SAS 2006 – IEEE Sensors Applications Symposium
Houston, Texas USA, 7-9 February 2006

A Wireless Gas Monitor with IEEE 1451 Protocol

Darold Wobschall
Esensors Inc., 4240 Ridge Lea Road, Amherst NY 14226
Phone: (716)837-8719, Fax: (716)837-8740, Email : designer@eesensors.com

Abstract **-** *A portable gas monitor capable of measuring the concentrations of several environmental and toxic gases is described. Interchangeable gas sensor heads with TEDS provide automatic ID and calibration. Data is transmitted to the Internet (via Ethernet) and wirelessly (point-to-point or Zigbee mesh network) with IEEE 1451.5 protocol. The portable monitor is intended to monitor gas levels in buildings by First Responders.*

Keywords - *IEEE 1451, gas, chemical, sensor, wireless*

I. INTRODUCTION

Chemical gas monitoring in buildings is needed both to detect acute gas releases, deliberate and accidental, and also to monitor chronic, undesirable gas buildup in the environment. Remote, often long-term, monitoring of groups of distributed sensors capable of detecting a variety of gases is usually required. Different gases require sensors of various technologies [5,7], with different signal conditioners and calibration/linearization requirements. However an easily used, common format readout in engineering units (e.g. ppm) is required, especially for emergency personnel. To accommodate this need, a versatile, multi-sensor electronics with an IEEE TEDS (for ID and calibration) has been developed [6].

II. DESCRIPTION

A. Signal Conditioners

The monitor is based on an electronic sensor signal conditioner which can automatically adapt to a wide variety of commercial off-the-shelf gas sensor elements and provide a digital output in a standard format. It has analog and digital sections (Fig. 1). The analog section consists of a sensor excitation sub-section and a signal amplification sub-section. The analog sections are controlled by the digital section (microcontroller). The digital section also converts the analog signal into digital form, reads the TEDS, applies calibration constants, and converts the signal into a standard, easily readable digital format.

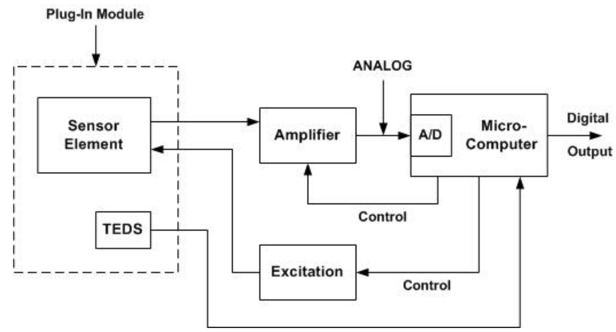

Fig. 1. Block Diagram of Plug-in Sensor Module with Signal Conditioner

Excitation or voltage current supply requirements for these sensors fall into two groups: {1} heaters (1 to 5 v, up to 200 ma) and/or {2} precision reference voltages (0.1 to 2.5 v). To supply the first group, a switching regulator (dc-to-dc supply) with feedback determined by a digital potentiometer is used (Fig. 2). It produces the required heater voltage between 1 and 5 volts (10-200 ma). Adjustment of the voltage is done through a serial digital (SPI) signal from the microcontroller. The heater current is measured by a 1-ohm shunt resistor (and amplifier) so that the heater current or current can be controlled to a specific set point.

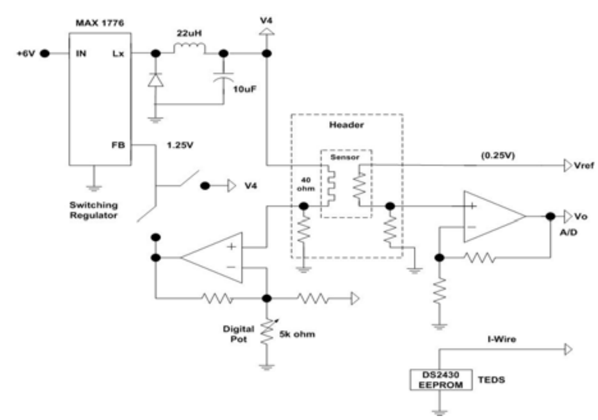

Fig. 2. Signal Conditioner Circuit (configured for a metal oxide sensor)

For sensors requiring a precision voltage source as the excitation, the voltage from a precision 2.5-volt reference is passed through a digitally controlled attenuator. Most sensor elements have a voltage output and most, but not all, require a specified load resistor. An amplifier section brings the voltage level up to that required by the analog-to-digital converter. Because some sensors are high impedance, the amplifier must have a low input bias current. Many sensors require a stable DC baseline or zero and therefore the amplifier must also have a low input offset voltage.

Sensors from different manufacturers are usually made with different technologies and have diverse shapes and electrical connections. To accommodate these differences, sensor modules specific to the sensor but which will plug into a common signal conditioner connector, are made. This approach allows a single connector or plug to be used for all sensor modules. In addition, load resistors or other circuit elements specific to the sensors are added if required. The sensor microcomputer has a 10-bit a/d which is accessed through a multiplexer from the analog section. This section also linearizes the signal and applies the calibrations factors. The output format is floating point (32 bit).

B. Transducer Electronic Data Sheet (TEDS)

A standard format for digital smart sensors (IEEE 1451.4 or Dot 4) has been developed by a national/international committee sponsored by NIST [5]. A major aim is to facilitate plug-and-play of sensors. One aspect is the Transducer Electronic Data sheet (TEDS) which allows sensor configurations and calibration information to be stored (in digital form) with a sensor, along with its ID. The TEDS format (one for each sensor) is as follows:

- UUID: Supplied by EEPROM (DS2430) manufacturer (6 bytes)
- Basic TEDS (8 bytes)
    - Manufacturer ID (14 bits)
    - Model Number (15 bits)
    - Version Letter (5 bits, A-Z)
    - Version Number (6 bits)
    - Serial Number (6 bits)
- Manufacturer's TEDS:
    - Sensor type and calibration (16 bytes)

When the sensor module is plugged in, the microcontroller reads the TEDS and reconfigures the excitation and amplifier sections for the signal conditioner to match. Additionally sensitivity and zero offset constants are provided for software conversion algorithms.

C. Microcomputer/smart sensor section

Another microcontroller processes the digital sensor data and, based on the TEDS data, converts it to engineering units (ppm in most cases). It also controls the timing of the data acquisition. To conserve battery power, many sensors, and also the communication interfaces, are turned on only for short periods. The power management section switches on the power supplies only when required. It also switches between power sources and handles charging the battery.

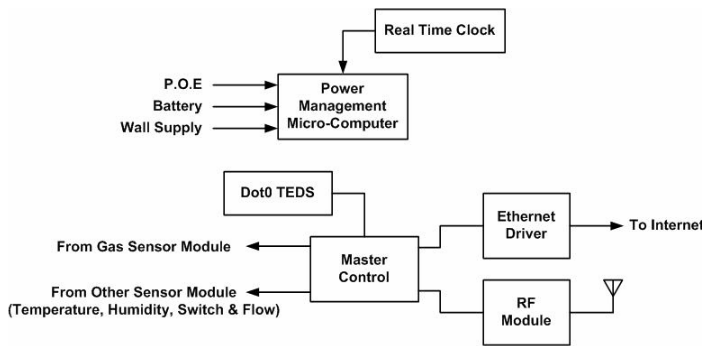

Fig. 3. Monitor Block Diagram

D. Internet/Ethernet Interface

The control microcomputer implements a mini-web server with TCP/IP format. It has Ethernet protocol implemented by a driver with 10-base T transformer/filter connected to Ethernet. Data from other monitors received wirelessly are retransmitted to the Internet. This provides a type of network for monitors within range.

E. Wireless Interface

Two different wireless interfaces are available. The simplest is a point-to-point Chipcon CC1000 transceiver operating at 433 MHz [7]. It has a range of 30-100 meters and is intended to communicate between an internal monitor and one located at an Ethernet jack or at a computer with an Ethernet connection.

The other wireless transceiver is a Zigbee (IEEE 802.15.4) operating at 2.4 GHz and which has mesh networking capability [8,9].

F. Packaging

The monitor circuit was implemented with three printed circuit boards in a case with plug-in sensor modules (Fig. 4).

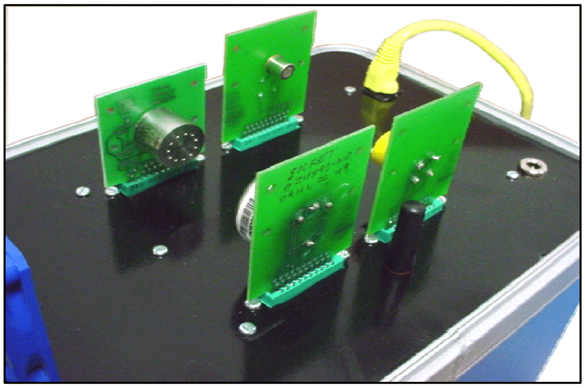

Fig. 4. Photo of Monitor with Four plug-in sensors

III. RESULTS

The responses of the monitor to two different types of gas sensors are shown in Figs. 5 and 6. The Volatile Organic Compound (VOC) sensor responds to a variety of solvents and is here tested with acetone. The data is shown is at the analog stage (Fig. 1). Using the calibration data, the gas concentration in units of parts per million (ppm) is subsequently calculated. The data, now in engineering units, are shown on the computer display in Fig. 7.

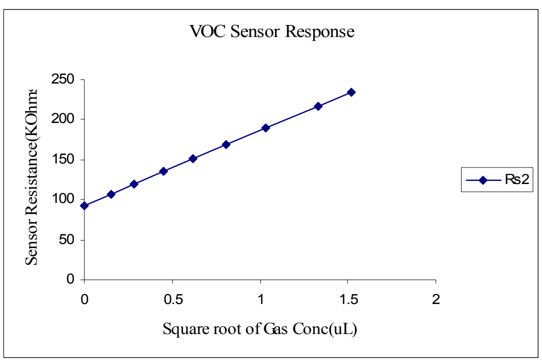

Fig. 5. Response of a VOC sensor to Acetone Vapor

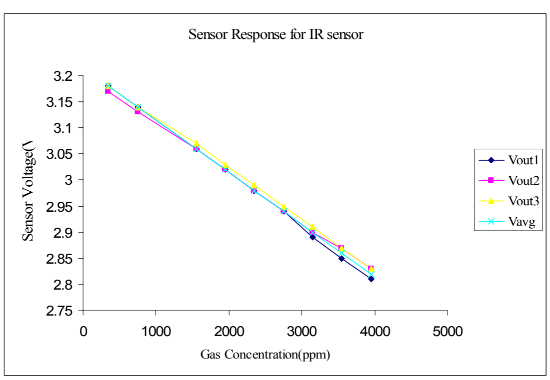

Fig. 6. Response of an IR sensor to Carbon Dioxide Gas

If another sensor is plugged in instead (Fig. 4), the electronics and software calculations reconfigure to the new sensor. It is our intention to convert the IEEE 1451.4 style data to the more standard IEEE 1451.0 format in the future.

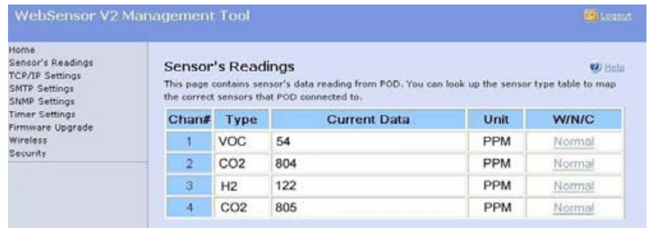

Fig. 7. Display of Gas Concentration in Engineering Units

We conclude that the method of implementing gas sensor plug and play is effective.

ACKNOWLEDGMENT

The support of the Dept. of Homeland Security (Task #2006, Contract # W91CRB-04-C-4184 from TSWG) is acknowledged.

REFERENCES

1. Esensors website; www.eesensors.com
2. D. Wobschall, "Websensor Design – Smart sensors with an Internet Address" Proceedings Sensors Expo (Philadelphia, Oct. 2001)
3. "Electronic Noses: Principles and Applications", J. Gardner and P. Bartlett, Oxford University Press (March 1, 1999)
4. Chemical sensor review: www.sandia.gov/sensor/SAND2001-0643.pd
5. IEEE 1451 information http://ieee1451.nist.gov/ and grouper.ieee.org/.../Review%20on%20the%20Proposed%20Survey%20of%20Wireless%20Sensor%20Requiremen.ppt
6. Darold Wobschall, "An IEEE 1451 NCAP Prototype with Multiple Serial Ports and Internet Access," Proc. Sensors Expo (June 2003) and ""Smart Signal Conditioner Technology for Networked Gas Sensors," Sensor Gov (Virginia Beach, Sept 2004)
7. Chipcon CC1000 transceiver http://www.chipcon.com/index.cfm?kat_id=2&subkat_id=12&dok_id=105
8. Freescale/Motorola http://e-www.motorola.com/brdata/PDFDB/docs/802_15_4FACT.pdf
9. The ZigBee Alliance: http://www.zigbee.org/