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TITLE

ANALOG CIRCUIT FOR DETERMINING THE RATIO AND PRODUCT OF TWO TIME FUNCTIONS*

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ABSTRACT

The circuit utilizes the phase properties of a two-element RC bridge in which the "C" is an abrupt-junction varactor. Applications described: 1) universal automatic noise-figure meter; 2) ratiometer, both of which are stable and accurate.

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SUMMARY

Alignment of broadband systems for best noise figure has been a major problem for some time, particularly, in the field of radiometry wherein receiver bandwidths in excess of several Gc/sec are not uncommon and system performance is strongly dependent upon system noise figure. Although the circuitry described in this paper was developed specifically to fill this need, it has much wider application.

The basic circuit is an analog ratiometer with several unique and unusual features. Two low-level, opposite-phase, fixed-frequency sinusoids with amplitudes A and B are compared without amplification in a simple RC bridge circuit. This arrangement is such that the phase of the output is related to the ratio $\frac{A}{B}$ of the inputs. The output and one of the inputs are amplified, limited, and compared on a phase detector to obtain an error signal that is used to adjust the bias on an abrupt-junction varactor in the bridge. In this way, a nearly constant phase relationship is maintained between the bridge output and the bridge inputs over the range of control provided by the varactor.

Two significant relationships result. First, the bias voltage on the varactor is linearly related to the ratio of the inputs, that is,

$$V = k_1 \frac{A}{B} + k_2; \qquad (1)$$

second, the amplitude of the bridge output is equal to the geometric mean of the amplitudes of the two bridge inputs.

Since no preamplification of the input signals is required, the circuit is inherently stable and accurate. Although the circuit is complicated, it is far less so than some existing ratiometers. [redacted]

As a ratiometer the range of input ratios that can be measured depends upon the breakdown voltage and the contact potential of the varactor, and is given approximately by

$$\frac{A}{B}\bigg]_{max} = \frac{V_B + \phi}{\phi} \qquad (2)$$

It is not difficult to design a circuit of this sort that will operate over a decade. For a constant ratio, the input dynamic range is typically 60 db.

This circuit was used to construct an automatic noise-figure meter that can be used with any receiver or amplifier, regardless of frequency or bandwidth. It requires a minimum DC input signal level of 10 millivolts across 220 K, has a 60-db input dynamic range, and is accurate within 0.2 db over a 10-db range of noise figure. The noise-figure range is set from 4 db below to 10 db above the excess noise temperature ratio of the noise source that is used.

A further application: with the addition of a chopper, two filters and a square-law detector, an instrument can be built which will continuously and simultaneously extract both the ratio and the product of two continuously varying DC inputs. This application is illustrated in Figure 1.

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FIGURE 1

Operational block diagram illustrating multiplication and division of two slowly varying DC voltages.

FIGURE 2

Front panel of universal automatic noise figure meter. Note scale calibration.