Development of Hardware and Software for a Non-Invasive Glucometer Based on A Microcontroller

Docent. Khaydarov A.Kh	*Tashkent State Technical University* E-mail: *fayyozsam@mail.ru*
Docent Eltazarov B.T	*Tashkent State Technical University* E-mail: *fayyozsam@mail.ru*
Sen. Lec.Kimizbayeva A.E.,	*Tashkent State Technical University* E-mail: *fayyozsam@mail.ru*
Master Tuychiev F.F.	*Tashkent State Technical University* E-mail: *fayyozsam@mail.ru*

ABSTRACT

Diabetes occurs when blood glucose levels exceed a threshold. Existing blood glucose testing methods are invasive methods based on needles that are inserted into a person's body to take a blood sample from the body, and then it is transferred to disposable test strips for chemical processing to determine the amount of glucose present in it. However, for patient pain relief and the use of test strips, these techniques have led to the development of non-invasive methods. Non-invasive methods use a near-infrared sensor to measure glucose levels at the fingertip without the use of needles or test strips. A near infrared (NIR) optical signal is transmitted through one side of the fingertip and then received on the other side of the fingertip, which predicts the molecular blood glucose count by analyzing the change in intensity of the received signal after it has passed. In this work, we have developed such a system using a microcontroller and other electronic parts. Before that, we developed a simulation model in the Proteus environment.

Keywords: diabetes mellitus, NIR method, invasive and non-invasive glucometer, microcontroller.

1. Introduction

The term "blood sugar" means the amount of glucose in the blood per unit volume. It is usually expressed in millimoles per liter (mmol/L) or milligrams per deciliter (mg/dL). The standard human blood sugar range is 4.5 to 6.5 mmol/L. In a healthy person, due to the homeostatic mechanism of regulation of glucose in the blood of the human body, its level is restored in the range of approximately 4.4 to 6.1 mmol / l. Blood glucose levels may rise briefly after a meal up to 7.8 mmol/L in people without diabetes [1]. According to the American Diabetes Association, blood glucose levels should be between 5.0 and 7.2 mmol/L before meals and less than 10 mmol/L after meals for people with diabetes. More or lower blood sugar values than this range leads to diabetes in the human body, and this, in fact, can cause serious health hazards. Therefore, the determination of blood sugar levels must be correct and accurate, without much discomfort for patients.

The strong spread of diabetic patients around the world has become a big problem at the present time. If patients cannot be diagnosed early and regular blood glucose monitoring cannot be done properly, this will become a major problem for everyone. In addition, if patients can independently determine the disease and its level, this will reduce the burden on medical workers. However, many patients are reluctant to use needle devices due to pain and health risks.

Therefore, a clinically effective method is the use of non-invasive technology based on the monitoring of blood glucose levels and, therefore, on its regulation.

On the other hand, a microcontroller-based system is inexpensive, small in size, and user-friendly. Microcontrollers are widely used in a number of automatic systems and devices for biomedical measurements and monitoring [4–5]. Therefore, this article describes how you can design and develop critical blood glucose monitoring devices based on non-invasive method and microcontroller technology. This will reduce the cost of commercialization in the marketplace, eliminate patient pain, and provide accurate readings of blood glucose detection capabilities. The results obtained using non-invasive blood glucose testing are very encouraging when they are satisfactory compared to the results of traditional invasive methods using a needle.

One of the major health problems facing the modern world is diabetes mellitus. This is a kind of metabolic disease in which blood glucose levels fluctuate from the normal range of 4.0-7.8 mmol/L [1]. If the glucose level is outside this range, it can affect the major organs of the human body if proper treatment is not provided in a timely manner. Therefore, early and accurate determination of glucose levels is necessary. Once a person is diagnosed with diabetes, he/she should be regularly monitored for blood glucose levels, and this is necessary to avoid further obstacles and maintain a healthy lifestyle. In developed countries, patients who want to monitor their blood glucose levels at home usually buy an electronic glucometer. However, two methods are widely used for blood glucose monitoring: For example, invasive and non-invasive methods. With an invasive method, a part of the body, usually at the tip of a finger, must be perforated by the patient in order to take a blood sample. But this method causes pain and anxiety. Sometimes this procedure can cause infection through the needles. On the other hand, with non-invasive blood glucose, there is neither pain nor any anxiety, since this method does not use needles, only reflected infrared light from the fingertips is taken to determine the blood glucose level [1-3].

Therefore, the objectives of the present study are to:

1. Learn non-invasive methods for measuring blood glucose levels;
2. Develop a simulation model for a glucometer based on NIR technology;.
3. Develop and implement a system for measuring blood glucose levels based on a non-invasive (infrared) method;
4. Measure and analyze blood glucose data.

2. Simulation And Software Development

2.1 Simulation model with Proteus

Proteus Design Suite is an CAD related software that is used for research and development type works in both academia and industry [7]. Design engineers and electronics technicians use it to draw circuits for modeling and verification, sketch and test electronic circuit board layouts before manufacturing them, and so on. It can work in Windows environment. It supports high speed design. It has about 800 different types of microcontroller chips that can be modeled based on the circuit diagram. Microcontroller simulation in Proteus works by using a hex file or debug file for the microcontroller portion of the schematic. It is then modeled in conjunction with any analog and digital electronic circuits associated with it. In addition, it can also simulate circuits based on PIC microcontrollers [6]. In such an environment, our simulation model was developed as shown in Fig. 1.

The simulation model was developed at Proteus before moving on to the implementation phase of our study. After completing the model design, we modeled our system. The developed scheme is shown in fig. 1. In the figure, the input signal value is taken by the microcontroller from the near infrared sensor.

The noise was then removed with a noise filter. This value was then filtered, amplified and connected to an npn transistor to obtain a negative value. This signal is connected to the analog port of the PIC16F876A microcontroller. Finally, the output value is displayed on the LCD monitor as shown in fig. 1. Figure 2 shows a block diagram of the program.

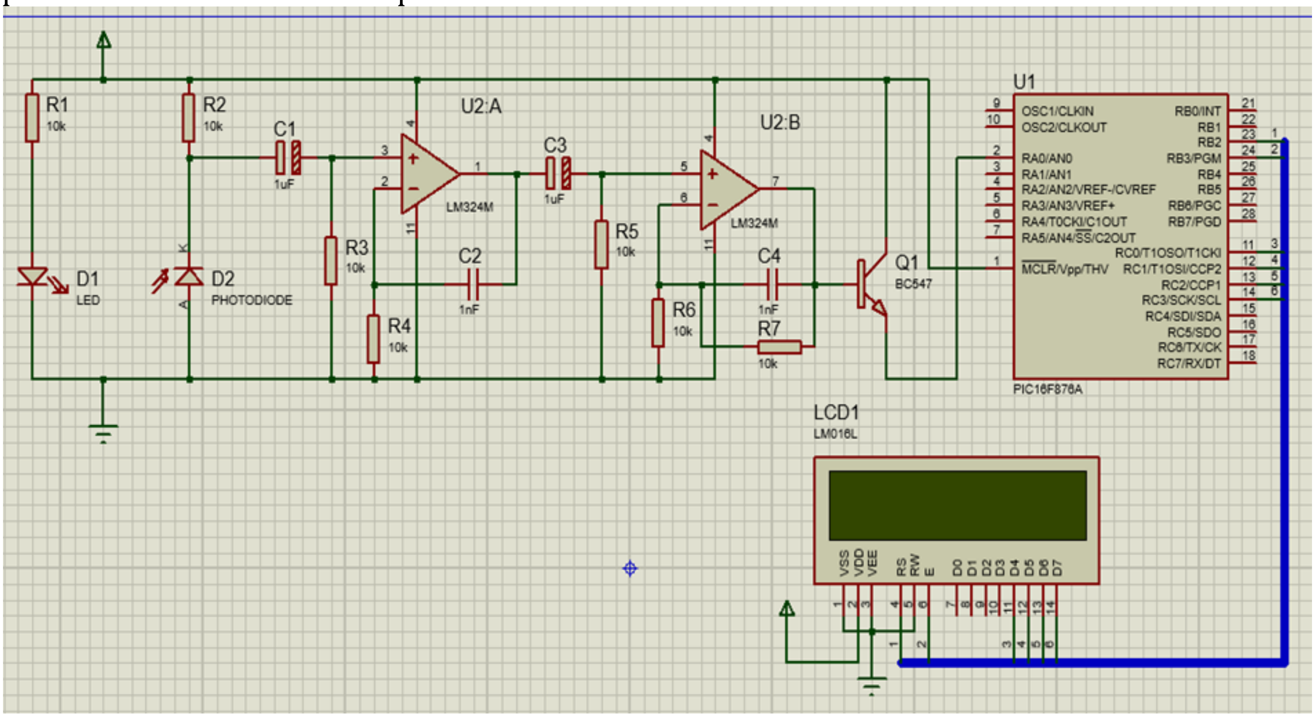

Fig. 1. Simulation model of the entire system.

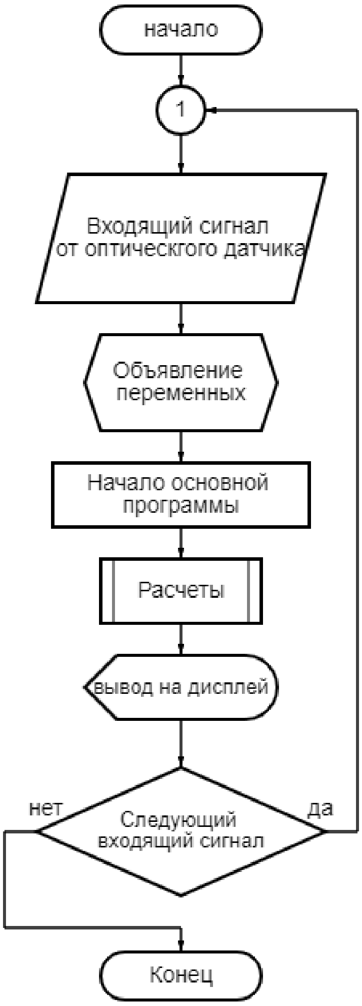

Fig.2: Program flowchart

3. Development Of A Glucometer Based On The Hardware

3.1 Equipment description

In this work, we used a PIC16F876A microcontroller, a near-infrared light-emitting diode (NIR-LED) and a photodetector (NIR-PD) as optical sensors, an LCD display, a power supply, etc. to develop a glucometer. We have tried to minimize the cost in the development of this measuring machine.

The PIC16F876A microcontroller is the heart of the meter. This is used for automatic control, calculation and data processing. Near Infrared LED/Photodiode, which is simply a p-n junction diode that produces an electric current by receiving an infrared light signal after reflecting off the human body. However, this diode must be operated in reverse bias mode. An infrared LED is a device that can detect a current signal and emit infrared radiation from it. The LM324 chip has four independent operational amplifiers. This is used for high gain voltage amplification. The main advantage of this IC is that it can be operated from a single power supply and thus reduces the cost of the hardware.

3.2 Operating procedures.

“A near-infrared LED and a photodetector detect the concentration of glucose in the blood. The concentration of glucose in the blood is calculated from the scattering and absorption of infrared light by the blood. The concentration level is displayed on the LCD display in the appropriate units.

First, we insert the fingertip between NIR-LED and NIR-PD as shown in the block diagram in fig. 3. The reflected signal is received by NIR-PD. The value derived from it will be filtered and then amplified. Then we will remove the noise with a noise filter. We filtered the signal again and amplified it to connect to the npn transistor to get a negative value and to display the value early on the LCD. After that, we connect the signal to the analog port of the PIC16F876A microcontroller. Finally, the output value is displayed on the LCD.

Fig. 3: Block diagram of the whole system

3.3 PCB design.

A printed circuit board (PCB) is used to mechanically support and electrically connect electronic components using a variety of conductive tracks, pads, and jumpers. This pattern is transferred to the copper sheet after various processes such as printing, chemical solution dipping, drying, pickling, grooving, drilling, cutting, peeling, laminating, etc. Through these processes, the copper sheet and thus is reduced use of wiring and thus reduce the number of malfunctions that can occur due to loose wiring. Finally, in order to accommodate various electronic components and microcircuits, soldering work must be done on the PCB. The printed circuit board developed by us is shown in fig. 4. A photograph of the 3D model of the device is shown in fig. 5.

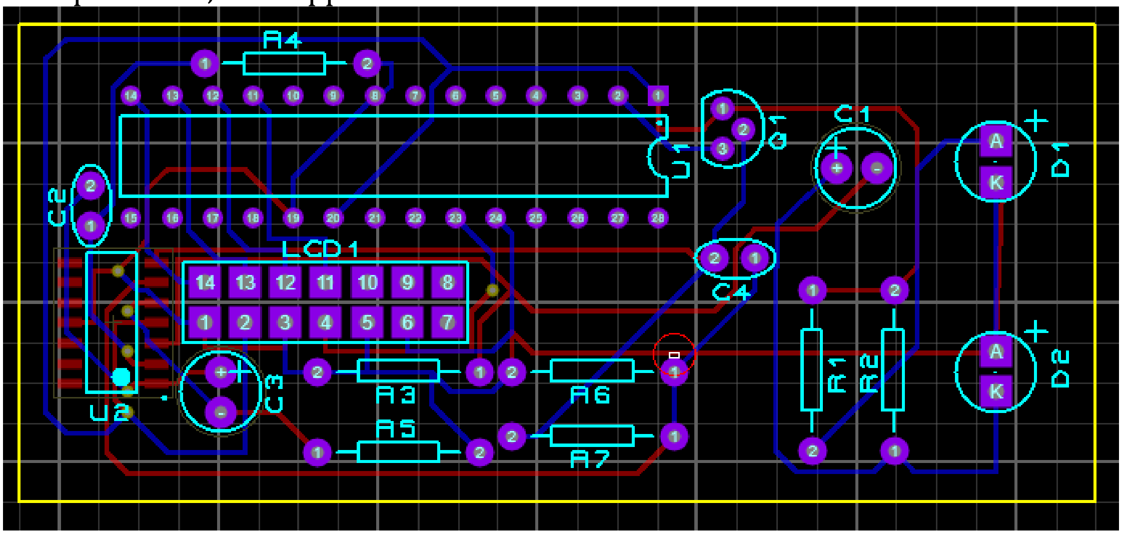

Fig. 4: PCB layout for hardware implementation.

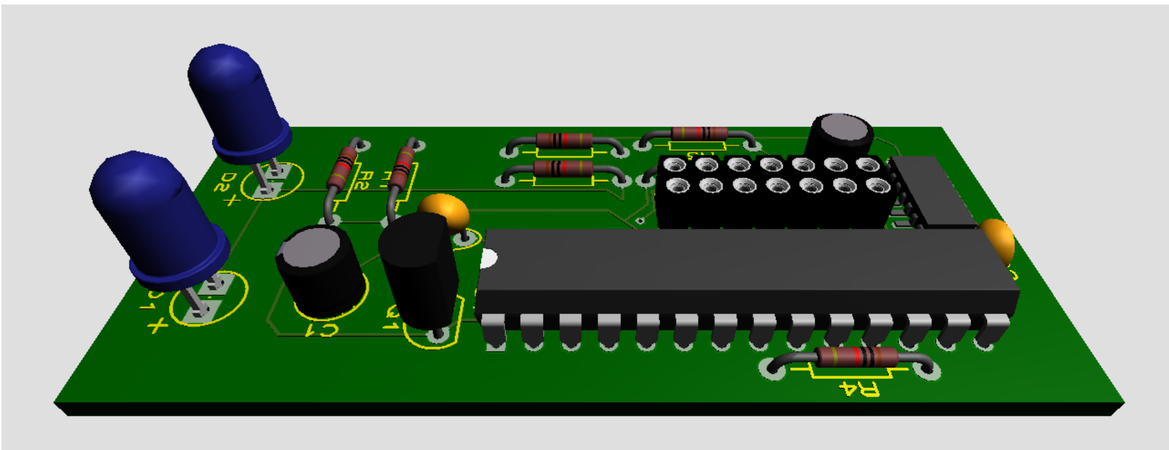

Fig. 5: View of the instrument's printed circuit board

3.4 Implementation costs.

The total prices, including details of the prices for the various components required to implement the system, are shown in Table 1. We see that only 157,500 UZS (Uzbek Sum) is required. However, if mass production is established, this price will drop sharply. Therefore, we can say that the cost of implementation has been kept to a minimum compared to existing glucometers available on the market.

The price of a non-invasive glucometer varies from 150,000 to 300,000 Sums. However, these machines require disposable test strips and needles, which are billed separately.

Table 1: Pricing Information for Various Components

№	Component name	Specification	Quantity	Unit price (UZS)	Total price (UZS)
1	PIC16F876A	-	1	35000	35000
2	LM324 IC	-	1	15000	15000
3	Photodiode	-	1	20000	20000
4	Light-emitting diode	-	1	20000	20000
5	Resistors	1k, 10k, 120, 5k	10	2000	20000
6	transistors	BC547	1	5000	5000
7	Capacitors	1 μF - 50 V	2	1000	2000
8	Capacitors	2 A - 104 J	2	3000	6000
9	Printed circuit board		1	12000	12000
10	LCD display	I2C, 1602	1	15000	15000
11	Connecting wires	-	15	500	7500
				Total:	**157500**

4. Conclusions

We have successfully achieved our goals by developing a device for the non-invasive determination of blood glucose concentration. This method has several advantages over conventional invasive methods, such as no need for test strips and penetrating needles at the fingertips, no pain, etc. This method eliminates patients' fear and anxiety because we used photographs in this method. - sensitive electronic components that non-invasively calculate blood glucose levels using a diffuse reflection circuit. This glucometer is a very cheap device. The device is used to measure glucose levels in a variety of people with and without diabetes, at different age levels.

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