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 microprocessor 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.

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

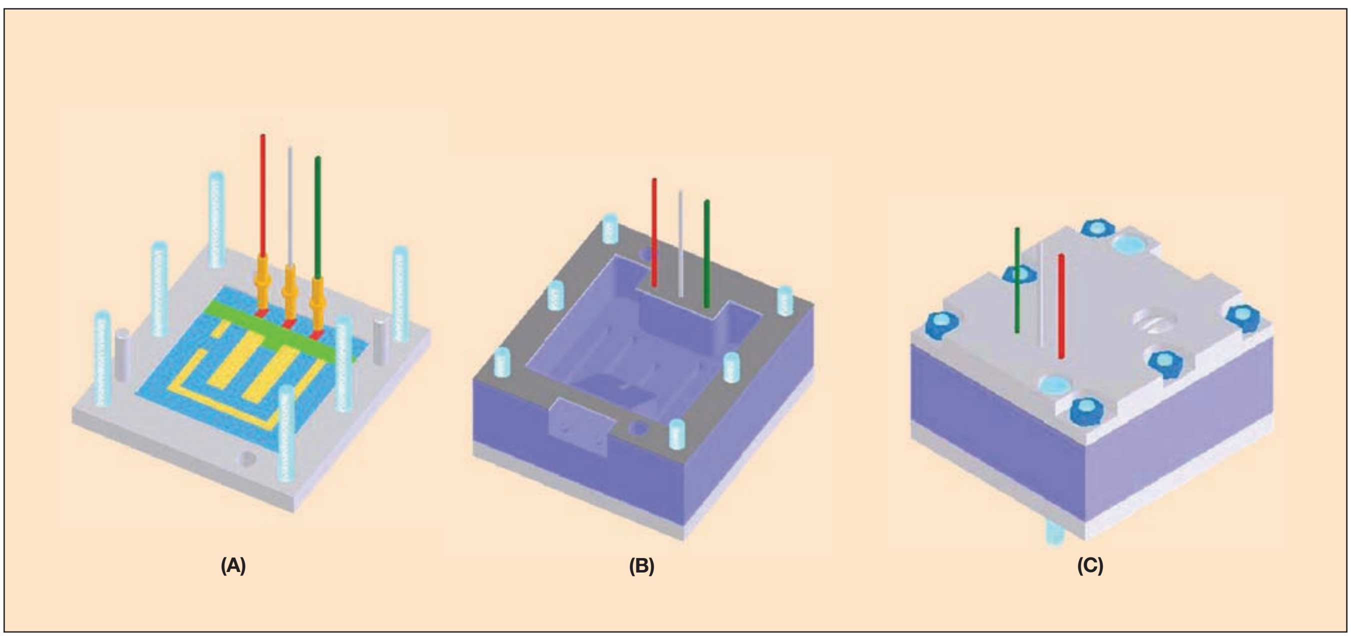
Portable Apparatus for Electrochemical Sensing of Ethylene

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 magnified 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.

tive-triple-point areas where the sensing electrode, electrolyte, and sample gas meet. These areas are formed by cutting openings in the electrolyte membrane. The electrode current generated from electrochemical oxidation of ethylene at the active triple points is proportional to the concentration of ethylene. An additional film of the solid-electrolyte membrane material is deposited on the sensing electrode to increase the effective triple-point areas and thereby enhance the detection signal.

The sensor chip is placed in a holder that is part of a polycarbonate housing. When fully assembled, the housing holds the solid-electrolyte membrane in contact with the chip (see figure). The housing includes a water reservoir for keeping the solid-electrolyte membrane hydrated. The housing also includes flow channels for circulating a sample stream of air over the chip: ethylene is brought to the sensing surface predominately by convection in this sample stream. The sample stream is generated by a built-in sampling pump. The forced circulation of sample air contributes to the attainment of a low detection limit.

In addition to the sensor and the sampling pump, the apparatus includes electronic circuitry for regulating the sensor potentials, measuring the sensing-electrode current, and displaying the ethylene-concentration reading. The electronic circuitry includes a data logger for digital collection via a serial port with an optional analog output.

Overall, the apparatus is capable of measuring ethylene concentrations from 5 to 5,000 ppb with a response time of less than 30 seconds. The magnitude of response of the sensor current is in the range of 5 to 50 picoamperes/ppb. The signal-to-noise ratio is greater than 3 at the low detection limit of 5 ppb.

The sensor is fairly selective for ethylene. It is not subject to interference by O_2 or CO_2. It does respond to NO, NO_2, and H_2S, but these gases are generally not expected to be present at significant concentrations in controlled plant-growth environments. The sensor also responds to some volatile compounds present in some soil samples. Further research will be necessary to reduce these interferences.

This work was done by Mourad Manoukian, Linda A. Tempelman, and John Forchione of Giner, Inc. and W. Michael Krebs and Edwin W. Schmitt of Giner Electrochemical Systems, LLC for Kennedy Space Center. For further information, contact:

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Refer to KSC-12825.

Increasing Linear Dynamic Range of a CMOS Image Sensor

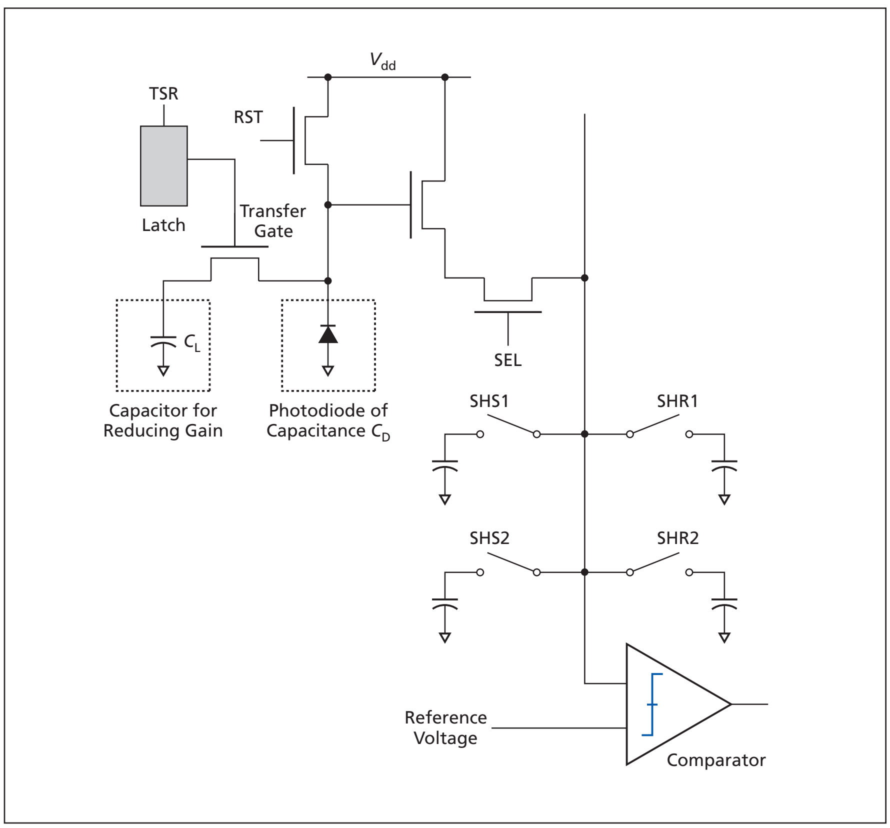
Dual-gain pixels are automatically switched to the most appropriate gain level.

NASA's Jet Propulsion Laboratory, Pasadena, California

A generic design and a corresponding operating sequence have been developed for increasing the linear-response dynamic range of a complementary metal oxide/semiconductor (CMOS) image sensor. The design provides for linear calibrated dual-gain pixels that operate at high gain at a low signal level and at low gain at a signal level above a preset threshold. Unlike most prior designs for increasing dynamic range of an image sensor, this design does not entail any increase in noise (including fixed-pattern noise), decrease in responsivity or linearity, or degradation of photometric calibration.

The figure is a simplified schematic diagram showing the circuit of one pixel and pertinent parts of its column readout circuitry. The conventional part of the pixel circuit includes a photodiode having a small capacitance, C_D. The unconventional part includes an additional larger capacitance, C_L, that can be connected to the photodiode via a transfer gate controlled in part by a latch.

In the high-gain mode, the signal labeled TSR in the figure is held low through the latch, which also helps to adapt the gain on a pixel-by-pixel basis.



The **Pixel and Column Readout Circuitry** enable operation in either of two gain modes and automatic choice of whichever mode is appropriate for the present illumination level.