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# Non-invasive method for blood glucose detection

**Lance Fernandes[1], Prathamesh Dalvi[2], Dr. Rajendra Sutar[3]**

[1,2]*B.Tech Electronics, Sardar Patel Institute of Technology, Mumbai*

[3] *Dean of Academics, Electronics Department, Sardar Patel Institute of Technology, Mumbai*

*Abstract* — ***Diabetes is metabolic disorder. Our body produces insulin to balance the sugar levels in our body. People having diabetes don't produce enough insulin and hence there is an imbalance in the sugar levels causing an increase in the sugar level in our body. Hence some diabetes patients need to continuously check their diabetes levels to keep it under control. Current technologies to measure diabetes require a needle to prick fingers and place a drop of blood on a strip to determine the blood glucose levels. It is invasive, painful, and expensive. If not handled properly it could lead to infections and other skin related diseases.***

***We have proposed two methods to detect the blood glucose levels non-invasively. The first one is using near infrared spectroscopy. In this method we will pass an infrared light through body and determine the change in amplitude with respect to blood glucose concentration. The other method is using human breath analysis. The sensor will detect the concentration of acetone and other volatile organic compounds in exhaled breath to determine the concentration of blood glucose levels.***

***Key words:*** *non-invasive, diabetes, glucose levels, blood glucose, exhaled acetone*.

## I. INTRODUCTION

Diabetes is metabolic disorder. Our body produces insulin to balance the sugar levels in our body. People having diabetes don't produce enough insulin and hence there is an imbalance in the sugar levels causing an increase in the sugar level in our body. Diabetes is on a rise due various reason such as poor diet, obesity, lack of exercise, etc. Nearly 392 million people were reported to have diabetes in the year 2013 according to the international Diabetes Federation. It is estimated that by 2035 nearly more 600 million people will have diabetes. High level of blood sugar increases the chances of long-term problems such as heart disease, stroke, blindness, amputations, etc. Hence it is very important to measure the blood glucose levels continuously. It will not only help to control the blood glucose level but also help to reduce the risk of diabetes. Current technologies include measure the blood glucose level by pricking the finger and taking a blood sample. This method is painful, invasive and expensive. If not handled carefully it can lead to infections and other skin related diseases. The other method consists of implanting a biosensor chip in human body for continuous blood glucose monitoring. This method is however very expensive and bio-compatibility is an issue.

In this study we have proposed two effective non-invasive methods. The first method is optical technique using near infrared spectroscopy. The NIR ranges from 800nm to 2500nm. This NIR light offers a penetration from 1mm to 100mm depending on the wavelength of light. As the wavelength increases the penetration also increases. As per various researches conducted glucose has absorption peaks at 940nm, 970nm, 1197nm, 1408nm, 1536nm, 1688nm. Two wavelengths particularly from two overtone regions i.e. 940nm and 1150nm are selected for effective measurement. This light is incident on human body part particularly with less body fat such as fingers or earlobe and the penetrated light is measured. According to light transport theory the incident light $I_o$ will be attenuated by a factor of attenuation constant $\mu_{effective}$ which depends on the blood glucose concentration. Increase in glucose concentration will increase the attenuation constant and hence decrease the penetration and vice-versa. Glucose concentration can be measured by observing the change in amplitude of incident and penetrated wave. The equation is $I = I_o e^{-\mu d}$.

The other method is detecting the glucose concentration non-invasively by determining the concentration of acetone and other volatile organic compounds in exhaled breath. Humans exhale various volatile organic compounds derived from various metabolic processes. In people with type-1 diabetes the body produces excess amounts of acetone and other volatile organic compounds because the body uses fats instead of glucose produce energy. During fasting, exercise, or diabetes the liver produces ketone bodies to act as an energy source. It is later metabolized into acetone and excreted through urine or breath. These methods are safe, non-invasive and inexpensive. The major disadvantage of these methods is that the measures levels are not on par with the traditional methods and hence these methods find it difficult to enter the mainstream markets

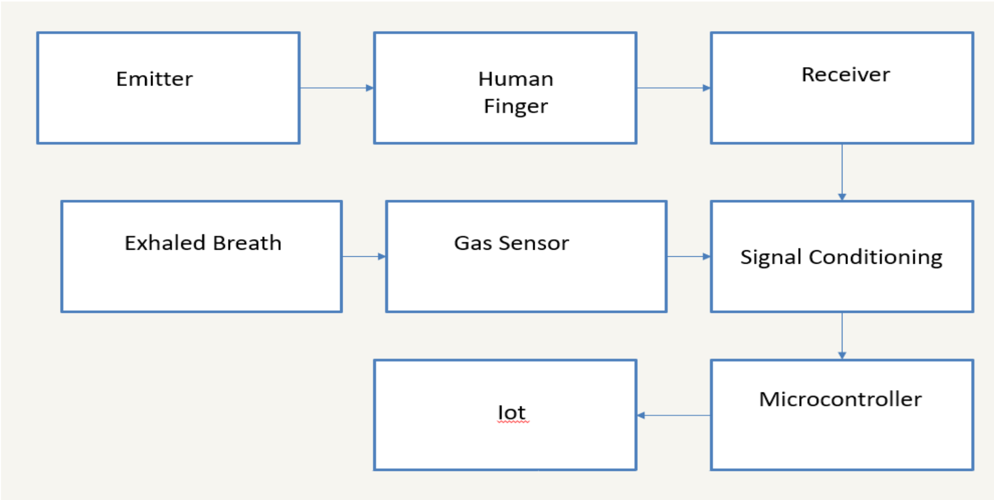


***Figure 1: Block Diagram of the system***

## II. METHODS

**2.1 Selection of wavelength**

The near infrared range varies from 800nm to 2500nm. As per various researches conducted glucose has absorption peaks at 940nm, 970nm, 1197nm, 1408nm, 1536nm, 1688nm. Although the absorption peak of glucose is less at 940nm it is chosen because signal attenuation by other materials such as water is minimum. For increased accuracy along with 940nm another infrared light from higher overtone regions could be chosen. The intended depth of penetration could be achieved.

**2.2 System and Hardware Design**

**2.2.1 Transmitter and receiver**

Figure 1 describes the block diagram of the entire system. The first block consists of an IR emitter. It is not recommended to use an IR beam as it harmful to the body. An IR LED of appropriate wavelength is used in the system. We have used an IR-333A LED which emits infrared light having a wavelength of 940nm. It is biased using an optocoupler circuit. The receiver consists of a photodiode. We have used PT333C photoreceiver which has peak sensitivity at 940nm. Its output current varies between 30mA to 100mA. The photodiode should not be exposed to ambient light as it will increase the error percentage at the output. The receiver is connected to signal conditioning circuit. The signal conditioning circuit consists of buffer amplifier, pre-stage amplifier, filter circuit, final-stage amplifier. The buffer amplifier has a unity gain and is use for impedance matching. The pre-stage amplifier has a gain of 5 and it amplifies the signal by a factor of 5. The notch filter is used to eliminate the line frequency noise. It is designed to give a notch (to eliminate) at 50Hz i.e. the line frequency noise. The final stage amplifier gives a final amplification and it has a gain of 20 and hence the overall gain is 100. The full implementation of the circuit along with the values is shown in the figure 2. We have used OP-AMP IC 741 for amplification purposes. To detect the concentration of acetone we have used MQ-9 gas sensor. This gas sensor is sensitive to various volatile organic compounds. It is calibrated to give us optimum output when acetone or other volatile organic compounds are detected. The output of the sensor is fed to the similar circuit as shown in figure 2. In figure 2 the input can be connected to either photodiode or the gas sensor.

**2.2.2 Microcontroller and IoT**

The output of the circuit is connected to a microcontroller. A microcontroller having high precision ADC is preferred so as to have an increased accuracy. We have used MSP432 by Texas Instruments. It has a 14-bit ADC and 3 stage pipeline which makes it very fast in processing the signal. The microcontroller is connected to an internet module CC3100. The data is sent to a cloud using MQTT protocol and the results is displayed on a web page. Figure 3 shows the basic GUI implemented to monitor the Glucose/voltage levels on any browser.

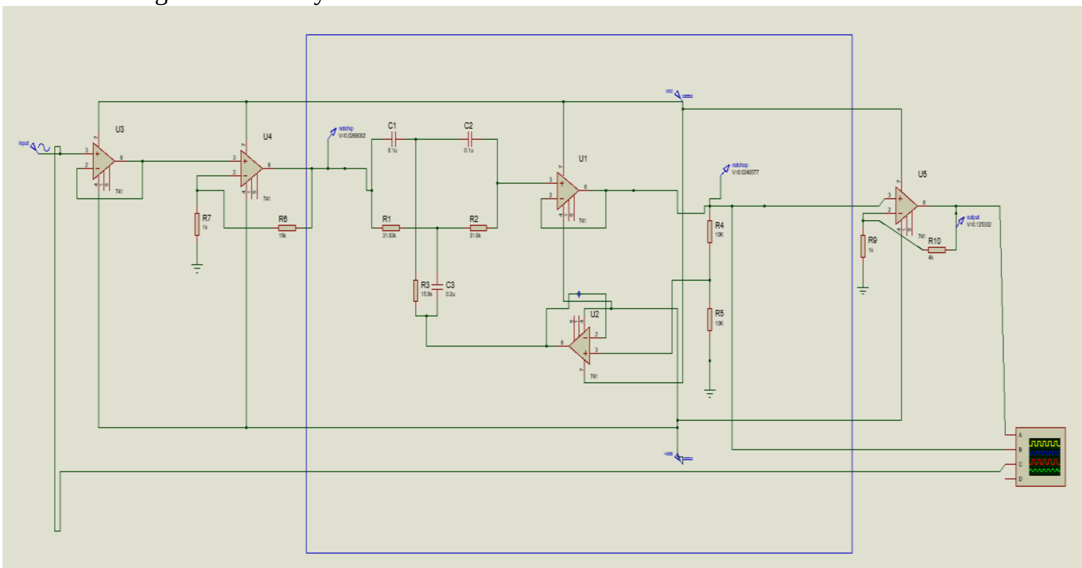


*Figure 2: Receiver circuit using OP-AMP IC741*

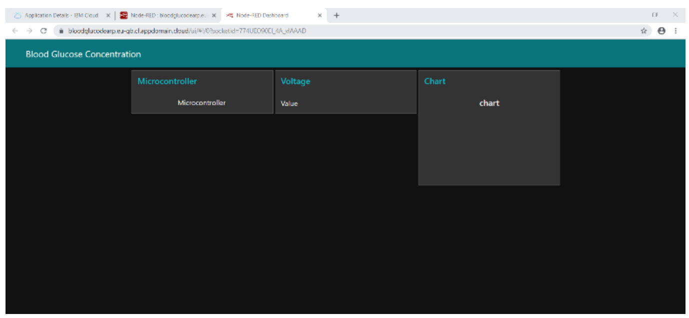


*Figure 3: GUI for monitoring*

## III. EXPERIMENT RESULTS AND ANALYSIS

### 3.1 Results using Infrared technique

The desired system is developed. Glucose solution of different concentration are made. Deionized water was used to make the solution. The experiment is conducted in reflectance mode. In this mode the transmitter and receiver are kept on one side of the glucose solution. More the glucose solution concentration more is the reflection of the infrared light and hence more is the output voltage. The result of the experiment conducted in mentioned in Table 1.

| Sr. no | Glucose Concentration (per 100ml) | ADC value |
|---|---|---|
| 1 | 50ml/42.27g | 546 |
| 2 | 90ml/76.06g | 592 |
| 3 | 10ml/8.45g | 528 |
| 4 | 120ml/101.44g | 689 |
| 5 | 200ml/169.07g | 710 |
| 6 | 125ml/105.67g | 692 |
| 7 | 150ml/126.60g | 637 |

*Table 1: ADC value with respect to glucose concentration*

The ADC used here is 10-bit so its maximum value is 1023. The graph of Glucose concentration versus the ADC value is shown in figure 4. The X-axis is the ADC value and the Y-axis is the Glucose concentration. The equation found out using linear regression is y = 0.645941x – 315.529, where y is the glucose concentration and x is the ADC value got from the microcontroller. This equation is fed to the microcontroller program to get the glucose concentration.

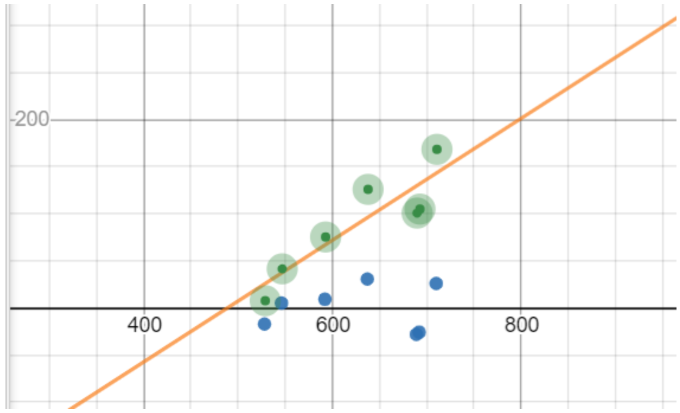


***Figure 4: Glucose concentration Versus ADC value***

**3.2 Results using Gas detection technique**

The MQ-9 gas sensor was connected to the desired circuit and the ADC value is obtained as shown in table 2. The graph of Acetone in ppm versus ADC value is shown in figure 5. The X-axis is ADC value and Y-axis is Acetone in ppm. The regression eqaution formed is y = 8.9984x – 725.5477. This equation is programmed in the microcntroller to get the desired results.

| Sr. No | Acetone PPM | ADC value |
|---|---|---|
| 1 | 1000ppm | 184 |
| 2 | 1500ppm | 256 |
| 3 | 2000ppm | 307 |
| 4 | 3000ppm | 409 |

***Table 2: Acetone PPM Versus ADC value***

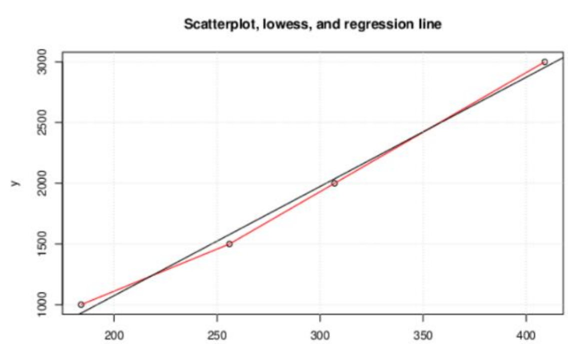


***Figure 5: Acetone in ppm versus ADC value***

## IV. CONCLUSION

In this study we performed Near infrared spectroscopy and Gas detection techniques on various glucose concentration and Acetone Concentration respectively. A good correlation was observed between the glucose concentration and output ADC value as seen in Fig 4. A good correlation was also observed between ppm concentration of acetone and ADC value as shown in figure 5. The accuracy of the circuit can be improved by improving the efficiency of the filter circuit for more effective noise cancellation. Instead of using IR LED of only 940nm a combination of IR LED's having wavelength in different overtone regions can be used for increased accuracy. More sensitive receivers can be used for improving accuracy. Instead of using MQ-9 Gas sensor a more accurate sensor can be used. An accurate sensor for detecting acetone is not readily available and hence one will have to fabricate it. An ADC of 14 bit can be used for increasing the accuracy. Thus, this method can be used for detecting blood glucose concentration.

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