

Wireless Communication for Sensor Area Network

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Abstract : Environment monitoring has become a necessity because of global warming and climate change. All across the globe researchers are trying to monitor the environmental parameters of temperature, humidity and pollutants gases more precisely in real time. Sensing system using sensor arrays has been developed to monitor indoor environment, however, these systems are costly and have not gained wide acceptance. Precise monitoring of building environment has a huge potential in terms of energy savings. In this paper, an effort has been made to develop a 4-channel energy efficient and low cost data logger for indoor environment. The Data logger is proposed to be developed with the use of PIC 18F4458. Real Time Clock and EEPROM are interfaced for sampled data with the instance of sampling time and month/date/year; these sampled data will be stored in the EEPROM to the note pad tabular form with the help of graphical user interface (GUI).

Keywords -Gas Sensors, GUI, Real Time Clock , ADC, Smart Transducer Interface, ZigBee

1. INTRODUCTION

Indoor environment and built-architecture are closely associated. The built environment affects indoor physical environments, and subsequently health and quality of life of occupants. There is evidence showing the pathways and mechanisms by which the built environment affects health and factor associated with specific aspects of physical and mental health. The problem has become acute in recent past because of the rapid industrial growth in last half century and has led to change in lifestyles (Become more dependent on indoor environment). The main factors of the environmental condition are the air quality and environmental parameter of the inside unconditioned environment. Across the world indoor air quality monitoring is gaining hotspot in present research works because recent study has put forth that 30 –40% of total natural resources are exploited by the buildings and almost 50% of energy resources is used to condition buildings in industrialized countries. The reality is that indoor air can be up to 10 times more polluted than outdoor air. The major contaminants of indoor environment pollution are CO₂, CO, O₃, SO₂ and NO₂. Many researchers are collect the data for different techniques, in different fields are facing similar difficulty in data collection *i.e.*, needs a user friendly system is able to collect data from the work place and buildings environment. Pardoet *al.* developed a gas measurement system based on the IEEE 1451.2 standard. They have used the 4-gas sensors (tin oxide), 1-temperature and 1-humidity sensor; this prototype system will be work as electronic nose. Camaraet *al.* developed a STIM (smart transducer interface module) based on the IEEE 1451 standard. This prototype system will be work with a lot of different transducers without the necessity of change of the control hardware and software. Available technologies for sensing these environmental parameters are developed by Onsear HOB0, Spectrum Technologies (Watch Dog weather conditions), TandD, Telaire (Wireless Monitoring Systems), Testo, Log Tag, Measurement Computing Corporation, Monarch Instruments, MSR Electronics GmbH, P3 International, Quality Thermistor, S3 Crop, Sensaphone, Sansatronics, Lascar, ICP, Graphtech, Exttech Instruments, Dickson, Dent Instruments, Davis, ACR System Inc, 3M International, and Acumen. But we found the developed system is not suitable for the real time monitoring of the indoor environment and will be required to store the information and data collection for the long duration. To focus on this problem we are trying to develop a low cost and energy efficient multi channel data logger for indoor environment. We face only 4-parameter such as temperature, relative humidity, SO₂, and NO₂. It can be summarized as follows-interface of LCD (to display the output of various modules), RTC and EEPROM with microcontroller and interface of the data logger to the personal computer by using the serial (RS-232) port, minimization of power consumption in order to enhance battery life and preparing the user friendly graphical user interface in visual language to operate the data logger.

2. SYSTEM ARCHITECTURE

ZigBee wireless sensor nodes mainly consists the sensor unit, monitoring and controlling unit consists of microcontroller (MCU), ZigBee modules, and other components. Micro-controller is responsible for collecting environmental information (such as temperature and humidity) and does analog to digital data conversion if required. Microcontroller is also responsible for controlling and managing the entire nodes. ZigBee modules are responsible for the communication between different nodes. Sensor unit is the basic unit of wireless sensor

network. Sensor unit is used for sensing the environment temperature and humidity values, collecting information and converting to digital signals and monitoring unit is comprised of data acquisition module and data processing module. Data acquisition module receives the data from sensor unit and data processing module makes the decisions according to the environment conditions.

2.1 System Design

The system may be classified into following two sections.

- Wireless Sensor Nodes
- Base Station GATEWAY

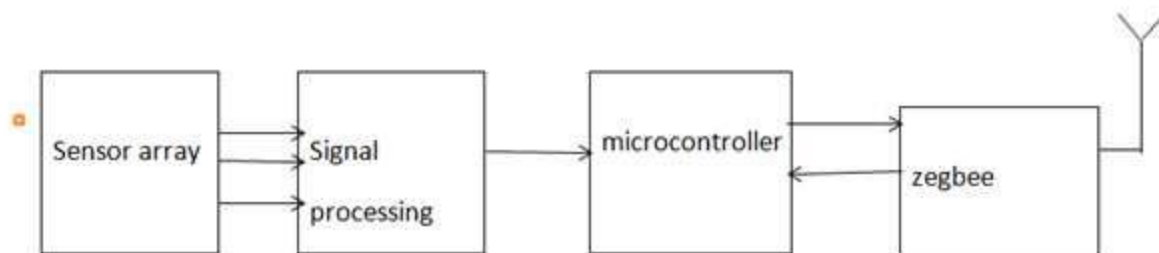


Figure 1: Block Diagram of Wireless Sensor Network

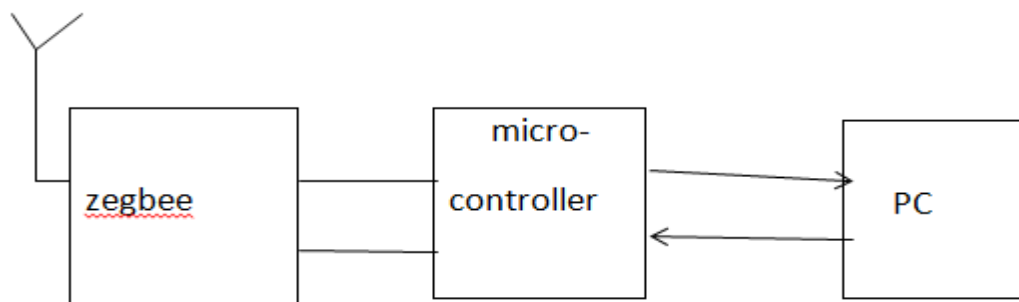


Figure 2: Block diagram of the Base Station-GATEWAY

Typically, the hardware of one sensor node is described as shown in Fig.1. In order to monitor the values of environmental parameters observed at remote location of the room, a PC based Base station is developed and presented in Fig.2. As depicted in Fig.2. The base station consist of the ZigBee module as the wireless receiver. The parameter values which are already calibrated at the sensor node is read serially into the PC and displayed on the monitor on specifically designed windows. This monitoring system involved capturing sensor values of various parameters as- sociated with indoor air quality by using different sensors. The system consists of processing unit, which is nothing but Arduino board. We used sensor node, which is nothing but boards containing Arduino board and all sensors together with ZigBee. Web server can either be the hardware or the software that helps to deliver Web content that can be accessed through the Internet. In system architecture Web portal is considered as a future work and is not part of the system in this thesis. Sensor Node is nothing but combination of Arduino, sensor board ZigBee module. It is part of wireless network and directly talks with coordinator and also with other routers. Graphical user interface (GUI) is developed on computer side for user-friendly environ- ment using VB.net. This GUI is having numerous functions, the detailed description of which is given in coming chapter. Depending upon requested task corresponding command is given to coordinator mote through Universal Serial Bus (USB).

We have used high level data communication protocol and have specific frame structure for reliable inter-communication. Coordinator node consist of Arduino board and ZigBee module. We have set up ZigBee module to work as coordinator by using X-CTU software. Arduino board is programmed in Arduino

programming language (based on wiring). Coordinator will broadcast this command packet using ZigBee wireless network. Wireless sensor network consists of sensor nodes, which are nothing but a bundle of Arduino board, Sensor shield and ZigBee module. Sensor shield consists of numerous sensors that measure concentration of various parameters present in air inside a house. Depending upon request, sensor nodes send back requested data to coordinator through ZigBee network. Coordinator forwards this data to computer through USB and GUI will either display it or save it on disc as per user request.

2.2 Hardware Parts

2.2.1 Temperature Sensor

The wireless measurement node uses a Pt-100 RTD temperature sensor module. The module provides outputs in the range of 0.1 V for temperature 0 to 100°C and a sensitivity of 10 mV/°C in temperature measurement. A conductor is a material in which the electrons of the outer orbit of the atom are less bonded. If the energy of the material is increased, for example by heating up, the atoms will move (vibrate) more and more and at a certain moment these electrons can leave their orbit and move freely in the space between the atoms. The higher the temperature, the more the atoms move and the more difficult it is for the electrons to move around in the space between the atoms, because there is less space in between them. You could say the resistance to move around has increased. This in fact means that the resistance of the material has increased. So this tells that there is a relationship between temperature and resistance. It is this relationship that is used to measure temperature. This relationship is given by

$$R(T) = R(T_0)(1 + T)$$

The normalized temperature range for Pt100 elements is -200°C to +850°C. For a Pt100 element, the next polynomials are used to describe the relationship. In the following table, a table gives an idea of the values for resistivity and temperature coefficient. (One can find these values on internet or literature but they are always a little different from source to source.)

2.2.2 Humidity Sensor

The sensor circuit develops a linear voltage vs. RH output that is ratio metric to the supply voltage. That is, when the supply voltage varies, the sensor output voltage follows in the same proportion. It can operate over a supply voltage range between 4.0 V to 5.8 V. At 5 V supply voltage (at room temperature) i.e., the output voltage ranges from 0.8 to 3.9 V as the humidity varies from 0

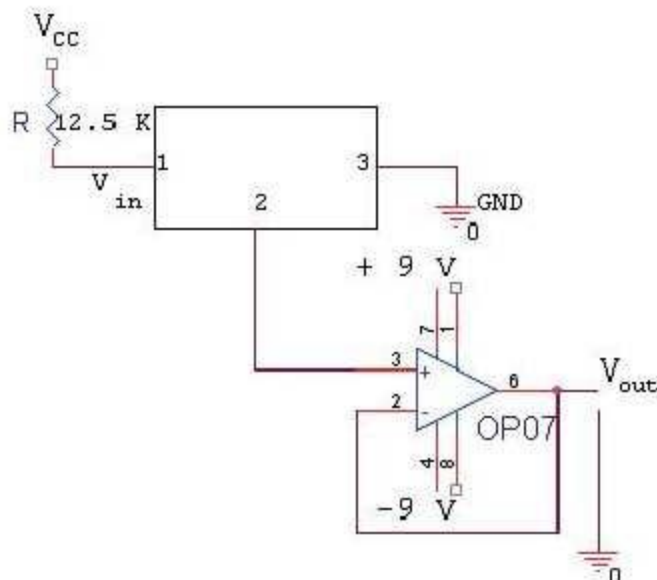


Figure 3: Operating circuit of humidity sensor HIH4000

2.2.3 Operating Circuit of the SO2 and NO Sensor

The SO2 and NO sensor operating circuit is shown in Figure 4. In general, the output of the IC1 is connected to the microcontroller pin AN2 and AN1 respectively.

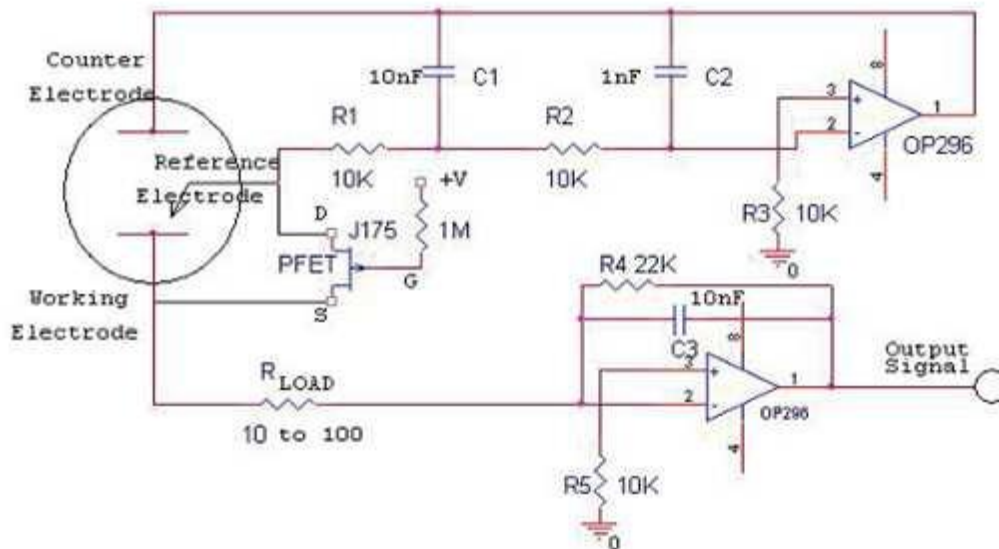


Figure 4 : Operating Circuit of the SO₂ and NO

2.2.4 Signal Conditioning

Signal Acquisition and Processing: The output range of the temperature sensor is very small and thus the signal needs to be amplified before processing to prevent introduction of errors. The signal chain has to handle the small signal accurately in presence of noise. TI's temperature sensor front-ends have an input multiplexer, high impedance PGA and high resolution sigma-delta modulator all integrated into a single chip. The low noise, chopper stabilized PGA provides the versatility of scaling the gain as needed in accordance with how small or large the output from the sensor is. High end products also have integrated features for system diagnostics and fault monitoring. A further level of system calibration could be implemented in the MCU. Traditional analog (4 - 20mA) interface remains the popular choice for industrial control and sensor applications. The other popular protocols include HART, Profibus and IO-Link. TI's IO-Link interface products have integrated regulators and diagnostic outputs. In addition, wireless options based on IEEE 802.15.4 protocols are becoming more prevalent. TI is committed to provide solutions for both traditional and emerging industrial interfaces.

2.2.6 ZigBee

The ZigBee standard is built on top of the IEEE 802.15.4 standard. The IEEE 802.15.4 standard defines the physical and MAC (Medium Access Control) layers for low-rate wireless personal area network. The physical layer supports three frequency bands with different gross data rates: 2.450 MHz (250 kbs-1), 915 MHz (40 kbs-1) and 868MHz (20 kbs-1) It also supports functionalities for channel selection, link quality estimation, energy measurement and clear channel assessment. ZigBee standardizes both the network and the application layer. The network layer is in charge of organizing and providing routing over a multi-hop network, specifying different network topologies: star, tree, peer-to-peer and mesh. The application layer provides a framework for distributed application development and communication. Aside from the agriculture and food industry, it is widely used in home building control, automation, security, consumer electronics, personal computer peripherals, medical monitoring and toys. These applications require a technology that offers long battery life, reliability, automatic or semiautomatic installation, the ability to easily add or remove network nodes, signals that can pass through walls and ceilings and a low system cost. Zigbee/IEEE 802.15.4 - General Characteristics:

- Dual PHY (2.4GHz and 868/915 MHz)
- Data rates of 250 kbps (@2.4 GHz), 40 kbps (@ 915 MHz), and 20 kbps (@868MHz)
- Optimized for low duty-cycle applications (≤ 0.113)
- CSMA-CA channel access
- Low power (battery life multi-month to years)
- Multiple topologies: star, peer-to-peer, mesh
- Addressing space of up to: 18,450,000,000,000,000 devices (64 bit IEEE address) 65,535 networks

- Range: 50m typical (5-500m based on environment)

2.2.7 Interfacing of EEPROM with Microcontroller

The EEPROM will store the digital value which is coming from analog to digital converter. We will require the 52.73 MB of EEPROM if we are sampling all analog channels at the rate of 1 sample/Second. We are using the EEPROM AT24C256 of ATMEL. This will store the sample data at different instants. This EEPROM having the following features - low voltage and standard voltage operation 5.0 (VCC = 4.5 V to 5.5 V), 2.7 (V = 2.7 V to 5.5 V), and 1.8 (VCC = 1.8 V to 5.5 V); 1 MHz (5 V), 400 KHZ (2.7 V) and 100 KHZ (1.8 V) compatibility, and 64-Byte page write mode [15,17,18]. shows the interfacing of EEPROM. We are using the I2C to interface the real time clock (RTC) and EEPROM to the micro-controller. The IC bus is the most popular of the 3 serial EEPROM protocols. shows the typical pin out of an I2C device, showing pins 1-3 as address pins A0, A1 and A2. Pin 4 is V, or ground. Pin 5 is SDA, the data line. Pin 6 is SCL, the clock signal. Pin 7 is write protect, and pin 8 is voltage, or VSS. Finally, many I2C chips include address pins as an easy way to have multiple chips on a single bus while still only using two connections to the microcontroller.

2.2.8 PC Interfacing with Microcontroller Using RS232 Serial Communication

Personal computer is interfaced with PIC 18F4458 using MAX232. It is the IC used to convert the TTL logic level to the RS232 logic level. RS232 is the serial communication protocol that does not require the clock along with data lines. Two data lines are there one is Tx and another is Rx for serial communication. MAX432 has two receivers (converts RS-232 logic level to TTL logic) and two drivers (converts TTL logic to RS232 level). Following Figure 8 shows the hardware interface of PIC with personal computer. Separate power supply has been provided because minimum power supply needed is 5 V and MAX232 consumes a lot of current for operation. External capacitors are required for internal voltage push to convert TTL logic level to RS232 level. For battery operated application MAX232 can be used as level converter instead of MAX232, it is low power consumption logic converter IC for RS232. It is pin compatible with MAX232.

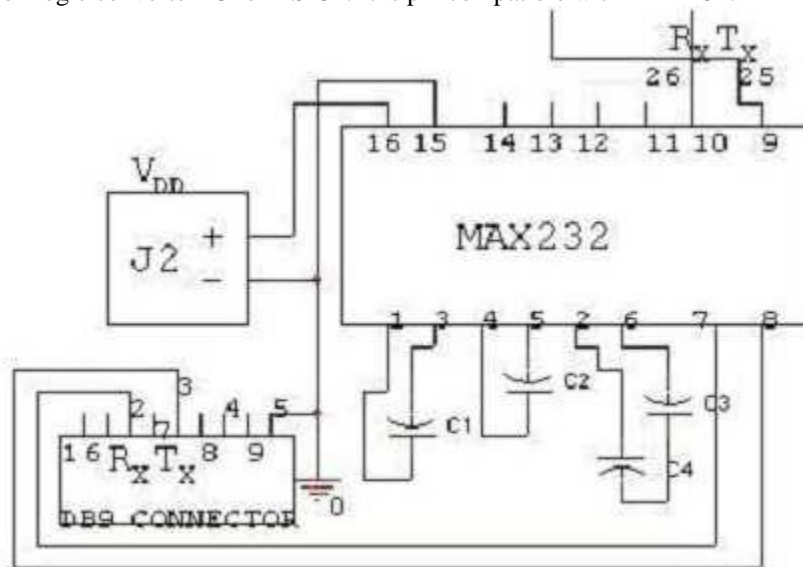


Figure 5: PC Interfacing with Microcontroller Using RS232 Serial Communication

3. GRAPHICAL USER INTERFACE

A program interfaced that takes advantage of the computer graphics capabilities to make the program easier to use. In this paper, the GUI is one of the important parts it displays the data from microcontroller for data monitoring and analysis. However, the main objective is to display data received in graphical form. As a

transducer detects and translate an analog signal, the data will go through a conversion at the ADC and become a digital format. This digital data is converted in a 12 bit data. This data will be stored to the EEPROM chip with the help of Visual Basic 6.0 software. Since the data used the serial RS232 communication, therefore an initialization needs to be done which are the baud rate, data bits, parity, stop bit and the COM port at the PC. The baud rate is the number of signal changes per second or transition speed between Mark (negative) and Space (positive) which range from 110 to 19200, data bits is the length of data in bit which has one least significant bit (LSB) and one most significant bit (MSB), the parity bit is an optional bit mainly for bit error checking. It can be odd, even, none Mark and Space. Stop bit is used to frame up the data bits and usually combined with the start bit. These bits are always represented by a negative voltage and can be 1, 1.5 and 2 stop bits. The commonly used setting to establish a serial RS232 communication is 9600 baud rate, none parity, 8 data bits, and 1 stop bit. As this paper relates with data collection, thus the data obtained from the microcontroller needs to be collected and saved. This can be done by using the GUI monitoring system where it automatically saves the data received in a note pad. The data being saved is the date and time during the data collected and data value it self. and , represents the graphical user interface and logged data in file

4. SOFTWARE DESIGN OF DATA LOGGER

This subsection includes the software design for all the modules interfaced with PIC 18F4458. It covers completesoftware design for data logger. The programs have been written to the environmental parameters and concentration level of SO₂ and NO₂ gases are monitored for 24 hours and save the data of EEPROM corresponding to the time and date.

4.1. Programming Steps for I2C Interface

I2C is also bi-directional. This is implemented by an “Acknowledge” system or “ACK” system allows data to be sent in one direction to one item on the I2C bus, than, that item will “ACK” to indicate the data was received.

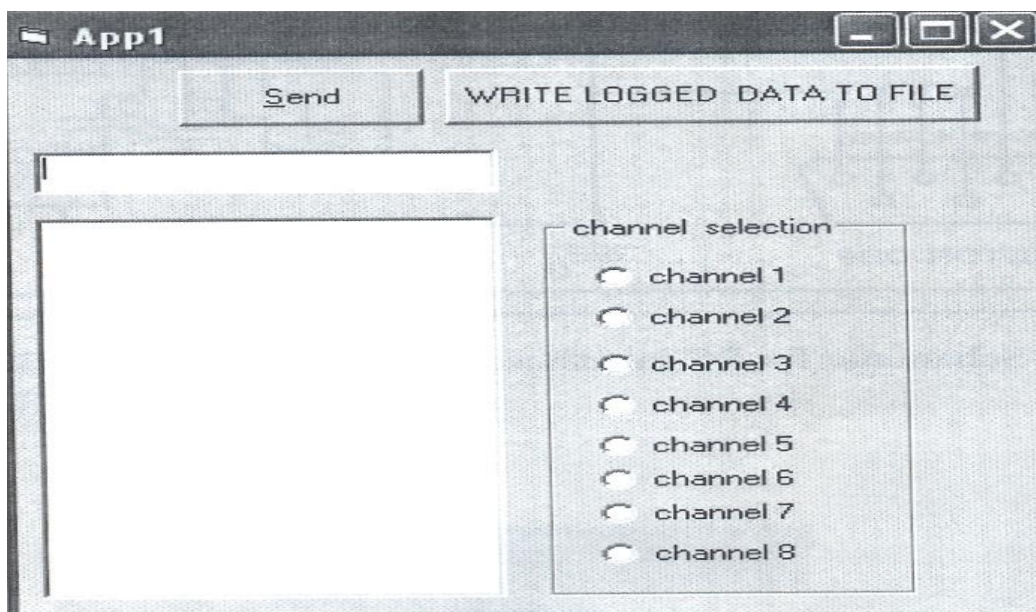


Figure 6.GUI for the data logger.

Date Time	Temp. (°F)	Temp. (°C)	RH (%)	so2 (ppm)	No2 (ppm)
06/01/09 06:00:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 06:10:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 06:20:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 06:30:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 06:40:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 06:50:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 07:00:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 07:10:00.0	89.48	31.93	49.04	0.022	0.004
06/01/09 07:20:00.0	89.48	31.93	49.04	0.024	0.004
06/01/09 09:10:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 09:20:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 09:30:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 09:40:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 09:50:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 10:00:00.0	88.74	31.52	48.32	0.025	0.004
06/01/09 10:10:00.0	89.48	31.93	49.04	0.025	0.004
06/01/09 10:20:00.0	89.48	31.93	49.04	0.025	0.004
06/01/09 10:30:00.0	89.48	31.93	49.04	0.025	0.004
06/01/09 10:40:00.0	89.48	31.93	49.04	0.025	0.009
06/01/09 10:50:00.0	89.48	31.93	49.04	0.027	0.009
06/01/09 11:00:00.0	89.48	31.93	49.04	0.027	0.009
06/01/09 11:10:00.0	89.48	31.93	49.04	0.027	0.009
06/01/09 11:20:00.0	90.22	32.34	49.78	0.027	0.009
06/01/09 11:30:00.0	89.48	31.93	49.04	0.027	0.009
06/01/09 11:40:00.0	90.22	32.34	49.78	0.027	0.009
06/01/09 11:50:00.0	90.22	32.34	49.78	0.030	0.009
06/01/09 12:00:00.0	90.22	32.34	49.78	0.030	0.009
06/01/09 12:10:00.0	90.22	32.34	49.78	0.030	0.009
06/01/09 12:20:00.0	90.22	32.34	49.78	0.030	0.010
06/01/09 12:30:00.0	90.22	32.34	49.78	0.030	0.010
06/01/09 12:40:00.0	90.22	32.34	49.78	0.030	0.010
06/01/09 12:50:00.0	90.22	32.34	49.78	0.030	0.010
06/01/09 13:00:00.0	90.22	32.34	49.78	0.030	0.010
06/01/09 13:10:00.0	90.96	32.76	50.54	0.030	0.010

Figure 6. Representation of the logged data in file.

Normally, the master device controls the clock line, SCL. This line dictates the timing of all transfers on the I2C bus. Other devices can manipulate this line, but they can only force the line low. This action means that item on the bus cannot deal with more data in to any device.

4.1.1. Writing to a I2C Chip

The function of writing to the EEPROM is shown here as “Control IN”, which represents putting the EEPROM in an “input” mode. Since we are only sending data to the EEPROM, we use the “Control IN” byte. We will use “Control OUT” later. Figure 7 shows the display of data saver memory (data writing of the memory). Next, the EEPROM acknowledges this byte; this is shown by the “A” after the byte. It is put on the next line to indicate this is transmitted by the EEPROM. Next the PIC microcontroller sends the address byte. The address byte contains the address of the location of the EEPROM; we want to write data. Since the address is valid the data is acknowledged by the EEPROM. Finally, we send the data we want to write. The data is then acknowledged by the EEPROM. When that finishes, we send a stop condition to complete the transfer. Remember the “STOP” is represented as the “T” block on the end. Once the EEPROM gets the “STOP” condition it will begin writing to its memory. The write will not occur until it receives the “STOP” condition.

4.1.2. Reading from an I2C Chip

The transfer will use the “Control IN” byte to load the address into the EEPROM. This sends data to the EEPROM which is why we use the “Control IN” byte. Once the address is loaded, we want to retrieve the data. So, we send a “Control OUT” byte to indicate to the EEPROM that we want data from it. The EEPROM will acknowledge this and then send the data we requested. When we are done getting data, we send a “NACK” to tell the EEPROM that we do not want more data. If we were to send an ACK at this point, we could get the next byte of data from the EEPROM. Since we only want to read one byte, we send a “NACK”. This is detailed in the specifications for the EEPROM. Figure 8 shows the display of outcome data saver memory (data reading and save outcome data in note pad form).

4.2. Programming Steps for Sensor Data Collection

There are connected four sensors temperature, humidity, SO2, and NO2. Data is collected by the ADC inbuilt in PIC. ADC provides 10 bit of data after the conversion is completed.

4.2.1 Data Collection of Sensor

Select the analog channel AN0, alignment of bits for ADRESH and ADRESL, sampling frequency, Vref, power on the ADC module by setting ADCON0, ADCON1 and ADCON2 registers. Start A to D

conversion by setting ADGO bit high and wait till ADIF flag will not indicate the completion of conversion and copy the results from ADRESH and ADRESL to variables.

4.2.2. Data Collection of Humidity Sensor

Select the AN3 and set other features of ADC as temperature sensor and after completion of conversion copies the result in variable.

4.2.3. Data Collection of NO2 and SO2 Sensor

Data collection from the NO2 sensor needs following actions to be carried out 1) Selecting the analog channel AN1, sampling frequency, and alignment of bits for ADRESH and ADRESL, 2) Vref and power on the ADC module by setting ADCON0, ADCON1 and ADCON2 registers, 3) starting analog to digital conversion by setting ADGO bit high (wait till ADIF flag will not indicate the completion of conversion), and 4) copy of results from ADRESH and ADRESL to variables. Now repeat the same process to collect the SO2 data on the channel number AN2.

5. RESULTS AND DISCUSSION

Sensors module, EEPROM, RTC, and LCD have been successfully interfaced to the microcontroller. EEPROM is successfully storing the logged data with time and date tag. The sensors data is being displayed on LCD module. A simple GUI has been designed to store a logged data to a text file, so that it can be analyzed further. The developed system is lowest cost and energy efficient system. The power consumption of the developed system is minimum (< 250 mA).

6. CONCLUSIONS

We have developed a low cost, 12 bit resolution data logger and successfully measured temperature, humidity, and concentration of SO2 and NO2 gases. The GUI designed gives a lucratively look to the functioning of data logger. Initial results of the data logger are encouraging and we are working on to improve the GUI model as well as the accuracy of data logger.

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