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A WIRELESS HEARTBEAT AND TEMPERATURE MONITORING SYSTEM FOR REMOTE PATIENTS

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Abstract— *This paper describes the development of a wireless heartbeat and temperature monitoring system based on a microcontroller at a reasonable cost with great effect. Most monitoring systems that are in use in today's world works in offline mode but it is of great need that a system must be designed so that patient can be monitored remotely in real time. The paper consists of sensors which measures heartbeat and body temperature of a patient which is controlled by the microcontroller. Both the readings are displayed in LCD monitor. Wireless system is used to transmit the measured data to a remote location. The heartbeat sensor counts the heartbeat for specific interval of time and estimates Beats per Minute while the temperature sensor measures the temperature and both the data are sent to the microcontroller for transmission to receiving end. Finally, the data are displayed in the LCD at the receiving end.*

Keywords: Microcontroller, Heart rate, Body temperature, Remote Monitoring, Fingertip sensor

1. INTRODUCTION

In today's world, the maximum use of resource is always complimented. So, the use of wireless technology is enhanced to meet the need of remote control and monitoring. Remote patient monitoring (RPM) is a technology that enables us to monitor patient outside of clinic or hospital without having to visit a patient. It may increase access to health services and facilities while decreasing cost. Remote Patient Monitoring saves time of both patient and doctor, hence increasing efficiency and reliability of health services.

Heartbeat and body temperature are the major signs that are routinely measured by physicians after the arrival of a patient [1]. Heart rate refers to how many times a heart contracts and relaxes in a unit of time (usually per minute). Heart rate varies for different age groups. For a human adult of age 18 or more years, a normal resting heart rate is around 72 beats per minute (bpm). A lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. Babies have a much higher rate than adults around 120 bpm and older children have heart rate around 90 bpm.

The heart rate increases gradually during exercise and returns to its normal value after exercise. The rate at which the pulse returns to its normal value is an indication of the fitness of a person. If the heart rate is lower than the normal heart rate, it is an indication of a condition known as bradycardia and if the heart rate is higher than the normal heart rate, it is an indication of a condition known as tachycardia [2].

Like heart rate, normal body temperature also varies from person to person and changes throughout the day. The body temperature is lowest in the early morning and highest in the early evening. The normal body temperature is about 37^{o} C or 98.6^{o} F [3]. However, it can be as low as 36.1^{o} C (97^{o}F) in the early morning and as high as 37.2^{o} C (99^{o} F) and still be considered normal. Thus, the normal range for body temperature is 97 to 100 degrees Fahrenheit or 36.1 to 37.8 degrees Celsius [4].

Temperature can be measured by using different types of sensors. These sensors come in different forms such as thermocouples, thermistors, resistance temperature detectors (RTD), and integrated circuit (IC) sensors. The temperature sensor produces analog output voltage which is proportional to the temperature. The temperature sensor requires analog to digital (A/D) converter so that the analog output voltage can be converted to digital form [5]. The output of the temperature sensor is connected to the Port A of PIC16F72 microcontroller. The microcontroller processes this data and displays it in LCD as well as sends it to the receiving end for displaying at the remote place. This paper describes the design of a very low-cost remote patient monitoring system which measures heart rate and body temperature of a patient and sends the data to a remote end where the data will be displayed and physician or doctor will be able to examine him/her. This device will be much needed during emergency period or for saving time of both patient and doctor.

2. SYSTEM HARDWARE

The device consists of two PIC16F72 microcontroller- one for the measuring and transmitting end while other for the receiving end. For measuring heartbeat, the device makes the use of photo diode and bright LED along with amplifier and filter while for measuring temperature, the device uses LM35 IC. The device measures heartbeat and temperature of the body and transmits it wirelessly with the help of RF transmitter and the data is received at the other end with the help of RF receiver, and finally the data is displayed on the LCD. Figure 1 and figure 2 shows the block diagram of the device of transmitting end and receiving end respectively.

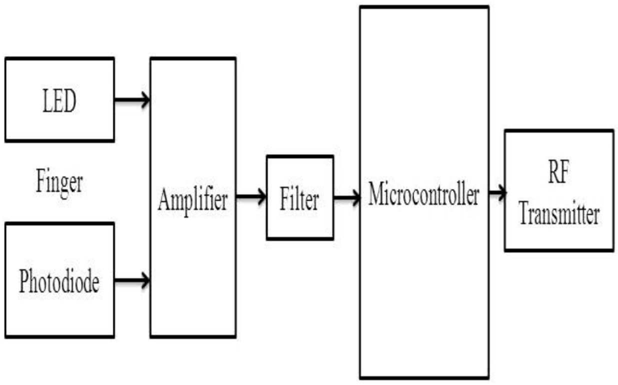


Fig. 1: Block diagram showing heartbeat and temperature measuring and transmitting sytem

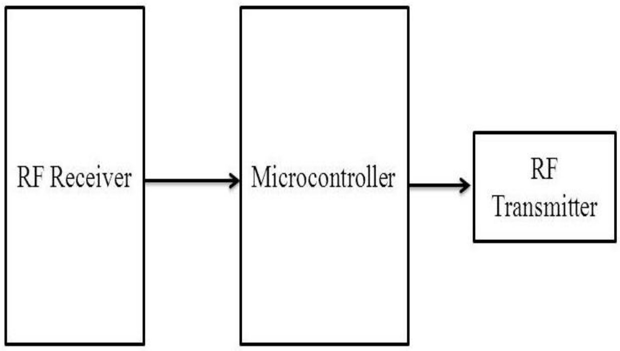


Fig. 2: Block diagram of receiving end showing display.

2.1 Heartbeat Monitoring Unit

This unit consists of optical sensor and an infrared light emitting diode (IR LED) to measure heartbeat in beats per minute (bpm). The optical sensor along with IR LED senses the change in blood volume and produces a signal which is amplified and then filtered. The filtered signal is processed in the microcontroller and finally the data is sent to receiving end with the help of RF transmitter where RF receiver receives the data. The received data is sent to another microcontroller at the receiving end to display the data on LCD.

2.1.1 Fingertip Sensor

The fingertip sensor consists of a photodiode and a bright LED. The LED and the photodiode are mounted on a tube made up of steel. The photodiode and LED are mounted opposite to each other as shown in Fig. 3. The light from LED is shone on the tissues of the finger that is inserted in the tube and variation in volume of the blood changes the amount of light falling on the photodiode. Thus, photodiode and LED are mounted on opposite sides to detect the change in the transmitted light. The tube which is round in shape is made up of steel in which the photodiode and LED are mounted. The LED and photodiode are held tightly in the tube by drilling holes in the tube so that LED and photodiode are held opposite to each other in the best possible position to detect the change in transmitted light. For tight grasping, both the devices are soldered onto the tube. The infrared filter of the phototransistor reduces interference from fluorescent lights, which have a large AC component in their output [6]. LED and photodiode are soldered for proper connection.

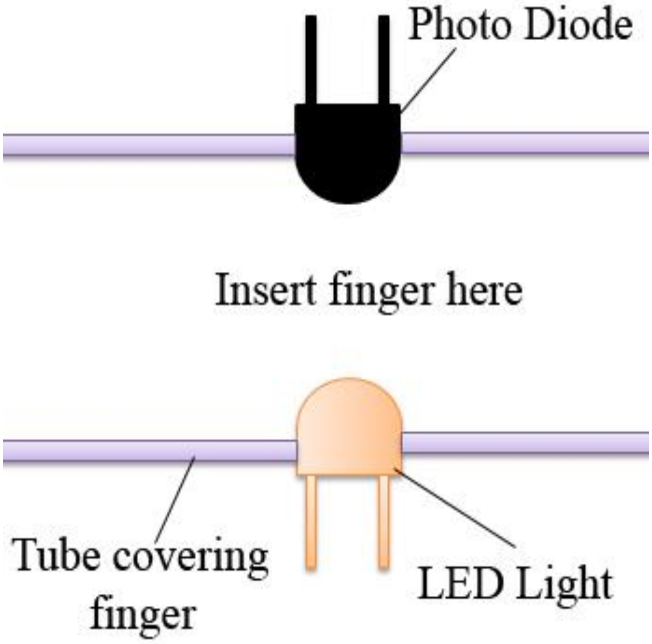


Fig. 3: Sensor arrangement in a tube.

2.1.2 Amplifier and Filter Stage

The change in blood volume with the heartbeat produces pulse at the output of photodiode. The signal obtained from photodiode is so small in magnitude that the signal cannot be detected directly by a microcontroller. Hence, the signal needs to be amplified by using operational amplifier. The amplification of the weak signal from photodiode is done by using LM358 operational amplifier. This operational amplifier consists of two independent, high gain, frequency compensated operational amplifier which is designed to operate from a single supply over a wide range of voltages.

This unit comprises of two stages of amplification by using operational amplifier. The operational amplifier is used in non-inverting mode in both the stages. The operational amplifier used in the circuit is low power quad operational amplifier. The signal is amplified to appropriate voltage level so that the pulses can now be counted by the microcontroller.

The signal from the photodiode also contains noise which requires filtering. The signal is affected by interference resulted from movement of artefacts like rings and mains 50Hz. It is known that the standard ECG signal has frequency components in the range 0.05-200Hz. If filtered to the range 0-50Hz, the signal does not suffer any significant loss of quality i.e. information within the signal is not lost [7].The amplifying and filter circuit arrangement is as shown in Fig. 4. Filtering is done by using simple resistance and capacitance as component. Resistance (R) and Capacitance (C) is arranged such that it acts as a low pass filter and blocks higher frequency noise components that are present in the signal. Capacitor is used at each input terminal to block the dc component in the signal. Finally, a green LED is placed at the output of this unit to indicate the pulse in analog form.

R5=R1, R2=R4

Gain of each stage=1+ (R5/R4)

=1+ (680k/6.8k)

=101

Cut-off frequency=1/ (2πRC)

=2.34Hz

2.2.1 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors. The output voltage of LM35 is linearly proportional to the celsius or centigrade temperature. The other temperature sensors are calibrated in ^{o}Kelvin. LM35 provides more accuracy of ±¼°C at room temperature and ±¾°C over a full -55^{o}C to +150^{o}C temperature range than other temperature sensors without the need of any external calibration. Thus, LM35 has an advantage over other sensors. LM35 has very low self-heating of less than 0.1^{o}C in still air as it draws very less current (60μA) from supply. This temperature sensor has linear output, low output impedance and provides accurate inbuilt calibration so that the control circuit is becomes easy. Only single power supply is needed to operate this temperature sensor. It is rated to operate over a temperature range of -55^{o}C to +150^{o}C [8].

Since, the temperature sensor LM35 does not have moving parts, it is accurate, does not require calibration, works under many environmental conditions and is consistent between readings. It is cheap and easy to use.

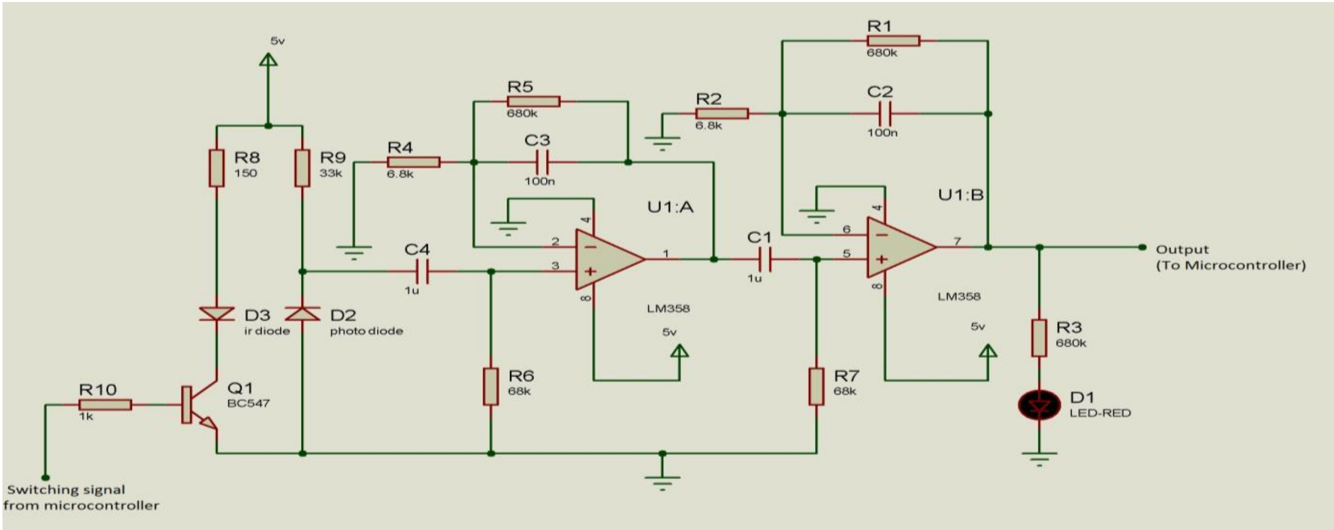


Fig. 4: Amplifier and Filter Circuit arrangement

This unit consists of a temperature sensor to measure the temperature of a patient which is connected directly to the microcontroller.. The temperature sensor used in this project is LM35, which is an analog sensor. The LM35 produces analog voltage which is directly proportional to the temperature sensed by it. The analog voltage produced by LM35 is fed to Analog to Digital Converter (ADC) to convert it into digital form so that the digital equivalent of the voltage can be used by the microcontroller for further processing. The microcontroller receives the data in analog form and converts it into digital form then sends it to the RF transmitter so that the data can be sent to the remote end. At the receiving end, RF receiver receives the data and sends it to microcontroller. The microcontroller does the processing and finally the data is displayed on the LCD along with the data of heartbeat.

For measuring body temperature, the left pin of LM35 is connected to the power (5V) and the right pin is connected to the ground. The middle pin will give us an analog voltage that is directly proportional (linear) to the temperature as shown in Fig. 5. The analog voltage is independent of the power supply. Thus, the middle pin is connected to the microcontroller PIC16F72 at port A (pin 2) for further processing. The scaling factor for LM35 is 0.01V/^{o}C. Body temperature is measured by holding LM35 with finger and corresponding change in temperature is converted into analog voltage which is then fed to microcontroller by the middle pin of LM35. The microcontroller has ADC in it and it does further processing and sends the measured data to the remote end via RF transmitter. At the remote end, the RF receiver receives the data and sends it to the microcontroller which then processes and displays the data in the LCD.

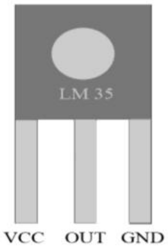


Fig. 5: Temperature sensor (LM35)

2.3 RF Module

The RF module consists of RF transmitter and RF receiver. The RF module operates at Radio Frequency. The digital data is represented as variations in the amplitude of carrier wave which means that it uses a digital modulation technique in which the amplitude of a carrier is altered to convey information. This kind of modulation is known as Amplitude Shift Keying (ASK). The reserach considered RF transmission over IR (infrared) because of several reasons. RF transmission is one of the cheapest way of wireless communication. RF module uses serial communication method. RF transmission is suitable for long range applications as the signals through RF covers larger distances. RF transmission is not much affected if there is obstruction between the transmitter and receiver but IR is affected. RF transmission is more strong and reliable than IR transmission. RF communication is not affected by other emitting source as it uses specific frequency but IR is affected by emitting sources.

The RF transmitter receives the data from pin 11 or Port C of PIC16F72 microcontroller. The RF transmitter then transmits the data through radio frequency to receiving end where the RF receiver receives the data and sends it to the microcontroller which finally helps in displaying data in LCD at the remote end.

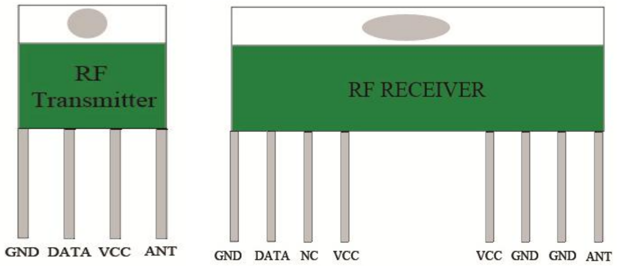


Fig. 6: RF MODULE

2.4 Circuit Diagram

The circuit diagram of the system is drawn by using Proteus software. The circuit diagram is shown in Fig. 7 where figure 7.1 shows transmitting end and figure 7.2 shows receiving end respectively.

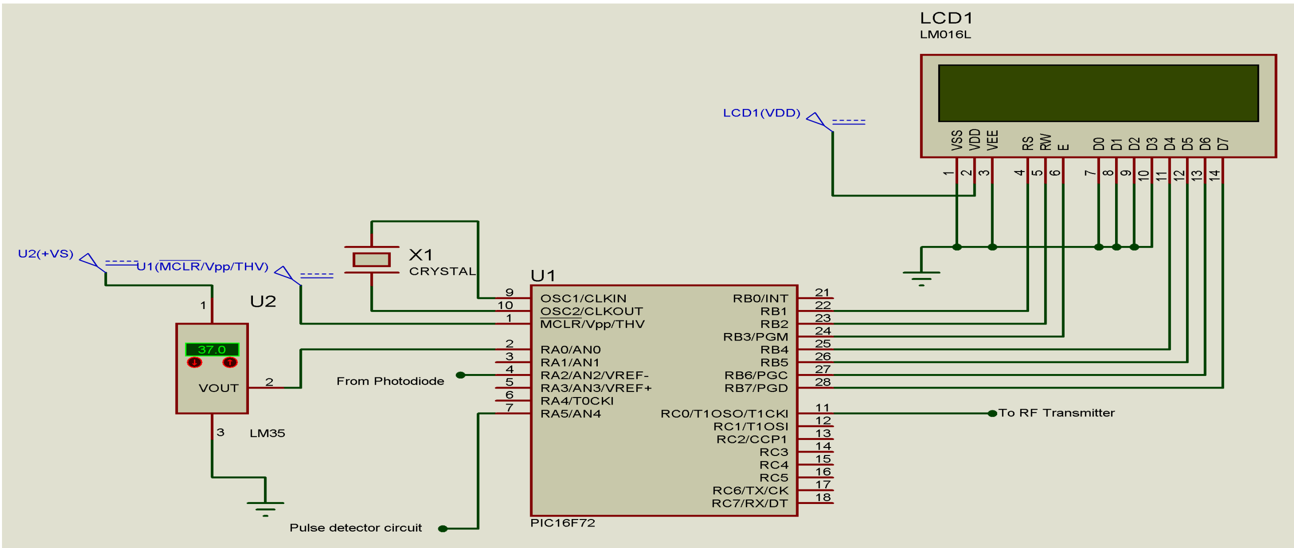


Fig. 7.1 Measuring and Transmitting End

The transmitter/receiver (Tx/Rx) pair in this project operates at a frequency of 433MHz. The range of RF module is 100 meters in open space under standard conditions. Antenna is connected at Pin 4 which is used to transmit the serial data, received by RF transmitter. The pins of RF transmitter and receiver are shown in Fig. 6. The transmission occurs at the rate of 1Kbps to 10Kbps. The data transmitted with the help of antenna is received by RF receiver at same frequency at which the transmitter was operating [9].

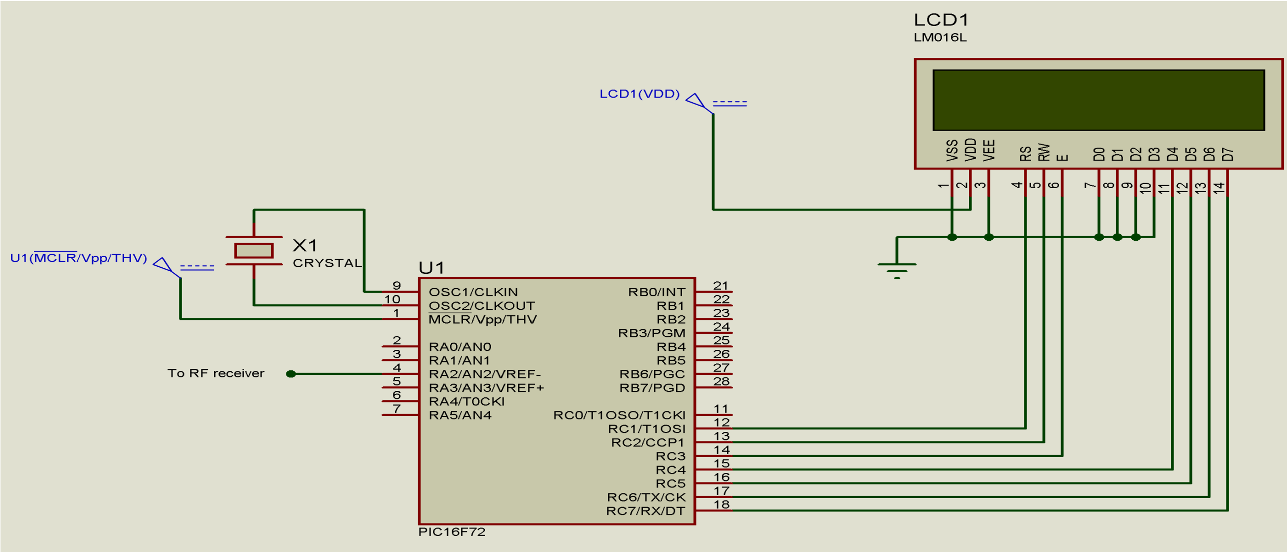
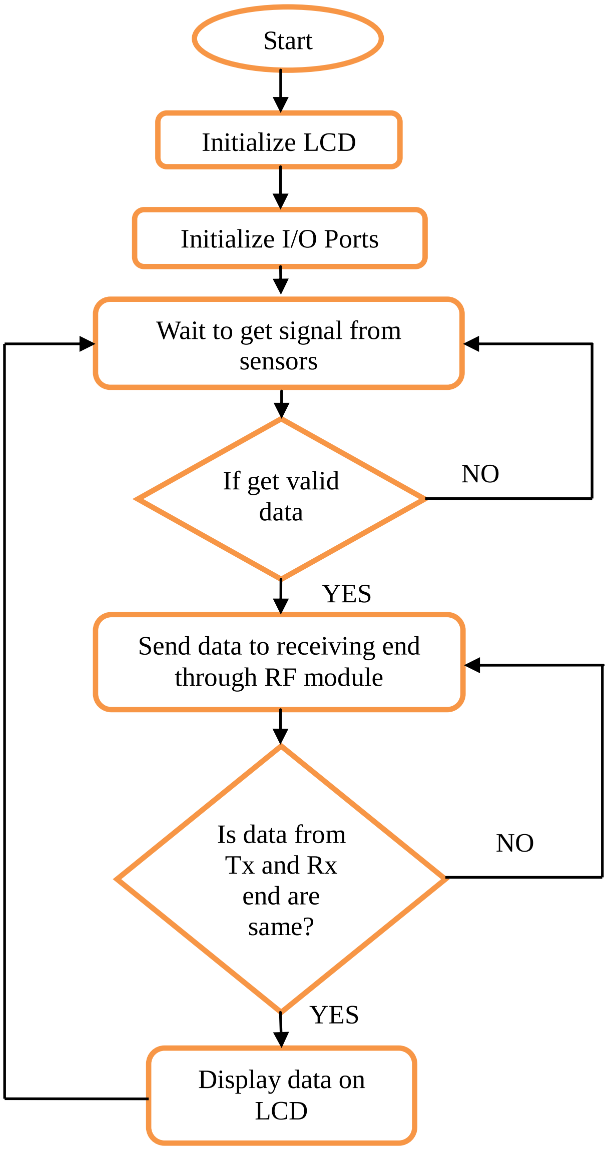


Fig. 7.2 Receiving and displaying End

Fig. 7: Complete Circuit Diagram

3. SYSTEM FLOW CHART



The flowchart of the system is shown in Fig. 8. The system is started by initializing the LCD and input/output ports of the microcontroller. Then, the system waits for the signal, which is to be received from the sensors (heartbeat sensor and temperature sensor). When the system receives a data, it checks if the data is valid. If the data is not valid then the system waits for another signal. But, if the received data is valid, the data is sent to the receiving end through RF module. The system then checks whether the data from the transmitting and receiving end are same. If the data is not same, the data is sent again. If the data is same, then the received data at remote end is displayed on the LCD.

4. CIRCUIT IMPLEMENTATON

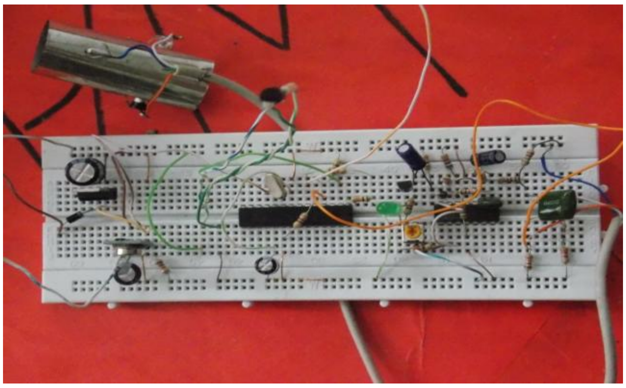


Fig. 9: Implemented circuit at Transmitting End

The implemented circuit is as shown in figure 9 and 10. Figure 9 shows the transmitting end circuit which consists of the measuring and transmitting devices. The use of this device is very simple. At first, the device at the transmitting and receiving end is connected to the power supply and the both ends are switched on by turning on the switch. Wait until the display on the LCD shows the message “Please put your finger”. Insert your finger into the arrangement after the message is displayed and the device will start measuring heartbeat. The device will show the heartbeat after 15 sec on LCD at the receiving end. Figure 10 shows the implemented circuit at receiving end.

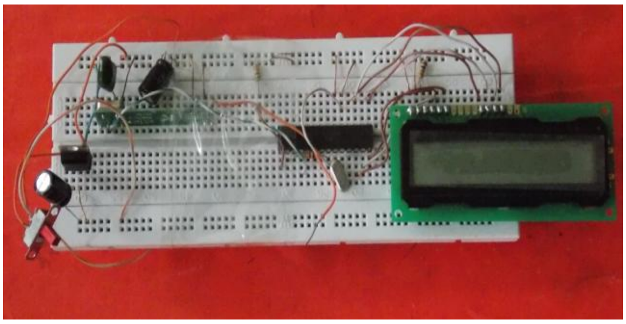


Fig. 10: Implemented Circuit at Receiving end

The body temperature and heartbeat of a patient were found out to be 37^{o}C and 70 bpm respectively as shown in Fig. 11.

Fig. 11: Output at the receiving end.

5. LIMITATIONS

The system has following limitations:

1. The RF module used in this project is able to handle one way data transfer but is not able send the other way around.
2. The RF module is not able to eliminate garbage data.
3. The device has 100 meter transmitting range in open space according to specification but we found it to be 15m only which can be solved by using XBee-PRO 868 which can be used for long range RF connectivity.

6. FUTURE WORKS

1. The device can be connected to PC by using serial output so that measured heartbeat and temperature can be sent to PC for further online or offline analysis.
2. Warning for abnormalities of health condition can be displayed.
3. Sound can be added to the device so that the device makes a sound each time a pulse is received and alarm is started for abnormal health condition.
4. The output can be sent to mobile phones by using GSM module or Bluetooth module for further analysis.
5. More parameters (like blood pressure) can be added to the device.

7. CONCLUSION

Optical sensor was used in this project which provides electrical isolation to the user. Simple operational amplifier with inverting and non-inverting configurations was used to amplify and filter the signal from sensor which narrowed the detecting range of heartbeat. Better configuration of instrumentation amplifier and other filters like Butterworth and Chebyshev filters with higher order can be used for better signal conditioning compromising to the complexity of the amplifier and filter circuit. PIC16F72 microcontroller contains in-built Analog to Digital Converter (ADC). So, extra Analog to Digital Converter device is not necessary. RF transmitter and receiver were preferred over IR transmitter and receiver as RF transmitter and receiver is superior over infrared device in many ways. The heartbeat was measured with the help of photodiode and bright LED while the temperature was measured by using precision integrated temperature sensor LM35. Both the data were processed in the microcontroller and sent to the remote end wirelessly by using RF transmitter and received at the remote end by using RF receiver. The received data was processed in the microcontroller and the data measured was displayed successfully with the help of LCD at the remote end. The wireless communication was preferred because it gives greater mobility to the sensor equipment and reduces the cost wherein there are multi-transmitting sections.

8. REFERENCES

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