

# *the* GENERAL RADIO Experimenter

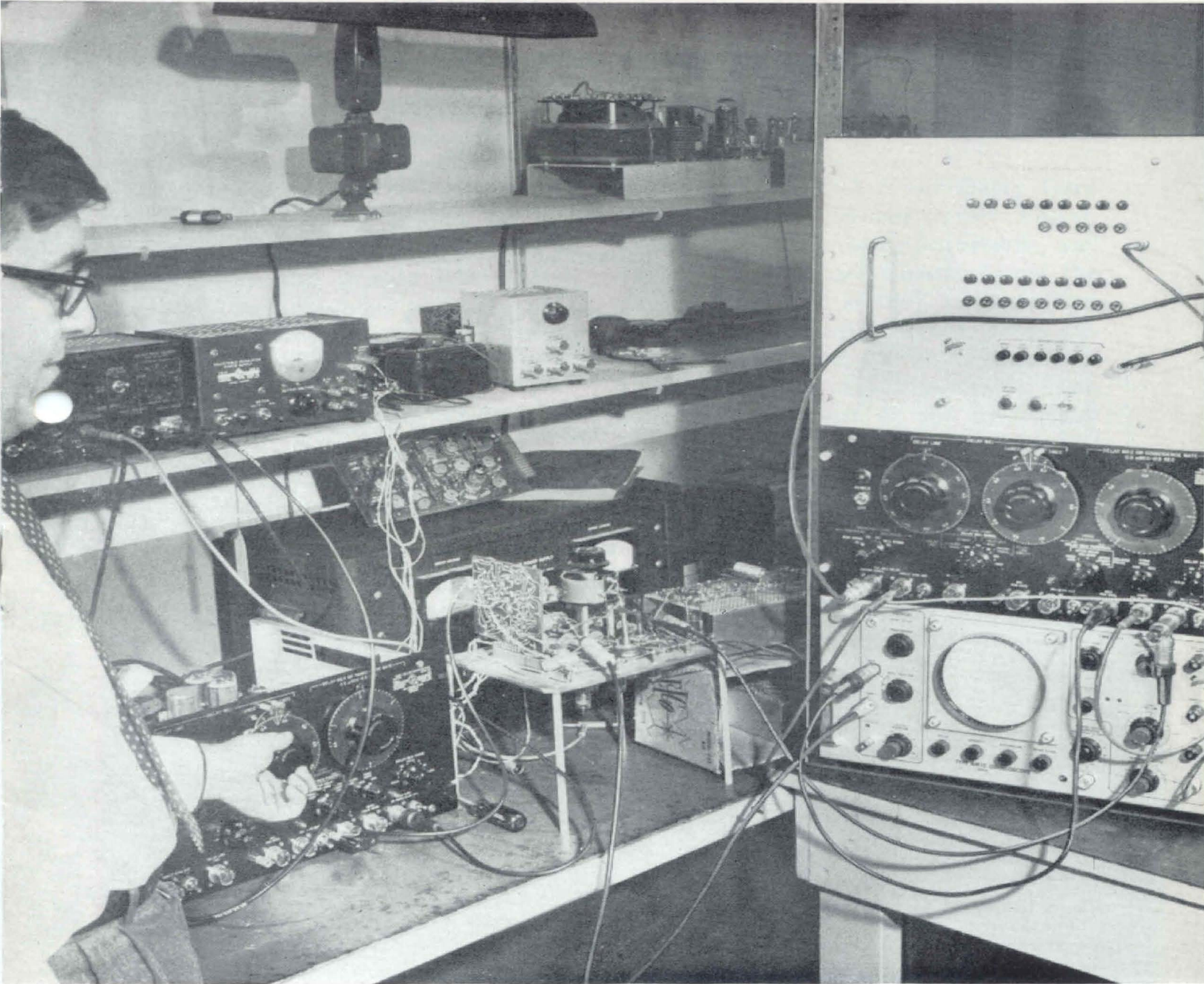


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VOLUME 32 No. 19

DECEMBER, 1958



*In This Issue*

A Precise Time-Delay Generator

# the GENERAL RADIO Experimenter



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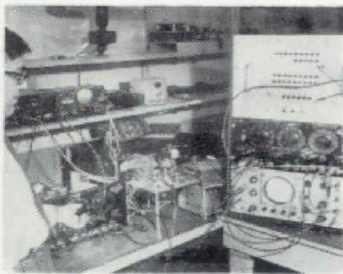
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### COVER



The new Type 1392-A Time-Delay Generator, described in this issue, brings a new degree of precision and adaptability to delay generation and measurement. Here, two of these generators are used in an experimental system for producing time-coherent tone bursts.



# HOW TO KILL TIME—ACCURATELY!

## A Generator of Precise Time Delays

The immediate acceptance accorded the TYPE 1391-A Pulse, Sweep, and Time-Delay Generator<sup>1</sup> upon its introduction in 1955 made it apparent that there was a general desire for precise, versatile, and accurate time-domain instrumentation. The TYPE 1392-A Time-Delay Generator to be described in this article uses portions of the TYPE 1391-A as a point of departure and extends its original circuitry to produce a new degree of precision and adaptability in a time-delay system.

The development of circuits for amplitude comparison by Holtje<sup>2</sup> and of highly stable and precise distributed-parameter variable delay lines by Lewis and Frazier<sup>3</sup> came about almost simultaneously with the availability of an

abundance of application information resulting from the introduction of the TYPE 1391-A Pulse, Sweep, and Time-Delay Generator. This combination of new circuits, new components, and field experience has resulted in the development of an instrument that will, we are certain, become a standard for accuracy and reliability in the field of analog time measurements. It is an excellent range calibrator for radar, sonar, and radio navigation systems.

The TYPE 1392-A Time-Delay Generator produces an accurately known time delay, continuously adjustable, and with 1% or 10-m $\mu$ sec accuracy over the range from 0 to 1 second. It contains a second, slightly less accurate, delay circuit adjustable over the time range from 0.5  $\mu$ sec to 0.5 second. This circuit, completely independent of the first delay circuit and capable of being calibrated by it, can be used:

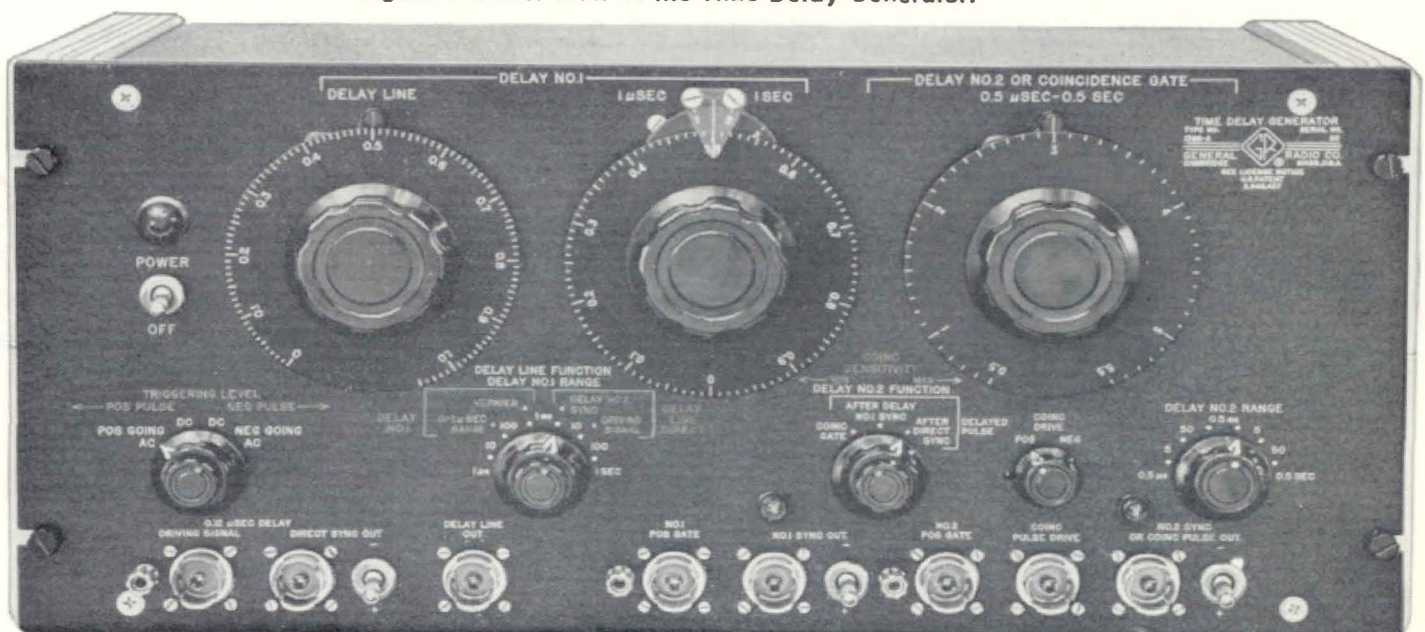
1. As a second "parallel" delay circuit.

<sup>1</sup>R. W. Frank, "A Versatile Generator for Time-Domain Measurements," *General Radio Experimenter*, 30, 12, May, 1956.

<sup>2</sup>M. C. Holtje, "A New Circuit for Amplitude Comparison," *General Radio Experimenter*, 30, 6, November, 1955.

<sup>3</sup>F. D. Lewis and R. M. Frazier, "Distributed-Parameter Variable Delay Lines Using Skewed Turns for Delay Equalization," *Proc. IRE*, Feb., 1957.

Figure 1. Panel view of the Time-Delay Generator.



2. As a second delay cascaded after the first delay in time.

3. As a coincidence "and" circuit enabling-gate started by the first delay. Since the gate can be reduced in duration to  $0.5 \mu\text{sec}$ , timing marks of PRF in excess of 1 Mc can be selected.

We believe that this is the first commercially available coincidence system capable of delay steps below  $1 \mu\text{sec}$  in an analog system.

The fact that this instrument is an analog generator capable of producing precise delays should be emphasized, because only in an analog system can the delay be produced from a start command pulse without some sort of gating transient or quantization error. With this new delay generator, it is also possible to establish delays with quartz-crystal-oscillator-controlled precision in any time unit, as in range (yards or miles). The advantage of this system should be immediately obvious to those working with radar, with rocks, with water, or with bats.

Another advantage accruing to the analog delay-circuit system is that the delay can be varied by an external con-

trol voltage. The amplitude comparator developed for this instrument (and described below) has a very high input impedance for the reference voltage and permits one to inject an external signal to control the magnitude of the delay over a decade. This makes the unit a linear time modulator for the production of pulse duration modulation, pulse position modulation, or plain jitter of known and controlled magnitude over modulating frequencies ranging from 3 c to 100 kc.

### DELAY LINE

Figure 2 shows the circuit system reduced to its simplest form. The delay line is shown connected in one of its four possible positions in the system. Here it acts as a 0 to  $1\text{-}\mu\text{sec}$  vernier on the electronic portion of the Delay 1 circuit. It can also be switched to:

1. Act as a first (0 to  $1\text{-}\mu\text{sec}$ ) range to produce a delay between the direct sync pulse and the Delay No. 1 sync pulse.
2. Delay by 0 to  $1 \mu\text{sec}$  the Delay No. 2 sync pulse (see page 7).
3. Delay directly any waveform applied to the PRF drive terminals.

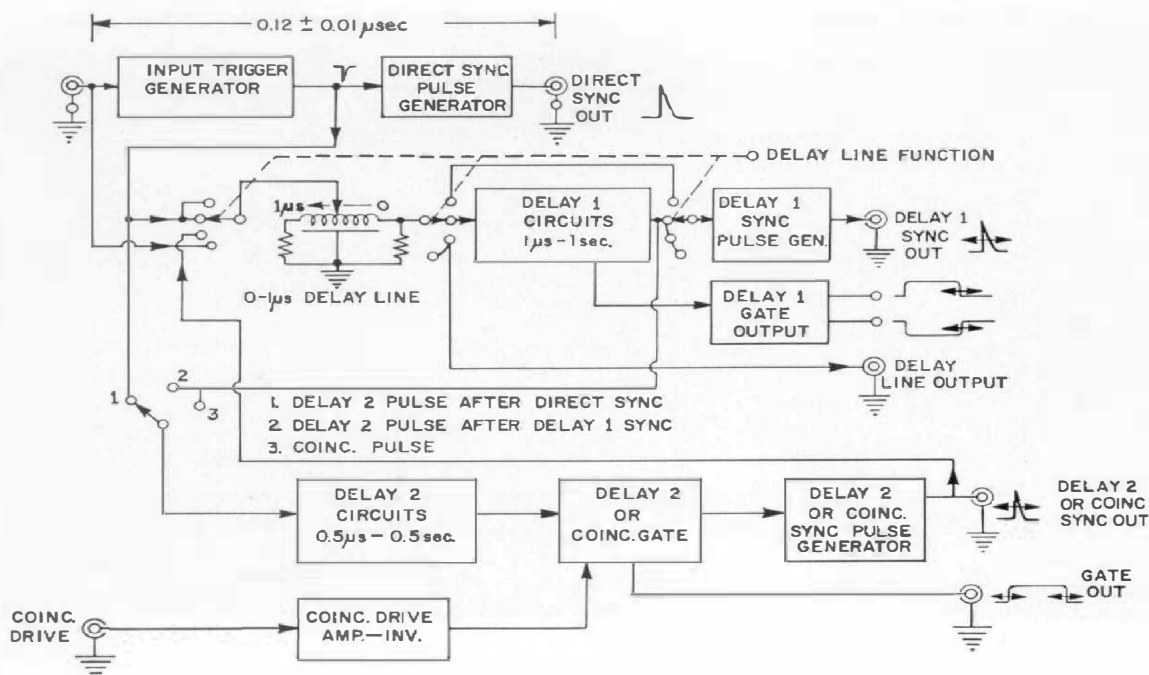


Figure 2. Simplified block diagram.

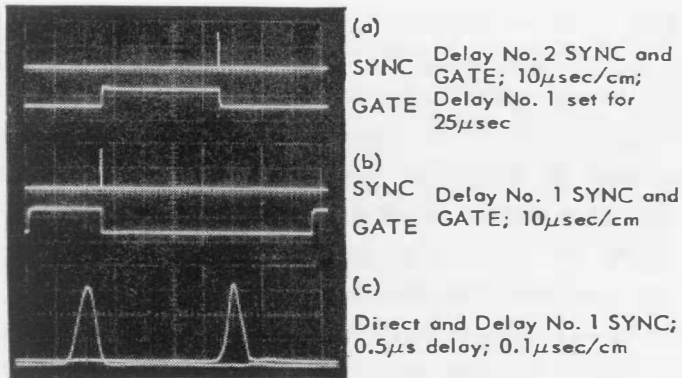


Figure 3. Typical waveforms.

### INPUT CIRCUIT

The input circuits comprise a trigger generator, which will accept almost any waveform having a peak amplitude of about 0.3 volt at frequencies ranging from dc to over 300 kc. This circuit produces a pretrigger, which is fed to the two independent delay circuits and an output sync pulse of standard shape, having a base duration of approximately  $0.1\mu\text{sec}$ , an amplitude of 20 to 25 volts, positive or negative, and a source impedance of 93 ohms (Figure 3c). The sync pulses produced by the Delay No. 1 and Delay No. 2 circuits are similar.

### DELAY NO. 1 CIRCUIT

Electronic circuits which will produce accurate, linear, and precisely controlled delays of less than  $1\mu\text{sec}$  are difficult to build and even if realizable are very expensive and complex. The first range, up to  $1\mu\text{sec}$ , is timed by a TYPE 1477-J1000

delay line. This line has an accurate, individually calibrated, four-inch dial graduated in  $0.01\text{-}\mu\text{sec}$  intervals and produces a delay between the direct sync pulse and the Delay No. 1 sync pulse of 0 to  $1\mu\text{sec}$  with an accuracy of  $\pm 0.01\mu\text{sec}$ .

To produce delays over  $1\mu\text{sec}$ , the electronic circuits are switched in cascade with the line as shown in Figure 2. These circuits are shown in some detail in Figure 4. They comprise a high-speed bistable gate, a precise linear sweep generator, an amplitude comparator, and a reset trigger generator followed by the Delay No. 1 sync-pulse generating circuit. When opened by the trigger from the delay line, the bistable gate starts the sweep and causes the associated buffer to produce an output pulse (positive 5 volts and negative 60 volts), which marks the delay interval. The sweep circuit, a highly linear "bootstrap," produces a saw tooth whose slope is determined by the decade range switch. This sweep of predetermined slope rises from a minimum of 10 volts to a maximum of 110 volts. The sweep is fed to one grid of the amplitude comparator, while the reference voltage from the 10-turn range potentiometer is fed to the other. When the sweep and reference voltages are equal, the comparator triggers and produces a reset pulse for

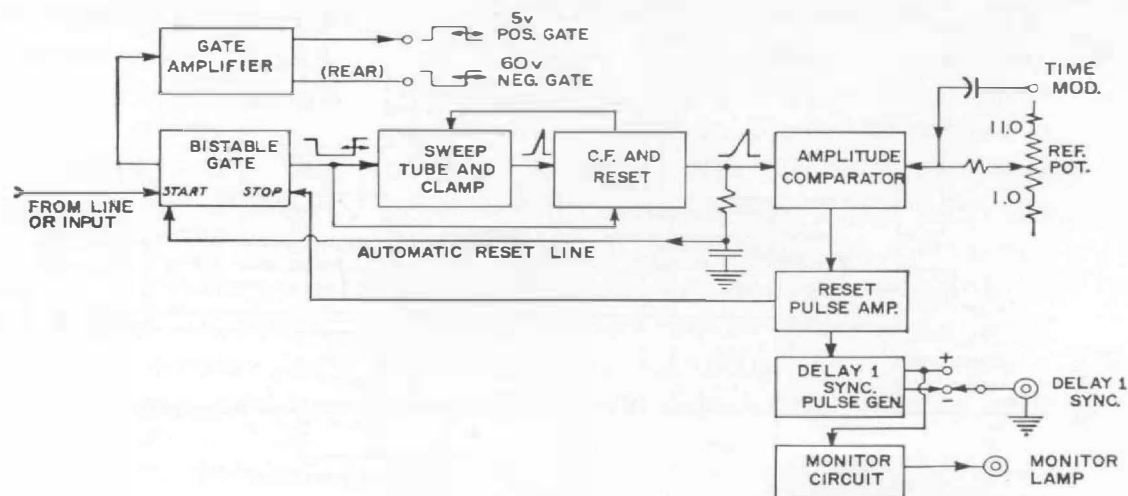


Figure 4. Functional diagram of Delay No. 1 circuits.

the gating bistable multivibrator and at the same time produces the Delay No. 1 synchronizing pulse. Thus, the loop consisting of the bistable gate, sweep generator, amplitude comparison circuit, and resetting circuits assumes a monostable characteristic.

**Stability**

Both long-term and short-term stability of delay has been assured by the use of precision resistance-capacitance components to establish the sweep slope; by the use of highly regulated and filtered dc voltages for the comparison reference voltage, plate supply, and heater voltage in the sweep generator and amplitude comparator; and by careful circuit design, which minimizes the effects of tube changes and tube aging on the accuracy of the circuit (Table I).

**Convenience Features**

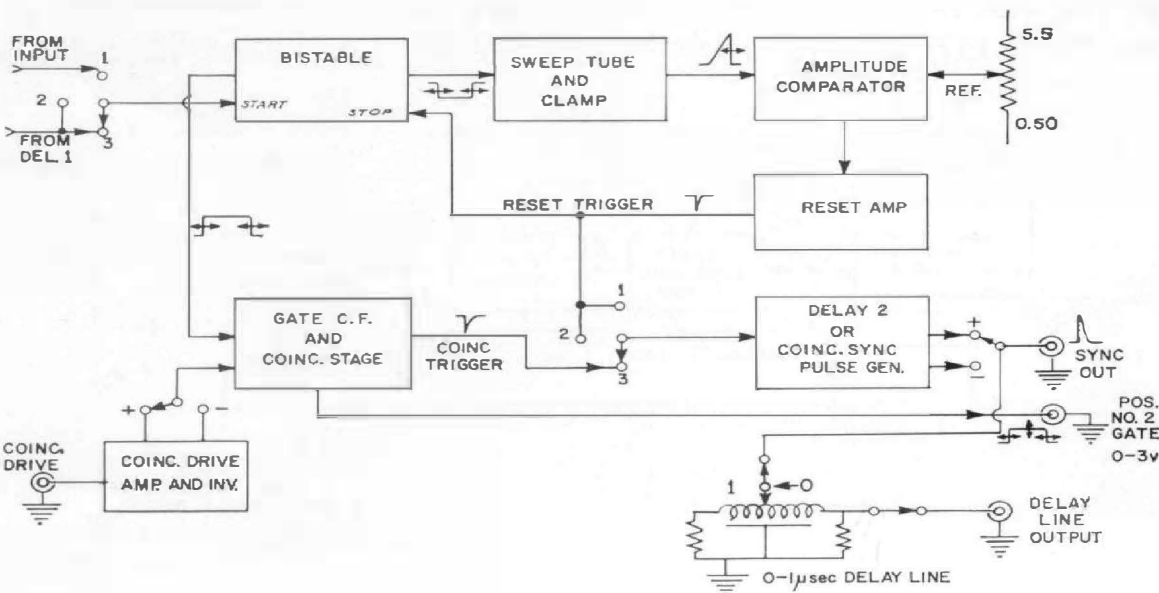
Both sweep and reference grids of the amplitude comparator are at high impedance, and provision has been made to permit the superposition of a modulating voltage on the reference voltage. A jack on the rear panel of the instrument provides for the injection of this voltage. The low-frequency cutoff of this coupling network is 3 cycles, while

the high-frequency performance will, of course, be determined only by the slope of the sweep voltage.

Several other features have been provided to increase the convenience of the Delay No. 1 circuit group in application. A 5-volt positive-gate waveform, corresponding to the delay interval set, is available at low impedance from a coaxial connector on the front panel, so that the delay interval can be observed on an oscilloscope over the entire range of delays where the 0.1- $\mu$ sec sync pulse may not be visible because of its brief duration (Figure 3b). This waveform, with a negative polarity and a 60-volt magnitude, is provided on the rear panel to drive auxiliary pulse-generating equipment such as the General Radio Type 1219-A Pulse Amplifier. In addition to this gate waveform a neon indicator lamp monitors the presence of the Delay No. 1 sync pulse.

**DELAY NO. 2 CIRCUITS**

The second group of delay circuits is identical in principle with the first (Figure 5). It lacks only the features of high accuracy and resolution. The delay reference voltage is provided by a 4" single-turn potentiometer with a resolu-



**Figure 5. Functional diagram of Delay No. 2 circuits.**

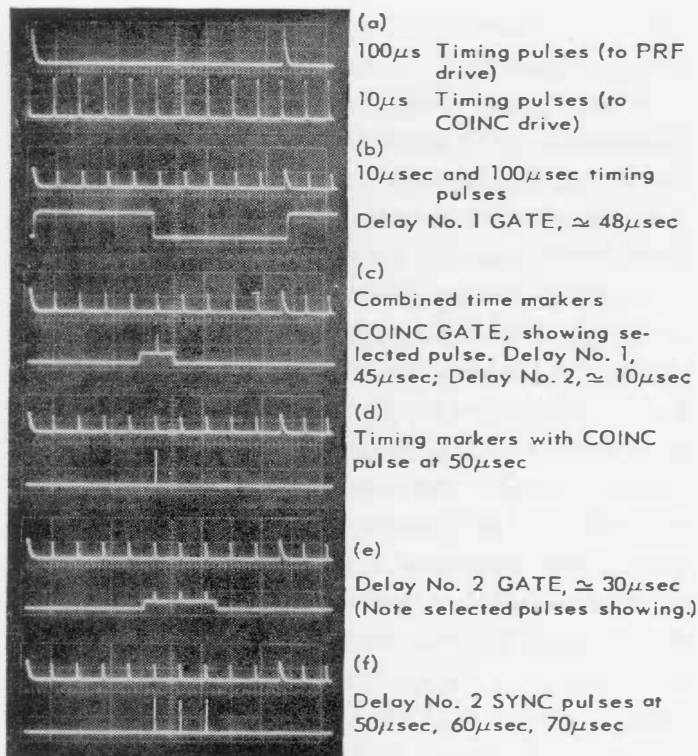


Figure 6. Coincidence circuit used for multiple pulses.

tion of 1 part in 2,000, and the accuracy is 3% everywhere over the six decade ranges from 0.5  $\mu$ sec to 0.5 second.

The action of this circuit can be initiated either by the direct sync pulse or by the sync pulse of the first delay circuit, so that the delay is either concurrent with the first delay or is initiated after the first delay interval. It should be pointed out here that, since the delay circuits can always be started concurrently, the first, more accurate delay can be used to calibrate the second.

●Outputs from the second delay circuit are similar to those of the first: A 5-volt positive gate and, marking the end of the delay interval, a 20-volt 0.1- $\mu$ sec pulse at 93-ohm impedance level.

When the function switch for the second delay circuit is in "coincidence" position,

1. The delay gating circuits are started after the Delay No. 1 sync pulse.

2. The Delay No. 2 sync-generating circuits are connected to be triggered by

the action of an "and" circuit.

The "and" circuit requires the simultaneous existence of the Delay No. 2 gate and an externally applied pulse to provide a trigger for the sync circuits. Photographs of the gate and output sync pulses are in Figure 6. An over-all photo of a precision delay-generating system involving the TYPE 1392 Time-Delay Generator and the Tektronix 180-A Time-Mark Generator, as a source of crystal-controlled time-coherent synchronizing pulses, is shown in Figure 7.

Since the shortest duration of the Delay No. 2 gate has been set at 0.5  $\mu$ sec, it is possible to select a single pulse from a timing pulse train whose frequency may be as high as 1.7 Mc. Precise 1- $\mu$ sec steps of delay are easily obtainable using the Tektronix 180-A as a crystal-controlled time-mark generator. If the gate produced by the Delay No. 2 circuits is made longer than the interval between the timing pulses from the marker generator, a group of pulses will be produced at the Delay No. 2 synchronizing-pulse terminal (Figure 6, (e) and (f)). The maximum rate at which pulses can be produced in the burst is to some extent determined by the amplitude and rise time of the trigger pulses provided by the timing source. The pulses produced by the Tektronix 180-A, for example, will typically produce a 200-kc burst.

### DELAY LINE CONNECTION

In addition to the delay-line connection described under Delay No. 1, the connection shown in Figure 5 makes it possible to delay the No. 2 sync pulse produced by coincidence. Thus, with the combination of a precise coincidence circuit and the passive line, it is possible to generate delays up to several hundred microseconds, accurate to 0.01  $\mu$ sec. Here, we should inject one word of cau-

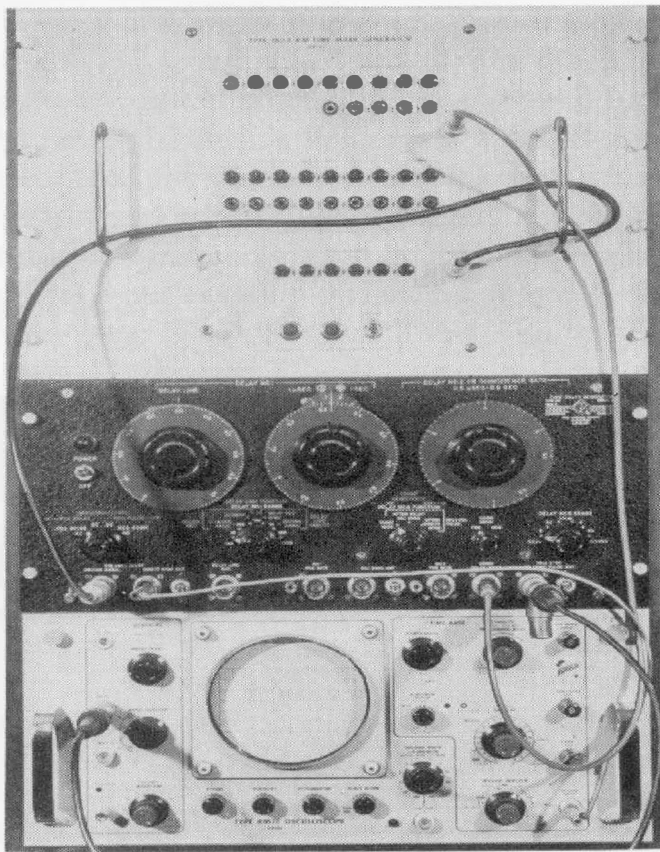


Figure 7. Precision time-generating system, consisting of the Type 1392-A Time-Delay Generator and the Tektronix 180-A Time-Mark Generator

tion. Timing generators like the Tektronix 180-A derive their lower frequency outputs by feeding each pulse-divider circuit from the next higher order divider. Since the trigger pulse has a finite and somewhat variable rise time (depending upon the bandwidth of the divider involved), there is an accumulation of delay between pulses within the timing chain. (One possible use for the coincidence circuit in the TYPE 1392-A Time-Delay Generator is, of course, the removal of this delay.) In order to make the steps of delay produced by the coincidence system exactly correct, some delay must be inserted in the path of the high-frequency pulses,<sup>4</sup> or the error must

<sup>4</sup>The General Radio TYPE 314-S86 0.5  $\mu$ sec Variable Delay Line is useful in equalizing these residual delays (independently of the Time-Delay Generator). F. D. Lewis and R. M. Frazier, "A New and Better Variable Delay Line," *General Radio Experimenter*, 31, 7, October, 1956.

be measured and subtracted from the delay readings.

The delay line connection shown in Figure 2, in which the 0 to 1- $\mu$ sec line is connected directly from the input terminal to the line output terminal, is also useful in many ways. In this case, the line will pass whatever waveform is available at the input terminals. This will, of course, make the input impedance of the instrument equal to the impedance of the line at about the 250-ohm level. Although the simplified switching of Figure 2 does not so indicate, the electronic portions of the TYPE 1392 are still operative. One use for the delay line in this connection is to permit a check on the delay generated in the input circuits. This delay is nominally about 0.12  $\mu$ sec between a fast driving pulse and a direct sync pulse.

### THE DELAY NO. 1 AMPLITUDE COMPARATOR

The amplitude comparator used in the Delay No. 1 circuit is new<sup>5</sup> and certainly useful elsewhere, so it will be described in some detail. This circuit was designed primarily for operation at repetition rates higher than those at which the comparator described by Holtje<sup>2</sup> will operate and for as great a dynamic range.

In the TYPE 1392-A, the amplitude comparator will operate at rates as high as 300 kc and over a range from 0 to 120 volts. It has the additional advantage of a very high input impedance at both signal and reference terminals. The complete circuit is shown in Figure 8. It is convenient to view the circuit as a bistable multivibrator (V-1), in which a differential amplifier (V-2) replaces the usual shunt-arm resistors of the cross-coupling network. Tube V-3 is a current source for V-2 and is only necessary

<sup>5</sup>Patent applied for.





when the maximum dynamic range at a given supply voltage is desired.

The circuit operates in the following manner: Suppose initially that the signal voltage is more negative than the reference voltage, then the current through the left-hand side of V-2 will be less than that in the right, and the grid voltage on V-1, left, will be more positive than V-1, right. V-1, left, will be on. This situation will persist until the reference and signal voltages are equal. At that point, the grid voltages of V-1 would be equal if it were not for the fact that V-1 is a bistable using  $R_{C1}$ - $R_{C2}$  and the plate resistance,  $R_p$ , of V-2 as cross-coupling resistors. Hence, at equal grid voltages on V-2, V-1 will remain stable as initially. Now, as the grid of V-2 is raised above the reference voltage, V-2, left, conducts more heavily and, by the differential connection of V-2, V-2, right, conducts less heavily. At low frequencies the gain to the bistable grids is<sup>6</sup>:

$$K = \frac{R_c}{r_{p2} + R_c}$$

and only a sufficient voltage needs to appear on the bistable grids to cause the bistable circuit to switch. The increase in grid voltage on V-1, right, reduces the amount by which this tube is below cut-off while the decreasing voltage on the left-hand grid of V-1 increases its plate voltage by the gain of this side of the flip-flop tube. It is therefore the left-hand side of the bistable going off which primarily contributes to the switching action.

The hysteresis which the circuit exhibits at the grid of the differential section is controlled by the magnitude of the excess grid voltage of the off flip-flop tube. This quantity is determined by

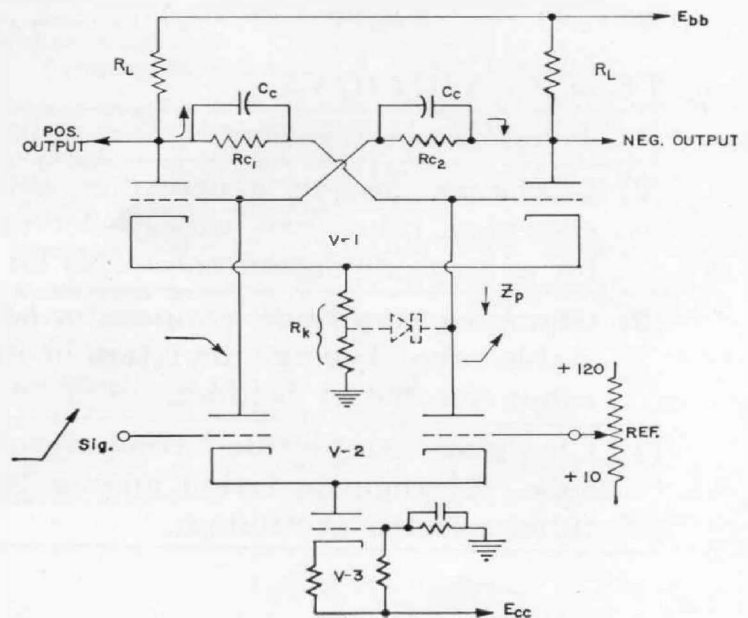
<sup>6</sup>Valley and Wallman, "Vacuum-Tube Amplifiers," Radiation Laboratory Series, Number 18, McGraw-Hill Book Co., 1948.

the current in the differential amplifier and, since this current is set by V-3, a well-stabilized stage, only very small excess voltages need be tolerated. Typical values of hysteresis for the circuit shown in Figure 8 are 10 to 100 mv.

An additional advantage of this circuit over a single-ended design is apparent at this point. The circuit is balanced with respect to changes in plate current caused by heater voltage fluctuations. Drift of the trigger voltage with line-voltage changes is reduced by about an order of magnitude over more conventional single-ended designs.

The action of the circuit at high frequencies is more complex than that described above. Space will not permit a detailed analysis here, but the limits on performance are clear. The cross-coupling capacitors will cause the loading of the differential amplifier to increase until, at very high frequencies, the load will be the plate load resistors,  $R_L$ , and the stray capacitances. Comparators for the megacycle range must be built with a differential amplifier capable of attaining high  $g_m$  and will, of course, have lessened sensitivity.

Figure 8. Functional schematic diagram of the amplitude comparator.



For high-frequency operation, overshoots of the grid waveform due to the flip-flop switching action should be eliminated both by reduction of the cross-coupling capacitors and by the application of positive and negative grid clamps. In the unit designed for the TYPE 1392-A, the flip-flop does not draw grid current, so only a negative clamp is used and, since the input waveform is unidirectional, only one clamp is necessary to improve recovery time.

Some characteristics of the comparator used in the Time-Delay Generator are shown in Table I. The hysteresis of this unit is of the order of 0.1 volt. The differential amplifier is heated with regulated dc both to minimize drift with changing line voltage and to reduce the hum-jitter in the delayed signal. The presence of the dc reduces the effects of 20% of variation in line voltage to an error in delay of 1 part in 10,000 and aids in attaining the specified jitter figure of 1 part in 30,000 at the worst. (Jitters lower than 1 part in 100,000 have been observed.) On the 1 to 11 msec range, the TYPE 1392-A has exhibited an absolute accuracy of delay of better than 0.1% over periods in excess of a week in continuous operation.

**APPLICATIONS**

The TYPE 1392-A can be applied anywhere that accurate delays are desired, either for the precise measurement of delay or for its generation. Its range of available delay plus the fact that it can be triggered by almost any sort of signal should make it an acceptable range calibrator for radar, sonar, and radio navigation systems. The ease with which the time of occurrence of the Delay No. 1 sync can be modulated renders it an ideal device for the simulation of a "noisy" target. The longer ranges of delay and the presence of the second delay with its associated gate signal should make the TYPE 1392-A a very useful tool for physiological nerve-transmission studies.

The use of the coincidence circuitry has been described in detail in connection with the processing of coherent signals. This system has another entire field of application in processing signals which are not coherent. Counting, time-vernier measurements, and the production of partial coherence between otherwise incoherent signals are examples of these applications. In the latter application, for example, coherent tone bursts in the megacycle range have been timed

**TABLE I**

| <i>TEST CONDITIONS</i>  | <i>ERROR AT 5 msec DELAY</i> |
|---|------------------------------|
| (1) Temperature transient.  | .005%/° C.                   |
| (2) Changing sweep generating and clamping tube, two tubes selected for average deviation among 25 lot. | 0.15% (worst tube .45%)      |
| (3) Changing amplitude comparator bistable tube. Average deviation in 10 tubes selected at random.      | .24% (worst tube 0.3%)       |
| (4) Changing amplitude comparator tube. Average deviation among 10 tubes selected at random.            | .47% (worst tube 0.9%)       |



by feeding the high frequency desired within the burst to the coincidence drive terminals and the burst recurrence rate signal to the PRF drive terminals. Specific uses are:

1. Calibration and precision sweep delay for oscilloscopes.
2. Radar target simulator.
3. Sonar target simulator.
4. Loran received pulse simulator.
5. Geophysical echo simulator.
6. Precision pulse timer — used with GR TYPE 1219-A Pulse Amplifier.
7. Delay and gate simulator for use with electronic computing systems — used with Tektronix 180-A Time-Mark

Generator to produce jitter-free pulses of crystal-controlled accuracy for any of above applications.

**ACKNOWLEDGMENT**

The development of this instrument resulted from the collaboration of many people. The author wishes to acknowledge specifically the aid of M. C. Holtje, on general design and power supply problems; of Carl Alsen, in finish model testing; of H. C. Sterling, in mechanical design; of H. T. Anderson, Production Engineer; and of William Pote, Laboratory Test Engineer.

— R. W. FRANK

**SPECIFICATIONS**

**INPUT SYSTEM**

**Input Signal:**  
 Sine Wave, 0.1 volt rms.  
 Square Wave, 0.3 volt, peak-to-peak.  
 Pulse (negative or positive), 1 volt peak.  
 Ac or dc, input trigger threshold control provided.

**Frequency:** dc to over 300 kc.

**Time Delay (Input to direct sync):** 0.12 ±0.02 μsec.

**Direct Sync Pulse:**  
 Amplitude, 15 volts or more, positive or negative.  
 Duration, 0.13 ± .02 μsec.  
 Impedance, 93 ohms or less.

**DELAY NO. 1**

**Delay Range:** 0-1.1 sec in seven ranges.

**Accuracy:** 1 μsec-1.1 sec range, ±1% of dial reading; 0-1 μsec range, ±0.01 μsec.

**Stability:** Jitter, 1:30,000 at worst  
 Drift, 1:10,000 with 20% line variations

**Resolution:** 0-1 μsec, 0.004 μsec  
 1 μsec, 1 sec 1:8800

**Duty Ratio Effects:** Less than dial accuracy to 60%  
 5% at duty ratio of 80%

**Delay One Sync:**  
 Duration, 0.1 ±0.2 μsec  
 Amplitude, 25 volts or more, positive or negative  
 Impedance, 93-ohm output impedance  
 Monitor Lamp  
 Max. PRF, 0-1 μsec range, 300 kc;  
 1 μsec-1.1 sec range, 250 kc (at 1 μsec).

**DELAY NO. 2 OR COINCIDENCE CIRCUIT**

**Range:** 0.5 μsec to 0.5 sec (six decade ranges).

**Accuracy:** ±3% of dial reading.

**Stability:** Jitter, 1:20,000  
 Line Drift, 1:5000 for 20% line change

**Resolution:** 1:2,000

**Delay Two Sync:**  
 0.13 μsec ±0.02 μsec  
 20 volts or more, positive or negative  
 93 ohms  
 Monitor Lamp

**Duty Ratio Effects:** Full scale, less than dial accuracy at 60% duty ratio; bottom of scale, less than dial accuracy at 20% duty ratio. Maximum PRF, 300 kc.

**Coincidence:**  
 Input, positive or negative pulse, 5 volts or over  
 Input frequency, 1 cps to 1.7 Mc (for single pulse selection)  
 Input pulse rise time, .1 μsec or less at 5v.

**Power Supply:** 105 to 125 (or 210 to 250) volts, 50-60 cycles, 180 watts at 115 volts. Power receptacle will accept either 2-wire (Type CAP-35) or 3-wire (Type CAP-15) Power Cord. Two-wire cord supplied.

**Dimensions:** 9 x 19 x 12 inches (rack mount).

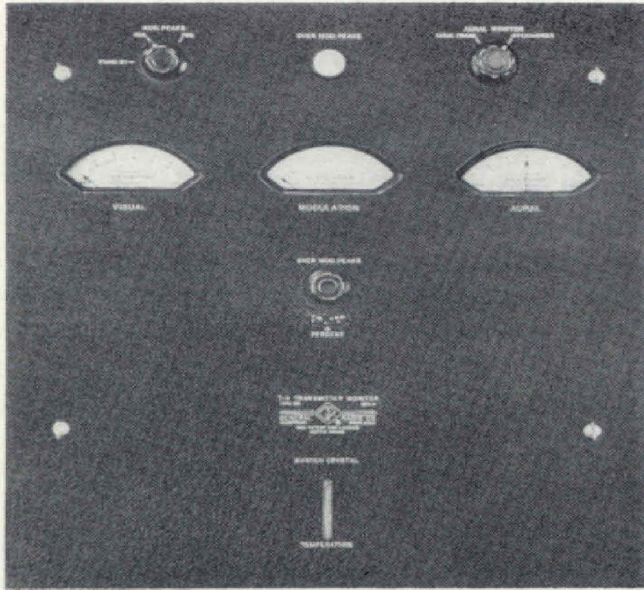
**Accessories Supplied:** Type CAP-35 Power Cord; spare fuses; test lead; 4 Type 874-C58 Cable Connectors.

**Net Weight:** 35 pounds.

| Type    |                       | Code Word | Price    |
|---------|-----------------------|-----------|----------|
| 1392-AM | Bench Model.....      | ENTRY     | \$985.00 |
| 1392-AR | Relay-Rack Model..... | EXTOL     | 985.00   |

U. S. Patent No. 2,548,457.

## 2-WEEK DELIVERY ON ALL GENERAL RADIO MONITORS FCC Type Approved



The Type 1184-A Television Station Monitor.

With the continuing trend to higher technical standards in broadcasting, a monitor that barely meets *today's* requirements is likely to become obsolete too soon to give good value. General Radio Monitors are designed *beyond* mere legal minimum requirements for

today's use. Thus protected against early obsolescence, these new instruments promise *long-term* value that far outweighs initial cost consideration.

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General Radio Monitors express a wholly new concept in mechanical design that gives convenience never before attained in an instrument of this type. Every operation in the installation, use, and maintenance of these new monitors can be handled from the front. You never need to go behind the instrument rack. The monitor slides out and tilts forward and back for easy access to tubes and adjustments. Chassis pin jacks permit a rapid check of current and voltage at critical points in the circuit. The unique chassis marking is so comprehensive that most maintenance can be performed without need for an instruction book or a circuit diagram.

| Type     |  | FCC Type Approval Number | Code Word | Price     |
|----------|--|--------------------------|-----------|-----------|
| 1184-A-A | Television Transmitter Monitor — Channels 2-13.....  | 3-105                    | GIANT     | \$3200.00 |
| 1184-A-A | Television Transmitter Monitor — Channels 14-83..... | 3-105                    | GIANT     | 3450.00   |
| 1181-BT  | TV Color-Subcarrier Monitor.....                     | not required             | MAJOR     | 1025.00   |
| 1181-B   | AM Frequency Deviation Monitor.....                  | 3-106                    | MALAY     | 1025.00   |
| 1931-B   | Amplitude-Modulation Monitor.....                    | 3-107                    | TARRY     | 625.00    |

### CHOICE OF PANEL FINISH

General Radio Black Crackle is standard. Other standard finishes to match transmitter equipment can also be supplied.



**General Radio Company**