BABU BANARSI DAS University

Internet of Things Project File

(NITBC4351)

SUBMITTED BY:
Adarsh Kumar | Abhinav Singh
|Netraja | Sakshi Choubey|
Class: IOTBC2

SUBMITTED TO:
Mr. Vikas Kumar

Project

Aim- To design a Smart Energy Monitoring and Theft Detection system using IoT that measures supply and load current, detects abnormal usage or theft, and alerts the user through display and buzzer.

Outcomes/Learning:

1) Detects theft and bypass conditions accurately.
2) Displays real-time supply and load readings on LCD.
3) Sends data to IoT dashboard for remote monitoring.
4) Activates buzzer and LED during theft conditions.

Required Tool:

1) ESP32 Microcontroller
2) 2 × CT Sensors (30A)
3) 16×2 LCD Display (I2C)
4) LED
5) Buzzer
6) Push Button
7) Breadboard
8) Jumper Wires (M–M, F–F, M–F)
9) Resistor
10) Extension Board

Working: Two CT sensors measure the supply and load current.
The ESP32 compares both readings — if the difference exceeds 0.6A or the supply is zero while load is active, theft or bypass is detected.
In normal conditions, the LCD shows live readings and sends data to the IoT platform.
During theft, the buzzer and LED turn ON to indicate alert.

Tool 1: ESP32 Micro-controller : The ESP32 is a micro controller with built-in Wi-Fi and Bluetooth used for IoT and embedded projects.

1. 3V3 (Pin 1): Provides 3.3V power output for components.

2. GND (Multiple Pins – e.g., 2, 14, 25, etc.): Connects to the circuit's ground.

3. EN (Pin 3): Enables or resets the ESP32 when toggled.

4. GPIO Pins (e.g., GPIO0–GPIO39): Used for digital input and output operations.

5. ADC Pins (GPIO32–GPIO39): Read analog sensor values.

6. DAC Pins (GPIO25, GPIO26): Generate analog output signals.

7. TX/RX Pins (TX0=GPIO1, RX0=GPIO3): Handle serial communication

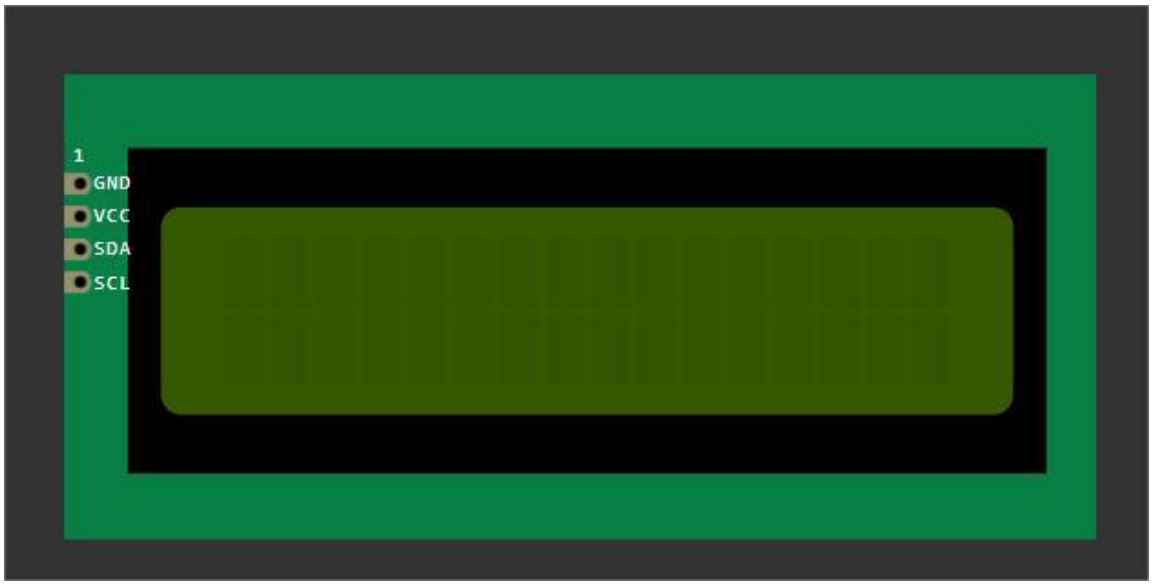
(transmit/receive).

8. SDA/SCL Pins (SDA=GPIO21, SCL=GPIO22): Used for I²C communication.

9. MOSI/MISO/SCK/CS Pins (MOSI=GPIO23, MISO=GPIO19, SCK=GPIO18, CS=GPIO5): Used for SPI communication.

Tool 2- CT Sensors (30A) : A CT sensor 30A measures alternating current by detecting the magnetic field generated around a conductor.

Tool 3 : 16×2 LCD Display (I2C) : A 16×2 LCD with I2C displays two lines of text (16 characters each) and communicates using only two data wires for easier connections.



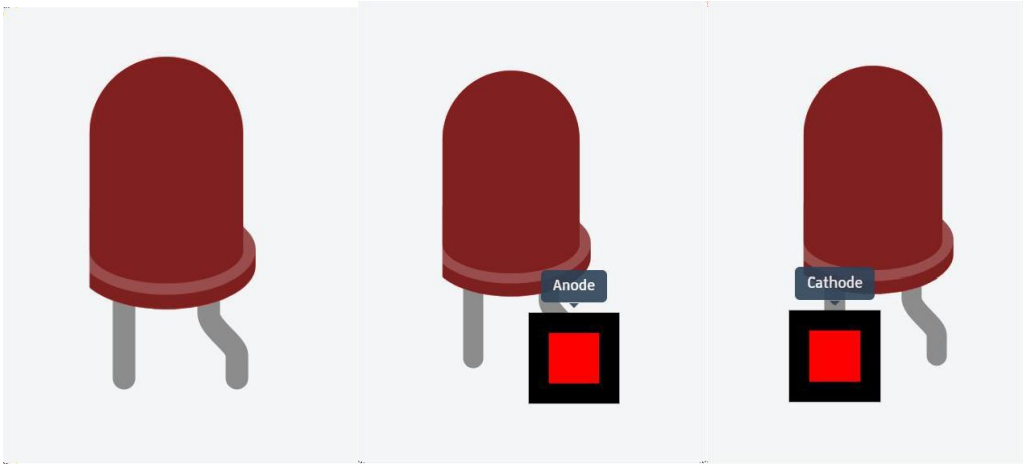
VCC: Supplies power to the LCD module.

GND: Connects to the circuit's ground.

SDA: Transfers data between the LCD and micro-controller.

SCL: Carries the clock signal for I2C communication.

Tool 4: LED :A light-emitting diode that glows when current passes through it.

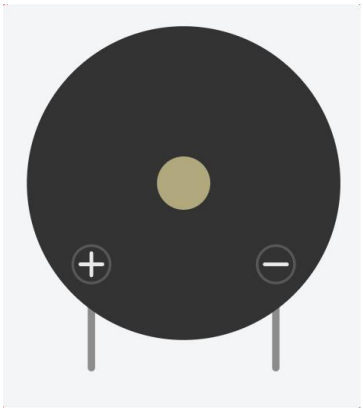


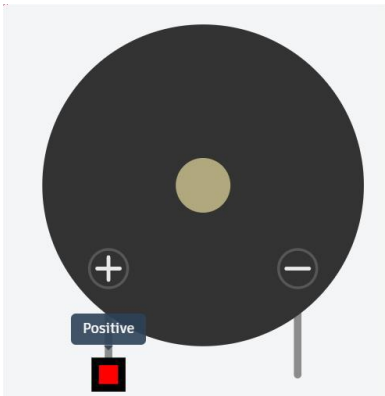
Anode (+): The longer leg of the LED. It is the positive terminal where

current enters.

Cathode (–): The shorter leg of the LED. It is the negative terminal where current exits.

Tool 5: Buzzer : A buzzer converts electrical signals into sound to provide audible alerts or indications.

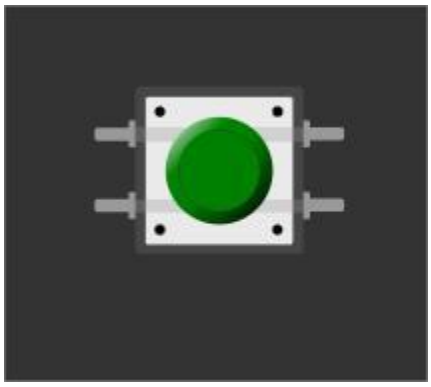




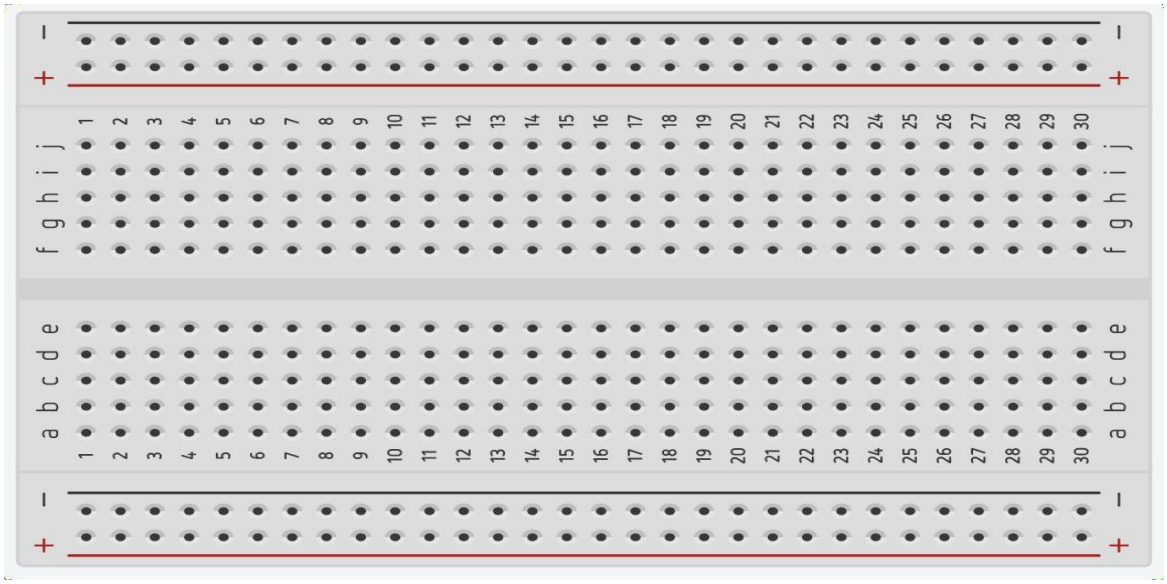
Positive pin: Connects to the power supply to activate the buzzer.

Negative pin: Connects to ground to complete the circuit.

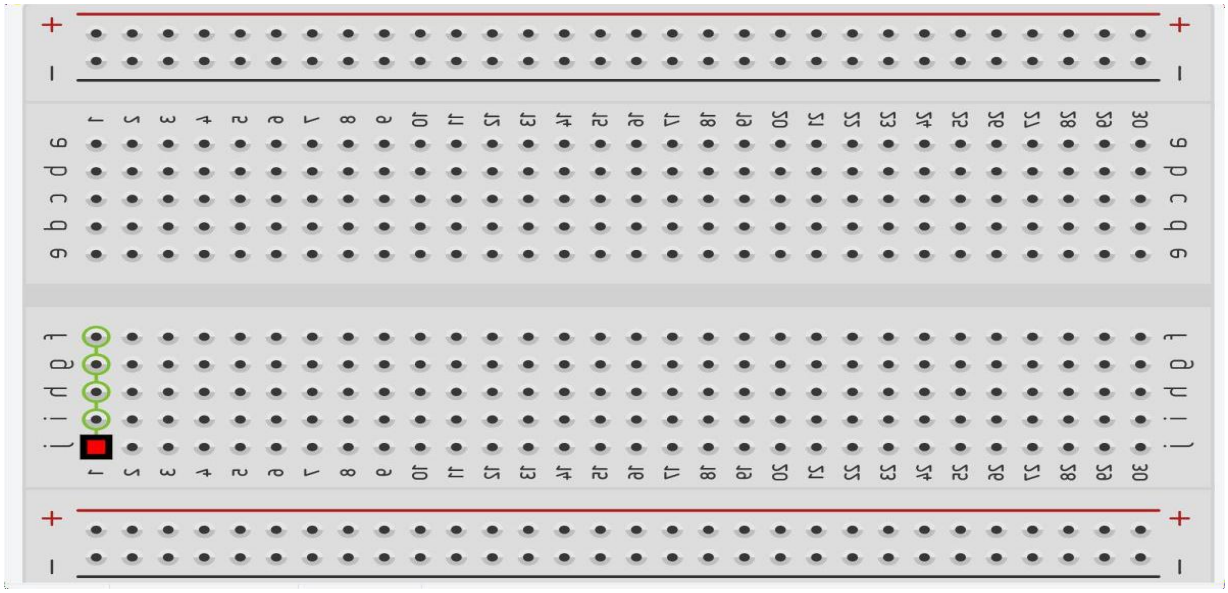
Tool 6 : Push Button : A push button is a simple switch that connects or disconnects a circuit when pressed.



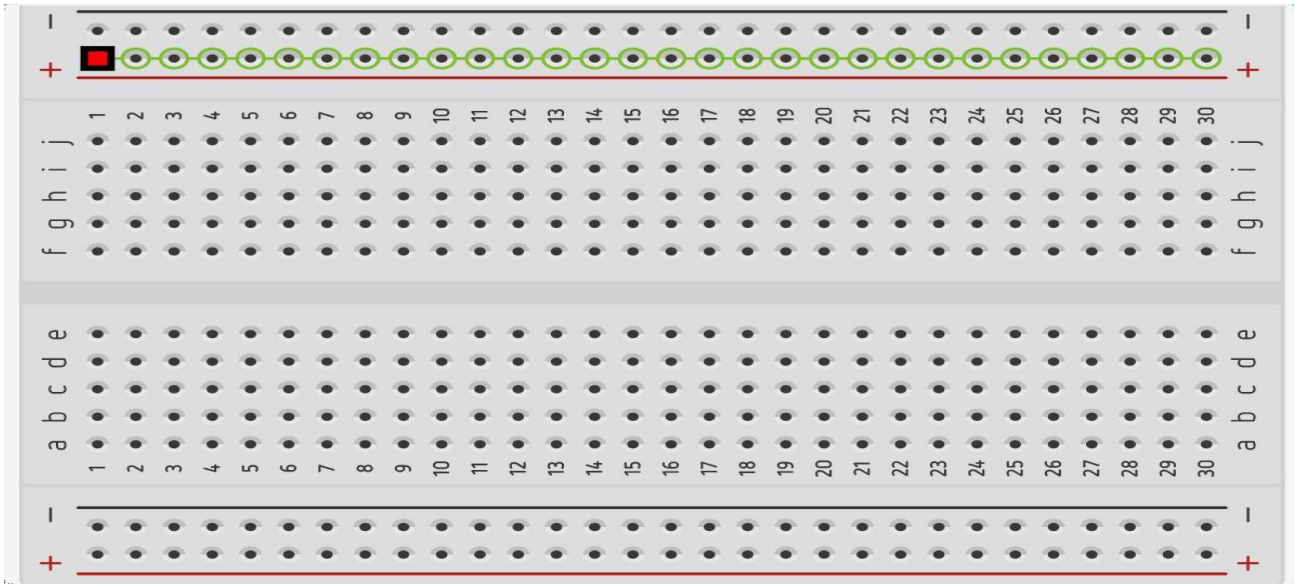
Tool 7: Breadboard: A board used to connect electronic components without soldering.



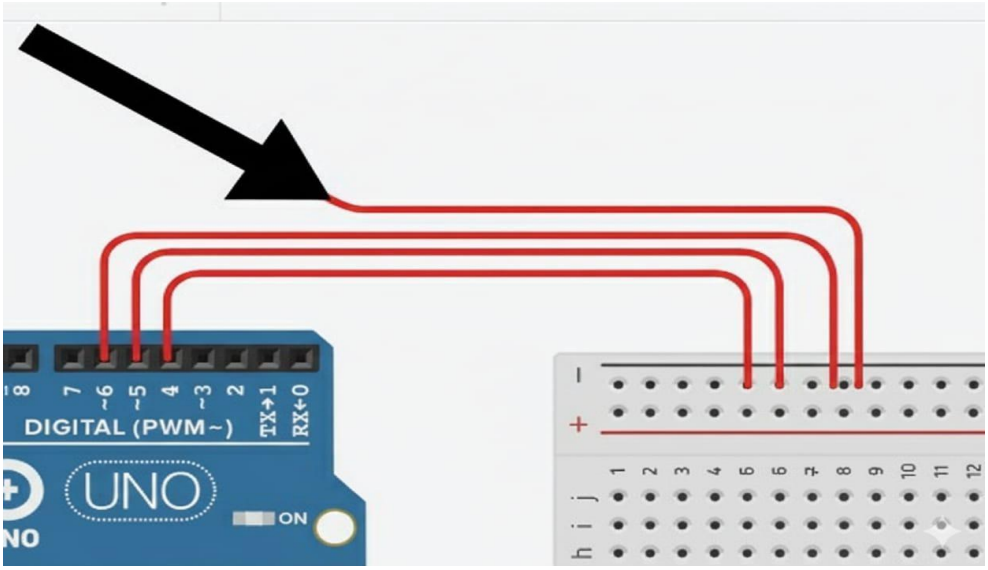
Vertical Lines: Side rails for power supply (+ and –).



Horizontal Lines: Middle rows where components are connected.



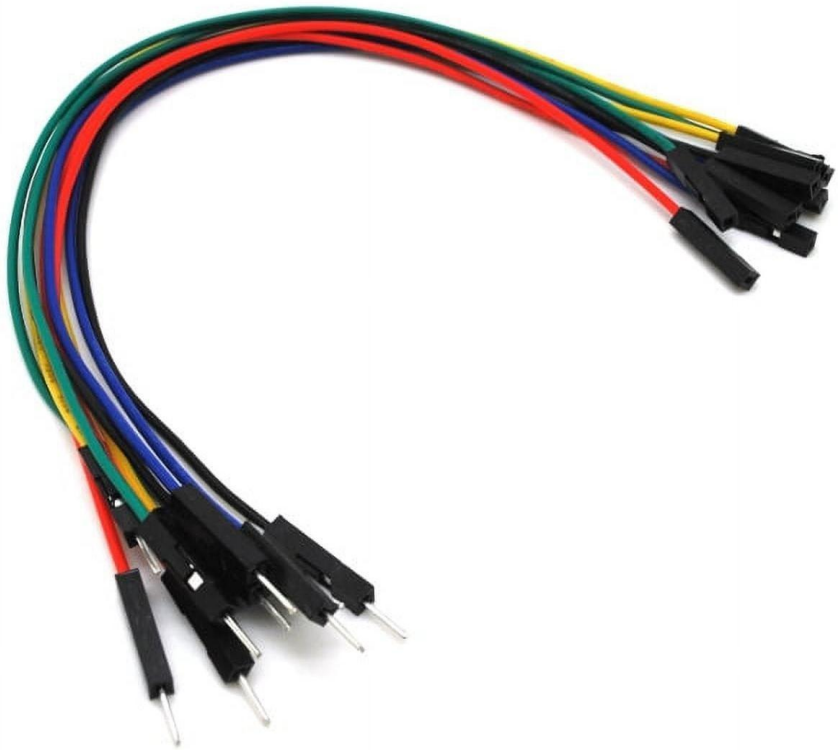
Tool 8: Jumper Wires : Jumper Wires: Small connecting wires used to make connections between components and the breadboard/Arduino.



Types of Jumping Wires:

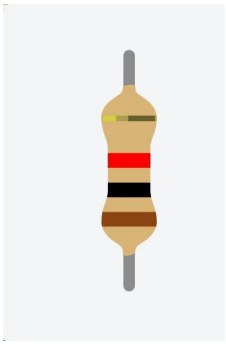
1- **Male to Male Jumper Wires: Used to connect two points on a breadboard from Arduino pins to the breadboard.**

2- Male to Female Jumper Wires: Used to connect Arduino pins (male) to components with female headers

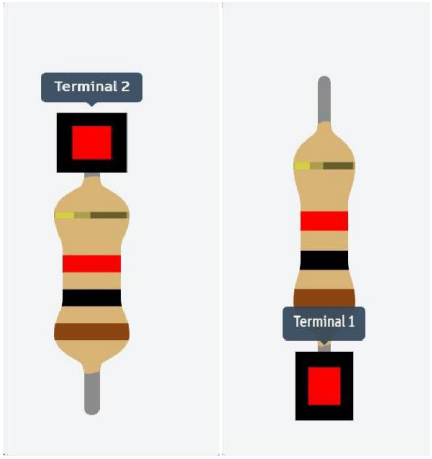


3- Female to Female Jumper Wires: Used to connect two components or modules that both have male pins.

Tool 9: Resistor: A resistor is an electronic component that opposes or limits the flow of electric current.



Terminal 1 & 2: Terminals are the two connection points of a component (like a resistor) where current enters and leaves.

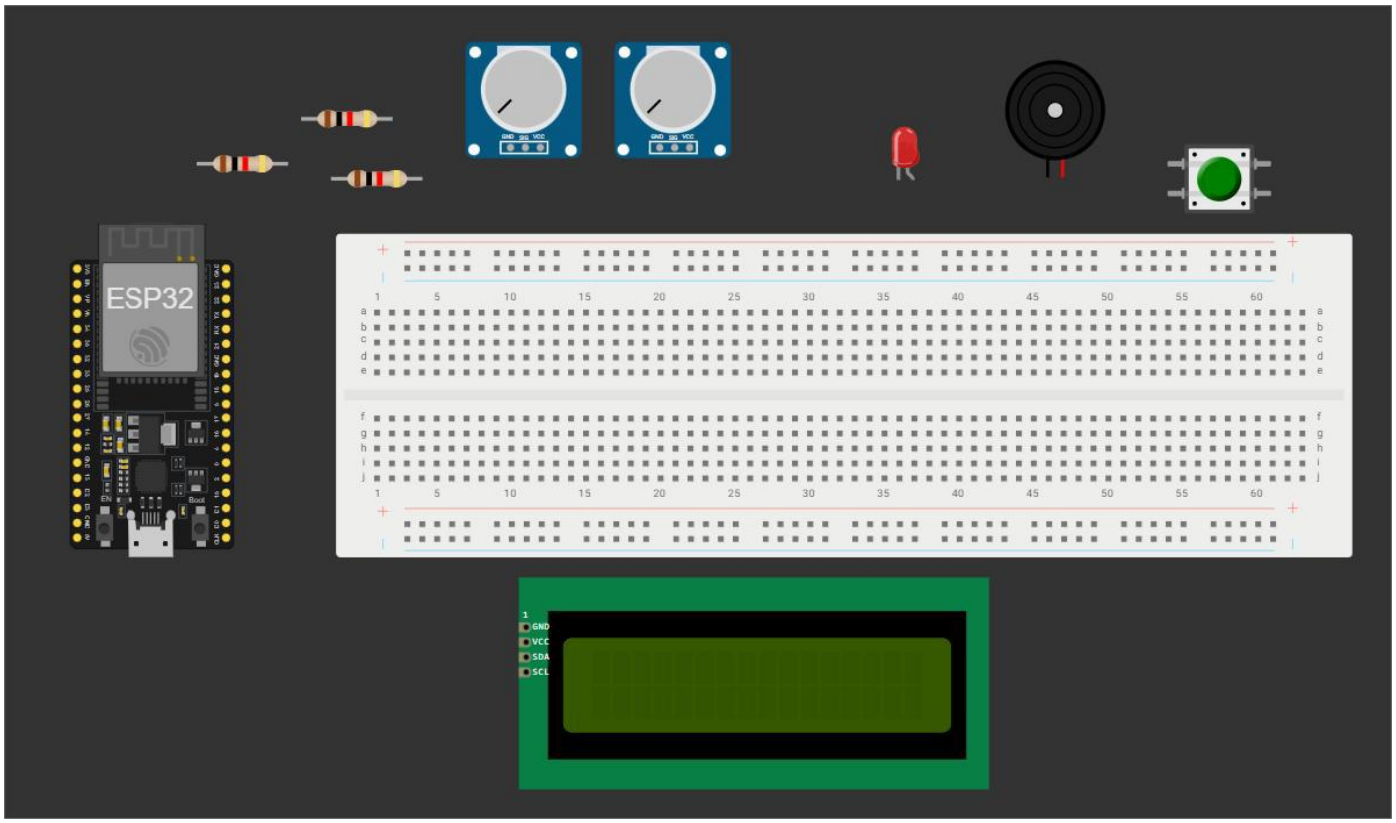


Tool 10 : Extension Boards : An extension board provides multiple power outlets from a single socket to connect several devices at once.

Working (in Wokwi Simulator) :

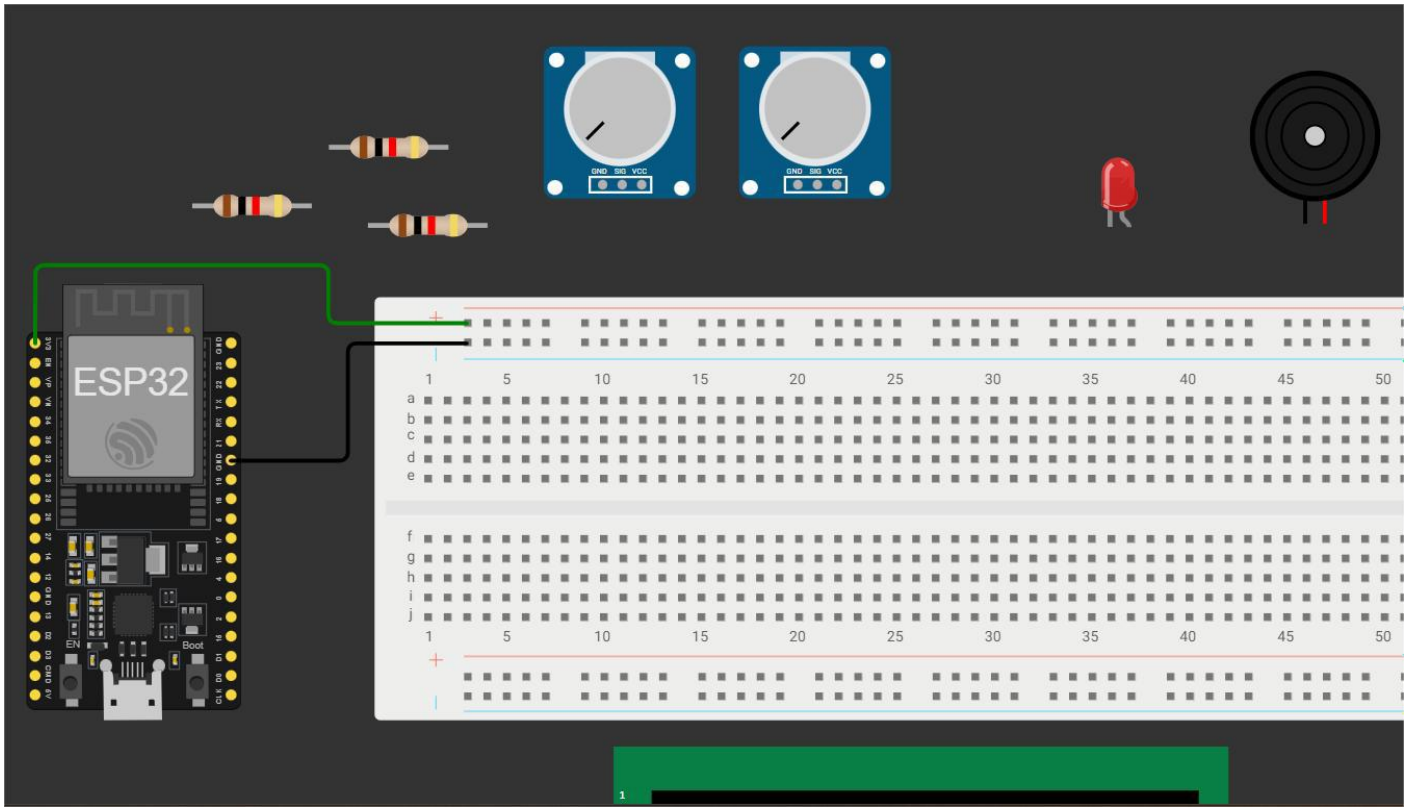
Note : Since Wokwi doesn't provide CT Sensors so, we will use Potentiometer to Demonstrate the project.

Step 1 : Gather all the required components (ESP32, Breadboard, Potentiometers, LCD 16×2(I2C), Buzzer, LED, Resistor, Push But t on)



Step 2- Make the necessary Connections with jumper wire.

Make common 3v3 and GND >> connect 3v3 to +ve rail of horizontal line of breadboard and GND to -ve rail of breadboard .



Also make 5v to positive rail of horizontal line below in Breadboard. Do same thing with GND.

Connections --

1. Potentiometer (Supply Sensor)

SIG → GPIO 34
VCC → 3.3 V rail
GND → GND rail

2. Potentiometer (Load Sensor)

SIG → GPIO 35
VCC → 3.3 V rail
GND → GND rail

3. LED

Anode (+) → 220 Ω resistor → GPIO 25

Cathode (–) → GND rail

4. Buzzer

Positive (+) → GPIO 26
Negative (–) → GND rail

5. Push Button

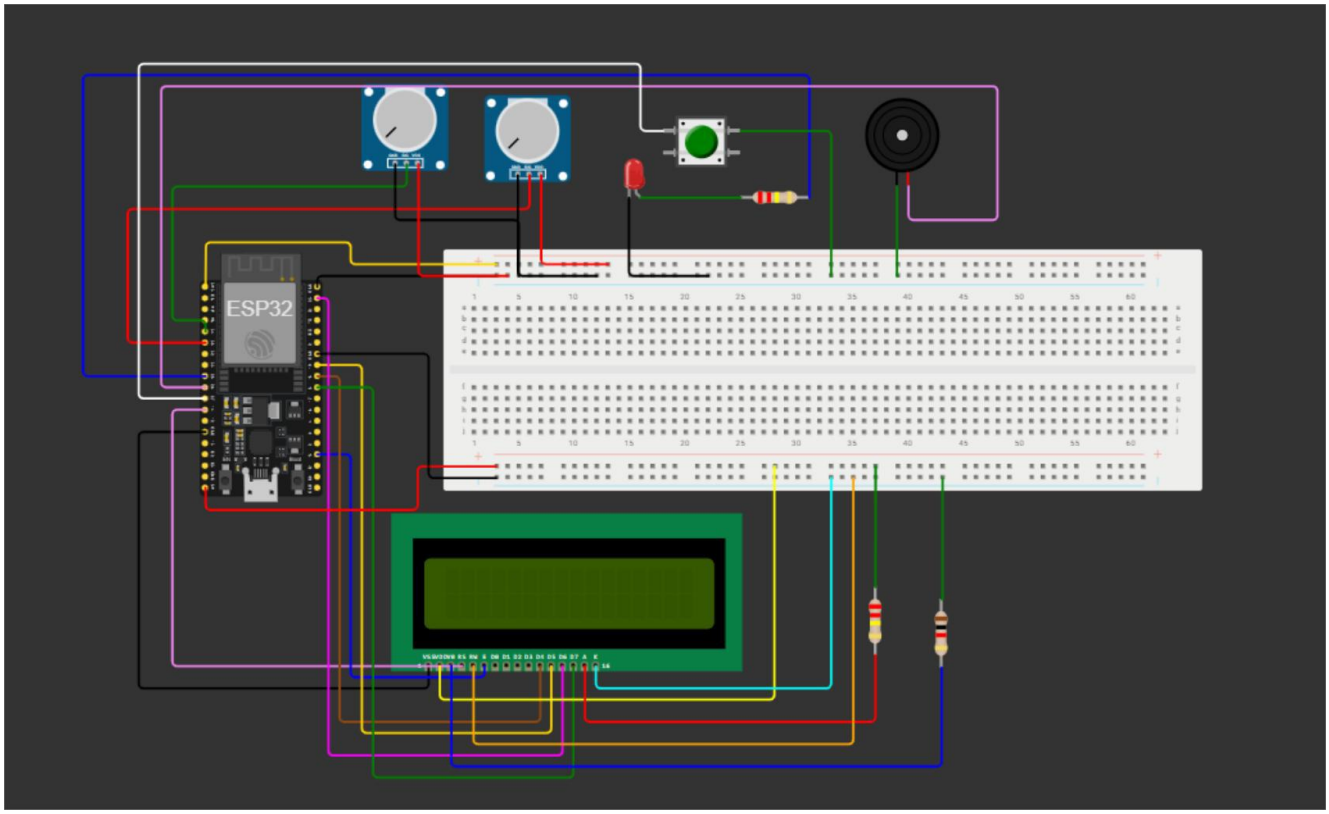
One leg → GPIO 27
Other leg → GND rail

6. 16×2 LCD (Without I²C)

VSS → GND rail
VDD → 5 V rail
V0 → GND via resistor (contrast control)
RS → GPIO 14
RW → GND rail
E → GPIO 15
D4 → GPIO 18
D5 → GPIO 19
D6 → GPIO 23
D7 → GPIO 5
A (Backlight +) → 5 V via 220 Ω resistor
K (Backlight –) → GND rail

7. Power Rails

3.3 V rail → ESP32 3V3 pin (for sensors)
5 V rail → ESP32 VIN pin (for LCD)
GND rail → ESP32 GND (common ground)



Step 3 - Upload the Code -

```ino
#include <LiquidCrystal.h>


const int potSupplyPin = 34;
const int potLoadPin   = 35;
const int ledPin       = 25;
const int buzzerPin    = 26;

// LCD pins: rs, en, d4, d5, d6, d7
LiquidCrystal lcd(14, 15, 18, 19, 23, 5);

const float I_MAX = 30.0;
const float V_NOM = 230.0;
const float COST_PER_KWH = 7.5;

const float I_OFF = 0.1;
const float I_ON  = 0.2;
const float I_MIN_THEFT = 0.5;
const float THEFT_PCT = 0.05;
const float REVERSE_THRESH = 0.1;

const unsigned long LCD_UPDATE_MS = 1000;

// ---------- Runtime state ----------
float iSupply = 0.0, iLoad = 0.0;
float prevLoad = 0.0;
float energy_kWh = 0.0;

unsigned long lastEnergyMillis = 0;
unsigned long lastLcdUpdate = 0;

// Theft flag
bool theftActive = false;

```

```ino

// Theft flag
bool theftActive = false;

// smoothing
const float EMA_ALPHA = 0.12;

// helper: ADC raw to Amps
float rawToAmp(int raw) {
  return (raw / 4095.0f) * I_MAX;
}

void setup() {
  Serial.begin(115200);
  pinMode(ledPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);

  digitalWrite(ledPin, LOW);
  digitalWrite(buzzerPin, LOW);

  lcd.begin(16, 2);
  lcd.print("System Ready");
  delay(1000);
  lcd.clear();

  lastEnergyMillis = millis();
  lastLcdUpdate = millis();
}

void loop() {
  unsigned long now = millis();

  // ---- Read pots ----
  int rawSupply = analogRead(potSupplyPin);
```

```
60  void loop() {
63    // ---- Read pots ----
64    int rawSupply = analogRead(potSupplyPin);
65    int rawLoad   = analogRead(potLoadPin);
66    float measuredSupply = rawToAmp(rawSupply);
67    float measuredLoad   = rawToAmp(rawLoad);
68
69    // smoothing
70    if (iSupply == 0.0f) iSupply = measuredSupply;
71    else iSupply = EMA_ALPHA * measuredSupply + (1 - EMA_ALPHA) * iSupply;
72
73    if (iLoad == 0.0f) iLoad = measuredLoad;
74    else iLoad = EMA_ALPHA * measuredLoad + (1 - EMA_ALPHA) * iLoad;
75
76    // ---- Calculate threshold ----
77    float threshold = max(I_MIN_THEFT, iSupply * THEFT_PCT);
78
79    // ---- Detect status ----
80    String status = "NORMAL";
81    theftActive = false;
82
83    // OFF
84    if (iLoad < I_OFF) {
85      status = "OFF";
86    }
87    // Bypass: supply ≈ 0, load present
88    else if (iSupply <= I_OFF && iLoad >= I_ON) {
89      status = "THEFT: Bypass";
90      theftActive = true;
91    }
92    // Illegal Load: load much greater than supply
93    else if (iLoad > (iSupply + threshold)) {
94      status = "THEFT: Illegal Load";
95      theftActive = true;
```

```
60  void loop() {
91    }
92    // Illegal Load: load much greater than supply
93    else if (iLoad > (iSupply + threshold)) {
94      status = "THEFT: Illegal Load";
95      theftActive = true;
96    }
97    // Sudden Drop
98    else if (prevLoad > 1.0 && iLoad < I_OFF) {
99      status = "THEFT: Sudden Drop";
100     theftActive = true;
101   }
102   // Reverse Flow
103   else if ((iSupply - iLoad) < -REVERSE_THRESH) {
104     status = "THEFT: Reverse Flow";
105     theftActive = true;
106   }
107
108   // ---- Alarm handling ----
109   if (theftActive) {
110     digitalWrite(ledPin, HIGH);
111     digitalWrite(buzzerPin, HIGH);
112   } else {
113     digitalWrite(ledPin, LOW);
114     digitalWrite(buzzerPin, LOW);
115   }
116
117   // ---- Energy calculation (only if NO theft) ----
118   if (!theftActive) {
119     unsigned long dt_ms = now - lastEnergyMillis;
120     if (dt_ms > 0) {
121       float P_load = V_NOM * iLoad;
122       energy_kWh += (P_load / 1000.0f) * (dt_ms / 3600000.0f);
123       lastEnergyMillis = now;
```

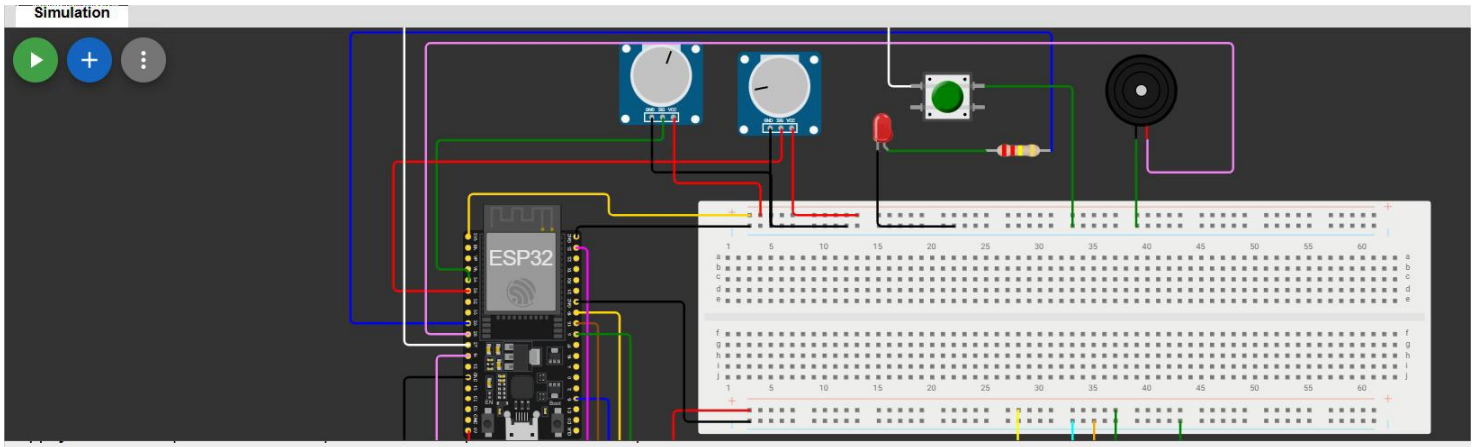
() {

```
60    void loop() {
117     // ---- Energy calculation (only if NO theft) ----
118     if (!theftActive) {
119       unsigned long dt_ms = now - lastEnergyMillis;
120       if (dt_ms > 0) {
121         float P_load = V_NOM * iLoad;
122         energy_kWh += (P_load / 1000.0f) * (dt_ms / 3600000.0f);
123         lastEnergyMillis = now;
124       }
125     } else {
126       // If theft is active, just freeze energy count
127       lastEnergyMillis = now;
128     }
129
130     // ---- Serial Print ----
131     Serial.print("Supply: ");
132     Serial.print(iSupply, 2);
133     Serial.print(" A | Load: ");
134     Serial.print(iLoad, 2);
135     Serial.print(" A | Thr: ");
136     Serial.print(threshold, 2);
137     Serial.print(" A | Status= ");
138     Serial.print(status);
139     Serial.print(" | Buzzer= ");
140     Serial.print(theftActive ? "ON " : "OFF ");
141     Serial.println();
142
143
144     // ---- LCD Update ----
145     if (now - lastLcdUpdate >= LCD_UPDATE_MS) {
146       lastLcdUpdate = now;
147       float cost = energy_kWh * COST_PER_KWH;
148       lcd.clear();
149       lcd.setCursor(0, 0);
```

```
60    void loop() {
144     // ---- LCD Update ----
145     if (now - lastLcdUpdate >= LCD_UPDATE_MS) {
146       lastLcdUpdate = now;
147       float cost = energy_kWh * COST_PER_KWH;
148       lcd.clear();
149       lcd.setCursor(0, 0);
150       lcd.print("Units: ");
151       lcd.print(energy_kWh, 3);
152       lcd.setCursor(0, 1);
153       lcd.print("Cost: Rs ");
154       lcd.print(cost, 2);
155     }
156
157     prevLoad = iLoad;
158     delay(250);
159   }
160
```

Step 4 - Click on “Start Simulation”

When we will turn the potentiometer we can observe the result in Serial Monitor.




```
Supply: 17.15 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.16 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.16 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.17 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.18 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.18 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.19 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.19 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.19 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
Supply: 17.20 A | Load: 3.78 A | Thr: 0.86 A | Status= NORMAL | Buzzer= OFF
```

Done!!!

Working in Real

We will do the same thing. Just few Differences.

Step 1 - Gather all the required components(ESP32, Breadboard, CT Sensor (30 A), LCD 16×2 (I2C), Buzzer, LED, Resistor, Push Button, Jumper wires).

Step 2 - Make the necessary Connections with jumper wire.

Make common 3v3 and GND >> connect 3v3 to +ve rail of horizontal line of breadboard (with F to M Jumper wire) .

GND to -ve rail of breadboard (with F to M Jumper wire).

As we did in Simulator.

Step 3 - We will Connect all the components with ESP32 and Breadboard.

Before that we need to cut the Male Audio Jack, we will get two wires inside , as we are using 2 sensors ,so we need a 4 pin Terminal Block .

Insert both wires of each sensor.

As we can see after that we can easily use jumper wires to connect CT sensor to ESP32.

Solder the I2C with LCD.

Take Two Extension Boards one will be Supply and other will be Load.

Place the phase wire of each extension board in CT sensor properly.

Do the Connection -----

CT Sensors (Current Transformers / Potentiometers in Wokwi)

These act as analog input sensors.

Supply Sensor (CT 1 or Potentiometer 1)

SIG → GPIO 32

VCC → 3.3V

GND → GND

Load Sensor (CT 2 or Potentiometer 2)

SIG → GPIO 35

VCC → 3.3V

GND → GND

2. LED (Indicates Theft / Alarm)

Used to show alert (ON during Theft / Bypass / Attention).

Anode (+) → GPIO 25 (via 220Ω resistor)

Cathode (–) → GND

3. Buzzer

Activates during theft or bypass or attention condition.

Positive (+) → GPIO 26

Negative (–) → GND

4. Push Button (Reset or Manual Control)

Used for manual reset / user interaction (optional).

One leg → GPIO 27

Other leg → GND

5. 16×2 LCD (with I²C module – as in this code)

You are using:

LiquidCrystal_I2C lcd(0x27, 16, 2);

That means I²C LCD, so only two data lines are used.

VCC → 5V

GND → GND

SDA → GPIO 21

SCL → GPIO 22

6. Power Lines

3.3V rail → For sensors (CTs / potentiometers)

5V rail → For LCD and possibly LED (through resistor)

GND rail → Common ground for all components

Step 4 - Now Connect ESP32 with Micro USB Cable.

Install Arduino IDE Software in Laptop.

Install Important Libraries--
LiquidCrystal I2C
Blynk (To send Data)
ESP32

Open IDE >> Click on Tools >> Boards >>
ESP32 >> Select “ESP32 Dev Module ” .
Select Tools again >> Ports >> Select the port.

St e p 5 - Install Blynk and Set up --

Blynk Setup (Quick Guide)

1. Install Blynk IoT app → Log in

2. Create Template

Name: Smart Energy Meter
Hardware: ESP32
Connection: WiFi
Copy Template ID + Auth Token

3. Add Datastreams (Virtual Pins)

V0 → Supply
V1 → Load
V2 → Difference
V3 → Status

4. Dashboard Widgets

Gauge → V0 (Supply)
Gauge → V1 (Load)
Gauge → V2 (Difference)

Label → V3 (Status)

5. Upload Code with:

WiFi name & password
Your Auth Token

6. Run ESP32 & App

Open Blynk → See live Supply, Load, Status readings

Step 6 - Upload the code --

```ino
#define BLYNK_TEMPLATE_ID "TMPL3Df-tjsGW"
#define BLYNK_TEMPLATE_NAME "Smart Energy Meter"
#define BLYNK_AUTH_TOKEN "_pGB1MQWeaZMhGkLcWDLVePirTpmn-dd"

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

// LCD Optional (you can disable if not needed)
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);

// WiFi credentials
char ssid[] = "B";              // Your WiFi Name
char pass[] = "123456789";      // Your WiFi Password

// CT Sensor Pins
const int ctSupplyPin = 32;
const int ctLoadPin   = 35;

// Output Pins
const int ledPin = 25;
const int buzzerPin = 26;

// Constants
float calFactor = 0.05;       // Adjust for your CT
int numSamples = 100;
float theftThreshold = 0.6;  // Theft detection threshold
float bypassLimit = 1.0;     // Bypass condition
float offLimit = 0.1;

// --- Fluctuation Tracking ---
```

Output

program_code.ino

```ino
  float offLimit = 0.1;

  // --- Fluctuation Tracking ---
  unsigned long lastCheckTime = 0;
  int fluctuationCount = 0;
  int fluctuationLimit = 25;   // If >25 fluctuations/min →
  unsigned long checkInterval = 60000; // 1 minute

  // Variables
  float prevSupply = 0, prevLoad = 0;

  void setup() {
    Serial.begin(115200);
    lcd.init();
    lcd.backlight();
    pinMode(ledPin, OUTPUT);
    pinMode(buzzerPin, OUTPUT);

    Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

    lcd.setCursor(0,0);
    lcd.print("Smart Energy Sys");
    delay(1500);
    lcd.clear();
  }

  void loop() {
    Blynk.run();

    float supplySum = 0, loadSum = 0;
    for (int i = 0; i < numSamples; ++i) {
      supplySum += analogRead(ctSupplyPin);
      loadSum += analogRead(ctLoadPin);
```

Output

program_code.ino

```ino
    float supplySum = 0, loadSum = 0;
    for (int i = 0; i < numSamples; ++i) {
      supplySum += analogRead(ctSupplyPin);
      loadSum += analogRead(ctLoadPin);
      delay(2);
    }

    float supply = (supplySum / numSamples) * calFactor;
    float load = (loadSum / numSamples) * calFactor;
    if (supply < 0.05) supply = 0;
    if (load < 0.05) load = 0;
    float diff = fabs(load - supply);

    // --- Fluctuation detection ---
    if (fabs(supply - prevSupply) > 0.5 || fabs(load - prevLoad) > 0.5) {
      fluctuationCount++;
    }
    prevSupply = supply;
    prevLoad = load;

    String status = "NORMAL";
    bool alarm = false;

    // --- Determine Status ---
    if (load <= offLimit) {
      status = "OFF";
    }
    else if (supply == 0 && load > bypassLimit) {
      status = "BYPASS";
      alarm = true;
    }
    else if (diff > theftThreshold) {
```

Output

program_code.ino

```ino
    }
    else if (diff > theftThreshold) {
      status = "THEFT";
      alarm = true;
    }

    // --- Check Fluctuation every 1 minute ---
    if (millis() - lastCheckTime >= checkInterval) {
      if (fluctuationCount > fluctuationLimit) {
        status = "ATTENTION";
        alarm = true;
        fluctuationCount = 0;
      } else {
        fluctuationCount = 0;
      }
      lastCheckTime = millis();
    }

    // --- Outputs ---
    digitalWrite(ledPin, alarm ? HIGH : LOW);
    digitalWrite(buzzerPin, alarm ? HIGH : LOW);

    // --- LCD Display ---
    lcd.setCursor(0,0);
    lcd.print("S:");
    lcd.print(supply,2);
    lcd.print(" L:");
    lcd.print(load,2);
    lcd.print("  ");

    lcd.setCursor(0,1);
    lcd.print("St:");
    lcd.print(status);
```

Output

program_code.ino

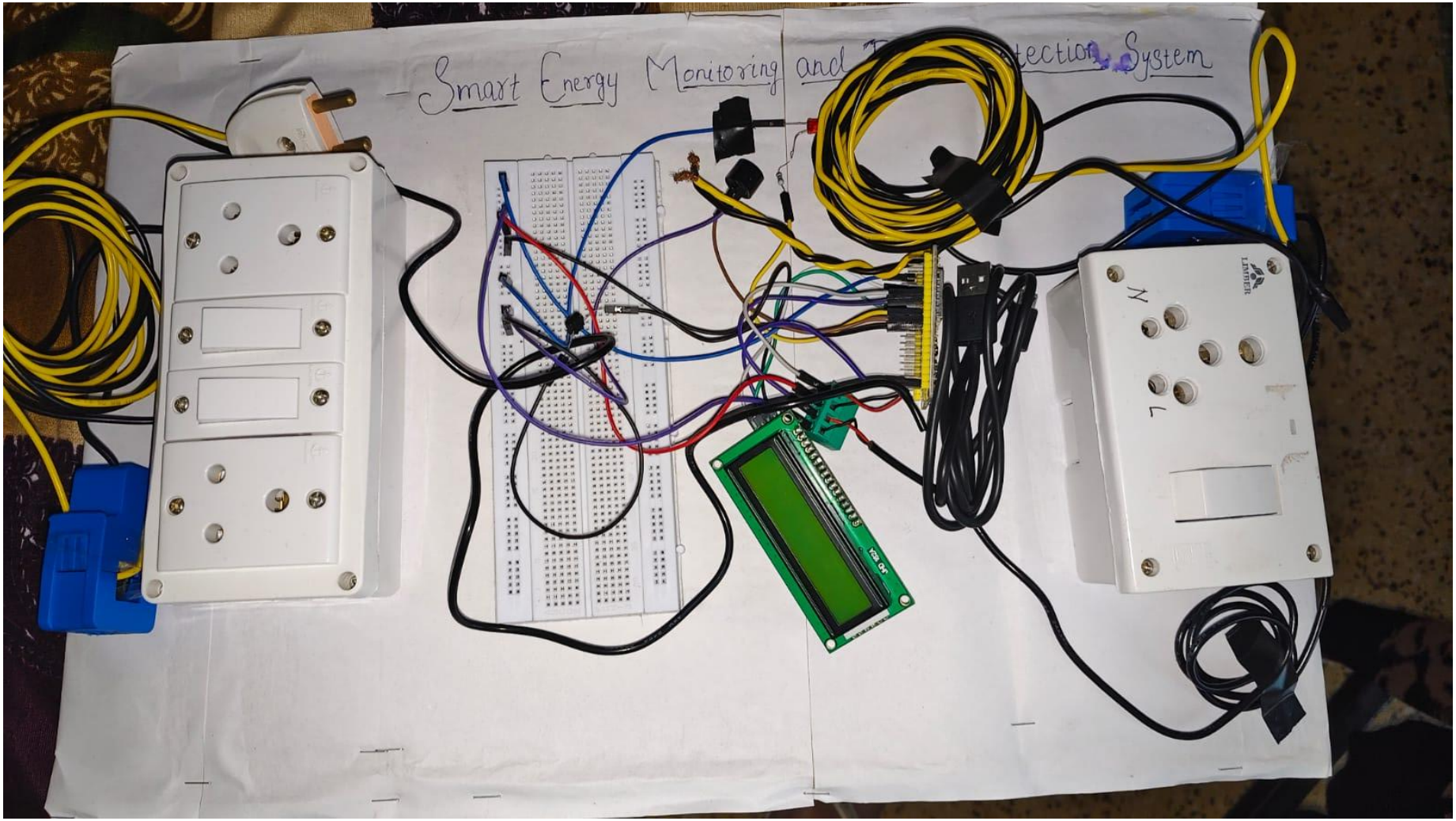
```
    lastCheckTime = millis();
  }

  // --- Outputs ---
  digitalWrite(ledPin, alarm ? HIGH : LOW);
  digitalWrite(buzzerPin, alarm ? HIGH : LOW);

  // --- LCD Display ---
  lcd.setCursor(0,0);
  lcd.print("S:");
  lcd.print(supply,2);
  lcd.print(" L:");
  lcd.print(load,2);
  lcd.print("  ");

  lcd.setCursor(0,1);
  lcd.print("St:");
  lcd.print(status);
  lcd.print("     ");

  // --- Send to Blynk ---
  Blynk.virtualWrite(V0, supply);
  Blynk.virtualWrite(V1, load);
  Blynk.virtualWrite(V2, diff);
  Blynk.virtualWrite(V3, status);

  Serial.print("Supply: "); Serial.print(supply,2);
  Serial.print(" | Load: "); Serial.print(load,2);
  Serial.print(" | Diff: "); Serial.print(diff,2);
  Serial.print(" | Status: "); Serial.println(status);

  delay(1000);
}
```

Output

Readings will be visible in Blynk.

Done !!!

Circuit --


-Smart Energy Monitoring and
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