University of Moratuwa

Department of Electronic & Telecommunication Engineering

EN2160-Electronic design realization

detailed design report – Coal miner protector

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Description of product and specifications

Coal mining stands out as one of the most hazardous occupations globally, largely due to the extreme environmental conditions miners endure deep within the mines. Also, apart from the immediate life threats they face, there is a risk of occurring long-term health hazards due to their exposure to poisonous air. Because of that it is essential keep track of the quality of environmental factors inside a mine to guarantee the safety of the miners' lives.

To protect miners' well-being and reduce risks, it's essential to closely monitor the mine's environment. Regular air quality checks help identify potential dangers early on, so authoritative people can take corrective action before any health or safety problems become serious. Inspecting the mine environment regularly and using technology for early warnings and evacuations also greatly improve safety.

Product description

As explained above, it's important to have proper monitoring system of crucial environment factors inside a coal mine. The "coal miner protector" device is to be developed in a manner where it will keep track of the humidity, temperature, and carbon monoxide gas levels inside the coal mine. It will trigger an alarm when any of the above-mentioned environmental factors gets to an extreme condition to human beings.

Specifications

• live monitoring of environmental factors inside the mine(temperature, humidity, CO gas level)

• mobile app development to examine stats from outside of the mine. (when the mobile app is installed the user can read live temperature and humidity inside the mine through the app.)

• An alarming system will activate sounding the alarm when even one of the environmental factors gets out of the healthy range

• Getting a notification to the phone alarming about risky environmental factors.

• Bluetooth module will be used to make connectivity between the device and the mobile phone.

Conceptual Design Stage

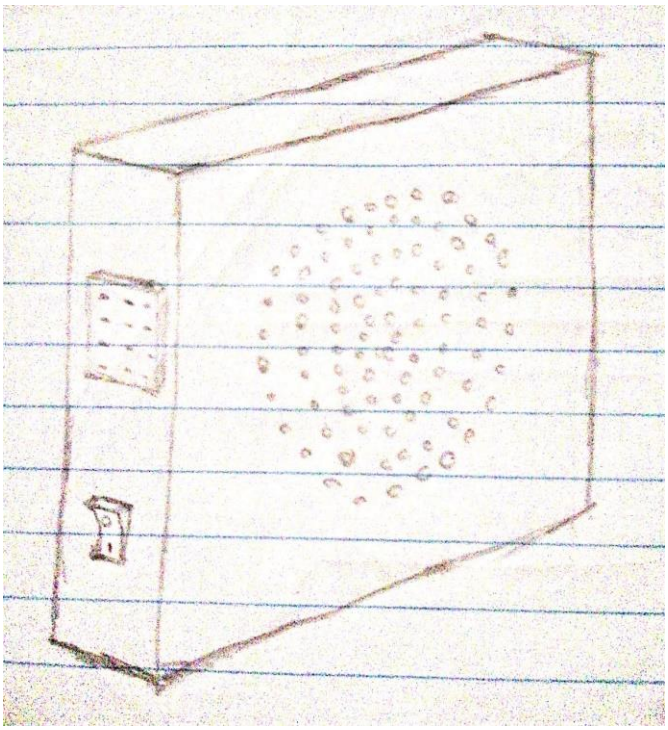
conceptual design

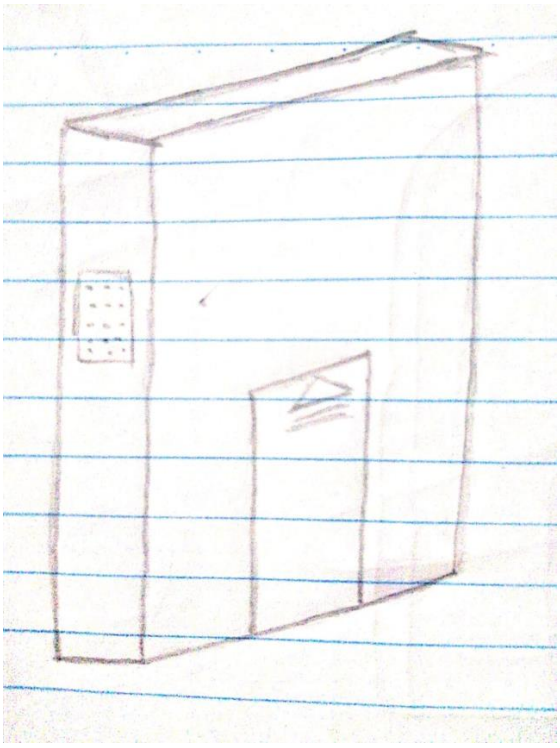
People who contributed to conceptual designing

1. Anuki Pasqual – 200445V
2. Tharusha Pathirana – 200449L
3. Navindu Gunawardena – 200201V
4. Lasitha Jananjaya – 200650U 6.
5. Chehal Jayasuriya – 200262G
6. Chamodh Kavinda – 200301D
7. Malanban Kuganenthiran – 200373X

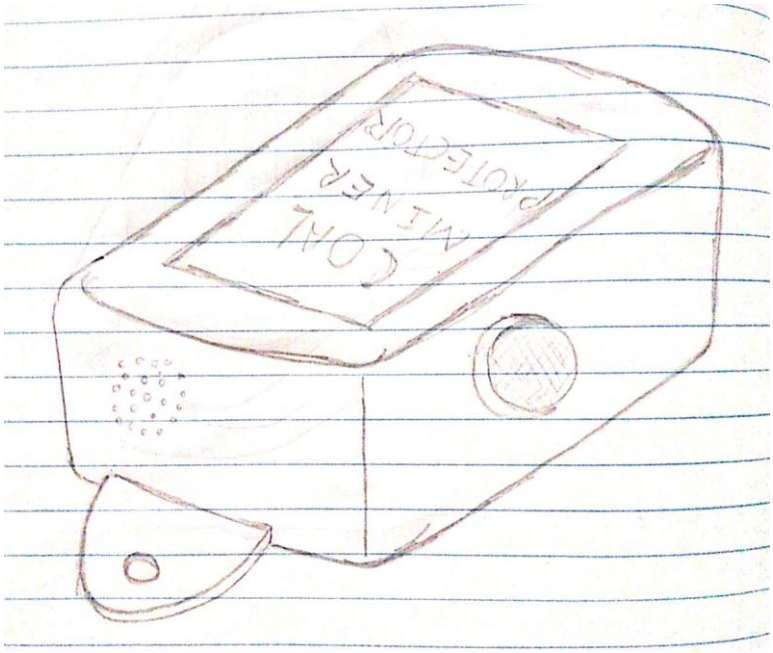
Proposed design sketches

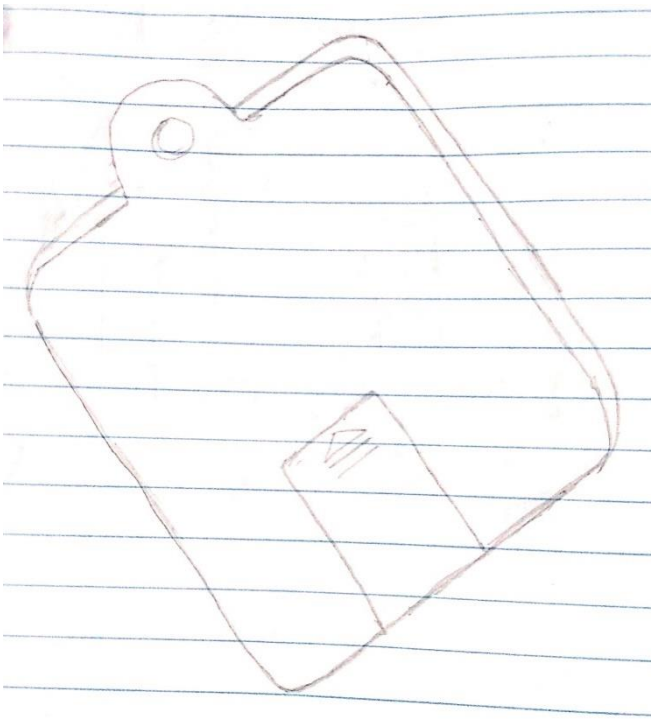
Sketch1



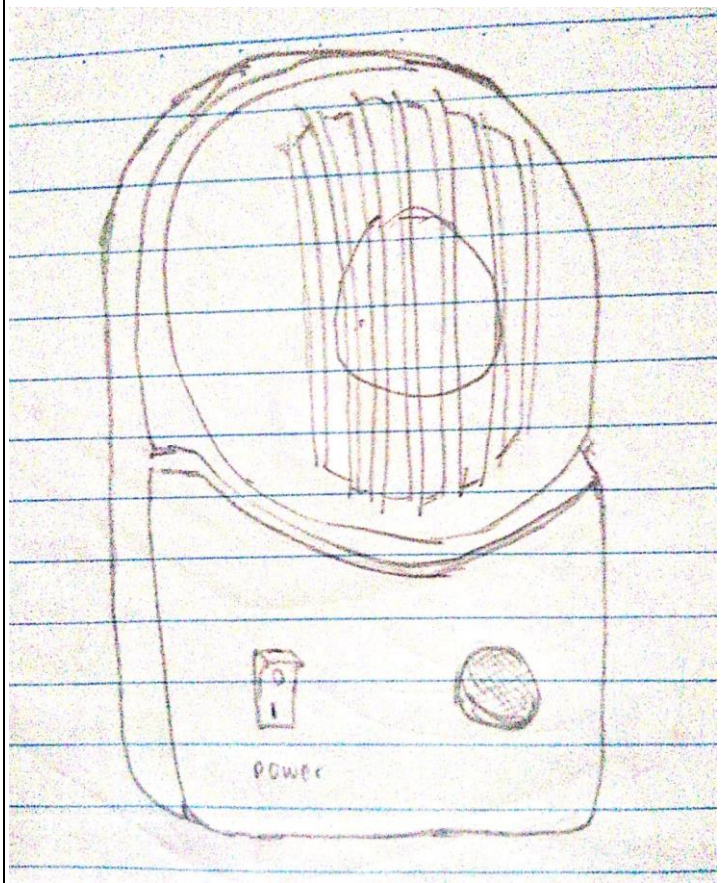


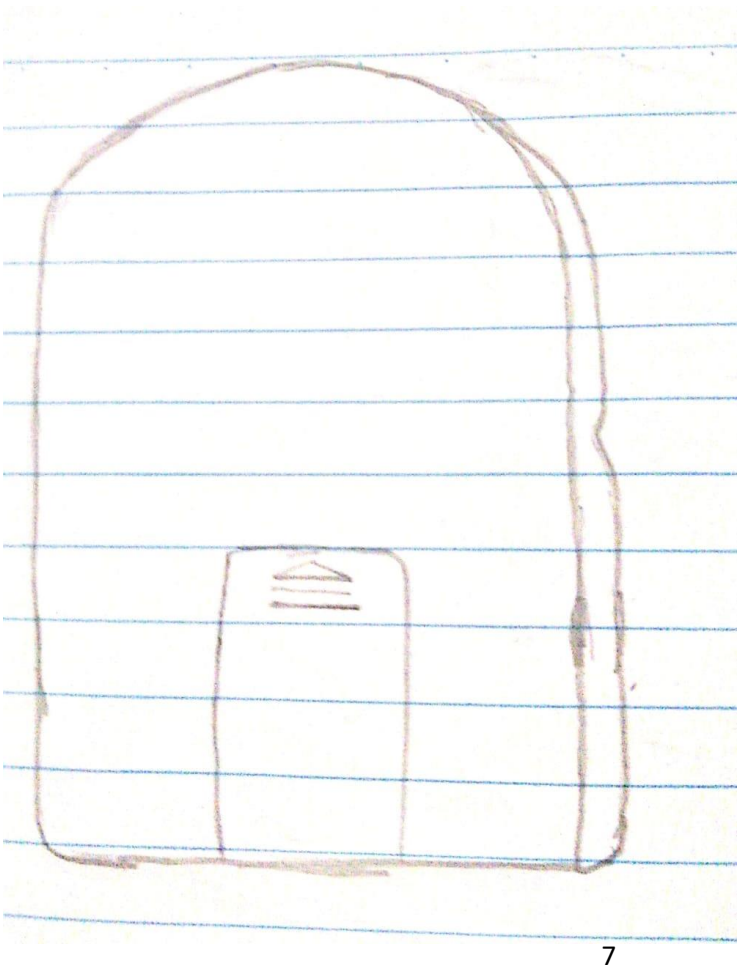
Sketch2



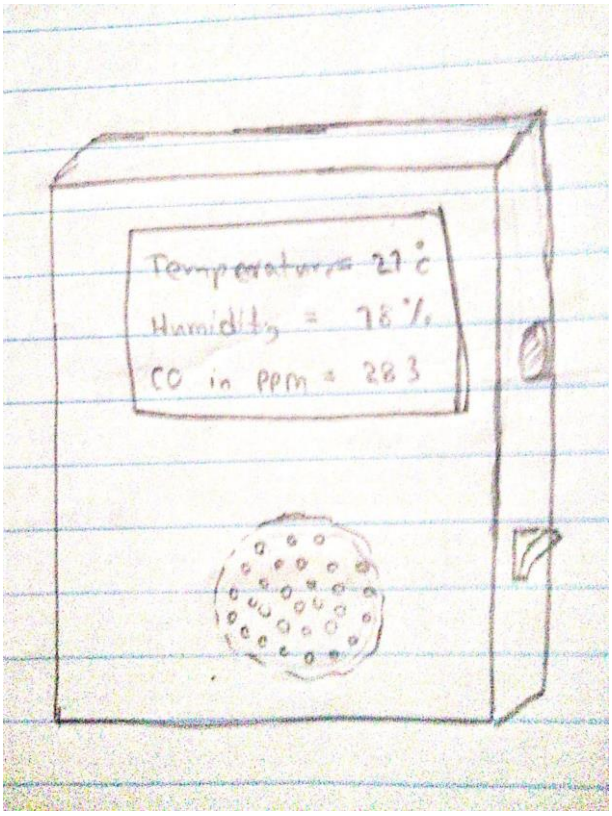


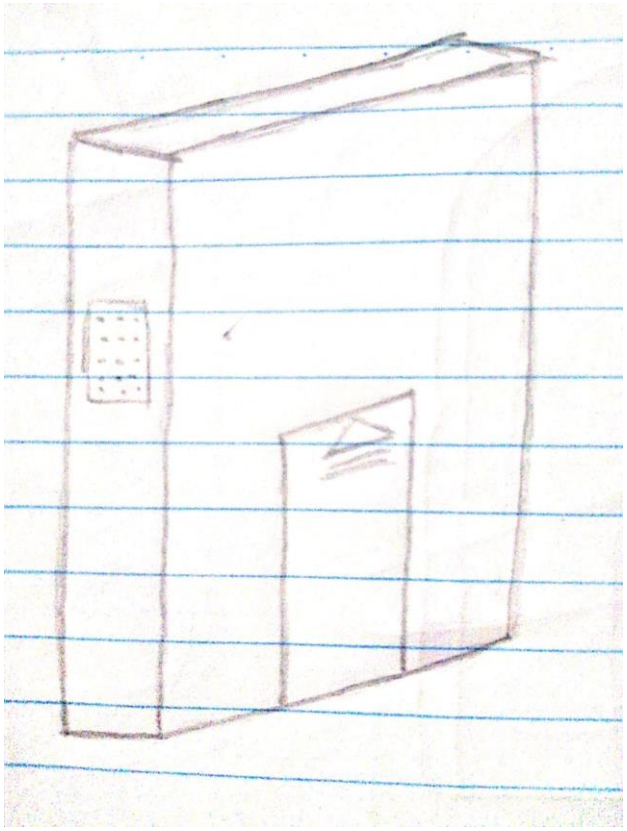
Sketch3





Sketch4





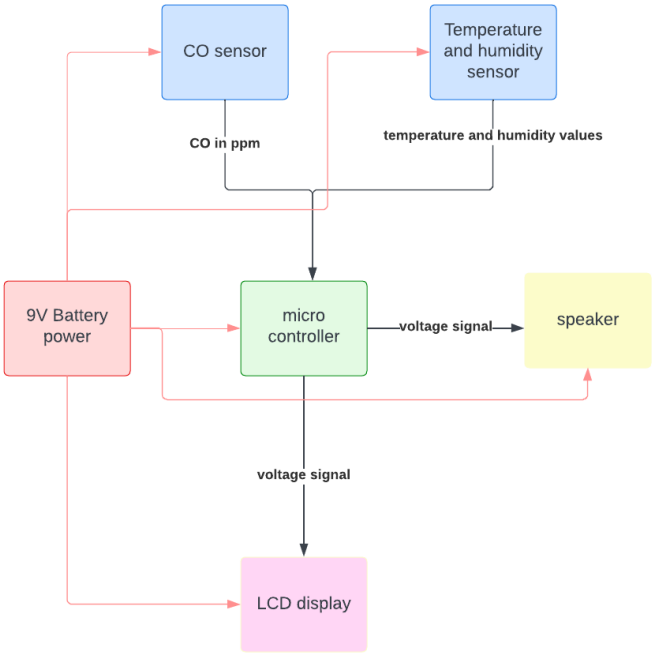
Evaluation of sketches

Rated on a scale of 1-10.

Evaluation criteria	Sketch1	Sketch2	Sketch3	Sketch4
Cost	8	9	5	7
Durability	8	8	4	8
User experience – easy interactions	7	8	7	8
Manufacturing feasibility	6	7	4	7
Aesthetics – user preference	5	6	8	7
Modularity	7	8	5	8
Safety compliance	8	8	7	6
functionality	5	9	7	8

Proposed schematic diagrams

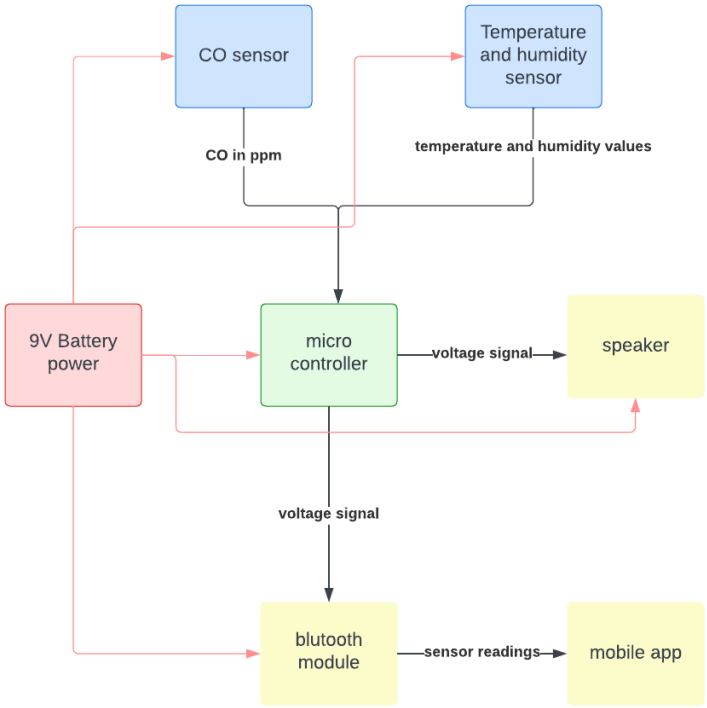
Schematic1



Added features

- Output : LCD display

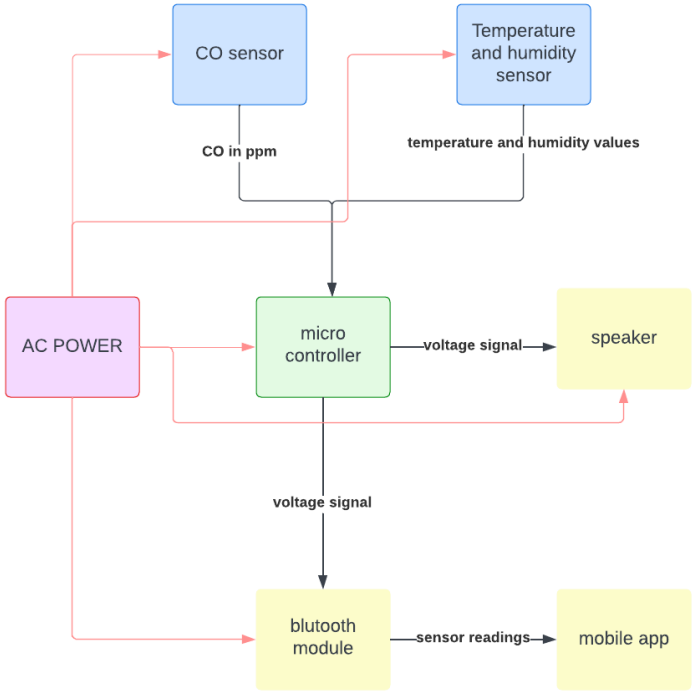
Schematic2



Added features

- Output : Mobile app

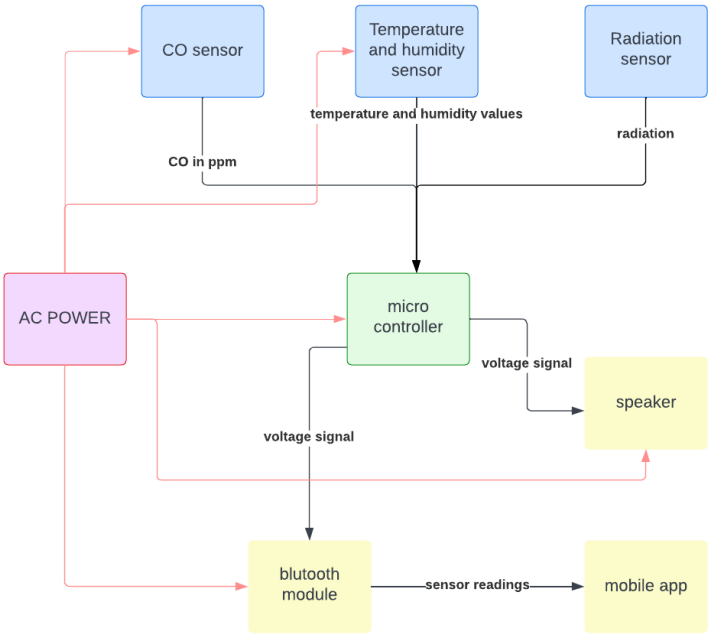
Schematic3



Added features

- Power : AC power

Schematic4



Added features

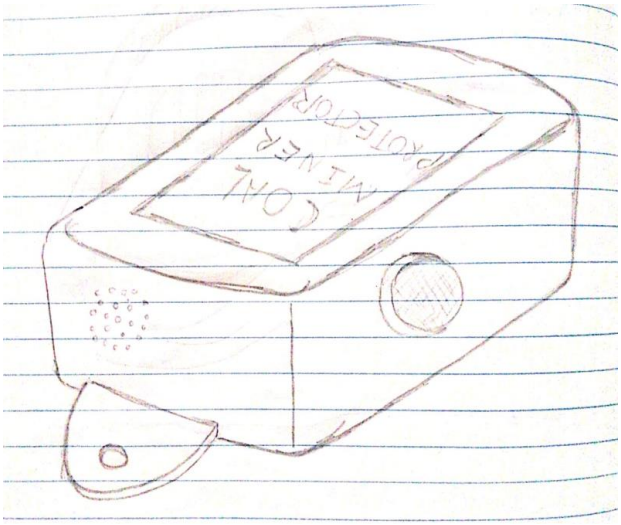
- Power : AC power
- Input : radiation level

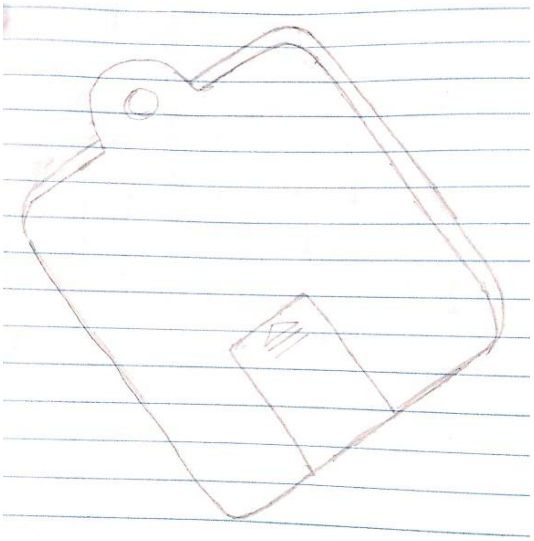
Evaluation of schematics

Rated on a scale of 1-10.

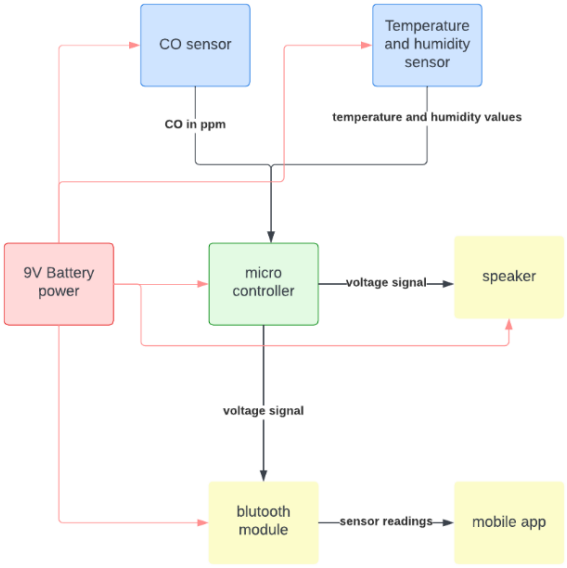
Evaluation criteria	Schematic1	Schematic2	Schematic3	Schematic4
Cost	5	9	7	3
Input and output	7	8	8	9
User experience – easy interactions	7	8	8	7
extensibility	8	8	7	7
Component interactions	8	8	8	8
Control and logic	7	8	5	8
Safety compliance	8	8	7	6
functionality	7	7	7	7

Considering all the criteria evaluations(sketches, schematic) selected design is,





selected functionality block diagram



Preliminary Design stage

Preliminary Design

People who contributed to conceptually improve the design

1. Anuki Pasqual – 200445V
2. Tharusha Pathirana – 200449L
3. Navindu Gunawardena – 200201V
4. Lasitha Jananjaya – 200650U 6.
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6. Chamodh Kavinda – 200301D
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User needs

Among the targeted market, the functionality of the product has been identified as an essential one, and all of them preferred to get all the environmental parameters to be represented in the mobile app rather than they been displayed on a LCD screen as it would be troublesome to always get near the product to check whether there is a possible danger. Users appreciate its ability to provide timely alerts, ease of use which enables miners to take immediate action when a dangerous situation arises.

When it comes to the enclosure of the product users recommended high tolerance to harsh environmental conditions. They were much more concerned about the strength of the product rather than the user experience because the most of in the interactions of the product can be handled through the mobile app.

So, considering the user needs analysis and the group members feedback mentioned in the conceptual design report we've chosen the following enclosure and schematic for the final product.

Enclosure

Problems/Improvements identified/proposed by members of your group.

- Not proper modifications are applied for upgradability
- Draft angles are not properly set

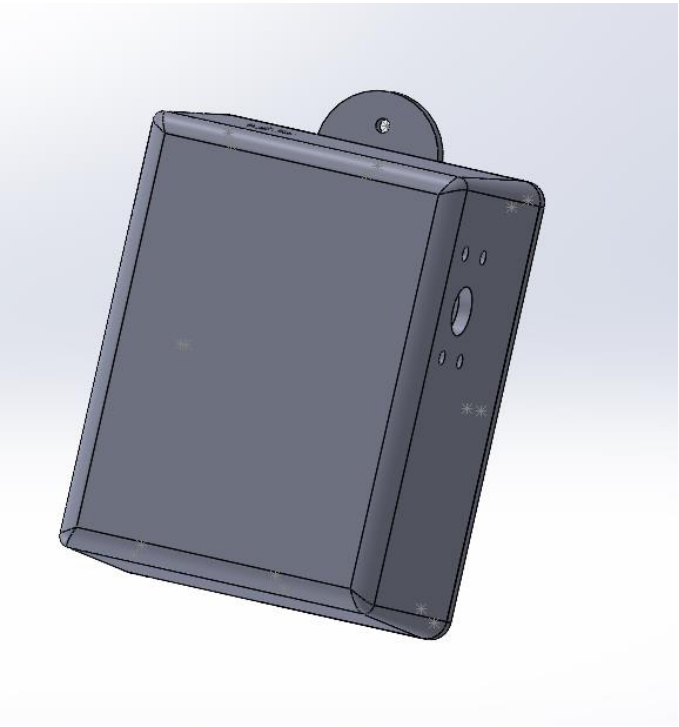
Problems/Improvements identified/proposed by users.

- Lack of aesthetics of the product
- Poor user experience

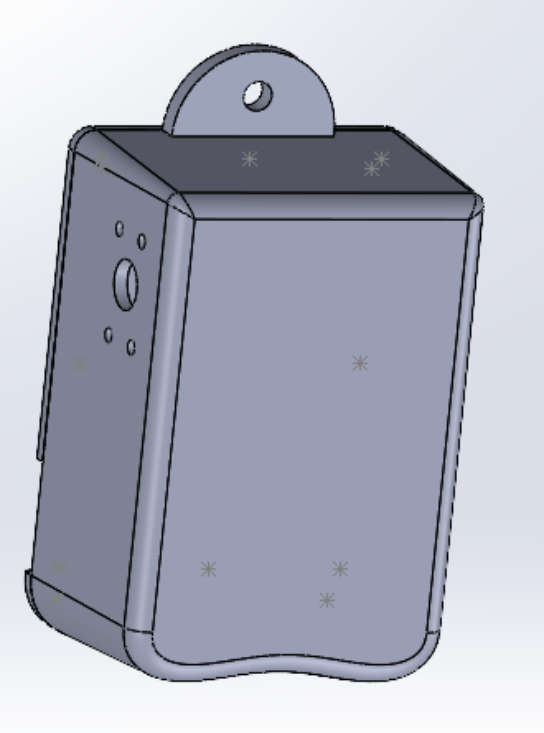
After applying the new knowledge gained from lectures, and considering the feedback received from the users and group members, changes have been made to the enclosure.

- Improved the aesthetics of the product.
- Added the features according to the improved schematic.
- Added drafts angles in order to be able to mold the product in mass production.

Initial product design VS improved version



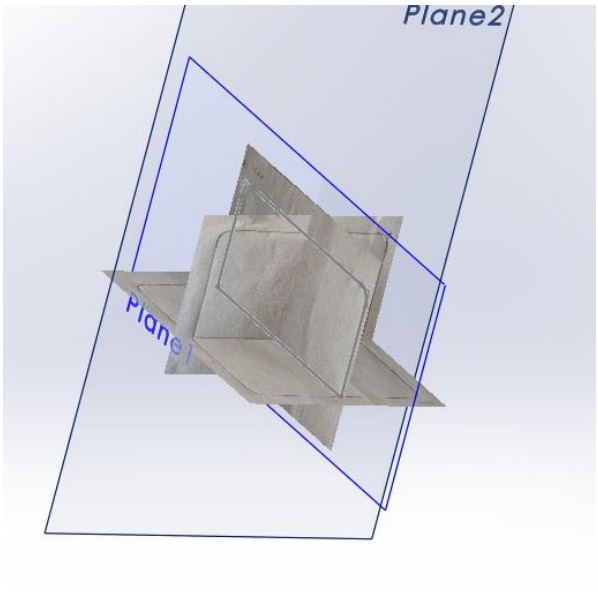
Previous design

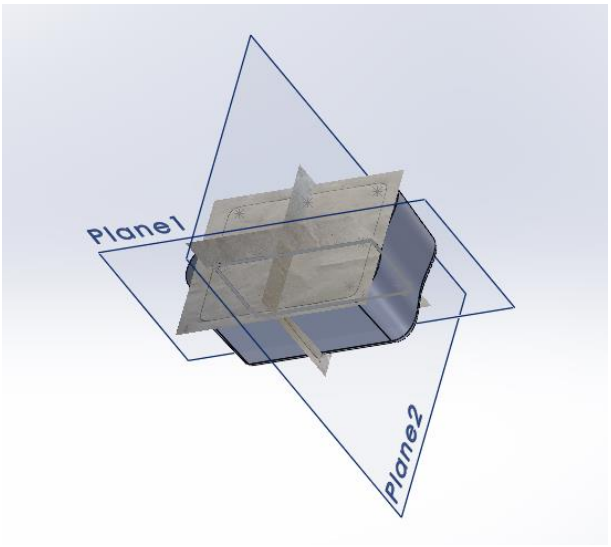


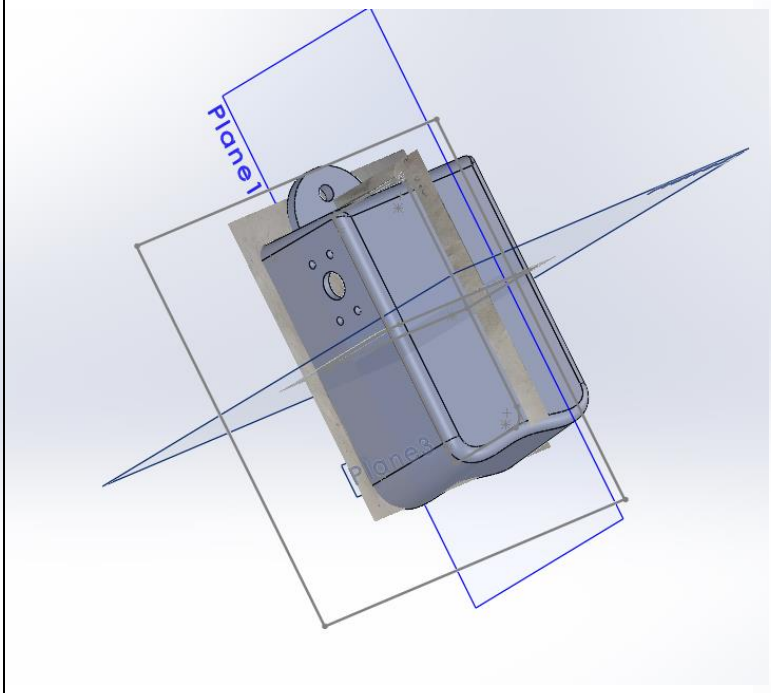
improved version

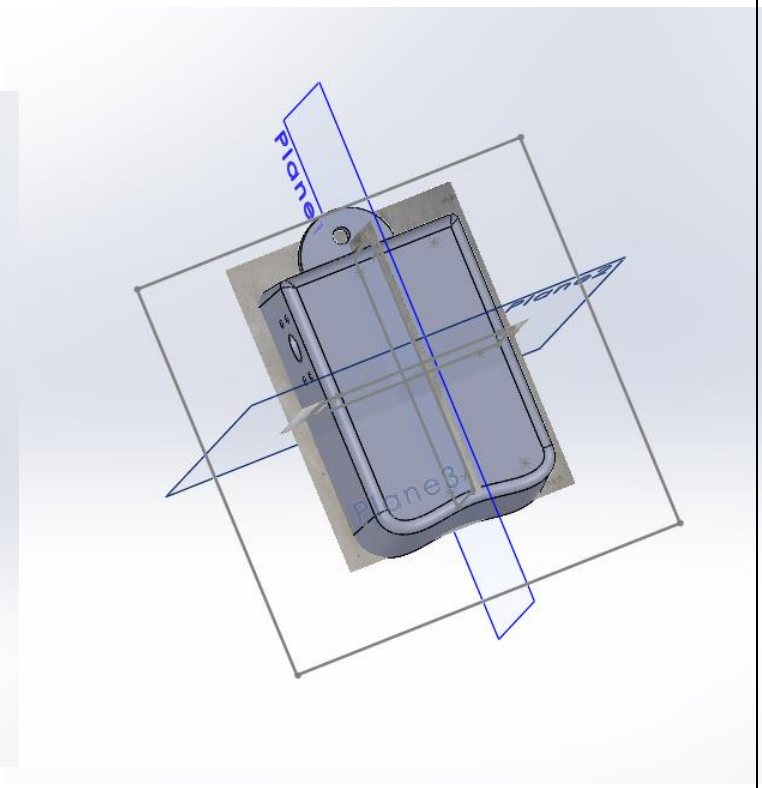
Solidworks design of the improved product - steps

Product with sketches

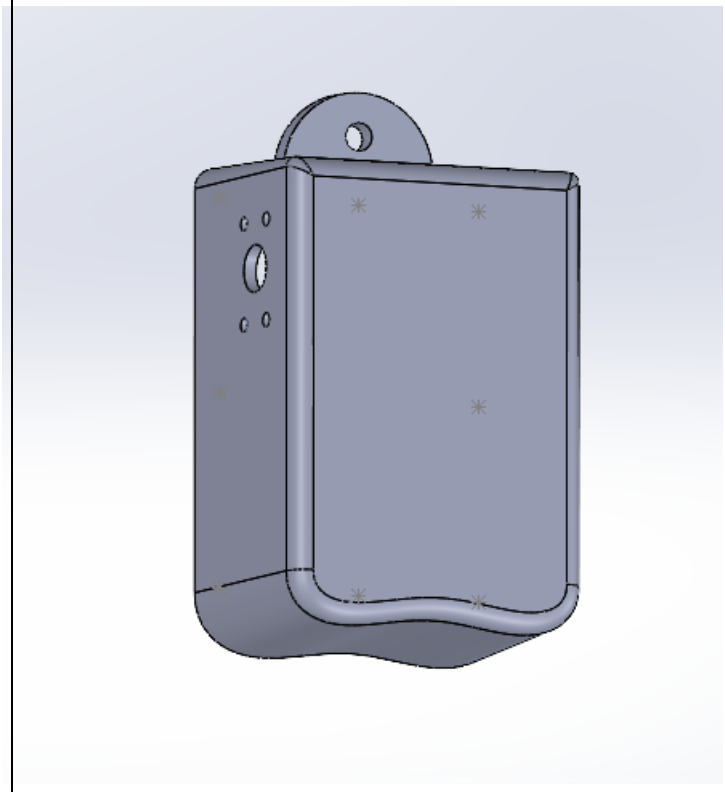


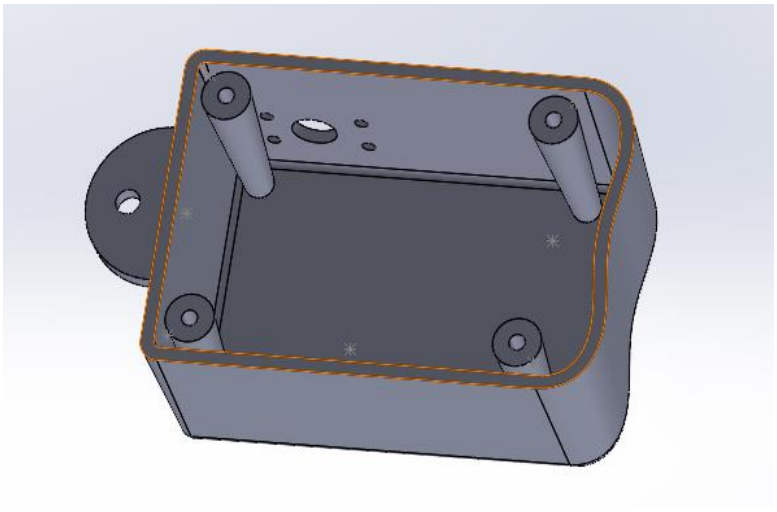




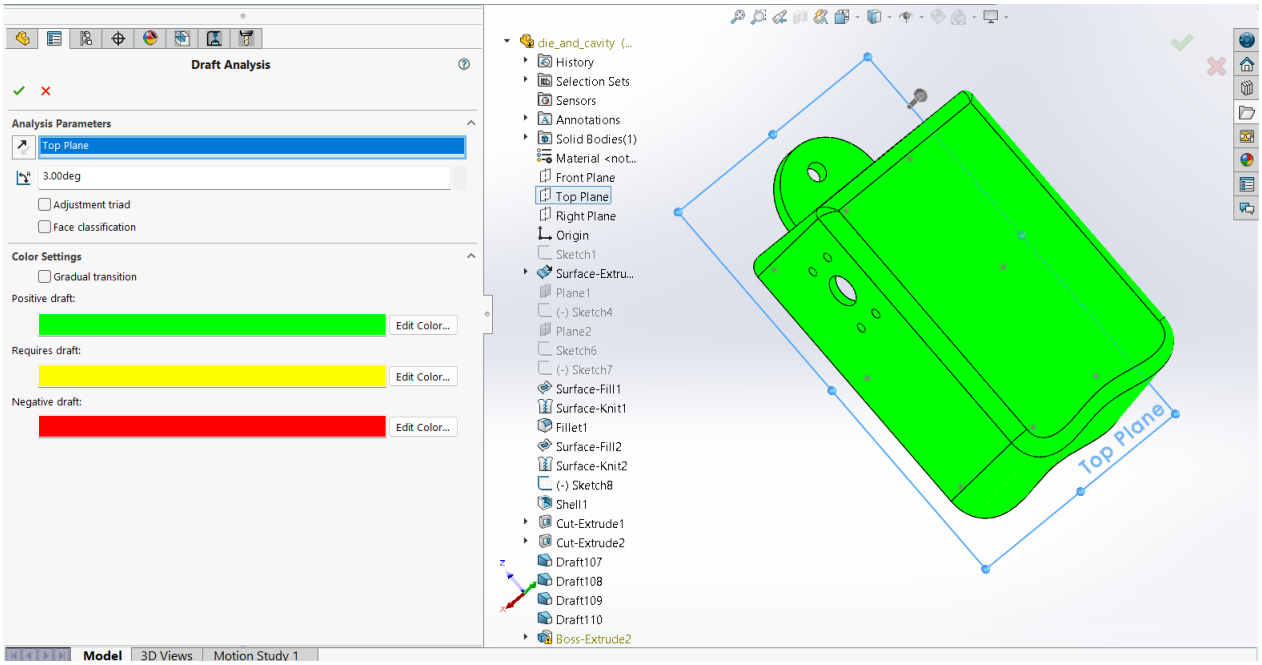


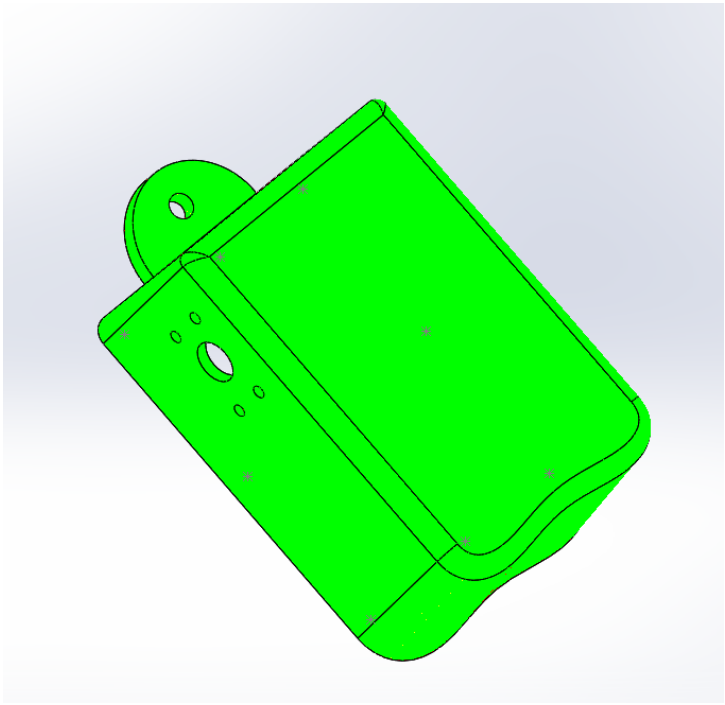
Product design

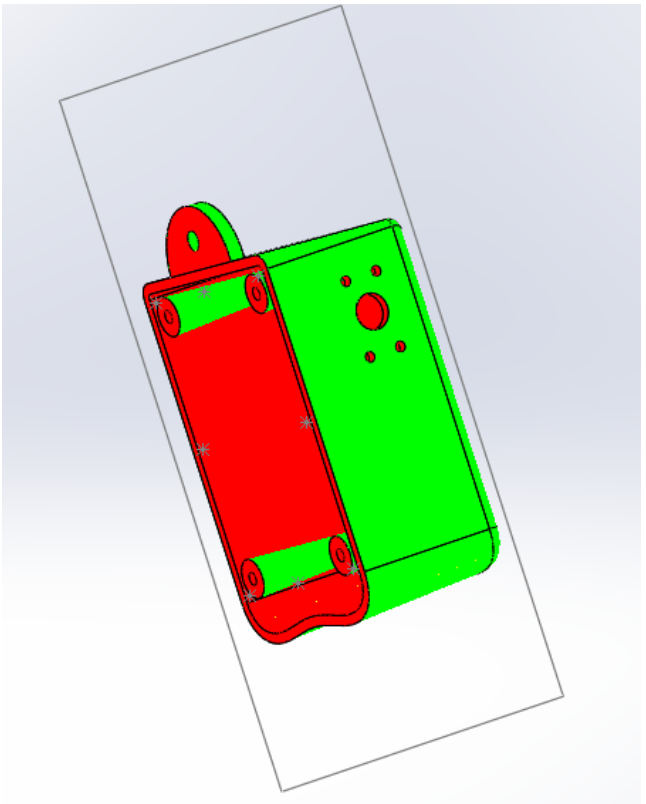




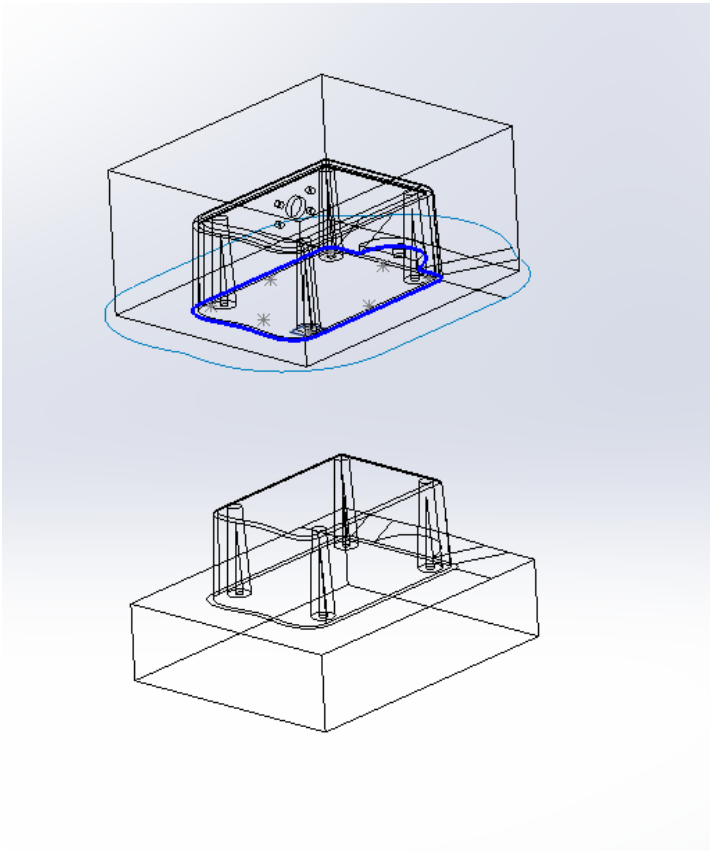
Draft Analysis

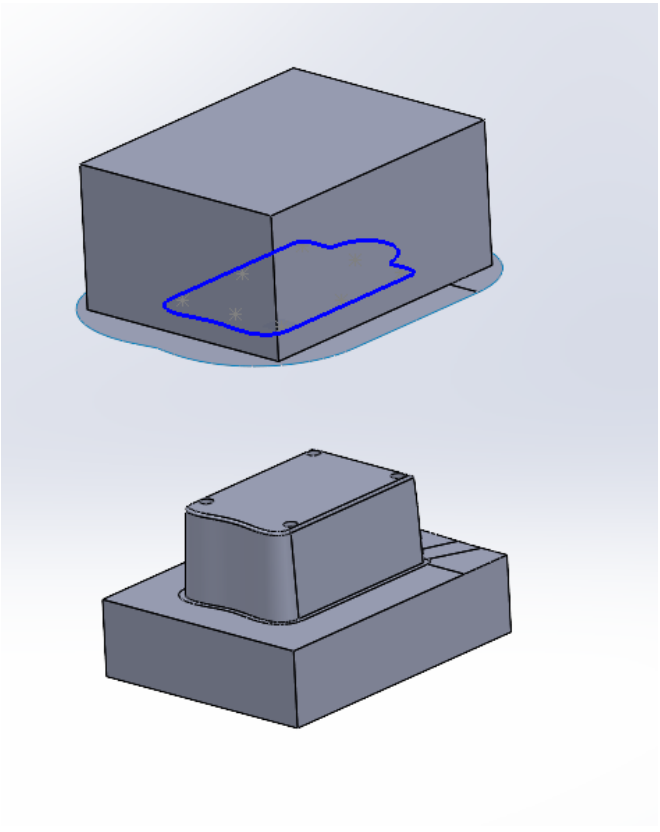


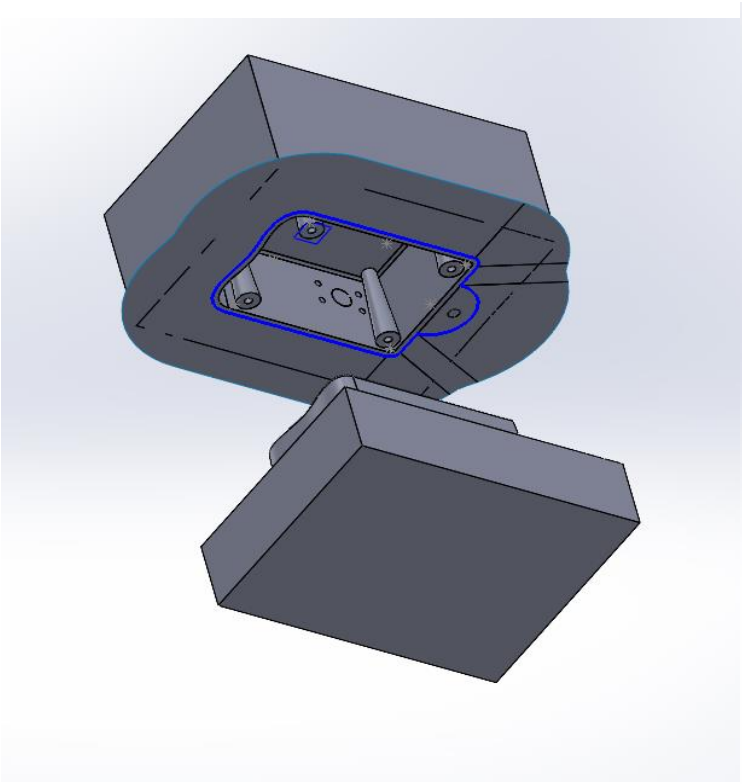


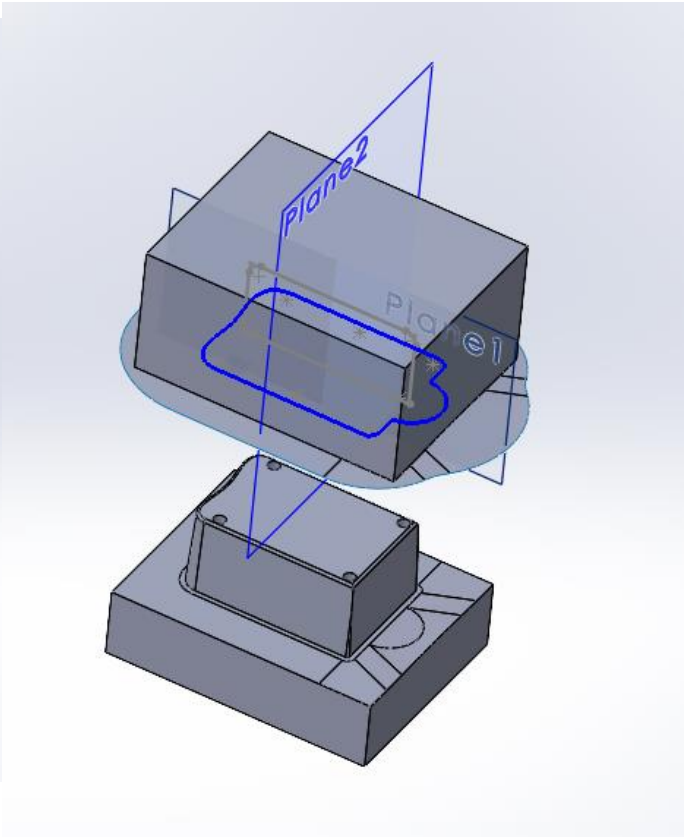


Die and cavity

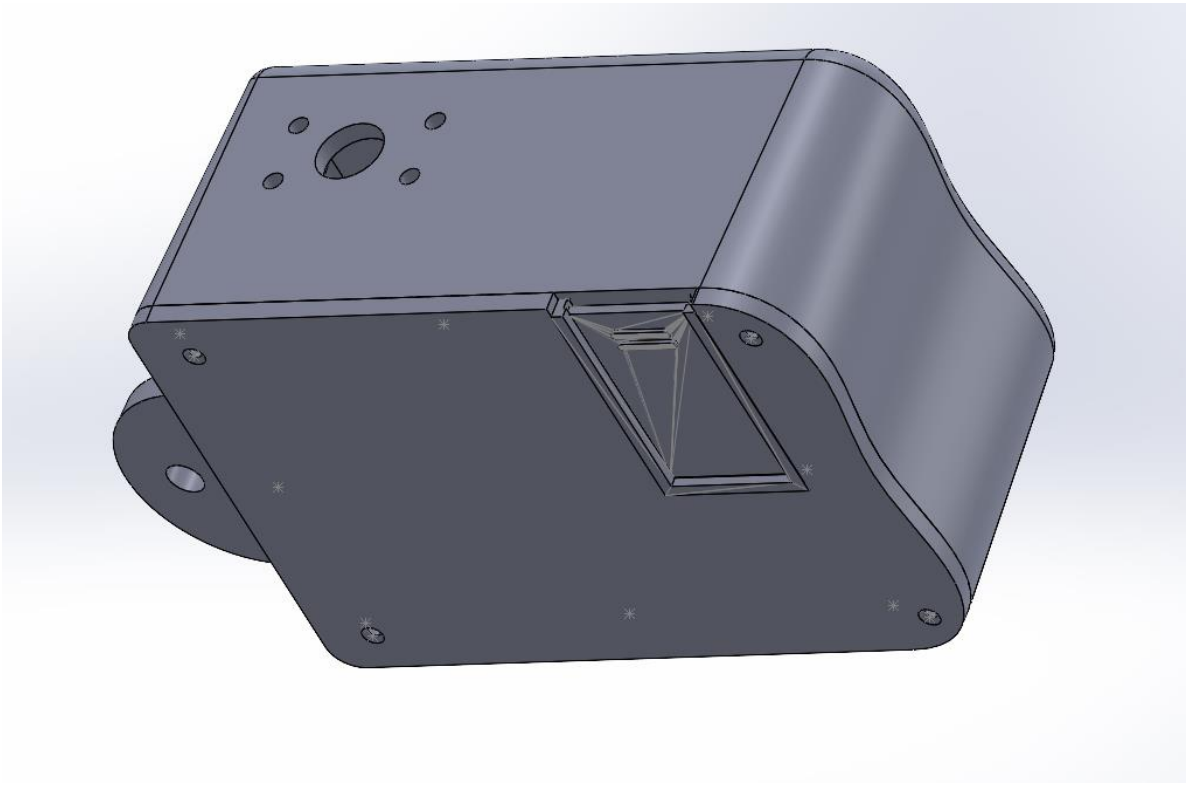


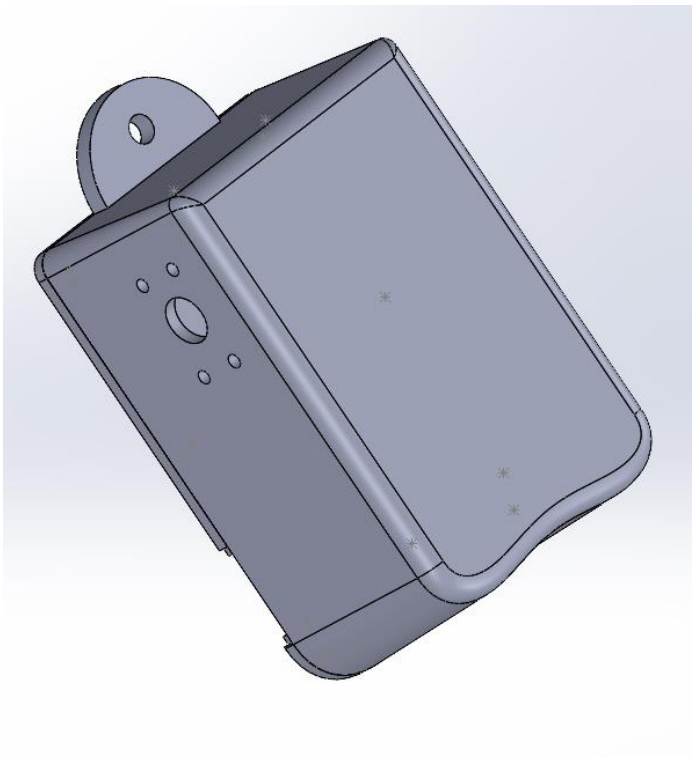


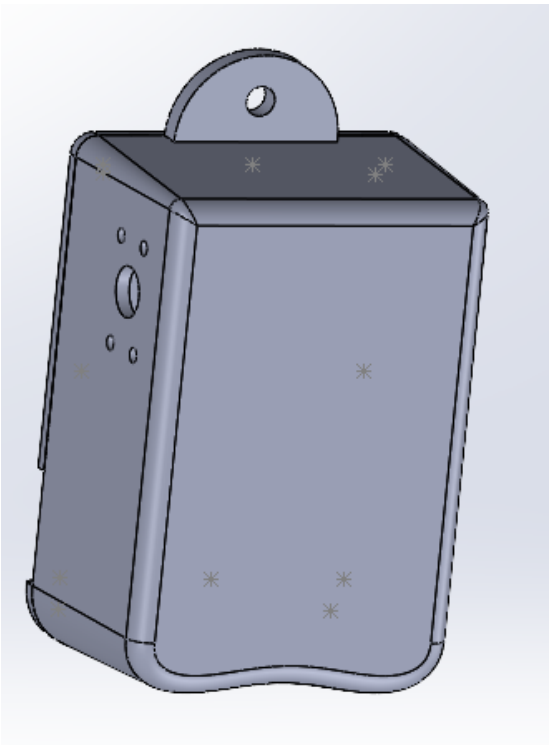




Final product







Schematic

Problems/Improvements identified/proposed by members of your group.

- Less clarity of the condition when it comes to repair/service the device
- Recommend to indicate power on using a some form of indication

Problems/Improvements identified/proposed by users.

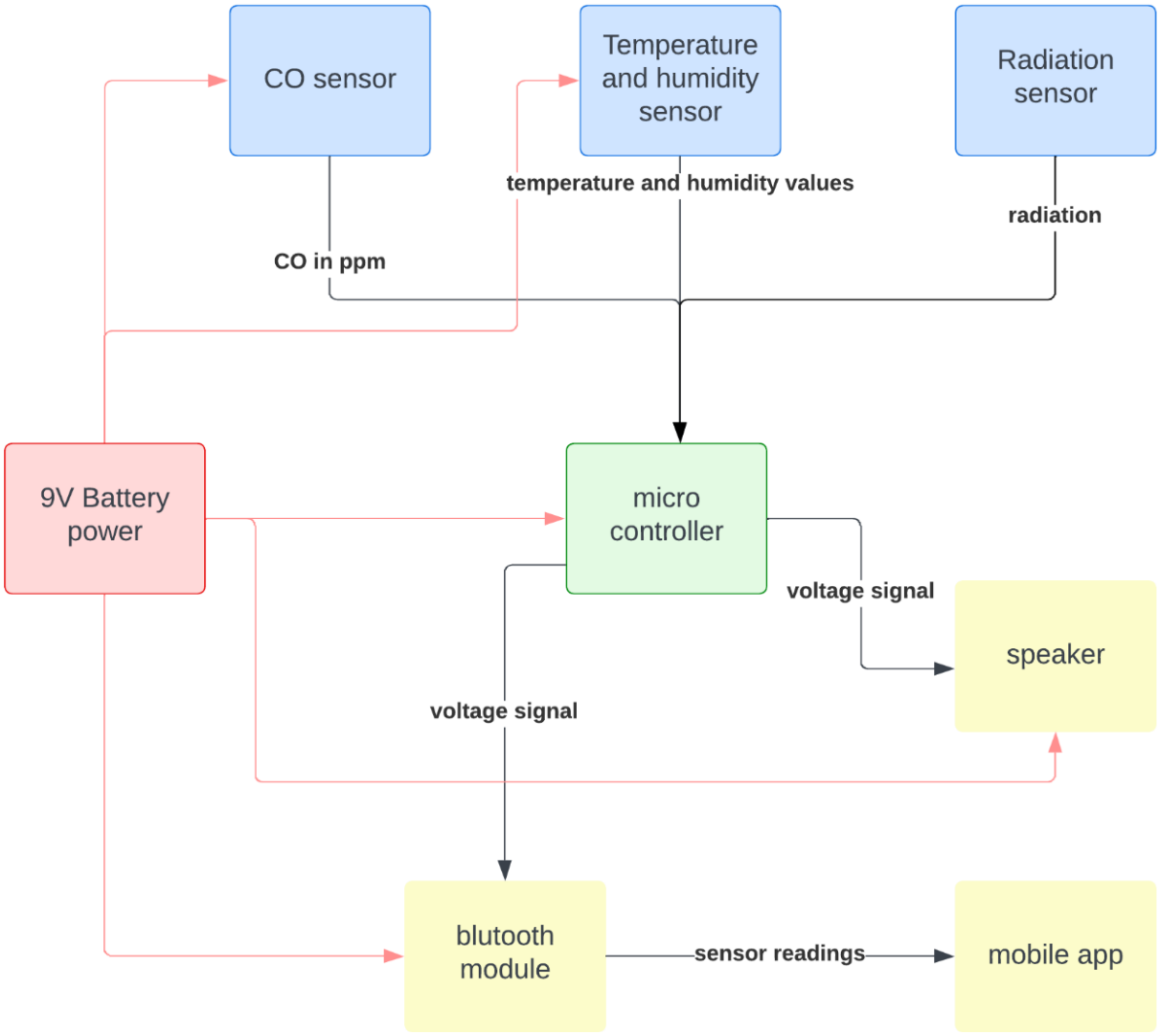
- Recommended the radiation levels measurement apart from the cost as it is critical to safety.
- A way to enter the critical user inputs as a user input

According to users requests of increasing user interactive Ness of the product following changes have been made to the already existing schematic diagram.

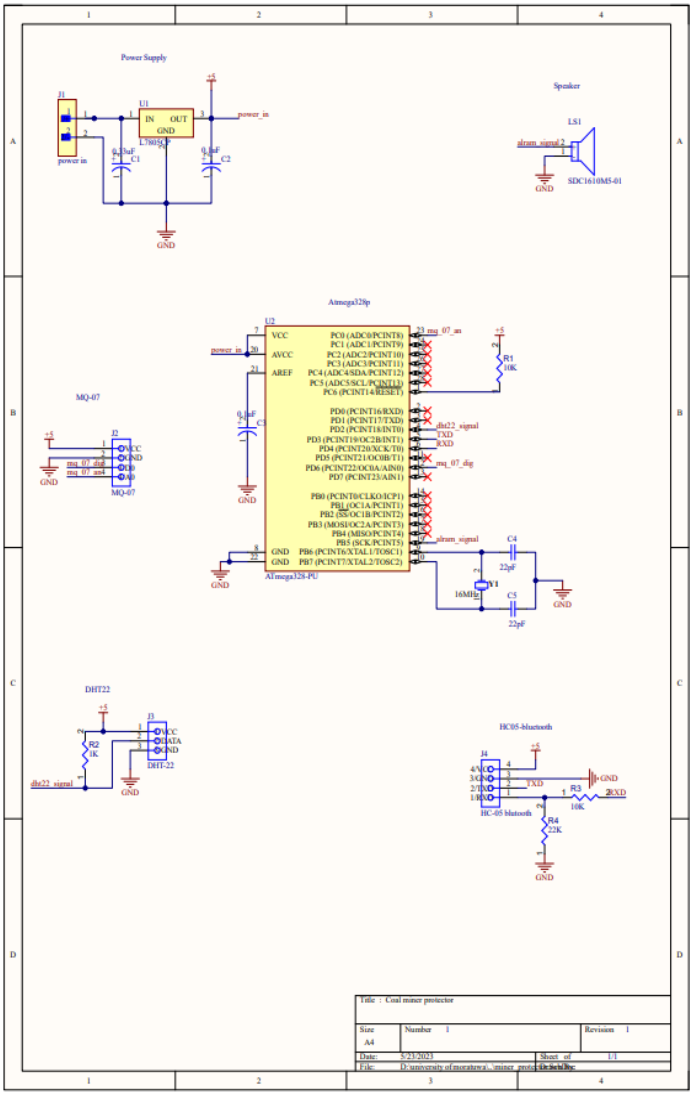
- LED indicating the power of the product is on
- LEDs indicating the Sensors and blutooth have been powered up without a failure.
- Apart from the alarm and mobile app notification, a LED indicating any critical situation.
- Added a radiation sensor to keep track of the radiation levels around the environment.

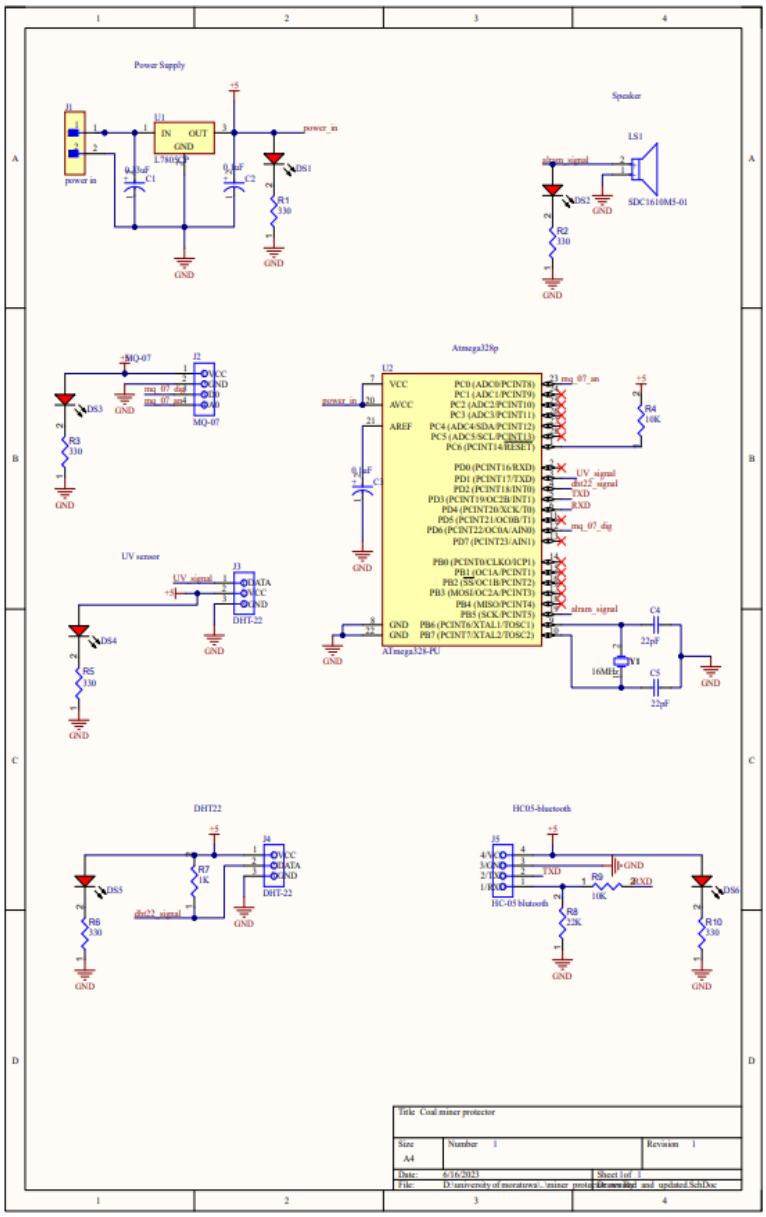
Functional block diagram according to the user/group recommendations and the problems identified considering the course content,

improved Block diagram



Comparison of old schematic vs improved schematic





Old schematic

improved schematic

Detailed Design stage

functional design

Product is developed using the DHT22 temperature and humidity sensor, MQ-07 carbon monoxide sensor, HC-05 Bluetooth module and Atmega328p chip as the main controller of the product.

DHT22 sensor

This sensor measures the temperature and humidity values and multiplex into a single signal send it to the microcontroller.

MQ-07 sensor

This sensor measures the carbon monoxide levels in the atmosphere and sends it as an ppm value to the micro controller.

HC-05 Bluetooth module

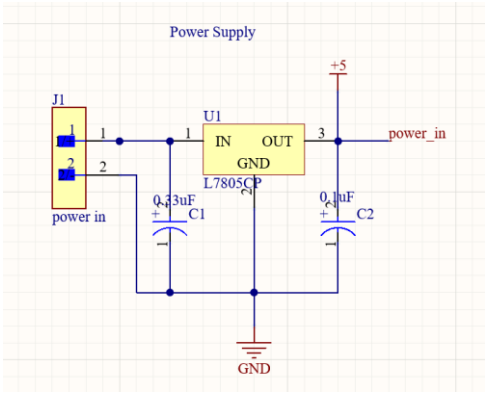
This Bluetooth module enables the communication between the product and the developed mobile app. It consists of a transmitter and a receiver which allows the user to enter user input and also to receive the respective environmental parameters via the mobile application.

Atmega328p micro controller

This is the main controller chip of the product which combines and communicates with each other collectively to achieve the objective task. The Atmega328p is a chip manufactured by Atmel. The chip has 32kB of flash memory, a CPU of 8-bit avr and performs 20 MIPS at 20 MHz. It consists of 28 pins where 23 pins can be used as I/O pins.

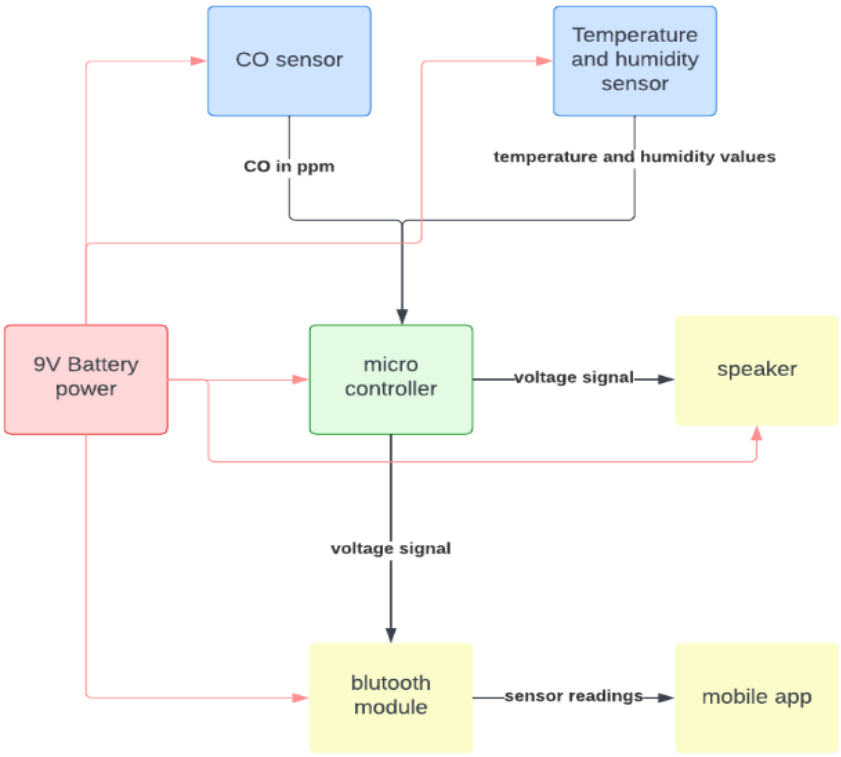
Power supply

The product is powered using a 9v battery with longer power capacity. In the power supply circuit the L7805CV 5v voltage regulator has been used as the Atmega328p micro controller, HC-05 Bluetooth module and all the sensors requires a 5v DC power supply for its optimal functionality.

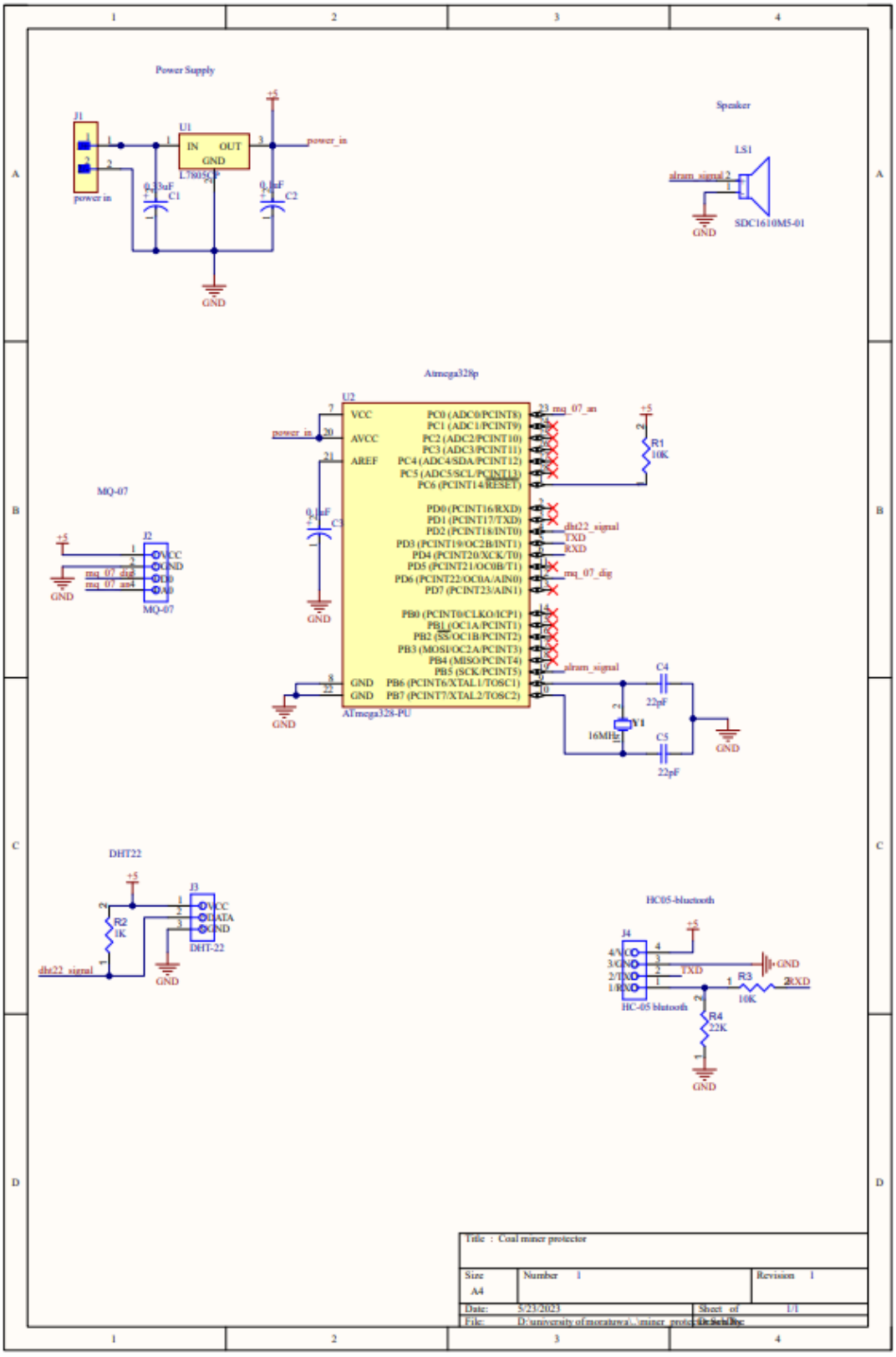


Implementing design

Functional block diagram



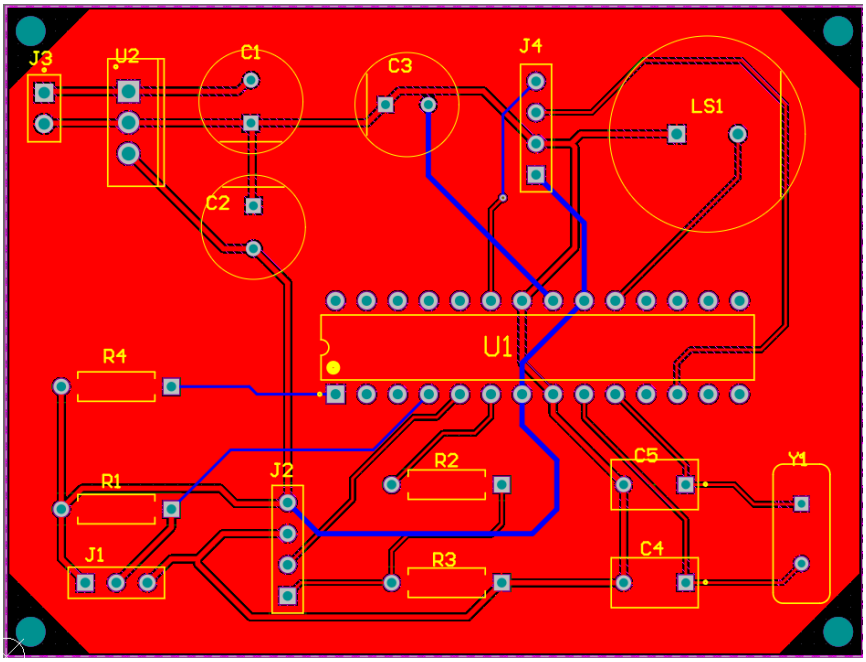
Schematic design



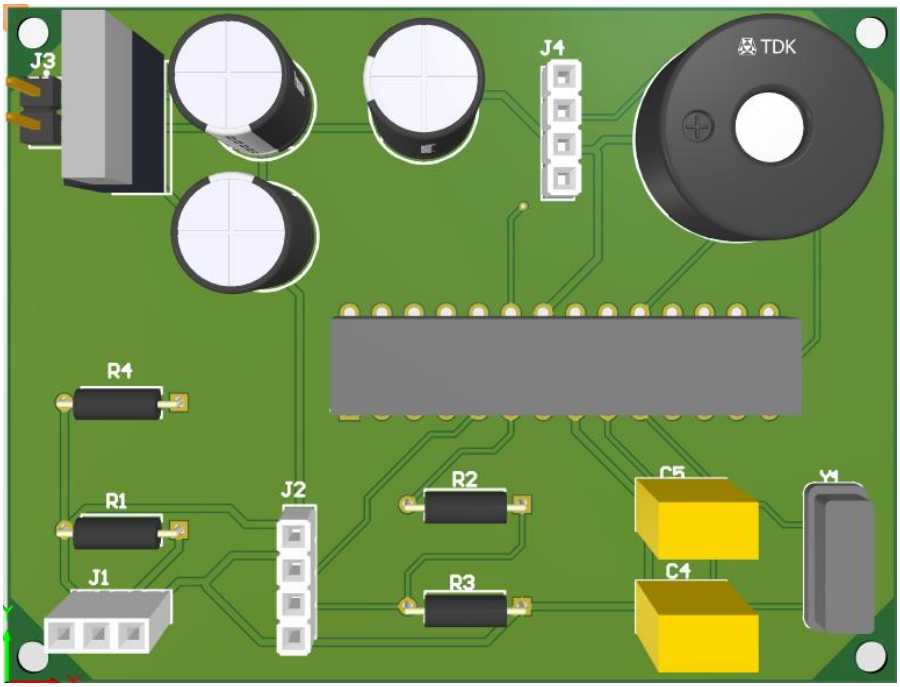
PCB design

Altium professional tools have been used to design the PCB

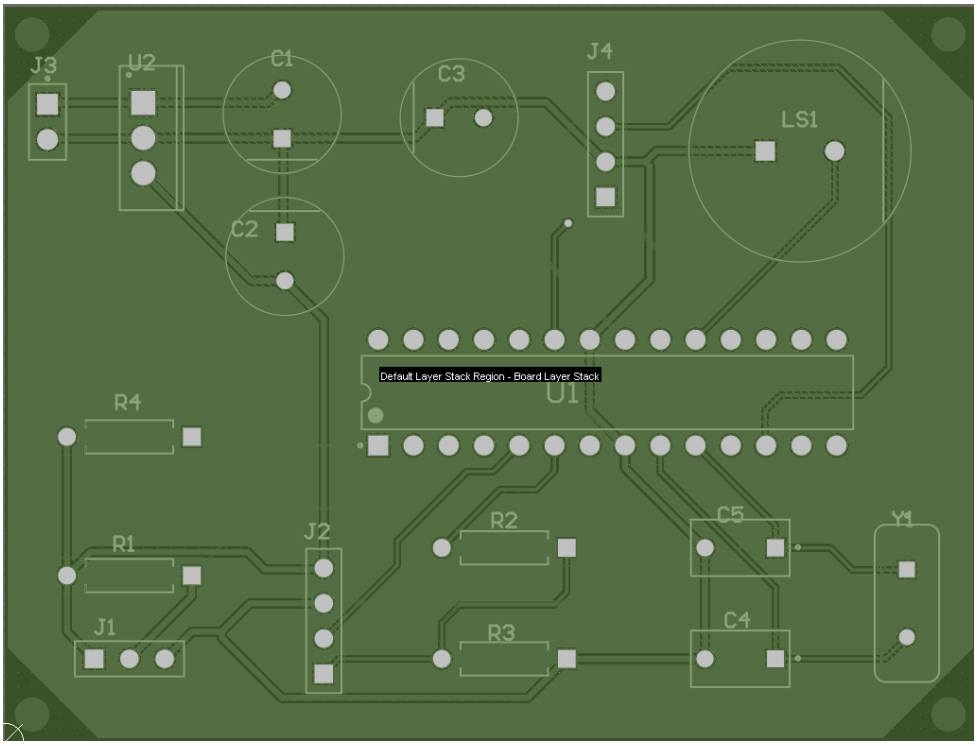
2D layout



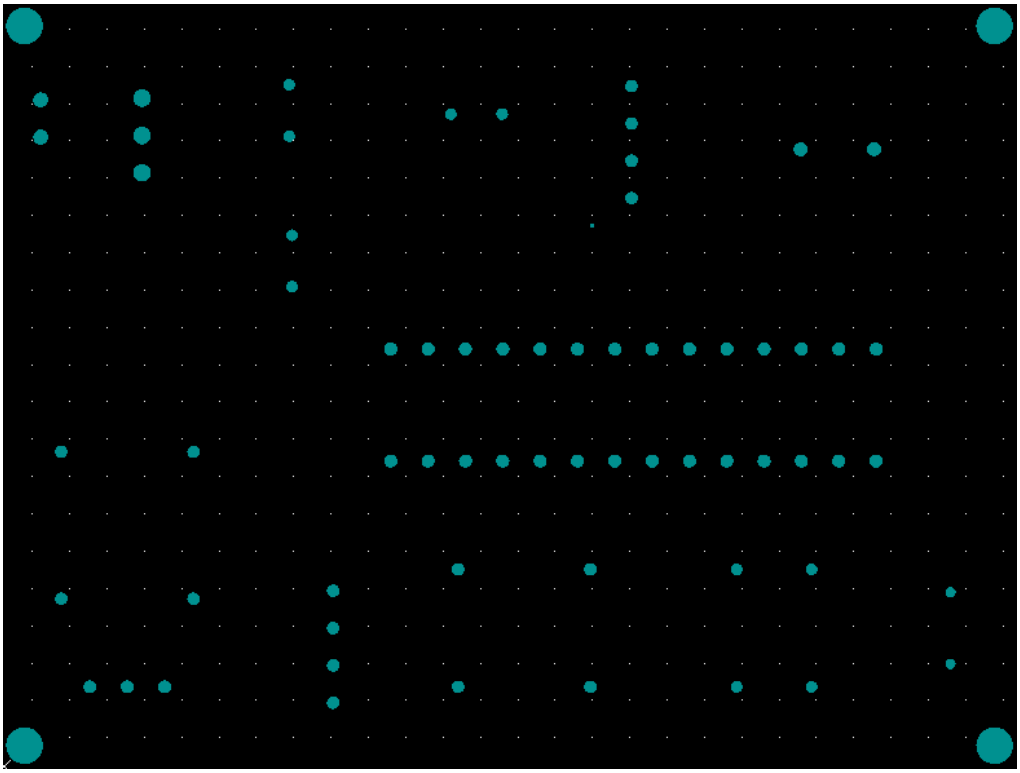
3D layout



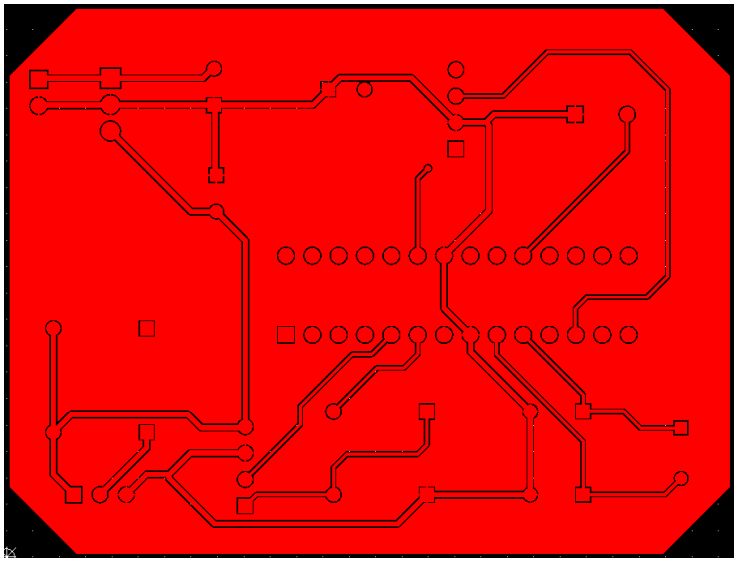
Board planning mode



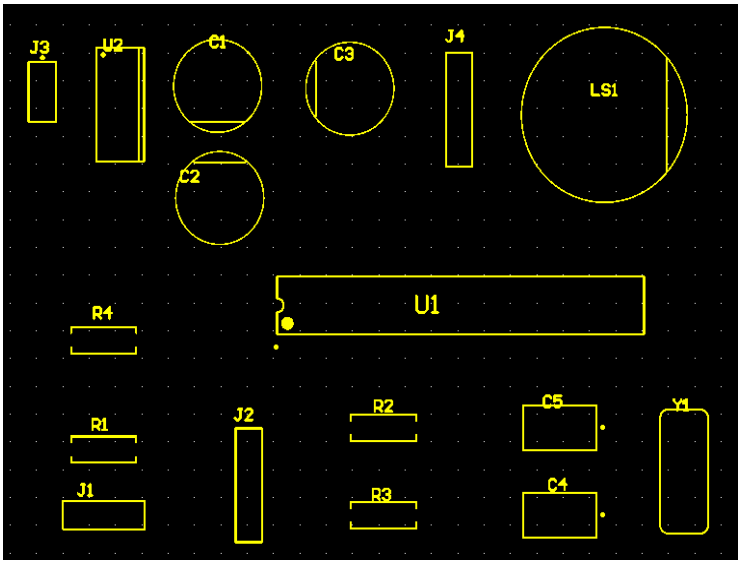
Drill view



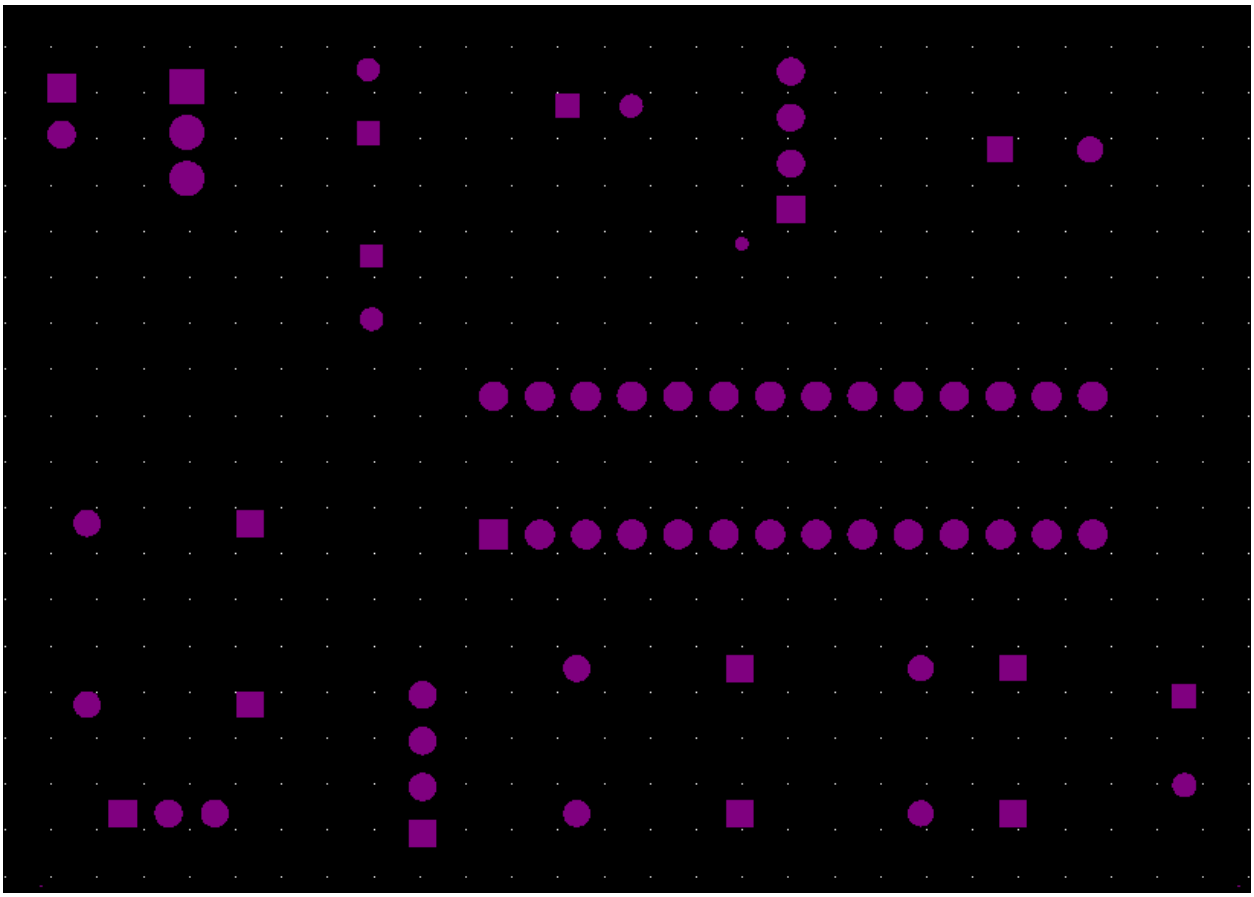
Top layer



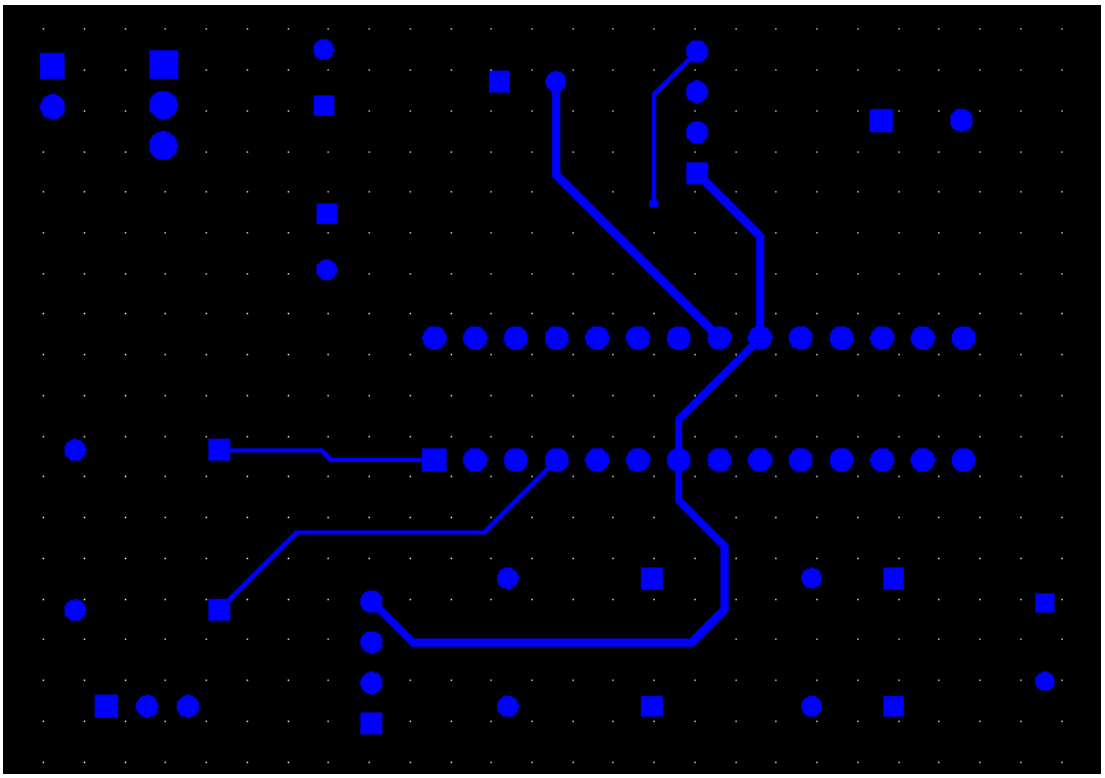
Top overlay



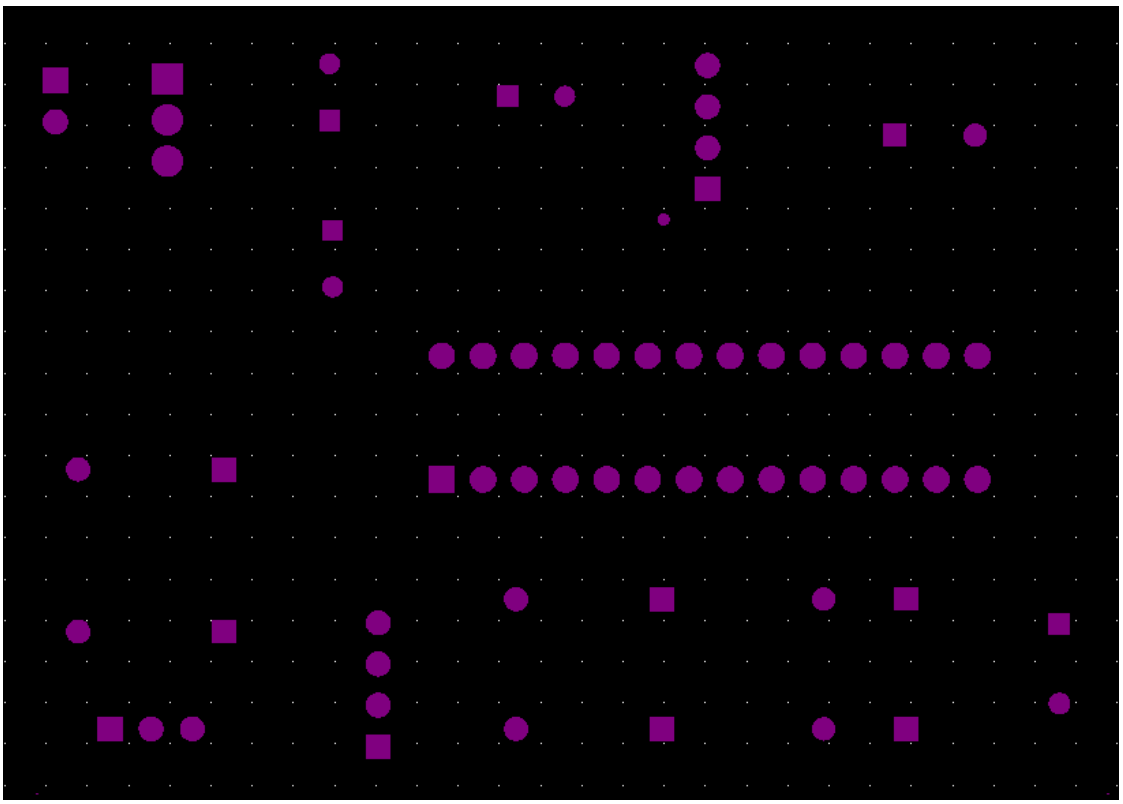
Top solder mask



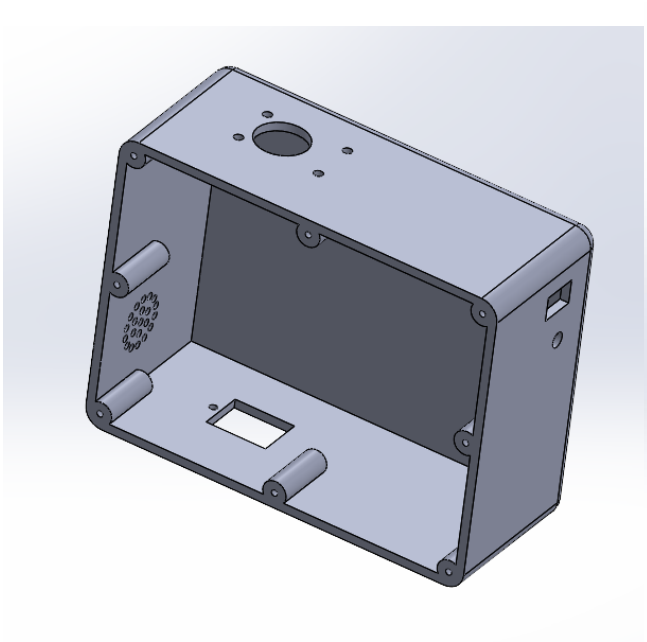
Bottom layer

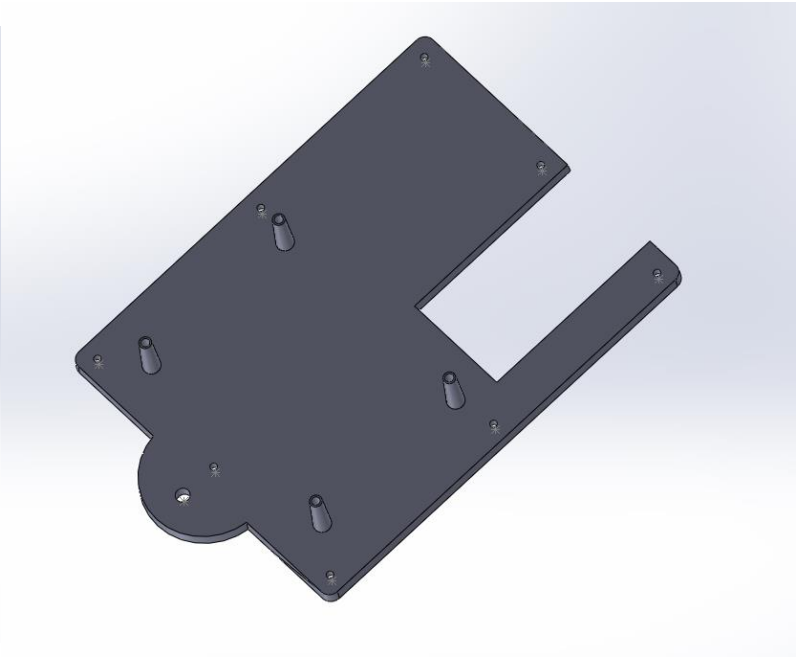


Bottom solder mask

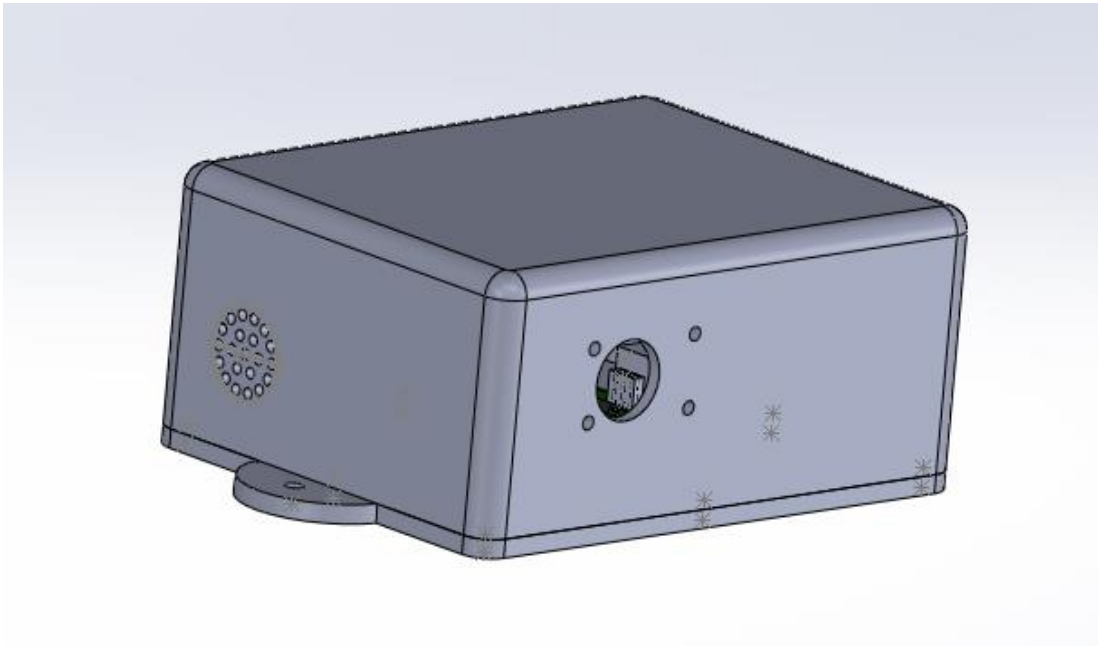


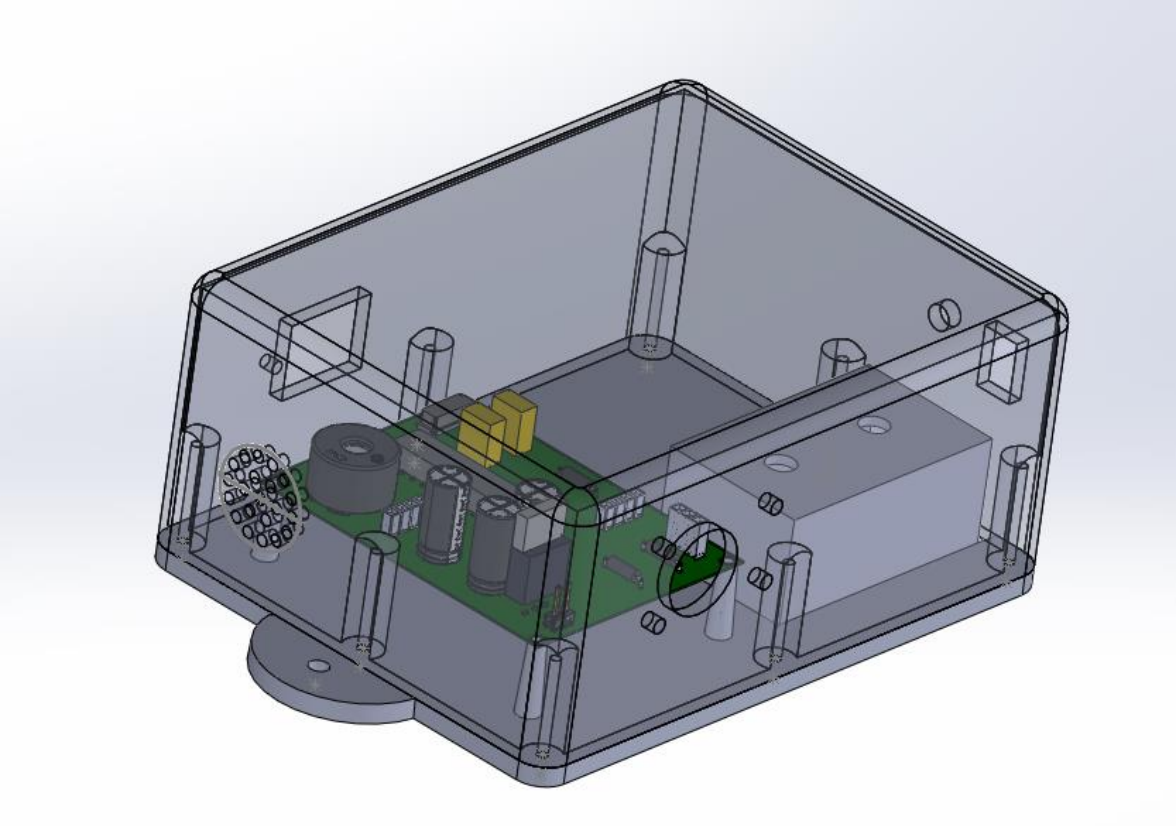
Enclosure design

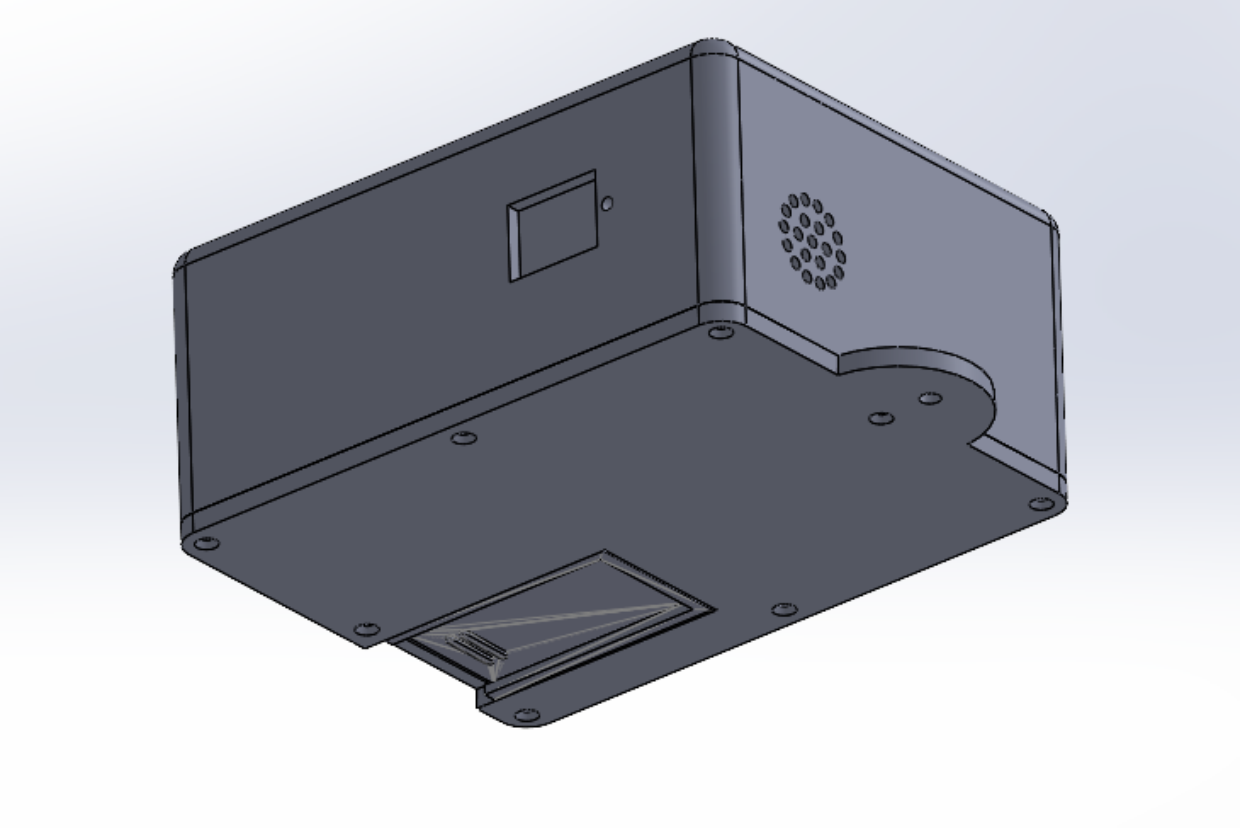




Assembly







Manufacturing process

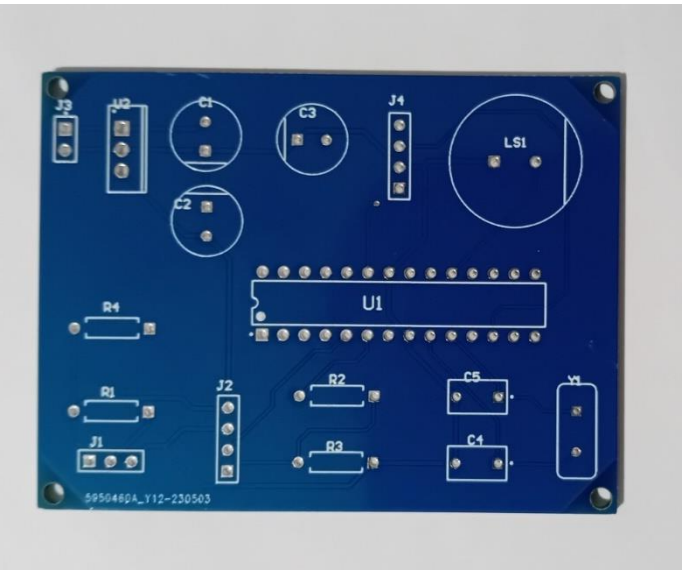
PCB manufacturing

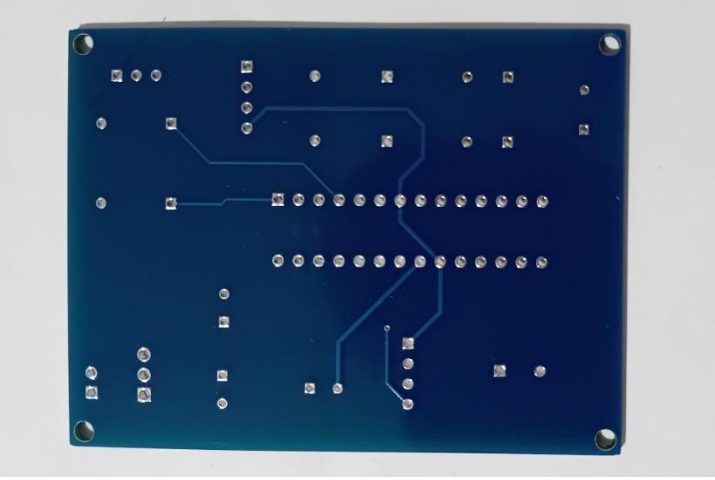
PCB manufacturing and fabrication process is done at JLC PCB manufacturers originated from China for high quality PCBs.

Visit manufacturers : JLC PCB

PCB specifications

- Base Material : FR-4
- PCB thickness : 1.6mm
- Copper Weight : 1 oz
- Dimension : 70 mm x 53 mm
- Surface finish : HASL(with lead)

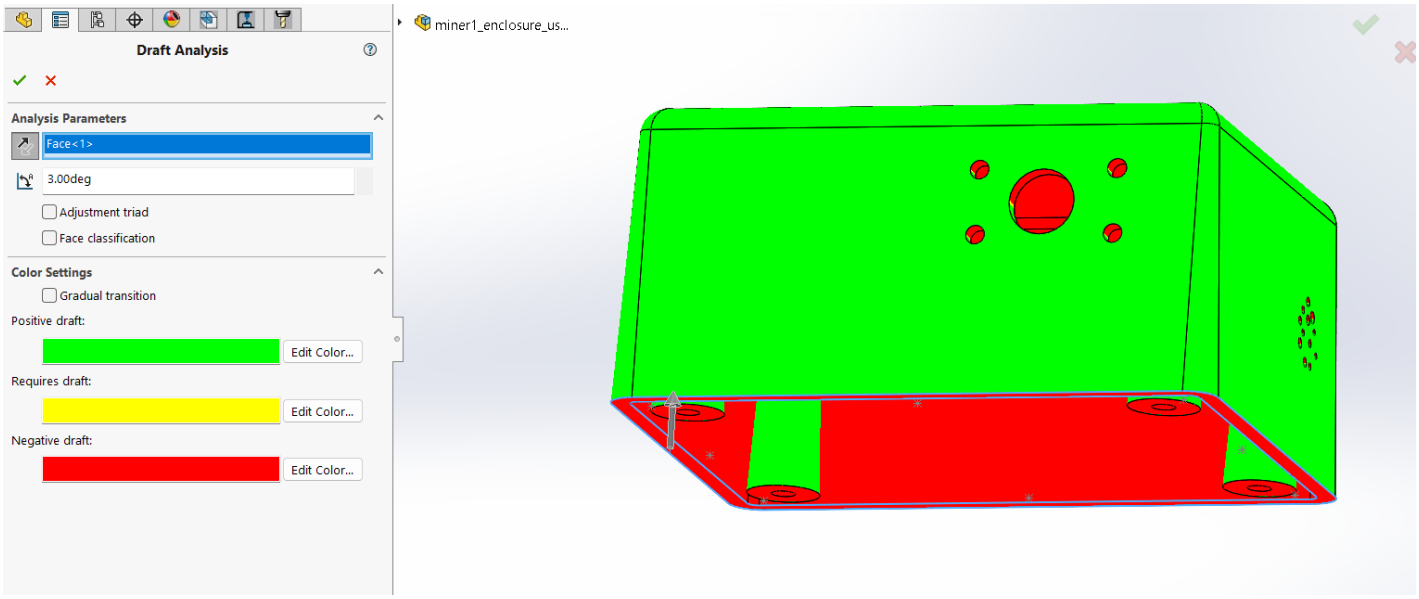


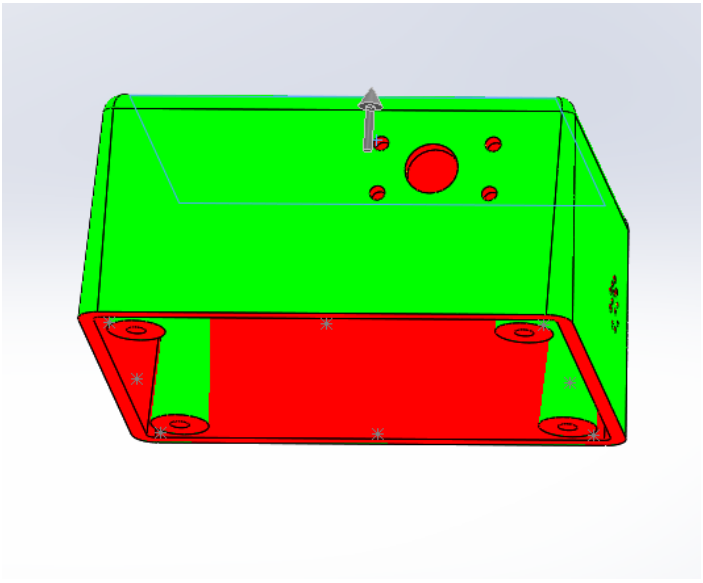


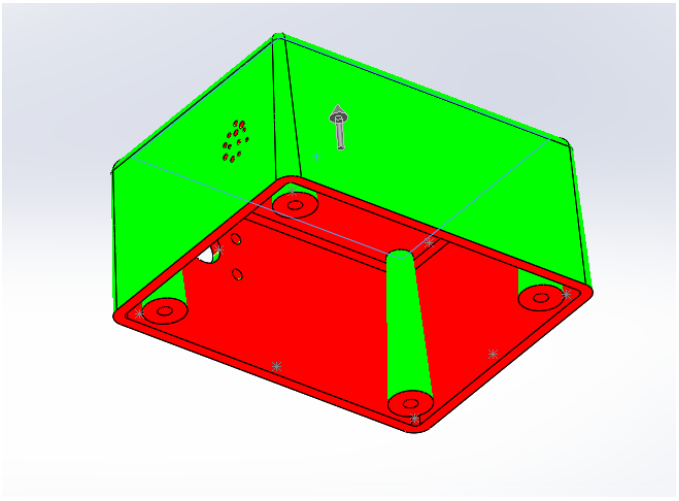
Enclosure manufacturing

The prototype enclosure is made using the 3D printing method, however when the enclosure is to be manufactured on a large scale it is decided to use the injection molding method. To make the mold draft analysis and mold designing is done as follows,

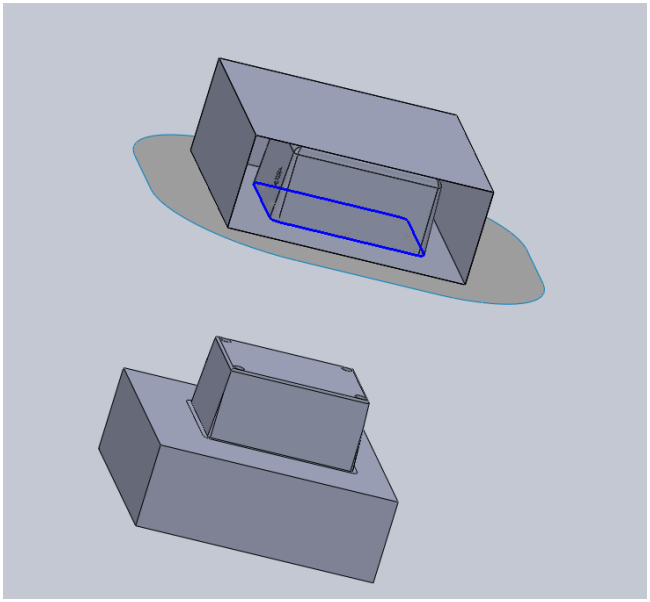
Draft analysis

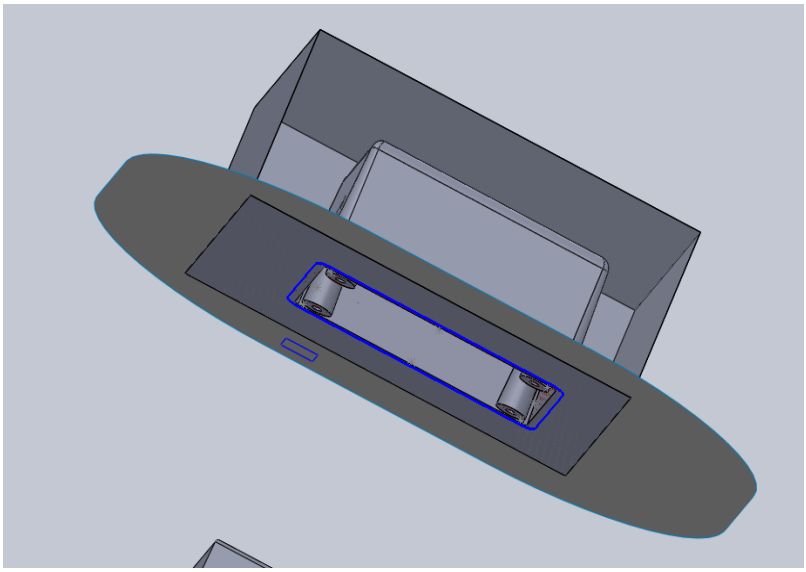


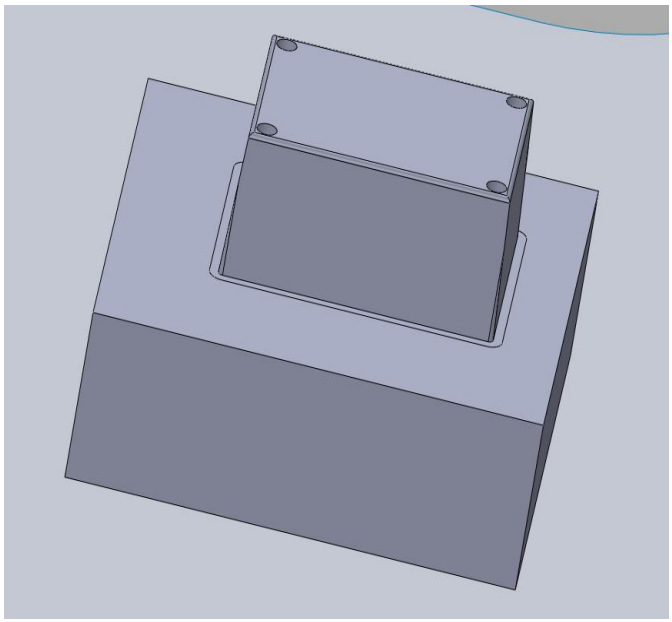


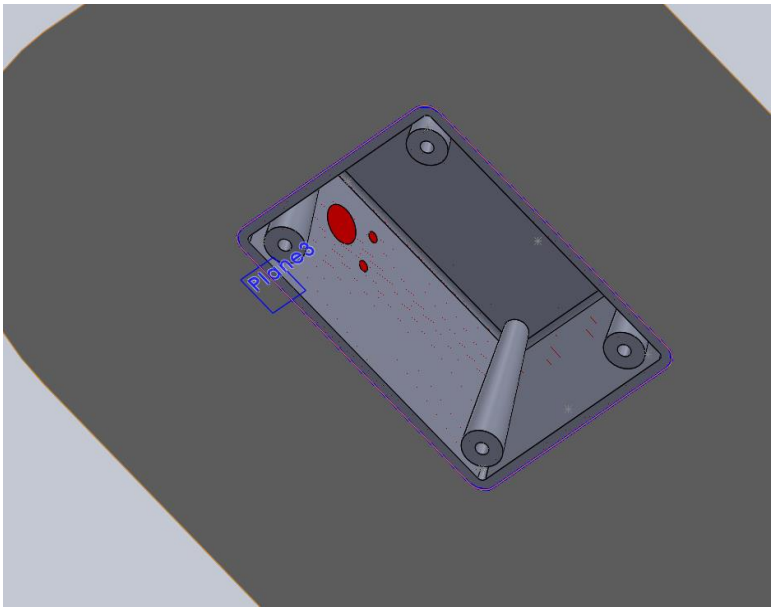


Mold design





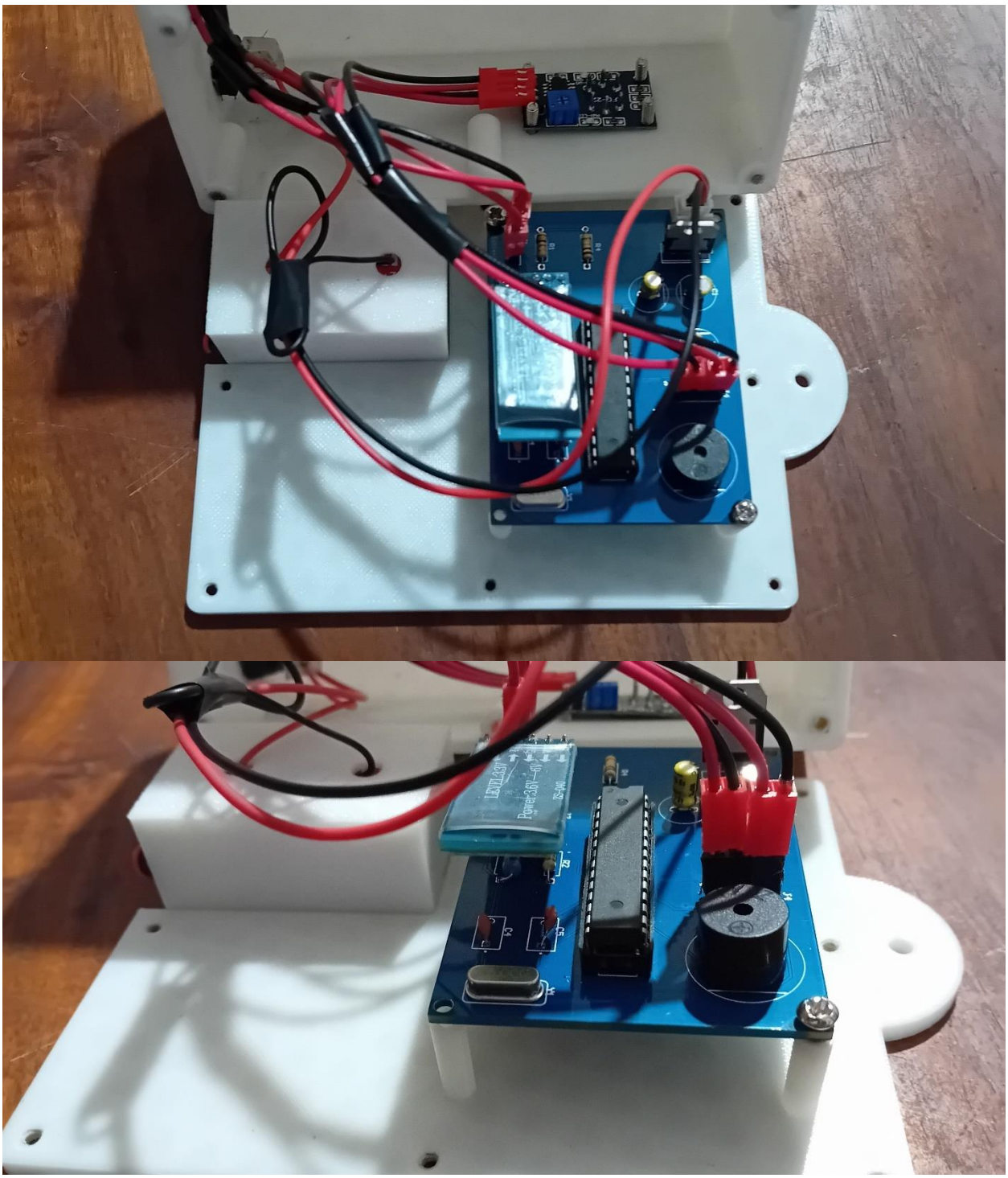




3d printed prototype

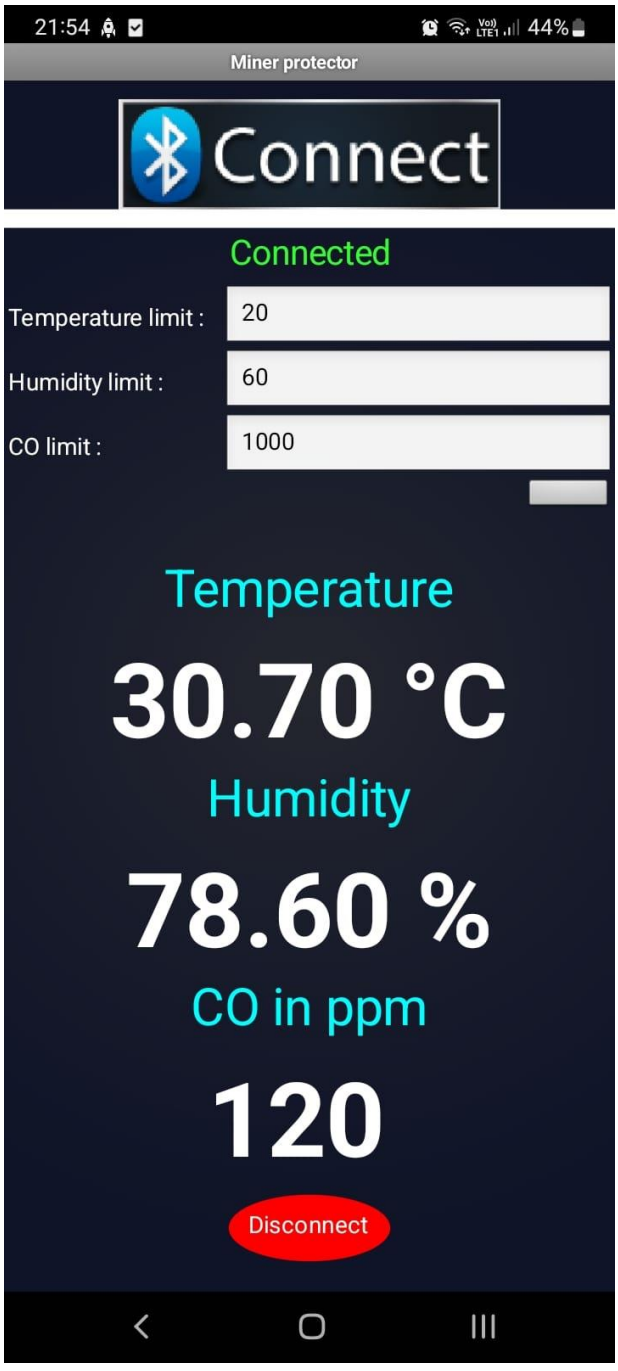
Fixing and soldering

Soldering of the prototype is done by hand, as the cost in minimized and production is done on a smaller scale. All the sensors have been fixed to the enclosure using screw nails. JST are used in wiring the components of the product.



User interface

Apart from the power on/off of the product user mainly interacts with the mobile app. Mobile app has been developed in a user friendly manner which has an intuitive interface to give user inputs and commands.



Code

```
#include <Adafruit_Sensor.h>
#include <DHT.h>
#include "Arduino.h"
#include <SoftwareSerial.h>

#define DHTPIN 2
#define DHTTYPE DHT22

DHT dht = DHT(DHTPIN, DHTTYPE);
const int AOUTpin=A0;
const byte rxPin = 3;
const byte txPin = 4;
SoftwareSerial BTSerial(rxPin, txPin);
bool configReceived = false; // Flag variable to check if configuration is received
float temp_lim = 50.0;
float hum_lim = 50.0;
float CO_lim = 5000.0;

void setup() {
  Serial.begin(9600);
  pinMode(13, OUTPUT);
  pinMode(6, INPUT);
  pinMode(AOUTpin, INPUT);
  pinMode(rxPin, INPUT);
  pinMode(txPin, OUTPUT);
  BTSerial.begin(9600);
  dht.begin();
}

void loop() {


  float h = dht.readHumidity();
  float t = dht.readTemperature();
  int gas_ppm = analogRead(AOUTpin);
  delay(600);

  if (isnan(h) || isnan(t)) {
    return;
```

```
 }

 if (BTSerial.available() && !configReceived) {

  temp_lim = BTSerial.parseFloat(); // Read temperature limit from Bluetooth
  hum_lim = BTSerial.parseFloat();  // Read humidity limit from Bluetooth
  CO_lim = BTSerial.parseFloat();   // Read CO limit from Bluetooth
  configReceived = true;
 }
 delay(500);

 BTSerial.print(t);
 BTSerial.print(" °C");
 BTSerial.print("|");
 BTSerial.print(h);
 BTSerial.print(" %");
 BTSerial.print("|");
 BTSerial.println(gas_ppm);


 if ((t > temp_lim) || (h < hum_lim)|| (gas_ppm > CO_lim)) {
  digitalWrite(13, HIGH);
  delay(600);
  digitalWrite(13, LOW);
  delay(50);

 }
 else {
  digitalWrite(13, LOW);
  delay(10);
 }
}
```

Bill of Materials - BOM

COMPONENT	MANUFACTURER	DEALER	Quantity	Price(Rs)
Atmega328-pu	Microchip Technology	LCSC	1	1700
DHT22-temperature sensor	Adafruit Industries	Mouser	1	820
MQ7 carbon monoxide sensor	Winsen	LCSC	1	550
Bluetooth module	HC Technology	Mouser	1	180
5v Buzzer	CUI Devices	Arrow	1	70
Connector - BCS-103-L-S-TE	Samtec	Arrow	1	100
L7805CP 5V Regulator	STMicroelectronics	LCSC	1	60
0.33uF Polarized Capacitor		Local supplier	1	10
0.1uF Polarized Capacitor		Local supplier	2	10
22pF Non-Polarized Capacitor		Local supplier	2	5
JST Connector	JST Corporation	Tronic.lk		350
1K Resistor		Local supplier	1	5
10K Resistor		Local supplier	2	5
22K Resistor		Local supplier	1	10
16MHz Crystal Oscillator		Mouser	1	25

User manual

Introduction

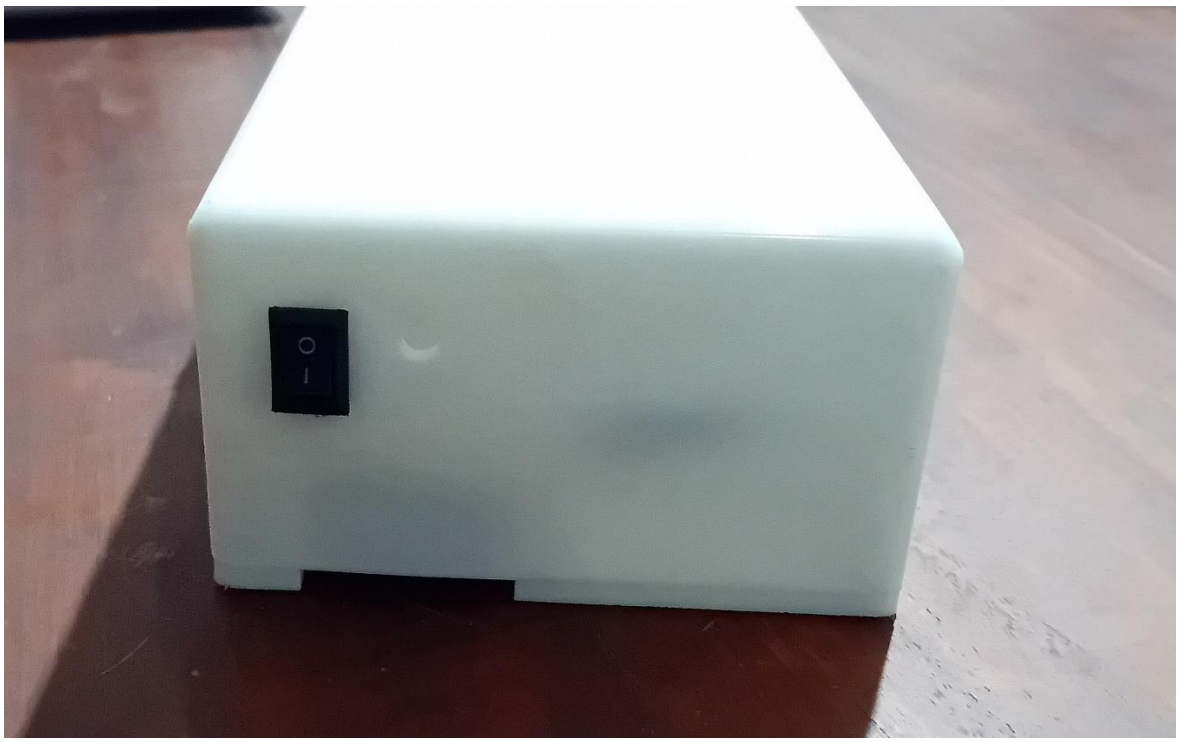
The coal miner protector is developed as a safeguard equipment for a coal mine. This device keeps track of some crucial environmental parameters and warns if any of the parameters reached beyond a certain critical level.

Package content

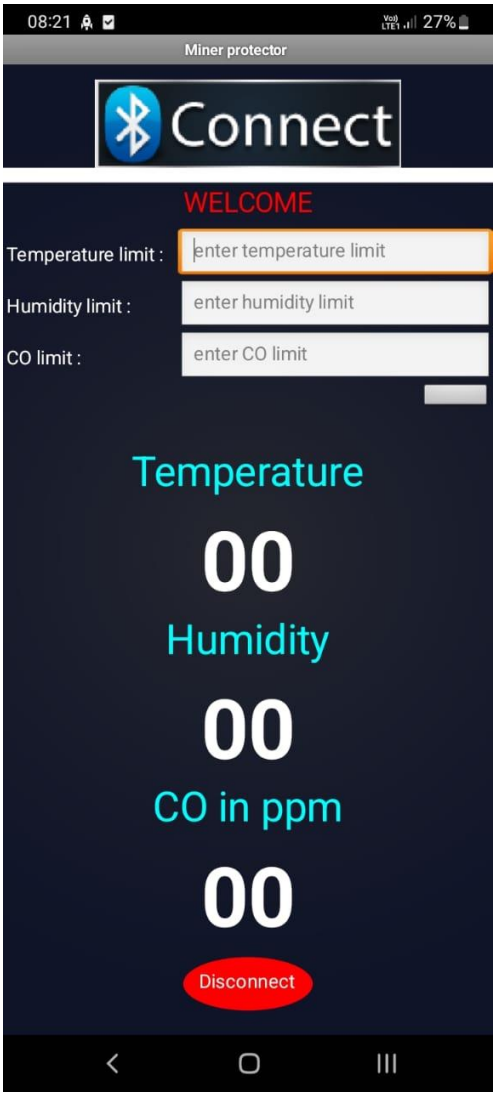
- Coal miner protector device
- User manual
- 9v battery
- Warranty card

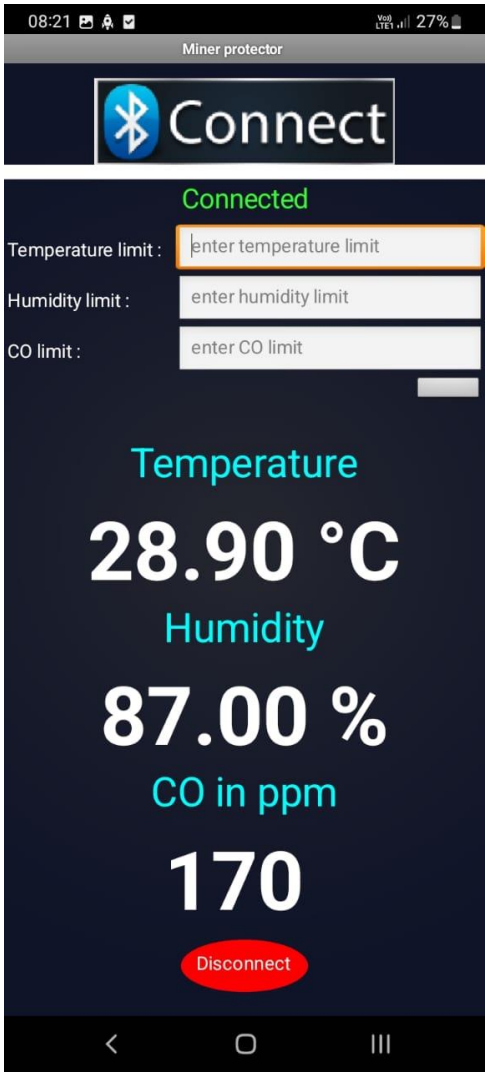
User instructions

✓ Turn on the device power using the power switch



- ✓ To check environmental factors, use the mobile app,
    1) Turn on the Bluetooth of the mobile phone
    2) In the app click on the “Bluetooth” button to get the list of Bluetooth devices
    3) Select the HC-05 device in the module
    4) After it connected the live environmental parameters should be visible

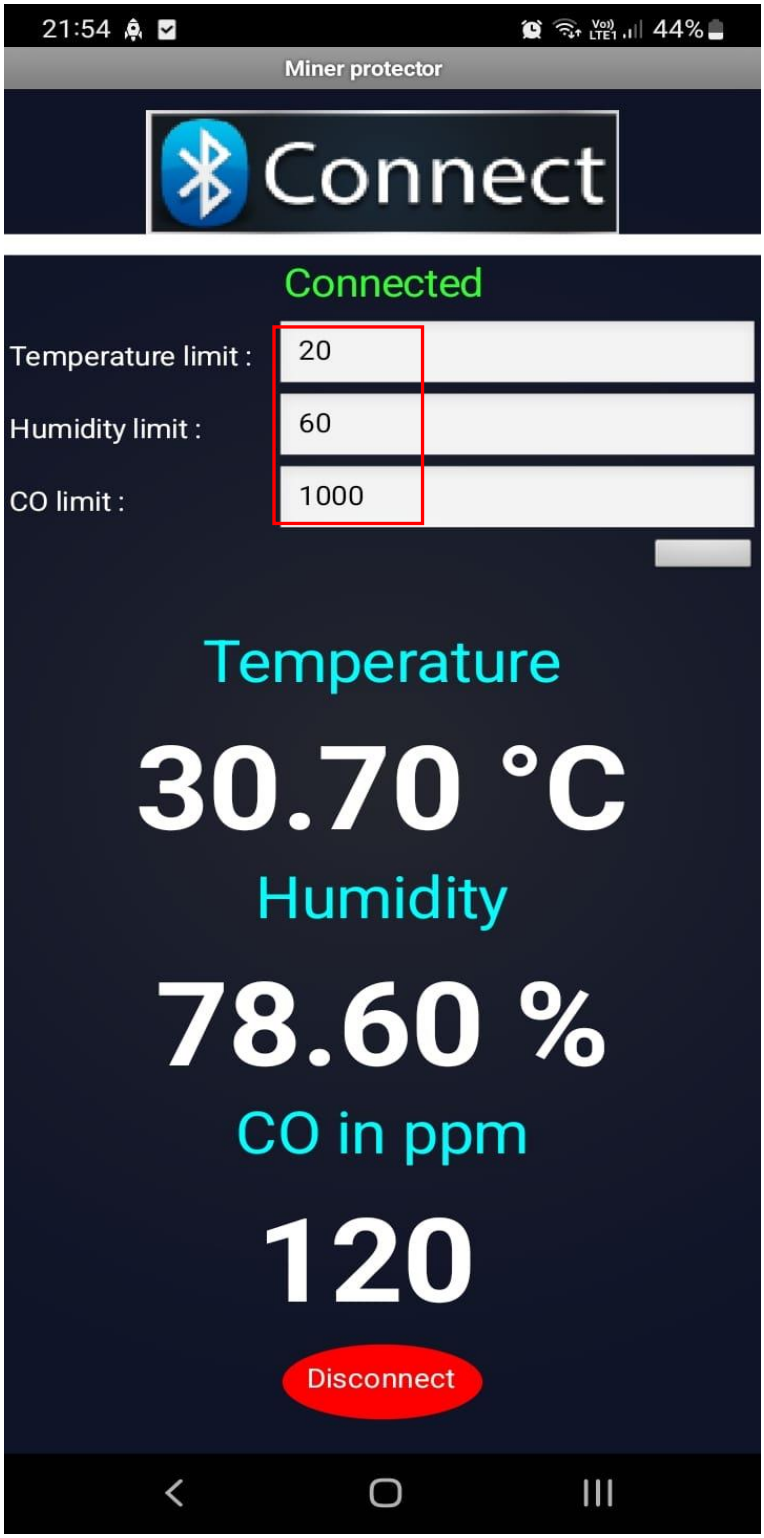




1) 2) 3),4)

✓ To set user preferred critical threshold levels

1) Enter the preferred user inputs in respective place
2) Click send button



Test functionality and troubleshooting

- No power : check whether the power button is at on position and the sensor power indicating red lights are turned on

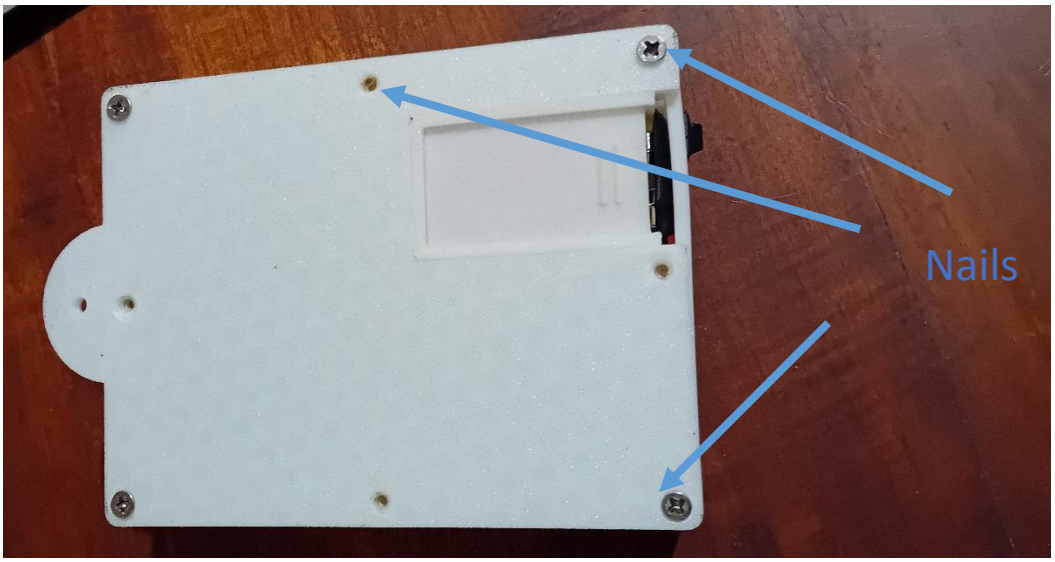
  If the power button is on and still not working,

  - ✓ check the battery is properly inserted with correct polarity
  - ✓ replace the existing batteries

- False sensor readings and alarms : check whether the sensors are directly in contact with surfaces which will result in faulty measurements.

- To check the functionality of the alarming system, user can select the user input thresholds to exceed the current sensor readings of the product.

Instructions for assembly



- To assemble place screw nails at screw holes as shown above
- Check whether the battery casing is properly closed.