Non-Invasive Blood Glucose Measurement

Authors

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ABSTRACT

The World Health Organization (WHO) report on global prevalence of diabetes for all age groups was estimated to be 2.8% in 2000 and 4.4% in 2030. This projects a rise in the total number of people with diabetes from 171 million in 2000 to 366 million in 2030. Over 62 million Indians have diabetes and many of them might not even know. Hence, the diabetes mellitus epidemic has emerged as a global health problem of the new era. The diabetic population is rising exponentially due to factors such as: sedentary lifestyles, increasing obesity, bad food habits, aging and population rise. These factors are responsible for rise the blood glucose levels, hence it is essential to monitor the blood glucose levels frequently. Methods as of today used to determine these BSLs are invasive which requires to take a prick on the desired body site. This method is painful, time consuming, uncomfortable and expensive as well. Hence; various non-invasive methods are being experimented to replace the conventional invasive methods. This paper proposes a non-invasive method to monitor blood glucose values using an Infrared (IR) sensor in the near-infrared (NIR) range. Occlusion spectroscopy technique is used to measure the optical parameters of the index finger as the body site. Blood glucose levels are monitored by the device and the level of glucose content either a high or low glucose are displayed using an LCD. This device is a primary approach to detect glucose levels non-invasively at ease. An algorithm is developed to relate values obtained from the non-invasive glucose meter to the actual glucose values obtained. This monitor proves to be a novel approach to the diabetic community to frequently monitor their blood glucose levels non-invasively.

Index Terms — Diabetes Mellitus, optical measurement, Non-invasive (NI) blood glucose monitor (NIBGM), Blood Sugar Levels (BSL) Near Infrared (NIR) frequency, and occlusion spectroscopy.

INTRODUCTION

Diabetes mellitus is a hormonal disorder. It is a medical condition in which the body does not adequately produce the quantity or quality of insulin needed to maintain a normal circulating blood glucose. Diabetes affects body’s ability to produce or utilize the insulin. Insulin is a hormone needed to process the blood glucose properly. It is the major cause of blindness, obesity, ageing population, heart diseases, stroke, amputations and renal failures. Due to these reasons various diabetic complications are caused such as diabetic retinopathy, kidney damage, heart diseases, hepatitis, HIV, neuropathy, and birth defects. Tight glycemic control is known to decrease the devastating and costly secondary micro- and macro vascular complications associated with diabetes. Thus, improving the quality of life for millions of diabetic patients and significantly reducing the health care expenditure. Tight glucose control has also been shown to provide clinical benefits in critically ill patients. [4]
2. BLOCK DIAGRAM

The paper describes a model of a non-invasive blood glucose monitor built using Near Infrared (NIR) frequency range for optical measurement and occlusion spectroscopy principle to obtain desired readings. Trial of this monitor was conducted on 8 subjects of the type: diabetic, hypertensive and healthy persons. The NIMBG was used to monitor glucose levels of this particular group and study the variation pattern in their actual glucose levels and the obtained frequency values. These readings were taken at certain interval of time to monitor the variation in glucose levels of subjects throughout the day. Below shown is the basic block diagram of the NIBGM.

The input to the NIGBM is the IR sensor with bellows, whereas; the outputs are obtained on LCD.

A. Experimental setup
The experimental setup comprises of an Infrared transmitter and receiver placed within the bellows. The finger is chosen as the body site to monitor the blood glucose levels. The subject’s finger is properly positioned into the bellows for line of sight transmittance of optical signal. First signal is obtained by applying no external pressure on the finger termed as before occlusion reading. Then an over systolic pressure is applied on the finger to obtain after occlusion reading, both in terms of frequency measures. The difference between the maximum peaks of the two frequencies obtained before and after occlusion is calculated. This difference is compared with the diabetic conditions of the blood glucose levels and is related with the obtained frequencies using an algorithm. The LCD is used to display the before and after occlusion values, and depending upon the condition satisfied the indication is made weather the glucose is low or high. Also, on system programming provision is made to make further modifications and up gradations in the device.

B. Infrared (IR) sensor
The Infrared transmitter and receiver pair used obtain the optical signal from the subjects body detecting sensor of transmittance type. The NIR frequency in the range 750-950nm is used to pass through the finger and obtain results of frequency depending upon the glucose concentrations. The sensors used come in the form of a bellows which have sensors within it for line of site transmission and reception. The sensor with bellows has a provision for filtering and amplification and gives the output in digital form. This sensor is accurate in giving quick results and is user friendly.

C. Op-Amp
The operational amplifier LM324 is used as a comparator. It is a unity gain amplifier with a large DC voltage gain of 100dB. Initially reading on the subject is taken by applying no external pressure, the reading obtained is termed as before occlusion frequency. Then by applying over systolic pressure we occlude the blow in the finger to obtain after occlusion reading. The difference between the frequencies before and after occlusion is obtained by comparison using op-amp. This difference signal estimates whether the subject is diabetic or not depending upon the frequency variation pattern.

D. Microcontroller
The 89C51 microcontroller is an 8-bit controller of the Philips family. It is a 40-pin IC with dual in line package. It has four bidirectional bit programmable ports for I/O operations. And also has an UART for serial communication. The controller is used to program the optical signal obtained from the IR receiver sensor. In built timer and counter are used for the same. The signals obtained over a period of time are stored in the memory and then programmed to output maximum peak readings into digital form. The signals obtained before and after occlusion are displayed digitally on an LCD.
E. LCD (Liquid Crystal Display)
A 16X2 line LCD display is used to display the outputs. It is usually used to digitally display the readings obtained by the NIBGM device. LCD screen is an electronic display module and finds a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike seven segments), animations. The digital output obtained from the microcontroller is converted into ASCII and then displayed onto LCD. The LCD is programmed to display before and after occlusion readings and the difference between the two. It is also used to indicate whether glucose values of subjects are low or high.

3. OBSERVATIONS AND RESULTS
It has been observed that there are wide variations in the frequency before and after occlusion in the diabetic patients. This difference and a high blood glucose level of the subject is displayed on the LCD.

3.1 NIBGM displaying “WELCOME”

Figure 2: The (NIBGM) system programmed to display “WEL-COME” on turning on the device.

3.2 Readings of healthy subject

Figure 3: Reading before and after occlusion.

Figure 4: Difference in reading and indication of glucose level.

3.3 Readings of highly diabetic subject

Figure 5: Reading before and after occlusion
3.4 Readings of hypertensive subject.

A healthy subject serial number 1 showed no difference in before and after occlusion readings indicating that the blood glucose level is normal.

Highly diabetic subjects serial numbers 4, 6, 7, 8 showed a remarkable variation in frequency which was above 12 Hz.

Hypertensive subject’s serial number 2, 3, and 5 showed less variation in frequency around 6 Hz.

**Table 1: comparison chart of actual blood sugar levels with observed frequency**

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>BSL (mmol/l)</th>
<th>BSL (mg/dL)</th>
<th>HB-A1C</th>
<th>Before occlusion ‘x1’ Hz</th>
<th>After occlusion ‘x2’ Hz</th>
<th>Difference y Hz</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>5.4</td>
<td>97</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>0</td>
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<td>126</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td>6</td>
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<tr>
<td>3</td>
<td>8.6</td>
<td>154</td>
<td>7</td>
<td>2</td>
<td>12</td>
<td>10</td>
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<td>183</td>
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<td>4</td>
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<td>12</td>
</tr>
<tr>
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<td>15</td>
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</table>

**CONCLUSION**

Near Infrared range of frequency and occlusion spectroscopy techniques have proved to be useful in obtaining the blood glucose values non-invasively. These values obtained are relatively close the actual
invasive blood glucose values in frequency measures. The LCD displays the before and after occlusion frequencies and a low or high glucose content. The NIBGM is low powered, compact, portable and close to accurate device.

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