

Design And Development Of A Microcontroller Based System For The Measurement Of Blood Glucose

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Abstract

Diabetes Mellitus is a group of metabolic diseases characterized by high blood sugar (glucose) levels which results from defects in insulin secretion. In the present study, a microcontroller based system for the measurement of blood glucose is designed and developed. It is based on the Amperometric method. A PIC 18F4520 microcontroller is used in the present study. LCD module is used to display measured values of blood glucose. The MAX232 is a dual line driver/receiver, converts signals from an RS-232 serial port to TTL compatible signals is interfaced with the microcontroller. Software is developed in C language using MPLAB IDE for the Microchip Technology, due to the inherent language flexibility, the extent of support and its potential for portability across a wide range of hardware. The instrument is tested and results are found to be satisfactory. The instrument is handheld, rugged, low cost, low energy consumption, wearable and cost effective compared to the other commercially available.

Keywords: *Blood glucose measurement, Amperometric method, PIC 18F4520 microcontroller, RS232 level translator and MPLAB embedded workbench IDE for microchip.*

I. INTRODUCTION

The blood glucose is an important criterion to discriminate the health condition of patients in clinical field. Blood glucose of a patient is measured 3-4 times per a day in constant timer interval. Diabetes is a disease where the body doesn't properly use or produce insulin [1]. Insulin is a hormone produced in the human body which is need for the conversion of sugar, starches and other food into energy. Without insulin the body would not be able to receive the amount of energy needed to function, which is why diabetes is such a serious disease. There are two types of diabetes Type I and Type II. Type I diabetes is where an individual's body doesn't produce insulin. Type II diabetes is where an individual body doesn't properly use insulin combined with a relative insulin shortage within the body. Type II diabetes is the more common type with about 90% of people with diabetes having this form. There is no cure for

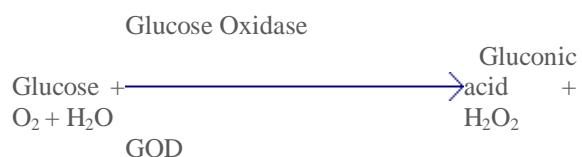
diabetes, so lifelong treatment is the only alternative with continuous monitoring with diet control. Blood glucose of a person has also been routinely measured at medical checkups. There are different methods of in blood glucose measurement, Amperometric method, Spectroscopic method, Calorimetric method. In self measurement blood Glucose meters amperometric method is mainly used [6]. Glucose measurement technique used glucose oxidation method. The whole operation is very simple with enzymes oxidation, which transfers electrons to electrodes.

There is evidence that the chorionic complications of diabetes are related to the duration and severity of hyperglycemia (diabetes control and complications Trial Research group 1993, UK prospective diabetes study group 1998). However good diabetic control is very difficult to achieve in many diabetic patients and frequent blood glucose testing is needed to detect hyper and hyperglycemia[7]. The most investigated technology for in vivo glucose monitoring is based on implanted Amperometric enzyme electrodes [2] (Mastrototaro, 2000, sachedina and Pick up, 2003).

Tight control of blood glucose levels achieved through frequent blood glucose monitoring has been shown to be effective in reducing complications such as Retinopathy, Nephropathy and Neuropathy [3,4]

Principle:

In the present paper, we measure the blood glucose based on Amperometric method. The glucose sensor [5] is an electrochemical diagnostic strip which used glucose oxidase enzymes. When blood sample is applied, the enzyme becomes catalytically active and mediator compound transfer electrons to the electrode. The electrical signal is then processed, amplified and converted into display by microcontroller.



II Experimental

A. Hardware Design

The block diagram of the microcontroller based system for the measurement of blood glucose is shown in fig 1. An Illustrative schematic diagram is shown in fig2.

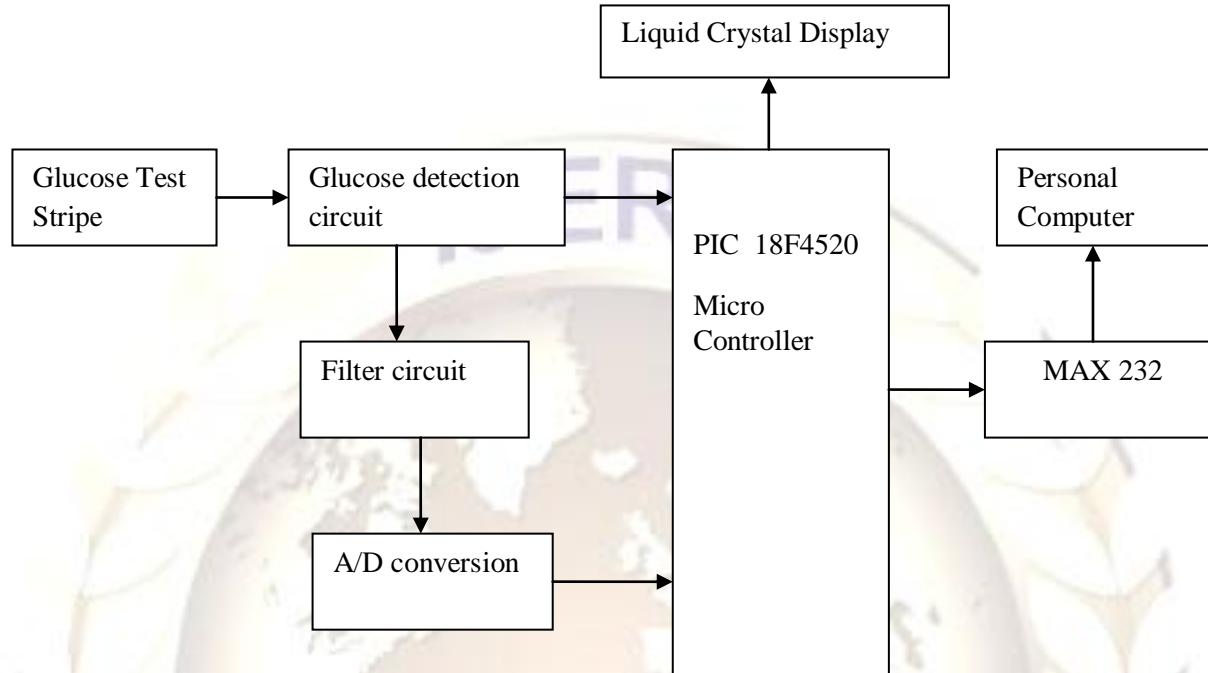


Fig1: Block Diagram of Design and Development of Microcontroller based system for the measurement of Blood Glucose.

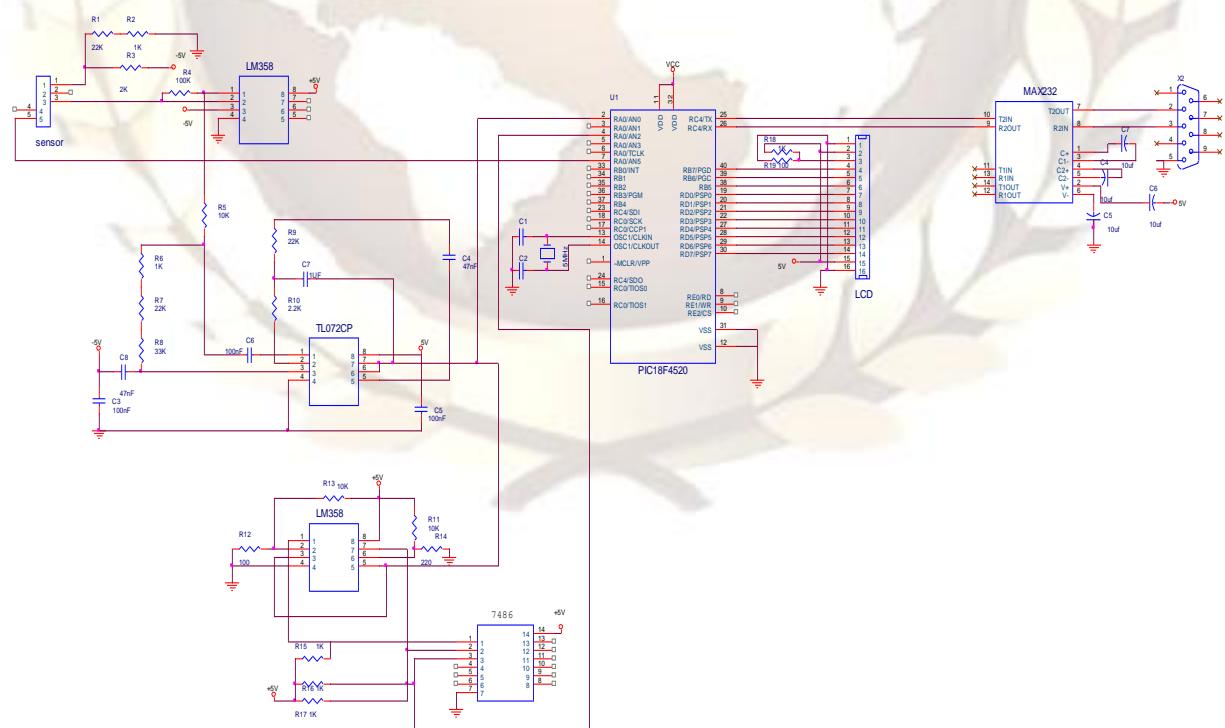


Figure 2: Schematic diagram of Design and Development of Microcontroller based system for the measurement of Blood Glucose.

Sensor unit with Biosensor

According to the American diabetes Association (ADA) [8], the term diabetes mellitus describes a metabolic disorder of multiple aetiology characterized by chronic hyper glycaemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action, or both. The effects of diabetes mellitus include long-term damage, dysfunction and failure of various organs. Diabetes mellitus may present with characteristic symptoms such as thirst, polyuria, blurring of vision, and weight loss.

A biosensor is a sensor that makes use of biological or living material for its sensing function. There are three main parts of a biosensor: (i) biological detection elements, which recognize the substance of interest, (ii) a transducer, which converts the biorecognition event into a measurable signal and (iii) a signal processing system, which converts the signal into a workable form.

The basic operation of glucose biosensor is based on the fact that the enzyme glucose oxidase (GOD) catalyses the oxidation of glucose to gluconic acid. The enzyme acts as a biorecognition element, which recognizes glucose molecules. These enzyme molecules are located on an electrode surface, which acts as a transducer. As soon as the enzyme recognizes the glucose molecules, it acts as a catalyst to produce gluconic acid and hydrogen peroxide from glucose and oxygen from the air. The electrode recognizes the number of electron transfer due to hydrogen peroxide/oxygen coupling. This electron flow is proportional to the number of glucose molecules present in blood. The glucose sensor is an electrochemical diagnostic strip which uses glucose oxidase enzymes in conjunction with three electrically conductive electrodes. Two of these electrodes are 'working' electrodes meaning they are the measured electrodes, and the third is a reference electrode as shown in fig 3.

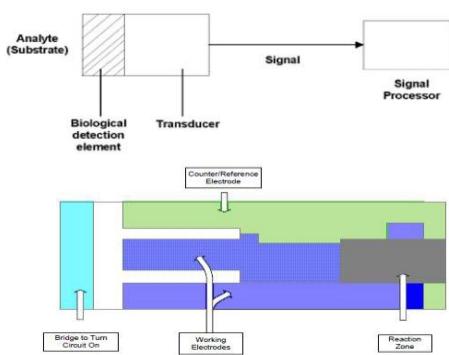


Fig 3: Schematic layout of a biosensor and test stripe

The signals from glucose sensor are transmitted to next stage of signal condition unit. The output of the

Biosensor is connected to amplifier LM358 and ADC.

Signal conditioning unit

In general any Instrumentation system consists of various units starting from sensors to data representation units, among that signal conditioning is a vital process. The glucose measurement originates as a small current generated by the chemical reaction occurring in the test strip. The test strip contains glucose oxidase, a chemical that binds to D-glucose to start a redox reaction. The redox reaction breaks down the glucose and releases electrons. The flow of electrons is known as current and is collected by electrodes built-in to the test strip. The current is converted to voltage through the use of a current-to-voltage converter.

When test stripe is inserted PIC micro controller sense the presence of the strip. The current output from the glucose test strip is connected to inverting input of the LM358 [9]. The LM358 dual operational amplifier, low power drain, a common mode input voltage range extending to ground/VEE, eliminating the necessity for external biasing components. The current is converted to a voltage in LM358. A current-to-voltage converter is simply an op amp with a feedback resistor. The op amp is used as a high impedance source that forces all of the current to flow through the resistor. The average current I produced by the glucose test strip is $20\mu\text{A}$. V is chosen to be 2 volts, then $R = 100000$ Ohms

The output of LM 358 is given to the filter circuit. The filter circuit uses a TL072 [10] Low Noise JFET Input Operational Amplifier and is configured as a 100 Hz Sallen-Key Low Pass Butterworth filter. The glucose measurement is taken from a single acquisition from the analog-to-digital converter. When a sample is applied to the test strip the voltage jumps to a peak value and then begins to decay linearly between 1 and 5 seconds. The voltage reading is taken after 2 seconds the sample is applied. Fig 4 shows a typical voltage curve for glucose.

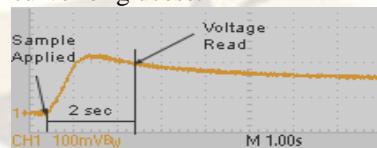


Fig 4: Glucose voltage curve.

The voltage level is then converted to a glucose concentration using equation

$$\text{Concentration} = (\text{voltage}) \times 922.23 - 22.9$$

The Micro controller PIC 18F4520 is used to connect each component of the meter. The processor is responsible for the analog-to-digital conversion, LCD control, user interface, and communication with a serial device. The

microcontroller uses a 5 MHz clock. The analog-to-digital converter is configured with two control registers, ADCON0 and ADCON1. ADCON0 is used to configure the conversion clock, the input channel. The analog-to-digital converter is set up to use an Fosc/8 conversion clock, read channel 0, and turn the module on. The maximum device frequency is 5 MHz.

Microcontroller

In the present study, we have used PIC18F4520 [11] microcontroller for the measurement of blood glucose. PIC18F4520 is an Enhanced Flash Microcontroller with Power Managed Modes. The PIC microcontrollers have high computational performance with the addition of high endurance, Enhanced Flash program memory. The PIC18F4520 introduces design enhancements that make these microcontrollers a logical choice for much high performance, power sensitive applications. It consists of Three programmable external interrupts, Four input change interrupts, Enhanced Capture/Compare/PWM (ECCP) module, Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI and I2C Master and Slave Modes, Enhanced Addressable USART module, 10-bit, 13-channel Analog-to-Digital Converter module, Dual analog comparators with input multiplexing, High-current sink/source 25 mA/25 mA RS-232 (Recommended Standard 232) is a standard for serial binary data signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports. Here, we use MAX 232 (RS-232) for serial communication in between microcontroller and personal computer [12].

Display unit

The measured Blood Glucose data are displayed on the Liquid Crystal display. In present work we are using LM16200 [13] (16 x 2 character) LCD display. The LCD connects to the microcontroller using 14 pins. There are eight parallel pins used for data transfer, three pins for enable, instruction/register select and read/write control. The data and instructions are sent through D0-D7 lines of LCD screen.

Lcd displays requires less power and it is used display any alpha-numeric and symbols. The display has a built in controller with synchronous serial and parallel interfaces. The display has a lifetime of about 10,000 hours.

B. Software

'C' programme language is used for the development of Blood glucose meter. The 'C' programming language is growing in importance and has become the standard high level language for real-time embedded applications.

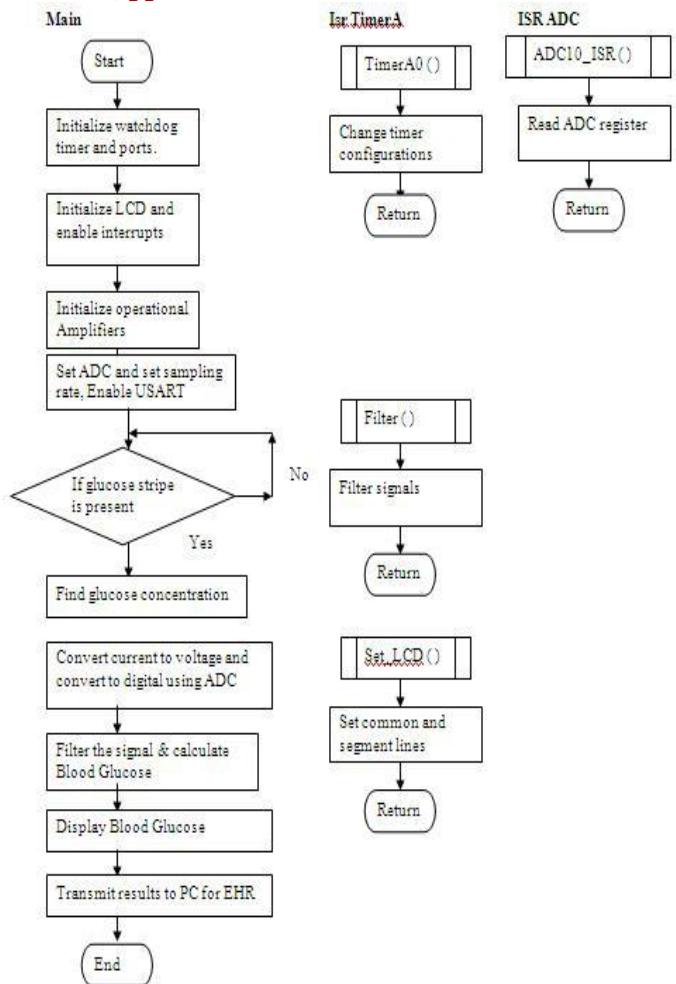


Figure 5: Flowchart for design and development of microcontroller based system for the measurement of blood glucose.

The PC is the standard computing device for the 'C' compiler. [14]. To development of C programs for an PIC18F4520 executing on a PC is now familiar with MPLab IDE for Microchip [15]. The flowchart of the program is presented in Figure 5. A software method of digitally sampling the concentration of glucose levels is described. The micro controller program controls the external devices and measures the input signals from the sensor and displays the output. Figures 5 contain the flow chart for the present designed instrument used to determine the blood glucose. When we insert a glucose test stripe in the meter, the microcontroller automatically detect the presence of stripe, when we drop blood sample, it measure the glucose concentration and display the output blood glucose.

III. RESULTS AND OBSERVATION

The performance of the microcontroller based system for the measurement of blood glucose is designed, developed and tested. Blood glucose values are illustrated on the two lines of the display and transfer values to personal computer. Constant attention has been made on applying blood sample 1

micro liter of blood is the required for testing. The blood sample is applied correctly in a reaction zone; the enzyme becomes active and mediator compound transfer electrons to the electrode. Low power consumption, long shelf life, and environmental operating characteristics (least affected by temperature, humidity, and pressure), were very important considerations in component and design selection. The blood glucose measurements were tested and the results are shown in Table 1.

S. No	Actual Blood Glucose values mg/dl	ACCU CHEK blood glucose meter mg/dl	Present designed Blood glucose meter mg/dl
1	93	93	92
2	136	134	135
3	213	211	212
4	183	182	182
5	149	148	149

Table 1: Blood Glucose values

The results of the present study are in good agreement with the standard blood glucose meters (ACCU CHEK & One Touch Ultra instruments). In the present study, a microcontroller based system, which converts the glucose concentration in the blood sample into voltages compatible with microcontroller input requirements. The microcontroller software determines the validity of the voltage and analyze. Once the test stripe has inserted in the meter, the glucose concentration corresponding to the applied blood sample is displayed as blood glucose. We got good accuracy when compared to YSI 2300 glucose analyzer [11].

IV. SUMMARY

The hardware and software features of a microcontroller based system for the measurement of blood glucose are described. The necessary software is developed in C, using MPPlab IDE for Microchip. The system is quite successful for the measurement of blood glucose with an accuracy of less than $\pm 2\%$. Our instrument protects data in the event of power loss and does not require periodic refreshing. This feature would enable the health care team to use the recorded data to perform diabetes mellitus variability studies. In the present paper, we used test strips designed for the One Touch Ultra glucose meter made by Life scan, PIC microcontroller, RS232 for transferring data to personal computer for further processing and LCD to display which operated with Less power and more bright. These are the novel parts when compared to others.

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