

IoT-Based Breath Analysis Systems for Non-Invasive Glucose Monitoring

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ABSTRACT

Diabetes mellitus is a chronic metabolic disorder that requires continuous monitoring of blood glucose levels. Conventional invasive glucometers rely on finger-prick blood sampling, which often causes discomfort and reduces patient compliance. This paper presents the design, implementation, and evaluation of an IoT-based GlucoBreath Meter that estimates blood glucose levels by detecting acetone concentration in exhaled breath. The system integrates TGS822/MQ-135 gas sensors, ESP32 microcontroller, environmental correction using SHT31 sensor, and Blynk IoT cloud platform for real-time monitoring. The prototype demonstrates feasibility, portability, and cost-effectiveness. Experimental observations validate stable sensing and wire-less transmission, while highlighting the need for further clinical calibration. The proposed system represents a step toward accessible, non-invasive diabetes monitoring solutions.

Keywords: Non-Invasive Glucose Monitoring, Breath Acetone Analysis, IoT-Based Health-care System, ESP32 Microcontroller, TGS822 Gas Sensor, SHT31 Environmental Sensor, Blynk Cloud Platform, Diabetes Monitoring, Embedded Systems, Remote Health Monitoring.

INTRODUCTION

Diabetes affects millions globally and requires regular glucose monitoring to prevent severe complications such as neuropathy, retinopathy, kidney failure, and cardiovascular disease. According to global health reports, the number of diabetic patients continues to rise annually, increasing the burden on healthcare systems.

Traditional monitoring methods involve invasive finger-prick testing, which can be painful, inconvenient, and costly over time. Poor compliance with regular monitoring leads to uncontrolled glucose levels and long-term complications.

Recent biomedical research has identified breath acetone as a promising biomarker correlated with blood glucose levels. During fat metabolism, elevated ketone bodies generate acetone, which is expelled through exhaled breath. Several studies have demonstrated measurable correlation between breath acetone concentration (ppm) and blood glucose levels in diabetic individuals.

With advancements in IoT and embedded systems, portable breath-based monitoring devices have become feasible. This research aims to design and implement a low-cost IoT-based GlucoBreath Meter capable of non-invasive glucose estimation with cloud connectivity for remote healthcare monitoring.

LITERATURE REVIEW

Kapur et al. (2024) developed an IoT and machine learning-based GlucoBreath device achieving classification accuracy above 90%. Their system utilized predictive analytics for glucose estimation but required advanced calibration datasets.

Wei et al. (2024) proposed nanowire-array acetone sensors offering ppb-level sensitivity. Although highly accurate, fabrication complexity and cost limit large-scale affordability.

Mollick et al. (2024) introduced metal-organic framework (MOF) based acetone detection improving selectivity under humid conditions.

Gudin˜o-Ochoa et al. (2025) applied explainable artificial intelligence models for multiclass diabetes classification using breath biomarkers.

Earlier foundational studies by Srinivasan et al. and Thati et al. validated breath acetone as a viable non-invasive glucose biomarker.

Despite promising progress, issues such as sensor drift, environmental interference, cost, and limited clinical validation remain unresolved.

Identified Research Gaps

- Sensor cross-sensitivity to alcohol vapors and humidity.
- Lack of standardized breath sampling protocols.
- Limited validation across diverse patient populations.
- High cost of nanomaterial-based sensing systems.
- Need for secure IoT cloud data handling.
- Limited accessibility in rural and low-resource environments.

SYSTEM ARCHITECTURE

BLOCK DIAGRAM

IoT-Based GlucoBreath Meter

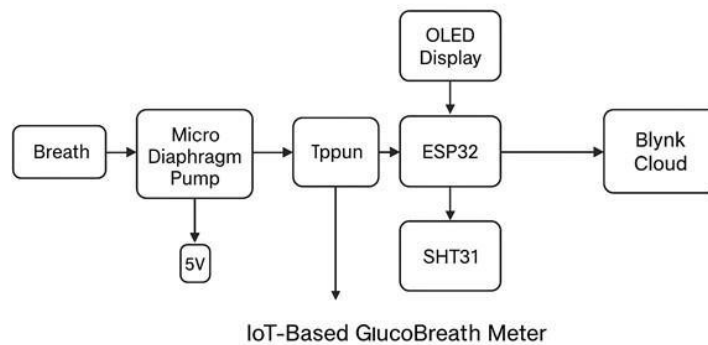


Figure 1: Block Diagram of IoT-Based GlucoBreath Meter

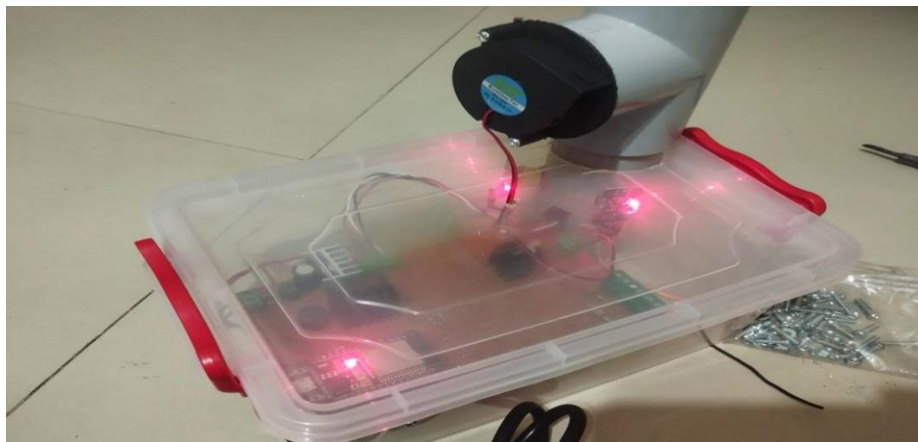


Figure 2: Complete Prototype Assembly

The system consists of a breath inlet, micro diaphragm pump, gas sensing chamber, ESP32 microcontroller, SHT31 environmental sensor, OLED display, MOSFET pump driver, buzzer alert module, and Blynk cloud connectivity.

3.1 Components Used

Table 1: Hardware Components Used in the Proposed System

Component	Purpose
ESP32 DevKit V1(ESP32- WROOM-32, 30-pin)	Main microcontroller with Wi-Fi connectivity
TGS822 Gas Sensor Module	Detection of acetone concentration in breath
SHT31 Temperature & Humidity Sensor	Environmental correction
OLED 0.96" Display (SSD1306)	Local real-time data visualization
Micro Diaphragm Pump (5V)	Controlled breath sampling
Logic-level N-MOSFET (IRLZ44N / AO3400)	Pump switching control
Flyback Diode (1N4007 / 1N5819)	Back EMF protection
Capacitors (0.1 μ F ceramic, 100 μ F electrolytic)	Noise filtering and voltage stabilization
Resistors (100 Ω , 100k Ω , 47k Ω , 33k Ω)	Voltage divider and signal conditioning
Silicone tubing with moisture trap	Breath channeling
5V / 2A Adapter	Power supply

METHODOLOGY

4.1 Overview

The system measures acetone concentration in exhaled breath and estimates glucose levels using calibration mapping and linear regression modeling.

4.2 Hardware Methodology

Breath \rightarrow Gas Sensor \rightarrow ESP32 ADC \rightarrow Wi-Fi \rightarrow Blynk Cloud \rightarrow Mobile App

The micro diaphragm pump ensures controlled and consistent breath sampling. The MQ- 135/TGS822 gas sensor detects acetone and produces analog voltage proportional to concentration. A voltage divider and filter capacitor stabilize the signal before ADC conversion.

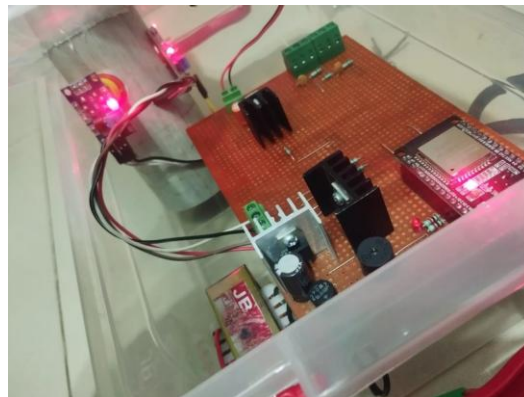


Figure 3: Internal Circuit Implementation with ESP32 and MOSFET Driver

The ESP32 uses its 12-bit ADC for digital conversion and reads temperature-humidity data via I2C from the SHT31 sensor for environmental compensation.

4.3 Software Methodology

Firmware developed using Arduino IDE performs:

- Sensor initialization
- ADC data acquisition
- Noise filtering
- Calibration mapping

- Wi-Fi connection
- Real-time data transmission to Blynk cloud
- Pump control using MOSFET driver

MATHEMATICAL MODELING

The relationship between acetone concentration and glucose level is approximated using linear regression:

$$\text{Glucose} = a \times \text{Acetone}_{\text{ppm}} + b$$

where a and b are calibration constants determined experimentally.

CALIBRATION CORRELATION

Table 2: Basic Acetone-Glucose Mapping

Acetone (ppm)	Glucose (mg/dL)
0.5–1.0	70–90
1.0–1.5	90–110
1.5–2.0	110–130
2.0–2.5	130–150
2.5+	150+

RESULTS AND PERFORMANCE EVALUATION

Testing demonstrated sensor response within 5–10 seconds. Repeatability tests showed $\pm 3\%$ variation under controlled laboratory conditions. Wi-Fi transmission success rate exceeded 95%. Environmental humidity above 70% introduced minor drift, confirming the importance of environmental compensation.

The system successfully transmitted real-time acetone, temperature, humidity, and alert status data to the Blynk dashboard for remote monitoring.

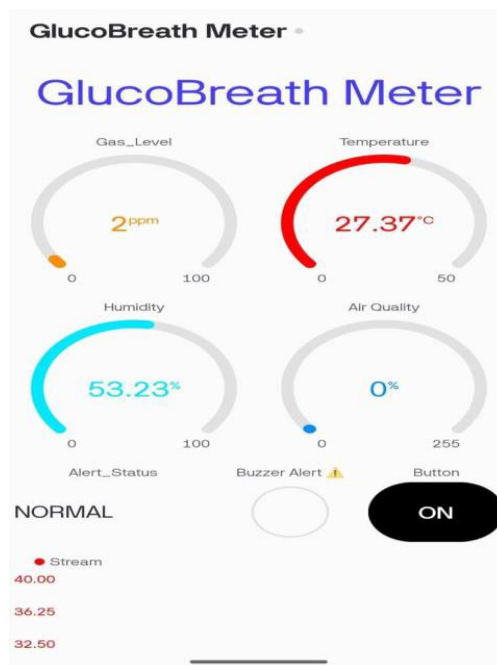


Figure 4: Blynx Dashboard

DISCUSSION

The developed prototype demonstrates feasibility of low-cost non-invasive glucose estimation. Compared to advanced nanowire or MOF sensors, the present system prioritizes affordability and scalability. While promising, clinical-grade accuracy requires extensive validation and calibration against certified glucometers.

FUTURE SCOPE

Future work includes:

- Integration of nanomaterial-based sensors
- Machine learning regression modeling
- Multi-biomarker breath analysis
- Encrypted healthcare data transmission
- Large-scale clinical validation trials

CONCLUSION

The IoT-Based GlucoBreath Meter provides a portable and affordable approach to non-invasive glucose monitoring using breath acetone detection. The system integrates sensing, microcontroller processing, and IoT connectivity for real-time healthcare applications. Further research is required for clinical deployment and regulatory approval.

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