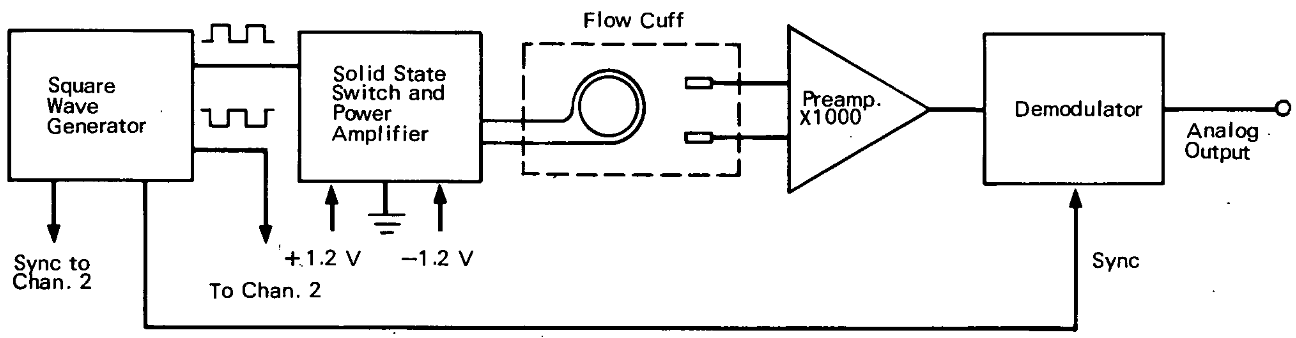
NASA TECH BRIEF
Ames Research Center

Miniature Battery-Operated Electromagnetic System for Blood Flow Measurements

The problem:

To provide more satisfactory equipment for blood flow measurements in cardiovascular studies, especially of unrestrained animals in a remote environment. Existing equipment is bulky, usually requires a 110 V power line with the attendant hazards and physical limitations, and cannot be readily modified for battery operation.



The solution:

A miniature, two-channel instrumentation system consisting of a solid-state electronics package and a pair of standard, commercially available flow-transducer cuffs. Two 1.2 V, penlight size, nickel-cadmium rechargeable batteries are used for field current; mercury cells provide power for signal conditioning.

How it's done:

Square wave current is used to excite the magnetic coil in the cuff, permitting a more accurate determination of zero flow than do other forms of excitation. The current is supplied to the cuff field coil so that a suitable magnetic field is generated across the blood vessel. The circuit amplifies and demodulates the low-level signal derived from the pickup electrodes in the cuff, providing an analog voltage proportional to the flow of blood.

A single channel of the intrumentation system is shown in the diagram. The second channel is similar to the first, but the two are operated 180° out of phase in order to keep the battery loading uniform and to reduce transients. A square-wave excitation current of 0.3 to 0.5 A is imposed on the field coil of the cuff. (This is considerably smaller than the 1.0 to 1.25 A previously employed.) The excitation current is drawn from a dual 1.2 V battery supply and is controlled by a low-resistance, solid state switch and power amplifier. The switching mode is completely on or off, and a constant voltage supply is used in place of a constant-current source to minimize power losses. Efficiencies on the order of 90% are obtained.

The amplified signal and its carrier are fed to the demodulator. Sync signals from the oscillator are used to gate on and off two sample-and-hold circuits, which are arranged to sample the last half

(continued overleaf)

of each positive and negative swing of the signal. By rejecting the first half of each swing, charge and discharge transients due to the inductance of the field coil are avoided, and stable zeroes are obtained. The output voltages from the two 180°-phased, sample-and-hold circuits are then differentially amplified by a conventional operational amplifier.

The square wave for the switch control is provided by a generator which consists of an astable multivibrator, typically operating at 600 Hz, coupled to a bistable multivibrator. Since a frequency division of two occurs, the output is about 300 Hz. This combination of circuitry achieves symmetry in the waveform without critical component adjustments and provides the quadrature gating signal required by the demodulator.

An air-core flow-transducer cuff was employed, in preference to the iron-core type, because switching transients are more rapidly quenched. The two platinum electrodes which sense the flow of blood present an impedance of 500 Ω or less to the amplifier, and typical maximum signal levels from the electrodes are 25 to 35 μV. A high input impedance low-noise preamplifier, with characteristics similar to those used for EKG or EEG signal amplification, is required. The preamplifier designed for this system has a 20 MΩ input impedance, a gain of 1000, and less than 1μV rms equivalent input of wideband noise for a 500 Ω source impedance. Capacitive coupling is used at the input and between the first and second stages to eliminate electrode polarization potentials. Component values are selected to allow the low-frequency response to extend to 1 Hz or less, thereby giving accurate amplification of the 300 Hz carrier.

The operating system has shown good zero stability and calibrations, and low noise levels. Physiological problems associated with tissue heating from electrical components and the transducer cuff are negligible because of operation at low power levels, and operational advantages have been obtained by the elimination of the warm-up period usually required for flowmeter devices of this kind.

Notes:

1. When low-power operation is not important for the experiment, the signal-to-noise ratio can be improved by adding batteries to increase the field current. The ±1.2 V can be increased to ±2.4 V or possibly ±3.6 V. The output can be readily applied to radio telemetry systems.
2. At a typical field current of 0.35 to 0.4 A, the two-channel system has operated continuously for 1 hour. Package size is approximately 10 $in.^3$, including batteries. For longer operating life, a 3 $in.^3$ rechargeable battery provides 10 hour operation.
3. Requests for further information may be directed to:

    Technology Utilization Officer
    Ames Research Center
    Moffett Field, California 94035
    Reference: TSP71-10477

Patent status:

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