NON INVASIVE BLOOD GLUCOSE MONITOR USING INFRARED SPECTROSCOPY

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Abstract : Blood glucose monitoring is essential for detecting patterns in glucose fluctuations influenced by diet, exercise, medication, and conditions like diabetes mellitus. Capillary blood glucose (CBG) testing, often done at home using a lancet, glucometer, and test strips, offers a convenient alternative to clinical plasma glucose tests. Modern glucometers require minimal blood and can sync data to smartphone apps for trend tracking and care planning. Alternate site testing (e.g., forearm, heel) can reduce discomfort and is effective under specific conditions. Accurate monitoring supports timely intervention and better diabetes management.

Keywords : Non invasive,Glucose Monitor,Continuous Glucose Monitor,Calibration,Accuracy,Glucometer,Fluctuations,Clinical Glucose Plasma Test

I.INTRODUCTION

Diabetes mellitus or commonly called diabetes is a worldwide epidemic caused by chronic hyperglycemia. Simplify the blood glucose monitoring and easy to use is an essential part of diabetes management. Currently, the use of blood glucose meters conventional in clinical practice needs sufficient reliability. Therefore, self-monitoring of blood glucose with a non-invasive method was presented. A non-invasive blood glucose monitoring device was initially for information on glucose level measurements. A non- invasive method to determine the level of glucose by applying the physical properties of the absorption of the laser sensor that can produce a voltage change at various glucose levels. In this paper, a glucose monitoring module was fabricated with dimensions of 25x27x15 cm which has a minimum system, sensor, and LCD as a display of glucose levels. A minimum system to control the output of data digital value using microcontroller. Experimentally, testing this module is by comparing the glucose monitoring modules that have been made with a gold standard. The result showed that non-invasive glucose monitoring is the potential for glucose level measurement a sensitivity, resolution, and accuracy of 0.86 mg/dL, 0.01 mg/dL, and 98.96%, respectively. The purposed module of glucose level monitoring offered simple testing for the rapid measurement of glucose levels.mammography, ultrasound, and magnetic resonance imaging (MRI), holds significant promise for advancing breast cancer detection. For instance, in mammography, image processing algorithms can help mitigate issues such as dense breast tissue, improving the detection of suspicious lesions. Similarly, in ultrasound and MRI, these techniques can enhance the visualization of subtle abnormalities, thereby enabling more accurate diagnosis and treatment planning.

Therefore, it is clear that an ideal CGM device should be non-invasive, portable, accurate, inexpensive, easy to use, and not require extensive calibration.Infrared (IR) radiation, with a wavelength range from 2500 nm to 25 µm, offers the highest selectivity for low-concentration compounds in complex organic media. In principle, most approaches using Infrared rely on the strong absorption of water in living tissue. Diffuse reflectance spectroscopy can access glucose molecules from the epidermal layer, whereas photothermal detectors can provide information from depths of 20–100 µm. A number of portable non-invasive blood glucose monitors have been developed that have demonstrated excellent blood glucose measurement and monitoring capabilities. Most non-invasive devices require frequent calibration, but current research that works on developing non-invasive devices is finding that the calibration process, its duration, complexity, and effectiveness are detrimental and not periodically 10 possible. In recent years, great efforts have been made to reduce or even eliminate the frequency of calibration . This paper presents a fuzzy logic-based calibration system to map the output voltage of IR sensor and controller into reliable glucose concentration using Clarke error grid. In this study, the fuzzy logic is responsible about estimating the error tolerance using the output voltage from controller and the estimated glucose concentration. According to the “IDF Diabetes Atlas” published in 2021, there are more than 530 million people in the world suffering from diabetes, and this number is expected to exceed 780 million by the end of 2045 . In view of current medical restrictions, there is no way to completely eradicate diabetes, but there are still many factors that affect the way diabetes is controlled. To reduce the risk of diabetes-related complications, patients are often advised to follow the guidelines of healthcare providers on diet, exercise, self-monitoring, and medication regimens . Among these measures, self-monitoring is crucial, as it allows patients to better understand their glycemic patterns and adjust their management strategies accordingly. In addition, early diabetes does not show obvious symptoms, making it difficult to distinguish and diagnose. Up to 70% of people with prediabetes eventually develop type 2 diabetes, which is one of the top 10 causes of death globally and is associated with comorbidities such as cardiovascular disease, kidney disease, neuropathy, and retinopathy . Therefore, monitoring blood glucose concentration plays an important role in the treatment and early screening of diabetes. Currently, the methods used for glucose monitoring are mainly invasive. Depending on the type of sampling, these methods can be concluded as blood glucose monitoring (BGM) and continuous glucose monitoring (CGM). Among them, BGM aims to collect blood from veins or capillaries, and then apply a chemical-based method to get a relatively accurate blood glucose reading. Nonetheless, for each measure reading, it is accompanied by a blood draw, which can be distressing for individuals who require frequent monitoring. CGM, on the other hand, continuously tracks glucose levels using a sensor implanted just under the skin. It measures glucose in the interstitial fluid (ISF) rather than directly from the blood, which can result in a slight “lagging effect” between the sensor reading and real-time blood glucose levels . Previously, CGM systems required regular calibration through fingerstick blood glucose readings to maintain.

II. Fuzzy Logic With GEG

A.Fuzzy Logic with CEG

The Clarke error grid, which is approved for clinical evaluation, was used as a marker of differences between test glucose measurement techniques and intravenous blood glucose baseline measurements. This method uses a Cartesian scheme in which values are predicted by displaying the method under examination on the y axis, and the values received from the reference method on the x axis. The country region represents an ideal match between the two, while the points below and above the line indicate the exaggerated estimates and reduced actual values, respectively. Region-A (acceptable) represents glucose values that deviate from the 20% reference value or lie within the blood glucose range.

B.Overview

Overview of invasive method Currently, the methods used for glucose monitoring are mainly invasive. Depending on the type of sampling, these methods can be concluded as blood glucose monitoring (BGM) and continuous glucose monitoring (CGM). Among them, BGM aims to collect blood from veins or capillaries, and then apply a chemical-based method to get a relatively accurate blood glucose reading. Nonetheless, for each measure reading, it is accompanied by a blood draw, which can be distressing for individuals who require frequent monitoring. CGM, on the other hand, continuously tracks glucose levels using a sensor implanted just under the skin. It measures glucose in the interstitial fluid (ISF) rather than directly from the blood, which can result in a slight "lagging effect" between the sensor reading and real-time blood glucose levels . Previously, CGM systems required regular calibration through fingerstick blood glucose readings to maintain accuracy. However, with the advent of factory-calibrated CGM devices, such as the Dexcom G6, calibration by the user is no longer necessary. Despite these advancements, CGM devices remain relatively expensive, and some users may experience skin irritation, contributing to psychological discomfort.. Control System Design: Designing a controller for a complex physical system involves the following steps: Decomposing the large-scale system into a collection of various subsystems. Varying the plant dynamics slowly and linearizing the nonlinear plane dynamics about a set of operating points. Organizing a set of state variables, control variables, or output features for the system under consideration. Designing simple P, PD, PID controllers for the subsystems. Optimal controllers can also be designed. Apart from the first four steps, there may be uncertainties occurring due to external environmental conditions. The design of the controller should be made as dose as possible to the optimal controller design based on the expert knowledge of the control engineer. This may be done by various numerical observations of the input output relationship in the form of linguistic, intuitive, and other kinds of related information related to the dynamics of the plant and the external environment. Finally, a supervisory control system, either manual operator or automatic, forms an extra feedback control loop to tune and adjust the **p**arameters of the controller, for compensating the variational effects caused by nonlinear and remodelled dynamics. In comparison with a conventional control system design, an FLC system design should have the following assumptions made, in case it is selected. The plant under consideration should be observable and controllable. A wide range of knowledge comprising a set of expert linguistic rules, basic engineering common sense, a set of data for input/output, or a controller analytic model, which can be fuzzified and from which the fuzzy rule the base can be formed, should exist. Also, for the problem under consideration, a solution should exist and it should be such that the control the engineer is working for a "good" solution and not especially looking for an optimum solution. The controller, in this case, should be designed to the best of our ability and within 20 an acceptable range of precision. It should be noted that the problems of stability and optimality are ongoing problems in the fuzzy controller design. In designing a fuzzy logic controller, the process of forming fuzzy rules plays a vital role. There are four structures of the fuzzy production rule system (Weiss and Donnel, 1979) which are as follows: A set of rules that represents the policies and heuristic strategies of the expert decision-maker. A set of input data that are assessed immediately prior to the actual decision. A method for evaluating any proposed action in terms of its conformity to the expressed rules when there is available data. A method for generating promising actions and determining when to stop searching for better ones. All the necessary parameters used in the fuzzy logic controller are defined by membership functions

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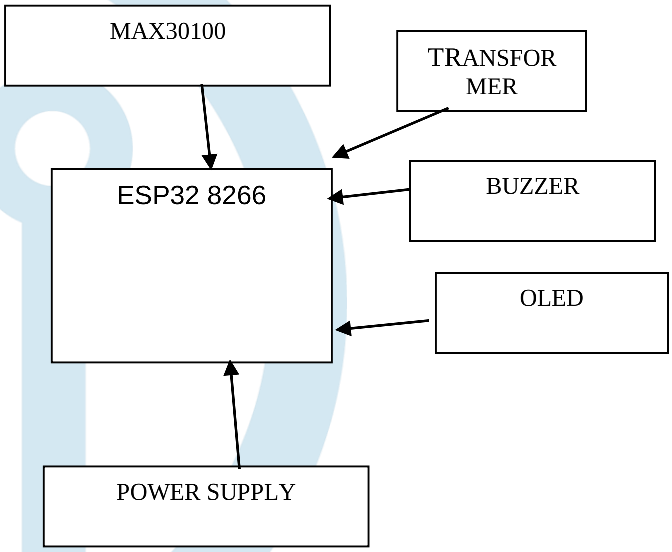


A.ESP8266

ESP 8266 A few years ago, the ESP8266 revolutionized the embedded IoT world. For less than, you could get a programmable, WiFi-enabled microcontroller capable of monitoring and controlling things from anywhere in the world. After the overwhelming success of the ESP8266, Espressif (the semiconductor company that created the ESP8266) has released a perfect supercharged upgrade – the ESP32. It incorporates not only WiFi but also Bluetooth 4.0 (BLE/Bluetooth Smart), making it ideal for any Internet of Things (IoT) application. The ESP8266 has become a game-changer for electronics enthusiasts and professional IoT developers alike. Imagine effortlessly bringing Wi-Fi capabilities to your projects without breaking the bank or battling with complex configurations. In just three steps, you'll have this versatile microchip up and running, fully programmed through the intuitive Arduino IDE. No intricate hardware knowledge required—just a few clicks, a bit of code, and your ESP8266 will be ready to power up your next IoT solution. Whether you're building a smart product or automating a process, the simplicity of this tutorial makes it all possible. Let's get started!. ➢ VCC: Connect to 3.3V power supply ➢ GND: Connect to ground of the UART or Arduino ➢ TX: Connect to RX of the UART or Arduino ➢ RX: Connect to TX of the UART or Arduino (use a voltage divider to step down from 5V to 3.3V if using Arduino) ➢ CH_PD (Chip Enable): Connect to 3.3V power supply ➢ GPIO0: Connect to ground (puts ESP8266 in Flash mode) -> Disconnect from GND after programming (Normal mode). If you're using an Arduino UNO and ESP8266 board, remember to set the RST pin to ground. This disables the Arduino's microcontroller, allowing it to act solely as a USB-to-serial converter for ESP8266 serial communication. To upload your code to the ESP8266, the module must enter Flash Mode, which is achieved by holding GPIO0 LOW (connecting it to GND) and resetting the ESP8266. You can reset the ESP8266 by momentarily grounding the RESET pin (you can attach a push button between the reset pin and ground) or cycling power (disconnect and reconnect the power).

B.OLED DISPLAY

An organic light-emitting diode (OLED), also known as organic electroluminescent (organic EL) diode, is a type of light-emitting diode (LED) in which the emissive electroluminescent layer is an organic compound film that emits light in response to an electric current. This organic layer is situated between two electrodes; typically, at least one of these electrodes is transparent. OLEDs are used to create digital displays in devices such as television screens, computer monitors, and portable systems such as smartphones and handheld game consoles. A major area of research is the development of white OLED devices for use in solid-state lighting applications. There are two main families of OLED: those based on small molecules and those employing polymers. Adding mobile ions to an OLED creates a light-emitting electrochemical cell (LEC) which has a slightly different mode of operation. An OLED display can be driven with a passive-matrix (PMOLED) or active-matrix (AMOLED) control scheme. In the PMOLED scheme, each row and line in the display is controlled sequentially, one by one, whereas AMOLED control uses a thin-film transistor (TFT) backplane to directly access and switch each individual pixel on or off, allowing for higher resolution and larger display sizes. OLEDs are fundamentally different from LEDs, which are based on a p–n diode crystalline solid structure. In LEDs, doping is used to create p- and n-regions by changing the conductivity of the host semiconductor. OLEDs do not employ a 25 crystalline p-n structure. Doping of OLEDs is used to increase radiative efficiency by direct modification of the quantum-mechanical optical recombination rate. Doping is additionally used to determine the wavelength of photon emission. OLED displays are made in a similar way to LCDs, including manufacturing of several displays on a mother substrate that is later thinned and cut into several displays. Substrates for OLED displays come in the same sizes as those used for manufacturing LCDs. For OLED manufacture, after the formation of TFTs (for active matrix displays), addressable grids (for passive matrix displays), or indium tin oxide (ITO) segments (for segment displays), the display is coated with hole injection, transport and blocking layers, as well with electroluminescent material after the first two layers, after which ITO or metal may be applied again as a cathode. Later, the entire stack of materials is encapsulated. The TFT layer, addressable grid, or ITO segments serve as or are connected to the anode, which may be made of ITO or metal. OLEDs can be made flexible and transparent, with transparent displays being used in smartphones with optical fingerprint scanners and flexible displays being used in foldable smartphones.

C.TRANSFORMER

12-0-12 1A Center Tapped Step Down Transformer is a general purpose chassis mounting mains transformer. Transformer has 230V primary winding and center tapped secondary 30 winding. The transformer has flying colored insulated connecting leads (Approx 100 mm long). The Transformer act as step down transformer reducing AC - 230V to AC - 12V. The Transformer gives outputs of 12V, 12V and 0V. The Transformer's construction is written below with details of Solid Core and Winding. The transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding. This varying magnetic flux induces a varying electromotive force (E.M.F) or voltage in the secondary winding. The transformer has cores made of high permeability silicon steel. The steel has a permeability many times that of free space and the core thus serves to greatly reduce the magnetizing current and confine the flux to a path which closely couples the windings.

C.Diodes:

In electronics a diode is a two-terminal electronic component with asymmetric conductance. It has low (ideally zero) resistance to current flow in one direction and high (ideally infinite) resistance in the other. A semiconductor diode, the most common type today is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals. A vacuum tube diode has two electrodes, a plate (anode) and heated cathode. Semiconductor diodes were the first semiconductor electronic devices. The discovery of crystals' rectifying abilities was made by German physicist Ferdinand Braun in 1874. The first semiconductor diodes called cat's whisker diodes, developed around 1906, were made of mineral crystals such as galena.

D.LIGHT EMITTING DIODE

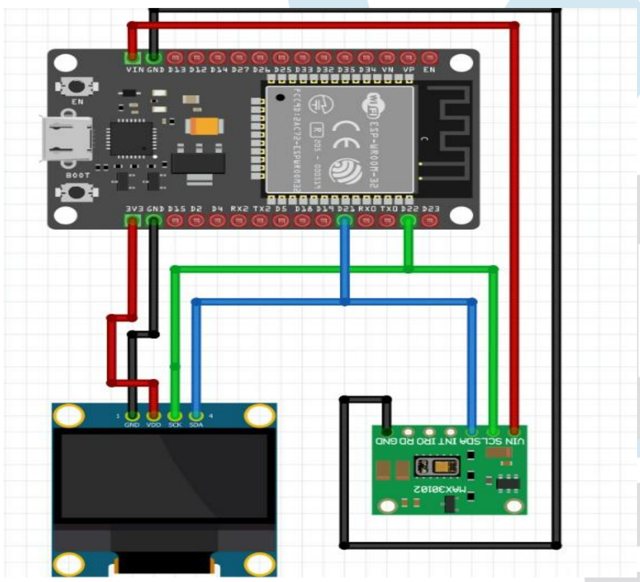
Light Emitting Diodes (LED): A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for general lighting. Appearing as practical electronic components in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

When a light-emitting diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. An LED is often small in area (less than 1 mm2), and integrated optical components may be used to shape its radiation pattern. LEDs have many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. However, LEDs 35 powerful enough for room lighting are relatively expensive, and require more precise current and heat management than compact fluorescent lamp sources of comparable output. Light-emitting diodes are used in applications as diverse as aviation lighting, automotive lighting, advertising, general lighting and traffic signals. LEDs have allowed new text, video displays, and sensors to be developed, while their high switching rates are also useful in advanced communications technology. Infrared LEDs are also used in the remote control units of many commercial products including televisions, DVD players and other domestic appliances. LEDs are used to create a new form of wireless internet access called Li-Fi, or light fidelity. LEDs are also used in seven-segment display.

E.MAX30100 Module Hardware

MAX30100 Module Hardware Overview The module features the MAX30100 – a modern, integrated pulse oximeter and heart rate sensor IC, from Analog Devices. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry (SpO2) and heart rate (HR) signals.On the right, the MAX30100 has two LEDs – a RED and an IR LED. And on the left is a very sensitive photodetector. The idea is that you shine a single LED at a time, detecting the amount of light shining back at the detector, and, based on the signature, you can measure blood oxygen level and heart rate.

CIRCUIT DIAGRAM



F BUZZER

There are many ways to communicate between the user and a product. One of the best ways is audio communication using a buzzer IC. So during the design process, understanding some technologies with configurations is very helpful. So, this article discusses an overview of an audio signaling device like a beeper or a buzzer and its working with applications.

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

Fig 6.10: BUZZER PIN DIAGRAM

The **pin configuration of the buzzer** is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

Specifications

The **specifications of the buzzer** include the following.

- Color is black
- The frequency range is 3,300Hz
- Operating Temperature ranges from – 20° C to +60°C
- Operating voltage ranges from 3V to 24V DC
- The sound pressure level is 85dBA or 10cm
- The supply current is below 15mA

Types of Buzzer

A buzzer is available in different types which include the following.

- Piezoelectric
- Electromagnetic
- Mechanical
- Electromechanical
- Magnetic

The piezo, also known as the buzzer, is a component that is used for generating sound. It is a digital component that can be connected to digital outputs, and emits a tone when the output is HIGH. Alternatively, it can be connected to an analog pulse-width modulation output to generate various tones and effects. The **Grove Buzzer** operates at both 3.3V and 5V with a sound output of 85 decibels. This module can be used to provide sound feedback to your application just like the click sound of a button on a digital watch.

G RESULT AND DISCUSSION

In this paper, a dual wavelength short infrared system is described for the detection of glucose levels. The system aims to improve the accuracy of blood glucose detection in a cost-effective and non-invasive way. The accuracy of the method is evaluated using real-time samples collected with the reference finger prick glucose device.

Diabetes is a chronic metabolic disorder which can lead to severe complications and affect all vital organs. The occurrence of complications due to diabetes can be prevented by regular monitoring and maintaining the blood glucose level in the normal range. Most of the commercially available devices for glucose measurement are invasive or minimally invasive. Invasive devices used for blood glucose monitoring are inconvenient and painful whereas minimal invasive devices have limited time span and stability. Thus, there is a need of an economic, compact, painless and convenient non-invasive device which can promote frequent blood testing which help in control of blood glucose level. In this paper various methods of glucose monitoring are reviewed and overall emphasis is laid on the development of IRS (Infrared spectroscopy) based non-invasive glucose monitoring. The motivation of this review is to demonstrate the prospects, limitations and technical challenges for development of IRS based non-invasive blood glucose measurement system.

Non-Invasive Methods of Blood Glucose Monitoring

The past few years have seen the development of several non-invasive methods, including transdermal techniques such as reverse iontophoresis and skin impedance spectroscopy, and optical methods like optical coherence tomography and Raman spectroscopy.

However, these techniques have their own drawbacks that have so far stopped them from becoming a standard blood glucose level monitoring method.

Infrared (IR) spectroscopy is a promising method for measuring blood glucose level as it is capable of identifying the highly specific vibrational modes or 'chemical fingerprints' of glucose molecules with very high sensitivity. Reports are, in fact, already available discussing the use of the IR spectroscopy for quantitative analysis of glucose molecules in dialysis fluid, blood and blood plasma[8-9].

The right IR laser needs to be used in IR spectroscopy in order to make the technique a viable option. The following are the key qualities to be possessed by an ideal IR laser:

- High tuning speed for rapid data acquisition
- Ability to tune with good power across the region of absorption of glucose molecules in the IR spectrum

However, to design a laser with a high tuning speed, one has to compromise in other areas. For sensitive (high signal-to-noise ratio) detection of glucose molecules, the quality of the light from the laser must not be compromised for the tuning speed. The laser should possess high beam quality and high spectral repeatability (low variability in wavelength and spectral content of the laser output) to enable highly consistent and accurate measurements.

CONCLUSION

- 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 infrared OLED is proposed in this paper. The glucose level in the blood which is obtained from the photo detector is displayed in both the OLED 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. The glucose level in the blood as detected by the photo detector is displayed on the O-LED display. By analysing error grids, it validates the proposed method. An innovative non-invasive portable blood glucose computing devices are an effective way to manage diabetic patients' health, this blood glucose monitor is portable and non-invasive. Patients can utilise the suggested model anywhere, and health care facilities can use it as well. The proposed method is validated using error grid analyses.
  This 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. An innovative non-invasive portable blood glucose computing devices are an effective way to manage diabetic patients' health, this blood glucose monitor is portable and non-invasive. Patients can utilize the suggested model anywhere, and health care facilities can use it as well.

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