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NASA TECH BRIEF

Improved Circuit for Measuring Capacitive and Inductive Reactances

The problem:

To devise a circuit for measuring very small changes of capacitive or inductive reactance, such as produced by a variable capacitance or a variable inductance displacement transducer. The circuit was specifically required to operate as the amplifying system for a displacement measuring seismograph which must be insensitive to changes in source impedance (a problem associated with dc seismograph amplifiers), or to Lenz Law effects exhibited by moving-coil seismographs. The output signal of the circuit should be of sufficient amplitude for use in telemetry or as an input to other circuits.

The solution:

An amplifier circuit employing reactance-sensing oscillators in which field effect transistors serve as the active elements.

How it's done:

The amplifier consists of four sections: (1) reactance-sensing oscillators, (2) a frequency doubler, (3) a sine-wave to square-wave converter, and (4) a phase detector.

The reactance-sensing oscillators are two synchronized Hartley-type oscillators using field effect transistors as the active elements. These oscillators shift phase with respect to each other whenever there is a small change in the reactance of their tuned circuits. Two ganged potentiometers adjust the amplitude of the synchronizing voltage between the two oscillators, and therefore adjust the sensitivity of the oscillators to reactance changes. The synchronizing voltage is taken from the untuned secondary of a feedback transformer to minimize unbalancing effects which are otherwise associated with each different gain setting of the sensitivity control.

The frequency doubling section serves two purposes. First, it gives a gain of two, since the phase shift of the second harmonic is exactly twice that of the fundamental. Secondly, it provides a convenient point in the circuit to introduce the 90° phase shift required by the phase detector. The phase of each doubler is adjusted 45° from that of its fundamental. The doubler in one channel is adjusted to lead its fundamental by 45°, and the other is adjusted to lag the fundamental by 45°. When both fundamentals are in phase, the second harmonics are 90° apart. This frequency doubling helps to overcome another serious limitation inherent in this circuit. By frequency doubling, the operational range (normally being ±90° from zero phase) in the fundamental is extended, because there is no danger of coming too close to the end points where oscillator synchronism is broken. The frequency doubler consists of a single rf-tuned transformer in the drain lead of each oscillator. This transformer also provides impedance matching between the oscillators and the squaring circuit.

The squaring circuit consists of two current-mode switching transistors which are biased at their switching point. A positive input will switch them on, and a negative input will switch them off. The output of the squarer is two constant-amplitude square waves whose phase is determined by the phase of the doubled fundamental of the sensing oscillators. The two square waves are then applied to the phase detector.

The phase detector has two distinct sections: (1) a pulse-duration generator and (2) an integrator. The pulse-duration generator is a *nand* gate. The two square waves from the squaring circuit are applied to the *nand* gate and produce a positive output whenever both square waves are negative. Since the doubling section provides a 90° phase shift, the output

(continued overleaf)

pulse from the *nand* gate will be positive for 90° and off for 270°, whenever the fundamentals of the oscillators are in phase with each other. This output pulse duration is unique so long as the fundamental signals are not over ±45° of each other, i.e., ±90° of the applied signal. The variable-duration, constant-amplitude pulse is then applied to an operational amplifier-type of integrator. The output of the integrator is a dc voltage whose amplitude is determined by the duration of the input pulse applied to it. Since the duration of the input pulse is directly related to the phase of the fundamental signals of the oscillators, which are, in turn, determined by the reactance of the transducer used, the output of the integrator is a faithful reproduction of the position of the transducer.

Notes:

1. This circuit should have application wherever accurate measurements of small displacements must be made with transducers of the variable capacitance or variable inductance type.
2. Inquiries concerning this circuit may be directed to:

   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama 35812
   Reference: B67-10513

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: I. Dalins
of Marshall Space Flight Center
and V. McCarty
of University of Alabama
Research Institute
under contract to
Marshall Space Flight Center

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