An Optimized Non-Invasive Blood Glucose and Temperature Body Measurement System

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***Abstract*—Diabetes is a disease in which the body does not adequately process food for energy production. Most of the food we consume is converted into glucose, or sugar, which our bodies use for energy. Moreover, the pancreas, which is an organ located near the stomach, produces insulin, a hormone that aids in the transport of glucose into our bodies' cells. Diabetes occurs when your body either does not produce enough insulin or does not use its own insulin the way it is supposed to. Sugars accumulate in your blood as a result of this. This is why diabetes is often referred to as "sugar". People with diabetes want to monitor their blood sugar levels constantly and they go to the health centers regularly for checkups. The aim of this paper is to provide a health care system for people, as it is a monitor for glucose level and temperature body. This paper includes a sensor for noninvasive blood glucose using near infrared spectroscopy and a sensor for measuring temperature body. Here, the implementation required less power consumption as the micro-controller will work on a standby mode as it will be activated only when there is a new change in any measure of these sensors.**

***Index Terms*—diabetes, health care system, near-infrared spectroscopy, noninvasive blood glucose monitoring, optical methods, human body temperature.**

I. INTRODUCTION

Wearable devices have received a lot of interest over the years because of their capacity to provide continuous and real-time clinical information. Wearable devices evaluate biochemical indicators in biological fluids such as sweat, tears, and interstitial fluids in a dynamic and noninvasive method. Recently, the usage of biosensors for non-invasive monitoring of biomarkers in healthcare and sports analytics has been a research focus[1]. Wearable devices offer a wide range of medical applications and are capable of monitoring changes in human physiology, biochemistry, and mobility, which is necessary for both diagnoses and therapy in sports and daily life (Fig. 1).

The intermittent nature of the Energy-harvesting sources is one of the primary problems of the wearable devices. A continuous source of power is required to prevent the operation of a wearable device from being disrupted[2]. Wearable technologies that rely on batteries have shown to be inefficient and restricted in their operation[3]. Because of the long-term charging and discharging cycle, which causes operational disruption and human involvement, this is the case. Despite the fact that battery-powered wearable devices can be constructed to have a big capacity, the increased weight and size is still a limitation[4].

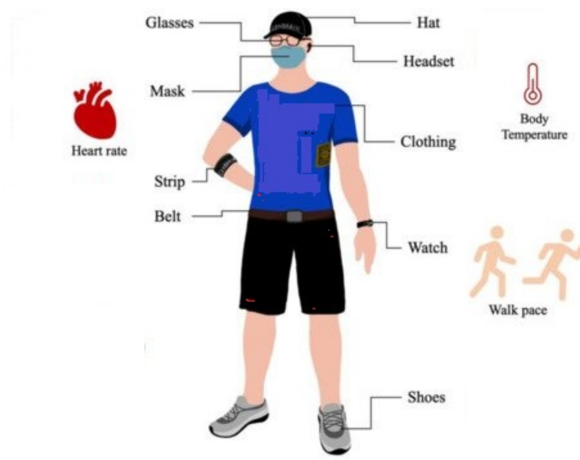

Fig. 1. Wearable devices for various regions of the human body.

By using the concept of Energy harvesting ,now all researches have a great interest in the field of measuring diabetes in the human body[5], as there are many people who are suffering from this disease, so in this paper we used a different technique with different algorithm to achieve the accurate measurements with reducing in power consumption[6].

Diabetes is a type of a metabolic disorder that occurs when the blood glucose level, is too high. As the Blood glucose is the main source of energy for bodies, and comes from the food[7]. In order to perform everyday activities, the body requires blood glucose levels in the normal range (80 to 150 mg/dl)[8]. Thus, a higher or lower glucose level can result in a variety of complications within the body. At the same time, insulin is a critical hormone produced within the body as a result of food consumption. Glucose is produced after digestion process and enters the Blood cell to provide energy while also aiding in development. If insulin is not adequately produced, blood glucose concentrations will rise[6].

Glucose monitoring methods that are often utilized are intrusive, and require finger puncture. These methods are invasive, and repeated pricking leads to calluses on the skin, as well as the possibility of spreading the infectious disease is increased[9]. As a result, there is a need to build a non-invasive monitoring system that can continually assess blood glucose with little effort. Blood glucose can be measured in many ways, as there are two categories of glucose sensors (i) point sample glucose sensors and (ii) continuous glucose sensors shown in fig. 1. Point sample glucose sensors depend on finger pricking glucometer or urine dipstick[10].

Invasive, minimally invasive, and noninvasive continuous glucose monitoring are the three types of continuous glucose monitoring[11]. Invasive sensors include microdialysis and intravenous implanted sensors. A minimally invasive sensors include micropore, sometimes known as a microneedle. Non-invasive blood sugar measurement is a painless and safe alternative to invasive procedures. Transdermal and optical glucose sensors are the two types of noninvasive glucose sensors. Transdermal sensors include impedance spectroscopy and the skin suction blister technique, and Near-infrared (NIR) spectroscopy, mid-infrared spectroscopy, fluorescence, Raman spectroscopy, and thermal infrared spectroscopy are examples of optical sensors[12].In this paper, using (NIR) spectroscopy to measure the concentration of glucose in human body.

II. LITERATURE REVIEW

A literature review on measuring blood glucose using NIR spectroscopy is offered in this section. Müller et al. employed an NIR diffuse reflectance spectra approach to quantify glucose from the finger in the range of 800–1350 nm in 1997. From 1.02 mmol/L (18.4 mg/dL) to 1.88 mmol/L (33.8 mg/dL), the cross validation root mean square error of prediction (RMSEP) was obtained[13].

In 1998, Danzer et al. used NIR diffuse reflectance in conjunction with partial least squares(PLS) regression and radial basis function (RBF) neural network analysis.[22] They employed NIR light with a wavelength of 800–1350 nm to assess glucose in the middle finger. RMSEP was found to be 2.0 mmol/L (36 mg/dL)[14].

AraujoAndrade et al. used a light source, a fibre optical measurement head, and an NIR spectrometer in their NIR diffuse reflectance approach in 2004. [15] The measurement was done using NIR light with a wavelength of 900–1700 nm,applying this wave length on human finger . The correlation coefficients obtained in this study are less than 0.744, and the RMSEP values obtained are greater than 0.89 mmol/L (16 mg/dL)[15].

Xu et al published an optical measurement condition reproduction technique in 2005. Lighting is provided by light emitting diodes (LEDs), and the system also includes a fibre probe, spectrometer, CCD camera, three-dimensional servo device, and a brocket[14]. They measured glucose from palms using NIR diffuse reflectance spectra in the region of 1100–1800 nm. The RMSEP measured varies between 0.8 and 1.1 mmol/L (15–20 mg/dL), with a correlation value greater than 0.8[16].

In 2010, Guevara and González combined NIR (700–1000 nm) and impedance spectroscopy (1–200 MHz) for the first time. They took glucose readings from the forearms of ten non-diabetic people and put the approach to the test in a controlled environment with temperature and humidity. RMSEP was found to be 1.2488 mmol/L (21.96 mg/dL)[17].

Srivastava et al. proposed an optical noninvasive approach to test blood glucose using a 940nm infrared light as the input signal on the finger in 2013[17]. The output signal might be digitised, amplified, and analysed on a microchip using a blood glucose level detection algorithm. The proposed procedure, however, has not been tested. Noninvasive blood glucose measures may be a good alternative to commercial glucometers in the near future, according to this article[18].

Pavithra et al. employed occlusionNIR spectroscopy to investigate the development of noninvasive blood glucose and haemoglobin detection systems in 2016.The circuit comprises of two NIR sensors that detect haemoglobin with an 870nm beam and glucose with a 1000nm beam. The device is tested on persons with various glucose and haemoglobin levels in this study. All subjects had the same minimum photodiode voltage, however the maximum photodiode voltage varied between 3 and 3.8 V[19].

In 2016, Yadav et al. attempted to develop a device for continuous and noninvasive blood glucose monitoring. The goal of this research was to create a noninvasive blood glucose sensor that utilised continuous wave from an NIR transmitter[20]. This paper's proposed system used a 940 nm infrared transmitter. The glucose sensor is attached to the person's arm with this arrangement. The technology was put through its paces in vitro and in vivo.Increased glucose concentration in aqueous solution resulted in a decrease in transmittance in an in vitro experiment. The optically measured signal and actual glucose concentrations had a significant connection in these trials. In vivo blood glucose levels of seven nondiabetic people aged 25–35 years were examined before and after eating Figure.. Food was tested using an NIR glucose sensor and commercially available glucometers [21].

In 2018 Guo et al. published a new noninvasive blood glucose monitoring method in 2015 that used four NIR spectra and a double artificial neural network analysis. They captured the transmission photoplethysmogram signal for four fingers concurrently using wavelengths of 820, 875, 945, and 1050 nm[22]. Experiments revealed that the prediction's RMSE ranges from 0.97 to 6.69 mg/dL, with an average of 3.80 mg/dL. In 2019, Tamilselvi and Ramkumar suggested a paradigm for noninvasive blood glucose testing utilising 940nm wavelength NIR spectroscopy[23]. The Global Positioning System module communicates the user's position coordinates along with the message to the physician[24].

III. HARDWARE CONFIGURATION

In this section, implementation of our proposed system for noninvasive glucose, and human body temperature. It is explained for noninvasive. To measure blood glucose, NIR spectroscopy was chosen. In the NIR range, there are three bands: combination overtone band ($2000–2500nm$), first overtone band ($1400–2000nm$), and second or higher overtone band ($750–1400nm$).

In the higher overtone regions, glucose has maximum absorption at wavelengths of939, 970, and 1197nm; in the first overtone region, it has maximum absorption at wavelengths of1408, 1536, 1688, and 1925nm; and in the combination region, it has maximum absorption at wavelengths of 2100, 2261, and 2326nm. NIR light with a wavelength of 950nm was utilised to assess glucose in this investigation. Although glucose absorption at 950nm is lower than the first and combination overtones, it has the least amount of optical signal attenuation from other components like water. As a result, the desired penetration depth could be reached at this wavelength. An exterior, optical 950nm IR filter and an internal, electronic 38kHz band-pass filter in the receiver module make the sensor sensitive to only IR light pulsing at that frequency

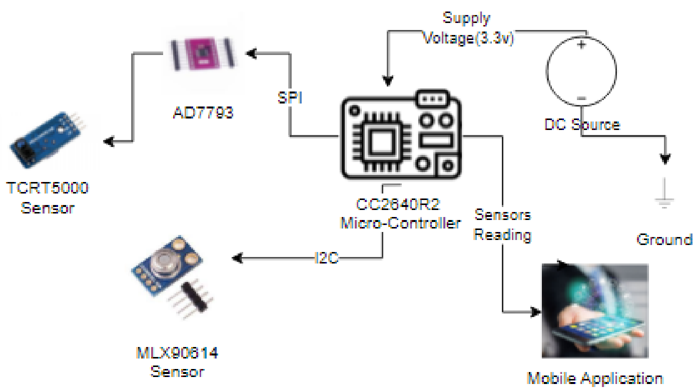

Fig. 2. The proposed system for non-invasive blood glucose and body temperature measurements

In this system, we purpose a suitable micro-controller (MCU) that can handle the medical markets, and applications where industrial performance is required. The CC2640R2F device is a 2.4 GHz wireless micro-controller (MCU) supporting Bluetooth 5.1 Low energy and proprietary 2.4GHz applications. The device is optimized for low-power wireless communication and advanced sensing. Also the design requires

• An external ADC-24 bit AD7793 in order to collect the analogue data from the NIR glucose sensor, a 24-bit external ADC was used in order to transfer the data to the MCU and it is used to increase the resolution.

• An Infra-red (IR) sensor is used to measure the concentration of glucose in human body .

• A MXL90514 sensor is used to measure the temperature of human body.

• An External Voltage source to supply the micro-controller with 3.3 voltage.

• A mobile Application is used to receive the collected data from IR and MLX90514 sensors.

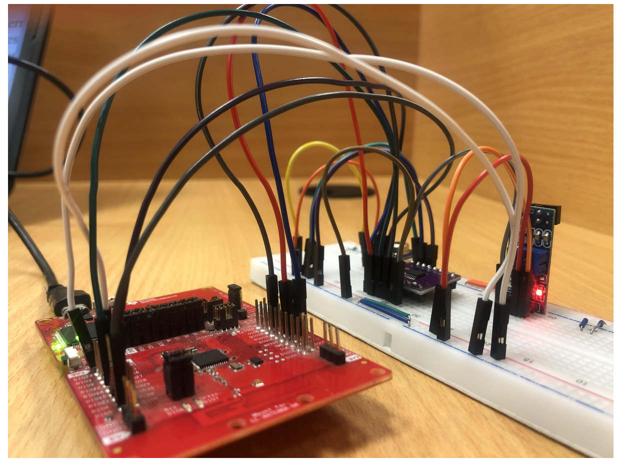

Fig. 3. The system design of the whole circuit

IV. SYSTEM FLOW CHART

Micro-controller use the external ADC to convert the analog signal to digital signal and carries out the processing. The Micro-controller calculates the average voltages received from the circuit caused by the radiation of each 950nm.The Micro programming is carried out using C Language with TI-RTOS SDK. In Fig. 4, explains the general flow of the micro-controller code without getting into too much details. the main purpose of this Flow chart is to illustrate the sequence of flower pollination Algorithm(FPA) [15], and achieving less power consumption, as when there is no any sensor used , the micro-controller gets into standby mode to consume less power .

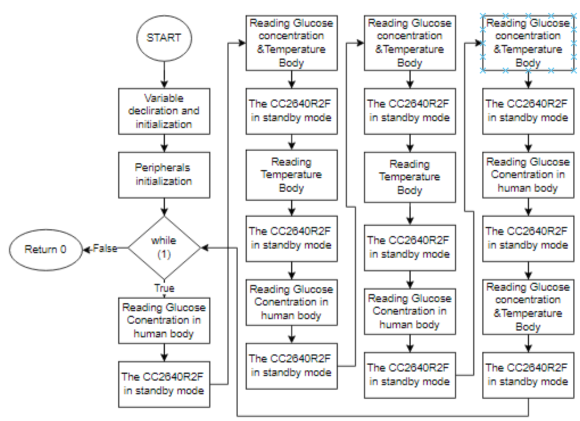

Fig. 4. The Flow Chart describes the whole System.

V. RESULT

This Section describes the output of power consumed in this system, as illustrates in fig. 5, there are four output for the power, the first output is the power consumed from the Glucose measurement, it equals 275mW. the second output is the power consumed from CC2640R2F micro-controller as it equals0.005uW . the third output is the power consumed from the temperature measurement, as it equals 30mW . the fourth output is the power consumed during both Glucose and temperature measurements, as it equals280mW.

It is a great achievement to save the power after reading values from the sensors.In consideration, the system measurement is divided into 10 slots, every slot is 5 sec, each 100 ms of them is used to read the measurement from the sensor, and the remaining time from this slot, the CC2640R2F micro-controller gets into standby mode to prevent consuming a large amount of power.

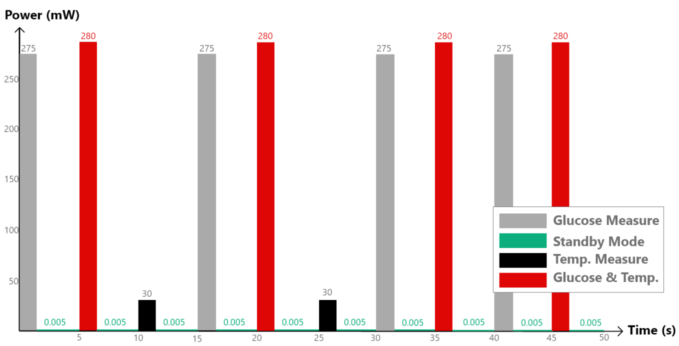

Fig. 5. The power consumed during the system work

The power consumed using FPA is less than the power consumed without using this algorithm, so the Energy level is also reduced, as it is calculated and equals 0.2282 joule .

CONCLUSION

In this study, a health care system developed using FPA[15]. The system included a sensor to measure the blood glucose using NIR spectroscopy, a sensor to measure the temperature body .and scheduling the measurement process to consume less power and energy .

This is the first study depends on the FPA as, it uses an algorithm to be applied into embedded system without using an equations of this algorithm, but it depends on the scheduling between measurement tasks, as there is no need to work all sensor at the same time, and the micro-controller does not need to be in active state all the time. if there is not any sensor works, the micro-controller is on the standby state, wait an event to turn on the sensors used.

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