

INSTRUCTION MANUAL

TYPE 109
PULSE GENERATOR

SN-897

Tektronix, Inc.

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WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or Representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial number with all requests for parts or service.

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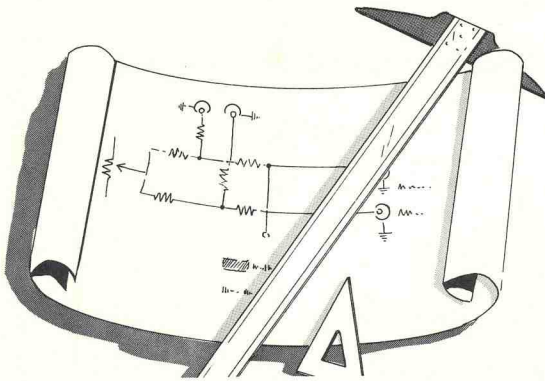
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Type 109

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.

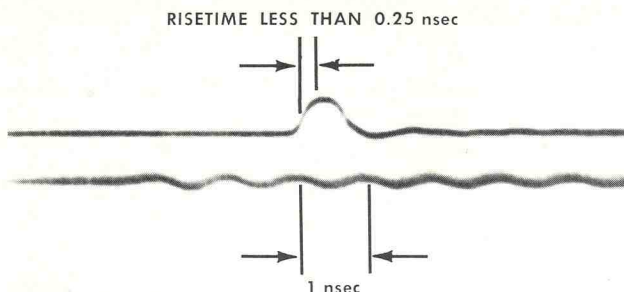


Fig. 1-1. A double exposure photograph of the output pulse from the Type 109 (no external charge line) and a 1 gigacycle/sec timing train. The waveforms are displayed on a Tektronix 0.12-nsec risetime research-type oscilloscope. This photograph shows the risetime to be well under 0.25 nsec. The minimum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

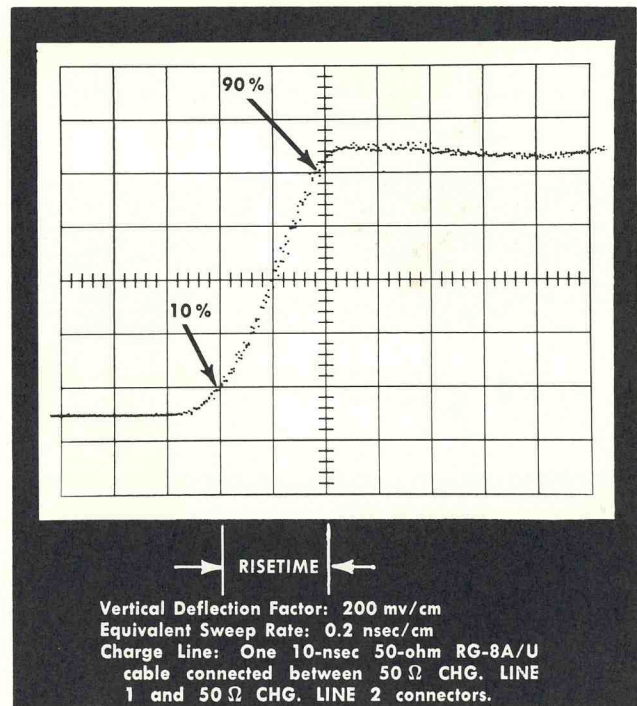


Fig. 1-2. Waveform showing the Type 109 pulse displayed on a Tektronix Type 661 (Sampling) Oscilloscope. Combined risetime of the system, between 10% and 90% amplitude levels, is less than 0.4 nanoseconds.

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.

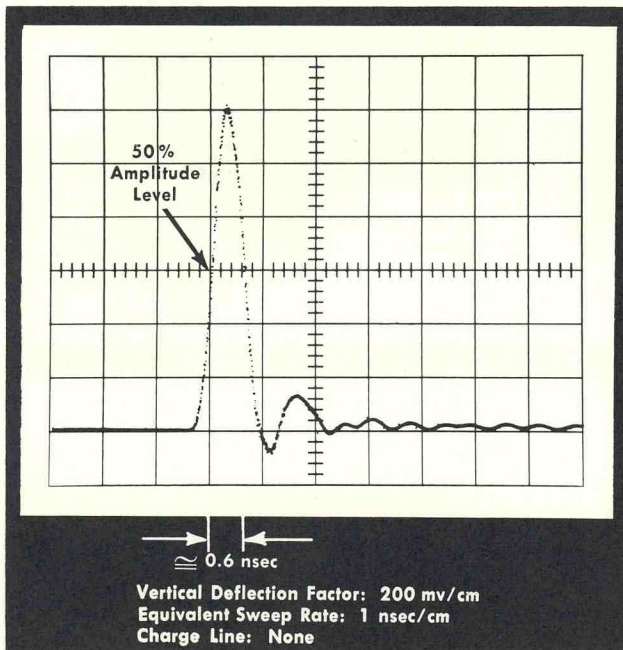


Fig. 1-3. Minimum pulse-width waveform as displayed on a Type 661 (Sampling) Oscilloscope.

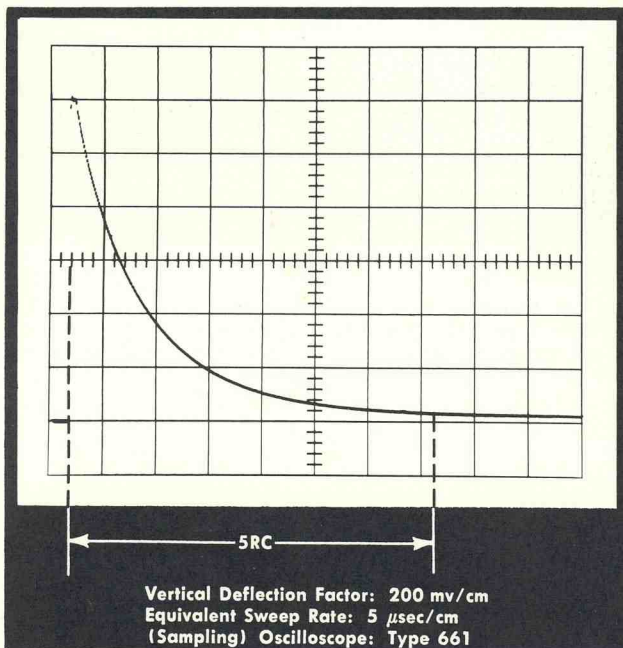


Fig. 1-4. Waveform produced by using the external charge network supplied as a standard accessory. The network connects to one of the 50 Ω CHG. LINE connectors on the Type 109 and grounds the unused connector.

Repetition Rate

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

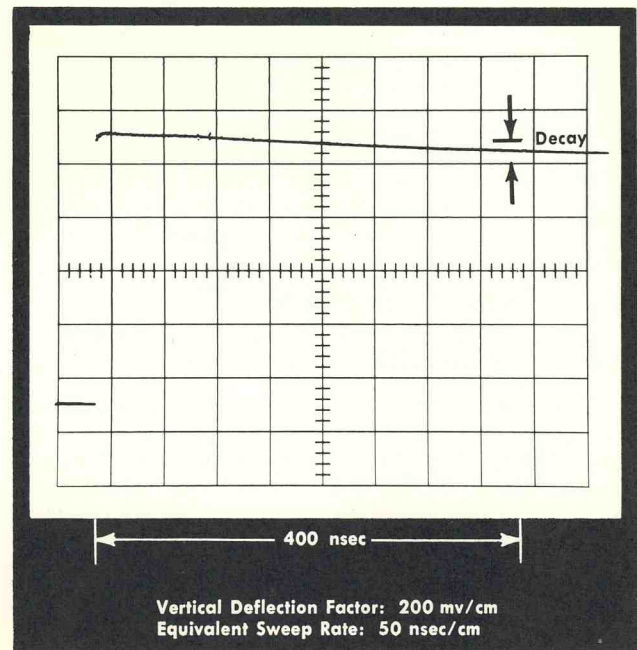


Fig. 1-5. Waveform obtained using the same charge network as described in Fig. 1-4 but the equivalent sweep rate of the Type 661 is increased to 50 nsec/cm. This photograph shows that the amplitude (or RC) decay is less than 10% in 400 nsec.

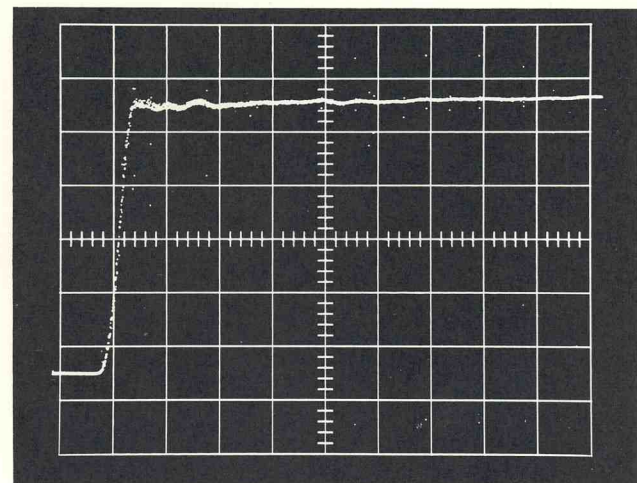


Fig 1-6. Same conditions as Figs. 1-4 and 1-5 except that the equivalent sweep rate is 1 nsec/cm.

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.

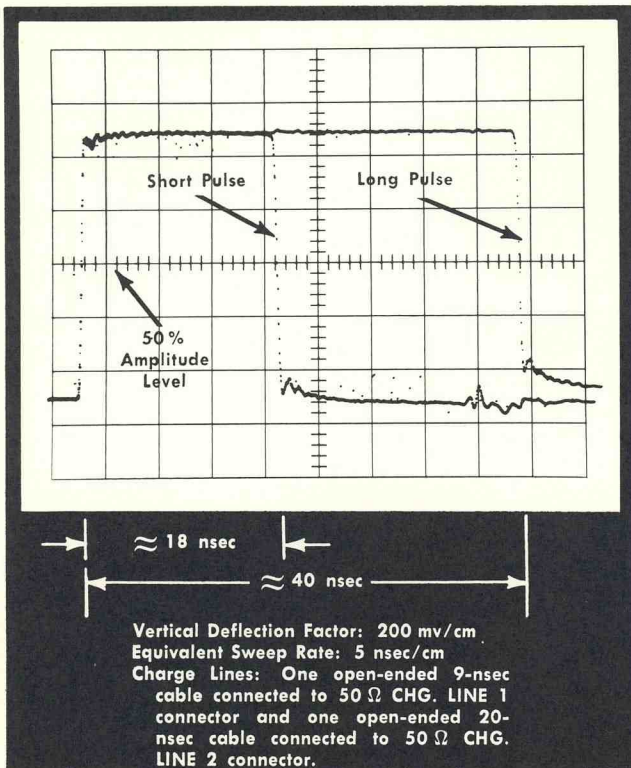
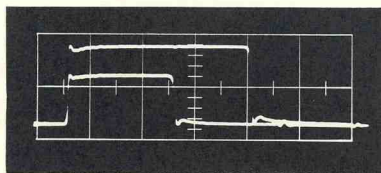
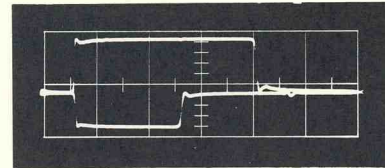


Fig. 1-7. Single-exposure photograph illustrating the alternate-pulse feature, using the internal power of the Type 109.



Vertical Deflection Factor: 9.5 v/cm
Sweep Rate: 5 nsec/cm
(Real-Time) Oscilloscope: Type 519

Fig. 1-8. Single-exposure photograph showing alternate recurring pulses of different widths and amplitudes produced by using 5-nsec and 8.8-nsec charge lines, and external charge voltages of the same polarity.



Vertical Deflection Factor: 9.5 v/cm
Sweep Rate: 5 nsec/cm
(Real-Time) Oscilloscope: Type 519

Fig. 1-9. Double-exposure photograph shows that similar conditions as those in Fig. 1-8 were used except the external charge voltages are of opposite polarities.

Output Impedance

50 ohms.

Power Requirements

Line Voltage—105 to 125 volts, or 210 to 250 volts, 50 to 800 cycles.

Power—Approximately 50 watts at 117 volts line voltage.

Mechanical

Construction—Light-weight, shock-resistant aluminum alloy.

Finish—Photo-etched, anodized front panel. Textured-aluminum cabinet with vinyl-based blue finish.

Dimensions—7 $\frac{7}{8}$ " high, 5" wide, and 11 $\frac{1}{2}$ " deep overall.

Net Weight—8 lbs. 7 ounces (Type 109 only).

Accessories

1—Power Cord, (161-010).

1—Three-wire to two-wire power cord adapter, (103-013).

3—5-nsec cables, 50-Ohm GR RG-8A/U, 40" long, (017-502).

1—Charge Network, (017-067).

2—Instruction Manuals, (070-299).

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SECTION 2

OPERATING INSTRUCTIONS

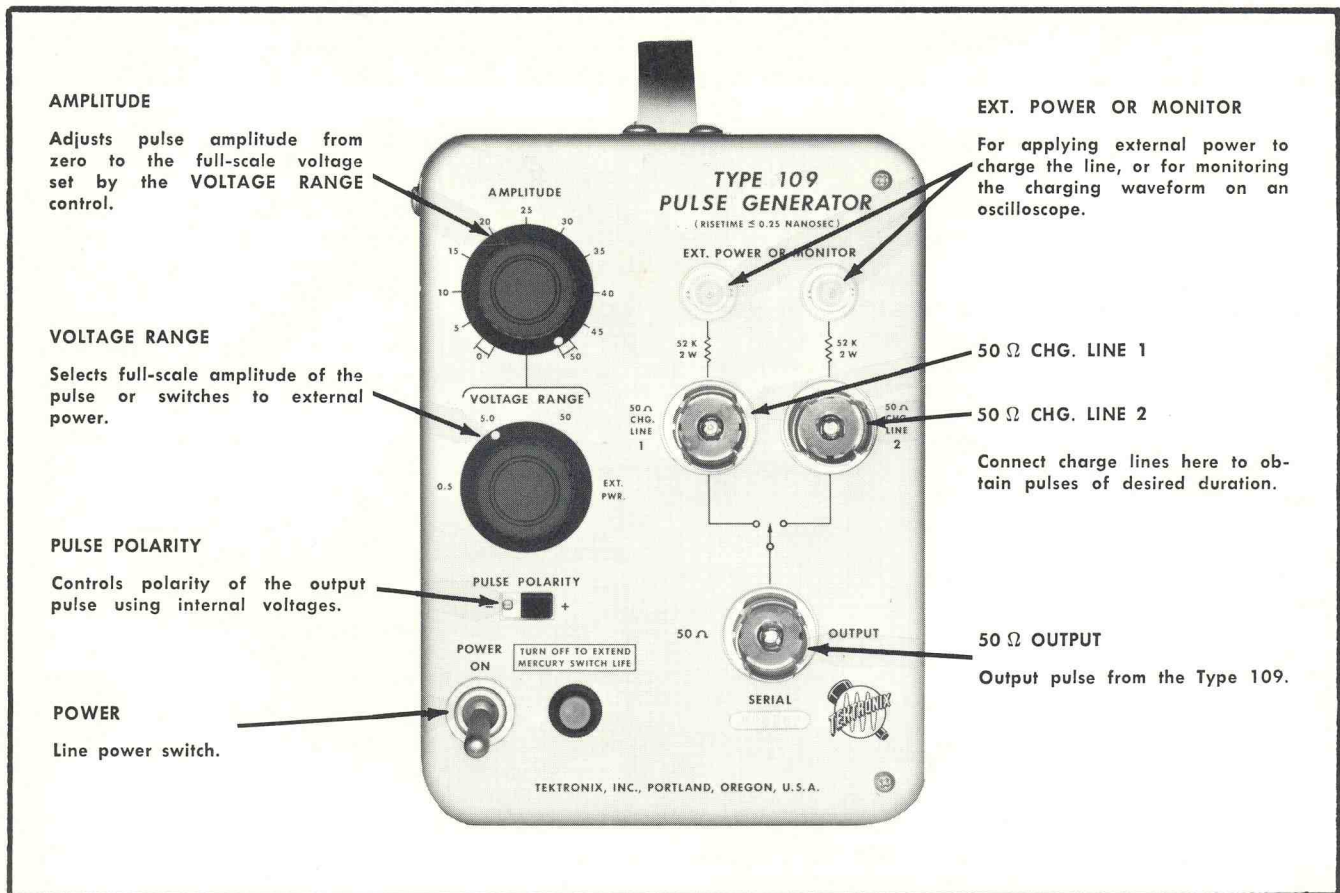
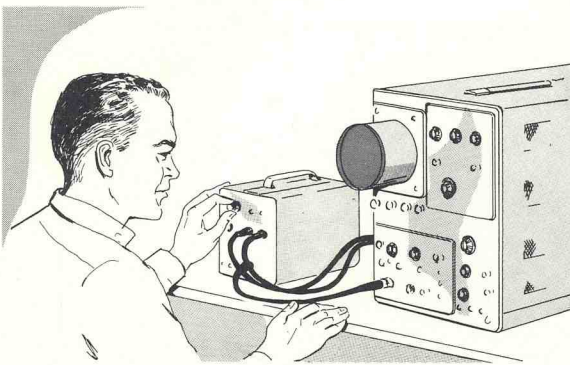


Fig. 2-1. Functions of the front-panel controls.

General Information

The Type 109 Pulse Generator produces fast rising pulses at a repetition rate between 550 and 720 cycles per second. The risetime of the pulses is less than 0.25 nanosecond, the polarity can be selected, and both the amplitude and duration are variable.

The Type 109 is intended for use with fast rise sampling (equivalent-time) systems or conventional (real-time) oscilloscopes.

The Type 109 is fully transistorized, except for a VR tube, and requires no warmup time before operating. As soon as the POWER ON switch is turned on, the Type 109 is ready to operate.

Power Requirements

The Type 109 can be operated from either 117 or 234 volts nominal. The only changes necessary to convert from one operating voltage to another are in the wiring of the power transformer primary. The power transformer, T601, has two separate primary windings. The windings are connected in parallel for 117-volt operation and in series for 234-volt operation.

A small metal tag located near the power receptacle at the rear of the instrument indicates the nominal line voltage for which the Type 109 was wired at the factory. If wired for 117 volts, the instrument will operate properly with

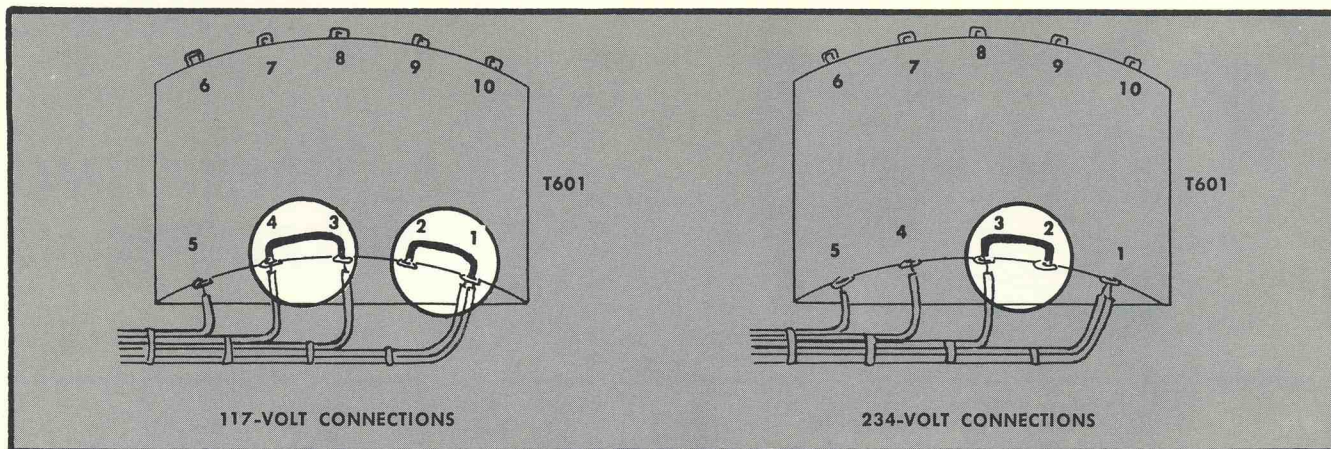


Fig. 2-2. Power transformer connections for 117- and 234-volt operation.

line voltages between 105 to 125 volts. If wired for 234 volts, the instrument will operate properly from 210 to 250 volts.

To change the power transformer connections for operation on another line voltage, change the location of the bare wire straps at the primary terminals. Fig. 2-2 shows the wire-strap connections required for each nominal operating voltage. When changing the location of the straps, it is not necessary to move any of the plastic insulated wires. After the transformer connections are changed, the voltage indicated on the metal tag should be covered with another tag which conforms to the new operating voltage.

Cooling

Before operating the Type 109, choose a location that will not block the ventilating holes in the cabinet. Allow at least two inches of clearance at the top and sides of the instrument. With sufficient clearance, air can freely circulate through the instrument and keep it cool.

If the temperature inside the instrument should become excessively high, a thermal cutout in the instrument will open, shutting off the power and the pilot light will go out. When the interior temperature of the instrument drops to normal, however, the cutout contacts will close and the pilot light will light to indicate that power is restored.

Normal Operating Position

The upright position is the normal operating position for the Type 109. If the instrument is placed on its side or turned upside down, the mercury in the mercury switch will flow to the contact end of the reed switch and short the contacts. Such a short circuit does not harm the instrument, but it does prevent the Type 109 from generating any output pulses.

Cabling Considerations

The Type 109 is designed for use with 50-ohm cables. The charge lines must be 50-ohms for proper impedance match. The output pulse must be applied through high-

quality 50-ohm cables or suitable impedance-matching devices to keep losses down and maintain the waveform. Use RG-8A/U for signal connections. If a signal delay cable is needed, use the Type 113 Delay Cable. The only exceptions are the cables used to supply external power to the EXT. POWER OR MONITOR connectors to charge the lines. The impedance of these cables is not critical, and virtually any value can be used.

If proper signal cables are not used, reflections and attenuations will occur which will produce undesirable side effects. The GR 50-ohm cable connectors are used because they easily connect together and they have reasonably constant impedance.

Selecting the Pulse Duration

1. Using External Charge Lines

Pulses from the Type 109 are generated by discharging charged coaxial lines into a load through a solenoid-operated mercury switch. The Type 109 uses two such charged lines with the mercury switch discharging them alternately. The charge lines must be connected externally to the 50Ω CHG. LINE 1 and 50Ω CHG. LINE 2 connectors on the front panel.

The physical length of the charge lines directly determines the duration of the output pulses. The output pulse duration is equal to twice the transit time of the charge line used, plus a small built-in charge time due to the lead length from the GR panel connectors to the mercury switch contact point.

The transit time of the cable is defined as the time required for a signal to pass from one end of the line to the other. For a 10-nsec charge line then, the duration of the output pulse would be 20 nanoseconds, plus about 0.5 nanosecond (minimum) due to the switch leads. Since two charge lines are alternately discharged into the load, it is possible to have alternate pulses with different time durations by using charge lines of different lengths. Fig. 1-7 in the Characteristics section demonstrates this feature.

It is also possible to have pulses of exactly the same duration by using the same charge line. For this application,

one end of the cable is connected to the 50 Ω CHG. LINE 1 connector and the other end of the cable is connected to the 50 Ω CHG. LINE 2 connector. Since the same cable is used to generate both pulses of a pair, all pulses have exactly the same duration and amplitude. This mode of operation results in an opposite polarity pip at the center of the pulse, due to capacitive coupling between the switch contacts of SW750. The pulse length will be twice the delay time of the charge line plus one nanosecond.

When using the same charge line between connectors, maximum pulse duration at full amplitude is limited by the amount of time that the reed of the mercury switch remains between contacts. This is the open-contact time. To assure that the charge line has sufficient time to fully charge during this time, the length of the charge line should not exceed 50 nanoseconds. Therefore, to generate pulses at their full amplitude, maximum pulse duration is limited to about 100 nanoseconds. If longer duration pulses are generated by using a longer charge line, the pulses may not reach full amplitude. In addition, each pair of pulses generated may not equal each other in amplitude due to variations in open-contact times.

To generate longer pulses at full repetition rate, two separate charge lines can be used. As an alternate method, a single unterminated charge line can be used if you disable the other line-charging network. To disable the network, ground the unused 50 Ω CHG. LINE connector or disconnect either R751 or R756. If the alternate method is used, the repetition rate of the pulses will be one-half the original rate. By using either of these methods, pulse durations up to 300 nanoseconds can be satisfactorily obtained.

2. Using the Charge Network Accessory

Included with your Type 109 is a special Charge Network designed to produce a fast-rise pulse that decays one RC in about 5 microseconds. The amplitude decay is only 10% in 400 nanoseconds (see Fig. 1-5, Characteristics section). The Charge Network plugs into the 50 Ω CHG. LINE 2 connector and the banana plug goes into the center conductor of the 50 Ω CHG. LINE 1 connector. The banana plug disables or grounds the unused contact of the mercury switch.

Since one set of contacts are used to generate the pulse, the repetition rate is one-half the normal rate. The output amplitude of the pulse is about one-tenth that indicated by the VOLTAGE RANGE and AMPLITUDE controls.

Maximum allowable external voltage that can be applied to the Charge Network is 50 volts.

Selecting the Pulse Amplitude

1. Using the Type 109 Power Supply

In most applications the coaxial lines which are used to generate the output pulses are charged by the internal 100-volt power supply of the Type 109. In these applica-

tions, the pulse amplitude is controlled by the VOLTAGE RANGE and AMPLITUDE controls. The VOLTAGE RANGE control determines the range of adjustment of the AMPLITUDE control. The scale of the AMPLITUDE control, when used with the setting of the VOLTAGE RANGE control, indicates the approximate pulse amplitude. Using the internal power supply, pulses with amplitudes between zero and 50 volts can be produced.

Alternate pulses of different amplitudes can be produced using the Type 109 internal voltage supply and separate charge lines. To do this, connect a rheostat across either of the EXT. POWER OR MONITOR connectors. If this is done, however, the front-panel amplitude settings will not be correct, due to the external loading.

2. Using an External Power Source

Pulses with amplitudes higher than 50 volts can be generated if an external power source is used to charge the coaxial lines. To use an external power source, first place the VOLTAGE RANGE control in the EXT. PWR. position. Then connect the external power source or sources to the EXT. POWER or MONITOR connectors on the front panel. The pulse amplitude obtained will be approximately one-half the power source voltage, up to approximately 100 volts. At some higher voltage, the relay will suddenly develop a higher arc drop resulting in a reflection at the relay. This reflection will cause the output to be less than one-half the power source. The voltage applied to the Type 109 to charge the lines should be limited to approximately 600 volts using one or both contacts to prevent damage to the 47-k 2-watt limiting resistors, R752 and R757.

An additional advantage in using external power to charge the coaxial lines is that alternate pulses of different amplitudes and/or polarity can be generated by using two different power sources. This can be combined with different length charge lines to produce not only different amplitudes but different pulse widths as well.

Selecting the Pulse Polarity

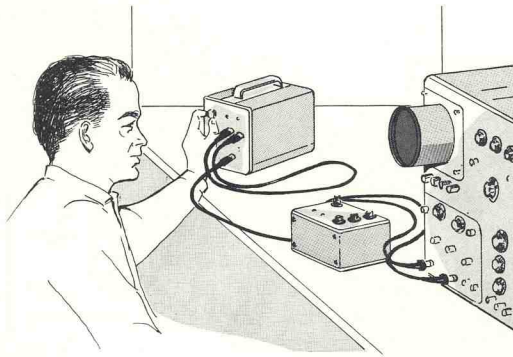
The PULSE POLARITY switch controls the output polarity of the pulses when internal power is used to charge the coaxial lines. The polarity of the output pulses is the same as the polarity of the charge voltage.

When external charge power is used, alternate positive and negative pulses can be obtained by charging one line with a positive source and the other line with a negative source. If identical pulse widths are required for both the positive and negative pulses, it will be necessary to select identical charge cables. (A single charge cable connected between the 50 Ω CHG. LINE 1 and 50 Ω CHG. LINE 2 connectors should not be used for this mode of operation because the cable cannot be charged simultaneously by both a positive and a negative voltage.)

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SECTION 3

APPLICATIONS



Introduction

Some fundamental factors to consider when preparing the Type 109 Pulse Generator for use with other equipment will be covered in this section of the manual. Several representative test systems including a few specialized examples will also be illustrated and discussed. These systems provide a basis for the development of other specialized systems as required by specific applications.

Pulse Definitions

The following terms are commonly used in describing pulse characteristics and are defined here for convenience. The terms are illustrated and applied in Fig. 3-1. The input pulse represents an ideal input waveform for comparison purposes. The other waveforms represent typical output waveforms in order to show the relationships. The terms are defined as follows:

Risetime t_r : the time interval during which the amplitude of the output voltage changes from 10% to 90% of the rising portion of the pulse.

Falltime t_f : the time interval during which the amplitude of the output voltage changes from 90% to 10% of the falling portion of the waveform.

Pulse Width (or Duration) t_w : the time duration of the pulse measured between the 50% amplitude levels of the rising and falling portions of the waveform.

Time Delay t_d : the time interval between the beginning of the input pulse ($t=0$), and the time when the rising portion of the output pulse attains an arbitrary amplitude of 10% above the base line.

Tilt: a measure of the tilt of the full amplitude, flat-top portion of a pulse. The tilt measurement is usually expressed as a percentage of the amplitude of the rising portion of the pulse.

Overshoot: a measure of the overshoot occurring generally above the 100% amplitude level. This measurement is also expressed as a percentage of the pulse rise.

Bear in mind that these definitions are for guide purposes only. When the pulses are very irregular (such as excessive tilt, overshoot, etc.) the definitions may become ambiguous. In such cases, a more complete description of the pulse will probably be necessary.

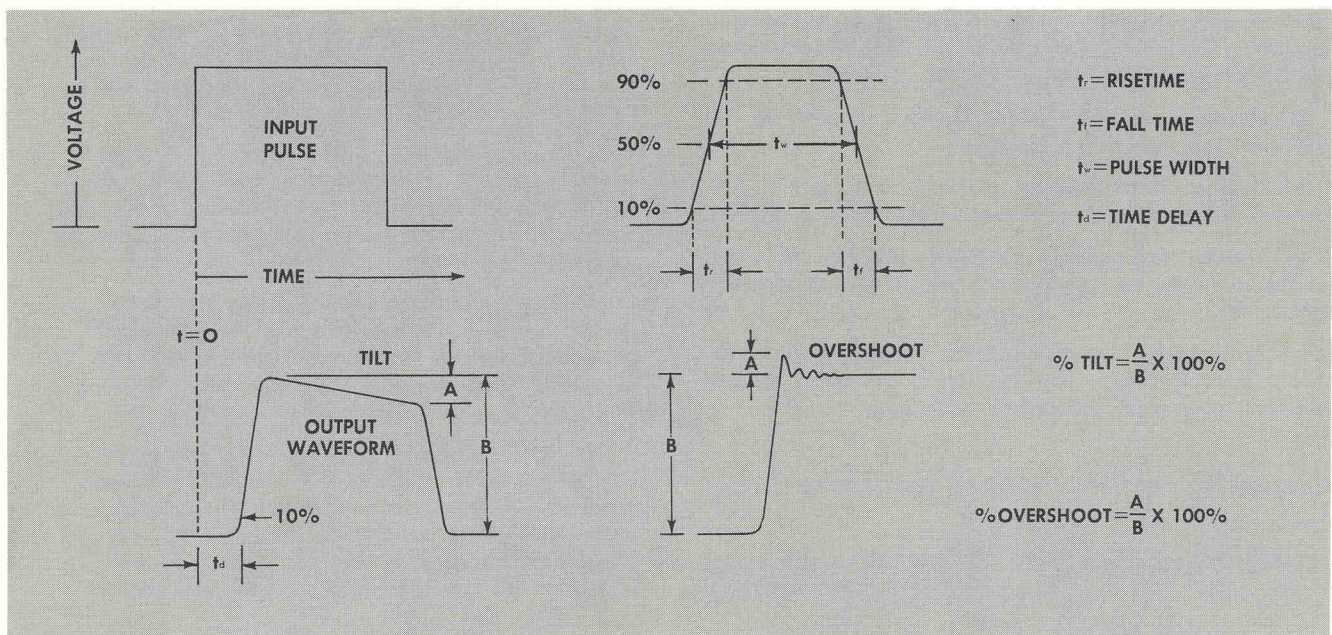


Fig. 3-1. Terms used in describing pulse characteristics.

Risetimes

The risetime of any particular assembly of the Type 109, an oscilloscope (conventional or sampling), and accessory pieces such as coax cables is a variable depending upon the cable characteristics as well as individual risetimes. The "root of the sum of the squares" method can generally be applied as an approximation method only, as skin effect losses of the cables do not add properly using this method. (The root-sum-squares method applies accurately to gaussian systems only.)

As a general rule, if the equipment or signal being measured has a risetime 10 times slower than the Type 109 and other related measuring equipment, the error is 1%. This amount is small and can be considered to be negligible. If the equipment being measured has a risetime three times slower than the related measuring equipment, the error is slightly less than 6%. By keeping these relationships in mind, the results can be interpreted intelligently.

Basic Precautions

For faithful reproduction of the pulse certain precautions should be followed. These can be summarized as follows:

(a) Use proper types of cables, terminations, attenuators, and impedance matching networks. Low-impedance coaxial cables are used with the Type 109 as signal conductors. It is important that these cables be terminated in their characteristic impedance (50Ω) to prevent reflections and standing waves unless you deliberately wish to improperly terminate the cables. One application for improper termination would be to boost the signal to an amplifier input by leaving the end of a transmission line unterminated.

(b) Keep unshielded wires of uncertain impedance short so that reflection and/or cross-coupling effects are not introduced. Keep ground-return paths short and direct.

(c) Shield measuring equipment leads to prevent undesired coupling to other parts of the circuit. Shielding is especially required where radiation is a problem and where high-impedance dividers or circuits are involved.

(d) Choose components which function properly at frequencies and risetimes encountered.

(e) Keep in mind inherent parameters in circuit components such as inductance present in capacitors or resistors.

(f) Consider the possible nonlinear behavior of circuit components due to changes in voltage or temperature coefficients.

(g) Consider the input impedance of measuring equipment. The impedance may be enough to cause loading effects, detuning or undesirable reflections.

Connecting the Type 109 to the Device Under Test

When connecting the Type 109 Pulse Generator output to the device under test, observe the following precautions:

1. A complete dc-return path must be provided between the device under test and Type 109 Pulse Generator 50Ω OUTPUT connector.

2. If the pulse is applied to a 50Ω load which has a dc potential across it, the actual amplitude of the pulse is the voltage set by the AMPLITUDE control less one-half the dc voltage across the load. Do not allow more than 200 volts dc to be applied to the Type 109 Pulse Generator 50Ω OUTPUT connector. This limit will keep the internal components of the Type 109 from being damaged.

As an example, assume that the Type 109 Pulse Generator output is connected to a load which has +10 volts across it and that the AMPLITUDE control is set to +1 volt. The actual amplitude is found by substituting these values in the following equation:

$$V_A = V_S - \frac{V_L}{2} = (+1) - \frac{(+10)}{2} = -4 \text{ volts}$$

where V_A is the actual pulse amplitude, V_S is the voltage setting of the AMPLITUDE control, and V_L is the dc voltage applied across the load.

3. If the load will not terminate the 50Ω output of the Type 109 Pulse Generator (because it is not practical or possible), then it will be desirable to use a 50-ohm coaxial lead (between the Type 109 and the load) which is long enough to delay the load's reflection until after the time of interest. The reflection will appear at a time equal to twice the output lead delay plus the pulse length.

Some representative test systems involving the Type 109 and other related equipment are described and illustrated in this portion of the manual. The systems to be described, as mentioned earlier, may be used as a basis for the development of other more specialized systems required by specific applications.

Using the Type 109 With Sampling Oscilloscopes

One of the primary applications of the Type 109 Pulse Generator is to use it for checking and calibrating sampling oscilloscopes which have internal triggering capabilities. Since this application is adequately covered in the instruction manual for the sampling oscilloscope involved, no detailed explanation will be provided here.

In the usual application the Type 109 is used to drive a test device so the output from the device can be observed and measured on the crt screen of the sampling oscilloscope. Fig. 3-2 shows how the connections for this application are made.

In other similar applications, using this setup, the test device could be a test fixture. An example of a test fixture that can be used is the Type 290 Transistor Switching Time Tester, available through your Tektronix Field Office.

Fig. 3-3 illustrates a sampling test setup where the device under test is inserted in series with the charge line. A clear picture of transmission-line characteristics can be made using this setup. The presence of discontinuities along a transmission line can be determined while the line is under study by means of the oscilloscope display.

The Type 109 when used in conjunction with a sampling oscilloscope provides an excellent means for measuring the impedances of certain devices and cables. In an application

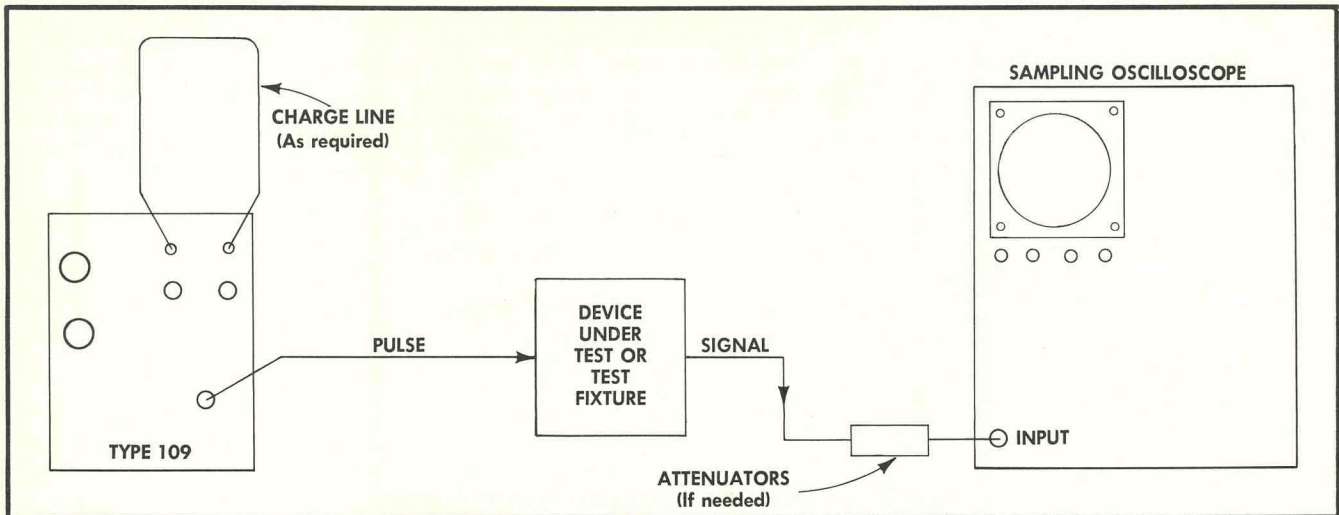


Fig. 3-2. Sampling test setup where the Type 109 is used to drive a test device or fixture.

of this sort, the device is connected as part of the charge line while the output from the Type 109 is applied to the oscilloscope input. If the impedance of the inserted device is exactly 50 ohms, it will merely increase the time that the amplitude of the Type 109 waveform remains constant. The displayed waveform will also indicate double the delay time for the inserted device.

The test device, such as a piece of coaxial cable, a connector assembly, or a delay line, can be connected into the charge line of the Type 109 in the manner shown in Fig. 3-3. In Fig. 3-4 the Type 109 waveform is shown when a length of 125-ohm cable is connected into the charge line in series with two lengths of 50-ohm cable. The portion of the waveform due to the 125-ohm section is about 60% as high as the first portion of the waveform due to the 50-ohm cable. The duration of the Type 109 waveform due to the 125-ohm cable is twice the delay time of the cable

so it is evident from the picture that the true delay time of the 125-ohm cable used is actually 5 nsec.

In Fig. 3-4 the relative amplitude of the portions of the waveform bear a definite relationship to the impedance of the device that generated that portion. The impedance of an unknown device can thus be measured by comparing the amplitude of the portion of the Type 109 waveform produced by it against the amplitude of the initial portion due to the 50-ohm system. The method is generally limited to the first reflection, unless the deviations are small, due to multiple reflections and reflection losses.

If we call the amplitude produced by the 50-ohm system V_o and the amplitude produced by the inserted device V_x , then the impedance of the inserted device is given by the formula:

$$Z = 50 \left(2 \frac{V_o}{V_x} - 1 \right)$$

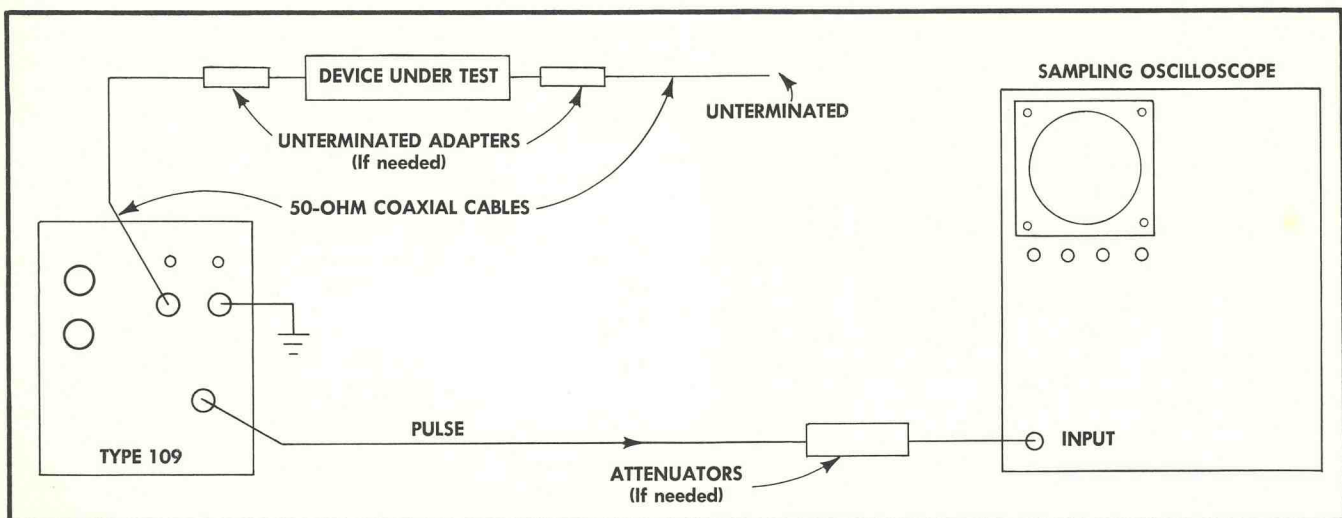


Fig. 3-3. Measuring impedance by reflection.

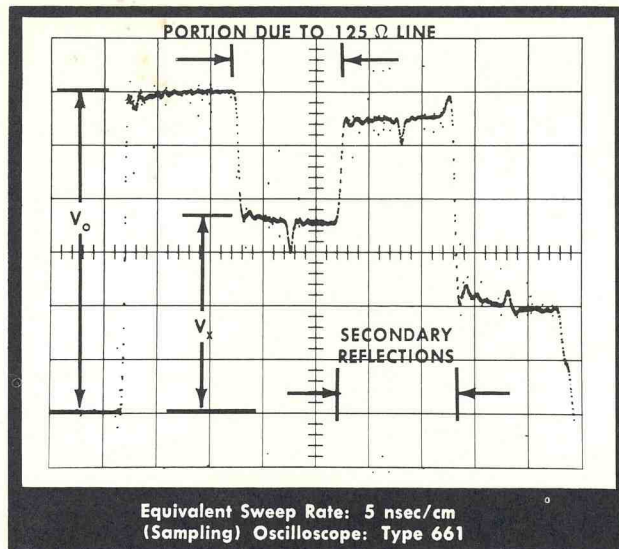


Fig. 3-4. Waveform obtained when a section of nominal 125-ohm cable is connected as part of the charge line for the Type 109.

In Fig. 3-4 the ratio of V_o to V_x is approximately 1.75. Using this in the above formula gives the correct impedance of 125 ohms used to produce the waveform.

It is essential in applications of the type described here that no shorts, terminations, terminated adapters, or attenuators having low shunt resistance to ground are used in the charge line of the Type 109. If devices such as these are used, they will prevent the charge line from charging to the correct voltage and will thereby prevent the Type 109 from producing an output waveform. Where it is necessary to match one type of connector to another, low-loss unterminated adapters should be used.

the 50 Ω cable (used as the reference) and determine their characteristics. If this pad is constructed and used, the formula for determining the impedance is as follows:

$$Z = \frac{50}{\frac{2V_o}{V_x} - 1}$$

where: Z = the unknown impedance.

V_o = the peak amplitude produced by the 50 Ω reference impedance.

V_x = the peak amplitude at the time of the reflection.

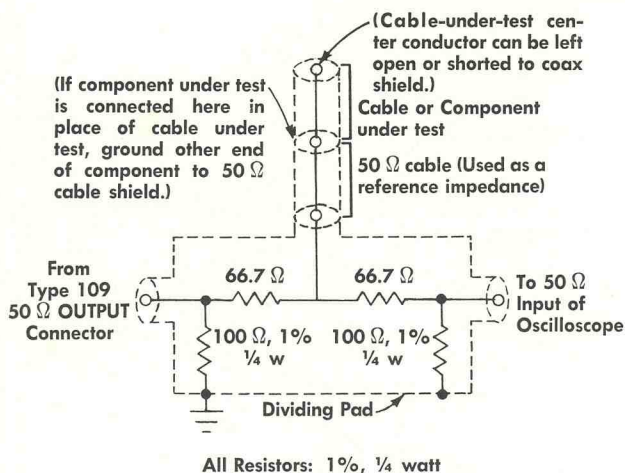


Fig. 3-5. Three-way dividing pad test circuit for measuring impedance by reflection.

As an alternate method, you can construct a dividing pad such as the one shown in Fig. 3-5. This pad overcomes a disadvantage of the previous method. With this pad you can connect low-shunt resistance components or devices to

Using the Type 109 With a Conventional Oscilloscope

The Type 109 can be used with conventional oscilloscopes in much the same manner as with sampling oscilloscopes that have internal triggering capabilities. Fig. 3-6 shows the connections required. The oscilloscope used in this setup must have an internal delay line if the signal from the device is fast-rise non-repetitive or has a low duty cycle.

This setup is useful where the frequency response of the device falls within the bandwidth limitations of the vertical amplifier system of the oscilloscope. Internal triggering on the applied signal is the method that must be used to trigger the sweep. This method of triggering is convenient since no external triggering connections are required.

A second system is shown in Fig. 3-7. Here the device under test, besides being pulsed by the Type 109, is able to provide external triggers to the oscilloscope. It is thereby possible to observe the shaping and amplification of a signal in the circuits of the device without resetting the oscilloscope triggering controls for each observation. If the external triggering signal is derived from the waveform at the input circuit of the device under test, the time relationship and phase between the output and input wave-

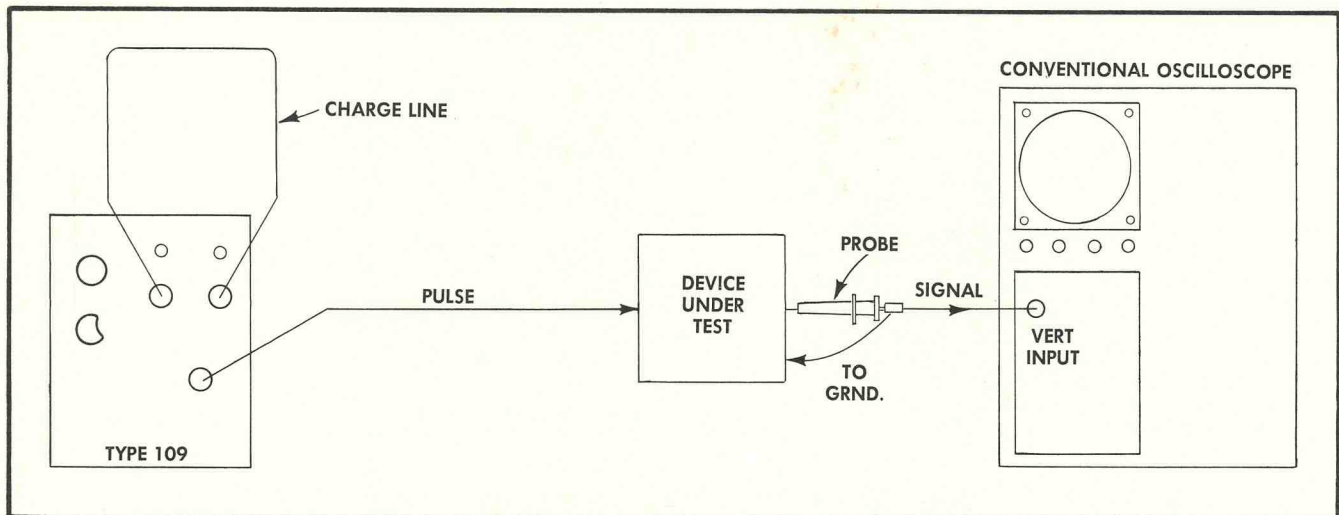


Fig. 3-6. Test setup where a conventional oscilloscope is used in conjunction with the Type 109.

forms may be seen and compared on the oscilloscope screen. Bandwidth limitations of the oscilloscope must be considered when using the setup. In addition, consider the fact that the oscilloscope should have an internal delay line so the leading edge of a single waveform, or fast-rise low-duty-cycle pulse can be observed.

Direct Connection to Deflection Plates

In some cases the output signal from a 50-ohm device under test can be observed by direct connection through coupling capacitors to the vertical deflection plates of a conventional oscilloscope. Thus, the limited bandwidth of the oscilloscope vertical amplifier can be bypassed. The discussion that follows first describes a method for coupling the Type 109 pulses to the vertical deflection plates. Next, a specific setup is used as an example to show the results that can be expected. When the setup is working properly,

the device under test can then be inserted into the signal line and the output from the test device observed.

The following factors pertaining to the vertical deflection plate system will be considered: dc operating potential of the plates, lead inductance, deflection plate capacitance, transit-time limitations, delay lines, and deflection factor. (If the last factor is a prohibitive limit, then a Tektronix Sampling Oscilloscope should be considered as another way to avoid the bandwidth limitations of the vertical amplifier and at the same time obtain excellent sensitivity.)

A typical circuit for ac-coupling directly to the vertical deflection plates is shown in Fig. 3-8. This circuit permits the internal vertical amplifier of the oscilloscope to be bypassed, but still allows the normal dc operating and positioning voltages to be applied to the deflection plates from the internal vertical amplifier. However, when using this circuit, you must use a high-quality external delay line

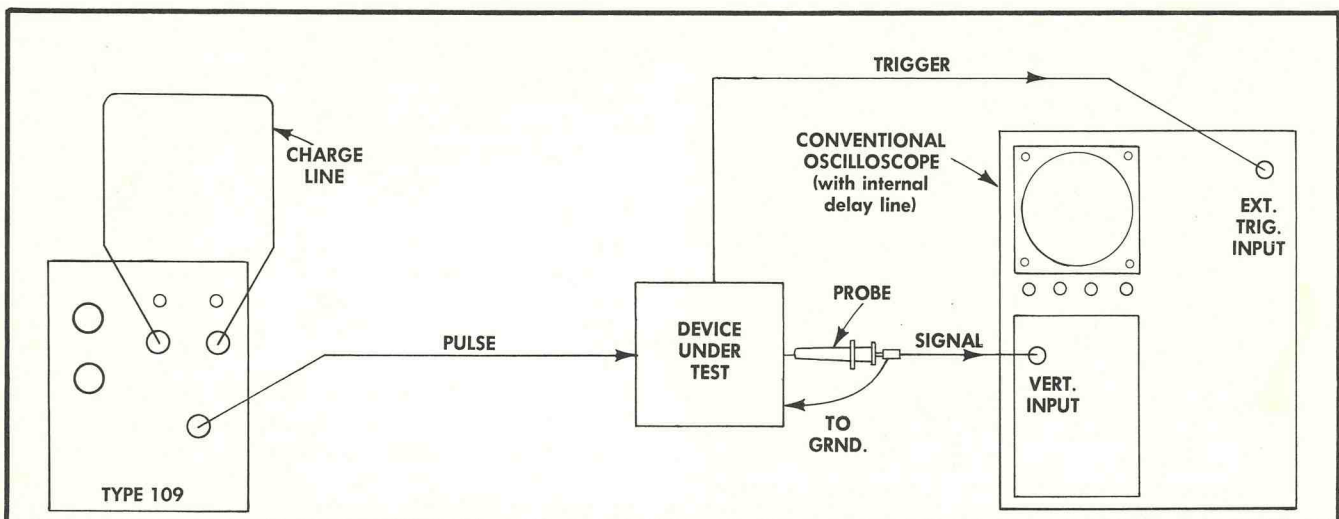


Fig. 3-7. Test setup where the oscilloscope is externally triggered by the device.

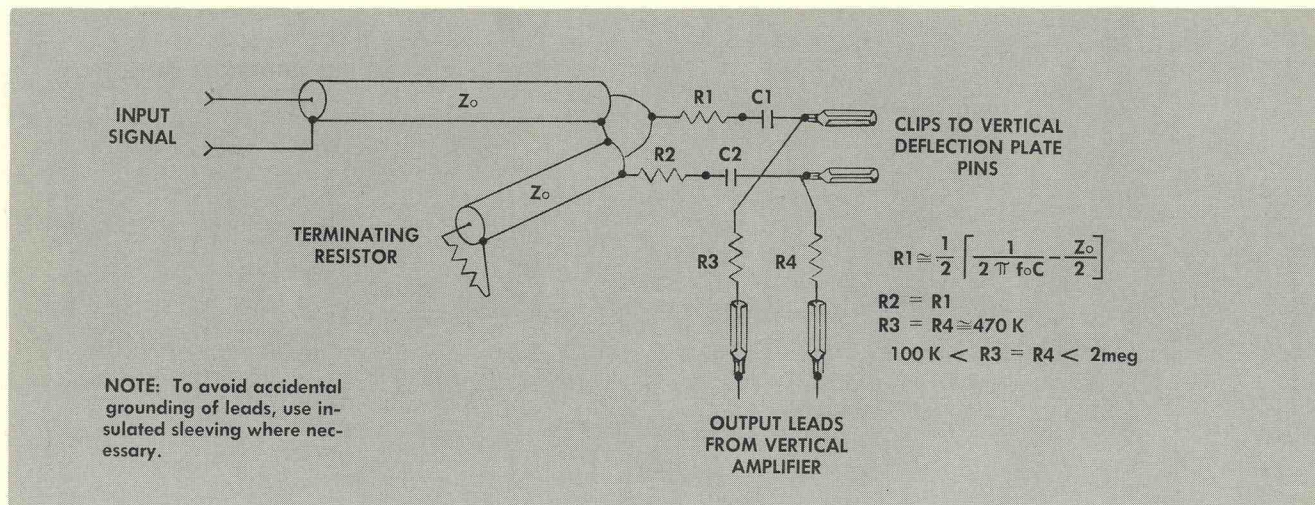


Fig. 3-8. Detailed method of ac-coupling the signal directly to the vertical deflection plates.

which will delay the pulse about 120 nsec to get the pulse on the crt screen.

Only approximate values for two of the parts are given. The values of these and all other parts depend upon the crt, cable impedance, and lead lengths. Later on, some setups employing a 540-Series Oscilloscope are illustrated and described to show how optimum results were obtained by modifying the circuit shown in Fig. 3-8 to suit the specific application.

The coupling capacitors, C1 and C2, provide the means for ac-coupling to the plates. When selecting these parts for use in the circuit, keep in mind that the physical size should be small to reduce the lead-length inductance.

The cable which connects to the terminating resistor should be long enough so that if a double-transit time reflection appears, it can be easily identified from the input signal. Then, the undesired termination error causing the reflection can often be corrected by physical or electrical adjustments at the termination.

To find the resonant frequency (f_0) of the lead inductance and the deflection plate capacitance (C) for use in the equation shown in Fig. 3-8, use the method that follows. Turn off the oscilloscope power and disconnect the vertical amplifier output leads to the crt. Cut a wire loop which equals the total length of C1, C2, R1, R2, R3, R4. Substitute the wire loop for these components between the vertical deflection plate pins. Bring a grid-dip meter near the loop and measure the resonant frequency.

A convenient method for making connections to the crt deflection plates is to use clips removed from a standard miniature tube socket.

After removing the wire lead, measure the total capacitance between the plates with a Tektronix Type 130 LC Meter, or equivalent, at the deflection plate pins. Capacitance between the plates can also be found by referring to a list of crt specifications.

The value of R1 is found by solving the equation in Fig. 3-8. Make R2 the same value as R1.

Since the deflection plates are placed close to the path of the electron beam, a small amount of current will flow in the deflection plate circuits. This current flow varies nonlinearly with the beam position. The values of the resistors R3 and R4 must be selected to keep the current flow from producing a large voltage drop at the deflection plates. If the resistances are too great, the voltage drops may become large enough to cause serious positioning difficulties, defocusing, or distortion. These effects are most noticeable when the beam is positioned near one side of the crt. On the other hand, if the resistances are too small the short r-c time constant of the coupling circuit may cause the low-frequency response to be limited.

The risetime limitation is a combination of the limitation imposed by the resonant frequency (f_0) (which limits the risetime arriving at the deflection plates), and the transit time (t_r) of the electron beam through the deflection plate system (which limits the deflection plates' ability to change the beam position rapidly).*

The deflection factor can be found from the reference chart, or it can be measured as follows: Connect a dc voltmeter between the vertical plates when the internal vertical amplifier is connected to the deflection plate pins. Measure the voltage change when the beam is positioned vertically over the full height of the graticule. Divide this voltage excursion by the graticule height in centimeters to obtain the deflection factor in volts per centimeter.

If the output leads from the internal vertical amplifier of the oscilloscope are disconnected and the power is on, do not allow the leads to come in contact with the chassis or tube shield. A short circuit of this type can damage the amplifier circuits.

Typical risetime figures for Tektronix cathode-ray tubes are listed in Table 3-1.

As a specific example, showing before and after results, a Type 540-Series Oscilloscope with a Type K Plug-In Unit was used in the setup shown in Fig. 3-9. In this example

* See I. A. D. Lewis and F. H. Well, *Millimicrosecond Pulse Techniques*, Second edition — 1959, Chapter 6, Pergamon Press, London and New York.

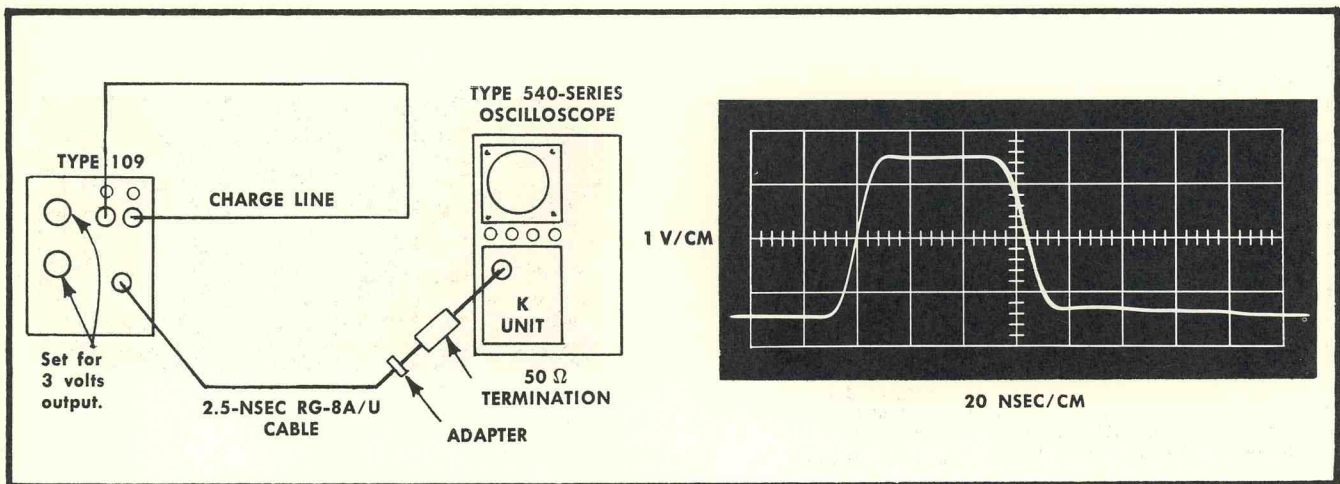


Fig. 3-9. Applying a fast-rise pulse from the Type 109 to the input of a Type 540-Series Oscilloscope. The illustration shows the setup that was used and the resultant waveform.

TABLE 3-1
CRT REFERENCE CHART

TEKTRONIX OSCILLOSCOPE TYPE (includes rackmounts)*	CRT (Type No.)	NOMINAL VERT. DEFLECTION FACTOR-volts/cm	NOMINAL RISETIME-nsec	COMPARATIVE WRITING RATE**
531, 535	T51	11.0 to 14.0	2.0	$\frac{1}{3}$ to $\frac{1}{4}$
531A, 533, 535A	T533	8.5 to 10.5	2.0	$\frac{1}{3}$ to $\frac{1}{4}$
541, 545	T54	6.0 to 7.0	2.5	$\frac{1}{3}$ to $\frac{1}{4}$
541A, 543, 545A	T543	6.0 to 7.0	2.5	$\frac{1}{3}$ to $\frac{1}{4}$
551	T551	6.0 to 6.5	3.0	$\frac{1}{3}$ to $\frac{1}{4}$
555	T555	6.4 to 7.3	3.0	$\frac{1}{3}$ to $\frac{1}{4}$
517A (12 kv)	T517 (T54-H)	7.0 to 8.0	2.0	$\frac{1}{3}$
517A (24 kv)	T517 (T54-H)	14.0 to 16.0	1.5	1
517 (12 kv)	5XP	17.0 to 30.0	1.5	$\frac{1}{3}$
517 (24 kv)	5XP	34.0 to 40.0	1.0	1

* Refer to the Instruction Manual for the oscilloscope you are using to determine sweep-rate limitations.

** Writing rate compared to Type 517 crt, 24 kv, P11 phosphor. Writing rate of T517P11 at 24 kv is 1000 to 1200 cm/ μ sec recorded on TRI-X film at f1.9 with 4.2 to 1 reduction. Writing rate is increased by a factor of 2 to 3 using POLAROID 3000 speed film, even faster for prefogged film. Writing rate is a function of film speed, lens f-stop, optical reduction factor, type of phosphor, sensitivity of film to color of phosphor, accelerating potential, and beam current. Consult your local Tektronix Field Engineer or Overseas Representative for more information on writing rates and phosphors.

the pulse from the Type 109 was applied to the Type K Unit to show how the pulse rise and fall times are limited by the bandwidth of the vertical amplifier.

Fig. 3-10 shows the setup which was used to apply the Type 109 pulse to the vertical deflection plates through a Deflection Plate Connector (Part No. 013-017). The resultant waveform is shown in the same illustration. The deflection plate connector circuit that was used is similar to the one shown in Fig. 3-11 except C3 and R5 were not added. The rolloff and gradual slope of the top portion of the waveform is caused by the use of the 120-nsec RG-8A/U cable. A long cable is necessary to obtain sufficient delay to display the leading edge of the waveform on the crt screen.

To obtain the best results, C3 and R5 were added (See Fig. 3-11). The setup and the resultant waveform are shown in Fig. 3-12. Even by using two Type 113's that contain

high-quality cable, some rolloff occurred and components C3 and R5 had to be added to sharpen the leading corner and make the top of the waveform as horizontal as possible. If cw signals are applied to the deflection plate connector instead of pulses from the Type 109, remove C3, R5, and the Type 113's. Use a short 50-ohm GR-8A/U cable in place of the Type 113's.

By inserting a test device in series with the signal delay cable using the same setup shown in Fig. 3-12, you can observe and measure not only the output of the device but also the time delay introduced by the device. If the device is linear, it is unimportant where the device is inserted into the signal delay cable. If the device is nonlinear, it may be advantageous to place the device between the delay cable and the deflection plate connector, especially if the delay cable risetime is significant, as when RG-8A/U cable is used in place of the two Type 113's.

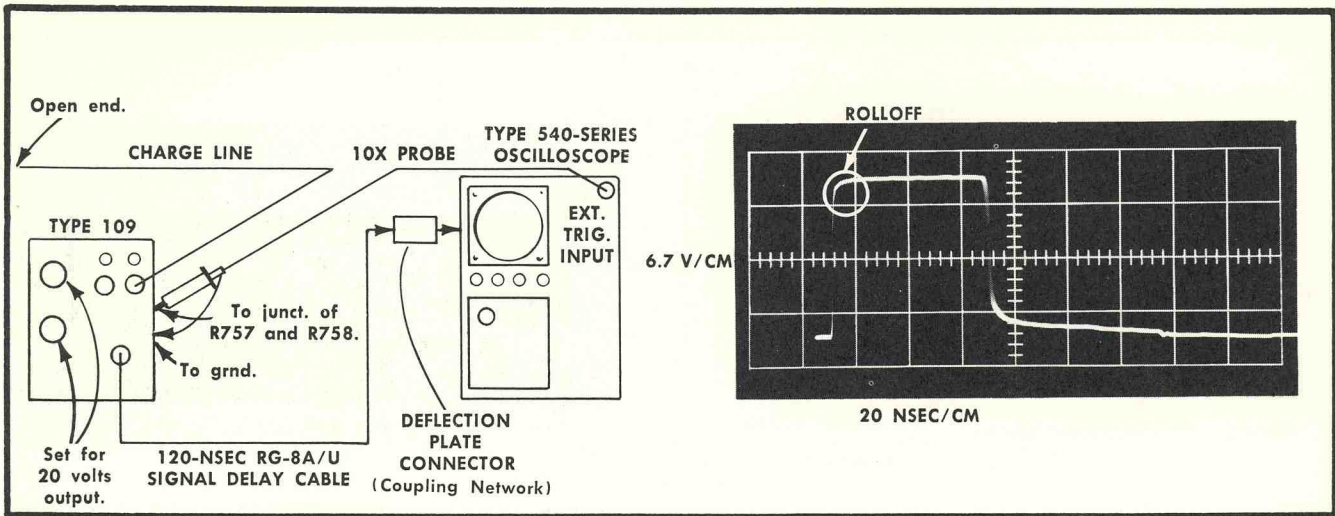


Fig. 3-10. Applying the Type 109 pulse through a deflection plate connector network to the crt vertical deflection plates. Note that the use of RG-8A/U cable as a signal delay line causes rolloff and a gradual upward slope of the waveform.

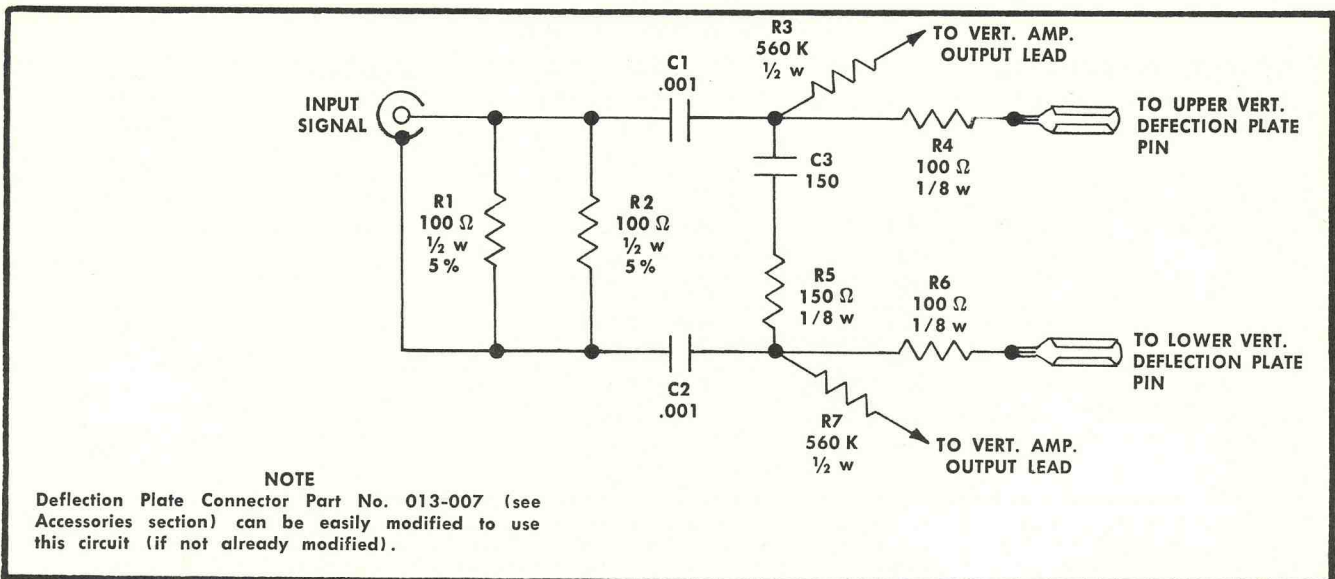


Fig. 3-11. Circuit diagram of actual circuit used to obtain the waveform shown in Fig. 3-12. Components C3 and R5 aid in sharpening the leading corner and flattening the top of the waveform to offset the slight deterioration caused by using a long signal delay line.

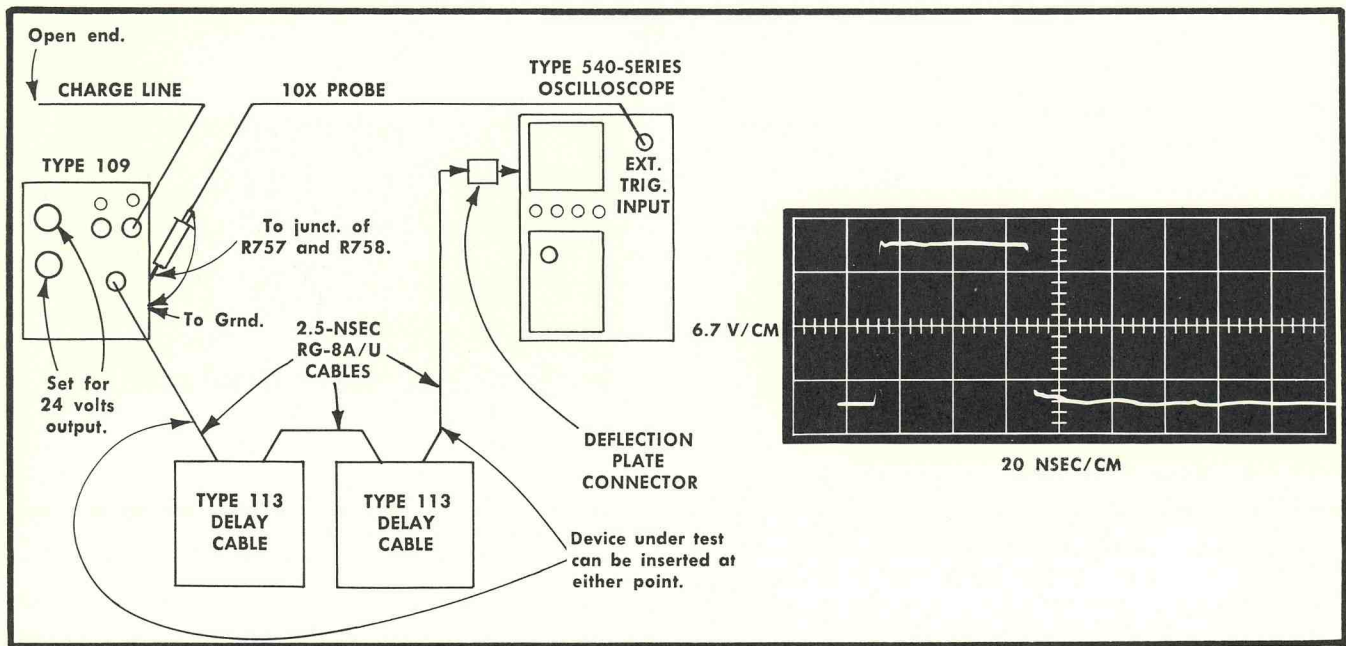
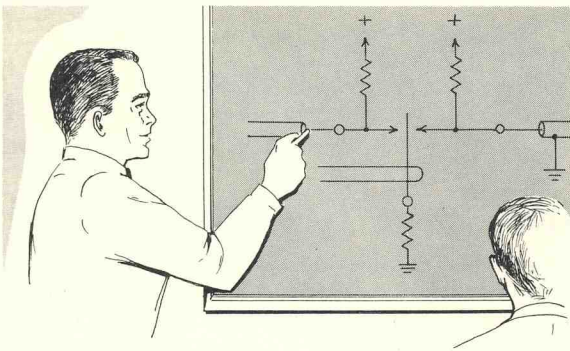


Fig. 3-12. Note the improved waveform response obtained by using two Type 113 Delay Cables as a signal delay line and by adding C3 and R5 to the deflection plate connector network.

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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

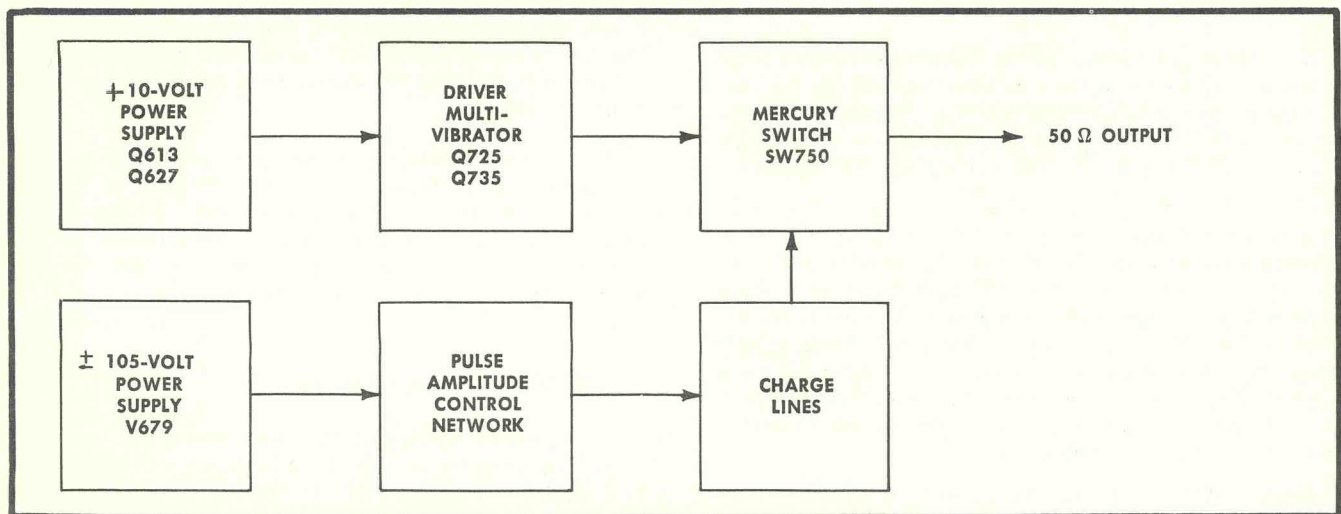


Fig. 4-1. Simplified block diagram of the Type 109.

Circuit Description—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 transients 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.

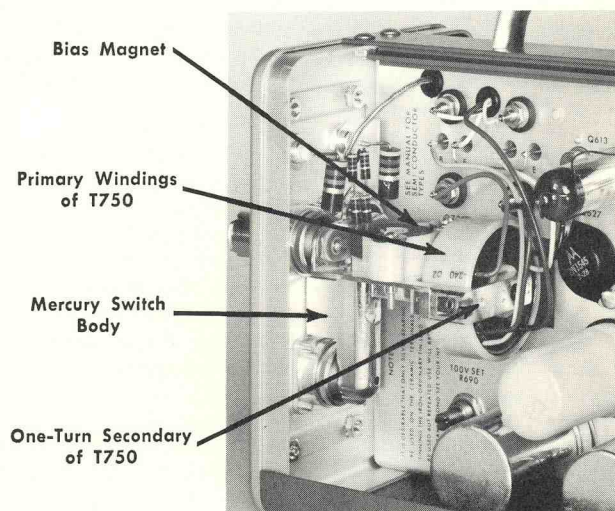


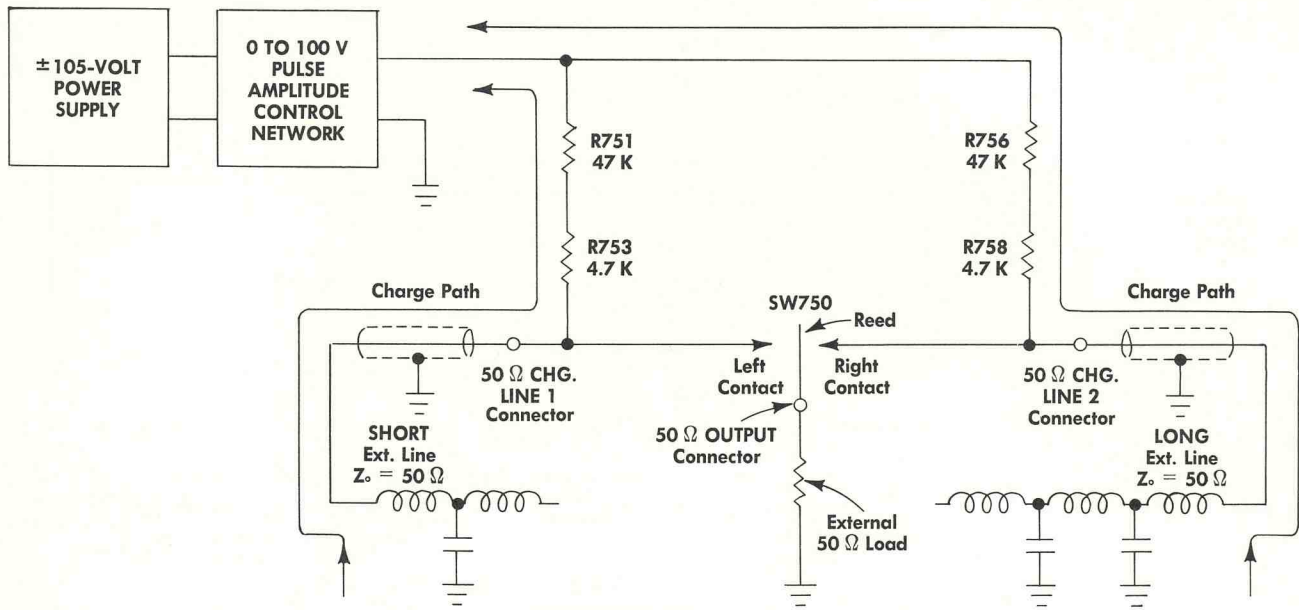
Fig. 4-2. Left front view of the Type 109 showing the pulser section.

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 μ sec 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.



SIMPLIFIED CHARGE CIRCUIT
(Using separate charge lines.)

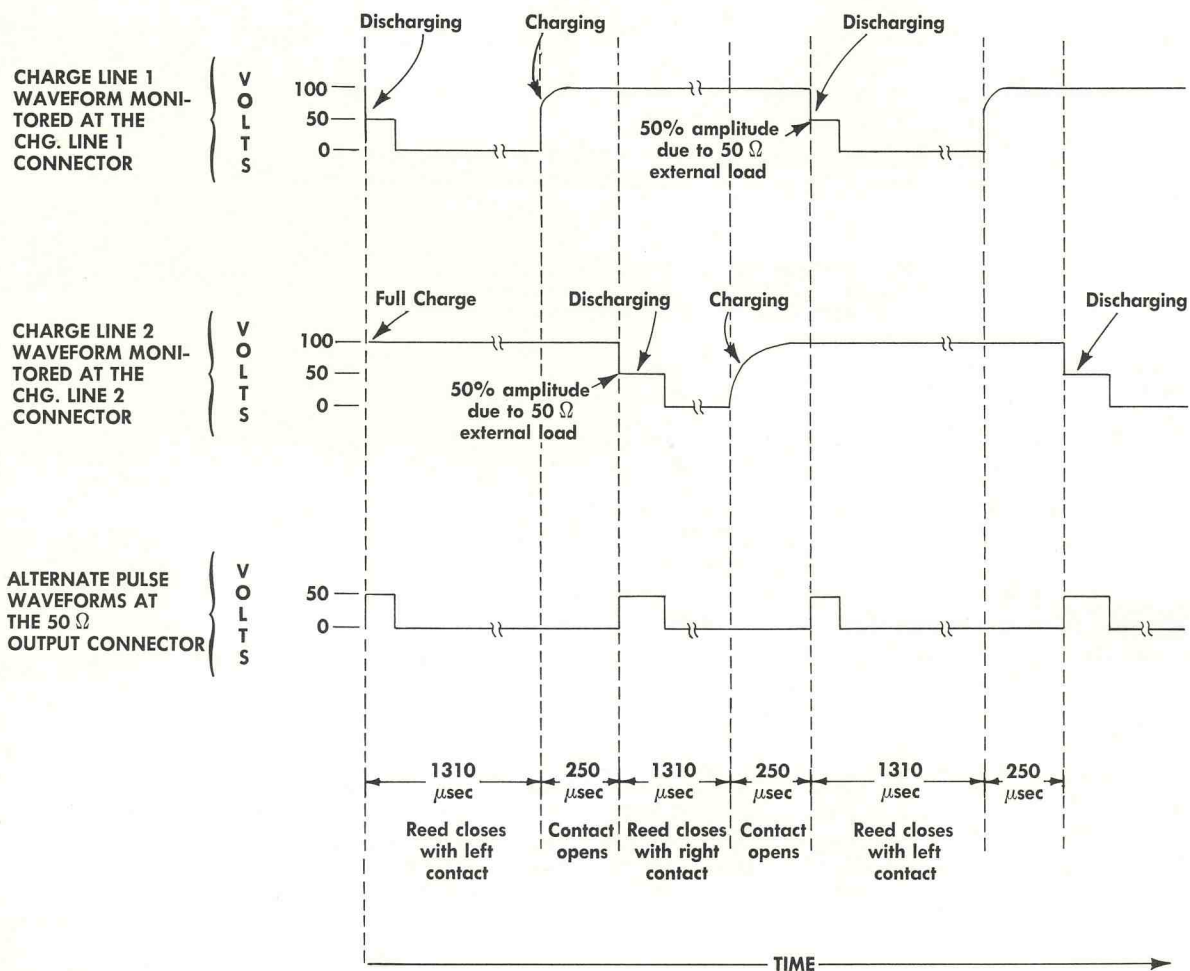


Fig. 4-3. Charge and discharge sequence using two separate different length charge lines. For this illustration CHARGE LINE 2 is twice as long as CHARGE LINE 1, the Type 109 output amplitude is ± 50 volts, and the nominal repetition rate of the pulses generated from each contact is 320 cps.

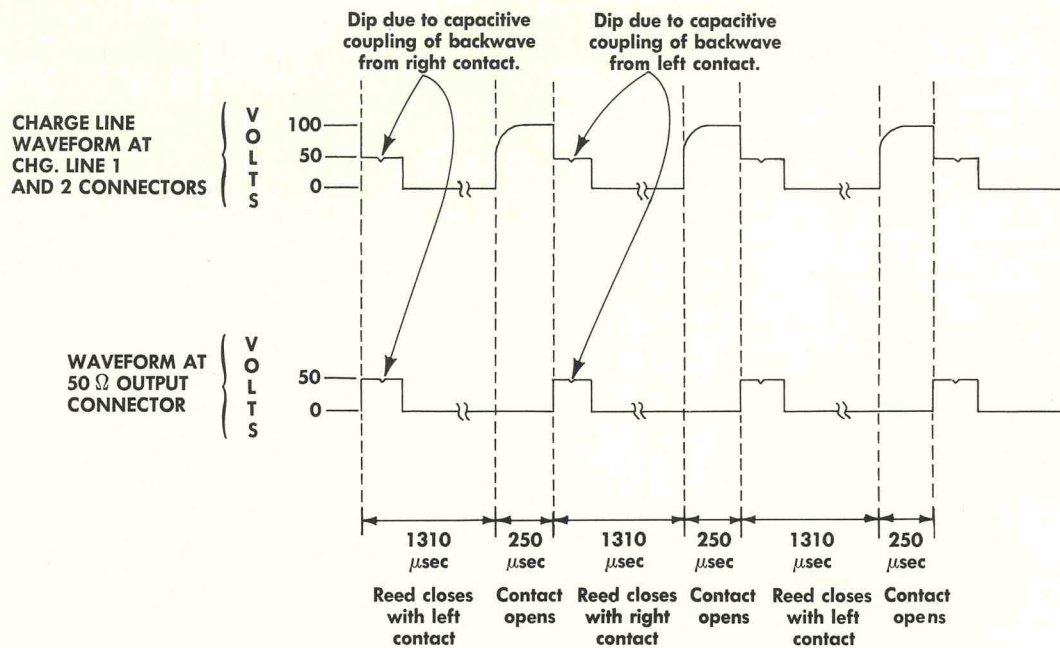
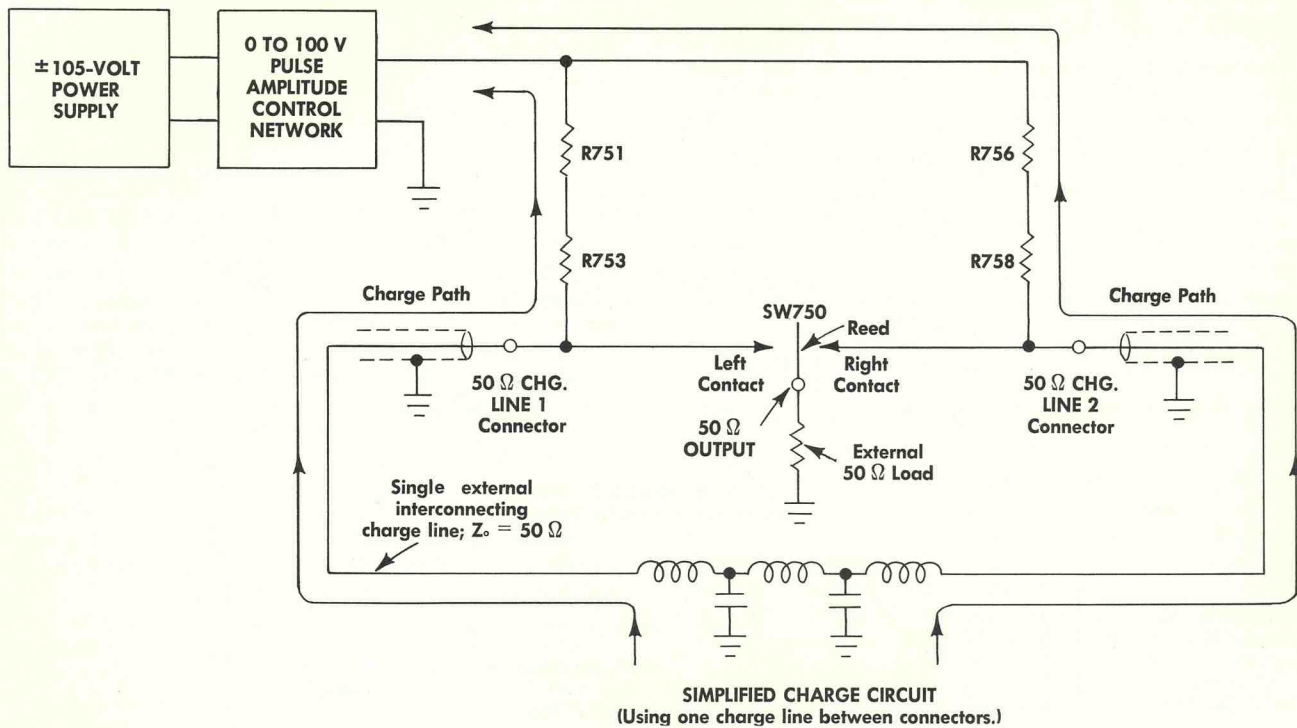


Fig. 4-4. Charge and discharge sequence using the same charge line. Type 109 output amplitude is +50 volts and the nominal repetition rate is 640 cps.

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 50 Ω 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.

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SECTION 5

MAINTENANCE



PREVENTIVE MAINTENANCE

Calibration

The Type 109 should provide many hours of trouble-free operation. However, if the reed switch should operate erratically, you may have to adjust the FREQUENCY control slightly in either direction to obtain smooth operation and clean pulse output. If adjusting the FREQUENCY control does not give the desired result, the bias magnet may have to be repositioned as well.

Other than the adjustments just mentioned, we suggest that you recalibrate the instrument after each 500 hours of operation (or every six months if used intermittently). Complete calibration procedures are given in Section 6.

Visual Inspection

You should visually inspect the Type 109 Pulse Generator periodically for possible defects. These defects may include such things as loose or broken connections, damaged connectors, improperly seated VR tube or transistor, scorched wires or resistors, or broken ceramic terminal strips. For most visual troubles the remedy is apparent; however, particular care must be taken when heat-damaged components are detected. Overheating of parts is often the result of other, less apparent, defects in the circuit. It is essential that you determine the cause of overheating before replacing heat-damaged parts in order to prevent further damage.

REMOVAL AND REPLACEMENT OF PARTS

General Information

Procedures for replacement of most parts in the Type 109 are obvious. Detailed instructions for the removal are therefore not required. In some cases, however, additional information will aid in the replacement of parts. This information is given in the subsequent portions of this section.

Because of the precision characteristics of this instrument, replacement of certain parts will require that you calibrate the instrument to insure proper operation. Refer to Section 6 for the calibration procedure.

Switches (Excluding the Mercury Switch)

Methods for removal of defective switches are, for the most part, easy to do and only a normal amount of care is required. Single wafers on the VOLTAGE RANGE switch

are normally not replaced. If one wafer is defective, the entire switch should be replaced. This switch can be ordered through your local Tektronix Field Office either unwired or with all parts and wire straps soldered in place, as desired. Refer to the Parts List for the part number to use.

Mercury Switch

Normal useful lifetime of the mercury switch is about 200 hours. If the mercury switch does not produce a clean output pulse even after adjusting the bias magnet and/or FREQUENCY control, the mercury switch may need replacing.

To remove the mercury switch SW750, proceed as follows:

1. Remove the bias magnet by removing the two 4-40 x 1 RHS screws located on each side of it.
2. Remove V679 from its socket.
3. Unsolder the two resistors where they connect to the printed circuit plate at the upper end of the switch.
4. Loosen the 0.050" hex setscrew located near the bottom of the mercury switch body (see Fig. 5-1).

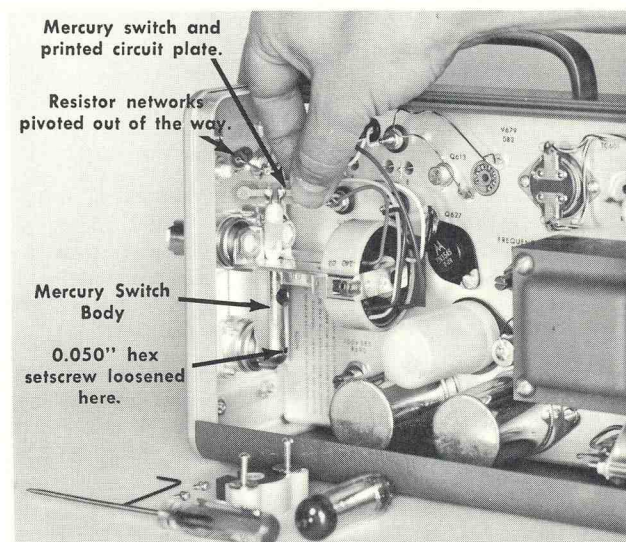


Fig. 5-1. Removing the mercury switch with circuit board attached.

5. Remove the two 2-56 x 1/4 RHS screws holding the printed circuit plate.

6. Pivot the resistor networks out of the way. Lift out the circuit plate and the switch as a unit (see Fig. 5-1).

WARNING

Mercury and mercury vapor are potential causes of heavy-metal poisoning. The mercury switch consists of a glass envelope containing contacts, the mercury reservoir, and gas under high pressure. If the glass is cracked or broken during removal or replacement, the envelope will likely explode. This could produce serious injury due to flying glass and mercury. Use safety glasses when you are working with the switch.

7. Unsolder the printed circuit plate from the switch terminals.

Install the replacement mercury switch as follows:

1. Check the single terminal located at one end of the replacement switch. If it is longer than the original switch, wrap the switch in cloth and cut the terminal for proper length. Use pliers to round out the cut end of the terminal.
2. Insert the replacement switch into the mercury switch body and tighten the setscrew near the bottom of the body.
3. Mount the printed circuit plate with the two 2-56 x 1/4 RHS screws.
4. Solder the two resistors and the terminals to the printed circuit plate.
5. Install the bias magnet and V679.
6. Adjust the magnet and the FREQUENCY control for proper reed operation as described in step 4 of the Calibration procedure (Section 6).

Soldering Precautions

In the production of Tektronix instruments, a special silver-bearing solder is used to establish a bond to the ceramic terminal strips. This bond can be broken by the repeated use of ordinary tin-lead solder, or by the application of too much heat. Occasional use of ordinary solder will not break the bond, however, if too much heat is not applied.

If you frequently perform work on Tektronix instruments, it is advisable that you have a stock of solder containing about 3% silver. This type of solder is used quite often for etched circuit boards and should be readily available. It may also be purchased directly from your Tektronix Field Engineer in one-pound rolls (part number 251-514).

Because of the slotted terminals in the ceramic strips, you will probably want to use a wedge-shaped tip on your soldering iron. A tip such as this allows you to apply heat directly to the solder in the slot and reduces the amount of heat required. It is important to use as little heat as is possible and not to twist the soldering iron. Twisting or turning the soldering iron in the slot can chip or break the ceramic strip.

Ceramic Terminal Strips

To remove a ceramic terminal strip, unsolder all components and connections, then pry the strip, with yokes

attached, out of the chassis. As an alternative method, use diagonal cutters to cut off one side of each yoke to free the strip but try not to damage the spacer.

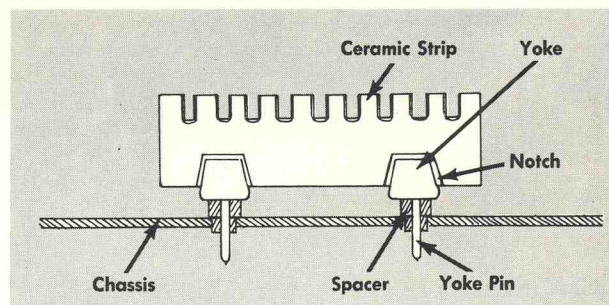


Fig. 5-2. Installation of ceramic terminal strips.

After removing the strip, the remainder of each yoke can be easily extracted from the chassis with a pair of pliers. The yokes need not be salvaged since new ones are furnished with the new strips. If spacers are not damaged, they may be re-used as long as they hold the strip assembly securely.

To install a new strip, place the spacers in the chassis holes, insert the yoke through the spacers, and press down on top of the strip above the yokes. Use a plastic or hard-rubber mallet, if necessary, to seat the yokes firmly. Be sure to tap lightly **above** the yokes and drive them down in equal increments to keep from placing too great a strain on the strip. Fig. 5-2 illustrates the way the parts fit together. If desired, the extending portion of the yoke pins can be cut off to within about 1/8" of the lower end of the spacers.

Use the soldering precautions described earlier when soldering the leads to the strip.

OBTAINING REPLACEMENT PARTS

Standard Parts

Replacements for all parts used in the Type 109 can be purchased through your Tektronix Field Office, at current prices. Many of the components, however, are standard electronic parts than can usually be obtained locally. Before purchasing a part, be sure to consult the Parts List to determine the tolerance and rating required. The Parts List gives the values, tolerances, ratings and Tektronix part numbers for all components used in the instrument.

Special Parts

In addition to the standard electronic components mentioned in the previous paragraph, special parts are also used. These parts are manufactured especially for Tektronix by other companies. These parts and most mechanical parts should be ordered through your Tektronix Field Office since they are normally difficult or impossible to obtain from other sources.

TROUBLESHOOTING

Introduction

In the event that trouble develops use the information in this portion of the Instruction Manual to more efficiently troubleshoot the Type 109. The information that follows begins with preliminary checks to make. Then it progresses to circuit troubleshooting. Troubleshooting tables are provided as an aid to locating the exact cause of the trouble.

PRELIMINARY CHECKS

Front-Panel Controls

When a trouble occurs in the Type 109, you should first recheck the settings of all controls to see that they are set properly. Then operate the front-panel controls to see what effect, if any, they have on the trouble. The normal or abnormal operation of each control will allow you to firmly establish the symptoms in your mind.

CIRCUIT TROUBLESHOOTING

Isolating the Trouble

After the symptoms have been clearly established, look for the obvious signs of trouble in the associated areas. For example, if there is no output pulse, check to see that the pilot light is on, listen for proper mercury switch reed operation, see that V679 glows normally, and look for overheated components.

In general, any troubleshooting procedure can be thought of as consisting of these steps:

1. Note the symptoms and the effect, if any, on the symptom when operating the front-panel controls.
2. Look and listen for the obvious signs of trouble.
3. Use the schematic diagram to determine which circuits to check first.
4. Make the check. If you don't find the trouble, make detailed checks until the exact cause of the trouble is found.
5. Make the repair.

In many cases, Tables 5-1, 5-2 and 5-3 will enable you to accomplish the first four steps quite easily. Just find the symptom in the first column of Table 5-1 that most closely approximates the one you notice about your instrument. Then, make the checks that are listed in the second column until you find the exact cause of the trouble.

Table 5-1 does not list every possible symptom or check, but it does have a few references which direct you to Tables 5-2 and 5-3. These last two tables are arranged so that they can be used individually to perform quick checks on the operation of specific circuits. Table 5-3 is a guide for troubleshooting the Driver Multivibrator stage and the +10-Volt Power Supply; Table 5-3 is a troubleshooting guide for checking the ± 105 -Volt Power Supply.

Checking Semiconductors

Semiconductor defects usually take the form of the transistor or diode either opening or shorting. A transistor-curve display instrument, such as the Tektronix Type 575, is useful for finding abnormal semiconductor difficulties. However, most failures can be located with an ohmmeter.

A check for open or shorted semiconductors, using an ohmmeter, should be made with the ohmmeter leads connected both ways between the terminals so that the effects of the polarity reversal of the voltage can be observed. Use of the RX1 scale of the ohmmeter should be avoided when checking Q613, because the low resistance in series with the transistor and the internal voltage source of the ohmmeter could conceivably cause damage to the transistor.

If there is doubt about whether a semiconductor is good or not, substitute another for it in the circuit. Be sure first, however, that the voltages and loads applied to the semiconductor are normal before making the substitution. If a transistor or diode is substituted without first checking out the circuit, the new semiconductor may immediately be damaged by some defect in the circuit.

Calibration After the Repair

When you have found the cause of a trouble in the Type 109 and have replaced a component, check the schematic diagram to determine if any adjustments in that area are affected by the repair. For example, if you replace V679, you will need to check the 100V SET adjustment.

TABLE 5-1
SYMPTOMS

Symptom	Possible Checks to Make
1. Pilot light does not light; mercury switch reed does not vibrate.	<ul style="list-style-type: none"> a. Check that line power is applied. b. Check fuse F601. c. Check POWER ON switch. d. Check line filter T600 for open circuit. e. If Type 109 interior temperature is over 175° F, TK601 is probably open. Find cause of overheating.
2. No output pulse; mercury switch reed does not vibrate; driving transformer T750 puts out a barely audible hum at about 640 cps.	<ul style="list-style-type: none"> a. Check bias magnet positioning and FREQUENCY adjustment (perform step 4 in Section 6). b. Check to see that T750 mounting screws are tight.
3. No output pulse; mercury switch reed does not vibrate.	Check waveform at collectors of Q725 and Q735. If waveform is correct, replace mercury switch SW750; if incorrect, go to Table 5-2, step 1.
4. No output pulse; VOLTAGE RANGE switch set to 0.5, 5.0 or 50; mercury switch reed vibrates normally.	<ul style="list-style-type: none"> a. Check for grounded reed terminal that connects to 50 Ω OUTPUT connector (hex setscrew located near bottom of casting could be loose). b. Check for a 100-volt reading at ungrounded end of AMPLITUDE control with VOLTAGE RANGE switch set to 50. If normal, check for trouble between wiper arm of AMPLITUDE control and SW750 contacts. If voltage reading is abnormal (zero volts), go to Table 5-3, step 1.
5. No output pulse when VOLTAGE RANGE switch is set to 5.0; mercury switch reed vibrates normally.	Check for open SW690 switch contact for that position.
6. No output pulse when VOLTAGE RANGE switch is set to 0.5; mercury switch reed vibrates normally.	Check for open SW690 switch contact for that position.
7. Jittery output pulse; mercury switch sounds normal.	Check for a loose 0.050" hex setscrew at extreme bottom end of the mercury switch casting. (This setscrew holds the center conductor of the 50 Ω OUTPUT connector tight.)
8. Jittery output pulse; mercury switch operates abnormally even when step 4 in Section 6 is performed.	Probably the mercury switch is defective; check by replacing it. (normal life of a mercury switch is about 200 hours.)
9. Risetime of the output pulse is more than 0.25 nsec.	Check for a loose 50 Ω OUTPUT GR connector.

TABLE 5-2
DRIVER MULTIVIBRATOR STAGE AND +10-VOLT POWER SUPPLY
(Refer to schematic diagram for typical waveform, voltages, and ripple amplitudes.)

Trouble	Possible Checks to Make
1. Waveform at collectors of Q725 and Q735 is incorrect.	<ul style="list-style-type: none"> a. Check voltage at emitters of Q725 and Q735. If normal, substitute Q725 and/or Q735. If voltage is appreciably high, go to step 2 in this table; if too low, go to step 3. b. Check continuity through T750. c. Check C750, R750 and R744. d. Check for broken leads.

TABLE 5-2 (continued)

Trouble	Possible Checks to Make
2. Voltage at emitters of Q725 and Q735 is appreciably higher than normal.	Check for open D612, Q613, Q627 or R614.
3. Voltage at emitters of Q725 and Q735 is appreciably lower than normal.	a. Check for shorted D612, Q613 or Q627. b. Check for open R610.
4. Voltage at emitters of Q625 and Q735 reads zero.	a. Check for shorted C627. b. Check for an open lead between the emitters and the +10-volt supply.
5. Excessive *120-cycle ripple at emitters of Q725 and Q735.	Check for open or defective C610 or C611.
6. Excessively high spikes on the waveform at collectors of Q725 and Q735.	Check for open C750 or R750.
7. Excessively high spikes (about 3 volts peak) are superimposed on the ripple waveform at emitters of Q725 and Q735. (Typical amplitude should be about 1½ volts peak.)	Check for open C627.
8. Excessively high ripple and spikes at base of Q613. Spikes are about 0.5-volt peak in amplitude. (Typical amplitude for the ripple and spikes should be about 5 mv.)	Check for open C614.
9. Ripple at junction of D602A and R610 is *60 cps instead of *120 cps.	a. Check for open D602A or D602B. b. Check T601 secondary winding that connects to terminals 8, 9 and 10.

* When connected to 60 cps main.

TABLE 5-3
105-VOLT POWER SUPPLY
(Refer to schematic diagram for typical voltages and ripple amplitudes.)

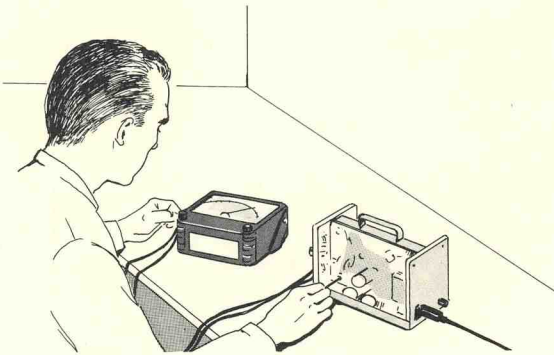
Trouble	Possible Checks to Make
1. Zero volts reading at ungrounded end of AMPLITUDE control (junction of R692 and R696).	a. Check for open R690 or R692. b. Check for open wiper contact on VOLTAGE RANGE switch SW690. c. Check for open T601 secondary winding that connects to terminals 6 and 7.
2. Voltage reading at R692/R696 junction is appreciably higher than normal; i.e., about 150 volts or more.	Replace V679.
3. Voltage reading at R692/R696 junction appreciably lower than normal.	a. Check for shorted C679 or C661. b. Check T601 secondary, that connects to terminals 6 and 7 for proper output.
4. Excessive *120-cps ripple at either the junction of C661A or C661B and R678.	Check for defective C661.
5. Ripple at junction of C661A and R661 and is 60 cps instead of *120 cps.	Check for open D662A, B, C or D.

* When connected to 60 cps main.

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SECTION 6

CALIBRATION



Introduction

A complete procedure for checking the operational standards and calibration of the Type 109 Pulse Generator is provided in this section of the manual.

Apparent troubles in the instrument are occasionally the result of an improper adjustment. Consequently, calibration checks should be an integral part of any troubleshooting procedure. Abnormal indications occurring during calibration checks will often aid in isolating troubles to a definite circuit or stage.

In the instructions that follow, the steps are arranged in proper sequence for a complete check and calibration of the instrument. Each numbered step contains the information required to make one check or adjustment or a series of related checks or adjustments. The steps are arranged to avoid unnecessary repetition of checks or adjustments.

Test equipment used in a particular step should be left connected at the end of that step unless instructions state otherwise. Similarly, controls not mentioned are assumed to be in positions they were in at the conclusion of the preceding step.

Equipment Required

The following equipment is required to perform a complete calibration of the Type 109.

- (1) Conventional test oscilloscope such as a Tektronix Type 540-Series Oscilloscope with a Type L Plug-In Unit, a Type P6000 10X Attenuator Probe and a Type P6027 1X Attenuator Probe. Substitute specifications: Bandpass 30 mc with the 10X probe; deflection factor, at least 50 mv per cm and at least 5 mv per cm at reduced band-pass.
- (2) Sampling test oscilloscope such as a Tektronix Type 561 Oscilloscope with a Type 3S76 and a Type 3T77 Plug-In Units. Substitute specifications: Risetime, 0.4 nsec or less; any deflection factor up to 20 volts per division. (The Tektronix Type 519 (conventional) Oscilloscope can also be used as an excellent substitute.)
- (3) One 50-ohm 20-nsec cable, 160", RG-8A/U, with GR 874 connectors on each end, Part No. 017-504.
- (4) One 50-ohm 5 nsec cable, 40", RG-8A/U, with GR 874 connectors on each end, Part No. 017-502.
- (5) One 50-ohm terminated cable assembled as shown in Fig. 6-1. Requires the following parts:

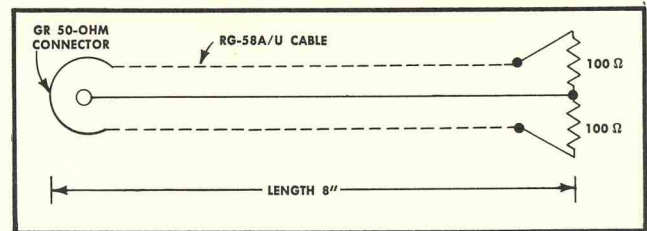


Fig. 6-1. 50-ohm terminated pigtail circuit.

- 1—8" RG-58A/U cable with a GR 874 connector on one end, the other end is pigtailed, Part No. 017-503.
- 2—100-ohm $\frac{1}{2}$ -watt composition resistor.

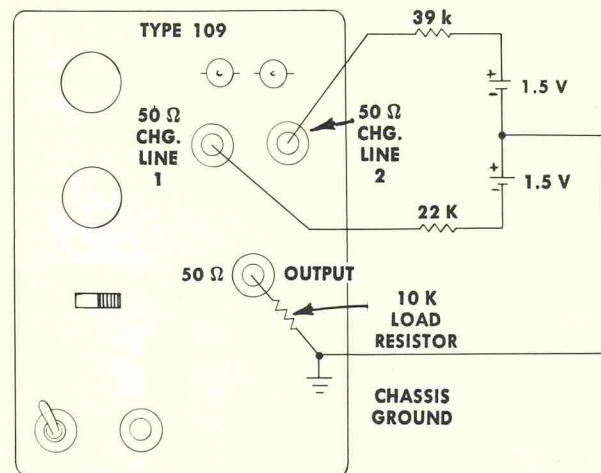


Fig. 6-2. Mercury switch tester circuit connected to the Type 109.

- (6) One mercury switch tester constructed similar to the one shown in Fig. 6-2. Use the following parts:
 - 2—1 $\frac{1}{2}$ -volt batteries
 - 1—22-k $\frac{1}{2}$ -watt composition resistor
 - 1—39-k $\frac{1}{2}$ -watt composition resistor
 - 1—10-k $\frac{1}{2}$ -watt composition resistor
 - 3—Banana plugs
 - 1—Alligator clip
 - 1—3" wire lead
 - 3—12" wire leads

CAUTION

When using this tester in step 4 of the calibration procedure, do not insert the banana plugs all the way without checking whether or not the plugs are too large. Most banana plugs can be safely inserted only part way without damaging the GR connectors.

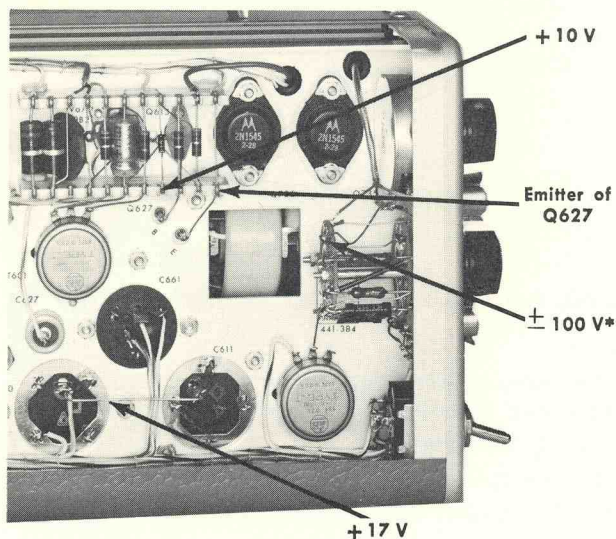
- (7) One VOM with a sensitivity of at least 5,000 Ω /volt.
- (8) An autotransformer with output voltage variable between 105 and 125 volts (or 210 and 250 volts if Type 109 is wired to operate in this range). Minimum rating of 0.070 KVA.
- (9) An accurate ac voltmeter capable of reading voltages from 105 to 125 volts (or from 210 to 250 volts if the Type 109 is wired for this operating range).
- (10) One 12" jumper lead with insulated alligator clips on each end.
- (11) One screwdriver.

Preliminary Procedure

Visually check the Type 109 and then preset the front-panel controls to these positions:

VOLTAGE RANGE 50
POWER OFF

Using the VOM, check the resistance to ground of each power supply at the test points listed in Table 6-1. Refer to Fig. 6-3 which shows the location of these test points.



*Polarity depends on setting of PULSE POLARITY switch. Be sure VOLTAGE RANGE switch is set to 50 for resistance and/or 100-volt readings.

Fig. 6-3. Left side view, front portion, showing the location of the test points.

After completing the resistance checks, disconnect the ohmmeter.

TABLE 6-1

Power Supply Test Points*	Ohmmeter Range	Approx. Resistance Readings**	PULSE POLARITY Switch Setting
$\pm 100V$	X1k	7k, 18k	+
$\pm 100V$	X1k	7k, 18k	—
+17V	R10	18 Ω , 30 Ω	+ or —

*Fig. 6-3 shows the physical locations of these test points.

**Reverse the ohmmeter leads to obtain both readings.

CALIBRATION PROCEDURE**Introduction**

The equipment used in this calibration procedure is the same as that specifically called out in the "Equipment Required" list. The front-panel control settings of this equipment are given where necessary for more detailed information. Corresponding control settings should be used if you are using substitute equipment. In addition, the following procedure is based on a Type 109 which was wired for 117-volt nominal operation and operated on a line frequency of 60 cps. If your Type 109 is wired for 234-volt operation and you are operating it on a line frequency other than 60 cps, allow for such differences when you are using this procedure.

1. 100-Volt Power Supply Adjustment

- a. Connect the autotransformer to a nominal 117-volt source (or 234-volt source if the Type 109 is wired for this nominal operating voltage).
- b. Connect the Type 109 and ac voltmeter to the output of the autotransformer.
- c. Set the POWER switch to ON and adjust the autotransformer for an output of 117 volts (or other voltage for which the instrument is wired).
- d. Set the PULSE POLARITY switch to +.
- e. Connect the VOM to the $\pm 100V$ test point (see Fig. 6-3).
- f. Adjust the 100 V SET control (see Fig. 6-4) to obtain a reading of exactly 100 volts.
- g. Set the PULSE POLARITY switch to — and check for a reading of 100 volts.

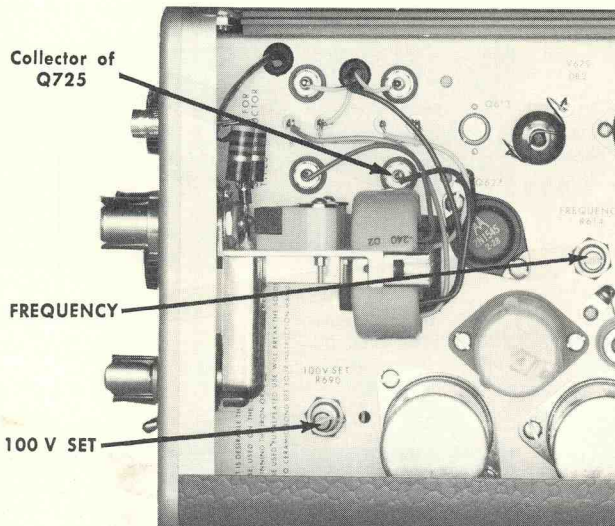


Fig. 6-4. Right side view, front portion of the Type 109, showing the location of the internal adjustments and the test point.

2. Check Power-Supply Regulation and Ripple

- Using the information given in Table 6-2, connect the VOM to the regulated supply under test to monitor the voltage.
- Connect the conventional test oscilloscope with the high-gain plug-in unit and 1X probe to the appropriate test point so the ripple amplitude can be checked simultaneously.

TABLE 6-2

Power Supply*	Output Voltage and Tolerance	120 cps Ripple Amplitude** (peak-to-peak max.)
± 100 V (regulated)	-100 volts, ± 0.5 volt	10 millivolts
± 10 V (regulated)	$+10$ volts, ± 1 volt	100 millivolts (Measure at emitter of Q627*)
$+17$ V (unreg.)	Approx. 15.5 to 18 volts (does not have to be monitored)	1.8 volts

*Fig. 6-3 shows the test point locations.

**Ignore the superimposed spikes on the waveform.

- Vary the output of the autotransformer between 105 and 125 (or 210 and 250) volts and check for proper regulation and ripple amplitude within the line voltage operating range.
- Set the autotransformer for an output of 117 (or 234) volts.
- Disconnect the VOM and the 1X probe.

3. Check Frequency Range and Amplitude

- Set the front-panel controls on the conventional test oscilloscope to the following settings:

Input coupling	DC
Volts/Cm	1 Volt
Variable Volts/Cm	Calibrated
Stability	Preset
Triggering Mode	AC
Triggering Slope	+
Time/Cm	1 Millisec
Variable Time/Cm	Calibrated
Horizontal Display	Normal ($\times 1$)

- Disconnect the 1X probe from the input of the oscilloscope and connect a 10X probe in its place.
- Connect the probe tip to the collector of Q725 (see Fig. 6-3).
- Adjust the oscilloscope controls to obtain a stable display.
- First, rotate the FREQUENCY control (see Fig. 6-4) fully clockwise and check the waveform according to the data given in Table 6-3 and Fig. 6-5. (Use the graticule markings on your test oscilloscope to determine the period and amplitude of the waveform.)

TABLE 6-3

Setting of FREQUENCY Control	Period (at 1 millisec/cm)	Multivibrator Frequency	Waveform Amplitude (typical)
(1) Fully clockwise	2.77 cm or less	360 cps or more	18 volts
(2) Fully counter clockwise	3.6 cm or more	275 cps or less	12 volts

- Then, rotate the FREQUENCY control fully counter-clockwise and check the minimum frequency range based on the information given in Table 6-3 and Fig. 6-5.

- Disconnect the probe.

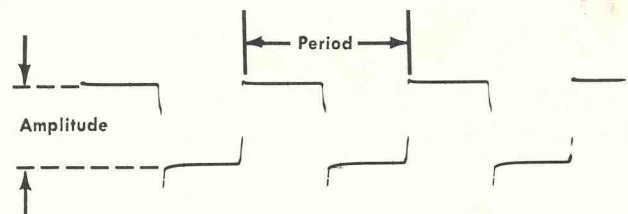


Fig. 6-5. Waveform measuring points.

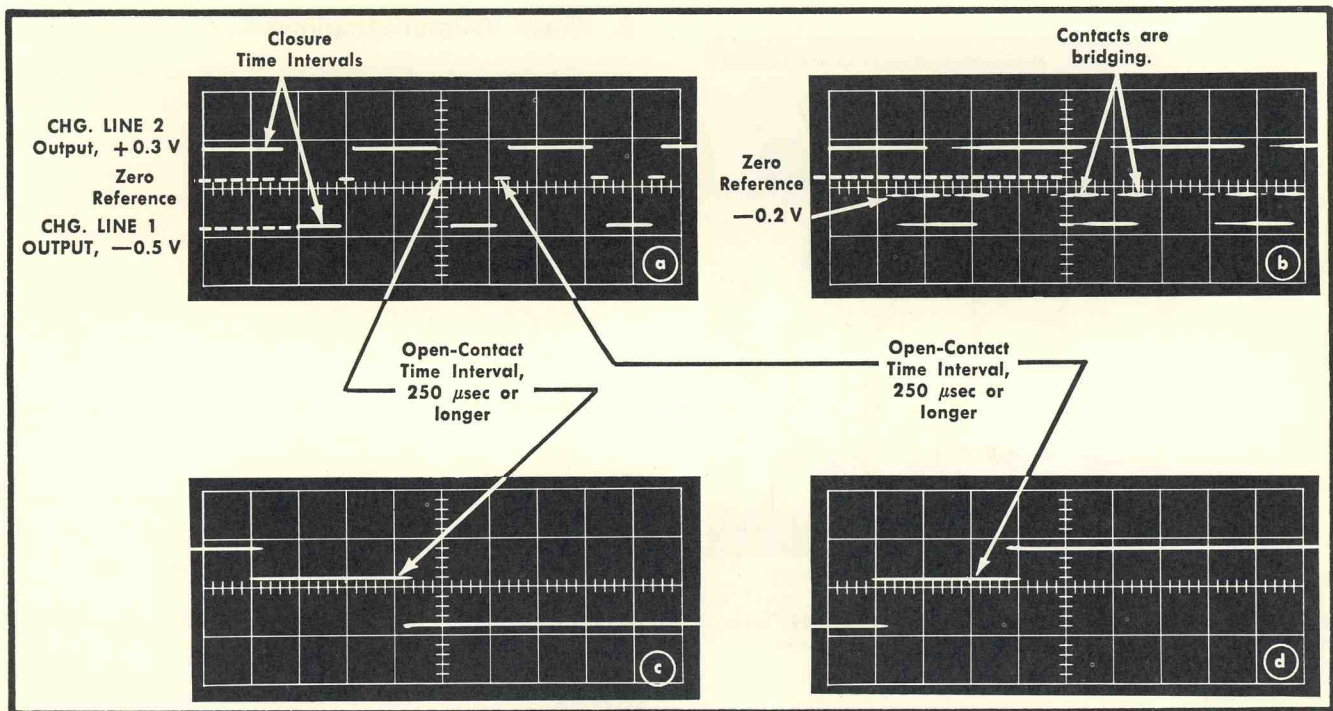


Fig. 6-6. (a) Proper and (b) improper waveform displays. Sweep rate is 1 millisc/cm. Waveforms (c) and (d) show the open-contact time intervals at a sweep rate of 100 μ sec/cm.

4. Adjust the Biasing Magnet and FREQUENCY control

- Set the Type 109 VOLTAGE RANGE switch to EXT. PWR.
- Connect the leads from the mercury switch tester to the Type 109 connectors as shown in Fig. 6-2. Use care when inserting the banana plugs into the connectors as explained previously.

The 22-k and 39-k resistors in the tester are used to produce pulses of different amplitudes across the 10-k load resistor. They also keep the battery drain low. The batteries are connected in the circuit to produce pulses of opposite polarity. The two pulses of opposite polarity and amplitude make it easy to observe the operation of the mercury switch under dynamic conditions.

- Set the Variable Volts/Cm Switch of the conventional test oscilloscope to .05.
- Rotate the Stability control on the test oscilloscope fully clockwise to obtain a free-running sweep.
- Ground the probe tip and position the trace to 2 millimeters above the graticule centerline to establish a convenient zero reference.
- Connect the probe across the 10-k resistor and adjust the test oscilloscope triggering controls to obtain a stable display.

There may be slight horizontal jitter due to mechanical closure of the reed and a spike on the leading corners of the waveform due to the tester's lead lengths.

- Vary the autotransformer between 105 and 125 (or 210 and 250) volts and check the waveform for the following characteristics:

- Check for a clean, steady waveform display similar to the one shown in Fig. 6-6a. The closure interval for one set of contacts does not have to be the same as the closure interval for the other set of contacts.
- Check that the contacts do not bridge; i.e., short together during open-contact time. If the contacts are bridging, you will notice that the open-contact time or step portion of the waveform will move below the zero reference level to about -0.2 volt (see Fig. 6-6b). The 0.2-volt change is equal to the drop across the 10-k load resistor in the tester due to "bridging" current.

- Check that the contacts remain open for 250 μ sec or longer. To check the open-contact time intervals, set the test oscilloscope Time/Cm switch to .5 Millisc and the 5X Mag. to ON (or 5X). The magnified step portions should appear similar to those shown in Fig. 6-6c and 6-6d. Return the oscilloscope controls to their former positions.

- Check that the closure time is longer than the open-contact time.

- If the mercury switch does not operate properly and produce a clean waveform with desirable characteristics as shown in Fig. 6-6a and as described previously, adjust the bias magnet and FREQUENCY control as follows:

- Set the FREQUENCY control to midrange.

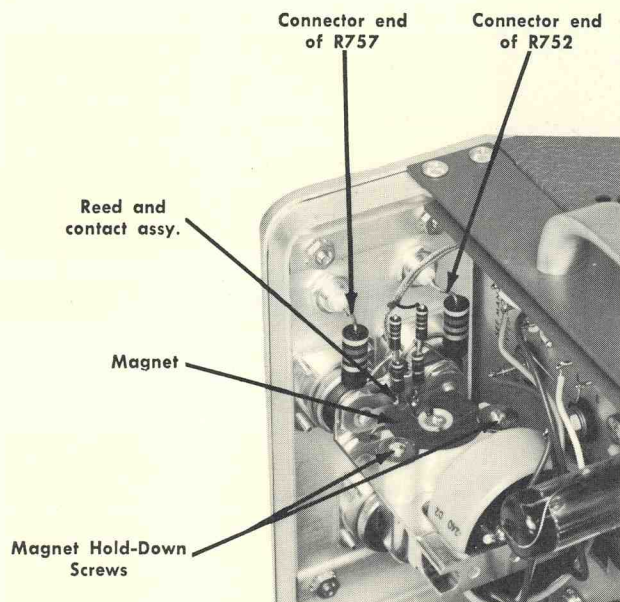


Fig. 6-7. Mercury pulser assembly. Test points for step 5h are shown also.

- (2) Loosen the magnet hold-down screws (see Fig. 6-7) and carefully move the magnet closer to or away from the reed and contact assembly. At the same time, shift the magnet slightly from side to side.

NOTE

Positioning the magnet too close to the reed tends to promote bridging; moving it too far away causes skipping; i.e., only one side is contacting. Moving the magnet too far to one side or the other can cause the reed to stop completely.

Position the magnet so the reed vibrates freely and buzzes smoothly. At the same time, adjust the FREQUENCY control until a steady waveform display is obtained. By carefully positioning the magnet and adjusting the FREQUENCY control together, find the point where a steady waveform with all the desirable characteristics explained earlier are obtained.

- (3) Then hold the magnet at that position, and carefully tighten the hold-down screws without disturbing the location of the magnet.
- (4) As a final touch-up, readjust the FREQUENCY control a few degrees in either direction to find the optimum point where the best waveform is obtained with least jitter over the line-voltage operating range.
- i. Disconnect the mercury switch tester leads and the 10X probe from the Type 109.
- j. Check that the autotransformer is set for an output of 117 (or 234) volts.

5. Check Output Amplitude

- a. Set the Type 109 AMPLITUDE control to 50 and the VOLTAGE RANGE switch to 50; set the PULSE POLARITY switch to +.
- b. Connect a 50-ohm 20-nsec cable to the 50 Ω CHG. LINE 1 and 50 Ω CHG. LINE 2 connectors.
- c. Connect a 8" 50-ohm terminated pigtail to the 50 Ω OUTPUT connector.
- d. Set the conventional test oscilloscope Volts/Cm switch to 2, the Time/Cm switch to .1 μ Sec, and the 5X Mag. switch to ON (or 5X).
- e. Connect the 10X probe tip to the pigtail termination, and the ground strap from the probe to the cable shield.
- f. Adjust the triggering and position controls on the oscilloscope to obtain a stable display within the graticule area.

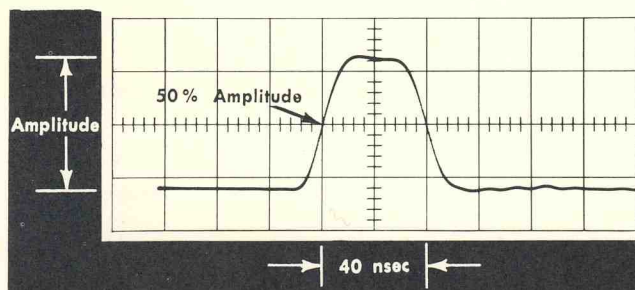


Fig. 6-8. Checking pulse duration and amplitude. Sweep rate is 20 nsec/cm.

TABLE 6-4

VOLTAGE RANGE Switch Setting	PULSE POLARITY Switch Setting	Oscilloscope Controls		Waveform Amplitude (peak)
		Volts/Cm Switch Setting	Trigger Slope Switch	
50	+	2	+	+50 volts, $\pm 3\%$
50	—	2	—	—50 volts, $\pm 3\%$
5	—	.2	—	—5 volts, $\pm 3\%$
5	+	.2	+	+5 volts, $\pm 3\%$
0.5	+	.05	+	+0.5 volt, $\pm 3\%$
0.5	—	.05	—	—0.5 volt, $\pm 3\%$
EXT. PWR.*	+ or —	.2	+	+5 volts, $\pm 10\%$

*For this check, turn off the Type 109, connect a 12" jumper lead from the +10 V test point (see Fig. 6-3) to the connector end of R752 (see Fig. 6-7) and turn on the Type 109. Check waveform amplitude and duration. Then, repeat the check by connecting the jumper lead between the same +10 V test point and the connector end of R757 (see Fig. 6-7).

- g. Check that the waveform has a pulse duration of about 40 nsec at the 50%-amplitude level (see Fig. 6-8).
- h. Check amplitudes using Table 6-4. For each check, adjust the test oscilloscope triggering and positioning controls for best display of the waveform. In addition, while checking the amplitude, check that the pulse duration is 40 nsec.
- i. Disconnect the jumper lead, the 10X probe and the pigtail termination.
- j. Turn off the conventional test oscilloscope.

6. Check Risetime

- a. Set the front-panel controls on the Type 561A (sampling) Oscilloscope with its Type 3S76 and 3T77 plug-ins to the settings that follow. (If you are using a substitute oscilloscope, set the oscilloscope controls to suitable positions for measuring the risetime of the Type 109.)

Power	On
A Position	Midrange
Mode	A only
Smooth-Normal	Normal
A Mv/Div.	100
A 2-200 Variable	Calib.
Dc Offset	Midrange
A Norm.-Inv.	Norm.
Internal Trigger	A
(Horizontal) Position	Midrange
Time/Div.	.2 nSec.
Variable (Time/Div.)	Calib.
Horiz. Mag.	$\times 1$
Dots Per Div.	100
Sweep Mode	Normal
Delay	Fully counterclockwise
Trigger Sensitivity	Fully counterclockwise
Recovery Time	Fully counterclockwise
Int.-Ext. Trigger	+Int.

- b. Set the Type 109 controls to these settings:

AMPLITUDE	10
VOLTAGE RANGE	5
PULSE POLARITY	+

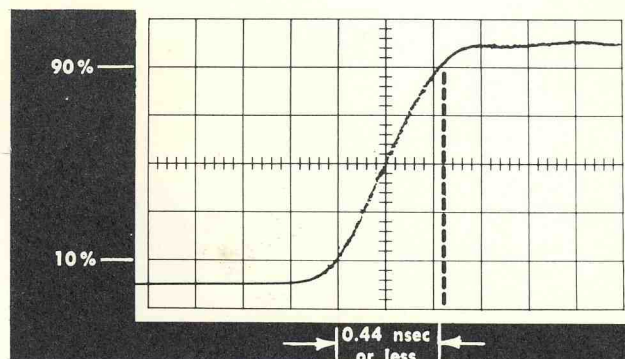


Fig. 6-9. Measuring the risetime. Equivalent sweep rate is 0.2 nsec/cm.

- c. Connect a 5-nsec cable between the 50 Ω OUTPUT connector on the Type 109 and Input A on the sampling oscilloscope.
- d. Advance the oscilloscope Trigger Sensitivity control until a sweep trace appears on the screen. Use the A Position, Dc Offset (if necessary) and the (Horizontal) position controls to position the trace to coincide with the bottom graticule marking.
- e. Advance the Delay control to display the rising portion of the pulse on the screen. Adjust the Type 109 AMPLITUDE control so the pulse waveform is exactly 5 cm in amplitude.
- f. Vertically position the waveform 5 mm above the bottom graticule marking (see Fig. 6-9).
- g. Horizontally position the waveform so the time interval between the 10% and 90% points on the rising portion of the waveform can be easily determined with the aid of the graticule markings.
- h. Measure the system risetime which should be 0.44 nsec or less.
- i. Disconnect the jumper lead, the 10X probe and the If the number of random dots inside the pulse-waveform envelope is more than 25, readjust the FREQUENCY control in either direction slightly to obtain a cleaner waveform.
- j. Turn off the conventional test oscilloscope. that will no longer be used.

SECTION 7

PARTS LIST AND SCHEMATICS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix Field Office.



Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number including any suffix, instrument type, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix Field Office will contact you concerning any change in part number.

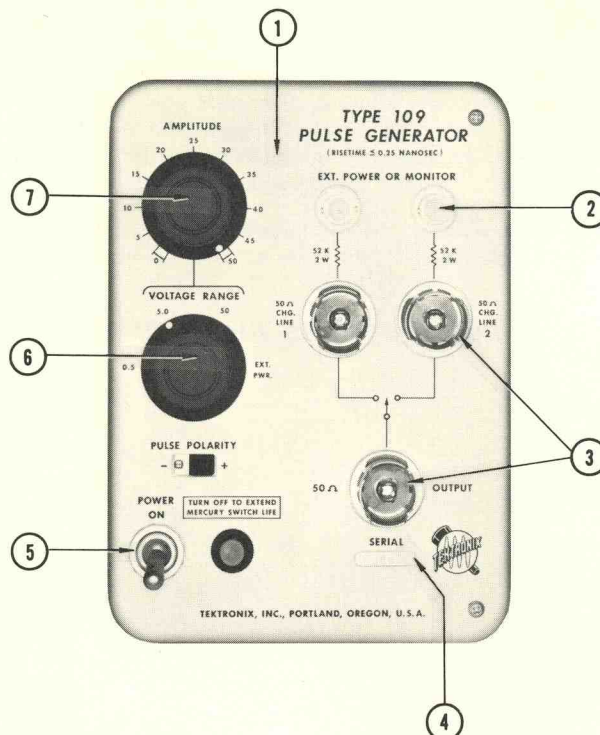
ABBREVIATIONS AND SYMBOLS

a or amp	amperes	mm	millimeter
BHS	binding head steel	meg or M	megohms or mega (10 ⁶)
C	carbon	met.	metal
cer	ceramic	μ	micro, or 10 ⁻⁶
cm	centimeter	n	nano, or 10 ⁻⁹
comp	composition	Ω	ohm
cps	cycles per second	OD	outside diameter
crt	cathode-ray tube	OHS	oval head steel
CSK	counter sunk	p	pico, or 10 ⁻¹²
dia	diameter	PHS	pan head steel
div	division	piv	peak inverse voltage
EMC	electrolytic, metal cased	plstc	plastic
EMT	electrolytic, metal tubular	PMC	paper, metal cased
ext	external	poly	polystyrene
f	farad	Prec	precision
F & I	focus and intensity	PT	paper tubular
FHS	flat head steel	PTM	paper or plastic, tubular, molded
Fil HS	fillister head steel	RHS	round head steel
g or G	giga, or 10 ⁹	rms	root mean square
Ge	germanium	sec	second
GMV	guaranteed minimum value	Si	silicon
h	henry	S/N	serial number
hex	hexagonal	t or T	tera, or 10 ¹²
HHS	hex head steel	TD	toroid
HSS	hex socket steel	THS	truss head steel
HV	high voltage	tub.	tubular
ID	inside diameter	v or V	volt
incd	incandescent	Var	variable
int	internal	w	watt
k or K	kilohms or kilo (10 ³)	w/	with
kc	kilocycle	w/o	without
m	milli, or 10 ⁻³	WW	wire-wound
mc	megacycle		

SPECIAL NOTES AND SYMBOLS

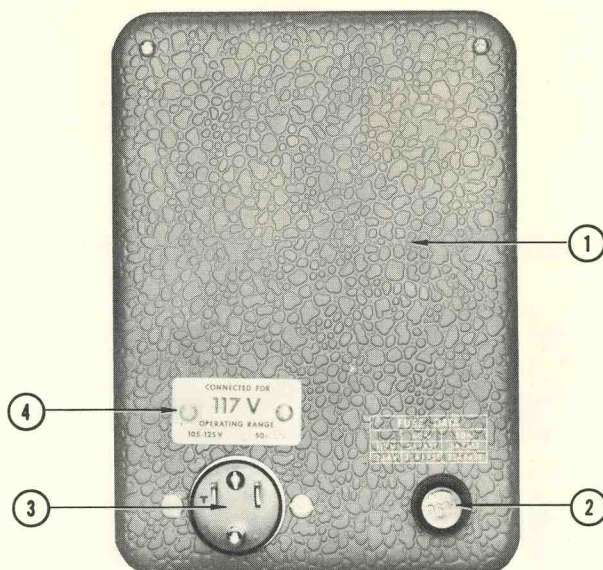
X000	Part first added at this serial number.
000X	Part removed after this serial number.
*000-000	Asterisk preceding Tektronix Part Number indicates manufactured by or for Tektronix, or reworked or checked components.
Use 000-000	Part number indicated is direct replacement.
	Internal screwdriver adjustment.
	Front-panel adjustment or connector.

FRONT



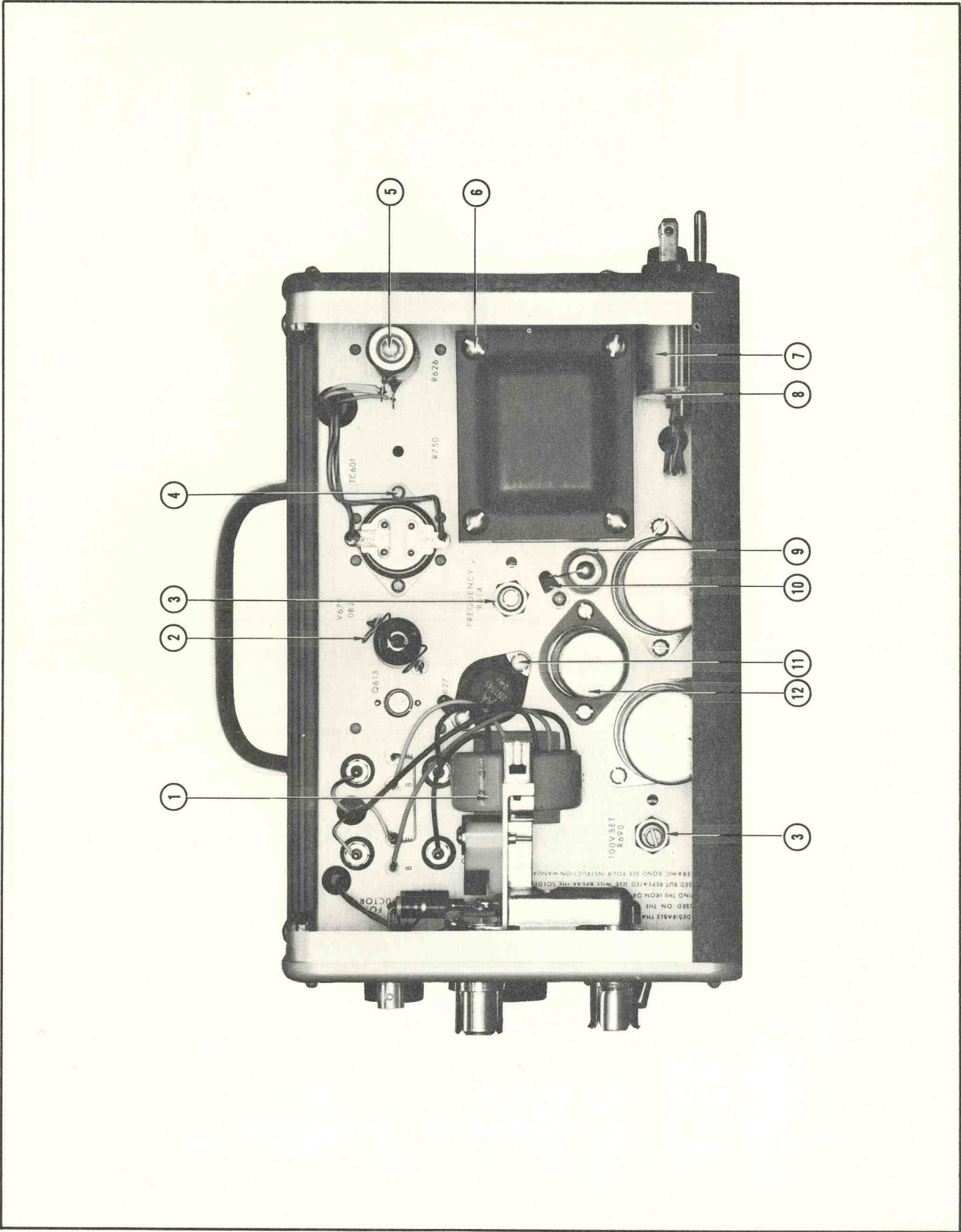
REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1	333-658			1	PANEL, front Mounting Hardware: (not included)
	213-034			2	SCREW, thread cutting, 4-40 x 5/16 RHS, phillips slot
	004-133			1	COVER, panel, plastic
	387-433			1	PLATE, front subpanel
2	131-106				Subpart of Mercury Switch Assembly (see Page ref. #1)
3	132-002				Subpart of Mercury Switch Assembly (see Page ref. #1)
4	334-679			1	TAG, metal serial no. insert
5	210-473			1	NUT, switch, 12 sided
	210-902			1	WASHER, .470 ID x 21/32 OD
	354-055			1	RING, locking, switch, 23/32 OD x 15/32 ID
6	366-145			1	KNOB, voltage range
	210-413			1	NUT, hex, 3/8-32 x 1/2
	210-840			1	WASHER, .390 ID x 9/16 OD
	210-013			1	LOCKWASHER, int, 3/8 x 11/16
7	366-145			1	KNOB, Amplitude
	210-413			1	NUT, hex, 3/8-32 x 1/2
	210-840			1	WASHER, .390 ID x 9/16 OD
	210-013			1	LOCKWASHER, int, 3/8 x 11/16
	210-207			1	LUG, solder, pot, plain, 3/8

REAR



REF. NO.	PART NO.	SERIAL NO.		QTY.	DESCRIPTION
		EFF.	DISC.		
1	387-615			1	PLATE, overlay, rear Mounting Hardware: (not included)
	213-034			2	SCREW, thread cutting, 4-40 x 5/16 RHS, phillips
	387-434			1	PLATE, rear subpanel
2	352-010			1	HOLDER, fuse
	200-015			1	CAP, fuse
	210-873			1	WASHER, rubber, 1/2 ID x 11/16 OD
3	131-102			1	CONNECTOR, chassis mt., coaxial, female Consisting Of:
	129-041			1	POST, ground, 4-40 thread one end
	200-185			1	COVER, 3 wire motor base
	210-003			2	LOCKWASHER, ext., #4
	210-551			2	NUT, hex, 4-40 x 1/4
	211-015			1	SCREW, 4-40 x 1/2 RHS
	214-078			2	PIN, connecting, motor base
	377-041			1	INSERT, black urea
	386-933			1	PLATE, motor base mounting Mounting Hardware: (not included)
	211-552			2	SCREW, 6-32 x 2 BHS
	210-457			2	NUT, keps, 6-32 x 5/16
4	334-650			1	TAG, voltage rating Mounting Hardware: (not included)
	213-034			2	SCREW, thread cutting, 4-40 x 5/16 PHS, phillips

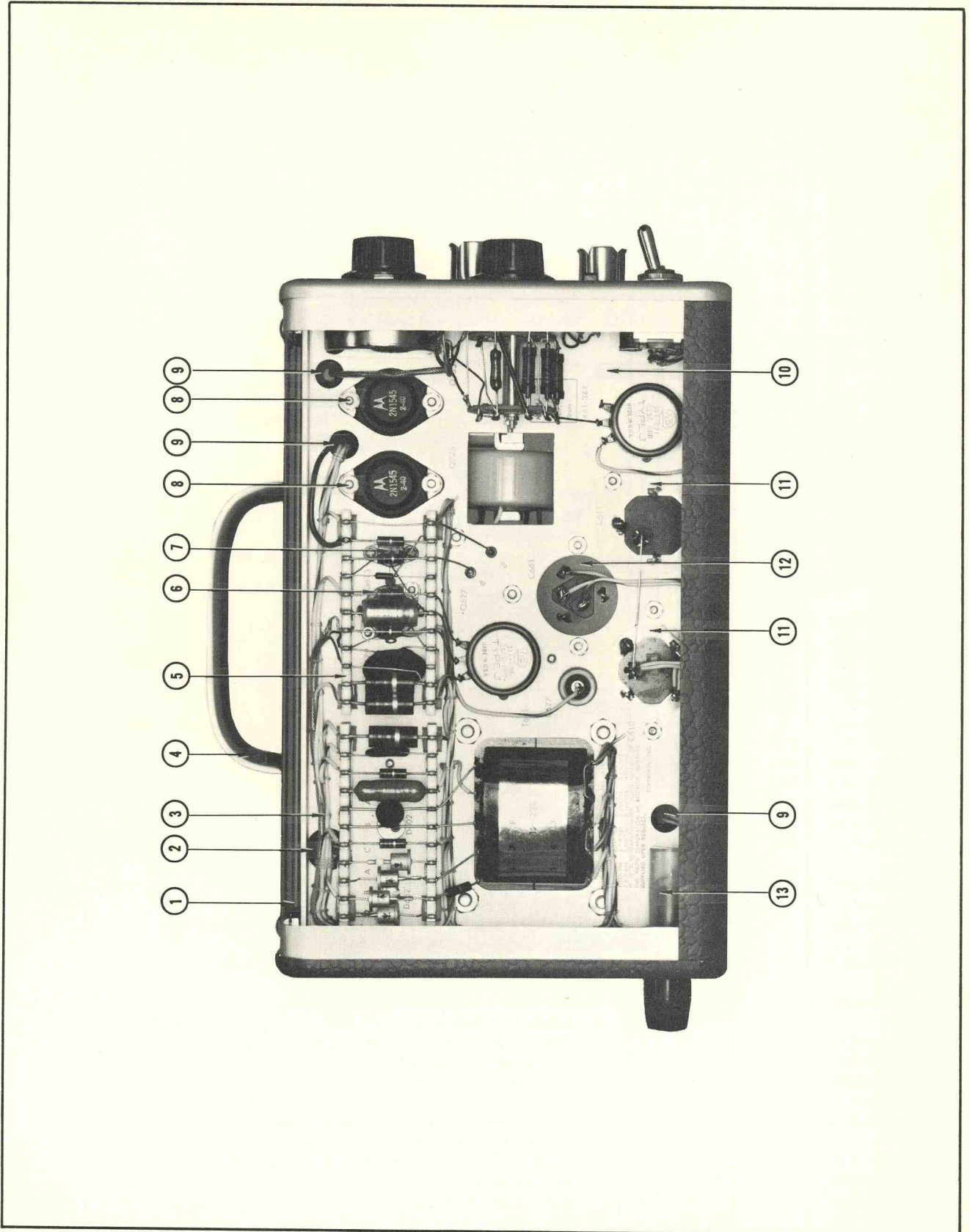
RIGHT SIDE



RIGHT SIDE

REF. NO.	PART NO.	SERIAL NO.		Q T Y.	DESCRIPTION
		EFF.	DISC.		
1	650-212			1	MERCURY SWITCH ASSEMBLY Includes:
	387-133			1	PLATE, switch mounting
	131-106			2	CONNECTOR, chassis mt., coaxial, female
	132-001			3	NUT, coupling
	132-002			3	SLEEVE, conductor, outer
	132-016			3	NUT, retaining
	132-028			3	INSULATOR
	132-029			3	CONDUCTOR
	132-030			3	TRANSITION, inner
	337-354			3	SHIELD, connector
	103-020			1	ADAPTER, lower, connector
	103-022			2	ADAPTER, upper, connector
	361-019			2	SPACER, disc, teflon, upper, connector
	361-020			1	SPACER, disc, teflon, lower, connector
	132-040			3	ADAPTER, panel Mounting Hardware For Each:
	211-038			4	SCREW, 4-40 x 5/16 FHS, phillips slot
	387-111			1	PLATE, printed circuit, glass laminated Mounting Hardware:
	211-001			2	SCREW, 2-56 x 1/4 RHS
	210-001			2	LOCKWASHER, int, #2
	204-042			1	BODY
	210-413			2	NUT, hex, 3/8-32 x 1/2
	210-012			2	LOCKWASHER, int, 3/8 x 1/2
	213-048			2	SCREW, set, 4-40 x 1/8 HHS, allen head
	352-027			1	HOLDER, magnet, nylon Mounting Hardware:
	211-019			2	SCREW, 4-40 x 1 RHS
	210-949			2	WASHER, 9/64 ID x 1/2 OD
	119-006			1	MAGNET, pocket
	211-512			1	SCREW, 6-32 x 1/2 FHS
	343-075			1	CLAMP, switch, toroid Mounting Hardware:
	211-564			2	SCREW, 6-32 x 3/8 hex, socket head cap Mounting Hardware for Switch: (not included)
	210-457			4	NUT, keps, 6-32 x 5/16
2	344-014			1	CLIP, spring, tube
3	210-413			2	NUT, hex, 3/8-32 x 1/2
	210-840			2	WASHER, .390 ID x 9/16 OD
4	213-044			2	SCREW, thread cutting, 5-32 x 3/16 PHS, phillips slot
5	212-037			1	SCREW, 8-32 x 1-3/4 Fil HS
	210-008			1	LOCKWASHER, int. #8
	210-809			1	WASHER, centering, resistor, 25 w
	210-462			1	NUT, hex, 8-32 x 1/2, 25 w resistor mounting
	212-004			1	SCREW, 8-32 x 5/16 BHS
6	212-516			4	SCREW, 10-32 x 2 in.
	210-812			4	WASHER, fiber, #10
	210-010			4	LOCKWASHER, int, #10
	210-564			4	NUT, hex, 10-32 x 3/8
7	361-015			1	SPACER, line filter
8	387-025			1	PLATE, line filter cap
9	354-068			1	RING, securing, poly.
10	210-201			1	LUG, solder, SE 4
	213-044			1	SCREW, thread cutting, 5-32 x 3/16 PHS, phillips slot
11	211-510			2	SCREW, 6-32 x 3/8 BHS
	210-202			1	LUG, solder, SE 6
	210-006			2	LOCKWASHER, int, #6
	210-407			2	NUT, hex, 6-32 x 1/4
12	200-256			1	COVER, capacitor, poly.

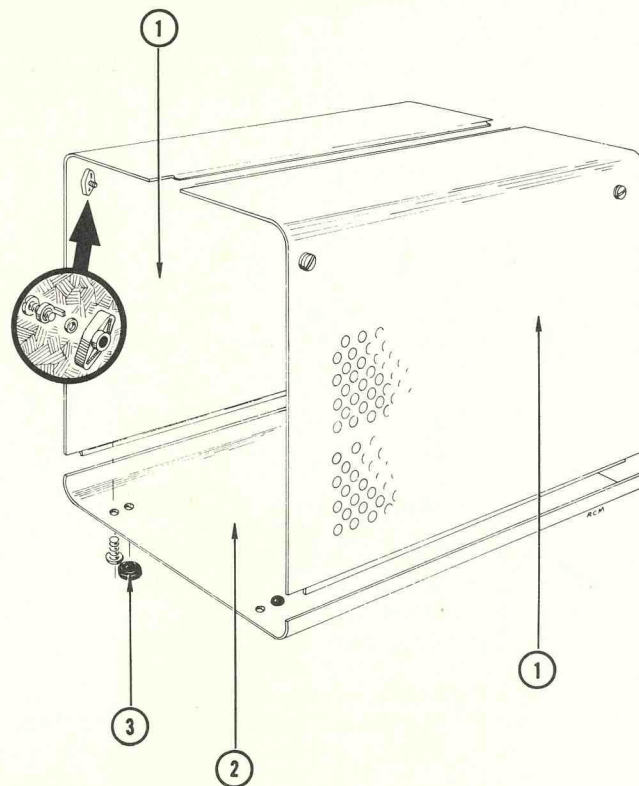
LEFT SIDE



LEFT SIDE

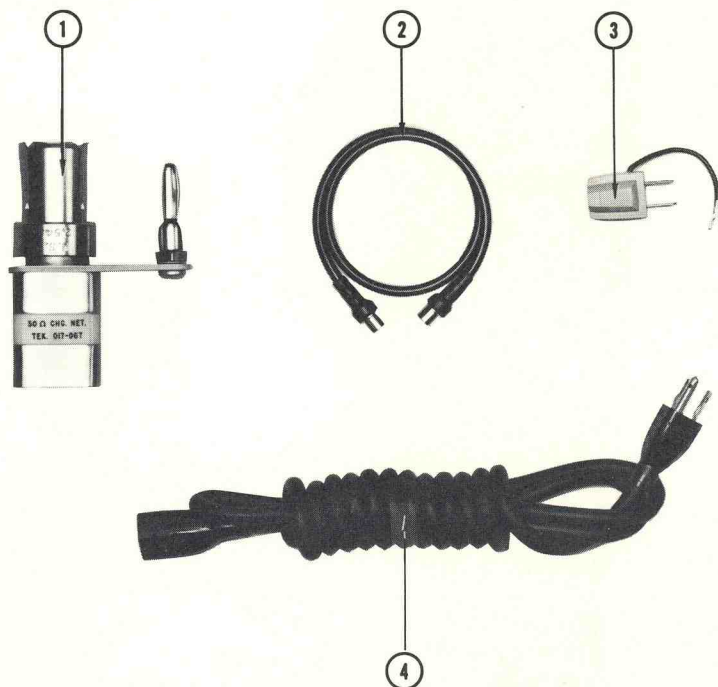
REF. NO.	PART NO.	SERIAL/MODEL NO.		Q T Y.	DESCRIPTION
		EFF.	DISC.		
1	381-174			1	BAR, extrusion channel, top support Mounting Hardware: (not included)
	211-542			4	SCREW, 6-32 x 5/16 THS, phillips slot
	210-457			4	NUT, keps, 6-32 x 5/16
2	348-005			1	GROMMET, rubber, 1/2
3	179-542	101	201	1	CABLE, harness
	179-669	202		1	CABLE, harness
4	367-007			1	HANDLE, drawer Mounting Hardware: (not included)
	212-023			2	SCREW, 8-32 x 3/8 BHS
5	124-091			4	STRIP, ceramic, 3/4 x 11 notches
	361-008			8	SPACER, nylon, molded
6	136-008			1	SOCKET, STM7G Mounting Hardware: (not included)
	214-034			2	BOLT, spade, 4-40 x 5/16
	210-801			2	WASHER, 5S x 9/32
	210-004			4	LOCKWASHER, int. #4
	210-406			2	NUT, hex, 4-40 x 3/16
7	136-095			1	SOCKET, 4 pin, transistor Mounting Hardware: (not included)
	213-113			2	SCREW, 2-32 x 5/16 RHS, phillips slot
8	129-049	101	579	4	POST, terminal, transistor mounting
	210-006			4	LOCKWASHER, int. #6
	210-407			4	NUT, hex, 6-32 x 1/4
	386-978	101	529	2	PLATE, mica, transistor insulating
	387-345	530		2	PLATE, insulator, anodized alum.
	210-900			4	WASHER, bakelite, transistor mounting (not shown)
	210-804	101	579	4	WASHER, 8S x 3/8 (not shown)
	210-008	101	579	4	LOCKWASHER, int. #8 (not shown)
	210-409	101	579	4	NUT, hex, 8-32 x 5/16 (not shown)
	210-202	580		4	LUG, solder, SE6
	210-803	580		4	WASHER, steel, 6L
	211-513	580		4	SCREW, 6-32 x 5/8 BHS
9	348-003			3	GROMMET, rubber, 5/16
10	441-384			1	CHASSIS Mounting Hardware: (not included)
	211-541			5	SCREW, 6-32 x 1/4 FHS, phillips slot
11	386-255			2	PLATE, metal, capacitor mounting Mounting Hardware For Each: (not included)
	211-534			2	SCREW, 6-32 x 5/16 PHS, w/lockwasher
	210-006			2	LOCKWASHER, int. #6
	210-407			2	NUT, hex, 6-32 x 1/4
12	386-252			1	PLATE, fiber, capacitor mounting Mounting Hardware: (not included)
	211-534			2	SCREW, 6-32 x 5/16 PHS, w/lockwasher
	210-006			2	LOCKWASHER, int. #6
	210-407			2	NUT, hex, 6-32 x 1/4
13	200-237			1	COVER, insulator, fuse holder

CABINET



REF. NO.	PART NO.	SERIAL NO.		Q T Y.	DESCRIPTION
		EFF.	DISC.		
1	387-212			2	PLATE, cabinet side, left & right
					Each Includes Mounting Hardware:
	105-009			2	STOP
	210-470			2	NUT, cabinet fastener
	210-870			2	WASHER, 9/64 ID x 5/16 OD
	213-040			2	SCREW, fastening, 6-32 x 3/8
2	387-211			1	PLATE, cabinet bottom
					Mounting Hardware: (not included)
	211-565			4	SCREW, 6-32 x 1/4 THS, phillips slot
3	348-013			4	FOOT, rubber, 1/2"

ACCESSORIES



REF. NO.	PART NO.	SERIAL NO.		Q T Y.	DESCRIPTION
		EFF.	DISC.		
1	017-060	101	209	1	CHARGING NETWORK
	017-067	210		1	CHARGING NETWORK
2	017-502			3	50 Ω 5 NSEC CABLE, RG 8/AU
3	103-013			1	ADAPTER, power cord, 3 wire to 2 wire
4	161-010			1	CORD, power, 16 ga. 8 ft., 3 wire

PARTS LIST

Values are fixed unless marked Variable.

Bulbs

Ckt. No.	Tektronix Part Number	Description	S/N Range
B601	150-019	Neon, Type NE-2E	Pilot Light

Capacitors

Tolerance $\pm 20\%$ unless otherwise indicated.

Tolerance of all electrolytic capacitors are as follows (with exceptions):

3 V — 50 V = -10% , $+250\%$

51 V — 350 V = -10% , $+100\%$

351 V — 450 V = -10% , $+50\%$

C600	281-559	1500 pf	Cer.	500 v	
C601	281-559	1500 pf	Cer.	500 v	
C610	*290-090	2000 μ f	EMC	20 v	
C611	*290-090	2000 μ f	EMC	20 v	
C614	290-107	25 μ f	EMT	25 v	
C627	290-015	100 μ f	EMT	25 v	
C661A,B	*290-040	2 x 40 μ f	EMC	250 v	
C679	283-008	.1 μ f	Disc Type	500 v	
C696	283-000	.001 μ f	Disc Type	500 v	
C750	Use 283-057	.1 μ f	Disc Type	200 v	X202-up

Diodes

D602A,B	152-035 (2)	1N563A	Silicon
D612	152-064	10 v $\frac{1}{4}$ w 10%	Zener
D662A,B,C,D	152-047 (4)	1N2862 (or equal)	Silicon

Fuses

F601	159-025	.5 Amp. 3AG Fast-Blo 117 v operation 50-60 cycle
	159-028	.25 Amp. 3AG Fast-Blo 234 v operation 50-60 cycle

Resistors

Resistor are fixed, composition, $\pm 10\%$ unless other wise indicated.

R601	302-683	68 k	$\frac{1}{2}$ w		
R610	308-165	.5 Ω	5 w	WW	5%
R612	301-621	620 Ω	$\frac{1}{2}$ w		5%
R614	311-008	2 k	2 w	Var.	FREQUENCY
R615	302-332	3.3 k	$\frac{1}{2}$ w		
R616	302-272	2.7 k	$\frac{1}{2}$ w		
R626	308-219	6 Ω	25 w	WW	5%
R660	302-100	10 Ω	$\frac{1}{2}$ w		
R661	306-182	1.8 k	2 w		
R678	306-152	1.5 k	2 w		

Resistors (continued)

Ckt. No.	Tektronix Part Number	Description			S/N Range		
R679	306-152	1.5 k	2 w	Var	Prec.	110-V SET	
R690	311-071	2.25 k					
R691	309-036	18 k	$\frac{1}{2}$ w				
R692	309-020	1.8 meg	$\frac{1}{2}$ w				
R694	309-153	20 k	$\frac{1}{2}$ w				
R695	309-279	180 k	$\frac{1}{2}$ w	Var.	Prec. WW	1% AMPLITUDE	
R696	311-053	20 k					
R744	302-681	680 Ω	$\frac{1}{2}$ w				
R750	308-013	200 Ω	10 w				
	302-181	180 Ω	$\frac{1}{2}$ w				
R751	306-473	47 k	2 w				101-201 202-up
R752	302-473	47 k	$\frac{1}{2}$ w				
R753	302-472	4.7 k	$\frac{1}{2}$ w				
R756	302-473	47 k	$\frac{1}{2}$ w				
R757	306-473	47 k	2 w				
R758	302-472	4.7 k	$\frac{1}{2}$ w				

Switches

	Unwired	Wired		
SW601	260-199		Toggle SPST	POWER ON PULSE POLARITY VOLTAGE RANGE
SW679	260-212		Slide	
SW690	260-410	*262-419	Rotary	
SW750	*260-334		Mercury Switch, Checked	
TK601	260-413		Thermo cut-out 175°F	

Transformers

T600	*120-164	Toroid 3T TD12
T601	*120-239	L. V. Power
T750	*120-240	Toroid TD36

Transistors

Q613	151-042	Transistor	2N1378
Q627	151-060	Transistor	2N1545
Q725	151-060	Transistor	2N1545
Q735	151-060	Transistor	2N1545

Electron Tubes

V679	154-075	0B2
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MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages. If it does not, your manual is correct as printed.

TYPE 109

PARTS LIST CORRECTION

CHANGE TO:

SW750

*260-0282-02

Mercury Switch, Checked

