Non-invasive Blood Glucose Monitoring System Using IR Radiation

Project Report submitted in partial fulfilment of the requirements for the award of the degree of

Bachelor of Technology

In

ELECTRONICS & COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the project titled **Non-invasive Blood Glucose Monitoring System using IR Radiation** submitted by **Abir Lal Manna (Enrolment No. 12021002002035), Rupayan Saha (Enrolment No. 12021002002037)**, **Sarthak Chakraborty (Enrolment No. 12021002002027)** and **Debasmita Das (Enrolment No. 12021002002064)**, Students of UNIVERSITY OF ENGINEERING & MANAGEMENT, KOLKATA, as submitted for the partial fulfilment of requirements for the degree of Bachelor of Technology in Electronics & Communication Engineering, is a bona fide work carried out by them under the supervision and guidance of Prof. Debanjana Ghosh during 7th and 8th Semester of academic session of 2024-25. The content of this report has not been submitted to any other university or institute for the award of any other degree.

I am glad to inform that the work is entirely original and its performance is found to be quite satisfactory.

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ABSTRACT

According to the International Federation of Diabetes (IDF), **diabetes** affects more than 285 million people worldwide. It is a pathological metabolic pathological condition that affects important body organs when it is diagnosed at a good time and is not treated. Regular monitoring of blood **glucose** levels is important to avoid further complications. Introducing a new method of blood glucose monitoring, the initiative provides diabetics with a painless, **non-invasive** technique to check their blood glucose levels. The device detects levels of glucose in the blood without the usage of conventional pinpricks through the integration of advanced sensor technology with methods for signal processing. This article uses **visual measurements** with almost asymptomatic measurements to overcome invasive method networks such as frequent failures, high repetitive consumption costs, and risk of spreading infections. To detect blood glucose levels, the gadget is made up of **near-infrared** LEDs with wavelengths between 700 and 1400 nm that are optically placed at the fingers. The amount of glucose in the blood determines the amount of light is received. The signal is then augmented and introduced as an entrance to the Arduino UNO microcontroller. The development and testing of a small, non-invasive blood glucose measuring framework has been accomplished.

Keywords—Diabetes, Non-invasive, NIR, Visual Measurements, Glucose

INTRODUCTION

One of the main health issues facing society is diabetes mellitus, a condition in which the body does not generate enough insulin. According to estimates from the World Health Organization, 177 million people worldwide will have diabetes in 2000 **[1].** Diabetes is often thought of as relatively unimportant in comparison to cancer or heart conditions, but it can cause blindness, kidney failure, and amputation. Diabetes is expected to be the seventh leading cause of mortality worldwide in 2030. Glucometers on the market are intrusive. Patients with diabetes must check their blood sugar levels two or three times every day **[2]**. The current invasive method of blood glucose monitoring is inferior to non-invasive methods. The scattering and absorption of light through the blood are used to compute the blood glucose content. On the LCD, the concentration level is shown. Therefore, from the standpoint of the end user, creating a non-invasive method of testing blood glucose would be far more convenient **[4]**.The primary benefits of a non-invasive glucose meter would be the minimization of medical waste and the relief of discomfort and irritation brought on by repeated finger pricks. Non-invasive glucose measurement reduces all of the aforementioned issues and, as a result, lowers medical expenses. This study presents a potential sensor-based system that uses near-infrared (NIR) radiation to monitor blood glucose non-invasively **[5] [6]**.

LITERATURE REVIEW

Nowadays, blood glucose is measured by pricking the finger, drawing blood, and using a glucose meter to analyze the results. However, the existing approach is suboptimal for ongoing blood glucose monitoring. A non-invasive technique can be utilized to eliminate these issues. A dielectric spectroscopy-based architecture for continuous, non-invasive blood glucose monitoring with a blood glucose sensor is described by Gelao et al. [1]. The PCB design, schematic, and electrical circuit were created. Blood glucose level is indicated by the frequency of both amplitude and phase, which can be determined using a dielectric constant. The glucose level can be determined by measuring the change in tissue permittivity using dielectric spectroscopy. Ashok et al. offer a technique that uses a trans-illuminated laser beam to measure the blood glucose levels of people with and without diabetes. This laser, which operates at a wavelength of 632.8 nm, is an atomic gas laser, commonly referred to as a He-Ne laser [2]. In order to remove mode interference noise, a single mode laser was employed as a monochromatic light source. By using this technique, the diabetic patient's blood glucose level may be continually and noninvasively monitored.The outcome demonstrates that blood flow and blood glucose levels are closely correlated. Various techniques for measuring blood glucose are described by Abdallah et al. In order to build a solid, non-invasive home monitoring system, fluorescence, infrared spectroscopy, and elastic and inelastic (Raman) scattering were discussed [3]. An optical multi-sensor is used in the suggested approach to monitor light scattering and fluorescence in the tissue optical window inside and around a visible range through the finger. An experimental strategy that minimizes correlation with blood glucose is described by Burmeister et al. for the collection of non-invasive human spectra.Five people with diabetes had their tongues exposed to a variety of first overtone transmission spectra in this work [4]. Despite the significant degree of dispersion, correlations were found to be unrelated to temporal fluctuations since the approach separates glucose concentration from time. Wang et al. described a method based on metabolic heat conformation (MHC) and developed a prototype. This method estimates the glucose level based on the degree of heat dissipation, the local tissue blood flow rate, and the blood oxygen saturation level [5]. The correlation coefficient between the blood flow rate utilizing this method and the Doppler blood flow meter was found to be 0.914 after clinical testing. This finding is still inappropriate for therapeutic use even though it is closer. Amir et al. developed a successful method that can be used therapeutically, which is what our study used. Or sense Ltd. developed occlusion spectroscopy technology using an NBM device, which is used in the non-invasive blood glucose testing method described by Amir et al. Here, the method is demonstrated and the efficacy of the device is evaluated [6].

METHODOLOGY

The following elements are necessary for the effective use of infrared radiation in a non-invasive blood glucose monitoring system:

1. Arduino Uno Board: A well-liked microcontroller board for electronics projects and prototyping, the Arduino Uno is based on the ATmega328P. It has USB connectivity, digital and analog I/O pins, and can be programmed using the Arduino IDE.

Figure 1: Arduino UNO

2. Photo Diode Module: A photodiode module is a sensor that converts light into an electrical current, commonly used for light detection and measurement. It is widely used in automation, optical communication, and security systems[3][4] .

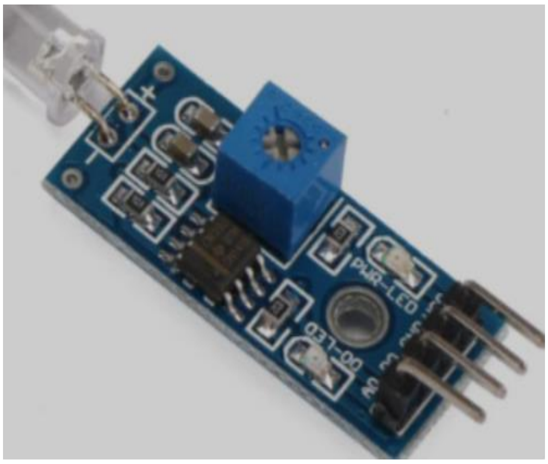

Figure 2: Photo diode Module

3. IR Sensor Module: An IR sensor module can be used in non-invasive blood glucose monitoring by analyzing infrared light absorption in the skin. Different glucose concentrations affect the absorption and reflection of IR light, allowing estimation of blood sugar levels[5].

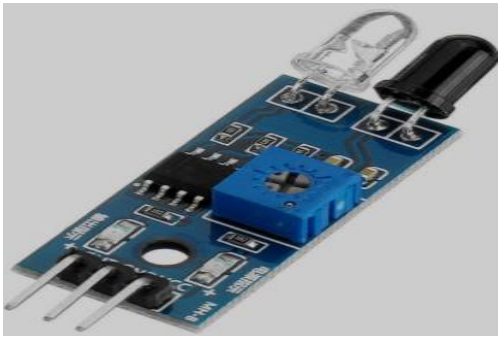

Figure 3: IR Sensor Module

4. Arduino Serial Monitor: The Arduino Serial Monitor is a built-in tool within the Arduino IDE that allows you to view and send data to and from your Arduino board via the serial port, making it useful for debugging and interacting with your code[2].

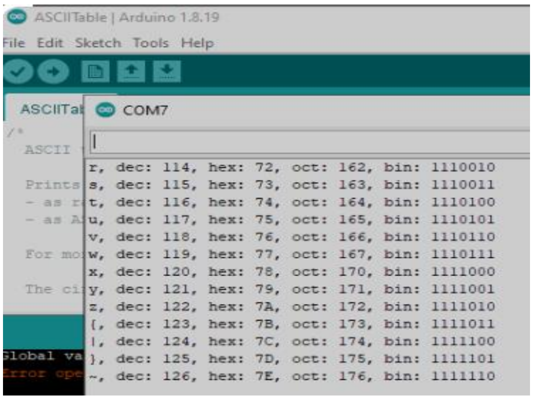

Figure 4: Arduino Serial Monitor

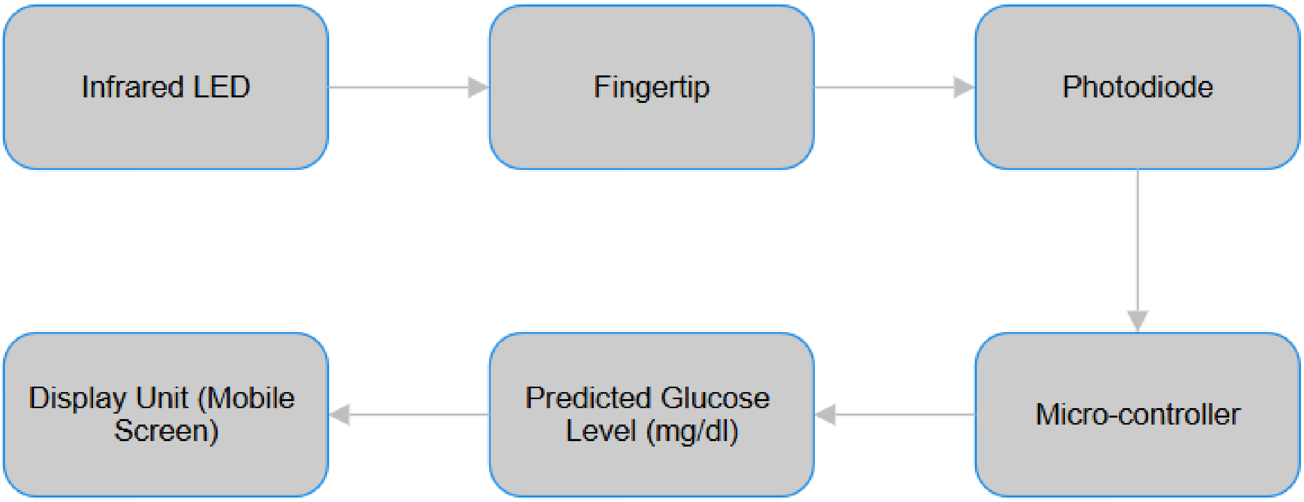

Figure 5: Block Diagram of the Setup

SCOPE OF STUDY

Here are six potential scopes of study for the **non-invasive blood glucose monitoring system using IR radiation**

1.Investigation of Infrared Absorption Properties

Examining the effects of glucose concentration on the way that particular infrared wavelengths are absorbed by human tissue[2].

2.Integration of Sensor Modules

Investigating the detection of transmitted or reflected infrared light through the fingertip using IR LED and photodiode modules[3].

3.Processing Analog Signals

The light intensity signal is amplified and converted into readable voltage levels that can be entered into a microcontroller[5].

4.Data Acquisition Using Microcontrollers

Implementing algorithms for glucose level estimation, processing data, and reading analog signals using an Arduino UNO.

5.Methods of Calibration and Mapping

Calibration curves are created and used to connect analog sensor readings to real glucose concentrations (mg/dL).

6.Mobile Interface and Display

Improving portability and user accessibility by sending processed data to a mobile screen for real-time display.

SIGNIFICANCE

Here are six significant aspects of non-invasive blood glucose monitoring system using IR radiation:

1.Monitoring Without Pain

In contrast to conventional techniques that necessitate pricking the finger, this device provides an entirely painless experience, enhancing user comfort and promoting more frequent blood glucose readings.

2.Economical Design

The device is cheaply feasible by using inexpensive parts like an Arduino UNO, photodiode, and infrared LED, particularly in low-resource environments or developing nations.

3.Enhanced Adherence by Patients

This non-invasive, user-friendly device encourages patients, particularly young people and the elderly, to routinely check their blood sugar levels, which improves diabetes care.

4.Monitoring Data in Real Time

Real-time glucose tracking and display is made feasible by the integration with Arduino and potential wireless modules, which can be crucial for prompt medical actions.

5.Adaptable and Open-Source

Flexible programming, open-source development, and customisation in accordance with specific needs or research requirements are made possible by the usage of Arduino UNO.

6.**Possibility of Smart Device Integration**

This configuration can be expanded to sync with cloud platforms or cellphones, enabling easy data sharing with healthcare providers, remote monitoring, and health trend analysis.

PROPOSED SOLUTION

Proposed Solutions for Identified Problems:

1.Problem: IR sensors can be affected by ambient light, skin color, or temperature, leading to inconsistent readings.
Justification: Infrared sensors are susceptible to influence from outside light sources, particularly sunshine or artificial lights. Furthermore, variations in body temperature and skin pigmentation may affect how infrared light is scattered or absorbed by the tissues, causing results to fluctuate.

Suggested Resolution:

Employ optical filters to prevent visible and ambient light and only permit the infrared wavelength to reach the photodiode.

To reduce light leakage and environmental disruptions, physically enclose the sensor setup (LED and photodiode).

Use temperature compensation algorithms to ensure more consistent results by correcting differences caused by body or room temperature.

2.Problem: Improper finger placement leads to variations in the optical path and light absorption. Justification: Measurement accuracy is decreased if the user positions their finger irregularly, such as too deeply, slanted, or off-center, as this changes the optical path length and causes differences in the amount of light absorbed.

Suggested Resolution:

To guarantee consistent placement each and every time, design and integrate a specific finger-holding enclosure or finger slot into the gadget.

To direct the user's finger to the proper place, employ alignment guidelines or tactile markers.

Before beginning a reading, use contact sensors or infrared proximity sensors to make sure the finger is positioned correctly.

3.Problem: Glucose absorption varies by person due to skin thickness, hydration, and other physiological factors.

Justification: Every individual has distinct physiological traits that impact the absorption of infrared radiation, such as blood composition, skin thickness, tissue density, and hydration levels. Because of this, not everyone will receive appropriate glucose readings from a one-size-fits-all calibration.

Suggested Resolution:

Provide a system that enables customized calibration profiles, in which each user's device is first calibrated using standard techniques and known glucose levels.

To enable the system to modify readings appropriately, store the user's profile in the non-volatile memory (SD card or EEPROM) of the device or associated mobile app.

Make use of machine learning models that adjust over time, gaining knowledge from previous measurements and improving the calibration for higher precision.

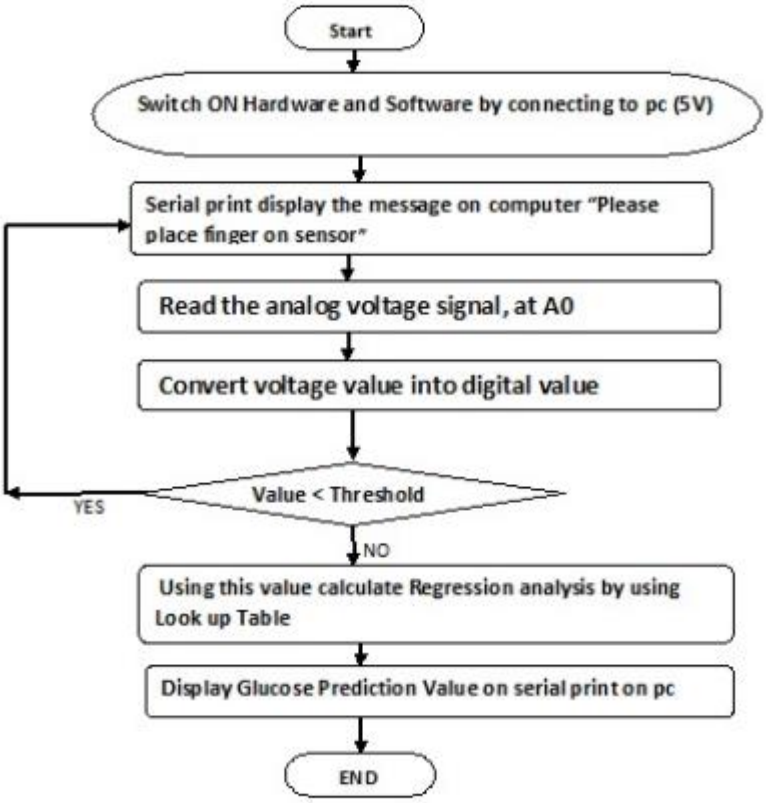

Figure 6: Flowchart

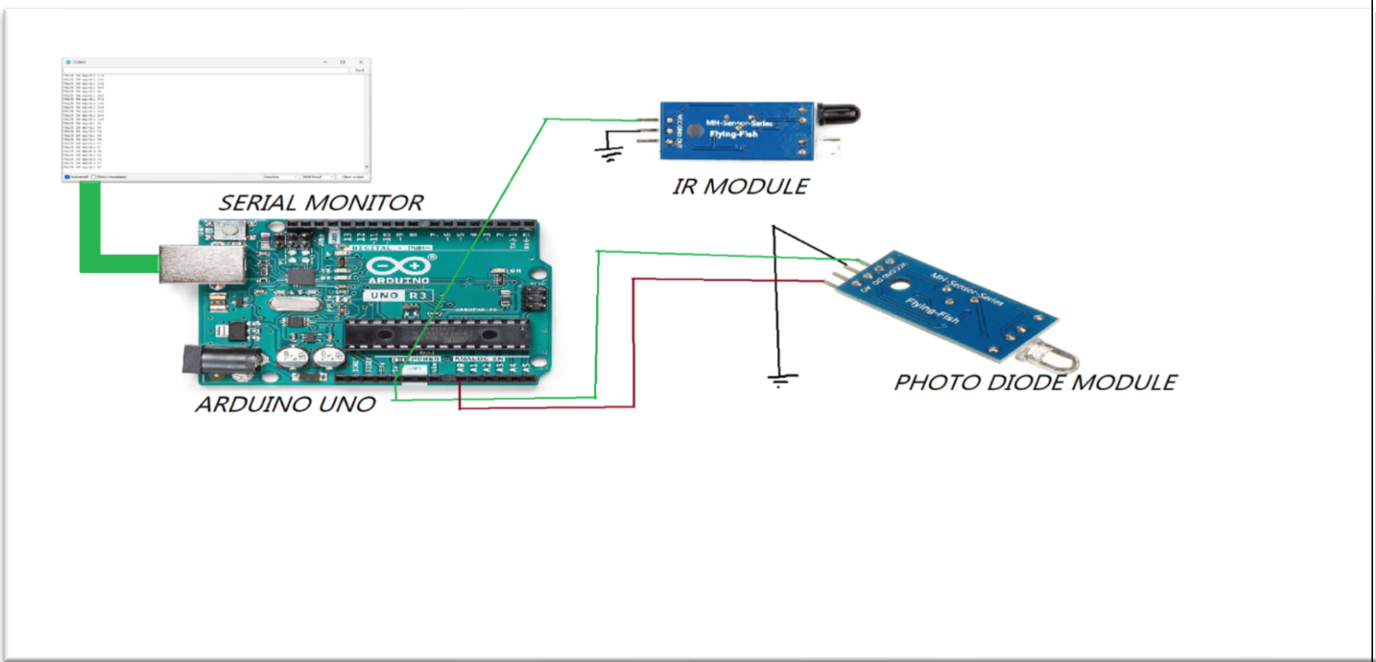

Figure 7: Circuit Diagram

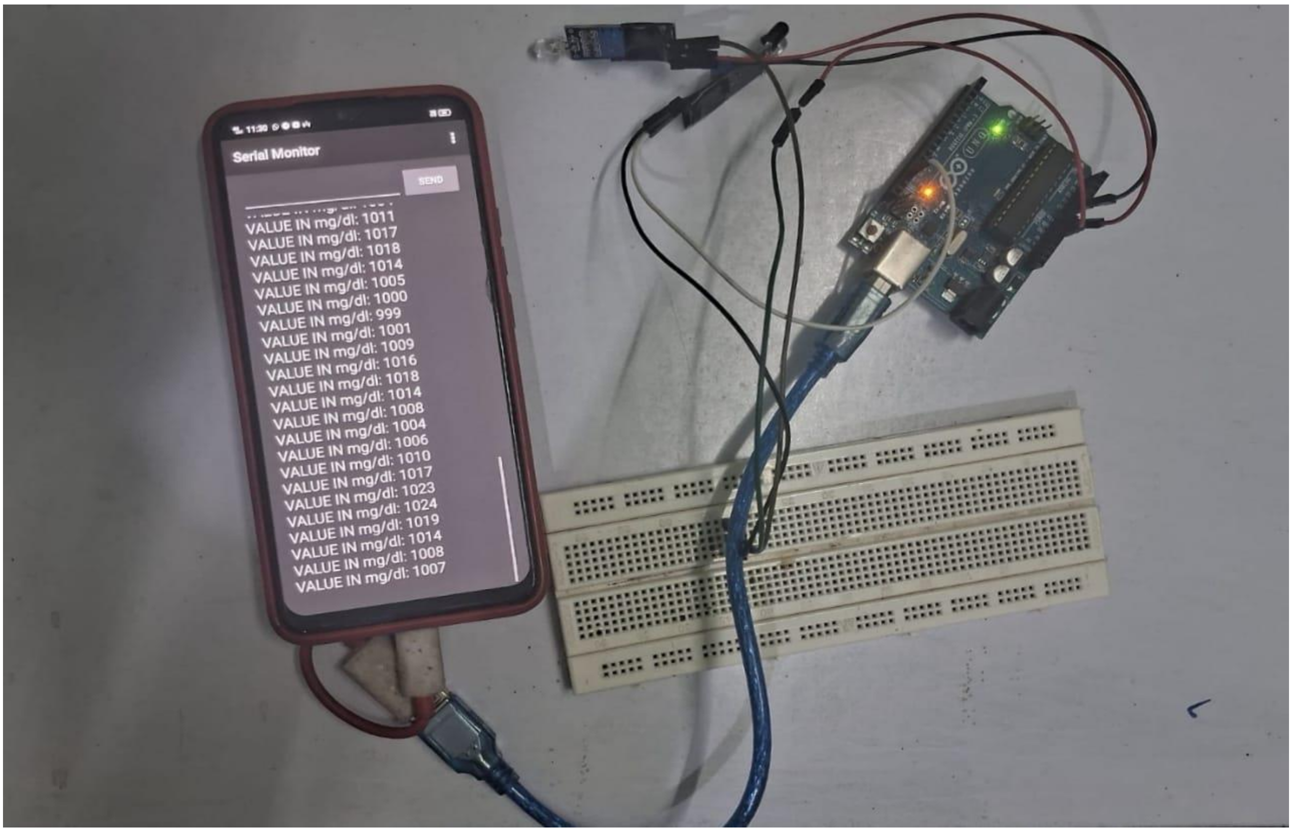

Figure 8: Woking Setup of the Model

Figure 9: Invasive Standard Glucometer

WORKING PRINCIPLE

The working principle of non-invasive blood glucose monitoring system using IR radiation involves the use of photodiode to measure and record the value. Here's how it typically works:

1. Infrared Light Emission

A concentrated beam of infrared radiation is produced by an Infrared Light Emitting Diode (IR LED). The light passes through the soft tissue of the finger when the user positions their fingertip between the photodiode and the infrared LED. The infrared wavelength was deliberately selected due to its ability to penetrate biological tissues and its sensitivity to glucose absorption.

2. Light Absorption by Glucose

Blood, water, fat, and glucose are among the tissue components that the infrared light reacts with as it passes through the finger. A certain quantity of infrared light is absorbed by glucose molecules, which lowers the transmitted light's intensity. More light is absorbed when blood glucose levels are higher. The photodiode receives the remaining light that is not absorbed after passing through the tissue.

3. Detection by Photodiode

A photodiode serves as the light-detecting sensor on the other side of the finger. The remaining infrared light that has penetrated the tissue is directed towards it. A higher glucose concentration results from increased absorption when less light is received, according to the photodiode, which transforms light intensity into a little electrical signal (voltage).

4. Analog Signal Processing

The photodiode frequently produces a very faint electrical signal. The Arduino UNO microcontroller's analog input pin (A0) receives this signal. If required, an operational amplifier (op-amp) circuit is used to boost the signal's resolution and guarantee precise measurement. To lessen noise, analog filtering methods such as low-pass filters can also be used.

5. Analog-to-Digital Conversion (ADC)

The Arduino UNO digitizes the analog voltage signal from the photodiode using its integrated 10-bit Analog-to-Digital Converter (ADC). The continuous voltage signal is transformed by this method into a discrete digital value between 0 and 1023, which typically corresponds to voltage levels between 0 and 5 volts. The amount of infrared light that was not absorbed is indicated by these digital figures.

6. Data Mapping Using Calibration

Glucose levels are not directly represented by the digital number that was acquired from the ADC. Consequently, a calibration procedure is required. Known glucose levels (obtained from laboratory testing or intrusive glucometers) are mapped to matching ADC values during calibration. The ADC measurement is converted into the glucose concentration, usually expressed in mg/dL, using a lookup table or calibration equation (either linear or non-linear). The system's ability to deliver valuable health data is guaranteed by this mapping.

7 Display/Transmission

Following calculation, the glucose level is either shown on an LCD screen or sent via Bluetooth or Wi-Fi to a mobile device. If abnormal glucose levels are found, a companion smartphone application can be used to collect the data, display historical trends, and potentially notify users or healthcare providers. An easy-to-use interface for real-time glucose monitoring is provided by this last stage.

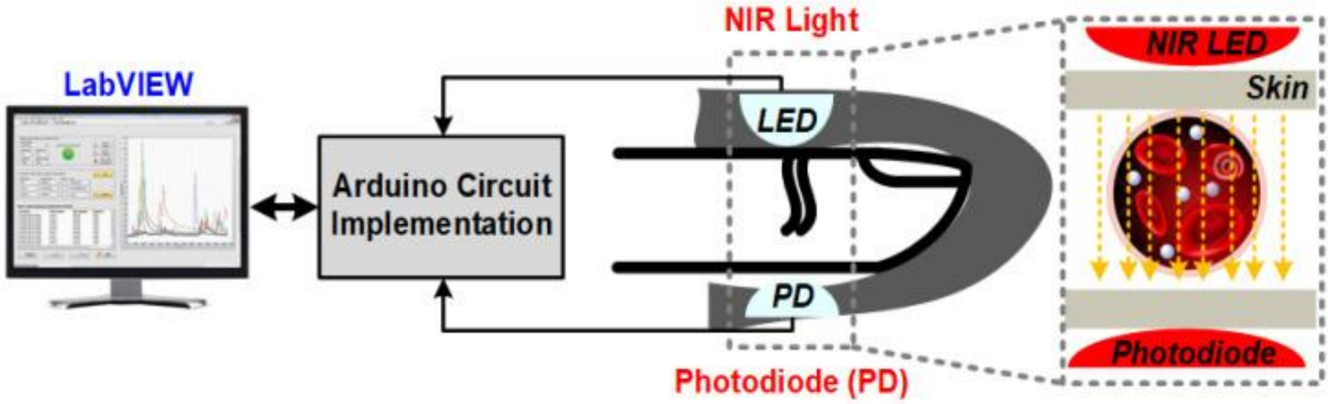

Figure 10: An NIR transmission spectroscopy prototype for a non-invasive glucose monitoring system with a wavelength of 940 nm.

RESULT AND ANALYSIS:

We’ve already done calibration and found a linear relationship of the form:

Glucose (mg/dl) = M x ADC value + B

Where M= slope , B= intercept , ADC= Analog to digital value

From calibration we got:

1. At ADC value 30, glucose= 90 mg/dl
2. At ADC value 80, glucose= 140 mg/dl

We can calculate the slope M and intercept B:

$$M = \frac{140-90}{80-30} = \frac{50}{50} = 1$$

$$B = 90 - (1 \cdot 30) = 60$$

So the equation becomes: Glucose=1*ADC Value + 60

Members	ADC Values	Glucose value(mg/dl)
1	33	93
2	33	93
3	35	95
4	34	94
5	32	92
6	37	97

Table 1: Pre meal Glucose Level

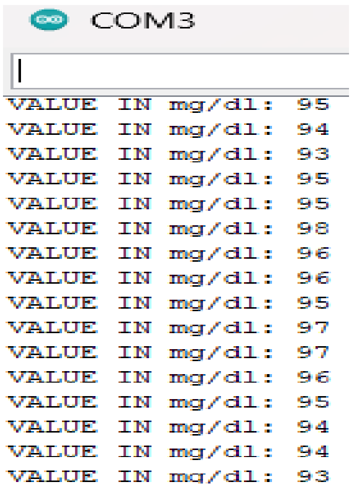

Figure 11: Serial Monitor Display of table 1

Members	ADC Values	Glucose value(mg/dl)
1	44	104
2	45	105
3	44	104
4	46	106
5	47	107
6	44	104

Table 2: Post meal Glucose level

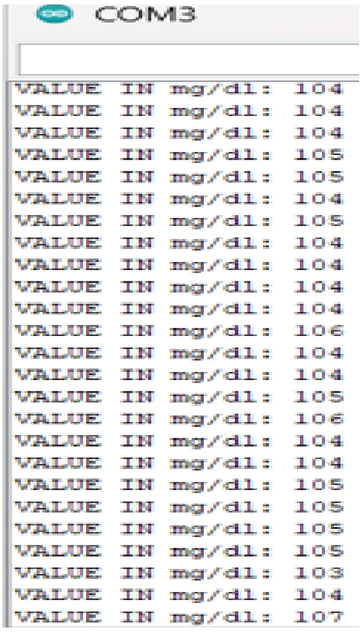

Figure 12: Serial Monitor Display of table 2

Our device used near-infrared spectroscopy with monochromatic infrared light to distinguish the effects caused by glucose from those caused by other components in blood. We tested the device on the different individuals whose blood samples had been collected , and recorded the glucose levels for each individual using non-invasive methods in both pre-meal and post-meal.

Sl. No.	Glucose concentration by proposed method (mg/dl)	Glucose concentration by prick method (mg/dl)	Percentage Error
1	93	90	3.33
2	95	88	7.95
3	92	98	-6.12
4	97	92	5.43
5	107	100	7.00
Mean	96.8	93.6	3.5

Table 3: Calculation Of Percentage Error

Percentage error = [(Measured value – Actual value)/ Actual value]*100

We then compared the results to see how well the non-invasive device performed compared to the traditional method. Our results showed that the non-invasive device was able to accurately measure blood glucose levels in most cases, with an acceptable amount of correlation coefficient compared to the invasive method.

Using Microsoft Excel, the glucose concentration using the prick and designed methods is then shown in this graph.

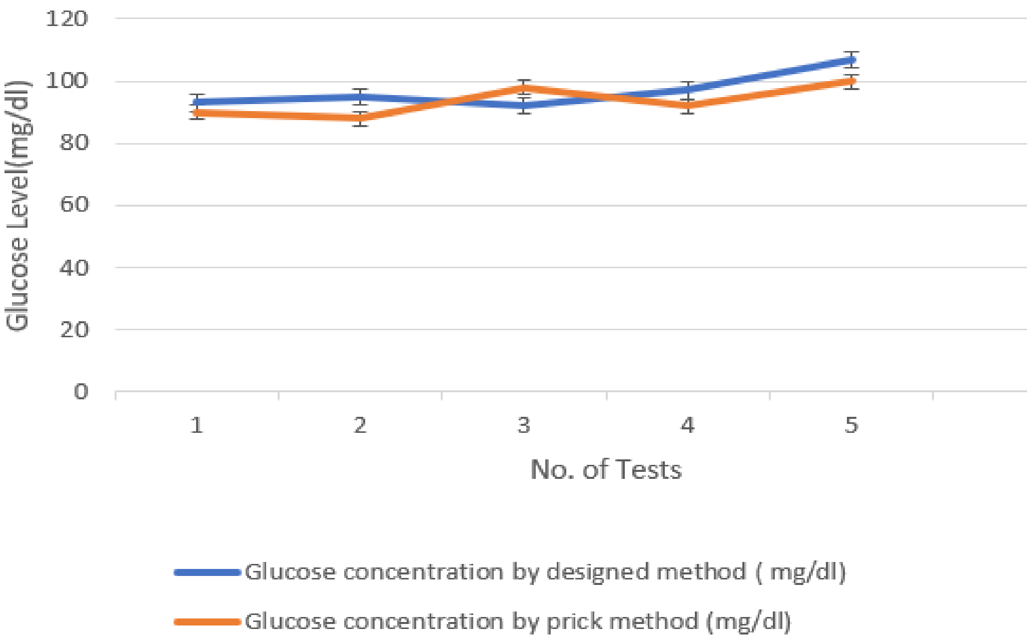

Figure 13: Prick Method vs. Designed Method

We can use the results to examine the designed technique by computing the processing gain, unprocessed and processed SNR, variance, sensitivity, and percentage error.

Voltage Calculation Formula:

$$\text{Voltage} = \left(\frac{\text{ADC Value}}{1023}\right) \times 5$$

Voltage Value (V)	Glucose value (mg/dl)
0.16	93
0.15	91
0.17	95
0.18	97
0.21	104
0.22	106
0.23	107

Table 4: **APPROXIMATE VOLTAGE AND PREDICTED GLUCOSE VALUE**

Below the equation states that the first order polynomial regression analysis can be found utilizing the preceding table. The glucose value is measured in real time [voltage intensity] using this equation.

$$y = 10.179x + 40.821$$

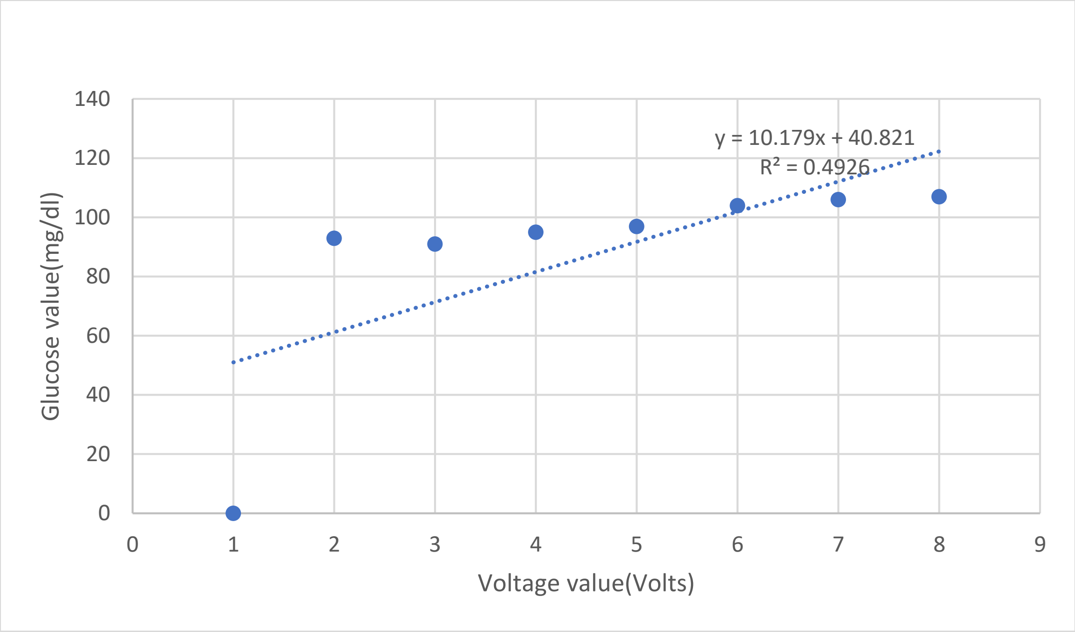

Figure 14: Regression analysis of glucose data with voltage

This work offers a novel solution to current issues such as excruciating pricking, high recurring costs, and the risk of infectious disease transmission during pricking. There is a correlation between the variation in voltage intensity and the glucose level, according to the data from the intensity variation study. The following table predicts the glucose concentration to be determined by this method based on regression analysis and the polynomial equation relation between voltage value and glucose concentrations. The estimation of the glucose concentration is validated using statistical analysis and tabulation of the results.

The amount of variance or dispersion of a set of data values from a suitable reference is measured by the standard deviation.

Sl. No.	**Glucose concentration by proposed method (mg/dl)**	**Glucose concentration by pricked method (mg/dl)**
1	93	90
2	95	88
3	92	98
4	97	92
5	107	100
Mean	96.8	93.6
Std. deviation	6.01	5.17
Variance	36.12	26.72

Table 5: Variance and Standard Deviation

The table indicates that the standard deviation of the expected glucose readings is 6.01, whereas the prick method's standard deviation is 5.17. As a result, we may conclude that the expected and projected glucose values are getting closer to the mean and better instrument performance csharacteristics.

FUTURE SCOPE

Future developments in non-invasive blood glucose monitoring systems hold significant promise for improving diabetes management. One major advancement could be the integration of Continuous Glucose Monitoring (CGM) technology, allowing real-time tracking of glucose levels to provide users with timely and detailed information. The incorporation of machine learning and AI algorithms could further enhance the system’s ability to analyze glucose trends and offer personalized recommendations, leading to more effective and adaptive care. Additionally, Bluetooth connectivity would enable seamless data sharing with healthcare providers, supporting remote monitoring and timely interventions when needed[1][2].

A key improvement would be the development of a smartphone companion application, providing users with a user-friendly interface to track and visualize glucose data over time, along with insights and trend analysis. Integration with automated insulin delivery systems could result in a closed-loop solution, automatically adjusting insulin administration based on real-time glucose readings. Expanding the system to support multi-parameter monitoring—such as heart rate or blood pressure—would give users a more comprehensive picture of their overall health[5].

Enhancing the wearable design to make the device smaller and more discreet would also increase convenience and comfort for daily use. Finally, making efforts toward global accessibility and affordability by reducing production costs would ensure that this life-changing technology reaches underserved populations and regions with limited healthcare infrastructure[6].

However, we did find that the device produced inaccurate readings in some cases, particularly in individuals with darker skin tones The readings would also vary if the photodiode came in contact with finger nail. With spontaneous changes in measurements, we could make it clear that our accuracy level was lower than that of intrusive approaches. All things considered, our research indicated that the non-invasive gadget might prove to be a helpful tool for blood glucose monitoring, especially for people who find conventional techniques difficult or painful. We are aware, therefore, that more investigation would be required to raise the device's accuracy.

CONCLUSION

In conclusion, the Glucometer system represents a remarkable leap forward in the field of blood glucose monitoring, offering a non-invasive and pain-free solution for individuals living with diabetes. By harnessing the principles of advanced sensor technology and intricate electronic components, this innovative system has the potential to revolutionize the way individuals manage their glucose levels. The integration of a photo sensor, strategically positioned on the skin, allows for the non-invasive detection of glucose levels in the underlying tissue. This breakthrough technology eliminates the discomfort associated with traditional needle pricking, a significant barrier to regular monitoring for many individuals. Furthermore, the system's capacity to provide real-time feedback on glucose levels empowers users to make timely adjustments to their medication, diet, and lifestyle choices. Beyond its immediate benefits, the Glucometer system addresses critical challenges associated with traditional blood sampling methods. By minimizing the risk of infections and complications, it significantly enhances the overall well-being of individuals with diabetes. Moreover, its user-friendly interface ensures that glucose readings are presented in a clear and easily interpretable manner. This innovative system exemplifies a holistic approach to healthcare technology, where engineering ingenuity intersects with medical science to create a transformative solution. As the Glucometer system continues to be refined and optimized, it holds the potential to improve the lives of millions of individuals worldwide affected by diabetes. It stands as a testament to the power of innovation in enhancing the quality of life for those managing chronic health conditions, and it paves the way for future advancements in non-invasive medical monitoring technology.

BIBLIOGRAPHY/REFERENCES

[1] S Coster, MC Gulliford, PT Seed, JK Powrie, R Swaminathan,"Monitoring blood glucose control in diabetes mellitus", a systematic review, Health Technology Assessment, vol. 4, no.12, 2000.

[2] B. Paul, M.P. Manuel, Z.C. Alex, "Design and development of non invasive blood glucose measurement system", Physics and Technology of Sensors (ISPTS), 2012 1st International Symposium,Pune, India,7-10 March 2012, pp.43 46.

[3] Komal lawand, Shital Patil ,Mahesh Parihar, " Non Invasive blood glucometer", Journal of International Advance Research In Science And Engineering(IJARSE), Vol. No.3, Issue No.12, December 2014.

[4] O. Abdallah, A. Bolz, J. Hansmann, H. Walles, and T. Hirth, " Design of a Compact Multi-Sensor System for Non-Invasive Glucose Monitoring Using Optical Spectroscopy" , IEEE Conference on Electronics, Biomedical Engineering and its Applications (ICEBEA'2012), Jan. 7-8, 2012 Dubai.

[5] S. F.Malin, T. L. Ruchiti, T. B. Blank, S. U. Thennadil, and S. L. Monfre," Noninvasive prediction of glucose by near-infrared diffuse reflectance spectroscopy," Journal of Clinical Chemistry, vol. 45, pp. 16511658, 1999.

[6] Jason J Burmeister, Mark A Arnold and Gary W Small," Noninvasive Blood Glucose Measurements by Near-Infrared Transmission Spectroscopy across Human Tongues", Journal on Diabetes Technology and Therapeutics, Volume: 2 Issue 1: July 5, 2004.