GENERAL RADIO COMPANY

engineering department

REPRINT A-94 NOVEMBER, 1961

Precise Delay Measurement

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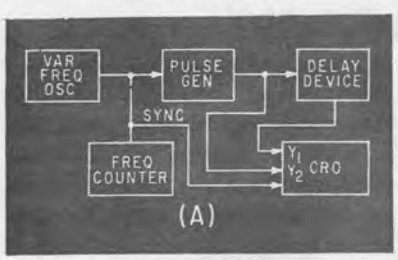
Reprinted from ELECTRONICS — January 13, 1961

PRECISE MEASUREMENT of delay time has become a subject of increasing interest in the design of modern electronic equipment. This article describes a technique that permits the measurement of repetitive delays with durations ranging from less than 0.1 microsecond to more than 1 millisecond, with a precision of a fraction of a nanosecond.

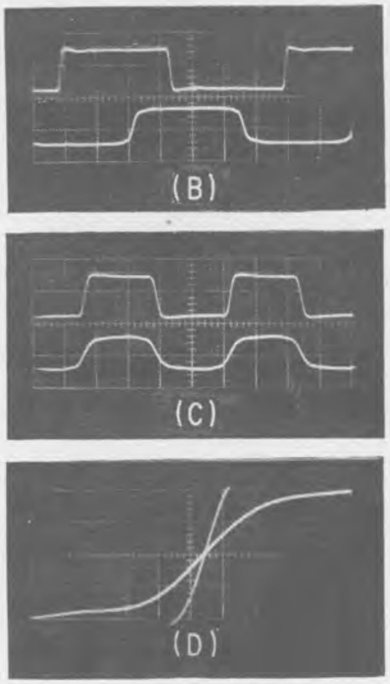
A block diagram of the measuring system (A) includes a variable-frequency synchronizing oscillator, pulse generator, delay device under test, cathode-ray oscilloscope and frequency counter to monitor the repetition rate of the oscillator and pulse generator. The output of the pulse generator, either a brief pulse or a sharp voltage step, enters the delay device. Both input and output voltages of the device are observed simultaneously on the oscilloscope. The repetition rate of the oscillator is adjusted until the output pulse of the delay device coincides in time with the next input pulse. At this point the delay time of the device is equal to the time interval between input pulses, that is, the oscillation period of the oscillator. Thus if the pulse repetition rate is such that a pulse emerges from the device just as a new pulse enters, the delay time of the device is equal to the interval between pulses. The frequency of the oscillator is measured by the frequency counter, and the time delay is calculated from $t = 1/f$.

Block diagram of delay measurement system (A).



A precise measurement requires an equally precise definition. Where brief pulses are of importance, one useful convention defines delay time as the interval between the peak amplitudes of the input and output pulses. Where voltage steps are of interest, delay time is often defined as the interval between the 50-percent amplitude points of the input and output voltage steps.

The waveforms shown were observed during the measurement of the voltage step delay of a developmental 0.45-μsec delay line. The input and output voltages of the delay line are shown in (B). In (C) the repetition rate has been adjusted for approximate coincidence of input and output voltages. In (D) the maximum oscilloscope sweep rate was used and the repetition rate adjusted for the closest observable coincidence of the half amplitude points. The oscilloscope was a Tektronix 543, with the sweep rate control at 0.1 μsec per cm and the sweep rate magnifier at 10, uncalibrated. These settings produced an observed sweep rate of about 14 nsec per cm. However, the actual sweep rate is unimportant, since the oscilloscope is used only as a coincidence indicator. Measurements of the oscillator frequency indicate a delay of 0.4380 μsec with a measurement reproducibility of 0.4 nsec.



Waveforms show input and output voltage steps of delay line, at a low repetition rate (B), approximate coincidence (C), and exact coincidence (D), with horizontal scales of 0.2, 0.1, and 0.014 μsec per cm, respectively.

The method is obviously limited to the measurement of those delay devices having zero recovery time. That is, the device under test must be able to accept an input pulse while producing an output pulse. Delay devices with finite recovery times can be connected in cascade so that the overall combination has zero recovery time while each device has the delay time of the rest of the combination in which to recover.

The measurement precision is restricted by the precision with which coincidence of input and output signals can be determined. This is restricted by the maximum sweep rate and bandwidth of the oscilloscope and the amplitude and transition times of the signals. In the measurement examples, a dual trace oscilloscope was used. The differential delay between the two traces must be determined—for example, by observation of the same signal on both traces. Both signals can be observed on the same trace by a signal-adding network. Determination of coincidence also depends on the jitter or frequency instability of the oscillator and pulse generator and on the jitter of the oscilloscope sweep. Finally, the precision of measurement is limited by the stability of the oscillator during the interval of measurement and by the precision with which the frequency of the oscillator can be measured. With modern techniques of frequency measurement the latter is seldom a limitation—except possibly in the measurement of long delays.

The method has been used to determine the temperature coefficient of delay networks and to test delay devices.

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Printed in U.S.A.