

commercial RF wafer probe station that has been modified to accommodate the rotating sampling antenna.

The sampling antenna (see Figure 2) is an open-ended rectangular waveguide that is spun by use of a small DC motor mounted on poly(methyl methacrylate) arm. The signal acquired by the sampling antenna is coupled

through a coaxial rotary joint to a detector that is also mounted on the arm. The arm, in turn, is attached to the shaft of a stepping motor, which is used to position the sampling antenna, in increments of a few degrees, along an arc that extends from  $-90^\circ$  to  $+90^\circ$  relative to the perpendicular to the plane of the wafer.

*This work was done by Rainee N. Simons of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland Ohio 44135. Refer to LEW-17462.*

## Low-Cutoff, High-Pass Digital Filtering of Neural Signals

Digital filtering overcomes the drawbacks of resistor-capacitor filtering.

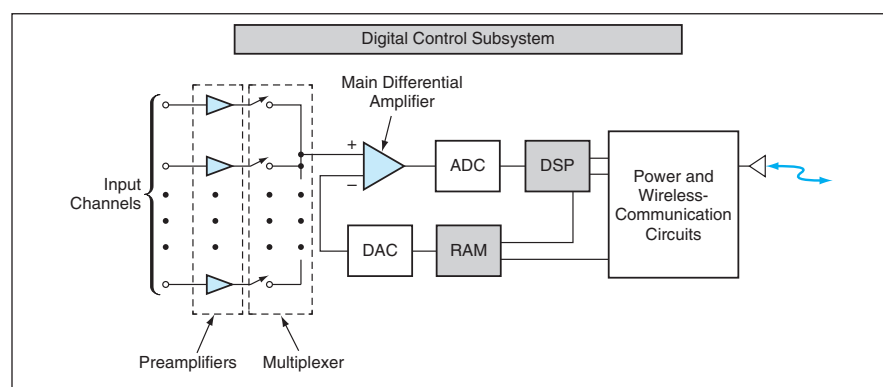
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The figure depicts the major functional blocks of a system, now undergoing development, for conditioning neural signals acquired by electrodes implanted in a brain. The overall functions to be performed by this system can be summarized as preamplification, multiplexing, digitization, and high-pass filtering.

Other systems under development for recording neural signals typically contain resistor-capacitor analog low-pass filters characterized by cutoff frequencies in the vicinity of 100 Hz. In the application for which this system is being developed, there is a requirement for a cutoff frequency of 5 Hz. Because the resistors needed to obtain such a low cutoff frequency would be impractically large, it was decided to perform low-pass filtering by use of digital rather than analog circuitry. In addition, it was decided to time-multiplex the digitized signals from the multiple input channels into a single stream of data in a single output channel.

The signal in each input channel is first processed by a preamplifier having a voltage gain of approximately 50. Embedded in each preamplifier is a low-pass anti-aliasing filter having a cutoff frequency of approximately 10 kHz. The anti-aliasing filters make it possible to couple the outputs of the preamplifiers to the input ports of a multiplexer. The output of the multiplexer is a single stream of time-multiplexed samples of analog signals. This stream is processed by a main differential amplifier, the output of which is sent to an analog-to-digital converter (ADC). The output of the ADC is sent to a digital signal processor (DSP).

One function of the DSP is to digitally extract the low-frequency component of the signal from each channel (the component that one seeks to filter out) and to store this component in a lookup table [more precisely, a random-access mem-



This **Signal-Conditioning System** is designed to be part of a system for monitoring neural electrical signals. This system implements a low-pass filter having a cutoff frequency of 5 Hz by digital means.

ory (RAM) configured to implement the electronic equivalent of a lookup table]. Another function of the DSP is to assign a gain vector (also stored in the lookup table) for each preamplifier. The gain vector for the preamplifier is presented to the main differential amplifier in synchronism with the arrival of the signal from that preamplifier. This approach prevents the saturation of the main differential amplifier and causes the output signal from every input channel to have optimum strength. Other functions of the DSP include sorting of signal spikes, data compression, and preparation of data for wireless transmission to an external data processor.

The gain of the main differential amplifier is dynamically adjustable. Furthermore, its negative input terminal receives offset signals from the lookup table via a digital-to-analog converter (DAC) for the purpose of subtracting the unwanted low-frequency components of the input signals and thereby performing high-pass filtering. Initial gain and offset values for each channel are determined empirically and stored in the lookup table in a calibration pro-

cedure. During subsequent operation, the offset and gain uniformity of each channel are constantly monitored by use of the combination of the main differential amplifier, ADC, DSP, and lookup table, and the lookup table is periodically refreshed with updated values of the unwanted low-frequency signal components (offsets) and gains.

*This work was done by Mohammad Mojarradi, Travis Johnson, Monico Ortiz, Thomas Cunningham, and Richard Anderson of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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