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Zigbee-Based Voice Recognition Wireless Home Automation System

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Abstract :

Due to the development of numerous wireless technologies, home automation systems have undergone tremendous modifications in recent years. Numerous standards have emerged as a result of the rapid advancements in wireless technology, particularly in the industrial, scientific, and medical (ISM) radio band. An IEEE 802.15.4 standard for data connections between consumer and business devices is called ZigBee. Applications requiring low data rates, extended battery life, and secure networking are the focus of Zigbee. With a specified rate of 250 kbits/s, Zigbee is ideal for transmitting a single signal from a sensor or input device or for periodic or intermittent data. Without altering the infrastructure, wireless home automation systems are meant to be installed in already-existing house settings. Low-power ZigBee wireless communication modules and a microcontroller are used in the automation, which focuses on spoken command recognition. The elderly and disabled, particularly those who live alone, are best suited for this technology because it recognizes voice, making it safe. The goal of the home automation system is to use voice commands to operate all of the electrical appliances and lighting in a house or business. Therefore, the purpose of this document is to create a wireless ZigBee-based home automation system with voice recognition.

Keywords - Microcontroller, ZigBee, voice recognition, power supply, and home automation.

I. INTRODUCTION

II. The Wireless Home Automation System is a comprehensive system designed to help the elderly and disabled by providing them with a simple, voice-activated home automation system. The system is easily installed, configured, operated, and maintained, and it is portable. One can operate household appliances from a wireless central control unit with a standard wireless home automation system. For most commercially available home automation systems, these appliances typically need to be custom engineered to work with the control unit and each other. In addition to allowing wireless control of lights, fans, air conditioners, televisions, security cameras, electronic doors, computer systems, audio/visual equipment, and other devices, the project showcases a system that can be combined into a single portable unit. It also enables users to turn on or off any device that is connected to a wall outlet, monitor the status of various sensors, and make decisions based on those findings. A microphone that is linked to an HM 2007 speech recognition chip controls the entire system. The microcontroller receives speech commands from this chip in a binary sequence. After making a choice, the base station unit uses a ZigBee transmitter to transmit commands to the remote station. The remote system executes the request function after receiving the orders via a ZigBee transceiver. By analyzing the difference in signal

strength between the access point and the user, the sensors unit can determine when the user enters or exits the room. In response, it may turn on or off appliances like lights and fans while sending its status back to the base station.

III. System Overview

IV. A base station and a remote station are both part of the home automation system. Every station will have its own PCB and be packed individually.

2.1 BASE STATION

The power source for the base station will be +5V. All of the base station's circuit components will use this voltage as their operating voltage. Close-up audio will be captured by the base station's microphone. The HM 2007 speech recognition chip will receive the audio signal from the microphone. After processing the audio and confirming that the commands are genuine speech commands, the HM 2007 chip will transmit them to a remote station via a microcontroller and ZigBee, where the appropriate command action will be carried out. The microcontroller communicates with a 16 x 2 LCD to show the on/off state of the relay switches and sensors. Both the base station and the remote station have a sound alert that indicates whether the water level is below the limit (to turn off the water motor) or overflowing (to turn off the water motor). The microphone audio signals are analyzed and recognized by the HM 2007 chip. The HM 2007 has a direct microphone interface, and the microcontroller has a ZigBee transceiver interface. The word length that will be identified will be chosen to be 1.92 seconds, the maximum amount. This will enable the 8K-byte memory to be used to memorize no more than 20 words. Since the spoken commands will never be longer than 20 words, this will meet the requirements of our product. monitoring the strength of the signals between the access point and, in response, turning on or off appliances like fans and lights while simultaneously transmitting its status back to the base station.

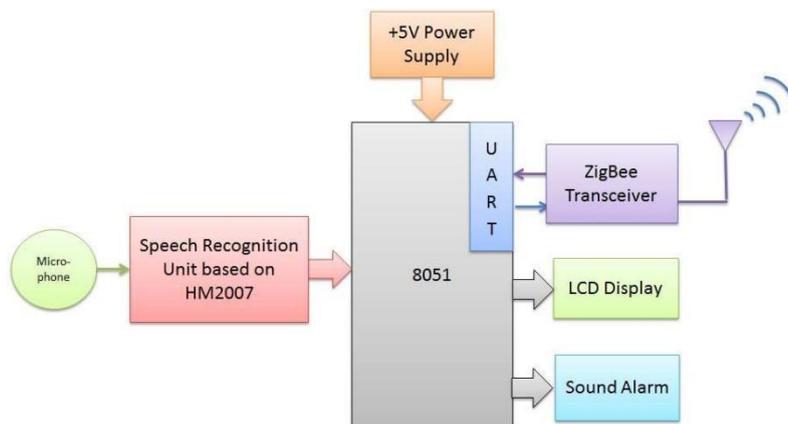


Figure 1. Handheld microphone with voice recognition unit in the base station

1.1 REMOTE STATION

The same +5 V power source will be used to run the remote station. Using the Zigbee wireless protocol, the base station sends digital signal commands to the remote station microcontroller, which then executes the request function. The relay switches board's status will be updated based on the command signals received. Additionally, it updates the remote station's LCD status by reading the sensor values. By analyzing the difference in signal strength between the access point and the user, the sensors unit can determine when the user enters or exits the room. In response, it

may turn on or off appliances like lights and fans while sending its status back to the base station.

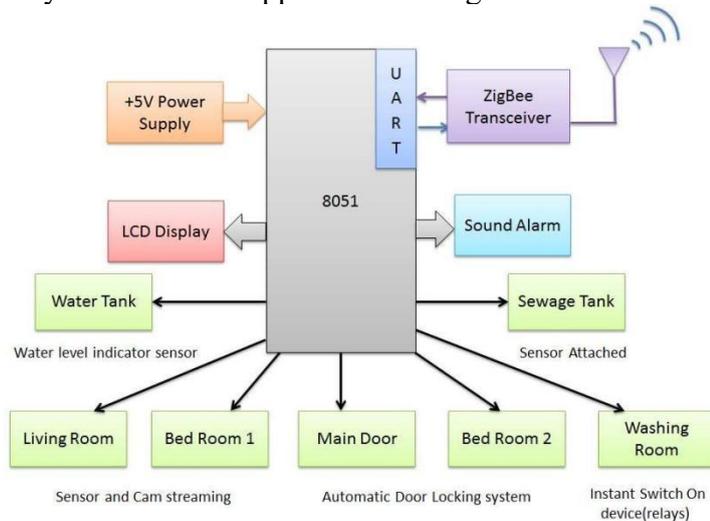


Figure 2. Functional Block Diagram of Remote station Unit

V. Project Design Methodology

VI. The design process for the ZigBee-based voice recognition wireless home automation system will be covered in this part. To make the design process modular, the project was broken up into several components. These components were swapped out for their specifications in the authors' prototype board:

3.1 Speech Recognition Unit: The HM2007 voice recognition IC is the central component of the speech recognition system. Twenty words with a length of 1.92 seconds each can be recognized by the IC.

3.2 ZigBee: It is a wireless networking protocol that is inexpensive and low-power. Because of its inexpensive cost, the technology may be widely used in wireless control and monitoring applications; its low power consumption allows for a longer battery life with smaller batteries; and its many networking topologies offer greater range and high dependability.

3.1 Microcontroller: Any 8-bit microcontroller can be configured with the system. Here we have used 8051 microcontroller(AT89S51)-full static CMOS controller, 8k Flash memory, 256 bytes RAM, 4 I/O ports of 8 bit wide, 3 timers/counters, 8 interrupt sources etc.

3.2 Liquid Crystal Display(HD 162A): 16x2 LCD that is 16 character per row.

3.3 Power supply unit.

3.4 Different sensors, relay switches board and sound alarm.

3.1 SPEECH RECOGNITION UNIT

The speech recognition system is a completely assembled and easy to use programmable speech recognition circuit. Programmable, in the sense that we can train the words that we want the circuit to recognize. This circuit board allows us to experiment with many facets of speech recognition technology. It has 8 bit data out which can be interfaced with any microcontroller for further development.

3.1.1 FEATURES

- User programmable
- Up to 20 word vocabulary of duration two second each
- Multi-lingual
 - Non-volatile memory back up with 3V battery backup which will keep the speech recognition data in memory even after power off.
- Easily interfaced to any microcontroller like 8051, PIC or AVR can be interfaced to data port.

3.1.2 HM2007

It is a single chip CMOS voice recognition LSI circuit with the on-chip analog front-end, voice analysis, recognition process and system control function.

1	GND	AGND	48
2	X2	VDD	47
3	X1	MICIN	46
4	S1	LINE	45
5	S2	VREF	44
6	S3	D7	43
7	RDY	D6	42
8	K1	D5	41
9	K2	D4	40
10	K3	D3	39
11	K4	D2	38
12	TEST	D1	37
13	WLEN	D0	36
14	CPUM	MR/MW	35
15	WAIT	ME	34
16	DEN	NC	33
17	SA0	NC	32
18	SA1	SA12	31
19	SA2	SA11	30
20	SA3	SA10	29
21	SA4	SA9	28
22	SA5	SA8	27
23	SA6	GND	26
24	SA7	VDD	25

Figure 3. Functional Pin Description of HM 2007

A 20 isolated word voice recognition system can be composed of external microphone, keyboard, 8K SRAM and other components, combined with a microcontroller, an intelligent recognition system can be built. It support two control mode: Manual mode and CPU mode. It is also available in 48-pin PDIP. The pin description of HM2007 is shown above. The keypad and digital display are used to communicate with and program the HM2007 chip. The keypad is made up of 12 normally open momentary contact switches. The 74LS373 8-bit registers feature 3- state outputs designed specifically for driving highly capacitive or relatively low-impedance loads. The high- impedance 3-state and increased high-logic-level drive provide these registers with the capability of being connected directly to and driving the bus lines in a bus-organized system without need for interface or pull-up components. The IC 7448 is BCD to 7-segment common cathode IC. To display the data, we have to convert it from BCD to 7-segment code. The IC makes this process. It has four inputs called BCD inputs and seven outputs to drive the display. The voice recognition system schematic diagram is shown below in fig.4.

A microphone is connected directly with pin 15(MICIN) of HM2007 which is shown below. On this system, voice is trained first and then recognized whenever a command is given through microphone.

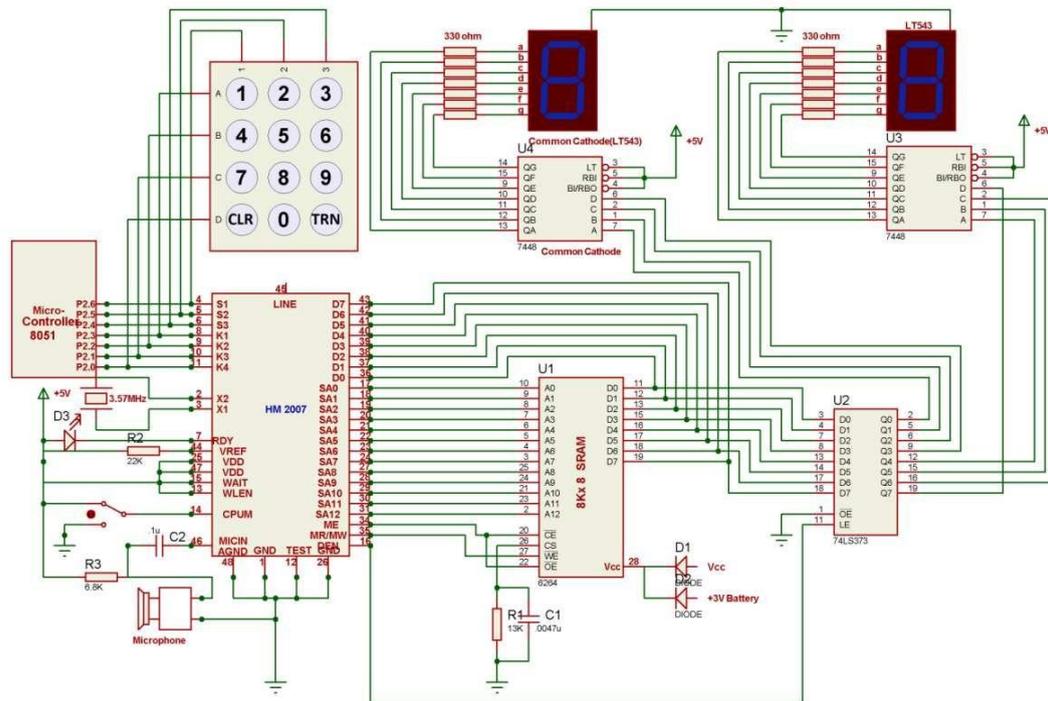


Figure 4. Schematic diagram of Voice Recognition System With Manual and CPU Mode Option

The speech recognition system is a completely assembled and easy to use programmable speech recognition circuit. Programmable, in the sense that we train the words (or vocal utterances) which we want the circuit to recognize. This board allows us to experiment with many facets of speech recognition technology. It has 8 bit data out which can be interfaced with any microcontroller for further development. Some of interfacing applications which can be made are controlling home appliances, robotics movements, Speech Assisted technologies, Speech to text translation, and many more. It has Non-volatile memory back up with 3V battery onboard which will keep the speech recognition data in memory even after power off.

3.1.3 SYSTEM WORKING

There are two mode which are supported by this system, Manual mode and CPU mode

3.1.3.1 MANUAL MODE

This mode is selected by connecting Pin 14(CPUM) to ground by using SPDT switch. When the circuit is turned on, “00” is on the digital display, the red LED (contacted with READY pin) is lit and the circuit waits for a command. By using this mode we can do following task:

- Training Words for Recognition:
- Testing Recognition:
- Error Codes Detection in 7-segment display. This happens when the voice command is too short or too long.
- Clearing Memory.

3.1.3.2 CPU MODE

This mode is used when we want to perform additional functions or want to make our system smart, this is done by connecting voice recognition system with the microcontroller. This mode is selected by connecting Pin 14(CPUM) to Vcc by using SPDT switch. In this mode K-bus is used as a bidirectional data bus between the microcontroller and HM2007 and S1 to S3 as R/W control pins. The several function provide by CPU modes which are similar to manual mode are :

- RECOG
- TRAIN
- RESULT
- UPLOAD
- DOWNLOAD
- RESET

3.2 ZIGBEE

The explosion in wireless technology has seen the emergence of many standards, especially in the industrial, scientific and medical (ISM) radio band. There have been a multitude of proprietary protocols for control applications, which bottlenecked interfacing. Need for a widely accepted standard for communication between sensors in low data rate wireless networks was felt. As an answer to this dilemma, many companies forged an alliance to create a standard which would be accepted worldwide.

It was this ZigBee Alliance that created ZigBee. Bluetooth and Wi-Fi should not be confused with ZibBee. Both Bluetooth and Wi-Fi have been developed for communication of large amount of data with complex structure like the media files, software etc. ZigBee on the other hand has been developed looking into the needs of communication of data with simple structure like the data from the sensors.

ZigBee has been developed to meet the growing demand for capable wireless networking between numerous low power devices. In industry ZigBee is being used for next generation automated manufacturing, with small transmitters in every device on the floor, allowing for communication between devices to a central computer. This new level of communication permits finely-tuned remote monitoring and manipulation.

The ZigBee and ZigBee Pro radio is made by Digi (formerly Maxstream) which is shipped with firmware implementing the IEEE 802.15.4 protocol. These modules use the IEEE 802.15.4 networking protocol for fast point-to-point or peer-to-peer networking. However, the most different part between ZigBee and ZigBee Pro is they have different cover distance range for communicate with own module. ZigBee can be covers around 30m at indoor and 100m at outdoor. Inversely, ZigBee Pro can cover higher distance range than ZigBee which is 100m at indoor and 1500m at outdoor. Both devices that have a UART interface so can be connected directly from microcontroller to pins of RF Module (ZigBee/ZigBee Pro). Using UART interface, we can use this wireless devices to communicate between microcontroller to microcontroller (two 8051's) or between PC to microcontroller or between PC to PC. Here, we will discuss how to use two ZigBee/ZigBee Pros to interface with microcontroller and how to send command for configuration ZigBee/ZigBee Pro Module. The role of the Zigbee module is to be as transparent as possible. It should be as if a wire was connecting the input to the output and connectivity is never lost. While this sounds simple, it's actually a very hard task to accomplish and error correction is a must, which the Zigbee's role in offering sound and reliable wireless communication. ZigBee pin diagram is shown below:

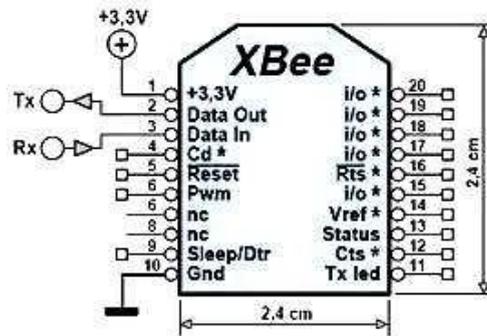


Figure 5. ZigBee pin configuration

Looking at the ZigBee pinout we can see right away the different types of input that can be translated and transmitted wirelessly:

- Digital I/O
- Analog I/O (10 bit resolution)
- Pulse with Modulation
- Serial Communication (SPI/RS232/I²C)
- CTS/DTR Control Signals

These are some the most common types of signals that are used in electronics and the ZigBee offer them all as inputs and outputs.

3.2.1 XBEE/XBEEPRO HARDWARE INTERFACE BETWEEN PC

Here I have used two different ZigBee starter kit one is USB compatible kit with PC and other one is RS232 protocol compatible with PC. I have connected one of the starter kit with the USB port and the other one with Serial Com port of same or different PC (depends upon choice). Bear in mind, ZigBee is designed for 3.3V system, this starter kit have inbuilt 3.3V regulated power supply so we don't need to worry about this. Those system in which we want to connect ZigBee as a stand-alone device will require extra work and component before ZigBee module could be embedded in the system. Next step is to set ZigBee Module Source address and Destination address, it is very important for us to transfer data by transparently from one ZigBee module Source) to another ZigBee module (Destination) so that it don't interfere with other module in the same network. Two ways to setting ID address which is using [X-CTU software](#) or using programming code to send specified command for ZigBee ID address setting. We will discuss only one way of configuring ZigBee module by using X-CTU software only since this is sufficient for our research paper work.

X-CTU which is a computer based software to communicate with ZigBee, to change configuration or

Transmit/Receive data. Double click the "setup_x-ctu.exe" file to install this Software.



Figure 6. Using X-CTU software to setting Source address or Destination address.

Launch the X-CTU Software and connect the USB cable from USB compatible starter kit to any of the USB port (without connecting to microcontroller board). Select "PC Setting" tab

under X-CTU software window→ select USB Serial Port (Here it is COM 12 appeared and unaltered all the other settings) → Now click “TEST/QUERY” as shown in Fig. 7.1. All the other settings like -Baud rate: 9600- Data bits: 8 - Parity: NONE - Stop bits: 1 and others are unchanged or could be changed according to data transmission rate required.

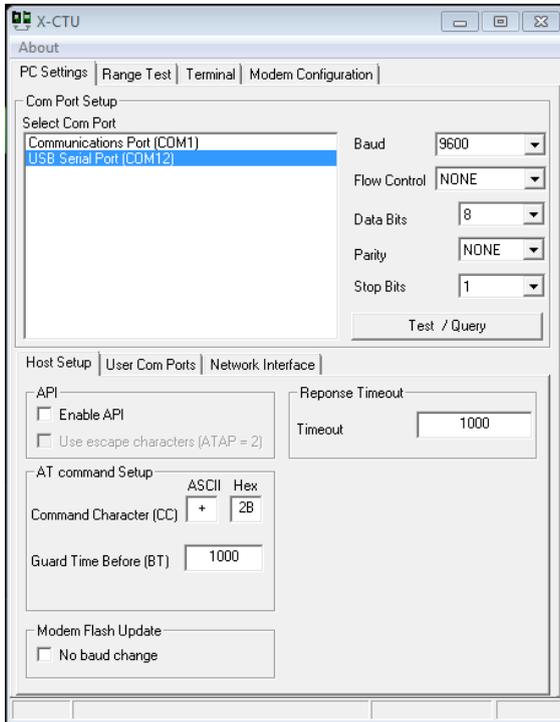


Figure 7.1
ZigBee Cordinator

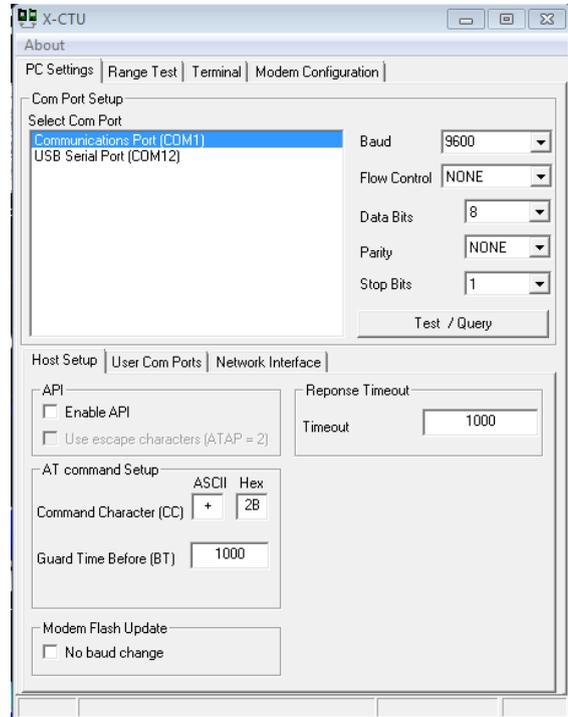


Figure 7.2
ZigBee Router (End Device)

Configuring By Using X-CTU Software.

If everything is fine, a dialogue box will appear as shown below in Fig.8.1, click “OK” to close this box:

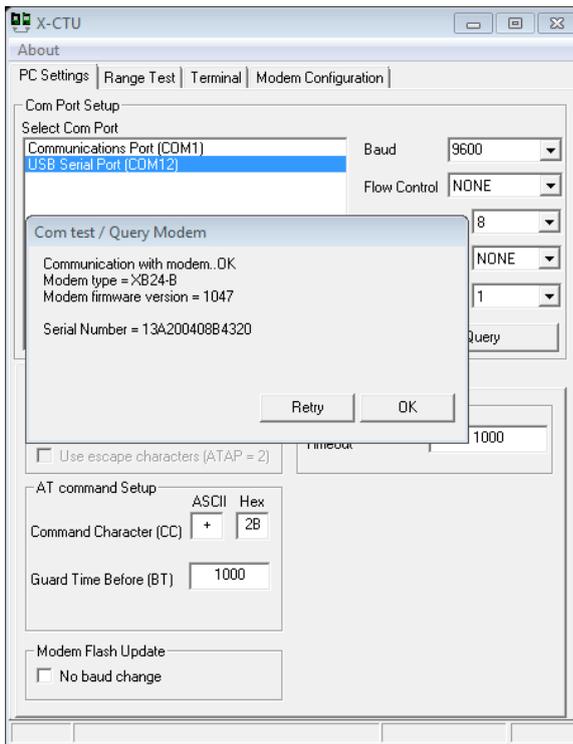


Figure 8.1
ZigBee Coordinator

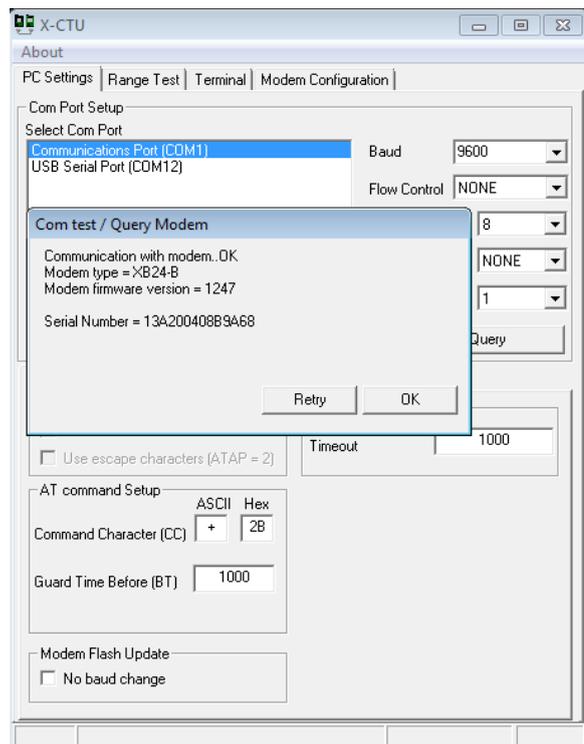


Figure 8.2
ZigBee Router (End Device)

Configuring By Using X-CTU Software.

Now repeat the same steps with the other serial com port compatible starter kit. Connect the cable of starter kit with the com port of PC. Run the X-CTU software. Select “PC Setting” tab under X-CTU software window→ select serial COM Port (Here it is COM 1 appeared and unaltered all the other settings) → Now click “TEST/QUERY” as shown in Fig. 7.2. If everything is fine, a dialogue box will appear as shown in Fig 8.2, click “OK” to close this box. Here we have used the single PC Serial Com Port and USB port for the testing purpose. As shown in the figure 8 the modem type is XB 24-B so click now on the Modem Configuration Tab.

- ➔ Select modem XBEE type (as it is XB 24-B)
- ➔ Click on the Function set and select Coordinator AT (For point to point communication AT command mode is simplest)
- ➔ Choose always update firmware
- ➔ Click on write.

Within a few seconds the new firmware will be installed on ZigBee. Keep the other settings unchanged as shown in Fig. 9.1. Similarly go to second X-CTU window as shown in the Fig. 8.2 here again the modem type is XB 24-B so click now on the Modem Configuration Tab.

- ➔ Select modem XBEE type (as it is XB 24-B)
- ➔ Click on the Function set and select Router/End Device AT
- ➔ Choose always update firmware
- ➔ Click on write

Within a few seconds the new firmware will be installed on ZigBee. Keep the other settings unchanged as shown in below Fig.9.2.

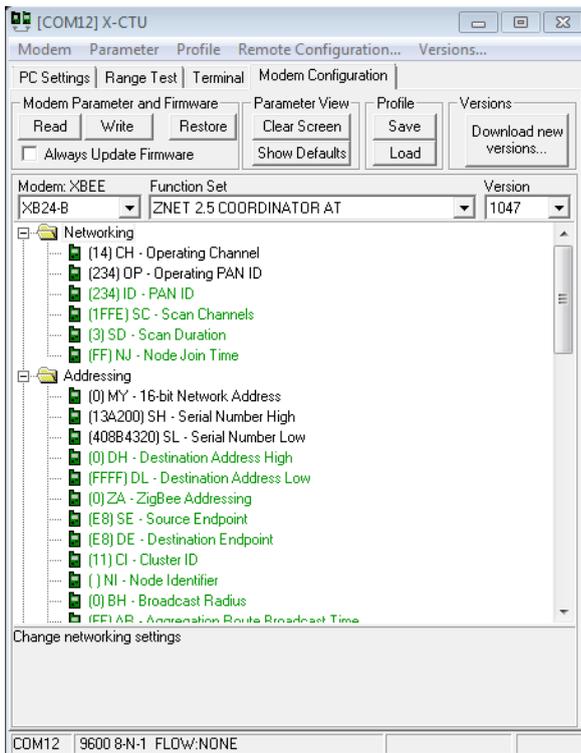


Figure 9.1
ZigBee Coordinator

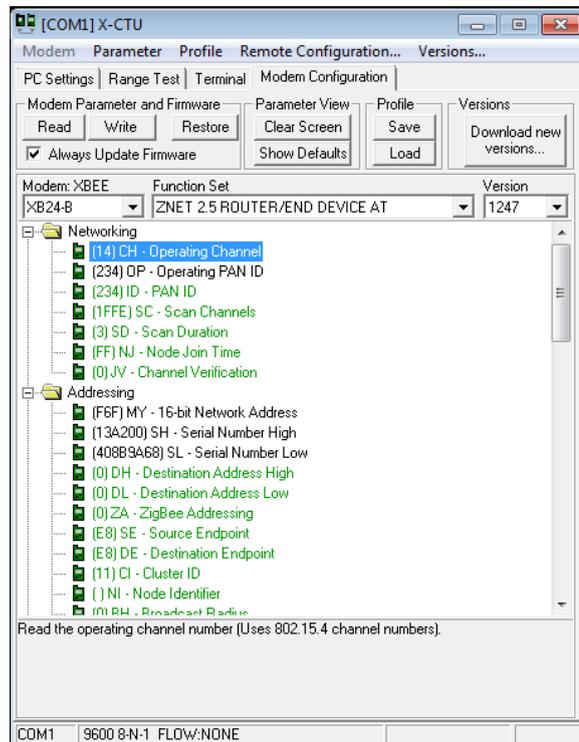


Figure 9.2
Zigbee Router (End Device)

Modem Configuration.

Now go to Range Test Tab and in both X-CTU windows click on start if everything is done correctly the both ZigBee start communicating each other as shown in below picture. Now both the ZigBee module are configured successfully and can be attached with remote station and base station microcontroller board. The range test is shown below in Fig.10 .

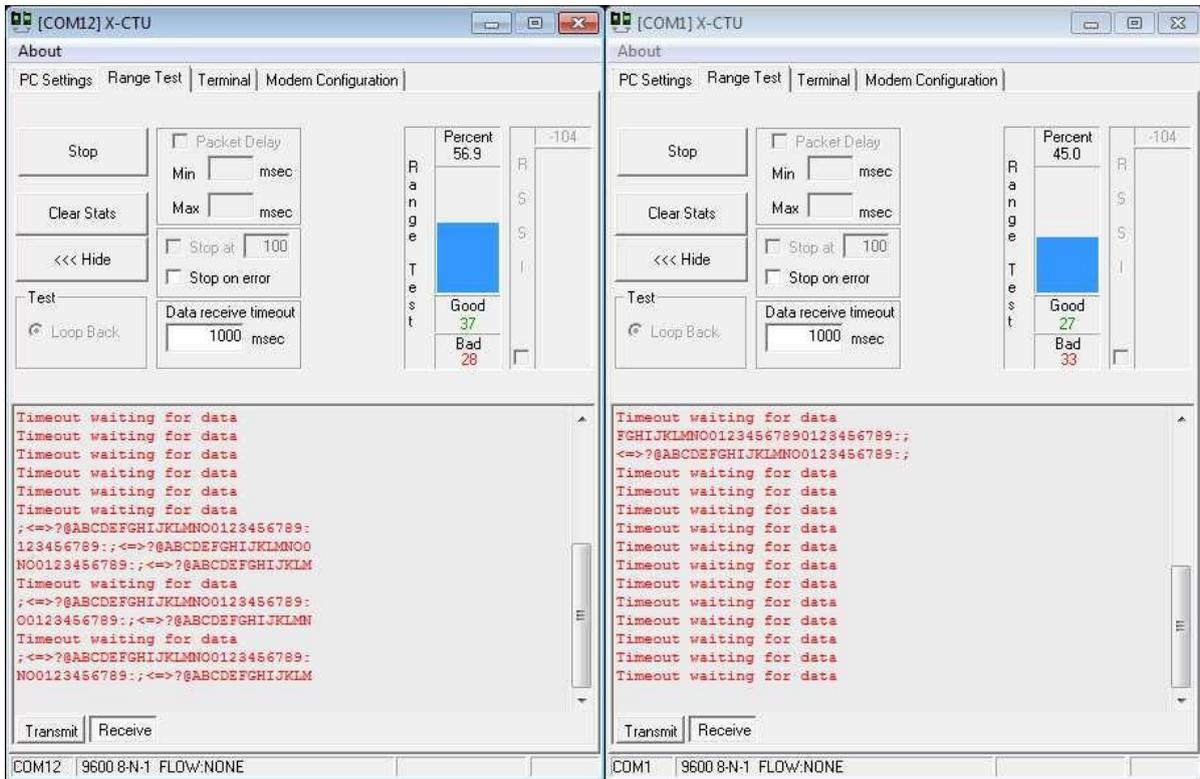


Figure 10. Range Test Between Co-ordinator and Router/End Device

3.2.2: ZIGBEE / ZIGBEEPRO HARDWARE INTERFACE BETWEEN MICROCONTROLLER

If we want to use coding to send the command to ZigBee, we have to ensure the hardware connection between Zigbee to microcontroller is complete. Any microcontroller with UART peripheral can be used to interface with ZigBee as shown below:

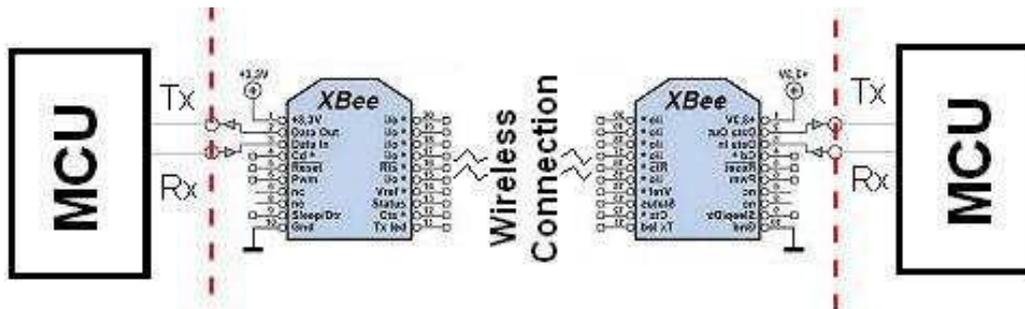


Figure 11. Standard ZigBee wireless communication link with microcontroller

The way we will be using the Zigbee is far easier. Straight out of the box, the Zigbee is normally configured for 9600bps serial communication and so to make things easier, we haven't change any of the configuration options. This means we will only be using the Vcc, GND, Din and Dout pins and left other pins unconnected. In Fig.11 we have connected RXD pin no.3of ZigBee to TXD pin of microcontroller and ZigBee TXD pin no. 2 to RXD pin of microcontroller.

3.3 MICROCONTROLLER 8051

Since the project's focus is on embedded hardware and software control, the

microcontroller is the heart of the system. The microcontroller selected for this project must be able to read values from sensors through analog to digital convertor, send and receive signals from RF module and must be able to display them to LCD. Any 8-bit microcontroller can be chosen for this purpose. The AT89S51 was selected as it satisfies these requirements. A 11.0592 MHz crystal oscillator was also used in conjunction with the 8051 to provide the necessary clock input. This speed is sufficient for the application. A pin diagram of the AT89S51 is provided in Figure 12.

The inbuilt capabilities of 8051 microcontroller (AT89S51) are

- It is a full static CMOS controller
- 8k Flash memory
- 256 bytes RAM
- 4 I/O ports of 8 bit wide
- 3 timers/counters
- 8 interrupt sources etc.

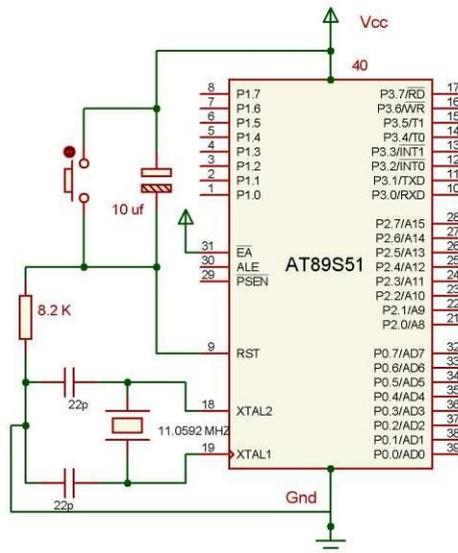


Figure 12. 8051 Microcontroller with basic connection

3.4 LIQUID CRYSTAL DISPLAY (LCD)

Here we are using a 16 x 2 LCD for displaying the values on the screen. It has 16 pins. It support 16 characters per rows and total no of rows are 2. It means that it can support up to 32 character at a time, which is sufficient for data display purpose. RS, R/W and Enable pins of LCD are connected with the receiving end microcontroller port pins. Data lines D0-D7 are connected to one of the output port of microcontroller.

The basic connection of LCD is shown below in figure 13. Here V_{DD} (contrast voltage) is adjusted by using a variable resistor connected with it.

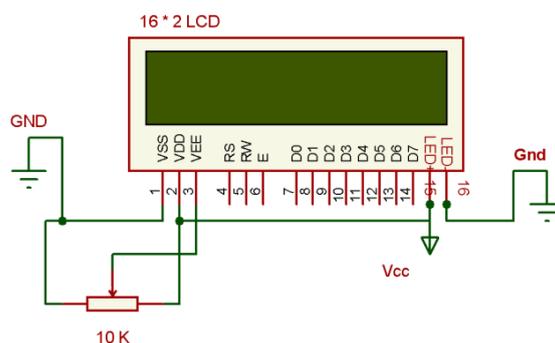


Figure 13. LCD Basic Connection Diagram

3.5 POWER SUPPLY UNIT

In the power section a simple 9-12V battery is connected with the transmitting end as well as receiving end. Since the microcontroller which is the central processing unit works on regulated +5V power supply so this can be achieved by connecting a +5 volt regulator at the output of battery. This is shown in figure 14.

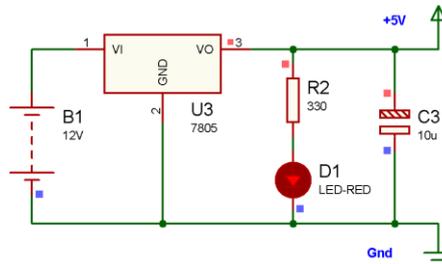


Figure 14. Battery operated +5V power supply

3.6 OTHER COMPONENTS:

A single relay switch connection to microcontroller are shown below. Any home appliance operating under A.C voltage supply could be connected directly with this relay interface circuit. A buzzer can also be connected by applying +12V at the common terminal of relay. Remaining relays of the interface circuit board could also be configured with the microcontroller in the similar fashion.

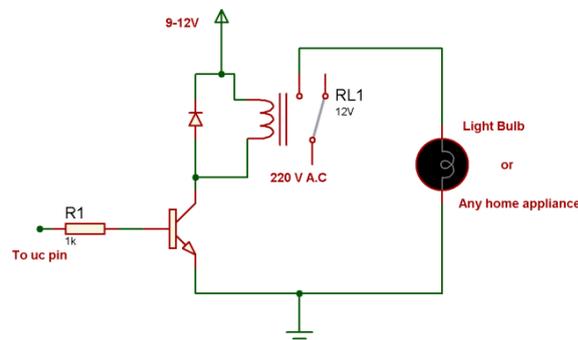


Figure 15. Relays switch board interfacing with the microcontroller

Similarly different sensors could be interface with the microcontroller by using analog to digital convertor or comparator circuit. So any sensors can be connected with the remote station according to the system requirement.

VII. Software Design

Software design includes voice recognition, transmission and reception of wireless signal using ZigBee transceiver, read the sensors, update the status of relay switches and display the status on LCD display accordingly.

The main program for this system is written by using the embedded C programming language. The schematic diagram for this system which consists of all the components was designed by using the Proteus ISIS 7 professional editions. The main program was developed in the Keil Integrated Development Environment by using the embedded C programming language. The .c program was converted into .HEX file in this IDE and burned into the ROM part of the AT89S51 microcontroller.

VIII. Scope And Conclusion

Voice recognition Wireless Home Automation Based on ZigBee is a very useful project for the adults and physically disabled persons, who are not able to do various activities efficiently when they are at home and need one's assistant to perform those tasks. With the Voice Recognition along with ZigBee network we can eliminate the complication of wiring in case of wired automation and also it prevent to get up and down again and again to on/off appliances. ZigBee Home Automation provides operating range much higher as compared to Bluetooth and other wireless sensor module .With the use of ZigBee Home Automation circuit considerable amount of power saving is possible and it is flexible and compatible with future technologies so it can be easily customized for individual requirements. On the other hand with voice recognition system, it provides secure access to home. So when we are living in a fast world where everything is changing with in no time such security is essential.

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