ISSN 2250-3153

Non-Invasive Glucose Estimation Using IR Spectroscopy

M.Vanitha, Glory Mathew, K.S.Divya, R.Vignesh

ECE, Sriram Engineering college

Abstract- Diabetes milletus is disquieting human lives. The key health issues such as cardiovascular diseases, damage of blood vessels, stroke, blindness, chronic kidney damage, nervous system diseases, amputation of foot due to ulceration and early deaths are caused by poor management of diabetes . The reason behind all these are negligence in continuous monitoring. Regular monitoring of blood glucose is important to avoid complication of diabetes. Commonly used glucose measurement means are offensive which generally involves finger puncturing. These methods are painful and frequent pricking cause lumps on the skin and have risk of spreading infectious diseases. Therefore there is need to develop a non-invasive nursing system which can measure blood glucose continuously without much problem. The present work is focused on evolution of non-invasive blood glucose measurement sensor system using Near-infrared technique. Later a Sensor patch was designed using LED and a photo diode to observe diffused reflectance spectra of blood from the human forearm. Diffused reflectance spectra of the patients obtained with this technique was also compared with commercially available invasive glucose-meter. The results are hopeful and show the potential of using NIR for glucose measurement.we use sensor to monitor the blood glucose level of the patient. When it is High Level Glucose, Insulin will be injected through a syringe from Servo Motor Side. High rise of glucose level may lead to heart attack or any difficulty situations so we use via SMAC- Server Updating the patient Condition easily for identification in the PC Unit. In case of any abnormal situation we use motor to automatically inject the medicine into the patient using the syringe.

I. INTRODUCTION

Continuous monitoring of blood sugar level is highly required for efficient management of diabetes mellitus. The existing "finger piercing" method, which measures the glucose level from blood sampling, is not practical for continuous measurement as it is painful. As technology grew vast world shrunk and our lives became easier then evolved non invasive methods allowing more frequent and even continuous measurement without any pain and bleeding. Many non-invasive glucose monitoring concepts were proposed and reported to have acceptable accuracy, few devices have even became saleable products. Nevertheless, none of them is yet successful due to their poor accuracy from systemic noises in practical environment or clinical applications one major challenge in non invasive glucose monitoring system is to achieve low noise in noisy environment.

In our paper, we present a high exactitude non-invasive glucose estimation IC which can estimate blood glucose level with multi-modal spectroscopy sensors. To enhance glucose estimation accuracy, the proposed multi-modal spectroscopy IC contains two independent glucose estimation circuits, an impedance spectroscopy (IMPS) circuit and a multi-wavelength near-infrared spectroscopy (mNIRS) circuit. These multi-modal spectroscopy techniques are based on different basic principles, electrical and optical characteristics. While IMPS uses electrical property change of tissue indirectly affected by blood glucose level, mNIRS uses optical scattering characteristics of blood glucose itself. Furthermore, IMPS and mNIRS have different human interfaces and systemic noises. Consequently, data combining of IMPS and mNIRS can compensate for glucose estimation error of one modality by the other and can achieve high estimation accuracy. Moreover, to improve accuracy in each spectroscopy method, a two-step IMPS and a three-wavelength NIRS are proposed. The measured glucose levels from two independent spectroscopy techniques are combined by an artificial neural network (ANN) algorithm in an external digital signal processor (DSP) for highly accurate glucose level estimation. The proposed multi-modal spectroscopy IC is verified and its results are compared with the previous finger stick method.

A. Basic Principles of Blood Glucose Estimation

Fig. 1 shows the basic principles of the IMPS and NIRS to estimate blood glucose level. A mechanism of that the glucose influences on the erythrocyte membrane is shown in Fig. 1(a). As glucose level increases, a glucose molecule in blood enters a cell through the glucose transporter in the cell membrane. Then, in the cell, the glucose molecule is converted to ATP energy by cellular respiration. The resulting ATP energy is mainly used to control the ion pump channel and the glucose transporter in the cell membrane, which changes the ion permeability of the cell membrane. As a result, blood glucose level variation changes the electrical characteristics of the surrounding tissues around blood vessel. This change of the electrical characteristics can be measured using RLC resonant frequency and resonant impedance. On the other hand, the NIRS uses optical scattering characteristics of the glucose itself as shown in Fig. 1(b). As blood glucose level increases, the intensity of the reflected near-infrared light also increases . As shown in Fig. 1, the IMPS and NIRS are based on different basic principles. While the IMPS uses the electrical property change indirectly affected by the blood glucose level, the NIRS directly measures the scattering property of the blood glucose. Consequently, a combination of the IMPS and the NIRS can compensate for the glucose estimation error of one modality by the other leading to better estimation accuracy.

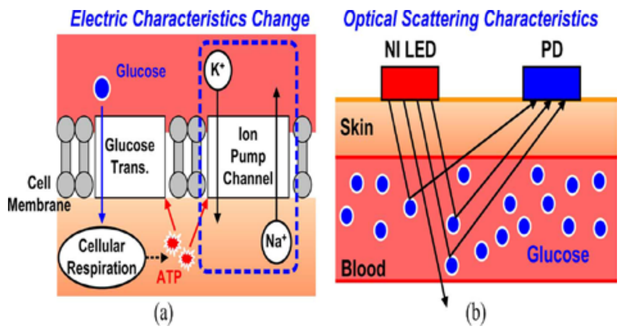


Figure 1: IMPS and mNIRS

B. Complete architecture of multimodal spectroscopy IC:

Fig. 2 displays the complete block diagram of the proposed multimodal spectroscopy IC architecture. It contains an IMPS circuit and a mNIRS circuit for highly accuracy in glucose estimation. For the IMPS operation frequency sweep current injector with bipolar electrode and a voltage sensor is implemented in the circuit. For the mNIRS operation, three near-infrared (NI) LED drivers to emit three wavelengths (850 nm, 950 nm, and 1,300 nm) NI light and trans-impedance amplifier (TIA) to detect the intensity of the reflected light from the photo diode. The measurement results of the IMPS and the mNIRS are converted to digital data in the 10 bit single slope A/D converter. Then, they are transmitted to the external DSP.

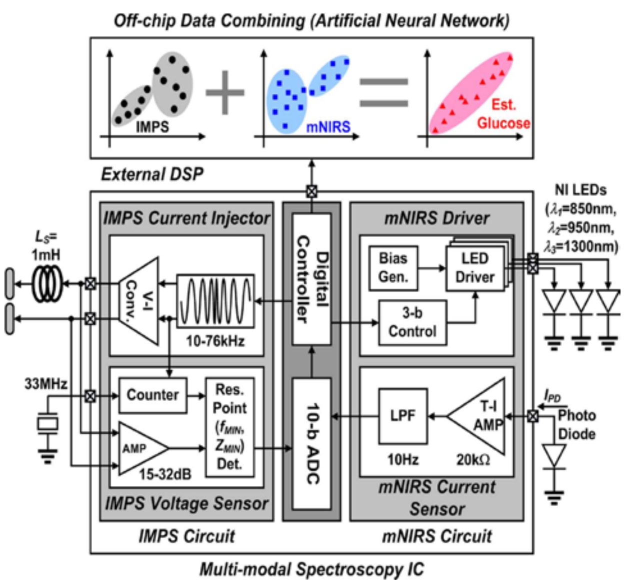


Figure 2: MULTIMODAL IC SPECTROSCOPY

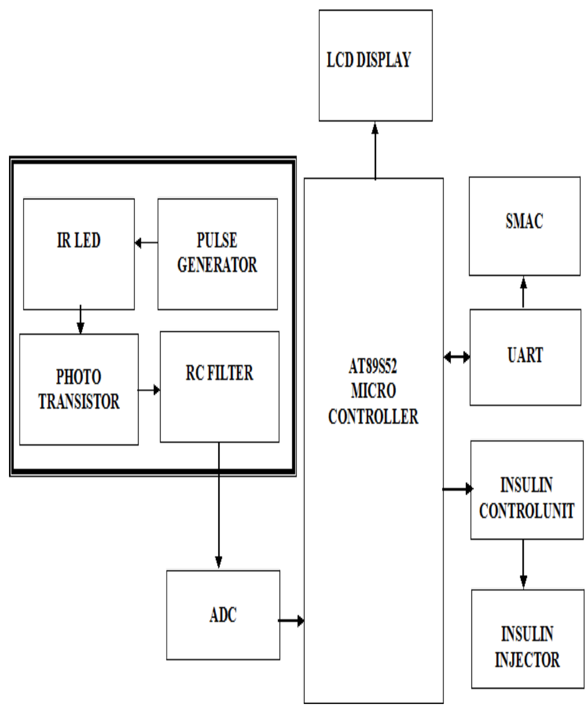
C. Artificial Neural Network (ANN) Data Combing Method

Two main methods used for multivariate data: Partial Least Square (PLS) , and Artificial Neural Network (ANN) . Since the ANN method is anon-linear statistical data modeling of biological neural systems that simulate mathematical functions such as complex relationships between inputs and outputs, the ANN method is shown to achieve better results in terms of the estimation accuracy of blood glucose concentration. Moreover, the non-linear characteristics of the ANN can reduce the performance degradation from the non-linearity of the sensor front-end including the ADC. Consequently, in this work, the measurement data of IMPS and mNIRS are combined by the ANN method in the external DSP. The proposed ANN combines four inputs (from 1 IMPS and three from mNIRS) for the accurate blood glucose level estimation. To estimate the blood glucose level using the proposed ANN, 20 multiply-accumulation operations and 5 sigmoid operations are required.

D. Combined Results:

To quantify the accuracy of the glucose estimation, two types of analysis are used: 1) mean absolute relative difference (mARD), and 2) Clarke grid error (CGE) analysis. The CGE analysis is used to quantify the clinical accuracy of blood glucose estimation generated by a blood glucose meter as compared to a reference value . The CGE analysis is accepted as one of the gold standard for determining the accuracy of blood glucose meters. In the CGE analysis, there are five regions: A (clinically correct decision), B (benign or no treatment), C (overcorrecting), D (dangerous failure), and E (erroneous treatment). Values in zone A and B are clinically acceptable, whereas values in zone C, D, and E are possibly dangerous and therefore are clinically significant errors.

II. BLOCK DIAGRAM



CONTROL UNIT:

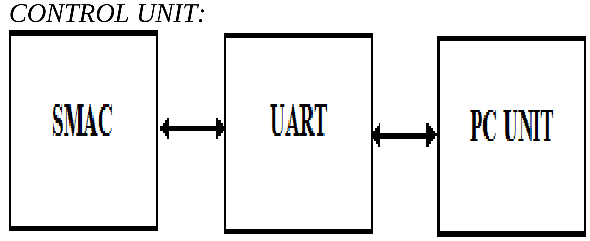


Figure 3: BLOCK DIAGRAM OF PROPOSED WORK

III. NON-INVASIVE GLUCOSE SENSORS

PULSE GENERATORS

The input pulse is sensed from the tissues of the body beneath the skin. Basically, a pulse generator is an electronic circuit or a section of electronic test equipment used to generate rectangular pulses. In our project, a 500Mhz high speed pulse generator is chosen to perform functional and parametric tests of fast digital circuits under program control.

PHOTO TRANSISTORS

These are solid state light detectors that possess internal gain. This makes them much more sensitive than photodiodes. These devices in our project provides an analog signal. It can be used as ambient light detectors. when used with LED, they are employed as an detector element.

IR LED

Two LEDs (LED 1550E) were used as the light source. Since conventional silicon photodiodes have limited spectral bandwidth, they can't be used for getting near infrared light. An Indium Gallium Arsenide (InGaAs) photodiode by dint of a high response about a wavelength of 1550nm was used. Infrared technique is used in our project because of its sensitivity, selectivity, low cost, portability.

In our project, we consider a NIR of wavelength 1550nm , since it has high signal to noise ratio for glucose signals. It allows blood glucose measurement in tissues by variations of light intensity established on transference and reflectance

RC FILTER

An RC low pass filter was also coupled to the output of the photodiode to reduce high frequency noise. The light receptors and transmitters nearby a wavelength of 1550nm are relatively low cost as compared to other wavelengths by way of equal or higher response to glucose. Apart from the level of glucose in blood, the transmittance of NIR light also hinge on on the amount of blood in the path of the light.

That is, for the same glucose level, a large amount of blood will result in lower diffusion, whereas less blood will result in a larger diffusion.

ADC

The ADC0809 data gaining component is a massive CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor well-suited control logic. The ADC0808, ADC0809 offers high speed, high accuracy, negligible temperature dependence, exceptional long-term accuracy and repeatability, and consumes minimal power. These features make this device perfectly suited to submissions from process and machine control to consumer and automotive applications. The analog signals from the sensor are converted to digital signals using ADC .

ATMEL(MICROCONTROLLER)

In our project, AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The measurement results of the IMPS and the mNIRS are converted to digital data in the 10 bit single slope A/D converter. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.

By merging a multipurpose 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a potent microcontroller which provides a highly malleable and profitable solution to many embedded control applications.

UART

The Universal Asynchronous Receiver/Transmitter (UART) controller is the key component of the serial communications subsystem of a computer. The UART receipts bytes of data and transfers the individual bits in a sequential fashion. At the destination, a second UART reconvenes the bits into whole bytes. Serial transmission of digital information (bits) through a single wire is much more profitable than parallel transmission through multiple wires.

A UART is used to translate the transmitted information amid its sequential and parallel form at each end of the link.

SMAC

S-MAC is a sensor medium-access control (MAC) protocol designed for wireless sensor networks. Wireless sensor networks use battery-functioned scheming and detecting devices. A network of these devices will collaborate for a common application such as environmental monitoring. Listen period is used to transmit and receive packets. S-MAC acceptsa periodic wakeup scheme , each node alternates between a fixed length listen period and a fixed length sleep period.

SERVOMOTOR

Servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position velocity or acceleration of the insulin injector. It consists of a suitable motor coupled to a sensor for positioning feedback and also required as relatively sophisticated controller. For a 45degree inclination of rotation, insulin gets injected based on its high/low level indication.

It is also an automatic device that uses error-sensing negative feedback to correct the performance of a mechanism. The term appropriately fits only to systems where the feedback or error-correction signals help control mechanical position, speed or other parameter.

IV. COMPARISONS

TABLE 1: MODEL COMPARISON

MODALITY	CGE(A&B)	USED MODEL
Near-Infrared Spectroscopy	58%	Human
Polarimetry	69%	Ex Vivo
Impedance Spectroscopy	78.4%	Human
Raman Spectroscopy	85%	Human
IMPS+mNIRS	100%	Human

V. CONCLUSION

Amongst all other methods, our method aids people by its high accuracy and automated diagnostic systems.Since the IMPS and mNIRS use the indirect dielectric characteristics of the surrounding tissue around blood and the optical scattering characteristics of glucose itself in blood, respectively, the proposed IC can remove various systemic noises to enhance the glucose level estimation accuracy. For the IMPS operation, a two-step IMPS circuitis implemented to find an accurate RLC resonant frequency and impedance with the high resolution of 2,865 steps. The proposed multi-modal spectroscopy IC and the ANN data combining method are verified by clinical test with the previous finger stick method. The proposed ANN data combining significantly reduces the mean absolute relative differences (mARD) to 8.3% from 15.0% of the IMPS and 15.0–20.0% of the mNIRS in the blood glucose level range of 80–180 mg/dL. From the Clarke grid error (CGE) analysis, all of the measurement results are clinically acceptable and 90% of total samples can be used for clinical treatment, such as insulin injection or sugar intake. The proposed multi-modal spectroscopy IC is expected to implement a compact and disposable non-invasive glucose monitoring system for continuous and convenient diabetes management.

REFERENCES

[1] The Diabetes Control and Compliance Trials, National Institute of Diabetes and Digestive and Kidney Disorders, NIH Publication, 1993.

[2] A. Tura et al., "Non-invasive glucose monitoring: Assessment of technologies and devices according to quantitative criteria," Diabetes Res. Clinical Practice, vol. 77, no. 1, pp. 16–40, Jul. 2007.

[3] C.-F. So et al., "Recent advances in noninvasive glucose monitoring," Medical Devices: Evidence Res., no. 5, pp. 45–52, Jun. 2012.

[4] S. K. Vashist, "Non-invasive glucose monitoring technology in diabetes management: A review," Analytica ChimicaActa, no. 750, pp. 16–27, Apr. 2012.

[5] K. Song et al., "An impedance and multi-wavelength near-infrared spectroscopy IC for non-invasive blood glucose estimation," in Symp. VLSI Circuits Dig. Tech. Papers, 2014.

[6] Y. Hayashi et al., "Dielectric spectroscopy study of specific glucose influence on human erythrocyte membranes," J. Physics D: Appl. Physics, vol. 36, no. 4, pp. 369–374, Jan. 2003.

[7] A. Caduff et al., "Non-invasive glucose monitoring in patients with diabetes: A novel system based on impedance spectroscopy," Biosens. Bioelectron., vol. 22, no. 5, pp. 593–604, Dec. 2006.

[8] Y.Miyauchietal.,"for development to noninvasive blood glucose measuring instrument by near-infrared confocal optical system," in Proc. SICE Annu. Conf., 2010.

[9] Product Specification for AFG3011C, Tektronix Inc., Richardson, TX, USA [Online]. Available: http://www.tek.com/products/ signal_sources

[10] Z. Tang et al., "MOS triangle-to-sine wave converter based on sub-threshold operation," Electron.sLett., vol. 26, no. 23, pp. 1983–1985, Nov. 1990.

[11] K. Pengwon and E. Leelarasmee, "A quadrature generator based on CMOS triangular-to-sine/cosine converter with 1/4 frequency output," in Proc. 4th IEEE Int. Conf. Circuits Syst. Commun., 2008.

[12] L.Yanetal.,"A3.9mW25-electrodere configured sensor for wearable cardiac monitoring system," IEEE J. Solid-State Circuits, vol. 46, no. 1, pp. 353–364, Jan. 2011.

[13] R. Yazicioglu, P. Merken, R. Puers, and C. V. Hoof, "A 60 W 60 nV Hz readout front-end for portable biopotential acquisition systems," IEEE J. Solid-State Circuits, vol. 42, no. 5, pp. 1100–1110, May 2007.

[14] I. Beckers, "Spectral Response of Glucose: Spectral Response Within Optical Window of Tissue," ANDOR Technology plc, Belfast, U.K. [Online]. Available: http://www.andor.com/learning-academy/spec- tral-response-of-glucose-spectral-response-within-optical-window-of- tissue

[15] A.Trabelsi and M.Boukadoum, "Comparison of two CMOS front-end transimpedance amplifiers for optical biosensors," IEEE Sensors J., vol. 13, no. 2, pp. 657–663, 2013.

AUTHORS

First Author – M.Vanitha, Associate professor, vanijsk79@gmail.com
Second Author – GloryMathew, UG Scholar, glorymathew95@gmail.com
Third Author – K.S.Divya, UG Scholar, divyas698@gmail.com
Fourth Author – R.Vignesh, UG Scholar, vigneshraghu77@gmail.com