

Development Heart Rate Monitoring using ZigBee

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Abstract—Nowadays, a few systems that provide a continuous health monitoring service for people or patient have been developed. However, the device is large and not mobile. A portable wireless technology heart rate monitor is a personal monitoring device which allows to measure and record heart rate for analysis at any time and any place wirelessly. This project objective is to implement an Electrocardiogram (ECG) and Digital Heart Rate counter using ZigBee wireless protocol and portable unit. The device is most useful if it is portable and it can be monitored from distant location. Generally, the project software application together with its Graphical User Interface (GUI) was developed using Microsoft Visual Studio in VB language for the computer platform. The microcontroller, PIC16F877A located on the main circuit board was programmed in C language using MPLAB IDE software and debugged together with the circuit design using Proteus 7 ISIS. The final prototype of the system was built to demonstrate the proposed functionality of the system. The limitation of this project is this device is able to detect the value of normal and abnormal condition only. It cannot detect the diseases and the category of diseases.

Keywords—Electrocardiogram; heart rate monitor; ZigBee; portable, wireless

I. INTRODUCTION

The electrocardiogram (ECG) is a device used for recording of the electrical activity of the heart. Each heartbeat is initiated by the excitation (depolarization) and recovery (polarization) phase of this electrical activity. An ECG recording, or trace, shows the various phases of the electrical activity above or below a baseline. The heart contract as the electrical impulse travels through the heart's conduction system. Each contraction is one heartbeat, and the atria contract before the ventricles. The process of blood flow is such that the blood empties into the ventricle before the ventricles contract. The heart rate is the number of heart per minute. A heart beat monitor is a device used to measure the heart rate. This device helps to detect heart malfunctions such as a tachycardia, bradycardia, or other diseases. By detecting the voltage created by the beating of the heart, its rate can be easily observed and used for a number health purpose. In general, the monitoring occurs by studying chart data or computing beats per minute [1].

ECG indicates the overall rhythm of the heard and weaknesses in different parts of the heart muscle. It is the best way to measure and diagnose abnormal rhythms of the heart,

particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by levels of dissolved salts such as potassium that are too high or low. ECG is easily recorded at the bedside using portable machines. Electrodes are placed in specified positions on the patient's bare skin, and a simultaneous recording from all the leads is processed via a computer and the result ECG printed out on standard paper.

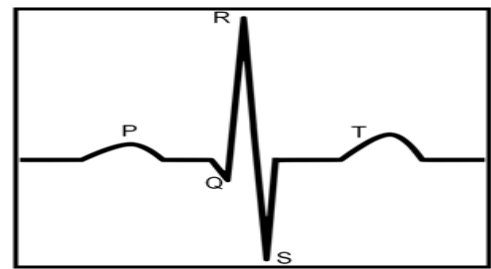


Figure 1. Typical heart rate signal

In above figure, there are 5 identifiable features in an ECG trace corresponds to different polarization stages that makes up a heartbeat. These deflections are denoted by the letters P, Q, R, S and T. By detecting the R peaks and measuring the time between them the heart rate can be calculated and then displayed. Measuring the heart rate using an electrical circuit can be done much quicker and more accurately [1].

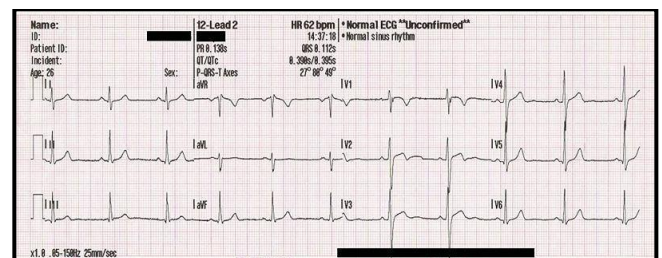


Figure 2. Example of Lead ECG

In real world applications, there are few systems that provide a continuous health monitoring service for people or patient. However, the device is a large and cannot suitable to bring at anywhere. The device is most useful if it is portable. The wireless device of heart rate monitor is a new way to solve this problem by implements an ECG and Digital Heart

Rate counter using ZigBee wireless protocol and portable. The challenge of this project is how far the data will transfer using ZigBee. It is because the ZigBee is wireless protocol device and accurate. If have any interruption such as blockage and noise, the transfer data might be lost. Another major challenge using ZigBee is, if the data transfer simultaneously from various heart rate monitor it might have congested and effect the real time measurement of the heart rate of patient.

The main objective of this project is to monitor the heartbeat wirelessly. Besides that, there have other objectives which are related each other such as implementation of portable heart rate monitoring system. This project also proposed to design and build the device that can measure the human heart rate and also to assist the people for monitor their healthy by referring their normal heart rate. This project focuses on into two parts, which are hardware and software development. In this project, it involves 2 parts in order to accomplish one complete system in monitoring system. For hardware development, it has two boards collectively from a ZigBee module network, one of which is transmitter and receiver circuit. After that, selecting of suitable heart rate sensor and types of PIC that want to be used and also study the literature of ZigBee wireless networking. Besides that, for software development and interfacing identify the suitable programming and its implementation into PIC microcontroller and ZigBee module. It also includes designing the system, built the hardware for the system connection between ZigBee modules using proper software to program the microcontroller PIC 16F877A and LCD interfaces for user purposes.

The main project's objective is to monitor the human heart beat. By monitor the heartbeat, the health's level can be easy identify or determine. It can be done by measure the normal heart rate and make it as reference. The heart rate will be measured consistently in order to check the health's level. Therefore, the benefits or contributions for this project are the heart in the important system in the human body. If the heart is failure, the person will dead. Therefore, by monitoring the heart rate, any change in the heart can be detected and the precaution step can be taken in order to make sure the heart beat is back to normal. Then, the device's operation is simple and easy to handle. Therefore, the people can measure their heart rate and monitor their health by themselves without guidance from the skilled people. Other benefits of this project are the designed device is portable and cost is not too expensive. Therefore, the people can buy it and can do the monitor process at home. Besides that, the people also can make the monitor process at any time that they want. It is very useful and suitable to the people whose are busy with their routine.

II. LITERATURE REVIEW

In order to monitor the heart rate, the device must be design and created. In this project, the device has 3 main parts which are sensor, signal processing and display. For sensor part is used for detect heartbeat from the body. For signal processing part, the Peripheral Interface Controller (PIC) microcontroller is used to process the input from the sensor and send to the display. After that, to make sure the input

signal is processing, the programming will be coded by using suitable computer language. For display part, the Liquid Crystal Display or LCD is used to display the output which is the heartbeat.

A. Wireless Network

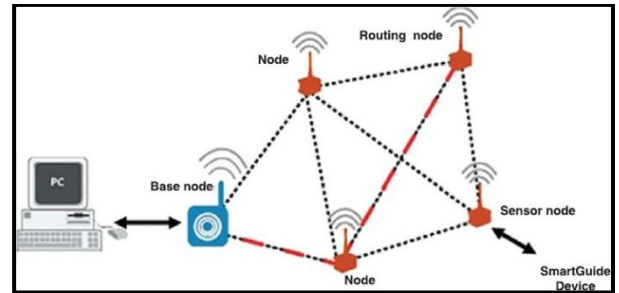


Figure 3. Wireless Network Architecture

Wireless network refers to any type of computer network that is not connected by cables of any kind. Wireless connectivity has been one of the prominent technological innovations of recent years, allowing freedom and ease of access to information. Telemedicine, which puts emphasis on the absence of direct contact between the patient and the physician, wireless devices are the basis for the development of efficient remote monitoring system, able to provide continuous, real time, and accurate information on the health condition of the patient. Besides that, wireless connection as a medium, a number of issues must be considered, ease of network creation, network robustness, data throughput, data loss, and in particular power consumption [2].

The communication between the nodes are performed by establishing the routing topology in the system before the data can be transmit from the certain sensor node to the collection point or host. There are many application of wireless network in the real time. For example, in military, the wireless network can use for intelligence secure, surveillance and reconnaissance. In health, wireless network is used to monitor patients besides it can also assist disable patients [3]. Wireless sensor nodes are small, low-cost, low-power, multifunctional sensor nodes with the capability of sensing certain physical properties, local data processing, and wireless communication. A large amount of such sensor nodes organize themselves in a dynamic manner to carry out a coordinated sensing task which potentially covers a large area such as an agricultural field. Unlike traditional networks, establishing wireless sensor networks has specific challenges owing to the fact that the nodes are resource constrained and, by and large, unattended during their operation [4].

B. ZigBee Protocol

ZigBee is a wireless network protocol specifically designed for low data rate sensors and control networks. The operational range for it is 10 to 75 meters compared to 10 meters for Bluetooth without a power amplifier. The data rate of ZigBee is 250 kbps at 2.4 GHz. ZigBee is a protocol that uses the 802.15.4 standard as a baseline and adds additional

routing and networking functionality. The ZigBee protocol was developed by the ZigBee Alliance. The ZigBee protocols define a type of sensor network for residential and commercial application. Generally used for home care, digital home control, industrial and security control. It combines IEEE 802.15.4, which defines the physical and MAC protocol layers, with network, security and application software layers as specified by the ZigBee Alliance, a consortium of technology companies [5].

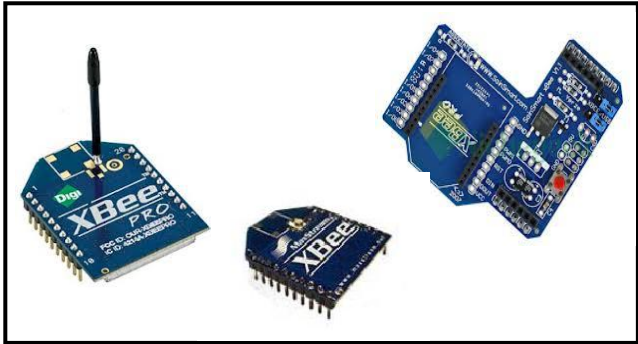


Figure 4. Zigbee Module

The 802.15.4 standard allows for communication in a point-to-point or a point-to-multipoint configuration. ZigBee is one of the most prominent wireless protocols and that transmitting real time ECG data can be good stress test in order to evaluate its capabilities. ZigBee can support a wide variety of network topologies such as tree topology, mesh topology and mesh topology. ZigBee is proving to be an interesting platform for the development of medical devices. The low power consumption, good transmission range and signal strength make it a viable solution for wireless monitoring, where low or medium data throughput is required [2].

The Xbee series 1 was used because it is cheaper than Xbee-PRO. When considering a wireless application, most users will compare the 2.4 GHz Xbee module with the slightly lower cost 433 MHz RF modules. The 433 MHz modules are low power because it used low frequency compared to Xbee and it only suitable for some very simple applications. The Xbee modules offer considerable advantages. ZigBee was designed for low power applications so it fits well into embedded systems and those markets where reliability and versatility are important but a high bandwidth is not. The lower data rate of the ZigBee devices allows for better sensitivity and range, but of course offers fewer throughputs. The primary advantage of ZigBee lies in its ability to offer low power and extended battery life [6]

C. Voltage Regulator

In this project, some of the components used +5 volts (V) direct current. Therefore in order to supply this voltage to the components need a regulator circuit to step down the voltage source like +9V alkaline battery to +5V. Since the regulator

Integrated Circuit (IC) is cheap and easily available, the regulator IC LM7805 is used in this project.

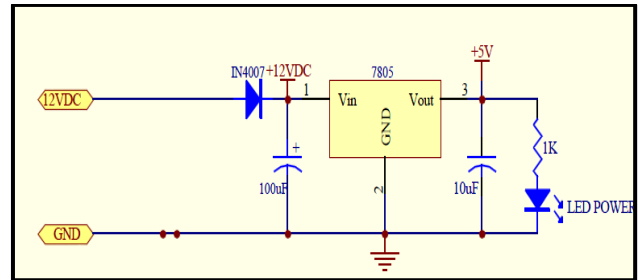


Figure 5. Common Power Supply

A voltage regulator can maintain a voltage level because is an electrical regulator. It can be used to regulate in AC or DC voltage. If the output voltage is too low, the regulation element is commanded, to produce a higher output voltage by dropping less of the input voltage for linear series regulators and buck switching regulators, or to draw input current for longer periods, if the output voltage is too high, the regulation element will normally be commanded to produce a lower voltage [7]

D. Light Dependent Resistor (LDR)

Light Dependent Resistor (LDR) is very useful especially in light or dark sensor circuits. Normally, the resistance of an LDR is very high, but when it's illuminated with light resistance drops dramatically. When the torch is turn on, the resistance of the LDR falls, allowing current to pass through it. This figure below show how LDR and LED work together. To measure the heart beat we need to put our finger between LDR and LED and it will detect our blood pressure that flow from our finger.



Figure 6. The LDR and LED work together

E. Software Development

The software development of this project consist the development of the project using the computer software such as Proteus Professional, Visual Basic and MPLAB IDE for the microcontroller. The MPLAB IDE software is provided by Microchip Technology to develop applications for Microchip microcontrollers such as PIC. In this project, the PIC acts as

an embedded controller which serves to perform a specific set of tasks which is to interpret received data from the ZigBee module and display at the LCD or computer. The PIC will also inherit feedback properties as to provide improved communication protocols in the system. This compiler compiles the final hex file for codes writes in C language which can be programmed into the PIC microcontroller via PIC burning tools. Also, the hex file created can be ported into circuit simulation software for hardware debugging purposes [8].

Graphical User Interface is allows user to interact with electronic device with images rather than text command. The Visual Basic language not only allows programmers to create simple GUI applications, but can also develop complex applications. Programming in VB is a combination of visually arranging components or control, specifying attributes and actions of those components, and writing additional lines of code for more functionality [9].

III. METHODOLOGY

In this part describes how this project will be carried out to achieve the objective of the project. The elements in methodology include the planning of study, flowchart of the research and analysis technique. Project planning is very important when to make a project. This included the understanding the designing of graphical user interface, learning new programming language such as Visual Basic and some basic knowledge about ZigBee as a wireless network connections.

A. Flowchart of Project

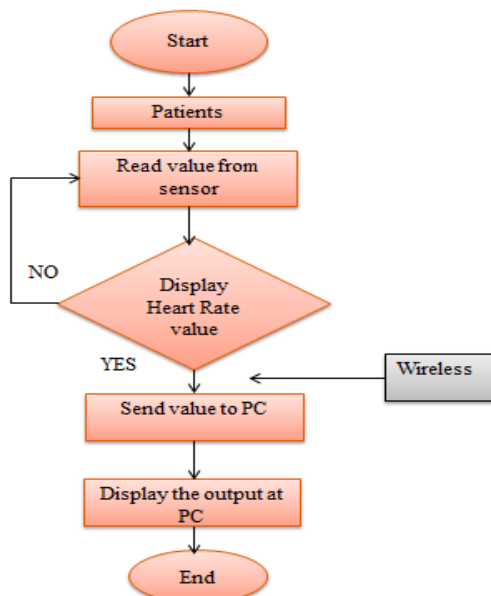


Figure 7. Flow Chart of Wireless Heart Rate Monitor

In this project, heartbeat sensor can be used on a fingertip on the skin between thumbs. It also can monitor the flow of blood. The heartbeat sensor used to receive the heartbeat signal from the patient or human and the output is digit from sent to computer. After the heartbeat sensor detects the value from human, it will be display at LCD or computer. For transmission medium the ZigBee protocol are used in this system to send the data at PC.

B. Flowchart of Project

The heart rate monitor is the project which needs to monitor the heart rate by using ZigBee. Therefore, the device must be design and create. In this project, there have three parts which are hardware part, programming part and monitoring part. Hardware refers to the development of the device itself including the circuit constructing and design. As for the software, it is focused on the program development specifically during the simulation, compilation and PIC 16F877A microcontroller burning process. Two of microcontrollers are used in this project. The first microcontroller is connected to the sensor circuit and ZigBee modules. This microcontroller is used to receive data from the sensor circuit and transmit it using the wireless modules. The other microcontroller is connected to LCD and the ZigBee modules. It will process the data from sensor circuit and display it to the LCD. Both microcontrollers communicate with each other wirelessly using ZigBee modules.

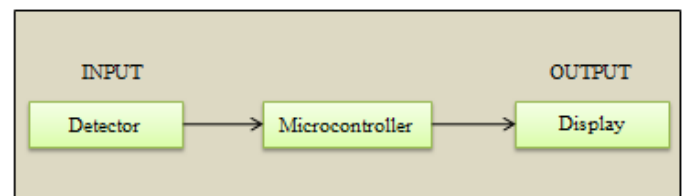


Figure 8. Basic Block Diagram

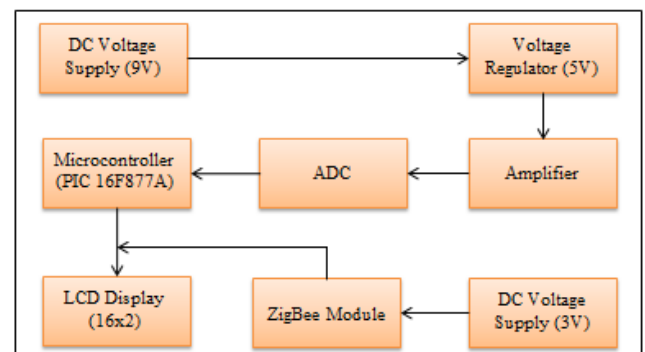


Figure 9. Transmitter Block Diagram

Figure 9 represent the block diagram of transmitter circuit which consist of voltage regulator, microcontroller PIC 16F877A, LCD display and ZigBee module.

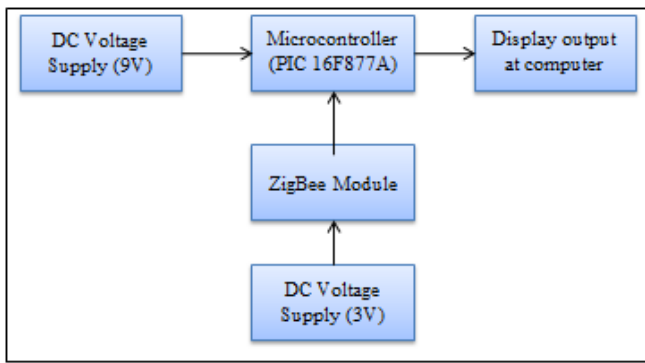


Figure 10. Receiver Block Diagram

Figure 10 represent the block diagram of receiver circuit which consists of ZigBee module, microcontroller and display output at computer.

In this parts also normally involved many parts of the process. The overall process includes layout printing, UV exposure, developing the image, spray washing, etching, resists stripping, scrub cleaning, cutting, drilling and last soldering process.

IV. RESULT AND DISCUSSION

In this part, all result of the project will be shown. The transmitter and receiver circuit are combine to build one complete prototype. Both ZigBee modules communicate with each other to transfer the signal within in range.

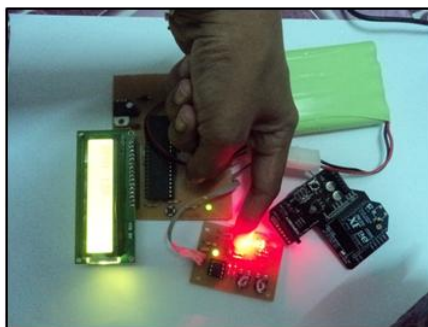


Figure 11. View of transmitter prototype

Figure 11 illustrate view of the transmitter prototype. It consists of 9V battery, ZigBee module, heart beat sensor, voltage regulator and PIC 16F877A microcontroller. The yellow LED indicates there is a signal that being transfer.

From the design, development and implement of heart rate monitor using ZigBee, it is clearly observed that when the heart beat displayed is normal range that have been setting in this project between 60 bpm to 120 bpm the green signal at interface will ON. If the sensed heart beat display abnormal range the red signal at interface will ON. The heart beat signal data are saved in text file and stored at VB interface.

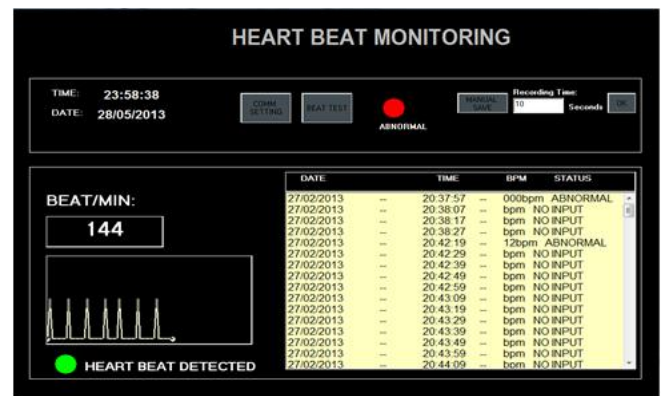


Figure 12. Output display at interface

No. of reading	Result	Condition
1		Normal reading
2		
3		Abnormal reading
4		

Figure 13. The result of normal and abnormal condition

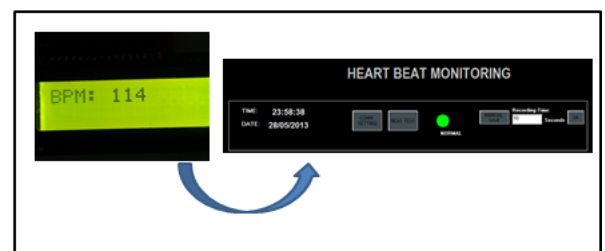


Figure 14. Green button will ON when reading in normal range

Integration of wireless capability into an observation system greatly increases the portability and effectiveness of the system. In this project, both hardware and software interface, it gives ease of accessibility to different types of people. Hardware user interface capability had been realized and fully functional in this project. With use of alphabetical LCD, users can easily communicate with the hardware effectively. As for the system in standby mode, it displays the current no input without connecting both ZigBee modules. Apart of being observation system, this hardware interface can also be used to configure the wireless module parameters. The range of wireless capability of the XBee module is up to 100 meters for line in sight and 30 meters for indoor or urban range. With such features, this system can be implemented for telemedicine especially at hospital or clinic. Heart rate measured either by the ECG waveform or by the blood flow into the finger. The pulse method is simple and convenient. When blood flows during the systolic stroke of the heart into the body parts, the finger gets its blood via the radial artery on the arm. The blood flow into the finger can be sensed photo electrically. To count the heart beats, a small light intensity on the other side are used. The blood flow causes variation in light intensity reaching the light dependent resistor (LDR), which results in change in signal strength due to change in resistance of the LDR.

V. CONCLUSION AND RECOMMENDATION

A. Conclusion

At the end of this project, this project was actually significantly interesting since it gave the opportunity to improve knowledge and skills especially in electronic field. During the project development, many other soft skills were also obtained such as a critical thinking, problem solving and experience in decision making process. The focus of ZigBee development was on maintaining simplicity by concentrating on the essential requirements that will leverage a successful standard. This system is cost effective, time efficient and works as high speed in its operation. The development of this wireless solution within the standards organization has the advantage of bringing several views together to define a better solution. Generally the main objective of this project is to monitor the human heart beat through wireless. Before design and build the device, the device's specification must be identified. The device's operation also needs to be clarified. As a conclusion for this report, this device is the new improvement to reduce the human use and cover the problem from the amplify signal from heart that always has a noise. Accordingly to the explanation above from introduction until the budget cost for this project, it will successful if the

progress in the time to time achieve from hardware making until the software programming to run and make sure this device is working at the end of this project.

B. Recommendation

Heart rate monitoring using ZigBee has a few of limitation. Firstly, this project only detects the value of normal and abnormal condition. It cannot detect the disease and what category of disease. This project can be improved by using the XBee-PRO ZigBee. It because the range of this module is 300 ft (90m) for the indoor range while, for the outdoor range is 1.6 km. The data can transfer more effective compare using the XBee module. With the development of modern society, the health care becomes more community-oriented. For future development, the designed a portable wireless must be more efficiency to detect real time signals, send arrhythmia alarms and the condition the patients.

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