AN OPTICAL METHOD FOR MEASURING BLOOD GLUCOSE NON INVASIVELY

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ABSTRACT

This paper investigates a possible method of measuring the Non Invasive Blood Glucose Concentration Level (NI-BGC), with the main objective of providing Preventive care against the onset of diabetes by frequent self monitoring. This paper rationalizes a method for NI-BGC through the use of Near Infrared Light (NIR) by emission from LASER and tries to find a relationship between absorbance of NIR by glucose. An apparatus based on transilluminated LASER beam via the sensitive part of human finger is considered. This device depends upon atomic gas Helium-Neon (He-Ne) laser operating at a wavelength of 620-630 nm. During measurement the index finger is inserted into the sensing unit and the LASER light is passed through it, and the transilluminated optical signal is detected by a photodiode and an equivalent electrical signal is obtained. With the help of look up table this electrical value is displayed in the form of direct blood sugar in mg/dL (milligram/deciliter).The result obtained shows a linear relationship of increase in glucose level as transmitted light intensity level decreases.

Keywords: Conversion table, Diabetes, LASER light, LCD display, Photo diode and Transilluminance

I.INTRODUCTION

World Health Organization (WHO) estimated that the worldwide figure of diabetes patient is expected to grow to 438 million by 2030, due to the poor food practices and lack of exercise of the present society. So it is the right time for the engineers to develop a health care system that is safe and convenient such that it can be used to control the rapid increase of diabetes mellitus among people. Present day technologies limit such monitoring due to the high cost of test strips and severe pain involved. Mainly pathologies like type 2 diabetes require frequent self monitoring of blood glucose which causes piercing of hand many times and usage of multiple costly test strips per day. For this reason it's essential to go for what is called non invasive? Because in non invasive technique there is no need for finger pricking to take BGC reading ,hence its quoted to be painless and also the cost is affordable. NI-BGC measurement does not measure glucose directly, instead it relies on the measurement of glucose level of other interstitial fluid of subcutaneous tissues[1]. In this proposal the design and experimental set up for NI-BGC measuring device is discussed in detail in section II and III and also the conversion technique used and the test results obtained are reported in following sections IV and V in detail. The main advantage of the system is its cost with no pain involved.

Diabetes mellitus is a condition of deficiency rather than a disease because people are said to be diabetic when their Pancreas (a gland in the digestive system) no longer produce insulin or when cells in the body stop responding to insulin. Insulin is used by human body to break and convert the raw food particles into glucose; this glucose provides energy which acts as fuel for human cells to do their work actively. Diabetes is classified into four types:

1.) Type 1 Diabetes: In this case the pancreas no longer produces insulin. This mostly occurs in childhood.
2.) Type 2 Diabetes: In this case, cells do not effectively use insulin that is produced. This accounts for vast majority of cases for about 90%-95% and is diagnosed in latter part of life at the age of forty.
3.) Gestational diabetes: This type is less common and occurs during pregnancy.
4.) Other forms of Diabetes: This includes Pre-Diabetes, Congenital Diabetes, Cystic fibrosis related Diabetes, Steroidal Diabetes.

Out of all these first two types are most commonly noticed ones. The symptoms of Diabetes include frequent urination, unusual thirst, weight loss, unusual hunger, fatigue, blurred vision, etc… [2]. Diagnosis of Diabetes can be done through blood test or urine analysis at some cast. The following table 1 indicates criteria for diagnosing diabetes.

Table1.Diagnosis criteria

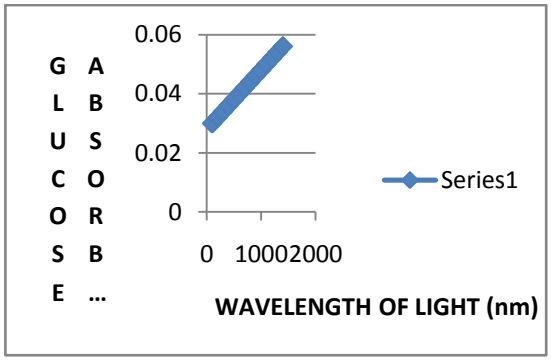
CONDITION	FASTING (in mg/dl)	POST PRANDIAL & RANDOM (in mg/dl)
NORMAL	60-110	60-160
TOLERANCE	≤126	≥160-200
DIABETES	>126	>200

The Diagnosis of diabetes can be carried out under three ways:- Invasive technique, minimally invasive technique and non invasive technique [3],[4].This non invasive measurement can be done optically using light source or non-optically using sweat, urine or tears as samples for analysis. This paper mainly concentrates on the optical method of testing blood glucose by using LASER light to impinge NIR light on the most sensitive part of skin and the transilluminated light from other end of the skin is collected by a photodiode to provide electrical equivalent of blood glucose.

The light focused on the skin is partly absorbed and scattered due to its interaction with the chemical components present in the tissue. Attenuation of light is given by $I = I_O \exp(-\mu_{eff} d)$, where I, I_O are reflected and incident light intensity and the effective attenuation coefficient, $\mu_{eff} = f(\mu_a, \mu_s)$. μ_a and μ_s are absorption and scattering coefficients [5],[6]. Changes in glucose concentration affects μ_a and μ_s and hence the intensity of light, I also gets varied.

The two main optical properties of glucose based on which blood glucose is measurable are the Absorbance property and Transmittance V_s Reflectance property [7]. The absorbance of light by glucose increases as wavelength increases as shown in Figure1.

Based on the analysis and investigation, transmittance set up is best suited for glucose measurement than Reflectance as shown in Figure 2.



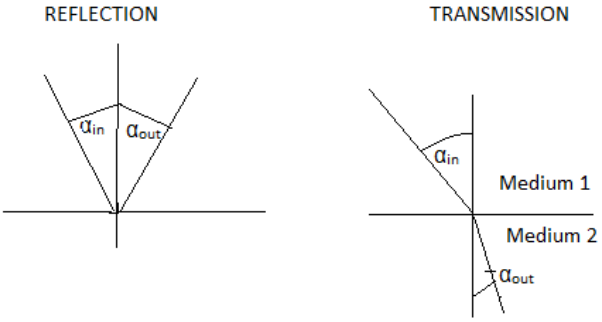


Figure 1. Absorbance property of glucose **Figure 2. Transmittance Vs Reflectance**

II. SYSTEM DESCRIPTION

The block diagram of the proposed system is shown below in Figure3.

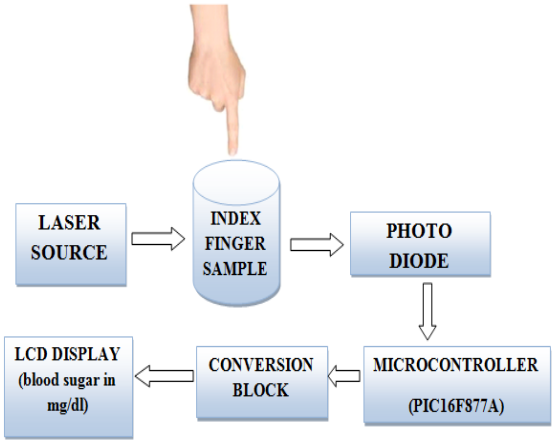


Figure 3. Block diagram of the system

In the above block the LASER light source operated at 630 nm is allowed to pass through the test sample (here it is the index finger). The incident light which falls on the human tissue is partly absorbed depending on the glucose present in the person's blood and other interstitial fluids [8]. Some amount of LASER light will get scattered also. To prevent this, an extra closed arrangement is made so as to minimize the error. The transilluminated light thus coming out at the other end is collected by the photodiode which operates under reverse bias condition. The photodiode used acts as a photo detector that converts the received light intensity into equivalent current or voltage reading (here voltage reading is considered) and the output of photodiode is used as analog input to the analog channel of PIC 16F877A kit. In this thesis work a 10 bit resolution ADC is used to get variations from 0 to 1023. The microcontroller is also interfaced to the LCD display unit to view the output in mg/dL. PIC16F877A kit is also programmed with a conversion table thus converting the voltage value from photodiode into appropriate blood glucose value. The flowchart explaining the working of entire system is shown in Figure 4.

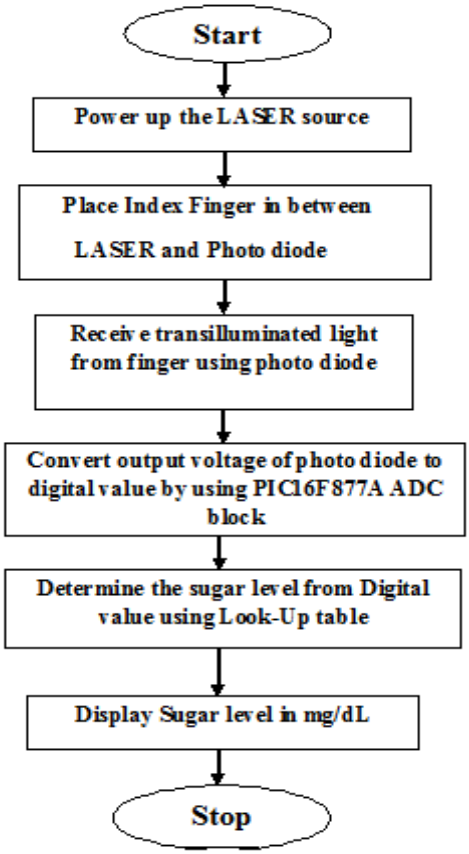
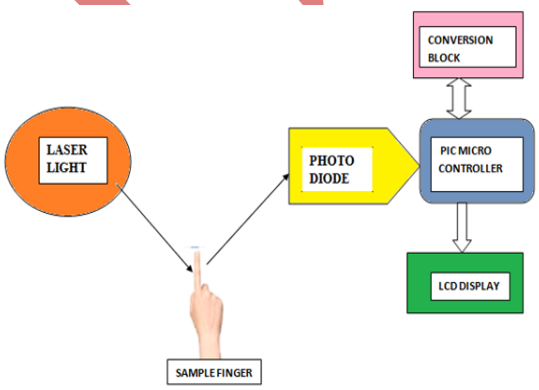


Figure 4. Workflow design

The circuit mainly works based on the principle of photometry. The Figure 5 denotes the photometric principle i.e., change in light intensity affects the output. The output of the photodiode varies depending on the variation of the wavelength of LASER light source as well as based on the concentration of glucose.

III.CIRCUIT DESCRIPTION

The circuit of the proposed system is as shown in Figure 6. It indicates mainly how the connections are made for the purpose of interfacing.



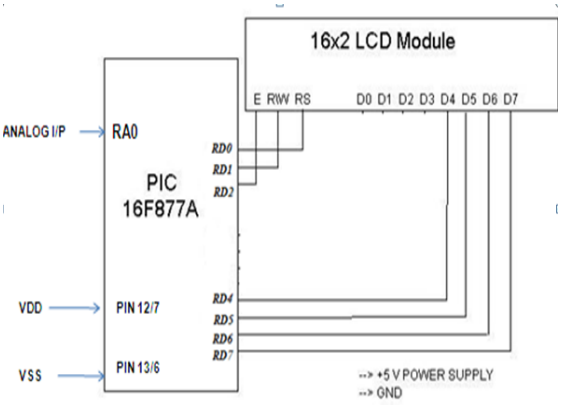


Figure 5. Photometric principle **Figure 6. Circuit description**

3.1 Interfacing with Microcontroller

The need for microcontroller interfacing here is to convert the analog voltage across the photodiode into its digital equivalent, since the analog value cannot provide wide range of variations. This interfacing helps to get a variation between 0 and 1023 for a supply voltage of 5. The analog to digital conversion proceeds as shown:

To do the A/D conversion and to see the digital value of blood glucose value

(In mg/dL) in LCD follow the steps given:

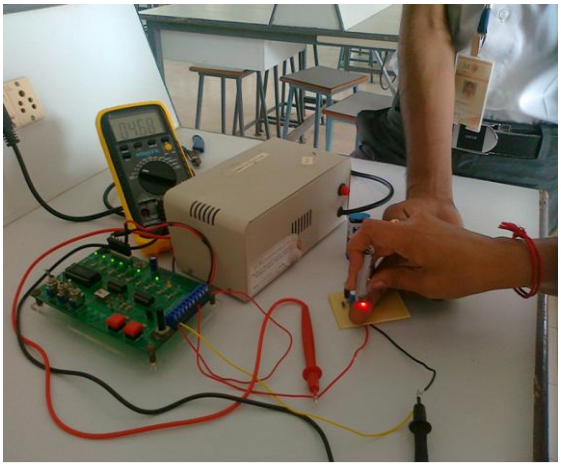
1. Configure the A/D module and LCD PINS.
2. Configure the A/D interrupt (if required).
3. Wait for the required Acquisition time.
4. Start conversion:
   Set GO/$\overline{\text{DONE}}$ bit HIGH.
5. Wait for A/D conversion to complete.
6. Read A/D result register pair.
7. For the acquired digital ADC value search for the Look up table to get the most nearby equivalent Blood glucose value.
8. Provide appropriate control signals to LCD display and enable it to display the blood glucose value in mg/dL directly and non- invasively.

IV. CONVERSION TABLE

The conversion technique used to convert the ADC value **(digital equivalent of input voltage)** into blood glucose value directly is a simple look up table (LUT).Look-up table processing is based on the list of tabulated values for computing the output value of blood glucose level for various diagnosis of different persons to achieve fast and real time blood glucose values non invasively. It is important to see what control like functions/value can be integrated into the LUT and at what cost. Several factors must be taken into account when designing a LUT such as block architecture, table sizing, value range to table mapping, choice for updating etc… Here in this paper, LUT for about 250 readings has been constructed in order to save memory. So when a person tries to take blood glucose reading he/she must switch on the set up, power the LASER source and the ADC value obtained will be sent to the look up table and a most prompt and near equivalent sugar value will be displayed in the LCD display. If the size of the LUT is increased, then the accuracy of the system as well as the efficiency increases with a small compensation in time to display the result.

V.RESULTS AND DISCUSSION

Testing of the non-invasive device was done by taking the readings from 250 persons in JEBI DIAGNOSTIC CENTRE and the results obtained for each person was cross checked with the conventional blood test taken in the same lab and it was found that the device correlated well with an accuracy of about 85% . Both the ADC value and blood sugar value are tabulated in table 2. It was well noticed that the ADC value increased as glucose value decreased, evidencing the Absorption as well as the Transmittance property of glucose. The experimental setup for the results obtained initially showing voltage across the photodiode and also the result of final setup showing direct blood glucose reading are shown in Figure 7 and Figure 8 respectively.



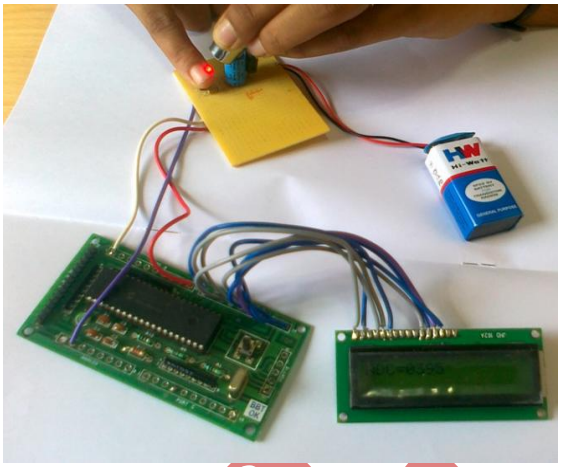


Figure 7. **Figure8.**

Figure 7. Shows experimental setup of result showing voltage across photodiode

Figure 8. Shows experimental setup of the final prototype showing direct blood glucose value.

The Table 2 shows the readings obtained in the laboratory using the newly designed non invasive blood glucose monitor. In the tabulation, readings of 15 persons among 250 are shown. It's found that ADC value increases as glucose value decreases based on the theoretical discussions made. One or 2 values deviates a little, due to the reasons such as: - tough skin tone, very thick skin surface and noise due to external light source.

The errors might have occurred because there is no means of aligning the light source with the 1 mm^2 area of photodiode. So there is a chance for scattering to take place. The Figure 9 shows a linearity graph for the readings in Table 2.

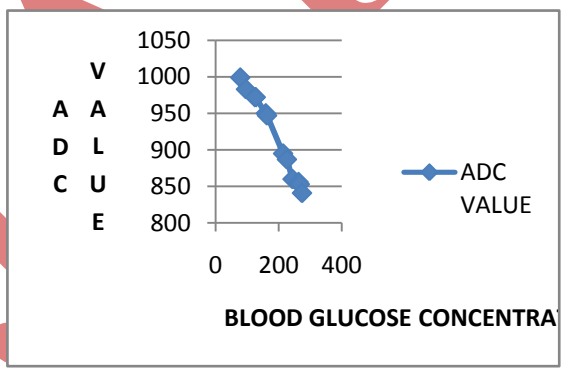


Figure 9. Graph showing relationship between ADC value and blood glucose value

VI.FUTURE WORK

The scope for future work in this area is more because the diabetes count keeps on increasing and in this scenario if a device comes with full accuracy to measure blood glucose with less cost and no pain then, it is the desired dream for all people who involve continuous monitoring. So the forth coming works may concentrate on increasing the accuracy by using LASER source of increased wavelength and some high quality detectors in place of photodiode. The scattering losses can be minimized by making a closed set up.

Table 2. Result obtained using LASER optic device

S.NO	NAME	BLOOD SUGAR VALUE (mg/dL)	ADC VALUE
1.	MURUGESAN	78	999
2.	MEENAKSHI	96	983
3.	NATARAJAN	96	980
4.	SAKTHIVEL*	111	992
5.	SHANMUGAM	126	972
6.	SAMUVEL RAJ	126	972
7.	TIRUMALAISAMY	159	950
8.	GOPAL	163	947
9.	SARASWATHI	214	895
10.	SHERFU NISHA	226	887
11.	MANOKAR	244	860
12.	SIVA SHANMUGAM	263	856
13.	THULASI AMMAL	267	853
14.	PRAKASH	274	841
15.	MYLSAMY*	281	900

(* Readings with little Deviations)

VII.CONCLUSION

Thus a device for measuring blood glucose non-invasively using a novel approach is designed and it is found to be very simple, painless and much economical. Though it deviates for certain persons because of their skin nature it is very good at diagnosing the blood sugar with 85% accuracy. In conclusion this paper has suggested a means for non –invasive diabetes diagnosis. Though it's at the initial stage it will take a lead in near future.

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