Department of Electronic & Telecommunication Engineering
University of Moratuwa

EN 2160 - Electronic Design Realization

Final Project Report

Glucometer

Submitted by:

Tilakarathna. U. A 200664P

Contents

Abstract

The project is a glucometer, that displays the glucose level of the body through invasive means. When the glucose strip is inserted and a blood drop is placed, the glucometer processes the reading to display the glucose level in mg/dL. The proportional current signal generated in the strip is amplified, converted to voltage and processed using the microcontroller and displayed finally..

1 Introduction

Diabetes is a prevalent and serious disease affecting approximately 400 million people worldwide, and it ranks as the 8th leading cause of death. Managing diabetes is crucial for patients to maintain healthy blood glucose levels and prevent complications. At pharmacies, patients can find a wide variety of blood glucose meters along with their accompanying test strips.

The glucometer functions through the action of a disposable test strip that should be connected into the meter. By performing a finger prick to obtain a small droplet of blood, and loading the blood onto the test strip the blood glucose level is read.

2 Product Specifications

After connecting the glucose test strip to the device while the device is switched on, the button on the box should be pressed after placing blood on the strip. Then the glucose level can be observed after 5 seconds that is taken to the reading to achieve steady state. The reading is fed to the atmega328p microcontroller which is connected to an arduino nano board, for processing, and the final output is displayed on a 0.96" OLED display.

The power is supplied by two 2032 3.6V coin cell batteries to ensure the light weight and portability of the device. Three power regulators are used to obtain the required voltages to power the amplifiers, and also for the functionality of the test strip connector.

3 Functionality

The device contains a Onetouch Ultra test strip connector to connect the glucose strip to the device. This reading is achieved by amplifying the current generated by the glucose strip, which is proportional to the glucose level of the body by an enzymatic chemical reaction. This current is converted to a voltage by the opamp circuit and is input to the microcontroller as an analog input. Reference voltages of 2.4V and 2.1V is used in the amplification by connecting the voltages to the test strip electrodes through the opamp circuitry.

The reading is generated by the atmega328p microcontroller which is in the arduino nano board connected. The reading should be calibrated before use. For this, an existing glucometer and also a control solution which has a specified glucose level is required. Depending on the values the code should be changed. An OLED display of 0.96" inches is used to display the reading to the user. These are connected to the microcontroller using SDA and SCL pins. Also, the button that resets the reading is also connected to the microcontroller.

Further, an analog switch CD4066BM96 is connected to reset the circuitry.

LM317LCDR is used to generate the 2.1 V. The output voltage of this regulator is adjustable. Therefore, a 1k variable resistor was used for the adjustments. A TPS76925DBVT is used to generate the 2.5V output. To generate the 5V required for the opamps, a 7805 regulator was used.

3.1 Functionality of the test strips

There are three electrodes printed into the test strips: a reference electrode, a counter electrode and a working electrode. A fixed voltage is applied and the resulting current after the blood is loaded is monitored. The current response is then related to the glucose concentration through calibration.

Typically the electrodes are coated such that an enzymatic chemical reaction occurs at the electrode surface and this reaction dictates the resulting current. The glucometer developed uses Onetouch Ultra test strips. Here, the current after a fixed time, which is after a short initial transient is used for calibration.

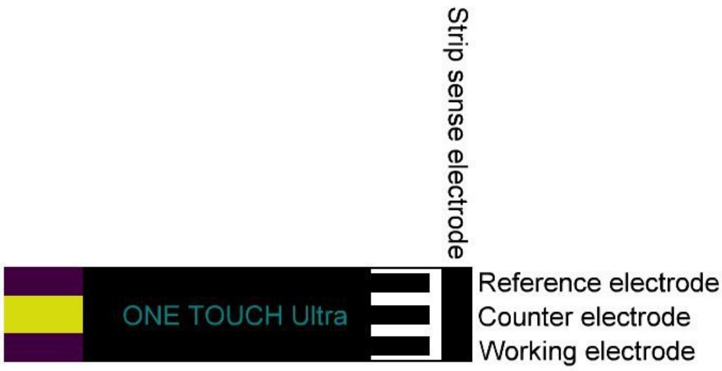

Figure 1: Onetouch Ultra Test Strip

4 Product Architecture

4.1 Block Diagram Abstraction of the Device

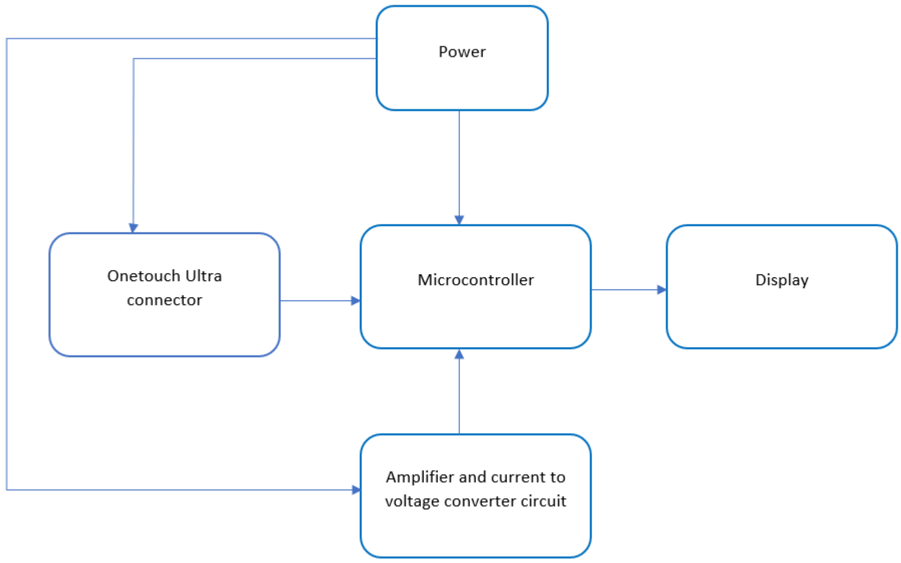

Figure 2: Block Diagram of the Device

5 PCB Design

5.1 Schematics

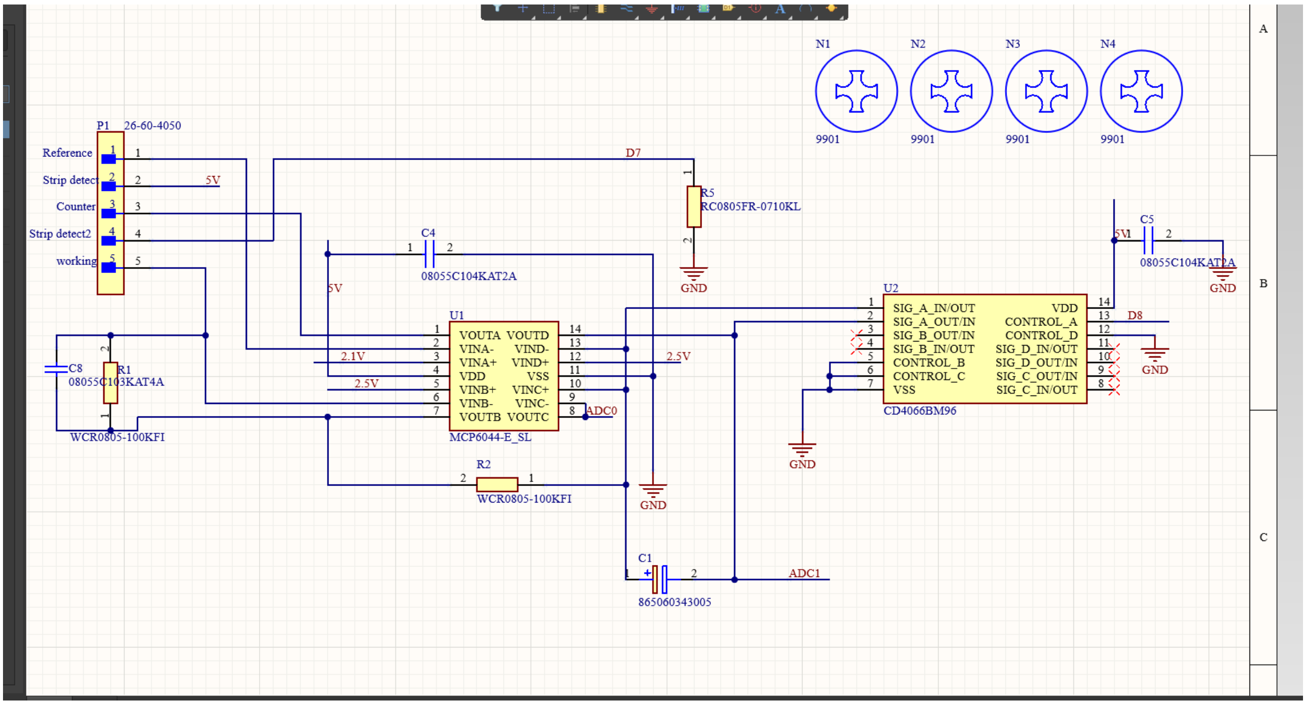

Figure 3: The Main Circuit

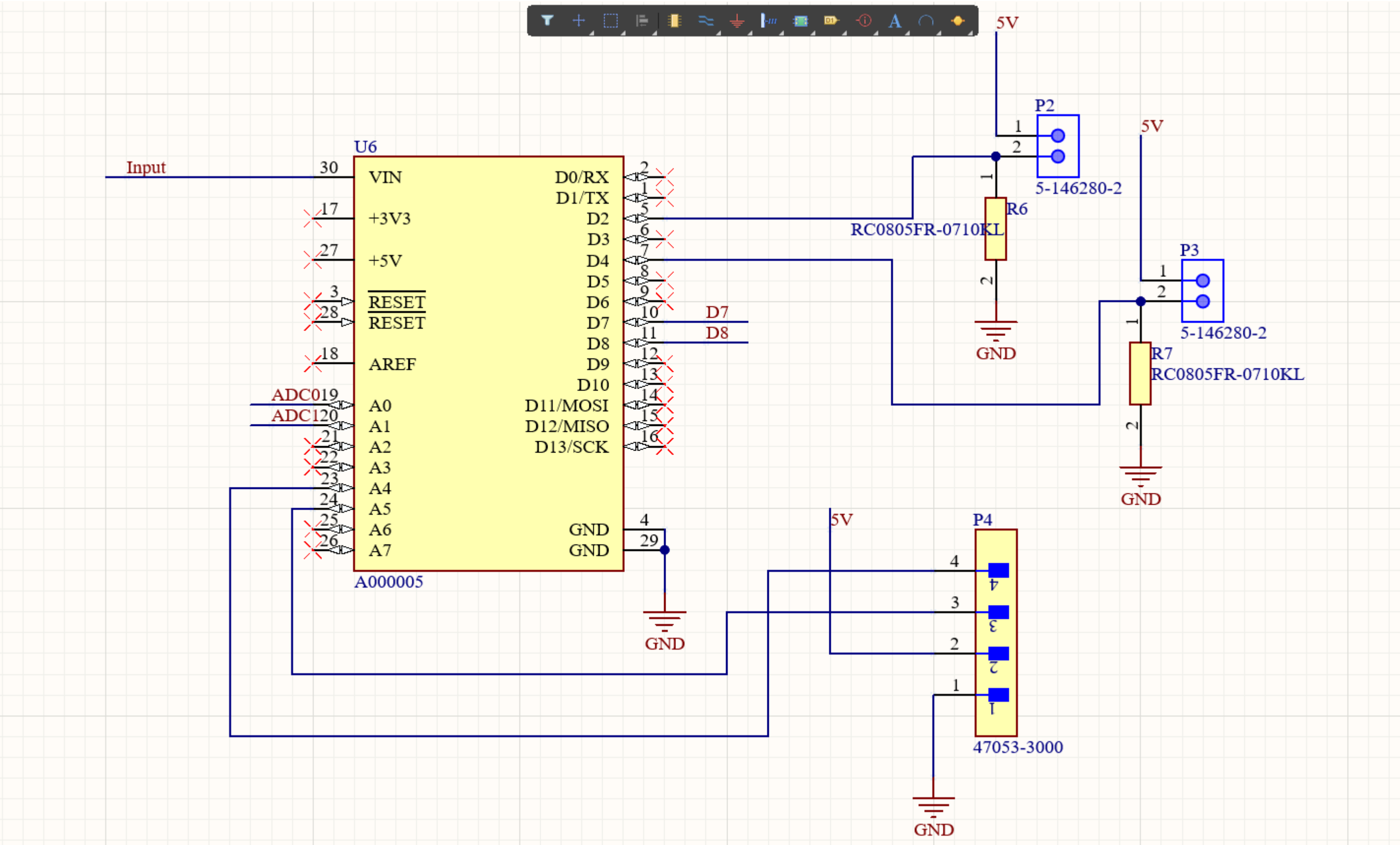

Figure 4: The Display Circuit

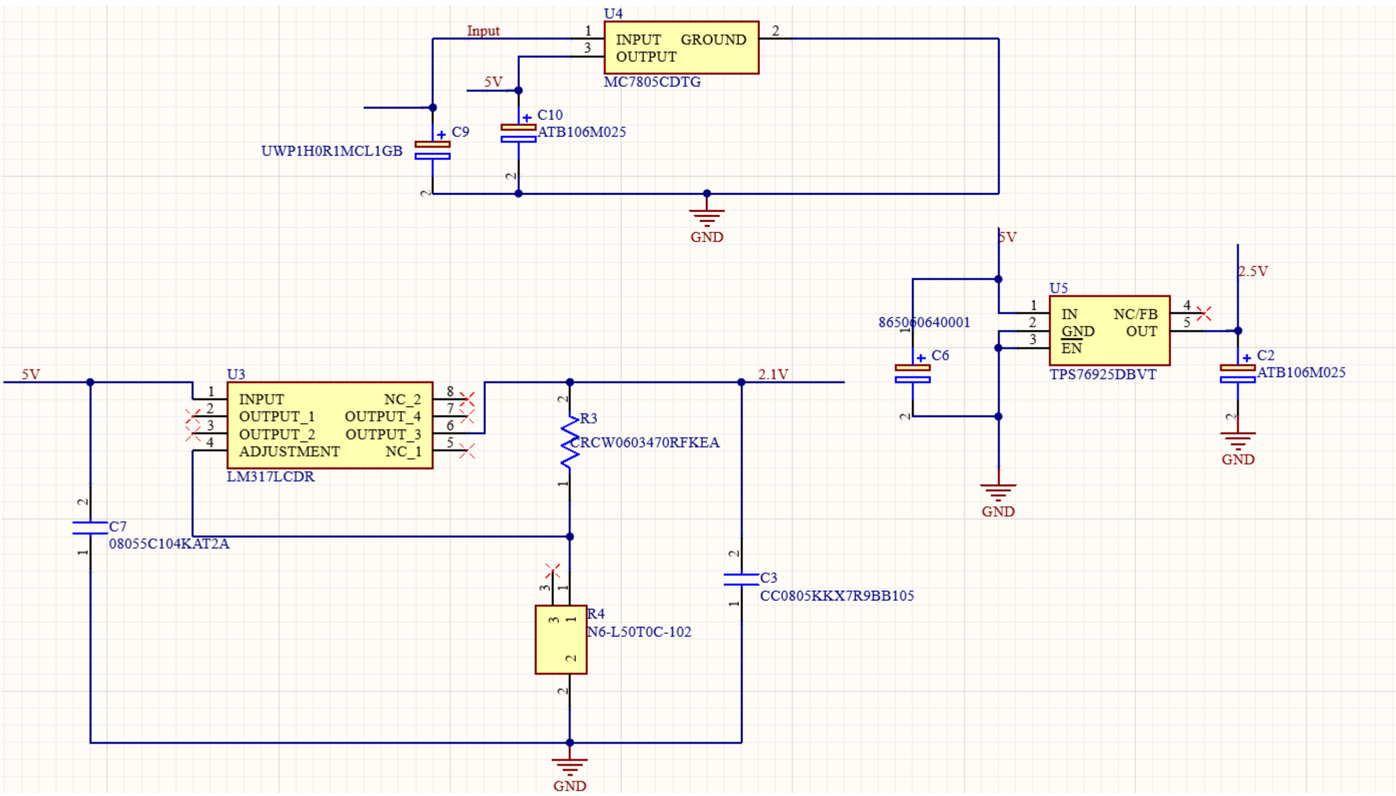

Figure 5: The Power Circuit

5.2 Bill of Materials

MOUSER ELECTRONICS

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	Mouser #	Mfr. #	Manufacturer	Customer #	Description	RoHS	Lif
1	581-08055C103KAT4A	08055C103KAT4A	KYOCERA AVX	10nF	Multilayer Ceramic Capacitors MLCC - SMD/SMT 50V 0.01uF X7R 0805 10%	RoHS Compliant By Exemption	
2	756-WCR0805-100KFI	WCR0805-100KFI	TT Electronics	100kOhm	Thick Film Resistors - SMD 100K ohm 1% 150V General Purpose SMT		
3	579-MCP6044-E/SL	MCP6044-E/SL	Microchip		Operational Amplifiers - Op Amps Quad 1.6V 10kHz	RoHS Compliant	
4	581-08055C104K	08055C104KAT2A	KYOCERA AVX	100nF	Multilayer Ceramic Capacitors MLCC - SMD/SMT 50V 0.1uF X7R 0805 10%	RoHS Compliant By Exemption	
5	603-RC0805FR-0710KL	RC0805FR-0710KL	YAGEO	10kOhm	Thick Film Resistors - SMD 10 kOhms 125 mW 0805 1%	RoHS Compliant By Exemption	
6	710-865060343005	865060343005	Wurth Elektronik	100uF Elec	Aluminum Electrolytic Capacitors - SMD WCAP-ASLL 100uF 16V 20% SMD/SN	RoHS Compliant	
7	595-CD4066BM96	CD4066BM96	Texas Instruments	Analog Switch	Analog Switch ICs Quad	RoHS Compliant	
8	595-LM317LCDR	LM317LCDR	Texas Instruments	U3	Linear Voltage Regulators 3-Trm 100mA Adj Pos Voltage Regulator	RoHS Compliant	
9	71-CRCW0603-470-E3	CRCW0603470RFKEA	Vishay	470 Ohm	Thick Film Resistors - SMD 1/10watt 470ohms 1%	RoHS Compliant By Exemption	
10	531-N6-L50T0C-1K	N6-L50T0C-102	Amphenol	1k Variable	Trimmer Resistors - Through Hole 1Kohms 6mm Top adj	RoHS Compliant	
11	603-CC805KKX7R9BB105	CC0805KKX7R9BB105	YAGEO		Multilayer Ceramic Capacitors MLCC - SMD/SMT 50V 1uF X7R 0805 10%	RoHS Compliant	
12	647-UWP1H0R1MCL	UWP1H0R1MCL1GB	Nichicon	0.1uF elec	Aluminum Electrolytic Capacitors - SMD 50volts 0.1uF AEC-Q200	RoHS Compliant	
13	598-ATB106M025	ATB106M025	Cornell Dubilier	10uF elec	Aluminum Electrolytic Capacitors - SMD 25VDC 10uF 20% 63mA a. 120Hz	RoHS Compliant	Ne
14	710-865060640001	865060640001	Wurth Elektronik	1uF elec	Aluminum Electrolytic Capacitors - SMD WCAP-ASLL 1uF 50V 20% SMD/SMT	RoHS Compliant	
15	595-TPS76925DBVT	TPS76925DBVT	Texas Instruments	2.5V	LDO Voltage Regulators 2.5V 100mA LDO	RoHS Compliant	
16	863-MC7805CDTG	MC7805CDTG	onsemi	7805	Linear Voltage Regulators 5V 1A Positive	RoHS Compliant By Exemption	

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Prices are reflected at the date and time shown.

Figure 6: Bill of Materials of Components

Price of components	Rs. 8450
PCB printing	Rs. 2650
3D printing	Rs. 4000
Other	Rs. 2000
Total prototype production type	Rs. 17,100

5.3 PCB Design

The following images are of the PCB design.

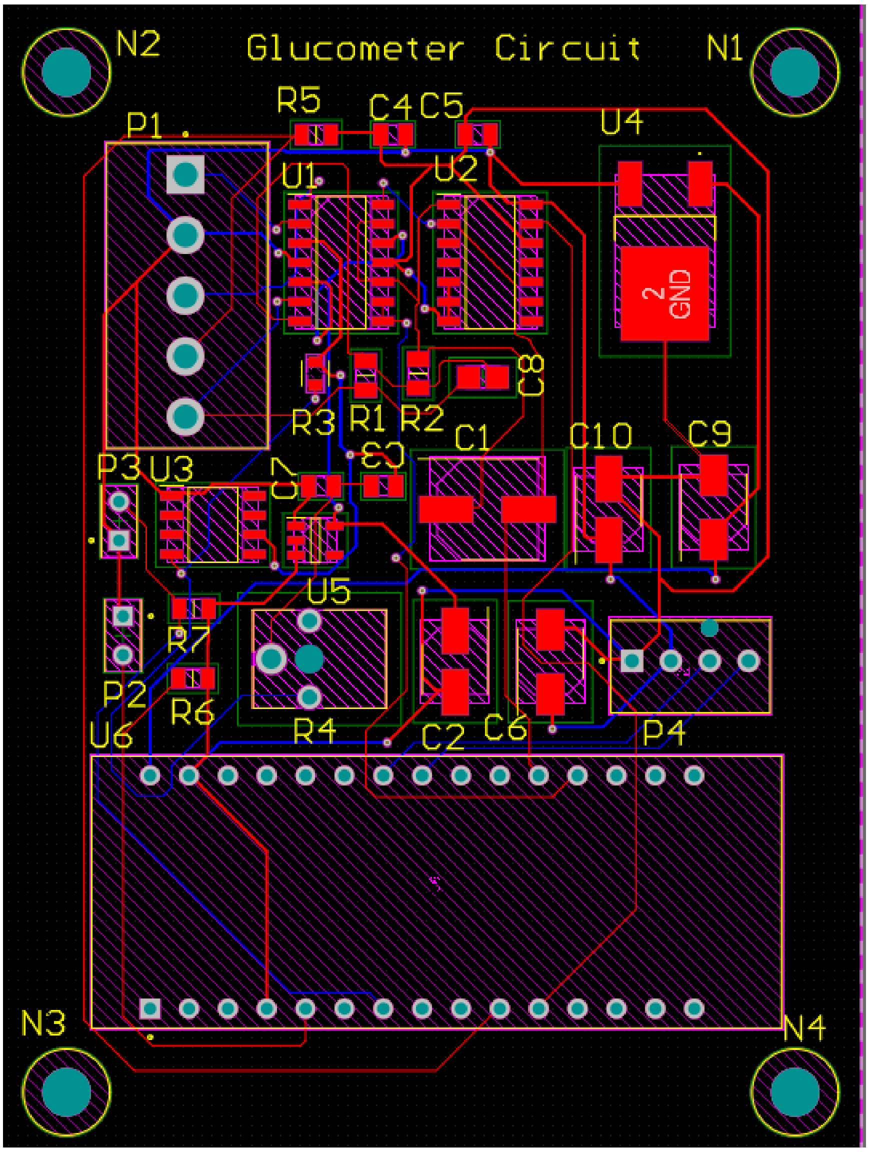

Figure 7: PCB Design

5.4 Programming the microcontroller

test2 | Arduino 1.8.19

File Edit Sketch Tools Help

test2

```
int strip_detect = 7;
int current = 0;
// measurement starts if transimpedance amp output voltage > threshold
float threshold = 2.8;

#include <Wire.h>
#include <Adafruit_SSD1306.h>
#include <Adafruit_GFX.h>
#include "RTClib.h"
RTC_Millis RTC;


#define SCREENWIDTH 128
#define SCREENHEIGHT 64
#define OLEDRESET -1 //same reset as the esp32
#define SCREEN_ADDRESS 0x3C

Adafruit_SSD1306 display(SCREENWIDTH, SCREENHEIGHT, &Wire, OLEDRESET);


void setup() {

   if (!display.begin(SSD1306_SWITCHCAPVCC, SCREEN_ADDRESS))
  {
    Serial.println(F("SSD1306 allocation failed"));
    for(;;);
  }
  Serial.begin(9600);
  // set the RTC to the date & time this sketch was compiled
  display.clearDisplay();
  Serial.println("Glucometer Starting...");
  delay(2000);
  display.clearDisplay();
  RTC.begin(DateTime(__DATE__, __TIME__));
  pinMode(strip_detect, INPUT);
```

```
}

void loop() {
  while(1) {
    if(digitalRead(strip_detect) == 1) break;
  }
  Serial.println("APPLY BLOOD");
  float current_voltage;
  while(1) {
    current_voltage = analogRead(0) * (5.0 / 1023.0);
    if(current_voltage > threshold) break;
  }
  // count down timer
  for(int i = 5; i > 0; i--) {
    delay(1000);
    Serial.print(i);
    if(i > 1) Serial.print(", ");
    else Serial.println("");
  }
  // compute concentration
  current_voltage = analogRead(0) * (5.0 / 1023.0);
  float concentration = 495.6 * current_voltage - 1275.5;
  Serial.print(concentration);
  Serial.println(" mg/dL");
  display_time();
  while(1) {
    if(digitalRead(strip_detect) == 0) break;
  }
  delay(1000); //debounce
}

void display_time() {
  DateTime now = RTC.now();
  Serial.print(now.year(), DEC);
  Serial.print('-');
```

```
  Serial.print(now.month(), DEC);
  Serial.print('-');
  Serial.print(now.day(), DEC);
  Serial.print(' ');
  Serial.print(now.hour(), DEC);
  Serial.print(':');
  Serial.print(now.minute(), DEC);
  Serial.print(':');
  Serial.print(now.second(), DEC);
  Serial.println();
}
```

6 Enclosure Design

The enclosure is made in such a way, that is portable and easy to use with minimal interactions with the device. The top part is connected with the display, and is made in such a way, that is removable for any repairs of the device. Also, the battery compartment can be open when needed.

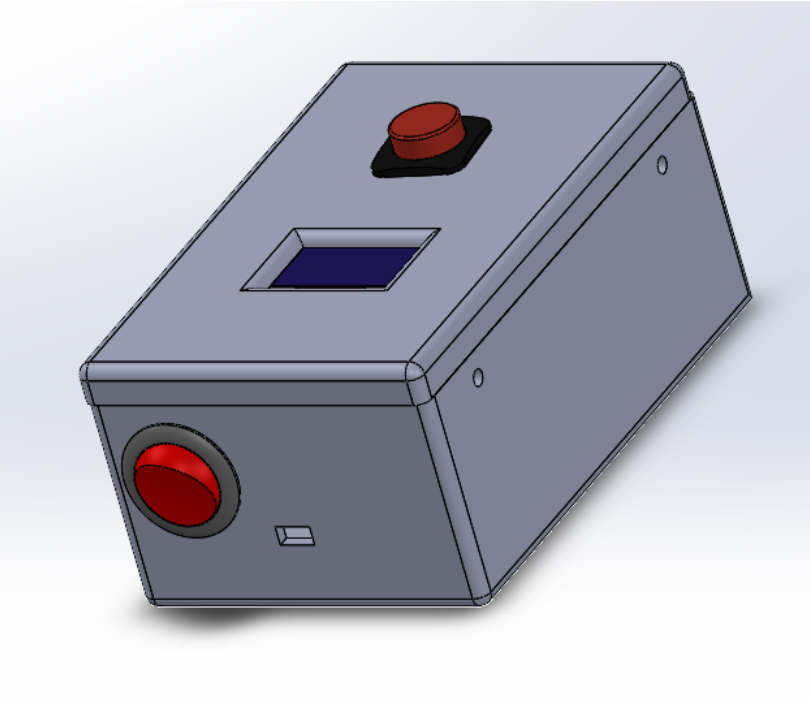

Figure 8: Top Appearance

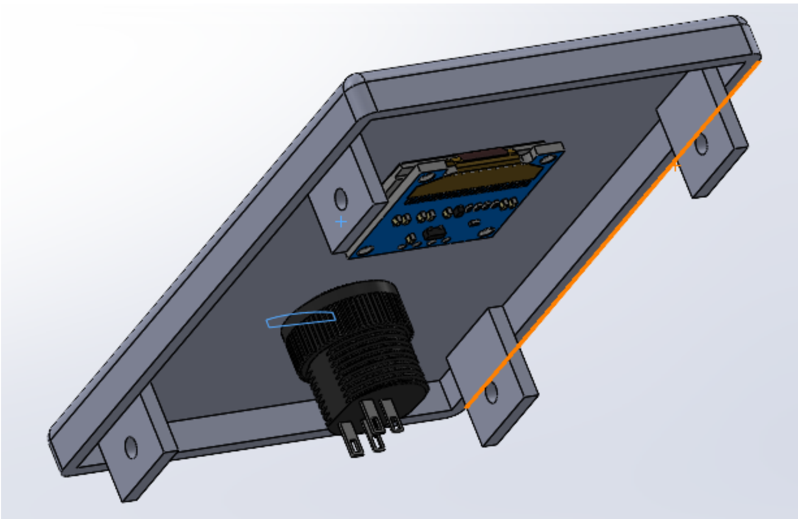

Figure 9: Top Lid Appearance

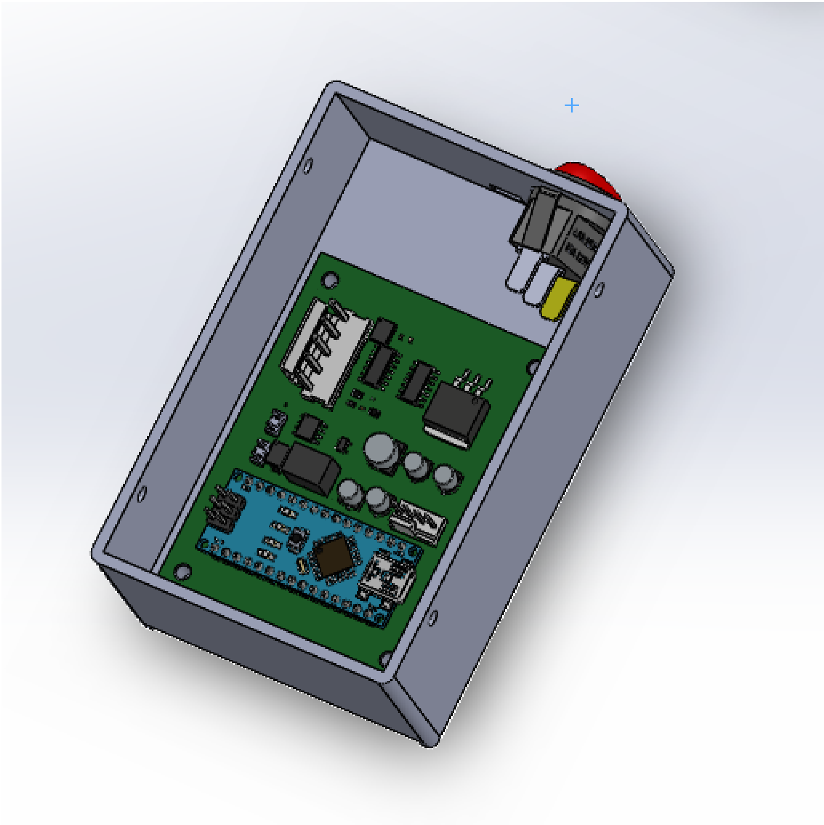

Figure 10: Interior Appearance

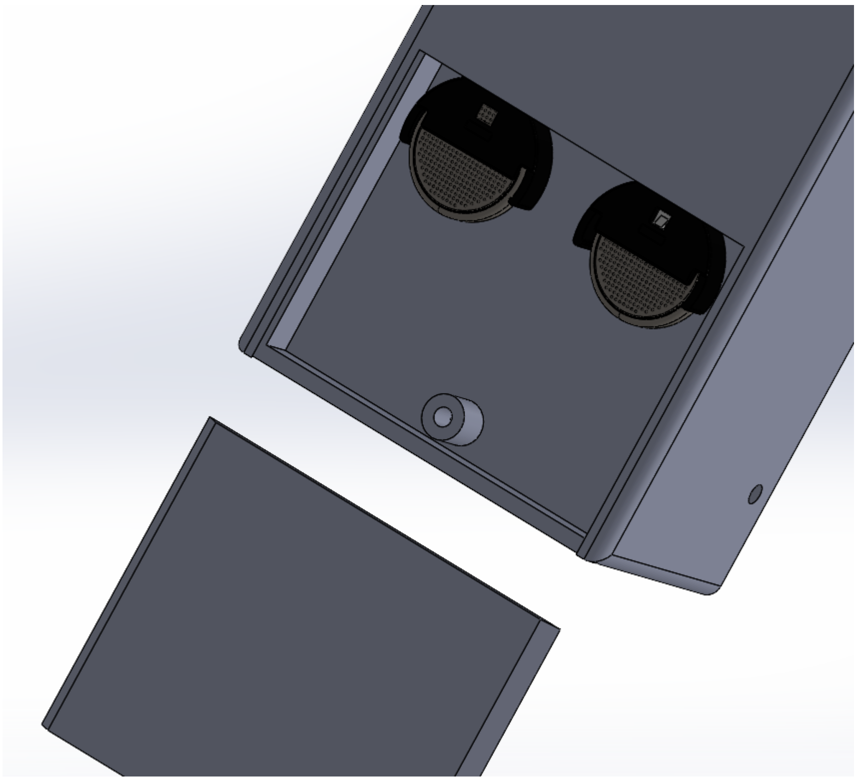

Figure 11: Battery Compartment

7 Instructions of Assembly

The battery compartment wires should be connected to the switches of the top lid first. Then, the PCB can be fixed, thereafter the display can be connected to the top lid, and then to the PCB through the wires. Finally, the top and bottom parts of the enclosure are to be firmly closed using the screws. The battery compartment should also be closed using screws.

8 Testing for functionality

8.1 Power Verification

First, check if the input terminal receives power.

Then, 1. Check the output of the 7805 regulator. 2. Check the output of the LM317LCDR regulator, and adjust the output voltage to 2..1V using the R4, 1k variable resistor. 3. Check the output of the TPS76925DBVT and verify whether the output is 2.5V.

8.2 Calibration

This is a very important part of the glucometer production. In mass production, testing the value of a known control solution is done. But here, after checking the values of two control solutions from a working glucometer, the code should be changed after finding the necessary coefficients of the y=mx+c graph.

8.3 Code Verification

The code should start working only when the test strip is connected, and the micro-controller receives the connected signal. The glucose value should be displayed only when the button on the top lid is pressed. The displayed value shoould be checked through calibration procedure. In any further issue, the code should be verified with the simulation.

9 Areas of possible improvement

- The ergonomics can be improved to give a better user experience.
- A memory block can be used to store previous values for reference, or, the value can be transmitted to the phone via bluetooth to strore the value.