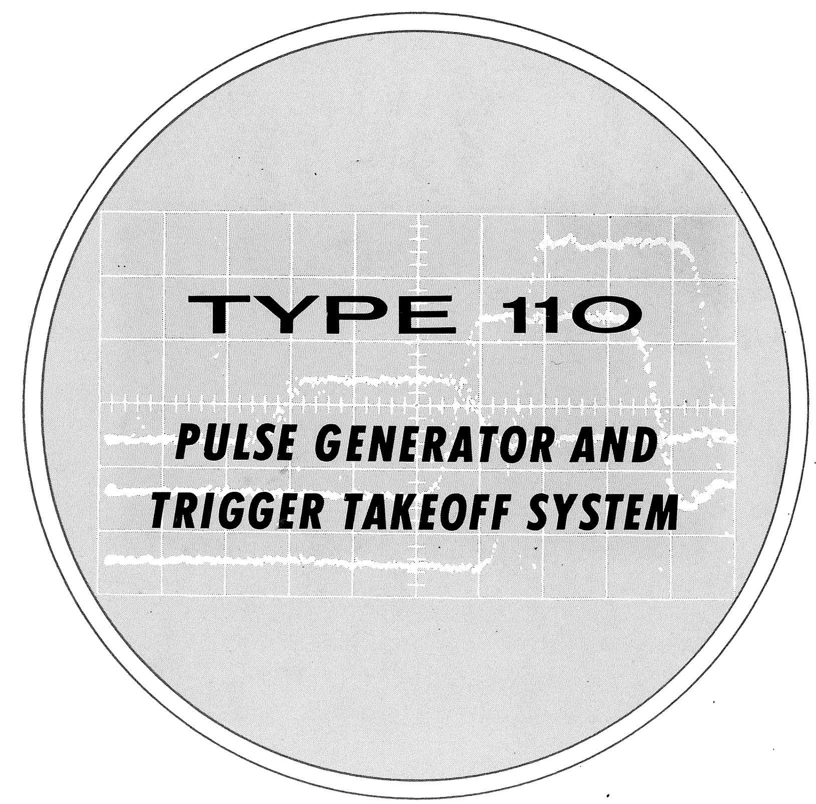
S/N 443

INSTRUCTION MANUAL

M-2040



TYPE 110

PULSE GENERATOR AND TRIGGER TAKEOFF SYSTEM

P. O. Box 500 • Beaverton, Oregon, U.S.A • Phone: MItchell 4-0161 • Cables: Tektronix

070-222

WARRANTY

All Tektronix instruments are fully guaranteed against defective materials and workmanship for a period of one year. Should replacement parts be required, whether at no charge under warranty or at established net prices, notify us promptly. You should include the instrument type, serial number, and sufficient details to identify the required parts. We will ship them prepaid (via air if requested) as soon as possible, usually within 24 hours.

Tektronix transformers manufactured in our own plant carry an indefinite warranty.

All price revisions and design modification privileges reserved.

CONTENTS

Section 1 Specifications

Section 2 Operating Instructions

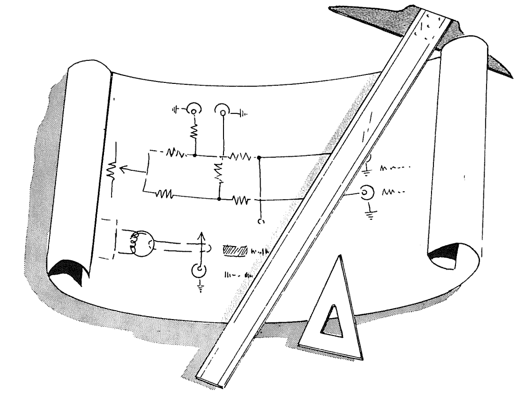
Section 3 Applications

Section 4 Circuit Description

Section 5 Maintenance

Section 6 Calibration Procedure

Section 7 Accessories Section



SPECIFICATIONS

INTRODUCTION

General Information

The Tektronix Type 110 Pulse Generator and Trigger Takeoff System is two instruments in one: a fast-rise pulse generator and a trigger takeoff system. The fast-rise pulse is generated by means of a high-repetition-rate mercury relay. The trigger takeoff system provides an efficient method of deriving triggers from incoming signals for use in triggering external equipment.

The Type 110 is designed to be used with 50-ohm nanosecond pulse systems. The Type 110 serves independently the two functions of pulse generation and an oscilloscope trigger source. Although the Type 110 can be used with most oscilloscopes, the large regenerated trigger output is designed especially to suit the Tektronix Sampling System. The system, when used with the Type 110, consists of the Type 113 Delay Cable, the Type N Sampling Plug-In Unit, and a Tektronix plug-in type oscilloscope.

The design of the Type 110 includes a high degree of inherent flexibility so that it may be used with other systems or devices. That is, wherever a fast-rise pulse and/or signal-derived trigger source is needed. The trigger can be efficiently derived from the pulse generator section of the Type 110 or from an external signal source without significantly disturbing the signal itself.

PULSE GENERATOR

Pulse Output

±50 volts maximum calibrated output on internal power supply; ±300 volts maximum allowed from external sources.

Pulse Risetime

Less than 0.25 nsec (nanosecond or 10^{-9} second). Photograph of pulse is shown in Fig. 1-1.

Pulse Duration

From approximately 0.5 nsec to a maximum of 40 nsec at 720 cps; a maximum of 300 nsec at 360 cps using a single contact (unused contact is disconnected from power supply). Pulses longer than 0.5 nsec obtained with external charge lines.

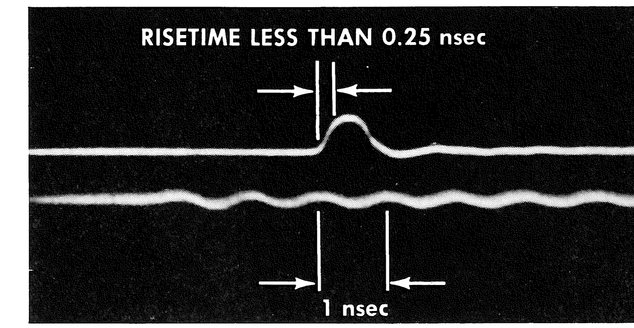


Fig. 1-1. A double exposure photograph of the output pulse from the Type 110 (no external charge line) and a 1 gigacycle/sec timing train. The waveforms are displayed on a Tektronix 0.12 nsec risetime research-type oscilloscope. This photograph shows the risetime to be well under 0.25 nsec. The minimum pulse width is approximately 0.5 nsec. Note the freedom from overshoot.

Output Impedance

50 ohms.

Repetition Rate

720 pulses per second nominal, free running or line sync.

Alternate Pulses

Unequal charge lines produce alternate pulses of different time durations (see Fig. 1-2).

External charge voltage permits alternate pulses of different amplitudes and/or polarity.

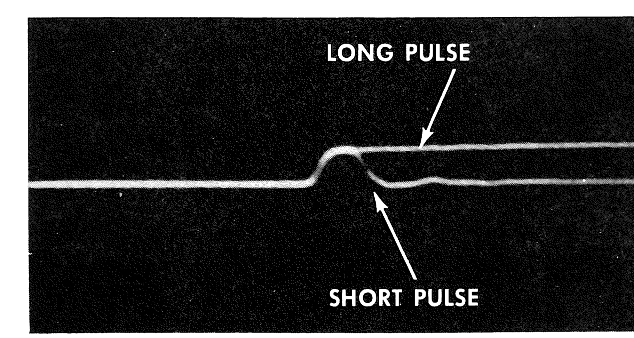


Fig. 1-2. The alternate pulse feature is used to show a short (no charge line) and a long pulse (20 nsec charge line) being generated by the Type 110. Note that there is no appreciable waveform discontinuity due to the addition of a charge line.

TRIGGER TAKEOFF SYSTEM

Input Impedance

50 ohms.

Transmission Loss and Reflections

Less than 2.5% of signal being viewed.

Direct External Trigger Input

With an input pulse of 3 nsec duration or longer: 4 mv to 10 volts, repetition rates to 10 mc, rising to 12 mv minimum at 100 mc.

Input Signals Through Takeoff System

The trigger takeoff system delivers 20% of the input signal voltage to the trigger channel; thus, 20 mv to 50 volts into the takeoff system provides essentially the same range of triggering signals as given under the "Direct External Trigger Input" heading above. (20% of the input signal voltage is applied to the trigger channel with only a 2% loss in the signal voltage; therefore the signal voltage returned from the trigger takeoff is 98% of the input.) Figs. 1-3 through 1-7 show the triggering characteristics of the Type 110.

Regenerated Trigger

Output Signal—±10 volts, 200 nsec duration, maximum repetition rate of 100 kc.

Resolving Time—10 nsec. The signal pulse period may vary irregularly to a minimum of 10 μsec (instantaneous signal repetition rate must be less than approximately 100 kc). When the signal period is less than 10 μsec, count down occurs. The signal repetition rate must be increasingly regular above 100 kc for satisfactory count down. If the signal residual FM is less than 0.1%, useful count down can be obtained up to approximately 100 mc.

External Trigger Output

Available without going through the regenerator, since in certain special cases one may desire to operate an oscilloscope directly, rather than on the regenerated trigger.

Regenerator Output Time Delay

Nominally 20 nsec with an additional 1 nsec switchable from the front panel.

OTHER SPECIFICATIONS

Power Requirements

Line Voltage—105 to 125 volts, or 210 to 250 volts, 50-60 cycles.

Power—Approximately 45 watts at 125 volts line voltage.

Mechanical

Construction—Aluminum alloy chassis.

Finish—photo-etched, anodized front and rear panels.

Textured-aluminum cabinet with a vinyl-based blue finish.

Dimensions—15$\frac{5}{8}$" long, 6$\frac{7}{8}$" wide, 10$\frac{1}{4}$" high overall.

Weight—14$\frac{1}{2}$ lbs.

Accessories

1—2 nsec cable, RG-58A/U, 17" long, (017-505).

1—5 nsec cable, RG-8A/U, 40" long, (017-502).

1—20 nsec cable, RG-8A/U, 157" long, (017-504).

1—Power cord.

1—Three wire adapter.

WAVEFORMS SHOWING MARGINAL CONDITIONS

The following waveform photographs were purposely chosen to illustrate the performance of the Type 110 Trigger Takeoff System under marginal conditions. The waveforms were displayed on a Tektronix Type 531 Oscilloscope and Type N Sampling Plug-In Unit combination. The Type 110 was used as the signal and trigger source to operate the combined instruments. A Type 113 Delay Cable Unit was inserted in series with the signal transmission line to delay the pulse the required amount of time.

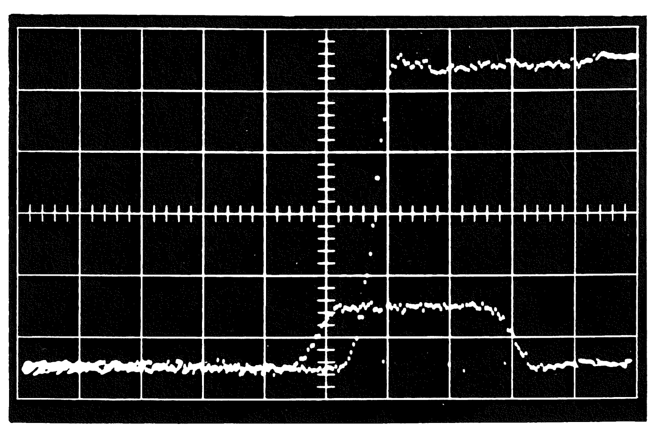


Fig. 1-3. The alternate pulse feature of the Type 110 pulse generator is being used to generate a large, long pulse and a short, small pulse. The trigger takeoff system's sensitivity is set for maximum. The signal level is 100 mv/cm, and the sweep speed is 1 nsec/cm. There is clearly less than 1 nsec time difference in triggering on the 100 mv, 3 nsec and the 500 mv long-step signals.

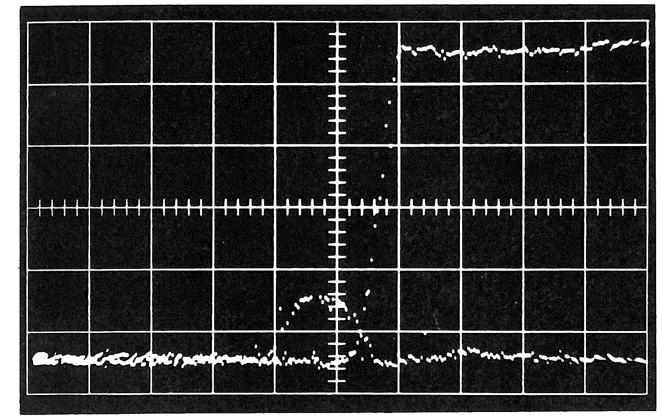


Fig. 1-4. This picture shows the same conditions as in Fig. 1-3, except the small pulse is now only 1 nsec wide. The time shift relative to the large step is just over 1 nsec.

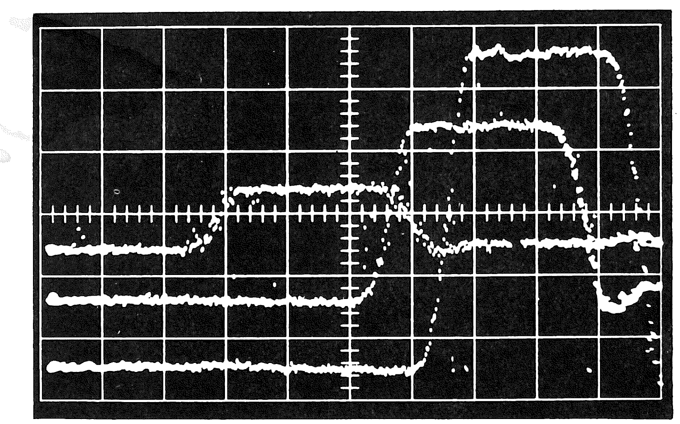


Fig. 1-5. The system is operating at a sensitivity of 20 mv/cm. A triple exposure, positioned vertically to align the 50% points, allows easy measurement of the time slip. Under these extreme conditions, the smallest pulse has an energy of about 24 millipicojoules. The trigger takeoff system then removes approximately 1 millipicojoule for application to the switched system of amplifiers and the trigger regenerator.

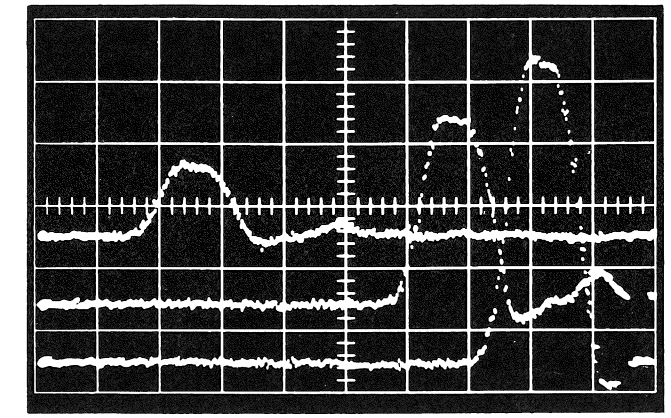


Fig. 1-6. The amplifiers in the trigger channel (used in the previous 3 pictures) are switched out. The sensitivity is 2 v/cm. The smallest of the 1 nsec wide pulses furnishes approximately 0.4 v to the trigger regenerator, through the trigger takeoff system. This picture is of interest since this is the narrow-pulse response which is obtainable with both the 110 and the N Units, when either unit is externally triggered with signals between 0.4 and 2 v.

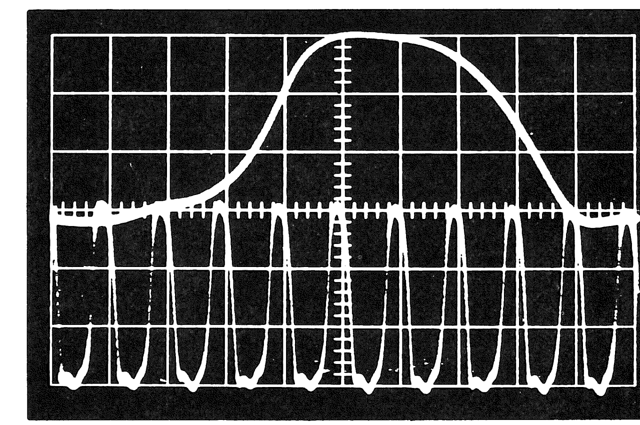
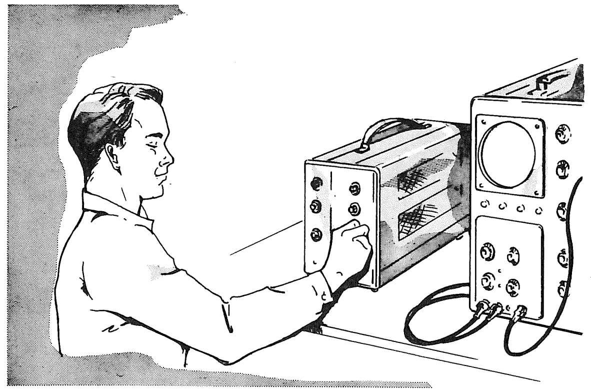


Fig. 1-7. Double exposure shows a 60-mv, 100-mc continuous pulse train at equivalent sweep times of 1 nsec/cm and 10 nsec/cm. The Type 110 derives a trigger from the signal, permitting the Tektronix Sampling System to operate without external triggers, counting down from 100-mc to the 100-kc sampling rate of the N Unit.



SECTION 2

OPERATING INSTRUCTIONS

GENERAL INFORMATION

The Type 110 Pulse Generator and Trigger Takeoff System is, as the name suggests, actually two units in one. The Pulse Generator portion of the instrument generates fast-rising pulses at repetition rates of approximately 670 to 770 cps. The risetime of the pulses is less than 0.25 nanosecond, and both the amplitude and duration are variable.

The Trigger Takeoff System of the Type 110 is intended primarily as a trigger source for an oscilloscope. A sample of the signal from some other device is amplified, attenuated, and/or inverted, as required, to form a suitable triggering signal for the oscilloscope. This triggering signal may be taken from either of two outputs on the Type 110. At one output the triggering signal is proportional to the input signal. At the other output the signal is a constant triggering pulse 10 volts in amplitude, about 250 nanoseconds in duration, with a repetition rate of 100 kc or less. The repetition rate, in most cases, depends upon the repetition rate of the incoming signal. The unit counts down from signal frequencies up to 100 megacycles. The 100-kc (or less) output can be used to trigger oscilloscopes that cannot be triggered at frequencies approaching 100 megacycles.

Although the Type 110 is intended primarily for use with the Tektronix Type N Sampling Plug-In Unit, it can be used equally well with other sampling systems and with conventional oscilloscopes. The Pulse Generator can, of course, be used whenever pulses are required with risetimes on the order of 0.2 nanosecond.

The Type 110 is fully transistorized and requires no warm-up time before operating; as soon as the power switch is turned on it is ready to operate.

Cabling Considerations

The Type 110 is designed for use with 50-ohm cables. All input and output signals must therefore be applied through 50-ohm cables or suitable impedance-matching devices. The only exceptions are the cables used to supply external power to the pulser section to charge the lines. The impedance of these cables is not critical, and virtually any value can be used.

If the proper signal cables are not used, reflections will occur which will produce undesirable side effects. The GR 50-ohm cable connectors were chosen for ease of connection and their reasonably constant impedance.

Physical Arrangement

The Type 110 is arranged physically so that the entire Pulse Generator section is on the left half of the instrument, and the Trigger Takeoff System is on the right half. This arrangement pertains not only to the location of front panel controls, but also to the location of plugs and receptacles at the rear. The POWER switch and pilot light, however, pertain to both sections.

PULSE GENERATOR SECTION

Selecting the Pulse Duration

Pulses from the Type 110 are generated by discharging charged coaxial lines into a load through a solenoid-operated mercury switch. The unit 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 back 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 ten-nanosecond 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 (see Fig. 1-3).

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 50Ω CHG. LINE 1 connector and the other end of the cable is connected to the 50Ω CHG. LINE 2 connector. Since the same cable is used to generate both pulses of a pair, all pulses have exactly the same duration. 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 SW 750. The pulse length will be twice the charge line delay plus about one nanosecond.

Maximum pulse duration is limited by the amount of time that the reed of the mercury switch remains between contacts. In normal operation, the maximum pulse duration is

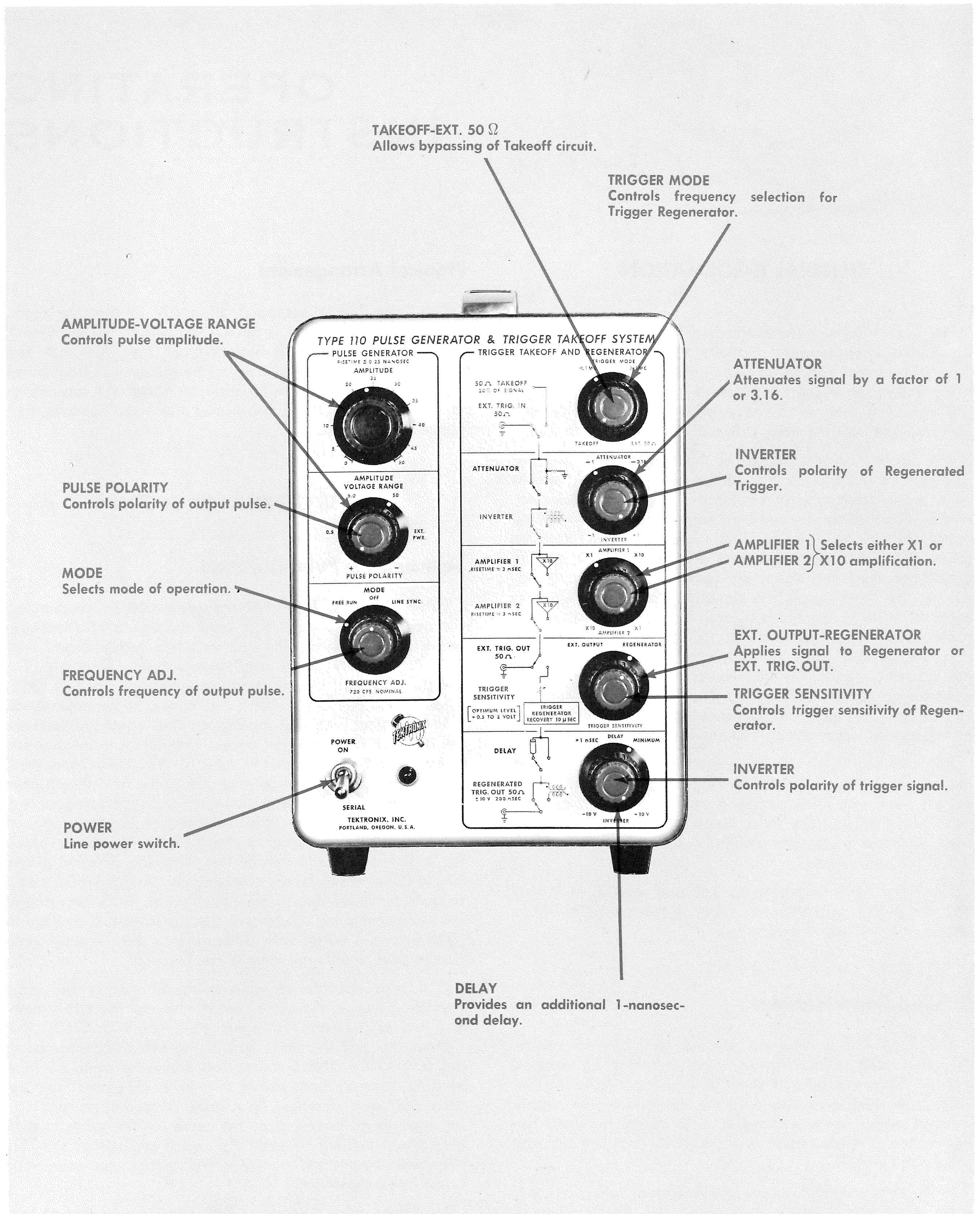


Fig. 2-1. Functions of the front-panel controls.

Operating Instructions — Type 110

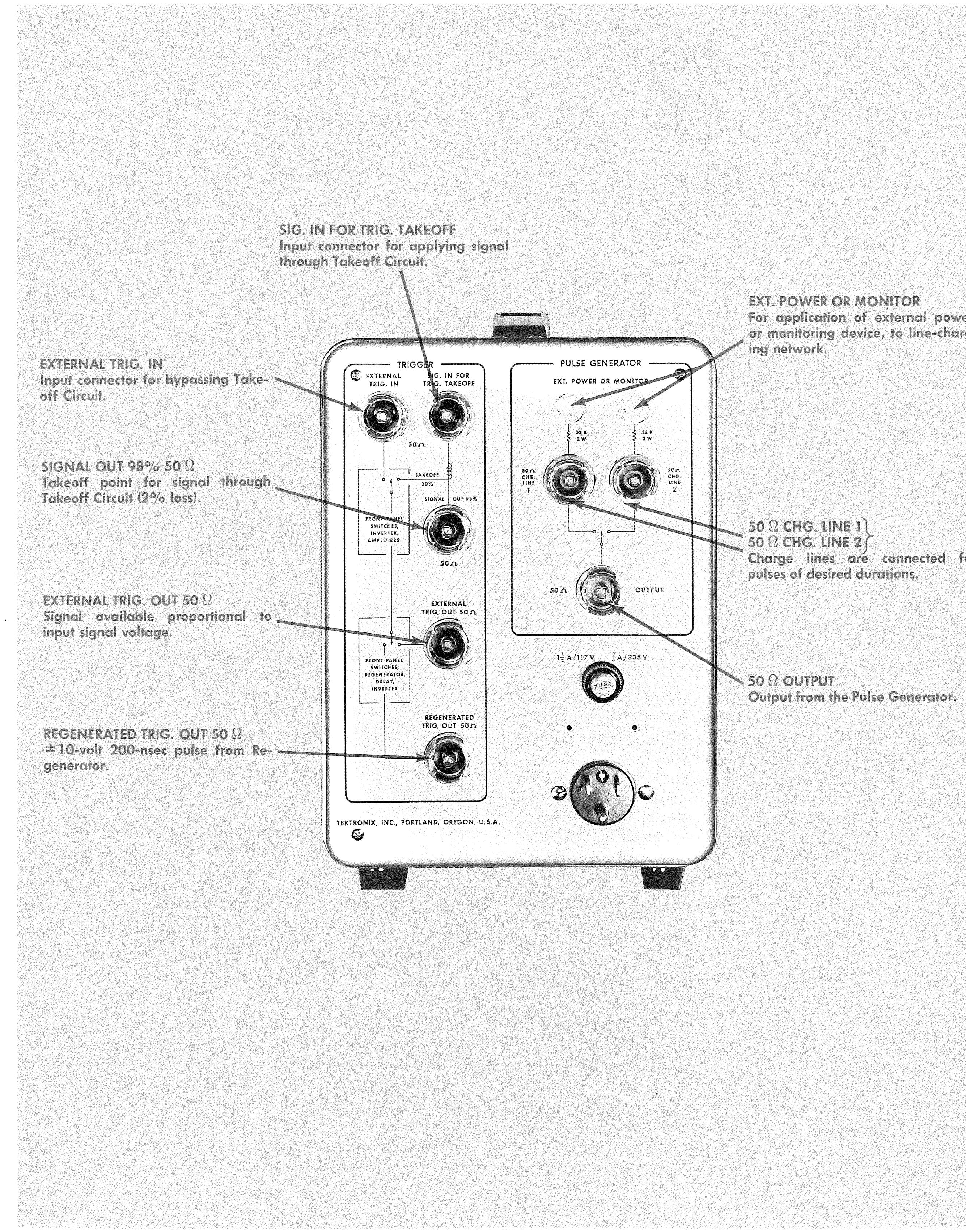


Fig. 2-2. Functions of the rear-panel connectors.

about 40 nanoseconds at a 720-cps repetition rate. To generate longer pulses, it is necessary to disable one side of the line-charging network by disconnecting either R751 or R756. Then, by using only one charge line, pulse durations up to 300 nanoseconds can be satisfactorily obtained. The repetition rate of these pulses will be in the vicinity of 360 cps rather than 720 cps. The minimum pulse duration in either case is fixed at about 0.5 nanosecond by the lead lengths within the Type 110.

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 110. In these applications, 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.

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. position. Then connect the external power source or sources to the EXT. POWER OR MONITOR connectors on the back 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 110 to charge the lines should be limited to approximately 600 volts 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 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. Alternate pulses of different amplitudes can also be produced when the internal voltage supply is being used by connecting 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.

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 negative source and the other line with a positive source. If identical pulse widths are required for both the positive and the negative pulses, it will be necessary to select identical charge cables. The same charge cable cannot be charged simultaneously by both a positive and a negative voltage; for this reason a single charge cable cannot be used.

Adjusting the Pulse Frequency

The output frequency can be adjusted between about 670 and 770 cps with the FREQUENCY ADJ. control.

Selecting the Mode

With the MODE switch in the FREE RUN position, the Pulse Generator will free run at a frequency determined by the setting of the FREQUENCY ADJ. control. This is the mode of operation which will be used for most applications of the Type 110. However, if desired, the output of the Pulse Generator may be synchronized with the 60-cps ac line voltage by placing the MODE switch in the LINE SYNC position and setting the FREQUENCY ADJ. control to approximately midscale. In this mode of operation, the output of the Pulse Generator will be 720 cps and will be synchronized with the ac line. Some jitter relative to the ac line will probably exist due to variations in the recovery and transit times of the mercury switch reed.

When only the Trigger Takeoff System is being used, the MODE switch should be placed in the OFF position to save wear on the mercury switch.

TRIGGER TAKEOFF SYSTEM

Selecting the Input Pulse

The Input Signal to the Trigger Takeoff System is applied through either of two connectors at the back of the instrument. When the signal is applied to the SIG. IN FOR TRIG. TAKEOFF connector, the TAKEOFF-EXT. 50Ω switch must be in the TAKEOFF position. When the signal is applied to the EXTERNAL TRIG. IN 50Ω connector, the TAKEOFF-EXT. 50Ω switch must be in the EXT. 50 Ω position.

A signal applied through the SIG. IN FOR TRIG. TAKEOFF connector is passed through a takeoff loop which taps off about 2% of the voltage of the signal. The remaining 98% of the signal is then available at the SIGNAL OUT 98% connector for observation or for use with other devices. The SIGNAL OUT 98% connector must be properly terminated in 50Ω for the Trigger Takeoff System to operate correctly. This termination may be either a 50Ω cable, connecting the signal to some other equipment, or a 50Ω termination network such as illustrated in Fig. 6-1.

The tapped-off portion of the input signal is stepped up, by step-up action of the takeoff loop, to an amplitude equal to about 20% of the amplitude of the input signal. The signal, then, is acted upon by the attenuator, inverter, and amplifiers to produce the desired triggering signal.

An input signal applied through the EXTERNAL TRIG. IN 50Ω connector bypasses the takeoff loop and is applied directly to the amplifier train.

The amplitude limits of the input pulses depend upon the use to which they are to be put.

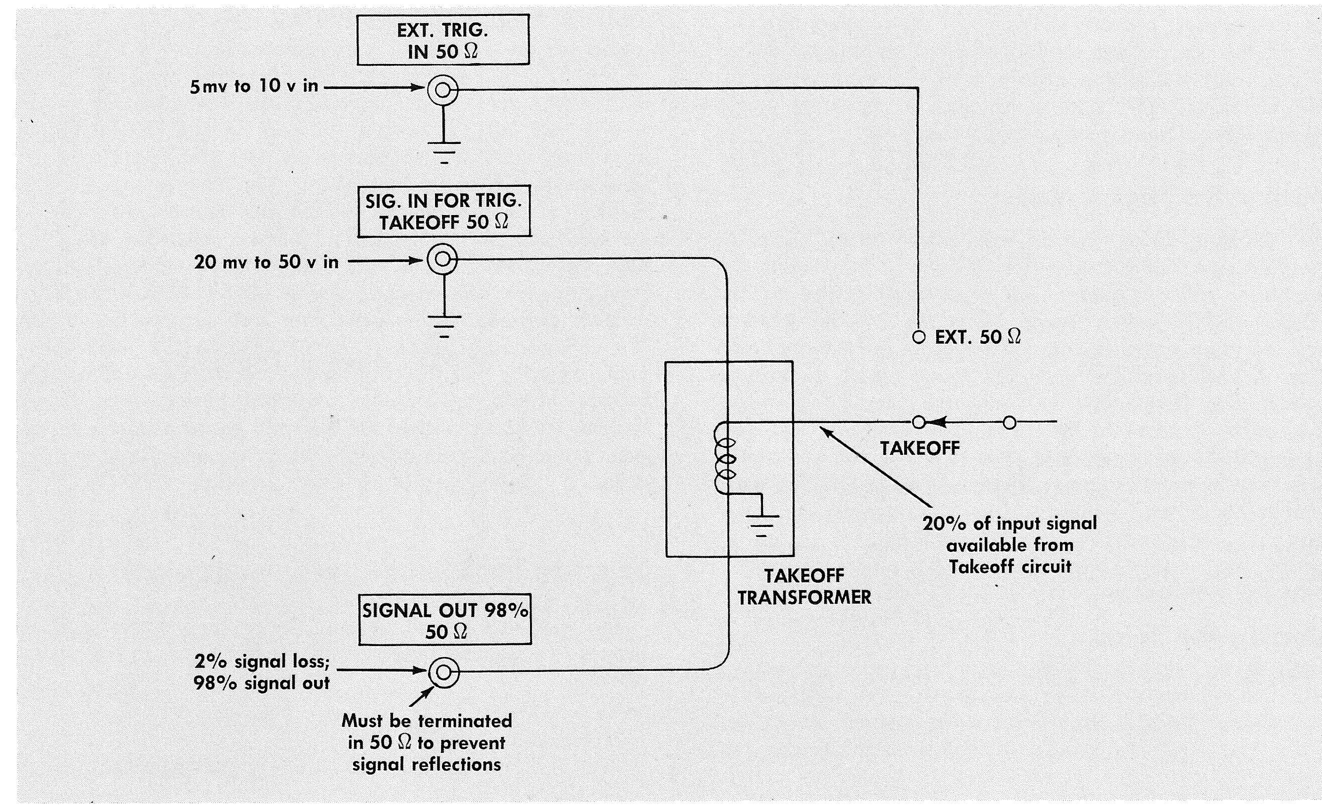


Fig. 2-3. Simplified diagram of the input connections for the Trigger Takeoff System.

Setting the Attenuator, Inverter, and/or Amplifiers

The input signal, from either the takeoff loop or the EXT. 50Ω OUT connector, is attenuated, inverted, and/or amplified as required to produce a signal of suitable amplitude and polarity at the EXT. OUTPUT-REGENERATOR switch.

The ATTENUATOR switch has two positions, ÷1 and ÷3.16. With the switch in the ÷3.16 position, the sample signal is attenuated by a factor of 3.16. With the switch in the ÷1 position, the signal bypasses the attenuator and no attenuation takes place.

When the INVERTER switch is in the —1 position, the incoming signal is inverted. When the INVERTER switch is in the +1 position, the signal bypasses the inverter and no inversion takes place.

Two X10 amplifiers are employed. When either of these amplifiers is switched into the circuit (switch in the X10 position), the signal is amplified by a factor of 10. When both amplifiers are switched in, the signal is amplified by a factor of 100. For proper operation, the output of neither amplifier should exceed about 1.5 volts peak-to-peak.

Through the use of the attenuator, inverter, and amplifiers a signal suitable for triggering the Trigger Regenerator may be obtained from any signal between 20 millivolts and 50 volts at the SIG. IN FOR TRIG. TAKEOFF connector or 5 millivolts to 10 volts at the EXT. 50Ω OUT. (Optimum triggering of the Trigger Regenerator occurs with a signal of 0.5 to 2.0 volts at the input to the Trigger Regenerator, although satisfactory triggering can occur outside these limits.)

Selecting the Output Trigger Pulse

The EXT. OUTPUT-REGENERATOR switch allows the output of the Trigger Takeoff System to be applied either to the EXT. TRIG. OUT 50Ω connector or to the input of the Trigger Regenerator. When the EXT. OUTPUT-REGENERATOR switch is in the EXT. OUTPUT position, the signal is applied to the EXT. TRIG. OUT 50Ω connector. This mode of operation is used primarily for troubleshooting the Type 110 (refer to Section 5), but it may be used when no regenerated trigger is desired. When the EXT. OUTPUT-REGENERATOR switch is in the REGENERATOR position, the signal is applied to the input of the Trigger Regenerator. If the signal is within the triggering requirements of the Trigger Regenerator, the Trigger Regenerator will produce a +10-volt, 200- to 250-nanosecond trigger pulse, provided the TRIGGER SENSITIVITY control is properly adjusted.

Adjusting the Trigger Sensitivity

When triggering signals are applied to the input of the Trigger Regenerator, the TRIGGER SENSITIVITY control must be adjusted to obtain stable triggering operation. To adjust the TRIGGER SENSITIVITY control, slowly rotate the control clockwise from the fully counterclockwise position until a steadily triggered signal is produced. Further clockwise rotation of the TRIGGER SENSITIVITY control will produce free-running operation. From the free-running position, back off the control and set for the most reliable triggering position. Best results are usually obtained by keeping the TRIGGER SENSITIVITY control as close to free running as possible without free running actually occurring.

Selecting the Trigger Mode

The counting down from an input signal up to 100 mc to an output signal of 100 kc or less is done in the Trigger Regenerator circuit. In general, for most stable triggering, the TRIGGER MODE switch should be in the >1 MC position when the input signal is over 1 megacycle in frequency and in the <1 MC position when the input signal is under 1 megacycle in frequency. At frequencies around 1 megacycle, either position of the switch can probably be used. Also, when the input signal is close to a low multiple of 100 kc, it may be advantageous to place the TRIGGER MODE switch in the >1 MC position.

Whenever there are triggering difficulties, it would be well to try the SYNC. MODE switch in both positions.

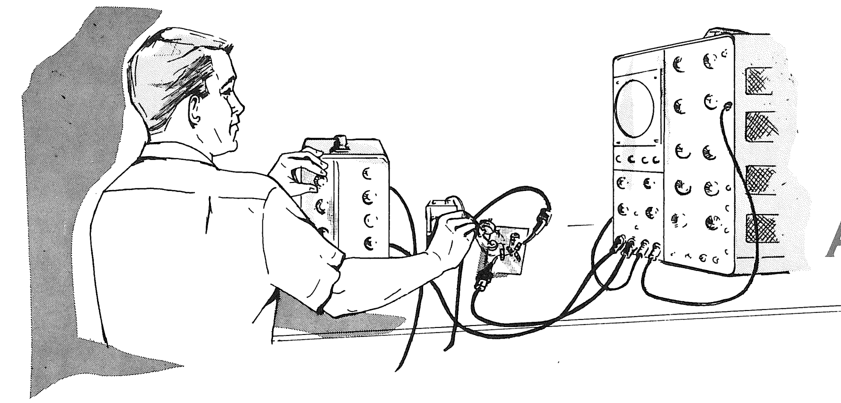
Selecting the Delay

There is an inherent signal delay through the Trigger Takeoff System and Trigger Regenerator of about 20 nanoseconds. Placing the DELAY switch in the +1 nSEC position introduces an additional 1 nanosecond delay at the output of the Trigger Regenerator. By observing the shift in the oscilloscope display as the additional 1 nanosecond delay is switched into the circuit (by moving the DELAY switch from the MINIMUM position to the +1 nSEC position), it is possible to calibrate the oscilloscope sweep speed. This method of calibrating the oscilloscope sweep speed should be used only with input signals of low repetition rates. At high repetition rates of the input signal, standing waves may influence triggering, and the DELAY control may not operate properly. These difficulties may occur when the delay in the cable between the REGENERATOR TRIG. OUT 50Ω connector and the oscilloscope becomes an appreciable fraction of the signal pulse repetition period. The DELAY control, therefore, should not be used as an absolute standard, but only as a handy tool which is quite useful in most cases.

Selecting the Regenerator Output Polarity

The +10-volt output of the Trigger Regenerator may be inverted by placing the lower INVERTER switch in the —10 V position.

SECTION 3



APPLICATIONS

GENERAL INFORMATION

Introduction

Some fundamental factors to consider when preparing the Type 110 Pulse Generator and Trigger Takeoff System for use with other equipment will be covered in this section of the manual. Several representative test systems will also be illustrated and discussed to provide a basis for the development of more 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 square-wave 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 t_w: the width 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 arbitary amplitude of 10% above the base line.

Tilt: a measure of the tilt of the top of the waveform when a long pulse is applied. 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.

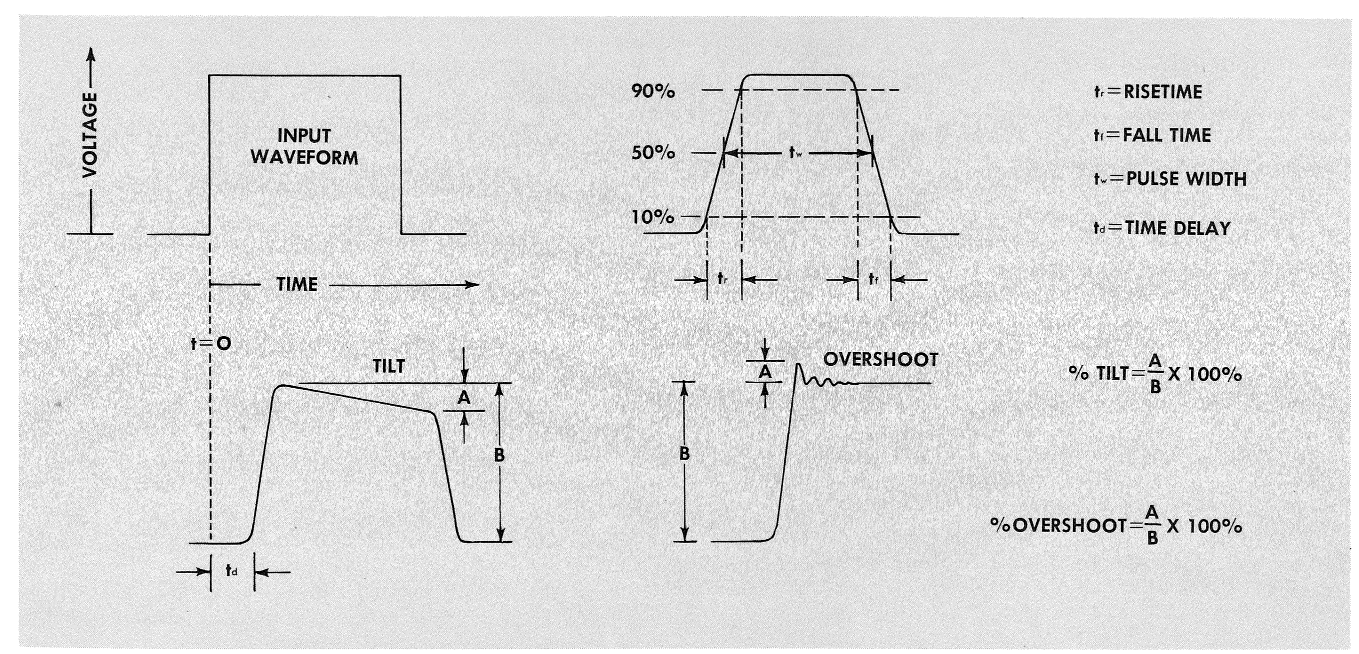


Fig. 3-1. Terms used in describing pulse characteristics.

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.

Risetimes

The risetime of any particular assembly of the Type 110, the Type N Sampling Plug-In Unit, and accessory pieces such as delay cables is a variable depending upon the delay 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 delay cables do not add properly using this method (the root-sum-square 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 110 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 110 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 double 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.

CABLE CONNECTIONS

Connecting the Type 110 to the Device Under Test

When connecting the Type 110 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 110 Pulse Generator 50Ω OUTPUT connector.

2. If the pulse is applied to a 50 Ω 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. The pulse is superimposed on the dc level applied across the load. Do not allow more than 200 volts dc to be applied to the Type 110 Pulse Generator 50 Ω OUTPUT connector. This limit will keep the internal components of the Type 110 from being damaged.

As an example, assume that the Type 110 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 pulse 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 50 Ω output of the Type 110 Pulse Generator (because it is not practical or possible), then it will be desirable to use a 50-ohm coaxial lead (between the Type 110 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.

Coupling Signals from the Device Under Test

Any of three methods may be used to "tap off" signal energy from the device under test for application to the Type 110 Trigger Takeoff System...series, shunt, or insertion.

1. The series method shown in Fig. 3-2 is basically as follows: Remove 50 ohms of any of the total resistance to ground across which the signal is being developed and connect a 50-ohm pigtail in its place. In actual practice, it may be possible, depending upon the value of R_L, to connect the pigtail between the lower end of R_L and ground without causing excessive change in loading.

2. In the shunt method, shown in Fig. 3-3, R_S must be selected large enough to have negligible loading effect on the circuitry. In some cases it may be desirable to increase R_L by an amount large enough to overcome this loading effect.

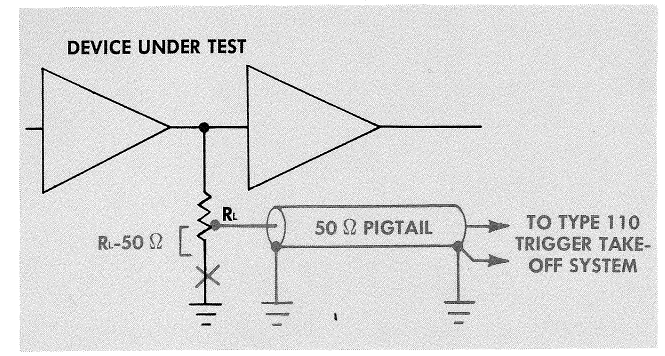


Fig. 3-2. Series method of tapping off signal for application to the Type 110 Trigger Takeoff System.

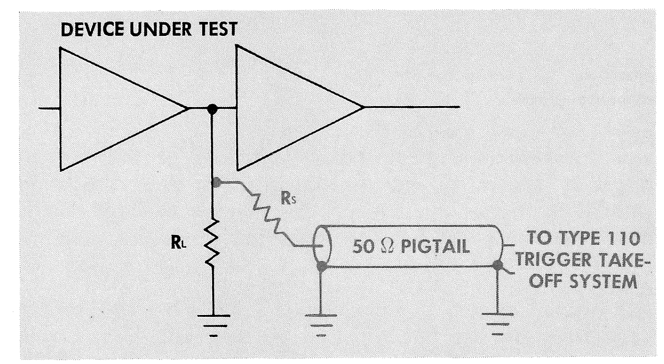


Fig. 3-3. Shunt method of tapping off signal for application to the Type 110 Trigger Takeoff System.

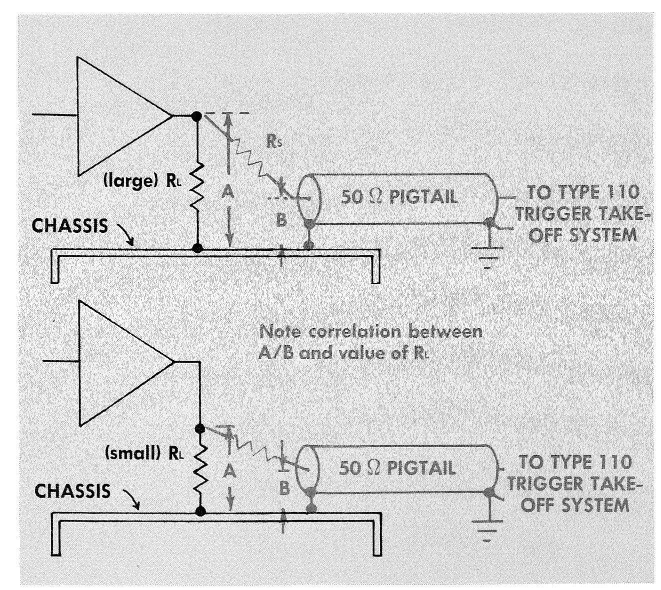


Fig. 3-4. Comparative physical positioning of R_S with large and small values of R_L.

The physical positioning of R_S, when using the shunt method, in relation to the chassis ground (see Fig. 3-4) will affect the pulse transmission fidelity. R_S should be positioned to provide the fastest rise, without overshoot, of the displayed pulse. In general, the larger the value of R_L, the higher the input end of R_S should be located or positioned above the chassis compared to the output end.

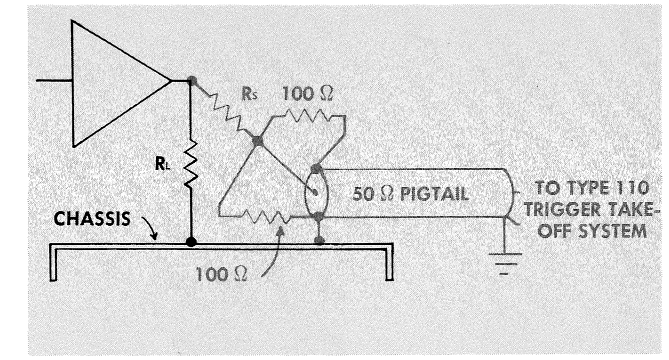


Fig. 3-5. Terminating the input end of the pigtail for use with the Type 110 Trigger Takeoff System.

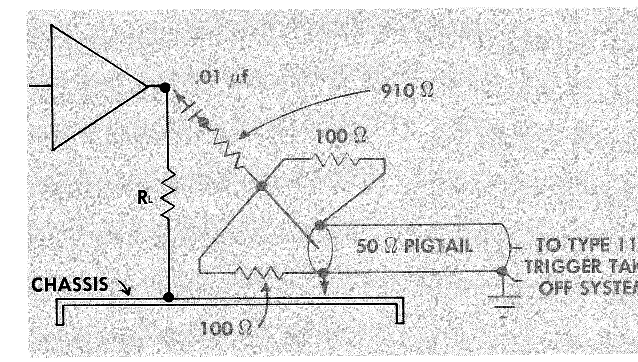


Fig. 3-6. Probe-type shunt method.

Two variations of the shunt method can be used when the input end of the pigtail is connected to a high impedance source. One method involves a series resistor which is connected to the input end of a 50-ohm pigtail or coaxial cable. If it is practical, it is frequently advantageous to have enough resistance in shunt with the 50-ohm cable to properly terminate reflections returning from a load. In Fig. 3-5, it is assumed $R_S + R_L >> 50\ \Omega$.

A second variation of the shunt method is shown in Fig. 3-6. This method is similar to the preceding one; the only difference is the addition of a small capacitor (.01 μf). Also, a typical value for R_S is indicated to be 910 ohms. As shown in the illustration, the pigtail can be used in the same manner as a low-capacitance probe to couple the signal from the device under test to the Type 110 Trigger Takeoff System.

3. The insertion method is the simplest of all. If the signal is already in a coaxial 50-ohm transmission line, the line is disconnected at a convenient point and the Type 110 Trigger Takeoff is connected in series to act as a "loop through" path to rejoin the signal transmission lines. This will cause a nominal 2% reflection at the Trigger Takeoff. The signal leaving the Trigger Takeoff will be attenuated 2%. The Trigger Takeoff System picks off a trigger signal which is 20% of the amplitude of the signal passed through

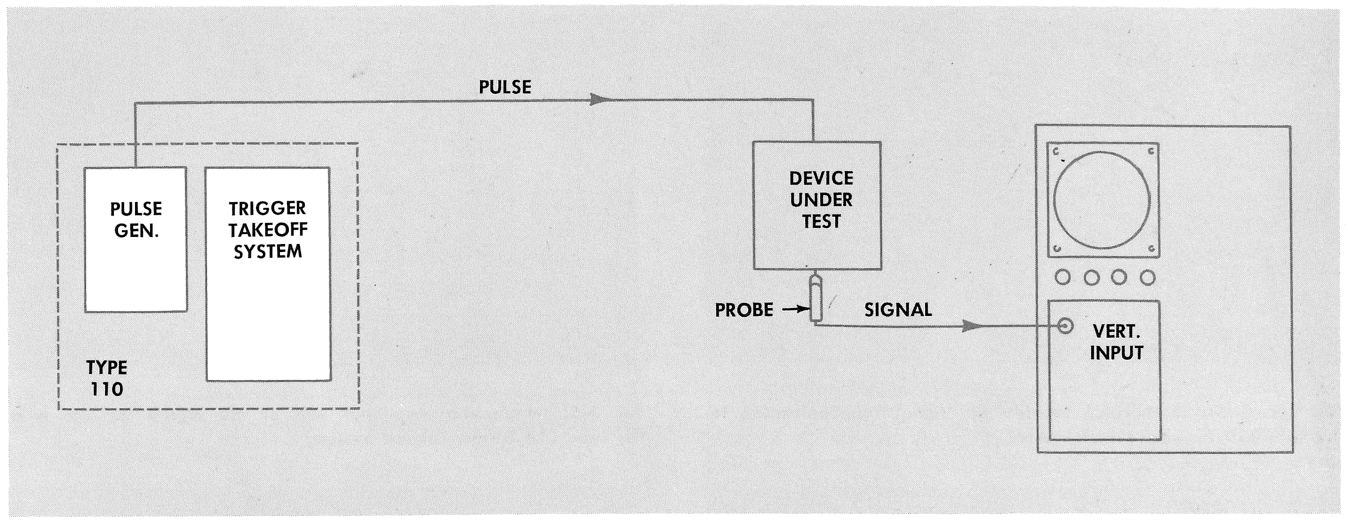


Fig. 3-7. Test setup where the device under test must be pulsed by the Type 110. The sweep is triggered internally from the signal being observed.

the system. The Type 110 can now be used to trigger an oscilloscope. The input signal to the oscilloscope may be obtained a number of ways, such as probes (when using conventional plug-in units), dividers (when using the Type N Unit), transformers, etc.

TEST SYSTEMS

Seven representative test systems involving the Type 110 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 more specialized systems required by specific applications.

The first system, shown in Fig. 3-7, is applicable where the device under test is pulsed by the Type 110 Pulse Generator. This system is used where the frequency response of the device falls within the passband limitations of the vertical amplifier system of the oscilloscope. Internal triggering is 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. 3-8. Here the device under test, besides being pulsed by the Type 110, 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 waveforms may be seen and compared on the oscilloscope screen. Passband limitations of the oscilloscope must be taken into consideration for this system as well as the next system to be described.

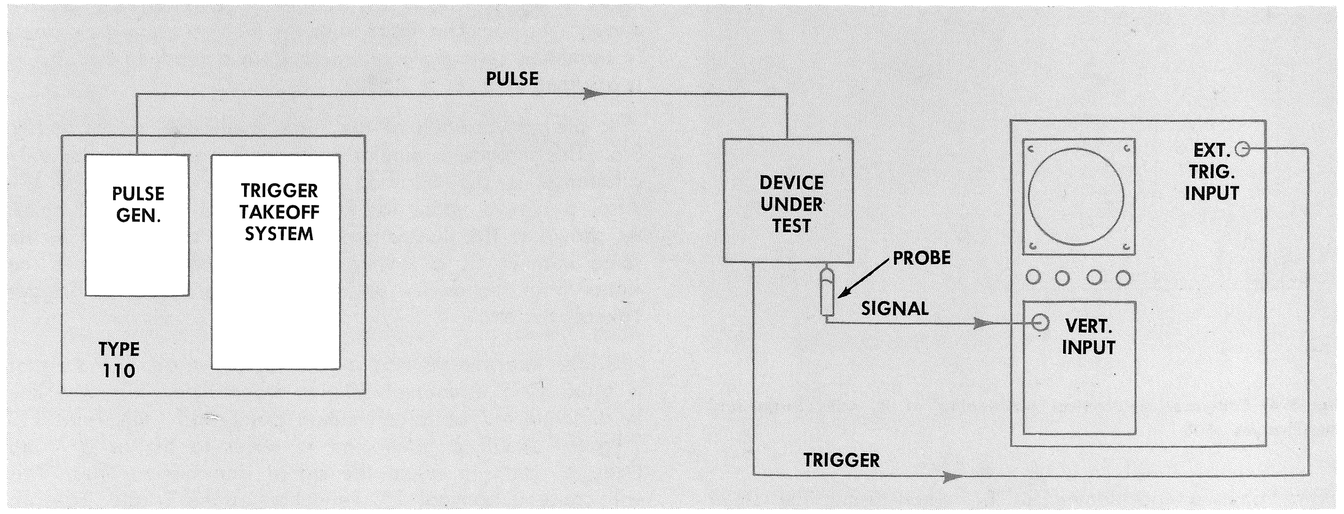


Fig. 3-8. Test setup where the device under test is pulsed by the Type 110. External triggers are obtained from the device under test.

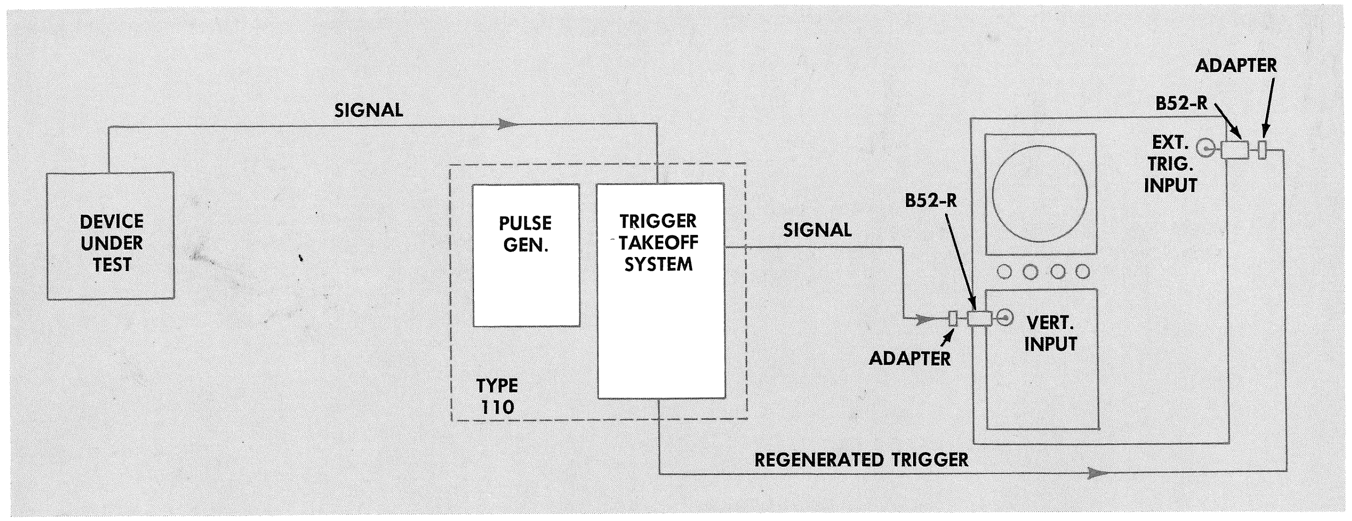


Fig. 3-9. Test setup where the Type 110 is used to derive a trigger from the output signal of the device under test.

The next system, illustrated in Fig. 3-9, is employed when the device under test cannot supply the required external trigger signal or where internal triggering by the oscilloscope is not desired. The signal is applied through the Trigger Takeoff System, 50-ohm coaxial cable, 50-ohm (B52-R) termination, and connector adapter to the input connector on the oscilloscope. A portion of the signal is picked off in the Trigger Takeoff System to drive the trigger regenerator in the Type 110. The regenerated trigger is applied through a 50-ohm coaxial cable, connector adapter, and 50-ohm (B52-R) termination to the external trigger input on the oscilloscope. The B52-R termination, Tektronix part number 011-001, will provide a good impedance match for use in this setup.

The next three test systems (Figs. 3-10, 3-11 and 3-12) involve the Type 110, Type 113 Delay Cable, and Type N Sampling Plug-In Unit, all of which comprise a sampling system. Observations of recurrent signals faster than the normal capabilities of general purpose oscilloscopes are made possible with the sampling test systems or setups to be described. Risetimes to approximately 0.6 nsec can be displayed by each setup.

The sampling test setup shown in Fig. 3-10 is applicable where the device under test cannot produce trigger signals which fall within the amplitude and duration requirements for triggering the Type N Unit. The Type N Unit by itself requires an external trigger either at the TRIGGER INPUT or at the REGENERATED TRIGGER INPUT connector. The re-

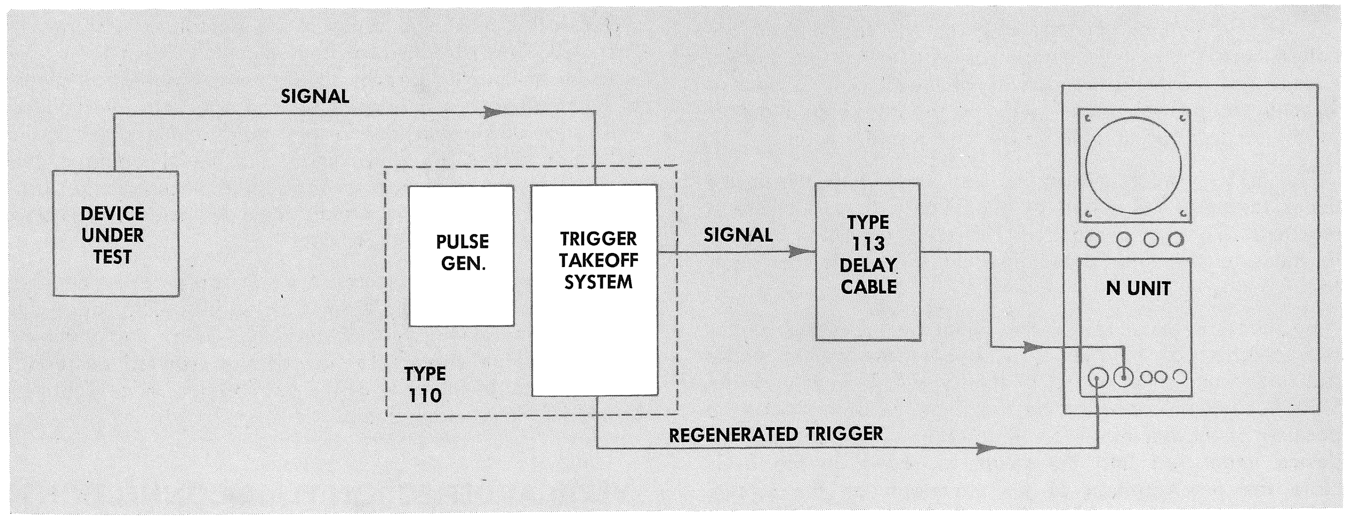


Fig. 3-10. Sampling test setup where the device under test cannot supply the required triggering signals to the N Unit.

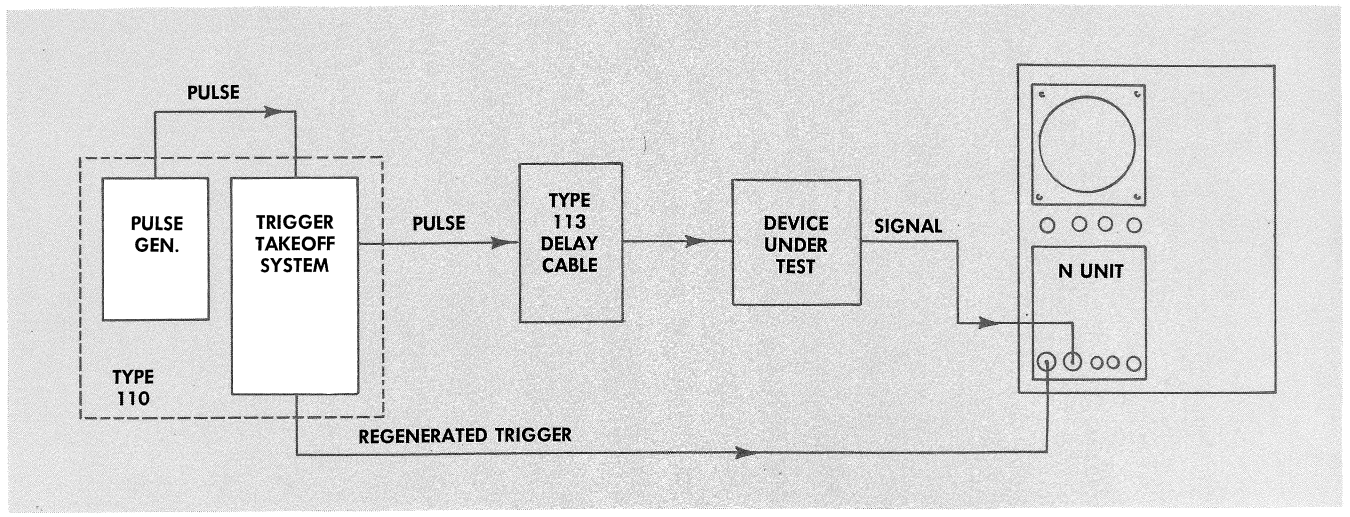


Fig. 3-11. Sampling test setup where the device under test must be pulsed and a measurement of the time delay is desired.

generated trigger must arrive 40 to 230 nsec ahead of the signal, as measured at the N-Unit REGENERATED TRIGGER and SIGNAL INPUT connectors.

The Type 113 Delay Cable is inserted to delay the signal by 60 nsec; thus, the associated regenerated trigger will arrive at the correct time, since the time delay through the Type 110 Trigger Takeoff System is 20 nsec.

Since the Type 113 Delay Cable has a risetime less than 0.1 nsec, it will not significantly alter the shape of any pulse which has a slower risetime than that of the N Unit (0.6 nsec).

In any of the sampling test setups shown it may be necessary to use attenuators to limit the signal going into the N Unit to a usable level. For simplicity of illustration, these attenuators are not shown.

Time and voltage measurements on the signal itself are determined in the same manner as with any other plug-in, except that the vertical sensitivity of the N Unit is fixed at 10 millivolts per centimeter. Refer to the instruction manuals for the oscilloscope and the N Unit being used.

Fig. 3-11 illustrates a sampling test setup where the device under test must be pulsed by the Type 110, and where a regenerated trigger is required. This setup may also be used to measure the time delay inherent in the device under test.

To measure the delay of the signal by the device under test, proceed as follows: First, bypass the device under test and connect the output of the Type 113 directly to the SIGNAL INPUT connector on the Type N Unit. Note the position of the waveform on the screen. Then, connect the device under test into the setup, as shown in Fig. 3-11. Note the new position of the waveform on the screen. Multiply the number of centimeters of shift by the setting of the Type N NANOSEC/CM switch. This is the delay of the device under test.

In some cases it may be desirable to reverse the order of the Type 113 and the device under test from that shown in Fig. 3-11. This is especially true where the device under test has a high output impedance or could be affected significantly by the arrival of interogating signals from the N Unit. Placing the Type 113 between the device under test and the N Unit will delay the interogating pulses sufficiently to prevent them from affecting the display on the oscilloscope.

The sampling test setup illustrated in Fig. 3-12 is used where the output of the device under test is much greater than the input, and where it is not necessary to measure the amount of delay. The advantage of this setup as compared to Fig. 3-11 is in triggering sensitivity; the input signal level to the device may be below the sensitivity level of the Type 110.

The last typical test setup to be described is shown in Fig. 3-13. This arrangement is used mainly when the signal is to be ac-coupled directly to the vertical deflection plates of a crt which has a lumped deflection system. A detailed illustration and instructions for making the connections at the deflection plates are given under the next heading in this section. A reference chart showing the deflection factor, risetimes, and comparative writing rates for various Tektronix cathode-ray tubes is also provided.

With lower repetition rates, a delay cable will be needed; in the case of the Type 530- and 540-series oscilloscopes, this delay is approximately 250 nsec. The delay cable quality should be high enough to provide the required passband. For example, in the case of the oscilloscope series just mentioned, RG-19/U is adequate.

VERTICAL DEFLECTION PLATE CONNECTIONS

Faster risetime pulses can, in some cases, be observed by direct connection through a coupling capacitor to the vertical

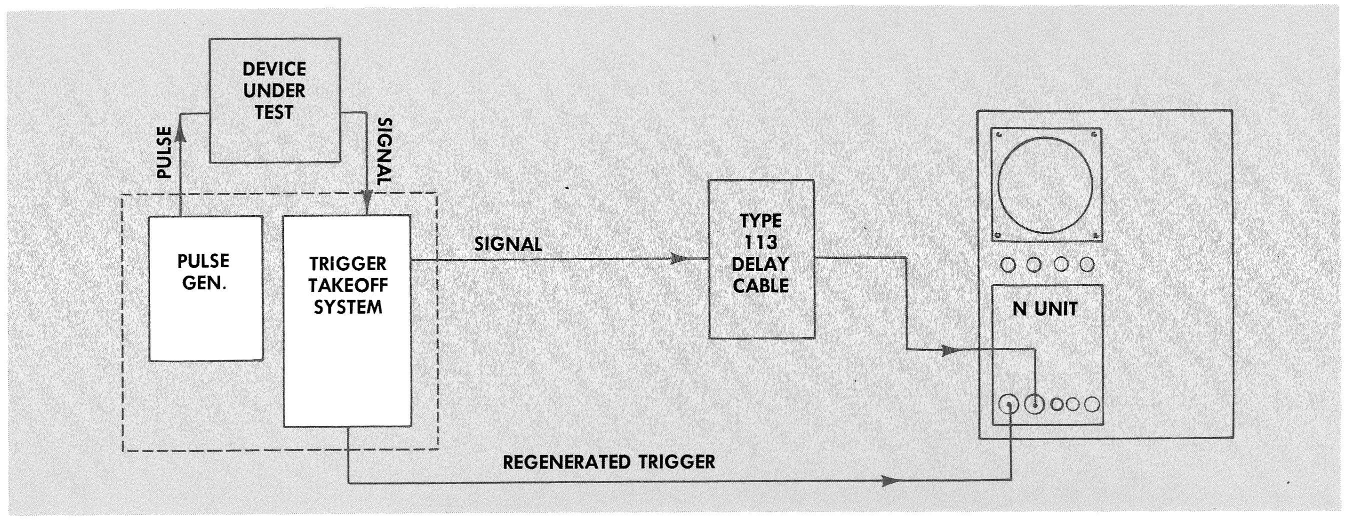


Fig. 3-12. Sampling test setup where the output of the device under test is much greater than the input.

deflection plates, bypassing the limited passband of the vertical amplifier in the oscilloscope. 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, and deflection factor (if the last factor is a prohibitive limit, then the Type N Sampling Plug-In should be considered as another way to avoid the passband limit of the main 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. 3-14. 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.

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.

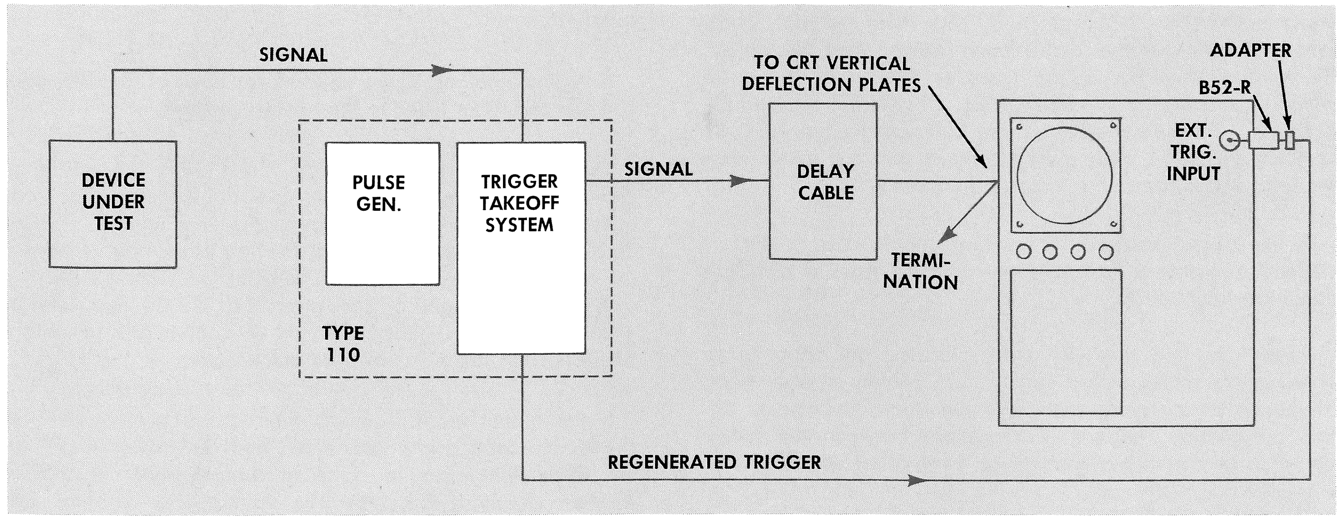


Fig. 3-13. Test setup where the signal is coupled directly to the vertical deflection plates. The Type 110 is used to derive a trigger from the output signal of the device under test.

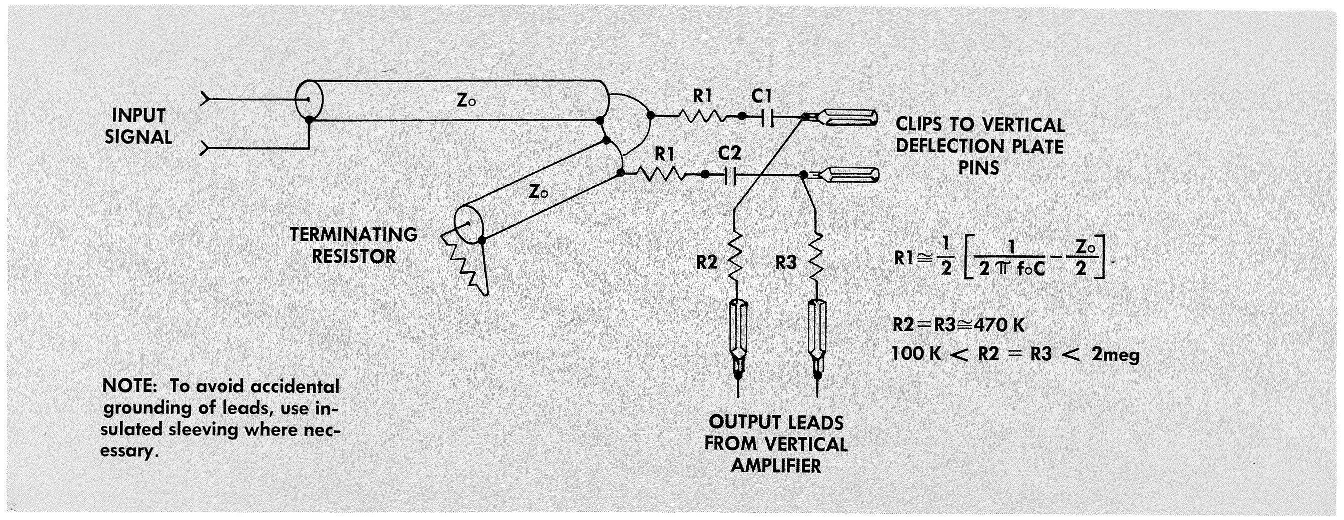


Fig. 3-14. Detailed method of ac-coupling the signal directly to the vertical deflection plates.

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 must be long enough so that if a double-transit time reflection appears, it can be easily identified separately 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_O) of the lead inductance and the deflection plate capacity (C) for use in solving the equation of Fig. 3-14, proceed with the method which follows. Turn off the oscilloscope power and disconnect the vertical amplifier output leads to the crt. Cut a wire which equals the total length of C1, C2, R1, R1, R2, and R3. Substitute the wire lead for these components between the vertical deflection plate pins. Bring a grid-dip meter near the lead 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 capacitance between the plates with a Type 130 LC Meter, or equivalent, at the deflection plate pins. Use the guard voltage to obtain an acurate reading. Capacitance between the plates can also be found by referring to a list of crt specifications.

The value for R1 is found by solving the equation given in Fig. 3-14.

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 nonlinearily with the beam position. The values of the resistors R2 and R3 must be selected to keep the current flow to a negligible value. If the resistances are increased, the voltage drops may become relatively large and may cause serious defocusing or distortion. If the resistances are decreased, the low-frequency response becomes limited. These effects are most noticeable when the display is positioned close to the limits of the crt graticule.

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

A typical risetime figure is given for each of the Tektronix cathode-ray tubes listed in the reference chart.

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. A short circuit of this type can damage the amplifier circuits.

* See I. A. D. Lewis and F. H. Wells, "Millimicrosecond Pulse Techniques", Third Impression—1956, Chapter 6, Pergamon Press, London & New York.

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	1/3 to 1/4
531A, 533, 535A	T533	8.5 to 10.5	2.0	
541, 545	T54	6.0 to 7.0	2.5	
541A, 543, 545A	T543	6.0 to 7.0	2.5	
551	T551	6.0 to 6.5	3.0	
555	T555	6.4 to 7.3	3.0	
517A (12 kv)	T517 (T54-H)	7.0 to 8.0	2.0	1/3
517A (24 kv)	T517 (T54-H)	14.0 to 16.0	1.5	1*
517 (12 kv)	5XP	17.0 to 20.0	1.5	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 the sweep-rate limitations.

** Writing rate compared to Type 517 (24 kv). The writing rate of the Type 517 (24 kv) crt, using P11 phosphor, is 1000 to 1200 cm/μsec recorded on TRI-X film, 4000 cm/μsec recorded on Polaroid 3000 film. Consult your Tektronix Field Engineer or write to Tektronix, Inc. (CRT Dept.) for more information on writing rates. Information about different kinds of phosphor is listed on the Phosphor Rating Data Sheet. Additional specialized uses for phosphors are also available from the CRT Dept.

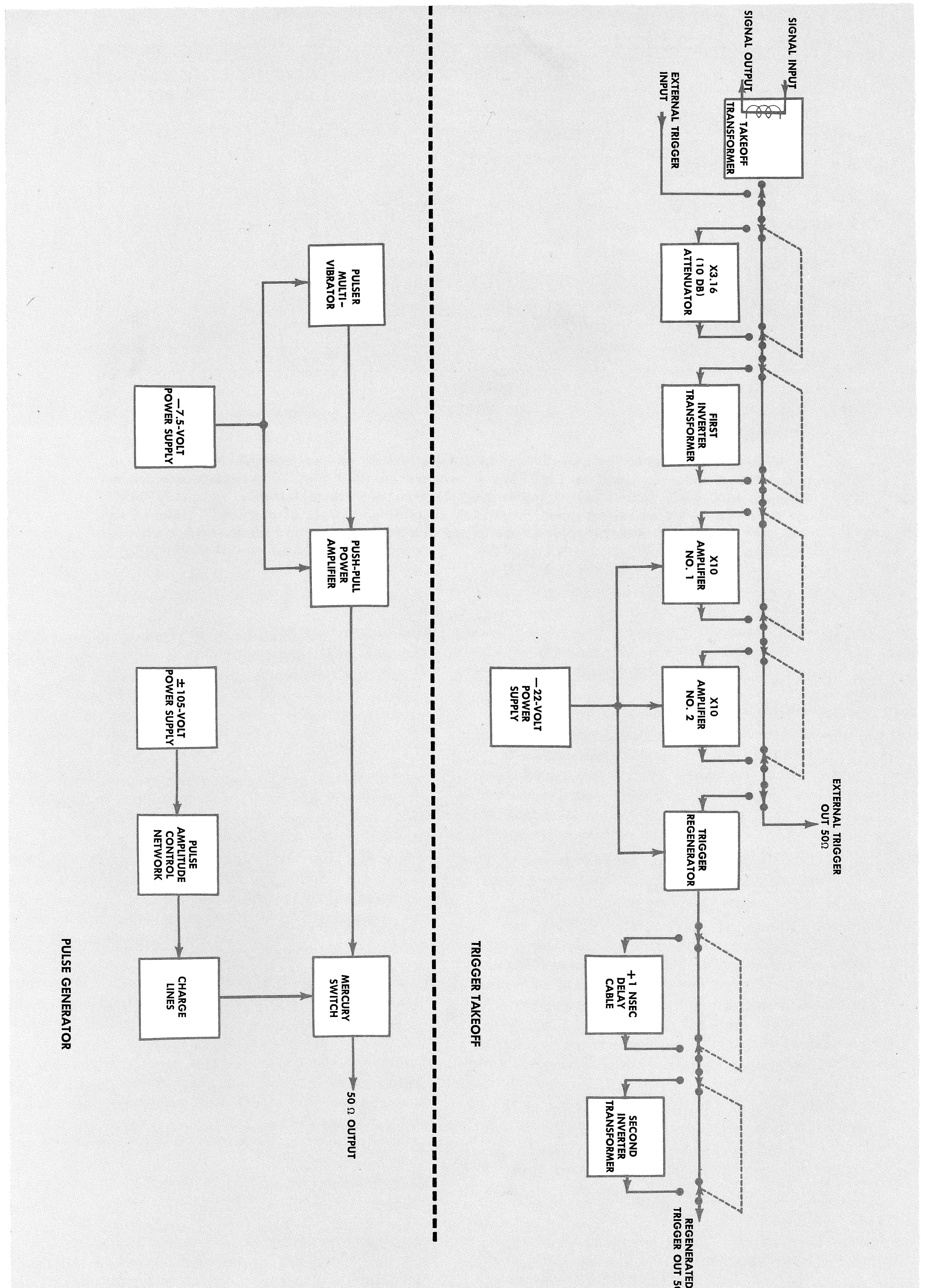
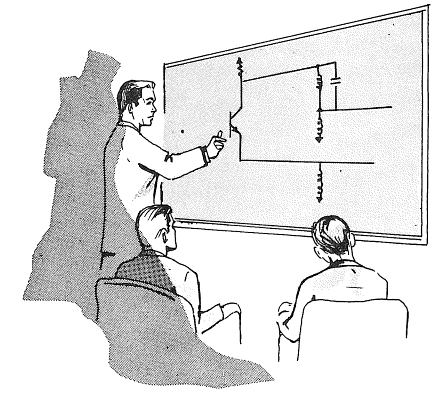


Fig. 4-1. Type 110 Pulse Generator and Trigger Takeoff System functional block diagram.



CIRCUIT DESCRIPTION

GENERAL DESCRIPTION

A block diagram representation of the Type 110 Pulse Generator and Trigger Takeoff System is shown in Fig. 4-1. From this diagram it can be seen that the Type 110 consists essentially of two separate and distinct sections. The Pulse Generator Section produces pulses with a risetime of less than 0.25 nanoseconds with both the amplitude and pulse duration variable. The Trigger Takeoff System derives a triggering signal, from a suitable input signal, by passing the input signal through a 50 Ω transmission line loop. There is also provision for direct external trigger inputs. The triggering signal obtained by either of these methods can then be used to trigger some external device (such as an oscilloscope).

A multivibrator in the Pulser Section produces the waveform which is ultimately used to control the operation of a mercury switch. The multivibrator operates at a nominal frequency of 360 cps. The output from the multivibrator is applied to a push-pull power amplifier stage where sufficient power is obtained to drive the mercury switch. Two external open-ended transmission lines are used as charge lines for the pulse generator. These lines are charged to a voltage obtained from a network between the 105-volt power supply and the charge lines. The mercury switch alternately discharges the two charged lines into the 50-ohm output load to form the output pulses. The two charge lines and the two sets of contacts in the mercury switch cause the output pulse frequency to be twice the multivibrator frequency, or nominally 720 cps.

The triggering signal produced by the Trigger Takeoff System Section is obtained by tapping off about 4% of the signal energy passing through the system to a load. The amplitude of the triggering signal thus obtained is approximately 20% of the original input signal amplitude. The output of the Takeoff Transformer may be applied to a X3.16 (10 db) attenuator, an inverter, and/or one or two 10X amplifiers. The triggering signal, modified in polarity and/or amplitude, is available for external use, or for operating the internal Trigger Regenerator. If the Trigger Regenerator is used, the triggering signal should be modified to be between +0.5 and 2.0 volts. The Trigger Regenerator is a blocking oscillator stage which produces a constant output, nearly independent of the triggering signal. The output of the Trigger Regenerator is a positive pulse approximately 10 volts in amplitude with a duration of approximately 200 nanoseconds. The maximum output repetition rate of the Trigger Regenerator is 100 kc, however the circuit "counts down" from higher triggering frequencies and can be triggered quite well from signals with frequencies up to 100 mc. The 100-kc maximum output frequency of the Trigger Regenerator can be used to trigger oscilloscopes that do not trigger well at high frequencies since stable triggering is obtained on most oscilloscopes when the triggering frequency does not exceed 100 kc.

The output of the Trigger Regenerator can be applied through an inverter and/or a +1-nanosecond delay cable to the external equipment to be triggered. The inverter allows you to obtain the required triggering signal polarity while the accurate 1-nanosecond delay allows you to check the sweep timing of an oscilloscope by the time shift method.

All the operations of amplifying, inverting, choosing inputs or outputs are performed with front-panel switches of special geometry. These switches approximate sections of 50-ohm transmission line.

PULSE GENERATOR

—7.5-Volt Power Supply

AC power for the Type 110 is applied through a receptacle on the rear of the unit to the primary windings of T601. A filter network in the primary circuit of T601 is used to reduce transients appearing on the power line. One secondary winding of T601 supplies the ac voltage for the —7.5-volt power supply. This ac voltage is applied to full-wave rectifiers, D601 and D602. The rectified voltage is then applied to a filter network consisting of T610, C610, and C611 where ripple voltage is reduced. The dc output from the filter network is applied to the collector of the series regulator transistor, Q627. The base of the series regulator is held at —7.5 volts by the action of Zener Diode, D622. Since the base of the transistor is at —7.5 volts, the emitter is also held at approximately —7.5 volts. Any tendency for the output voltage to change produces a change in the bias of the transistor. This changes the impedance of the transistor causing the output voltage to return to normal. Capacitor C627, on the output of the supply, provides additional filtering of the output voltage. The output from this supply provides the operating voltages for the Pulser Multivibrator and Power Amplifier stages.

±105-Volt Power Supply

A secondary winding of T601 supplies the ac voltage to full-wave rectifiers D661 and D662. The output of the rectifiers is then applied to an RC filter network consisting of R661, C661A, and C661B. The output of this filter is applied to the first voltage regulator tube, V669. Resistors R668 and R669 set the current passed by V669 at a value which allows this tube to regulate the voltage across it at 150 volts. This regulator compensates primarily for line voltage changes. Resistors R678 and R679 set the current carried by the second voltage regulator tube, V679. The voltage across the terminals of V679 and the output of the supply is maintained at 105 volts by the regulator.

The polarity of the output of the 105-volt power supply is controlled by the PULSE POLARITY Switch. By grounding either of the two 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 100 V ADJ. 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 AMPLITUDE VOLTAGE RANGE Switch, except EXT. PWR. This means that the voltage drop across R690 also remains constant regardless of the position of the AMPLITUDE VOLTAGE RANGE Switch. The 100 V ADJ. Control is set so that the voltage at the AMPLITUDE VOLTAGE RANGE Switch side of the resistor is 100 volts.

The voltage across the AMPLITUDE Control, R696, is always equal to twice the setting of the AMPLITUDE 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 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 Fig. 4-2). One hundred microseconds is allowed for the charge line capacitances to be charged to the voltage obtained from the wiper arm of the AMPLITUDE control, with 720 cps operation. With 360 cps operation (one charge line disconnected), about 1.25 milliseconds is available.

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 a 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 AMPLITUDE 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

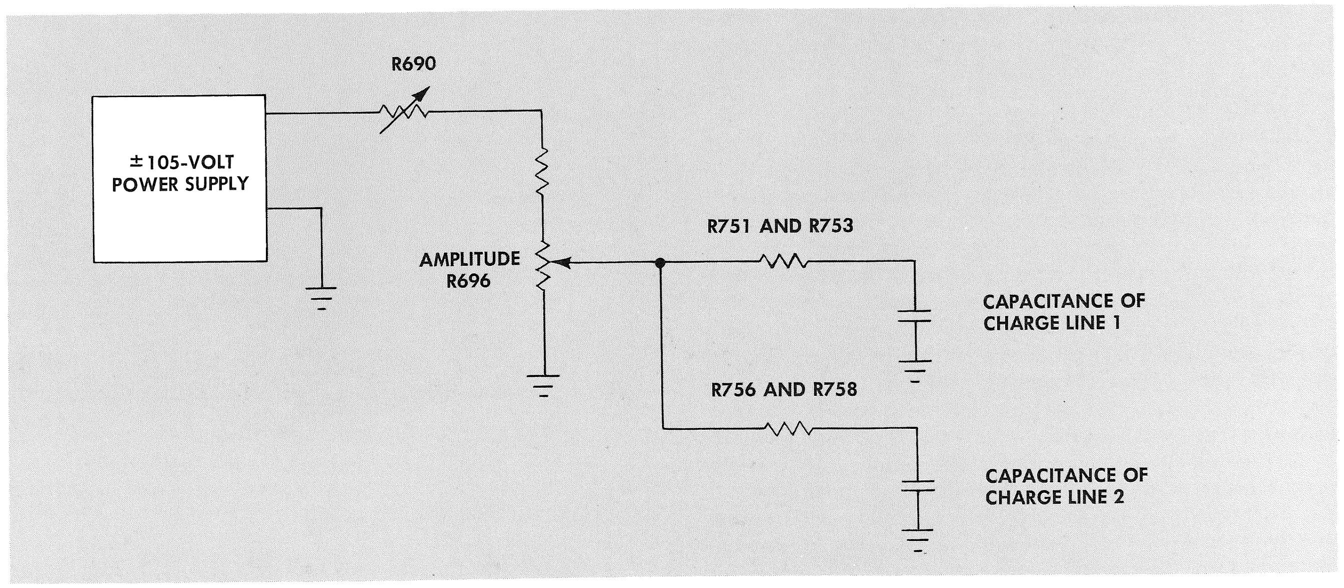


Fig. 4-2. Simplified charge circuit for pulser charge line capacitances.

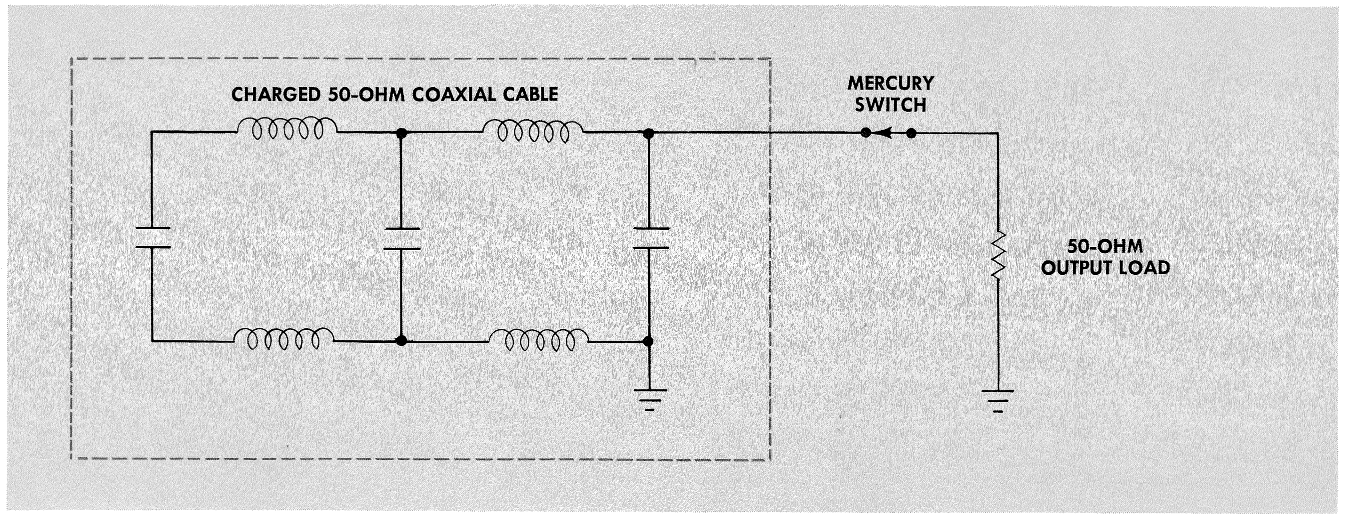


Fig. 4-3. Simplified pulse generator circuit.

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. 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. The operation of the unit 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 due to capacitive coupling of the backwave 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 0.2 nanosecond delay lines causing pulses to be 0.4 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 110 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, 2w resistors limit the external voltage applied to about 600 volts and the output pulse amplitude to approximately 300 volts. Another advantage which may be obtained when 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.

Pulser Multivibrator

The Pulser Multivibrator, Q725 and Q735, free-runs at approximately 360 cps. Initial starting of the multivibrator depends on slight unbalance between the two transistors in the circuit. As the power is applied, one transistor goes into conduction before the other. (For purposes of explanation, let us assume that Q725 conducts first.) As Q725 goes into conduction, its collector voltage goes in a positive direction. This positive rise in voltage is coupled through C725 to the base of Q735 holding Q735 in cutoff. As the collector voltage of Q725 reaches a steady state, capacitor C725 discharges, permitting the base voltage of Q735 to drop. When the voltage at the base of Q735 drops to a point where the base-emitter junction of Q735 is forward biased, Q735 conducts. The collector voltage of Q735 then goes in a positive direction. This change in collector voltage is applied to the base of Q725 through C735, causing Q725 to cut off. Capacitor C735 then discharges permitting the base voltage of Q725 to go in a negative direction. As the base voltage of Q725 drops, the transistor goes into conduction, cutting off Q735. This sequence of operation then continues as each transistor alternately conducts and then cuts off.

The operating frequency of the Pulser Multivibrator is determined by the RC time constant of the coupling circuits and the bias voltage applied to the base of two transistors. Both of these factors are changed by adjustment of either the 720 CPS ADJ. Control, R726, or the FREQUENCY ADJ. Control, R725. The settings of these two controls determine the amount of time required for the coupling capacitors to discharge sufficiently to allow the transistors to conduct. Decreasing the resistance of either R725 or R726 reduces the time constant of the coupling circuits and increases the negative voltage on the base of Q725 and Q735. Both factors tend to increase the multivibrator operating frequency.

Transformer T610 applies 120-cycle ripple from the —7.5-volt power supply to the bases of the two transistors. The

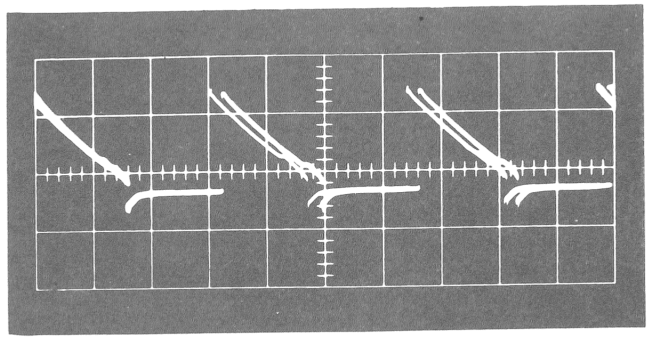


Fig. 4-4. Waveform at the base of transistor Q725 with the MODE Switch in the LINE SYNC position. The apparent double trace is caused by the 120-cycle ripple voltage superimposed on the waveform. Sweep Speed-1 millisecond per centimeter. Vertical Deflection Factor-0.5 volts per centimeter.

120-cycle ripple voltage is superimposed on the RC discharge curve at the base of the transistor that is cut off (refer to Fig. 4-4). This ripple voltage causes the transistor to conduct a short time earlier than normal. The ripple voltage can thus be used to synchronize the multivibrator at 360 cps when the MODE switch is placed in the LINE SYNC. position. When the MODE switch is placed in the FREE RUN position, the primary winding of T610 is opened, eliminating the ripple voltage from the transistor bases. When the MODE switch is placed in the OFF position, the ground return for the —7.5-volt power supply is disconnected, thereby eliminating power for the multivibrator and the power amplifiers. The OFF position of the MODE switch permits the Trigger Takeoff System of the 110 to be operated without necessitating operation of the Pulse Generator Section. This prolongs the life of the mercury switch by eliminating unnecessary operation.

Push-Pull Amplifiers

The output of the Pulser Multivibrator is taken from the collectors of Q725 and Q735 and applied to the bases of Q744 and Q754. The effective signal used to drive the bases of the power output transistors is quite small due to the limiting action produced by the base current of Q744 and Q754. As either Q725 or Q735 cuts off, its collector voltage goes toward —7.5 volts. However, this causes the base current of the corresponding power transistor to increase. This increased base current passes through the collector load resistor for the multivibrator transistor thereby limiting the permissible collector voltage swing to less than 1 volt.

Although this small a collector swing does not produce great frequency stability, the multivibrator frequency is sufficiently stable for the purpose of driving the reed of the mercury switch. The push-pull output of the power amplifiers is applied to the primary winding of T750. Transformer T750 provides approximately a 200-to-1 step down into a one-turn secondary (see Fig. 4-5) which couples the energy to the mercury switch, and serves as the switch housing and 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. A permanent mag-

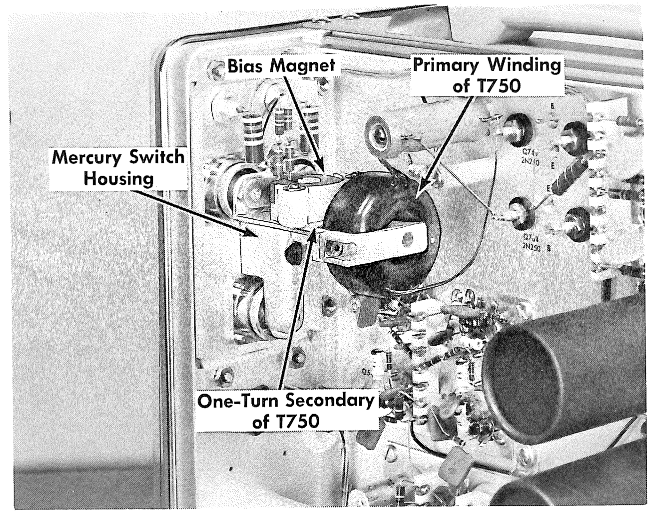


Fig. 4-5. Left rear view of the Type 110 Unit showing the pulser section.

net 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 mulitivibrator, or nominally 720 cps.

TRIGGER TAKEOFF SYSTEM

—22-Volt Power Supply

Power for the —22-Volt Power Supply is obtained from a secondary winding of T601 and applied to full-wave rectifiers D640, D641, D642, and D643. The pulsating dc output of the bridge rectifier is connected across filter capacitor C647 and through resistor R647 to Zener Diode, D647. Resistor R647 sets the current through the Zener Diode at the proper level to allow regulation. The voltage across D647 is maintained at 36 volts by the Zener Action. Diode D647 is used primarily to compensate for line voltage fluctuations. The output from the first Zener Diode is applied through R648 to the second Zener Diode, D648. The voltage is maintained at 22 volts across D648 by the Zener Action. The second Zener Diode compensates primarily for load variations. Operation of the —22-Volt Power Supply is very similar to the operation of the ±105-Volt Power Supply.

Takeoff Transformer

Signals to the Takeoff Transformer are applied at the SIG. IN FOR TRIG. TAKEOFF 50 Ω connector and taken back out at the SIGNAL OUT 98%, 50 Ω connector. As indicated by the panel markings, the signal amplitude out is 98% of the signal amplitude in. Between the two connectors is a section of 50-ohm coaxial cable. The inner conductor of

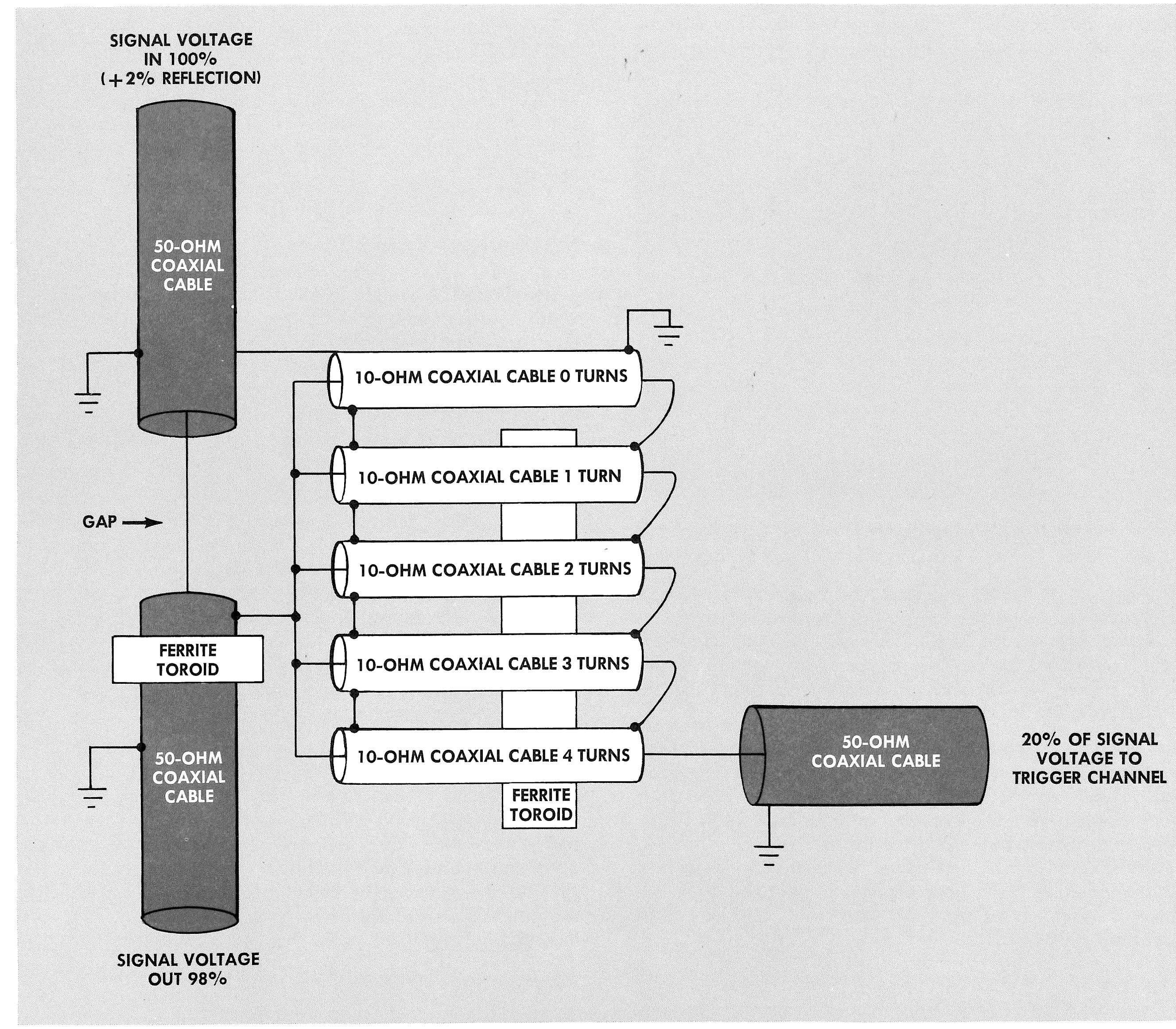


Fig. 4-6. Simplified Takeoff Transformer diagram.

this cable is undisturbed; however, a small gap is made in the outer conductor (refer to Fig. 4-6). Across this gap are connected five 10-ohm coaxial cables in parallel. The five cables in parallel produce an impedance of 2 ohms across the gap in the outer conductor. This makes the coaxial cable appear to have an input section of 50 ohms and an output section of 52 ohms. The slight mismatch produces approximately a 2% reflection at the break in the outer conductor. The voltage that appears across the 50-ohm load on the output of the takeoff Transformer is approximately 98% of the input signal voltage. The voltage appearing across the gap in the outer conductor of the 50-ohm cable is approximately 4% of the input signal voltage. Since the five 10-ohm coaxial cables are connected across the gap in the outer conductor in parallel, each 10-ohm cable also has a voltage across it equal to approximately 4% of the input signal voltage. The output end of the five 10-ohm coaxial cables are connected in series, i.e. the inner conductor of each is connected to the shield of the next. With the five cables connected in series on one end and in parallel on the other, the output from all but one of the cables would be shorted out if some provision was not made to effectively isolate the two ends of the cable from one another. This is done by wrapping the 10-ohm cables around a toroid core. The number of turns varies from 0 to 4 from top to bottom of the series-connected cables shown in Fig. 4-6. The toroid core effectively isolates one end of the outer conductor of each cable from the other end. In this series output connection the individual signals across each cable are additive. Each cable has 4% of the original input signal across it. This means that the series combination supplies an output of 20% of the original input signal voltage. The series connection at the output ends of the 10-ohm cables also means that individual impedances of the cables are additive. The 5 cables in series thus have a total impedance of 50 ohms. This arrangement then provides a 5 times voltage step-up and a 25 times impedance step-up. The output from the five 10-ohm cables is applied through a 50-ohm coaxial cable to the trigger channel. The equivalent circuit is shown in Fig. 4-7.

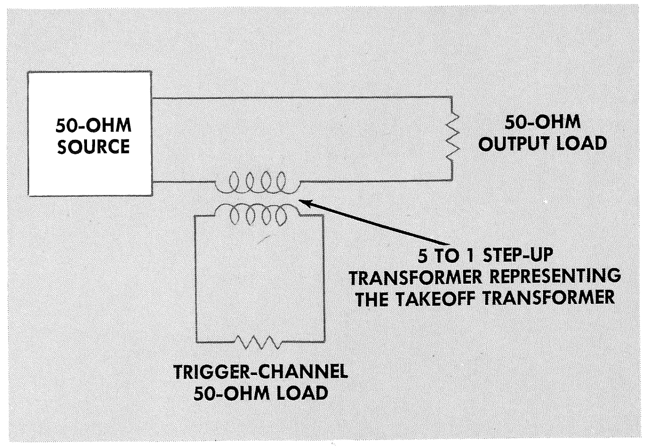


Fig. 4-7. Equivalent Takeoff Transformer Circuit.

The gap in the outer conductor of the 50-ohm cable is prevented from being shorted out by the addition of a ferrite toroid around the cable between the gap and the output connector. Unless this is done, no voltage is developed across the gap and consequently no output can be obtained from the Takeoff Transformer.

An optional method for connecting triggering signals into the triggering channel involves application of the triggering signal directly to the EXTERNAL TRIG. IN 50 Ω Connector. Signals applied here are bypassed around the Takeoff Transformer and applied directly to the trigger channel. The EXT. 50 Ω-TAKEOFF Switch determines whether the triggering signal applied to the trigger channel is obtained from the Takeoff Transformer or from the EXTERNAL TRIG. IN 50 Ω Connector.

Attenuator

Triggering signals in the trigger channel are applied first to the ATTENUATOR Switch. This control allows you to switch in a X3.16 attenuator or to bypass it as desired. The X3.16 attenuator can be used to reduce large amplitude triggering signals to a usable level. The attenuator is a T-pad with an input and output impedance of 50 ohms (refer to Fig. 4-8).

First Inverter Transformer

The INVERTER Switch, SW4B, is used to switch the first Inverter Transformer in or out of the triggering channel. When the transformer is switched in, signals proceeding down the triggering channel are inverted before being applied to the AMPLIFIER 1 Switch, SW24A. The Inverter Transformer thereby permits the proper triggering signal polarity to be obtained regardless of the polarity of the input signal to the Trigger Takeoff System.

The Inverter Transformer is actually a short length of coaxial cable which, due to the way it is connected, inverts the triggering signal (see Fig. 4-9). At the input end of this cable, the signal is applied to the outer conductor and the inner conductor is grounded. At the output end of the cable the connections are reversed; the signal is obtained from the inner conductor and the outer conductor is grounded. Since the polarity of the signal in the outer conductor is opposite that of the signal in the inner conductor, the signal polarity is reversed in passing through the cable.

The outer conductor of the Inverter Transformer Cable is connected on one end to the input signal and on the other end to ground. Normally the only thing isolating the input signal from ground is the small amount of inductance in the outer conductor. This inductance alone would provide only a momentary delay before the signal was completely shorted to ground. To increase the inductance in the outer conductor, the cable is wound six times through a ferrite toroid. This inductance greatly increases the time constant of the outer

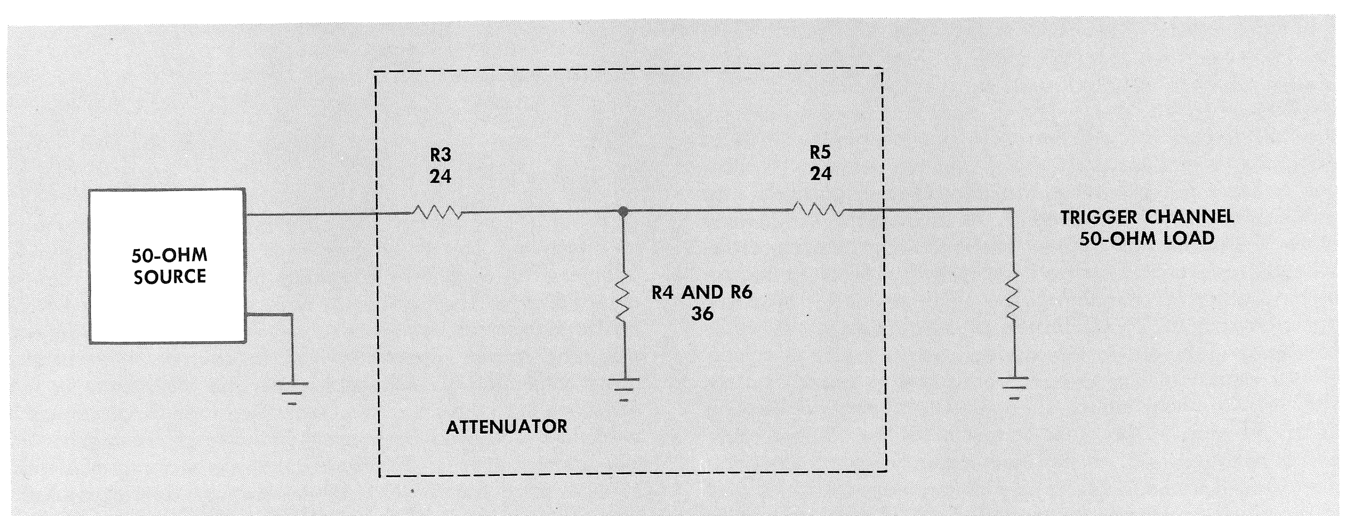


Fig. 4-8. Simplified attenuator circuit showing the input and output connections.

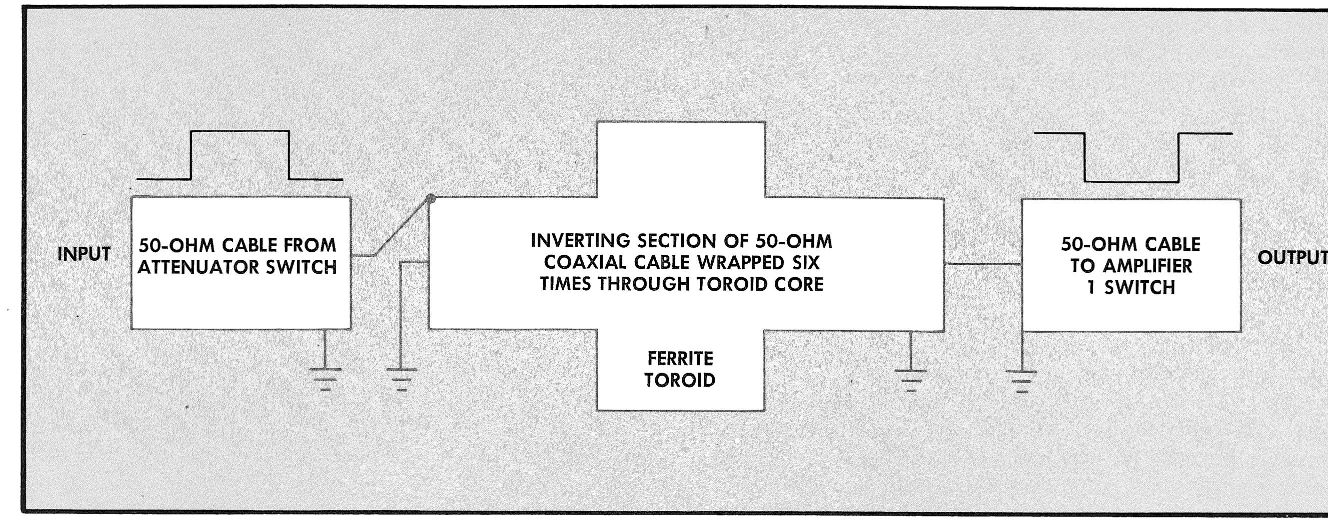


Fig. 4-9. Simplified Inverter Transformer diagram.

conductor. The core and windings serve to effectively isolate one end of the cable from the other for a relatively long time duration.

Amplifier 1 and Amplifier 2

Signal amplitudes can be increased by a factor of 10 or 100 by switching 1 or 2 10X amplifiers into the triggering channel. The amplifiers can be switched in or out as desired through use of the AMPLIFIER 1 and AMPLIFIER 2 Switches. When the amplifiers are switched out, they are bypassed with a length of coaxial cable which produces approximately the same signal delay as that obtained when the amplifiers are used. This maintains the same nominal 20-nanosecond time delay through the system, whether triggering on small signals (with the amplifiers) or large signals (without the amplifiers).

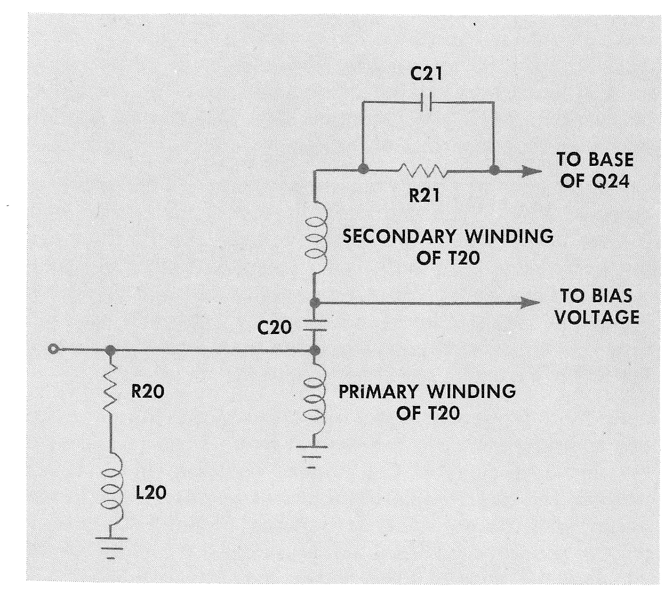


Fig. 4-10. Input circuit of X10 Amplifier No. 1.

The two 10X amplifiers each have a gain of approximately 10 and a risetime of about 3 nanoseconds. Since the amplifiers are identical, only one of them need be described in detail. The following description covers Amplifier 1.

Input signals to Amplifier 1 are applied through transformer T20 to the base of Q24. For ac signals, capacitor C20 is effectively shorted out causing T20 to act as an autotransformer with a 2-to-1 voltage step-up (see Fig. 4-10). The transformer is used to match the impedance of the base circuit of Q24 to the input impedance of the amplifier. The 50-ohm input impedance of the amplifier serves as a termination for the 50-ohm coaxial cable leading to the amplifier. Since the input impedance of the transistor is time variant, R20, L20, C21, and R21 are used to make the terminating impedance more uniform.

A voltage divider consisting of R22 and R23 supplies the bias voltage for Q24. Capacitor C20 prevents the bias voltage from being shorted to ground through the primary winding of T20. The bias voltage is applied through the secondary winding of T20 and a high-frequency peaking network to the base of Q24.

Resistor R25 sets the collector current of transistor Q24 at approximately 10 ma. The collector voltage of Q24 is then determined by the voltage drop across R28 and R29 produced by the 10 ma collector current. The large amount of dc stabilization produced by R25 in the emitter circuit makes the circuit relatively insensitive to temperature changes.

The second half of the amplifier is very similar to the first. Collector current is set at approximately 7 ma by R35 in the emitter circuit. The collector voltage of Q34 is determined by the voltage drop across R38 produced by the 7 ma collector current. Again, the dc stabilization provided by R35 is used to make the stage relatively insensitive to temperature changes. The output of the amplifier is taken from the secondary winding of T38. This transformer is operated in the same manner as the input transformer, T20. For ac signals, C38 is effectively shorted causing T38 to be operated as a 2-to-1 step down auto-transformer. The 50-ohm load on the secondary winding of T38 is reflected back into the collector circuit of Q34 as a 200-ohm load.

Signals applied at the base of Q24 are inverted in the collector circuit of Q24 and applied to the base of Q34. The signals are again inverted in the collector circuit of Q34 causing the output of the amplifier to have the same polarity as the input. High-frequency compensation is used in the base and emitter circuits of both Q24 and Q34 to compensate for the tendency of β to decrease at higher frequencies. This compensation is necessary to obtain the 3-nanosecond amplifier risetime.

The two 2N700 transistors are selected for a nominal amplifier gain of 10. A low β transistor is used as Q24 while a higher β unit is used for Q34. This selection of transistors provides the optimum balance of gain and signal handling capabilities. The amplifier should be capable of supplying outputs of ±1 volt before distorting. In order to obtain a swing of ±1 volt at the output of the amplifier, it is necessary for the voltage across the primary of T38 to swing ±2 volts due to the 2-to-1 stepdown ratio of T38.

EXT. OUTPUT-REGENERATOR Switch

The EXT. OUTPUT-REGENERATOR Switch determines whether triggering signals in the trigger channel are applied to the Trigger Regenerator Circuit or to the EXTERNAL TRIG. OUT 50 Ω connector. Triggering signals at this point in the triggering channel have an amplitude from 0.065 to 20 times as great the signal originally applied to the Takeoff Transformer. The polarity of the triggering signal may be the same or opposite that of the input signal. The triggering frequency is the same as the frequency from which it was derived.

Trigger Regenerator

When the EXT. OUTPUT-REGENERATOR Switch is in the REGENERATOR position, triggering signals in the trigger channel are applied through C70 to the Trigger Regenerator Blocking Oscillator. These triggering signals will normally be between +0.5 and +2.0 volts in amplitude.

The blocking oscillator transistor, Q80, is normally biased slightly into cutoff by the setting of the TRIGGER SENSITIVITY Control, R82. The emitter of Q80 is held at approximately −6.2 volts by the action of Zener Diode, D78. Resistors R82 and R81 form a voltage divider network from −6.2 volts to ground. The TRIGGER SENSITIVITY Control, R82, is used to set the voltage on the base of Q80 slightly positive with respect to the emitter voltage, thereby holding the transistor in cutoff.

When a positive triggering signal is applied, it is coupled through D71 to the collector circuit of Q80. The positive triggering signal on the primary of T80 induces a negative voltage at the base of the transistor, causing Q80 to conduct. Conduction by Q80 then causes the collector voltage to go in a positive direction, inducing a still greater negative voltage at the base. This regenerative action continues

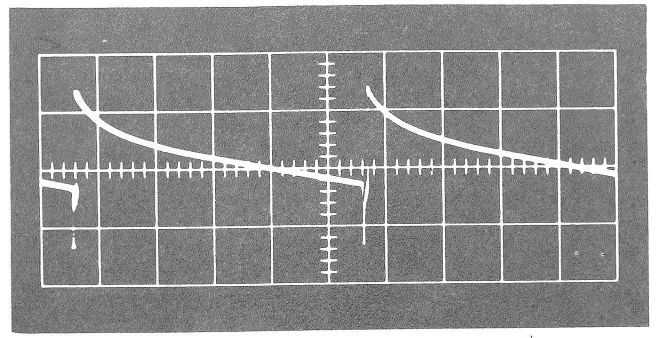


Fig. 4-11. Waveform at the base of transistor Q80 with the TRIGGER MODE Switch at >1 MC and the TRIGGER SENSITIVITY Control fully clockwise. Sweep Speed-10 microseconds per centimeter. Vertical Deflection Factor-5 volts per centimeter.

until the transistor is driven into saturation. When the transistor is saturated, collector current is determined primarily by the charge on C90 and by the 50-ohm load reflected into the collector circuit from the output secondary of T80. As current through the magnetizing inductance of T80 increases, the transformer is driven toward saturation. Also during this time capacitor C80 is charged in a positive direction. As the transformer is saturated, the induced negative voltage drive to the base becomes insufficient to overcome the charge on C80 and the transistor cuts off. Circuit values have been chosen so that the output of the Trigger Regenerator is a positive gate approximately 10 volts in amplitude and over 200 nanoseconds in duration.

When Q80 cuts off, the energy stored in the field of T80 is returned to the circuit in the form of a backswing. Diode D80 is forward-biased by this backswing however, and limits it to a small amplitude.

The charge on C80 prevents the blocking oscillator from being triggered again immediately after the completion of an output gate. As C80 discharges, the bias voltage is gradually reduced until it is possible for a positive triggering pulse to again cause Q80 to conduct. The amount of time required for C80 to discharge to this point is determined by the setting of the REP. RATE LIMIT control R89. This control sets the maximum repetition rate of the circuit.

Input triggering signals are superimposed on the discharge curve of C80. When the algebraic sum of the two voltages is more negative than the emitter voltage, the transistor conducts to generate an output gate. Since a number of closely spaced triggering signals can be applied before one actually brings the transistor into conduction, the Trigger Regenerator Circuit is capable of counting down from frequencies above the 100 kc maximum repetition rate of the circuit.

At high triggering signal frequencies, the trigger pulses are spaced very close together in time. Since the slope of the discharge curve of C80 is quite flat, (see Fig. 4-11) it is possible for considerable instability of operation to be introduced with closely spaced triggering signals. To prevent this, a special circuit is used to steepen the slope of the curve at the base of Q80. When a gate is produced, C86 and L86 are shock excited, causing them to ring. This ringing waveform is then added to the waveform due to the

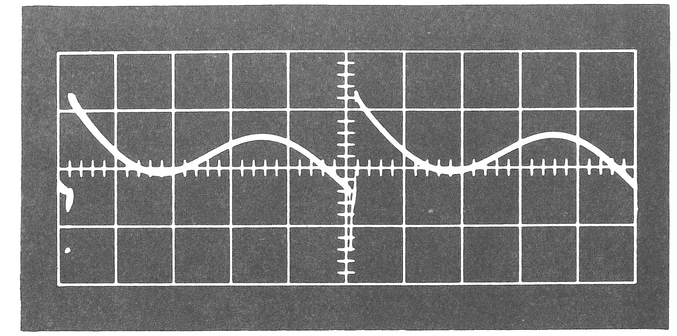


Fig. 4-12. Waveform at the base of transistor Q80 with the TRIGGER MODE Switch at <1 MC and the TRIGGER SENSITIVITY Control fully clockwise. Sweep Speed-10 microseconds per centimeter. Vertical Deflection Factor-5 volts per centimeter.

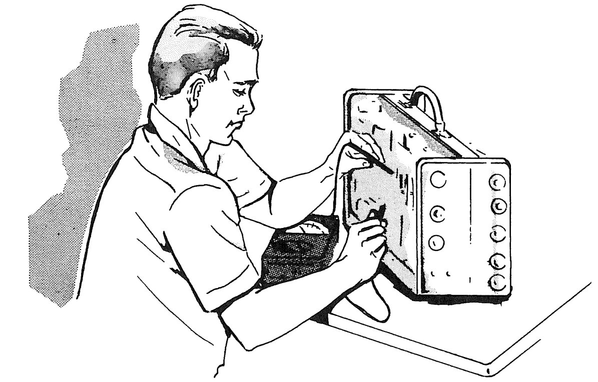
discharge of C80 (see Fig. 4-12). This effectively increases the slope of the curve at the base of Q80 thereby producing stable triggering at frequencies up to approximately 100 mc. When the MODE switch is placed in the <1 MC position, R86 is placed in parallel with L86. The resistor provides sufficient damping to prevent the circuit from ringing.

+1 Nanosecond Delay Cable

The output from the Trigger Regenerator Circuit is applied to the DELAY Switch SW92A. When the switch is in the +1 nSEC position, the triggering signal is delayed 1 nanosecond more than when the switch is in the MINIMUM position. The added delay is produced by a short length of coaxial cable. The two positions of the DELAY Switch permit the Regenerated Triggering Signal to be shifted 1 nanosecond in time. This time shift is useful for checking the sweep timing of oscilloscopes used with the Type 110. If the delay is used for this purpose, care must be taken to see that the Regenerated Trigger Output is properly terminated. If reflections occur at the load, the 1-nanosecond delay may become inaccurate when the time delay of the returning reflections becomes an appreciable fraction of the triggering signal period.

Second Inverter Transformer

The second inverter transformer is identical to the inverter transformer described previously in this section. This inverter permits either a positive or negative 10-volt, 200-nanosecond gate to be applied to the REGENERATED TRIG. OUT 50 Ω Connector.



SECTION 5

MAINTENANCE

PREVENTIVE MAINTENANCE

Visual Inspection

You should visually inspect the Type 110 Pulse Generator and Trigger Takeoff System periodically for possible circuit defects. These defects may include such things as loose or broken connections, damaged binding posts, improperly seated tubes, scorched wires or resistors, missing tube shields, or broken 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.

Recalibration

The Type 110 Pulse Generator and Trigger Takeoff System is a stable instrument that will provide many hours of trouble-free operation. However, to insure the reliability of measurements 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.

REMOVAL AND REPLACEMENT OF PARTS

General Information

Procedures required for replacement of most parts in the Type 110 Pulse Generator and Trigger Takeoff System are obvious. Detailed instructions for their removal are therefore not required. Removal and replacement of the mercury switch, however, is sufficiently complex to warrant the inclusion of specific instructions. Because of the nature of the instrument, replacement of certain parts will require that you recalibrate it to insure proper operation. Refer to Section 6 for complete calibration procedures.

Removal and Replacement of Mercury Switch

To remove the mercury switch SW750, first remove the pulse generator magnet by removing the two screws at either side of it. Then unsolder the two resistors connected to the fiber printed-circuit board at the upper end of the switch. Loosen the socket-head screw in the casting at the bottom of the switch. Remove the two screws holding the fiber printed-circuit board in place, and lift out the board and the switch as a unit. Unsolder the printed-circuit board from the switch leads.

Replacement of the switch is accomplished by the reverse of the above steps.

WARNING

Mercury and mercury vapor are potential causes of heavy-metal poisoning. If a mercury switch develops a mercury leak, handle with care, and dispose of all the mercury.

Replacement of Switches

Methods for removal of defective switches are, for the most part, obvious, and only a normal amount of care is required. Single wafers are normally not replaced. If one wafer is defective, the entire switch should be replaced. Switches may be ordered from Tektronix either wired or unwired as desired.

Tube Replacement

Care should be taken both in preventive and corrective maintenance that tubes are not replaced unless they are actually causing trouble. Many times during routine maintenance it will be necessary to remove tubes from their sockets. It is important that these tubes be returned to the same sockets unless they are actually defective. Unnecessary replacement or switching of tubes will often necessitate recalibration of the instrument. If tubes do require replacement, it is recommended that they be replaced by previously checked high-quality tubes.

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 repeated use of ordinary tin-lead solder, or by the application of too much heat. However, occasional use of ordinary solder will not break the bond if too much heat is not applied.

It is advisable that you have a stock of solder containing about 3% silver if you frequently perform work on Tektronix instruments. This type of solder is used frequently in printed circuitry and should be readily available. It may also be purchased directly from Tektronix in one-pound rolls (order by part number 251-514).

Because of the shape of the terminals on the ceramic strips, it is advisable to use a wedge-shaped tip on your soldering iron when installing or removing parts from the strips. A wedge-shaped tip allows you to apply heat directly to the solder in the terminals and reduces the amount of heat required. It is important to use as little heat as possible.

Due to the wide band requirements of the Type 110, many of the parts are soldered in place with very short leads. The proper technique for soldering and unsoldering short-lead componets requires: (1) the use of needle-nose pliers between the soldering point and the component to act as a heat shunt; (2) use of a very hot iron for a short time; and (3) careful manipulation, because some of the small components have weak leads.

REPLACEMENT PARTS

Standard Parts

Replacements for all parts used in the Type 110 Pulse Generator and Trigger Takeoff System can be purchased directly from Tektronix at current net prices. However, since most of the components are standard electronic parts, they can generally be obtained locally in less time than required to obtain them from the factory. Before ordering or purchasing parts, be sure to consult the parts list to determine the tolerances and ratings 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 in the assembly of the Type 110 Pulse Generator and Trigger Takeoff System. These parts are manufactured or selected by Tektronix to satisfy particular requirements or are manufactured specially for Tektronix by other companies in accordance with Tektronix specifications. These parts and most mechanical parts should be ordered directly from Tektronix since they are normally difficult or impossible to obtain from other sources. All parts may be obtained either directly from the factory or through the local Tektronix Field Office.

Parts Ordering Information

Each part in the Type 110 Pulse Generator and Trigger Takeoff System has a six-digit Tektronix part number. This number, and a description of the part, will be found in the parts list. When ordering parts, be sure to include both the description of the part and the part number. For example, a replacement for a given capacitor should be ordered as follows: Capacitor, C610, 4000 μf, 15 volt, part number 290-091, for Type 110 Pulse Generator and Trigger Takeoff System, Serial Number ________. When parts are ordered in this manner, we are able to fill your orders promptly, and delays that might result from transposed digits in the part number are avoided.

Since the production of your instrument, some of the parts may have been superseded by improved components. In such cases, the part numbers of these new components will not be listed in the Parts List. However, if you order a part from Tektronix and it has been superseded by an improved component, the new part will be shipped in place of the part ordered. Your local Tektronix Field Engineering office has knowledge of these changes and may call you if a change in your purchase order is necessary.

Replacement information sometimes accompanies the improved components to aid in their installation.

TROUBLESHOOTING

Introduction

This portion of the Instruction Manual provides brief troubleshooting information which can be used to isolate a trouble to a certain circuit or stage. The information is divided into sections according to trouble symptoms. When trouble occurs in the instrument, the proper troubleshooting procedure can be quickly found under the paragraph heading describing the symptoms shown.

Before attempting any troubleshooting work, you should check all controls for proper settings, as described in the Operating Instructions section of this manual. Often an apparent trouble can be caused only by an improper setting of one or more controls.

Many apparent troubles may also be due to improper calibration of the instrument. One of the first steps in any troubleshooting procedure should be to check the calibration of the suspected circuit. Calibration procedures are given in Section 6 of this manual.

Separate circuit diagrams for each circuit and a block diagram of the entire instrument are contained in the Parts List and Schematic Diagrams Booklet used in conjuction with this manual. The reference designation of each electronic component of the instrument is shown on the circuit diagrams.

In cases where the circuit diagram shows more than one section to a switch, each section is coded to indicate its position on the wafers of the switch in the instrument. The wafers are numbered from the front of the switch to the rear. The letters F and R indicate whether the front or the rear of the wafer is used to perform the particular switching function.

No Pulse Output

If there is no output pulse from the Pulse Generator portion of the instrument, first listen to determine if the reed in the mercury switch SW750 is vibrating. The reed vibrates at about 720 cps with a definite metallic sound. The driving transformer, T750, puts out a barely audible hum at about 360 cps.

If the reed is vibrating, the trouble is probably in the line-charging network or in the 100-volt power supply. Set the mode switch to the OFF position, the PULSE POLARITY switch to the + position, and the AMPLITUDE control fully clockwise. Measure the voltage between the inner and outer conductors of the 50 Ω OUTPUT connector. It should be about twice the setting of the VOLTAGE RANGE switch, the inner conductor positive with respect to the outer conductor. If this voltage is present, the mercury switch is probably faulty and should be replaced. (Replacement procedures are presented in a previous paragraph of this section.)

If there is no voltage present at the 50 Ω OUTPUT connector, measure the voltage between pins 1 and 2 of V679. The voltage here should be slightly in excess of 100 volts, with pin 1 positive with respect to pin 2. Presence of this voltage indicates that the trouble lies in one of the resistive networks or switches between V679 and the 50 Ω OUTPUT connector. Absence of the voltage indicates that the trouble lies in the 100-volt power supply.

If the reed in the mercury switch is not vibrating but the transformer hum is present, the trouble is probably in the mercury switch itself or in the coupling between the transformer and the switch. First check the pulse generator magnet positioning according to instructions given in the Calibration section of this manual, and check to see that the transformer mounting screws are tight. If adjusting the position of the magnet and tightening the transformer mounting screws does not cause the reed to start vibrating, check the waveform at the collectors of the multivibrator output amplifier transistors, Q744 and Q754. The waveform should be an approximate square wave similar to that shown in Fig. 5-1, with a minimum amplitude of 10 volts peak-to-peak and capable of being set at 360 cps with the FREQUENCY ADJ. control. If this waveform is correct, the switch itself is probably faulty and should be replaced.

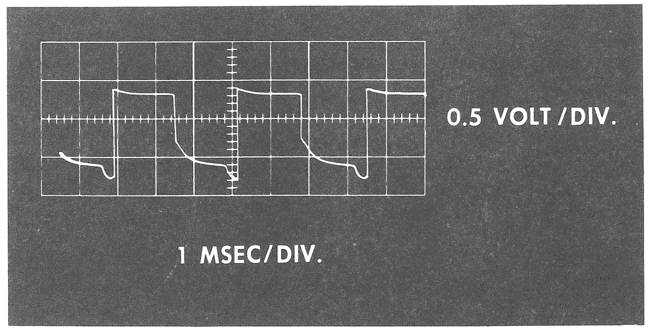


Fig. 5-1. Waveform at collector of Q754.

If there is no transformer hum, measure the voltage on the terminal at the end of the nylon post just below R750, at the upper left rear of the chassis. There should be —7.5 volts at this point. Absence of this voltage indicates that the trouble lies in the —7.5-volt power supply. Presence of this voltage indicates that either the multivibrator, Q725 and Q735, or the multivibrator output amplifier, Q744 and Q754, is faulty. Checking the waveforms at the collectors of Q725, Q735, Q744, and Q754 should give an indication of where the trouble lies. The waveform at the collectors of Q744 and Q754 should be an approximate square wave similar to that shown in Figure 5-1. The waveform at the collectors of Q725 and Q735 should be an approximate square wave similar to that shown in Figure 5-2.

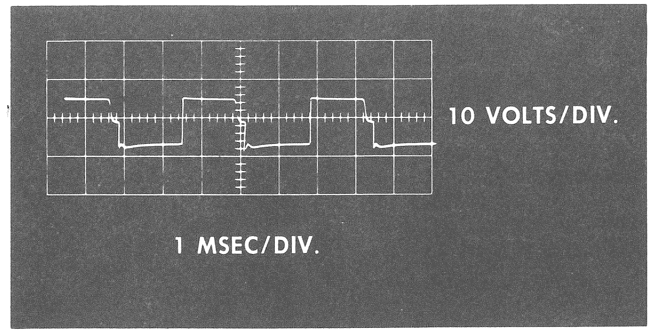


Fig. 5-2. Waveform at collector of Q735.

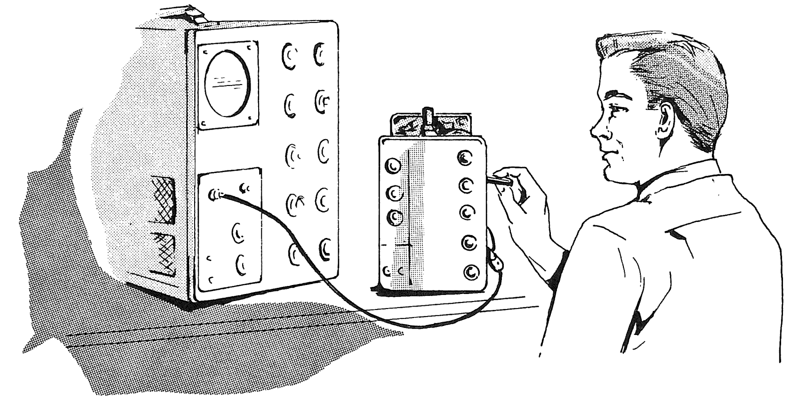
If the Type 110 operates properly in the FREE RUN mode but not in the LINE SYNC mode, the trouble is probably in SW610 or T610.

No Regenerated Trigger Out

If there is no regenerated trigger output when the Type 110 has been set up as prescribed in the Operating Instructions section of this manual, proceed as follows to isolate the trouble to one circuit. First, set the DELAY switch and the lower INVERTER switch, one at a time, to their opposite settings. If the regenerated trigger appears as one of these switches is moved, then the trouble is in that circuit. If the regenerated trigger does not appear as the DELAY and lower INVERTER switches are moved, free-run the Trigger Regenerator by turning the TRIGGER SENSITIVITY control fully clockwise. If there is still no regenerated trigger output, the trouble is in the Trigger Regenerator circuit. If the regenerated trigger does appear when the TRIGGER SENSITIVITY control is set fully clockwise the Trigger Regenerator is not receiving proper signal from the amplifier train for triggered operation.

Set the EXT. OUTPUT-REGENERATOR switch to the EXT. OUTPUT position, and check the waveform at the EXTERNAL TRIG. OUT 50 Ω connector at the back of the unit. The presence of a positive pulse between 0.5 and 2.0 volts in amplitude indicates that the coupling between the switch (SW70) and the Trigger Regenerator is faulty. The absence of such a pulse indicates that the trouble lies in the amplifier train.

To isolate a trouble in the amplifier train, set the four switches in the train for "straight-through" operation (ATTENUATOR switch to +1, upper INVERTER switch to +, AMPLIFIER 1 switch to X1, and AMPLIFIER 2 switch to X1). Then set each of the switches, one at a time, to its opposite position. After each setting check for the presence of a pulse at the EXTERNAL TRIG. OUT 50 Ω connector. If the trouble is in the amplifier train, this should isolate it to a particular stage. If no pulse appears at the EXTERNAL TRIG. OUT 50 Ω connector regardless of the positions of the four amplifier train switches, then the trouble is probably in the takeoff circuitry. This can be checked by setting the 50 Ω TAKEOFF-EXT. TRIG. IN switch to the EXT. TRIG. IN position, applying a signal through the EXTERNAL TRIG. IN connector, and noting the presence or absence of the signal at the EXTERNAL TRIG. OUT 50 Ω connector.



SECTION 6

CALIBRATION PROCEDURE

INTRODUCTION

The information contained in this section is provided to aid you in calibrating and checking the operation of the Type 110 Pulse Generator and Trigger Takeoff System. In addition, this section may also be used to aid you in isolating troubles occurring within the instrument.

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

In each calibration step only the required information is given. Detailed instructions pertaining to normal operation of the instrument are not included. If you are in doubt as to the proper operation of the controls, refer to the Operating Instructions.

Controls not mentioned in a particular calibration step are assumed to be in the positions they were in during the previous step. All test equipment used in any particular step should remain connected at the end of that step unless you are instructed to the contrary.

If a single control requires adjustment, it can be adjusted as described in the applicable step of this procedure without performing other steps as well. It may be necessary, however, that you refer to the calibration steps immediately preceding the adjustment you wish to make to determine the proper setting for the controls not mentioned in that step. The location of the internal adjustments is shown in Figs. 6-9 and 6-10.

EQUIPMENT REQUIRED

The following equipment or its equivalent is required to completely calibrate the Type 110.

(1) Tektronix Type 540-Series Oscilloscope with a Type K or L Plug-In Unit and a 10X Attenuator Probe. Substitute specifications: bandpass, 30 mc; vertical deflection factor, 0.05 to 20 volts per cm.

(2) Square-wave generator, Tektronix Type 105. Substitute specifications: output frequencies from 90 kc to 1 mc; output amplitude, 5 volts.

(3) Signal Generator, Tektronix Type 190 or Type 190A. Substitute specifications: output frequencies from 20 mc to 50 mc; output amplitude, 5 volts.

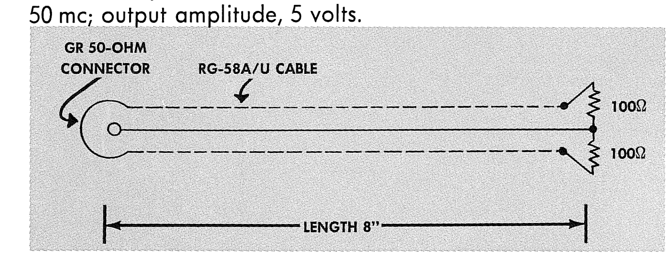


Fig. 6-1. 50-ohm terminated pigtail circuit.

(4) Two terminated cables (50 Ω impedance) requiring the following parts: two 8" RG-58A/U cables; two GR 874-C58 (General Radio) 50 Ω connectors; four 100 Ω ½ w resistors. Assemble as shown in Fig. 6-1.

(5) Mercury switch tester made from the following parts: two 1½-volt batteries; one 22 k, ½ w resistor; one 39 k, ½ w resistor; one 10 k, ½ w resistor; three banana plugs; one alligator clip; one 3" wire lead; three 12" wire leads. Connect components as shown in Fig. 6-2.

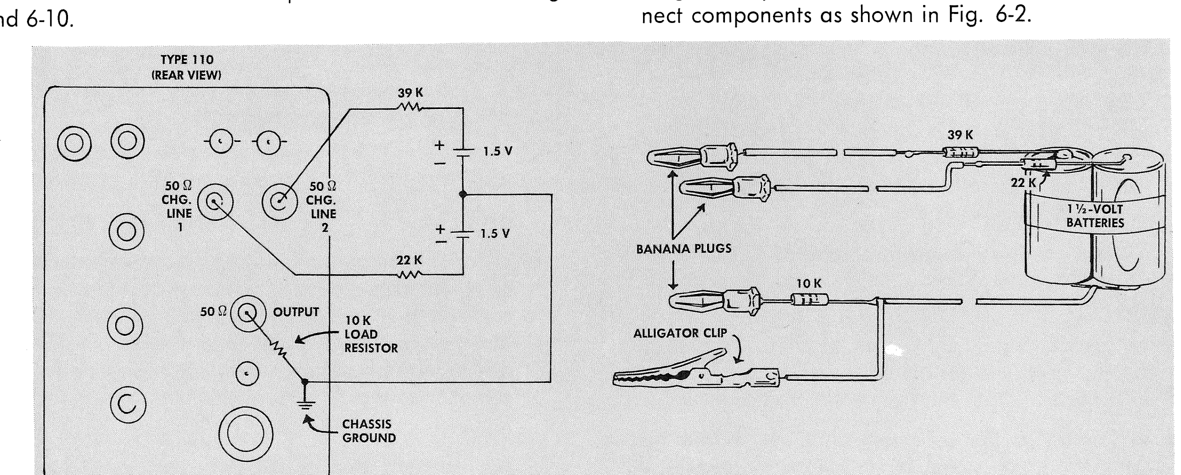


Fig. 6-2. Mercury switch tester circuit connected to the Type 110 (left); pictorial diagram of tester assembly (right).

CAUTION:

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 connector.

(6) Interconnecting cables, 50 Ω impedance. The following cables are needed: one 2-nsec cable, one 5-nsec cable, one 20-nsec cable.

(7) Tektronix 10X (20 db) attenuator pad, 50 Ω impedance.

(8) UHF to GR 50 Ω connector adapter.

(9) DC voltmeter with sensitivity of at least 20,000 Ω/volt.

(10) Small screwdriver, 3" shank.

POWER SUPPLIES

1. Check —7.5- and —22-volt Power Supplies

Connect the Type 110 to the power source and turn on the power switch. Place the MODE switch in the FREE RUN position. Connect the DC voltmeter to the —7.5-volt test point and measure the voltage. Connect the dc voltmeter to the —22-volt test point and measure the voltage. The tolerance allowed for these readings is ±10%.

PULSE GENERATOR

2. Pulse Generator Amplitude Adjustment

Set the PULSE POLARITY switch at +. Rotate the AMPLITUDE control fully clockwise and set the AMPLITUDE VOLTAGE RANGE switch at 50. Connect the dc voltmeter between the wiper arm of the AMPLITUDE control and ground. Adjust the 100 V ADJ. (R690) control for a reading of exactly +100 volts; disconnect the voltmeter.

3. 720 CPS Adjustment

The 720 CPS ADJ. control (R726) sets the output multivibrator frequency of the pulse generator. The frequency at the collector test point is 360 cps. The pulse output frequency is twice the 360-cps rate due to the two-position switching action of the mercury pulser.

Set the VOLTAGE RANGE switch at EXT. Place the MODE switch at the LINE SYNC. position. Rotate the FREQUENCY ADJ. control to mid-range.

Set the test oscilloscope controls as follows: Triggering switch at +LINE, TIME/CM switch at 1 MILLISEC., VOLTS/CM switch at .5, vertical input selector switch at DC.

Connect the probe to the collector of Q754. Adjust the 720 CPS ADJ. control to obtain a stationary display at a frequency of 360 cps. Three cycles will be displayed on 8.33 centimeters of the screen. Disconnect the probe from the test point.

4. Check Operation of Mercury Switch Contacts

Connect the test battery leads to the rear terminals of the Type 110 as shown in Fig. 6-2. Do not insert the banana plugs in all the way as this may damage the GR connectors. The 22-k and 39-k resistors are used in this circuit to obtain two different output voltages from the batteries. These voltages are applied through the reed contacts to the probe. The voltage difference allows you to tell if the mercury switch contacts are "bridging" or not. The 10-k resistor is used as a load resistor.

Set the test oscilloscope controls as follows: Triggering switch at +INT., vertical VOLTS/CM switch at .05, TIME/CM switch at 1 MILLISEC and input selector switch at DC.

First, obtain a free-running sweep on the test oscilloscope screen. Then position the trace to the horizontal centerline. Connect the (properly compensated) probe across the 10-k load resistor and adjust the test oscilloscope triggering controls for a stable display. If the reed is not vibrating (no signal displayed), it will be necessary to adjust the magnet first as explained in Step 5. Overlook the erratic horizontal shifting of the display caused by changes in the reed phasing and overlook the spike on the leading edge caused by the length of the test leads. But, do check the waveform as shown in Fig. 6-3 for the following characteristics:

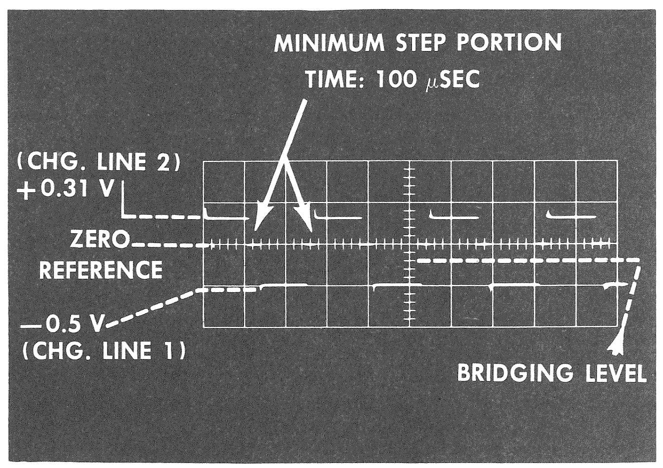


Fig. 6-3. Typical appearance of the pulse generator output waveform when using the mercury switch tester.

(a) Output frequency should be 360 cycles at the mid-range position of the FREQUENCY ADJ. control.

(b) There should be no bridging of contacts and both contacts should produce an output signal. When the contacts are bridging, you will notice that the step portion will move down from the zero reference line. If one set of contacts are not producting an output signal, no signal will appear from that set of contacts.

(c) The contacts should remain open for a minimum interval of 100 µsec at the step portion of the waveform. The open time between the rise and fall portions should be as close to being equal as is possible.

This is to assure that there will be sufficient time to charge a 20-nsec cable (for a 40-nsec pulse) to 99% of the supply.

(d) Set the test oscilloscope triggering switch at +INT. Place the Type 110 MODE switch at the FREE RUN position. As the FREQUENCY ADJ. control is rotated through its full range, check the appearance of the waveform for the (b) and (c) characteristics described in this step.

5. Pulse Generator Magnet Positioning

The magnet, in conjuction with the pulser multivibrator, controls the movement of the mercury pulser reed.

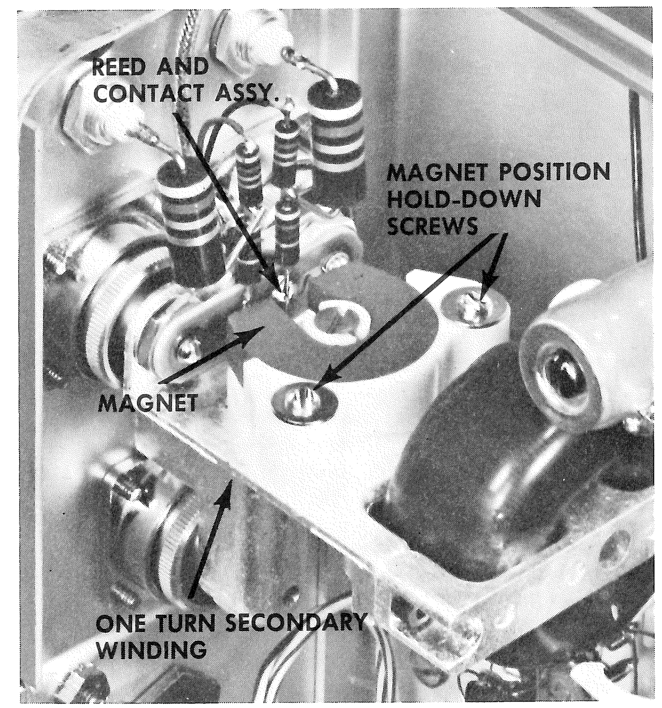


Fig. 6-4. Mercury pulser assembly.

Mark the location of the magnet so that you can return to the same spot if necessary. Loosen the magnet hold-down screws (see Fig. 6-4) 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. 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. The magnet is positioned so that the reed vibrates freely and is checked for proper operation as described in Step 4. When the magnet is positioned correctly, carefully tighten the hold-down screws without disturbing the lccation of the magnet. Disconnect the battery leads and the probe.

6. Check Pulse Generator Output Signal

This check is made to test the pulse duration and amplitude when a charge line of known delay is used.

Set the test oscilloscope controls as follows: trigger switch at +INT., TIME/CM switch at .1 µSEC., 5X MAGNIFIER at ON, and the VOLTS/CM switch at 2.

Connect a 20-nsec cable from the 50 Ω CHG. LINE 1 connector to the 50 Ω CHG. LINE 2 connector. Connect a terminated pigtail to the 50 Ω OUTPUT connector. Check to see that the AMPLITUDE control is at 50 and the MODE switch is at the FREE RUN position. Place the AMPLITUDE VOLTAGE RANGE switch at 50. Connect the probe to the terminated pigtail. The pulse which is generated by the double-transit discharge time of the cable has a 40-nsec duration.

(a) Observe the display to check that the pulse does have a time duration of 40 nsec at the 50% level (see Fig. 6-5), a flat top, an amplitude of +50 volts, and is free of reflections just after the pulse.

(b) Place the AMPLITUDE VOLTAGE RANGE switch at 5. Set the test oscilloscope VOLTS/CM switch at .2 Check for a 5-volt amplitude signal.

(c) Place the AMPLITUDE VOLTAGE RANGE switch at .5 and place the test oscilloscope VOLTS/CM switch at .05. Check for a 0.5-1 volt amplitude signal. Disconnect the probe and the terminated pigtail.

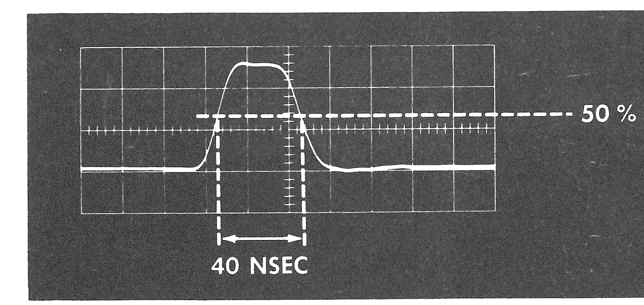


Fig.6-5. Illustrating the method of determining the time duration of the pulse using a Type 540-Series Oscilloscope with a Type K or L Unit.

TRIGGER TAKEOFF SYSTEM

7. Check Attenuator and Amplifier Train

Connect a 2-nsec cable from the Pulse Generator 50 Ω OUTPUT connector to the SIG. IN FOR TRIG. TAKEOFF connector. Connect the 50 Ω terminated pigtail to the SIGNAL OUT 98% connector. Connect a second 50 Ω terminated pigtail to the EXT. 50 Ω OUTPUT connector. Place the Type 110 controls as follows:

AMPLITUDE	50
AMPLITUDE VOLTAGE RANGE	50
TAKEOFF-EXT. 50 Ω	TAKEOFF
ATTENUATOR	+1
INVERTER	+1
AMPLIFIER 1	X1
AMPLIFIER 2	X1
EXT. OUTPUT-REGENERATOR	EXT. OUTPUT

Set the test oscilloscope VOLTS/CM switch at .5 and connect the probe to the terminated pigtail (connected to the 50 Ω EXT. OUTPUT connector.) Adjust the oscilloscope triggering controls for a stable display and make the following checks:

(a) Amplitude of the output signal should be from +8 volts to +10 volts with not more than a 10% tilt of the top portion of the waveform.

(b) Place the ATTENUATOR switch at ÷3.16. Set the test oscilloscope VOLTS/CM switch at .1. The amplitude should now be approximately 3 volts (±20%).

(c) Place the INVERTER switch at —1. To observe the waveform set the test oscilloscope trigger slope switch at —INT. Check to see that the waveform is inverted and that it is —8 volts to —10 volts in amplitude.

(d) Set the AMPLITUDE control at 25 and the AMPLITUDE VOLTAGE RANGE switch at 5. Place the test oscilloscope controls as follows: trigger slope switch at +INT., 5X MAG. switch at OFF (X1), VOLTS/CM at .05. Set the Type 110 ATTENUATOR switch at 1. Place the INVERTER switch at +1 and rotate the AMPLITUDE control to obtain a 0.5-volt amplitude pulse as observed on the oscilloscope. Remember or record the setting of the AMPLITUDE control for this step so that you can return to it. Place a 10X attenuator pad in series with the 2-nsec cable from the Pulse Generator output. Set the AMPLIFIER 1 switch to X10. The signal amplitude should be between 0.4 and 0.75 volt. This corresponds to an amplifier gain of 8 to 15. Increase the setting of the AMPLITUDE control gradually to check if the output from AMPLIFIER 1 can be increased to ±1 volt without causing saturation (indicated by flattening and widening of the peak portion of the waveform). The minus 1-volt check can be made by setting the PULSE POLARITY switch to — and the test oscilloscope trigger slope switch to —INT. After making this check, set the PULSE POLARITY switch back to + and the test oscilloscope trigger switch back to +INT.

(e) Place the AMPLIFIER 1 switch at X1 and the AMPLIFIER 2 switch at X10. Check the gain and overload as explained in part (d) above.

(f) The cascaded gain of the two amplifiers must be at least 100. To check the cascaded gain, set the AMPLIFIER 1 switch to X10 and set the AMPLITUDE VOLTAGE RANGE switch to .5. Rotate the AMPLITUDE control to the dial setting noted in part (d) above. The output amplitude displayed on the oscilloscope should be at least 0.5 volt.

8. Set Repetition Rate Limit Adjustment

In this step the REP. RATE LIMIT control is adjusted to obtain the correct waveshape at the base return circuit of the blocking oscillator when the ringing coil network (L86 and C86) is connected in the circuit by means of the TRIGGER MODE switch.

Set the test oscilloscope controls as follows: TIME/CM switch at 10 μSEC, VOLTS/CM switch at .5. Disconnect the terminated cable from the EXT. 50 Ω OUT connector and

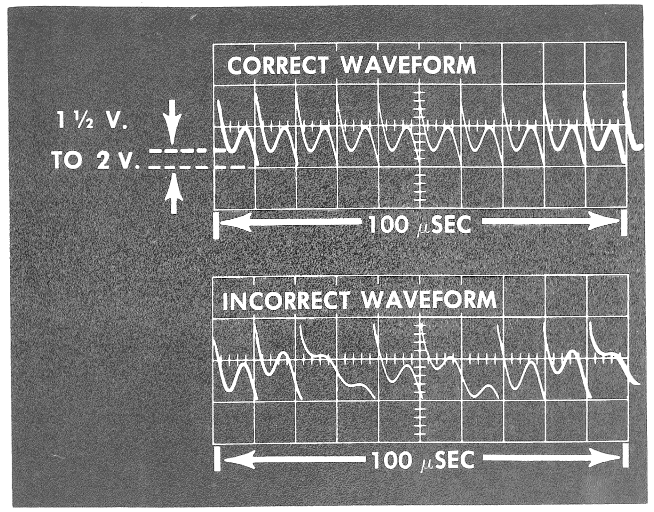


Fig. 6-6. Correct and incorrect waveforms obtained at the base circuit of Q80 when the TRIGGER MODE switch is place at the >1 MC position.

connect it to the REGENERATED TRIG. OUT 50 Ω connector. Place the EXT. OUTPUT-REGENERATOR switch at the REGENERATOR position. Rotate the TRIGGER SENSITIVITY control fully clockwise to free run the trigger regenerator. Place the TRIGGER MODE switch at >1 MC. Connect the probe to the junction of C86 and R88 in the base return circuit of Q80. Set the oscilloscope triggering controls for a stable waveform. Compare the displayed waveform with the correct waveform shown in Fig. 6-6. If necessary, adjust the REP. RATE LIMIT control (R89) to obtain the correct waveform. The bottom of the first negative ringing cycle should be 1½ to 2 volts above the start of the fast-rise portion of the waveform as noted in the illustration. To check for stable operation, rotate the TRIGGER SENSITIVITY control slowly counterclockwise through the free-running range and check to see that the waveform remains correct. Leave the TRIGGER SENSITIVITY control at the free-running position.

9. Check Free-Running Frequency of Trigger Regenerator

Continuing with the procedure given in Step 8, check the frequency of the trigger regenerator waveform. The frequency should be 100 kc nominal, ±10%.

10. Check for Absence of Ringing

In this step the trigger regenerator waveform is checked for correct waveshape when the ringing coil circuit is disconnected by means of the TRIGGER MODE switch.

With conditions remaining as in the previous step, place the TRIGGER MODE switch at <1MC. Make certain the displayed wavform has a smooth fall time with no sign of ringing as shown in Fig. 6-7. The frequency of the waveform should be 100 kc ±10%. Disconnect the probe from the test point junction.

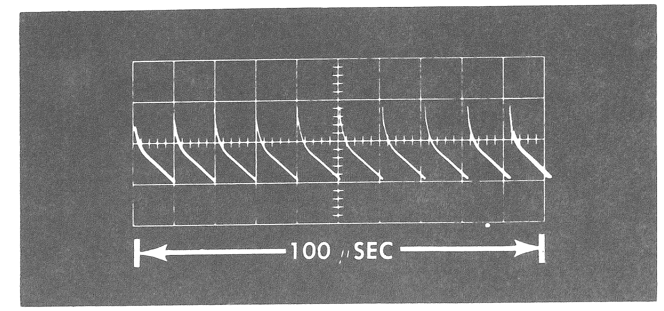


Fig. 6-7. Correct waveform obtained at the base circuit of Q80 when the TRIGGER MODE switch is placed at the <1 MC position.

11. Check Regenerator Out Signal Amplitude

Set the oscilloscope TIME/CM switch at .1 μSEC. Connect the probe to the terminated pigtail at the REGENERATED TRIG. OUT 50 Ω connector. Measure the signal amplitude and the time duration of the output signal. The amplitude should be 10 volts (±20%). The time duration measured at the 7-volt amplitude level should be at least 200 nsec (see Fig. 6-8). Disconnect the 2-nsec cable and the 10X attenuator pad from the SIG. IN FOR TRIGGER TAKEOFF connector.

12. Check Triggering Ability of Trigger Regenerator

The purpose of this step is to check the scaling (count-down or lock-in) ability of the trigger regenerator.

Connect one end of a 10-nsec cable through the UHF/GR connector adapter to the output of the Type 105; connect the other end of the cable to the SIG. IN FOR TRIGGER TAKEOFF connector on the Type 110. Place AMPLIFIER 1 and AMPLIFIER 2 switches at X1. Connect the probe to the pigtail termination which is connected to the SIGNAL OUT 98% connector. Set the amplitude control of the Type 105 to produce a 5-volt deflection on the test oscilloscope. Set the TRIGGER SENSITIVITY control just below the free-running position. Reconnect the probe to the termination at the REGENERATED TRIG. OUT 50 Ω connector. Proceed as follows:

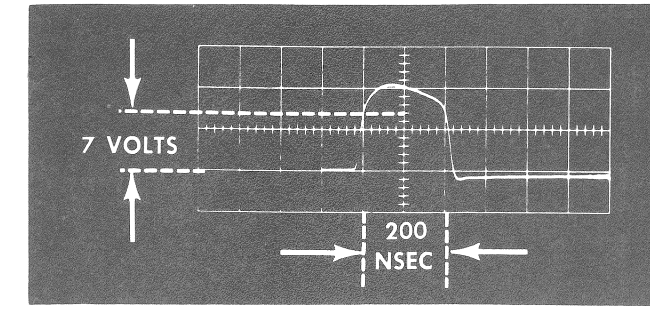


Fig. 6-8. The time duration of the regenerated trigger at the 7-volt level should be at least 200 nsec.

(a) Set the output frequency of the Type 105 at 250 kc and rotate the variable frequency control from 250 kc to 90 kc. Check to see that the trigger regenerator circuit scales smoothly when the Type 105 output frequency is varied near 100 kc (±10%).

(b) Rotate the variable frequency control of the Type 105 up to 1 mc and check scaling. You may encounter some scaling difficulties when approaching multiples of 100 kc; in these cases, set the TRIGGER MODE switch at >1 MC. Disconnect the Type 105 from the Type 110.

(c) Use the UHF/GR connector adapter to connect between the Type 190 attenuator head and the SIG. IN FOR TRIGGER TAKEOFF connector. Use the probe to set the output at the SIGNAL OUT 98% terminated lead for an amplitude of 5 volts at 20 mc. Reconnect the probe at the REGENERATED TRIG. OUT 50 Ω connector and gradually increase the frequency of the Type 190 from 20 mc to 50 mc. Normally, to obtain smooth scaling while covering this frequency range and while checking the operation of the trigger regenerator circuit, the setting of the TRIGGER SENSITIVITY control may have to be altered slightly each time instability occurs.

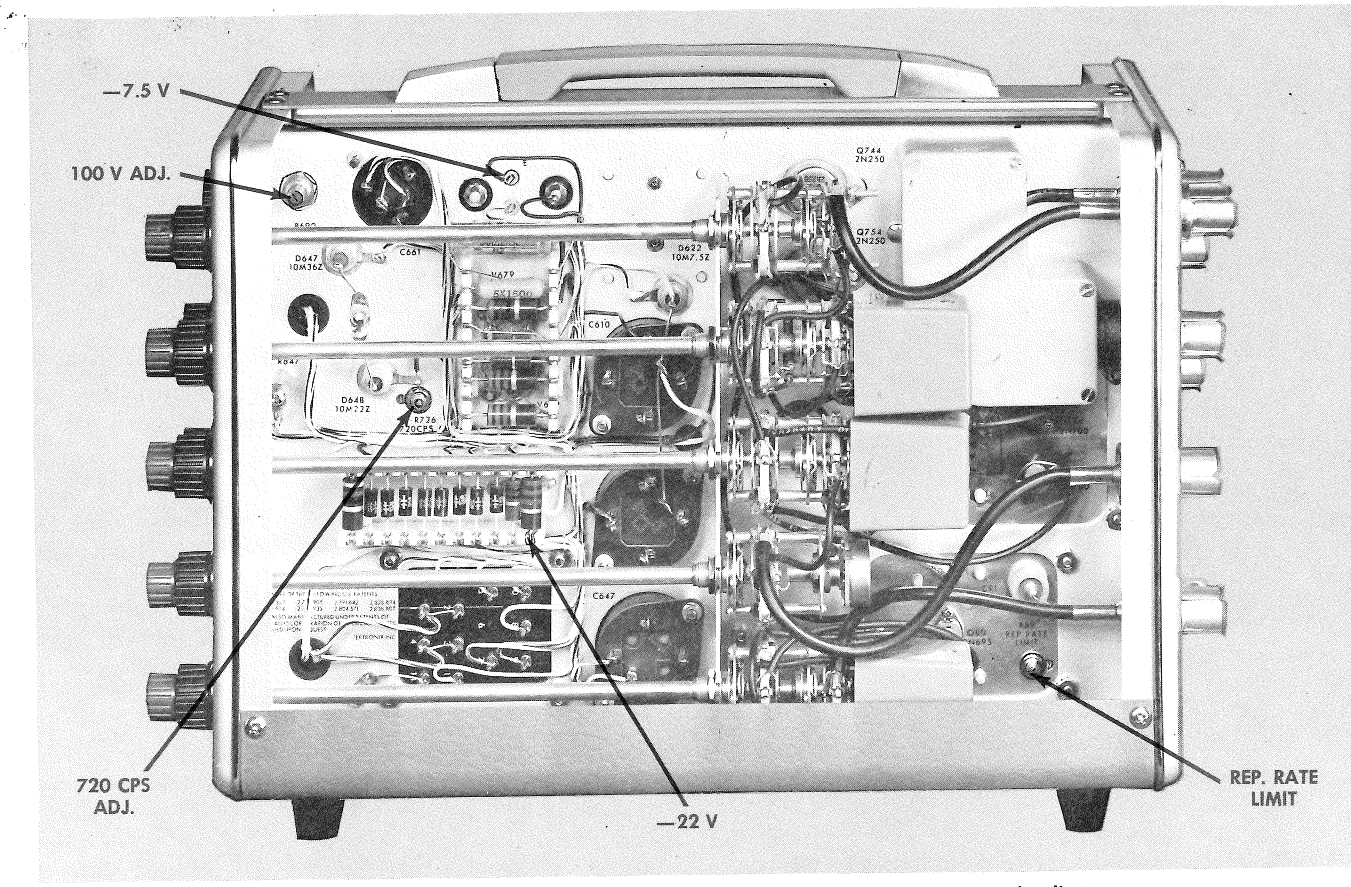


Fig. 6-9. Right side view showing the location of test points and internal adjustments.

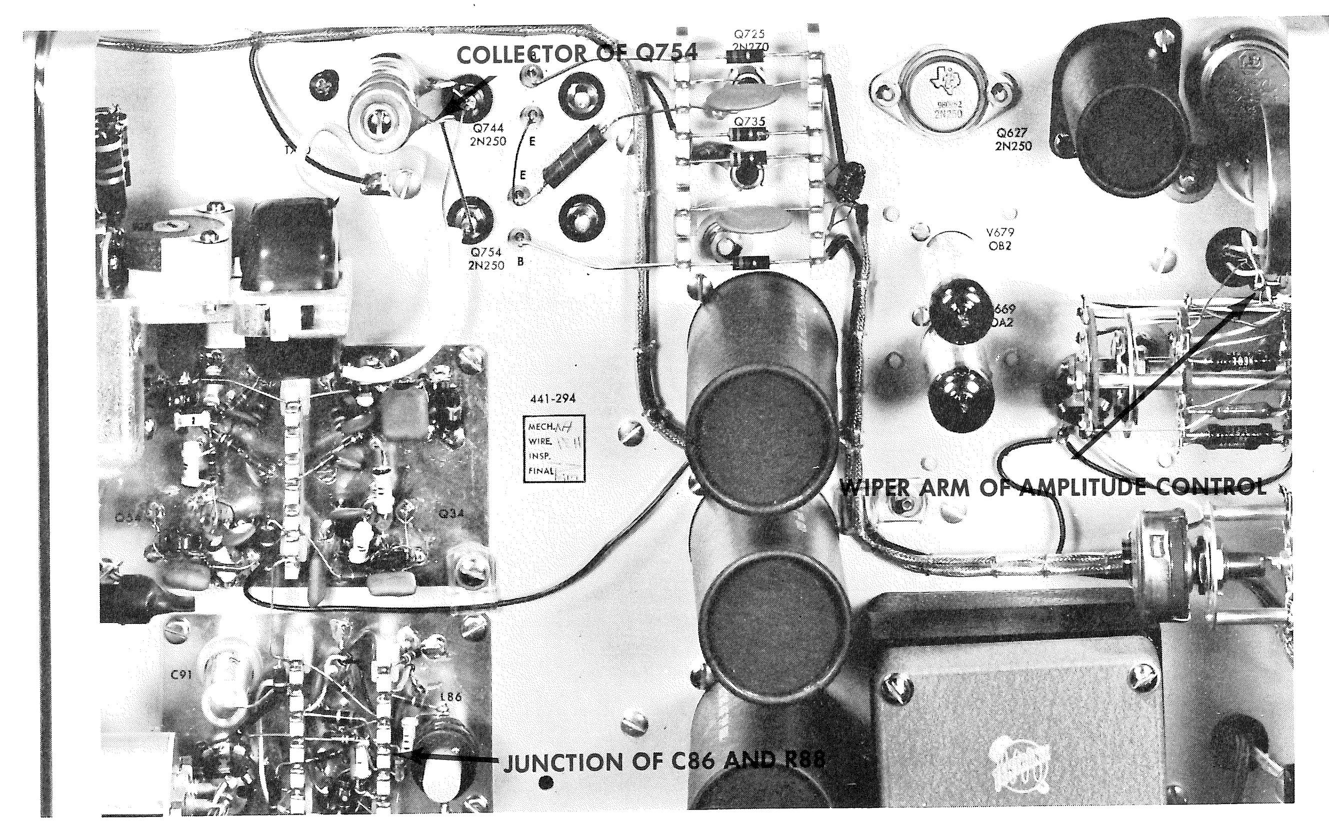
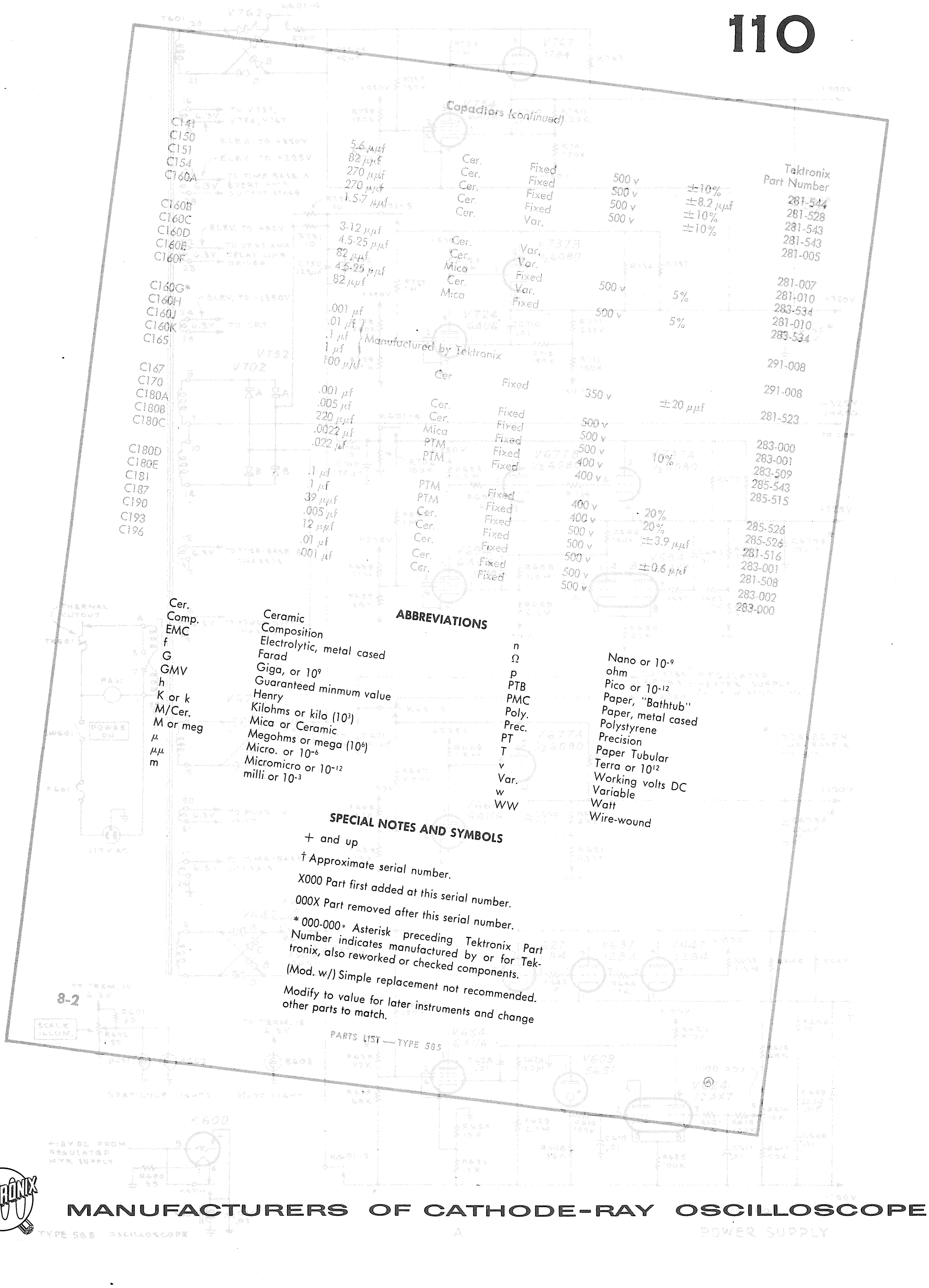


Fig. 6-10. Left side view showing the location of test points.

PARTS LIST *and* SCHEMATIC DIAGRAMS

000443

TYPE 110



MANUFACTURERS OF CATHODE-RAY OSCILLOSCOPES

HOW TO ORDER PARTS

Replacement parts may be purchased at current net prices from your local Tektronix Field Office or from the factory. Most of the parts can be obtained locally. All of the structural parts, and those parts noted in the parts list "Manufactured by Tektronix", should be ordered from Tektronix.

When ordering from Tektronix include a complete description of the part, and its 6-digit part number. Give the type, serial number, and modification number (if any) of the instrument for which it is ordered.

Structural parts are not listed in the parts list. Their part numbers are usually stamped directly on the metal. If not, a complete physical description of the part will suffice.

If the part which you have ordered has been replaced by a new or improved part, the new part will be shipped instead. Tektronix Field Engineers are informed of such changes. Where necessary replacement information comes with new parts.

PARTS LIST

Values fixed unless marked Variable.

Tolerance ±20% unless otherwise indicated.

Bulbs

		Tektronix Part Number
B605	Incandescent #12 Pilot light	150-018

Capacitors

C20		.1 μf	Discap	30 v		283-024
C21	101-140X	39 μμf	Cer.	500 v	±3.9 μμf	281-516
C25	101-140	39 μμf	Cer.	500 v	±3.9 μμf	281-516
C25	141-up	22 μμf	Cer.	500 v	±4.4 μμf	281-510
C26		.1 μμf	Discap	10 v		283-023
C29		.001 μf	Discap	500 v		283-000
C31	101-140X	47 μμf	Cer.	500 v	±4.7 μμf	281-519
C35	101-140	47 μμf	Cer.	500 v	±4.7 μμf	281-519
C35	141-up	39 μμf	Cer.	500 v	±3.9 μμf	281-517
C36		.1 μμf	Discap	10 v		283-023
C38		.1 μf	Discap	30 v		283-024
C39		.1 μf	Discap	30 v		283-024
C40		.1 μf	Discap	30 v		283-024
C41	101-140X	39 μμf	Cer.	500 v	±3.9 μμf	281-516
C45	101-140	39 μμf	Cer.	500 v	±3.9 μμf	281-516
	141-up	22 μμf	Cer.	500 v	±4.4 μμf	281-510
C46		.1 μf	Discap	10 v		283-023
C49		.001 μf	Discap	500 v		283-000
C51	101-140X	47 μμf	Cer.	500 v	±4.7 μμf	281-519
C55	101-140	47 μμf	Cer.	500 v	±4.7 μμf	281-519
	141-up	39 μμf	Cer.	500 v	±3.9 μμf	281-517
C56		.1 μf	Discap	10 v		283-023
C58		.1 μf	Discap	30 v		283-024
C70		.01 μf	Discap	150 v		283-003
C73		.01 μf	Discap	150 v		283-003
C78		.01 μf	Discap	150 v		283-003
C80	101-140	.001 μf	Discap	500 v	5%	283-031
	141-350 {	.001 μf	Discap	500 v		283-031
		470 μμf	Cer.	500 v		281-525
	351-up	1500 μμf	Discap	500 v		283-035
C82		.1 μf	Discap	10 v		283-023
C84		.005 μf	Discap	500 v		283-001
C86		470 μμf	Discap	500 v	5%	283-032
C90		.02 μf	Discap	150 v		283-004
C91		100 μf	EMT	25 v		290-015
C600		1500 μμf	Discap	500 v		281-559
C601		1500 μμf	Cer.	500 v		281-559
C610		4000 μf	EMC	15 v		290-091
C611		4000 μf	EMC	15 v		290-091
C627		100 μf	EMT	25 v		290-015
C647		1000 μf	EMC	50 v		290-123

Capacitors *(continued)*

						Tektronix Part Number
C661		2 x 40 μf	EMC	250 v		290-040
C679	101-140	.1 μf	Discap	500 v		283-008
	141-up	.1 μf	MT	400 v		285-526
C696		.001 μf	Discap	500 v		283-000
C725		2.2 μf	Discap	3 v		283-019
C735		2.2 μf	Discap	3 v		283-019

Fuses

F601	1-½ amp	3 AG	Fast Blo		159-016

Inductors

L20	.18 μh	*108-009
L40	.18 μh	*108-009
L83	2.2 μh on 47 Ω, ½ w res. with 39 μμf, Cer. Cap.	*108-203
L86	15000 μh	*108-008

Resistors

R3		24 Ω	½ w	Comp.	5%	301-240
R4		68 Ω	½ w	Comp.	5%	301-680
R5		24 Ω	½ w	Comp.	5%	301-240
R6		75 Ω	½ w	Comp.	5%	301-750
R20		68 Ω	¼ w	Comp.	10%	316-680
R21	101-140X	470 Ω	¼ w	Comp.	10%	316-471
R22	101-140	1.2 k	¼ w	Comp.	10%	316-122
	141-350	995 Ω	½ w	Prec.	2%	309-085
	351-up	1 k	⅛ w	Comp.	1%	318-049
R23	101-140	2.7 k	¼ w	Comp.	10%	316-272
	141-350	3 k	½ w	Prec.	1%	309-182
	351-up	3.01 k	⅛ w	Prec.	1%	318-035
R25	101-140	560 Ω	¼ w	Comp.	10%	316-561
	141-up	910 Ω	¼ w	Comp.	5%	315-911
R26	101-140	43 Ω	½ w	Comp.	5%	301-430
	141-350	49.5	½ w	Prec.	1%	309-215
	351-up	49.9 Ω	⅛ w	Prec.	1%	318-046
R28	101-140	390 Ω	¼ w	Comp.	10%	316-391
	141-350	390 Ω	¼ w	Comp.	5%	315-391
	351-up	392 Ω	⅛ w	Prec.	1%	318-048
R29	101-140	1.2 k	¼ w	Comp.	10%	316-122
	141-up	2.2 k	¼ w	Comp.	5%	315-222
R31	101-140X	470 Ω	¼ w	Comp.	10%	316-471
R35		910 Ω	¼ w	Comp.	5%	315-911
R36	101-140	43 Ω	½ w	Comp.	5%	301-430
	141-350	60 Ω	½ w	Prec.	1%	309-067
	351-up	60.4 Ω	⅛ w	Prec.	1%	318-047
R38	101-140	1.2 k	¼ w	Comp.	10%	316-122
	141-up	620 Ω	¼ w	Comp.	5%	315-621
R39		22 Ω	½ w	Comp.	10%	302-220

Resistors *(continued)*

							Part Number Tektronix
R40		68 Ω	¼ w		Comp.	10%	316-680
R41	101-140X	470 Ω	¼ w		Comp.	10%	316-471
R42	101-140	1.2 k	¼ w		Comp.	10%	316-122
	141-350	995 Ω	½ w		Prec.	2%	309-085
	351-up	1 k	⅛ w		Prec.	1%	318-049
R43	101-140	2.7 k	¼ w		Comp.	10%	316-272
	141-350	3 k	½ w		Prec.	1%	309-182
	351-up	3.01 k	⅛ w		Prec.	1%	318-035
R45	101-140	560 Ω	¼ w		Comp.	10%	316-561
	141-up	910 Ω	¼ w		Comp.	5%	315-511
R46	101-140	43 Ω	½ w		Comp.	5%	301-430
	141-350	49.5 Ω	½ w		Prec.	1%	309-215
	351-up	49.9 Ω	⅛ w		Prec.	1%	318-046
R48	101-140	390 Ω	¼ w		Comp.	10%	316-391
	141-350	390 Ω	¼ w		Comp.	5%	315-391
	351-up	392 Ω	⅛ w		Prec.	1%	318-048
R49	101-140	1.2 k	¼ w		Comp.	10%	316-122
	141-up	2.2 k	¼ w		Comp.	5%	315-222
R51	101--140X	470 Ω	¼ w		Comp.	10%	316-471
R55		910 Ω	¼ w		Comp.	5%	315-911
R56	101-140	43 Ω	½ w		Comp.	5%	301-430
	141-350	60 Ω	½ w		Prec.	1%	309-067
	351-up	60.4 Ω	⅛ w		Prec.	1%	318-047
R58	101-140	1.2 k	¼ w		Comp.	10%	316-122
	141-up	620 Ω	¼ w		Comp.	5%	315-621
R70		56 Ω	¼ w		Comp.	10%	316-560
R71		8.2 k	¼ w		Comp.	10%	316-822
R73		47 Ω	¼ w		Comp.	10%	316-470
R78		1.2 k	¼ w		Comp.	10%	316-122
R81		390 Ω	¼ w		Comp.	10%	316-391
R82		200 Ω		Var.	Comp.	Trig. Sensitivity	311-178
R84		27 Ω	½ w		Comp.	10%	302-270
R86		2.7 k	¼ w		Comp.	10%	316-272
R88		10 k	¼ w		Comp.	10%	316-103
R89		20 k		Var.	Comp.	Rep. Rate Limit	311-159
R90		22 Ω	½ w		Comp.	10%	302-220
R91		22 Ω	½ w		Comp.	10%	302-220
R605		47 Ω	2 w		Comp.	10%	306-470
R622		15 Ω	2 w		Comp.	10%	306-150
R647		120 Ω	5 w		WW	5%	308-163
R648		180 Ω	2 w		Comp.	10%	306-181
R660		10 Ω	1 w		Comp.	10%	304-100
R661		1.5 k	5 w		WW	5%	308-002
R668		680 Ω	2 w		Comp.	10%	306-681
R669		680 Ω	2 w		Comp.	10%	306-681
R678		2.2 k	1 w		Comp.	10%	304-222
R679		2.2 k	1 w		Comp.	10%	304-222
R690		2.2 k	1 w	Var.	Comp.	100 V Adj.	311-071
R691		18 k	½ w		Prec.	1%	309-036
R692		1.8 meg	½ w		Prec.	1%	309-020

Resistors *(continued)*

						Tektronix Part Number
R694	20 K	½ w		Prec.	1%	309-153
R695	180 k	½ w		Prec.	1%	309-279
R696	20 k		Var.	WW	Amplitude	311-053
R721	3.3 k	½ w		Comp.	5%	301-332
R722	68 Ω	½ w		Comp.	10%	302-680
R723	270 Ω	½ w		Comp.	5%	301-271
R724	1.2 k	½ w		Comp.	10%	302-122
R725	300 Ω		Var.	Comp.	Frequency Adj.	311-052
R726	1 k		Var.	Comp.	720 CPS Adj.	311-155
R731	3.3 k	½ w		Comp.	5%	301-332
R733	270 Ω	½ w		Comp.	5%	301-271
R744	0.5 Ω	1 w		WW	1%	308-087
R750	50 Ω	25 w		WW	5%	308-164
R751	47 k	½ w		Comp.	10%	302-473
R752	47 k	2 w		Comp.	10%	306-473
R753	4.7 k	½ w		Comp.	10%	302-472
R756	47 k	½ w		Comp.	10%	302-473
R757	47 k	2 w		Comp.	10%	306-473
R758	4.7 k	½ w		Comp.	10%	302-472

Switches

		Wired	Unwired
SW1,A&B	Trigger Mode		*260-300
SW4,A&B	Attenuator & Inverter	*262-275	*260-300
SW24,A&B	Amplifier, 1 and 2	*262-276	*260-300
SW70	External Output & Regenerator		*260-301
SW92,A&B	Delay & Inverter	*262-278	*260-300
SW601	Power		260-134
SW610	Mode	*262-273	*260-303
SW690,A&B	Voltage Range & Pulse Polarity	*262-272	*260-302
SW750	Mercury, selected		*260-334

Transformers

T1	Trigger Take-off Ass'y	*650-205
T8	Toroid, TD15	*120-174
T20	Toroid, TD4	*120-155
T38	Toroid, TD4	*120-155
T40	Toroid, TD4	*120-155
T58	Toroid, TD4	*120-155
T80	Toroid, TD3	*120-154
T96	Toroid, TD15	*120-174
T600	Toroid, TD 12	*120-164
T601	Power	*120-162
T610	Toroid, TD5	*120-156
T750	Toroid, TD13	*120-163

Diodes

		Tektronix Part Number
D71	Germanium, Q6-100	152-026
D73	Germanium, Q6-100	152-026
D78	Zener, 6.2 to 8.0 volts	152-004
D80	Germanium, DR746	152-007
D84	Germanium, DR746	152-007
D601	Silicon, 400 V PIV 500 MA	152-011
D602	Silicon, 400 V PIV 500 MA	152-011
D622	Zener, 10 M 7.5Z	152-019
D640	Silicon, 400 V PIV 500 MA	152-011
D641	Silicon, 400 V PIV 500 MA	152-011
D642	Silicon, 400 V PIV 500 MA	152-011
D643	Silicon, 400 V PIV 500 MA	152-011
D647	Zener, 10 M 36Z	152-021
D648	Zener, 10 M 22Z	152-020
D661	Silicon, 400 V PIV 500 MA	152-011
D662	Silicon, 400 V PIV 500 MA	152-011

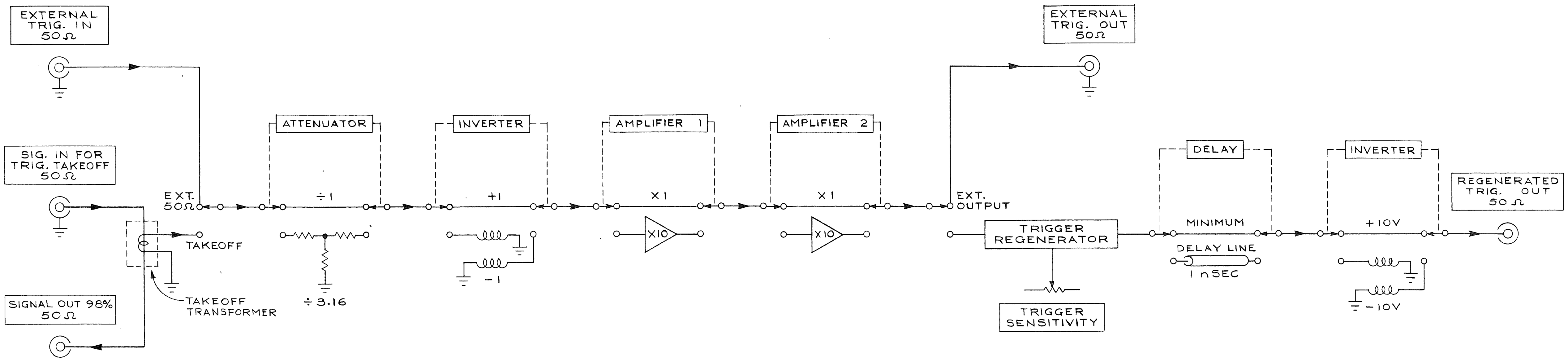
1N2070

Transistors

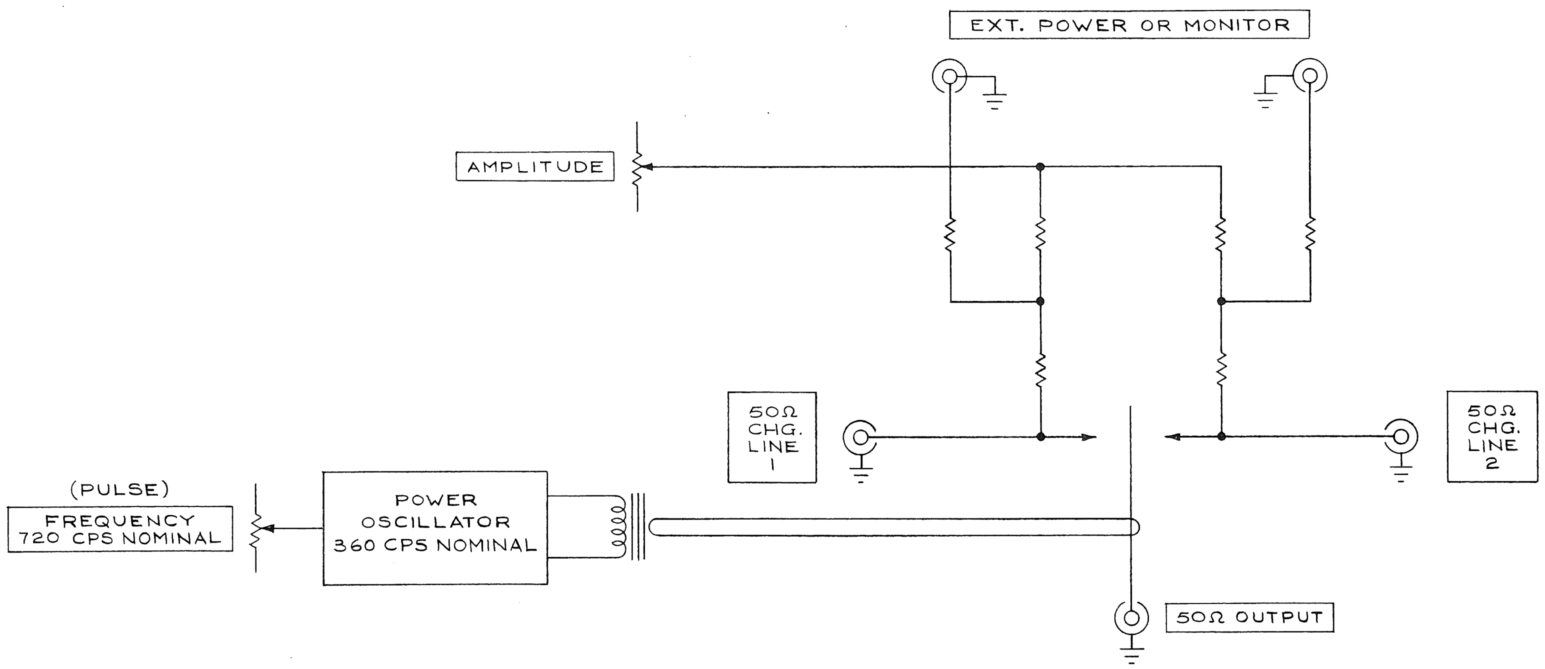
Q24	101-140	2N700	Selected, Beta 13.5 to 21	*153-507
	141-up	2N700	Selected, Beta 8-10.2	*153-512
Q34	101-140	2N700	Selected, Beta 21 to 26.5	*153-506
	141-up	2N700	Selected, Beta 10.2 to 13	*153-513
Q44	101-140	2N700	Selected, Beta 10.5 to 13.5	*153-508
	141-up	2N700	Selected, Beta 8 to 10.2	*153-512
Q54	101-140	2N700	Selected, Beta greater than 26.5	*153-505
	141-up	26700	Selected, Beta 10.2 to 13	*153-513
Q80		SM-04/2N695		151-032
Q627		2N250		151-018
Q725		2N270		151-007
Q735		2N270		151-007
Q744		2N250		151-018
Q754		2N250		151-018

Electron Tubes

V669	OA2	154-001
V679	OB2	154-075



TRIGGER TAKEOFF SYSTEM

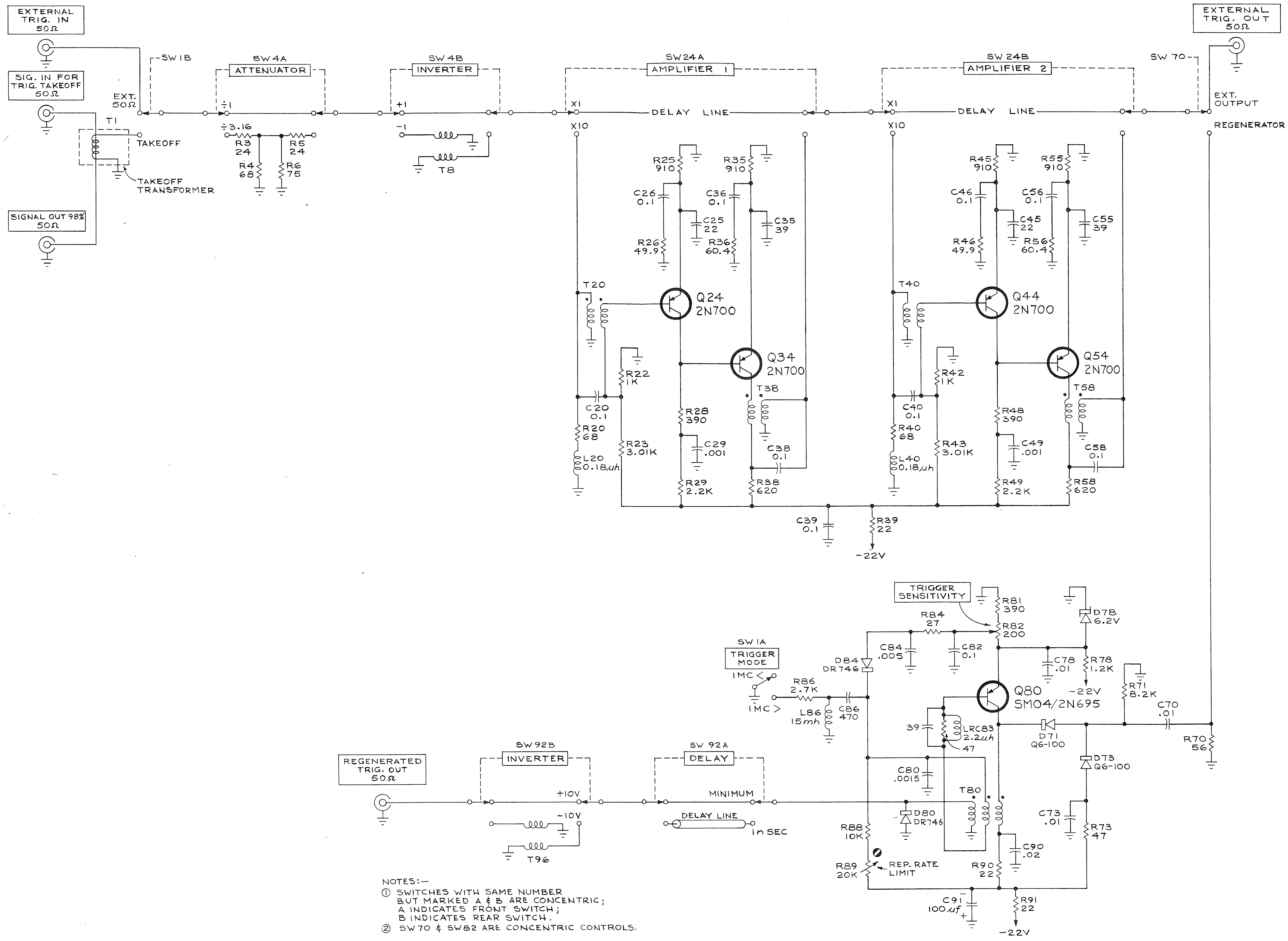


PULSE GENERATOR

TYPE 110

A_1

MRH
4-11-60
BLOCK DIAGRAM



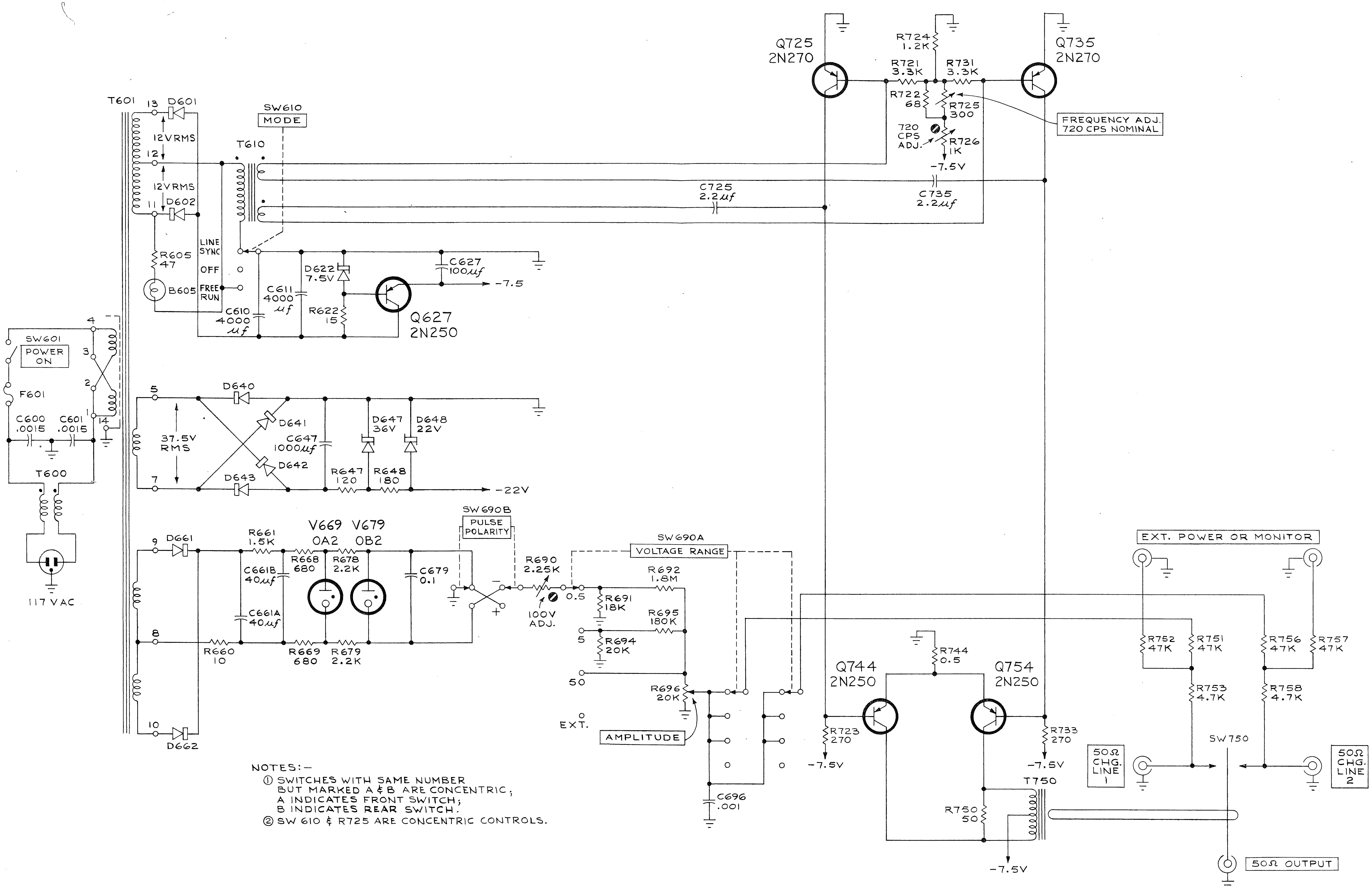
NOTES:—

① SWITCHES WITH SAME NUMBER BUT MARKED A & B ARE CONCENTRIC; A INDICATES FRONT SWITCH; B INDICATES REAR SWITCH.

② SW70 & SW82 ARE CONCENTRIC CONTROLS.

MRH
4-11-60

TRIGGER TAKEOFF SYSTEM



NOTES:–
① SWITCHES WITH SAME NUMBER BUT MARKED A & B ARE CONCENTRIC; A INDICATES FRONT SWITCH; B INDICATES REAR SWITCH.
② SW 610 & R725 ARE CONCENTRIC CONTROLS.

MRH
4-11-60