

# TELEMETRIC SENSORS FOR THE SPACE LIFE SCIENCES

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## Abstract

Telemetric sensors for monitoring physiological changes in animal models in space are being developed by NASA's Sensors 2000! program. The sensors measure a variety of physiological measurands, including temperature, biopotentials, pressure, flow, acceleration, and chemical levels, and transmit these signals from the animals to a remote receiver via a wireless link. Thus physiologic information can be obtained continuously and automatically without animal handling, tethers, or percutaneous leads. We report here on NASA's development and testing of advanced wireless sensor systems for space life sciences research.

## Introduction

Monitoring and acquiring physiologic data from unrestrained space flight research subjects is currently intermittent, labor intensive, and heavily biased toward ground-based pre and post flight testing periods. Continuous signals are typically acquired with hardwired sensors and tethered animals<sup>1</sup>. Because future mission durations will be longer the ability to acquire physiologic data from untethered subjects, chronically and automatically during flights, is being requested by the space life sciences research community<sup>2</sup>. In addition, multiple channels, higher bandwidths, and chemical parameters are needed. To meet this need for advanced sensor systems for space life sciences research, NASA's Sensors 2000! program is developing wireless biotelemetry data acquisition systems<sup>3</sup>. We report here on the development of biocompatible sensors, implantable biotelemeters, and radio receivers.

## NASA's Sensors 2000! Program

Sensors 2000! (S2K!) is a NASA Ames Research Center engineering initiative designed to provide biosensor and bioinstrumentation systems expertise to NASA's life sciences space flight programs. The programs include both international and multidisciplinary missions and payloads, including collaborative unmanned flights (Bion-10 & 11) Space Shuttle flights (Neurolab), and future Space Station flights. S2K! covers the full spectrum of sensor technology applications, ranging from space flight hardware design and

fabrication to advanced technology development, transfer and commercialization. Biotelemetry systems and components currently under development by S2K! and its university and industry collaborators include an *in vivo* pH sensor, a 4 channel, implantable biotelemeter and portable receiver, a DSP-based signal decoder, and a multichannel, microcontroller-based PCM system.

## Telemetric Sensors and Systems

### pH Sensor

The pH sensor is based on a polymeric H<sup>+</sup>-sensitive neutral carrier membrane cast around the tip of a microbore PVC catheter. It consists of two single lumen catheters (physically combined or separated); one lumen each for the reference and pH electrodes (Fig. 1). The membrane composition is high molecular weight poly (vinyl chloride), bis (2-ethyl hexyl) adipate, and potassium tetrakis (4-chlorophenyl) borate. Tri-n-dodecylamine is used as the H<sup>+</sup> ionophore.

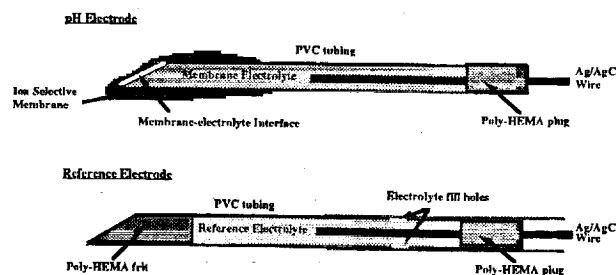


Figure 1: Diagram of the pH and reference electrodes

Our microbore pH sensors exhibit response characteristics similar to larger, commercially available pH electrodes. Baseline drift is on the order of 2-4 mV (.03-.07 pH units) every 24 hours. Sensor sensitivity is in the expected range of 57-60 mV/pH unit at room temperatures (Theoretical = 59 mV/pH @ 25°C), and sensitivity loss is only 1-2% over a 12 day period. For the particular ionophore used, response linearity breaks down around pH 5. However, for our applications, the range of interest (6.8-8.0) falls within the linear range of the sensor. Response

times are rapid with roughly 95% of the response achieved within less than 3 seconds. These response characteristics are not notably changed following subcutaneous implantation in rats for up to 12 days.

### Biotelemetry & Receiver

A totally implantable, digitally encoded biotelemetry for measurement of pH, temperature, and heart rate has been designed, prototyped, and successfully bench tested in conjunction with our microbore pH electrode. The circuit (Fig. 2) employs a low power A/D converter, a digital-encoding IC (Manchester), and transmits a pulse modulated 455 kHz carrier. It dissipates less than 420  $\mu$ W. The device has been miniaturized in thick film hybrid form and will be packaged with a 3/4 Amp-hour battery inside a biocompatible ceramic enclosure. A portable receiver acquires and demodulates the RF carrier, demultiplexes and decodes the 3 data channels, and presents the output to liquid crystal displays (LCD) on the front of the receiver chassis. A prototype receiver has been successfully tested with implants in sheep.

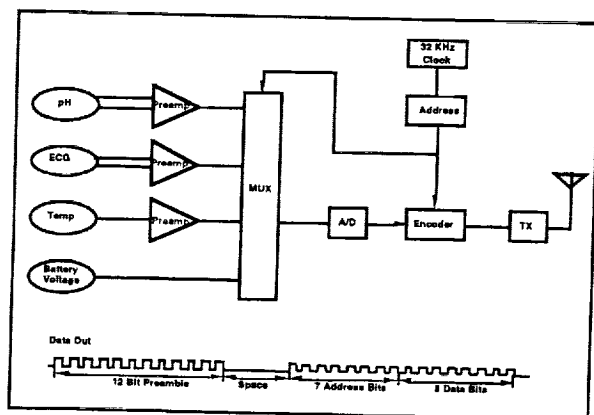


Figure 2: Block diagram of the digitally encoded biotelemetry and sample data packet

### DSP Decoder

We are evaluating the ability of a Digital Signal Processing chip (Texas Instruments TMS320C5X) to decode and display physiologic signals from a variety of commercial and S2K1 biotelemetrys. Commercially available biotelemetrys encode physiologic information using pulse position modulation schemes. The DSP chip is programmed to measure time intervals between pulses and display the decoded physiologic signals on a flat panel LCD screen. The chip can also decode the pulse code modulation (PCM) encoding schemes used with the S2K1 biotelemetrys. The inclusion of a DSP device in a receiver provides signal processing capability to filter, decimate, interpolate, amplify, and attenuate signals, or process them to compute diagnostically useful information such as heart rate from an ECG signal. This technology will be incorporated into our receiver subsystems in order to make them physically smaller, more flexible and adaptable, and consume less space and power.

### Microcontroller-based Biotelemetry System

A micropower controller (Motorola MC68HC705 series) is being used to orchestrate the acquisition, processing, and PCM encoding of physiologic signals within a totally implantable bi-directional biotelemetry<sup>4</sup>. The controller also supervises the power utilization of portions of the biotelemetry circuit, and interprets and acts on commands received from an external inlink transmitter. An FSK-modulated RF transmitter transmits the serial PCM code. The transmitted bandwidth is ~300 kHz within the 174-216 MHz band, and the center frequency is adjustable via the inlink commands.

### Summary

NASA's Sensors 2000! program, working with University and industry collaborators, is designing, fabricating and testing biotelemetry systems and components including miniaturized, neutral carrier-based pH sensors, totally implantable digital biotelemetrys, digital biotelemetry systems, and portable, easy-to-use receivers and decoders. The technology will be used with animal models on the Space Shuttle and Space Station to further our general understanding of physiological adaptation to the space environment.

### References

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