IJIRAE:: International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.61

Wearable Glucose Monitoring System

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Publication History
Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10142
Research Article | Open Access | Double-Blind Peer-Reviewed |Article ID:IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10142
Received:22,February 2026, Revised: 01, March 2026, Accepted: 16,March 2026,Published Online: 25, March 2026.
https://www.ijirae.com/volumes/Vol13/iss-03/61.AEMR26.MRAE10142.pdf
Article Citation: Dr.Geetha,Jaiyashivani,Akilandeshwari,Dayana(2026),Wearable Glucose Monitoring System, IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 492-497
Doi:> https://doi.org/10.26562/ijirae.2026.v1303.61
BibTeX Key: Dr.Geetha@2026Wearable
IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, https://doi.org/10.26562/ijirae.2026.v1303.61 The journal's official abbreviation is IJIRAE. Orcid: https://orcid.org/0009-0004-9398-7488

Abstract: Monitoring glucose levels is essential for diabetic patients, but traditional glucose measurement methods require invasive finger-prick tests that can cause pain and inconvenience. This paper presents a Non-Invasive Glucose Monitoring System that estimates glucose levels using physiological parameters without penetrating the skin. The proposed system integrates sensors such as a heartbeat and SpO sensor, sweat and skin detection analyzer, and a wemos micro controller for data processing and wireless communication. The collected physiological data is analyzed to estimate glucose variations and monitor the patient's health condition in real time. Analarm module is incorporated to alert users when abnormal health conditions or glucose fluctuations are detected. The system aims to provide a portable, cost-effective, and user-friendly healthcare solution for continuous health monitoring.
Keywords: Non-invasive glucose monitoring, Wemos microcontroller, SpO sensor, heartbeat sensor, sweat analyzer, wearable healthcare device, IoT monitoring.

I. INTRODUCTION

Diabetes is one of the most common chronic diseases worldwide, requiring continuous monitoring of blood glucose levels to prevent serious health complications. Conventional glucose monitoring techniques involve invasive methods such as finger-prick blood tests, which can cause discomfort and discourage patients from frequent testing. Recent advancements in wearable sensors and Internet of Things (IoT) technology have enabled the development to non- invasive health monitoring systems. These systems use physiological signals such as heart rate, oxygen saturation, skin condition, and sweat composition to estimate changes in glucose levels without drawing blood. Recent advancements in wearable sensors and Internet of Things(IoT) technology have enabled the development of non- invasive health monitoring systems. These systems use physiological signals such as heart rate, oxygen saturation, skin condition, and sweat composition to estimate changes in glucose levels without drawing blood.

II. LITERATURE REVIEW

Heikenfeld et al. studied wearable sensors capable of analyzing body fluids such as sweat for health monitoring applications. Their research demonstrated that sweat contains biomarkers that can be useful for estimating metabolic conditions. However, sensor calibration and accuracy remain challenging in practical applications. [1] Bandodkar and Wang proposed electrochemical wearable sensors for monitoring biochemical markers in sweat. Their work showed that wearable biosensors can enable continuous health monitoring. However, long-term sensor stability and environmental effects can influence the accuracy of measurements. [2] Patel et al. investigated the use of wearable physiological sensors for health monitoring systems. The study highlighted the importance of combining multiple physiological signals to improve monitoring accuracy. However, integrating different sensors increases system complexity. [3] Kim et al. proposed a flexible wearable biosensor system capable of measuring various biochemical signals from the skin. Their system demonstrated promising results for continuous monitoring. However, power consumption and data processing remain important challenges. [4]Gao et al. developed wearable sweat sensors capable of detecting biochemical markers related to metabolic health. Their research showed that sweat analysis could support non- invasive health monitoring systems. However, sensor sensitivity and reliability still require improvement. [5] Sempion at to et al. developed wearable electrochemical sensors capable of analyzing sweat biomarkers for real-time health monitoring.
Their research showed that wearable biosensors can detect various physiological parameters continuously. However,

challenges remain in improving sensor durability and ensuring accurate measurements during daily activities. [6] Ray et al. studied flexible wearable biosensors for non- invasive monitoring of health parameters. Their work demonstrated that integrating multiple sensors into wearable devices can provide valuable physiological in sights. However, maintaining sensor stability and minimizing noise in collected data are significant challenges. [7] Leeetal. Proposed a skin-interfaced bio sensor system for continuous monitoring of physiological signals. The study highlighted that non-invasive sensors can improve patient comfort and enable long-term monitoring. However, factors such as skin temperature and humidity can affect sensor performance.[8] Zhang et al. developed a wearable sweat sensor platform capable of detecting biochemical markers related to metabolic conditions. Their research indicated that sweat-based analysis could be used for non-invasive health monitoring. However, further improvements are required to enhance sensor sensitivity and reliability. [9] Liuetal**.** Investigated wearable health monitoring devices integrated with IoT technology for real-time physiological monitoring. Their study demonstrated that IoT-enabled sensors allow remote healthcare monitoring and early detection of health abnormalities. However, data security and system reliability remain important concerns. [10]

II. PROPOSED SYSTEM

The proposed system is a Non-Invasive Glucose Monitoring System designed to monitor physiological parameters associated with glucose level variations without requiring blood sampling. The system integrates wearable sensors, a microcontroller-based processing unit, and IoT communication to enable continuous health monitoring. By analyzing physiological signals such as heart rate, oxygen saturation, and skin conductivity, the system estimates possible glucose fluctuations and alerts the user in case of ab normal conditions. The primary goal of the proposed system is to develop a portable, cost-effective, and user-friendly monitoring device that allows continuous tracking of health parameters related to glucose metabolism. The system is designed to support real- time monitoring and early detection of potential health risks, thereby assisting users in better management of their health conditions. The overall architecture of the system consists of four major subsystems: sensor acquisition subsystem, control and processing subsystem, IoT communication subsystem, and alert subsystem. These subsystems work together to collect physiological data, process the signals, and notify the user when abnormal conditions are detected.

A. Sensor Acquisition Subsystem

The sensor acquisition subsystem collects physiological signals from the user using a heartbeat and SpO sensor and a sweat and skin detection analyzer. The heart beat and SpO sensor measures heart rate and blood oxygen saturation levels, which provide important information about the user's cardiovascular condition. The sensor is typically placed on the fingertip to obtain accurate pulse signals. The sweat and skin detection analyzer monitors skin conductivity and moisture levels, which may indicate metabolic changes related to glucose variations. The collected sensor data is then transmitted to the microcontroller for further processing and analysis**.**

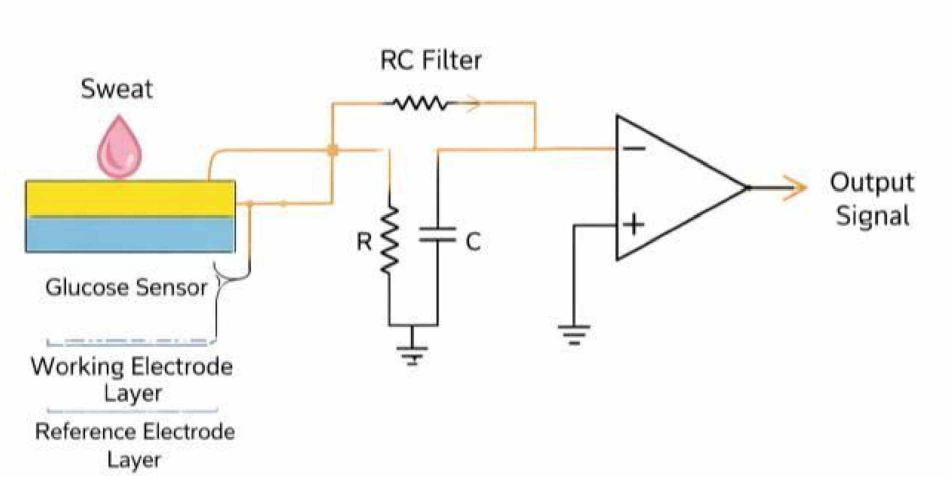

Fig.1: SDACIRCUIT

B. Wemos Control and Processing Subsystem

The control and processing subsystem acts as the central unit of the monitoring system. It is implemented using a Wemos microcontroller, which receives the physiological signals from the connected sensors. The microcontroller processes the collected data using embedded software algorithms. The raw sensor signals are filtered and converted into meaningful physiological parameters such as heart rate, oxygen saturation, and skin conductivity. These parameters are analyzed to estimate possible glucose fluctuations in the body. The microcontroller also manages system operations and coordinates communication between the sensors, IoT platform, and alert modules.

C. IoT Communication Subsystem

This allows users and healthcare providers to monitor physiological parameters in real time from remote locations. The stored data can also be used for long-term health analysis and monitoring of glucose-related conditions. This allows users and healthcare providers to monitor physiological parameters in real time from remote locations. The stored data can also be used for long-term health analysis and monitoring of glucose-related conditions.

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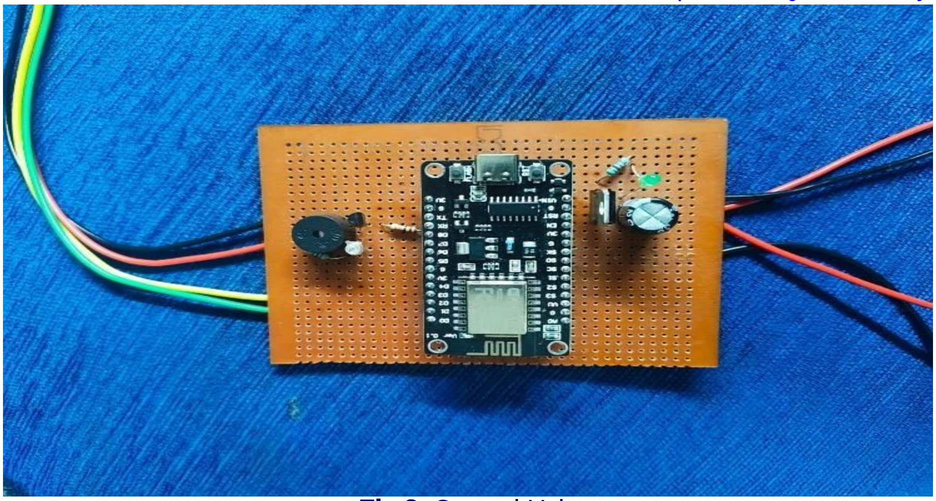

Fig.2: Control Unit

D. Alert Subsystem

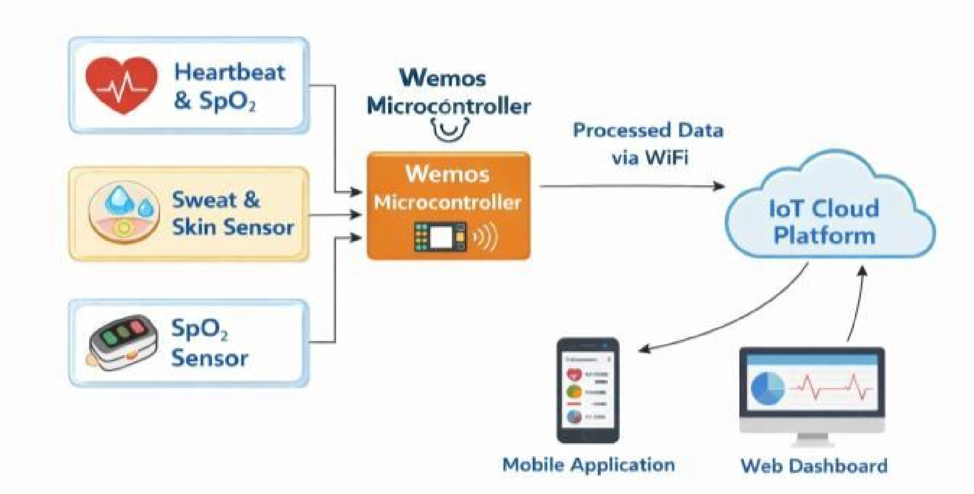

Fig.3: IoT integration

III. DESIGN OF GLUCOSE MONITIRING

The non-invasive glucose monitoring system is designed as a wearable device that monitors physiological parameters related to glucose variations without blood sampling. It integrates multiple sensors, a microcontroller, and an IoT communication module to collect and analyze health data in real time. The design focuses on portability, comfort, and continuous monitoring, using lightweight components and compact circuitry for long-term wearable use.

A. Sensor Integration Structure

The sensor integration structure forms the core sensing unit of the system and includes a heartbeat and SpO sensor and a sweat and skin detection analyzer to capture physiological signals. The heartbeat and SpO sensor is placed on the fingertip to measure heart rate and oxygen saturation, while the sweat the alert subsystem provides immediate notification when abnormal physiological conditions are detected. An alarm or buzzer module is integrated into the system to alert the user if sensor readings exceed predefined threshold limits. This early warning mechanism helps users take timely action and reduces the risk of health complications related to glucose fluctuations. The alert subsystem therefore plays an important role in ensuring the safety and reliability of the monitoring system. And skin analyzer detects skin conductivity and moisture levels related to metabolic changes. The sensors are arranged in a compact design to ensure accurate signal detection and user comfort during continuous monitoring

B. Signal Processing and Control unit

The collected sensor data is filtered and converted into meaningful physiological parameters such as heart rate, oxygen saturation, and skin conductivity. These parameters are analyzed to estimate possible glucose fluctuations in the body. The microcontroller coordinates all system operations and ensures continuous monitoring of the user's health parameters. The collected sensor data is filtered and converted into meaningful physiological parameters such as heart rate, oxygen saturation, and skin conductivity. These parameters are analyzed to estimate possible glucose fluctuations in the body. The microcontroller coordinates all system operations and ensures continuous monitoring of the user's health parameters.

IoT Communication and Monitoring

The system uses an IoT-based communication module with the built-in Wi-Fi capability of the Wemos microcontroller to transmit sensor data wirelessly to a cloud platform or mobile application.

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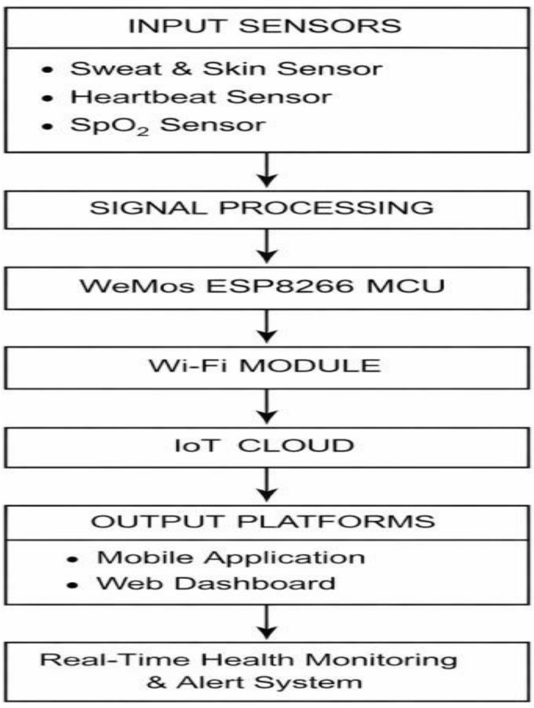

Fig.4: Block Diagram

This enables real-time and remote monitoring of physiological parameters by users and healthcare providers. The collected data can also be stored for long-term analysis and continuous health monitoring, improving the overall effectiveness of the system.

C. Alert and Safety Mechanism

The system includes an alarm or buzzer module that alerts the user when abnormal physiological conditions are detected. Threshold values for parameters such as heart rate, oxygen saturation, and skin conductivit**y** are predefined in the software. When these limits are exceeded, the alarm is activated to notify the user immediately. This mechanism enables early detection of potential health risks and ensures safe and continuous wearable health monitoring.

IV. HARDWARE AND SOFTWARE IMPLEMENTATION

The proposed Non-Invasive Glucose Monitoring System was developed by integrating various physiological sensors with a microcontroller-based processing unit. The system architecture consists of hardware components responsible for sensing physiological parameters and software components responsible for data processing and analysis. The implementation focuses on continuous monitoring of physiological signals related to metabolic activity and glucose fluctuations.

A. Hardware Implementation

The hardware implementation of the proposed system consists of several sensors and electronic components that work together to collect physiological data from the human body. The Wemos microcontroller acts as the central control unit of the system and is responsible for receiving and processing data from all connected sensors. It also provides Wi-Fi connectivity, which enables the possibility of wireless data transmission and remote monitoring. A heart beat and SpO sensor is used to measure the heart rate and blood oxygen saturation levels of the user. These parameters provide important information about cardiovascular health and metabolic conditions. The sensor detects pulse signals from the fingertip and converts them into electrical signals that are processed by the microcontroller. The system also includes a sweat and skin detection analyzer that measures skin conductivity and sweat-related parameters. Sweat contains certain biochemical lindicators that may reflect metabolic changes in the body. Monitoring these parameters helps in estimating possible glucose elevel variations in a non-invasive manner. An alarm or buzzer module is integrated into the system to provide alerts when abnormal physiological conditions are detected. If the sensor readings exceed predefined threshold values, the alarm is triggered to notify the user immediately. This feature enhances the safety of the monitoring system by providing early warnings in case of abnormal health conditions. All the hardware components are connected through appropriate interfaces to ensure stable data communication and reliable operation of the system.

B. Software Implementation

The software implementation of the proposed system is based on Internet of Things (IoT) technology, which enables real-time monitoring and remote access to physiological data. The system was programmed using the Arduino Integrated Development Environment (Arduino IDE) to control the Wemos microcontroller, which includes built-in Wi-Fi capability for wireless communication. The software continuously collects data from the connected sensors, including the heart beat and SpO sensor and the sweat and skin detection analyzer. The sensor readings are processed by the microcontroller to obtain meaningful physiological parameters such as heart rate, oxygen saturation level, and skin conductivity.

These parameters are then transmitted through the Wi-Fi module of the Wemos to an IoT cloud platform or monitoring application for real-time data visualization and storage. The IoT-based software allows users and healthcare providers to monitor the health parameters remotely using a mobile device or web interface. Threshold values are defined within the program to detect abnormal physiological conditions. When the sensor readings exceed the predefined limits, the system activates the alarm module and can also send alerts through the IoT platform. This IoT-enabled approach improves the efficiency of the monitoring system by allowing continuous data tracking, remote health monitoring, and early detection of abnormal conditions. The integration of IoT technology with wearable sensors makes the system suitable for modern **smart** healthcare applications and supports improved management of glucose- related health conditions.

V. RESULTS AND DISCUSSION

The proposed Non-Invasive Glucose Monitoring System was successfully implemented using a Wemos microcontroller, integrated with multiple physiological sensors including a heartbeat and SpO sensor and a sweat and skin detection analyzer. The system was designed to continuously monitor important physiological parameters related to metabolic activity and possible glucose level variations. During the experimental testing phase, the sensors were connected to the Wemos microcontroller, which collected the data and processed it in real time. The system demonstrated reliable data acquisition and stable communication between the sensors and the microcontroller, confirming the feasibility of the hardware integration for continuous health monitoring applications. The heart beat and SpO sensor was used to measure heart rate and blood oxygen saturation levels. During the testing process, the sensor produced stable and consistent readings, indicating its ability to monitor cardiovascular parameters effectively. These measurements provide valuable insights into the physiological condition of the user, as changes in metabolic activity may influence heart rate and oxygen saturation levels. The sensor readings were successfully transmitted to the microcontroller and processed for further analysis, demonstrating the capability of the system to perform real-time physiological monitoring. The sweat and skin detection analyzer played an important role in monitoring skin-related parameters such as moisture level and skin conductivity. Sweat contains biochemical components that may reflect metabolic changes occurring within the body. During testing, the sensor detected variations in sweat and skin conductivity levels under different conditions. These readings were used as indirect indicators that could help estimate possible glucose level fluctuations. By combining this data with other physiological signals, the system attempts to provide a more comprehensive understanding of the user's metabolic condition. The alarm module integrated into the system was also successfully tested. When the monitored parameters exceeded predefined threshold limits, the alarm was activated to alert the user. This feature is particularly useful for detecting abnormal physiological conditions and providing early warning signals. The alarm system enhances the safety aspect of the device by enabling users or caregivers to respond quickly to potential health risks. The experimental results demonstrate that the integration of multiple physiological sensors with an IoT-enabled microcontroller can support the development of non-invasive health monitoring systems. The use of the Wemos microcontroller allows efficient data processing and provides the possibility for wireless communication and remote monitoring through IoT platforms. This capability is beneficial for continuous patient monitoring, especially for individuals requiring regular health supervision. Although the system produced promising results during testing, certain limitations were observed. Sensor accuracy may be affected by environmental conditions such as temperature, humidity, and user movement. Therefore, proper calibration and advanced signal processing techniques are required to improve the accuracy of glucose estimation. Additionally, incorporating more advanced biosensors and data analysis techniques could further enhance the reliability of the monitoring system..

Fig.5: Result Dash board

Overall, the proposed system demonstrates the feasibility of using wearable sensor technology and IoT-based monitoring systems for non-invasive glucose monitoring and real-time health monitoring applications. The results highlight the potential of combining physiological sensors with intelligent data processing to create cost-effective and user-friendly healthcare solutions

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CONCLUSION AND FUTURE SCOPE

This paper presented a Non-Invasive Glucose Monitoring System designed to estimate glucose level variations using physiological parameters without the need for invasive blood sampling. The proposed system integrates sensors such as heart beat and SpO sensors, sweat and skin detection analyzers, along with a Wemos microcontroller for data collection and processing. These sensors continuously monitor important physiological parameters related to metabolic activity and help in identifying possible glucose level fluctuations. The inclusion of an alarm module allows the system to alert the user when abnormal conditions are detected, ensuring quick response and improved patient safety. The system offers a portable, cost- effective, and user-friendly healthcare solution for continuous monitoring. In the future, the system can be improved by incorporating advanced biosensors capable of directly detecting glucose levels through sweat or skin analysis to enhance measurement accuracy. Integration with mobile applications and cloud platforms can enable remote monitoring by doctors and caregivers. Additionally, the use of machine learning algorithms can help analyze collected health data and predict glucose trends more accurately. Further improvements in sensor technology, device miniaturization, and power efficiency can lead to the development of fully wearable, real- time non-invasive glucose monitoring systems for better diabetes management.

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