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Nine Axis Accelerometer Telemetry System

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We have undertaken the task of telemetrically monitoring the accelerations along six degrees of freedom of a human head (three orthogonal linear and three orthogonal angular) under impact conditions. The total instrument: accelerometers, signal conditioners, telemetry transmitter, and power supply to be built into a boxer's mouthpiece. A contract for us to build one prototype and two additional systems is sponsored by the U. S. Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts. A demonstration of the electronic telemetric system is scheduled for April 20th, a prototype by June 30th, and two additional systems by the Fall of 1976..

The mouthpiece will contain nine single-axis accelerometers, three orthogonal sensors at a central reference point, and three additional orthogonally sensitive pairs of sensors, each pair positioned outboard of the central reference point along each of the three orthogonal axes. The decision to use nine accelerometers instead of six is to achieve greater overall accuracy, and is based upon the work of Dr. King, previously reported. The mouthpiece will also contain a power supply (batteries plus electronic regulation), a ten channel telemetry system, and a telemetry transmitter.

The individual accelerometers are designed to have a full scale range of $\pm$ 150 g's, although a lower range can be selected. The accelerometers are in principle, simple cantilever beams with a Full Scale output of 10 mV, a

resonant frequency greater than 4 KHz, and a damping ratio of between 0.3 and 0.5. Flat frequency response is designed to be greater than 1 KHz.

The mouthpiece electronics are based on a biomedical telemetry system developed by us for NASA-Ames , which uses an analog to Pulse Width Modulated (PWM) system to encode the parallel data channels to a serial data train. Frequency response is from 0.1 to 500 Hz, ±3dB, power is 9 mW, and 20 minute operation is specified, with a transmission range of 20 feet. System resolution is 0.1 %, sample rate is 1250 Hz/channel.

The transmitter has several interesting features. THe system is basically a ten-channel device, nine of the channels used for data transmission, and the tenth channel sub-commutated to provide system framing, zero reference, and mid-scale and full scale gain reference in both plus and minus signal polarity. In addition, all nine channels are fed through sample and hold electronic circuits so that the multiplexing sequence will not introduce phasing errors in the output.

The receiver is a modified Heathkit AJ 15, which has been successfully used for our other multichannel telemetry systems.

The demodulator for the telemetry system is of an all-new digital design, which interfaces with a built in microprocessor. Each channel has 10 bit resolution (i.e., 0.1 %). All nine linear inputs and the three computed (by the microprocessor) outputs are fed through a nine pole Butterworth filter to achieve the desired output. Output has two scales, ±1 or ±5V F.S., per 150 g's or 5,000 rad/sec.^{2}.

Nine Channel Accelerometer

The built-in microprocessor (using Intel 3000 series chips) has a 16 bit parallel pipeline configuration, 100nsec. cycle time, and will handle up to 4000 instruction executions per data sample set time. The unit is capable of a 16 bit addition in 0.2 μsec., and a 16 bit multiplication in 15 μsec., thus permitting real time data computation for the angular channel outputs.

The microprocessor is also programmed to make individual channel offset and gain corrections, and to combine channel data outputs to extract $\dot{\omega}$ from the signals from sets of linear accelerometers. Provisions for Read Only Memories (ROM's) are built in, so seperate ROM's for separately calibrated mouthpieces can be inserted into the demodulator as desired.