Portable Gas Analyzer with Wireless Transmission of Gas Concentrations and GPS Coordinates

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1. Introduction

A new 4-channel analyzer (one to four sensors in the unit), the Model 106, was introduced by PID Analyzers in 2005. The Analyzer consists of a readout unit that contains the processor board, 2 line by 16 character display readout, 4 channel by 16 bit ADC wit multiplixer, battery and pump. The Snap On Head contains a 4 or 5 channel amp board, a sensor board sensor caps and tubing. The amplifiers can measure nanoamps, microvolts, potentiomentric, amperometric, or fuel sensors and a Wheatstone bridge can be used for a thermal conductivity, combustible gas or infrared sensors. The user can select from more than 40 different sensors and technologies such as Photo-Ionization Detector (PID), Infrared (IR), Thermal- Conductivity Detector (TCD), Combustible Gas (CG), capacitance, temperature, and electrochemical sensors. This microprocessor-based analyzer calculates and displays the concentrations on its screen, and it has the capability of logging >7,000 points or automatically. The data can be downloaded to a PC via the RS232 port & the Grapher software that is provided.

We have considerably increased the functionality and utility of the Analyzer by adding a wireless data transmission capability. This allowed us to send the data in real time to a database in a remote computer, with a nearly unlimited size of the database. Multiple analyzers can collect and supply the data from different locations in the working area simultaneously. A geographic position sensor (GPS) has also been incorporated into the new Analyzer. Now, the user can easily generate real-time concentration & location profiles of the contaminants in areas like landfills, hazardous waste sites, where chemicals are being loaded or unloaded, fuel tank farm systems, indoor air quality, gas pipeline leaks from a moving vehicle, etc. Each RF Mote has its own specific identity. This is particularly important for EPA method 21 (1) for large chemical & petrochemical plants that have to monitor large numbers (thousands) of valve & flange leaks several times per year on a routine basis.

There are several wireless data collection systems available in the market, with different ranges, sensor technologies, and sizes of the individual modules [1-4]. Radiofrequency (RF) wireless “motes” are low power, inexpensive transceivers that usually have, embedded sensors (temperature, humidity, light, pressure, acceleration). They also have several analog inputs for connecting external sensors. A Mesh Network of such motes has been developed, for example, for monitoring microclimate [2]. Usage of a wireless mote for monitoring air quality in a home networking was also reported [3].

The interfacing of motes in the Mesh Network with multiple gas sensors would significantly expand the applications of the wireless networks.

We have found the Crossbow's MICA2 radio platform [4] to be the most suitable for incorporating in the PID-106 Analyzer. The Crossbow MRP-410 radio (MICA2) mote works on the frequency of 433 MHz and can be programmed to function together with one of additional boards available, including the boards with several 12-bit or 16-bit Analog-to Digital Converters (ADC) and the board with the GPS module. The PID-106 Analyzer's sensor conditioning board supplies the analog signals from each sensor to the microprocessor, and the same analog outputs can be connected to the analog inputs of the ADC board working together with the radiofrequency (RF) transmitter/receiver module MICA2. Use of the 433 is important in several ways including an absoption minimum for water vapor at this frequency and a greater ability to penetrate walls than the higher frequency transmitters.

The data collected by the "field mote" is relayed to an RF "base mote" that is connected to a computer. Multiple motes, each with a unique ID number, can be used in the system, with one mote (or two motes in case the GPS module is added) in each Analyzer. With the on-board GPS, the sensor location data is automatically known and updated. The motes belong to a Mesh Network, so the data from each Analyzer can be transmitted to the base station directly or, if this direct communication is not available due to distance or position limitations, through other RF module(s) in the Network selected automatically.

2. Design

The Crossbow MICA2 radio transmitter/receiver MPR-410 and the 8-channel 16-bit resolution ADC board MDA320 were used to collect and transmit data from the 4 sensors board to the base station (Fig 1).

PID-106 amplifier board, MICA2, and MDA-320 board

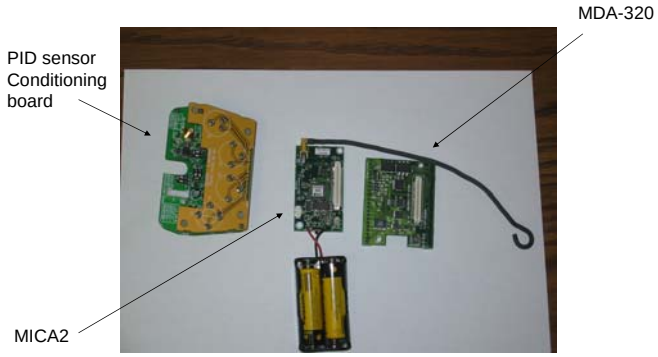


Fig.1. PID sensor board, MICA2 radio, and MDA320 8-channel 16-bit resolution Analog to Digital Conversion board.

The battery holder was removed from the MICA2, and a US1117 voltage converter (0.5”x0.5”) was added to the readout unit to deliver a stable +3.3 V voltage to both boards from the internal 6-volt battery of the Analyzer. Due to small size of the MICA2 + MDA320 unit without the batteries, it was possible to fit these units into the PID-106 Head even with 3 or 4 sensors installed – oxygen, carbon monoxide, and combustible gas sensor~~s~~ (Fig. 2).

PID-106 with the MICA2 radio and MDA320 ADC boards

Fig.2. PID-106 Analyzer with 3 gas sensors and the MICA2+MDA320 module installed.

Crossbow supplies the MoteView software for programming motes, operating the Mesh Network, storing the data in a database in the base workstation (computer), and the real-time display~~ing~~ of the data as a table or multiple graphs. There is a set of standard precompiled applications (firmware) for different radio + sensor board combinations. The XMDA320 application had been loaded into the MICA2 module allowing the collect~~i~~on and wirelessly transmission of the data from 4 A/D channels on the MDA320 board. To receive the data by the base workstation, the 2nd MICA2 module was programmed with the XMeshBase application and was connected to the computer USB port via the MIB520 USB Interface Board. This Mesh Network configuration was tested and was shown to operate successfully.

Since each MICA2 radio can operate with only one sensor board connected to it, the addition of the GPS module to the analyzer required an additional MICA2 radio programmed to collect and transmit the GPS coordinates of the board.

The GPS module has a built-in step-up voltage converter to boost +3 V voltage available from two AA batteries on the MICA2 radio to the +3.3 V necessary for its

operationg. With the US1117 voltage converter already installed in the analyzer, these AA batteries are not needed anymore and can be removed saving the space. However, it was found that connecting +3.3 V directly to the GPS module resulted in interference with the radio transmission. This effect had been found and described earlier by Craig Pataky [4] who had resolved the issue by removing the built-in converter from the GPS module. Following this advice, we also removed the built-in converter and operated the MICA2+GPS module from the +3.3 V source available in the modified PID-106 Analyzer.

The GPS module with the MICA2 radio does not require any signals from the Analyzer and can operate as an independent unit, powered from 2 AA batteries, or it can be modified as described above and connected to the +3.3 V power available from the Analyzer. It can be attached to the Analyzer as an option, with its active GPS antenna attached to the Analyzer or placed, for example, on the roof of a vehicle when scanning the work area with a moving analyzer (the antenna has a 5-m cable). If we could increase the dimensions of the PID-106 head, this would allow us to incorporate the GPS module inside the PID-106 Analyzer as well. The Crossbow's GPS module has its own sensors on the board such as temperature, humidity, pressure, and 2-axis acceleration. This is transmitted together with the GPS coordinates and can be used in analysis and interpretation of the gas sensor data.

Fig.3 shows the working setup of the Mesh Network with the MICA2+MDA320 board installed in the PID-106 Analyzer, the base mote connected to the USB port of the computer, and the MICA2 + GPS module as a separate unit.

The MoteView software stores the data in the POSTGRES database. The data can be exported in different formats – including an SQL database, SQL table, and the Excel worksheet.

The system was tested at PID's industrial site in the model experiment where the Analyzer with GPS was moved from one position to another, and the calibration gas (about 2,500 ppm of methane in air) was into the analyzer input while the Analyzer was in rest. The graphs of the latitude, longitude, and the gas concentration as a function of time are shown in Fig.4, a-c. The horizontal parts of the graphs (a) and (b) where neither the latitude nor the longitude of the analyzer was changing correspond to the positions where the Analyser was not moving and the

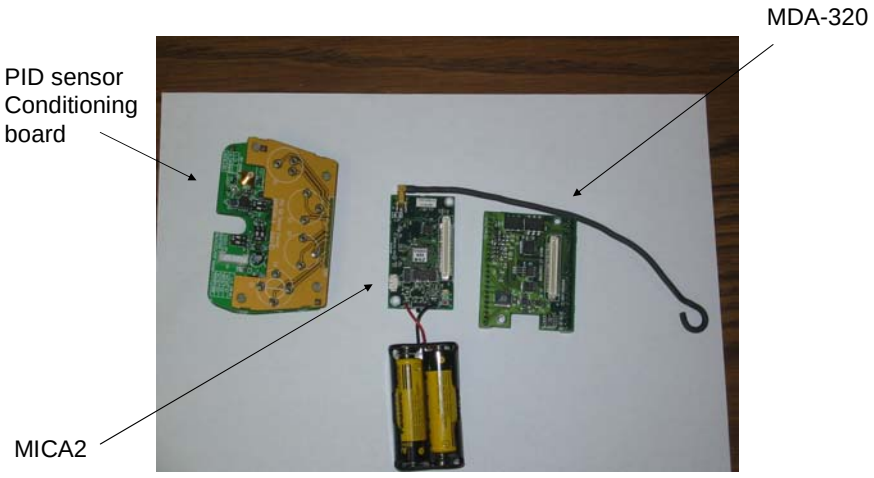
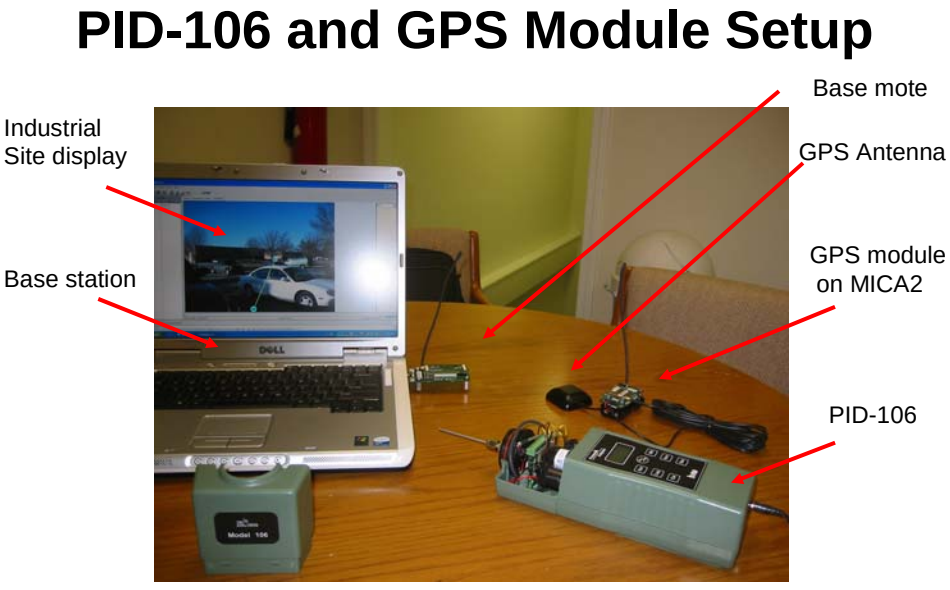


Fig.3. Elements of the Mesh Network: the computer with the base mote, PID-106 with MICA2+MDA320 module installed, and the MICA2+GPS module.

gas from the cylinder was injected into the Analyzer, graph (c).



Model 106 with Base station and Components

Fig.5, *a* shows the graph of the positions of the Analyzer in the latitude – longitude coordinates, and the Google Earth satellite image of the industrial site is shown on the Fig.5, *b*.

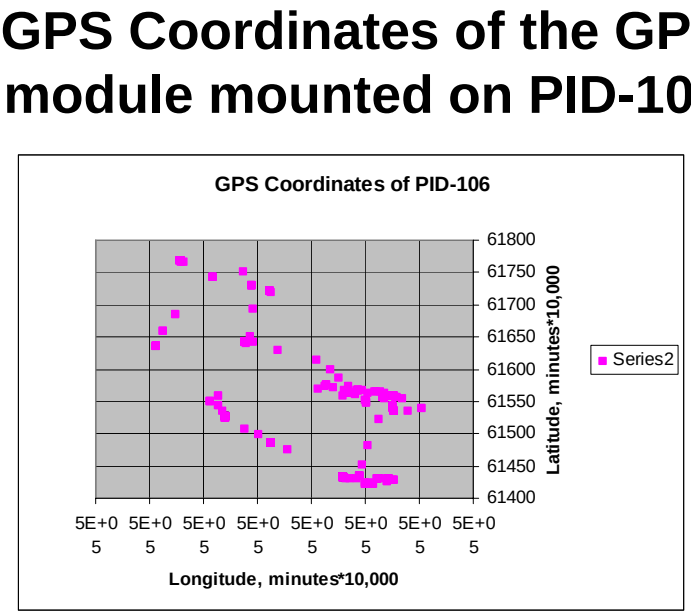
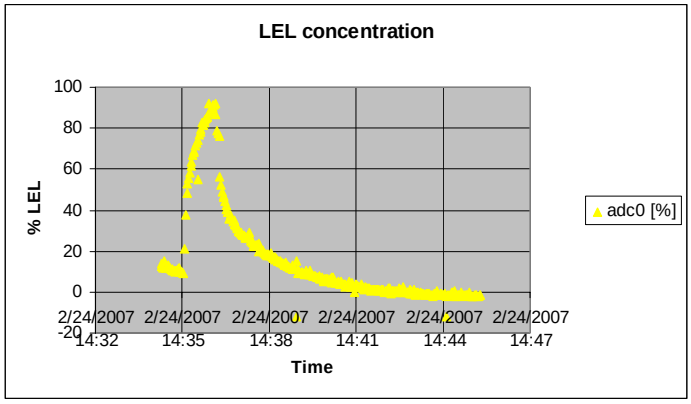


Fig.5, a. GPS graph of the motion of the PID-106 Analyzer with wireless data and GPS coordinates transmission.

Fig.5, b. Satellite image of the industrial site where the wireless sensor Mesh Network was tested.

LEL Concentration
Data taken with PID-106



The MoteView software can send commands from the base computer to the motes in the Network. The data collection rate can be changed, and a particular mote can be rebooted, or ~~to~~ reprogrammed remotely. With an Internet connection available in the computer, the user can control the system remotely from any location in the world using, for example, the Remote Desktop™ feature of Microsoft Windows XP.

Summary

A wireless data transmission system has been integrated into a battery operated analyzer, the PID Model 106. We have achieved real time data collection and transfer from 3 gas sensors to the base station via RF motes in a wireless network. The wireless mote fits into the Head that contains the sensors. We have also attached a GPS module to PID-Model 106 that provided real time measurements of the analyzer's position in the field or plant.

The wireless gas sensor system developed for the PID-Model 106 handheld gas analyzer and the Crossbow wireless motes is easy to use ad can find a wide variety of applications for the real time automatic multi-parameter monitoring of landfills, manufacturing plants, chemical and petrochemical plants, hazardous waste sites, technology processes, storage facilities, etc.

References

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3. Wan-Young Chung and Sung-Ju Oh, “Remote monitoring system with wireless sensors module for room environment”. *Sensors and Actuators B: Chemical*, V. 133, Issue 1, January 2006, pp. 64-70.
4. Graig Pataky, “The Mote-Enabled GPS Server V2.0” – August 2005 www.oregonembedded.com/MoteGPS.pdf

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