Department of Electronics and Telecommunication Engineering

Faculty of Engineering

University of Moratuwa

EN2160 Electronic Design Realization

Final Report

Madhushan R.M.S.

200363R

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General Information

Overview

The objective of the project was to create a commercially viable electronic product, incorporating novel functionalities to fulfill an existing demand. It is decided to make a digital multimeter which has a DC power supply compatibility as an extra feature. A multimeter, short for "multiple meter," is an indispensable tool in the realm of electrical and electronic measurements. This ingenious device serves as an all-in-one instrument, combining the functionalities of several meters into a single, compact unit. Its versatility makes it an essential companion for technicians, engineers, electricians, hobbyists, and anyone dealing with electrical circuits and systems.

In this fast-paced world of electronics and electrical engineering, the multimeter remains an enduring and vital instrument. As technology continues to evolve, these devices evolve too, incorporating innovative features and improvements to meet the ever-changing demands of the modern era. Whether you're a seasoned professional or an enthusiastic beginner, a multimeter is an invaluable asset, empowering you to confidently explore the intricacies of the electrical world.

Functionality

The focal attributes of this product comprise a primary switch and a two-way switch. The primary switch serves the purpose of activating or deactivating the product, while the second switch is responsible for seamlessly transitioning between the multimeter and 5V power supply modes. Additionally, the product incorporates two rotary switches, where one is designated for mode selection and the other is dedicated to adjusting the ohmmeter's scale. The readings obtained from the various functionalities are conveniently displayed through the utilization of an LED display. Notably, this product boasts a rechargeable battery system, eliminating the necessity for battery replacement, as it comes equipped with an integrated charger mechanism.

Specifications

- This product is mainly a multimeter. Also this can be used as a 5V DC power supply.
- Multimeter has four modes.

1. Voltmeter
    - Measurement range = 0V to 50V

2. Ammeter
    a. Measurement range = 1mA to 2A

3. Ohmmeter
    a. Measurement range = 0 ohm to 1M ohm
    b. There are four resistance scales.
    c. 0 to 1K ohm
    d. 1K to 100K ohm
    e. 100K to 400K ohm
    f. 400K to 1M ohm

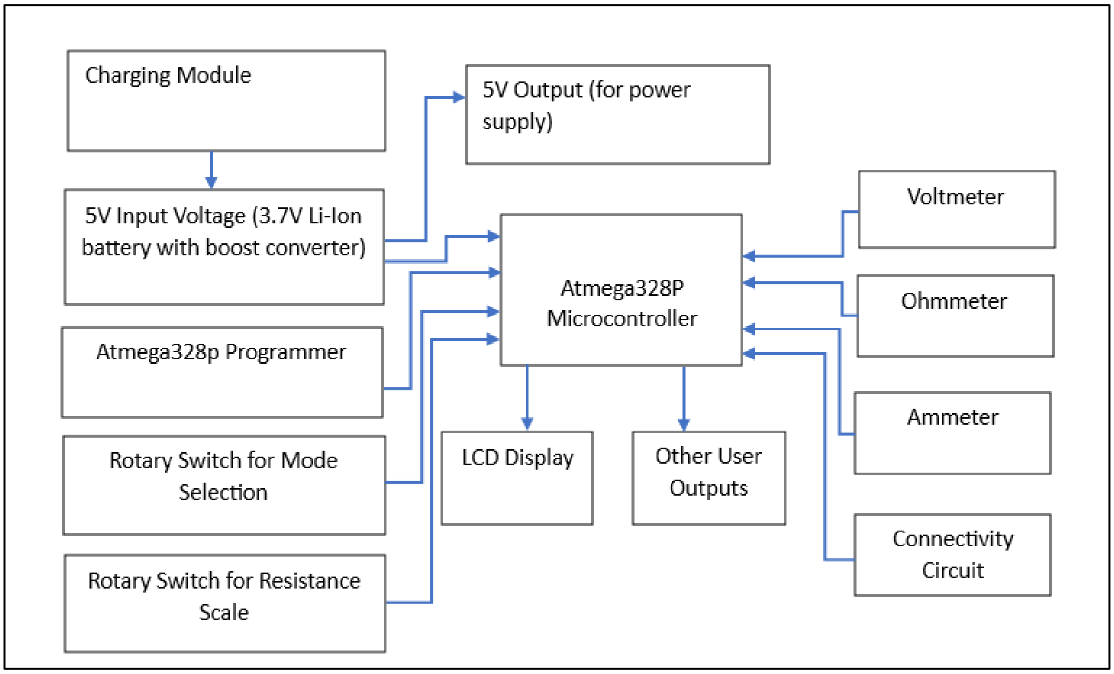
4. Continuity checker

- Probes do not have to change when it is working as an ammeter.
- This product has a charging feature.
- Once it is fully charged, it can be used 12 hours straight.
- There is a two way switch to change the mode between multimeter and power supply.
- weight = 500g
- Dimensions = 13cm × 9cm × 2.5cm

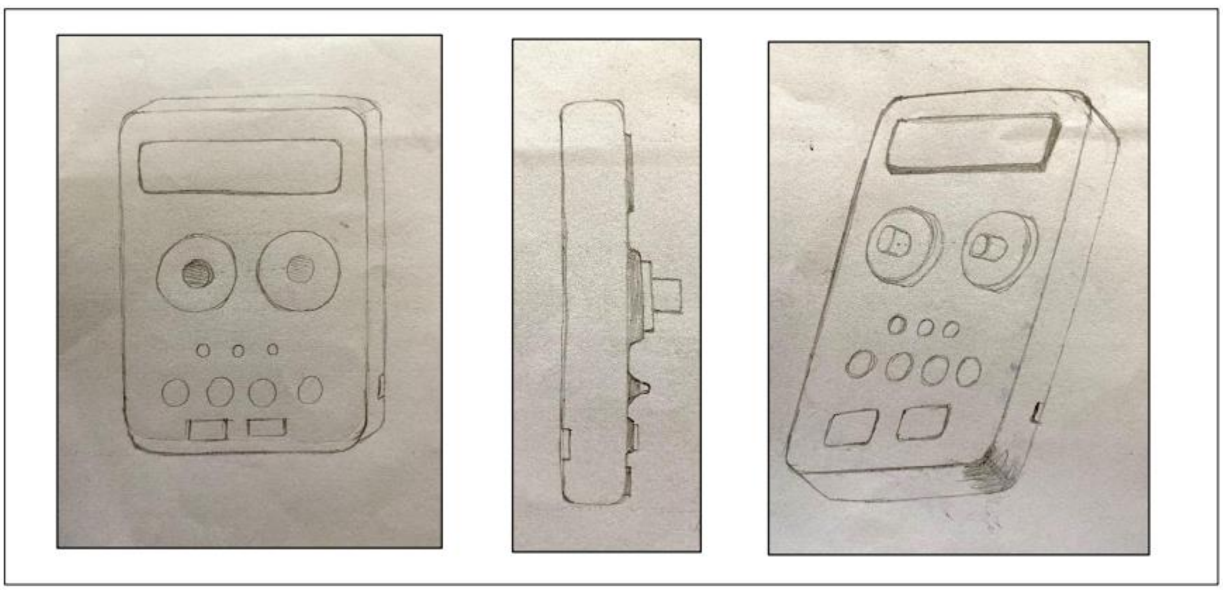
Conceptual Designs

Design 1

Block Diagram 1

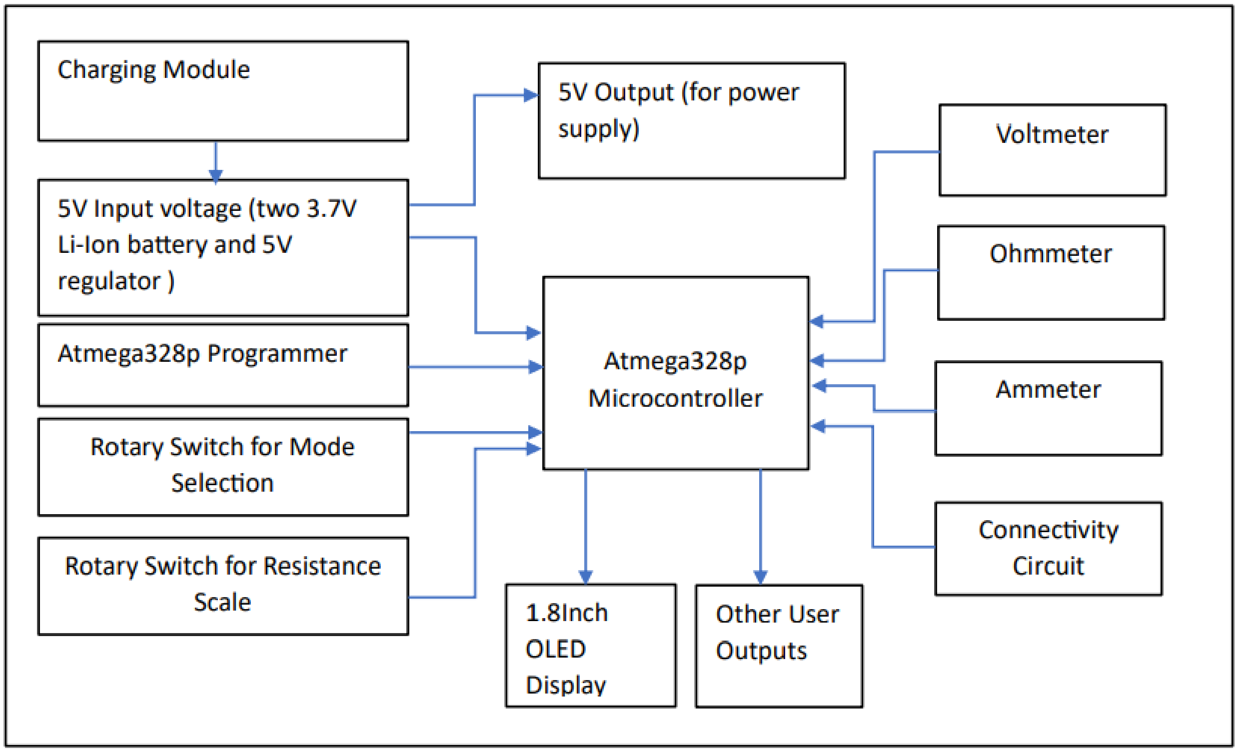


Enclosure Design 1

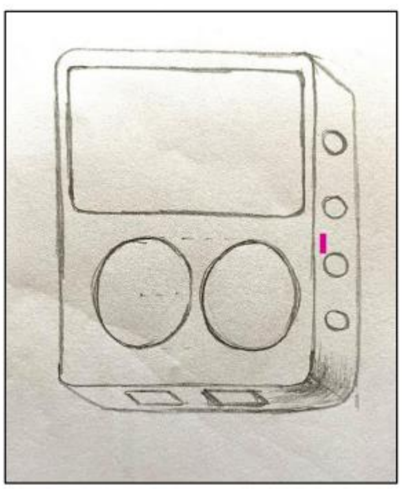


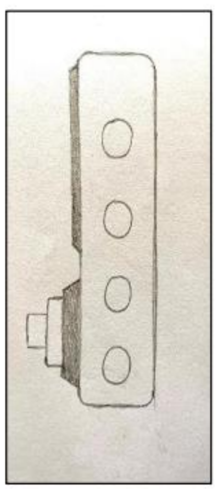
Design 2

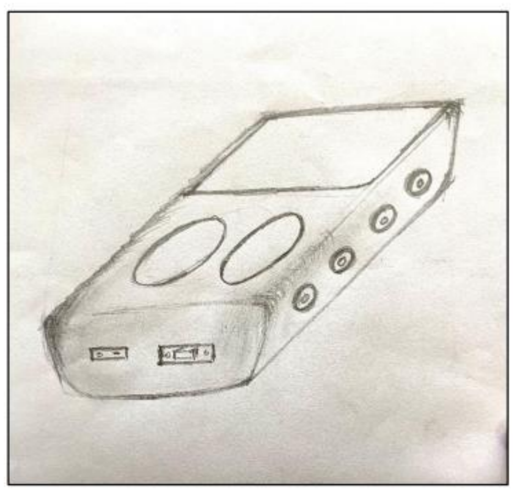
Block Diagram 2



Enclosure Design 2

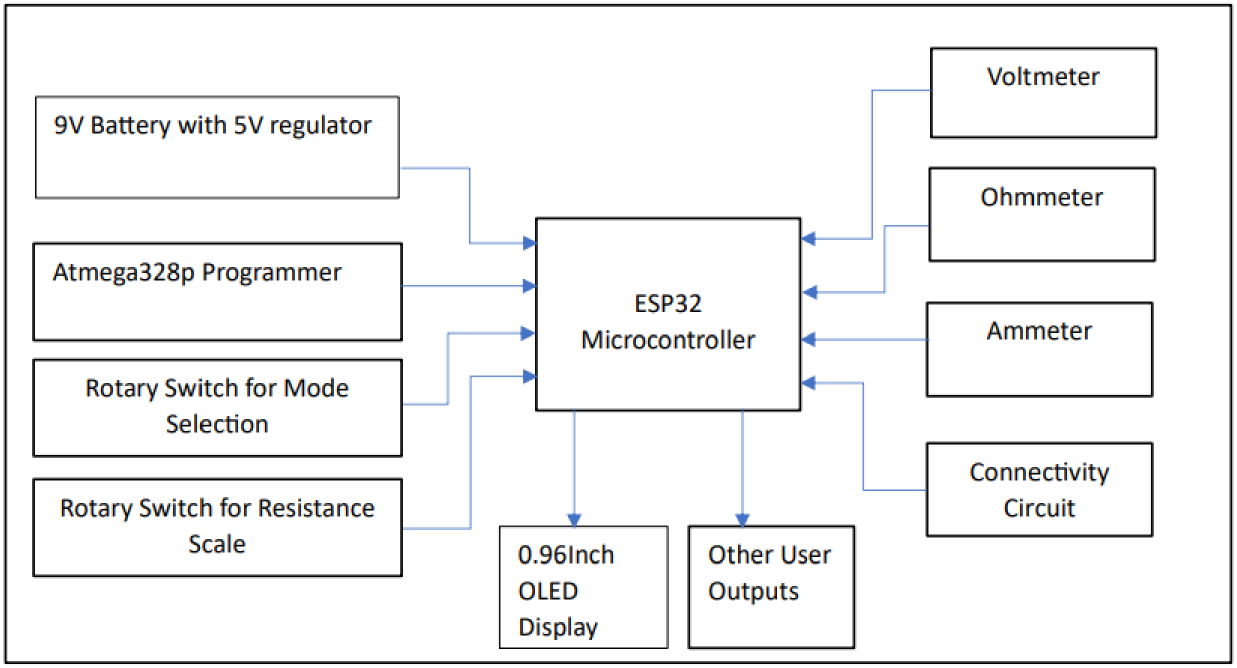




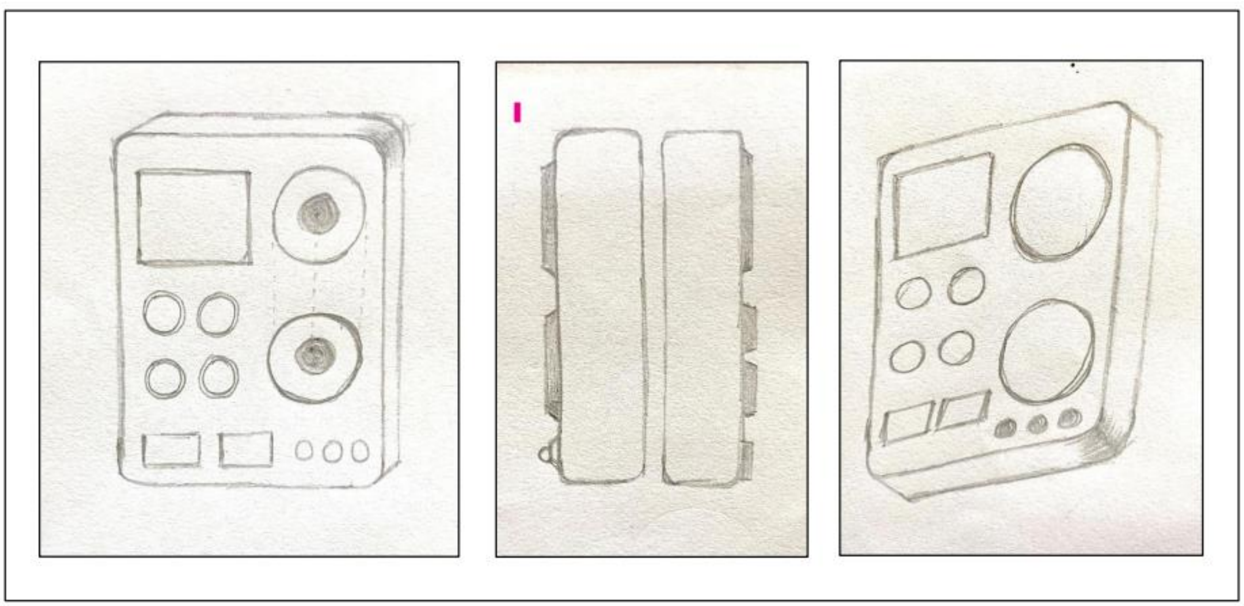


Design 3

Block Diagram 3



Enclosure 3



Comparison of Block Diagram 1 and 2

- Instead of one Li-Ion battery, two batteries are added to block diagram 2. Therefore, the total power that the circuit can utilize is higher than the 1st block diagram.
- Instead of using buck/boost converter, 5V voltage regulator is used since the regulator is inexpensive when compared buck/boost converter which is used in block diagram 1.
- In this design, a much larger OLED display is used compared to block diagram 1.

Comparison of Block Diagram 1 and 3

- 5V Power supply option is removed in the design.
- The charging feature is removed.
- One 9V battery is used compared to block diagram 1.
- A smaller OLED display is used in this block diagram.
- Buck/boost converter is not used to reduce the cost.

Evaluation

Evaluation of Block Diagram

Criteria :

1) Functionality
2) Accuracy
3) User Friendliness
4) Cost
5) Power Consumption
6) Reliability
7) Compatibility – (Capability of replacing device or systems that perform the same process or part of the process)

	Block Diagram 1	Block Diagram 2	Block Diagram 3
Functionality	10	9	9
Accuracy	9	8	8
User Friendliness	9	7	7
Cost Effectiveness	8	7	9
Power Efficiency	8	8	9
Reliability	9	9	9
Compatibility	7	7	7
Total	59	55	58

Evaluation of Enclosure Design

Criteria :

1) Durability
2) Attractiveness
3) Cost Effectiveness
4) User Safety – Prevention from electric leakage
5) Compatibility – Capability of attaching the device to a certain place
6) Repairability
7) Weight and Hardness

	Enclosure 1	Enclosure 2	Enclosure 3
Durability	9	9	9
Attractiveness	8	7	7
Cost Effectiveness	8	7	8
User Safety	8	8	8
Compatibility	8	7	8
Repairability	8	5	7
Weight and Hardness	8	8	8
Total	57	51	55

According to the evaluation, block diagram 1 and enclosure design 1 has been chosen.

Components

Atmega328P Microcontroller

The ATmega328P is a widely used 8-bit microcontroller from the AVR family, manufactured by Atmel (now Microchip Technology). It offers a versatile and efficient solution for a wide range of embedded systems and DIY electronics projects. With a clock speed of up to 20 MHz, it can handle tasks quickly and precisely. The microcontroller comes equipped with 32KB of Flash memory for storing program code, 2KB of SRAM for temporary data storage, and 1KB of EEPROM for non-volatile data storage. Its GPIO pins allow for flexible interfacing with external devices, while the built-in 10-bit ADC enables the conversion of analog signals to digital values. Additionally, the ATmega328P features multiple timers and counters, which are valuable for generating accurate timing, PWM signals, and event counting. Its popularity and ease of use make it a favored choice among hobbyists, engineers, and developers seeking a reliable microcontroller for their projects.

All voltmeter, ammeter, ohmmeter, continuity checker circuits are connected to the relevant pins of this microcontroller. Once it is set to the appropriate state for the ammeter, volmeter, ammeter ohmmeter, continuity checker, the microcontroller will send the reading to the display.

Rotary Switch

The 3P4T switch is a rotary switch commonly used in electronics. It has three poles, allowing control of three separate circuits, and four positions, enabling the selection of different circuit combinations with a single actuator. This switch is frequently employed in devices like audio equipment and electronic instruments for straightforward and reliable circuit switching.

In this product, two 3 pole 4 state switches are used. One is for multimeter modes and for the other one is for resistance scale.

The mode selection rotary switch has four modes.

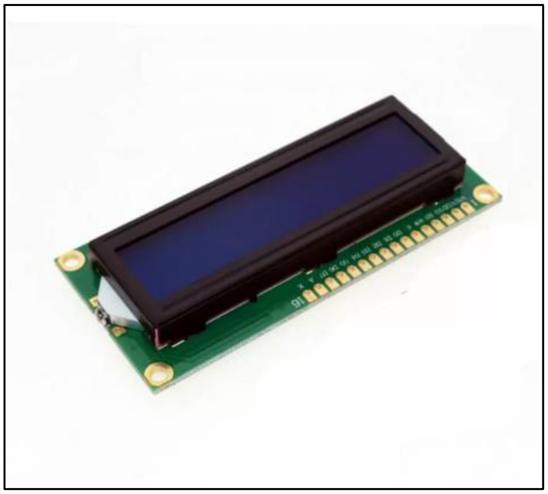
1. Voltmeter
2. Ammeter
3. Ohmmeter
4. Continuity Checker

When the modes are changed, corresponding probes connection also changes accordingly. Therefore the user does not have to change the probes when the mode is being changed.

Resistance scale rotary switch has four scales.

1. 1K ohm
2. 100K ohm
3. 400K ohm
4. 1M ohm

LCD Display



The 16x2 LCD display is a widely used alphanumeric display module in the field of electronics and embedded systems. It consists of 16 columns and 2 rows, providing a total of 32 characters (16 characters per row) that can be displayed at once. Each character position is typically composed of a 5x8 dot matrix, allowing the display of letters, numbers, symbols, and simple graphics.

Single Pole Double Throw Switch

A Single-Pole, Double-Throw (SPDT) switch is a basic and commonly used type of electrical switch. It consists of a single input terminal (pole) and two output terminals (throws). When in the "ON" position, the common terminal connects to one of the two output terminals, and when in the "OFF" position, it disconnects from the first output and connects to the second one. This simple but versatile configuration allows SPDT switches to toggle between two different circuits, making them suitable for various applications, such as controlling lights, motors, and electronic devices.

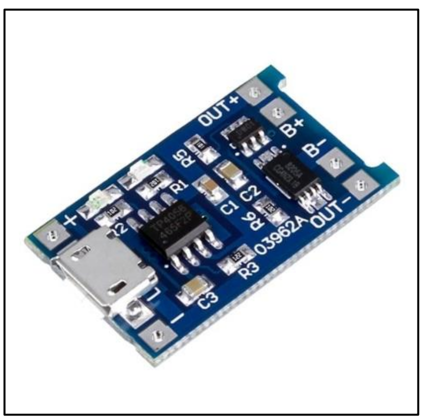
This switch is used to change the mode between multimeter and 5V DC power supply.

Battery

The LiPo (Lithium Polymer) 1200mAh battery is a compact and lightweight rechargeable power source widely used in portable electronics and hobbyist projects. With a capacity of 1200 milliampere-hours (mAh), it can supply a steady electric current of 1.2 Amps for one hour, or proportional current over a longer duration. This outputs 3.7V.

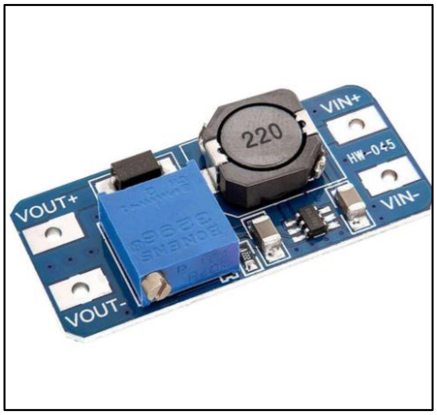
Instead of 18650 Li-Ion 1200mAh battery, it is decided use this battery. Main reason for that is the size of this battery. It is a compact battery so that the product size also can be more small.

Charging Module



The TP4056 is a popular and widely used single-cell lithium battery charging module. It is designed to charge lithium-ion (Li-ion) and lithium-polymer (LiPo) batteries safely and efficiently. This compact module integrates a charging chip, power management components, and status indicator LEDs into a single package, making it convenient for charging applications. Therefore this module has been chosen for the charging module for the device.

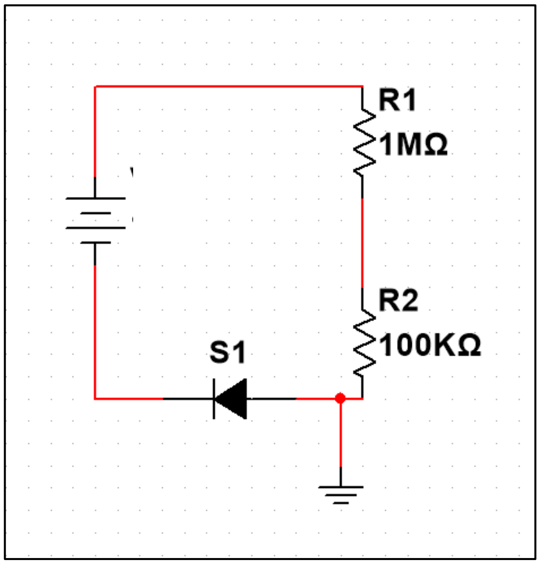
Boost Converter



The MT3608 is a versatile and widely used DC-DC boost converter module designed to step up voltage levels efficiently. Since Li-Po battery only output 3.7V it should be convert to 5V. In order to do that, this module has been chosen.

Circuit Diagrams

Voltmeter Circuit

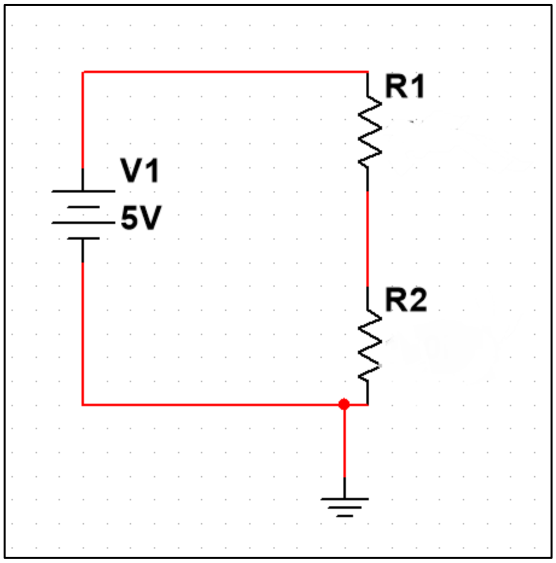


$$V_{out} = (\frac{R2}{R1+R2}) \times (V_{in} - V_{diode})$$

$$V_{in} = \left(\frac{R1}{R2} + 1\right) \times V_{out} + V_{diode}$$

- In this circuit, R1 and R2 are chosen in such a way that the voltage measuring range can be maintained around 50V.
- 1N4001 diode is used to block the current to the other direction.
- Here V1 act as the voltage source we want to measure the voltage.
- When V1 is set, there is a voltage drop across the R2 resistor and that voltage drop is measured from analog input pin from atmega328p microcontroller.
- After taking that V_{out} value, according to the above calculation Vin can be found.

Ohmmeter Circuit



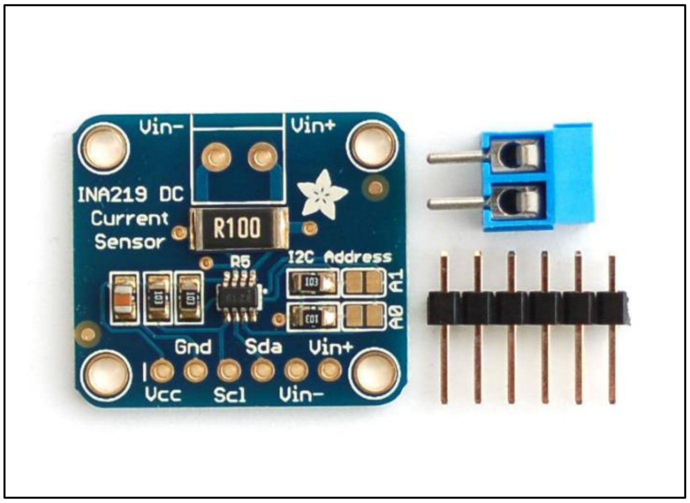
$$V_{out} = \left(\frac{R2}{R1 + R2}\right) \times 5V$$

$$R2 = \frac{R1}{\left(\frac{5}{V_{out}} - 1\right)}$$

- R2 is the unknown resistor.
- There are four R1 resistors chosen according to various scale.
- 1K, 10K, 50K and 100K are the R1 resistor values.
- According to the R2 value user can set the corresponding R1 value with a rotary switch and then more precisely resistance can be measured.
- 5V is being supplied from the atmega328p microcontroller.
- After supplying that voltage, there is a corresponding voltage drop across R2 and that will be measured from analog input of the atmega328p microcontroller.
- Then according to the above calculation, R2 can be found.

Ammeter Circuit

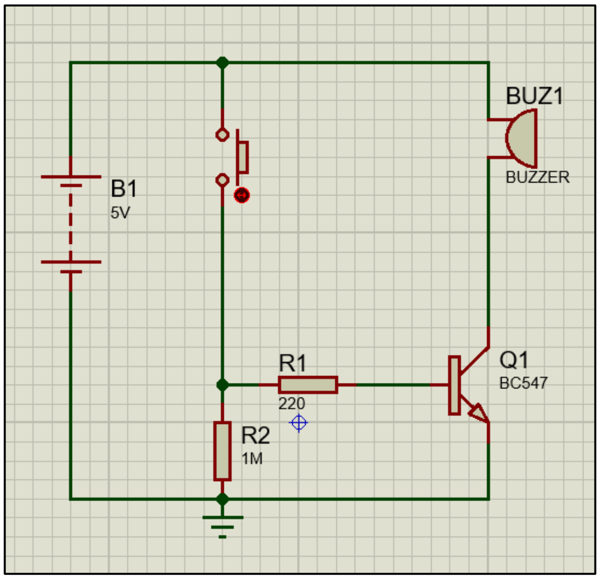
For ammeter, INA219 module is used.



The primary functionality of the INA219 is current sensing. It is specifically designed to accurately measure the current flowing through a load in electrical systems. This is achieved through a high-side current shunt resistor incorporated within the IC.

When current flows through the load, a voltage drop occurs across the shunt resistor. The INA219 measures this voltage drop with high precision. By utilizing Ohm's law (V = I * R), where V is the voltage across the shunt resistor, I is the current flowing through the load, and R is the resistance of the shunt, the INA219 calculates the current value.

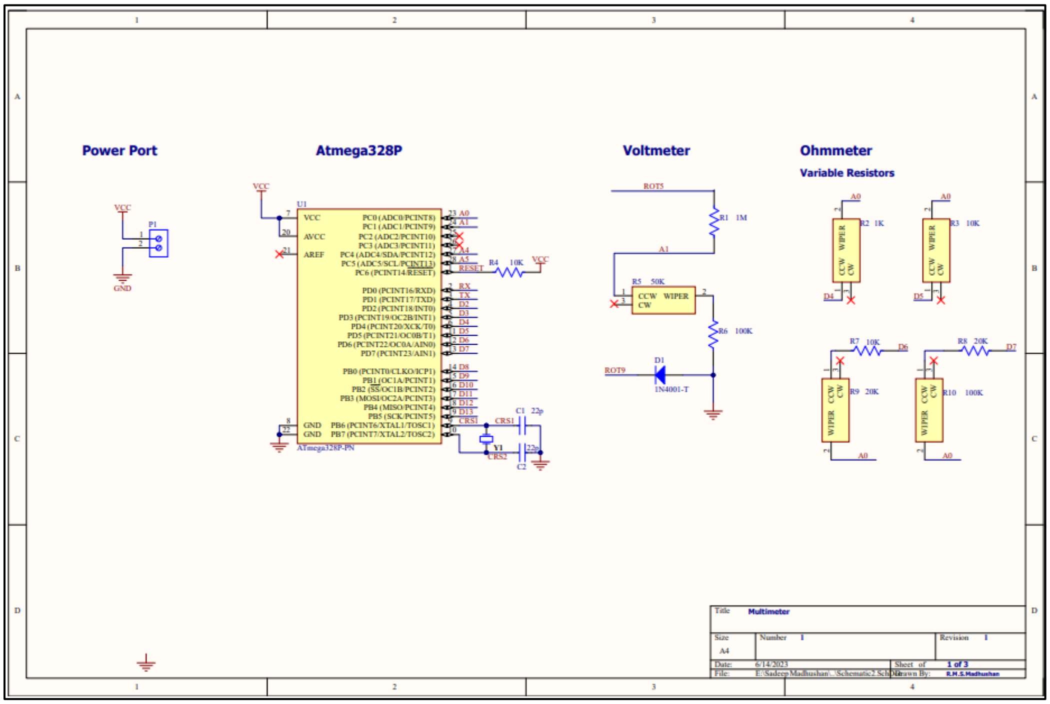
Continuity Checker Circuit



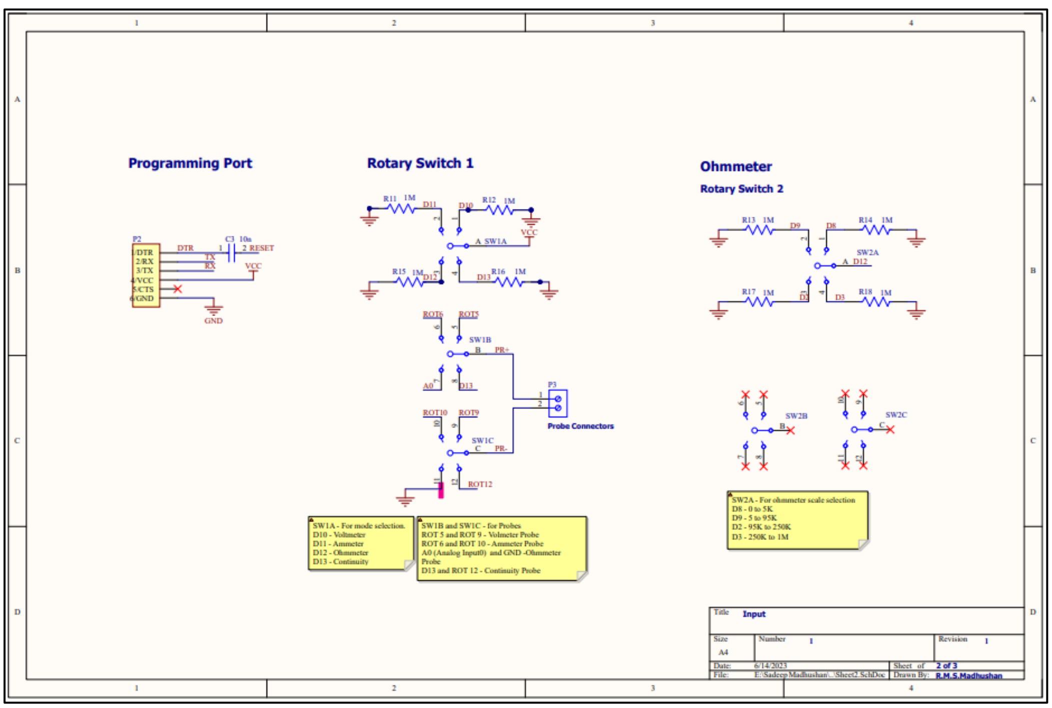
- Instead of push button, two probes are set there.
- therefore when there is connection between those two probes, circuit will be fully connected.
- Then, there will be base current and the transistor will act as a closed switch and buzzer will be on.

Schematic Design

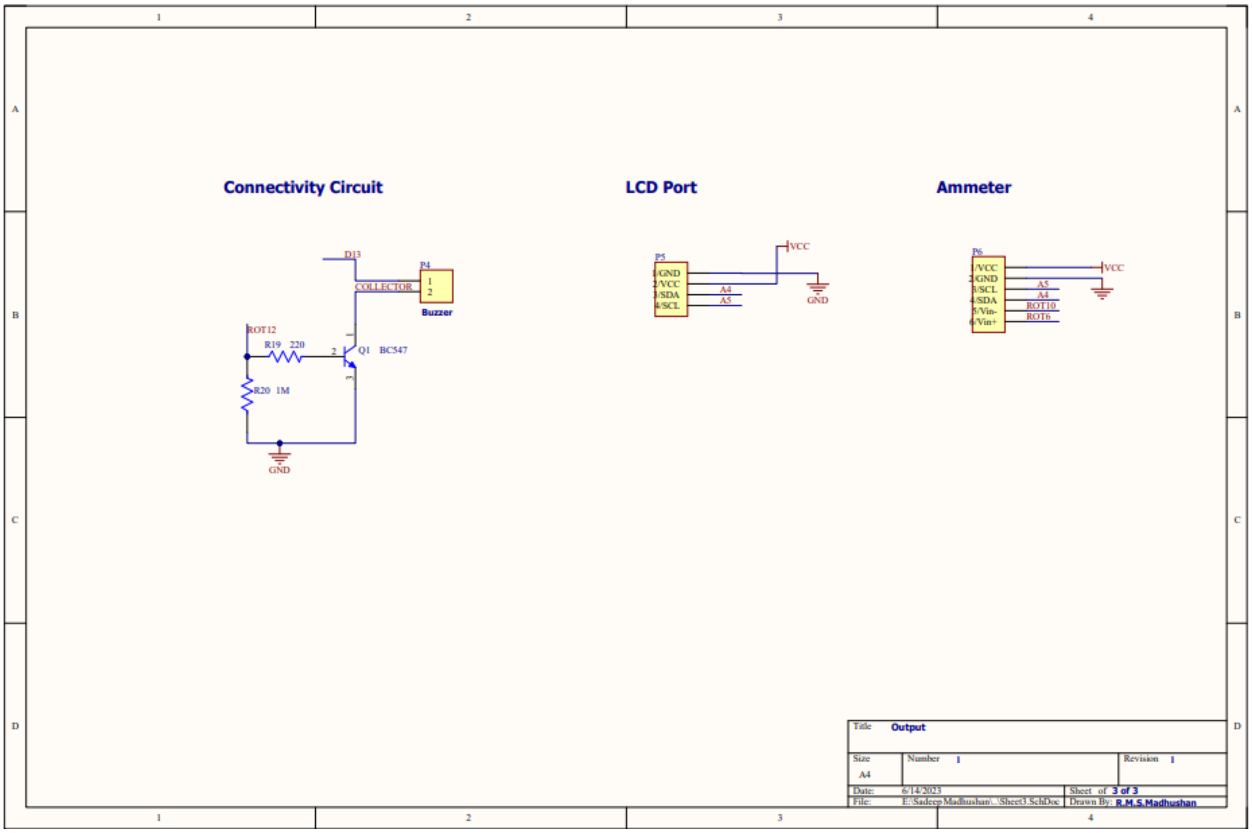
Sheet 1 of 3



Sheet 2 of 3



Sheet 3 of 3

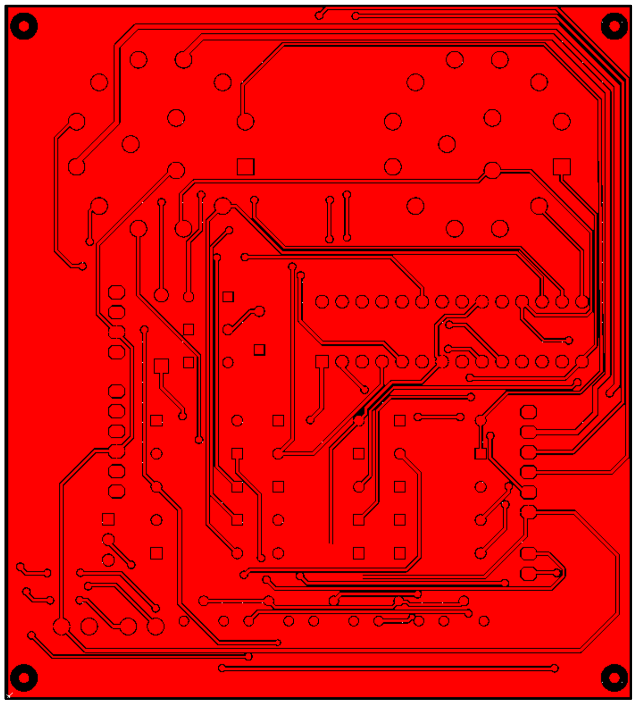


Connectivity Circuit
LCD Port
Ammeter
D13
P4
COLLECTOR
Buzzer
ROT12
R19 220
Q1 BC547
R20 1M
GND
P5
1/GND
2/VCC
3/SDA
4/SCL
A4
A5
VCC
GND
P6
1/VCC
2/GND
3/SCL
4/SDA
5/Vin-
6/Vin+
A5
A4
ROT10
ROT6
VCC
Title Output
Size A4
Number 1
Revision 1
Date: 6/14/2023
Sheet of 3 of 3
File: E:\Sadeep Madhushan\..\Sheet3.SchDoc
Drawn By: R.M.S.Madhushan

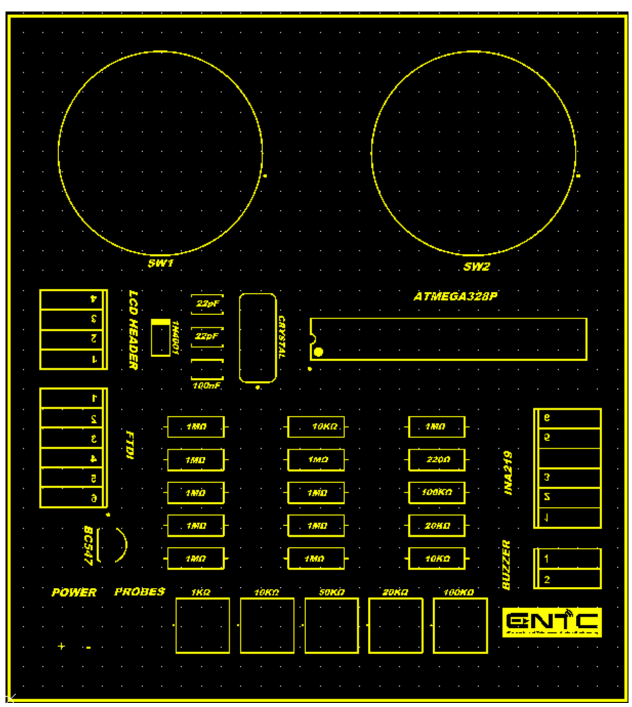
Printed Circuit Board

Gerber Files Details

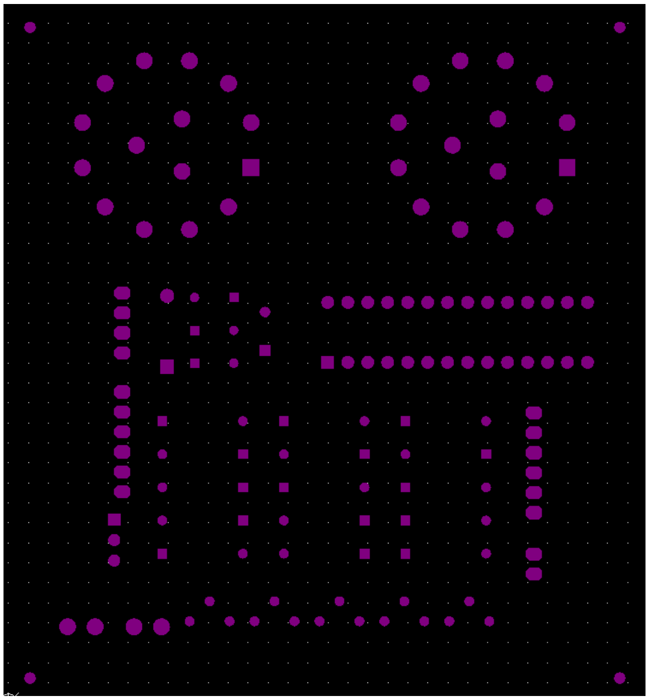
Top Layer Gerber Data



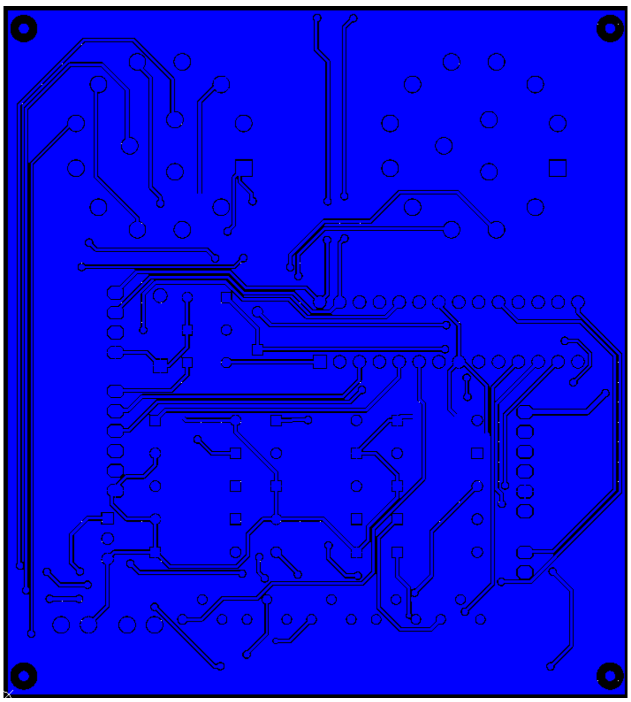
Top Overlay Gerber Data



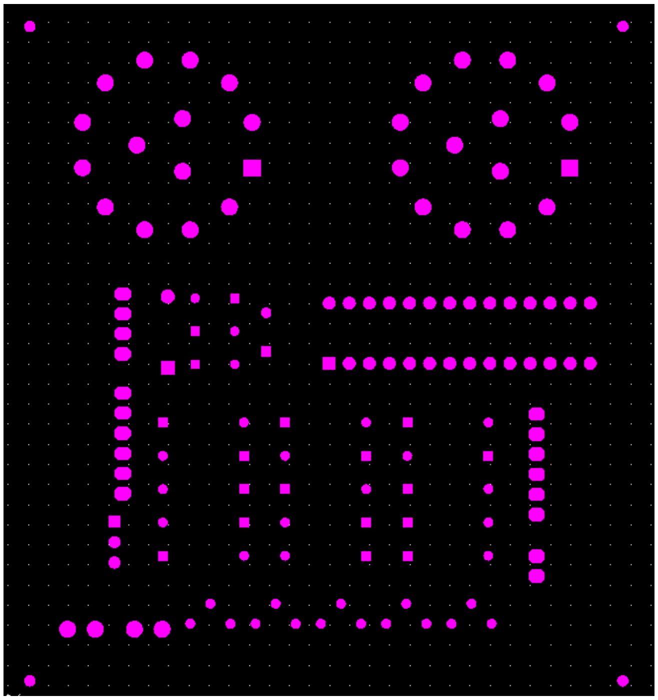
Top Solder Mask Gerber Data



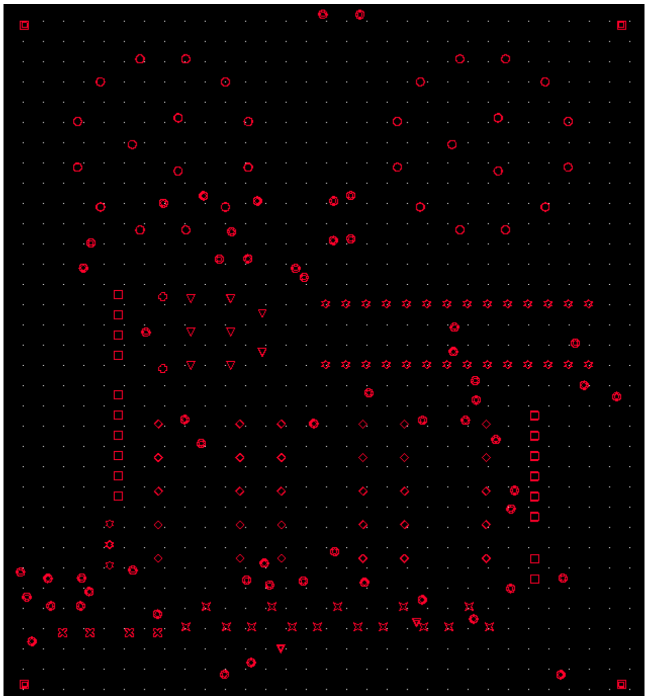
Bottom Layer Gerber Data



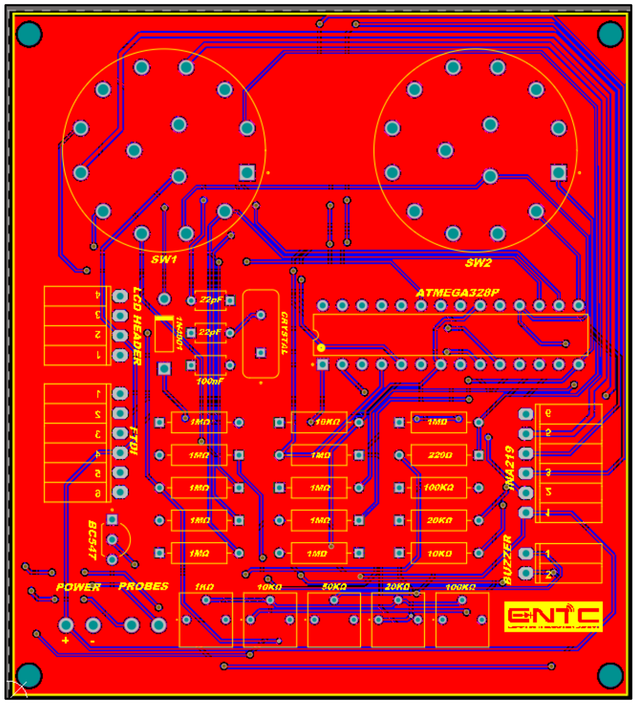
Bottom Solder Mask Gerber Data

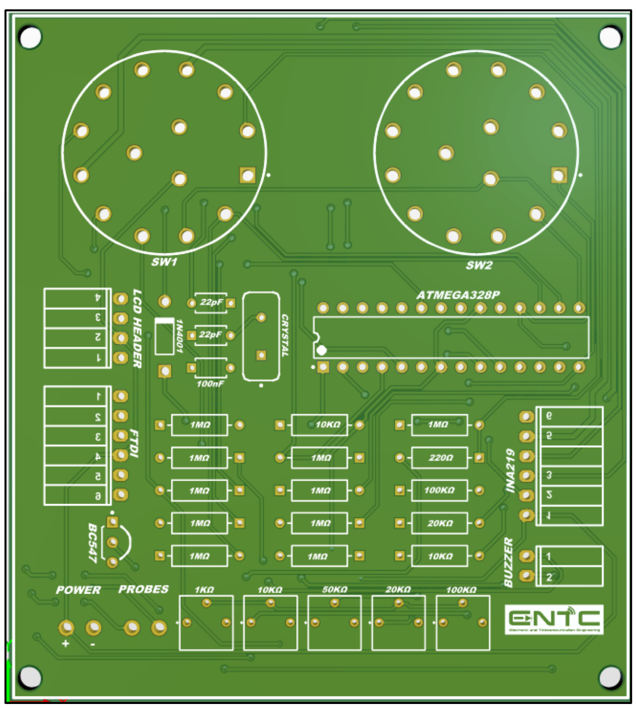


Drill Drawing Layer Pair Gerber Data



2D View


SW1
SW2
ATMEGA328P
LCD HEADER
FTDI
CRYSTAL
22pF
22pF
100nF
1N4001
BC547
INA219
BUZZER
POWER
PROBES
1KΩ
10KΩ
50KΩ
20KΩ
100KΩ
1MΩ
220Ω
ENTC


SW1
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BC547
INA219
BUZZER
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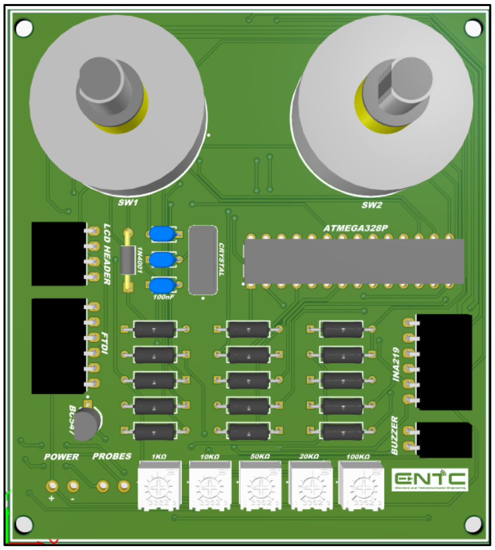
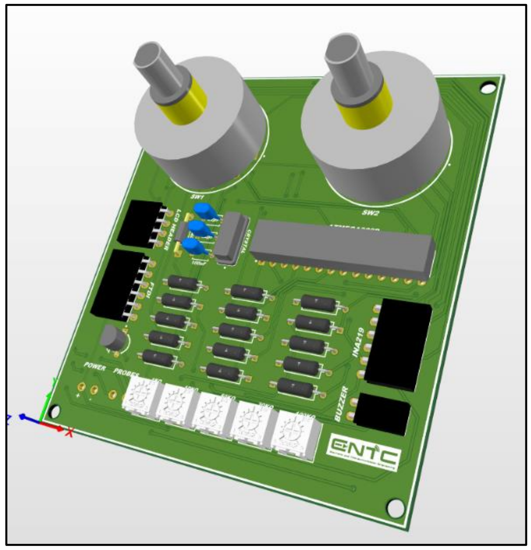
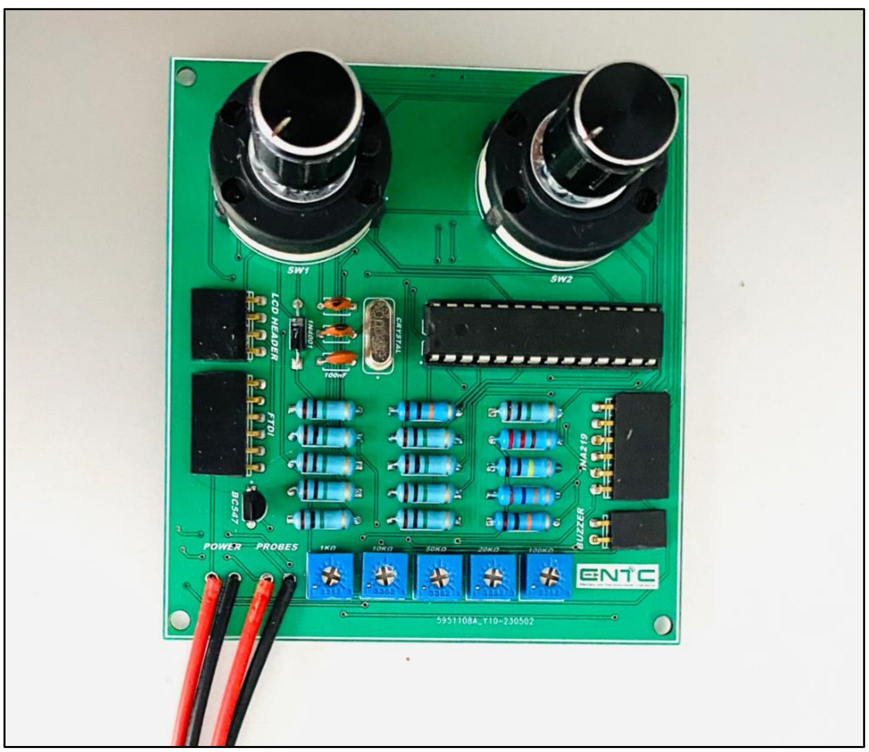
PROBES
1KΩ
10KΩ
50KΩ
20KΩ
100KΩ
1MΩ
220Ω
ENTC

3D View

After Soldering:



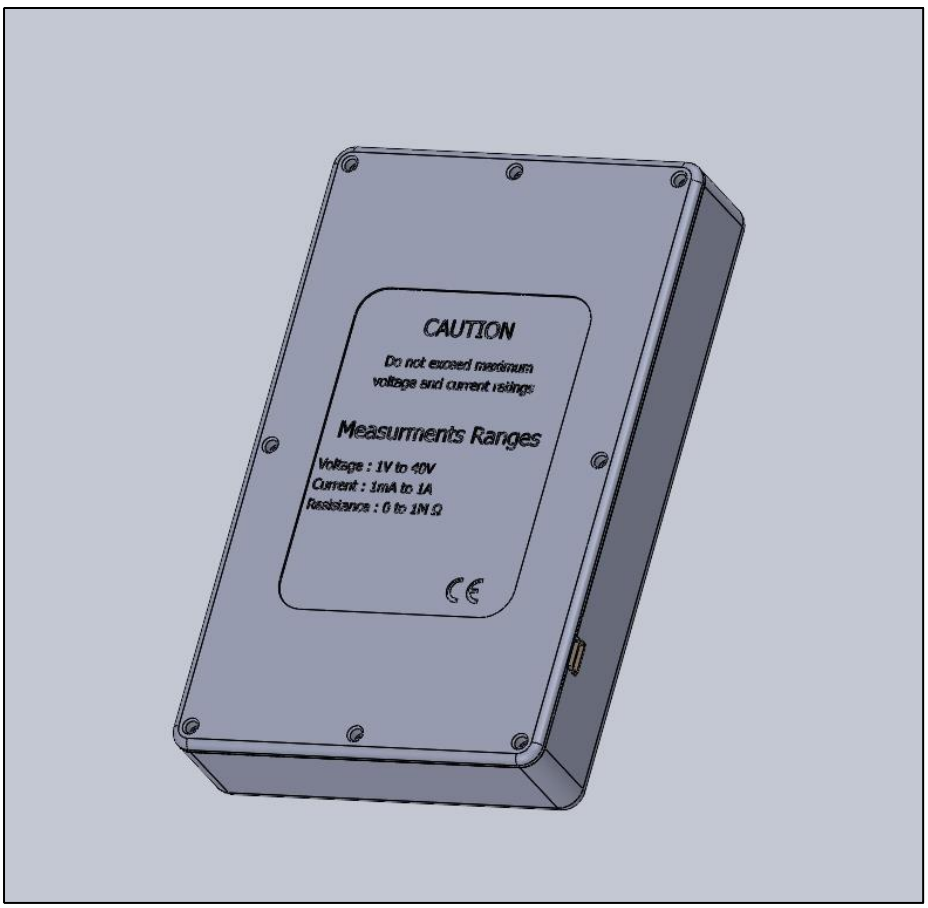
Bill of Materials

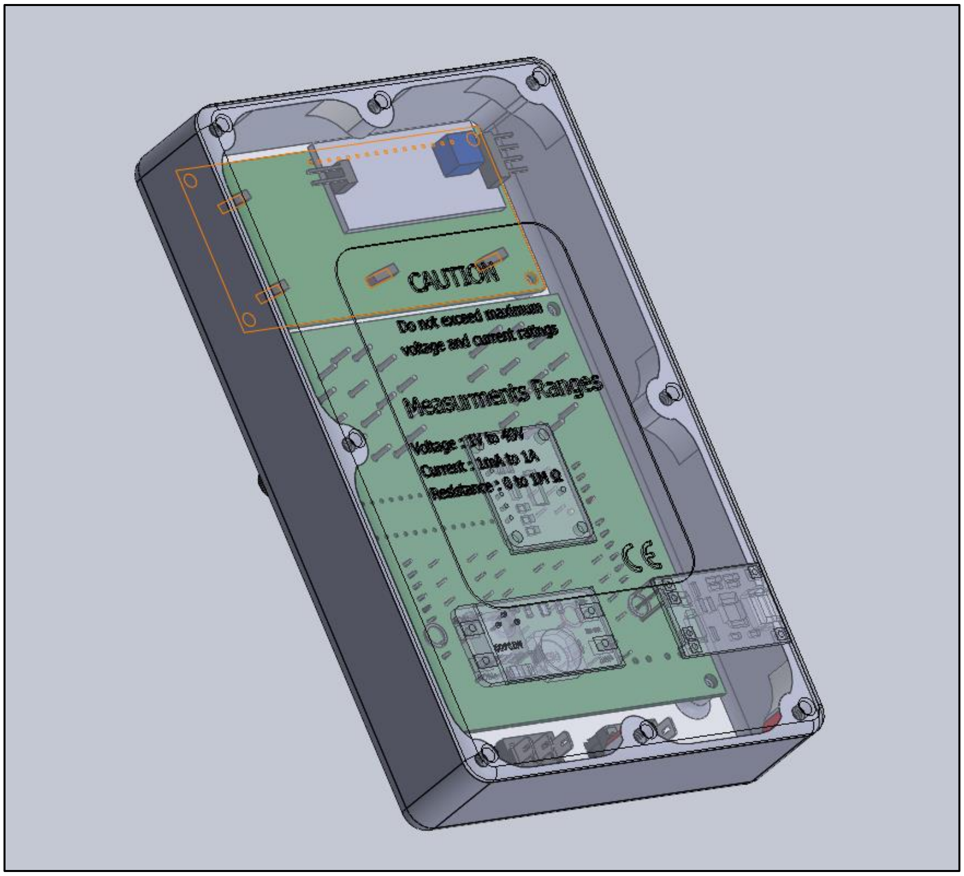
Value	Description	Designator	Quantity
22p	Ceramic Capacitor 22pF ±5% 50V C0G Radial	C1, C2	2
10n	Ceramic Capacitor 22pF ±5% 50V C0G Radial	C3	1
1N4001-T	1.0 A Rectifier, 15 pF, 50 V, -65 to 150 degC	D1	1
691214110002	Serie 2141 - 3.50 mm Horizontal Entry Modular with Rising Cage Clamp W	P1, P3	2
Header 6	Header, 6-Pin	P2, P6	2
Header 2	Header, 2-Pin	P4	1
Header 4	Header, 4-Pin	P5	1
BC547	Amplifier Transistor, NPN Silicon, 3-Pin TO-92, Pb-Free, Tape and Reel	Q1	1
1M	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R1, R11, R12, R13, R14, R15, R16, R17, R18, R20	10
1K	Resistor	R2	1
10K	Resistor	R3	1
10K	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R4, R7	2
50K	Resistor	R5	1
100K	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R6	1
20K	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R8	1
20K	Resistor	R9	1
100K	Resistor	R10	1
G001R1000FE1280	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R16, R19, R22, R23, R24, R25	6
220	Res Wirewound 0.1 Ohm 1% 1W ±90ppm/°C	R19	1
3362P-1-203LF	Resistor	R20, R21, R26, R27	4
A30403RNZQ	A Series Rotary Switch, 3 Poles, 4 Positions, 30 deg Angle of Throw, -30 to	SW1, SW2, SW3	3
ATmega328P-PN	8-bit AVR Microcontroller, 32KB Flash, 1KB EEPROM, 2KB SRAM, 28-pin PD	U1	1
FOXSLF/160-20	Resistance Weld Thru-Hole Crystal, 16 MHz, -20 to 70 degC, 2-Pin THD	Y1	1

Suppliers and Manufacturers

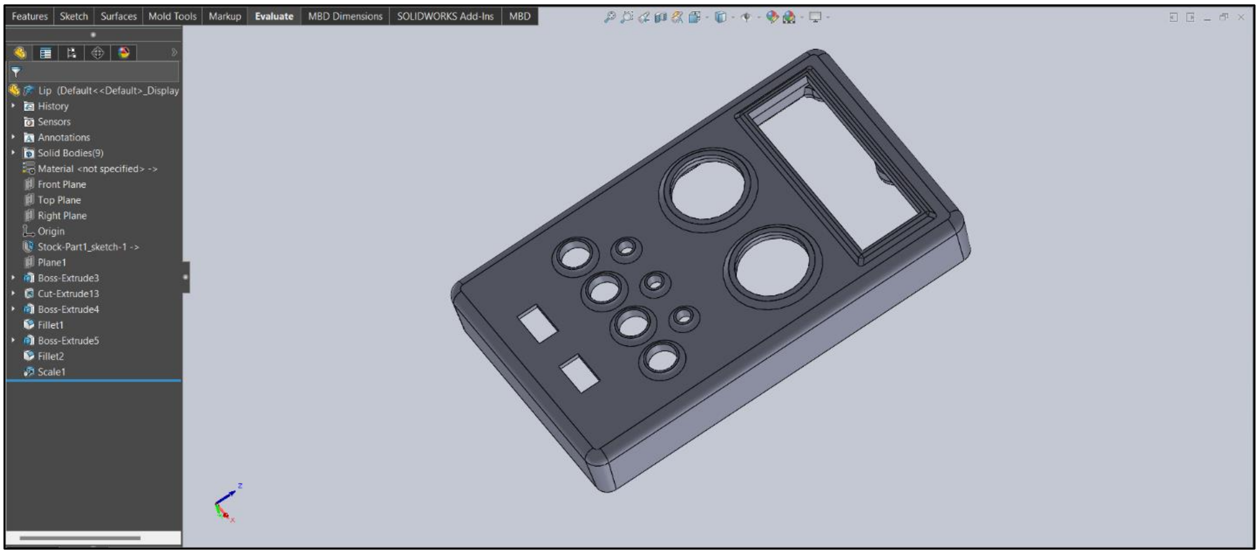
Component	Quantity	Manufacturer	Supplier	Price (LKR)
22pF Capacitor	2		Local Supplier	10
1M Resistors	10		Local Supplier	50
1K Resistors	1		Local Supplier	5
10K Resistors	3		Local Supplier	15
20K Resistors	1		Local Supplier	5
50K Resistors	1		Local Supplier	5
100K Resistors	1		Local Supplier	5
1K Preset Potentiometer	1	Bochen	LCSC Electronics	20
10K Preset Potentiometer	1	Bochen	LCSC Electronics	20
20K Preset Potentiometer	1	Bochen	LCSC Electronics	20
50K Preset Potentiometer	1	Bochen	LCSC Electronics	20
120K Preset Potentiometer	1	Bochen	LCSC Electronics	20
Atmega328P	1	Microchip Technology	Mouser Electronics	2000
16MHz Oscillator	1		Local Supplier	20
BC547 Transistor	1		Local Supplier	5
3P4T Rotary Switch	2		Local Supplier	600
1N4001 Diode	1		Local Supplier	5
INA219 Sensor	1	Adafruit	Mouser Electronics	3000
TP4056 Module	1		Local Supplier	160
3.7V Li-Po Battery	1	TinyCircuits	Mouser Electronics	2000
MT3608 Boost Converter	1		Local Supplier	280
LCD Display	1		Local Supplier	700
SPDT Switch	1		Local Supplier	20
On-off switch	1		Local Supplier	10
JST cables and other wires			Local Supplier	300

Enclosure
Assembly

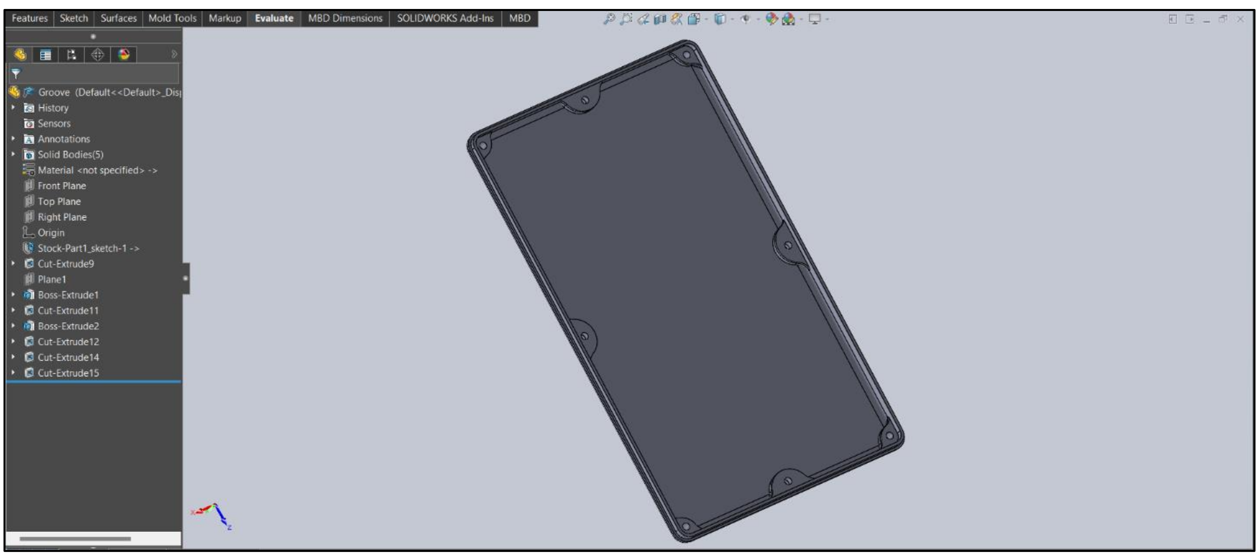



CAUTION
Do not exceed maximum
voltage and current ratings
Measurments Ranges

Top Cover

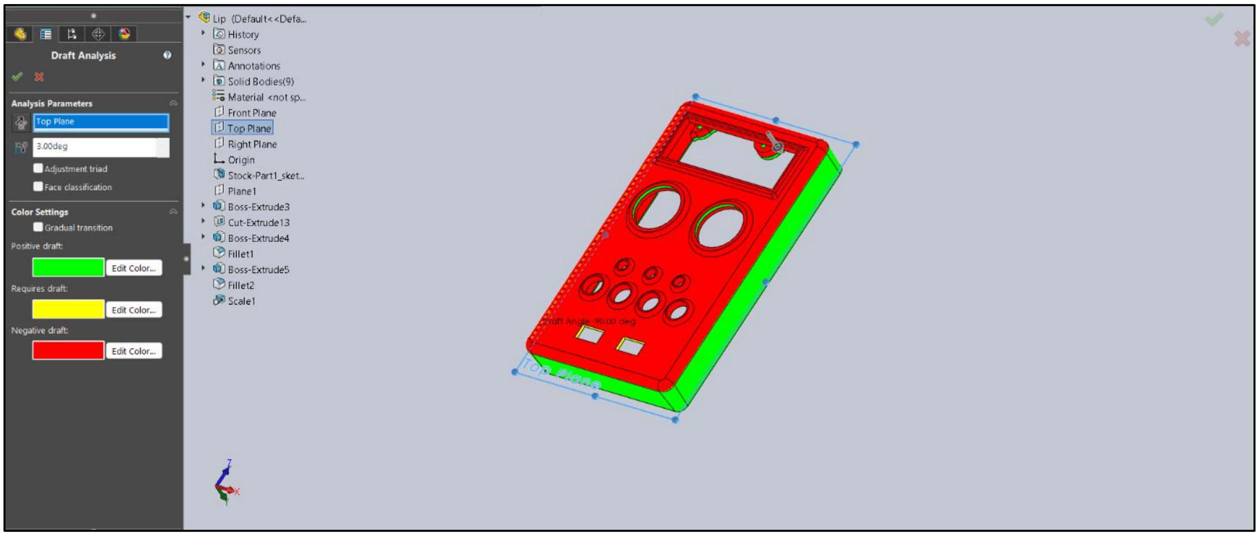


Bottom Cover

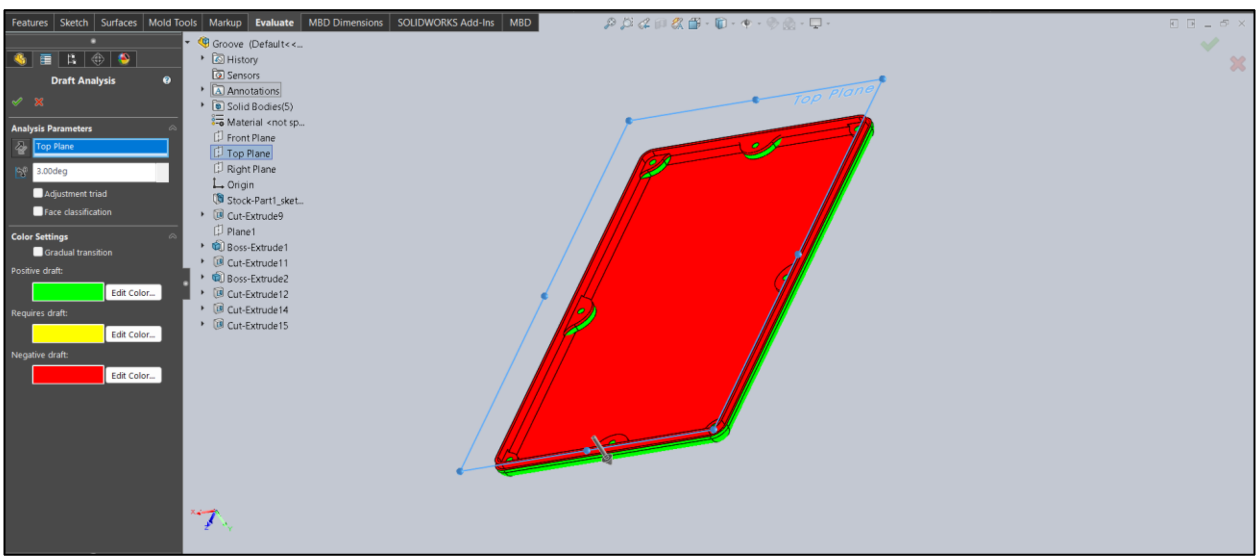


Draft Analysis

Top Cover



Bottom Cover



Manufacturing Details

PCB Manufacturing

PCB Manufacturer: Jia Li Chuang (Hong Kong) Co., Limited (JLC PCB)

PCB Specifications

- Base Material : FR-4
- Layer : 2
- Dimensions : 79.19mm * 87.33mm
- PCB Color : Green
- Silkscreen Color : White
- Surface Finish : HASL(with lead)
- Copper weight : 1 oz
- For PCB Manufacturing, the total cost : 3000LKR (with TAX and shipping cost)

Enclosure Manufacturing

- Prototype has been 3D printed locally.
- For mass production it must be used injection molding.
- Enclosure Manufacturing, total cost : 6500LKR

Cost

- Cost for PCB = 3000
- Cost for enclosure = 6000
- Cost for components = 10000
- For the prototype, total cost = 3000 + 6000 + 10000 = 19000 LKR

- When mass producing for the enclosure estimated cost (by using injection molding) = 20 LKR
- When mass producing for the PCB estimated cost = 200 LKR
- For components = 500 LKR
- Total cost = 720 LKR

Estimated Price when it releases to the market = 1000LKR

Code

- Coding is done by Arduino Programming Language.
- The printed circuit board (PCB) is equipped with a designated port intended for interfacing with the FTDI module, facilitating the programming of the atmega328p microcontroller. By utilizing this port, the programming process is efficiently accomplished.

```
#include <Wire.h>
#include <Adafruit_INA219.h>
#include <LiquidCrystal_I2C.h>3
#define INA219_ADDRESS 0x40
#define LCD_ADDRESS 0x27
int delay_time = 100;

LiquidCrystal_I2C lcd(LCD_ADDRESS,16,2);
Adafruit_INA219 ina219;

////////////////////////////////////////// Mode Rotary Switch Inputs /////////////////////////////////////

int VOLTMETER = 10;
int AMMETER = 11;
int OHMMETER = 12;
int CONTINUITY = 13;

////////////////////////////////////////// ohmmeter ///////////////////////////////////////////////////////

// rotary switch inputs
int R1K_input = 8 ;  // 0 - 5K
int R10K_input = 9 ;  // 5K - 40K
int R27K_input = 2 ;  // 40K - 100K
int R100K_input = 3 ; // 100K - 450K

// selecting scale pins
int R1K_output = 4 ;
int R10K_output = 5 ;
```

```
int R27K_output = 6 ;
int R100K_output = 7 ;

// resistors values
float R1K = 1.0;
float R10K  = 10.0 ;
float R27K  = 30.0 ;
float R100K = 120.0 ;

///////////////////////////////////// end of ohmmeter ////////////////////////////////////////////////////

/////////////////////////////////////////Voltmeter //////////////////////////////////////////////////////
int res1_vol = 1000 ;
int res2_vol = 100 ;
int diode_val = 0.6 ;
///////////////////////////////////////End of Voltmeter //////////////////////////////////////////////////

// reference voltage given from buck converter
int Vref = 5;

// constants oh ohmmeter
float Vout_ohm, new_Vout_ohm, Vref_div_newVout_ohm, R2 ;

void setup() {

  // analog reference and lcd displlay initializing
  lcd.init();
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(4,0);
  lcd.print("MULTIMETER");
  delay(3000);
```

```
/////////////////////////////// INA219 initializing ///////////////////////////
Serial.begin(115200);
while (!Serial) {
    // will pause Zero, Leonardo, etc until serial console opens
    delay(1);
}

if (! ina219.begin()) {
  Serial.println("Failed to find INA219 chip");
  while (1) { delay(10); }
}

// Serial.println("Measuring voltage and current with INA219 ...");
//////////////////////////////////End of INA219 /////////////////////////////////////

// Mode Rotary Switch pins initializing
pinMode(VOLTMETER,INPUT);
pinMode(AMMETER,INPUT);
pinMode(OHMMETER,INPUT);
pinMode(CONTINUITY,INPUT);

// ohmmeter pins intializing
pinMode(R1K_input,INPUT);
pinMode(R10K_input,INPUT);
pinMode(R27K_input,INPUT);
pinMode(R100K_input,INPUT);

pinMode(R1K_output,INPUT);
pinMode(R10K_output,INPUT);
pinMode(R27K_output,INPUT);
pinMode(R100K_output,INPUT);
```

```
  pinMode(A0, INPUT);  // Vout_ohm reading pin
  // end of ohmmeter initializing
}
void loop() {

    if (digitalRead(VOLTMETER) == HIGH) {
    Serial.println("voltmeter");
      pinMode(VOLTMETER,INPUT);
      pinMode(AMMETER,OUTPUT);
      pinMode(OHMMETER,OUTPUT);
      pinMode(CONTINUITY,OUTPUT);

      lcd.clear();
      lcd.setCursor(4,0);
      lcd.print("VOLTMETER");
      delay(1000);

    while (true) {
    voltmeter();
    if (digitalRead(VOLTMETER) != HIGH) {
      delay(delay_time);
      break;}
    }

}
  if (digitalRead(AMMETER) == HIGH) {
    Serial.println("ammeter");
      pinMode(VOLTMETER,OUTPUT);
      pinMode(AMMETER,INPUT);
      pinMode(OHMMETER,OUTPUT);
      pinMode(CONTINUITY,OUTPUT);

      lcd.clear();
```

```
    lcd.setCursor(4,0);
    lcd.print("AMMETER");

   while (true) {
   ammeter();
   if (digitalRead(AMMETER) != HIGH) {
     delay(delay_time);
     break;}
   }
}

  if (digitalRead(OHMMETER) == HIGH) {
   Serial.println("OHMmeter");
     pinMode(VOLTMETER,OUTPUT);
     pinMode(AMMETER,OUTPUT);
     pinMode(OHMMETER,INPUT);
     pinMode(CONTINUITY,OUTPUT);

     lcd.clear();
     lcd.setCursor(4,0);
     lcd.print("OHMMETER");
     delay(1000);

  while (true) {
   ohmmeter();
   if (digitalRead(OHMMETER) != HIGH) {
     delay(delay_time);
     break;}
   }
   }

  if (digitalRead(CONTINUITY) == HIGH) {
   Serial.println("continuity");
```

```
    pinMode(VOLTMETER,OUTPUT);
    pinMode(AMMETER,OUTPUT);
    pinMode(OHMMETER,OUTPUT);
    pinMode(CONTINUITY,INPUT);

    lcd.clear();
    lcd.setCursor(4,0);
    lcd.print("CONTINUITY");
    lcd.setCursor(4,1);
    lcd.print("CHECKER");
    delay(1000);

  while (true) {
  if (digitalRead(CONTINUITY) != HIGH) {
    delay(delay_time);
    break;}
  }
  }
}
void ohmmeter() {

  // 0 - 1K
 if (digitalRead(R1K_input) == HIGH) {

  pinMode(R1K_output,OUTPUT);
  pinMode(R10K_output,INPUT);
  pinMode(R27K_output,INPUT);
  pinMode(R100K_output,INPUT);
  digitalWrite(R1K_output, HIGH);


  R2 = 0 ;
 for (int i=0; i < 1000; i++) {
```

```
Vout_ohm = analogRead(A0);
new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
Vref_div_newVout_ohm = Vref / new_Vout_ohm ;
R2 += (R1K) / (Vref_div_newVout_ohm - 1) ;}
R2 = R2/1000.0 ;
Serial.print("1K  ");
Serial.println(new_Vout_ohm);

if (new_Vout_ohm > 4.2) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Increase scale /");
  lcd.setCursor(0,1);
  lcd.print("Change Resistor");
  while (true) {
    if (digitalRead(R1K_input) != HIGH){
      delay(delay_time);
      break;}
    Vout_ohm = analogRead(A0);
    new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
    if (new_Vout_ohm < 4.00) {
      delay(delay_time);
      break;}
      }
  }

else {
if (R2<1){
  lcd.clear();

  R2 = R2*1000;

  lcd.setCursor(0,0);
```

```
      lcd.print("Resistance");
      lcd.setCursor(0,1);
      lcd.print(R2);
      lcd.setCursor(5,1);
      lcd.print(" Ohms");
      delay(1000);}
    else if (R2>1) {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Resistance");
      lcd.setCursor(0,1);
      lcd.print(R2);
      lcd.setCursor(5,1);
      lcd.print("K Ohms");
      delay(1000);
      }
   }
}

//   1K - 100K
  if (digitalRead(R10K_input) == HIGH) {

    pinMode(R1K_output,INPUT);
    pinMode(R10K_output,OUTPUT);
    pinMode(R27K_output,INPUT);
    pinMode(R100K_output,INPUT);
    digitalWrite(R1K_output, 0);
    digitalWrite(R10K_output, 1);
    digitalWrite(R27K_output, 0);
    digitalWrite(R100K_output, 0);

    R2 = 0 ;
  for (int i=0; i < 1000; i++) {
```

```
Vout_ohm = analogRead(A0);
new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
Vref_div_newVout_ohm = Vref / new_Vout_ohm ;
R2 += (R10K) / (Vref_div_newVout_ohm - 1) ;}
R2 = R2/1000.0 ;
Serial.print("10K  ");
Serial.println(new_Vout_ohm);

if (new_Vout_ohm > 4.56) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Increase scale /");
  lcd.setCursor(0,1);
  lcd.print("Change Resistor");
  delay(1000);
  while (true) {
    if (digitalRead(R10K_input) != HIGH){
      delay(delay_time);
      break;}
    Vout_ohm = analogRead(A0);
    new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
    if (new_Vout_ohm < 4.56) {
      delay(delay_time);
      break;}
      }
  }
else if (new_Vout_ohm < 1.66 && new_Vout_ohm > 0.5 ) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print(" Decrease scale");
  delay(1000);
  while (true) {
    if (digitalRead(R10K_input) != HIGH){
```

```
          delay(delay_time);
          break;}

        Vout_ohm = analogRead(A0);
        new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
        if (new_Vout_ohm > 1.68 ) {
          delay(delay_time);
          break;}
      }
      }
    else {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Resistance");
      lcd.setCursor(0,1);
      lcd.print(R2);
      lcd.setCursor(5,1);
      lcd.print("K Ohms");
      delay(1000);
    }}
//
  // 100K - 250K
  if (digitalRead(R27K_input) == HIGH) {

    pinMode(R1K_output,INPUT);
    pinMode(R10K_output,INPUT);
    pinMode(R27K_output,OUTPUT);
    pinMode(R10K_output,INPUT);
    digitalWrite(R27K_output, HIGH);

    R2 = 0 ;
  for (int i=0; i < 1000; i++) {
    Vout_ohm = analogRead(A0);
```

```
new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
Vref_div_newVout_ohm = Vref / new_Vout_ohm ;
R2 += (R27K) / (Vref_div_newVout_ohm - 1) ;}
R2 = R2/1000.0 ;
Serial.print("27K  ");
Serial.println(new_Vout_ohm);

 if (new_Vout_ohm > 4.55) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Increase scale /");
  lcd.setCursor(0,1);
  lcd.print("Insert Resistor");
  delay(1000);
  while (true) {
    if (digitalRead(R27K_input) != HIGH){
      delay(delay_time);
      break;}
    Vout_ohm = analogRead(A0);
    new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
    if (new_Vout_ohm < 4.550) {
      delay(delay_time);
      break;}
      }
  }

else if (new_Vout_ohm < 3.85 && new_Vout_ohm > 0.8) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print(" Decrease scale");
  delay(1000);
  while (true) {
    if (digitalRead(R27K_input) != HIGH){
```

```
        delay(delay_time);
        break;}
      Vout_ohm = analogRead(A0);
      new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
      if (new_Vout_ohm > 3.88 ) {
        delay(delay_time);
        break;}
    }}
  else {
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Resistance");
    lcd.setCursor(0,1);
    lcd.print(R2);
    lcd.setCursor(5,1);
    lcd.print("K Ohms");
    delay(1000);
  }}

//  300K - 1M
 if (digitalRead(R100K_input) == HIGH) {

  pinMode(R1K_output,INPUT);
  pinMode(R10K_output,INPUT);
  pinMode(R27K_output,INPUT);
  pinMode(R100K_output,OUTPUT);
  digitalWrite(R100K_output, HIGH);

  R2 = 0 ;
 for (int i=0; i < 1000; i++) {
  Vout_ohm = analogRead(A0);
  new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
  Vref_div_newVout_ohm = Vref / new_Vout_ohm ;
```

```
R2 += (R100K) / (Vref_div_newVout_ohm - 1) ;}
R2 = R2/1000.0 ;
Serial.print("120K  ");
Serial.println(new_Vout_ohm);

 if (new_Vout_ohm > 4.5) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Out of Range /");
  lcd.setCursor(0,1);
  lcd.print("Insert Resistor");
  delay(1000);
  while (true) {
    if (digitalRead(R100K_input) != HIGH){
      delay(delay_time);
      break;}
    Vout_ohm = analogRead(A0);
    new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
    if (new_Vout_ohm < 4.50) {
      delay(delay_time);
      break;}
      }
  }

  else if (new_Vout_ohm < 3.55 && new_Vout_ohm > 0.5) {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print(" Decrease scale");
  delay(1000);
  while (true) {
    if (digitalRead(R100K_input) != HIGH){
      delay(delay_time);
      break;}
```

```
        Vout_ohm = analogRead(A0);
        new_Vout_ohm = (Vout_ohm*Vref) / 1024 ;
        if (new_Vout_ohm > 3.56 ) {
          delay(delay_time);
          break;}
      }}
    else {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Resistance");
      lcd.setCursor(0,1);
      lcd.print(R2);
      lcd.setCursor(5,1);
      lcd.print("K Ohms");
      delay(1000);
    }}
  }

void voltmeter() {
  float dc = 0 ;
  for(int i=0; i<1000; i++) {
    dc += (analogRead(A1)*4.85*11/1023);
  }
  dc = dc / 1000 ;

  if (dc == 0 ) {dc += 0 ;}
  else if (dc > 0 && dc < 1) {dc += 0 ;}
  else if (dc > 1 && dc < 4) {dc += 0.25 ;}
  else if (dc >4 && dc < 5) {dc += 0.28;}
  else if (dc > 5 && dc < 6) {dc += 0.3;}
  else if (dc > 6 && dc < 8) {dc += 0.33;}
  else if (dc > 8 && dc < 10) {dc += 0.34;}
  else if (dc > 10 && dc < 12) {dc += 0.35;}
```

```
  else if (dc > 12 && dc < 16) {dc += 0.36;}
  else if (dc > 16 && dc < 22) {dc += 0.37;}
  else if (dc > 22 && dc < 25) {dc += 0.38;}
  else {dc += 0.39;}

  Serial.println(dc);
  // float dc = (analogRead(A1)*4.85*11/1023) ;
  if (dc > 0 && dc < 1){
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Voltage is not");
    lcd.setCursor(0,1);
    lcd.print("in Range !");
    delay(1000);}
  else {
    dc += 0.075 ;
    lcd.clear();
    Serial.println(dc);
    lcd.setCursor(0,1);
    lcd.print(dc);
    lcd.setCursor(6,1);
    lcd.print("volts");}
  delay(1000);}

void ammeter(){
  float current_mA = 0;

  for(int i=0; i<5000; i++) {
  current_mA += ina219.getCurrent_mA();}
  current_mA = current_mA / 5000.0 ;

  if (current_mA <= 0 ) {
    lcd.clear();
```

```
  lcd.setCursor(0,0);
  lcd.print("Ammeter");
  lcd.setCursor(0,1);
  lcd.print("Check Probes !");
  //delay(1000);
  }
else {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Ammeter");
  lcd.setCursor(0,1);
  lcd.print(current_mA);
  lcd.setCursor(6,1);
  lcd.print("mA");

} }
```

Testing the product Functionality

Testing a multimeter is essential to ensure its functioning. Also by doing those testing, we can find how accurate the multimeter is.

Initial Testing

- At the beginning, it's important to check the product for any faulty components or loose connections. If any such issues are found, they should be fixed promptly to ensure the product works properly as intended. Ignoring these problems may result in the product not functioning as it should.

Output Testing

- Conduct initial testing to ensure proper switching between multimeter mode and power supply mode.
- If switching is successful, set the device to multimeter mode.
- Verify voltmeter functionality and compare readings with a laboratory voltmeter.
- If readings do not match, identify and rectify potential faults.
- Repeat the process for ammeter, ohmmeter, and continuity checker.
- After inspecting the multimeter, switch the mode selection to power supply mode.
- Verify the output of 5V DC voltage.
- If the output is incorrect, identify and address the issue promptly.

Future Improvements

The pursuit of further improvements in a product is of paramount importance. By continuously enhancing its features, performance, and overall quality, a product can adapt to the changing demands of consumers and stay ahead in a competitive market. Such ongoing refinements foster customer satisfaction, loyalty, and expansion of market share. Moreover, they offer opportunities to rectify shortcomings, optimize resources, and achieve cost efficiencies, contributing to the product's long-term success and sustainability. The following improvements can be done to this product in order to improve the product features and capabilities.

- For PCB, Surface Mounted components can be used instead of through holes. Then, PCB size can be further reduced so that the product size can be more reduced.
- Inside wiring can be reduced so that it is more capable of maintenance.
- 16 bits ADC could be used inside the PCB so that the readings will be more accurate.
- One rotary switch could be used so that it is more user friendly.

User Manual

Introduction

Welcome to the Multimeter user manual! This innovative device is equipped with two-way switch that seamlessly transitions between multimeter and 5V power supply modes, catering to your various needs. The user-friendly design features two rotary switches - one for mode selection and the other for adjusting the ohmmeter's scale. All your readings are displayed clearly through the LED display, ensuring precision and accessibility. Notably, this product boasts a built-in charger, eliminating the need for battery changes and providing uninterrupted usability.

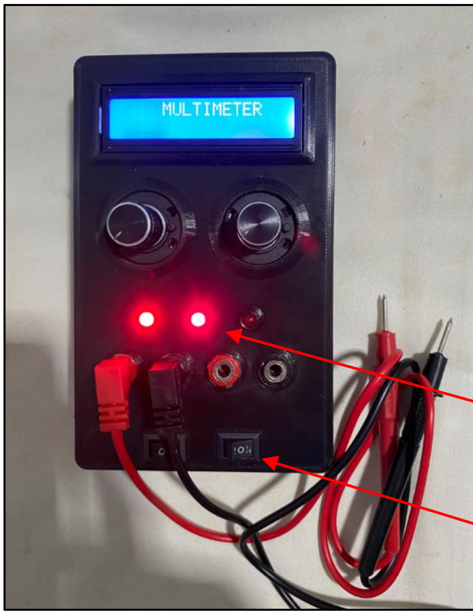
Package Content

- ✓ Digital Multimeter with DC Power Supply
- ✓ Pair of Banana Cable
- ✓ Charging Cable
- ✓ User Manual
- ✓ Warranty Card

Instructions for User

- This LED indicates that the product is powered now.

Power On-Off Switch Mode Selection between Multimeter and Power Supply



- After switching the second switch it will work as a multimeter.
- This second LED indicates that the device is now in Multimeter Mode and user can see it from the LCD display.

Multimeter Mode indicating LED

Switch is turned on to right side

- This state of rotary switch 1,product works as a voltmeter.

Voltmeter state

- This state of rotary switch 1, product works as an ammeter.

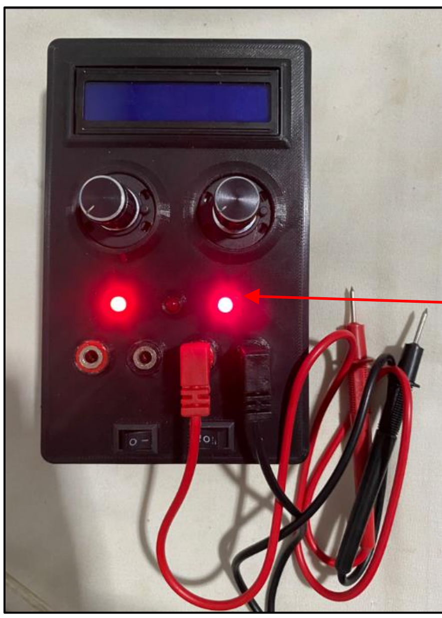
Ammeter State

- This state of rotary switch 1, product works as an ohmmeter.
- Ohmmeter has four scales and particular scale value can be chosen from rotary switch 2.

Ohmmeter scale rotary switch

Ohmmeter state

- This state of rotary switch 1, product works as a continuity checker.



- When second switch turn to the left side, product works as a 5V DC power supply.
- This second LED indicates that it is switched to the power supply mode.

Power Supply Mode indicating LED

- When changing the mode of multimeter, user does not have to change the probes. Probes can be put in first two holes accordingly for every state of multimeter.
- When it works as a power supply, user has to put the probes in second two pair of holes accordingly.