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Implementation of Wireless Smart Sensor Platform for Industrial Application

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Abstract

Today, wireless sensor networks (WSN) are potentially one of the most important technologies of the 21st century. The utilization of wireless sensor based control systems have been augmented to a very great extent due to reduced cost, better power management, ease in maintenance, effortless application in remote and hazardous areas [1]. This paper describes the design and implementation of a Smart Sensor node while supporting secure wireless communication. The architecture also provides approach to update operating and monitoring parameters of the distributed system. This smart sensor platform has been realized on the basis of a low power microcontroller AVR ATmega-16L, an RF transceiver CC2500, Accelerometer and LPG sensors and uses the SPI protocol.

Key Words—Serial Peripheral Interface, Smart Sensor, Wireless Sensor Network

1. Introduction

A transformative advancement in the field of sensor technology has been the development of smart sensor systems. The term Smart Sensor was actually invented in the mid-1980 [6], and since then it has got a variety of meanings from various researchers. The most acceptable definition of smart sensor is "when a primary sensor is interfaced with a smart sensor interface unit which consist of an Analog to Digital Converter (ADC), microcontroller and includes feature as communication capability, provides some internal signal conditioning such as linearization, on board diagnostics that deliver information to monitor the system is called as smart sensor" [6, 10]. A Smart sensor is a rich domain that involves both hardware and system design which enables connectivity and intelligence for sensor applications which will provide wireless data acquisition, machine monitoring and maintenance, smart buildings and highways, environmental monitoring, site security, automated on-site tracking of expensive materials, safety management, and in many other areas. It consists of sensor devices that are "small in size and able to sense, process data, and communicate with each other, typically over an RF channel". Their purpose is to collect and process data from the environment, produce a detection event and then forward the information to a specific destination. A typical smart sensor consists of separately distributed sensors to cooperatively monitor physical or environmental conditions, such as temperature, pressure, sound, vibration, flow, level, viscosity, density [4]. The Smart Sensor Architecture is as shown in Figure 1.

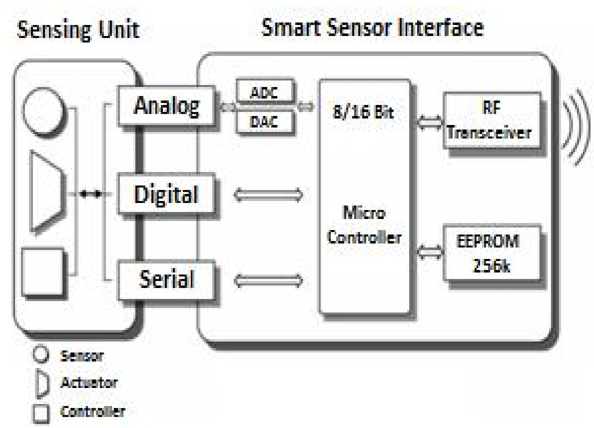

Figure 1. Smart sensor architecture (Source 1)

In the industrial monitoring and control field, requirement of the industry control techniques grows day by day. There are disadvantages to conventional Monitoring analytical Maintenance systems, in which the information is read by periodic "walk-around" data collection. The walk-around structure requires a human to periodically "walk" the path taking data manually for later analysis [5, 7]. Existing industrial control and monitoring systems make use of wired links for data communication. There are several reasons why wires may be inconvenient and expensive such as High installation cost, High maintenance costs, Failure rate of connectors, Trouble shooting, etc.. Also there are no wire net line equipments for real-time control in some industrial fields such as metallurgy, mine, etc., which forces wireless telecommunication technique for the development in the distance monitoring field [7, 5].

In the accomplished work, the sensing unit consists of primary sensors Accelerometer MMA1260 and MQ-6 LPG sensor. The Smart sensor interface unit comprises of AVR ATmega-16 controller, RF transceiver CC2500 for wireless communication and power supply module. The communication between ATmega-16 and CC2500 is established using Serial peripheral interface protocol.

The organisation of this paper is as follows. Section 2 discusses the system composition which covers the description of hardware mechanism together with the terminologies used in the development of smart sensor system. Section 3 focus on the real time implementation which highlights the design issues considered for the development of smart sensor model along with the exhaustive description of real time execution according to the flowchart and block diagram. Section 4 illustrates the experimental results obtained in real time in the developed model. Finally, section 5 provides conclusions on the accomplished work.

2. System Composition

A The main objective of the smart sensor platform is to create a general purpose hardware interface for diverse sensors and actuators, and craft a central data processing infrastructure at the backend to implement the various real time applications such as industrial monitoring and control. The anticipated solution consists of a collection of sensors communicating with the central control unit using standard RF-links. As per the architecture of smart sensor shown in Figure 1, the principal components of the smart sensor platform are Primary sensors for sensing the data from the environment, Microcontroller for processing the digitised data and RF module for wireless communication. The detailed information about the mechanism used in the development of smart sensor platform is presented here.

2.1. MQ-6 LPG sensor

This semiconductor gas sensor detects the presence of LPG, isobutane, and propane at concentrations from 300 to 10,000 ppm. This gas sensor senses the concentrations of LPG, isobutane, and propane in the air and outputs its reading as an analog voltage. Some of the vital features of MQ-6 are High sensitivity to LPG, Iso-butane, Propane, Small sensitivity to alcohol, smoke, Fast response, Stable and long life, Simple drive circuit. It is operated at 5V,150 mA within temperature range of 10 to 50°C. They are used in gas leakage detecting equipments in family and industry, are suitable for detecting of LPG, iso-butane, propane, LNG, avoid the noise of alcohol and cooking fumes and cigarette smoke.

2.2. Micro Machined Accelerometer (MMA1260)

The micro machined accelerometer is a capacitive accelerometer which measures the acceleration in units of "g"(where 1g = 9.81 m/s^2) just by sensing the change in capacitance.MMA 1260 can measures the acceleration in the range of -1.5 to +1.5g. It is available in the 16 pin DIP package. Some of the important features of MMA1260 are integral signal conditioning, linear output, robust design and high shock survivability. It is operated at 5V within temperature range of 40 to 125°C. MMA1260 has got numerous applications like vibration monitoring and recording, appliance control, mechanical bearing monitoring, computer hard drive protection, computer mouse and joysticks, virtual reality input devices, sports diagnostic devices and systems.

2.3. AVR ATmega16 microcontroller

The ATmega16L is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves. 'AT' refers to Atmel the manufacturer, 'Mega' means that the microcontroller belong to MegaAVR category, '16' signifies the memory of the controller, which is 16KB. Some of the essential features of ATmega16 are 131 powerful instructions – most single-clock cycle execution, up to 16 MIPS throughput at 16 MHz, 16k bytes of in-system self-programmable flash program memory, 8-channel, 10-bit ADC, Master/Slave Serial Peripheral Interface. Operating voltage is within a range of 2.7 - 5.5V for ATmega16L.

2.4. RF Transceiver CC2500

The wireless communication is achieved by using Chipcon CC2500 RF transceiver module. The circuit combines very low power and efficient operation with support for IEEE 802.15.4. It operates in the 2.4- 2.483 GHz Industrial-Scientific-Medical(ISM) free radio frequency band, with 16 channels. It provides extensive hardware support for Packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication and wake on radio. The radio module performs Automatic Reception (Rx) Polling using low power RC oscillator, with 460 Hz filter bandwidth and 250 kbps data rate. The output transmitting power of the module can be controlled ranging from 1db (Highest) to -30db. Some of the special features of CC2500 are low power consumption, operated in ISM band (2.4- 2.483 GHz), Supports SPI interface. It can be operated between 1.8~3.6 Volts within a temperature range of -40 to +85°C. there are various applications of CC2500 as Car & Home security system and Automation system, Remote keyless entry / Garage door controller, Wireless game controllers/mouse/keyboard/audio.

2.5. Serial Peripheral Interface

Serial Peripheral Interface (SPI) bus is a synchronous serial data link standard introduced by Motorola in 1979. It is a High speed (about 9.5MBPS), Full duplex and synchronous bus and later adopted by others in the industry. Sometimes SPI is also called a "four wire" serial bus. The Serial Peripheral Interface or SPI-bus is a simple four wire serial communication interface used by many microprocessor/microcontroller peripheral chips that enables the controllers and peripheral devices to communicate each other. The SPI bus, which operates at full duplex (means, data transfer is possible in both directions simultaneously), is a synchronous type data link setup with a Master / Slave interface and can support up to 1 mega baud or 10Mbps of speed. Both single-master and multi-master protocols are possible in SPI. The peripherals can be a Real Time Clock s, converters like ADC and DAC, memory modules like EEPROM and FLASH, sensors like temperature sensors and pressure sensors, or some other devices like signal-mixer, LCD controller, USB controller.

An SPI protocol specifies four data and control lines.

i. Master Out Slave In (MOSI) - MOSI signal is generated by Master and recipient is the Slave.
ii. Master In Slave Out (MISO) - Slaves generate MISO signals and recipient is the Master.
iii. Serial Clock (SCLK or SCK) - SCLK signal is generated by the Master to synchronize data transfers between the master and the slave.
iv. Slave Select (SS) from Master to Chip Select (CS) of Slave - SS signal is generated by Master to select individual slave/peripheral devices. The SS is an active low signal.

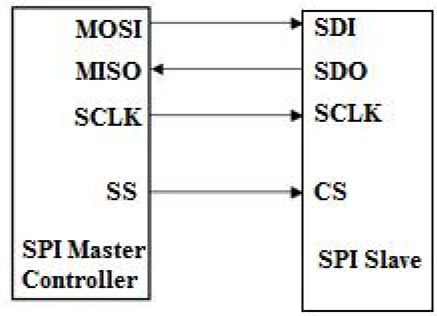

Figure 2. SPI Implementation

Among these four logic signals, two of them MOSI and MISO can be grouped as data lines and other two SS and SCLK as control lines.

The device can be operated in either Master or Slave mode. The algorithms for both master and slave modes are explained below.

a) For Master mode:
1. Set SS, MOSI and SCK pin as output pins.
2. Enable MSTR bit to make it master device.
3. Program SPR [1:0] bits to select SCK frequency.
4. Set SPE bit to enable SPI.
5. Copy data in SPDR register to send.
6. Wait until SPI interrupt flag get set.

b) For slave mode:
1. Select MISO pin as output and rest of the pins as input pins.
2. Set SPE to activate SPI.
3. Wait until SPI interrupt flag get set.
4. Receive data from SPDR register.

3. Implementation

The smart sensor network can be compared to “fixed-wireless”, where the equipment is static, but uses wireless technology for communication. Design issues must be considered for the development of smart sensor network, which also can be used for industrial applications are explained below.

- System building: A hierarchical system building technique enhances the system flexibility, robustness and reliability.

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- Fault tolerance: Service guarantee is required in the communication system in the form of a confidence level.
- Energy efficiency: As energy-saving is a critical issue in the industrial organization, the system set up must be designed with energy minimization techniques.
- Multiple interface requirements: The system to be designed must be interfaced with any number nodes and performance should not get affected due to some physical parameters such as distance between the nodes, surrounding environment conditions.
- Connectivity: Multiple sensor networks may be connected through sink nodes, along with existing wired networks.

3.1. Hardware Design

The generalized block diagram representation is shown in Figure 3. The block diagram can be divided into two parts, first part contains one Master and second part contains 'n' number of slaves. Master consists of various blocks such as AVR microcontroller, RF Module, Power supply, LCD, PC interface. Similarly slave consists of AVR microcontroller, RF Module, Power supply, Sensor. The RF Module and the Microcontroller are interfaced using Serial Peripheral Interface.

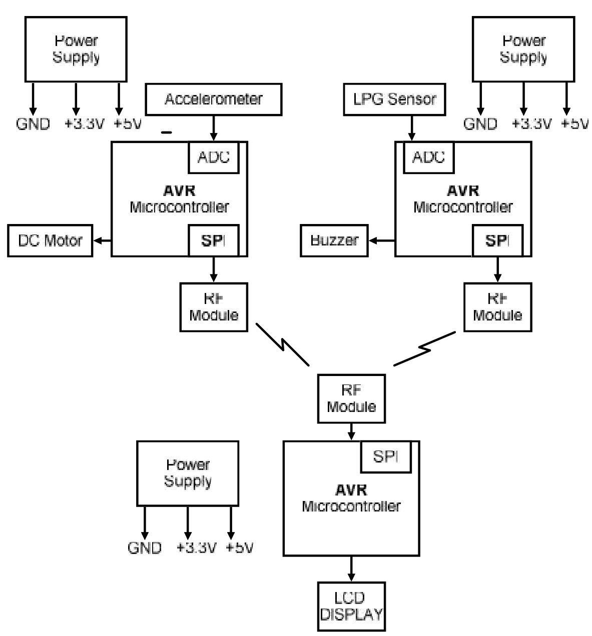
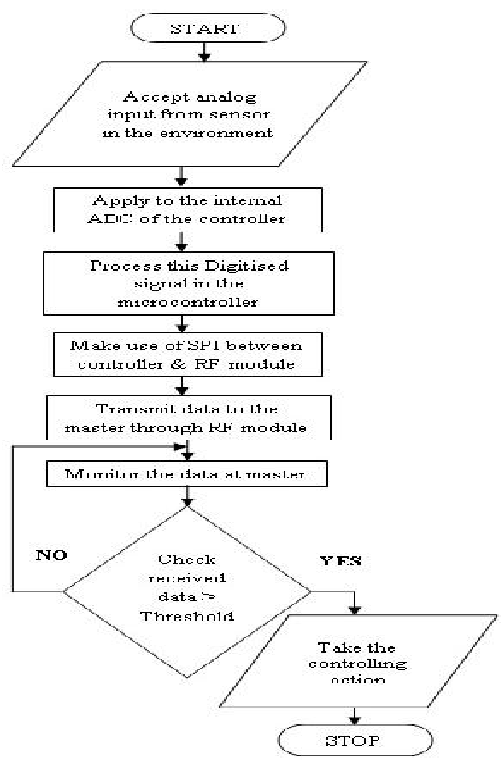


Figure 3. Block Diagram Representation

At the slave part the sensor will sense the parameters from the environment. The output of the sensor is analog data, generally analog voltage. This data would be converted into digital using internal ADC of the controller. The data is further processed and given to RF module through serial peripheral interface. The RF module will convert the digital data in RF waves. This data would be received by the RF module at master side. This data is continuously monitored and processed in the microcontroller and displayed on the LCD and PC. When the incoming data at the master crosses the threshold value set at the master then instantly, the AVR microcontroller at the master side will send the command to the respective slave through the RF module in between the master and that particular slave as well as will take the controlling action.

In this system, two node Smart sensor model is developed by considering one node as MQ-6 Gas sensor and another one is Accelerometer MMA1260. The master circuitry consists of ATmega16 microcontroller, RF module and an LCD display. The RF module is used for transmition and reception of data. The ATmega16 microcontroller fetches the data from RF module through SPI protocol and monitors it continuously on LCD display.

The actual implementation of Smart sensor platform is described with the help of following flowchart.



3.2. Software Tool: AVR Studio

AVR Studio is an Integrated Development Environment (IDE) for writing and debugging AVR applications in Windows 9x/ME/NT/2000/XP/VISTA environments. AVR Studio provides a project management tool, source file editor, simulator, assembler and front-end for C/C++, programming, emulation and on-chip debugging. AVR Studio supports the complete range of ATMEL AVR tools and each release will always contain the latest updates.

4. Experimental results

All the real time Experimental measurements conducted to study the relevant performance of LPG MQ-6 sensor, Accelerometer MMA1260 and RF module obtained by realistic observations is represented in the form of tables and discussed comprehensively.
The MQ-6 gas sensor has been tested for various values of gas concentration for supply voltage = 5V at temperature 36°C.

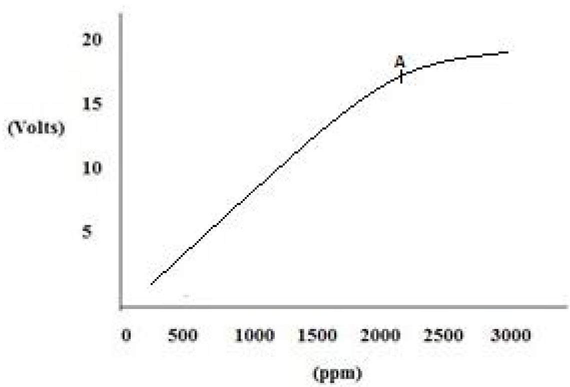


Figure 4. Sensitivity Curve for MQ-6 sensor

The Fig. 4 represents the Sensitivity Curve for MQ-6 sensor showing the variation between gas concentration (ppm) and sensor voltage (volts). From the sensitivity curve it is observed that, as the LPG gas concentration increases 500 to 2300 ppm the analog voltage i.e. sensor voltage obtained at the output pin of the sensor increases very rapidly but after point ‘A’ i.e. 2300 ppm the sensor voltage increases slowly. This process takes place because as the gas concentration varies from low to high in a particular step, the resistance of sensor goes on decreasing as per the gas concentration. As the resistance of sensor decreases the current flowing through load resistor increases which in turn increases voltage across the load resistor i.e. sensor voltage.

The Accelerometer MMA1260 has been tested for various values of vibration of motors for supply voltage of 5V at temperature 36°C. The unit for the measurement of acceleration is earth’s gravity ‘g’ where 1g = 9.81 m/s^2. The Sensitivity Curve for accelerometer MMA1260 is shown in fig. 5 showing the variation between acceleration (g) and sensor voltage (volts).

From the sensitivity curve it is observed that, as the vibrations of motor concentration increases 0.1 to 0.4 the analog voltage i.e. sensor voltage obtained at the output pin of the sensor increases very slowly but after point ‘P’ i.e. 0.4 g the sensor voltage increases rapidly. This process takes place because as the vibrations of motor varies from low to high in a particular step, the distance between the plates decreases, due to which capacitance increases which in turn increases voltage across the load resistor i.e. sensor voltage.

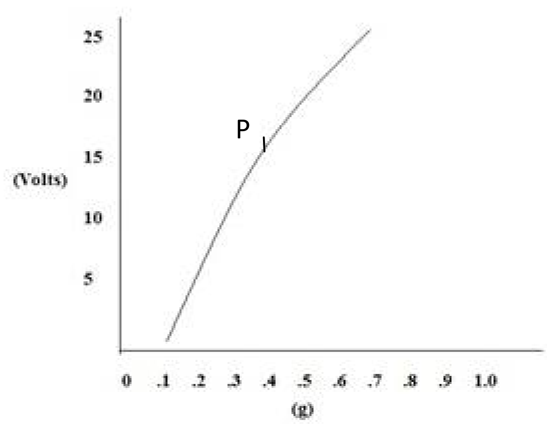


Figure 5. Sensitivity Curve for MMA1260 sensor

When these sensors are interfaced with the microcontroller, they have undergone linear operation without considering the changes in the environment situation like temperature change.

The RF module CC2500 has been tested experimentally and it is found that the maximum line of sight range for wireless communication is 30 meters. Competing traffic is also an important parameter affecting the system performance. Competing traffic can be changed by adding and removing sensor nodes from the system. To summarize, the effects of the following parameters on delay of RF transceiver CC2500 are:

- Distance: With increasing distance, the delay becomes larger and jittery.
- Traffic: No considerable effect

5. Conclusion

The main intend of interfacing diverse primary sensors with the smart sensor interface unit using Serial peripheral interface and wireless communication has been achieved successfully. The experimental results show that a sustained near real time system can be set up with the smart sensor nodes. The gas sensor and accelerometer used provides linear results experimentally. Also the AVR microcontroller used is SPI compatible and also reduces the need for external ADC. The RF module provides the maximum line of sight 30 meters range for wireless communication. It is found that the use of Serial peripheral interface communication protocol provides very high data transfer rate than any other communication protocol. The central monitoring system which is consisting of Master & slave in the smart sensor platform reduces the human efforts and cost to a large extent. These dynamic features of smart sensors can provide the critical data to the end user in a more rapid, reliable, robust, economical and efficient way.

References

[1] H. Ramamurthy, B. S. Prabhu, R. Gadh, and A. Madni, "Smart Sensor Platform for Industrial Monitoring and Control", 4th IEEE Sensors 2005, Irvine, California, Oct 31 – Nov3, 2005.

[2] F. L. Lewis, "Wireless Sensor Networks", Smart Environments: Technologies, Protocols, and Applications ed. D.J. Cook and S.K. Das, John Wiley, New York, 2004.

[3] G. Zhao, "Wireless Sensor Networks for Industrial Process Monitoring and Control: A Survey", Network Protocols and Algorithms ISSN 1943-3581 2011, Vol. 3, No. 1

[4] J. Agajo Federal Polytechnic Auchi Edo State, Nigeria/Nnamdi Azikiwe University Awka Nigeria. "Wireless Sensor Application for Industrial Monitoring".

[5] T. Brooks, "Wireless Technology for Industrial Sensor and Control Networks", 3e Technologies International, Inc., SIcon'Ol Sensors for Industry Conference Rosemount, Illinois, USA, 57 November 2001.

[6] R. Frank, "Understanding Smart Sensors", 2^{nd} Ed., Artech House, Norwood, MA, 2000.

[7] U.S. Doe, "Industrial Wireless Technology for the 21st Century" – Report, Technology Foresight, winter 2004/ TF-2004-1.

[8] K. Najafi, Center for Integrated Sensors and Circuits, Department of Electrical Engineering and Computer Science, University of Michigan, "Smart sensors", Ann Arbor, MI 48109-21 22, USA J. Micromech. Microeng. 1 (1991) 86-102. Printed in the UK.

[9] J. Wiczer, "Smart Interfaces for Sensors", Sensor Synergy, Inc.

[10] J. J. Sammarco, R. Paddock, E. F. Fries and V. K. Karra, "A Technology Review of Smart Sensors With Wireless Networks for Applications in Hazardous Work Environments", Information Circular 9496, Department of Health And Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health Pittsburgh Research Laboratory.

[11] G. W. Hunter, J. R. Stetter, P. J. Hesketh, C.C. Liu, "Smart Sensor Systems", The Electrochemical Society Interface • Winter 2010.

[12] L. R. Garcia, L. Lunadei, P. B. and J. I. Robla, "A Review of Wireless Sensor Technologies and Applications in Agriculture and Food Industry: State of the Art and Current Trends", Sensors 2009, 9, 4728-4750; doi:10.3390/s90604728.

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