Visvesvaraya Technological University

Belgaum, Karnataka-590 018

A Project Report on

"NON – INVASIVE GLUCOSE MONITORING SYSTEM"

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
In
Electrical & Electronics Engineering

Submitted by

AMRITHA ROHINI K V 1CR17EE005
ANINDITA BISWAS 1CR17EE006
ANNAPURNA J U 1CR17EE007
ARYA R 1CR17EE010

Under the Guidance of
Dr . V . AGALYA
Associate Professor, Department of Electrical & Electronics Engineering
CMR Institute of Technology

CMR Institute of Technology, Bengaluru-560 037

Department of Electrical & Electronics Engineering

2020-2021

CMR INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

AECS Layout, Bengaluru-560 037

Certificate

Certified that the project work entitled **"NON – INVASIVE GLUCOSE MONITORING SYSTEM"** carried out by Ms. AMRITHA ROHINI K V ,USN: 1CR17EE005 ; Ms. ANINDITA BISWAS , USN: 1CR17EE006 ; Ms. ANNAPURNA J U, USN: 1CR17EE007; Ms. ARYA R, USN: 1CR17EE010 are bonafied students of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of Bachelor of Engineering in Electrical & Electronics Engineering of the Visvesvaraya Technological University, Belgaum, during the year 2020-2021. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

Signature of the Guide	*Signature of the HOD*	*Signature of the Principal*
-----------------------------	--------------------------------	-----------------------------
Dr. V . Agalya , Associate Professor EEE Department CMRIT, Bengaluru	Dr. K. Chitra Professor & HOD EEE Department CMRIT, Bengaluru	Dr. Sanjay Jain Principal, CMRIT, Bengaluru

External Viva

Name of the Examiners Signature & Date

1.

2.

CMR INSTITUTE OF TECHNOLOY
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
AECS Layout, Bengaluru-560 037

DECLARATION

We, [Ms. **AMRITHA ROHINI K V (1CR17EE005),** Ms. **ANINDITA BISWAS (1CR17EE006),** Ms. **ANNAPURNA J U (1CR17EE007),** Ms. **ARYA R (1CR17EE010)],** hereby declare that the report entitled **"NON – INVASIVE GLUCOSE MONITORING SYSTEM"** has been carried out by us under the guidance of **Dr. V . AGALYA,** Associate Professor, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirement for the degree of **BACHELOR OF ENGINEERING in ELECTRICAL & ELECTRONICS ENGINEERING**, of Visveswaraya Technological University, Belgaum during the academic year 2020-21. The work done in this report is original and it has not been submitted for any other degree in any university.

Place: Bengaluru

Date:

AMRITHA ROHINI K V
(1CR17EE005)

ANINDITA BISWAS
(1CR17EE006)

ANNAPURNA J U
(1CR17EE007)

ARYA R
(1CR17EE010)

Abstract

Diabetes mellitus is a complex group of syndromes that have in common a disturbance in the body's use of glucose, resulting in an elevated blood sugar. Once detected, sugar diabetes can be controlled by an appropriate regimen that should include diet therapy, a weight reduction program for those persons who are overweight, a program of exercise and insulin injections or oral drugs to lower blood glucose. The most commonly used method to measure glucose level in blood is an invasive method which is painful, expensive and increases danger of spreading infectious diseases. Blood glucose monitoring by the patient and the physician is an important aspect in the control of the devastating complications (heart disease, blindness, kidney failure or amputations) due to the disease. Intensive therapy and frequent glucose testing has numerous benefits. With ever improving advances in diagnostic technology, the race for the next generation of bloodless, painless, accurate glucose instruments has begun.

The main objective of this project is to design a portable non-invasive blood glucose monitoring device. The device should be able to detect glucose level in the blood using the optical rays and display the results on the LED screen. Also the use of non-invasive approach will allow us to overcome the disadvantages of invasive approach and continuously monitor the patient's blood glucose levels. Hence, these early checks can help us reduce serious complications and mortality due to diabetes mellitus.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of people, who are responsible for the completion of the project and who made it possible, because success is outcome of hard work and perseverance, but stead fast of all is encouraging guidance. So with gratitude we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the project work.

We take great pleasure in expressing our sincere thanks to **Dr. Sanjay Jain**, **Principal, CMR Institute of Technology, Bengaluru** for providing an excellent academic environment in the college and for his continuous motivation towards a dynamic career. We would like to profoundly thank **Dr. B Narasimha Murthy**, Vice-principal of CMR Institute of Technology and the whole **Management** for providing such a healthy environment for the successful completion of the project work.

We would like to convey our sincere gratitude to **Dr. K Chitra**, **Head of Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru** for her invaluable guidance and encouragement and for providing good facilities to carry out this project work.

We would like to express our deep sense of gratitude to **Dr . V . Agalya , Associate Professor, Electrical and Electronics Engineering, CMR Institute of Technology, Bengaluru** for his/her exemplary guidance, valuable suggestions, expert advice and encouragement to pursue this project work.

We are thankful to all the faculties and laboratory staffs of **Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru** for helping us in all possible manners during the entire period.

Finally, we acknowledge the people who mean a lot to us, our parents, for their inspiration, unconditional love, support, and faith for carrying out this work to the finishing line. We want to give special thanks to all our friends who went through hard times together, cheered us on, helped us a lot, and celebrated each accomplishment.

Lastly, to the **Almighty**, for showering His Blessings and to many more, whom we didn't mention here.

CONTENTS

Title Page	i
Certificate	ii
Declaration	iii
Abstract	iv
Acknowledgements	v
Contents and index	vi-vii
List of Figures	viii
List of Abbreviations and Symbols	ix

INDEX

Chapter 1: INTRODUCTION	**01–03**
1.1 Brief Background of the Research	01
1.2 Objectives of the Thesis	02
1.3 Layout of the Thesis	03
Chapter 2: LITERATURE REVIEW	**04–06**
2.1 Basic Principle	04-06
Chapter 3: PROPOSED MODEL	**07–10**
3.1 Block Diagram of Proposed model	07
3.2 Flow Chart of Proposed model	08-09
3.3 Circuit Diagram	10
Chapter 4: DESIGN PROCESS	**11–16**
4.1 Selection of Wavelength	11
4.2 System Hardware	12
4.3 Experimental Analysis	12
4.4 Program Code	14
Chapter 5: RESULT	**17-22**
5.1 Simulation Result	19
5.2 Hardware Model	20
5.3 Product Model	22

Chapter 6: FUTURE WORK **23**

REFERENCES **24**

LIST OF FIGURES

Figure 1:	Effect of glucose on light path	05
Figure 2:	Block diagram of proposed model	17
Figure 3:	Flowchart of proposed model	18
Figure 4:	Cross Section of Skin and Light Path	10
Figure 5:	Regression analysis of glucose data with analog Voltage data	14

LIST OF ABBREVIATIONS AND SYMBOLS

WHO - World Health Organization

NIR - Near - infrared

ADC - Analog to Digital Converter

LCD - Liquid Crystal Display

CHAPTER 1

INTRODUCTION

1.1 Brief Background of the Research

Diabetes is a type a metabolic diseases in which the blood glucose (blood sugar) level in human body increases drastically from its normal level. The increase in sugar level is either due to inadequate production of insulin in blood cells or can be because of improper response of body cells to the insulin or can be because of both the reasons. diabetes can lead to major complications like heart failure and blindness in the human body. Hence regular monitoring of glucose level is important. The World Health Organization (WHO) estimated that the number of people with diabetes is more than 200 million.

Diabetes is a state of a body where it not able to produce the quantity of insulin sufficiently required to maintain normal level of blood glucose. There are mainly two types of diabetes patients, although having the same effect they imply due to different reasons .Type 1 diabetes has its adverse effects due to lower insulin production in the body. However, type 2 diabetes is due to the fact that the body organ fail to respond to insulin, a condition also known as insulin resistance. This condition does not allow the sugar to enter into blood there by increasing the level of sugar in the blood as well as the urine . This is also known as hyperglycaemia .So, diabetic patients need to regulate their blood glucose levels through proper diet as well as by injecting insulin. For the effective treatment of diabetes, patients have to measure the level of blood glucose periodically .

At present, blood glucose level is measured using invasive figure pricking instrument knows as glucose meter to know the concentration of blood glucose.

1.2 Objectives of the Thesis

Currently, the main methods for blood glucose measurement are categorized into three techniques: invasive , minimally invasive, and non-invasive. Invasive techniques in blood glucose measurement devices are widely used as it has high measurement accuracy. The most common and inexpensive invasive technique is finger prick which requires blood extraction from the finger by using a lancet (small , sharp needle) . Some common practices allow the blood extraction to be obtained from other sites of the body such as the upper arm, forearm, base of the thumb and thigh. However the reading of blood glucose level might vary compared to the reading obtained from the fingertip .

The blood sample will be used to measure blood glucose level using a glucometer. Inside a glucometer, a series of chemical reactions will take place and as a result of chemical reaction Potassium Ferro cyanide is produced and it reacts with the metals on electrode layer and causes the electric current to flow through the electrodes. More the concentration of glucose in the blood, more the Potassium Ferro cyanide production and more the current through the electrode. This strength of current is used to predict the glucose level present in the blood .

One of the major drawback of invasive glucometer is that it causes immense pain and puncturing the body with needle of a diabetic patient is not a safe method because due to this disease the process of curing body wound and power to resist from bacteria becomes slow and week which increase the chances of getting infection such as septicaemia , fouling with blood clots and embolism.

Since invasive method of glucose level measurement is painful and causes damage to nerves, non-invasive method is used as an alternative.

1.3 Layout of the Thesis

So, the development of a non-invasive blood glucose measurement system will be boon to the diabetic patients. The method of blood sugar measurement in the human blood non-invasively using the painless near infrared based optical technique. The designed system consists of LED emitting signals of 940 nm wavelength. These optical signals are sent through the earlobe tissue and reflected signals are detected by phototransistor placed beside the LED. The glucose concentration in the blood is determined by analyzing the variation in the intensity of received signal obtained after reflection. The results obtained from the designed system shows the feasibility of using NIR based non-invasive method for the measurement of blood glucose.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Principle

The various optical methods for the non-invasive measurements includes near-infrared, photo acoustic spectroscopy, Raman’s spectroscopy, polarization technique and light scattering techniques Trans illuminated laser beam is used to measure glucose concentration. As described by Tang, metabolic heat conformation technique can be also used for blood glucose measurement.

In the Near Infrared (NIR) Spectroscopy, glucose cells will produce the weakest NIR absorption signals in the human body as glucose is one of the biological component present inside the human body. In measuring the glucose level, the NIR spectroscopy enables the penetration of signals inside the tissue within the range of 1 to 100 millimeters depth. Penetration depth decreases as the signal wavelength value increases. Recently few authors incorporated neural network techniques in the non-invasive blood glucose measurement.

When a light ray interact with human body tissues, it is attenuated by scattering as well as by absorption by the tissues. Due to the mismatch between the refraction index of extracellular fluid and the cell membrane, light scattering occurs in tissues. Refraction index of extracellular fluid varies with the glucose concentration whereas the cellular membrane index is assumed to be remain relatively constant. Beer-Lambert Law plays a major role in absorbance measurement which states that absorbance of light through any solution is in proportion with the concentration of the solution and the length path travelled by light ray.

Figure 1 shows the description of effect of glucose molecules on the light path . Less glucose leads to more scattering, more path length and hence less absorption whereas more glucose tissues result in less scattering, less optical path length and hence more absorption by the tissues. Due to more absorption in high glucose tissue reflected light is having less intensity compared to tissue with less glucose content. Light transport theory describes light attenuation as

$$I = I_0 \, e^{\mu eff \, L}$$

where,

I is the reflected light intensity

I_0 is the incident light intensity

L is the length of optical path inside the tissue.

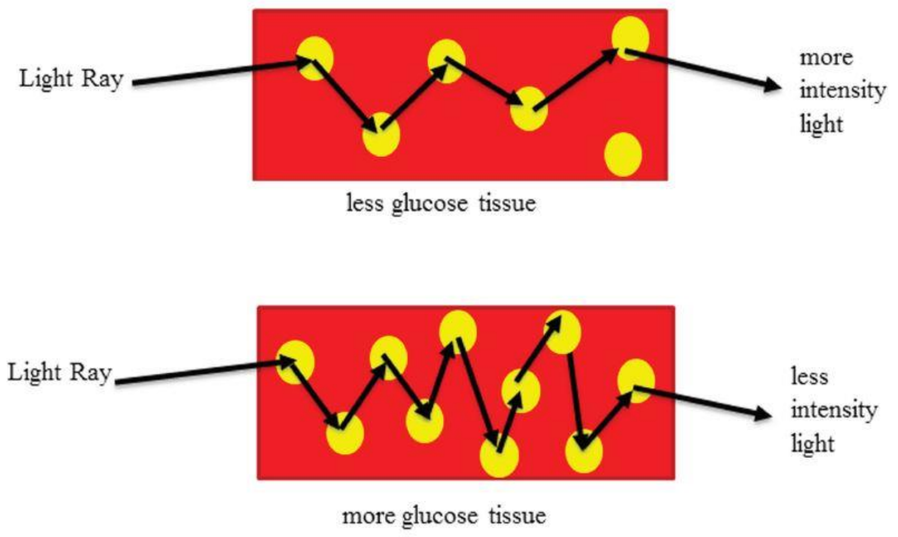


Figure 1. Effect of Glucose On light Path.

Attenuation of light inside the tissue depends on the coefficient known as effective attenuation coefficient (μ_{eff}), which is defined as

$$\mu_{eff} = \sqrt{3\mu a(\mu a + \mu s')}$$

The absorption coefficient (μ_a) is describes as the probability of absorption of photons inside tissue per unit path length and is given by

$$\mu_a = 2.303 \, \epsilon C$$

ϵ is the molar extinction coefficient and C is the tissue chromophore concentration and the reduced scattering coefficient ($\mu_S{'}$) is given by

$$\mu_S{'} = \mu_S \, (1-g)$$

where, g defines the average of the cosine of the scattering angles which has a representative value of 0.91 and μ_s defines the scattering coefficient.

With increase the glucose concentration path length decreases. With the assumption that refractive index of blood cell remains constant (approximately 1.350-1.460) with increase in the glucose concentration scattering properties decreases. From the equations above it can be concluded that μ_a also depends on the blood glucose concentration, the increase in the glucose concentration increases the value of absorption coefficient μ_a and hence the effective attenuation coefficient μ_{eff} also increases which in terms results in increase in the attenuation level. Hence it can be concluded that increase in attenuation decreases the intensity of reflected light.

In the project, the device indirectly measures glucose fluctuation in the earlobe tissue. The light from the transmitter falls on the small capillaries present in the earlobe and the reflected light is measured by the receiver in the device . Glucose molecules have the ability to vary the refractive angle of light proportional to its concentration. It has several light absorption peaks at different wavelengths. At 940nm wavelength the attenuation of optical signals by other constituents of blood like water, RBCs, etc, is minimum. From the refractive angle, concentration of glucose present in the blood is calculated.

CHAPTER 3

PROPOSED MODEL

3.1 Block diagram of proposed work

The proposed work is based on NIR optical technique. NIR light source of 940 nm wavelength is chosen because it is suitable for measuring blood glucose concentration. The sensing unit consists of NIR emitter and NIR receiver (photo detector) positioned on either side of the measurement site (earlobe) as shown in figure. When the NIR light is propagated through the earlobe in which it interacts with the glucose molecule, a part of NIR light gets absorbed depending on the glucose concentration of blood and remaining part is passed through the earlobe. The amount of NIR light passing through the earlobe depends on the amount of blood glucose concentration.

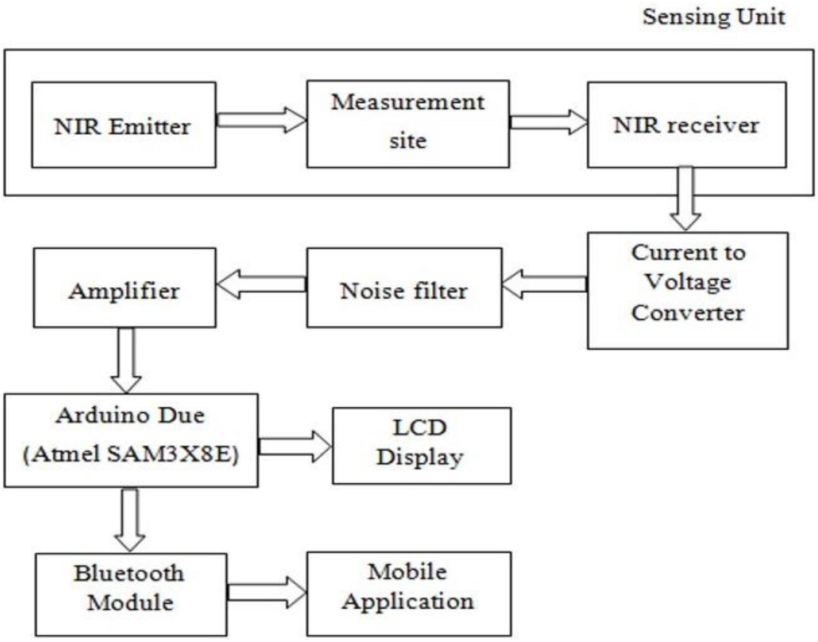


Figure: Block diagram of non-invasive glucose monitoring unit

The transmitted signal is detected by the photo detector. The output current of the photo detector is converted into voltage signal and then it is filtered and amplified.

This amplified signal is fed into Atmel SAM3X8E microcontroller. The inbuilt ADC block is used for converting the received analog signal to digital form. This digital signal is processed by using second order regression analysis to predict the blood glucose value and the blood glucose value is displayed on the LCD display. A mobile application (App) is created in order to view and store the predicted blood glucose value after receiving it via Bluetooth. Atmel communicates to the mobile app via Bluetooth by connecting a Bluetooth module (HC-05) to it.

3.2 Flow Chart of proposed work

The flow chart of proposed work is shown in the figure given below.

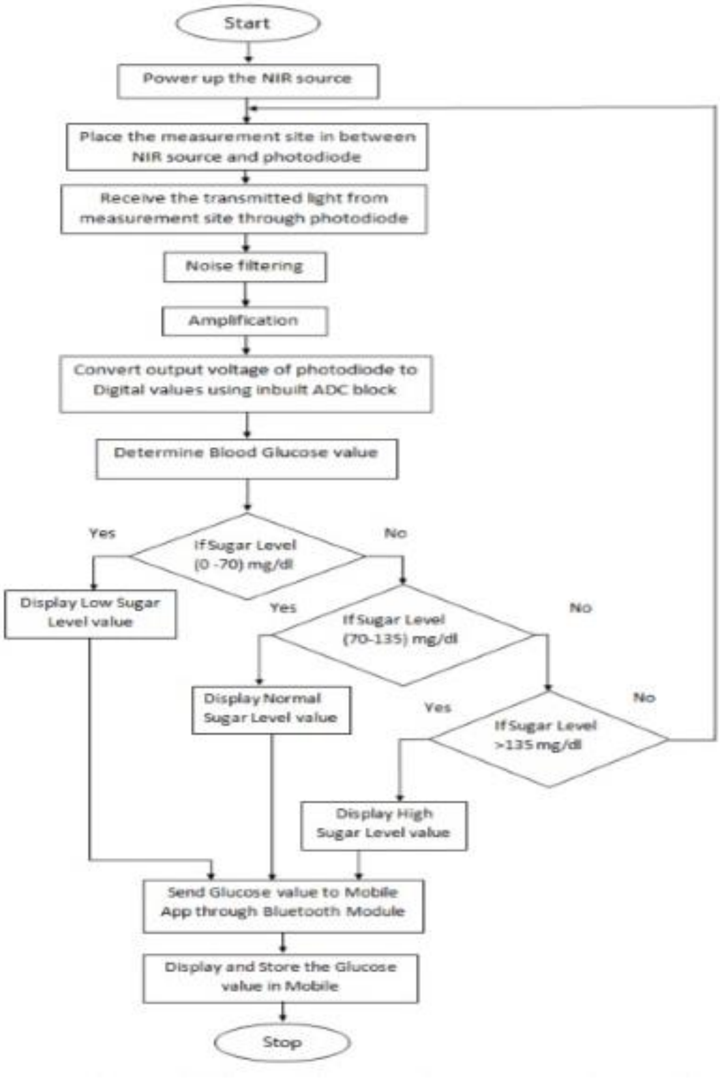
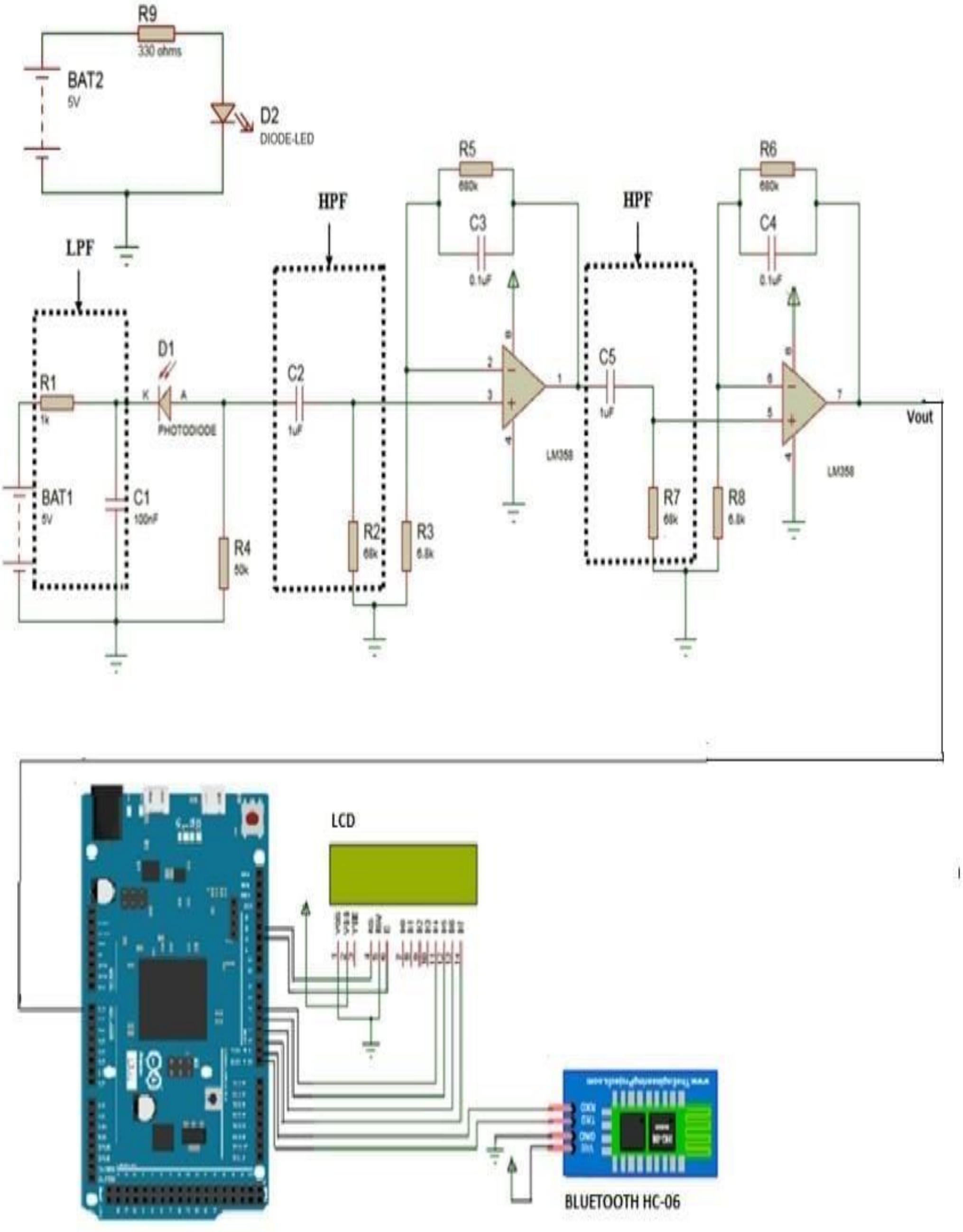


Figure: Flow chart of proposed work

Optical measurements dependent on concentration changes in all body compartments measured, as well as changes in the ratio of tissue fluids (as altered by activity level, diet or hormone fluctuations) and this, in turn, effects the glucose measurement. Problems also occur due to changes in the tissue after the original calibration and the lack of transferability of calibration from one part of the body to another. Tissue changes include: body fluid source of the blood supply for the body fluid being measured, medications that affect the ratio of tissue fluid, day-to-day changes in the vasculature, the aging process, diseases and the person's metabolic activity.

However, the ratio of body fluids (intracellular, interstitial, plasma) are affected by factors such as activity level, diet or hormone fluctuations, but also by blood circulation, body temperature shift, metabolic activity and medication. All these factors are capable of influencing the optical parameters and, consequently, impacting the blood glucose measurement. Moreover, day-to-day changes in vasculature and tissue texture as well as the aging process may affect the long-term stability of glucose monitoring.

3.3 Circuit Diagram



CHAPTER 4

DESIGN PROCESS

4.1 Selection of wavelength

Human skin tissue consists of epidermis, dermis and subcutaneous tissue layers.
In dermis great number of capillary vessels are present so the accuracy of glucose detection is better .When optical signal is sent perpendicularly into the earlobe the signal passes through epidermis layer and gets reflected in dermis layer and follows banana shaped path as shown in figure.

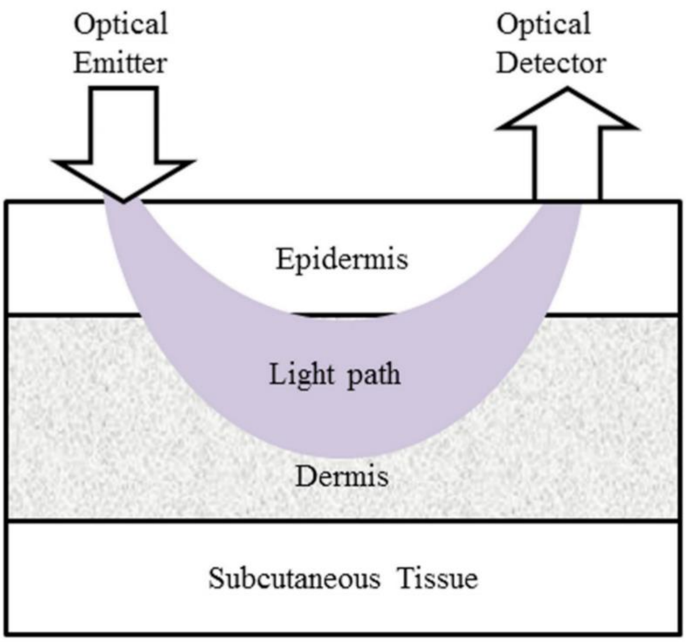


Figure: Cross Section of Skin and Light Path.

Light in the range of 700 nm to 2500 nm comes under the near infrared region which interact with the tissue with low energy radiation. 600 nm to 1300 nm is considered as the near-infrared window which is also known as therapeutic window or optical window. The range of wavelengths where light possesses its maximum penetration depth in tissue is referred as Near Infrared window. Glucose has light absorption peaks at different wavelengths .

The wavelength at which light absorbs glucose are 940 nm, 970 nm, 1197 nm, 1408nm,1536nm, 1688nm, 1925 nm, 2100nm, 2261nm and 2326nm1, But at 940 nm wavelength the attenuation of optical signals by other constituents of the blood like water, platelets, red blood cells etc. is minimum, hence a desired depth of penetration can be achieved and actual glucose concentration can be predicted.

4.2 System Hardware

LED is chosen as emitter as it emits optical signals of 940 nm wavelength. Its physical dimensions are smaller and it is less cost. LASER also affects the biological tissues and also costly. Hence LED is the best option to be considered as an emitter in biological systems.

For maintaining strength of emitted optical signal to be constant, emitter is powered with a constant current source. Phototransistor which is having peak sensitivity at 940 nm is used to detect the attenuation of optical signals with change in the glucose concentration in the blood. Transistor is connected in the common emitter configuration. Output of the detector circuit is passed through an instrumentation amplifier to increase the output signal strength and the output range.

Microcontroller is programmed considering the regression equation formed by glucose concentration measures with the help of glucometer for the reference and the liquid crystal display is used to display the blood glucose concentration. To detect the reflected signals properly, emitter and detector are placed besides each other on the same side of the earlobe as there occurs a phase shift of 1800 between transmitted and reflected signals.

4.3 Experimental Analysis

With the help of designed system and commercially available, Glucose is measured for different people for different conditions like before and after meal and corresponding voltage values at the amplifier output terminal are recorded. Based on the recorded voltage values and corresponding glucose concentration a 2nd order polynomial regression equation is computed which is used to calculate glucose concentration.

The analog voltage measured at analog pin A0 of Arduino due microcontroller and the corresponding glucose concentration measured by the invasive method in the laboratory are plotted on a graph and shown in figure 5. The polynomial equation relating the analog voltage and the glucose level is computed by using regression tool and shown below.

y = (8*10-5) x2 + 0.1873x + 46.131

where x and y are analog voltage (mV) and glucose level (mg/dl) respectively.

Table -1 Analog Voltage and the Glucose Level of Samples

S.No	Analog Voltage (mV)	Glucose Level (mg/dl)	S.No	Analog Voltage (mV)	Glucose Level (mg/dl)
1	499	142	13	607	196
2	509	146	14	627	191
3	519	156	15	695	167
4	519	157	16	735	220
5	548	177	17	612	244
6	524	159	18	847	247
7	543	209	19	833	248
8	568	133	20	867	276
9	573	179	21	935	302
10	583	224	22	999	321
11	592	175	23	1136	338
12	597	187	24	1538	516

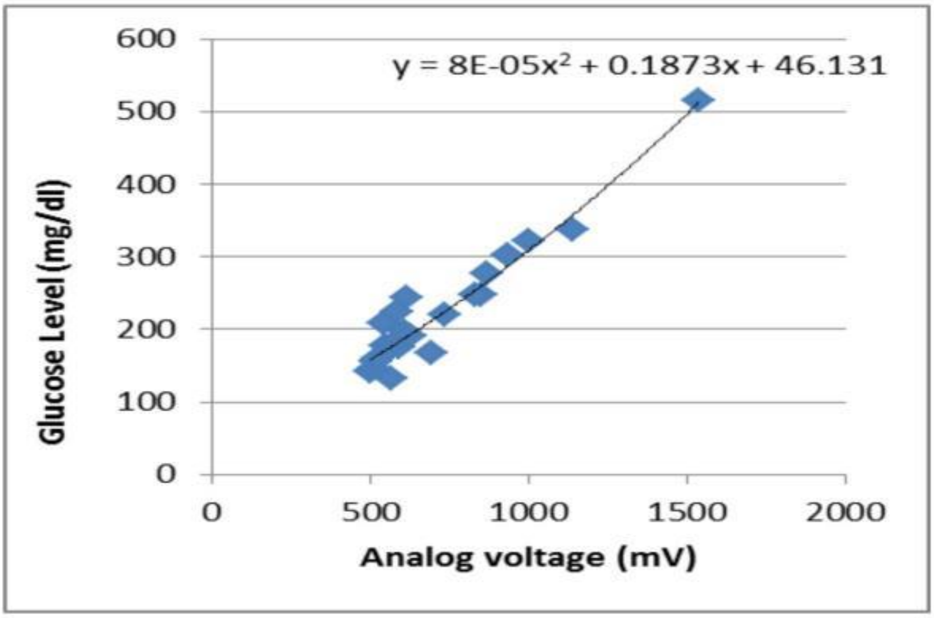


Figure 5. Regression analysis of glucose data with analog voltage data

4.4 Program code

```
#include<LiquidCrystal.h>

LiquidCrystal lcd(2, 3, 4, 5, 6, 7);

const int soil =  A0;

int ir1state=0;

int ir2state=0;

int vout=0;

int xout=0;

int yout=0;

int zout=0;

void setup()

{

pinMode(soil,INPUT);

Serial.begin(9600);

lcd.begin(16,2);

delay(500);

}

void loop()

{

ir1state=analogRead(soil);
```

```
ir2state=(8*10^-5)*ir1state^2;


xout=0.1873*ir1state;

yout=ir2state+xout+46.131;

vout=yout*(-1);

zout=vout/100;

Serial.println(ir1state);

Serial.println(ir2state);

Serial.print("GL:");

Serial.print(zout);

Serial.print("mg per dL");

lcd.clear();

lcd.setCursor(0,0);

lcd.print("GL");


if ((ir1state<=300)&&(ir1state>=20))

{

  lcd.clear();

  lcd.setCursor(0,0);

  lcd.print("GL:");

  lcd.print(zout);
```

```
lcd.print("mg per dL");

}

else

{

lcd.clear();

lcd.setCursor(0,0);

lcd.print("GL:")

}

}
```

CHAPTER 5

RESULT

In earlobe great number of capillary vessels are present, has boneless tissue and small thickness and hence the accuracy of glucose detection is better in this method. The glucose concentration for different patients will be measured using the sensors and will be compared with conventional glucometer. A non-invasive blood glucose meter can provide glucose measurements painlessly, without a blood sample or finger pricks.

The non – invasive glucometer can be used for self monitoring of blood glucose levels. They are used for hospital hyperglycemia screening and hospital subcutaneous insulin dosing. They are also used in ICU. The Non – invasive glucometer reduces discomfort and risks of infection or tissue damage which is a major drawback in the invasive blood monitoring system.

It does not use blood glucose test strips unlike the invasive glucometer , thus making it cost effective. Making additional improvements to the system helps in continuous monitoring of blood glucose levels.

The expected output in tabular form is as follows:

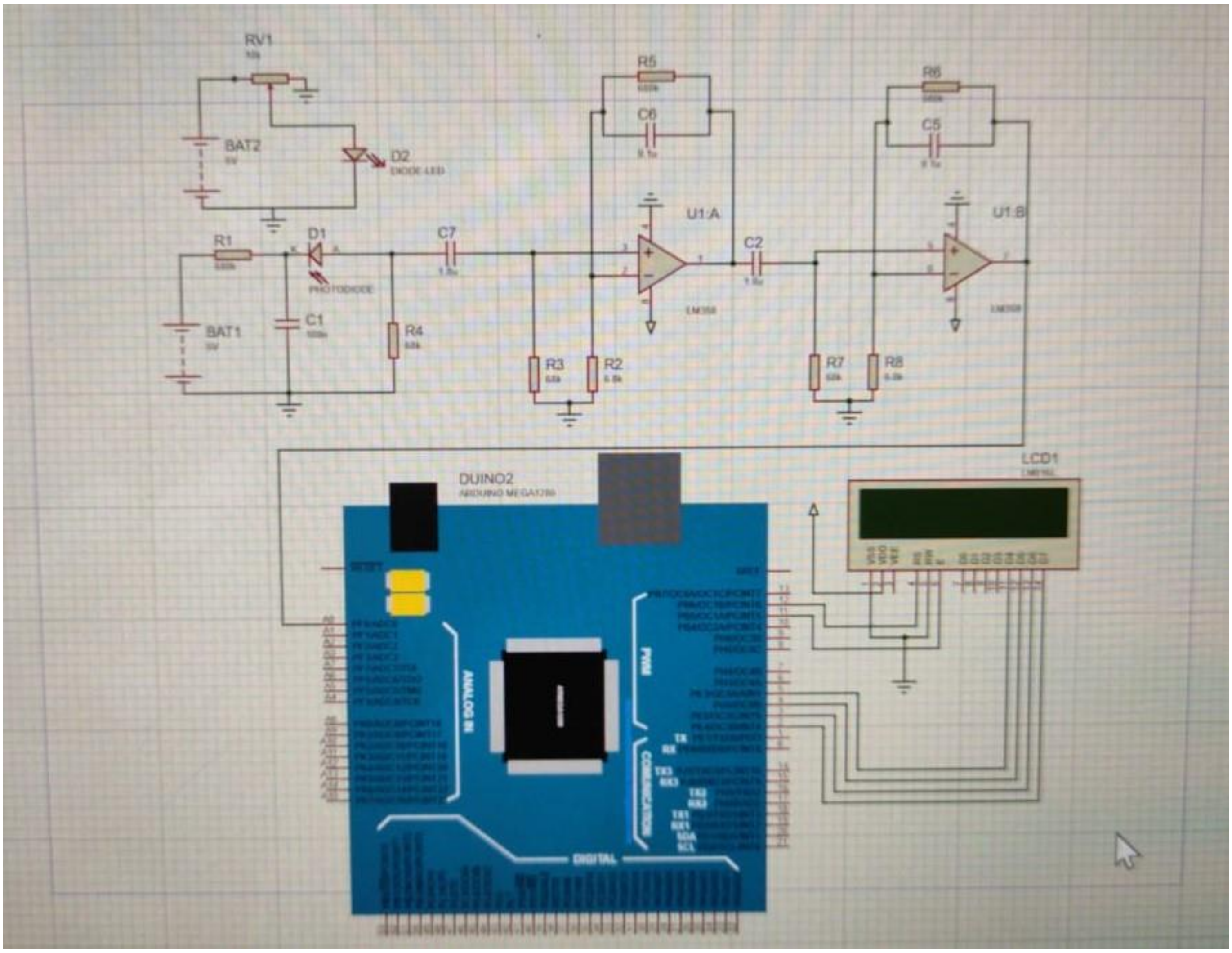
Table 2: Expected output table

S. No.	Analog Voltage (mV)	Glucose Level (mg/dl)
1.	499	159.5
2.	509	162.2
3.	519	164.8
4.	519	164.8
5.	548	172.8
6.	524	166.2

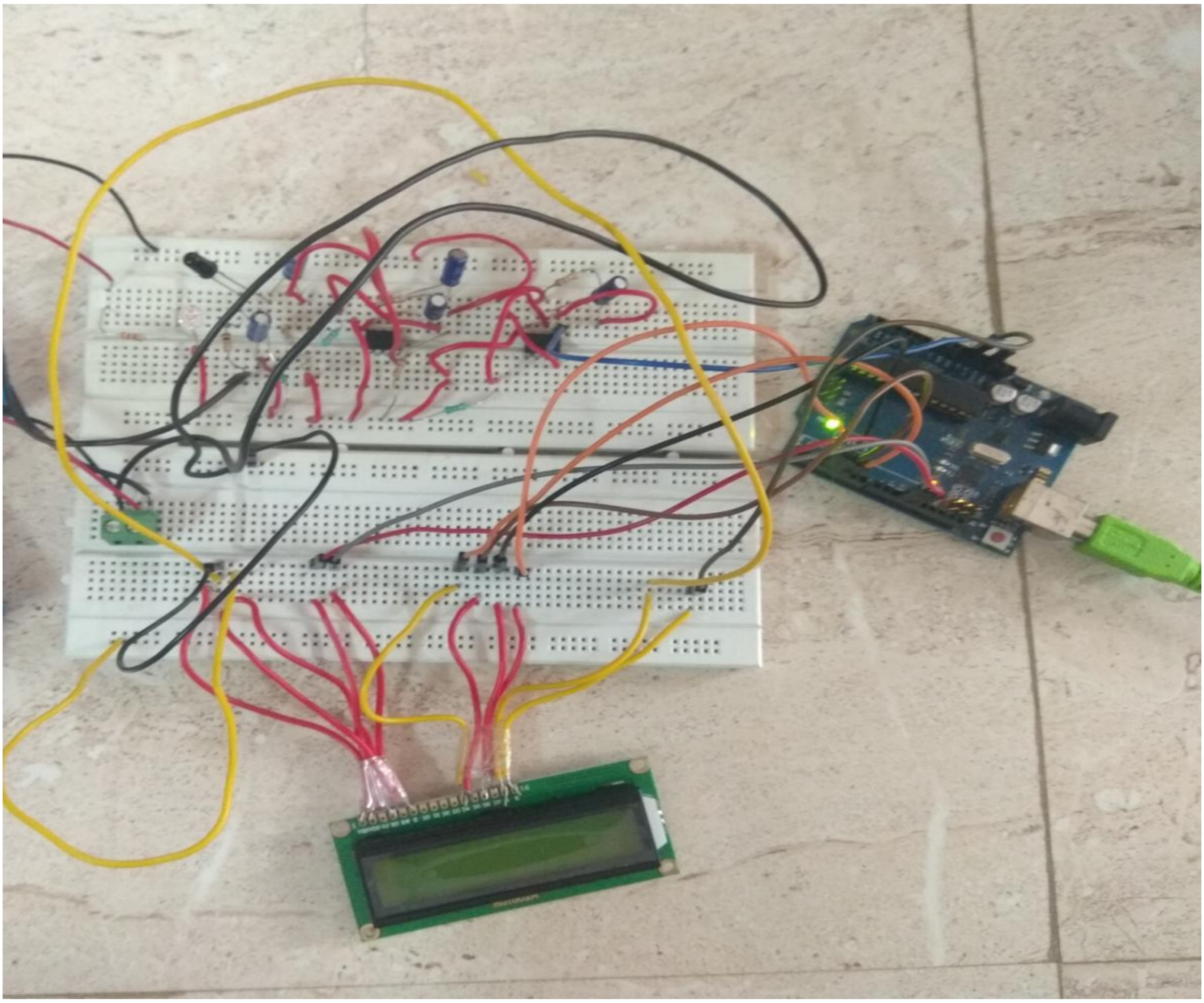
7.	543	171.4
8.	568	178.3
9.	573	179.7
10.	583	182.5
11.	592	185.0
12.	597	186.4
13.	607	189.2
14.	627	195.0
15.	695	214.9
16.	735	227.0
17.	612	190.7
18.	847	262.1
19.	833	257.6
20.	867	268.6
21.	935	291.1
22.	999	313.0
23.	1136	362.1
24.	1538	523.4

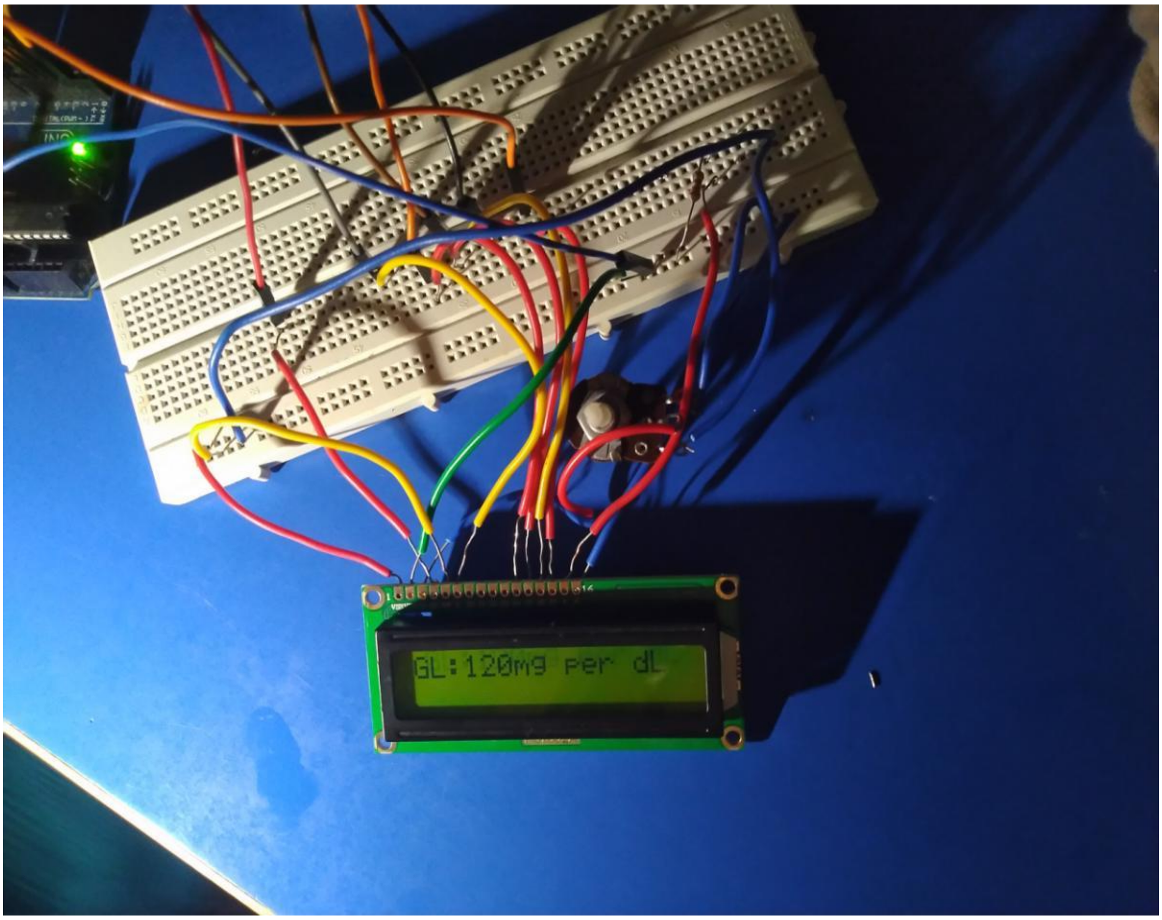
As the voltage is varied the glucose level changes in the simulation circuit. But due to the lack of sensor or earlobe specimen the expected output table is yet to be verified.

5.1 Simulation Result

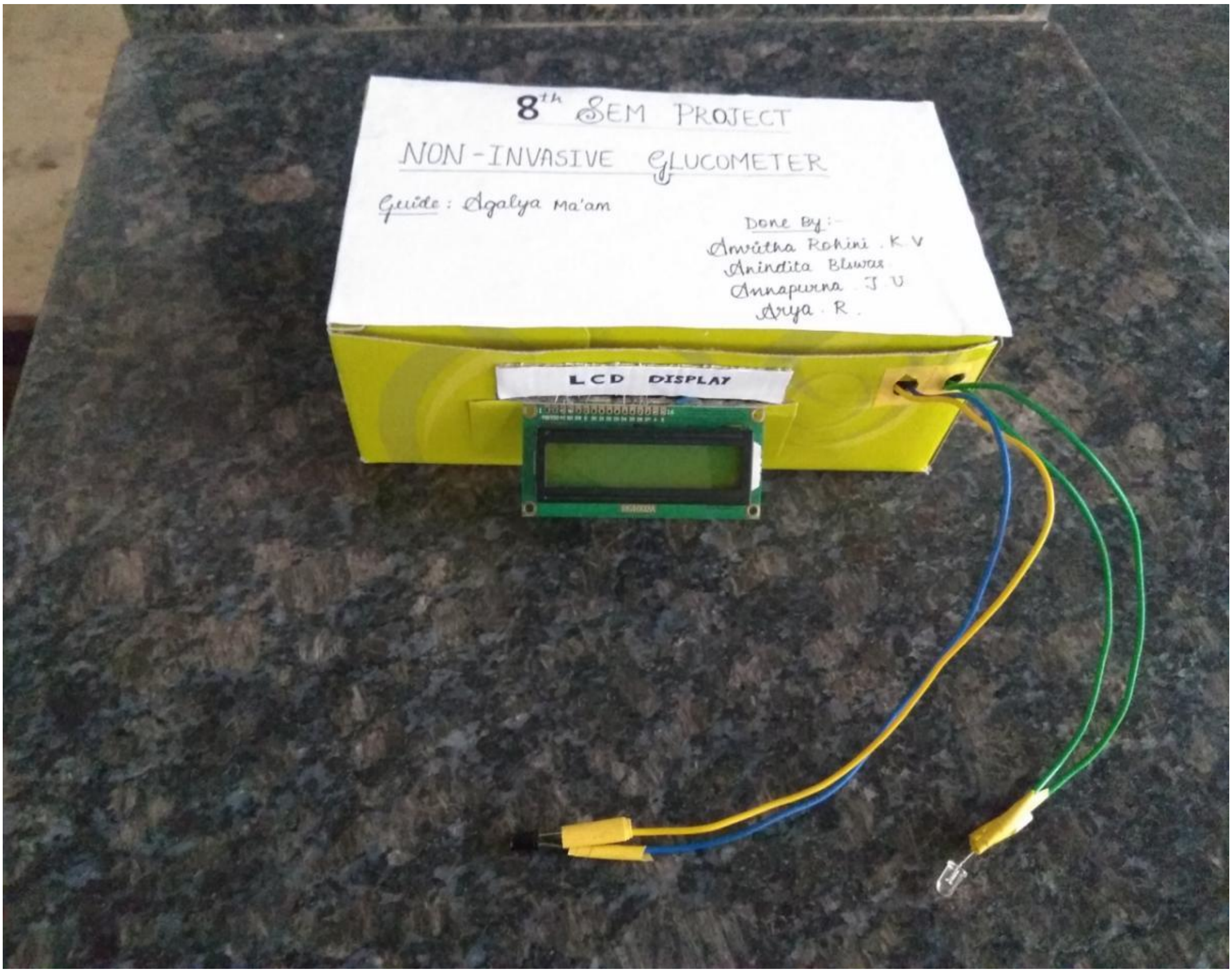


5.2 Hardware model




GL:120mg per dL

5.3 Product model



CHAPTER 6

FUTURE WORK

Smartphone based glucometer : Further changes can be made for continuous monitoring and to receive the reading on smartphones which helps to store and retrieve data when required.

Alerting family members in case of an emergency : Very high or low (<50 mg/dL) blood glucose levels can lead to lose of consciousness or a seizure , so alerting a family member will ensure the person receives necessary medication .

Diet tips based on blood glucose levels : Recommendations for diet change in case of a higher or lower blood glucose level , so as to maintain normal glucose levels.

REFERENCES

Stone MP, Agrawal P, Chen X, Liu M, Shin J, Cordero TL, Kaufman FR. "Retrospective analysis of 3-month real-world glucose data after the MiniMed 670G system commercial launch", Diabetes Technol Ther ,20, pp 689-92,2018.

Ryosuke Kasahara, Saiko Kino, Shunsuke Soyama, and Yuji Matsuura, "Noninvasive glucose Monitoring using midinfrared absorption spectroscopy based on a few wave numbers ,Biomedical Optics express 289, Vol. 9, No. 1, 2018.

American Diabetes Association, "Diagnosis and classification of diabetes mellitus," Diabetes Care, vol. 37, Supplement 1, 2014