

OPERATING INSTRUCTIONS



TYPE 1217-B

UNIT PULSE GENERATOR

GENERAL RADIO COMPANY
G·H

OPERATING INSTRUCTIONS

TYPE 1217-B

UNIT PULSE GENERATOR

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West Concord, Massachusetts, USA

G E N E R A L R A D I O C O M P A N Y
WEST CONCORD, MASSACHUSETTS, USA

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SPECIFICATIONS

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 cps to 500 kc with calibrated points in a 1-3 sequence from 10 cps to 300 kc, and 500 kc, all $\pm 5\%$. Continuous coverage with an uncalibrated control.

Externally Controlled: Aperiodic, dc to 1 Mc with 1 v, rms, input (0.5 v at 500 kc and lower); input impedance, at 0.5 v, rms, approximately 100 kilohms shunted by 50 pf. Output pulse is started by the negative-going input transition.

OUTPUT-PULSE CHARACTERISTICS

Duration: 100 nsec to 1 sec in seven decade ranges, $\pm 5\%$ of reading or $\pm 2\%$ of full scale or ± 25 nsec, whichever is greater.

Rise and Fall Times: Into terminated 50- or 100-ohm cables all transitions will have rise times less than 20 nsec (typically 12 nsec). On high-voltage output (40 v at 1 kilohm) transition times are limited by load capacitance and are typically 60 nsec + 2 nsec/pf external load capacitance.

Voltage: Positive and negative 40-ma current pulses available simultaneously. DC coupled, with dc component negative with respect to ground. 40 v, peak, into 1-kilohm internal load impedance for both negative and positive pulses. Output control marked in approximate output impedance.

Overshoot: Overshoots and noise in pulse, less than 5% of amplitude with correct termination. **Ramp-off:** Less than 1% everywhere.

Synchronizing Pulses:

Pre-pulse: Positive and negative 10-v pulses of 150-nsec duration. If positive sync terminal is shorted, negative pulse can be increased to 50 v. Sync-pulse source impedance:
positive — approx 300 ohms; negative — approx 1 kilohm.

Delayed Sync Pulse: Consists of a negative-going transition of approximately 5 v and 100-nsec duration coincident with the late edge of the main pulse. The duration control reads the time between the prepulse and the delayed sync pulse. This negative transition is immediately followed by a positive transition of approximately 5 v and 150 nsec to reset the input circuits of a following pulse generator.

Stability: PRF and pulse-duration jitter are dependent on power-supply ripple and regulation. With TYPE 1201 Power Supply (recommended), input terminals short-circuited, prf jitter and pulse-duration jitter are each 0.01%. With TYPE 1203 Power Supply, they are 0.05% and 0.03%, respectively. (Jitter figures are typical, may vary somewhat with range switch settings, magnetic fields, etc.)

GENERAL

Power Requirements: 300 v at 55 ma, 6.3 v at 3 amp. TYPE 1201-B Unit Regulated Power Supply is recommended.

Accessories Available: TYPE 1217-P2 Single-Pulse Trigger.

Cabinet: Unit Instrument.

Dimensions: Width $10\frac{3}{4}$ (15 with power supply), height $5\frac{3}{4}$, depth $6\frac{1}{2}$ inches (275 by 150 by 165 mm), over-all. Rack adaptor panel, 19 by 7 inches (485 by 180 mm).

Net Weight: $4\frac{1}{2}$ pounds (2.1 kg).

Shipping Weight: 12 pounds (5.5 kg).

Refer to *General Radio Experimenter*, Vol. 36, Nos 1&2, January-February, 1962.

Reprints of an article entitled "Precise Delay Measurement" are available. To receive a copy, just fill out and mail the card enclosed with this manual.

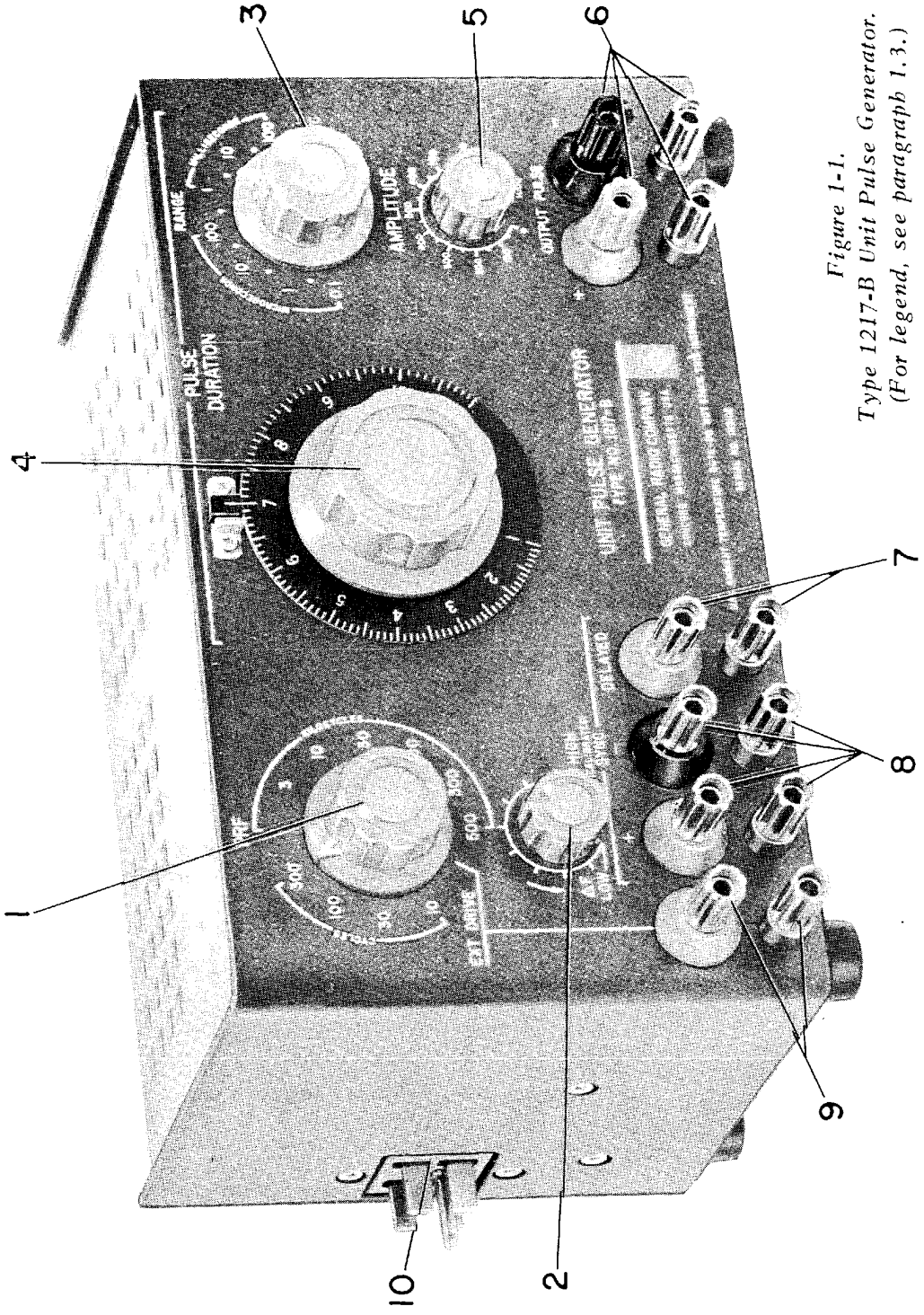


Figure 1-1.
 Type 1217-B Unit Pulse Generator.
 (For legend, see paragraph 1.3.)

SECTION 1

INTRODUCTION

1.1 PURPOSE.

The Type 1217-B Unit Pulse Generator (Figure 1-1) is a general-purpose instrument intended primarily for laboratory use. The repetition rates of pulses may be either internally controlled, at frequencies from 2.5 to 500,000 cycles per second, or controlled by an external signal source, at rates up to 1 megacycle. In addition to the main positive and negative output pulses, the instrument also supplies synchronizing pulses corresponding to the beginning and end of the main pulse. The early synchronizing pulse ("prepulse") is intended chiefly for synchronizing an oscilloscope with the Pulse Generator, while the late ("delay") pulse makes the instrument an accurate time-delay generator.

1.2 GENERAL DESCRIPTION.

The Type 1217-B comprises three main circuit groups:

- (1) a combination input circuit and oscillator, to establish the repetition rate of the main pulse;
- (2) a pulse-timing circuit, started by a trigger generated by the input circuit (this circuit controls the duration of the main pulse);
- (3) an output circuit, consisting of a pair of current sources switched on and off by the timing circuit.

The repetition frequency, duration, and amplitude of the main output pulse are adjustable by front-panel controls. The instrument is housed in a compact Unit-type cabinet designed for bench mounting. A relay-rack adaptor panel, Type 480-P4U3, is available for rack mounting of the Unit Pulse Generator and companion Unit Power Supply.

1.3 CONTROLS AND CONNECTORS.

The following table lists controls and connectors on the Type 1217-B.

Ref. (Fig. 1-1)	Name	Type	Function
1	PRF	12-pos rotary switch	Sets PRF range. In EXT DRIVE, changes PRF oscillator to aperiodic input circuit.

(Continued)



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Ref (Fig. 1-1)	Name	Type	Function
2	PRF (ΔF)	Continuous rotary control	When this control is fully clockwise, PRF switch is calibrated. Adjusts PRF continuously between calibrated switch positions. With PRF switch at EXT DRIVE, sets triggering level of pulse-generating circuits.
3	PULSE DURATION RANGE	7-pos rotary switch	Sets pulse duration range.
4	PULSE DURATION	Continuous rotary control (no stop)	Sets duration of main pulse.
5	AMPLITUDE	Continuous rotary control	Sets pulse amplitude and output impedance. Calibrated in approximate output impedance, in ohms.
6	OUTPUT PULSE + -	Jack-top binding-post pair	Positive main output pulse terminals.
7	SYNC DELAYED	Jack-top binding-post pair	Delayed synchronizing pulse terminals.
8	SYNC + -	Jack-top binding-post pair	Positive prepulse terminals.
9	EXT DRIVE	Jack-top binding-post pair	Input terminals for external drive signal.
10	none	5-terminal male connector	Power input connector.

1.4 POWER SUPPLY.

Power requirements for the Type 1217-B are 300 volts dc at 55 ma and 6.3 volts ac at 3 amperes. Neither positive nor negative dc supply terminals should be connected to the chassis of the Type 1217-B. The General Radio Type 1201-B Unit Regulated Power Supply is recommended because its low dc ripple will produce less time jitter of both pulse period and pulse duration. If jitter requirements are not critical, the Type 1203-B Unit Power Supply (unregulated) can be used. In some special applications (as, for instance, where pulse load impedance is to be externally adjusted over a wide range), it is desirable to regulate both positive and negative supplies separately with respect to the Type 1217-B chassis ground. For such applications, Type 1205-B Adjustable Regulated Power Supplies are recommended. The positive supply should be set to 150 volts and the negative supply to -150 volts with respect to the Type 1217-B chassis ground.

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The power input connector on the left-hand side of the Pulse Generator mates directly with any of the Unit Power Supplies mentioned above. A mating connector is supplied with the Pulse Generator for use with other power supplies. The dc supply voltage should be connected to terminals 15 (positive) and 16. The 6.3-volt terminals are 13 and 14.

SECTION 2

OPERATING PROCEDURE

2.1 PRELIMINARY CONSIDERATIONS.

As it is important that the interior of the instrument be adequately ventilated, make sure that the air holes in the cover are not blocked. Connect the power supply (refer to paragraph 1.4) to the Type 1217-B. Apply power by turning the power supply on.

In the following instructions, the term "main pulse" refers to the principal output of the instrument, available at the OUTPUT PULSE binding posts; "prepulse" refers to the synchronizing pulses (positive and negative) supplied just before the start of the main pulse and available at the SYNC + and - binding posts; "delayed pulse" refers to the pulse coincident with the end of the main pulse and available at the DELAYED binding posts. "Internal operation" is that mode in which the pulse repetition frequency is determined by the Pulse Generator itself and controlled by the PRF controls on the front panel. "External operation" refers to use of the Pulse Generator to generate pulses only when triggered by signals applied to the EXT DRIVE terminals. In external operation, therefore, the pulse repetition frequency is externally controlled.

2.2 NORMAL INTERNAL OPERATION.

2.2.1 PRF ADJUSTMENT. The pulse repetition frequency is adjusted by the PRF controls (1 and 2, Figure 1-1), over a range of from 2.5 cps to 500 kc. The PRF switch is calibrated to indicate PRF correctly only when



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the PRF control is fully clockwise. Turning the PRF control counter-clockwise lowers the PRF to well below the next lower PRF switch setting. The range of adjustment of the PRF control is more than enough to span any one of the ranges set by the PRF switch, affording continuous coverage of the PRF range from 2.5 cps to 500 kc. It is important to remember, however, that the only calibrated frequencies are those indicated by the PRF switch positions, and that these are accurate only when the PRF control is fully clockwise.

2.2.2 PULSE DURATION ADJUSTMENT. Duration of the main pulse is adjusted by the PULSE DURATION controls (3 and 4, Figure 1-1). The RANGE switch (3) selects one of seven decade ranges, and the range selected is covered by the PULSE DURATION control. This control consists of a knob linked by a slow-motion drive to a dial that is calibrated from 1 to 11 in tenths of a unit. The overlap beyond the decade span is provided to ensure continuous coverage of all durations.

2.2.3 AMPLITUDE ADJUSTMENT. Amplitude of the main pulse is adjusted by the AMPLITUDE control. Since output amplitude is directly proportional to output impedance, the control is calibrated in approximate output impedance. When this control is fully clockwise, the amplitude is 40 volts, the output impedance 1000 ohms.

2.2.4 USE OF OSCILLOSCOPE. The best way to become familiar with the Pulse Generator is to connect it to an oscilloscope and watch the pulses themselves. The procedure is as follows:

- a. Connect the OUTPUT PULSE + terminals to the oscilloscope vertical input, using either open leads or a probe.
- b. Connect the SYNC + terminals to the oscilloscope SYNC or TRIGGER input.
- c. Connect any of the ground binding posts to oscilloscope ground.
- d. Adjust the oscilloscope triggering mode, polarity, and level controls to synchronize on the 10-volt, 100-nanosecond, positive prepulse being produced by the Type 1217-B.
- e. Set the oscilloscope writing rate controls for a 2-msec sweep.
- f. Set the oscilloscope vertical gain controls to provide a sensitivity of about 20 volts/cm.
- g. On the Type 1217-B, set the PRF switch to 1 kc.
- h. Set the PRF control fully clockwise.
- i. Set the PULSE DURATION control to 5.0.
- j. Set the PULSE DURATION switch to the 100 μ sec- 1 msec range.
- k. Set the AMPLITUDE control fully clockwise.

The oscilloscope should now show the 1-kc square wave from the Pulse Generator. Shorten and lengthen the pulse using the PULSE DUR-

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ATION control. Then set the PULSE DURATION RANGE switch to the next lower range. Decrease the PRF first by turning the PRF control counterclockwise, and then by turning the PRF switch to the next lower position. Readjust the oscilloscope sweep controls to keep both pulse duration and frequency under observation. To decrease the amplitude of the pulse, turn the AMPLITUDE control counterclockwise.

If the oscilloscope has a dc-coupled vertical amplifier, set it for dc, disconnect the pulse, and establish the ground reference trace. Now reconnect the positive pulse and vary its amplitude. Then move the connector from the + OUTPUT PULSE to the - OUTPUT PULSE terminals, and vary the amplitude again. Note that the pulse contains a dc component negative with respect to ground. The positive pulse starts from -40 volts and rises to ground during its active interval. The negative pulse starts from ground and falls to -40 volts during its active interval.

If, during any of the above procedures, the pulse is defective or the pattern becomes confused, check to make sure that the pulse duration has not been made too long for the pulse repetition frequency. The Type 1217-B can produce pulses of very long duration. To observe these properly, an oscilloscope with a dc-coupled vertical amplifier must be used.

2.3 NORMAL EXTERNAL OPERATION.

The Type 1217-B will produce externally triggered pulses at frequencies from dc to 1 Mc. The driving signal should be applied to the EXT DRIVE terminals, and should be at least 0.5 volt rms up to 500 kc, 1 volt rms up to 1 Mc.

For external operation, set the PRF switch to EXT DRIVE and apply the external signal at the EXT DRIVE terminals. The PRF control now becomes a triggering level adjustment; the input circuits are set for maximum sensitivity when this control is centered.

The input circuit is dc-coupled, so that the Pulse Generator will operate from pulses of any low frequency desired. The input signal must therefore be either at a dc potential close to ground or be ac-coupled, with an external blocking capacitor.

To observe external operation on an oscilloscope, proceed as follows:

- a. Set up the equipment to display a 1-kc square wave, as described in paragraph 2.2.4.
- b. Set the PRF switch to EXT DRIVE.
- c. Connect an adjustable audio-frequency generator to the EXT DRIVE terminals. Set this generator to produce a 1-kc signal of at least 1 volt rms.
- d. Set the PRF control to center scale. The oscilloscope should display a square wave as described in paragraph 2.2.4.



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e. Decrease the frequency of the audio-frequency generator. Note that the external generator controls the PRF of the Type 1217-B.

f. Reset the audio-frequency generator to 1 kc and reduce the amplitude of the driving signal. When the Type 1217-B fails to synchronize, adjust the PRF control until synchronization is reestablished. When no further adjustment of the PRF control will reestablish synchronization, the triggering threshold has been reached (this should be at about 0.3 volt peak-to-peak to 1 kc). A plot of typical sensitivity is given in Figure 2-1.

g. Reset the amplitude of the external generator to 1 volt rms. If possible, display the driving waveform and the output pulse simultaneously on the oscilloscope.

h. Adjust the PRF control while observing the starting point of the pulse. Note that the PRF control adjusts the phase at which the pulse is formed, and that the pulse always starts during the negative-going input transition.

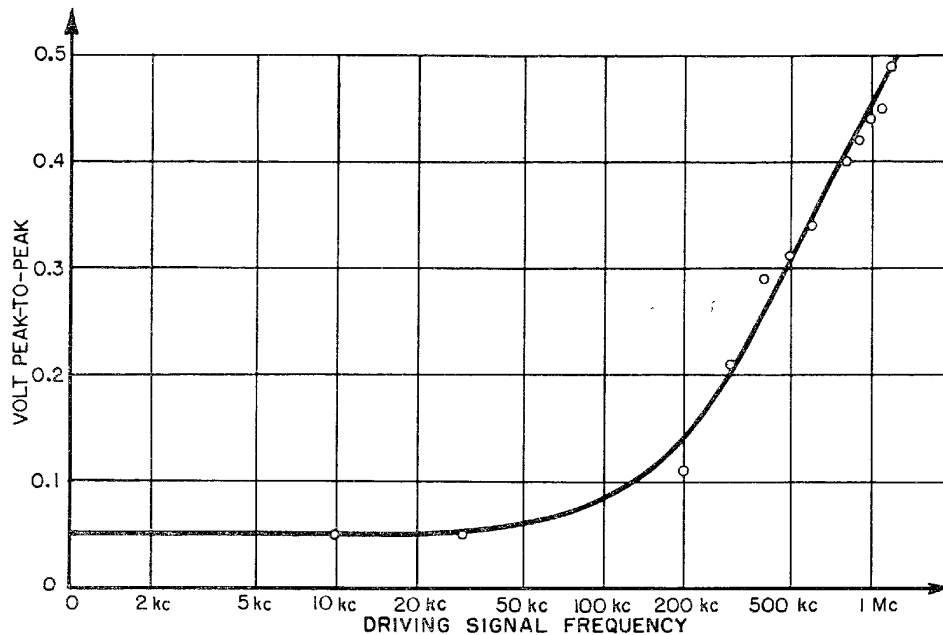


Figure 2-1. Typical sensitivity-vs-frequency characteristic.
Voltage is minimum for 1-to-1 synchronization.

2.4 LOCKING TO HIGH-FREQUENCY SIGNALS.

If an external signal is applied at the EXT DRIVE terminals and the PRF switch is set to one of numbered positions, the internal oscillator of

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the Type 1217-B will lock on the incoming signal. For instance, if a 50-kc signal is applied at the EXT DRIVE terminals and the PRF switch is set to 10 kc (with the PRF control fully clockwise), the main output pulse of the Type 1217-B will be at 10 kc, locked to the 50-kc external signal. In other words, the Pulse Generator is operating as a 5-to-1 frequency divider, supplying one output pulse at each fifth input pulse. The Type 1217-B can be phase locked in this manner to frequencies well above the maximum PRF rate of the internal oscillator.

To observe the above operation, connect an oscilloscope and an audio-frequency generator to the Type 1217-B as described in paragraph 2.3. If possible, observe the waveform of the external generator on the oscilloscope, together with the Type 1217-B output. Then proceed as follows:

- a. Set the PRF switch on the Type 1217-B to 1 kc.
- b. Set the PRF control fully clockwise.
- c. Set the external generator frequency to 1 kc.
- d. Set the gain of the external generator to minimum, and then advance it until the Type 1217-B locks.
- e. Set the frequency of the external generator to 2 kc, 3 kc, 4 kc, etc, each time advancing the signal amplitude to lock the Type 1217-B. In this way the Type 1217-B can be locked at very high ratios.

2.5 SINGLE-PULSE OPERATION.

There are two very effective methods for producing a single pulse: (1) by rotation of the PRF control with the PRF switch at EXT DRIVE, and (2) by touching the EXT DRIVE terminal, with the PRF switch at EXT DRIVE and the PRF control near the center of its range. The second method is useful only for very long pulses.

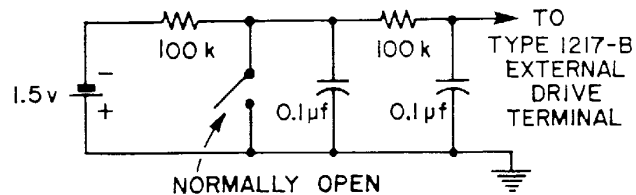
In the first method, set the PRF switch to EXT DRIVE and rotate the PRF control about 20 or 30 degrees clockwise from its center position and then reverse direction of rotation. The pulse will be produced as the control is moved counterclockwise past the center position. Very little rotation is necessary to reset and to start the input circuits. Be careful not to touch the input terminal while rotating the PRF control, since a pulse burst may be produced by the injected hum.

For the generation of single pulses, it may be desirable to use a pushbutton actuating circuit. Such a device is available as the Type 1217-P2 Single-Pulse Trigger, shown schematically in Figure 2-2. To use such a device, set the Pulse Generator PRF switch to EXT DRIVE and set the PRF control between three-quarters and fully clockwise.



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Figure 2-2. Schematic diagram of single-pulse trigger.



2.6 PRF VS PULSE DURATION.

There is no restriction on the duty ratio of the Type 1217-B. (Duty ratio is the ratio of the pulse "on" time to the total time of the period established by the PRF setting). Therefore, the PULSE DURATION controls may be mistakenly set for a duration longer than the total period established by the PRF control settings. (Period is the reciprocal of PRF.) The instrument cannot be damaged by such settings, but the user may be confused by the resulting oscilloscope display.

Three effects are produced by a duration setting too long for the PRF setting. They are, in order of increasingly longer duration settings:

(1) When the pulse occupies more than 60 percent of the total period, the dial reading of duration will become erroneous. This effect is due to insufficient recovery time for the pulse-forming circuits.

(2) When the duration controls call for a pulse exactly equal to the pulse period, the instrument will fail completely, and both duration and PRF will become indeterminate.

(3) When the duration is set longer than the pulse period, the pulse-timing circuits will "count down," producing one pulse for each 2, 3, 4, ---n input periods. In general, the pulse duration will not be precisely controllable, due to lack of recovery time. However, such frequency division may be useful in some experiments, and it should be remembered that the Type 1217-B can be used as a frequency divider of arbitrary scale by such operation.

2.7 SPECIAL PRECAUTIONS FOR VERY LONG OR VERY SHORT PULSES.

2.7.1 GENERAL. When pulses of very long or very short duration are to be produced and observed, the user must give special attention to the apparatus setup and interconnections. Bandwidth considerations are fundamental, and oscilloscopes having desired frequency response must be chosen as indicators.

2.7.2 LONG PULSE DURATIONS. An oscilloscope with a frequency response to dc is necessary to observe very long pulses. The low-frequency cutoff of most oscilloscopes not having dc amplifiers is about 5 or 10 cps,

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and these oscilloscopes will show "ramp-off" effects with pulse durations over 10 milliseconds. (Ramp-off is slope on the flat top and bottom.) Almost any indicator will have adequate high-frequency response for long-duration pulses, since the "flats" are usually of more interest than are the rapid rise and fall of voltage. The Type 1217-B uses a direct-coupled output system, and will not cause "ramp-off" at any duration.

2.7.3 SHORT PULSE DURATIONS. The faithful reproduction of very short pulses or of the rapidly changing voltage of the leading or trailing edge of such a pulse requires wide-bandwidth amplifier and indicator systems. For example, if one attempts to display a pulse with a rise time of 0.05 microsecond on an oscilloscope whose amplifier has a rise time of 0.05 microsecond, the indicated rise time will be 0.07 μ sec. For a system having n individual components of specified rise time, the equation for over-all rise time is ¹

$$T_r = \sqrt{T_1^2 + T_2^2 + \dots + T_n^2} \quad (1)$$

The rise time of an amplifier system, T_r , is related to the 3-db bandwidth, B , by equation (2) ², where the factor of 0.35 should be used if the overshoot is less than 5 percent.

$$T_r = \frac{0.35 \text{ to } 0.45}{B} \quad (2)$$

With very short pulses, it is necessary to take care in the wiring of system components. Short, direct wires should be used for both signal and ground if open wiring is used, and coaxial cables should be terminated properly. A common sign of improperly connected ground or of an inductive loop in the wiring is the presence of high-frequency ringing (damped oscillation) on the pulse transitions.

2.8 RISE AND FALL TIMES.

The Type 1217-B has very short rise and fall times (5 to 7 nsec negative and 14 to 17 nsec positive transitions) of output current into the internal 1-kilohm loads and their associated stray capacitances. The internal stray capacitances are about 30 pf, resulting in open-circuit rise and

¹Valley, G. E., and Wallman, Henry, *Vacuum-Tube Amplifiers*, Radiation Laboratory Series, Vol 18, McGraw-Hill, 1948, p 77.

²Ibid, p 80.



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fall times of about 70 nsec across the internal 1-kilohm load. The rise and fall times will increase directly (or linearly) with external capacitance and decrease linearly with external resistance, the final transition time being about 2.2 RC. The intrinsic rise time can therefore be observed only if a resistance of 100 ohms or less is connected across the output terminals. With an open-circuit connection, the Type 1217-B output circuit is capacitance-limited; therefore, the voltage transition varies exponentially with time and no overshoot is possible. Because of this important feature, the Type 1217-B can be used to check almost any amplifier system for overshoot - including any oscilloscope having an input impedance over 1 kilohm.

For further information on rise and fall times, refer to paragraph 2.11.

2.9 THE TYPE 1217-B AS A DELAY GENERATOR.

The delayed synchronizing pulse from the Type 1217-B can be used to operate the input circuits of a second Type 1217-B with a minimum of adjustment. The delayed pulse consists of a negative-going transition of about 5 volts and 100-nsec duration, followed immediately by a positive transition of about 5 volts and 150 nsec duration. The initial negative-going transition will trigger the input circuits and start the main pulse of a following Type 1217-B. The positive-going transition will then reset the input circuits of the second Type 1217-B to prepare it for the next delayed pulse. Figure 2-3 shows connections and timing waveforms of such a system.

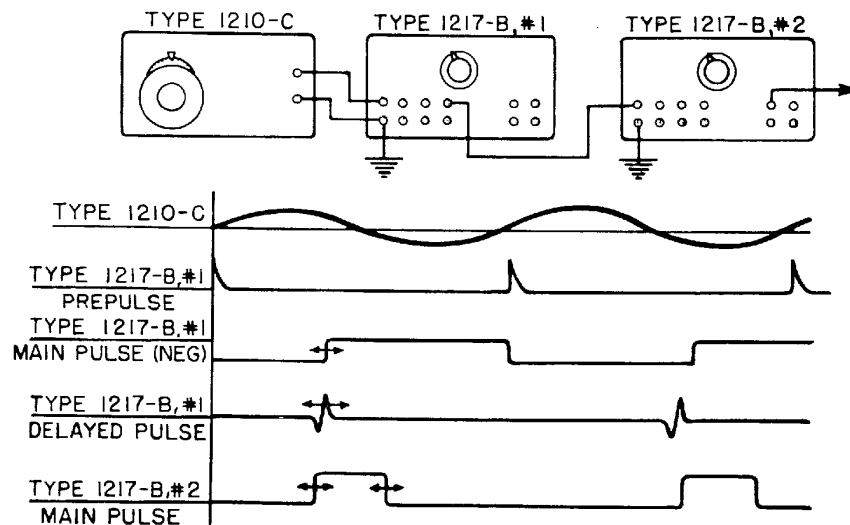


Figure 2-3. Connection of two Type 1217-B's as a delay generator.

2.10 USE OF SEVERAL PULSE GENERATORS TO PRODUCE COMPLEX WAVEFORMS.

Since the output circuit of the Type 1217-B is essentially a current source feeding a resistive load, the outputs of two or more pulsers can be directly paralleled to produce complex additive waveforms. The output impedance of n pulse generators so paralleled is $1000/n$ ohms and the peak voltage is still 40 volts. A complex waveform and the system for producing it are shown in Figure 2-4.

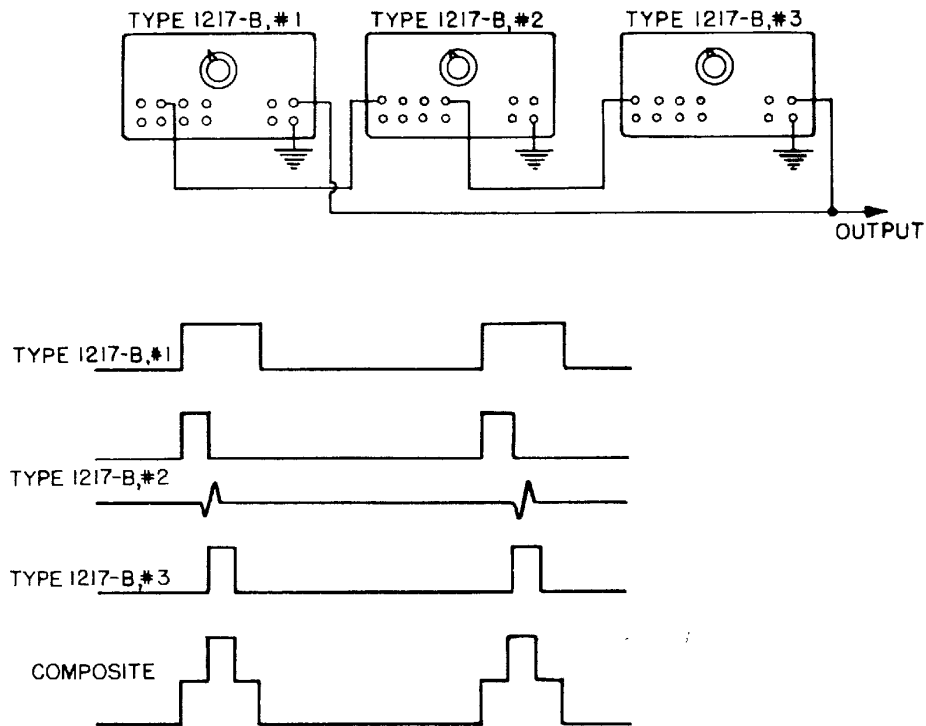


Figure 2-4. System for producing the complex waveform shown.

2.11 EXTERNAL-LOAD CONSIDERATIONS.

The output circuits of the Pulse Generator are as stable as possible for an instrument of such simplicity. Some important points to remember when using the Type 1217-B are:

- (1) The output tubes act as current sources, producing 40-ma pulses into a parallel combination of the AMPLITUDE control potentiometers and whatever external load is connected to the instrument.
- (2) The pulses are direct-coupled to the OUTPUT PULSE terminals, and therefore contain a negative dc component of 40 ma.



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(3) In order to produce the cleanest possible pulses at low levels, the output potentiometers are used as potentiometers rather than as rheostats, so that the output tubes always produce their pulses into a full 1000-ohm load.

Figure 2-5. Equivalent circuit for Type 1217-B output system feeding high external load impedance.

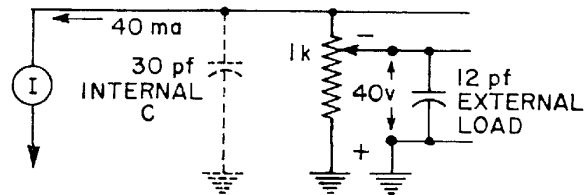


Figure 2-5 shows an equivalent circuit for the Type 1217-B output system as it appears when feeding a high external load impedance (e. g., a 12-pf, 10-megohm oscilloscope probe). The pulses from this circuit will be capacitance-limited by the 42-nanosecond RC time constant, and a rise time of 80 nanoseconds results (Figure 2-6). As the AMPLITUDE control setting is reduced, load capacitance is essentially removed and finally, at very low output impedances, the rise time is limited only by the stray capacitance inherent in the instrument; in this instance the rise time is about 60 nanoseconds. The appearance of a brief pulse at output settings of 4 volts and 0.4 volt is shown in Figures 2-6B and 2-6A.

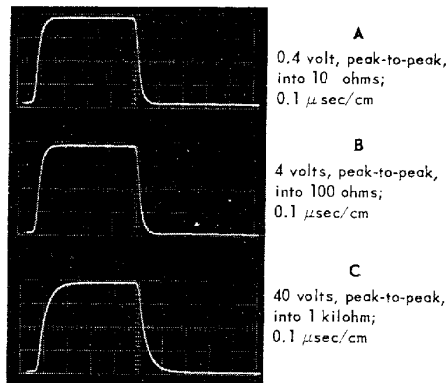


Figure 2-6. Pulses from circuit of Figure 2-5.

Two important features should be noted from the above: (1) the rise time can be controlled by the addition of fixed external capacitance, according to the equation

$$T_r \text{ (nsec)} = 2.2 (30 \text{ pf} + C_{\text{ext}}) \quad (3)$$

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and (2) the ultimate rise time can be realized only by use of maximum AMPLITUDE control setting with a low-impedance external load. The circuit for such a connection is shown in Figure 2-7. Here the time constant of the output circuit is about 1.5 nanoseconds, and the fast rise and fall of the current pulse can be observed. In this connection, the negative transition will typically be less than 10 nsec and the positive transitions less than 18 nsec. See Figure 2-8 for the typical appearance of waveforms under terminated conditions.

2.12 DC COMPONENT.

In certain applications it may be desirable to remove or to change the dc component of the main output pulse. There are two methods of doing this: the simplest is to add an external coupling capacitor large enough to prevent ramp-off for the desired pulse duration. Where the pulses are very long or circuit impedances are low, it may be desirable to translate the pulse dc component, using an external power supply connected to the OUTPUT PULSE terminals through a resistor so that it approximates a current source. Such a connection is shown in Figure 2-9, where the output impedance of the Pulse Generator is reduced to 800 ohms and a 32-volt pulse is produced.

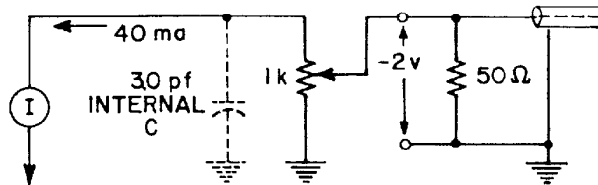
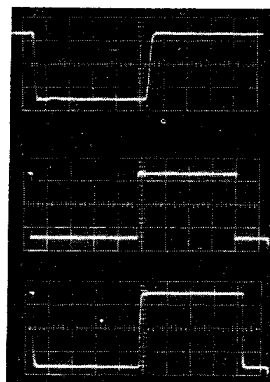


Figure 2-7. Equivalent circuit for achieving ultimate rise time.



A
2-volt, 0.5- μ sec pulse;
50-ohm termination;
0.1 μ sec per division

B
2-volt, 5- μ sec pulse;
50-ohm termination

C
As in (B), but with
open-circuit termination,
40-volt pulse

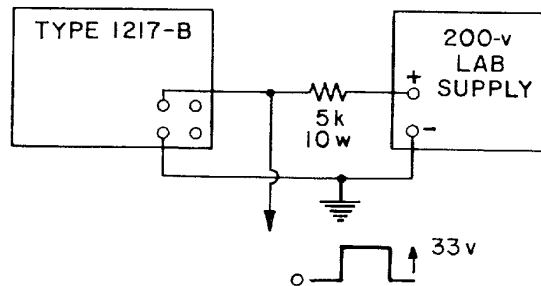


Figure 2-9. Connection for translating pulse dc component by means of external power supply.

Figure 2-8. Typical waveforms under terminated conditions.



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A precaution when the instrument is used under conditions of varying output impedance: In some unusual applications where dc translation is used as described above or where an external rheostat is used to adjust pulse amplitude and output impedance, it will be observed that the frequency of the PRF oscillator will change slightly with variations in the load current. If this effect is annoying, two courses of action are open: (1) change to external operation or (2) supply power to the Pulse Generator from two power supplies rather than from one ungrounded 300-volt supply. Connect a regulated +150-volt supply (such as a Type 1205-B Adjustable Regulated Power Supply) to pin 15 of the power input connector and a regulated -150-volt supply to pin 16. Connect the commons of the two supplies to the Type 1217-B chassis ground.

SECTION 3

PRINCIPLES OF OPERATION

3.1 INPUT CIRCUIT AND PRF OSCILLATOR.

3.1.1 EXTERNAL OPERATION. Figure 3-1 is a simplified schematic diagram of the PRF oscillator and input circuit system. Let us first consider the circuit as an aperiodic input circuit, i.e., with the PRF switch set at EXT DRIVE. V102 is a Schmitt circuit. If the grid voltage of V102A is less than, say, 45 volts, V102A will be off and V102B will conduct. R113 and R115 set the grid potential of V102B at about 48 volts. The common cathode potential is about 50 volts. If the grid voltage of V102A is now increased to over 45 volts, this tube will turn on. The resulting drop in its plate voltage switches V102B off. As V102B turns off, its decreasing plate current lowers the common cathode voltage, further decreasing the bias of V102A. This action is therefore regenerative. V102A turns on and V102B off, both very rapidly.

In order to reverse the conductive states of V102A and V102B, the grid voltage of V102A must be lowered considerably below the level that was necessary to cause the switching action in the first place. Thus the

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circuit presents a voltage hysteresis effect. V101A and R102 operate as a voltage divider to set the grid voltage of V102A to a level near the center of this hysteresis region (exactly at center for maximum sensitivity with a symmetrical waveform). V101A is connected as a voltage amplifier so that the hysteresis is reduced in voltage as presented to the EXT DRIVE terminals. R107 is factory-adjusted so that the hysteresis effect referred to the EXT DRIVE terminals is symmetrical with respect to ground when the PRF control (R103) is centered. A single pulse can be produced (paragraph 2.5) by rotation of the PRF control through its center position. This rotation simply sets and resets the Schmitt trigger.

A positive pulse is required to trigger the pulse-forming circuits and start the output pulse. This pulse is produced when V102B turns off. V102A must therefore be turned on by a positive-going grid voltage. Therefore the grid of V101A must be driven negative to start the output pulse. These polarities and levels are shown in Figure 3-1.

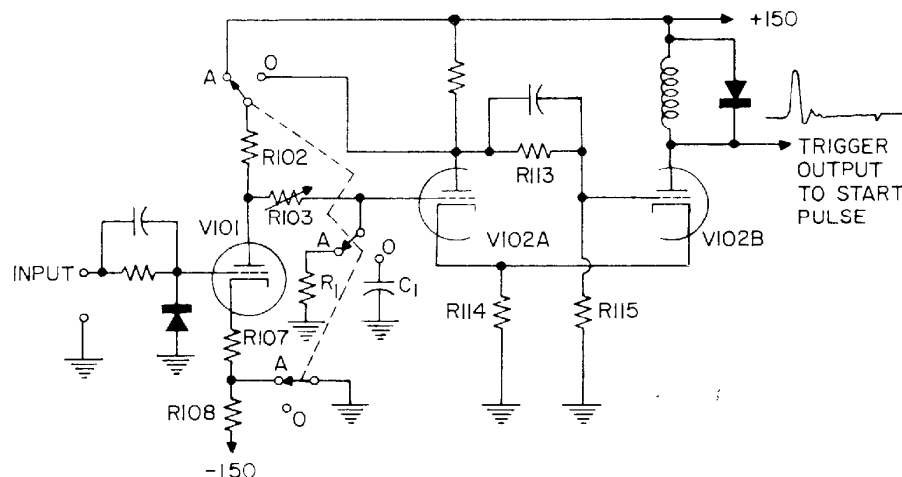


Figure 3-1. Simplified schematic diagram of PRF oscillator and input circuit system.

3.1.2 INTERNAL OPERATION. In Figure 3-1, S101, the PRF switch, is shown in the EXT DRIVE position. Setting this switch to any of the other positions converts the input amplifier and Schmitt circuit into the PRF oscillator. No important circuit changes are made in the Schmitt trigger. S101 converts the input amplifier to a current source, which translates the plate swing of V102B so that it is symmetrical around its own grid voltage. The switch ungrounds the junction of R107 and R108 and switches R102 from the plate supply voltage to the plate of V102A. The PRF control (R103) and R102 together are the resistance in the frequency-determining network, while the PRF switch adds capacitance from the grid of V102A to ground. The mechanism of oscillation may be seen from Fig-



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ure 3-2. Suppose that V102A is off, its plate voltage high. C1 will charge through R103 and R102 until V102A turns off. When V102A turns on, its plate voltage will fall and C1 will begin to discharge, and will continue to do so until V102A again turns off. The Schmitt circuit thus oscillates with V102A's grid voltage "trapped" within the hysteresis region. The PRF is changed by adjustment of capacitance with the PRF switch and resistance with the PRF control.

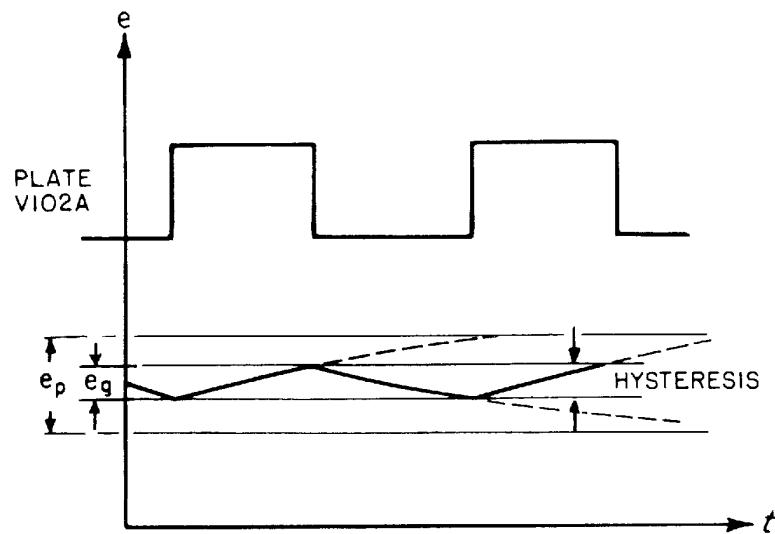


Figure 3-2. Diagram showing operation of internal oscillator.

The output frequency of this oscillator has good stability. Parameters important in controlling frequency are R, C, and the magnitude of the hysteresis effect. R and C are stabilized by use of high-quality components. The magnitude of the hysteresis is stabilized by the Schmitt circuit design, where both sections of V102 operate far from zero bias so that R114 provides current feedback, stabilizing the circuit against the effects of changing tube characteristics. Typical warmup and drift characteristics are shown in Figure 3-3.

3.2 PULSE TIMING CIRCUITS.

The pulse timing circuit consists of the bistable transistor circuit Q101 and Q102, sweep generator V103A, clamp tube V103B, and Schmitt circuit V104. This circuit and the output circuit are shown in simplified form in Figure 3-4.

Q101 of the bistable ("flip-flop") circuit is normally on and saturated. Therefore V103A is on and diode V103B is conducting and keeping the potential at the junction of R118 and R122 at a level determined by the

PRINCIPLES OF OPERATION

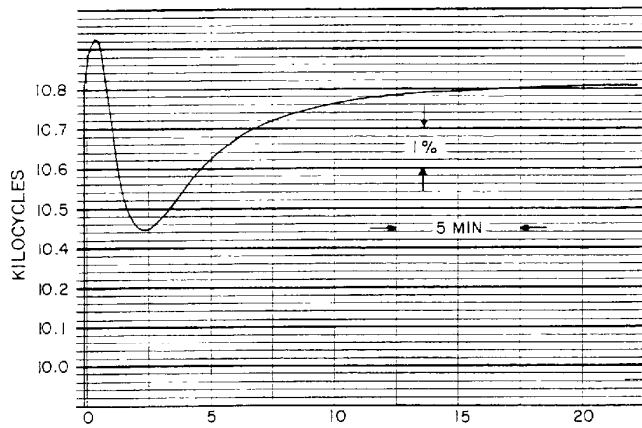


Figure 3-3a. (Left) Typical warmup characteristics.

Figure 3-3b. (Below) Typical drift characteristics.

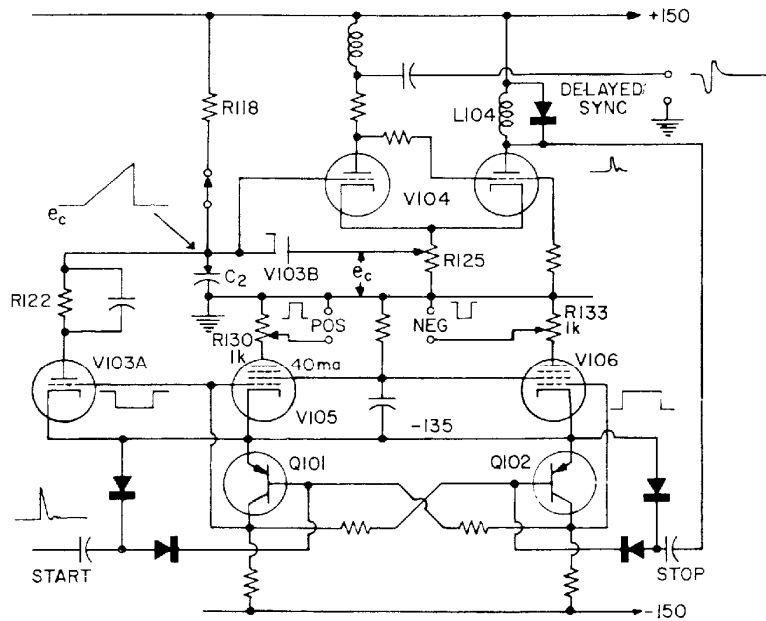
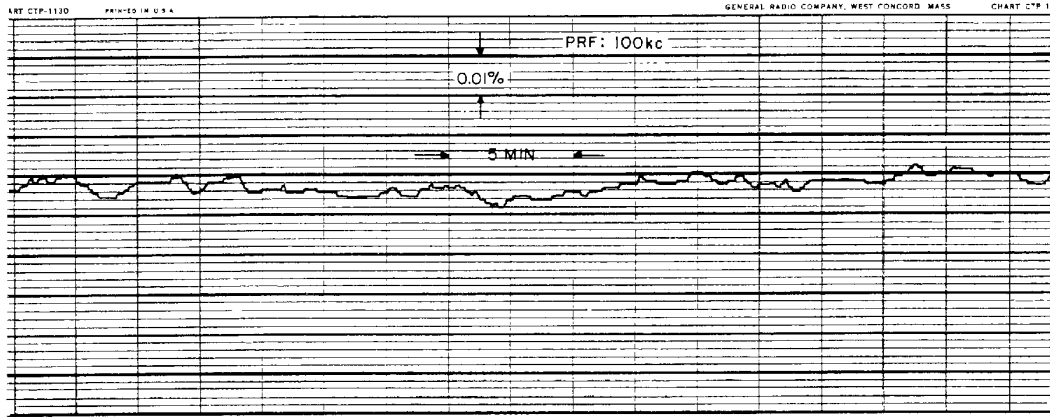


Figure 3-4. Schematic diagram of pulse-timing and output circuits.



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setting of R125, the PULSE DURATION control. Since Q101 is on, V105 is also on, producing a current in R130, the positive pulse output load resistor. A positive pulse from the input Schmitt circuit (V102) turns Q101 off. V103A and V105 then go off. C2 begins to charge through R118, and the grid voltage of V104A rises until this tube conducts and the Schmitt circuit changes state, as described in paragraph 3.2. When V104B goes off, the positive pulse produced across L104 turns Q102 off, Q101 on, and reestablishes the original circuit conditions. The circuit is now ready for the next "start" triggering pulse. Pulse duration is therefore controlled by R118, C2 (set by the PULSE DURATION RANGE switch), and the initial potential on C2 established by the PULSE DURATION control through V103B.

Since the common cathode voltage of the Schmitt comparator circuit is established by precision resistors in the grid of V104B, and since circuit design keeps V104A and V104B well away from grid current, the circuit structure is highly stable, permitting accurate control of duration. The circuit is very tolerant of tube variations and of tube aging. Since the duration-determining capacitor has one side grounded, any noise present at the grid of V104B is attenuated as the range setting is increased and the reactance of C2 is decreased. The jitter is therefore nearly a constant fraction of the duration.

3.3 PULSE OUTPUT CIRCUIT.

The pulse output system consists of pentodes V105 and V106, which are switched by the transistor bistable circuit Q101 and Q102. As described in the preceding paragraph, Q101 is normally on, Q102 off. Thus V105 is normally on at nearly zero bias and V106 is off. During the active pulse portion of the cycle, Q101 goes off and V105 is turned off by the falling collector voltage of Q101. Q102 saturates, turning V106 on. The screen voltage of V105 and V106 sets their zero-bias current at 40 to 45 ma. When V105 goes off, the voltage across R130 rises to ground, producing the positive pulse. V106, in turning on, produces a negative pulse of 40 to 45 volts with respect to ground across R133.

SECTION 4

SERVICE AND MAINTENANCE

4.1 GENERAL.

The two-year warranty given with every General Radio instrument attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.2 REMOVAL OF COVER.

To open the instrument for access to components, loosen the large fluted screw at the rear of the right-hand side of the cabinet. Then grasp the panel by the top and bottom edges with one hand, and with the other hand slide the aluminum dust cover away from the panel and off the rear.

All components are easily accessible. See Figures 4-2, 4-3, and 4-5 for location of components.

4.3 TROUBLE-SHOOTING PROCEDURE.

4.3.1 GENERAL. If the Pulse Generator is inoperative, make the following simple checks before removing the cover:

a. Check the power line voltage and frequency to make sure they are as required by the power supply.

b. Check line cord, fuses, and voltage from the power supply (B + demands are 300 volts at 55 ma).



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c. See if the prepulse is present at the SYNC terminals. If this pulse is present and the main pulse is defective, refer to paragraph 4.3.2. If the prepulse is present and there is no main pulse, refer to paragraph 4.3.3. If neither prepulse nor main pulse is present, refer to paragraph 4.3.4. If prepulse is absent and main pulse is present, refer to paragraph 4.3.7.

4.3.2 DEFECTIVE MAIN PULSE.

4.3.2.1 Overshoot. Under normal conditions, with a high-impedance load, overshoot is not possible on any transition. Therefore, check the oscilloscope probe compensation and check the oscilloscope for overshoot first. If overshoot occurs with a low-impedance terminated system, check the system for proper grounding and make sure that all wiring is as short as possible. Note that some overshoot may be present on negative pulse transitions, as shown in Figure 2-8.

4.3.2.2 Large Imbalance in Pulse Amplitudes, or Slowly Falling Negative-Going Edge of the Positive Pulse. These defects can be caused by weakening of one of the output tubes. These tubes (V105, V106) are chosen for balance at the factory; if either is defective, therefore, order a replacement set or choose a balanced pair if possible. After replacing the output tubes, reset R147 (Figure 4-3) to produce -150 volts at pin 16 of PL101 with a 300-volt regulated power supply.

4.3.2.3 Output Pulse Occasionally Fails, and Starts Only When RANGE Switch Setting is Changed. These are two possible causes of this difficulty: (1) The ionization voltage of V107 has drifted sufficiently so that the automatic restarting circuit no longer functions, or (2) a tube has developed heater-to-cathode leakage. First check the voltage from pin 13 or 14 of PL101 to chassis ground, using a vacuum-tube voltmeter of at least 100 megohms input impedance. The proper voltage is -70 ± 5 volts behind 5 megohms. If this voltage is correct, the trouble is a defective V107, and a new NE-96 should be installed. If the voltage measured is not correct, check all tubes for heater-to-cathode leakage.

4.3.2.4 Errors in Pulse Duration. An error in duration on only one setting of the RANGE switch is an obvious indication that a time-determining component for that range has drifted or failed.

A uniform error on all ranges points to a defective amplitude-comparison circuit (V104 and associated components). For instance, a decrease in resistance of R127 would make all pulses too long at all settings of the PULSE DURATION controls, while an increase in this resistance would reverse the effect.

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If the output pulse is of fixed, long duration, independent of the PULSE DURATION controls, V103B is not functioning, and a new 6DJ8 (or 6922 should be inserted).

Another difficulty traceable to a defective V103 would be excessive duration at the high end of each range, especially at longer duration ranges. It is probable that V103 is not remaining cut off, and it should be replaced.

4.3.3 NO MAIN OUTPUT PULSE, SYNCHRONIZING PULSES PRESENT. If no output pulses are present and V107 flashes continually, check V103 and V104 and replace if necessary.

If V107 is not flashing, measure the voltage at the +OUTPUT PULSE terminal. If it is -40 volts with respect to chassis ground, the trouble is either (1) a defective transistor Q102 or (2) failure of the start triggering circuits. Check for the presence of a 15-volt, 0.15- μ sec positive trigger pulse at pin 6 of V102. Check L103 for a short or open circuit. Then remove Q101 and check the front-to-back ratio of diode CR106 with an ohmmeter.

4.3.4 MAIN AND SYNCHRONIZING PULSES BOTH ABSENT. This indicates trouble in the input circuits. First check V101 and V102. (After replacing V101, center the PRF control and adjust R107 for optimum sensitivity with an external signal.) If this fails to pinpoint the problem, check voltages against those given in Table 4-1.

4.3.5 INCORRECT FREQUENCIES AT ONE OR MORE PRF SWITCH SETTINGS. If the frequency error occurs at only one setting of the PRF switch, the fault is certainly in one of the timing capacitors, C108 through C117. Replace the appropriate capacitor.

If all frequencies are in error by about the same amount with the PRF control fully clockwise, check R102, R108, R104, and R105.

4.3.6 PULSER FAILS TO SYNCHRONIZE ON EXTERNAL SIGNAL. If the instrument operates normally on internal operation but will not synchronize on external signals, check the input network. An extremely high transient voltage may have caused CR101 to short circuit.

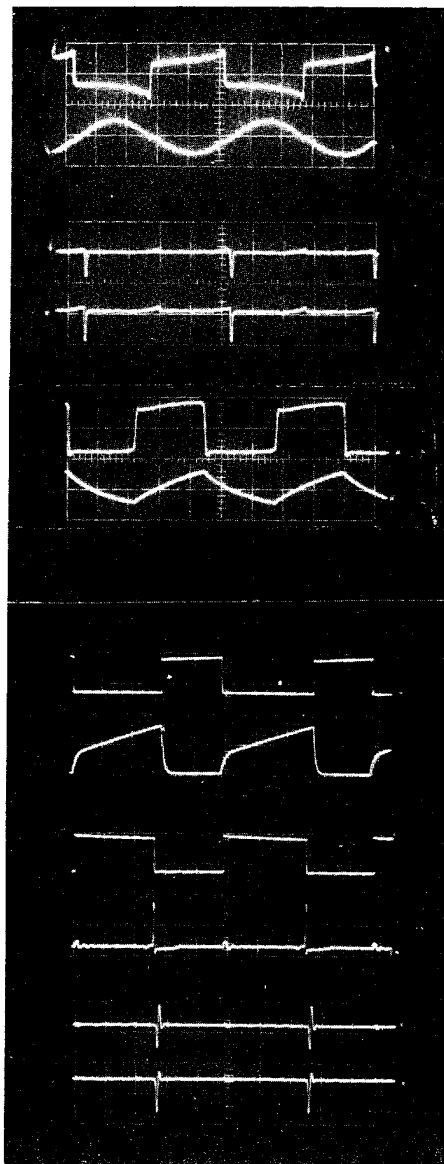
4.3.7 MAIN PULSES PRESENT, NO SYNCHRONIZING PULSES. Check V101 and the components associated with V101B.



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4.3.8 TEST VOLTAGE AND WAVEFORM DATA. Test voltage and waveforms are given in Table 4-1 and Figure 4-1, respectively. If the foregoing trouble-shooting procedure fails to reveal the difficulty, measure voltages and resistances at all tube pins, comparing data with values given in Table 4-1 (deviations of up to $\pm 20\%$ should not be considered abnormal). Use of an oscilloscope to compare waveforms with those given in Figure 4-1 should also prove helpful in isolating trouble.

Figure 4-1. Trouble-shooting waveforms. (All oscillograms taken at 100-kc PRF 2- μ sec/cm writing rate, with 10-megohm, 12-pf probe.)



V102 pin 1, 10v/cm
V102 pin 2, 10v/cm

V101 pin 7, 10v/cm
V101 pin 8, 10v/cm

V102 pin 2, 10v/cm (1v ext sync)
V102 pin 1, 10v/cm (1v ext sync)

V103A pin 2, 10v/cm
V104 pin 2, 20v/cm

V106 pin 2, 10v/cm
V102 pin 6, 5v/cm

Delayed sync pulse, 5v/cm
V104 pin 1, 10v/cm

SERVICE AND MAINTENANCE

TABLE 4-1
TABLE OF VOLTAGES AND RESISTANCES

Tube or Transistor (Type)	Pin	Dc Volts to Gnd	Ohms to Gnd (See Note 4)	Tube or Transistor (Type)	Pin	Dc Volts to Gnd	Ohms to Gnd (See Note 4)
V101 (6DJ8)	1	33	36k	V105 (6CW5)	1	-136	480
	2	-0.2	Diode		2	-136	480
	3	0.5	57.8k		3	-136	470
	6	146	1k		7	-45	1k
	7	0	22k		8	-45	1k
	8	4	1k		9	-87	49k
V102 (6DJ8)	1	120	3k	V106 (6CW5)	1	-150	480
	2	34	169k		2	-150	480
	3	3.9	3.3k		3	-136	470
	6	150	3		7	0	1k
	7	31	67k		8	0	1k
	8	3.9	3.3k		9	-87	49k
V103 (6DJ8)	1	-125	111k	V107 (NE-96)	+	44	68k
	2	-140	480		-	-75	5M
	3	-141	470	Q101 (2N1500)	E	-136	470
	6	41	5.7k		C	-136	500
	7	41	5.7k		B	-136	5k
	8	40.5	68k		Q102 (2N1500)	E	-136
V104 (6922)	1	148	1.5k	C		-146	500
	2	44	68k	B		-135	5k
	3	53	5.2k				
	6	150	3				
	7	51	66k				
8	53	5.2k					

NOTES

1. All heaters are at -70v potential.
2. Power Supply: Type 1201-B
Unit Regulated Power Supply.
3. PRF setting: 1 kc.
 Δf control centered.
PULSE DURATION: 0.1 μ sec.
4. For resistance measurements, ground all terminals of PL101, and remove Q101 and Q102.

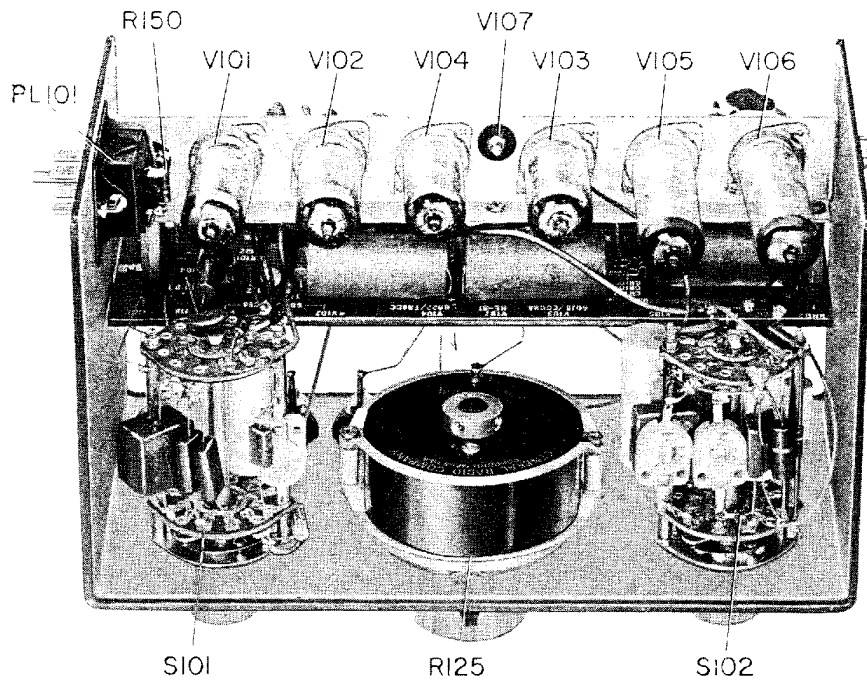


Figure 4-2. Top rear interior view.

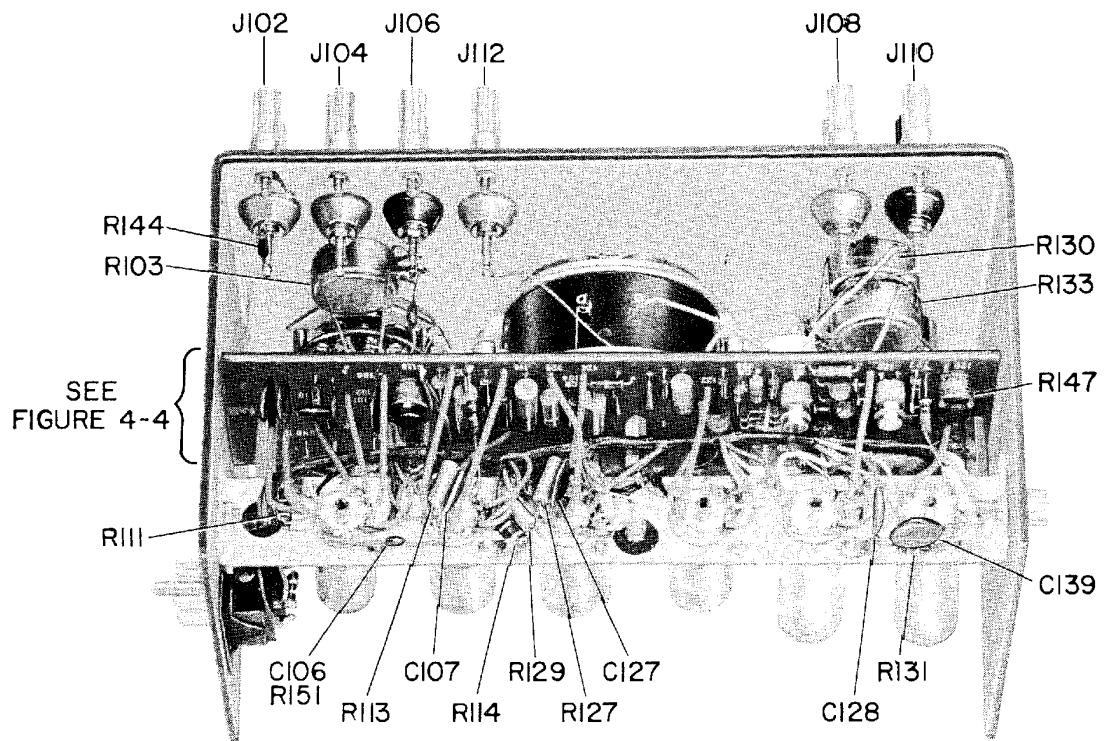


Figure 4-3. Bottom rear interior view.

PARTS LIST

REF NO.	DESCRIPTION	PART NUMBER
R101	RESISTOR, Composition 33k Ω \pm 5% 1/2 w	6100-3335
R102	RESISTOR, Film 33.2k Ω \pm 1% 1/2 w	6450-2332
R103	POTENTIOMETER, Composition 250k Ω \pm 10%	6010-2000
R104	RESISTOR, Film 34.1k Ω \pm 1% 1/4 w	6350-2340
R105	RESISTOR, Composition 3k Ω \pm 5% 1/2 w	6100-2305
R106	RESISTOR, Composition 2M Ω \pm 5% 1/2 w	6100-5205
R107	POTENTIOMETER, Composition 500 Ω \pm 20%	6040-0300
R108	RESISTOR, Film 55.6k Ω \pm 1% 1/2 w	6450-2549
R109	RESISTOR, Composition 1k Ω \pm 5% 1/2 w	6100-2105
R110	RESISTOR, Composition 1k Ω \pm 5% 1/2 w	6100-2105
R111	RESISTOR, Composition 110k Ω \pm 5% 1/2 w	6100-4115
R112	RESISTOR, Composition 3k Ω \pm 5% 1 w	6110-2305
R113	RESISTOR, Film 100 k Ω \pm 1% 1/4 w	6350-3100
R114	RESISTOR, Composition 3.3 k Ω \pm 5% 1 w	6110-2335
R115	RESISTOR, Film 51.1k Ω \pm 1% 1/4 w	6350-2511
R116	RESISTOR, Film 150k Ω \pm 1% 1/4 w	6350-3150
R117	RESISTOR, Power 4.3k Ω \pm 5% 5 w	6660-2435
R118	RESISTOR, Composition 68 k Ω \pm 5% 1/2 w	6100-3685
R119	RESISTOR, Film 270k Ω \pm 1% 1/4 w	6350-3270
R120	RESISTOR, Film 2.74M Ω \pm 1% 2 w	6195-4274
R121	RESISTOR, Composition 56 Ω \pm 5% 1/2 w	6100-0565
R122	RESISTOR, Composition 43k Ω \pm 5% 1 w	6110-3435
R123	RESISTOR, Composition 1.2k Ω \pm 5% 1/2 w	6100-2125
R124	RESISTOR, Composition 1k Ω \pm 5% 1/2 w	6100-2105
R125	POTENTIOMETER, 5k Ω	0975-4050
R126	RESISTOR, Composition 1.5k Ω \pm 5% 1/2 w	6100-2155
R127	RESISTOR, Film 191k Ω \pm 1% 1/4 w	6350-3191
R128	RESISTOR, Composition 130 Ω \pm 5% 1/2 w	6100-1135
R129	RESISTOR, Film 100k Ω \pm 1% 1/4 w	6350-3100
R130	POTENTIOMETER, Ganged 1k Ω \pm 10%	Part of 1217-0400
R131	RESISTOR, Composition 10 M Ω \pm 5% 1/2 w	6100-6105
R132	RESISTOR, Composition 15k Ω \pm 5% 1/2 w	6100-3159
R133	POTENTIOMETER, Ganged 1k Ω \pm 10%	Part of 1217-0400
R134	RESISTOR, Composition 910k Ω \pm 5% 1/2 w	6100-4915
R135	RESISTOR, Composition 910k Ω \pm 5% 1/2 w	6100-4915
R136	RESISTOR, Composition 100 Ω \pm 5% 1/2 w	6100-1105
R137	RESISTOR, Composition 680 Ω \pm 5% 1/2 w	6100-1685
R138	RESISTOR, Composition 510 Ω \pm 5% 1/2 w	6100-1515
R139	RESISTOR, Composition 4.7k Ω \pm 5% 1/2 w	6100-2475
R140	RESISTOR, Composition 4.7k Ω \pm 5% 1/2 w	6100-2475
R141	RESISTOR, Composition 510 Ω \pm 5% 1/2 w	6100-1515
R142	RESISTOR, Composition 200 Ω \pm 5% 1/2 w	6100-1205
R143	RESISTOR, Composition 2k Ω \pm 5% 1/2 w	6100-2205
R144	RESISTOR, Composition 1M Ω \pm 5% 1/2 w	6100-5105
R145	RESISTOR, Composition 2.2k Ω \pm 5% 2 w	6120-2225
R147	POTENTIOMETER, Composition 50k Ω \pm 20%	6040-0900
R148	RESISTOR, Composition 30 Ω \pm 5% 1/2 w	6100-0305
R149	RESISTOR, Composition 30 Ω \pm 5% 1/2 w	6100-0305
R150	RESISTOR, Composition 10 M Ω \pm 5%	6100-6105
R151	RESISTOR, Composition 100k Ω \pm 5% 1/2 w	6100-4105
C101	CAPACITOR, Ceramic 51 pf \pm 5% 500 dcwv	4410-0515
C102	CAPACITOR, Ceramic 68 pf \pm 10% 500 dcwv	4410-0688
C103	CAPACITOR, Ceramic 0.01 μ f \pm 20% 500 dcwv	4406-3109
C104	CAPACITOR, Ceramic 0.01 μ f \pm 20% 500 dcwv	4406-3109
C105	CAPACITOR, Ceramic 0.01 μ f \pm 20% 500 dcwv	4406-3109
C106	CAPACITOR, Ceramic 100 pf \pm 10% 500 dcwv	4404-1108
C107	CAPACITOR, Ceramic 22 pf \pm 10% 500 dcwv	4410-0228
C108	CAPACITOR, Plastic 1 pf \pm 2% 100 v	4860-8002
C109	CAPACITOR, Plastic 0.316 μ f \pm 2% 200 v	4860-7977
C110	CAPACITOR, Plastic 0.0909 μ f \pm 2% 100 v	4860-7880
C111	CAPACITOR, Plastic 0.0301 μ f \pm 2% 200 v	4860-7602
C112	CAPACITOR, Mica 0.00887 μ f \pm 1% 300 dcwv	4780-0088
C113	CAPACITOR, Mica 0.00301 μ f \pm 2% 500 dcwv	4780-0030
C114	CAPACITOR, Mica 825 pf \pm 2% 300 dcwv	4690-4070
C115	CAPACITOR, Mica 549 pf \pm 1% 300 dcwv	4690-4030

PARTS LIST (CONT)

REF NO.	DESCRIPTION	PART NUMBER
C116	CAPACITOR, Mica 121 pf $\pm 2\%$ 500 dcwv	4650-0212
C117	CAPACITOR, Trimmer 7-45 pf	4910-0100
C118	CAPACITOR 20 μ f 250 dcwv	1130-0480
C119	CAPACITOR 20 μ f 250 dcwv	1130-0480
C120	CAPACITOR, Plastic 1 μ f $\pm 10\%$ 200 v	4860-8275
C122	CAPACITOR, Mica 61.9 pf $\pm 2\%$ 500 dcwv	4650-0110
C123	CAPACITOR, Mica 0.001 μ f $\pm 2\%$ 300 dcwv	4690-4200
C124	CAPACITOR, Mica 0.01 μ f $\pm 2\%$ 300 dcwv	4780-0300
C125	CAPACITOR, Plastic 0.1 μ f $\pm 2\%$ 200 v	4860-8252
C126	CAPACITOR, Plastic 1.0 μ f $\pm 2\%$ 100 v	4860-8002
C127	CAPACITOR, Ceramic 82 pf $\pm 10\%$ 500 dcwv	4410-0828
C128	CAPACITOR, Ceramic 0.01 μ f $\pm 20\%$ 500 dcwv	4406-3109
C129	CAPACITOR, Electrolytic 30 μ f 150 dcwv	4450-1900
C130	CAPACITOR, Ceramic 82 pf $\pm 10\%$ 500 dcwv	4410-0828
C131	CAPACITOR, Ceramic 150 pf $\pm 5\%$ 500 dcwv	4406-1155
C132	CAPACITOR, Ceramic 0.01 μ f $\pm 20\%$ 500 dcwv	4406-3109
C133	CAPACITOR, Ceramic 33 pf $\pm 10\%$ 500 dcwv	4410-0338
C134	CAPACITOR, Ceramic 33 pf $\pm 10\%$ 500 dcwv	4410-0338
C135	CAPACITOR, Ceramic 0.01 μ f $\pm 20\%$ 500 dcwv	4406-3109
C136	CAPACITOR, Ceramic 0.01 μ f $\pm 20\%$ 500 dcwv	4404-2109
C138	CAPACITOR, Ceramic 0.047 μ f $\pm 20\%$ 250 dcwv	4408-3479
C139	CAPACITOR, Ceramic 0.022 μ f $\pm 20\%$ 500 dcwv	4407-3229
CR101	DIODE, Type 1N625	6082-1012
CR103	DIODE, Type 1N118A	6082-1006
CR104	DIODE, Type 1N118A	6082-1006
CR105	DIODE, Type 1N118A	6082-1006
CR106	DIODE, Type 1N118A	6082-1006
CR107	DIODE, Type 1N118A	6082-1006
CR108	DIODE, Type 1N118A	6082-1006
L101	CHOKER, Molded 120 μ h $\pm 10\%$	4300-3600
L102	CHOKER, Molded 82 μ h $\pm 10\%$	4300-3400
L103	CHOKER, Molded 150 μ h $\pm 10\%$	4300-3810
L104	CHOKER, Molded 39 μ h $\pm 10\%$	4300-3000
L105	CHOKER, Molded 56 μ h $\pm 10\%$	4300-3200
L106	CHOKER, Molded 5.6 μ h $\pm 10\%$	4300-1800
L107	CHOKER, Molded 5.6 μ h $\pm 10\%$	4300-1800
J101	BINDING POST, EXT DRIVE (Insulated)	4060-0100
J102	BINDING POST, EXT DRIVE (Uninsulated)	4060-1800
J103	BINDING POST, SYNC + (Insulated)	4060-0100
J104	BINDING POST, SYNC + (Uninsulated)	4060-1800
J105	BINDING POST, SYNC - (Insulated)	4060-0100
J106	BINDING POST, SYNC - (Uninsulated)	4060-1800
J107	BINDING POST, OUTPUT PULSE + (Insulated)	4060-0400
J108	BINDING POST, OUTPUT PULSE + (Uninsulated)	4060-1800
J109	BINDING POST, OUTPUT PULSE - (Insulated)	4060-0200
J110	BINDING POST, OUTPUT PULSE - (Uninsulated)	4060-1800
J111	BINDING POST, DELAYED SYNC (Insulated)	4060-0100
J112	BINDING POST, DELAYED SYNC (Uninsulated)	4060-1800
S101	SWITCH, Rotary Wafer	7890-2700
S102	SWITCH, Rotary Wafer	7890-2710
Q101	TRANSISTOR, Type 2N1500	8210-1500
Q102	TRANSISTOR, Type 2N1500	8210-1500
V101	TUBE, Type 6DJ8*	8360-4510
V102	TUBE, Type 6DJ8*	8360-4510
V103	TUBE, Type 6DJ8*	8360-4510
V104	TUBE, Type 6922*	8380-6922
V105	TUBE, Type 6CW5*	
V106	TUBE, Type 6CW5*	1217-0360**
V107	LAMP, Neon, Type NE-96	8390-0960

*Amperex is preferred.

**Matched pair.

NOTE: When ordering replacement parts, please specify the instrument type number as well as the part numbers of the items required.

GENERAL RADIO COMPANY

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* Repair services are available
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