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IoT-Based Non-Invasive Blood Glucose Monitoring System

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***Abstract* - Diabetes mellitus is a multifaceted set of disorders that share an abnormality in the body's utilization of glucose, leading to hyperglycemia. Once identified, sugar diabetes can be managed with a suitable regimen which includes insulin injections or oral medications to lower the level of glucose in the blood, nutrition therapy, weight loss programs for overweight individuals, and exercise. The most popular technique for determining blood glucose levels is an invasive one that is costly, unpleasant, and raises the risk of infectious disease transmission. Monitoring blood glucose levels by both the doctor and the patient is crucial to preventing the disease's deadly consequences, which include heart disease, blindness, renal failure, and amputations. There are many advantages to intensive therapy and frequent glucose monitoring. The race to develop the next generation of bloodless, painless, accurate glucose instruments has begun as a result of the rapid advancements in diagnostics. This project's primary goal is to create a portable, non-invasive blood glucose monitoring tool. Using optical radiation, the device should be able to measure the blood's glucose level and show the results on the LED panel. Additionally, by using a non-invasive strategy, we may avoid the drawbacks of an intrusive approach and keep a constant eye on the patient's blood glucose levels. Thus, by detecting diabetes mellitus early, we can lower the risk of major complications and death from the disease.**

Keywords: ESP8266, NIR Sensor, MAX30102 heart rate & Oximeter sensor, LCD, IOT.

I. INTRODUCTION

Diabetes is a class of metabolic disorder in which the body's blood glucose level quickly rises over normal. Either insufficient insulin synthesis in blood cells, an inappropriate reaction by body cells to insulin, or a combination of the two may be the cause of the rise in blood sugar. Diabetes can cause serious side effects in humans, such as heart failure and blindness. Thus, it's critical to regularly check your blood glucose levels. More than 200 million people worldwide are estimated to have diabetes by the World Health Organization.

Frequent blood glucose testing is necessary for managing diabetes in order to guarantee appropriate medication and lifestyle choices modifications. The intrusive procedures used in today's blood glucose testing technologies, like fingerstick testing, can be uncomfortable, unpleasant, and deter regular monitoring. By offering a simple, painless substitute, non-invasive blood glucose monitoring has the potential to greatly enhance the quality of life for those who have diabetes. There are now three primary categories of blood glucose testing techniques: minimally invasive, non-invasive, and invasive, invasive methods in blood. Equipment for measuring glucose levels is frequently used because of its high degree of measurement accuracy. The finger prick is the most common and least expensive invasive technique.

This entails using a tiny, sharp needle (a lancet) to draw blood from the finger; some standard procedures allow blood to be drawn from other body parts as well, such as the thigh, base of the thumb, upper arm, and forearm; however, there is a possibility that the blood glucose level reading will differ from the fingertip reading. One of the main disadvantages of invasive glucometers is that they are extremely painful, and using a diabetic patient's body to puncture is not a safe method because diabetes slows down the healing process and reduces the body's ability to fight off bacteria, which increases the risk of infection, including septicemia, fouling from blood clots, and embolism. The non-invasive approach of measuring glucose levels is employed as a substitute because the intrusive method is uncomfortable and damages nerves.

II. BLOCK DIAGRAM OF PROPOSED WORK SYSTEM

A) Sensing Unit

As seen in the picture, the sensing unit is composed of up of an NIR emitter and an NIR receiver (photo detector), and this are placed on either side of the measuring location (earlobe). Sensor Unit as shown in Figure 1. The NIR emitter, measurement place (as it may be a finger or earlobe), and NIR receiver form up the sensing device. The 940 nm wavelength

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of the NIR light source was selected because it may be employed for measuring blood glucose levels.

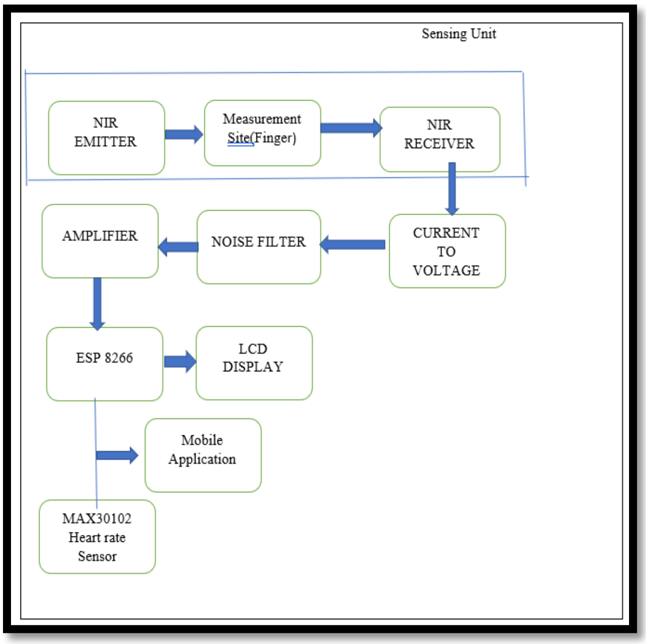

Figure 1: Block Diagram

As you can see in the picture, the sensing unit is made consists of an NIR emitter and an NIR receiver (photo detector), which are placed on either side of the measuring location (earlobe). Depending on the blood glucose levels, some of the NIR light is absorbed as it travels through the earlobe where it binds with the glucose molecule, with the remaining portion passing through the earlobe. The amount of blood glucose concentration determines the amount of NIR light that enters the earlobe. Once the anticipated blood glucose value is obtained The photodetector's output current is transformed into voltage signal and then it is filtered and amplified. This amplified signal is fed into ESP8266 microcontroller. The inbuilt ADC block is used for converting the received analog signal to digital form. Voltage is created by translating the photodetector's output current.

B) ESP32

ESP 32 module is a compact prototyping board and is simple to program via the Arduino IDE. It has a 2.4 GHz dual mode WiFi and a BT wireless connection. ESP32 offers a complete and self-contained WiFi networking solution; it can be used to host the application or to offload WiFi networking functions from another application processor. ESP32 the Arduino IDE can be used to simply program the Node MCU ESP32 module, which is a small development board. It has a BT wireless connection as well as a dual-mode 2.4 GHz WiFi. It is possible to use ESP32 to host the application or delegate WiFi networking tasks to another application processor, providing a comprehensive and self-contained WiFi networking solution. The application launches immediately from an external flash when ESP32 hosts it. Cache has been integrated into the system to improve its performance in these types of applications. The ESP32 is one of the most integrated WiFi chips available; it includes all necessary components and requires minimal circuitry. It integrates the antenna switches, RF balun, power amplifier, low noise receive amplifier, filters, and power management modules. Including the front-end module, is designed to occupy minimal PCB area. 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. A mobile application (App) is created to view and store the predicted blood glucose value after receiving it via WiFi. ESP32 communicates to the mobile app via WiFi includes a front-end module & is designed to use up the minimal PCB area. The blood glucose value is calculated using this digital signal using regression analysis, and the result is shown on the LCD. Once a predicted blood glucose value is received via WiFi, a mobile application (App) is developed to display and store it. WiFi is used by the ESP32 to connect to the mobile app.

III. SELECTION OF WAVELENGTH

Human skin tissue consists of epidermis, dermis and subcutaneous tissue layers. In dermis great number of capillary vessels is 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 3.

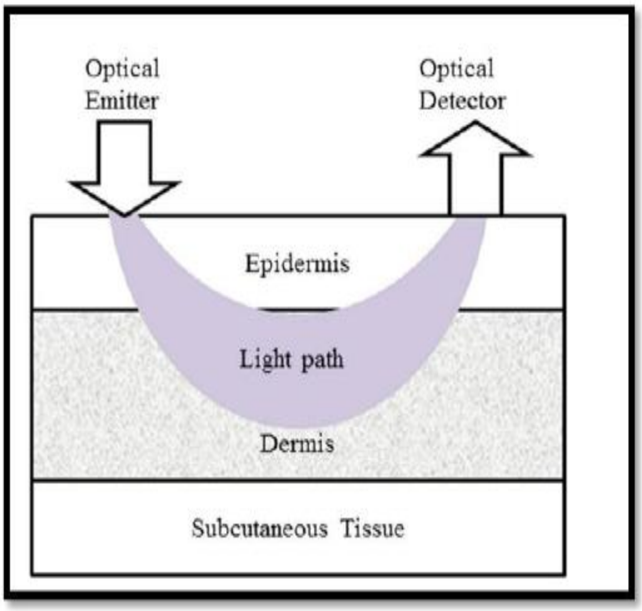

Figure 2: Cross Section of Skin and Light Path

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IV. CIRCUIT DIAGRAM

IoT-based noninvasive blood glucose monitor system's circuit diagram Figure 3 illustrates the filtering and amplification stages of the developed system's circuit schematic. The load resistance R4= 50kΩ is positioned at the anode side of the photodiode to convert the electrical current obtained from the photo detector into voltage.

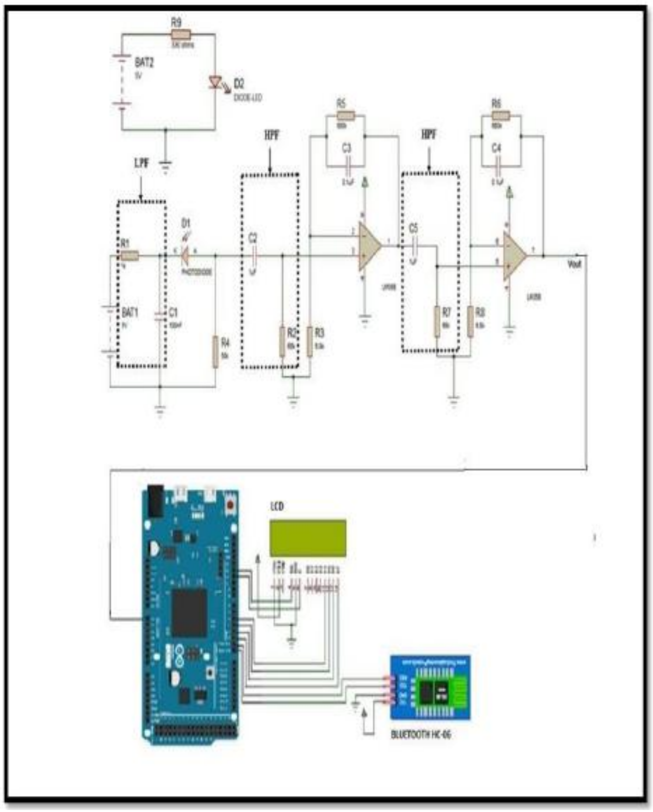

Figure 3: Circuit diagram of IoT based noninvasive blood glucose monitoring system

The low pass filter's cut-off frequency is 1.59 kHz, while the high pass filter's is 2.34 Hz. LPF cutoff frequency = $1/(2\pi R1C1) = 1/[2\pi (1*103)(100*10-9)] = 1.59$ kHz HPF cutoff frequency = $1/(2\pi R2C2) = 1/[2\pi (68*103)(1*10-6)] = 2.34$Hz $1 + (Rf / Rin) = 1 + [(680*103)/(68*103)]$ is the voltage gain. = 101 The Arduino microcontroller's analog pin A0 is connected to the increased output voltage for The Arduino microcontroller's analog pin A0 is linked to the amplified output voltage in order to transform the analog signal into digital values. The glucose level is represented by this digital figure. Using the polynomial regression algorithm, the actual glucose level is calculated from this digital value. The glucose levels measured invasively in the laboratory were used to create this equation. The predicted glucose value is shown in a mobile application. The Arduino Due microcontroller is linked so that it can communicate via WiFi with the mobile app.

V. RELATED WORK

A) Flow Chart

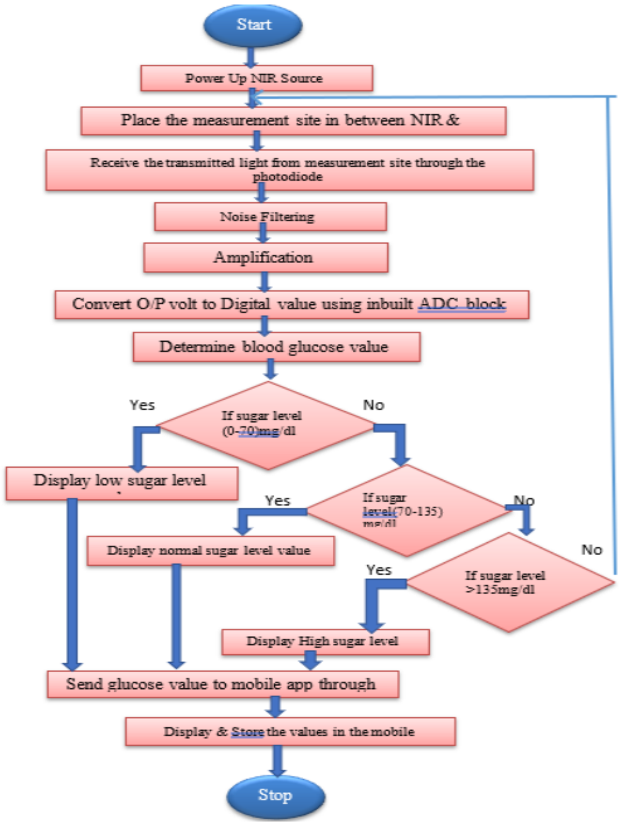

Figure 4: Flow Chart of Proposed work system

VI. 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. The polynomial equation relating the analog voltage and the glucose level is computed by using

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

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

Table 1: The expected output in tabular form is as follows:

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Table 1: Expected output table

Sr. 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

VII. RESULTS

A) Hardware

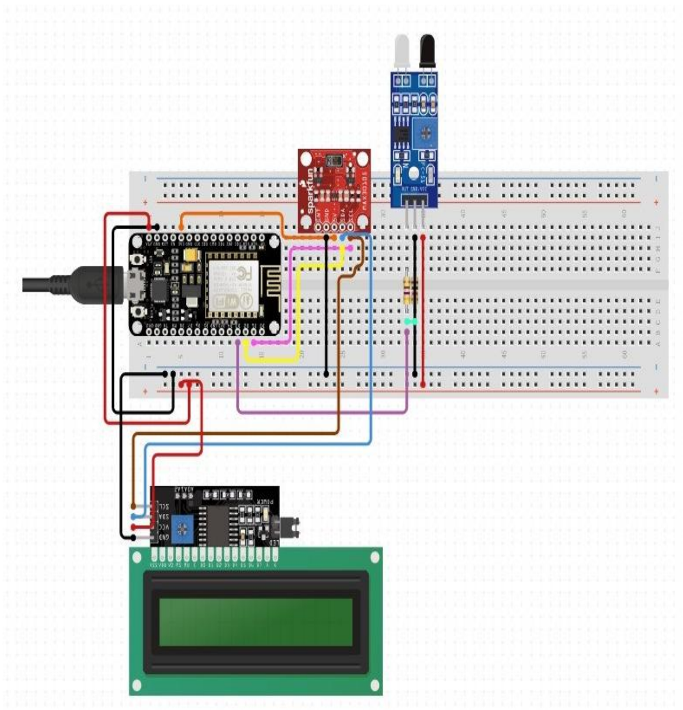

Figure 5: Hardware connection

B) Results Using IOT

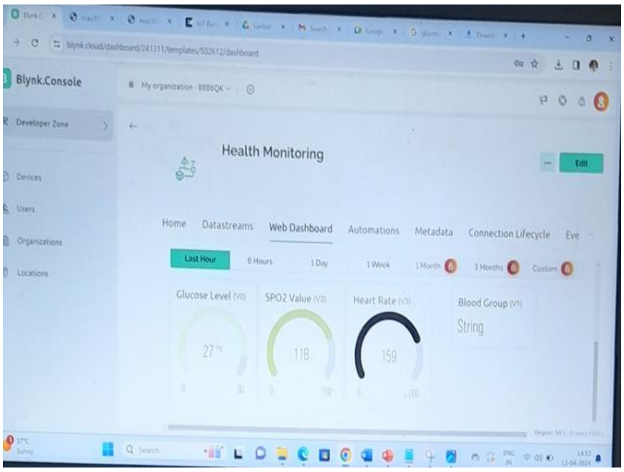

Figure 6: Observed output on Display

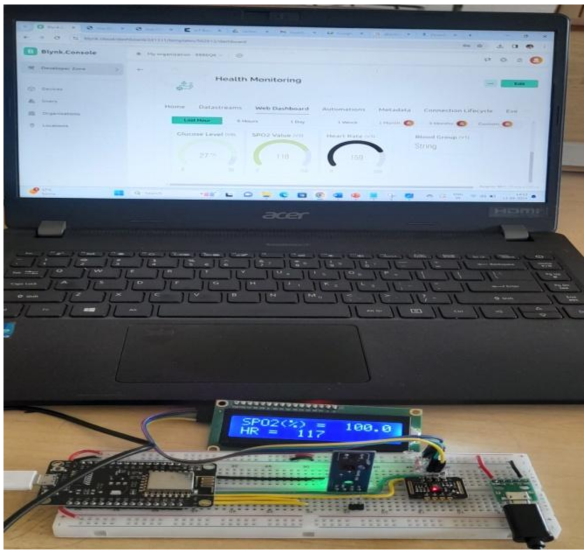

Figure 7: Result using IoT values displayed on lcd and IoT

VIII. SUMMARY

We had studied various reputable research papers and were knowledgeable of the various methods related to blood glucose determination. The studies mentioned above offered both benefits and drawbacks; we examined them and used their information to develop a new approach. This suggested technology solves the issues of human mistake, time consumption, and very huge machines. The suggested gadget is readily available, affordable, and small.

Invasive method of glucose measurement is painful, costly and discomfort. It also has a risk of infection and not used for continuous monitoring. In order to overcome the above disadvantages, a noninvasive method for blood glucose measurement using near-infrared LED is proposed in this paper. The glucose level in the blood which is obtained from the photo detector is displayed in both the LCD display and the developed mobile app. The proposed method is validated using error grid analyses. This portable noninvasive blood glucose monitor provides a very effective means for assisting the health care management of diabetic patients. This can be used for monitoring blood glucose level of the patients in the home as well as health care centers.

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