



## New 0.07-10 Microsecond General-Purpose Pulse Generator

THE new -hp- 212A generates pulses which have extremely good waveform and which are adjustable in duration over a range from at least 0.07 to 10 microseconds. These pulses are obtained from a circuit that has been maintained at a convenient value (50 ohms) to permit ready use without deterioration of the pulse shape in practical loads. In other respects the -hp- 212A has been made as flexible as possible: the maximum output voltage of 50 volts loaded or 100 volts open circuit is sufficiently high for most types of test work, an output attenuator reduces the output voltage in known steps, pulses can be generated at any repetition rate from 50 to 5000 pps, and the circuit can be triggered from an external synchronizing or sync in pulse.

In addition to the major output pulse, the -hp- 212A generates a trigger or sync out pulse of approximately 2 microseconds duration. The time of occurrence of the sync out pulse is fixed at 15 microseconds following an input synchronizing pulse. The time

of occurrence of the major output pulse, however, is continuously adjustable from 10 microseconds before to 100 microseconds after the occurrence of the sync out pulse.

Photographs of oscilloscope traces of three typical major output pulses of different duration are shown in Figure 1. The time of rise and decay of the pulses is distinguishable only in the photograph of the shortest pulse, where the pulse width is 0.07 microsecond. It can be seen that the rise and decay times are each less than 0.02 microsecond.

The degree of freedom from jitter is indicated by the sharp trace on the leading and trailing edges of the pulses in Figure 1. These photographs were made from a synchroscope whose sweep was triggered from the trigger pulse generated by the -hp- 212A; that is, the synchroscope sweep was not internally synchronized. Thus, these photographs, which were exposed for a large fraction of a minute, include the jitter in the trigger pulse and the major pulse itself, as well as any jitter in the sweep circuit of the synchroscope.

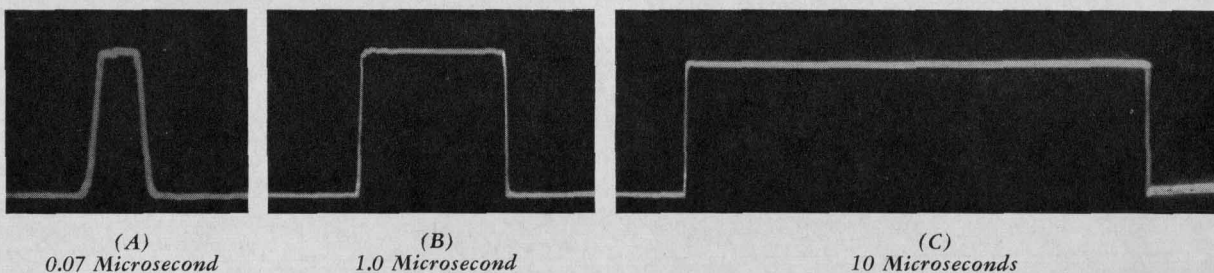


Figure 1. Typical Pulses Generated by -hp- Model 212A.

Pulse Lengths Are Measured at Half-Voltage Points.

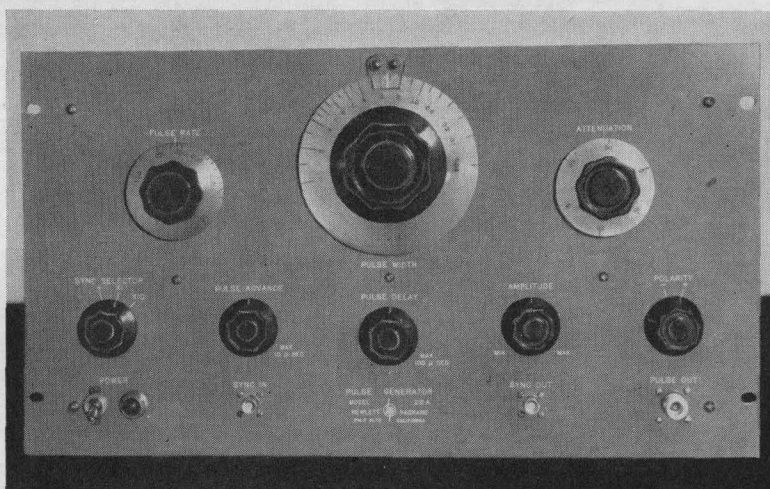


Figure 2. -hp- Model 212A Pulse Generator.

### CIRCUIT DESCRIPTION

The basic pulse-generating circuit uses a delay line in combination with a pair of hydrogen-filled thyratrons (3C45). Such thyratrons have a relatively short ionization and de-ionization time, and, in combination with their large power-handling capacity and very long life, are well suited to pulse-generating circuits. In order to generate pulses of variable length with a pulser of this type without cumbersome switching to different-valued pulse-forming networks, some special circuit arrangement must be used.

Figure 3 illustrates the basic pulse-generating circuit. Tube V1 is the pulse-generating tube, while tube V2 controls the length of the pulse and forces the trailing edge of the pulse to decay rapidly. Both V1 and V2 are hydrogen thyratrons. In the steady-state condition between pulses, V1 and V2 are not ionized, although sufficient anode voltage exists across the pulse-forming network of V1 for ionization to occur when the grid of V1 is driven positive.

At the proper time  $t_a$ , tube V1 is fired by a short pulse that is supplied by the pulse repetition-rate circuits. The subsequent drop in anode voltage of V1 is transferred to an unter-

minated delay line or pulse-forming network having a two-way transit time of 10 microseconds. Since the delay line is open-ended, the negative voltage wave traveling down the line is reflected without phase reversal from the open end of the line. Upon arriving back at the anode of V1, the reflected voltage causes the anode voltage to fall to zero and extinguishes the tube. This action generates a 10-microsecond pulse across the cathode resistance R1.

The positive pulse voltage at the cathode of V1 supplies anode voltage to V2, although V2 does not yet conduct because its grid is biased off. Now, at a time not exceeding 10 microseconds later than  $t_a$ , a short positive pulse is applied to the grid of V2 at time  $t_b$  by the pulse length-determining circuits, thus firing V2. The anode current of V2 flows through R2, causing a rapid drop in voltage across V2. Since the anode voltage of V2 was first increased by the original pulse across R1 and then reduced 10 microseconds or less later by the firing of V2, a pulse is formed at the anode of V2. The duration of the pulse is determined by the adjustable interval between  $t_a$  and  $t_b$ . Irregularities in the top of the pulse are minimized by the clipper tube V3, for, when the amplitude of the pulse exceeds the positive bias on the cathode of V3, this diode conducts and maintains the pulse amplitude quite constant. The pulse generated by the above action is applied to the output amplifier V4, which provides either positive or negative output pulses. V4 also aids in obtaining a fast rise-time for the output pulse, because the grid

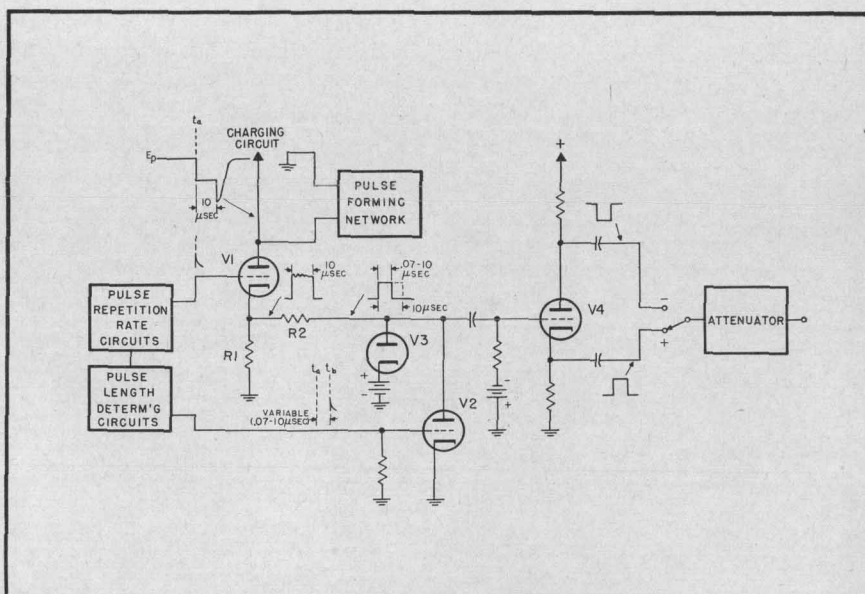


Figure 3. Basic Pulse-Generating Circuit.

circuit of V4 is biased beyond cut-off so that only a portion of the grid drive is used.

The above circuit is simple and reliable, yet is capable of generating very short pulses having continuously-variable length, constant amplitude, rapid rise and decay, and ample peak voltage for the majority of testing purposes.

### PULSE LENGTH CONSIDERATIONS

The minimum pulse length obtainable from the circuit is determined primarily by the time required for a hydrogen thyratron of the type used to ionize. As stated above, this time is about as short as that for any other present thyratron, being in the order of 0.02 microsecond. Since ionizing action in tube V2 cannot begin until the leading edge of the pulse at the cathode of V1 is at least partially formed, V2 does not become ionized until approximately 0.035 microsecond after the start of the pulse. This ionization time plus stray capacities in the circuit thus limit the minimum pulse width obtainable. Pulses of 0.05 microsecond duration are usually available from the circuit, although the Model 212A is conservatively rated as generating 0.07-microsecond pulses.

The maximum pulse length obtainable from the circuit is determined by the maximum duty cycle at which the thyratron V1 must operate and by the average current for which the tube is rated. These factors are such as to limit the longest pulse that is available under all conditions to 10 microseconds.

### PRF CIRCUITS

The circuits that generate the trigger voltages for the output pulse-generating circuit of Figure 3 are related in block form in Figure 4. The Repetition-Rate multivibrator can operate either free-running or triggered by external positive or

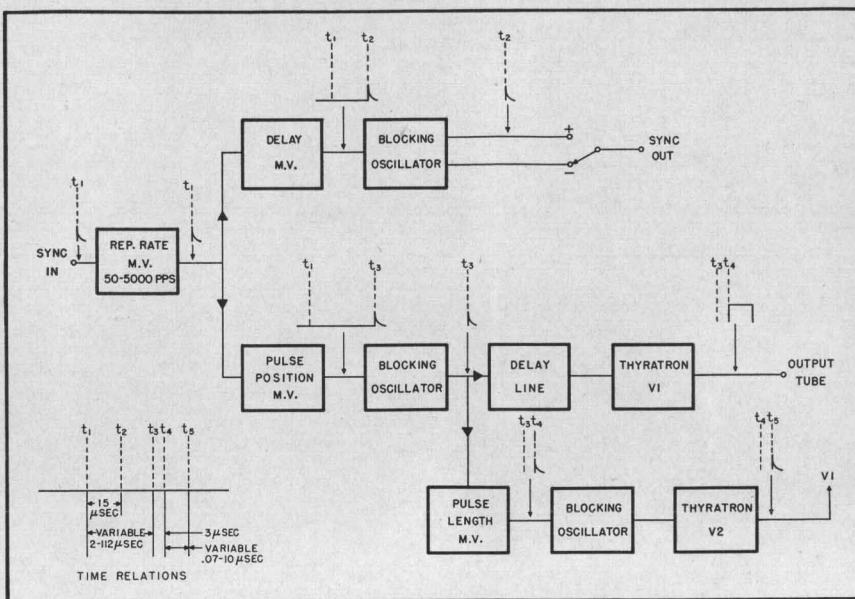


Figure 4. Block Diagram of PRF Circuits.

negative (Sync In) pulses. When free-running, the Repetition-Rate multivibrator can operate at any pulse repetition frequency from 50 to 5000 pps, as determined by the setting of a calibrated panel control. When triggered by an external pulse, the Repetition-Rate multivibrator and succeeding circuits are capable of operating at practically any repetition frequency up to 5000 pps, depending upon the repetition frequency of the external pulses. In the free-running condition, the output of the Repetition-Rate multivibrator is equivalent to a Sync In pulse.

The output of the Repetition-Rate multivibrator triggers both the Delay and Pulse-Position multivibrators. These are one-shot multivibrators which cycle once when initiated by a trigger voltage. The Delay multivibrator introduces a fixed delay interval of 15 microseconds between the Sync In pulse and the Sync Out pulse. The trailing edge of the pulse from the Delay multivibrator initiates the operating cycle in a single-action or monostable blocking oscillator which generates a high-voltage pulse of approximately 2 microseconds duration for external trigger

purposes. This Sync Out pulse is available at either positive or negative polarity.

The Pulse-Position multivibrator is a one-shot circuit which is triggered by the output of the Repetition-Rate multivibrator and which generates pulses whose duration is determined by the setting of a panel control. The purpose of this multivibrator is to control the time interval between the occurrence of the Sync In pulse and the start of the major output pulse. The Pulse-Position multivibrator thus serves the same purpose with regard to the major output pulse as does the Delay multivibrator to the Sync Out pulse. However, the pulse from the Pulse-Position multivibrator is adjustable in duration and permits the starting time of the major output pulse to be adjusted over a range of 110 microseconds (5 to 115 microseconds following the start of the Sync In pulse at time  $t_1$ ). To accomplish this, the Pulse-Position multivibrator generates a pulse that is adjustable in duration over a range from 2 to 112 microseconds. Slight delays distributed over ensuing parts of the circuit add to the delay inserted by the

Pulse-Position multivibrator to allow the start of the major output pulse to be adjusted over a range from 5 to 115 microseconds following the start of a Sync In pulse.

The trailing edge of the 2-112 microsecond pulse from the Pulse-Position multivibrator triggers the succeeding monostable blocking oscillator which provides a fast-rising pulse of relatively high voltage to fire thyatron V1. A 2-microsecond delay line is inserted between the Pulse-Position blocking oscillator and the grid of V1 to compensate for a 2-microsecond delay in the circuits that trigger V2.

The output of the blocking oscillator, as well as firing V1, triggers the Pulse Length multivibrator, a one-shot type circuit. This multivibrator then generates a pulse whose duration is variable (2-12 microseconds) and is adjusted by the setting of a large 6-inch panel dial. The trailing edge of this pulse triggers a blocking oscillator, which, in turn, fires the thyatron (V2 in Figure 3) that determines the length of the major output pulse in the manner described heretofore.

## OUTPUT SYSTEM

The major output pulse is applied to the output terminals through a step-attenuator that provides 50 db of attenuation in 10-db steps. Use of the attenuator does not cause any deterioration of pulse shape, even when small pulse voltages are desired. A continuously-variable amplitude control is also provided for making fine adjustments of output voltage. Maximum amplitude of the major output pulse is at least 50 volts into a 50-ohm load.

## DOUBLE PULSE

For some applications such as the determination of resolution time of pulse counters, it is desirable to have a double pulse that is separated by a known and variable interval. Such a

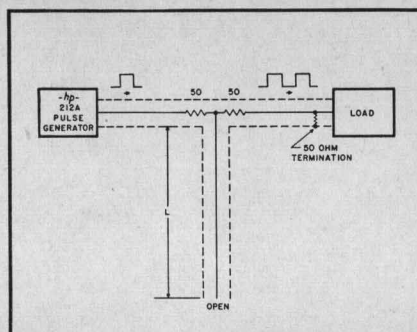


Figure 5. Circuit For Generating Double Pulses.

double pulse can be obtained using the -hp- 212A in combination with the cable system illustrated in Figure 5.

The pulse generated by the -hp- 212A is applied through a 50-ohm cable to a tee that connects to other 50-ohm cables and resistors as shown. One of the latter cables connects to the pulse counter or other device whose resolution is to be measured. The second cable is open at one end and the cable length is such that the delay in the cable corresponds to one-half of the desired time interval between leading edges of the double pulse.

The output pulse from the -hp- 212A travels toward the tee and sends a voltage pulse in both directions down the tee. The pulse traveling toward the counter is absorbed without reflection by the terminating resistance. The pulse traveling down the open-ended cable, however, is reflected at the open end of the line without phase reversal back through the tee to the counter as a second pulse. The time interval between the pulses is determined by the length  $L$  of the open-ended cable. Cable lengths from 25 to several hundred feet of typical 50-ohm cable may be required for the open-ended cable, depending upon the pulse length and the desired inter-pulse interval. Double pulses of approximately 12 volts amplitude can be obtained from the above arrange-

ment in combination with the -hp- 212A.

The reflected pulse suffers some deterioration in addition to some attenuation caused by the long length  $L$  of the cable. This system is therefore of greatest use when testing equipments whose resolution time is less than a few microseconds.

—G. S. Kan

## SPECIFICATIONS FOR MODEL 212A PULSE GENERATOR

**PULSE LENGTH:** Continuously-variable from at least 0.07 to 10 microseconds; controlled by direct-reading 6" front panel dial.

**PULSE AMPLITUDE:** At least 50 volts into 50-ohm load.

**PULSE SHAPE:** Rise and decay time approximately 0.02 microsecond each (10% to 90% of maximum amplitude). Variation of crest voltage less than 5% at 50 volts output; use of continuously-variable amplitude control causes some increase in crest variation; step attenuator causes no discernible deterioration.

**PULSE POLARITY:** Positive or negative.

**INTERNAL IMPEDANCE:** 50 ohms or less, either polarity.

**REPETITION RATE:** 50 to 5000 pps; internally controlled.

**SYNCHRONIZATION:** Can be triggered from external 5-volt positive or negative pulse at rates up to 5000 pps.

**AMPLITUDE CONTROL:** 0 to 50 db attenuator in 10 db steps; also continuously-variable control having range of at least 10 db to supplement attenuator.

**TRIGGER PULSE:** 40 volts positive or 25 volts negative trigger supplied to 200-ohm or more load; positive or negative polarity; approx. 2 microseconds duration at half-voltage points with less than 0.25-microseconds rise time.

**DELAY PROVISION:** Main pulse delayable from 0 to 100 microseconds with respect to trigger (Sync Out) pulse.

**ADVANCE PROVISION:** Main pulse can be advanced from 0 to 10 microseconds with respect to Sync Out pulse. Delay and advance provisions embodied in one panel control.

**PANEL CONNECTORS:** PULSE OUT, female type N (UG-58/U); SYNC IN and SYNC OUT, female type BNC (UG-290/U).

**CABLES SUPPLIED:** 7 foot power cable permanently attached to unit.

**DIMENSIONS:** 19" wide, 10 1/2" high, 12" deep.

**POWER:** Operates either from 115- or 230-volt, 50/60 cycle supply. Requires 260 watts maximum.

**WEIGHT:** 45 lbs.; shipping weight, approx. 75 lbs.

**MOUNTING:** Supplied only in rack-mounting style; end frames can be provided at slight extra cost to convert to table mounting style but are not essential to table use.

**PRICE:** \$550.00 f.o.b. Palo Alto, Calif., (Specify Model 212A). End frames \$5.00 per pair f.o.b. Palo Alto, Calif. (Specify #17).

Data subject to change without notice