NASA TECH BRIEF

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Reduction of Quantization Error in Measurement of Frequency

The problem:

In modern electronic systems, such as radars, collision avoidance, altimeters, and navigation systems, frequencies are measured by counting the integral number of periods per time interval. However, there is always a quantization error involved in counting because a fraction of a period must be missed. Several techniques have been tried to reduce this error, for example:

(a) averaging of the quantization error over a longer time interval,

(b) use of high-frequency oscillators to increase resolution, and

(c) multiplication of the frequency by some constant.

However, these techniques may extend processing time, not provide sufficient error reduction, and may require high-speed counters. Sometimes these techniques may become another source of error.

The solution:

A more precise method reduces quantization errors, using a new digital circuit. The circuit provides a very high resolution (10^{-2} to 10^{-3} Hz) without high-speed counters. It lends itself to microminiaturization and is simple to construct.

How it's done:

Basically, the unknown frequency is compared to a standard frequency by means of a zero-crossing coincidence-detecting circuit. The process is an electronic

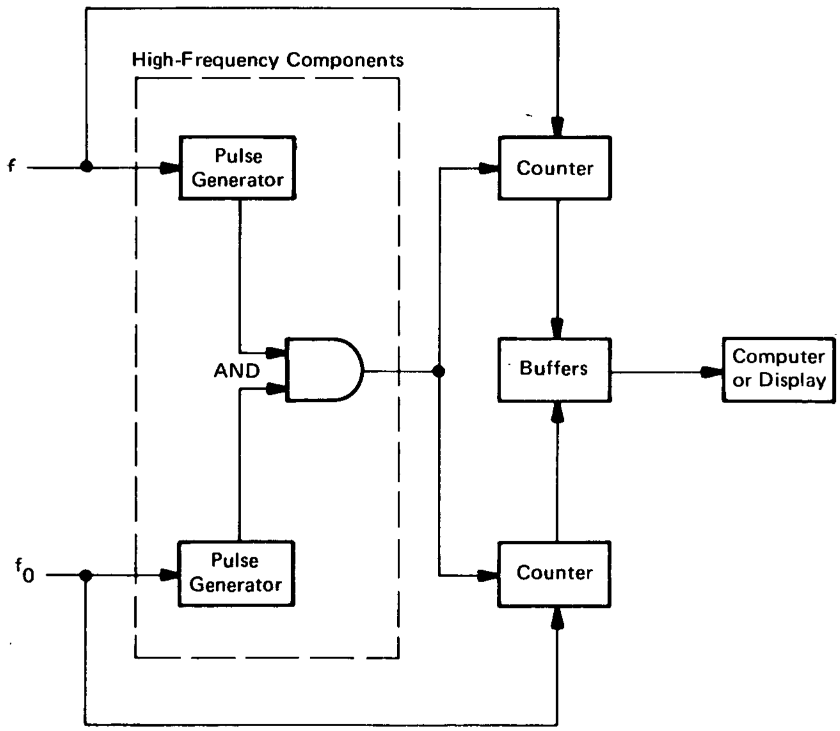

Figure 1. Coincidence Detector and Frequency-Counting Circuit

(continued overleaf)

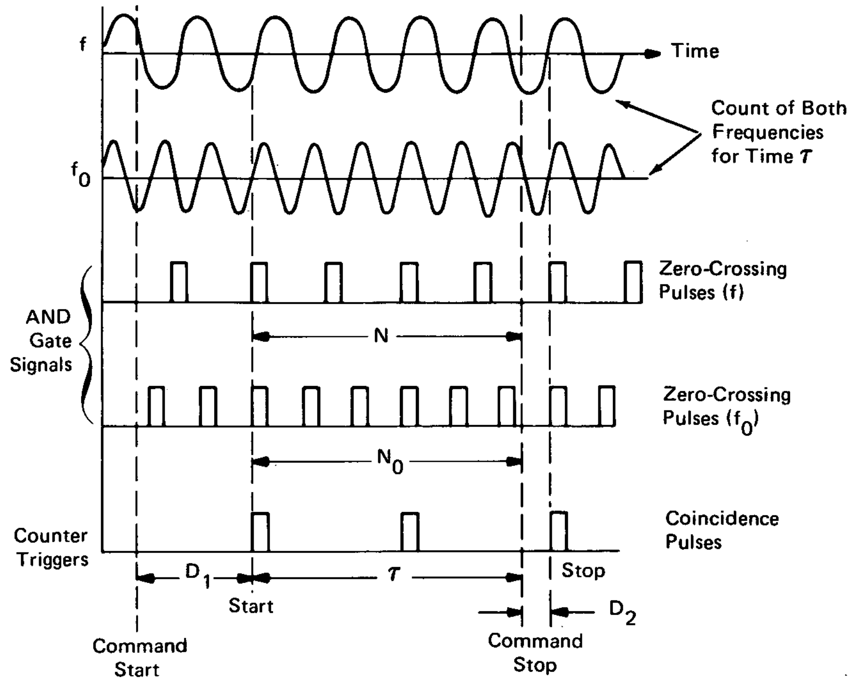

Figure 2. Timing Scheme

equivalent to that of the mechanical vernier caliper. In the vernier caliper, the measurement precision is expanded by reading the coincidence of the scale markings of two nearly equal scales. The digital method uses an analogous approach. It employs zero crossing of a known stable frequency and the unknown frequency as the "scale markings," and a coincidence-detector circuit to determine where a zero-crossing coincidence has occurred between the two frequencies.

In the circuit shown in Figure 1 an unknown frequency f and reference frequency f_0 each feed into two paths, counters and pulse generators. The counters are actuated for the time interval determined by the coincidence detector, and the pulse generators convert the signals to a train of narrow pulses (1 to 100 nanoseconds is typical) every period at the zero crossing (see Figure 2). The pulses are fed to an AND gate which generates a pulse whenever the two input pulses coincide. As an optional feature buffers are employed to store the counts for periodic sampling by a computer or to drive a display.

The output pulse from the AND gate is used as a trigger to start and stop the counters. The time between the start and stop is the time interval over which the frequency is measured. This interval is obtained from the count in the reference-frequency counter, i.e.,

$$\tau = N_0/f_0$$

where N_0 is the count of reference frequency f_0. The unknown frequency f is derived from its measured frequency counter N and the previously measured line interval τ as follows:

$$f = \frac{N}{\tau} = \frac{N}{N_0} f_0$$

Note:

Requests for further information may be directed to:

Technology Utilization Officer
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Reference: TSP74-10191

Patent status:

This invention is owned by NASA and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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