Low Cost Heart Rate Monitoring Device Using Bluetooth

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***Abstract*— Body health monitoring is very important to us to make sure our health is in excellent condition. One of the vital parameter for this matter is the heart rate (HR) data. Other than that the parameters such as temperature, weight and blood pressure also significant to body health monitoring. In this paper we described the design of low cost heart rate monitoring device based on the Bluetooth technology. The entire system is comprised to several parts such as heart rate module, computer Graphic User Interface (GUI) and Bluetooth module. The HR module is used to pick up heart rate signal from the subject (patients) and sends it (signal) wirelessly to computer or server using Bluetooth transceiver. This system can be incorporated and integrated as a part of telemedicine component. The data received from heart rate module can be saved and view for further medical usage such as to get hourly or daily data. The result from this project shown great outcome, indeed we had tested the Bluetooth's signal of this system within our building facilities which blocked by gypsum's partition and the signal can be transmitted between 15 to 20 meters radius. Some issue that can be improve for this system such as sizing and arrangement of the components so that it can be custom made in compact sizing and more convenient to the users for mobility purpose.**

Keywords— telemedicine; health monitoring; bluetooth; heart rate; medical device.

I. INTRODUCTION

Health monitoring is important to be checked regularly in order to make sure our body constantly maintain in healthiness and excellent condition. Generally the vital parameters observed for health monitoring such as Heart Rate (HR), temperature, weight, blood pressure, glucose and ECG. These parameters will interpret some important information regarding to body health, for example high temperatures indicate someone having fever while unstable heart rate is sign to heart problem.

One of the methods to do health monitoring is to use remote patient monitoring. This device operates remotely by collecting and sends data to a monitoring station for display, interpretation and storage for patient history record. Such "home telehealth" applications might include using telemetry devices to capture a specific vital sign. Such services can be used to supplement the use of visiting nurses or to get medical consult from the doctor [1].

Telemedicine is the method which allow medical devices to send data wirelessly through telecommunication such as GSM modem [2], using internet [3], Radio Frequency (RF)[4], monitoring telemetry system using ZigBee [5] et cetera. The important of telemedicine nowadays become more increasingly by increasing of health care awareness. Another factor is due to increasingly incident of sudden death at home or at area which faraway from medical facility. It can happen to anyone especially the elderly and people who suffer with chronic disease or poor health, therefore continuously monitoring is important to these kinds of peoples.

According to R. Gonzalez-Landaeta et al. [6] The HR is a basic health indicator, useful in both clinical measurements and home health care. Current home care systems often require the attachment of electrodes or other sensors to the body, which can be awkward to the patient. In [6] works they introduces novel technique for HR measurement using plantar bio impedance measurement.

Pulse Oximetry is a method of monitoring the HR and the level of oxygen in the blood stream of a human body[7]. Pulse oximetry is based on a relatively new concept, using the pulsatile variations in optical density of tissues in the red and infrared wavelengths to compute arterial oxygen saturation without need for calibration. The method was invented in 1972 by Takuo Aoyagi, a bioengineer, while he was working on an ear densitometer for recording dye dilution curves [8].

Previous work as presented by [9], introduced low cost design of heart beat monitoring device (HBMD). Their design employ reflectance mode photoplethysmography (PPG) to extract the pulse signal from the finger which is equivalent to the heart beat. They used several stages in their design such as amplify, filter and digitize the extracted heart beat and also interfacing technique via parallel port to computer to calculate and display the heart rate [9].

Plethysmograph is a combination of the Greek word, 'plethysmos' meaning increase and 'graph' is the word for write. It is an instrument used mainly to determine and register the variations in blood volume or blood flow in the body.

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These transient changes occur with each heartbeat. There are several different types of plethysmograph, which vary according to the type of transducers used such as air, impedance, photoelectric, and strain gauge plethysmograph [10].

In other work by N. M. Z. Hashim et al. [11] they development optimal photo sensors based heart pulse detector with improvements by using LCD for display the counter heartbeat in unit beat per minute, they had shown and prove; each photo sensor has differences significant wavelength. The aim of their project is to develop simple photo sensor that is easy to be used for monitoring pulse (health condition) everywhere, comfortable, reliable, accurate result and also using low cost.

Work done by [12] is regarding on photoplethysmographic imaging using a cellular phone or computer camera and user or people also do not need to wear any special equipment. The method they used by put an area of skin placed in the front of camera lens for several seconds as consecutive images are captured by the camera and then processed by computer vision and advanced signal processing technology, relative physiological signals such as HR, respiratory rate, HRV and oxyhemoglobin saturation are acquired. The advantage of photoplethysmographic imaging for medical applications is the intrinsic safety since there is no electrical contact between the patient and the equipment.

This paper presents low cost heart beat monitoring device using Bluetooth technology. Bluetooth wireless technology is chosen because it is easy, free cost, easy to communicate between devices such as computers and mobile phones. This prototype employed the concept of reflectance mode photoplethysmography (PPG). The basic optical sensor of this consists; an infrared light emitting diodes (LED's) and a photo sensor. This prototype used components such as amplifier, filter, microcontroller Peripheral Interface Controller (PIC), and interfacing serial using Bluetooth for wireless data transmission to computer for display the result using Graphic User Interface (GUI). The uses of Bluetooth transmission to computer can be consider as Telemedicine function. All components used can be bought easier and inexpensive, intended to produce low cost and affordable heart beat monitoring device.

II. METHODOLOGY

The block diagram shown in Figure 1 illustrates the overall picture of low cost heart beat monitoring device using Bluetooth. This system can be divided into several parts which are the sensor board, microcontroller, Bluetooth communication and computer. In sensor board the components consist of sensor, microcontroller and communicate with Bluetooth transceiver. At computer side consist of Bluetooth transceiver, comm. module, monitor and server. The signal is taken from the human finger. This signal will be capture by IR diode and photodiode by applied the principle of Plethysmography (PPG). The signal pickup from the sensor will be processed by microprocessor and the data will be passing to Bluetooth communication module in PIC board and transmitted to computer. The data will be captured by Bluetooth transceiver at computer side and beat rate will be displayed in GUI at computer display another display can be viewed at LCD embedded at microcontroller board. The data also will be stored for further action.

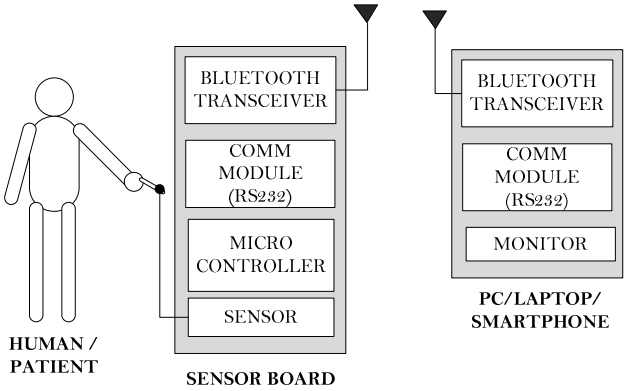

Figure 1: System overall for this telemedicine

A. Microcontroller

In this prototype PIC 16F877A microcontroller is used, intended to attain low cost objective, using this PIC microcontroller is much cheaper compare to other controller for instance ATMEL microcontroller. To activate this microcontrolle, seven pins in PIC need to be connected; one pin from power supply, four pins from reset pin and another two pins from oscillator. Figure 2 shows the schematics of PIC 16F877A microcontroller. This PIC via Pin 4 (RA4) is connected with heart beat circuitry via pin 7 in operational IC LM358N. For Bluetooth transmission RX/TX pin RC6/RC7 is connected to MAX 232 pin14/13 this for converts signal from RS232 serial port to signals fitting for use in TTL compatible digital logic circuit. For LCD display, pin RB4 and RB5 in port B and RD4 to RD7 from port D are used.

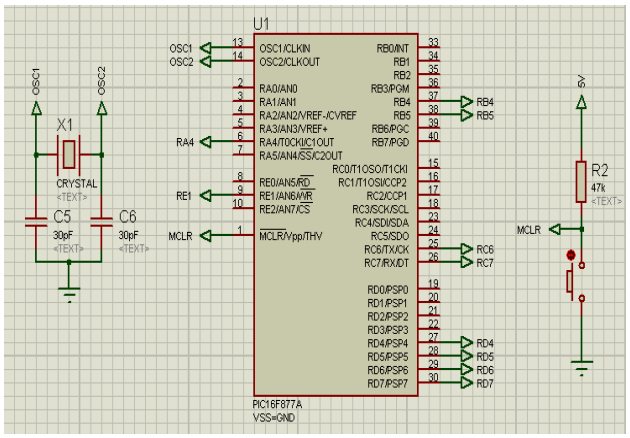

Figure 2: Microcontroller

B. Heart Beat Sensor

The high intensity light emitted by led originally falls on photo sensor (Figure 3). This is the state where the heart beat is calibrated to zero using resistors RV_3. When a patient places his finger in between infrared (IR) diode and photo sensor the

light is restricted by the finger. The intensity of light penetration decreases if the blood is pumped into the finger. If the blood is not pumped then the light intensity is high. This high and low light intensity helps to measure heart beat. The duration of light disturbed is measured which gives the time duration of every heart beat pulse, inverse of this time gives the heart rate count per minute. This signal is amplified in two stages using dual operational amplifiers LM358N. The resistor RV_4 is used to adjust the square wave pulse achieved, C_{40} is used as feedback capacitor. The output after amplification is obtained at pin number 7 of operational amplifier LM358N and fed to microcontroller PIC 16F877A.

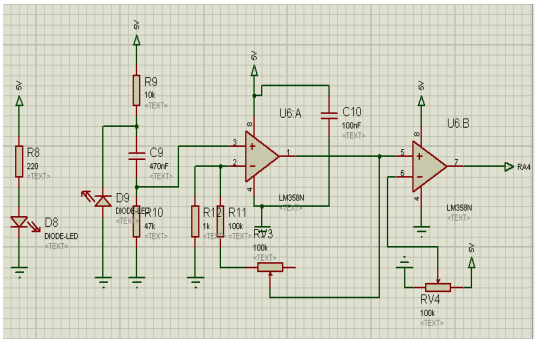

Figure 3: Heart Beat Schematic

C. *Power supply*

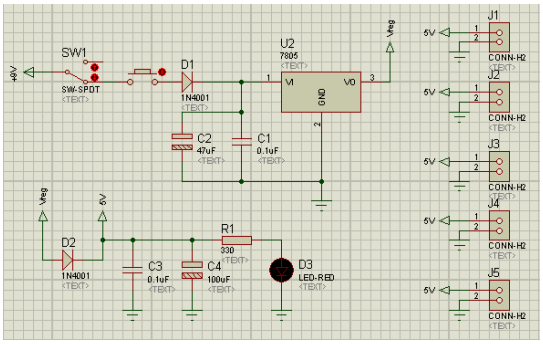

Figure 4: Power supply voltage regulator connection schematic

Voltage regulator used in this prototype as shown by Figure 4, where constant linear output voltage is produced by this voltage regulator. This circuitry commonly used to convert AC to DC power supply. It can also be used to convert the DC to DC voltage. Single IC is used in this system where it is from the 7805 series design for positive output. The output voltage is +5 V DC and for input shouldn't more than 18V or less than 8 V. There are two capacitors in this voltage regulator circuit, where it helps to produce a regulated voltage at the output smooth. Electrolytic capacitors are used in this circuit.

D. *Liquid Crystal Display (LCD)*

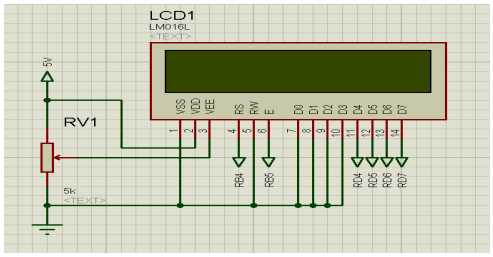

Figure 5: LCD connection schematic

For this prototype a Liquid Crystal Display (LCD) is used like shows by Figure 5 simulated using Proteus software. This LCD is used to allow users (medical staff) to view through the LCD the result from the reading of heart rate. This LCD is good because it is used less power consumption and it does not generate electromagnetic radiation such as CRT and also the display is in digitalized form. In this project, 2x16 LCD is used to display the system status to the user where 2x16 means 2 lines and 16 characters can be showed in LCD display.

E. *Bluetooth Conection*

Illustration layout of ward arrangement as shown in Figure 6, can be estimated approximating length of patient bed 6.24975ft, gap between beds 6 ft therefore length of one room (4 patients beds) is 6.24975ft x 2 beds + 6ft = 18.4995ft in long run. If the Bluetooth signal can cover 30 meter (98.4252ft) thus more than three cubicle wards can be covered. Therefore this low cost heart rate monitoring device can handle the signal transmission within that area.

Figure 6: ward layout arrangement using open concept for patient monitoring

Bluetooth communication is used in this prototype to connect controller board (include heart beat circuitry) and computer in order for transmission data signal. The data (pulse rate) will be sending using serial communication via Bluetooth. The connector J1 via; pin 1, pin 2 and pin 3 (Figure 7) are to connect the Bluetooth module with micro controller thru pin RC6 for pin 2 and RC7 for pin 3 while pin 1 is supply 3V taken from voltage regulator. This Bluetooth used is known as BlueBee from Cytron Company. This Bluetooth module can transmit data in range between 20 meter and 30 (these range is sufficient for small ward or home) like in Figure 6.

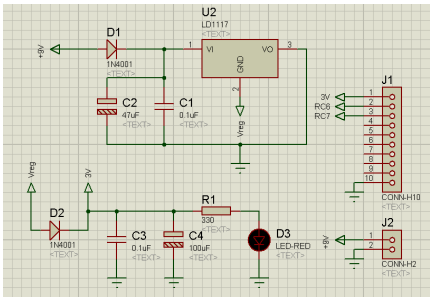

Figure 7: Bluetooth connection schematic

III. RESULT AND DISCUSSION

This prototype is functioning when the user put their finger between IR and photo sensor, the luminous of IR will be block by the flow of blood pumped in out when heart pumping the blood to the entire body. This signal is capture by the heart beat sensor and sends to PIC microcontroller. Figure 8 shows the status of heart rate when the patient puts the finger on the heart rate sensor. Data collected will be transferred to the PIC16F877A microcontroller and will be display on the LCD monitor.

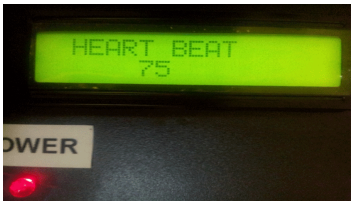

Figure 8: LCD display the result

This graphic user interface (GUI) (Figure 9) used to display data from HR board. This GUI has three main parts. At the left of the interface is the port setting and test measurement. For the port setting, this setting will search the available communication port in computer while for test measurement, the reading will display heart beat test (bps) and time test also display in real time each test measurement taken. Lastly, at the right of the interface there will be the saving file, where the user (e.g. nurse) can key in patient's name and save their recorded data in computer or server. After connection is complete, Bluetooth from the sensor circuit will send the data and the GUI will show the user HR data in (bps), time and date during the measurement is taken.

Result presented in Table 1 are obtained from 18 persons who are participate in this examination using this developing prototype device, they are from two different genders (9 Female and 9 male). These groups are from different age between 20 to 30 years old and all of them in good health condition and did not engage with any tension activities (e.g. run, work, and climbing). For this experiment each volunteer data will go for each separation distance, the data acquired were averaged over a 30 s time interval. To get 60s interval for Beat per Minute (BPM) the 30 s time interval will be multiply by 2 and the average valued as listed in Table 1

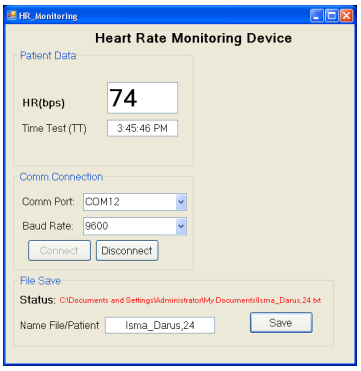

Figure 9: Computer GUI for Telemedicine

TABLE 1:
Data Collection of HR

Age	Sex	Average HR (BPM)
23	Female	70
24	Female	68
25	Male	72
26	Male	85
23	Male	80
22	Male	84
20	Female	70
21	Female	84
22	Female	73
24	Female	74
28	Female	76
30	Male	86
29	Male	89
28	Male	92
20	Male	87
21	Female	70
23	Female	72
25	Male	87

Refer to Figure 10, average of HR are between 68 and 92 BPM, in these data shows two group of genders (male and female) between age 20 and 30 were participated in this test. Their conditions before experiment are in good condition with no stress and fatigued state. Therefore the result shows normal HR reading from this prototype device.

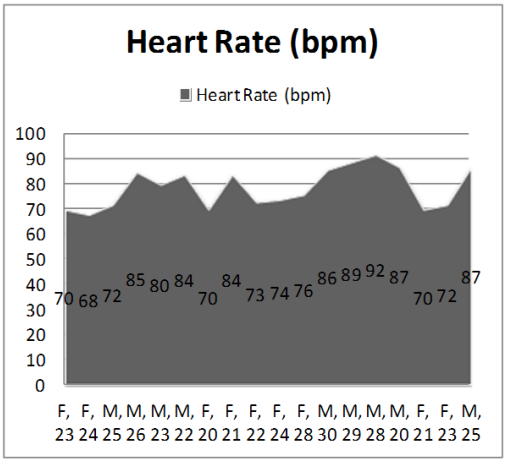

Figure 10: Graph from plot using Data Collection of HR

In this system Bluetooth module is used because Bluetooth technology can easily connected to most of electronic stuff for instance smart phone, tablet computer et cetera, for this system we interface to computer for monitoring the HR data. To know the strength of the propagation Bluetooth signal we had tested and run the system within our building facilities this to ensure the signal can be received by the central main computer/server. This to know the performance and to measure the optimum range the signal can be received by the Bluetooth module. We also run this test in different level of the building ground floor as illustrated in Figure 11 and first level as illustrated in Figure 12. The results show that for ground level the radius of signal propagation are between 15 to 20 meter while for first level the radius propagation is 10 meters. Table 2 shows the summaries of voltage and current used by the main components.

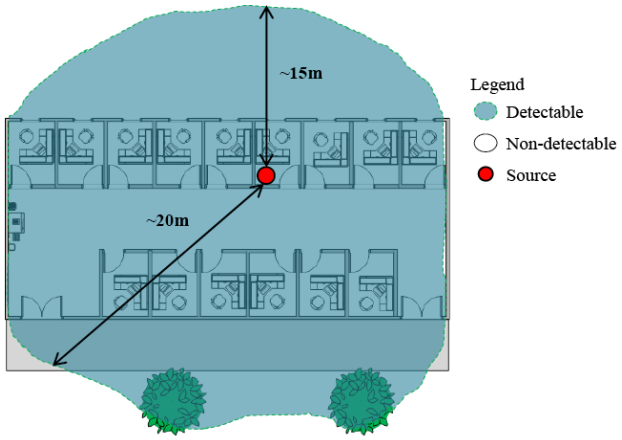

Figure 11: Rough estimation of Bluetooth connection range (Ground floor)

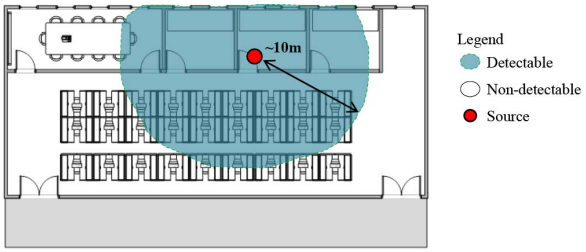

Figure 12: Rough estimation of Bluetooth connection range (First floor)

TABLE 2 :
Required Supply of System Circuit

Item	Input Voltage (Vdc)	Input Current (mA)
PIC16F877A	5 V	250 mA
MAX232	5 V	10 mA
ULN2003A	5 V	1.35 mA
Relay	5 V	89.3 mA
Humidity Sensor	5 V	2 mA
BlueBee	5 – 12 V	300 mA

IV. CONCLUSION

This project was developed successfully and run smoothly where all parts functioned and achieved according to the objective, even though this prototype used inexpensive components purposely to target the low cost high end product but quality of this device is make sure to be remain. This prototype as mentioned in subsection E capable to cover more than three standard four beds cubicle ward and also standard home environment. This prototype can support in Telemedicine application because it have capability to communicate with computer using Bluetooth technology. For future development this system connected to other parameters such as temperature, ECG data, and blood pressure and so on and also support other display e.g. can be viewed from smart phone and tablet computer.

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