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Blood Glucose Estimation by Non-invasive Optical Technique

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ABSTRACT

Diabetes is a metabolic pathological condition, which affects important organs of human body if not diagnosed and treated on correct time. Now a days glucose measurements methods are invasive which generally involves puncturing of finger. These methods are painful and has difficulties of spreading infectious diseases. Therefore, there is need of developing a non-invasive monitoring system which measures blood glucose without any pain.

In this paper, the non-invasive type blood glucose prototype is designed by optical technique. Light is exposed on the region of interest through an optical source with the human intervention. The transmitted light from the optical source is detected using an equivalent photodiode. The analog signal from photodiode is converted and is amplified by the signal conditioning unit of microprocessor and the corresponding blood glucose value is identified and displayed in LCD.

Index Terms: Non-invasive, Blood Glucose, Near Infrared (NIR), LED, Photo detector, Transmittance, Absorbance.

1. INTRODUCTION

Diabetes is emerged as a major healthcare problem in India. Today approximately 8.32% of global adult population is suffering from Diabetes. Diabetes mellitus is a medical concern in which the body is not producing the quantity or the quality of insulin needed to maintain the normal blood glucose in the body. Insulin is the hormone in the human body that enables glucose (sugar) to enter the body cells to get energy. There are two types of diabetes. Type I or Insulin dependent diabetes mellitus (IDDM) and Type II or Non-insulin Dependent Diabetes Mellitus (NIDDM).

The technologies available in the market for blood glucose measurement are invasive. Invasive methods are painful, time consuming, expensive and also there is a potential risk of spreading diseases like Hepatitis & HIV. This makes the process of continuous blood glucose monitoring a tedious one.

Blood glucose monitoring is to measure the amount of glucose in blood, for the patients with symptoms of abnormally high or low blood glucose levels in the body. The patients with low glucose level have to take appropriate insulin doses on time. Now a days home-use glucometers are available, which helps in the continuous monitoring process and improve the quality of life of diabetic patients. However, such monitors require new test-strips that are expensive.

Non-invasive blood glucose methods are without pain, convenient and cost effective glucose monitoring for diabetic patients. Non-invasive blood glucose measurement is one which can be used for continuous monitoring of glucose levels in human body for both Type I and Type II diabetic patients. Improving glucose measurement techniques to make the measurement simple and reliable, continuous monitoring has received a lot of attention from both academic and industrial researchers. Near-IR (NIR) is one of the most widely recommended optical region because of its high penetration in skins. Several methods have been

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used to measure total blood glucose. The most common method is spectrophotometric analysis of light absorbance based on Beer–Lambert law.

Measurement of blood glucose in a painless and non-invasive manner involves passing a selected beam of wavelength of near-infrared light through the human tissue. For the accuracy of blood glucose values the viable spectral regions are studied [1].

In this paper, the design issues and development of non-invasive blood glucose measuring device is discussed using the optical techniques. The suitable NIR band of 940nm wavelength for glucose absorption is identified [2]. The absorption band arises from combination and overtone molecular vibrations associated with C-H and O-H bonds of the glucose molecules. Apart from glucose, water, protein and fat are also found to be the absorbers of NIR light [3].

2. OPTICAL TECHNIQUES

Raman Spectroscopy: It is based on the usage of a laser light to stimulate oscillation and rotation in molecules. Consequent emission of scattered light influenced by this molecule vibration, depends on the concentration of the glucose molecule [2]. This is economical because of the usage of fixed wavelength lasers that relatively costs low. This method suffers due to the instability of the laser wavelength and intensity, and long spectral acquisition times.

Fluorescent spectroscopy: This technique analyzes the fluorescence from the sample. It has also been proven that fluorescence intensity is depending on the glucose concentration in the solution [2]. Light in the visible spectrum can be used and sufficient for studying fluorescence of tissues. The addition of fluorescent materials, in tissues, lead to strong scattering.

Polarization change: When polarized light transverses a solution containing optically active solutes polarization changes occurs which is stimulated by the glucose molecules. This method is reported to be the first proposed non-invasive technique or glucose measurement in humans [7]. This make use of visible region of light. The major drawback found is that, it is sensitive to the scattering properties of the examined tissue, because scattering depolarizes the light.

Mid Infrared spectroscopy: It is based on light in the 2400–10,000nm spectrums. Its physical principle is same as that of NIR. Due to the higher wavelength, mid-infrared emits decreasing scattering, and increasing absorption when compared to NIR [2]. Mid-infrared compared to NIR produces sharper peaks. But the penetration depth is poor.

Near infrared spectroscopy (NIR): The light focused on the body is partially absorbed and scattered, due to its excitation of molecular vibrant within the tissue. Glucose concentration can be estimated by variations of light intensity by transmission through the glucose molecule in the tissue and reflected by the tissue itself. The penetration depth is very high. But the measured signal is very weak.

Near Infrared region: The following three regions are generally accessible.

The combination region: 2.0 to 2.5 microns (5000 - 4000 cm^{-1})

The first overtone region: 1.54 to 1.82 microns (6500 - 5500 cm^{-1})

The short wav elength near infrared (sw-NIR) region: 0.7-1.33 microns (14,286 - 7500 cm^{-1}) [1]. Glucose has its absorption in both combination and first overtone region.

The entire near infrared region of the electromagnetic spectrum includes light with wavelength ranging from 0.7 to 2.5 microns [4] (14,286 – 4000 cm^{1} wavenumbers).Near infrared spectroscopic information corresponds to harmonics of overtones and combination region of fundamental vibrational transitions more frequently associated with mid-infrared spectroscopy. NIR's overtone and combination absorptions are based on CH, OH and NH molecular groups

3. METHODOLOGY

Proposed work: In order to overcome the difficulties of Invasive Blood Glucose measurements the concept of Non-Invasive blood glucose measurements arises. Here the Non-invasive blood glucose device is developed using the optical techniques. The optical technique used here is the Near-Infrared (NIR) due to its high penetration in skin. The circuit is designed with LED (TSAL6200) of 940nm wavelength with equivalent photo detector (TSOP38238).Since the photo detector is having the pre-amplifier, the pre-amplification is done. The corresponding voltage reading is obtained.

The electrical and optical characteristics of the LED and the photo detector is studied by their waveforms. Here the transmittance is considered hence it is easy to find the absorption by the negative logarithmic of absorption. The transmittance of NIR light depends on the amount of glucose molecules in the path of light.

The Near Infrared emitting diode (TSAL6200) LED of 940nm wavelength is placed opposite to a photodiode that detects the light from LED which is the transmitted signal from the human intervention. TSOP38238 is the photo detector used for LED of 940nm wavelength. Then the values are amplified and calibrated by microcontroller and displayed in LCD.

3.1. Component Description

LED emitter module: TSAL6100 is an infrared emitting diode with high radiant power and high speed moulded in a blue-grey plastic package. Its peak wavelength is 940nm.

Feature: High reliability, High radiant power, High radiant intensity, Low forward voltage, suitable for high pulse current operation.

Photo Detector Module: TSOP38238 is the photo detector module for the equivalent TSAL6100 LED module. It is a 3 pin IR receiver module with 1 = out, 2 = Ground, 3 = Vs. It has AGC amplifier for amplifying the input signal and band pass filter. The demodulator demodulates the output signal and can be directly connected to microprocessor.

Features: Very low supply current, photo detector and preamplifier in one package, internal filter, improved shielding,

Supply voltage: 2.5v to 5.5v, improved immunity against ambient light, insensitive to supply voltage and ripples.

Microcontroller: ATMEL AT89S52 is one of the most advanced microcontroller. This controller is widely used for experimental and modern application because of its low price, wide range of applications, high quality, and ease of availability. It is an 8-bit microcontroller with 8k*14 bit flash program memory,

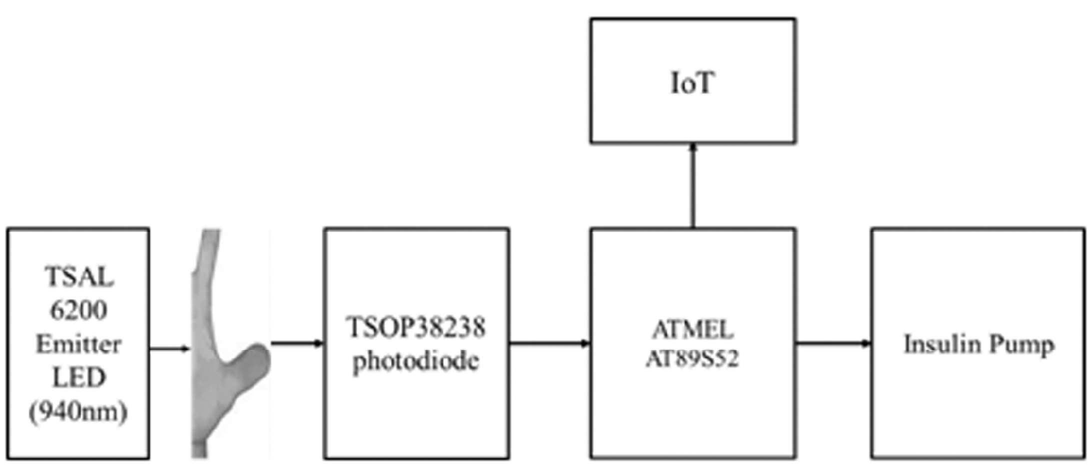

Figure 1: Block Diagram of Non-Invasive Module

368 bytes of RAM and many other extra peripherals like ADC, USART, timers, pulse width modulation modules, and analogue comparators. It is based on the reduced instruction set computer (RISC) architecture. The microcontroller processes the photo detector output and calibrate the equivalent voltage values to the glucose values with specific algorithm. The internal ADC of the microcontroller is used to convert the analogue output of the photo detector into the equivalent digital value and displayed in LCD.

4. IMPLEMENTATION OF NON-INVASIVE MODULE

When the supply is switched on, the LED (TSAL6200) of 940nm wavelength starts blinking. With the human intervention of the LED light, transmitted light is detected by the photodetector (TSOP38238). This output voltage is measured. The preamplifier in the photodetector amplifies the detected signal. Amount of transmitted light depends on the glucose concentration present in blood.

5. RESULTS AND DISCUSSIONS

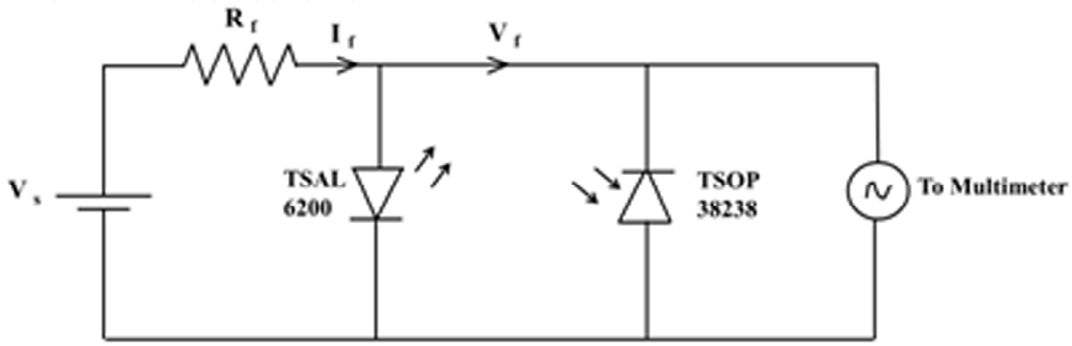

Figure 2: Non-invasive module

The experimental setup is developed with LED and photo detector along with signal conditioning unit. The area of measurement identified is the finger web. Light is passed through the finger web and the transmitted voltage is measured. The measurement was performed for 57 patients along with the corresponding clinical glucose values. A database is created with these measurements. Thus a look up table is created for wide range of glucose values ranging from 80mg/dl to 450 mg/dl. This look up table is fed to the microcontroller. Table 1 shows glucose values and the measured voltage values for 10 patients as reference. From the table, we can observe that there is a linear relationship between the measured glucose value and the detected output voltage. Fig 2 shows the corresponding plot.

Table 1
Measured output Vs Clinical Glucose

S. No	Patient	Glucose Value(mg/dl)	Output Voltage(V)
1	p1	160	2.66
2	p2	175	2.756
3	p3	180	2.98
4	p4	184	2.99
5	p5	204	3.02
6	p6	200	3.02
7	p7	207	3.05
8	p8	229	3.39
9	p9	250	3.55
10	p10	256	3.63

Curve fitting is done using MATLAB for the measurement and the related equation is obtained.

The equation for the fitted graph is as follows.

$$Y = 1e + 02 * x - 1.4e + 02 \quad (1)$$

Human blood not only contains glucose, but also water fat protein and hemoglobin. So the detected output voltage not only depends on the glucose concentration. The amount of interferences obtained from other components contribute to the constant value in the equation. From this equation for any detected output voltage, we can obtain the glucose value.

This module is developed as a prototype using ATMEL AT89S52 microcontroller. The detected voltage from the photodiode after amplification and signal conditioning is fed to the microcontroller. The measured output voltage is mapped to a glucose value with reference to the look up table.

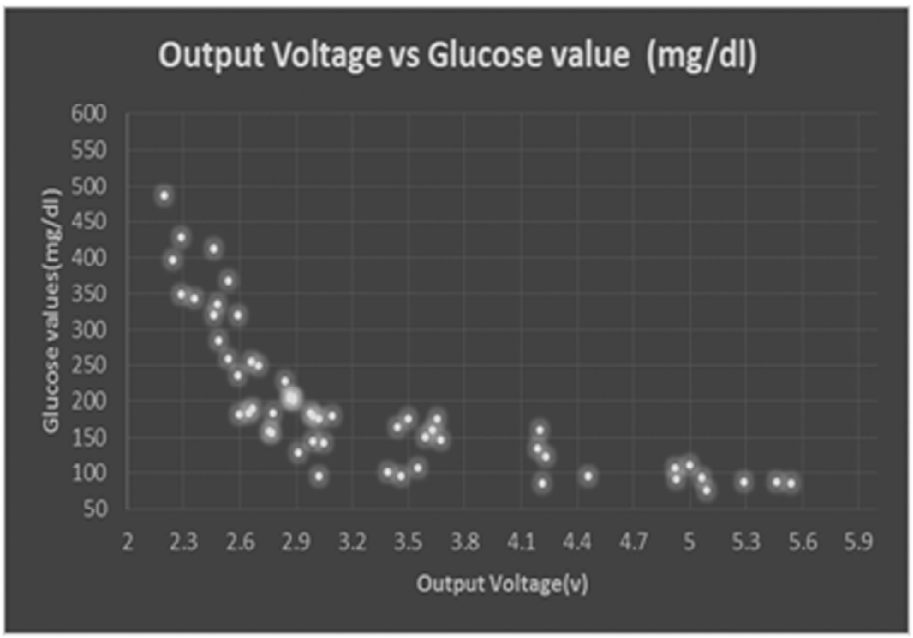

Figure 3: Output voltage vs Glucose concentration

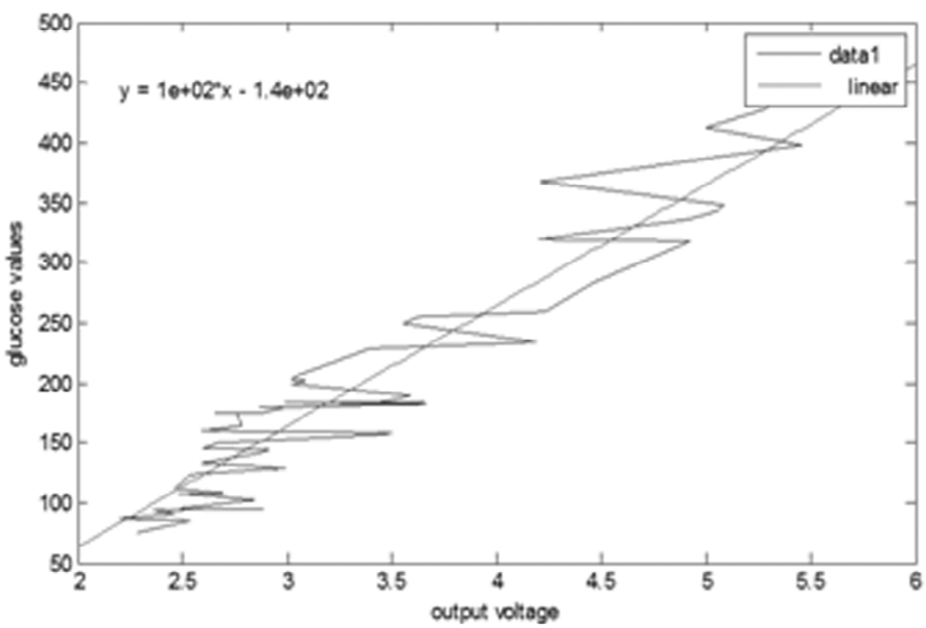

Figure 4: Fitted curve

6. CONCLUSION

In the present work, a non-invasive device is developed which helps for continuous monitoring of blood glucose in an economical way. When light is impinged on the area under measurement, the photodetector voltage is mapped with the database to obtain the current glucose value.

7. FUTURE WORK

The continuous glucose monitoring for IDDM (Insulin Dependent Diabetes Mellitus) and NIDDM (Non-Insulin Dependent Diabetes Mellitus) patients has to be done by multivariate calibration method by adding some more compactible LED's which is best suitable for continuous blood glucose monitoring. The glucose values have been recorded in cloud IoT for future reference of doctor and patients. For IDDM (Insulin Dependent Diabetes Mellitus) patient's insulin pump has to be developed by running the stepper motor where the reservoir and cartridge is connected with motor which acts as insulin pump to inject insulin to patients automatically according to their need.

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REFERENCES

[1] Neda Jahangir, Alireza Bahrampour, "Non-invasive Techniques for determination of blood glucose levels": A Review Article

[2] Jason J. Burmeister and Arnold Mark A, "Spectroscopic Consideration for Non-Invasive Blood Glucose Measurements with Near-Infrared Spectroscopy"

[3] Gary W. Small, Mark A. Arnold", Data Handling Issues for Near-Infrared Glucose Measurements"

[4] Jaspreet Kaur, Jagdish Kumar, H K Sardana, R Bhavnagar, and N S Mehla Central" Non- invasive blood glucose measurement using optical method: Feasibility study and Design Issues".

[5] Masab Ahamad, Awais Kamboh, "Designing Non-Invasive Blood Glucose Monitor".

[6] S Coster, MC Gulliford, PT Seed, JK Powrie, R Swaminathan, "Monitoring blood glucose control in diabetes mellitus: a systematic review", *Health Technology Assessment*, vol. 4, no.12, 2000.

[7] S.J. Yeh1, C. F. Hanna and O. S. Khalil, "Monitoring blood glucose changes in cutaneous tissue by tissue by temperature-modulated localized reflectance. Measurements", *Clinical Chemistry*, vol. 49, no.6, pp.924-934, 2003.

[8] O Amir, D Weinstein, M.D. Silviu Zilberman, M. Less, D. PerlTreves, H. Primack, A. Weinstein, E. Gabis, B. Fikhte, and A. Karasik, "Continuous noninvasive glucose monitoring technology based on occlusion spectroscopy," *Journal of Diabetes Science and Technology*, vol.1, no.4, pp. 463–469,July 2007.

[9] Anuj Srivastava, Md Koushik Chowdry, Dr.Shiru Sharma, Dr.Neeraj Sharma," Blood Glucose Monitoring using non-invasive optical method: Design and challenges"

[10] Mestry Dipti,"Overview of Non-Invasive Glucose measuring Techniques".

[11] O. Abdallah, A. Bolz, J. Hangman, H. Walles, and T. Hirth*:" Design of a Compact Multi-Sensor System for Non- Invasive Glucose Monitoring Using Optical Spectroscopy*", International Conference on Electronics, Biomedical Engineering and its Applications (ICEBEA'2012), Jan. 7-8, 2012

[12] Gennaro Gelao, Roberto Marani, Vito Carriero and Anna Gina Perri:"Design of a Dielectric Spectroscopy Sensor for Continuous and Non-Invasive Blood Glucose Monitoring", *International Journal of Advances in Engineering and Technology*, May 2012

[13] V.Ashok, A.Nirmalkumar, and N.Jeyashanthi:" A Novel Method for Blood Glucose Measurement by Noninvasive Technique Using Laser", World Academy of Science, Engineering and Technology, 2011.

[14] Prof.Mrs.A.A.Shinde, Dr.R.K.Prasad"Non Invasive Blood Glucose Measurement using NIR technique based on occlusion spectroscopy", International Journal of Engineering Science and Technology (IJEST), Vol. 3, December 2011.K. Elissa.

[15] O. Amir, D. Weinstein, S. Zilberman, M. lka Less, D. Perl-Treves, H. Pri-mack, A. Weinstein, E. Gabis, B. Fikhte, and A. Karasik: "*Continuous Noninvasive Glucose Monitoring Technology Based on "Occlusion Spectroscopy"*, Journal of Diabetes Science and Technology, July 2007.