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Vital Signs Monitoring System

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A thesis submitted to the faculty of Electronic and Electronic Engineering partial fulfillment of the requirements for the degree of

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Vital Signs Monitoring System

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Declaration

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ABSTRACT

Homecare is the provision of health care services to patients in their own home. One of the main purposes of homecare telemedicine is to develop a wireless, low-cost and user friendly system which allows patients to measure their own vital signs, such as heart rate and temperature, and provide the health care professionals with the facility to remotely monitor the patient's vital signs quickly and easily. The availability of heart pulse instruments grew rapidly in market since 21st century. However, the heart pulse detector is expensive due to the complicated system and it is used widely only in hospitals and clinics. There is a huge market for non-invasive methods of measurement of these vital signs. The objective of this project is to design and implement a reliable, cheap, low powered, non-intrusive, and accurate system that can be worn on a regular basis and monitors the vital signs. The project is targeting to develop a significant photo sensor to the medical fields that is easy to use and monitor heart rate by the user everywhere.

The project can further be developed to monitor other vital signs like blood pressure and body temperature in an integrated device. The introduction of GSM module would allow sending data to the medical personnel for instant assistance.

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INTRODUCTION

1.1 Background

Health care costs have risen exponentially in the last decade. Some of the statistics are-

The US has the highest health spending in the world - equivalent to 17.9% of its gross domestic product (GDP), or $8,362 per person. And it's not all private - government spending is at $4,437 per person.[1]

In many countries, 'pay as you go' health care is all that's available. Some of them are very poor, such as Congo or Eritrea.

Cuba has some of the highest government health spending in the world - 91.5% of all health spending. The result is 67.23 doctors per 10,000 people, the highest of any major country

But it's beaten by the UK on nurses - it has 101 per 10,000 people, only behind countries like Norway and Germany. The UK also spends $3,480 per year on health - 9.6% of health spending - with government spending making up 83.9% of all health spending.

Qatar has the lowest health spending in the world, 1.8% of GDP, followed by Burma (Myanmar) and Pakistan at 2.2%. The WHO says Burma's government spends only $4 per person on healthcare.

A report from December, 2009 highlights the per capita healthcare costs by age as compared between five countries (U.S.A., Germany, U.K., Sweden and Spain).

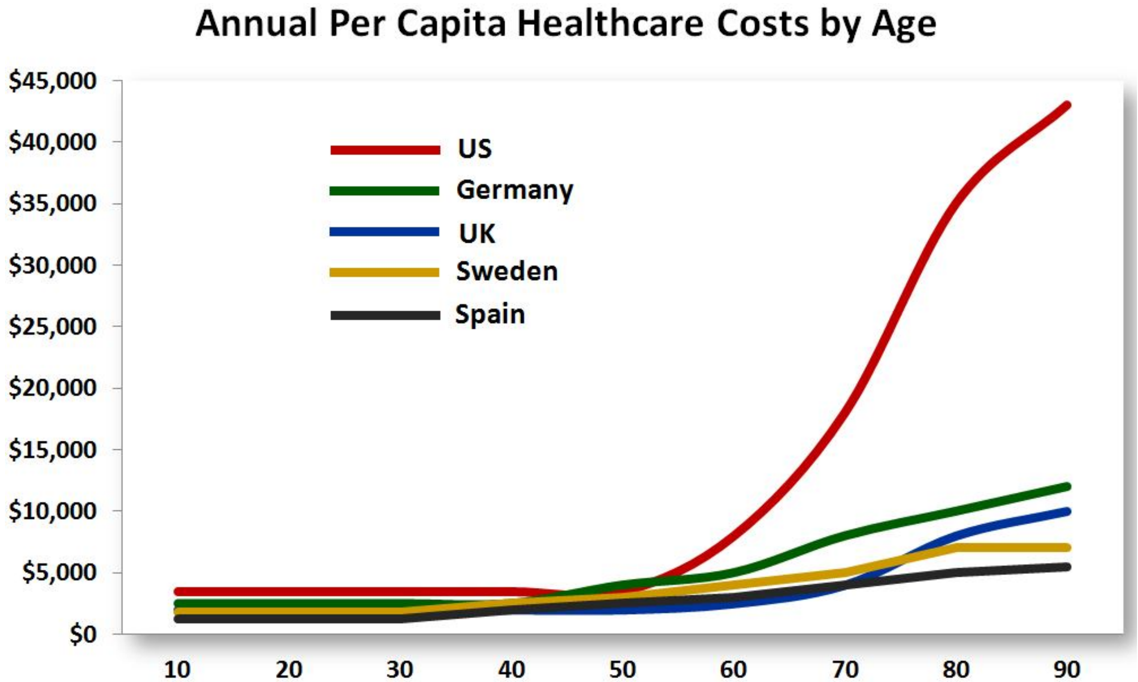


Fig 1.1.1 Annual per capita healthcare costs [2]

As observed from the statistics, individuals over 65 years of age have higher health care costs and a significant portion of these costs are a consequence of the services provided by the physicians. Old people have to make frequent visits to their doctor to get their vital signs measured. Regular monitoring of vital signs is essential as they are primary indicators of an individual's physical well-being. And these vital signs include-

1. Heart rate
2. Blood pressure
3. Body temperature

1.2 Objective

The goal of this project is to develop a low cost, low power, reliable, non-intrusive, and non-invasive vital signs monitor that processes and analyses the data acquired from sensors to determine if they are within a “normal” range.

Our first target is to develop a heart rate monitor and then include blood pressure and temperature monitor to an integrated device. The device should be able to contact the physicians for emergency medical attention in case of the data monitored is out of normal range.

1.3 Heart Rate

Heart rate, or heart pulse, is the speed of the heartbeat measured by the number of heartbeats per unit of time — typically beats per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. Activities that can provoke change include physical exercise, sleep, anxiety, stress, illness, ingesting, and drugs.

The normal resting adult human heart rate ranges from 60–100 bpm.[3]

The heartbeat consists of alternating contractions and relaxations of the heart.

There are four stages to each heartbeat: [4]

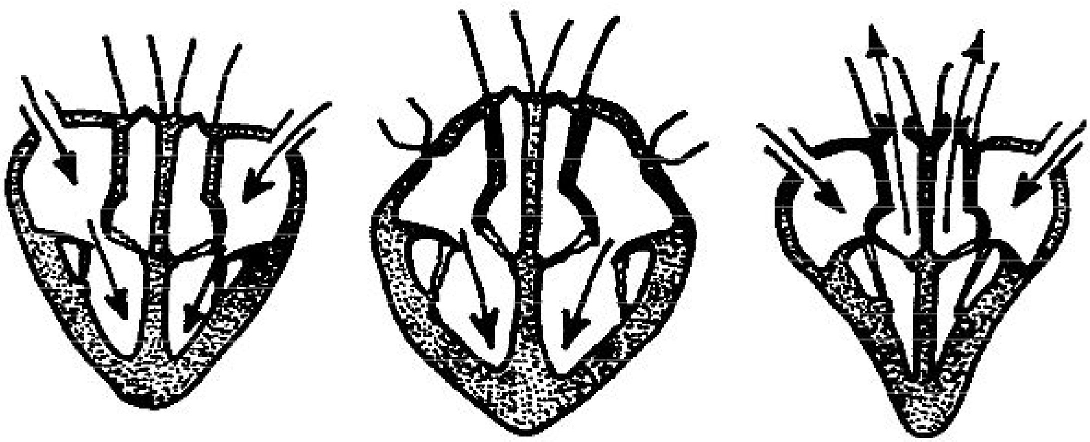
1. Each atrium relaxes so that blood can enter. Blood flows from the body via the vena cava into the right atrium. At the same time, blood flows from the lungs via the pulmonary vein into the left atrium [see figure 1.3.1(a)].

2. The atrio-ventricular valves open and both ventricles relax. The atria contract and blood flows from the right atrium into the right ventricle and from the left atrium into the left ventricle [see figure1.2.1(b)].

3. The ventricles contract and the atrio-ventricular valves snap shut to stop blood flowing back into the atria. This is the first sound of the heartbeat that can be heard with a stethoscope [see figure1.3.1(c)].

4. The semi-lunar valves open and blood is pumped out of the right ventricle to the lungs. At the same time, blood is pumped out of the left ventricle into the aorta and so to the rest of the body. When the ventricles stop contracting the semi-lunar valves snap shut to stop blood flowing backwards.

This is the second sound of the heartbeat. Blood flows into the atria again as they relax and the cycle is repeated.



(a) (b) (c)

Fig 1.3.1 (a) First stage, (b) Second stage, (c) Third Stage of a heartbeat

The heartbeat of a healthy person looks like this:

Fig 1.3.2 Heartbeat of a healthy person

1.4 Methodology

1.4.1 Photoplethysmography

The method used to obtain the pulse rate is called Photoplethysmography. In this method, a pulse oximeter is usually used which illuminates the skin and measures changes in light absorption.[5] A conventional pulse oximeter monitors the perfusion of blood to the dermis and subcutaneous tissue of the skin.

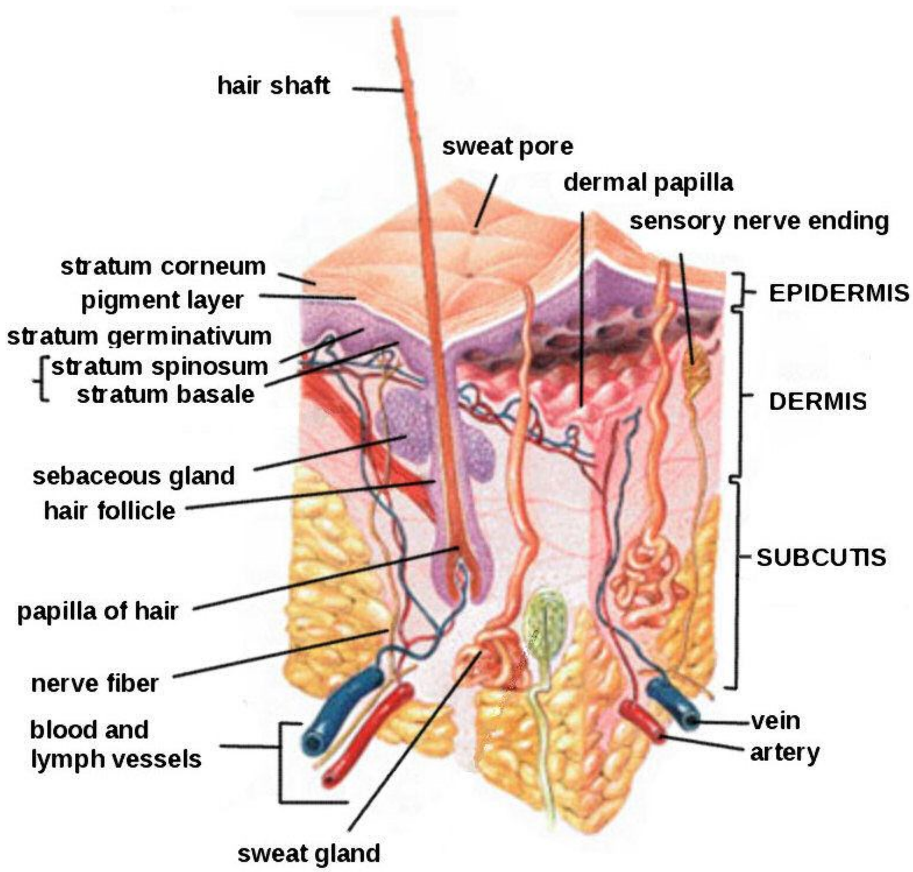


Fig 1.4.1 Diagram of the layer of human skin

With each cardiac cycle the heart pumps blood to the periphery. Even though this pressure pulse is somewhat damped by the time it reaches the skin, it is enough to distend the arteries and arterioles in the subcutaneous tissue. If the pulse oximeter is attached without compressing the skin, a pressure pulse can also be seen from the venous plexus, as a small secondary peak.

The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected to a photodiode. Each cardiac cycle appears as a peak, as seen in the figure. Because blood flow to the skin can be modulated by multiple other physiological systems, the PPG can also be used to monitor breathing, hypovolemia, and other circulatory conditions.[6] Additionally, the shape of the PPG waveform differs from subject to subject, and varies with the location and manner in which the pulse oximeter is attached.

1.4.2 Reflective Method

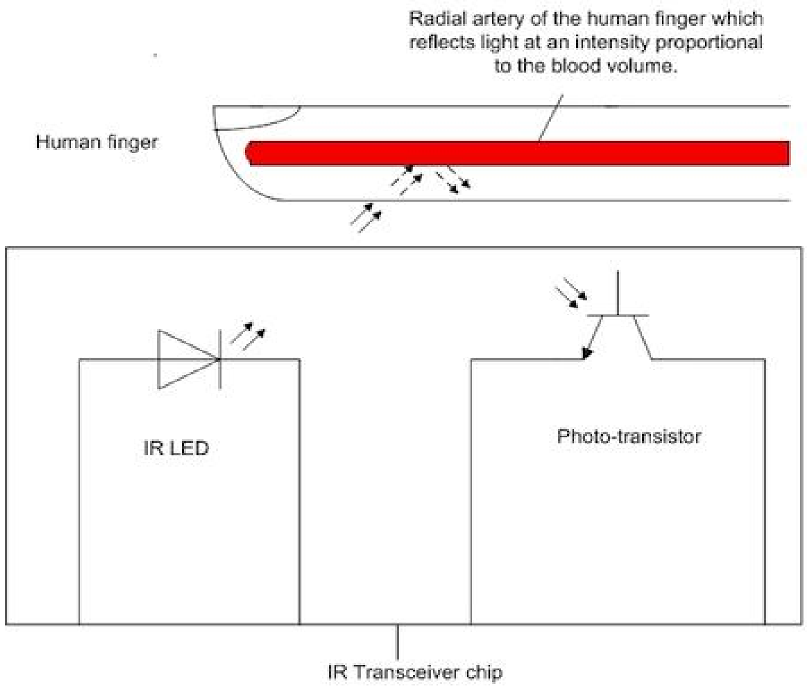


Fig 1.4.2 Reflective Method

In this method, the light source and the light detector are both placed on the same side of a body part. The light is emitted into the tissue and the reflected light is measured by the detector.

1.4.3 Transmission Method

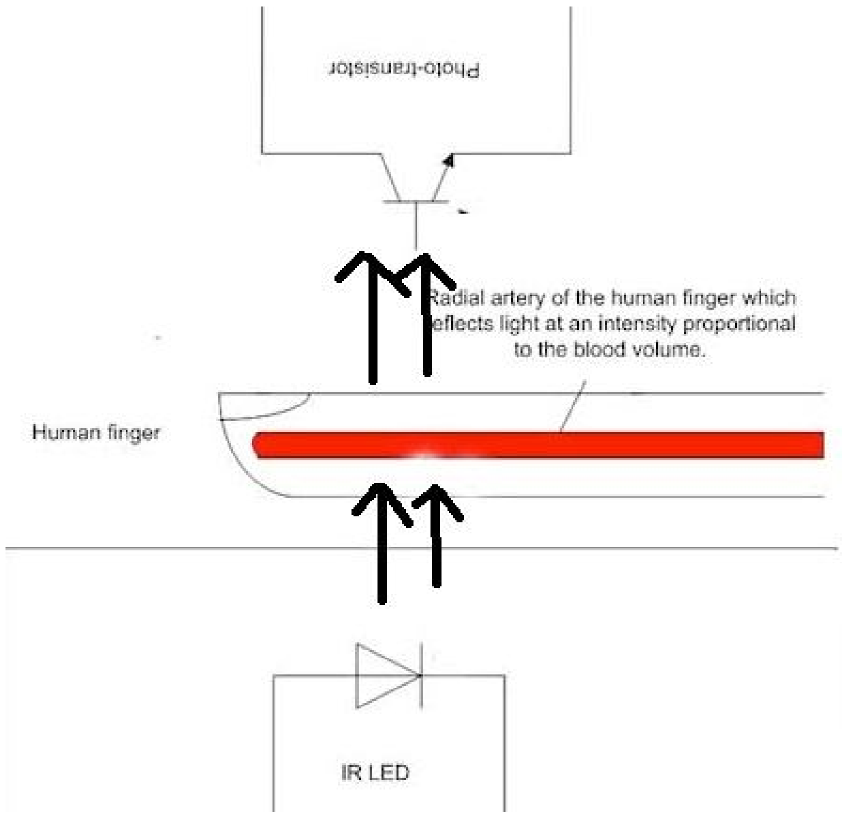


Fig 1.4.3 Transmission Method

In this method, light is shone through the skin with LEDs on one side of the body part containing artery and the photo sensor is placed on other side to obtain the characteristic of the light transmitted through the skin.

In our device, we used the transmission method.

ELECTRICAL PART

2.1 Simplified Circuit Diagram

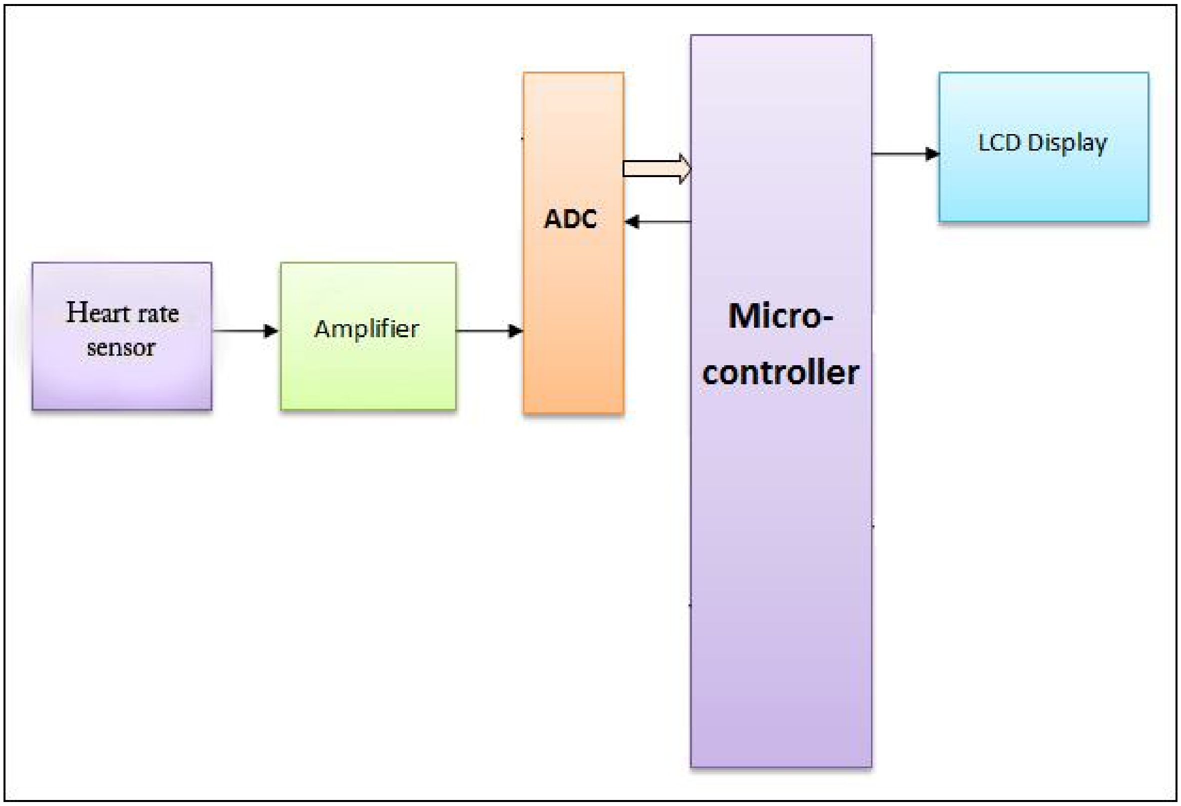


Fig 2.1.1 Simplified Circuit Diagram

This is a simplified circuit diagram. The pulse sensor detects the pulse and the output is fed into the LM324 quad op-amp. The input signal goes through two stage amplification (each with a 100 gain) and the output is fed into Atmega8.Microcontroller does the necessary calculations and sends the data to the LCD display. The microcontroller and sensors are supplied via a +5v regulated supply. Regulated supply comes from a 12v DC source which is converted into a +5v supply.

2.2 Components

2.2.1 ATmega8 Microcontroller

Key Features: We selected this microcontroller for the following features:

- Fully Static Operation
- Wide operating voltages (4.5V - 5.5V)
- 8Kbytes of In-System Self-programmable Flash program memory
- Two 8-bit Timer/Counters
- Real Time Counter with Separate Oscillator
- 8-channel Analog-to-Digital converter
- Programmable Serial USART
- On-chip Analog Comparator
- Speed Grades 0 - 16MHz
- Low power consumption

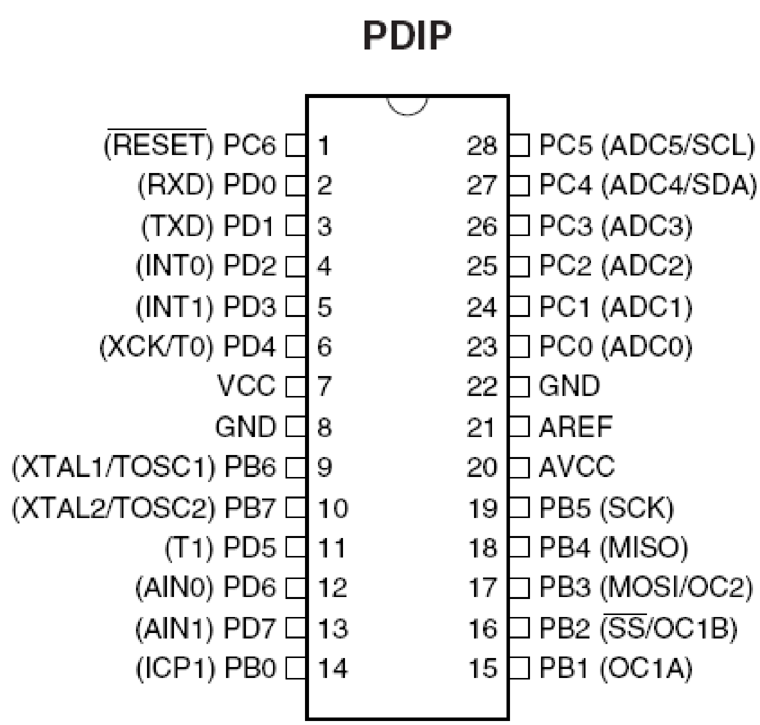


Fig 2.2.1 Pin Diagram of ATmega8

2.2.2 LM324 Quad Operational Amplifiers

Key Features:

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100dB
- Wide Power Supply Range: 3V~32V (or ±1.5 ~ 16V)
- Large Output Voltage Swing: 0V to VCC -1.5V
- Power Drain Suitable for Battery Operation

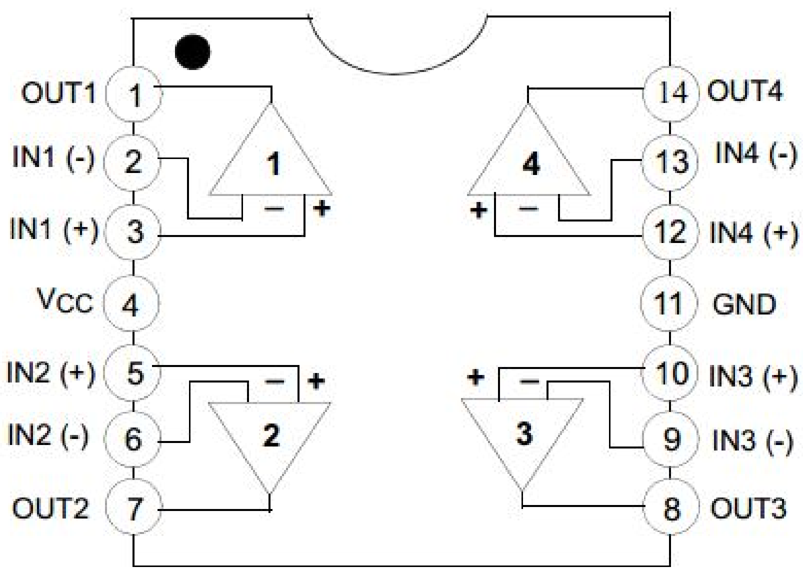


Fig 2.2.2 Pin Diagram of LM324

2.2.3 Photo Resistor

A photoresistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity.

Fig 2.2.3.1 Photoresistor

Key features:

- Fast response time (rise time 20ms)
- Average power consumption 100mW
- Spectral Peak 540 nm

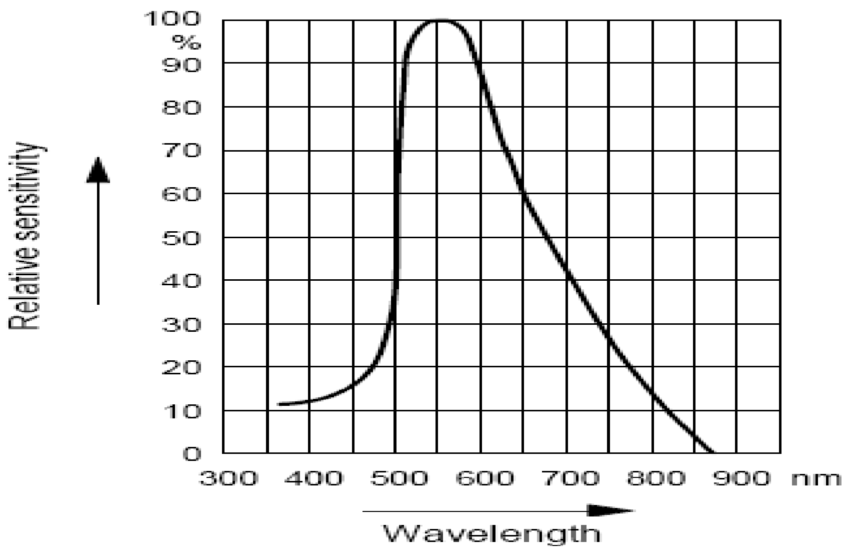


Fig 2.2.3.2 Photoresistor sensitivity[12]

2.2.4 Red LED

Key Features:

- 1.8-2.2VDC forward drop
- Max current: 20mA
- Suggested using current: 16-18mA
- Luminous Intensity: 150-200mcd

Fig 2.2.4 Red LED

2.2.5 LCD display

Model JHD 162A Series LCD with16characters x 2 rowis used since this project shows the Heart Rate in the output.

Fig 2.2.5 16x2 LCD

2.2.6 Contact layout

Pin No	Name	Function	Description
1	Vss	Power	GND
2	Vdd	Power	+ 5 V
3	Vee	Contrast Adj.	(-2) 0 - 5 V
4	RS	Command	Register Select
5	R/W	Command	Read / Write
6	E	Command	Enable (Strobe)
7	D0	I/O	Data LSB
8	D1	I/O	Data
9	D2	I/O	Data
10	D3	I/O	Data
11	D4	I/O	Data
12	D5	I/O	Data
13	D6	I/O	Data
14	D7	I/O	Data MSB

Fig 2.2.6 LCD pin layout

OPERATIONAL PART

3.1 Operational Flow Chart

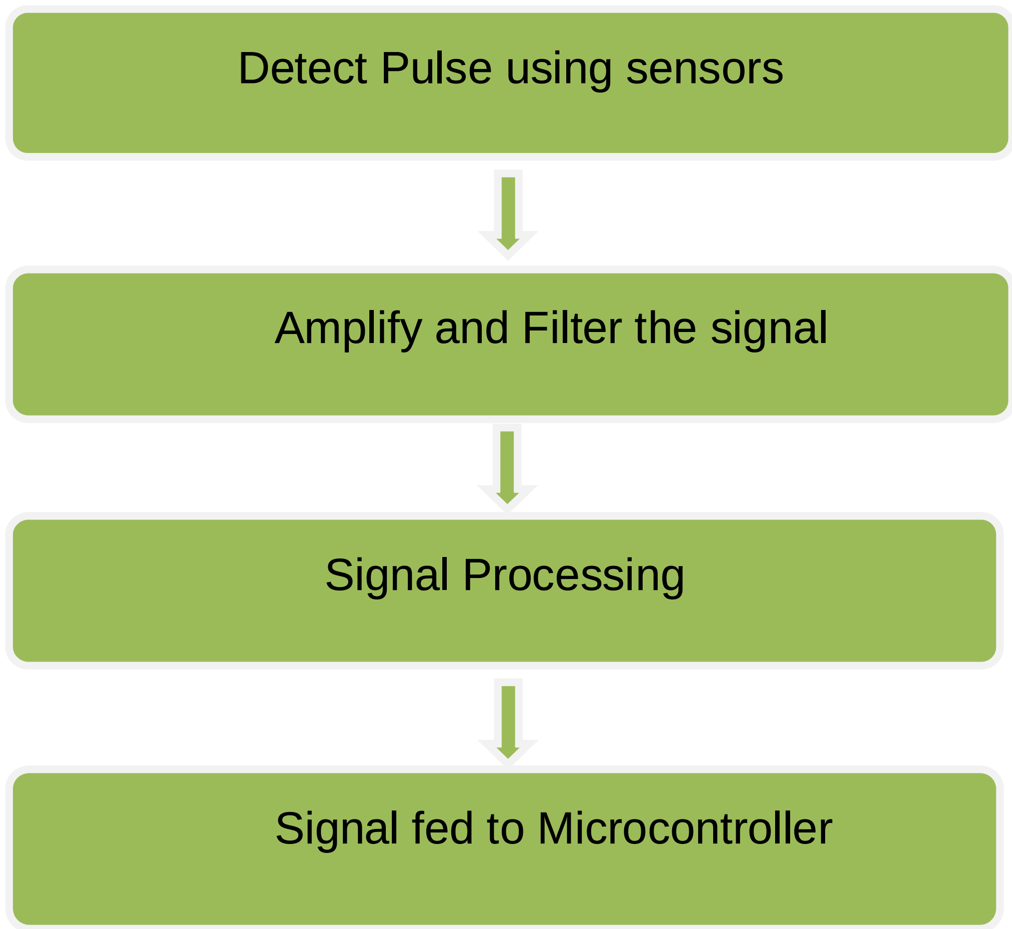


Fig 3.1 Flow Chart of Operation of the Device

The sensor unit consists of an infrared light-emitting-diode (IR LED).The IR LED transmits an infrared light into the fingertip, a part of which is reflected back from the blood inside the finger arteries. The photo diode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, every time the heart beats the amount of reflected infrared light changes, which can be detected by the photo diode. With a high gain amplifier, this little alteration in the amplitude of the reflected light can be converted into a pulse.

The reflected IR signal detected by the photo diode is fed to a signal conditioning circuit that filters the unwanted signals and boost the desired pulse signal. Two stage operational amplifiers are configured as active low pass filters. The cut-off frequencies of both the filters are set to about 2.5 Hz, and so it can measure the pulse rate up to 2.5*60 = 150 bpm. The gain of each filter is about 100, which gives the total 2-stage amplification of 10000. This is good enough to convert the weak pulsating signal into a TTL pulse.The number of pulses counted within this interval is multiplied by 4 to get actual beats per minutes (bpm).

3.2 Microcontroller Operation

3.2.1 Timer Operation

Weused timer1 of ATmega8 to count the pulses of the signal received at T1 pin2 (PB1)and use the normal mode. we will start counting the pulses and make a delay of ten seconds then we stop the timer and read it's register (TCNT1) which contains the number of pulses (counts).

If Timer1 makes an overflow (which is unlikely due to the nature of human pulse rate), we enable the overflow interrupt of timer1 and we count the number of overflows made by timer1 and the overflow means that timer1 has made 2^16 count (65536 counts as it's a 16 bit register) so the number of pulses in ten second will be calculated using the following equation:

Frequency = 10*(i*2^16 + TCNT1)

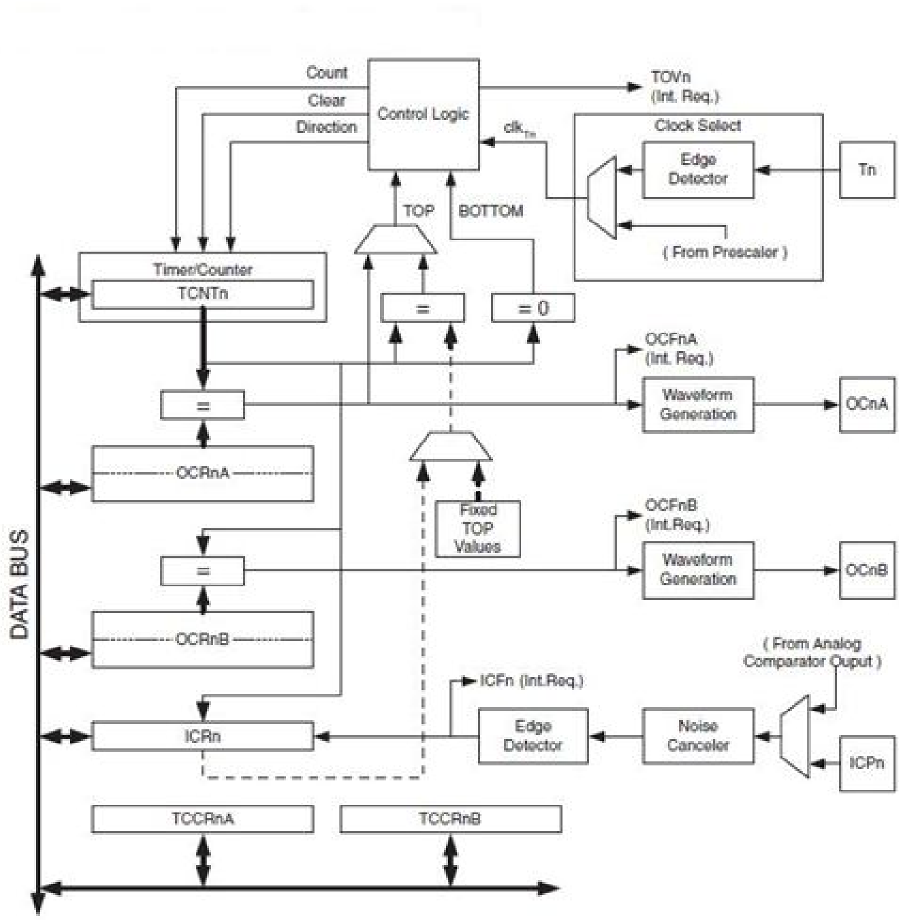


Fig 3.2 16-bit Timer Block Diagram

3.2.2 Registers

The *Timer/Counter* (TCNT1), *Output Compare Registers* (OCR1A/B), and *Input Capture Register* (ICR1) are all 16-bit registers. Special procedures must be followed when accessing the 16-bit registers. The *Timer/Counter Control Registers* (TCCR1A/B) are 8-bit registers and have no CPU access restrictions.

Interrupt requests (abbreviated to Int.Req. in the figure) signals are all visible in the *Timer Interrupt Flag Register* (TIFR). All interrupts are individually masked with the *Timer Interrupt Mask Register* (TIMSK). TIFR and TIMSK are not shown in the figure since these registers are shared by other timer units. The Timer/Counter can be clocked internally, via the prescaler, or by an external clock source on the T1 pin.

The Clock Select logic block controls which clock source and edge the Timer/Counter uses to increment (or decrement) its value. The Timer/Counter is inactive when no clock source is selected. The output from the clock select logic is referred to as the timer clock (clkT1).The double buffered Output Compare Registers (OCR1A/B) are compared with the Timer/Counter value at all time. The result of the compare can be used by the waveform generator to generate a PWM or variable frequency output on the Output Compare Pin (OC1A/B). The Compare Match event will also set the Compare Match Flag (OCF1A/B) which can be used to generate an Output Compare interrupt request.

The Input Capture Register can capture the Timer/Counter value at a given external (edge triggered) event on either the Input Capture Pin (ICP1) or on the Analog Comparator pins. The Input Capture unit includes a digital filtering unit (Noise Canceler) for reducing the chance of capturing noise spikes.

The TOP value, or maximum Timer/Counter value, can in some modes of operation be defined by either the OCR1A Register, the ICR1 Register, or by a set of fixed values. When using OCR1A as TOP value in a PWM mode, the OCR1A Register cannot be used for generating a PWM output. However, the TOP value will in this case be double buffered allowing the TOP value to be changed in run time. If a fixed TOP value is required, the ICR1 Register can be used as an alternative, freeing the OCR1A to be used as PWM output.

3.2.3 Code

C Code for Pulse Rate Measurement:

```
#include <mega8.h>

// Alphanumeric LCD Module functions
#asm
   .equ __lcd_port=0x18 ;PORTB
#endasm
#include <lcd.h>
#include <delay.h>
#include <stdlib.h> // this library is used to display
variables on lcd

unsigned long int pulse; // to store value of pulse rate value
unsignedint i=0,dur; //i=number of overflows in one second
// dur to store the value of TCNT1 register
char buffer[8];
/* to store the pulse rate value as a string to be displayed
on LCD */
floatpulsef;
/* used to display the fractions of pulse rate with the
suitable unit as shown later */

// Timer 1 overflow interrupt service routine
interrupt [TIM1_OVF] void timer1_ovf_isr(void)

{
```

```
i++ ;// count the number of overflows in one second
}


void main(void)
{
PORTB=0x00;
DDRB=0x00;

PORTC=0x00;
DDRC=0x00;

PORTD=0x00;
DDRD=0x00;

// Timer/Counter 0 initialization
// Clock source: System Clock
// Clock value: Timer 0 Stopped
TCCR0=0x00;
TCNT0=0x00;

TCCR1A=0x00;
TCCR1B=0x00;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x00;
ICR1L=0x00;
```

```
OCR1AH=0x00;
OCR1AL=0x00;
OCR1BH=0x00;
OCR1BL=0x00;

ASSR=0x00;
TCCR2=0x00;
TCNT2=0x00;
OCR2=0x00;

// External Interrupt(s) initialization
// INT0: Off
// INT1: Off
MCUCR=0x00;

// Timer(s)/Counter(s) Interrupt(s) initialization
TIMSK=0x04;

// Analog Comparator initialization
// Analog Comparator: Off
// Analog Comparator Input Capture by Timer/Counter 1: Off

ACSR=0x80;
SFIOR=0x00;



// LCD module initialization
```

```
lcd_init(16);

// Global enable interrupts
#asm("sei")

while (1)
      {
            TIMSK=0x04;
      TCCR1B=0x07;
delay_ms(1000);
      TCCR1B=0x00;
      TIMSK=0x00;
dur=TCNT1;
pulse = 10*(dur + i*65536);
      TCNT1=0x0000;
      i=0;
lcd_gotoxy(0,0);
lcd_putsf("pulse=");
lcd_gotoxy(0,1);
if(pulse>=1000000)
      {
pulsef=(float)pulse/1000000;
ftoa(pulsef,3, buffer);
lcd_puts(buffer);
lcd_putsf("/Minute");
      }
else if (pulse>=1000)
```

```
      {
pulsef=(float)pulse/1000;
ftoa(pulsef,3, buffer);
lcd_puts(buffer);
lcd_putsf("/Minute");
      }
else
      {
ltoa(pulse, buffer);
lcd_puts(buffer);
lcd_putsf("/Minute");
      }
      };
}
```

CIRCUIT

4.1 Full Schematic Design

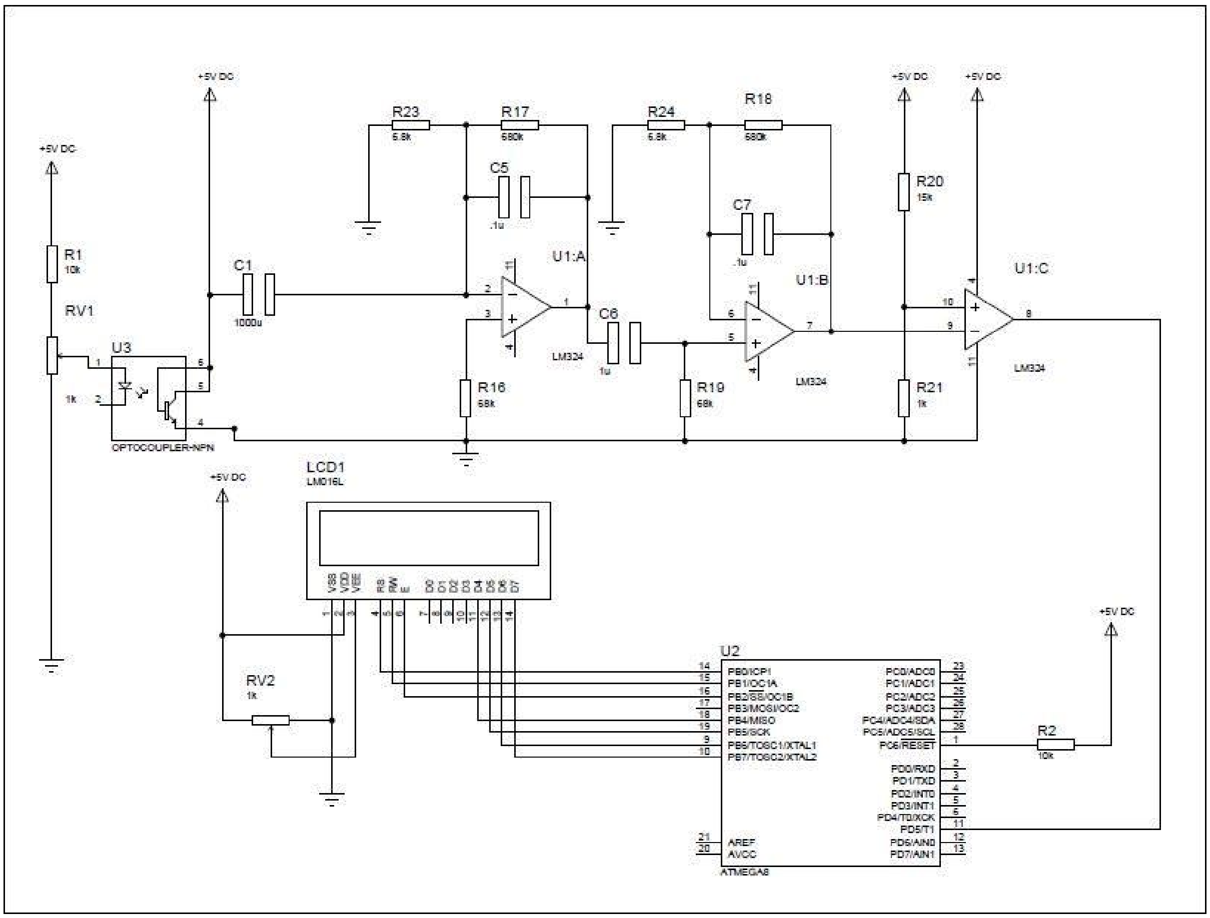


Fig 4.1: Full Schematic Design

4.2 PCB Layout

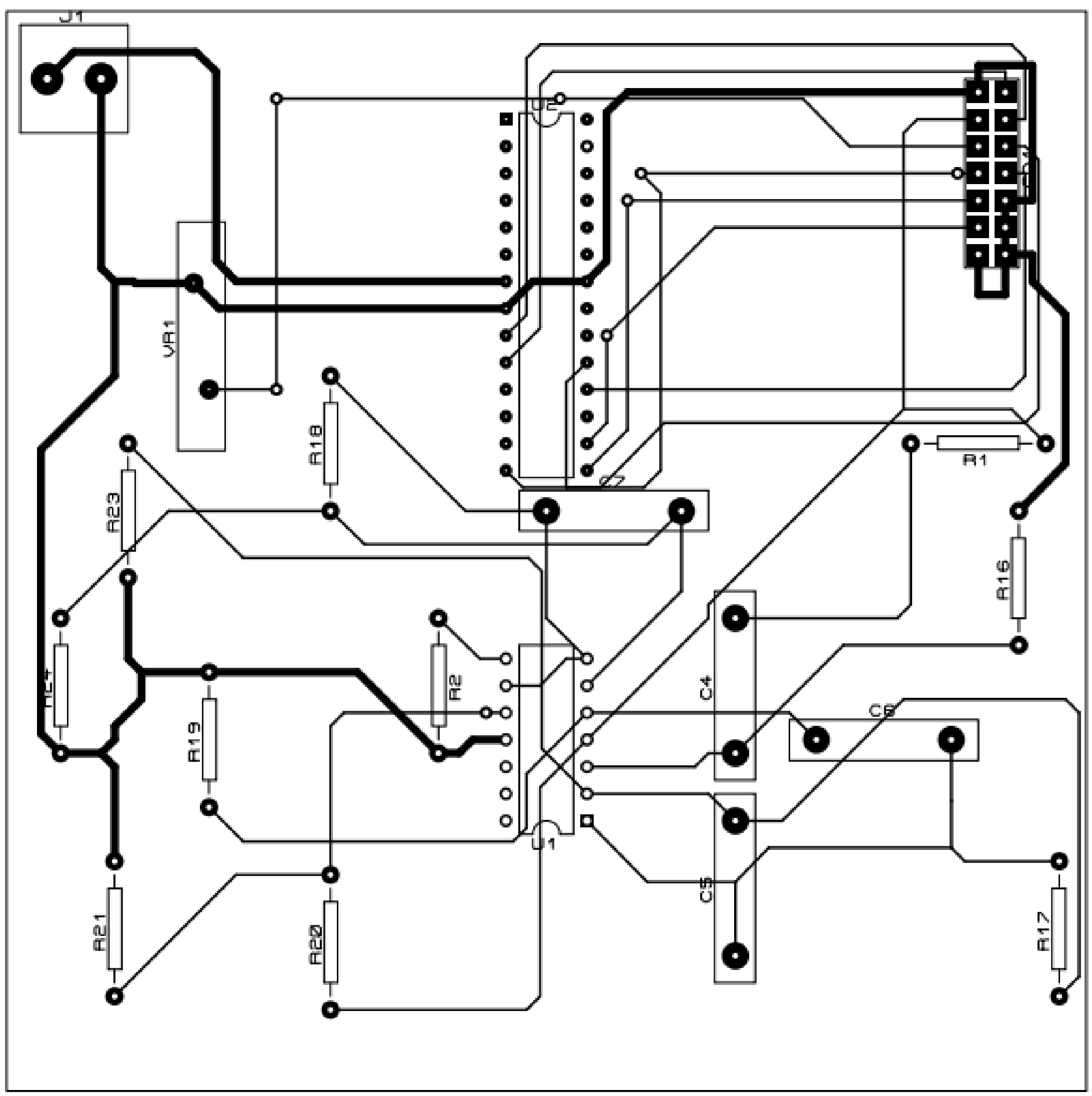


Fig 4.2 PCB Layout of the device

4.3 Three Dimensional Layout

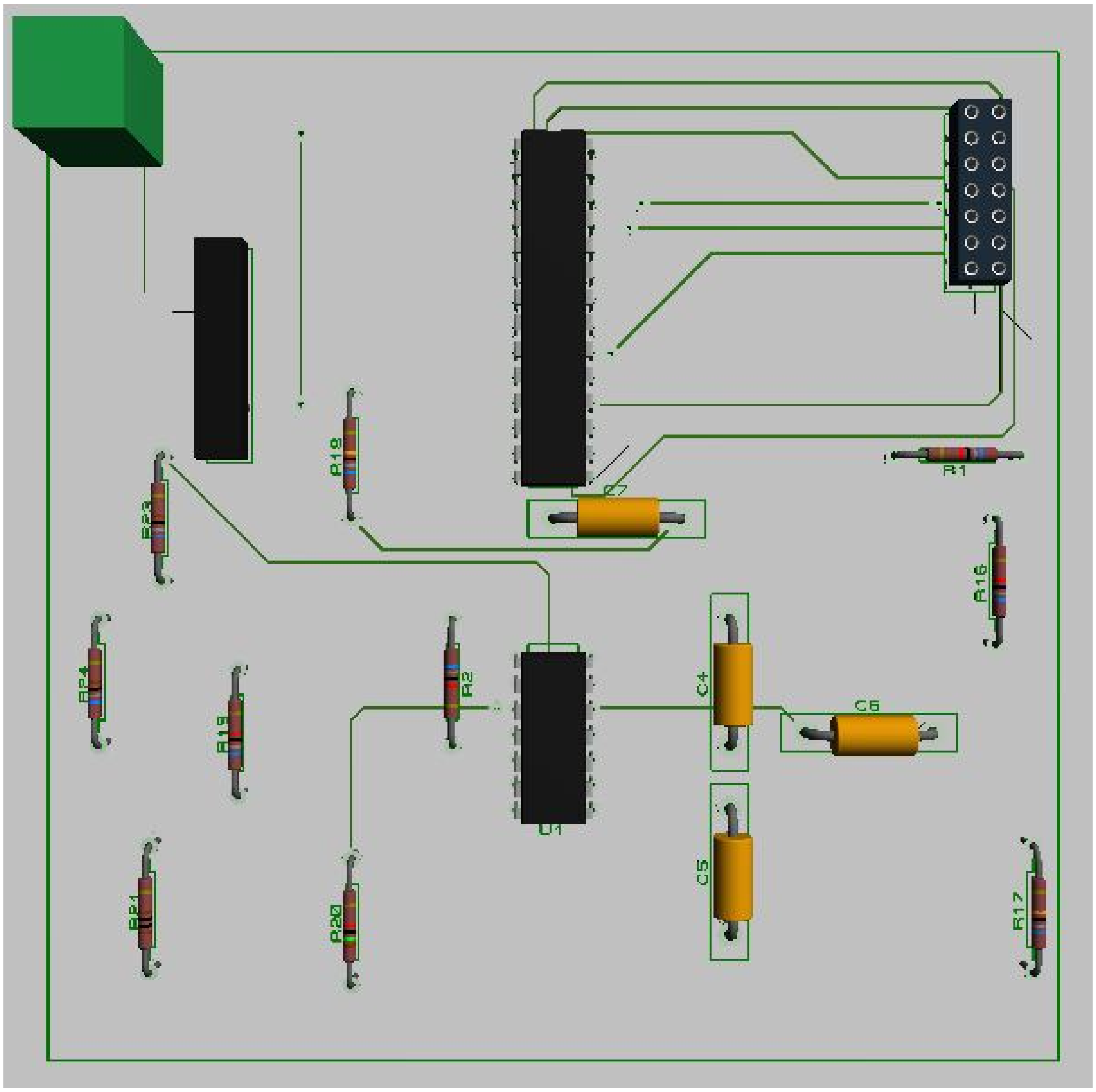


Fig 4.3 3D Circuit Layout simulation using Proteus

FUTURE WORK

With the components available and the work done already, we are hoping to add the following features to the device in near future:

- Heat Sensor: Adding a simple Heat sensor will enable this device to measure body temperature as well. For the coding part, we can use the ADC of the Atmega8 to convert the thermistor reading into LCD output.
- Blood Pressure: With Photoplethysmography, it is possible to measure the blood pressure, too with the same circuitry. But the algorithm is yet to be developed. This is included in our future works.
- Bluetooth connectivity: Adding a simple Bluetooth device to it will enable it to connect to a Smartphone and use the Smartphone display as the output. This feature will add to the mobility and reduce wires. With Bluetooth enabled, this can be turned into a wireless device.
- GSM Module: In case Smart Phone is not available, a GSM Module can be added to it. Our device can constantly monitor the vital signs. Therefore, a GSM device able to call in case of emergency will make it an acceptable alternative to human monitoring. Whenever there will seem to be a problem with the pulse rate or blood pressure or temperature, the GSM Module will automatically establish communication with pre-assigned mobile device of medical personnel.
- Making it Wearable: Our device is small and mobile but still not as thin as wearable. If we can design the same with LilyPad Arduino and construct a frame for the Sensors, then this can be worn on the fingertip or earlobe.

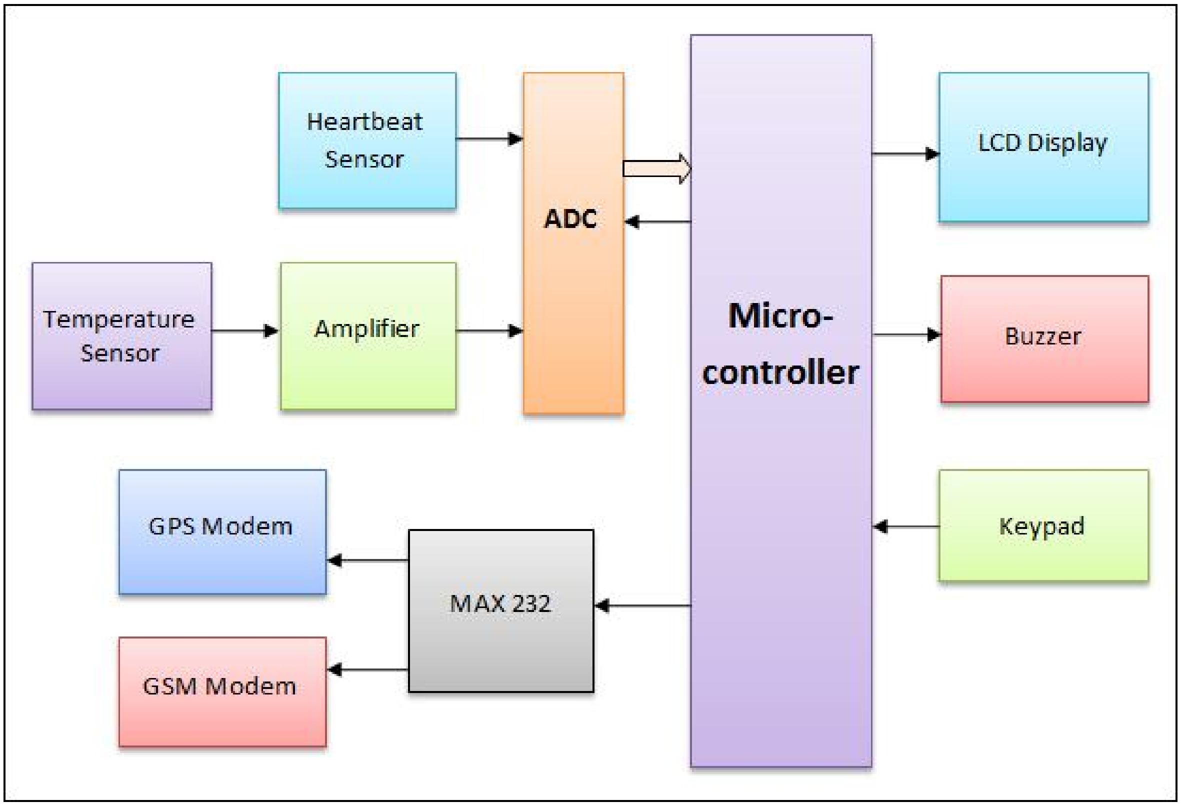


Fig 5.1 Proposed Development of the Project

CONCLUSION

The objective of this project was to build a low power, low cost, reliable, non-intrusive, and non-invasive monitoring system that would accurately measure the vital signs. However, a reliable and continuous heart rate monitoring system targeted towards individuals has been successfully built. The resulting system was also low in power and cost, non-invasive, and provided real time monitoring. It is also easy to use and provides results close to accurate measurements. By some trial run by the device and comparing the result to the accurate heart rate measured by medical monitoring device, we concluded that the percentage of error of our device is ~ 5% plus/minus which is tolerable. We could not add blood pressure and temperature monitoring system due to time shortage and availability of the components. But in future, we would like to complete the proposed project if we get enough time and scopes.

NOMENCLATURE

ADC	:	Analogue to Digital Converter
BPM	:	Beats per Minute
CPU	:	Central Processing Unit
DC	:	Direct Current
EEE	:	Electrical and Electronic Engineering
GDP	:	Gross Domestic Production
GPS	:	Global positioning System
GSM	:	Global System for Mobile Communication
IR	:	Infrared
IRLED	:	Infrared Light Emitting Diode
LCD	:	Liquid Crystal Display
LDR	:	Light Dependent Resistor
LED	:	Light Emitting Diode
OCR	:	Output Compare Registers
PCB	:	Printed Circuit Board
TIFR	:	Timer Interrupt Flag Register
TIMSK	:	Timer Interrupt Mask Register
TTL	:	Transistor-Transistor Logic
WHO	:	World Health Organization

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