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Multipoint Temperature Data Logger and Display on PC through Zigbee using PSoC.

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Abstract: The vast potential of wireless sensor networks (WSN) is an emerging area of research in recent years. WSN consists of spatially distributed autonomous sensors to monitor the physical or environmental conditions like temperature, sound, pressure and to cooperatively pass their data through the network to the main location. The advantage of wireless sensor network is that they can be used with ease in the environment where wired system cannot be used or if used, are to be treated with caution. The WSN is built of nodes, may vary from few to several thousands. Each sensor node has typically several parts- radio transceiver with internal or external antenna, a microcontroller for interfacing with the sensors, energy source or battery. Zigbee is one of the latest and upcoming technologies in the field of WSN**.** In this paper we present the multipoint temperature monitoring using embedded PSoC microcontroller and Zigbee technology through a wireless data logger and display the temperature on the PC's screen.

Keywords: Multipoint temperature, Wireless sensor networks, Zigbee technology, PSoC microcontroller, LM35 sensor.

I. INTRODUCTION

Precise temperature measurement is fundamental for successful process operations in a variety of Industries. With the desired temperature requirements in every field of Social life, Industrial and agricultural productions, it's becoming more and more important for measuring and controlling the temperature. The temperature measuring system is widely applied in every field of social life, and the wireless transmission with convenience and low cost has been adopted [1].

Multipoint data logging is a method of automatic data capture where reading from a sensor is input at regular intervals. This data can then be processed to provide analysis of the environment. In Industries, plants and manufacturing units during certain hazards it is very difficult to monitor the parameters through wired communication systems and analog devices such as transducers. To overcome these problems we use wireless communication systems to monitor the parameters, so that we can take the necessary steps in worst cases. Also the logged data can be used to investigate the causes in case of a disaster, so that it can be avoided in the future.

In this paper, we present the measurement and transfer of temperature over every certain regular intervals of time using the temperature sensor LM35 and wireless communication technology, Zigbee. The rest of this paper is organized as follows: Section 2 describes the proposed system. The section 3 focuses on the System design. The section 4 includes the advantages and applications of the proposed system. Results and discussion are reported in section 5. Finally, section 6 summarizes the paper and presents the concluding remark, with scope for future work.

II. PROPOSED SYSTEM

A. Architecture overview

The block diagram of the proposed system for the transmitter and receiver are shown in fig. 1 and 2 respectively. The system consists of two parts. One is the transmitter part and another one is receiver part. Here the

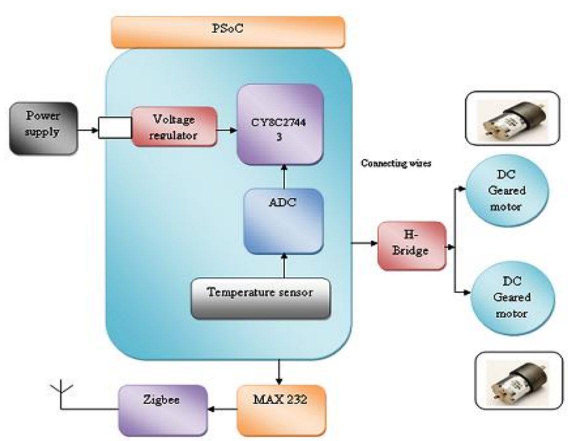

Fig. 1 Block diagram of transmitter

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Vol. 2, Issue 9, September 2013

Fig. 2 Block diagram of receiver

temperature is transmitted from the transmitter to the multiple receiver sections connected by the Zigbee receiver that are attached to different PC's [3].

To achieve this we are using the temperature sensor LM35, because in the real world the temperature is totally in the physical form or analog form. The temperature could also be measured using a thermistor but the LM35 sensor will give more accuracy and it generates a higher output voltage than thermocouples and may not require that the output voltage be amplified. The LM35 has three terminals. First terminal is Vcc (operating voltage of the temperature sensor that is +2.7V to 5.5V). The second terminal is the analog output voltage Vout and the third terminal is ground (GND). The analog output of the temperature sensor is given to the ADC (Analog to digital converter) that is inbuilt of the PSoC microcontroller. Thus the temperature is converted into digital form.

The total setup (PSoC+ Temperature sensor+ Zigbee transmitter+ Power supply unit+ DC geared motors+ H-bridge) is placed on a robot. The purpose of the robot is that it can move in different directions that are in forward, backward, left and right directions. To drive the robot we are using two DC geared motors each of 60 rpm each. To drive the DC geared motors we are using the driver device known as H-bridge. The purpose of the H-bridge is to drive the DC geared motors in different directions, by changing the polarities of the voltage. The H-bridge IC L293D is a 16 bit dual in line package. The entire assembly of the robot is balanced on two wheels and a caster wheel, which is a free moving ball which can move in any direction.

Basically the PSoC is a mixed signal array and it will be having both analog and digital signal blocks. The PSoC IC (CY8C27443) is a 28 pin dual in line package. In this we will be having 3 ports. In each port we will be having 8 I/O pins.. The operating voltage of the PSoC is 3.3V to 5.5V; a reset pin is there to reset the processor in case it gets hanged. The remaining pin is for the oscillator, the frequency of the crystal oscillator which is connected to the PSoC is 32KHz. Inbuilt of the PSoC are two types of memories ROM and RAM. The program code which is to be deployed is stored inside the ROM. The RAM stores temporary data during the execution of the program, and the temperature values which are to be transmitted are also buffered in the RAM.

The communication between the transmitter and receiver is done by wireless communication Zigbee. Alternatively we could have use Bluetooth but it can control seven devices at a time and its bandwidth is up to 1 Mbps, but the power consumption for the data transfer is on the higher side. Zigbee can control 254 devices at a time and has a data transfer rate of 250 kbps.

The mechanism of the Zigbee device for the data transfer is as follows. Zigbee devices communicate with each other in a particular packet format. Packet consists of Preamble bits, Sync word and CRC, which are inserted by the Zigbee transmitter and then at the receiver end removed by the receiver. Zigbee packet consists of data, which is then forwarded to the RS232 device by the receiver. When a particular amount of Preamble bits are sent, which are combination of ones and zeros, Zigbee transmitter sends a Sync word that is unique to the receiver. CRC (cyclic redundancy check) is generated by the transmitter for error purposes.

TABLE I.

ROBOT MOVEMENT CONTROL

Preamble Bits (1010.1010)	Sync Word	Data Field	CRC

Whenever a device wants to send a data packet, it has to check for channel. If the channel is idle, device can send a packet else it has to wait. If the receiver is full functional device (FFD) then transmitter can send the packet any time because its transceiver always remains ON. However if the receiver is reduced functional device (RFD) then there are chances that its transceiver is OFF to save power. So to avoid data loss all RFDs send a packet to their corresponding parent device as soon as their transceiver comes to ON position to get the data packet which was send to them when they were in sleeping mode. The entire process of data transfer can be described by the flowchart as shown in fig 4. Zigbee is implemented using OSI protocol (open system interconnections). The advantage of Zigbee is that the signals are secure as the data transmitted cannot be corrupted [6].

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Vol. 2, Issue 9, September 2013

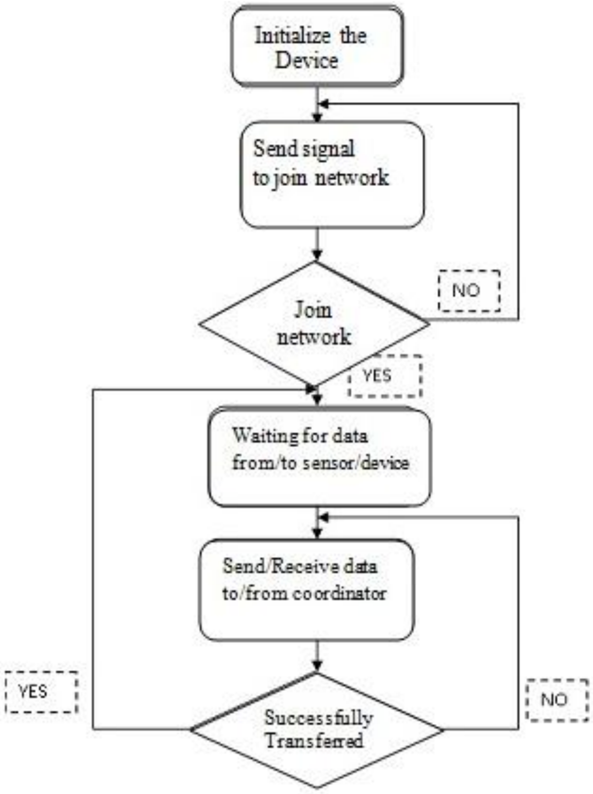

Fig. 4 Flow Chart showing working of Zigbee device.

In the receiver side we are using two or more Zigbee devices that are the Zigbee receivers so that the data can be wirelessly received and displayed on the PC. To allow compatibility among data communication equipment, an interfacing standard called RS232 is used, and to connect any RS232 to a microcontroller system, voltage converters such as MAX232 are used to convert the TTL logic levels to the RS232 voltage levels and vice versa. MAX232 is a specialized circuit which makes standard voltages as required by RS232 standards.

To ensure data transfer between PC and microcontroller, the baud rate and voltage levels of microcontroller and PC should be the same [1]. The voltage levels of microcontroller are logic1 and logic0 that is, logic1 is +5V and logic0 is 0V. But for PC, RS232 voltage levels are considered and they are: logic1 is taken as -3V to -25V and logic0 as +3V to +25V. So in order to equal these voltage levels, MAX232 IC is used, which converts RS232 voltage levels to microcontroller voltage levels and vice versa.

As the transmitter module (Robot) is switched ON, the Zigbee link is established between the Zigbee terminal that is the receiver which is connected to the PC serial port and the Zigbee transmitter which is placed on the Robot. The temperature values are transmitted to the PC over the serial cable in an encrypted manner to the hyper terminal. The GUI interface that is the hyper terminal window of the PC is set up to a baud rate of 9600bps, to receive the values. This hyper terminal logs the received values and displays it on the PC in real time. Once the values are received on the PC hyper terminal, the Robot can be moved in any direction by using the control keys that is the number keys of the PC. The robot moves in the manner as shown in table II.

TABLE II.

ROBOT MOVEMENT CONTROL

Sl.No	Number Key On The Keyboard	Robot Movement
1.	2	Forward
2.	4	Right
3.	6	Left
4.	8	Backward
5.	5	Stop

When the Robot moves the temperature sensor records the temperature values from the different sections of the location and the same values are logged to the PC hyper terminal. The photographic view of the transmitter circuit (robot) and receiver circuit is shown in fig 5.

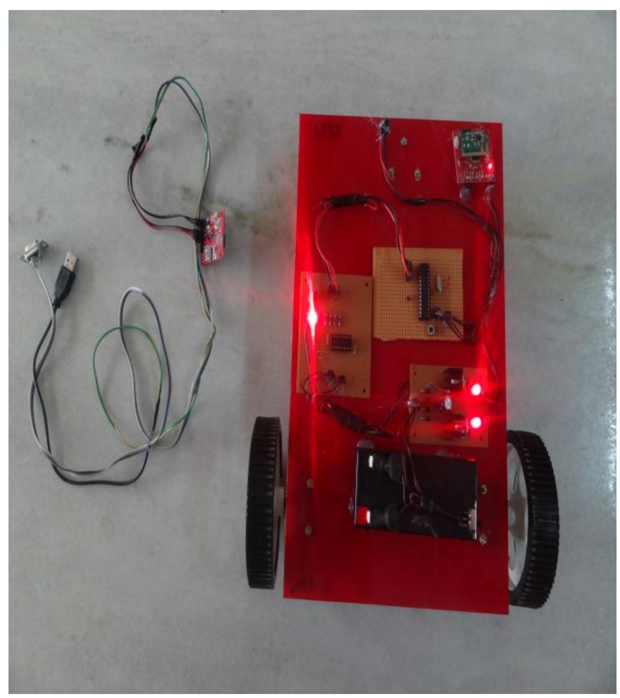

Fig 5 photographic view of the transmitter and receiver Circuit

B. Limitations

As the proposed system is using the temperature sensor LM35 for multipoint temperature measurement, it is suitable for remote applications and its range is restricted from -55º

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 9, September 2013

C to +150º C. So the sectors where the temperature is above +150º C, the proposed system is not feasible.

III. THE SYSTEM DESIGN

A. The Hardware design

The circuit schematic for the transmitter circuit and the receiver circuit is shown in fig. 6 and 7 respectively.

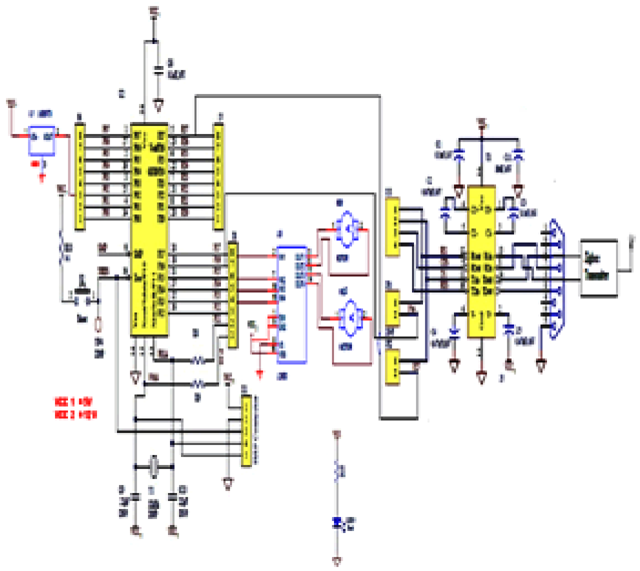

Fig. 6 Circuit schematic of Transmitter circuit

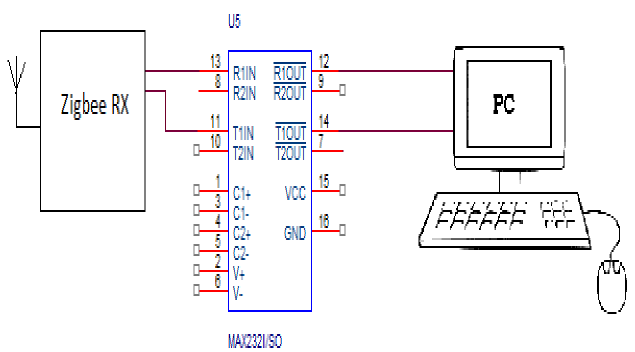

Fig. 7 Circuit schematic of Receiver circuit

B. The main controlling unit

The PSoC is a family of integrated circuits made by Cypress semiconductors. These chips include a CPU and a mixed signal arrays of configurable digital and analog peripherals [7]. With a unique array of configurable digital and analog blocks, the PSoC is a true system level solution, offering a modern method of signal acquisition, processing and control with exceptional accuracy, high bandwidth and superior flexibility. The PSoC chip CY8C27443 is adopted as the core microcontroller unit. The pin details of PSoC CY8C27443 device is shown in fig. 8 and the specifications are shown in table III.

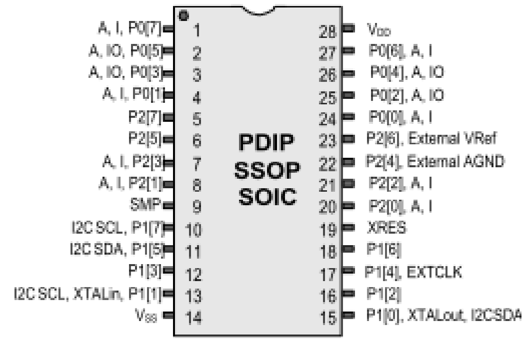

Fig. 8 CY8C27443 28-pin PSoC Device

TABLE III.

PSOC SPECIFICATION

Sl.No	Specifications
1.	Family name: PSoC 1
2.	Device core: M8C
3.	Program memory type: flash
4.	Flash size (bytes): 16 KB
5.	RAM size: 256 B
6.	Speed: 24 MHz
7.	No of I/O lines: 24
8.	Interface type/ connectivity: I2C/SPI/UART
9.	Peripherals: I2C/SPI/UART/Watchdog/PWM
10.	Supply voltage: 3 to 5.25V

B. Temperature measurement

Temperature is a physical property that finds its usefulness in every field of science, and also of great importance to mankind. For this utility of temperature in the day to day activities, its measurement is important. The temperature sensors are actually specific devices which are implanted, and surrounded by insulating materials. Analog temperature sensors are actually chips that record the surrounding temperature [4].

The temperature measurement is done by using the temperature sensor LM35. The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (centigrade)

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 9, September 2013

temperature [2]. The LM35 thus has an advantage over linear temperature sensors calibrated in º Kelvin. The LM35 does not require any external calibration or trimming to provide typical accuracies of ± 1/4º C at room temperature and ± 3/4º C over a full -55º C to +150º C temperature range. The LM35's low output impedance, linear output, and precise inherent calibration makes interfacing to readout or control circuitry especially easy. The LM35 is rated to operate over a -55º C to +150 º C temperature range [8]. The fig. 9 shows the connection diagram of LM35 sensor.

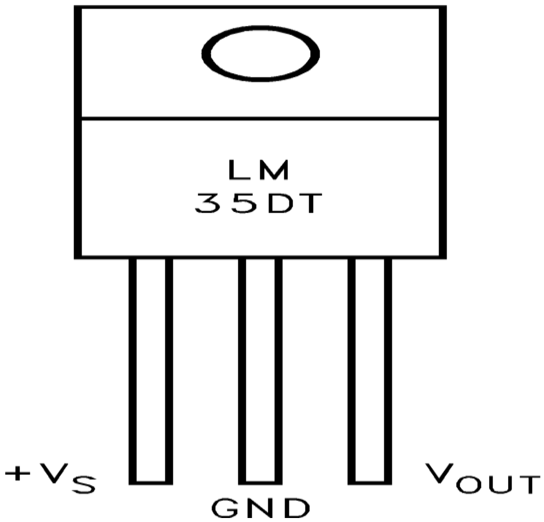

Fig. 9 LM35 connection diagram

C. *H-bridge*

An H-bridge is an electronic circuit which enables DC electric motors to run forwards or backwards. These circuits are often used in robotics. H-bridges are available as integrated circuits, or can be built from discrete components. H-bridge is an electronic power circuit that allows motor speed and direction to be controlled. Often motors are controlled from some kind of "brain" or microcontroller to accomplish a mechanical goal. The microcontroller provides the instructions to the motors, but it cannot provide the power required to drive the motors. An H-bridge circuit inputs the microcontroller instructions and amplifies them to drive a mechanical motor. The H-bridge takes in the small electrical signal and translates it into high power output for the mechanical motor.

The term "H-bridge" is derived from the typical graphical representation of such a circuit as shown in fig. 10

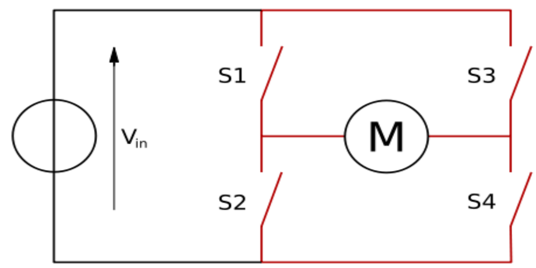

Fig. 10 General layout of H-bridge

An H-bridge IC L293D is used as the driver device for the system. The pin details of H-bridge IC L293D are shown in fig. 11

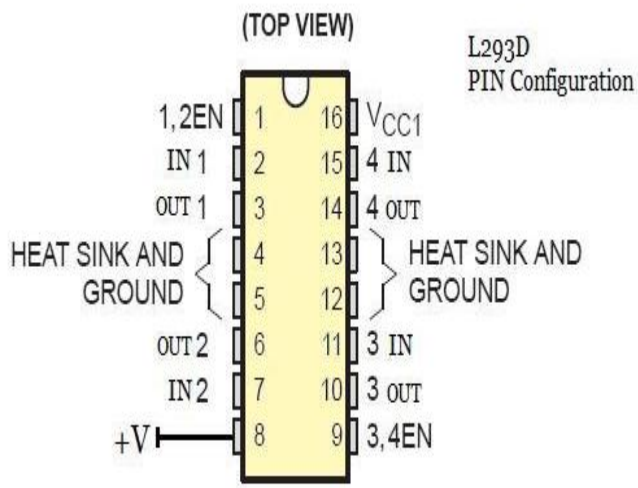

Fig. 11 Pin details of L293D.

D. *DC geared motors*

A geared DC motor has a gear assembly attached to the motor. The speed of the motor is counted in terms of rotations of the shaft per minute and is termed as RPM. The gear assembly helps in increasing the torque and reducing the speed.

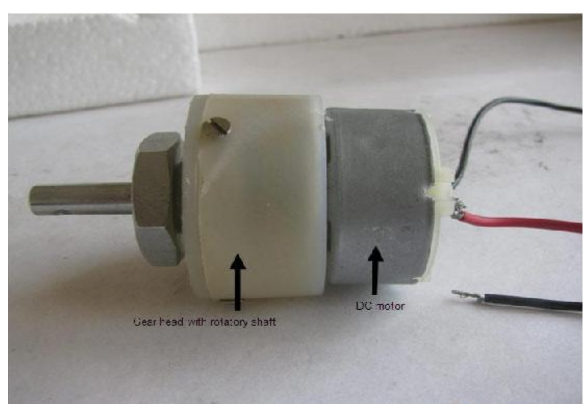

Fig. 12 DC geared motor.

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ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 9, September 2013

Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. A geared DC motor is as shown in fig. 12

Most DC motors can rotate in two directions depending on how the battery is connected to the motor. Both the DC motor and battery are two terminal devices that have positive and negative terminals. In order to run the motor in forward direction, connect the positive motor wire to the positive battery wire and negative to negative. However, to run the motor in reverse direction just switch the connections; connect the positive battery wire to the negative motor wire, and the negative battery wire to the positive motor wire.

The system adopts two DC geared motors of 60 RPM each. The specifications of the DC geared motor are as given in table IV.

TABLE IV.

DC GEARED MOTOR SPECIFICATIONS

Sl.No	Specifications	Dimensions
1	Gear box diameter	37mm
2	Motor diameter	28.5mm
3	Length without shaft	63mm
4	Shaft length	15mm
5	Weight	300gm
6	Torque	38kgcm
7	No load current	800mA (Max)
8	Load current	9.5 A (Max)

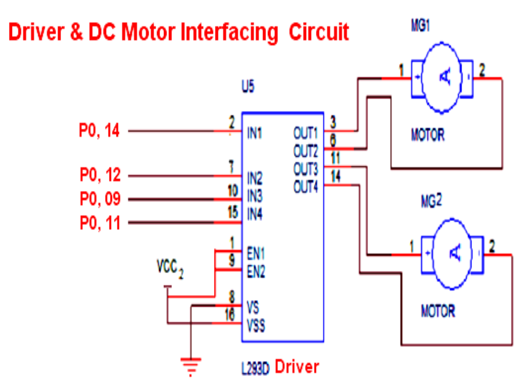

Fig. 13 Circuit schematic for H-bridge and DC geared motors interfacing

E. Wireless transmission

Zigbee is a protocol specification and industry standard for a type of wireless communication technology generally known as Low rate wireless personal area networks (LR-WPAN) based on the IEEE 802.15.4 standard. Zigbee is low cost, low power, wireless network standard. Low power usage allows longer life with small battery. Zigbee has been developed to meet the growing demand for capable wireless networking between numerous low power devices [3][5][6]. So it is widely deployed for wireless monitoring and control applications. The system adopts the Zigbee transceiver CC2520, operating at 2.4 GHz based on the IEEE 802.15.4 standard.

F. Power supply unit

To initiate the PSoC we need 5V DC and to initiate the DC geared motors we need 12V DC. For this we are using 12V, 1.3 ampere/hour DC lead acid battery. We are using 7805 voltage regulator. It steps down 12V DC to 5V DC. Alternatively we are also using 7812 voltage regulator to run the DC geared motors using the H-bridge. The entire power supply and regulator unit is called as regulated power supply unit (RPS). Similarly we are giving power supply to the Zigbee receiver module using the USB cable which is connected to the PC.

G. The Software design -PC hyper terminal program for Communication & display, and Communication protocol design

The PC is the upper layer of the wireless temperature transmission system. Using the PC as the main controlling machine, that is, through the number keys on the keyboard. The communication between the PC and the PSoC microcontroller is through COM1 port. The PC communicates with the PSoC microcontroller through the RS 232 serial communication interface using MAX 232. The function of the PC is calling all other functions of the system: the system basic information and communication parameter settings, real time temperature displaying. The use of wireless channel to communicate with the wireless terminals and the cable connection for the PC solves the adverse affects in wireless communication network due to the application environment. The system connects the serial port 2 of the PSoC microcontroller to the Zigbee transmitter through the communication with the terminal nodes; transmits the collected temperature data from the terminal nodes to the PC in real time.

In serial communication parameters such as serial number, baud rate, data bits and parity bits can be set. The communication protocol is for baud rate of 9600bps, no parity, 8 data bits and 1 stop bit. The type of data transmit is in binary format. Four bytes represent a temperature signal; the beginning and end are the parity bits, the second bytes for temperature decimal part and the third bytes for temperature integer part. The PC once after receiving four bytes gives the corresponding processing.

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 9, September 2013

IV. ADVANTAGES AND APPLICATIONS OF THE PROPOSED SYSTEM

A. *Advantages*

The system design has adopted temperature sensor LM35 with “1-wire” bus interface, several functional modules, components and a PC. The system constructed by digital signal and modular circuit hardware is highly integrated, solid structure, durable and hard to be damaged. The system shows high precision in real time temperature measurement and is easy to connect, less of serial port and less complicated. The system shows good performance, has lower power consumption and convenient usage. The output of the system is spontaneous and as we are using the digital modules, the system is insensitive to weather and environmental conditions. As we are using Wireless communication Zigbee technology, the range supported by Zigbee is much longer than other equivalent technologies like Bluetooth, WI-FI etc.

B. *Applications*

- In Industries

To operate any process efficiently, it is essential to measure, actuate record and control. Precise temperature measurement is fundamental for successful process operations in a variety of Industries. The proposed system with its short response time can meet the most demanding process requirements.

- In server room monitoring

The various servers, hard disks and routers located in server room form the heart of a modern company- when the network is down, the business is down. The proposed system can be designed to provide with an early warning should temperature in server room start to rise too high. Linked to the network via serial ports, devices can send the email alerts when the temperatures exceed a preset temperature limit.

- In Hospitals

Refrigerators and freezers where drug and lab samples are stored, the proposed system can be used for temperature logging. Incubators can also be monitored and historical data logs can be kept. Since the temperature sensor LM35 can record the low temperature ranges starting from -55°C, the proposed system can be easily implemented.

- In Museums and galleries

Paintings and artwork are quite sensitive to temperature. In some cases, curators can implement the proposed system in storage or display rooms or individual display cases to log ambient temperatures. It is important to understand the specific temperature requirements of each art work and configure the alert threshold accordingly to make sure that they are protected from conditions that can accelerate their decay. Humidity conditions are particularly important when working with artwork and paintings with wood frames.

- In environmental monitoring

Apart from general weather monitoring, the proposed system can be used to log temperatures over large areas particularly in labs where scientists and researchers need to maintain temperature ranges for specimens or experiments. Apart from that the proposed system can be used in temperature monitoring in glaciers, rain forests, mountains and Polar Regions where weather is extreme and locations are remote. Similarly the system can also be used for monitoring of rivers, lakes and soil temperatures.

V. RESULTS AND DISCUSSIONS

The experimental results were carried out under different environmental conditions in two different locations namely location 1 and location 2. The first one in location 1, that is in an M-tech Digital electronics room temperature with a distance span of 20 meters and the second one in location 2 that is, in an air conditioned room with a distance span of 20 meters. The following temperature values were recorded in degree Celsius and displayed on the PC screen through Zigbee wireless receiver.

A. *Discussions on result*

From the results we can observe that there is a difference in temperature values in two different locations. In the first case that is location 1, the temperature values that were displayed on the PC were according to the room temperature with slight variations in different sections of the room like when the module is near the Computer section, near professor cabin, at the exit door and just outside the room.
In the second case, that is location 2 we can observe that the temperature values that were displayed on the PC were according to the cooling effect of the air conditioner with some variations in different sections of the room like, when the module is very close to the AC, just close to the AC, far away from AC, and very far away from AC. As the module is traversing away from AC, an increase in temperature variation is observed.
The experimental results were carried out carefully. The selection and calibration of sensor are very important to improve the consistency of measurement and accuracy for the overall system. The results also show that higher efficiency is indeed achieved using the embedded system according to the requirement of the user.

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 9, September 2013

B. *Temperature display*

The real time multipoint temperature values are displayed on the PC screen using the PC hyper terminal program. Hyper terminal is a program that is used to connect to other computers, telnet sites, host computers etc. In the PC based projects, the output will be seen in the hyper terminal window. In the proposed system the temperature values will be displayed on the PC hyper terminal window using the following procedure.

The screenshot shown in fig. 14 shows how to start the hyper terminal program. To start the hyper terminal program click the Windows start button and follow the path programs.

Accessories => Communications => HyperTerminal.

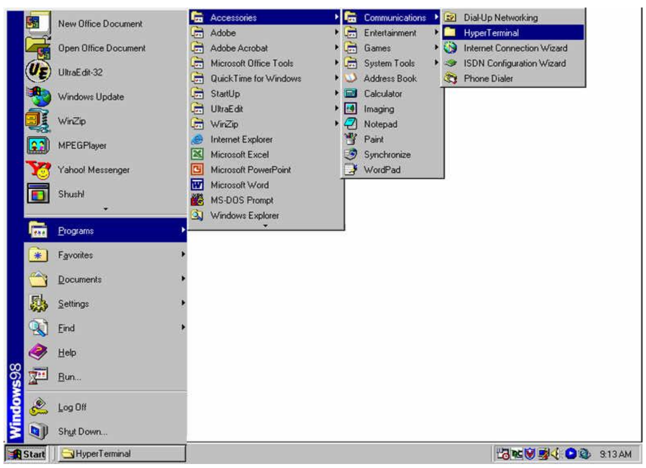

Fig. 14 Hyper terminal set up

The screenshot shown in fig. 15 shows that, after opening the hyper terminal program a window appears having a dialog box in which there is name block. In this block we have to enter any name or at least an alphabet to move for the next window. After this press ok, then another window appears as shown in fig. 16.

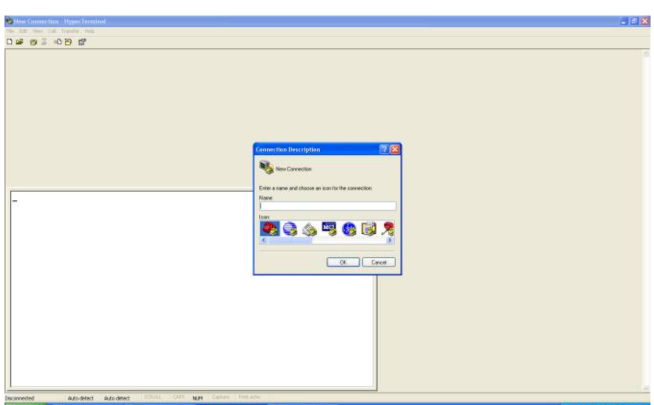

Fig. 15 Dialog box with name block

The screenshot shown in fig. 16 shows a window with a connection block. We will be having two options COM1 and TCP/IP protocol. The first option, COM1 is issued for communicating the PC with the microcontroller, whereas the second option TCP/IP protocol is used for communicating PC to PC. In the proposed system, the communication between the PSoC microcontroller and the PC is required. Therefore we need to select the COM1 option. After selecting COM1, press ok in order to move towards further window.

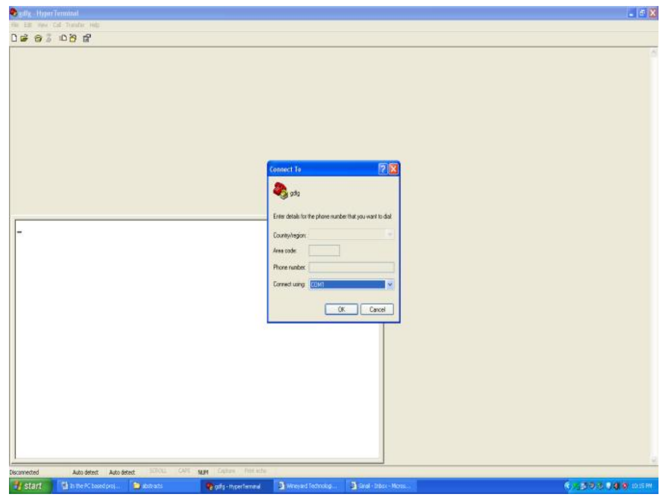

Fig. 16 Window with a connection block for using the COM port

The screenshot shown in fig. 17 shows the selection of baud rate. To ensure data transfer between PC and microcontroller, the baud rate of PC and microcontroller should be the same. By default the baud rate is 2400bps. We need to restore the defaults. Click on the restore defaults and press ok. The baud rate changes from 2400bps to 9600bps.

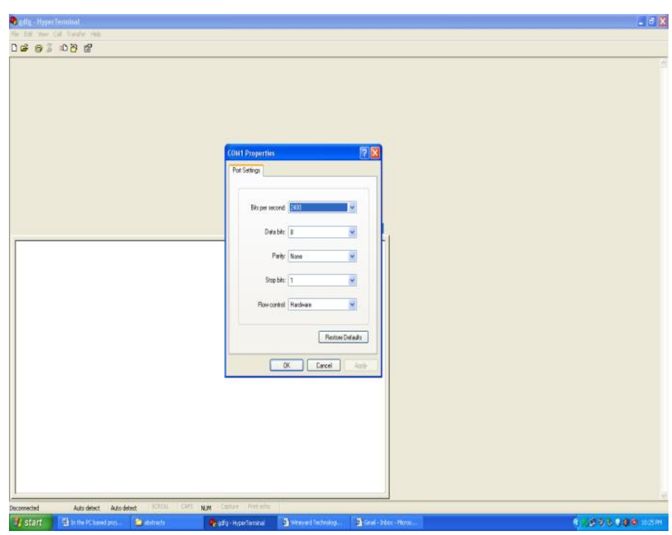

Fig. 17 Default baud rate of 2400bps changed to baud rate of 9600bps.

The screenshot shown in fig.18 shows the window in which the cursor will be blinking, this means the hyper terminal window has been activated or ready to perform. As the robot is switched "ON", the temperature values will be displayed on the PC hyper terminal

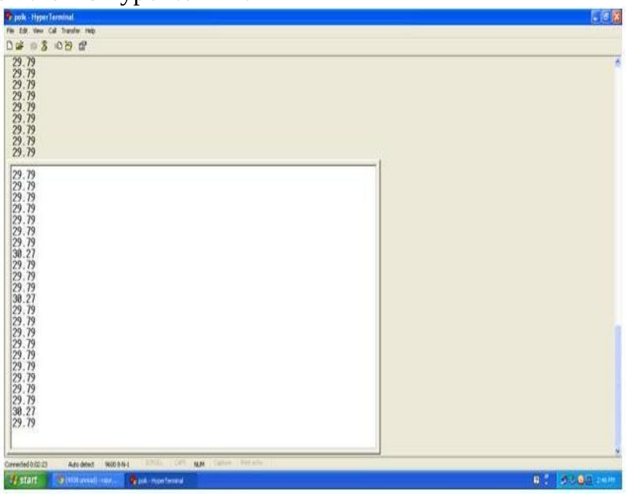

Fig. 18 Temperature values being displayed on the PC hyper terminal.

VI. Conclusion And Scope For Future Work

In this paper we present a new and precise temperature measurement system, by using wireless communication module, realizing wireless transmission is simpler but also low cost, high reliability, easy maintenance and less interference in transmission etc. In addition the system uses low power consumption through Zigbee using PSoC as control core, through its strong internal functional module and rapid information processing capability, the close environment temperature measurement is realized, saving energy, more economical and stable.

Zigbee based multipoint temperature data logger serves as a reliable and efficient system for effectively monitoring the temperature. Wirelessly monitoring of temperature not only allows the user to monitor and log the temperature but it also allows the user to take precautions before any disaster.

The proposed system can measure the temperature ranging from -55ºC to +150ºC. This is the main aspect that we can improve in our system. Temperatures that are too high cause excessive energy consumption. Only an accurate and robust high temperature measurement solution will satisfy the need for balance between quality and cost. So to meet the requirements of high temperature applications from +150ºC to as high temperature as 3000ºC, the proposed system can be implemented with temperature sensor Sensy temp TSH series. In future according to the need of the user the proposed system can be implemented with different temperature sensors.

Similarly the proposed system can be implemented for measuring the different parameters like pressure, viscosity, humidity, and sound and gas detection with the help of respective sensors.

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