure photograph of the output pulse from the Type 109 (no external charge line) and a 1 gigacycle/sec timing train. The waveforms are displayed on a Tektronix 0.12-nsec risetime research-type oscilloscope. This photograph shows the risetime to be well under 0.25 nsec. The minimum pulse width is approximately 0.5 nsec. Note the freedom from overshoot.

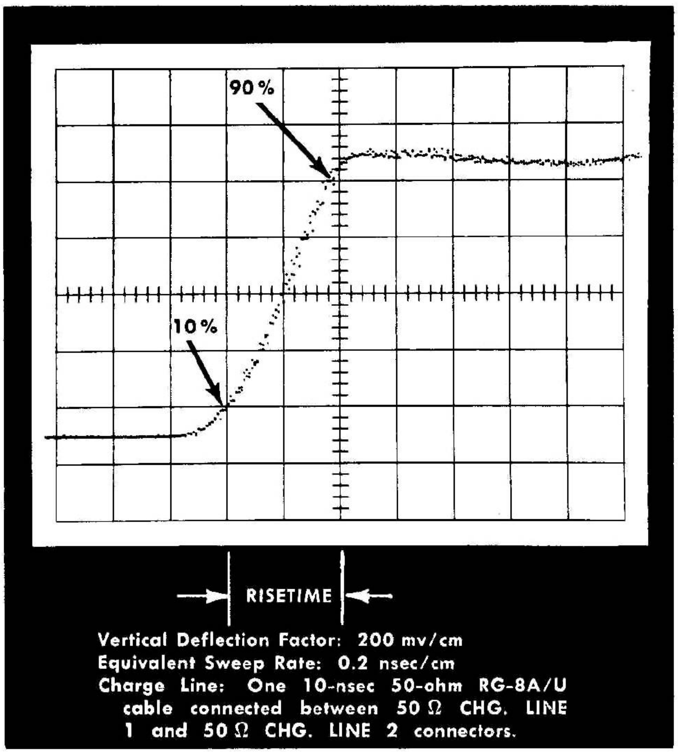


Fig. 1-2. Waveform showing the Type 109 pulse displayed on a Tektronix Type 661 (Sampling) Oscilloscope. Combined risetime of the system, between 10% and 90% amplitude levels, is less than 0.4 nanoseconds.

Duration

From approximately 0.5 nsec measured at the 50% amplitude level (see Figs. 1-1 and 1-3), to a maximum of 100 nsec at a repetition rate between 550 to 720 cycles using a single charge line to both contacts; 300 nsec at half repetition rate by using either one open-ended charge line with the unused contact grounded or by using two separate open-ended charge lines.

An accessory, a special external charge network supplied with the Type 109, provides a fast-rise pulse with an RC decay (see Fig. 1-4) and a pulse amplitude which is about one-tenth that indicated by the front-panel marking. Decay is only 10% in 400 nsec (see Fig. 1-5). Fig. 1-6 shows the pulse waveform at an equivalent sweep rate of 1 nsec/cm.

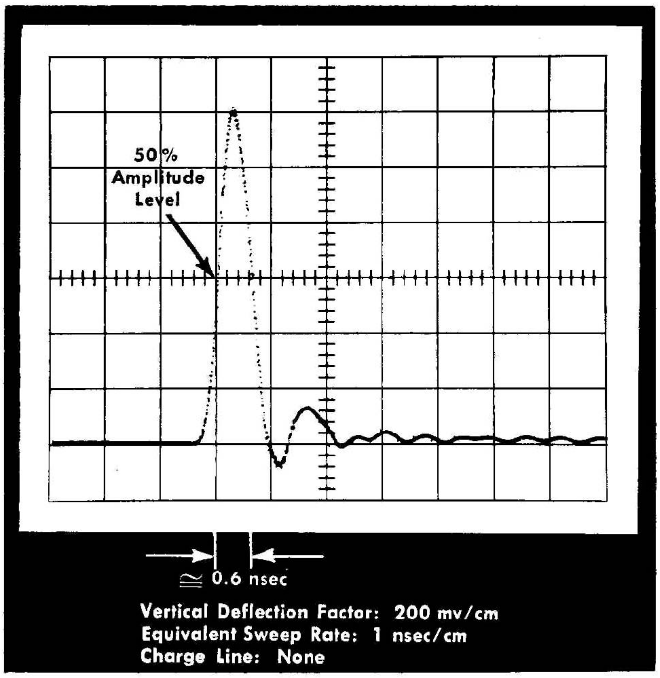


Fig. 1-3. Minimum pulse-width waveform as displayed on a Type 661 (Sampling) Oscilloscope.

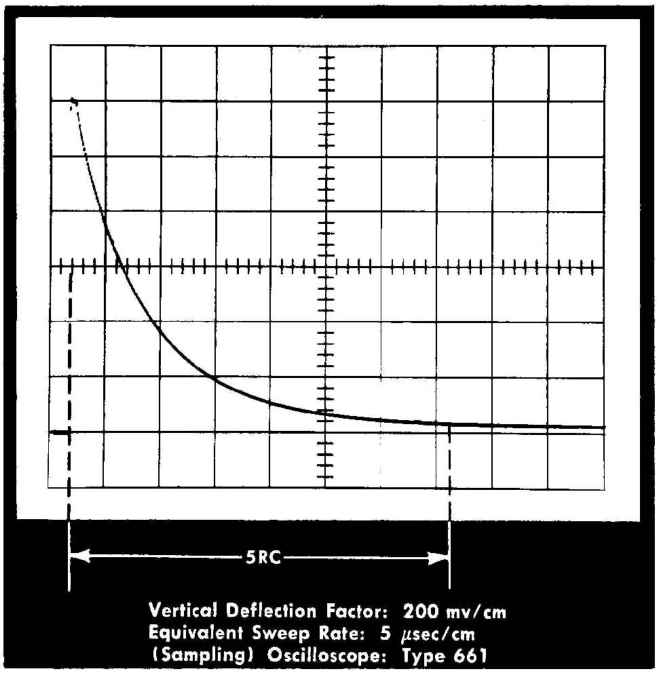


Fig. 1-4. Waveform produced by using the external charge network supplied as a standard accessory. The network connects to one of the 50 Ω CHG. LINE connectors on the Type 109 and grounds the unused connector.

Repetition Rate

Internally adjustable for proper operation at a rate between 550 to 720 pulses per second.

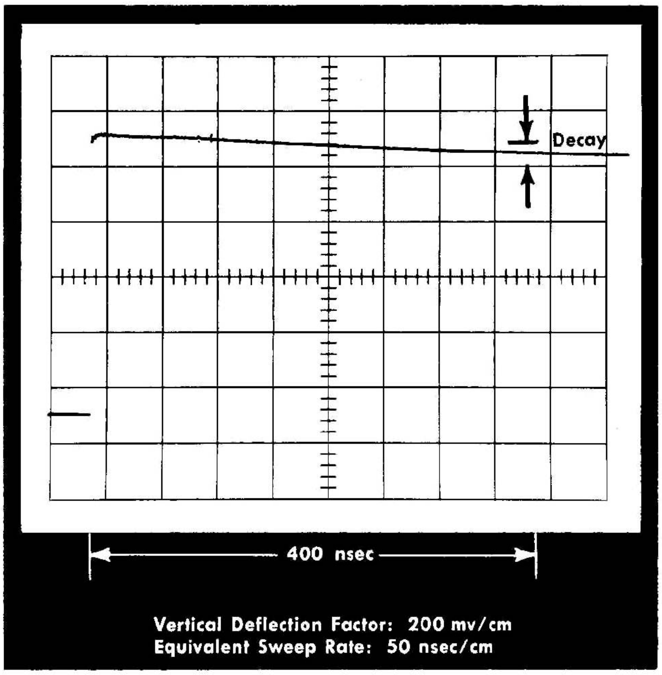


Fig. 1-5. Waveform obtained using the same charge network as described in Fig. 1-4 but the equivalent sweep rate of the Type 661 is increased to 50 nsec/cm. This photograph shows that the amplitude (or RC) decay is less than 10% in 400 nsec.

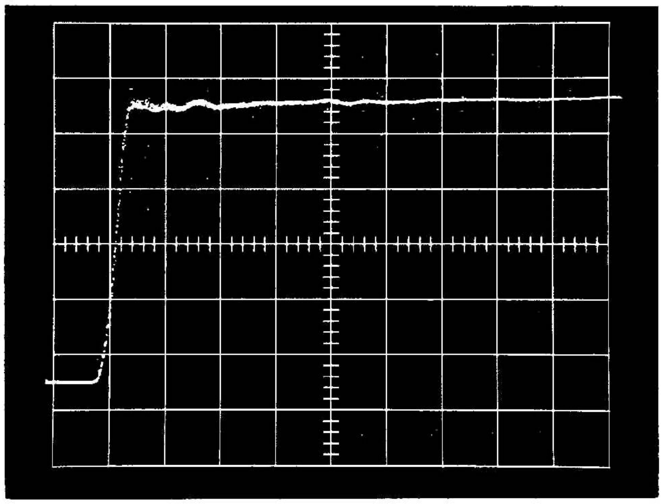
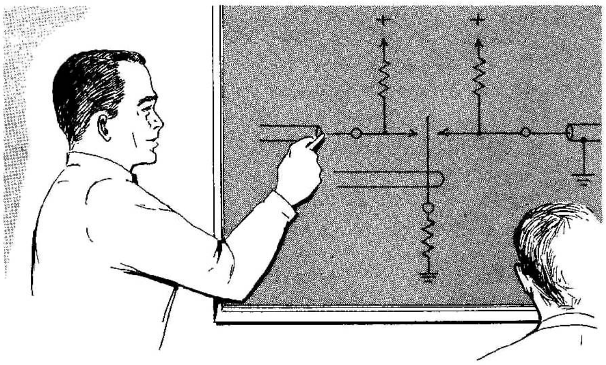


Fig 1-6. Same conditions as Figs. 1-4 and 1-5 except that the equivalent sweep rate is 1 nsec/cm.

Alternate Pulses

Unequal charge lines produce alternate pulses of different time durations but of the same amplitude and polarity using the Type 109 internal power supply as shown in Fig. 1-7.

External charge voltages permit alternate pulses of different amplitudes and/or polarity to be generated as shown in Figs. 1-8 and 1-9.



SECTION 4

CIRCUIT DESCRIPTION

General Description

A block diagram representation of the Type 109 Pulse Generator is shown in Fig. 4-1. From this diagram it can be seen that the Type 109 contains two power supplies; namely, +10-volt and ±105-volt. The +10-volt power supply provides power to operate the Driver Multivibrator. The output from the ±105-volt power supply is applied to the pulse amplitude control network.

The Driver Multivibrator drives the mercury switch at a nominal frequency of 320 cps. Two external open-ended transmission lines can be used as charge lines for the Type 109. These lines are charged to a voltage set by the pulse amplitude control network. The mercury switch alternately discharges the two charge lines into the 50-ohm output load to form the output pulses. The two charge lines and two sets of contacts in the mercury switch cause the output pulse frequency to be twice the multivibrator frequency, or nominally 640 cps.

Use the schematic diagram at the rear of this manual while reading the detailed circuit description that follows next.

Transformer T601 Primary Circuit

AC power for the Type 109 is applied through a receptacle on the rear of the unit to the primary windings of T601. Two primary windings are used. The two windings are connected in parallel for 117-volt operation and in series for 234-volt operation.

A filter network, consisting of T600, C600 and C601, is used to reduce power line transients. Thermal cutout TK601 protects the Type 109 against excessively high interior temperature. If the temperature inside the instrument becomes too high, the contacts of TK601 will open and turn off the power applied to the primary circuit. When the interior temperature drops back to normal, the contacts will close and reapply the power.

+10-Volt Power Supply

The secondary winding of T601 that ties to terminals 8, 9 and 10, supplies the ac voltage for the +10-volt power supply. This ac voltage is applied to a full-wave rectifier, D602A and D602B. The rectified voltage is then applied through R610 to filter capacitors C610 and C611, all of which reduce the ripple voltage. Besides reducing ripple, R610 acts as an overload fuse for the circuit. If a short circuit or other overload occurs, it is likely that this resistor will burn out before any other component fails.

The filtered, unregulated dc voltage is then applied to R612 and Zener D612 for regulation. The voltage drop across the Zener is nominally 10 volts. This 10-volt drop is applied to a voltage divider consisting of a FREQUENCY

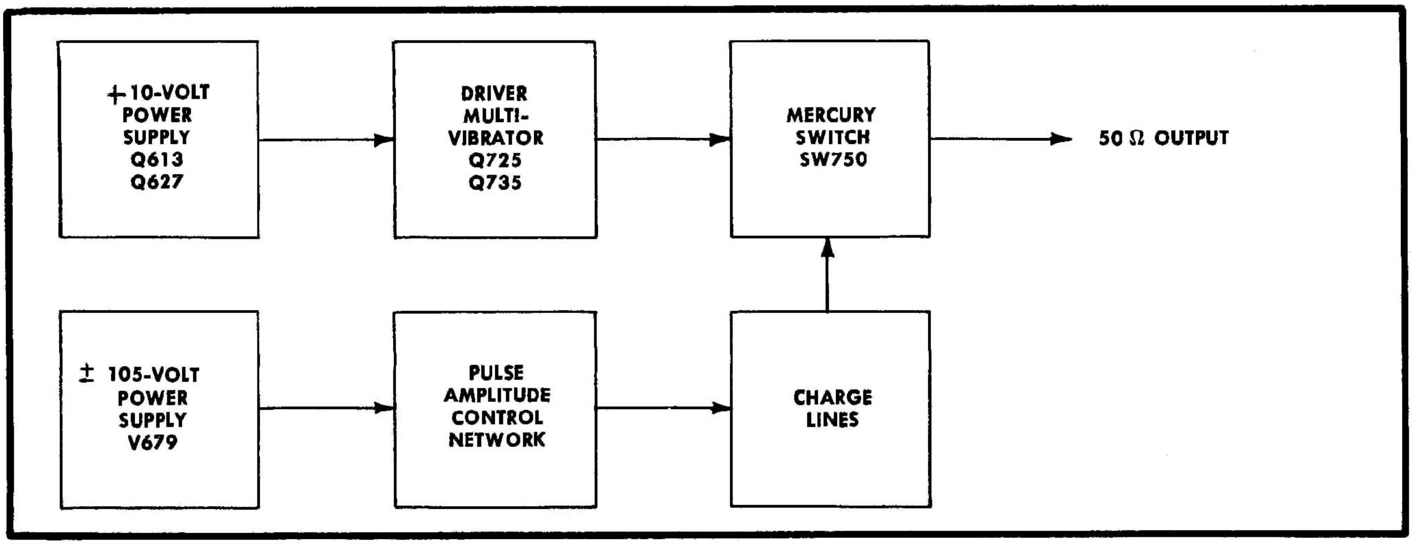


Fig. 4-1. Simplified block diagram of the Type 109.

control R614 and a resistor R615. The FREQUENCY control sets the voltage applied to the base of Q613. Transistor Q613 is an emitter follower whose output is tied to the base of another emitter follower, Q627. This second emitter follower stage has the required current capabilities for controlling the voltage applied to the Pulser Multivibrator stage.

Capacitors C614 and 627 provide additional filtering of the supply. They reduce the amplitude of the multivibrator spikes getting into the supply from the Driver Multivibrator stage.

Driver Multivibrator

The Driver Multivibrator stage is basically a saturating core square-wave oscillator. Transistors Q725 and Q735, function as high-speed switching elements. They are used in conjunction with transformer T750 to provide a saturating multivibrator circuit. During operation, the core materials of the transformer exhibit rectangular hysteresis loops designed to produce a square-wave output.

This stage operates from the voltage set by the FREQUENCY control. Bias for the two transistors is obtained from R744. Initial operation of the multivibrator depends on a slight unbalance between the transistors. When power is first applied to the instrument, one of the two transistors conducts first. For descriptive purposes, assume that Q725 conducts.

As Q725 conducts, current passing through one half of the primary of T750 induces a negative voltage at the base of Q725 and positive voltage at the base of Q735. This causes Q725 to conduct more heavily and holds Q735 in cutoff. This regenerative action continues until the core of T750 saturates.

When the transformer core saturates, the driving voltage at the bases of the two transistors is reduced. This causes current flow through Q725 to decrease, which in turn causes the induced voltages at the bases of the two transistors to shift polarity. With a negative voltage on the base of Q735, this transistor then conducts thereby inducing a still greater negative voltage at its base. This action then repeats as Q725 and Q735 alternately saturate the core in opposite directions.

The operating frequency of the Driver Multivibrator stage is determined by the amount of time required for the core to saturate and switch the multivibrator. The amount of time for this action to take place is dependent on the number of turns in T750 and the drive voltage on the transformer primary.

Since the number of turns of T750 are fixed, the multivibrator frequency can be changed by varying the drive voltage. To accomplish this, FREQUENCY control R614, when adjusted, changes the operating voltage on transistors Q725 and Q735. By changing the transistor operating voltages, core saturation time changes, thus changing the multivibrator frequency. By adjusting the FREQUENCY control the multivibrator frequency can be varied between approximately 275 and 360 cycles per second.

Resistor R750 reduces the amplitude of the switching transsients or "spikes". Some instruments below S/N 202 and all instruments S/N 202 and up were modified by adding C750. This capacitor blocks the dc path between collectors of Q725 and Q735, decreases the ripple and spike amplitudes at the emitter of Q627, and improves the 10-volt power supply regulation at low-line voltage. In addition, as an indirect effect, the capacitor increases the operating frequency of the multivibrator slightly.

Driving the Mercury Switch Reed

Transformer T750 provides approximately a 200-to-1 step down into a one-turn secondary (see Fig. 4-2) which couples the energy to the mercury switch, and serves as both a switch body (or housing) and a coaxial return. The one-turn secondary permits a large current to flow and thus a large magnetic field to be generated to drive the reed of the mercury switch.

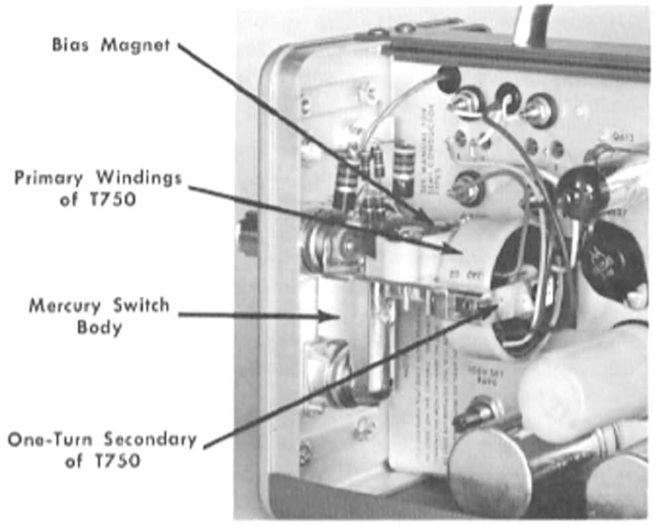


Fig. 4-2. Left front view of the Type 109 showing the pulser section.

A permanent magnet is used to provide magnetic bias for the reed of the mercury switch. The field set up by the one-turn secondary adds to or subtracts from this bias and causes the reed to move from one contact to the other. The double set of contacts causes the frequency of the output pulses to be twice the frequency of the multivibrator, or nominally 640 cps.

The permanent magnet is adjusted so the period of closure with each contact is at least 250 μsec or longer. Use of the mercury switch eliminates contact bounce at the start of the pulse and the resulting irregularities in the generated pulse. Use of high pressure in the mercury switch prevents precontacting ionization.

105-Volt Power Supply

The secondary winding of T601 that connects to terminals 6 and 7 supplies the ac voltage to full-wave rectifier D662A, B, C and D. The output of the rectifier is applied to an RC filter network consisting of C661A, R661, and C661B. The output of this filter is applied to a voltage regulator tube, V679.

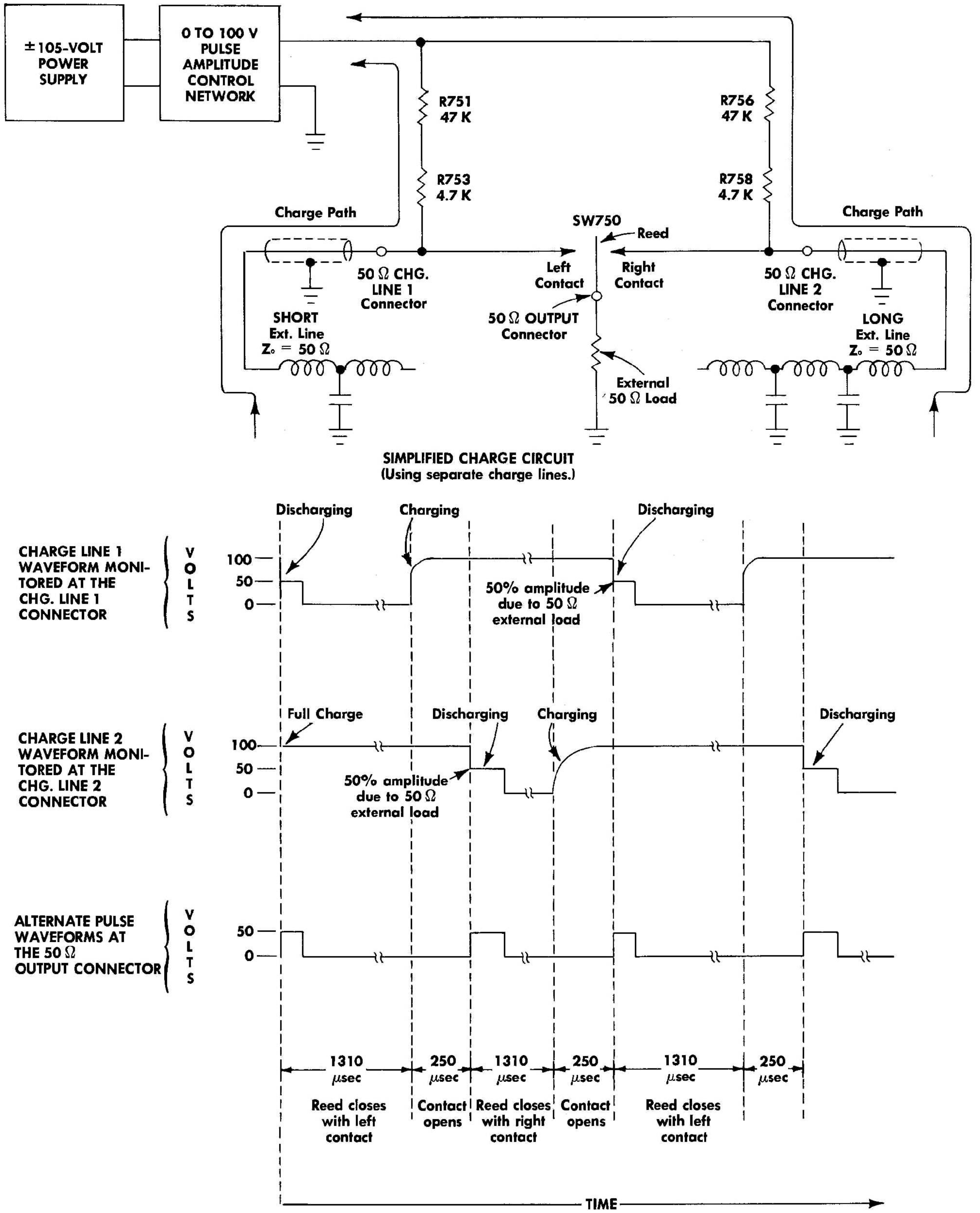
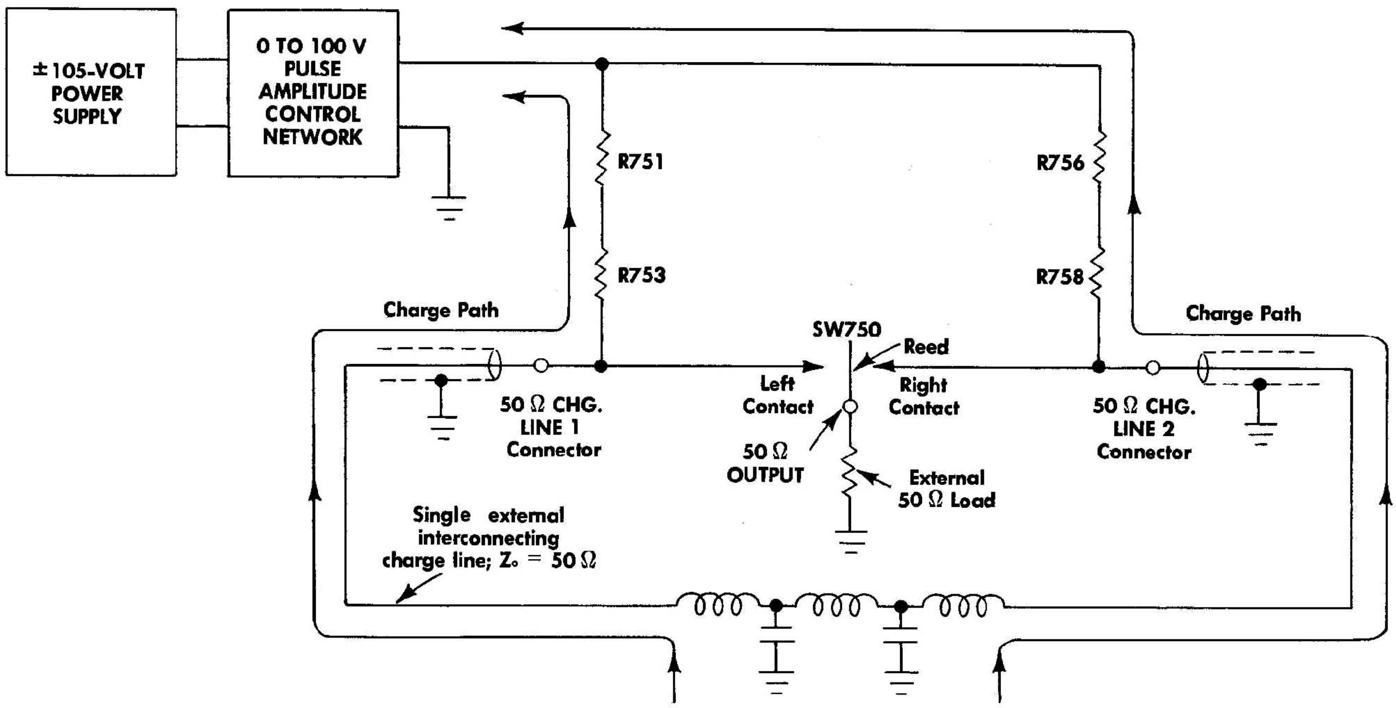


Fig. 4-3. Charge and discharge sequence using two separate different length charge lines. For this illustration CHARGE LINE 2 is twice as long as CHARGE LINE 1, the Type 109 output amplitude is +50 volts, and the nominal repetition rate of the pulses generated from each contact is 320 cps.



SIMPLIFIED CHARGE CIRCUIT
(Using one charge line between connectors.)

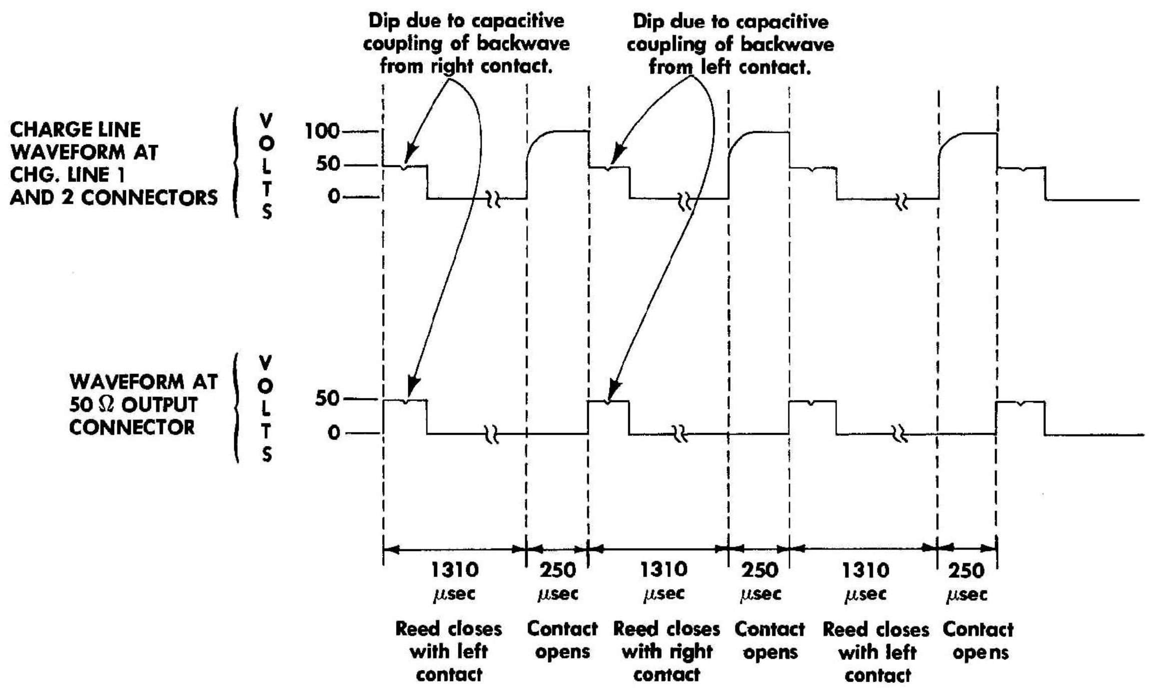


Fig. 4-4. Charge and discharge sequence using the same charge line. Type 109 output amplitude is +50 volts and the nominal repetition rate is 640 cps.

Resistors R678 and R679 set the current passed by V679 at a value which allows this tube to regulate properly within the line-voltage operating ranges specified for the Type 109. The regulator tube compensates primarily for line voltage changes within those operating ranges. The voltage across the terminals of V679 and the output of the supply is maintained by V679 at nominally 105 volts.

Capacitor C679 reduces the amplitude of the spikes that originate from the mercury switch. Resistor R660 serves as an overload fuse for this supply. The purpose of R660 is similar to that of R610 in the 10-volt supply.

The polarity of the output of the 105-volt power supply is controlled by the PULSE POLARITY switch, SW679. By grounding either of the output leads, either polarity of output voltage can be obtained. The output of the power supply is applied to the pulse amplitude control network.

Pulse Amplitude Control Network

The 100V SET control, R690, sets the voltage across the AMPLITUDE control, R696. The current drawn from the ±105-Volt Power Supply by the pulse amplitude control network is approximately 5 ma in all positions of the VOLTAGE RANGE switch, except EXT. PWR. This means that the voltage drop across R690 also remains constant regardless of the position of the VOLTAGE RANGE switch. The 100V SET control is adjusted so that the voltage at the ungrounded end of the AMPLITUDE control is set to exactly 100 volts.

The voltage across the AMPLITUDE control is always equal to twice the setting of the VOLTAGE RANGE switch. The pulse amplitude control network is designed to provide a nearly constant load on the power supply while at the same time dropping the voltage across the AMPLITUDE control to the proper value. The AMPLITUDE control, when used in conjunction with the VOLTAGE RANGE switch, permits the application of any voltage between zero and 100 volts through resistors R751 and R753 or R756 and R758 to the charge lines (see simplified schematic diagram in Fig. 4-3). Approximately 250 microseconds is allowed for a single, interconnecting charge line capacitance to be charged to the voltage obtained from the wiper arm of the AMPLITUDE control. The 250-microsecond time duration is the open-contact time of the mercury switch. Using separate charge lines, about 1.8 milliseconds charging time is available at a nominal repetition rate of 320 cps from each contact. This is the total time that it takes for the reed to leave the contact, go to the other contact and return.

Mercury Switch

The two charged coaxial cables are alternately discharged through the 50-ohm output load by the mercury switch SW750. As the mercury switch closes, one of the charge lines momentarily acts as voltage source (see Fig. 4-3). The internal impedance of this voltage source is 50 ohms and the load impedance is also 50 ohms. Consequently, only one half of the voltage to which the line was charged appears across the load. (This explains why the ranges of the VOLTAGE RANGE switch are only half the actual charging voltage.)

If we assume that the line was originally charged to +100 volts, then a +50-volt output pulse is obtained. A 50-volt pulse also travels down the charge line toward the open end (called the back wave). As the pulse reaches the open end, it is reflected in phase and returns toward the mercury switch. As the reflected pulse reaches the mercury switch, the charge in the cable drops to essentially zero and the output pulse ends. The duration of the output pulse is thus twice the transit time of the charge line. The output pulse contains all the energy (excluding losses) originally contained in the charge line.

As the mercury switch opens, it allows the charge line to recharge preparatory to the generation of the next pulse by that line. When the reed of the mercury switch disconnects from one contact, it moves across and closes with the other contact. This then discharges the second charge line in the same manner as the first. The mercury switch then continues this operation of discharging first one and then the other charge line. If both charge lines are charged to the same voltage, then both sets of output pulses will have the same amplitude. Furthermore, if both charge lines are exactly the same length, both sets of output pulses will have the same duration. The amplitude, polarity, and duration of the alternate sets of pulses can be made the same or different by selecting the charge voltages and charge lines. Fig. 4-3 shows a waveform obtained when different length charge lines are used.

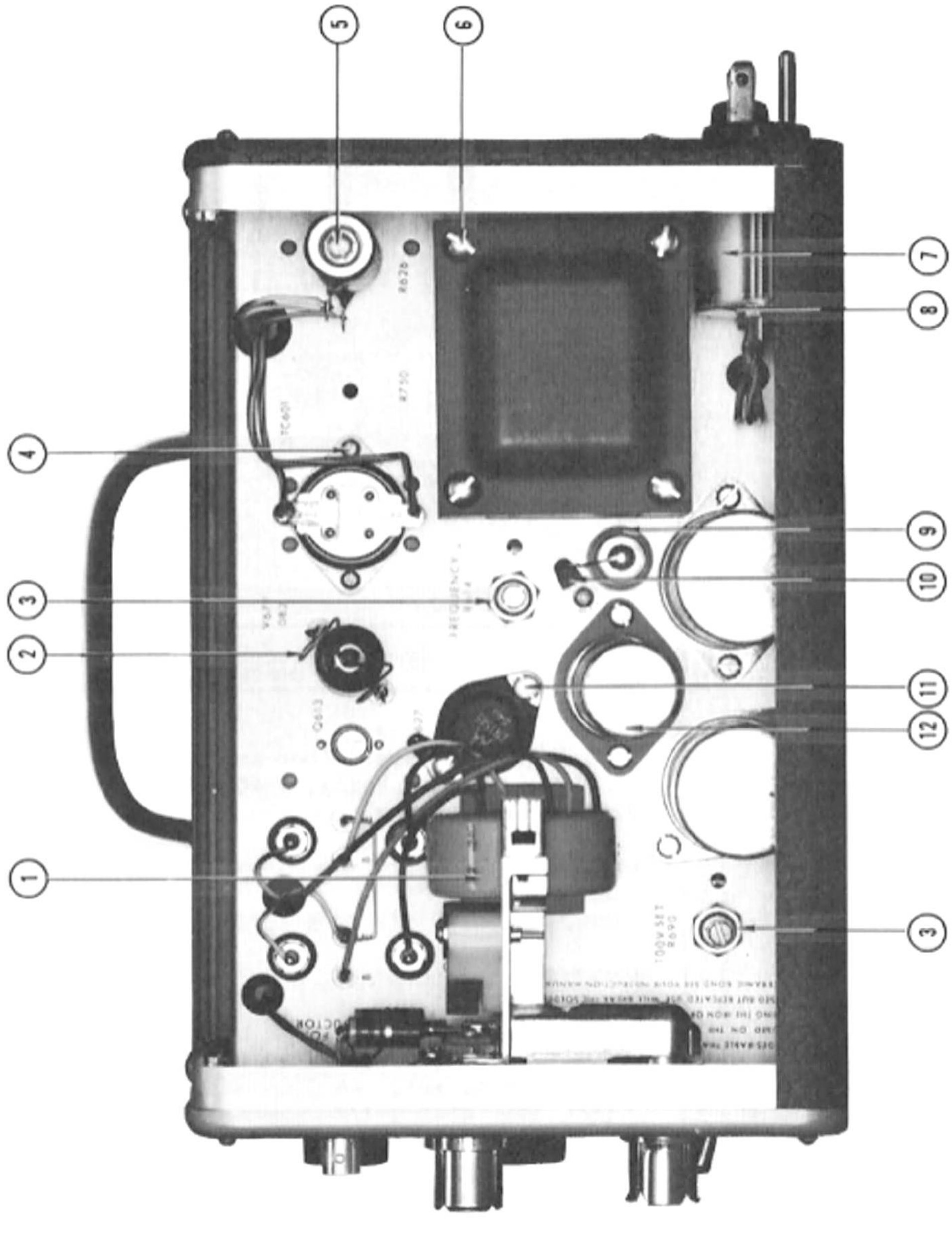
A single charge line may be used to generate both sets of output pulses by connecting one end of the cable to the 50Ω CHG. LINE 1 connector and the other end of the cable to the 50 Ω CHG. LINE 2 connector (see Fig. 4-4). The operation of the Type 109 is the same as before except that instead of having an open-ended coaxial cable, the cable is terminated in a resistance of approximately 52 k. This high resistance produces practically total reflection.

There is a dip in the center of the generated pulse waveform (see Fig. 4-4) due to capacitive coupling of the back-wave from the unused contact. Other than this, however, there is essentially no difference between the pulses generated by a single line and the pulses generated using two separate lines. The panel connectors act as 0.25 nanosecond delay lines causing pulses to be 0.5 nanoseconds longer than when one end of the cable is open. Use of a single charge cable insures that the alternate sets of pulses have exactly the same time duration.

The charge lines used with the Type 109 can be charged by an external source of power as well as by the internal power supplies. If an external source is used, the charging current is applied through the EXT. POWER OR MONITOR connectors, the 47k resistors, and the 4.7k resistors to the charge lines. The advantage of using external charge power lies in the ability to use higher charge voltages to generate high amplitude pulses.

The two 47k, 2-watt resistors limit the external voltage applied to about 600 volts and the output pulse amplitude to approximately 300 volts. Another advantage of using an external charging source is that a negative charge can be applied to one charge line while a positive charge is applied to the other line. This permits the generation of alternately positive and negative pulses.

RIGHT SIDE



IMPORTANT:

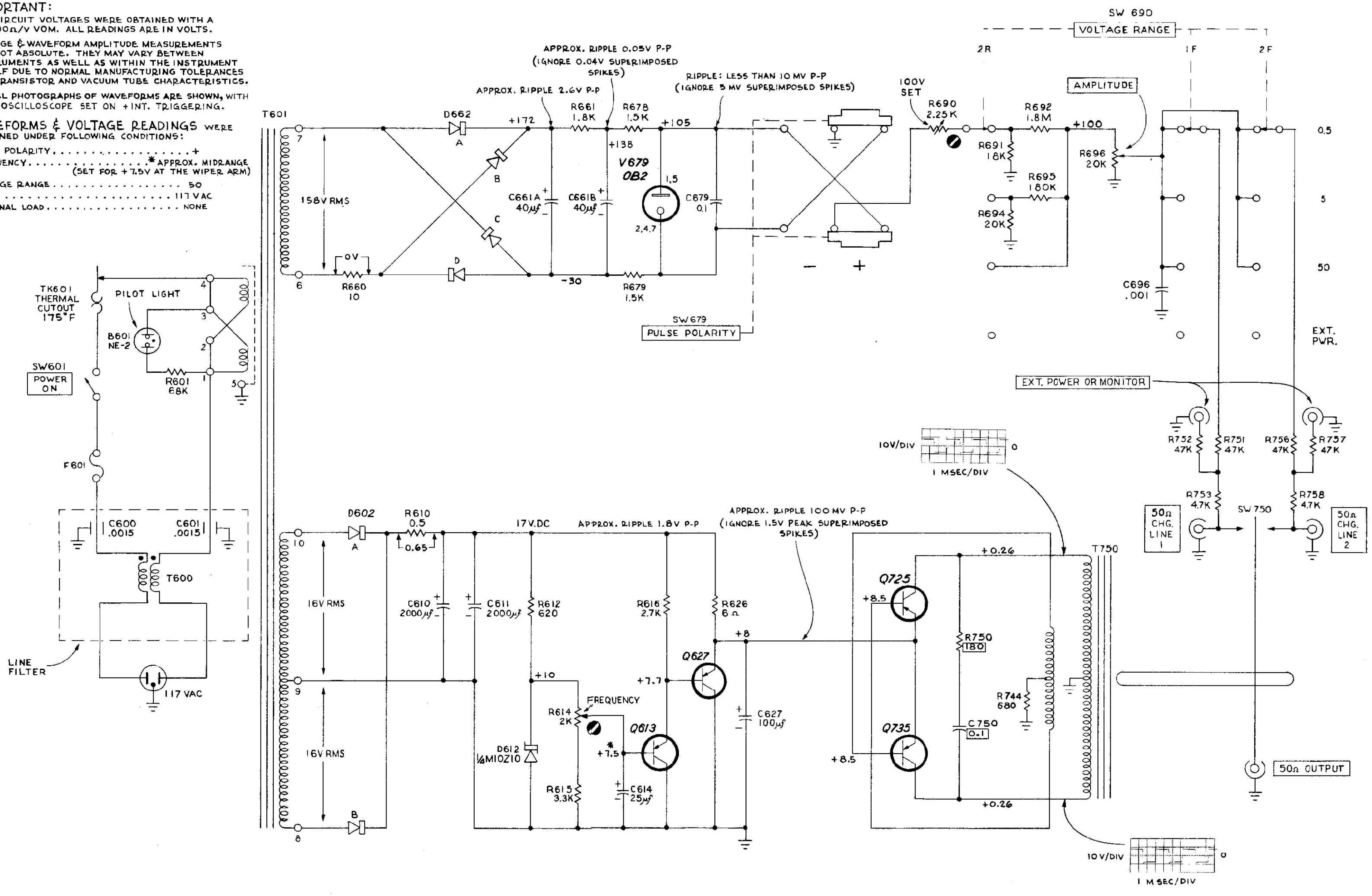
ALL CIRCUIT VOLTAGES WERE OBTAINED WITH A 20,000Ω/V VOM. ALL READINGS ARE IN VOLTS.

VOLTAGE & WAVEFORM AMPLITUDE MEASUREMENTS ARE NOT ABSOLUTE. THEY MAY VARY BETWEEN INSTRUMENTS AS WELL AS WITHIN THE INSTRUMENT ITSELF DUE TO NORMAL MANUFACTURING TOLERANCES AND TRANSISTOR AND VACUUM TUBE CHARACTERISTICS.

ACTUAL PHOTOGRAPHS OF WAVEFORMS ARE SHOWN, WITH TEST OSCILLOSCOPE SET ON +INT. TRIGGERING.

WAVEFORMS & VOLTAGE READINGS WERE OBTAINED UNDER FOLLOWING CONDITIONS:

PULSE POLARITY . . . . +
FREQUENCY . . . . *APPROX. MIDRANGE (SET FOR +7.5V AT THE WIPER ARM)
VOLTAGE RANGE 50
LINE . . . . 117 VAC
EXTERNAL LOAD . . . . NONE



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

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PULSE GENERATOR