Department of Electrical Engineering

Indian Institute of Technology

EE 344 : Electronic Design Lab

Group No. DD-11

Non-Invasive Glucometer

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Project Abstract :

According to the International Diabetes Federation (IDF) in 2017 approximately 425 millions adults (20-79 years) were living with diabetes and this number will rise to 629 million by 2045. It is metabolic pathological condition of concern, which effects vital organs of body if not diagnosed and treated on time.Regular monitoring of blood glucose is important to avoid any further complications. Commonly used glucose measurement methods are invasive which generally involve finger puncturing. These method causes pain and damage to tissues ,often leads to irritation due to regular repeated punchings which may sometimes cause infection. Also these methods generates lot of medical wastes which requires careful management otherwise there is high risk of spreading infectious diseases if the needle is contaminated and used more than once. Therefore there is a need to develop a non-invasive glucose monitoring system which can measure glucose and is easy to use for diabetic populations.

Contents

1 Introduction

1.1 Background and motivation

There are some methods which can be used for Non invasive glucometer Blood Glucose Measurement like Near infrared spectroscopy, photoacoustic spectroscopy, Raman spectroscopy, Polarisation. Using these methods we can predict the concentration of glucose in a sample infrared spectroscopy is most common as its results are more accurate. It is relatively easy to implement in hardware so we will use this method in our project.

The major challenge to NIR detection of glucose level is the multiple internal features (which cannot be measured non-invasively) like Haemoglobin, Water , tissues, Melanin and other components in blood . These components also absorb infrared lights so it would be difficult to distinguish between the effects caused by glucose and that caused by these factors .

Fortunately we have a solution for this problem. By using Monochromatic infrared light we can indeed take the effects caused by only glucose. There is basic law of spectroscopy i.e. different materials or chemical have their own spectrum. Same applies to glucose. It has its own absorption peak points which is unique to it . For ex. 950nm is a peak point for glucose which is relatively very less absorbed by other components listed above . By Transmitting only 950nm IR light inside the sample , we can easily detect the the received intensity at the opposite end based on the amount by which intensity is reduced we can get a proportional voltage at the output .

1.2 Project Objectives

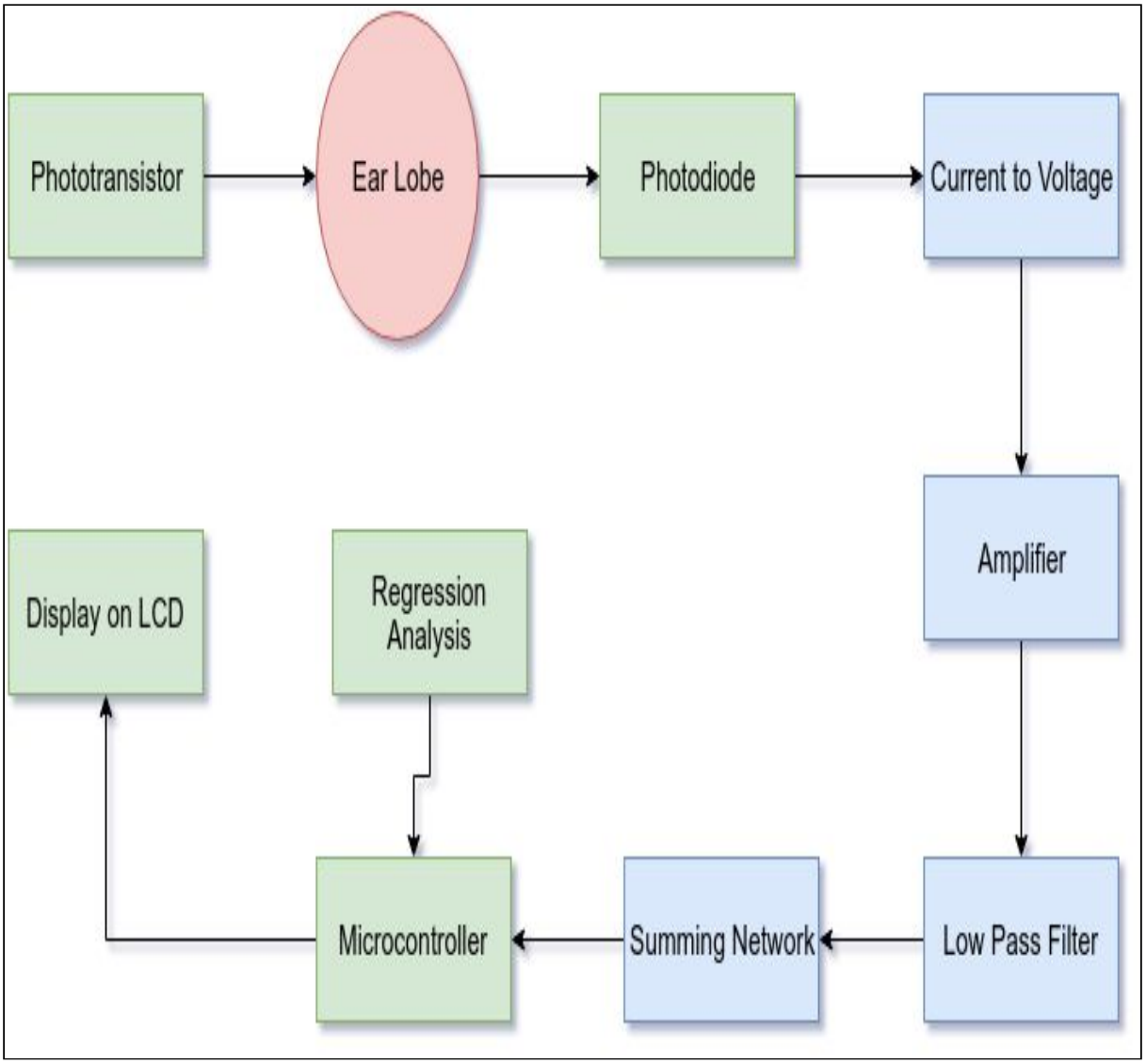
- To Predict the level of glucose in blood non invasively and displays it on LCD with maximum possible accuracy.
- Deliver an alternative low cost solution to traditional invasive glucose testing method for the control of glucose related diseases.

1.3 Deliverables Planned to Achieve Throughout the Project

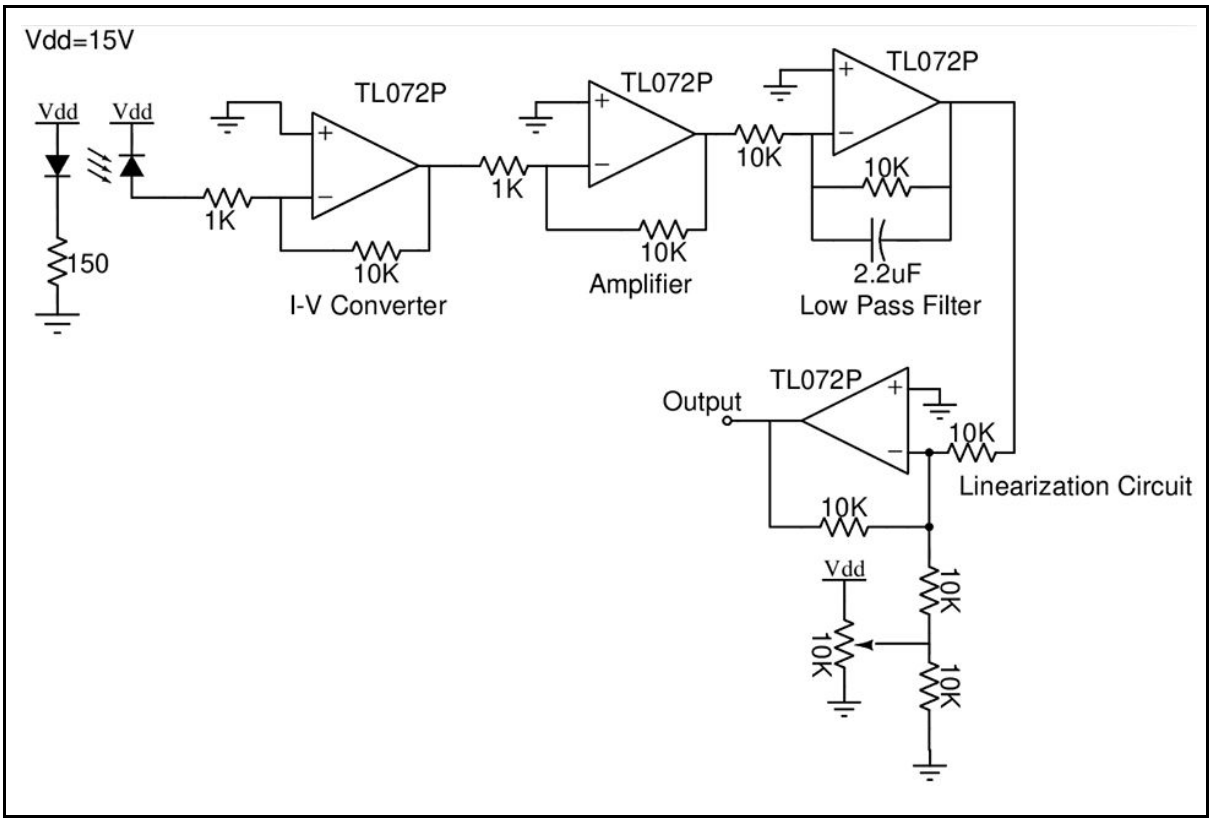
- Use of NIR Spectroscopy on a part of the ear lobe to predict the relative glucose level
- Design an analog circuit model to get the amplified voltage level for corresponding relative glucose level and to feed this voltage to the microcontroller
- Achieve a Multiple Linear Regression Model for predicting glucose level from the voltage value received
- Showing the voltage value and the corresponding glucose level on the LCD screen

2 Project Design and Implementation

2.1 Block Diagram for the Model



2.2 Circuit Diagram



Compete Circuit Diagram of the Analog Circuit Used In The Project

2.3 Details of the Subsystems (SubCircuits) Developed

Here we have provided two paragraphs for explanation, first one explains about how exactly is circuit achieving our requirements, and second one is about how exactly we arrived/finalized at this circuit for the particular design requirements.

1. **Photodiode & Photo Transistor**

   The primary objective is to analyze the detection of the infrared through glucose concentration and the human sample. The infrared wavelengths used for this purpose is of 940nm. The method employed is that we are emitting an infrared wavelength to pass through the finger. Then, the wavelength that passes through it is being received by photodiode which act as a photo sensor. The value of the voltage increases as the glucose concentration value increases.

   Since we had decided to use transmission of IR light (as we had arrived at conclusion that IR light of wavelength 940nm is best suited for absorption by glucose) , thus this circuit of photodiode and phototransistor was the standard circuit that we finalized.

2. I-V Converter

Current output by the Photo Transistor is input to I-V Converter which is converted to a Voltage. Op-amp TL072 has been used in the circuit to achieve the required Voltage output.

After receiving the current from the phototransistor, we had to amplify the voltage corresponding to it (as we had to deal with the voltage values finally), thus the use of I-V converter. Furthermore while choosing the Op-amp we had to keep in mind the maximum supply current that can be provided by the opamp, as due to the output impedance if this required supply current exceeds the maximum supply current that the opamp can provide then the value of voltage (voltage to be amplified)will be altered and we will no longer be getting required results.

3. Amplifier Circuit

Used to amplify the output voltage of I-V Converter to a considerable value.This will affect the amplitude of the signal and beside that; the purpose is to step up the small value output into suitable high value outputs. The input of this stage is from the previous stage which is I-V converter stage where the voltage that been given from the photodiode is very small and needs to be amplified with gain 10.

For the amplification part we simply approached this standard circuit. Further as stated earlier we had to keep in mind about the input impedance for this circuit (i.e. output impedance of previous circuit) for the reason stated in the explanation of previous part (I-V converter explanation). Resistance values chosen had to be finalized during the experiment.

4. Filtering Stage

Amplified voltage from the amplifier circuit is now provided in this circuit for noise removal.This is a stage that is designed to pass a desired signal and frequencies, reject and attenuate the other unwanted signal such as noise. The circuit is the combination of resistor and capacitor in parallel. Low pass filter is used to eliminate the frequency higher than 7Hz. The frequency below 7Hz is used to define glucose in the blood.

For the above-mentioned reason we had to use the circuit and for filtering this was the standard op-amp circuit that we approached

5. Linearization Circuit

Further this voltage value needs to be converted to a fixed range which is acceptable by the microcontroller as input, this is achieved by the summing network as described in the circuit diagram.

Purpose that had to be achieved by the summing amplifier was the linearization of range of output voltage to the desired voltage range(i.e. Between 0-5V to use it as input to Arduino). And summing network is the standard circuit approach for this.

6. Microcontroller (Arduino Mega) Circuit and LCD Display

Final voltage from the analog circuit is now provided as input to arduino and this will give us the estimated blood glucose concentration and display it on LCD.

Need of a microcontroller was obvious in this part as we had to move from analog to digital arena and Arduino Mega has DAC in it. Furthermore we had to supply the input voltage and our linear regression model could be applied to this voltage through Arduino. We could feed in the regression model that is to be obtained by us with the help of the data collected to the microcontroller and we could convert the voltage reading to the glucose concentration that we are required to show on the LCD as desired. Thus we chose Arduino Mega as it satisfied all the requirements as desired for this step.

7. Approach for Data collection

Initially we were not sure about the body location where we should consider taking readings. So first we took the readings on finger but we got highly corrupted values due to larger thickness of finger as compared to ear lobe and due to interference from bones and muscles whereas for ear lobe interference from muscles is not that much. Thus we did stick with earlobe as final body part to be considered during observations.

3 Performance Evaluation

3.1 Data and Software Test Results

We collected and analysed the data samples and arrived at final conclusion as explained below.

3.1.1 Table 1

Data Samples Collected for Blood Glucose and Corresponding Voltage

Here we have tabulated the collected data for blood samples and corresponding voltages which will be utilised for obtaining the regression model. Furthermore skin tone was assigned on the scale of 1 to 5 for different individuals so as to check whether we will need to take its effect in consideration.

Name	Glucometer Reading (mg/dL)	Voltage Output (V)	Skin Tone
Rishik Kumar	85	0.24	2.5
RA	91	0.6	3
RA2	94	0.74	4
Chandan	99	0.85	3
Shashank	101	0.68	2.5
Sai Krishna	118	0.87	3
Aneeb	89	0.49	1
Ashutosh	117	0.84	2
Suraj WEL	94	0.67	2.5
Sanidhya	87	0.64	1
Navoj	96	0.75	4
Irina	98	0.6	2
TA	91	0.73	1
TA1	107	0.69	1
TA2	90	0.67	1.5

3.1.2 Table 2

For Multiple Linear Regression Model(Considering Voltage and Skin Tone both)

We ran Multiple Linear Regression and using the obtained parameters we arrived at the below mentioned equation. We chose Linear regression as our aim is to achieve a linear relationship between three different parameters.

Y = 68.53056472 + 43.16820486(Voltage) -0.1538415199(Skin Tone)

For Multiple Linear Regression		
Glucometer Reading (mg/dL) - Predicted	**Residuals**	**(Residuals)^2**
78.50633009	6.493669913	42.16774894
93.96996308	-2.969963076	8.820680675
99.85967024	-5.859670237	34.33573528
104.7620143	-5.762014291	33.20080869
97.50034023	3.499659775	12.24761854
105.6253784	12.37462161	153.13126
89.52914358	-0.5291435815	0.2799929298
104.4841738	12.51582624	156.6459064
97.06865818	-3.068658176	9.416663004
96.00437431	-9.004374311	81.07875672
100.2913523	-4.291352285	18.41570444
94.1238046	3.876195404	15.02489081
99.88951275	-8.889512748	79.0234369
98.16278455	8.837215447	78.09637685
97.2224997	-7.222499696	52.16450186
AVG[(Residual)^2]		51.60333881
SQRT(AVG[(Residual)^2])		7.183546395

3.1.3 Table 3

For Linear Regression Model (Considering only Voltage)

We ran Linear Regression and using the obtained parameters we arrived at the below mentioned equation(For two variable linear regression just this equation can be obtained by using the best fit line as well). We went for Linear regression as our aim is to linearly relate two different parameters.

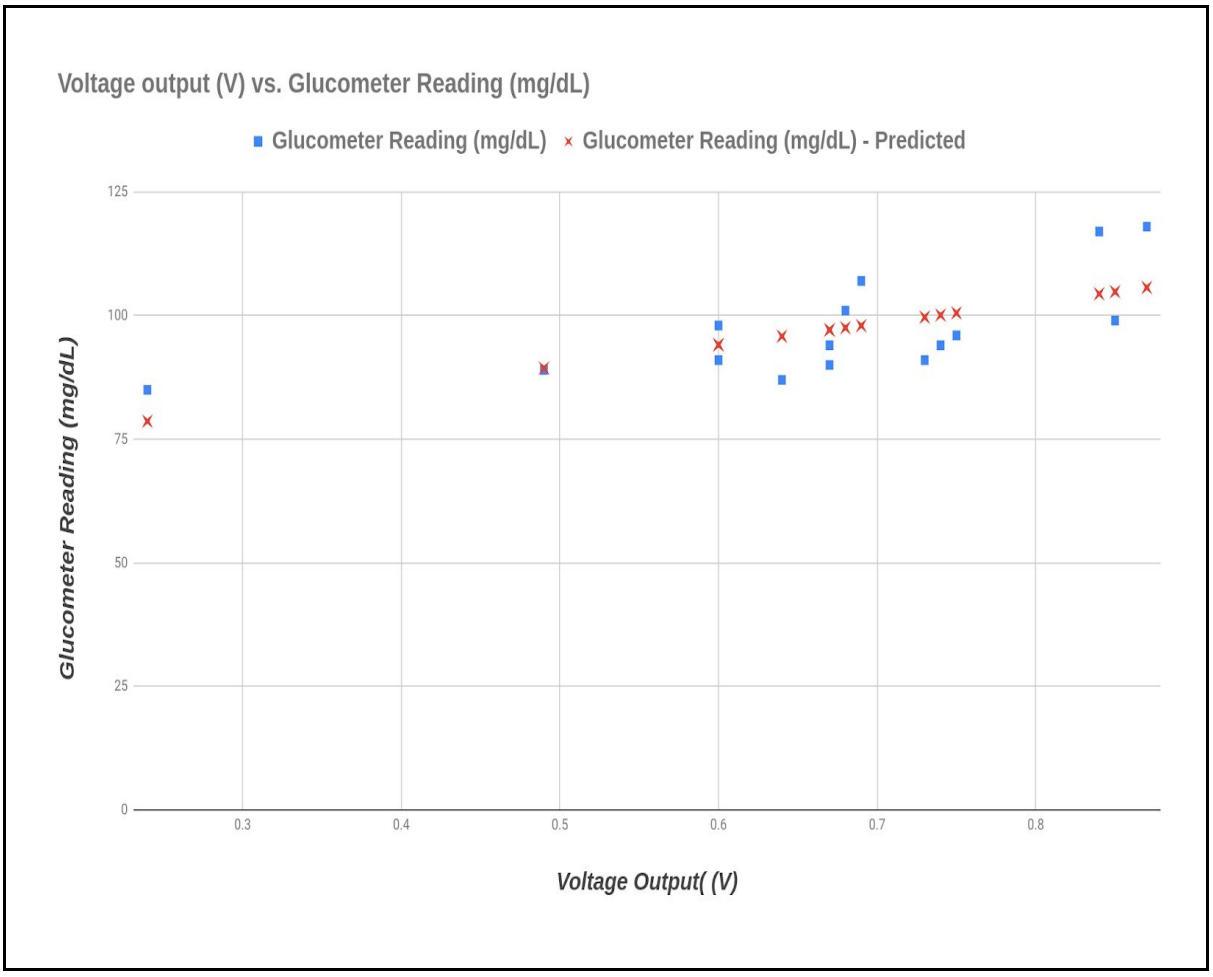
Y = 68.33970292 +42.93284852(Voltage)

For Linear Regression		
Glucometer Reading (mg/dL) - Predicted	**Residuals**	**(Residuals)^2**
78.64358656	6.356413435	40.40399176
94.09941203	-3.099412032	9.606354944
100.1100108	-6.110010825	37.33223228
104.8326242	-5.832624162	34.01950462
97.53403991	3.465960086	12.01287932
105.6912811	12.30871887	151.5045602
89.37679869	-0.3767986948	0.1419772564
104.4032957	12.59670432	158.6769598
97.10471143	-3.104711428	9.639233054
95.81672597	-8.816725973	77.73465688
100.5393393	-4.53933931	20.60560137
94.09941203	3.900587968	15.2145865
99.68068234	-8.68068234	75.35424588
97.9633684	9.036631601	81.6607107
97.10471143	-7.104711428	50.47692448
AVG[(Residual)^2]		51.62562793
SQRT(AVG[(Residual)^2])		7.185097629

We finally considered results from Table 2 only to be fed into the Arduino Mega. As the factor corresponding to Skin Tone was observed to be quite less and it was not affecting the root mean square of residuals till two decimal places, thus it could be safely ignored for our model.

3.2 Plots

Glucose Concentration (Actual and For Linear Regression) vs measured Voltage Output



We see here that the final glucose concentration predicted (Glucometer Reading - Predicted i.e RED crosses) is linear with Voltage Output. Furthermore we found out the root mean square of residuals to be 7.18 in case of Linear Regression.

3.3 Problems Faced

3.3.1 Hardware

Finalizing the Op-Amp : We had to take in consideration the maximum supply current that the op-amp can manage to supply. This had to be considered to make the model much more cost effective, as otherwise we would have to take in consideration the use of buffer after each of the stage.

Managing the Distance Between the LED and Photosensor : In this model as we are using clip as a component thus special care needs to be taken to maintain the distance between these two components at a constant level. As variable distance alters the readings and we are bound to get errors.

3.3.2 Software

Obtaining the maximum possible accuracy was the biggest challenge in this project. To achieve this with the software method used we had to have much more number of data samples as compared to the number of samples we have used, so that the model could give us the better results.

4 Conclusion and Future Work

4.1 Conclusion

We were able to achieve the goal of this project as we could successfully get the glucose concentration level for individuals with the help of the voltage measured using our circuitry. Furthermore results obtained were having some deviation from the actual value that one would get using the invasive methods. And root mean square(RMS) of these deviations would lie close to 7.18(For dataset we observed it was found to be exact 7.18) which can be called a good accuracy considering the fact that the glucose levels that we would be getting for the diabetic individuals are more 120 mg/dL -126 mg/dL. Although it is not the best possible accuracy that can be achieved and further modifications are needed in this model which can be achieved in the below mentioned manner.

4.2 Future Modifications Possible

Results at the end of this project were achieved with the help of mere 15 data points. But it was observed that as we increase the number of data points the model gets better and better. So to further improve in this project one needs to have as fair enough number of data samples to get a good model.

Tip: *If someone is reading this report and planning to take up this project then you can look for any blood donation camp where you will be able to find enough of data points(samples), unfortunately we could not found one during the time window for this project.*