International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

OPTICAL BASED NON INVASIVE GLUCOMETER WITH IOT

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Abstract - Diabetes mellitus (DM) nicknamed as sugar is becoming one of incurable and critical challenge to medical field. Serious illness such as premature mortality even cause of death, which can be identified by continuous monitoring from a remote location. The traditional and conventional method such as finger pricking's demerits such as pain and damage to tissues that cause infection. Such type of infections can be overcome by non-invasive technique. The objective of this paper is to monitor glucose level using non-invasive technique by optical and IoT technology. The proposed sensor circuit consists of IR LED's of wavelength 650–2500nm for optical blood glucose measurement and NIR photodiodes (InGaAs) to receive the reflected light from body parts to determine the glucose level. The Beer-Lambert law is used for signal processing along with WIFI based IoT real time information transmission. The project is implemented using Arduino IDE for finding the performance matrix of the system as well as various analytical studies. With the rapid development of wearable technology and transdermal biosensors, non-invasive blood glucose monitoring will become more efficient, affordable, robust, and more competitive on the market.

Key Words: Diabetes mellitus, blood glucose measurement, WIFI based IoT, wearable technology

1.INTRODUCTION

Diabetes mellitus is one of the leading causes of death, disability, and economic loss throughout the world. WHO estimates there are 171 million people worldwide with diabetes mellitus in 2000 and estimates that 366 million people will suffer from diabetes mellitus by 2030. The International Diabetes Federation estimates that another 314 million people have glucose levels above normal levels, and that number will increase to 472 million by 2030. In the United States, for instance, as much as 6.3% of the populace experienced diabetes mellitus in 2002. The US Centers for Disease Control and Prevention assesses that 13 million individuals in the United States have analyzed diabetes mellitus and an extra 5.2 million have the illness however have not yet been analyzed. In 2015, Indonesia was positioned seventh in the world for the most elevated pervasiveness of diabetes on the planet alongside China, India, the United States, Brazil, Russia, and Mexico with an expected 10 million individuals with diabetes. The percentage of deaths due to diabetes in Indonesia is the second-highest after Sri Lanka. The prevalence of diabetes has an upward trend of 5.7% in 2017 to 6.9% in 2013.

In prevention efforts, diabetics must do regular health checks, avoid cigarette smoke, and don't smoke, be diligent in physical activity, maintain a balanced diet, get adequate rest, and manage stress correctly. Health checks in the form of checking blood glucose levels can be done independently at home or visit the nearest health facility. The diagnosis of diabetes depends on monitoring blood glucose. Monitoring of blood glucose levels needs to be done at least 4 times a day to get blood samples or about 1800 times per year and requires a testing time of about 2 hours. There are many reports of infections caused by injections. Infection occurs because people with DM cannot produce insulin in the body. As an alternative, approaches to measuring glucose concentrations in body fluids including urine, saliva, and tear fluid, have great potential for noninvasive diagnosis (diagnosis of disease without injuring the patient's body) of diabetes.

Currently, testing for blood glucose levels can only be done on an invasive basis. A person with diabetes must perform a test in the laboratory by taking a blood sample. Besides, currently there is also a blood glucose level measuring device that can be used independently at home. However, the patient still has to bleed the sample to be tested. In testing using a blood sample, the patient is exposed to the risk of developing a hematoma or bruise, a condition in which blood pools outside the blood vessels. This condition is caused by damaged blood vessels.

A. Problem Statement

The problem statement of non-invasive glucometer is that traditional blood glucose monitoring methods for people with diabetes require frequent finger-stick testing, which can be painful and inconvenient. This leads to poor compliance with glucose monitoring and can result in poor glycemic control, which can lead to serious health complications. Additionally, traditional blood glucose monitoring methods can also increase the risk of infection, especially if the equipment used for testing is not properly sanitized.

B. Aim and Objective

- To develop a technology that can measure blood glucose levels through non-invasive means, such as using light or other forms of energy to detect glucose levels in body fluids.
- To create a device that is easy to use and provides accurate readings of blood glucose levels.
- To make glucose monitoring more convenient and accessible for people with diabetes, allowing them to monitor their glucose levels more frequently and with less discomfort.
- To reduce the risk of infection and other complications associated with traditional blood glucose monitoring methods.
- To improve the quality of life for people with diabetes by providing a more comfortable and convenient way to monitor their blood glucose levels.

2. Methodology

The system is designed based on the proposed methodology to be non-invasive, user-friendly, and cost-effective compared to traditional invasive methods of glucose monitoring. It can be used by individuals with diabetes or other glucose-related conditions to monitor their glucose levels continuously without the need for frequent blood tests. The system can also provide real-time alerts or notifications in case of abnormal glucose level readings, helping individuals to take immediate corrective actions.

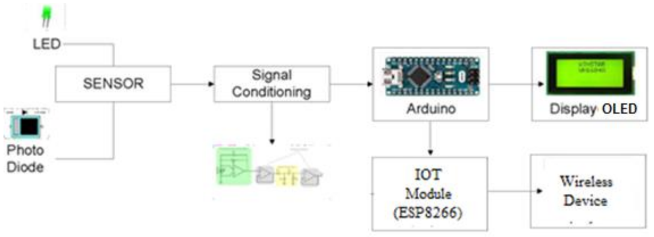

Fig -1: Block diagram of the Non-invasive Glucometer with IOT

The proposed block diagram Fig -1 shows the components of a non-invasive glucometer system. The IR sensor is used to measure the glucose levels in the blood non-invasively. The signal from the IR sensor is processed by an Atmega328 Arduino microcontroller, which runs a glucose level algorithm and sends the data to an IoT device via a Wi-Fi module. The IoT device then transmits the data to a smartphone app, which displays the glucose levels to the user. The IR sensor consists of an IR LED and a photodiode. The IR LED emits light, which is absorbed by the blood and reflected back to the photodiode. The photodiode measures the intensity of the reflected light, which is proportional to the glucose concentration in the blood. The Atmega328 Arduino microcontroller is responsible for processing the signal from the IR sensor and running the glucose level algorithm. It also communicates with the IoT device via a Wi-Fi module, which transmits the data to the smartphone app. The IoT device serves as a bridge between the ESP8266 Arduino and the smartphone app, allowing the user to remotely monitor their glucose levels. The smartphone app displays the glucose levels to the user and can also provide alerts and notifications based on the user's preferences. Overall, this block diagram shows a basic architecture of a non-invasive glucometer system that uses IR sensor, ESP8266 Arduino, and IoT technology to provide a convenient and non-invasive way of monitoring glucose levels.

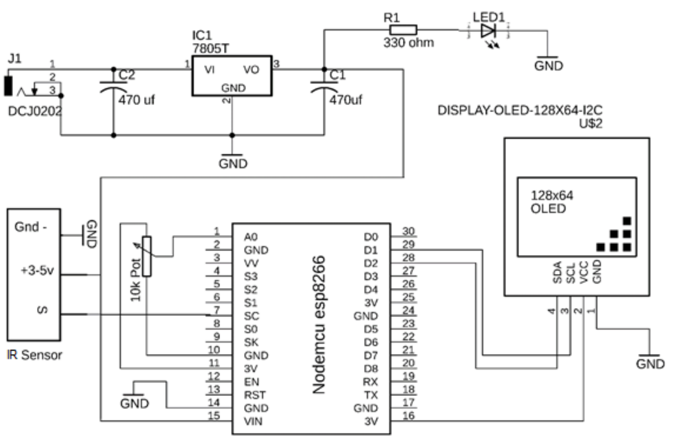

Fig -2: Circuit diagram of the Non-invasive Glucometer with IOT

The proposed system of the non-invasive glucometer with ESP8266 Arduino, IR sensor, and IoT involves the use of an IR sensor to detect the glucose level in the blood non-invasively as shown in Fig -2. The IR sensor emits infrared light onto the user's skin and measures the reflected light to determine glucose levels non-invasively. The ESP8266 reads data from the IR sensor, processes it, and communicates with both the OLED display and the IoT module for data transmission. To ensure a consistent power supply, a voltage regulator steps down the battery voltage to appropriate levels for all components. OLED display provides real-time glucose level readings to the user, making it convenient for monitoring. This module connects the glucometer to the internet via Wi-Fi or cellular data and sends glucose level data to a cloud platform for remote monitoring. The system is powered by a rechargeable battery, which can be recharged as needed.

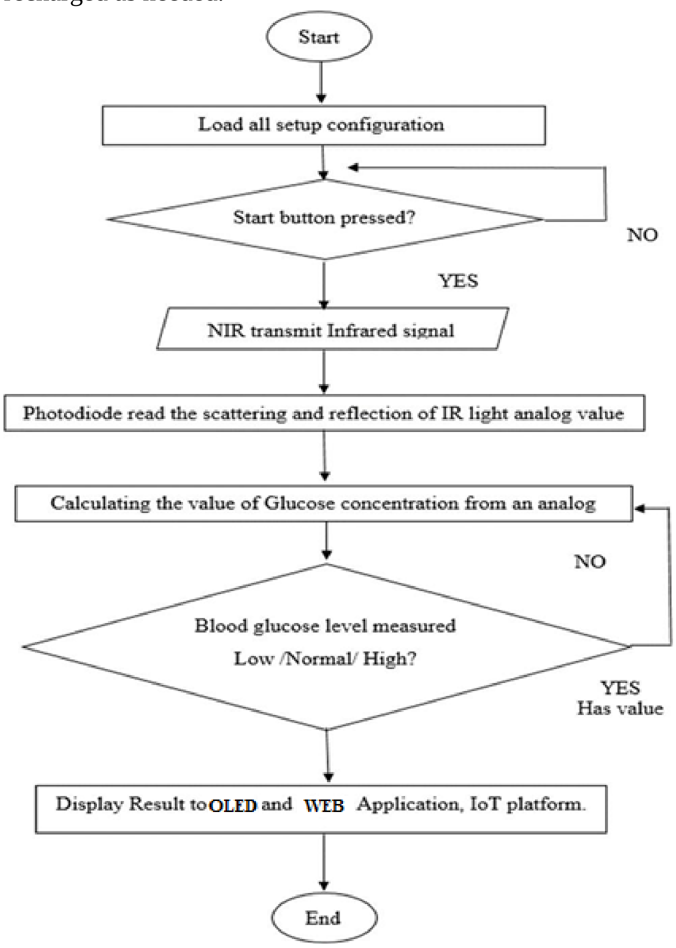

Fig -3: System Operation Flowchart

Fig -3 show the flow chart of a Portable Non-Invasive Blood Glucose Monitoring Device. The device process was initiated once there is a power supply in at input. Next, this device needs the user to press the start button to begin the process. Insert any finger at the sensor location, or both of the sensor devices. Infrared LED devices and photodiode devices is always placed parallel to the finger so that the light can be transferred through the finger and the photodiode can be detected. A photodiode will therefore receive an infrared signal that would be converted to a relative voltage value. Also, the transmitter LED used is an IR light emitter from element14 that has a wavelength of 1023 nm. An Indium Gallium Arsenide (InGaAs) from photodiode

(S5971) is an element14 where it has a high reaction around 1000 nm wavelength has been used as a receiver. The Light transmitters and receivers at a wavelength of 1023 nm are significantly less expensive compares favorably to other wavelengths with equivalent or higher glucose response.

In addition, the NodeMCU as a microcontroller will use these photodiode voltage values as a variable to measure the glucose concentration and evaluate its level based on the mathematical equation in the programming process. The value of glucose concentration will be in mg/dL. Finally, the data of concentration glucose will be sent to the internet via NodeMCU Wi-Fi Module ESP8266 then displayed on a mobile phone by using the Blynk application, IoT platform, and displayed at OLED.

3. Hardware Implementation

A. IR Photodiode Sensor

An IR photodiode is a semiconductor device that is commonly used as a detector for infrared radiation. In a non-invasive glucometer, an IR photodiode is used to measure the amount of light that is transmitted through a patient's skin, which is proportional to the amount of glucose present in their blood.

The non-invasive glucometer consists of a light source and an IR photodiode. The light source emits a beam of IR radiation, which is directed towards the patient's skin. The IR radiation passes through the skin and is partially absorbed by glucose molecules present in the blood. The remaining IR radiation is transmitted through the skin and detected by the IR photodiode. The amount of IR radiation that is transmitted through the skin is directly proportional to the amount of glucose present in the blood. The IR photodiode generates a current that is proportional to the amount of IR radiation it detects. This current is then converted into a glucose reading by the glucometer's circuitry. Fig -4 shows the IR sensor.

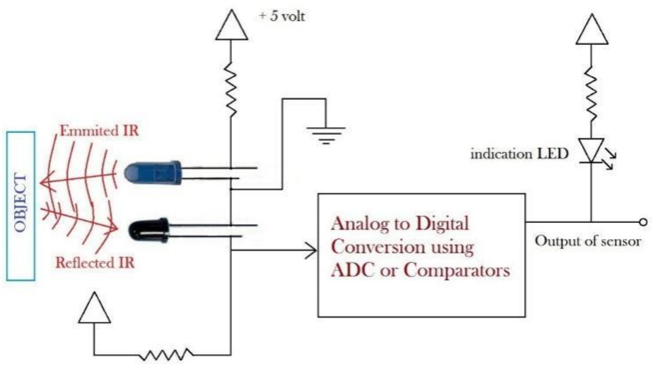

Fig -4: IR sensor

B. ESP8266 Microcontroller

Esp8266 is a microcontroller board with a built-in wifi module, it’s great for making IoT and Home automation projects. ESP8266 is gaining popularity in the field of electronics because of its low cost, reliability, and easy availability in the market.

ESP8266 contains a built-in 32-bit low-power CPU, ROM, and RAM. It is a complete and self-contained Wi-Fi network solution that can carry software applications as a stand-alone device or connected with a microcontroller (MCU). The module has built-in AT Command firmware to be used with any MCU via COM port.

Esp8266 wifi-based microcontroller is available at the cost of 4 $ to 10$ in the online market. Like Arduino-based development boards, this also allows controlling input and output functions. The major advantage of Esp8266 over Arduino is it has built-in wifi modules that make it able to connect with the internet and make cool IoT based products. Fig -5 shows the ESP8266 Microcontroller.

Fig -5: ESP8266 Microcontroller

C. OLED Display

This is a 0.96 inch blue OLED display module. The display module can be interfaced with any microcontroller using SPI/IIC protocols. It is having a resolution of 128×64. The package includes display board, display, and 4 pin male header pre-soldered to board. Fig -6 shows the OLED Display.

OLED (Organic Light-Emitting Diode) is a self-light-emitting technology composed of a thin, multi-layered organic film placed between an anode and cathode. In contrast to LCD technology, OLED does not require a backlight. OLED possesses high application potential for virtually all types of displays and is regarded as the ultimate technology for the next generation of flat-panel displays.

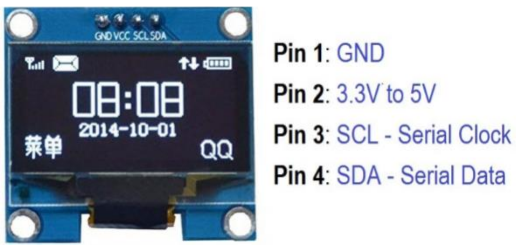

Fig -6: OLED Display

D. Regulated Power Supply

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. As a result, power supplies are sometimes referred to as electric power converters. Some power supplies are separate standalone pieces of equipment, while others are built into the load appliances that they power. Examples of the latter include power supplies found in desktop computers and consumer electronics devices. Other functions that power supplies may perform include limiting the current drawn by the load to safe levels, shutting off the current in the event of an electrical fault, power conditioning to prevent electronic noise or voltage surges on the input from reaching the load, power-factor correction, and storing energy so it can continue to power the load in the event of a temporary interruption in the source power (uninterruptible power supply). Fig -7 shows the block diagram of regulated power supply.

All power supplies have a power input connection, which receives energy in the form of electric current from a source, and one or more power output connections that deliver current to the load. The source power may come from the electric power grid, such as an electrical outlet, energy storage devices such as batteries or fuel cells, generators or alternators, solar power converters, or another power supply. The input and output are usually hardwired circuit connections, though some power supplies employ wireless energy transfer to power their loads without wired connections. Some power supplies have other types of inputs and outputs as well, for functions such as external monitoring and control.

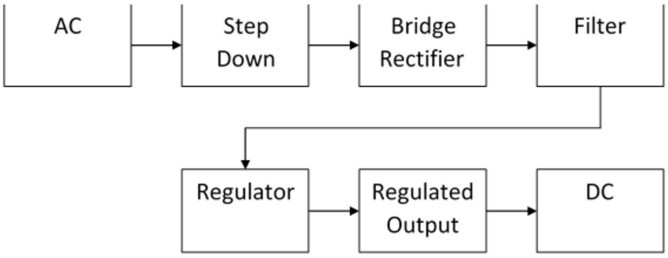

Fig -7: Block diagram of regulated power supply

4. Software Implementation

- Arduino Compiler
- Programming Language: C

The Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language. It originated from the IDE for the languages Processing and Wiring. It was created for people with no profound knowledge of electronics.

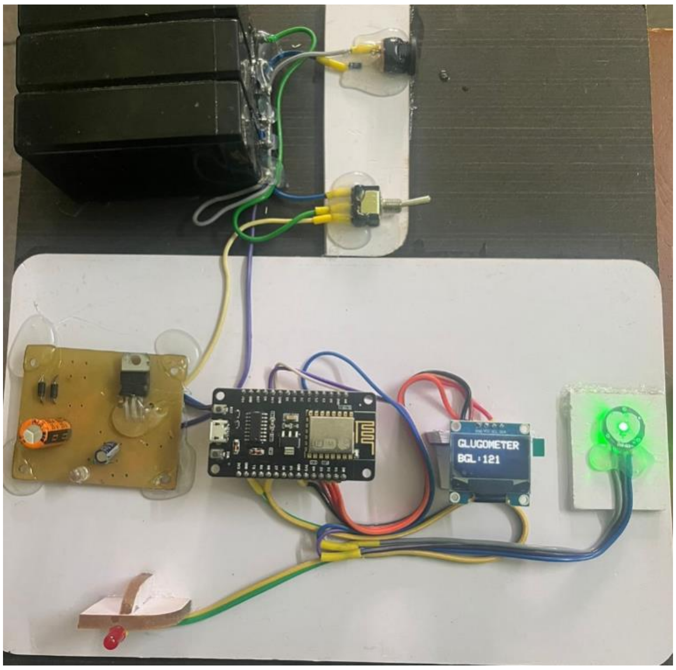

Fig -8: Designed Noninvasive Glucometer

5. Result and Discussions

The non-invasive glucometer system would offer users a more convenient way to monitor their glucose levels compared to traditional invasive methods like finger pricking. Users can easily check their glucose levels without discomfort or pain. With the integration of an OLED display, users can receive real-time glucose level readings on the device itself, making it easier to manage their condition.

The IoT technology would enable remote monitoring and data storage on platforms like ThingSpeak. This means that healthcare providers and caregivers could access the patient's glucose level data from anywhere, enhancing patient care and allowing for timely interventions if needed. Data collected on ThingSpeak or a similar platform can be analyzed over time to identify trends and patterns in glucose levels. This analysis can provide valuable insights into the patient's health and help in making informed decisions regarding treatment and lifestyle adjustments.

The system can be programmed to send alerts or notifications to both the user and healthcare professionals when glucose levels fall outside of predefined ranges. This can help in the early detection of hypo- or hyperglycemic episodes. The accuracy of the IR sensor is crucial for the success of the system. Ensuring that the sensor provides reliable glucose level measurements without invasive procedures is a significant technical challenge.

When using IoT technology to transmit health data to cloud platforms like ThingSpeak, data security and patient privacy are paramount. Implementing robust encryption and access control mechanisms is essential. Regular calibration of the system is necessary to maintain accuracy. This involves comparing the system's readings to those obtained from traditional invasive methods to ensure consistency.

The success of such a system depends on user adoption. Users must find it easy to use, comfortable, and reliable. Education and training may be required to encourage adoption. Medical devices, even non-invasive ones, are subject to regulatory requirements and standards. Ensuring compliance with these regulations is essential for safety and market acceptance. Data collected on ThingSpeak can be visualized using charts and graphs, providing a clear picture of glucose level trends over time. This visualization can be a valuable tool for both patients and healthcare providers.

Thus this non-invasive glucometer system that integrates an IR sensor, ESP8266 Arduino, OLED display, and IoT technology to send data to platforms like ThingSpeak has the potential to offer convenience, real-time monitoring, and improved healthcare outcomes for individuals with diabetes. However, it also presents technical and regulatory challenges that need to be carefully addressed to ensure accuracy, security, and user acceptance. Proper testing and validation are essential before deploying such a system in a healthcare setting. The designed smart helmet is shown in Fig -8.

A. Advantages

Non-Invasive Monitoring: One of the most significant advantages of this system is that it allows for non-invasive monitoring of glucose levels. Users can obtain their glucose readings without the need for finger pricking, reducing discomfort and the risk of infection.

Real-Time Data: The system provides real-time glucose level data on the OLED display, allowing users to monitor their levels instantly and make timely adjustments to their diet or insulin dosage.

Remote Monitoring: The integration of IoT technology enables remote monitoring of glucose levels. Healthcare providers and caregivers can access this data from anywhere, which is particularly beneficial for patients who require continuous monitoring or live in remote areas.

Data Analysis: Glucose level data collected over time can be analyzed to identify trends, patterns, and correlations with other factors such as diet, physical activity, and medication. This analysis can provide valuable insights into diabetes management.

Alerts and Notifications: The system can be programmed to send alerts and notifications to users or healthcare professionals when glucose levels fall outside of target ranges, facilitating early intervention.

Data Storage: The data can be securely stored on platforms like ThingSpeak, ensuring that historical records are easily accessible for reference and analysis.

User-Friendly Interface: The OLED display provides a user-friendly interface for displaying glucose readings and system status, making it accessible to a wide range of users.

B. Applications

Diabetes Management: The primary application of this system is for individuals with diabetes to monitor and manage their glucose levels effectively. It helps them make informed decisions regarding insulin dosage, dietary choices, and overall lifestyle.

Clinical Monitoring: Healthcare professionals can use this system in clinical settings to monitor glucose levels in patients, especially those who require continuous monitoring or frequent testing.

Telemedicine: The remote monitoring capabilities of the system make it suitable for telemedicine applications. Doctors can remotely monitor and provide guidance to patients with diabetes.

Research and Clinical Trials: Researchers can use this system to collect glucose level data for clinical trials and studies related to diabetes and its management.

Home Healthcare: Caregivers and family members can use this system to monitor the glucose levels of their loved ones, ensuring their health and safety.

Fitness and Wellness: The system can be adapted for fitness and wellness applications, where individuals without diabetes may use it to monitor their blood sugar levels as part of a broader health monitoring program.

6. Conclusion

The novel methodology is proposed for the development and implementation of a non-invasive glucometer system that incorporates an IR sensor, ESP8266 Arduino, battery for regulated power supply, OLED display, and IoT technology to monitor glucose levels and transmit data to platforms like ThingSpeak offer a promising solution for diabetes management and healthcare monitoring. This system provides several key benefits, including non-invasive glucose monitoring, real-time data access, remote monitoring, data analysis, and user-friendly interfaces. It has a wide range of applications, from individual diabetes management to clinical use, telemedicine, research, and beyond.

The successful implementation of this system represents a significant advancement in the field of healthcare technology, enhancing the quality of life for individuals with diabetes and facilitating better healthcare outcomes. However, it's essential to recognize that further work is needed to refine and optimize the system for broader adoption and increased efficacy.

7. Future Work

The non-invasive glucometer system represents an innovative approach to glucose monitoring with the potential to improve the lives of individuals with diabetes. While it has already made significant strides, future work should focus on enhancing accuracy, security, user experience, and clinical acceptance, ultimately bringing the technology to a broader audience and making it an integral part of modern healthcare.

Accuracy Improvement: Continuous efforts should be made to enhance the accuracy of the IR sensor and calibration algorithms. Research and development should focus on making non-invasive glucose measurements as reliable as traditional invasive methods.

User Experience Enhancement: Future iterations of the system should prioritize user experience, making it even more user-friendly and accessible. This includes ergonomic design, intuitive interfaces, and ease of use for individuals of all ages and backgrounds.

Security and Data Privacy: Ensuring the security and privacy of patient data is paramount. Future work should focus on robust encryption, data anonymization, and compliance with healthcare data protection regulations.

Clinical Validation: Extensive clinical validation and testing should be conducted to validate the system's accuracy and reliability. Collaborations with healthcare institutions and professionals are crucial to gaining acceptance in clinical settings.

Integration with Healthcare Ecosystem: Efforts should be made to integrate the glucometer system with electronic health records (EHR) systems and other healthcare platforms to streamline data sharing and healthcare decision-making.

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