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# "Smart" Sensor Module

Ajay Mohan Mahajan

*University of Akron, main campus*

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## Miniature Intelligent Sensor Module

**This unit performs signal-conditioning, data-processing, and health-monitoring functions.**

*Stennis Space Center, Mississippi*

An electronic unit denoted the Miniature Intelligent Sensor Module performs sensor-signal-conditioning functions and local processing of sensor data. The unit includes four channels of analog input/output circuitry, a processor, volatile and nonvolatile memory, and two Ethernet communication ports, all housed in a weathertight enclosure. The unit accepts AC or DC power. The analog inputs provide programmable gain, offset, and filtering as well as shunt calibration and auto-zeroing. Analog outputs include sine, square, and triangular waves having programmable frequencies and amplitudes, as well as programmable amplitude DC.

One innovative aspect of the design of this unit is the integration of a relatively powerful processor and large amount of memory along with the sensor-signal-

conditioning circuitry so that sophisticated computer programs can be used to acquire and analyze sensor data and estimate and track the “health” of the overall sensor-data-acquisition system of which the unit is a part. The unit includes calibration, zeroing, and signal-feedback circuitry to facilitate health monitoring. The processor is also integrated with programmable logic circuitry in such a manner as to simplify and enhance acquisition of data and generation of analog outputs.

A notable unique feature of the unit is a cold-junction compensation circuit in the back shell of a sensor connector. This circuit makes it possible to use K-type thermocouples without compromising a housing seal.

Replicas of this unit may prove useful in industrial and manufacturing settings

— especially in such large outdoor facilities as refineries. Two features can be expected to simplify installation: the weathertight housings should make it possible to mount the units near sensors, and the Ethernet communication capability of the units should facilitate establishment of communication connections for the units.

*This work was done by Russell S. Beech of NVE Corp. for Stennis Space Center.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to:*

*NVE Corporation*

*11409 Valley View Road*

*Eden Prairie, MN 55344-3617*

*(952) 996-1602*

*E-mail: beech@nve.com*

*Refer to SSC-00246, volume and number of this NASA Tech Briefs issue, and the page number.*

## “Smart” Sensor Module

**This is a prototype building block of advanced engineering-health-monitoring systems.**

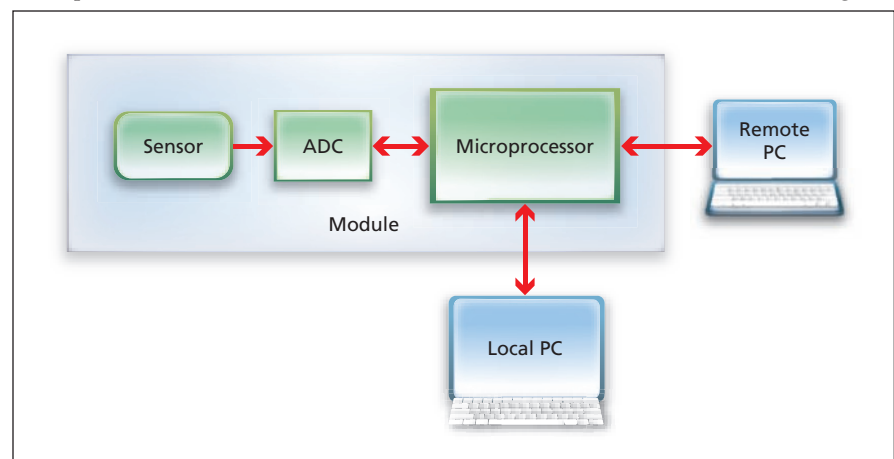
*Stennis Space Center, Mississippi*

An assembly that contains a sensor, sensor-signal-conditioning circuitry, a sensor-readout analog-to-digital converter (ADC), data-storage circuitry, and a microprocessor that runs special-purpose software and communicates with one or more external computer(s) has been developed as a prototype of “smart” sensor modules for monitoring the integrity and functionality (the “health”) of engineering systems. Although these modules are now being designed specifically for use on rocket-engine test stands, it is anticipated that they could also readily be designed to be incorporated into health-monitoring subsystems of such diverse engineering systems as spacecraft, aircraft, land vehicles, bridges, buildings, power plants, oilrigs, and defense installations.

The figure is a simplified block diagram of the “smart” sensor module. The analog sensor readout signal is

processed by the ADC, the digital output of which is fed to the microprocessor. By means of a standard RS-232 cable, the microprocessor is connected to a local

personal computer (PC), from which software is downloaded into a random-access memory in the microprocessor. The local PC is also used to debug the



The “Smart” Sensor Module is programmed by use of the local PC and thereafter operated by the remote PC. In addition to preprocessed sensory data, the module generates an indication of the reliability of the data (and, hence, of the health of the sensor).

software. Once the software is running, the local PC is disconnected and the module is controlled by, and all output data from the module are collected by, a remote PC via an Ethernet bus. Several "smart" sensor modules like this one could be connected to the same Ethernet bus and controlled by the single remote PC.

The software running in the micro-processor includes driver programs for operation of the sensor, programs that implement self-assessment algorithms, programs that implement protocols for communication with the external computer(s), and programs that implement evolutionary methodologies to enable the module to improve its performance

over time. The design of the module and of the health-monitoring system of which it is a part reflects the understanding that the main purpose of a health-monitoring system is to detect damage and, therefore, the health-monitoring system must be able to function effectively in the presence of damage and should be capable of distinguishing between damage to itself and damage to the system being monitored. A major benefit afforded by the self-assessment algorithms is that in the output of the module, the sensor data indicative of the health of the engineering system being monitored are coupled with a confidence factor that quantifies the degree of reliability of the data. Hence, the output includes information on the

health of the sensor module itself in addition to information on the health of the engineering system being monitored.

*This work was done by Ajay Mahajan of Southern Illinois University for Stennis Space Center.*

*Inquiries concerning rights for its commercial use should be addressed to:*

*Southern Illinois University at Carbondale  
Department of Mechanical Engineering  
and Energy Processes*

*Carbondale, IL 62901*

*Attn: Dr. Ajay Mahajan*

*(618)453-7007*

*mahajan@engr.siu.edu*

*Refer to SSC-00242, volume and number of this NASA Tech Briefs issue, and the page number.*

## Portable Apparatus for Electrochemical Sensing of Ethylene

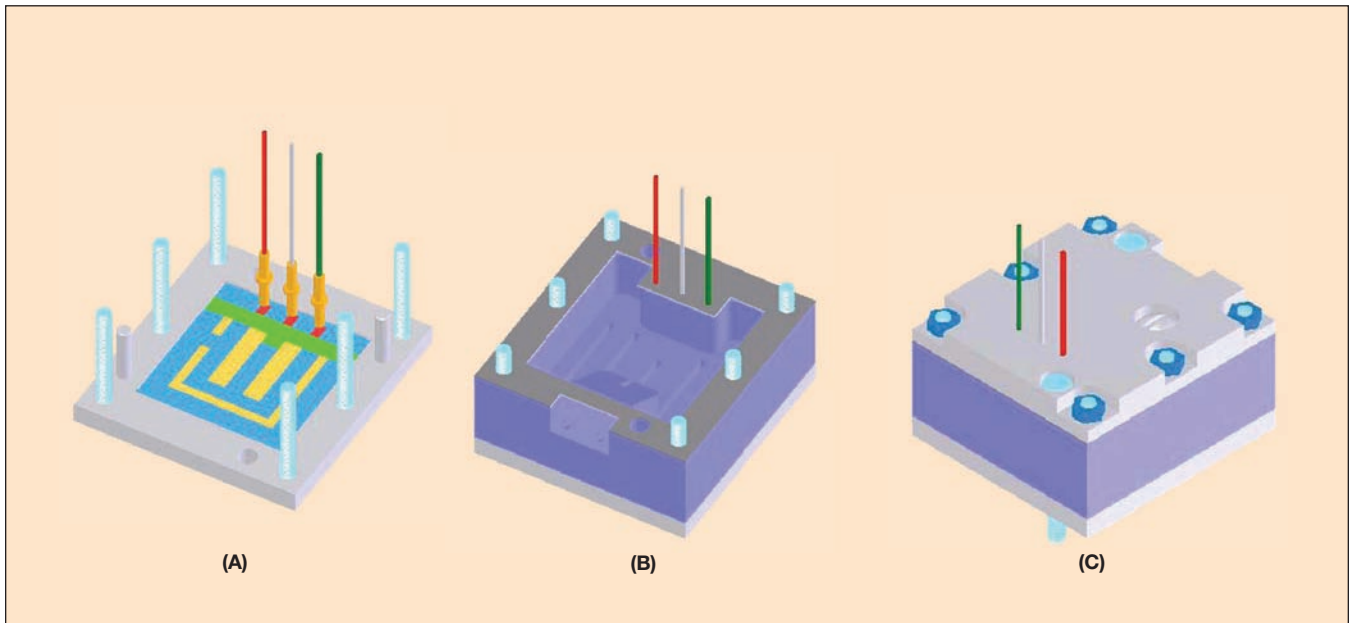
Concentrations between 5 and 5,000 ppb can be measured.

*John F. Kennedy Space Center, Florida*

A small, lightweight, portable apparatus based on an electrochemical sensing principle has been developed for monitoring low concentrations of ethylene in air. Ethylene has long been known to be produced by plants and to stimulate the growth and other aspects of the development of plants (including, notably, ripening of fruits and vegetables), even at concentrations as low as tens of parts per billion (ppb). The effects are magni-

fied in plant-growth and -storage chambers wherein ethylene can accumulate. There is increasing recognition in agriculture and related industries that it is desirable to monitor and control ethylene concentrations in order to optimize the growth, storage, and ripening of plant products. Hence, there are numerous potential uses for the present apparatus in conjunction with equipment for controlling ethylene concentrations.

The ethylene sensor is of a thick-film type with a design optimized for a low detection limit. The sensor includes a noble metal sensing electrode on a chip and a hydrated solid-electrolyte membrane that is held in contact with the chip. Also located on the sensor chip are a counter electrode and a reference electrode. The sensing electrode is held at a fixed potential versus the reference electrode. Detection takes place at ac-



The **Sensor Chip and Solid-Electrolyte Membrane** are packaged together in a housing that contains airflow channels and a reservoir for water to keep the membrane wet. In the illustrated design, (A) the sensor chip is shown in its holder with its three electrical lead pins and (B) the upper portion of the sensor housing is shown with the water reservoir and slots to hydrate Nafion (or equivalent) membrane, which is placed over the sensor chip. The assembled sensor ready for installation in the ethylene monitor is shown in (C). It measures 4 by 4 by 2.2 cm.