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GSM Based Needleless Blood Glucose Monitoring System

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Abstract - *Diabetes is a common chronic disease in mostly all countries worldwide. The most commonly used method to measure glucose level in blood is an invasive method which is painful, expensive and danger in spreading infectious diseases. Over a long term, the invasive method results in damage of finger tissues. As an alternative, the noninvasive method can be used which facilitates frequent testing, relieves pain and discomfort caused by frequent finger pricks. A noninvasive method of glucose level measurement is proposed in this project .In this method we look into using infrared light to measure the blood sugar levels .The variation in the intensity of NIR light received from the photo detector after passing through the finger is used to determine the glucose level of blood. The measured glucose level is displayed in LCD display.*

***Key Words*: Diabetes; Blood glucose; GSM module; Non- invasive method.**

1. INTRODUCTION

Diabetes is considered as one of the major death contributors in non-contagious diseases the current method uses self monitoring glucose meter, these methods are invasive. The main disadvantage of such method is that, it requires pricking of finger, extracting the blood from forearm and doing chemical analysis which uses test strips. This also gives pain and discomfort due to frequent finger pricks. Non-invasive techniques are more useful and user friendly. It reduces the health care cost and other difficulties involved in invasive method of glucose monitoring method of glucose determination.

Diabetes is one of the biggest challenges faced by the people in the 21st century which has affected millions of people worldwide. It is responsible for the cause of blindness, heart disease, stroke, obesity and renal failures. Blood glucose is the main source of energy in our body. Glucose is produced from the food we eat. Diabetes affects body's ability to produce insulin, which is a hormone that is needed to process blood glucose in our body .

Diabetes is caused when our body's sugar level or glucose level is high. Insulin is a hormone produced by pancreas which helps the blood to carry glucose to all cells in our body. Sometimes our body doesn't produce enough insulin causing glucose to stay in our blood without reaching the body's cells. Thus blood glucose levels in our body gets too high causing diabetes. As a result, blood sugar level should be kept under control by following strict diet and insulin injections. Periodic and self monitoring of blood glucose level is necessary for the patients suffering from diabetes .

There are mainly three types of diabetes namely, type1, type 2 and gestational diabetes. In type 1 diabetes, pancreas cannot produce enough insulin as the β cells in pancreas are destroyed, so the pancreas cannot produce sufficient insulin needed by the body, It is also known as insulin dependent diabetes or Juvenile diabetes. In type 2 diabetes, the body is unable to use the secreted insulin since the cells cannot absorb glucose because of the problems with receptors. It is also known as non-insulin dependent or adult onset diabetes. Gestational diabetes occurs during pregnancy, which leads to type 2 diabetes after delivery. Gestational diabetes occurs during pregnancy as a result of hormonal changes in the pregnant mother, it develops during the middle stage of pregnancy.

Methods of Monitoring Blood Glucose

Blood glucose monitoring is very important to keep glucose level under check, but diabetes cannot be cured. Blood glucose monitoring methods can be classified into two methods; they are invasive glucose monitoring method and non-invasive glucose monitoring method .

Invasive glucose monitoring method is the most common method used for monitoring blood glucose level. It involves pricking of hands or fingers to monitor glucose level. The blood from the patient is taken and given to disposable test-strip, which calculates the blood glucose concentration .

Non-invasive glucose monitoring method is the most recently advanced method for glucose monitoring which is being studied and further researches are carried out. Polarimetry, Raman spectroscopy, photo acoustic spectroscopy, Mid-infrared spectroscopy and Near infrared spectroscopy, Fluid extraction from skin Optical rotation of polarized light are some common methods used for non-invasive blood glucose monitoring .

In this paper, the design of a non-invasive glucose blood monitoring device using the absorbance principle is proposed. The proposed device is designed to be able to detect glucose level in blood using near infrared rays. The design of the device is not only intended for diabetic patients but are also for non- diabetic patients, to help maintain a normal blood glucose level for a healthy life style.

2. LITERATURE SURVEY:

PAPER 1: Simon C.H. Lam, Joanne W.Y. Chung, K.L. Fan and Thomas K.S. Wong School of Nursing, "Non-invasive blood glucose measurement by near infrared spectroscopy: Machine drift, time drift and physiological effect".

A non-invasive approach is the painless method for blood glucose measurement. However, no noninvasive blood glucose meter currently in use has provided consistently reliable results, due to many interfering non-specific physiological signals during the measurement (especially for long-term measurement). According to Danzer et al., the long-term unreliability might be due to the physiological differences amongst subjects and time drift factors. Thus, diabetic patients still need to rely on painful finger-prick sampling for daily glucose measurement.

PAPER 2: P.Daarani & A.Kavithamani , "Blood glucose level monitoring by noninvasive method using near infra red sensor".

In this paper, when a light ray passes through biological tissues, it is both absorbed and scattered by the tissues. Light scattering occurs in biological tissues due to the mismatch between the refraction index of extracellular fluid and the membranes of the cells. Variation in glucose level in blood affects the intensity of light scattered from the tissue.

PAPER 3: Sathiyanarayanan, Sivagnanam.R, Smrithisri.V.K, Dr.V.Thulasi Bai, "Smartphone Based Non-Invasive Glucose Monitoring".

In this paper, design uses the NIR spectroscopy techniques to detect the concentration of glucose level in blood through non-invasive. A sensor clip giving nearinfrared radiation of 950nm wavelength is used as the transmitter, which penetrates through tissue and attenuates the light signal. And the attenuated signal is perceived by the photodiode, of wavelength 900nm placed in the opposite side of the sensing clip. The sensor part is placed at earlobe for blood glucose level detection. The attenuated rays are converted to respective voltages by the photodiode. In which, the analog signal received from the photodiode is converted into digital signal by the Arduino (Microcontroller) using the analog port.

3. METHODOLOGY:

BLOCK DIAGRAM OF PROPOSED WORK

The proposed work is based on NIR optical technique. NIR light source of 940 nm wavelength is chosen because it is suitable for measuring blood glucose concentration. The sensing unit consists of NIR emitter and NIR receiver (photodetector) positioned on either side of the measurement site (fingertip) as shown in figure1.When the NIR light is propagated through the fingertip in which it interacts with the glucose molecule, a part of NIR light gets absorbed depending on the glucose concentration of blood and remaining part is passed through the finger tip. The amount of NIR light passing through the fingertip depends on the amount of blood glucose concentration.

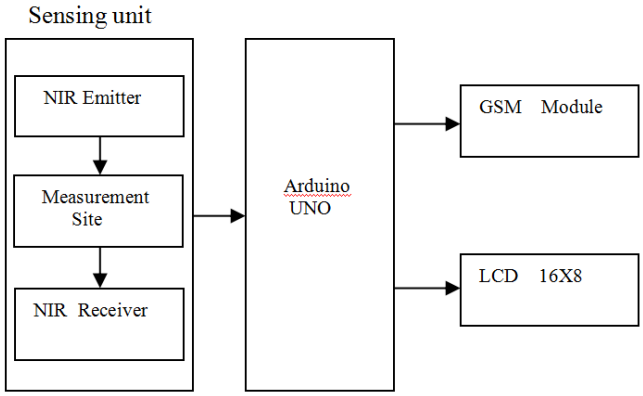

Fig -1: Block Diagram of proposed methodology

The transmitted signal is detected by the photodetector. The output current of the photo detector is converted into voltage signal and then it is filtered and amplified. This amplified signal is fed into Arduino microcontroller. The inbuilt ADC block is used for converting the received analog signal to digital form. This digital signal is processed by using second order regression analysis to predict the blood glucose value and the blood glucose value is displayed on the LCD display.

DESIGN

The circuit diagram of the designed system consists of filtering stage and amplification stage as shown in figure 3. The electrical current obtained from the photo detector is converted into the voltage by placing the load resistance R4= 50kΩ at the anode side of photodiode. The cut-off frequency of high pass filter and low pass filter are designed as 2.34 Hz and 1.59 kHz respectively.

Cut off frequency of LPF = $1/(2\pi R1C1)$

$= 1/[2\pi(1*103)\ (100*109)] = 1.59$ kHz

Cut off frequency of HPF = $1/(2\pi R2C2)$

$= 1/[2\pi\ (68*103)(1*10\text{-}6)] = 2.34$Hz

Voltage gain = 1 + (Rf / Rin)

= 1+ [(680*103)/ (68*103)] = 101

The amplified output voltage is connected to analog pin A0 of Arduino due microcontroller for converting the analog signal into digital values. This digital value corresponds to the glucose level. From this digital value, the actual glucose level is determined using polynomial regression equation. This equation is formed from the glucose levels obtained from the laboratory using invasive measurement.

The polynomial equation relating the analog voltage and the glucose level is computed by using regression tool and shown below,

y = (8*10-5) x2 + 0.1873x + 46.131,

Where x and y are analog voltage (mV) and glucose level (mg/dl) respectively.

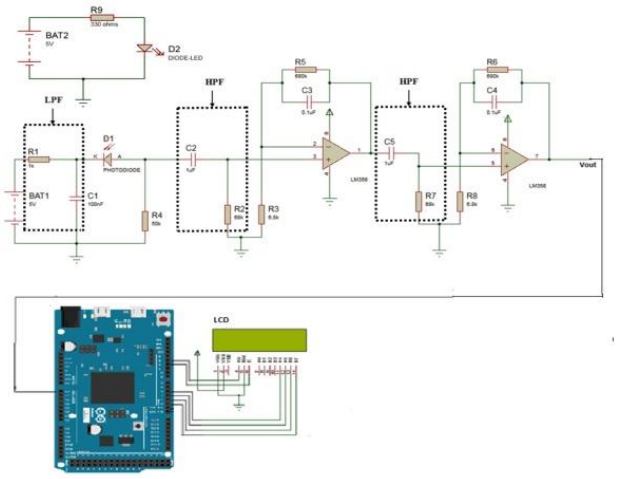

Fig -2: Circuit diagram for sensor

4. HARDWARE IMPLEMENTATION

The non-invasive blood glucose monitor designed contains a sensor unit, processing unit and display unit. The sensor unit also acts as a transducer which detects the signal from the patients and converts it to the electrical form and transmit it to the processing stage. The processing stage sends the processed data to the output unit to display the results. The sensor contains transmitter and receiver on both the ends respectively. The below given Figure 3 shows the hardware model of GSM based needleless blood glucose monitoring system.

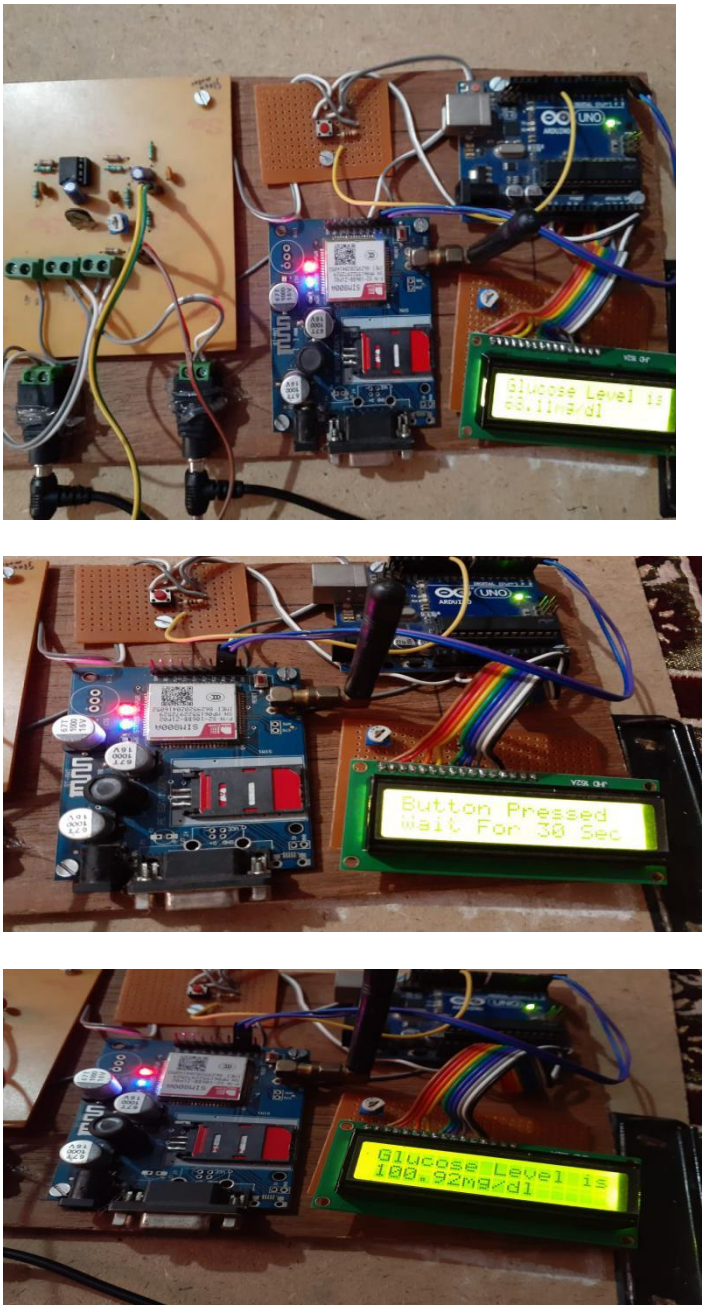

Fig -3: Hardware model of GSM based needleless blood glucose monitoring system.

A processing time of about 30 seconds is required for the LCD to display the results, the obtained results shown on LCD and are transmitted using the GSM module.

5. RESULTS

Table -1: Comparison table for invasive and non-invasive glucose concentration

S.no	Glucose concentration measurement		Error %
	Invasive (mg/dL)	Non-Invasive (mg/dL)	
1.	138	87.2	19.7
2.	127	1115	9.5
3.	107	127.4	4.33
4.	113	96.4	17.21
5.	160	150.4	6
6.	165	152	7.87
7.	170	161	5.29
8.	143	130	10.4
9.	121	117.2	3.14
10.	110	95	13.6

Thus the design of blood glucose monitoring device is implemented and tested successfully. The results obtained from two methods were compared and we observed that the non-invasive system designed by us found more than 85% accurate than compared to the invasive method.

6. CONCLUSION

This proposed system eliminates the risk of spreading infections by finger pricking and is more comfortable and low cost than invasive technique. It provides an easy way of measuring blood glucose levels of the diabetic patients at home and even without the need of a specialist to monitor blood glucose level.

This design provides the data sharing facility to transmit the patient glucose level and location to the doctor for patient investigations .The accuracy of the design is similar to that of the currently available invasive methods.

7. FUTURE SCOPE

With the addition of battery this design can monitor blood glucose levels while travelling or when the external current is not available. Further the processing time needed by LCD which is 30 seconds in our design can be further decreased by calibration.

It can be also provided with a dark box to place the sensor to prevent external light from passing through it as sensor contains a photo-detector, which detects IR light emitted by photo-emitter passing through the blood which can get attenuated by external light.

A tight band can be worn over the hands to prevent them from shaking in order to prevent disturbances in blood flow and hence more accurate results can be obtained.

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