# Design, Development & Implementation of a Temperature Sensor using Zigbee Concepts

T.C.Manjunath, *Ph.D.* ( *IIT Bombay* ) & Fellow IETE, Ashok Kusagur , Shruthi Sanjay, Saritha Sindushree, C. Ardil



***Abstract*—**This paper deals with the design, development & implementation of a temperature sensor using zigbee. The main aim of the work undertaken in this paper is to sense the temperature and to display the result on the LCD using the zigbee technology. ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and 2.4 GHz in most jurisdictions worldwide. The technology is intended to be simpler and cheaper than other WPANs such as Bluetooth. The most capable ZigBee node type is said to require only about 10 % of the software of a typical Bluetooth or Wireless Internet node, while the simplest nodes are about 2 %. However, actual code sizes are much higher, more like 50 % of the Bluetooth code size. ZigBee chip vendors have announced 128-kilobyte devices. In this work undertaken in the design & development of the temperature sensor, it senses the temperature and after amplification is then fed to the micro controller, this is then connected to the zigbee module, which transmits the data and at the other end the zigbee reads the data and displays on to the LCD. The software developed is highly accurate and works at a very high speed. The method developed shows the effectiveness of the scheme employed.

***Keywords*—**Zigbee, Microcontroller, PIC, Transmitter, Receiver, Synchronous, Blue tooth, Communication.

## I. INTRODUCTION

THIS section gives a brief introduction about the work, which describes all the components namely Zigbee, temperature sensor, PIC16F873. Zigbee is a wireless network protocol specifically designed for low data rate sensors and control networks. Also, a brief literature survey of the work related to the research topic is also presented in the following paragraphs.

T.C. Manjunath, a Ph.D. from IIT Bombay is currently, Professor & Head in Electronics and Communications Engg. Dept. of New Horizon College of Engg., Bangalore-87, Karnataka, India.
E-mail: tcmanjunath@rediffmail.com ; tcmanjunath@gmail.com.
Ashok Kusagur is currently, Assistant Professor in HMS Institute of Tech., in the department of E & C Engg., Tumkur, Karnataka,
C. Ardil is with the National Academy of Aviation, AZ 1056 Baku, Azerbaijan.

Zigbee is a consortium of software, hardware and services companies that have developed a common standard for wireless, networking of sensors and controllers. While other wireless standards are concerned with exchanging large amounts of data, Zigbee is for devices that have smaller throughout needs.

The other driving factors are low cost, high reliability, high security, low battery usage, simplicity and interoperability with other Zigbee devices. Compared to other wireless protocols, Zigbee wireless protocol offers low complexity. It also offers three frequency bands of operation along with a number of network configurations and optional security capability. It requires a supply voltage in the range of 2.8V to 3.3V. Hence, we design a power supply, which converts 230V to 3.3V. Here, we use a whip antenna to transmit the temperature sensed by LM35 temperature sensor to the receiving section. The LM35 series are precision integrated circuit temperature sensor whose output voltage is linearly proportional to the Celsius temperature [1].

The LM35 thus has an advantage over the linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The microcontroller used here is PIC16F873. It belongs to a class of eight-bit microcontrollers of RISC architecture & a Program Memory (FLASH) for storing a written program. Since the memory is made in FLASH technology, it can be programmed and cleared more than once & makes this microcontroller suitable for device development. It has inbuilt ADC and USART. In the receiving section, the temperature is displayed on $16 \times 2$ backlit LCD. If the temperature displayed exceeds 40 degree Celsius, then the buzzer goes on.

The paper is organized in the following sequence. A brief introduction about the work undertaken in this paper and the relevant literatures were presented in the previous paragraphs. Introduction about the microcontroller & its design is considered in the section 2. Section 3 depicts about the background literature about the temperature sensor. The transmitter & receiver part is presented in section 4. Section 5 describes about the zigbee concepts & its design. The design and development of the temperature sensor is presented in section 6. Working principle is presented in the next section. This is followed by the conclusions in section 8, followed by the references.

## II. Description about the Microcontroller

This section gives a brief idea about the PIC microcontroller, its advantages over microprocessors, its core features, block diagram, pin diagram and its description.

### A. *INTRODUCTION*

Circumstances that we find ourselves today in the field of microcontrollers had their beginnings in the development of technology of integrated circuits. This development had made it possible to store hundreds of thousands of transistors into one chip. That was a prerequisite for production of microcontrollers, and adding external peripherals such as memory, input-output lines, timers and other made the first computers. Further increasing of the volume of the package resulted in creation of integrated circuits. These integrated circuits contained both processor and peripherals. That is how the first chip containing a microcomputer, or what would later be known as a microcontroller came out [2].

### B. *MICROCONTROLLER VERSUS MICROPROCESSORS*

Microcontroller differs from a microprocessor in many ways. First and the most important is its functionality. In order for a microprocessor to be used, other components such as memory, or components for receiving and sending data must be added to it. In sort that means that microprocessor is the very heart of the computer. On the other hand, microcontroller is designed to be all of that in one. No other external components are needed for its application because all necessary peripherals are already built in to it. Thus, we save the time and space needed to construct devices.

### C. *PIC16F873*

It belongs to a class of eight bit microcontrollers of RISC architecture.

#### 1) *Program Memory (FLASH)*

This concept is used for storing a written program. Since memory is made use of in FLASH technology, it can be programmed and cleared more than once, it makes this microcontroller suitable for device development.

#### 2) *EEPROM*

It is that device wherein the data memory needs to be saved when there is no supply. It is usually used for storing important data that must not be lost if supply suddenly stops. For instance, one such data is an assigned temperature in temperature regulators. If during a loss of supply this data is lost, we would have to make the adjustment once again upon return of supply. Thus our device looses on self reliance.

#### 3) *RAM*

Data memory used by a program during its execution. In RAM are stored all inter-results on temporary data that are not crucial to running a device during a loss of supply.

#### 4) *PORTA, PORTB AND PORTC*

These are physical connections between the microcontroller and the outside world. PORTA has five pins, PORTB and PORTC has eight pins.

#### 5) *FREE TIMER*

It is an eight-bit register inside a microcontroller that works independently of the program. On every fourth clock of the oscillator, it increments its value until it reaches the maximum, and then its starts counting over again from zero. As we know the exact timing between each two increments of the timer contents, timer can be used for measuring the time, which is very useful with some devices.

#### 6) *CENTERAL PROCESSING UNIT*

It has a role of connective elements between other blocks in the microcontroller. It coordinates that work of other blocks and executes the user program.

### D. *CISC AND RISC*

It has already been said that PIC16F873 has RISC architecture. This term is often found in computer literature. Harvard architecture is a newer concept than von-Neumann's. It rose out of the need to speed up the work of a microcontroller. In Harvard architecture, data bus and address bus are separate. Thus, a greater flow of data is possible through the central processing unit, and of course, a greater speed of work. Microcontrollers with Harvard architecture are also called "RISC microcontrollers." RISC stands for reduced instruction set computer. Microcontrollers with von-Neumann's architecture are called as the "CISC microcontrollers". The title CISC stands for 'complex instruction set computer'. Since PIC16F873 is a RISC microcontroller that means that it has a reduced set of instructions, more precisely 35 instructions.

### E. *MICROCONTROLLER CORE FEATURES*

- High performance RISC CPU
- Only 35 Instructions to learn
- All Single cycle instructions except for program branches, which are two cycles
- Operating speed : DC-20MHz clock input
- DC-200ns instruction cycle
- Up to 8K × 14 words of FLASH program memory
- Up to 368 × 8 bytes of data memory (RAM)
- Up to 256 × 8 bytes of EEPROM data memory
- Power-on reset (POR)
- Power saving SLEEP mode
- Low-power, high-speed CMOS FLASH / EEPROM technology
- Wide operating voltage range: 2V TO 5.5 V
- Low power consumption:
- < 2mA typical @ 5V, 4MHz, 20μA typical @ 3V, 32 kHz, < 1μA typical standby current

### F. *PIN DIAGRAM*

The pin diagram of PIC16F873 is as shown in the Fig. 1.

### G. *DEVICE OVERVIEW*

PIC16F873 device comes in 28-pin package. This does not have a parallel slave port implemented.

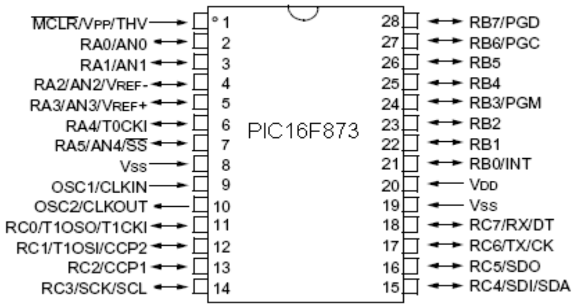
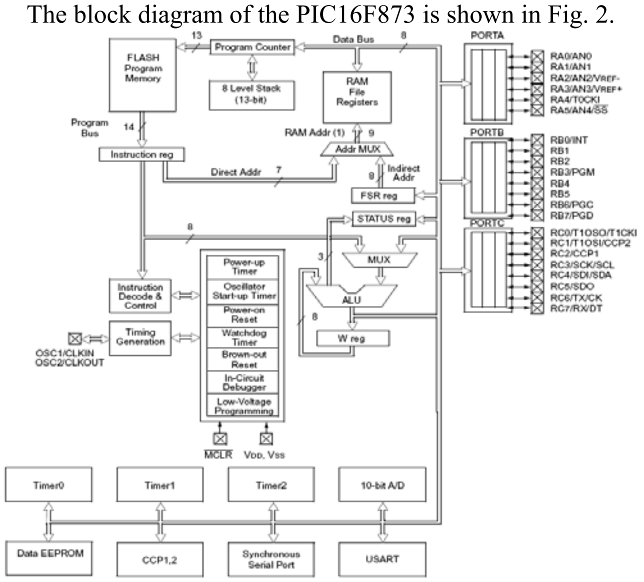



Fig. 1 Pin details of PIC μC

### H. PIC16F873 BLOCK DIAGRAM

The block diagram of the PIC16F873 is shown in Fig. 2.




| Device | Program FLASH | Data memory | Data EEPROM |
|---|---|---|---|
| PIC16F873 | 4K | 192 Bytes | 128 Bytes |

Fig. 2 Block diagram of the PIC16F873 microcontroller

### İ. STATUS REGISTER

The STATUS register contains the arithmetic status of the ALU, the RESET status and the bank select bits for data memory. The STATUS register can be the destination for any instructions, as with any other register. If the STATUS register is the destination for any instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the TO and PD bits are not writable, therefore, the result of an instruction with the STATUS register as destination may be different intended. For example, CLRF STATUS will clear upper three bits and set the Z bit. This leaves the STATUS register as 000u u1uu (where *u* = uncharged). It is recommended, therefore, that only BCF, BSF, SWAPF and MOVWF instructions are used to after the STATUS register, because these instructions do not affect the Z, C or DC bits from the STATUS register. For other "instructions set summary."

### J. OPTION_REG REGISTER

The OPTION_REG register is a readable and writable register, which contains various control bits to configure the TMRO pre-scaler / WDT post-scaler (single, assignable register known also as pre-scaler), the external INT interrupt TMRO and the week pull-ups on PORTB. The detailed description about each bit of status register and option register is also studied prior to the design [3].

### K. MEMORY ORGANIZATION

There are three memory blocks in PIC16F873. The program memory and data memory has separate buses so that concurrent access can occur and is detailed in this section.

### L. Program memory organization

PIC16F873 have program counter capable of addressing an 8K × 14 program memory space. The reset vector is at 0000h and the interrupt vector is at 0004h.

### M. Data memory organization

The Data Memory is partitioned in to multiple banks, which contain the general- purpose register and special function register bits RP1 (STATUS <6>) and RP0 (STATUS <5>) are the bank select bits as shown in the table 1.

TABLE 1 REGISTER BANKS

| RP1 : RP0 | Bank |
|---|---|
| 00 | 0 |
| 01 | 1 |
| 10 | 2 |
| 11 | 3 |

### N. PROGRAM MEMORY MAP AND STACK

The program memory map and stack organization with its addresses was also studied in brief prior to the design of the temperature sensor. It consisted of 8 stack levels. The on chip program memory was divided into pages. The program memory address ranges from 0000h to 1FFFh. When a call instruction is executed, the address of the next instruction will be stored into the stack memory. The stack works on first in first out manner. After the return instruction is executed, the address stored in the stack is retrieved and loaded back into the program memory.

## III. BACKGROUND LITERATURE SURVEY ABOUT THE TEMPERATURE SENSOR

This section gives a brief information about the temperature sensor LM35, its connection diagram and its features.

### A. GENERAL DESCRIPTION

The LM35 series IC's are precision integrated circuit temperature sensors whose output voltage is linearly proportional to the Celsius temperature. The LM35 thus has an advantage over the linear temperature sensors calibrated in

Kelvin as the as the user is not required to subtract a large constant voltage from its output to obtain convent centigrade scaling. The LM35 does not require any external calibration to provide typical accuracies of + or – ¼°C at room temperature and + or – ¾°C over a full –55 to +150°C temperature range.

The LM35's low output impedance linear output and precise inherent calibration make interfacing to readout or control circulatory especially easy. It can be used with single power supplies, or with plus and minus supply; it has very low self-heating less than 0.1 degrees Celsius in still air. The LM35 is rated to operate over a –55° to +150°C temperature range, while the LM35 is rated for a –40° to +110°C range. The LM35 series is available packaged in hermetic TO-46 transistor packages. The LM35D is also available in an 8 lead surface mount small outline package and a plastic TO-220 package.

### *B. FEATURES*

Calibrated directly in °Celsius (centigrade).
Linear + 10.0 m V / °C scale factor.
0.5° C accuracy guarantee able (at +25° C).
Rated for full -55° to +150° C range.
Operates from 4 to 30 volts.
Low self-heating, 0.08°C in still air.
Low impedance out put, 0.1Ω for 1 mA load.

### *C. CONNECTION DIAGRAM*

The connection diagram for LM35 packages is shown in Fig. 3. Here we are using TO-220 plastic package temperature sensor. It has three leads namely +Vs, ground and $V_{out}$.

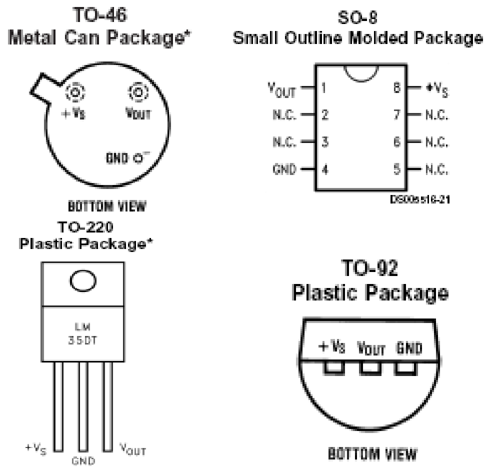



Fig 3 LM35 Connection diagram

ABSOLUTE MAXIMUM RATINGS
Supply voltage +35V to 0.2V
Output voltage +6V to −1V
Output current 10 mill amperes

STORAGE TEMPERATURE
TO 46 package −60° C to +180° C
TO 92 package − 60° C to +150° C
SO-8 package −65° C to +150° C
TO-220 package −65° C to +150° C
LEAD TEMPERATURE
TO-46 package 300°C
TO-92 and TO-220 package 260°C
Vapor phase 215°C
Infra red 220°C

## IV. UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER AND TRAMSMITTER

This section gives a brief description of the USART and the registers used for its operation at the transmitter and receiver section. The universal synchronous asynchronous receiver and transmitter (USART) module is one of the two serial input or output modules. USART is also known as a serial communications interface or SCI. The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices such as analog to digital or digital to analog integrated circuits. The USART used here is inbuilt in the PIC microcontroller. The USART can be configured in the following modes [4].

Asynchronous (full duplex)
Synchronous-master (half duplex)
Synchronous - slave (half duplex)

The registers used in the operation of USART are

- TXSTA (TRANSMIT CONTROL AND STATUS REGISTER)
- RCSTA (RECEIVE CONTROL AND STATUS REGISTER)
- The TXSTA is used to control the transmission of data.
- The RCSTA is used to control the reception of data.

### *A. REGISTERS*

TXSTA transmit status and control register (Add 98h) was also studied from the data manuals. RCSTA receive status and control register (Add 18h) was also studied from the data manuals.

### *B. USART BAUD RATE GENERATOR* (*BRG*)

Baud rate supports both asynchronous and synchronous moods of the USAIT. The SPBRG register controls the period of a free running 8-bit timer. In asynchronous mode, bit BRGH (TXSTA <2>) also controls the baud rate. In asynchronous mode, bit BRGH is ignored.

TABLE II BAUD RATE TABLE

| SYNC | BRGH = 0 (Low Speed) | BRGH = 1 (High Speed) |
|---|---|---|

| | | |
|---|---|---|
| 0 | (Asynchronous) Baud rate = Fosc / (64(X+1)) | Baud rate =Fosc/(16(X+1)) |
| 1 | (Synchronous) Baud rate = Fosc / (4(X+1)) | NA |

Given the desired baud rate and FOSC, the nearest integer value for the SPBRG registers can be calculated using the formula shown in the table. From this, the error is baud rate can be determined. The table 2 gives the formula to calculate the Baud rate.

*C. USART ASYNCHRONOUS MODE*

In this mode, the USART uses standard non-return to zero (NRZ) format (one start bit, eight or nine data bits and one stop bit). The most common data format is eight bits. The USART transmits and receives the LSB first. The USART'S transmitter and receiver are functionally independent; but use the same data format and baud rate. Asynchronous mode is stopped during SLEEP. Asynchronous mode is selected by clearing bit synchronous (TXSTA<4>).

*D. USART ASYNCHRONOUS TRANSMITTER*

The USART transmitter block diagram is as shown in Fig. 4. The heart of the transmitter is the transmit (serial) shift register (TSR). The shift register obtains its data from the read / write transmit buffer, TXREG. The TXREG register is loaded with data in soft wear. The TSR register is not loaded until the STOP bit has been transmitted from the previous load. As soon as the stop bit is transmitted the TSR is loaded with new data from the TXREG register (if available).

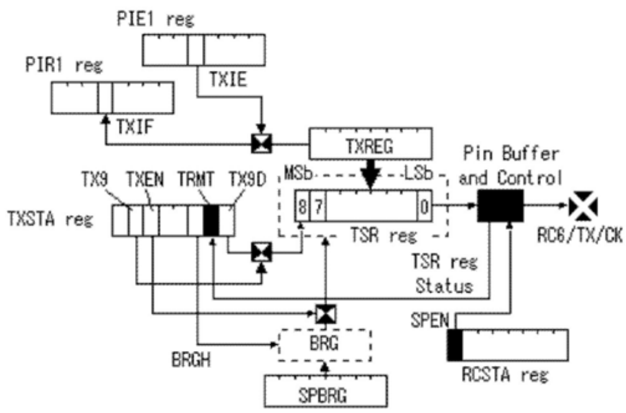



Fig. 4 USART asynchronous transmitter

Once the TXREG registers transfers the data to the TSR register (occurs in 1 T cycle), the TXREG register is empty and flag bit TXIF (PIR1 <4>) is set. This interrupt can be enabled / disabled by setting / clearing enable bit TXIE (PIE1<4>). flag bit TXIF will be set regardless of the state of enable bit TXIE and cannot be cleared in software.

It will reset only when new data is loaded in to the TXREG register while the flag bit TXIF indicates the states of the TXREG register, another bit TRMT (TXSTA<1>) shows the status of the TSR register. Status bit TRMT is a read only bit, which is set when the TSR register is empty.

Note that the TSR register is not mapped in data memory so it is not available to the user. Flag bit TXIF is set when enable bit TXEN is set. TXIF is cleared by loading the TXREG.

Transmission is enabled by setting enable bit TXEN (TXSTA<5>).The actual transmission will not occur until TXREG register has been loaded with data and the baud rate generator (BRG) has produced a shift clock. The transmission can also be started by first loading the TXREG register and then setting enable bit TXEN. Normally, when transmission is first started, the TSR register is empty. At that point, transfer to the TXREG register will result in an immediate transfer to TSR, resulting in an empty TXREG [5].

A back-to-back transfer is thus possible. Clearing enable bit TXEN during a transmission will cause the transmission to be aborted and will reset the transmitter. As a result, the RC6 / TX / CK pin will revert to hi-impedance. In order to select 9-bit transmission, transmit bit TX9 (TXSTA <6>) should be set and the ninth bit should be written before writing the 8-bit data to the TXREG register. This is because of a data write to the TXREG register can result in an immediate transfer of the data to the TSR register (if the TSR is empty). In such a case, an incorrect ninth data bit may be loaded in the TSR register.

*E. STEPS FOLLOWED IN ASYNCHRONOUS TRANSMISSION*

- Initialize the SPBRG register for the appropriate baud rate. If a high speed baud rate is desired, set bit BRGH.
- Enable the asynchronous serial port by clearing bit synchronous and setting bit SPEN.
- If interrupts are desired, then set enable bit TXIE.
- If 9-bit transmission is desired, then set transmit bit TX9.
- Enable the transmission by setting bit TXEN, which will also set bit TXIF.
- If 9-bit transmission is selected the ninth bit should be loaded in bit TX9D.
- Load data to the TXREG register (starts transmission)

*F. USART ASYNCHRONOUS RECEIVER*

The receiver block diagram is as shown in the Fig. 5. The data is received on the RC7 / RX / DT pin and drives the data recovery block. The data recovery block is actually high speed shifter operating at × 16 times the baud rate, where as the main receive serial shifter operates at the bit rate or at FOSC. Once asynchronous mode is selected, reception is enabled by setting bit CREN (RCSTA <4>). The heart of the receiver is the receive (serial) the received data in the RSR is transferred to the RCREG register (if it is empty). If the transfer is complete, flag bit RCIF (PIR1<5>) is set.

The actual interrupt can be enabled / disabled by setting/clearing enable bit RCIE (PIE1<5>) flag bit is a read only bit which is cleared by the hardware. It is cleared when the RCREG register has been read and is empty. The RCREG is a double-buffered register (i.e., it is a two deep FIFO). It is possible for two bytes of data to be received and transfer RCREG FIFO and the third byte to begin shifting RSR register. On the detection of the STOP bit of the third byte, if the RCREG register is still full, the over run error bit OERR (RCSTA <1>) will be set.

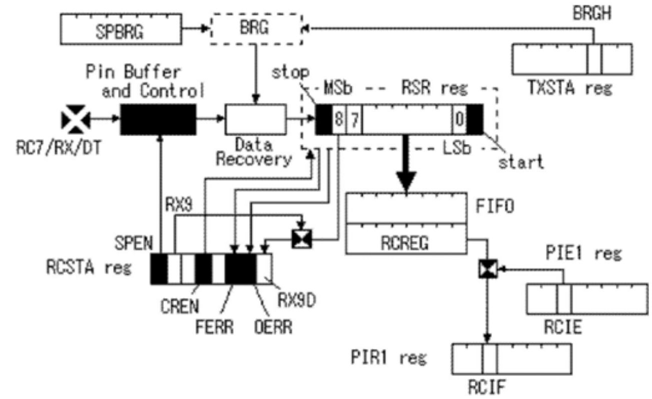



Fig. 5 USART asynchronous receiver

The word in the RSR will be lost. The RCREG register can be read twice to retrieve the two bytes in the FIFO. Overrun bit OERR has to be cleared in software. This is done by resetting the receive logic (CREN is cleared and then set). If bit OERR is set, transfers from the RSR register to the RCREG register is inhibited, so it is essential to clear error bit OERR if it is set. Framing error bit FERR (RCSTA <2>) is set if a stop bit is detected as clear. Bit FERR and the ninth receiver bit or buffer the same way as the receive data. Reading the RCREG will load bit RX9D and FERR with new values therefore it is essential for the user to read the RCSTA register before reading RCREG register in order not to lose the old FERR and RX9D information.

### *G. STEPS FOLLOWED IN ASYNCHRONOUS RECEPTION*

- Initialize the SPBRG register for the appropriate baud rate. If a high speed baud rate is desired set bit BRGH.
- Enable the asynchronous serial port by clearing bit SYNC and setting bit SPEN.
- If interrupts are desired, then set enable bit RCIE.
- If 9-bit reception is desired, then set bit RX9.
- Enable the reception by setting bit CREN.
- Flag bit RCIF will be set when reception is complete and an interrupt will be generated if enable bit RCIE is set.
- Read the RCSTA register to get ninth bit (if enable) and determine if any error occurred during reception.
- Read the 8-bit received data by reading the RCREG register.
- If any error occurred, clear the error by clearing enable bit CREN.

## V. CONCEPTS OF ZIGBEE DESIGN

This section gives the information about Zigbee, which is the major component used, its characteristics and its working, differences between Blue tooth and Zigbee, different topologies used to form the network and the applications of Zigbee

### *A. INTRODUCTION TO ZIGBEE*

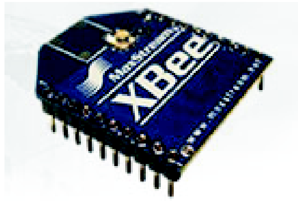



Fig. 6 ZIGBEE chip

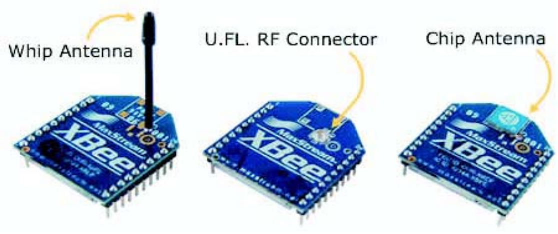
Zigbee is a wireless network protocol specifically designed for low data rate sensors and control networks as shown in Fig. 6. Zigbee is a consortium of software, hardware and services companies that have developed a common standard for wireless, networking of sensors and controllers. While other wireless standards are concerned with exchanging large amounts of data, Zigbee is for devices that have smaller throughout needs. The other driving factors are low cost, high reliability, high security, low battery usage, simplicity and interoperability with other Zigbee devices [6].

Compared to other wireless protocol that Zigbee wireless protocol offers low complexity. It also offers three frequency bands of operation along with a number of network configurations and optional security capability. In health care, Zigbee can be used for patient monitoring process control, assuring compliance with environmental standards and energy management. Used correctly, Zigbee enabled devices can give a warning before a breakdown occurs so that repairs can be made in the most cost effective manner. They will be used for controlling our home entertainment systems, lights, garage door openers, alarms, panic buttons and many other uses.

### *B. DIFFERENCE BETWEEN BLUETOOTH AND ZIGBEE*

Zigbee looks rather like blue tooth but is simpler, has a lower data rate and spends most of its time in snoozing. This characteristic means that a node on a Zigbee network should be able to run for six months to two years on just two AA batteries. The operational range for it is 10 to 75 meters compared to 10 meters for blue tooth (without a power amplifier). Zigbee sits below blue tooth in terms of data rate. The data rate of Zigbee is 250 kbps at 2.4 GHz 40 kbps at 915 MHz and 20 kbps at 868 MHz where as that of blue tooth is 1 Mbps.

Zigbee uses a basic master slave configuration suited to static star networks of many infrequently used devices that talk via small data packets. It allows up to 254 nodes. Blue tooth protocol is more complex since it is geared towards handling voice, images and file transfers in ad hoc networks, blue tooth devices can support scatter nets of multiple smaller non synchronized networks. It only allows up to 8 slave nodes in a basic master slave Pico net setup. When Zigbee node is powered down, it can wake up and get a packet in around 15 milliseconds where as a blue tooth device would take around 3 seconds to wake up and respond.



(a) (b) (c)

Fig. 7 Antenna types for Zigbee

### C. HOW DOES ZIGBEE WORK ?

Zigbee hardware typically consist of an eight bit microcontroller combined with a miniature transceiver a small amount (example 32 KB) of flash memory and RAM. Most of the Zigbee stack is provided in ASIC. Zigbee operates with ISM 2.4 GHz frequency band and is pin for pin compatible with maxstream's Zigbee product.

There are three radio frequencies used for Zigbee radio frequency communications 2.4 GHz with 16 channels and a data rate of 250 kbps for world wide coverage, 868 MHz with a single channel and a data rate of 20 kbps in Europe and 915 MHz with 10 channels and a data rate of 40 kbps in America. For comparison even at 250 kbps the data throughput is only about one tenth that of blue tooth.

Another wireless networking solution but more than sufficient for monitoring and controlling usage. Broadcast range for Zigbee is approximately 70 meters. Theoretically Zigbee networks can contain up to 64 k (65,536) network nodes. Current testing has not reached anywhere near that level. The name zigbee is said to come from the domestic honeybee, which uses a zigzag type of dance to communicate important information to other hive members.

### D. DIFFERENT TYPES OF ANTENNA OF ZIGBEE

The 3 different antennas for Zigbee are as shown in the Fig. 7 such as the Whip antenna, UFL RF connector & the Chip antenna. The chip and integrated whip antennas are suited for any application, but are especially useful in embedded applications. Since the radios do not have any issue radiating through plastic cases or housings, the antennas can be completely enclosed in those types of applications.

The UFL Connector is used in conjunction with an adaptor cable that can be connected to a dipole or gain antenna if the housing is metal or if that solution is more desirable mechanically. Range can differ somewhat with different antenna types, so that should be a consideration when choosing what type of antenna you want to use.

### E. *Different types of topologies*

The three types of topologies that Zigbee supports are shown in Fig. 8 such as the Star topology, Peer to peer topology & the Cluster tree.

#### 1) STAR TOPOLOGY

In the star topology, the communication is established between the devices and a single central controller called PAN coordinator. The PAN coordinator may be mains powered while the devices will most likely be battery powered. Applications that benefit from this topology include home automation, personal computer (PC) peripherals, toys and games. After an FFD is activated for the first time it may establish its own network and become the PAN coordinator. Each star network chooses a PAN identifier, which is not currently used by any other network within the radio spear of influence. This allows each star network to operate independently.

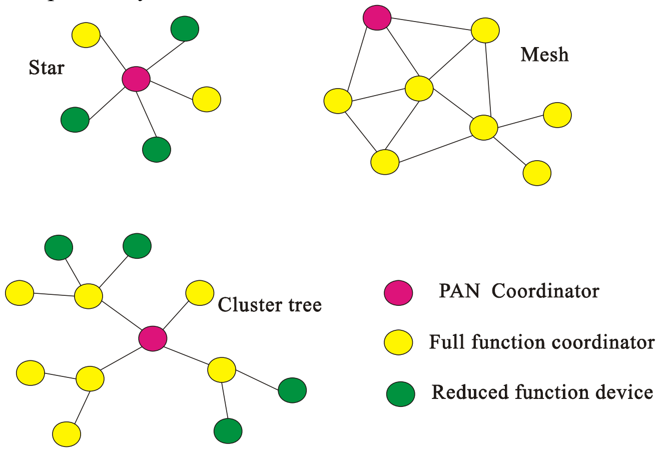



Fig. 8 Different Network Topologies

#### 2) PEER TO PEER TOPOLOGY

In the Peer-to-Peer topology, there is also one PAN coordinator. In contrast to star topology, any device can communicate with any other device as long as they are in range of one another. A Peer-to-Peer network can be adhoc, self-organizing and self-healing. Applications such as industrial control and monitoring, wireless sensor networks assert and inventory tracking wood benefit from such a topology. It also allows multiple hope to root massages from any device to any other device in the network. It can provide reliability by multipath rooting.

#### 3) CLUSTER TREE TOPOLOGY

Cluster tree network is special case of Peer-to-Peer network in which most devices are FFD's and an RFD may connect to a cluster tree network as a leave node at the end of a branch. Any of the FFD can act as a coordinator and provide synchronization services to other devices and coordinators.

Only one of this coordinator however is the PAN coordinator. The PAN coordinator forms the first cluster by establishing itself as the cluster head (CLH) with a cluster identifier (CID) of zero, choosing an unused PAN identifier, and broadcasting beacon frames to neighboring devices. A candidate device receiving a beacon frame may request to join the network at the CLH.

If the PAN coordinator permits the device to join it will add this new device as a child device in its neighbor list. The newly joined device will add the CLH as its parent in its neighbor list and begin transmitting periodic beacons such that other candidate devices may then join the network at that device. The advantage of this clustered structure is the increased coverage area at the cost of increased message latency.

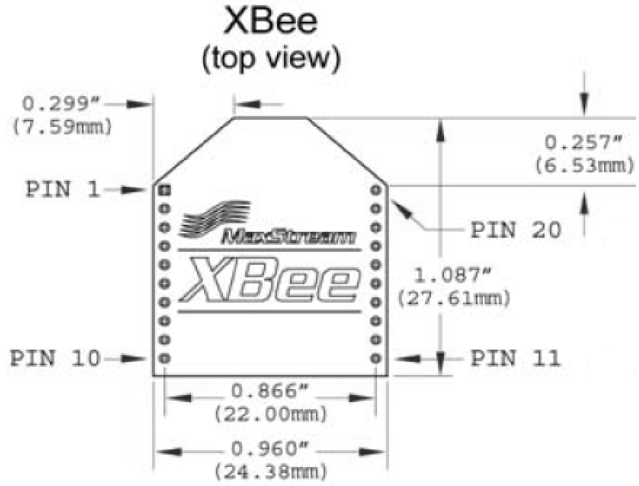



Fig. 9 Top View of Zigbee

### F. PRODUCT SUMMARY

- ISM 2.4 GHz operating frequency.
- 1 milli watt (0dBm) power output (up to 100 m range).
- U.FL RF connector, chip or whip antenna options.
- Industrial (-40 to 85 degree Celsius) temperature rating.
- Approved for use in the United States, Canada and Europe.
- Advanced networking and low power modes supported.

### G. TOP VIEW OF ZIGBEE

The top view of the Zigbee is as shown in the Fig. 9.

### H. PERFORMANCE, NETWORKING, POWER, GENERAL AND PHYSICAL PROPERTIES OF ZIGBEE & KEY FEATURES

- Price to performance value.
- Low power consumption.
- Receiver sensitivity.
- Worldwide acceptance in USA, CANADA & EUROPE.

Systems that contain Zigbee modules can operate under the certifications obtained by maxstream. Further testing is not required.

### İ. RANGES FOR ZIGBEE

Indoor / urban range up to 100′ (30m)
Outdoor line-of-sight range up to 300′ (100m)
Transmit power output 1mw (0dBm)
Power – down current <10µA
Operating frequency 2.4 GHz

### J. ZIGBEE ALSO OFFERS

Low power consumption : optimized for low battery operation.

License free operation in the 2.4GHz band.

Simple protocol definition – can be implemented on low – cost micro controllers.

Hundreds of devices per network.

Network flexibility – star, cluster tree or mesh configuration.

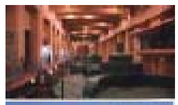
Data rate up to 250 kbps.

Small size – The developed solution will be less than 9mm X 9mm.

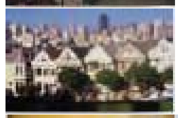
### K. APPLICATIONS OF ZIGBEE

There are a number of applications that can benefit from the Zigbee protocol: Building automation networks, home security systems, industrial control networks, remote metering and PC peripherals are some of the many possible applications.

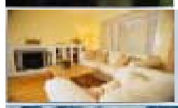
Security systems and lighting controls.



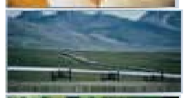
Home automation and building control.



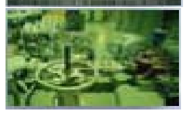
Home appliances and fire alarms.



Monitoring of remote systems.



Sensor data capture in embedded networks.



## VI. DESIGN OF TEMPERATURE SENSOR UNIT

This section gives a brief description about the design, implementation & operation of the different components used for the design and fabrication of temperature sensor unit, namely ADC, power supply, amplifier and LCD.

### A. ANALOG TO DIGITAL CONVERTER MODULE

The analog to digital converter module has five inputs for the 28-pin devices. The analog input charges a sample and hold capacitor. The output of the sample and hold is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The analog to digital conversion of the analog input signal results in a corresponding 10-bit digital number. The analog to digital converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in SLEEP mode, the analog to digital clock must be derived from the analog to digital internal RC oscillator. The A/D module has four registers. These registers are

1. A/D result high register (ADRESH)
2. A/D result low register (ADRESL)
3. A/D control register 0 (ADCON0)
4. A/D control register 1 (ADCON1)

*B. ADCON0 Register (Address : 1Fh)*

ADCON0 register controls the operation of the A/D module. The ADCON1 register, configures the functions of the port pins. The port pins can be configured as analog inputs are as digital input or output.

*C. ADCON1 Register (Address 9Fh)*

The ADRESH and ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded in to this A/D result register pair, the GO/DONE bit (ADCON0 (second bit)) is cleared and the A/D interrupt flag bit ADIF is set. After the A/D module has been configured as desired the selected channel must be acquired before the conversion is started. The analog input channels must have there corresponding TRIS bits selected as a input.

*D. Steps to be followed for doing the analog to digital conversion*

- Configure the A/D module
- Configure analog pins / voltage reference and digital input or output (ADCON1)
- Select analog to digital input channel (ADCON0).
- Select analog to digital conversion clock (ADCON0).
- Turn on analog to digital module (ADCON0).
- Configure analog to digital interrupt (If desired)
- Clear ADIF bit.
- Set ADIE bit.
- Wait the required acquisition time.
- Start conversion
- Set GO / DONE bit (ADCON0)
- Wait for analog to digital conversion to complete by either:
- Polling for the GO / DONE bit to be cleared **OR** Waiting for the analog to digital interrupt
- Read A/D result register pair (ADRESH : ADRESL), clear bit ADIF if required.
- For next conversion go to step1 or step 2 as required. the analog to digital conversion time per bit is defined as TAD. A minimum wait of 2TAD is required before next acquisition starts.

*E. POWER SUPPLY USED FOR ZIGBEE*

There are four sections in the design of the regulated power supply for the sensing units, viz., first we have step down transformer, bridge rectifier, RC filter and amplifier. The step down transformer reduces the voltage to 12V. Bridge rectifier: In which we use four diodes (IN4007).

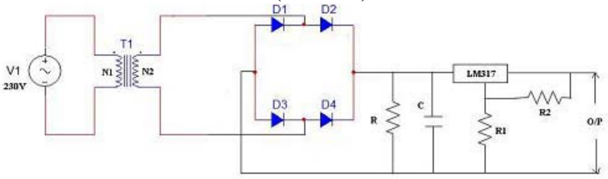



Fig. 10 Schematic circuit diagram of the power supply

This section cut-offs the AC and gives only DC output. The output of the bridge rectifier is given to the RC filter to remove noise. The output of this section is given to voltage regulator LM317. It controls the voltage to 3V. There is an LED, which indicates the turn on and turn off of power supply, The Fig. 10 shows the power supply module used for Zigbee along with the photographic view of the power supply in Fig. 11 respectively.

Fig. 11 Circuit diagram of power supply

*F. AMPLIFIER*

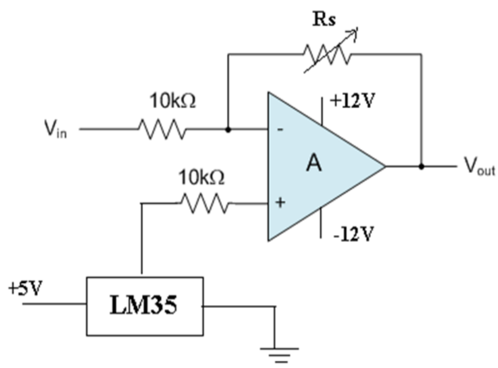



Fig. 12 Amplifier circuit

The Fig. 12 shows the amplifier circuit designed for the unit. LM35 Temperature sensor, senses the temperature and gives the output in terms of voltage. This output voltage is in terms of milli-volt.

For room temperature we get 0.3V output, which needs to be amplified to 0.5V to display 25 degree Celsius. Hence this weak output signal is fed to the amplifier. The feedback resistor is designed so as to obtain required voltage.

*G. LIQUID CRYSTAL DISPLAY (LCD)*

LCD-liquid crystal display is shown in Fig. 13 along with their photographic views.

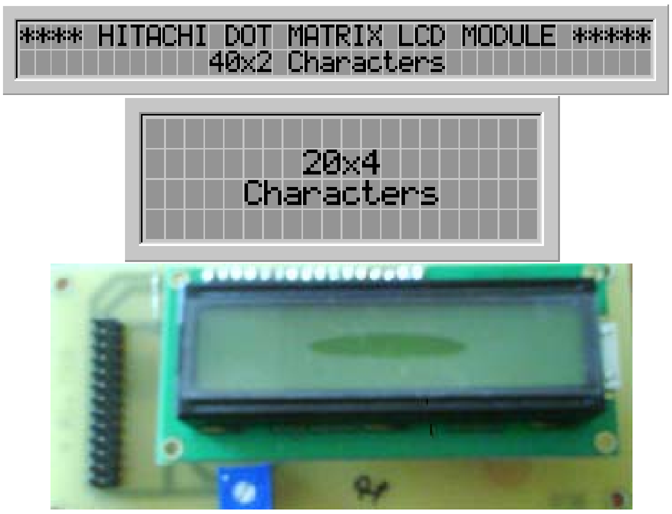



Fig. 13 Liquid Crystal Display

### *H. Operation of the HD44780*

The HD44780 has two 8 bit registers, an instruction register (IR) and a data register (DR). The IR stores instruction codes such as display clear and cursor shift, and address information for display data RAM (DD RAM) and character generator RAM (CG RAM). The IR can be written from the MPU but not read by the MPU.

The DR temporarily stores data to be written into the DD RAM or the CG RAM and data to be read out from the DD RAM or the CG RAM. Data written into the DR from the MPU is automatically written into the DD RAM or the CG RAM by internal operation. The DR is also used for data storage when reading from the DD RAM or the CG RAM.

When the address information is written into the IR, data is read into the DR from the DD RAM or the CG RAM by internal operation. Data transfer to the MPU is then completed by the MPU reading DR. After the MPU reads the DR, data in the DD RAM or CG RAM at the next address is sent to the DR for the next read from the MPU. Register selector (RS) signals make their selection from these two registers.

The different instruction sets and codes used to control the operation the LCD is shown in the table 3. The different operations in the control process are as follows :

- CLEAR DISPLAY
- RETURN HOME
- ENTRY MODE SET
- DISPLAY ON/OFF
- CURSOR AND DISPLAY SHIFT
- FUNCTION SET
- SET CGRAM ADDRESS
- SET DDRAM ADDRESS
- READ BUSY FLAG AND ADDRESS
- WRITE DATA TO CG OR DD RAM
- READ DATA FROM CG OR DD RAM
- INSERT DATA HERE

Table III Different instructions and its codes

| | RS | R/W | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
|---|---|---|---|---|---|---|---|---|---|---|
| Clear Display | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Return Home | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | * |
| Entry Mode Set | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | I/D | S |
| Display ON/OFF | 0 | 0 | 0 | 0 | 0 | 0 | 1 | D | C | B |
| Cursor and Display Shift | 0 | 0 | 0 | 0 | 0 | 1 | S/C | R/L | * | * |
| Function Set | 0 | 0 | 0 | 0 | 1 | DL | N | F | * | * |
| Set CG RAM address | 0 | 0 | 0 | 1 | A | A | A | A | A | A |
| Set DD RAM address | 0 | 0 | 1 | A | A | A | A | A | A | A |
| Read busy flag and address | 0 | 1 | BF | A | A | A | A | A | A | A |
| Write data to CG or DD RAM | 1 | 0 | D | D | D | D | D | D | D | D |
| Read data from CG or DD RAM | 1 | 1 | D | D | D | D | D | D | D | D |

## VII. Overall Working of the Unit

This section explains the block diagram of the designed & fabricated system, working of the transmitter and receiving section with the circuit diagram and flow chart.

### *A. Over View*

The temperature is sensed by the LM35 temperature sensor. The output of LM35 is a voltage signal, which is very weak. This signal is not enough to display 25 degree centigrade of room temperature. At room temperature LM35 gives 0.3 milli-volts of voltage so an amplifier is used to amplify this voltage to 0.5 milli-volts, which produces 25 degree centigrade at LCD. The amplifier amplifies this signal.

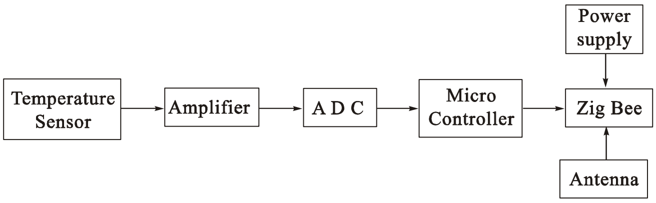



Fig. 14 Block diagram of the transmitting section

The output of the amplifier is given to the PIC microcontroller as shown in the Fig. 14. The inbuilt ADC of PIC microcontroller converts this analog data to digital form. The parallel data received is converted to serial data by the inbuilt USART. The Zigbee with whip antenna transmits this data. Power supply of 2.8V to 3.3V is designed for the operation of Zigbee. The Zigbee at the receiving side receives the transmitted data.

The similar power supply is designed for receiving Zigbee as in the transmitter as shown in the Fig. 15. This data is fed to the PIC microcontroller through pin 18. The serial data received is converted into parallel data by the inbuilt USART and is displayed on the four byte LCD. The buzzer is connected to pin 15 of PIC microcontroller. If the sensed temperature exceeds 40 degree C, the buzzer is on.

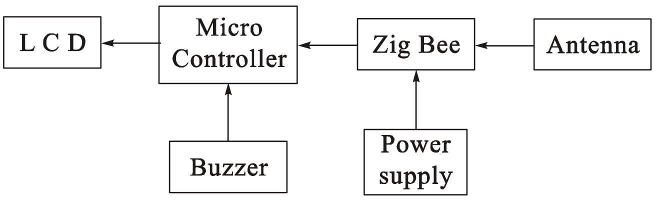



Fig. 15 Block Diagram of receiving section

The block diagram of the system is shown in the Figs. 14 & 15 respectively. It gives the over view of the designed & implemented system and information about different components used. The LM35 series sensors are precision integrated-circuit temperature sensors whose output voltage is linearly proportional to the Celsius temperature. The LM35 requires no external calibration as it is inherently calibrated.

It outputs 10mv for each degree of centigrade temperature. The amplifier in the above diagram is used to increase the strength of the signal, which can be accessed by the microcontroller. Microcontroller uses binary values but the output of amplifier is analog. Hence we need an analog to digital converter to translate the analog signals to digital numbers, so that the microcontroller can access them. The ADC chip used here is 0808 [7].

Microcontroller used here is the PIC16F873. It has Harvard architecture, whose memory organization is divided into data memory and program memory as separate units. It has three ports namely PA, PB, PC. It has four register banks with thirty-five-instruction set. It has inbuilt ADC and USART. Zigbee is a recently developed two-way wireless communications protocol designed to meet very low Power consumption and low cost (half that of Blue tooth) requirements.

Protocol features include automatic network configuration, full handshaking for packet transfers (reliable data transfer), data rate of 20kbps at 868 MHz, 40kbps at 915 MHz and 250kbps at 2.4 MHz, power management features. Zigbee needs an input power between 2.8 to 3.3v. Hence, we design a power supply, which converts 230v to 3.3v. Here, we use whip antenna to transmit the signal from transmitter to the receiver [8].

## *B. TRANSMITTER*

- The temperature is sensed by LM35 temperature sensor .
- The output of LM35 is a voltage signal, which is very weak. The amplifier amplifies this signal.
- The output of the amplifier is given to the PIC microcontroller.
- This analog data is converted to digital form by the inbuilt ADC.
- The parallel data received is converted to serial data by the inbuilt USART.
- The Zigbee with whip antenna transmits this data.
- Power supply of 2.8V to 3.3V is designed for the operation of Zigbee.

## *C. TRANSMITTING SECTION*

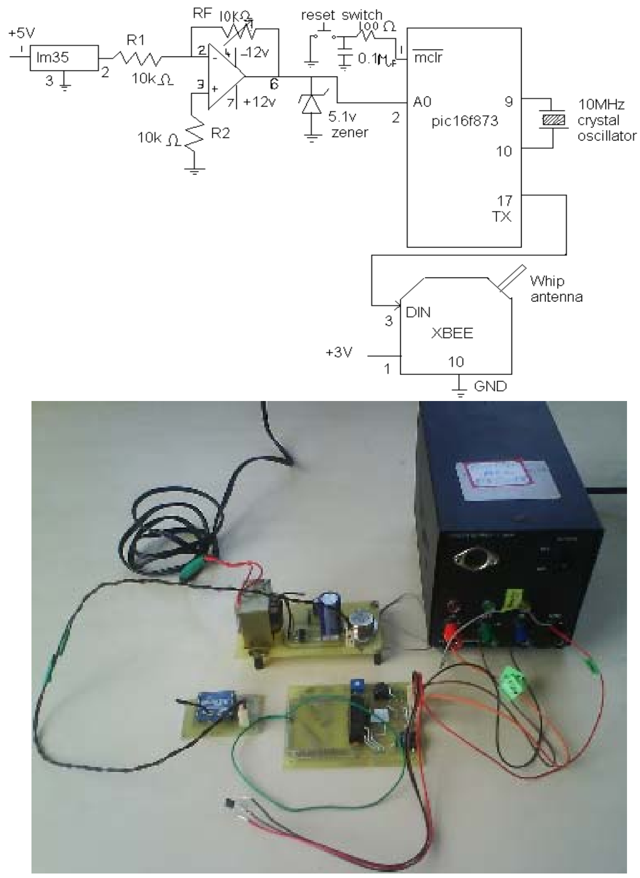



Fig. 16 Transmitter circuit

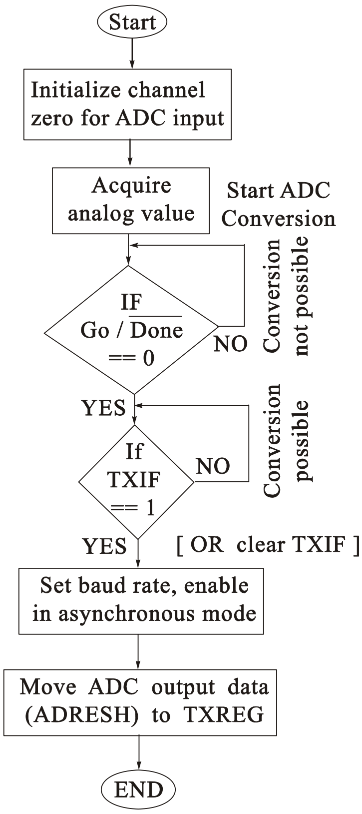



Fig. 17 Flow chart for transmitting section

The Fig. 16 shows the circuit diagram of the transmitting section. The major components used at the transmitting section are the temperature LM35, an amplifier, voltage regulator, PIC microcontroller and Zigbee.

### D. FLOW CHART FOR THE TRANSMITTER

The flow chart for the transmitting section is shown in the Fig. 17.

### E. RECEIVER

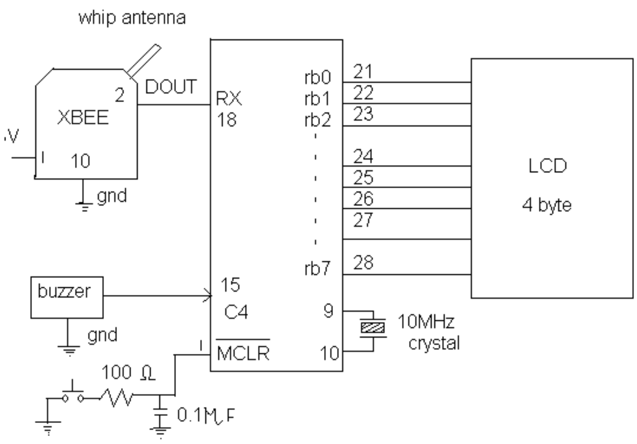



Fig. 18 Circuit diagram of the receiver

The Zigbee at the receiving side receives the transmitted data. The similar power supply is designed for receiving Zigbee as in the transmitter. This data is fed to the PIC microcontroller through pin 18. The serial data received is converted into parallel data by the inbuilt USART and is displayed on the four byte LCD. The buzzer is connected to pin 15 of PIC microcontroller. If the sensed temperature exceeds 40 degree C, the buzzer is on.

### F. RECEIVING SECTION

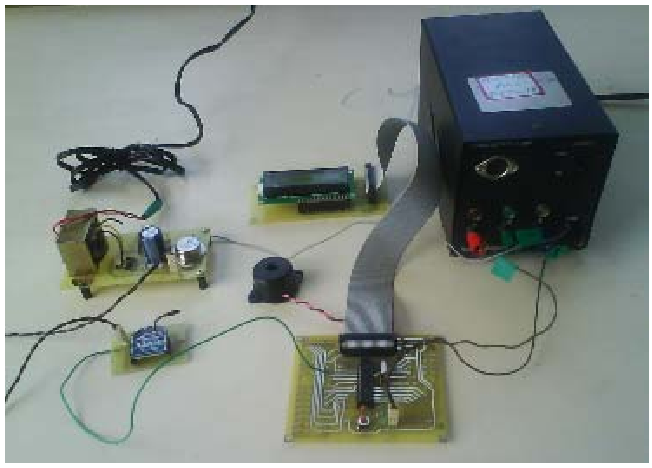


Fig. 19 Photographic view of the Receiver circuit

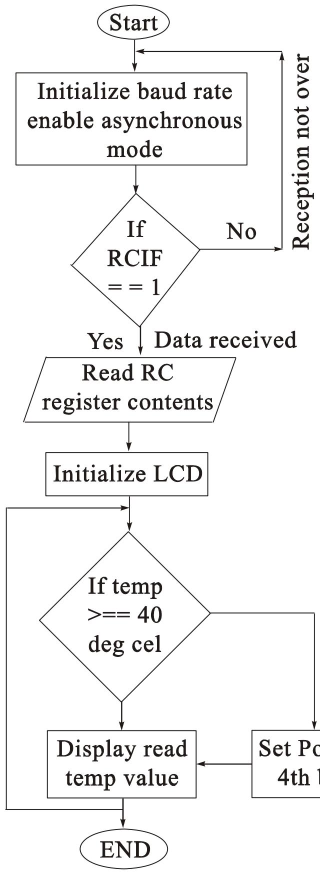



Fig. 20 Flow chart for receiving section

The Fig. 18 shows the circuit diagram of the receiving section along with the flow-chart of the receiving section in Fig. 19. The flow chart for the receiver circuit is shown in

Fig. 20. The major components used at the receiving section are PIC microcontroller, LCD, Zigbee and its power supply.

*G. APPLICATIONS*

Temperature sensor using Zigbee has numerous applications. Few are listed below.

- Used in communication industry
- Used in process control industries
- Used in defense
- Used in domestic and industrial applications(boilers and heaters)
- Used in Data loggers
- Used in the R & D industries
- Used in home automation
- Used in data acquisition systems
- Used in automotive industries
- Used in online testing of machines

## VIII. CONCLUSION

Temperature sensing unit was designed & tested successfully. The successful operation of the unit was also carried out in the presence of numerous tests. We have done for one parameter, but the same can also be done for 2 or more parameters like pressure, viscosity and humidity in real time applications. This system is cost-effective and time efficient in its operation and works as high speed and is very accurate in its operation.

The development of wireless solution within the standards organization has the advantage of bringing several views together to define a better solution. The quick development of the standard was due to the proactive participation of several developers and users of the technology. The focus of Zigbee development was on maintaining simplicity by concentrating on the essential requirements that will leverage a successful standard.

The main goal of this effort has been to address applications that could benefit from wireless connectivity and enable new ones that cannot use higher-end wireless application. The value will be in the application, not in the technology. Some of the future developments could also be discussed as follows. With the facilities provided, we were successful in sensing the temperature as one of the data and displaying the same on the LCD.

We can add other parameters say voltage, pressure, viscosity, humidity etc to the existing work done in this paper or for transfer of data using Zigbee in the place of internet and could have made it more efficient. The graphical LCD can also replace the typical LCD so that the user can know the status of the parameter being measured using the graphical LCD rather than the typical LCD, so that the designed unit can be more user friendly and user interactive.

## REFERENCES

[1]. Sepoo Scottsdale, AZUSA, “Znterim Meeting Minuts”, Scan Middletom, Philip semi conductors.

[2]. www.eg3.com/zigbee

[3]. www.zigbee.org

[4]. www.palowireless.com/zigbee

[5]. www.enbedded.com/showarticle.jhtml

[6]. www.wisegeetc.com

[7]. G Ding, Z Sahinoglu, B Bhargava, P Orlik, J Zhang , “Reliable Broad cast en Zigbee networks”, *Proc. of IEEE conference on Zigbee*.

[8]. U Mohammad , “Performance Evaluation of IEEE 802.15.4 Protocol for Automotive application”, *IEEE Manuals*.