

A Zigbee Based Framework for Low Power Voice Communication System

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Abstract

IEEE standard 802.15.4 defines two layers for low rate WPANs, which are physical layer and media access control layer, which restrict the data rate to 250 kbps. This alliance took low level PHY and MAC layers as the base for the development of the network protocol, security and application for the Zigbee. To solve the Problem of reduce cost and power consumption to make this technology easily available for common crowd. This system shows the total working details of the network, i.e., wireless voice communication. This work has been done to reduce the cost of entire production of such devices that contributes in home automation system and similar projects. The main objective of the research was to transfer voice over low-power micro-controller such as 8-bit micro-controller by the implementation of Zigbee.

Keywords: ZigBee; Voice; Micro-Controller; Automation; Efficiency.

1. Introduction

The Zigbee Alliance came into existence in the year 2002. The main task of this alliance is to enhance or provide a base or both public and private industries that work upon wireless technologies, so that they are able to build an effective and efficient wireless sensors and control systems that require less amount of energy, can operate on low data rate, require low cost for manufacturing and as well as maintenance.

The zigbee specification was introduced in the year 2006, it has reached to the sky since and now it is clear that it will over shadow the global control/sensor network standard and will rule the residential, medical, industrial and commercial application. Zigbee provides two way communications for command and control, covers the range of 75-100 meters and provides control sensors that help us to achieve several tasks.

If we talk about residential applications we have a number of devices such as lighting control unit, smoke or CO2 detectors, fire detector, HVAC control, security, wireless transmission for television's set top box and remote control.

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Zigbee is now also implemented in the cell phones, that will allow you to use your cell as remote device also, i.e., you can use your phone as a remote for televisions and air-conditioners. If we talk about industry, there is a massive amount of area where Zigbee has started playing its prominent role such as, monitoring, automation, medicines and etc. The main secret behind the success of Zigbee is its flexible nature which allows Zigbee to fit in any kind of task. Zigbee's data rate is extremely lower as compared to WiFi's but if we see to it, actually it does not require any higher rate or clarity in data transmission. For example, if we talk about intrusion sensor, low data rate is sufficient enough for this purpose. As we know low data rate in turn consumes low power and hence our device becomes energy efficient. This energy efficiency of zigbee technology allows Zigbee to get a firm foot hold in the industry as compared to other technologies.

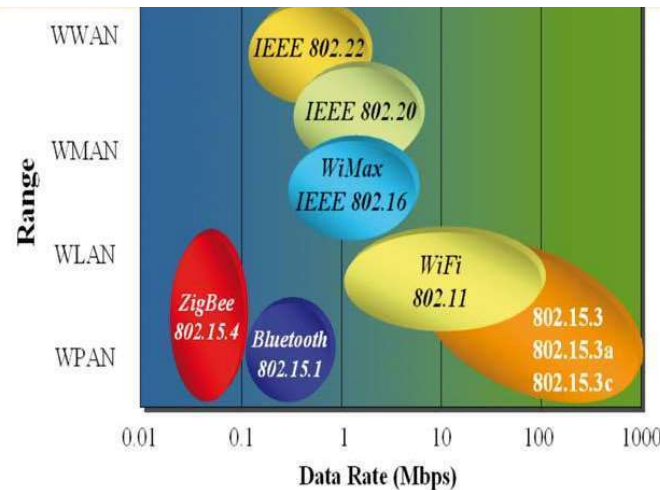


Fig. 1. Comparison of Zigbee in terms of Range and Data rate

A. ZIGBEE DEVICE TYPE

Zigbee devices are of three types:

1) Zigbee coordinator (ZC): A coordinator is must, in real world as well in the computer world. This is the most capable and efficient device, the coordinator acts as a root of the entire network structure and also bridges the gap between other networks. Each network should or must contain one coordinator for effective operation. The main task of the Coordinator is to store the information about the nodes present in the network, as well as acting as the commander that ensures the security as well as integrity of the entire system.

2) Zigbee Router (ZR): a network also requires gateways or intermediate nodes for routing or we can say path formation for the message, this task is achieved by the Zigbee routers that actually form the entire network under the supervision of the coordinator.

3) Zigbee End Device (ZED): We have the coordinator and the network but still we require a device that actually communicates with the real world or we can say the physical world. The devices that actually communicate with the physical world are termed as the ZED. They remain in-active or in the sleep mode until any alien factor invoke them, hence saving handsome amount of electric power.

B. Operating Modes and Low Power Consumption

Zigbee technology provides us two main modes for communication so that it is able to support various kinds of two-way data traffic: non-beacon mode and beacon mode.

The first mode is the beacon mode, which is especially implemented for battery-powered coordinators or the coordinators those do not have any continuous power supply hence saving maximum amount of energy, whereas the second mode which is the non-beacon mode serves especially for the coordinators who have continuous power supply.

In beacon-mode networks, the coordinator device wakes up or become active periodically and send beacons or signal messages to the routers or the intermediate nodes present in its network. This message signal alerts other devices or the nodes to check whether there is any message or information signal or any in coming data in the network. If there is no incoming information or message, both the coordinator and the intermediate nodes go back to the in-active mode or in general words we can say that they fell asleep. Now we can clearly notice that a beacon-oriented network works in time slots or time periods – in other words, nodes are active only when there is any information or beacon in the network. Hence the result of such a network is longer battery lives and shorter cycle for the duty, because of the fact that the nodes are active only when there is any message or information signal in the network otherwise they are inactive and as a result utilizing less amount of electrical power.

In non-beacon mode, the operation is quite different; some of the devices remain active permanently while others shift their roles. The nodes such as coordinator and the routers do not sleep because they are expecting the data from other devices; hence they have to remain active permanently. This mode requires average amount of power supply but is still more than that of the beacon-mode, but still if we talk about its overall power consumption then it is low because most of the network devices or nodes can remain inactive or in sleep over long periods.

In short the amount of power utilized by the Zigbee devices is extremely low as compared to any other technology such as Bluetooth and Wi-Fi, the fact behind this is operation mode of the Zigbee devices that allow them to remain active or inactive on the basis of the area where it has been implemented.

The ability to switch between modes provides Zigbee with an effective feature to save a large amount of electrical energy and makes it the leader of wireless technology. zigbee specification was introduced in the year 2006, it has reached to the sky since and now it is clear that it will over shadow the global control/sensor network standard and will rule the residential, medical, industrial and commercial application[1]. Zigbee provides two way communications for command and control, covers the range of 75-100 meters and provides control sensors that help us to achieve several tasks. If we talk about residential applications we have a number of devices such as lighting control unit, smoke or CO2 detectors, fire detector, HVAC control, security, wireless transmission for television's set top box and remote control. Networking can be found in almost all fields of automation and computerization. We all are familiar with normal techniques of networking; we know what an IP address means when we talk about computers, we all are familiar with OSI layers, functionalities of each layer. Networks allow us to connect different machines and let them to share their resources among themselves, which in return enhances sharing of resources and makes computation extremely easy and cheap. When we talk about automation system, then also we require networking among the devices to achieve automation. But when we talk about low-power micro-controllers [2], i.e. 8-bits/16 bits then networking is quite a challenge. The main motive for the following research work is to construct a network for devices having low power micro-controllers, such as various home appliances, and to wirelessly communicate voice over it to provide a means for automation [3, 4].

C. ZigBee Works Principle

Zigbee and 802.15.4 standard provides us two kind of devices in general. First one is full function devices (FFDs) and the second one is reduced function devices (RFDs). Both the devices consist of 64 bit IEEE addresses [4, 6], but to reduce the packet size they can also be allocated with short 16 bit addresses. The FFDs may be implemented as the coordinators of the networks that will coordinate and manage entire network or they can be implemented as routers, while the devices that in real interact with real world are basically the RFDs. A coordinator is mandatory in all the networks and has the information about the notes present in its network. The coordinator sets up the network and maintains it, and It stores information about the network and check security. Routers act as intermediate gateways that provide channels or passages for the information to go from one device to another. They have less functionality as compared to the coordinator, hence reduce complexity and cost for manufacturing and requires limited amount of energy as well as memory.

2. Literature Review

A great amount of literature exists on the subjects of ZigBee and wireless communication: this technology is discussed regularly in various publications and conferences on computer science and software engineering such as International Conference. In addition, a growing number of special issues and conferences are dedicated to distribute to reduce risk and improve recognition techniques of software. The articles are selected for this issue present new approaches and ideas for automatic toll rate determination system and reports on the applications of some techniques in industry. Previous System.

Previous system used laying sensor to detect axle of vehicle in lane leading to the toll booth when vehicle possesses through the sensor after sensing that vehicle generate a signal and processing device processed the signal by which to know about the exact number. Electronic toll collection System overlap on microcontroller and electronic toll collection system collect the toll on basic of weight of the vehicle.

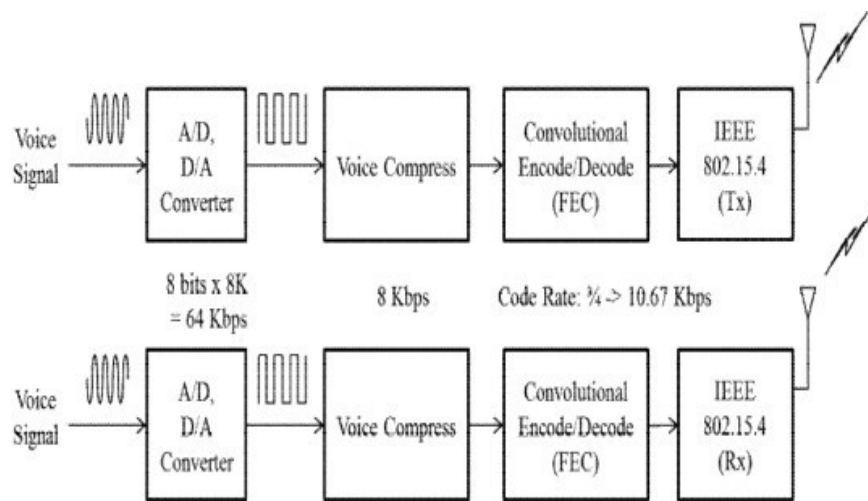


Fig. 2. VoSN system Block

The Mobile Node consists of following parts, such as, Voice Codec, DSP, CC2431, battery, speaker, buzzer, MIC, flash RAM, etc. Following figure shows the MN structure and components.

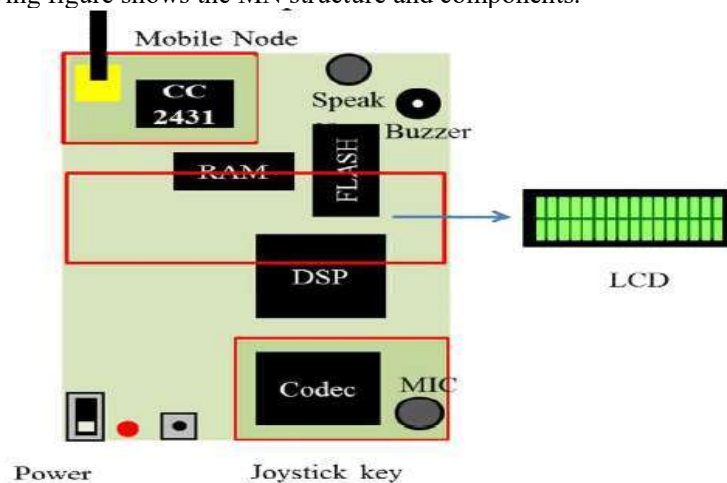


Fig. 3. Mobile Node

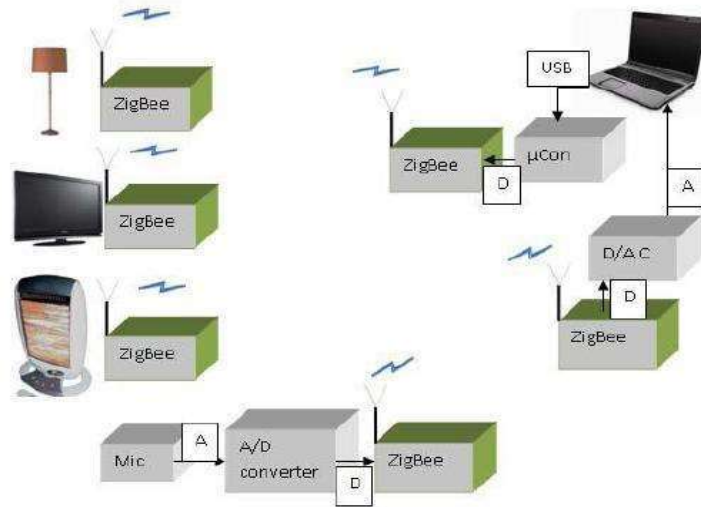


Fig. 4. Home automation System

3. Proposed Methodology

A. Hardware Description of Transmitter

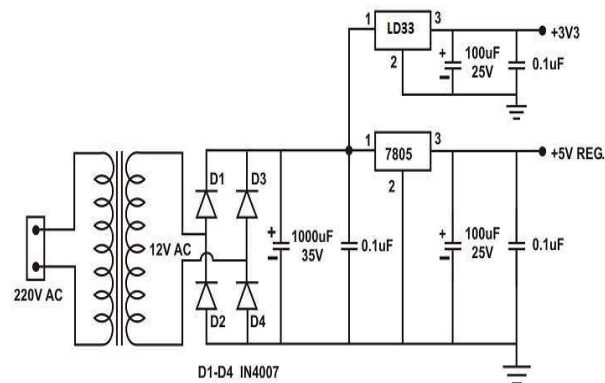


Fig. 5. Power Supply of Transmitter

The system or the prototype is supplied by 220V AC supply as an input. The amount of voltage supply is extremely high; hence it is lowered to 12V AC by deploying a step down transformer. A bridge rectifier then transforms this 12V supply in full rectified AC signal. The output is then passed from the main filter capacitor, and this produces an unregulated 12V DC. An additional filter capacitor is also present in the circuit that eradicates noise.

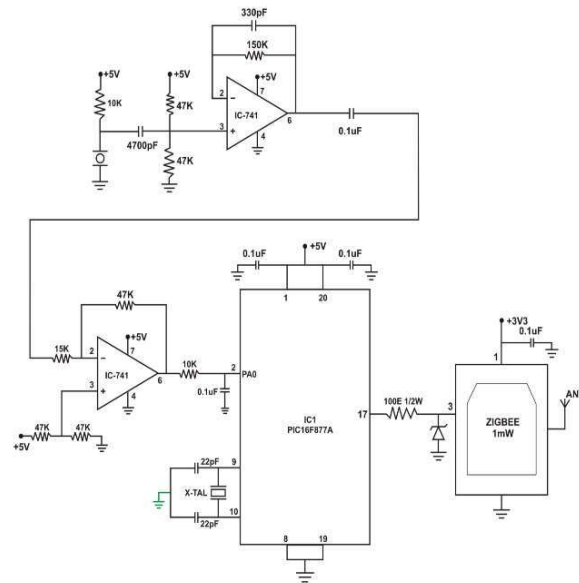


Fig. 6. Circuit design for transmission section

The noise free signal is then passed to two ICs, LD33 and 7805. LD33 provides an output of 3.3V DC which is fed to the Zigbee, whereas IC7805 produces 5V DC, which is provided to mic. Mic that is used for the voice input is a condenser mic, main function of this mic is to convert audio signal into the electrical signal. The output from the mic is centered on the 5V DC, as shown below (Figure 5).

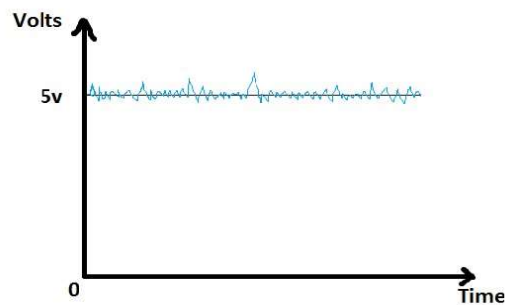


Fig. 7. Audio Signal input at mic centred at 5V

This output is then passed through capacitor (4700 μ F) that acts as a coupling capacitor. This output is fed across resistor R1 and R2 acting as voltage divider. The main objective of voltage divider is to shift down the reference voltage to 2.5V DC as shown in the given figure 5.

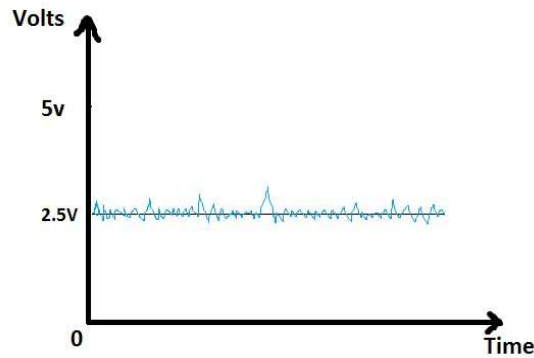


Fig. 8. Audio Signal after voltage divider centred at 2.5V

This output is passed to the first amplifier and then again is passed to the second amplifier which produces an output amplified audio/voice signal that varies between 0 Volts to 5V and is centered around 2.5V, as represented in the given figure 6.

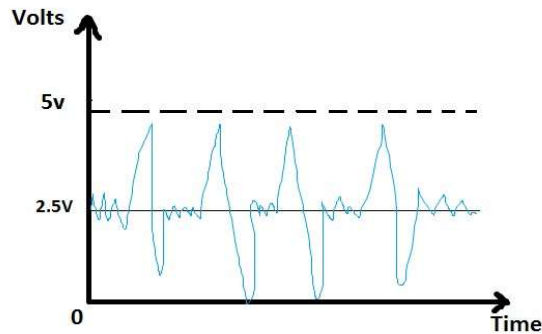


Fig. 9. Final Amplified Voice Signal ranging from 0 to 5V

This output is then fed to the 8-bit microcontroller PIC16F876 microcontroller is used is a 28 pin microcontroller. Pin description of microcontroller is shown in the Table below (Table 1).

Table 1. Pin description of microcontroller	
Pin No.	Description
2	Input from current Limiter
9,10	Crystal Oscillator
19,28	Ground
1	Memory Clear (Active Low pin) = 1
20	Vcc
17	Output of microcontroller

The output from the microcontroller is then fed to the transmitter Zigbee.

B. Hardware Description of Receiver

Similar to the transmission section, here at the receiver side the system or the prototype is supplied by 220V AC supply as an input. The amount of voltage supply is extremely high; hence it is lowered to 12V AC by deploying a step down transformer. A bridge rectifier then transforms this 12V supply in full rectified AC signal. The output is then passed from the main filter capacitor, and this produces an unregulated 12V DC. An additional filter capacitor is also present in the circuit that eradicates noise. This 12V DC is then fed to three ICs, LD33, 7805, 7809. These are three terminal Voltage Regulator ICs. Output for the LD33 IC is 3.3V DC, for 7805 is 5V DC and for 7809 is 9V DC.

At the receiver end, Zigbee receives the signal and demodulates the received signal. Signal produced by the Zigbee varies between 0V and 3.3V. The pin description of Zigbee on the receiver section is shown in the table below:

Table 2. Pin description of Zigbee

Pin No.	Description
1	Vcc
14	Ground
2	Down Converted Digital Data Output

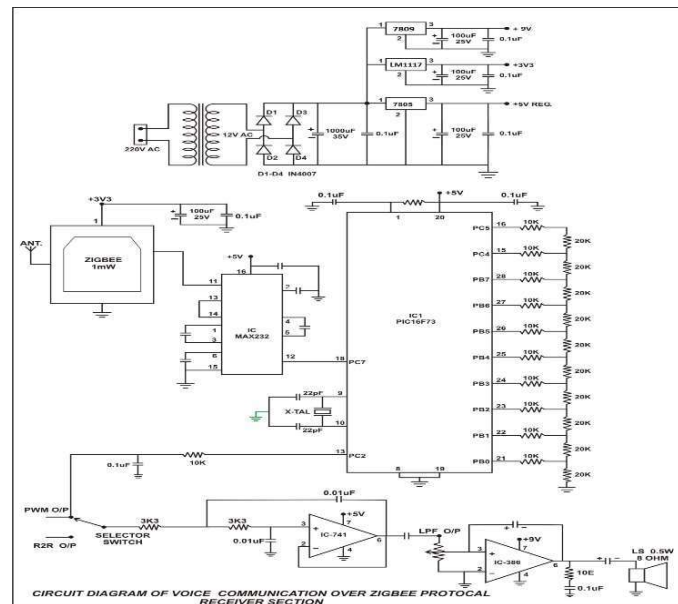


Fig. 10. Circuit design for receiver section as well as Power supply

The micro controller cannot operate on 3.3V data signal; hence the signal needs to be amplified. This is achieved by using IC MAX 232. The pin description of IC MAX232 implemented on this section is shown in table 3 below:

Table 3. Pin description of IC MAX232

Pin No.	Description
11	TTL Input
14	RS232 Output
13	RS232 Input
12	TTL Output

The output produced by MAX 232 is a digital signal. This signal has amplitude which alters between 0Volts and 5Volts. This signal is then fed as an input to the micro controller. The pins of micro controller are described in the given table 4:

Table 4. Pin description of Microcontroller

Pin No.	Description
18	Input from MAX232
9,10	Crystal Oscillator (8 MHz)
8,19	Ground
1	Memory Clear (Active Low Pin) = 1
20	Vcc
21-28,15,16	R-2R Resistors

13	PWM Output
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This output is passed to the first amplifier and then again is passed to the second amplifier which produces an amplified voice signal, which is then passed to the speaker.

4. Results and Discussion

The prototype of this system has been fabricated and tested. The models have been constructed using off the shelf-components that has reduced the cost at drastic amount.



Fig. 11. Model of Transmitter

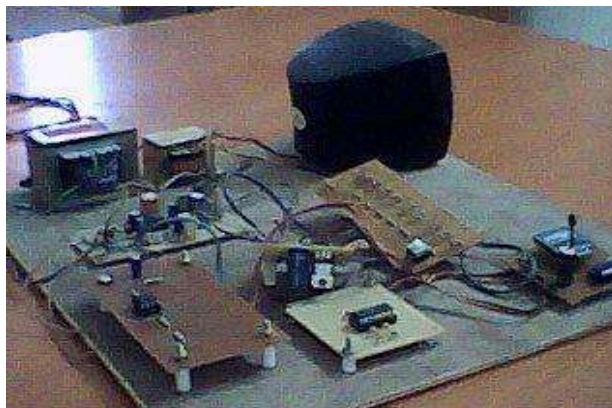


Fig. 12. Model of Receiver

A. Following figures represents the waveforms at different terminals of the transmitter section:-

The audio signal that is being fed in the system by the help of the mic. Mic that is used for the voice input is a condenser mic, main function of this mic is to convert audio signal into the electrical signal. The output from the mic is centered on the 5V DC, as shown below.

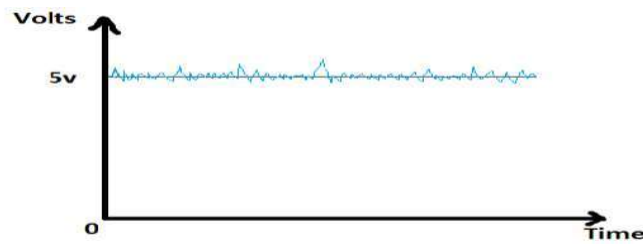


Fig. 13. Audio Signal input at mic centered at 5V

This output is then passed through capacitor ($4700\ \mu\text{F}$) that acts as a coupling capacitor. This output is fed across resistor R1 and R2 acting as voltage divider. The main objective of voltage divider is to shift down the reference voltage to 2.5V DC as shown in the given figure 5.

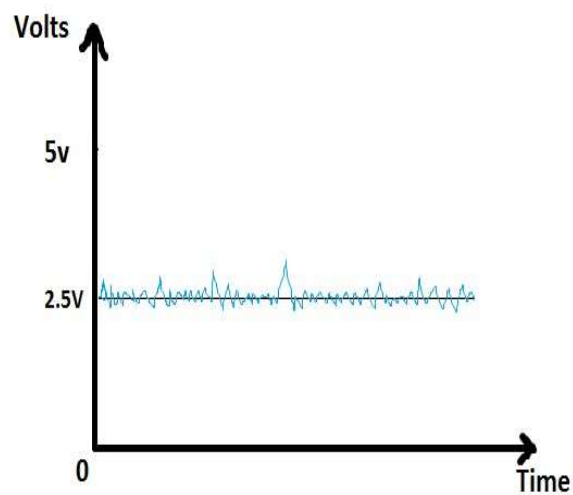


Fig. 14. Audio Signal after voltage divider centered at 2.5V

This output is passed to the first amplifier and then again is passed to the second amplifier which produces an output amplified audio/voice signal that varies between 0 Volts to 5V and is centered around 2.5V, as represented in the given figure.

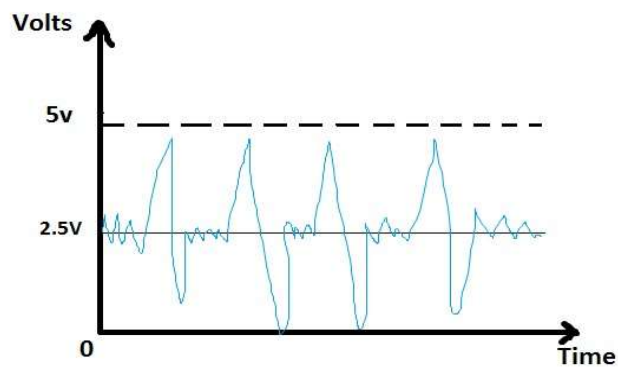


Fig. 15. Final Amplified Voice Signal ranging from 0 to 5V

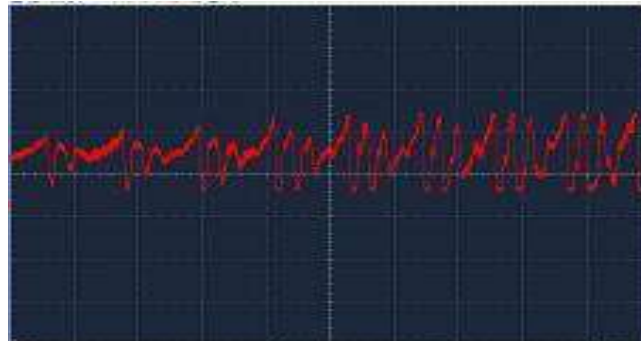


Fig. 16. Amplifier Output

The above figure represents the amplified output signal from the second amplifier.

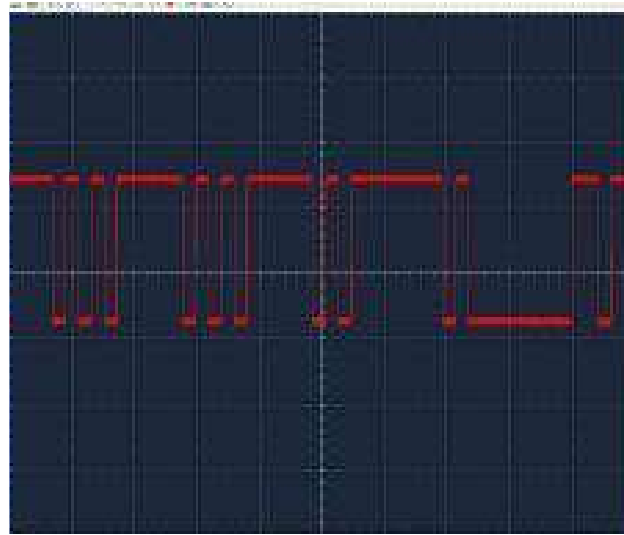


Fig. 17. Waveform at Micro Controller Serial Output

The above figure represents the output signal after the signal is fed into the micro-controller and then is collected from the Micro-controller serial output. This output is then fed to the 8-bit microcontroller PIC16F876 microcontroller is used is a 28 pin microcontroller. The output from the microcontroller is then fed to the transmitter Zigbee.

4.2 Following figures represents the waveforms at different terminals of the Receiver section

At the receiver end, Zigbee receives the signal and demodulates the received signal. Signal produced by the Zigbee varies between 0V and 3.3V. The pin description of Zigbee on the receiver section is shown in the table below:

Table 5. Pin description of Zigbee	
Pin No	description
1	VCC
14	GND
2	Down Converted Digital data Output

The micro controller cannot operate on 3.3V data signal; hence the signal needs to be amplified. This is achieved by using IC MAX 232. The pin description of IC MAX232 implemented on this section is shown in table 5 below:

Table 6. Pin description of IC MAX232

Pin No	description
11	TIL Input
14	RS232 Output
13	RS232 Input
12	TIL Output

The output produced by MAX 232 is a digital signal. This signal has amplitude which alters between 0Volts and 5Volts.

This signal is then fed as an input to the micro controller. The pins of micro controller are described in the given table 6:

Table 7. Pin description of Microcontroller

Pin No	description
18	Input from MAX32
9,10	Crystal Oscillator(8 MHz)
8,19	GND
1	Memory Clear (Active low Pin)=1
20	VCC
21-28,15,16	R-2R Register
13	PWM Output

The PWM output from the micro controller is collected from pin 13 and then demodulated using a RC low pass filter. The two outputs obtained from R-2R and PWM are connected through switch S. Depending on the position of the switch, respective outputs are obtained, which is then fed through an active low pass filter. This output is passed to the first amplifier and then again is passed to the second amplifier which produces an amplified voice signal, which is then passed to the speaker.

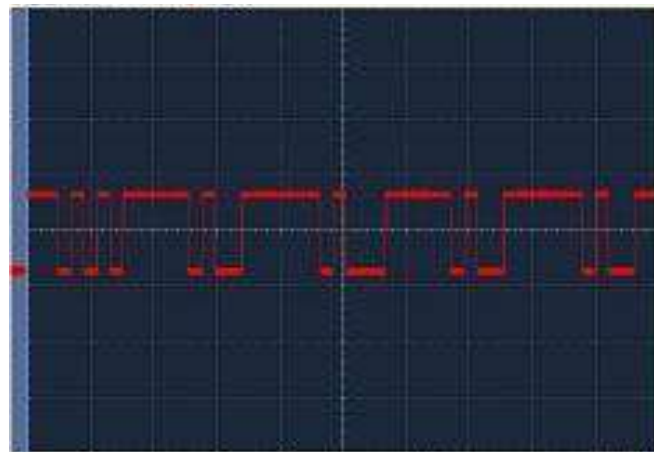


Fig. 18. Waveform at Zigbee output at 3.3V

The above figure represents the output signal from the receiver's Zigbee unit.



Fig. 19. Waveform at Micro Controller Input

The above figure represents the waveform of the signal that is to be fed into the micro-controller



Fig. 20. Waveform at Micro Controller PWM output

The above figure represents the output PWM signal from the micro-controller.

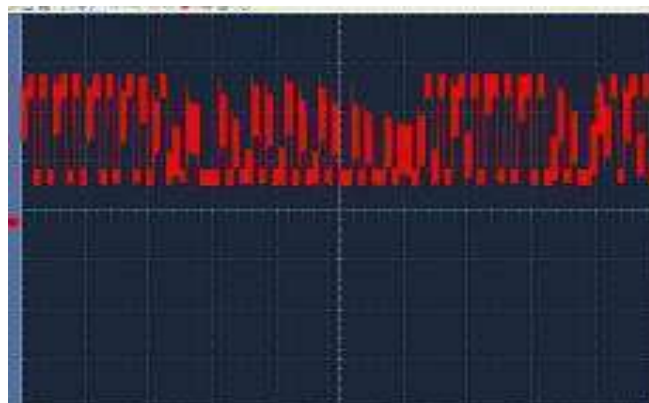


Fig. 21. PWM Demodulated by LPF

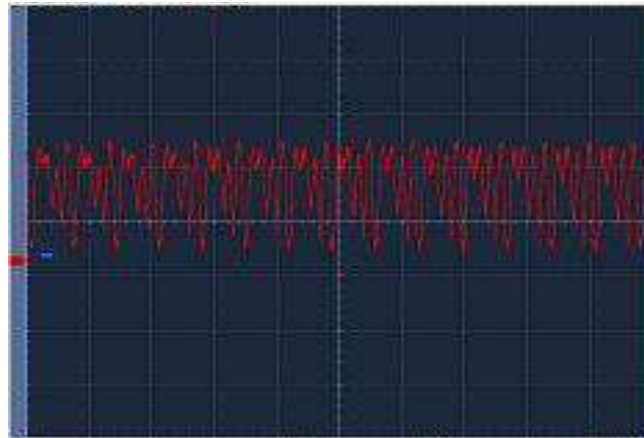


Fig. 22. Waveform at R-2R Output

The prototype was tested well and it performed extremely well up to 25 m.

5. Conclusion

The research contributions gives a significant method for the communication of voice over low power micro-controllers wirelessly. This system shows the total working details of the network, i.e., wireless voice communication. This work has been done to reduce the cost of entire production of such devices that contributes in home automation system and similar projects. The main objective of the research was to transfer voice over low-power micro-controller such as 8-bit micro-controller by the implementation of Zigbee. Till date Zigbee is only implemented on 32-Bits microcontroller not on low power microcontrollers. The main focus of this paper is to implement Zigbee on 8/16 bits microcontroller to decrease complexity, cost, processing power and power consumption.

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