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Design of Digital Blood Glucose Meter Based on Arduino UNO

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Abstract:

In this paper we present an electronic system to perform a measurement of the blood glucose based on Arduino UNO. A glucose sensor is an electrochemical diagnostic strip which used glucose oxidizes enzymes; INA219 current sensing module converts signals from glucose sensor (milliamp) to voltage interfaces with the Arduino UNO. LCD module is used to display the measured value of the blood glucose. Software is developed in C language.

Key words: Blood Glucose Sensors, Current Sensing, Embedded System

I. Introduction

Millions of people throughout the world have been suffered from diabetes, which is a kind of metabolic diseases. It is characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both [1]. Many methods have been used for the detection of glucose, such as amperometric [2, 3], spectrophotometric [4], fluorometric methods [5, 6]. Compared to conventional methods, biosensors can provide improved specificity, detection limits and speed of response [7]. A lot of effort has to be done in exploring nonenzymatic electrochemical glucose sensors which depend on direct oxidation of glucose by using noble and transition metals as electrocatalysts. Noble metals such as platinum [8, 9], gold [10], and palladium [11] have been explored in nonenzymatic glucose sensors. It is well known that noble metals are expensive moreover, they being depleted, in order to resolve this problem and maximize the usage of a noble metal, novel nanoparticles with core and shell structure have been explored recently. Ni core/ Pt shell nanoparticles have been used in oxidation of some alcohols [12, 13] but to the best of our knowledge it is the first time to use this combination in glucose oxidation. In the present investigation, we measure the blood glucose based on Amperometic method. The glucose sensor [5] is an electrochemical diagnostic strip which used glucose oxidizes 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 and converted via INA219 module to Arduino UNO and displayed by LCD module [14, 15, 16].

II. Electronic Monitoring System Design

In this paper, the design of monitoring system has two parts.

a. Hardware Design,
b. Software Design

Initially the hardware design is considered with the components. Each one is described briefly. For such design the suitable board has been considered as Arduino UNO. Each of those units is explained along with the design procedure and as follows. The block diagram of the monitoring based system for the measurement of blood glucose is shown in Figure 1.

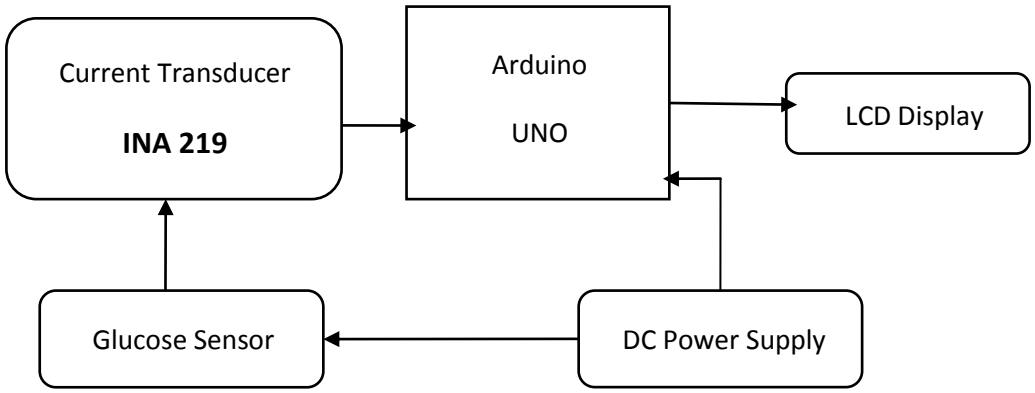

Fig1: Block diagram of the monitoring system

The Arduino UNO microcontroller serves as the brain of the system to facilitate programming. It is a microcontroller board based on ATMega328 that comprises 14 digital pin entries (input) 6 analog production entries (output), a 16 MHz ceramic resonator, USB connection, power jack, ICSP header, and reset button. The board is equipped with the features needed to support the microcontroller by connecting it to a computer using a USB cable. The **UNO** can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Ground and Vin pin headers of the power connector. The board can operate on an external supply of 6 to 20 volts. The **UNO** can be programmed with the Arduino 1.6.4 software. Select "Uno from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer.

III. Bio 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, disfunction 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 oxidize (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 oxidizes 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 Figure 2. The signals from glucose sensor are transmitted to next stage of signal condition unit. The output of the Biosensor is connected to INA219 Current Sensing.

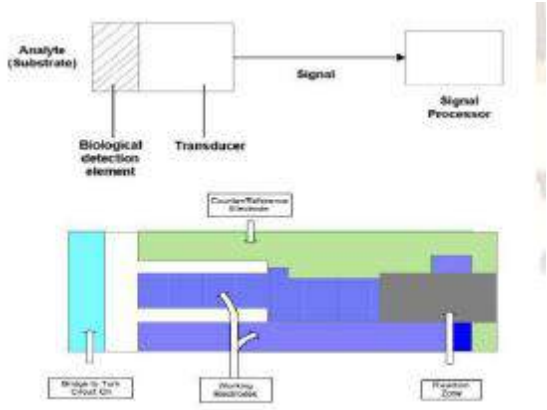

Fig 2: Schematic layout of a biosensor and test strip

IV. INA216 Current Sensing connected to an Arduino

The INA219 is a high-side current shunt and power monitor with an I^2C interface. The INA219 monitors both shunt drop and supply voltage, with programmable conversion times and filtering. A programmable calibration value, combined with an internal multiplier, enables direct readouts in amperes. An additional multiplying register calculates power in watts. The I^2C interface features 16 programmable addresses. The INA219 senses across shunts on buses that can vary from 0V to 26V. The device uses a single +3V to +5.5V supply, drawing a maximum of 1mA of supply current. The INA219 operates from –40°C to +125°C. The pin connection of INA219 current sensing is shown below in Figure 3.

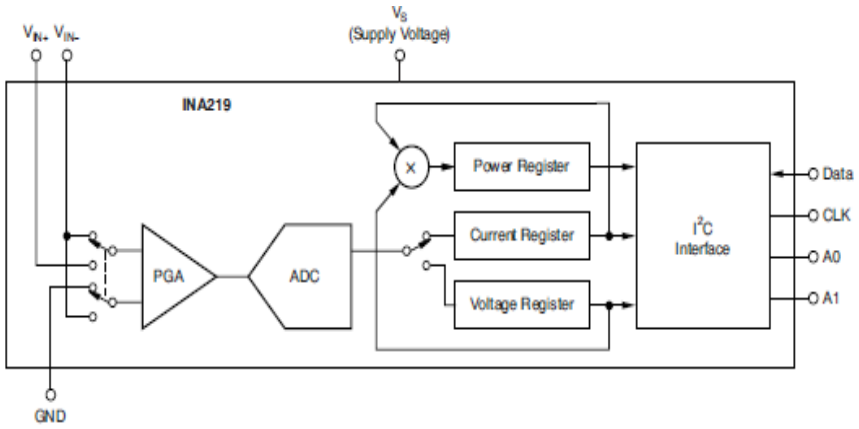

Fig. 3: Pin connection of INA219 current sensor.

The INA219 current sensor is used in the implementation of this digital Glucose meter. As the circuit connection of INA219 current sensing to Arduino for displaying blood glucose is shown below in Figure 4, connect the Arduino 5V to the INA219 VCC and the Arduino GND to the INA219 GND. To read the output voltage level, connect the Arduino SDA (analog pin 4) to the INA219 SDA and connect the Arduino SCL (analog pin 5) to the INA219 SCL. As current passes from V_{IN+} through R_S to V_{IN-}, it creates a voltage drop across R_S. The op-amp inside of the INA219 chip measures the difference between the V_{IN+} and V_{IN-} voltages and outputs a voltage based on that difference. The output of the op-amp is amplified through the internal transistor, which sources a current out of the INA219 chip. As that current passes through R_L to ground, a voltage level is generated at V_{OUT}.

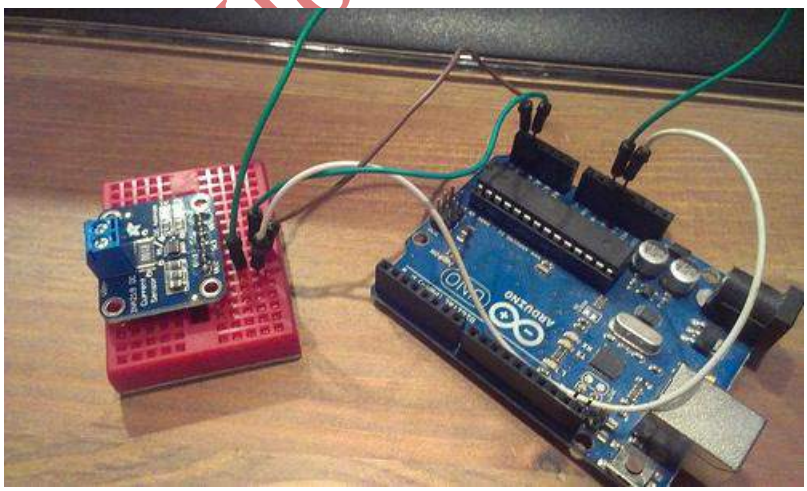

Fig. 4: Pin connection of INA219 current sensor to Arduino UNO.

V. Interfacing LCD to Arduino UNO.

LCD modules form a very important part in many Arduino based embedded system designs. LMB162AFC is the LCD module used here. LMB162AFC liquid crystal display (LCD) is used to get the output of the blood glucose meter. The LMB162AFC has 16 pins and can be operated in 4-bit mode or 8-bit mode. Here we are using the LCD module in 4-bit mode. The pin connection of interfacing LCD to Arduino for displaying blood glucose is shown in Figure 5. RS pin of the LCD module is connected to digital pin 12 of the Arduino. R/W pin of the LCD is grounded. Enable pin of the LCD module is connected to digital pin 11 of the Arduino. In this project, the LCD module and Arduino are interfaced in the 4-bit mode. That means only four of the digital input lines (DB4 to DB7 of the LCD are used). This method is very simple, requires less connections and you can almost utilize the full potential of the LCD module. Digital lines DB4, DB5, DB6 and DB7 are interfaced to digital pins 5, 4, 3 and 2 of the Arduino. The 10K potentiometer is used for adjusting the contrast of the display. 560 ohm resistor R1 limits the current through the back light LED.

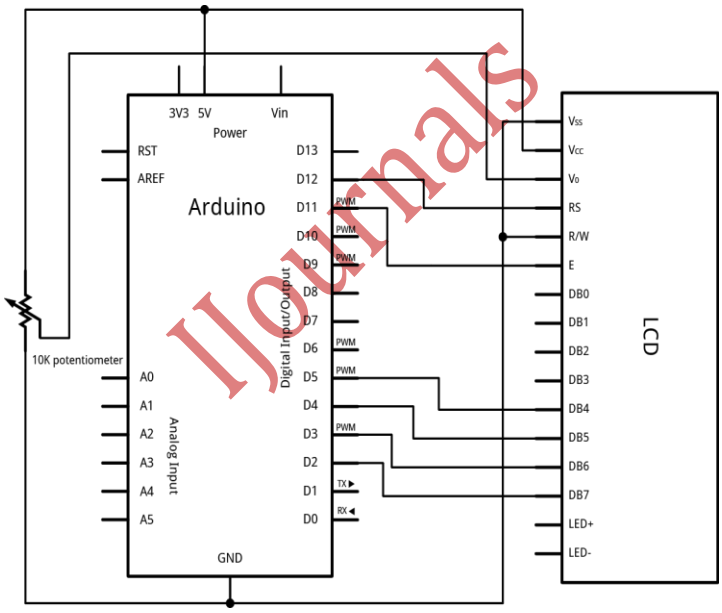

Fig. 5: Pin connection of LCD to Arduino UNO

VI. Software

The software program of this digital blood glucose meter is listed below by "C" programming language. The "C" programming language is growing in importance and has become the standard high level language for real-time embedded applications. This part shows how to write the C program for using the INA216 current sensor Breakout Board; as current passes through the shunt resistor, a voltage is generated. Use an analog read and some math to determine the current and then converted to blood glucose value via lookup table which stored in Arduino memory.

The current value and the concentration of glucose value in the blood are displayed through the LCD Module. The C program is as follow:

```
1.  // include the library codes:
2.  #include <Wire.h>
3.  #include <Adafruit_INA219.h>
4.  #include <LiquidCrystal.h>
5.  Adafruit_INA219 ina219;
6.  // initialize the library with the numbers of the interface pins
7.  LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
8.  void setup()
9.  {
10. ina219.begin();  // Initialize current sensing board (default address 0x40)
11. // set up the LCD's number of columns and rows:
12. Lcd.begin(16,2) ;
13. // initialize the serial communications:
14. Serial.begin(9600);
15.  }
16. void loop()
17. {
18. float shuntvoltage = 0;
19. float current_mA = 0;
20. float bloodglucose =0;
21. shuntvoltage = ina219.getShuntVoltage_mV();
22. current_mA = ina219.getCurrent_mA();
23. //set the cursor to column 0, line 0
24. Lcd.setcursor (0,0);
25. Lcd.print("Current: "); Lcd.print(current_mA); Lcd.println(" mA");
26. Lcd.setcursor (0,1);
27. Lcd.print("Blood Glucose: "); Lcd.print(Blood_mM); Lcd.println(" mMole");
28. Lcd.println("");
29. // Delay program for a few milliseconds
30. delay(500);
31. }
```

VII. Conclusion

In this study, the hardware and software features of Arduino UNO based system used to determine the approximate concentration of glucose in the blood is described. We used Bio sensor for monitoring blood glucose levels. The necessary software is developed in C, using Arduino 1.6.4 software. In the present paper, we used test strips, when a drop of blood is placed on the test strip it interacts with the elements on the strip that causes a reaction and an electric is generated. The current is sent to IMA219 current sensing module and convert to voltage. This voltage is sent to Arduino UNO for further processing and LCD to display which operated with less power and brighter. The accuracy of the system can be improved with a large set of data.

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