IoT based Smart Energy Meter

SMART ENERGY METER

DONE BY RUMESH

Agenda

- Problem Statement
- Solution & Implementation
- Platforms & Interfaces
- Challenges

Problem Statement

- Current Approach : Need to visit to meter point take the reading
- Domestic Purpose - Tariff

Monthly Consumption (kWh)	Unit Charge (Rs./kWh)	Fixed Charge (Rs./month)
0-60	7.85	N/A
61-90	10.00	90.00
91-120	27.75	480.00
121-180	32.00	480.00
>180	45.00	540.00

Table 1: Electricity Tariff

Electricity bill for 180 units

➔ 90 + 90 = [(7.85*60) + (10*30) + 90] + [(7.85*60) + (10*30) + 90] = 861 + 861 = 1722.00

➔ 85 + 95 = [(7.85*60) + (10*25) + 90] + [(7.85*60) + (10*30) + (27.75*5) + 480] = 811 + 1389.75 = 2200.75

478.75 LKR

If meter reading taken different intervals that will effects the charges as well.

Proposed & Implemented Approach : IoT based Smart Energy Meter

Table Source: https://ceb.lk/commercial-tariff/en

IoT based Smart Energy Monitor - Specification

Data Measurement
- Current Sensing (Irms)
- Voltage Sensing (Vrms)

Calculations
- Power/Energy Monitoring
- Tariff Calculations
- Alerts (High Power Consumption/Device status)

Data Visualization
- Cloud Integration
- Web Dashboard
- Mobile App

Monthly E-Bill
- Storing Data in Database (MySQL)
- Database to pdf (fpdf)
- E-mail E-Bill pdf as attachment (phpmailer)
- Telegram Notifications(BOT API)

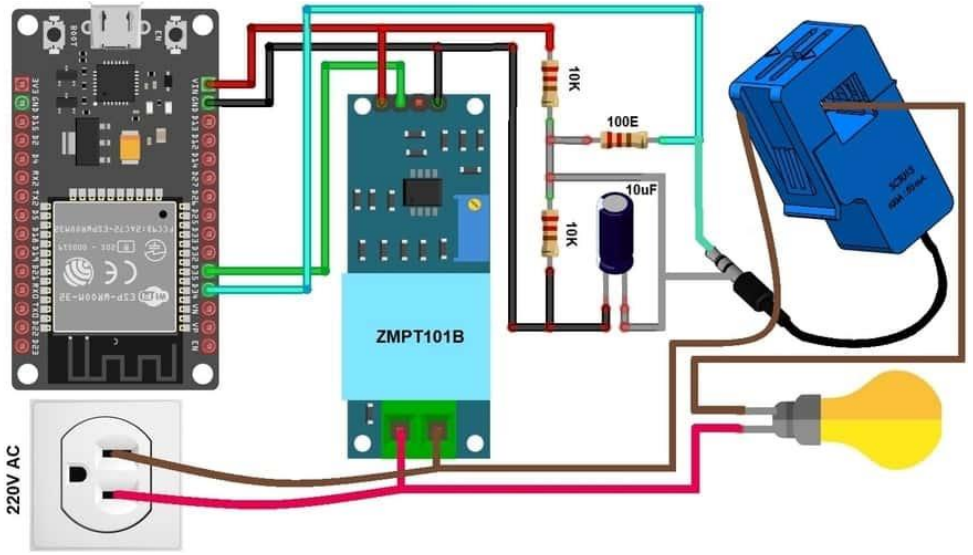
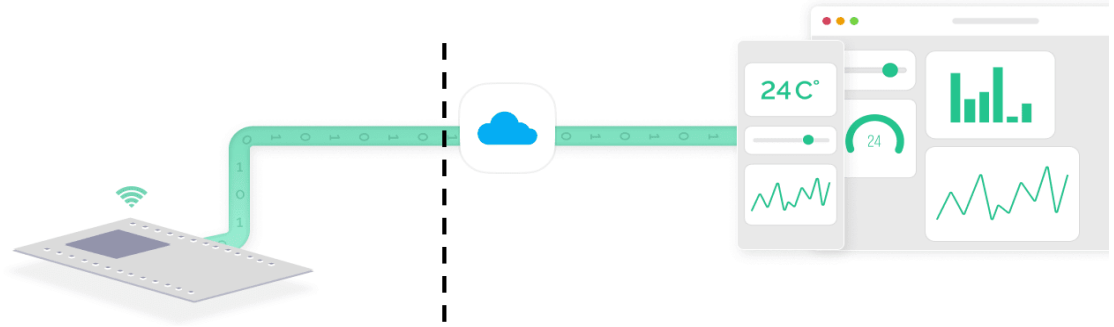


Figure: Circuit Diagram

Image Source: https://how2electronics.com/iot-based-electricity-energy-meter-using-esp32-blynk

Platforms & Interfaces



Hardware

- ESP 32 (ESP32-D0WDQ6 Rev 1)
- Current Sensor (SCT-013-030)
- Voltage Sensor (ZMPT101B)
- Resistors & Capacitors
- 16x2 LCD Display & POT
- Battery Charger Module (TP4056)
- MT3608 (DC-DC Boost Converter)
- Battery

Software

- Blynk 2.0
  - Blynk.Cloud
  - Blynk.Air
  - Blynk.Console
  - Blynk.App
- Arduino IDE & VS Code
- PHP/ Apache/ MySQL
- fpdf, phpmailer libraries
- Telegram BOT API
- Easy EDA

ESP32

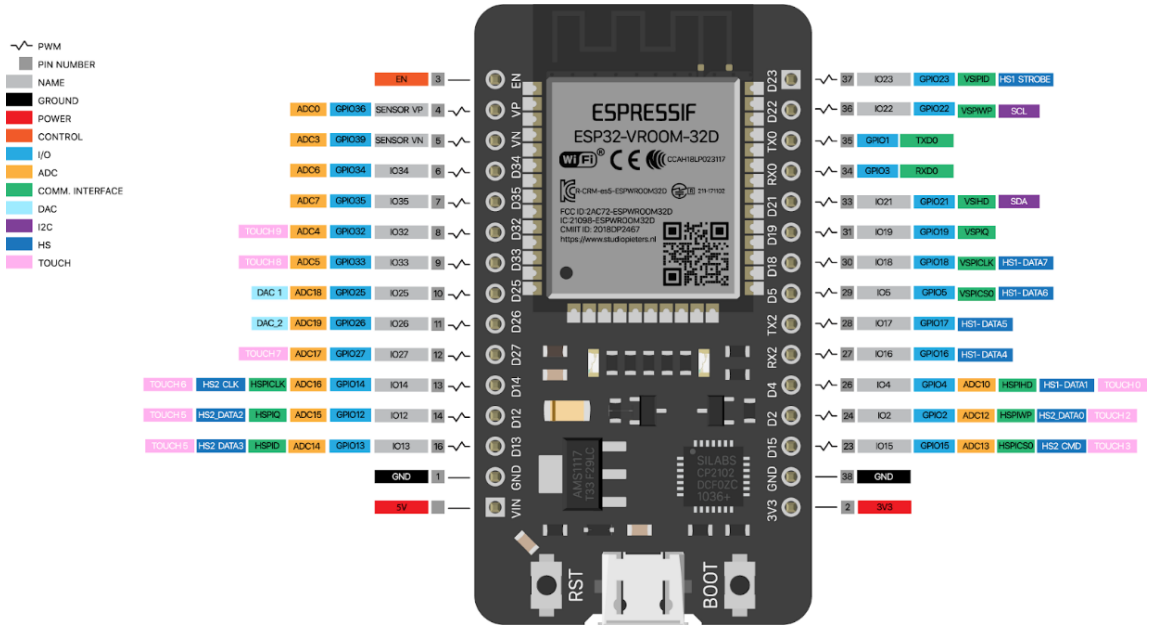


Figure: ESP32 Pin Layout

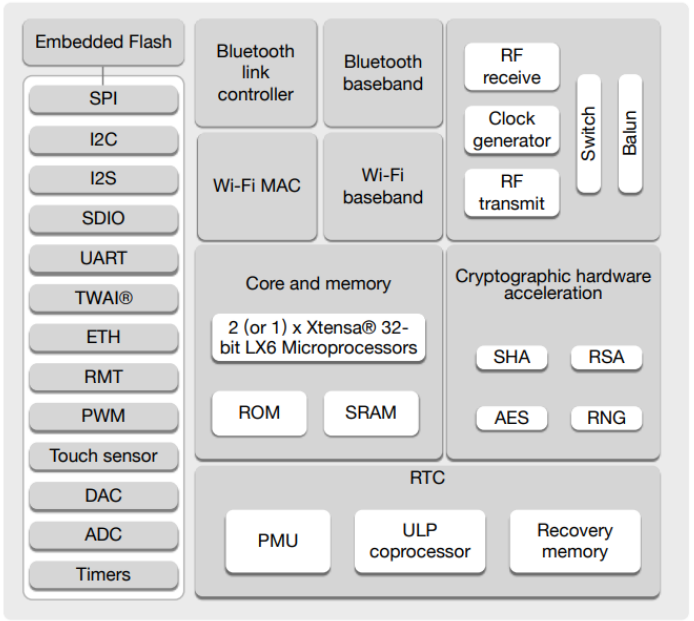
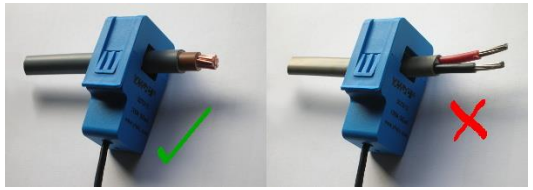


Figure: Functional Block Diagram

- Optimal operating voltage: 3.3 V, 500mA
- 34 GPIO pins
- 12-bit SAR ADC up to 18 channels
- Power modes:
  - Active mode: Chip radio is powered on. The chip can receive, transmit, or listen (Max 240 mA)
  - Deep sleep mode: Only the RTC memory and RTC peripherals are powered on. ULP coprocessor is functional. (Max 150 µA)

Source: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf

Current Sensor/Current Transformer(CT)

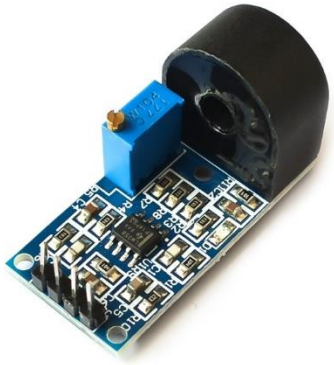


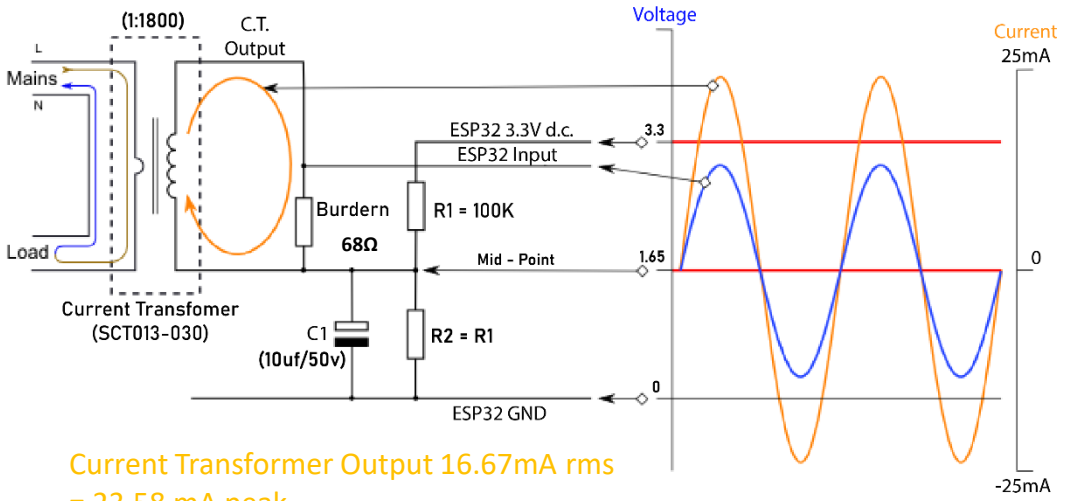
- Working Principle: Alternating current flowing in the primary produces a magnetic field in the core, which induces a current in the secondary winding circuit.
- Used model: SCT013-030 (Turns ratio 1:1800 = 30A:17mA)
- A "current output" CT needs to be used with a burden resistor. The burden resistor completes the CT secondary circuit.
- Burden Resistor (ohms) = (REF x CT Turns) / (2√2 x max primary current)

  = (3.3 x 1800)/(2√2 x 30)

  = 70 Ω

  = Standard resistor 68 Ω





Current Transformer Output 16.67mA rms
= 23.58 mA peak
= 46.08 mA peak-to-peak
Generates a voltage of:
= 46.08mA x 68 ohms
= 3.133V peak to peak to ESP32

Source: https://learn.openenergymonitor.org/electricity-monitoring/ctac/ct-and-ac-power-adaptor-installation-and-calibration-theory

Current Sensor

Accuracy

- Misalignment of the cores, which may introduce an air gap. Even a very small gap might cause the output to drop by 10% .(eg. introducing a thin piece of paper 0.1 mm thick into one side of the core caused the output to drop by 7% at 100 A)

Calibration

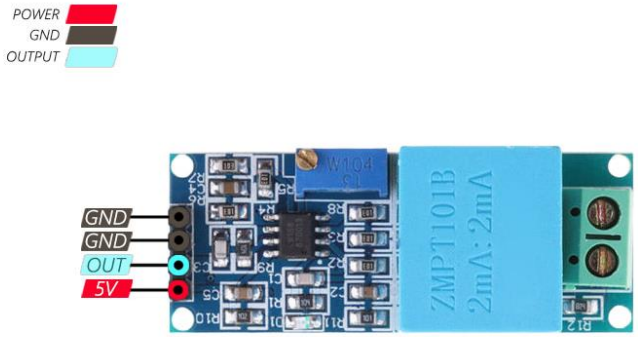
- Current consumed for core excitation, losses, phase error (Ip & Is angle not zero)
- Measurement **Implications of ADC Resolution at Low Current Values**
  - **Q**: Why does CT read Amps when there is no current flowing?
  - **A**: It's because ADC in the ESP32 chip is not perfect. ESP32 ADC input comes from the current sensor. It may also come from digital noise generated by the ESP32 itself, or outside noise picked up by the PCB or the wiring.

*Ip – Primary Current , Is – Secondary Current

Voltage Sensor

- Voltage up to 250 volts can be measured
- Lightweight with an on-board micro-precision voltage transformer
- Operating temperature: 40ºC ~ + 70ºC
- Supply voltage 5 volts to 30 volts, **Offset Max Vcc/2 ➔2.5V**

***Latency in Vrms & Irms Calculation**



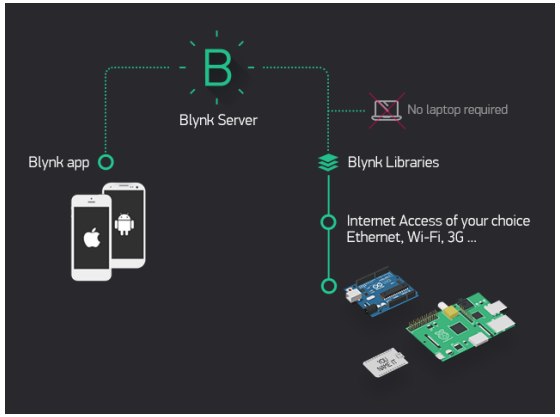
LCD Display

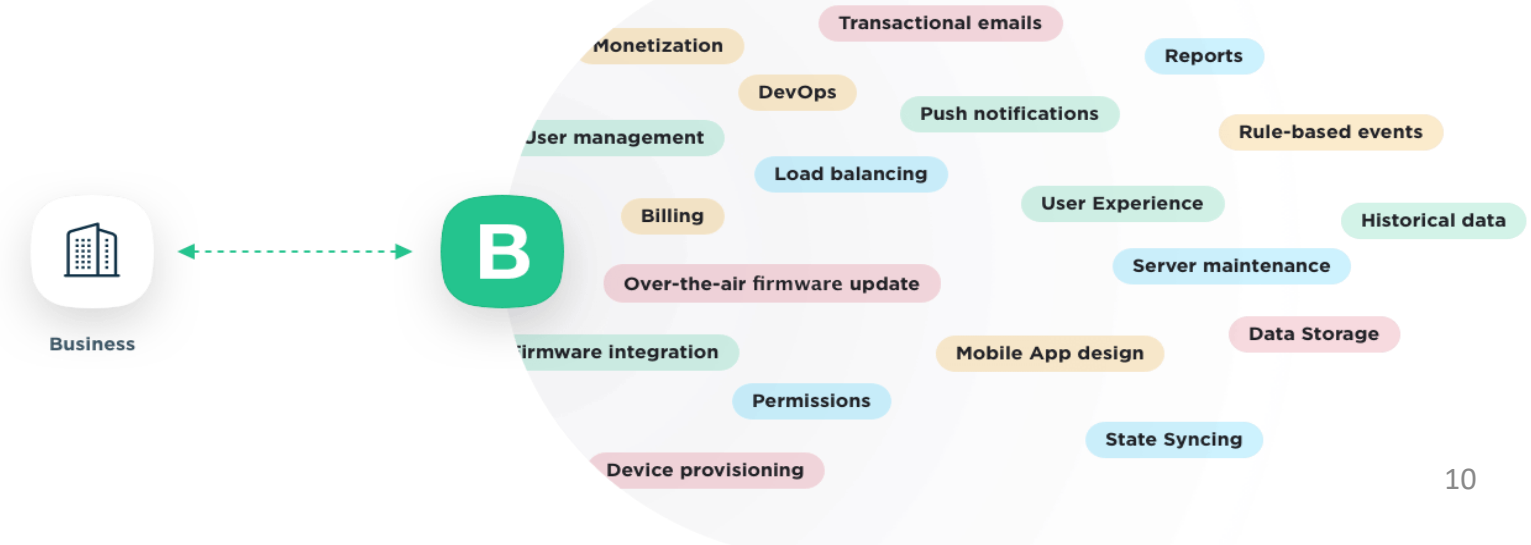
- LCD Pin ➔ ESP32 Pins
- PIN01-VSS ➔ GND
- PIN02-VDD ➔ 5V
- PIN03 V0 ➔ 50K Pot (Middle pin)
- PIN04 RS ➔ GPIO13
- PIN05 RW ➔ GND
- PIN06 E ➔ GPIO12
- PIN07-10 D0-D3 ➔ NOT USED
- PIN11 D4 ➔ GPIO14
- PIN12 D5 ➔ GPIO27
- PIN13 D6 ➔ GPIO26
- PIN14 D7 ➔ GPIO25
- PIN15 A ➔ 5V
- PIN16 K ➔ GND

Blynk 2.0

- **App**:
  - Standalone Mobile Apps, Branded Web IoT portal
- **Device Management**
  - 10,000 devices, Update supported OTA
- **Security**
  - Encrypted communication between Cloud, apps, and devices, 24/7 incident monitoring
- **Connectivity Management**
  - Open-source hardware libraries to connect any device to Blynk.Cloud - WiFi, Ethernet, Cellular (2G, 3G, LTE) connection
- **Blynk Community Support**

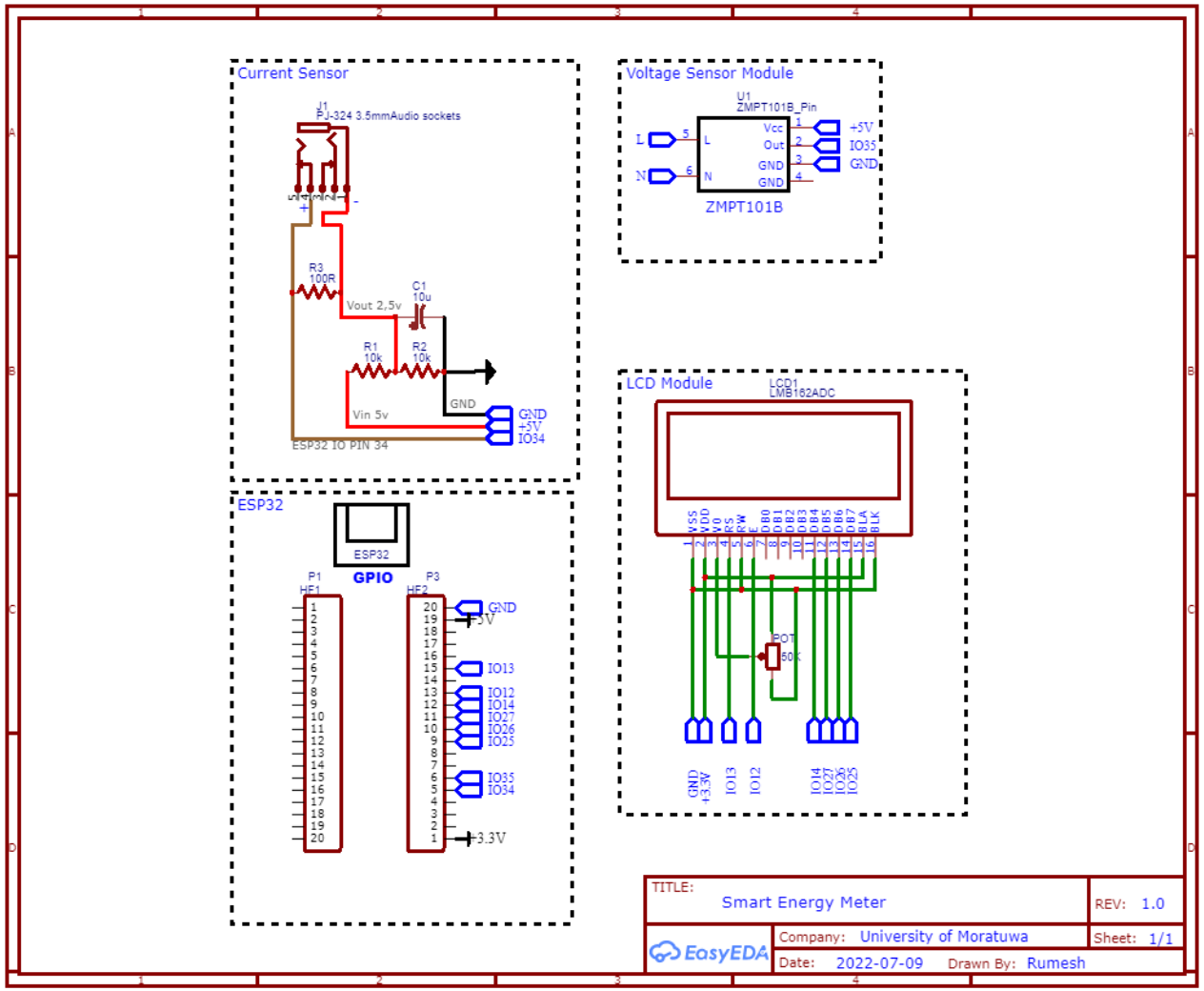
Blynk Cloud Servers have 99.99% uptime since May 2015

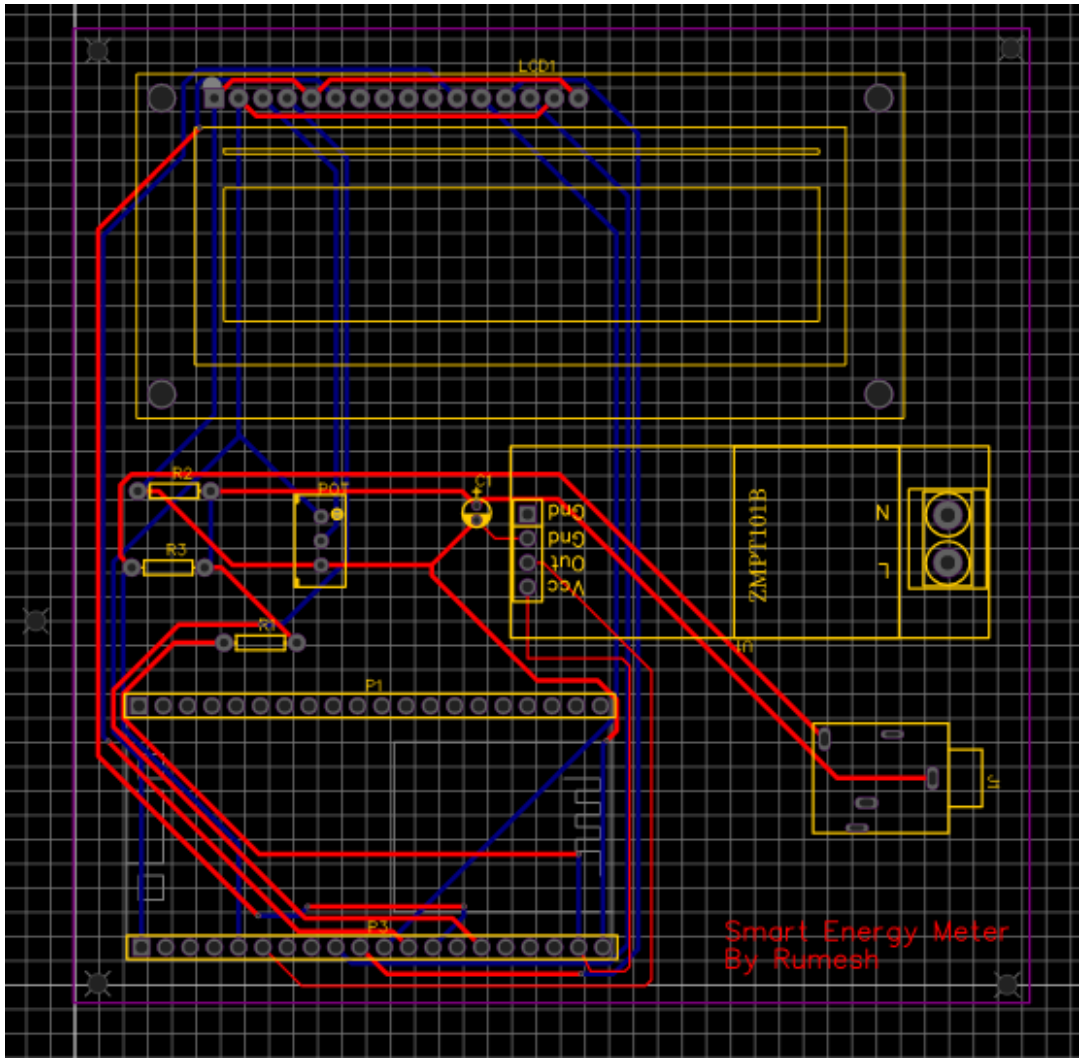




https://examples.blynk.cc/
https://docs.blynk.io/en/

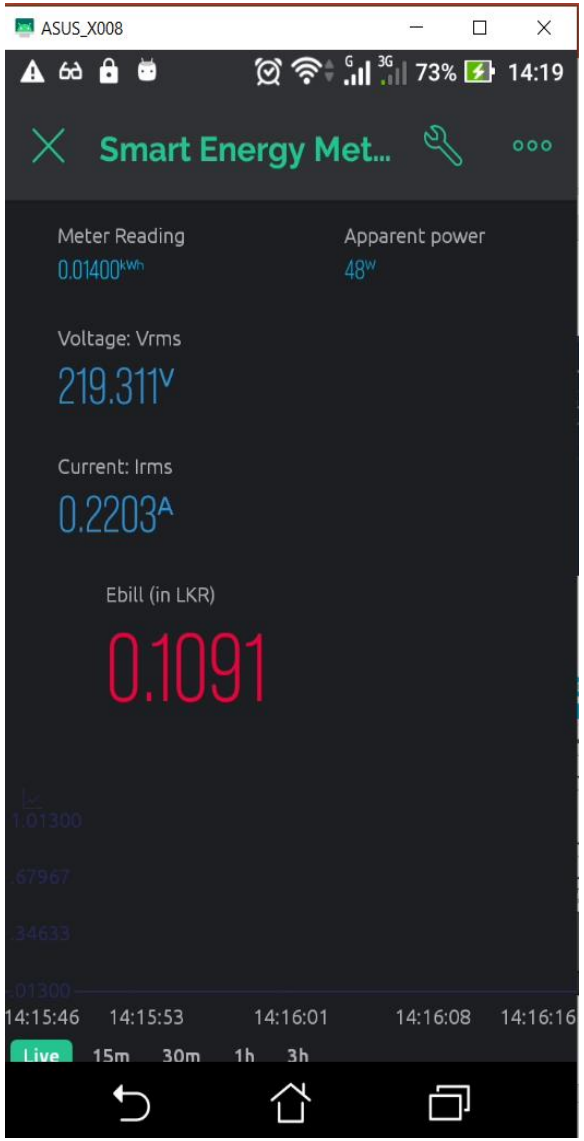
Schematic Design & PCB Design

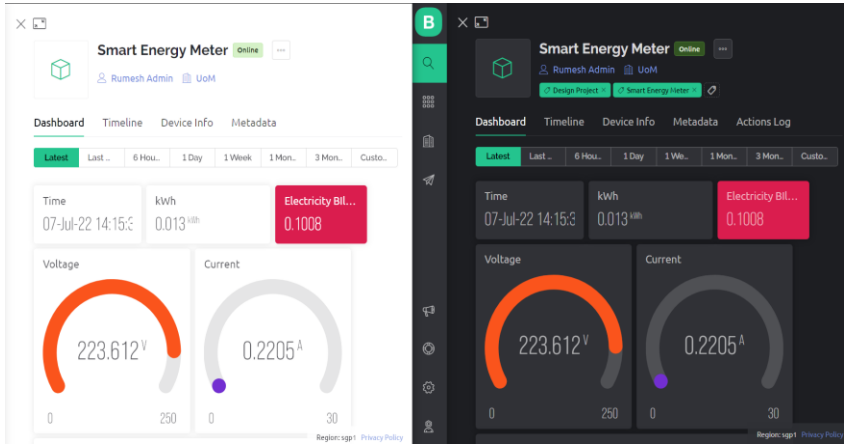


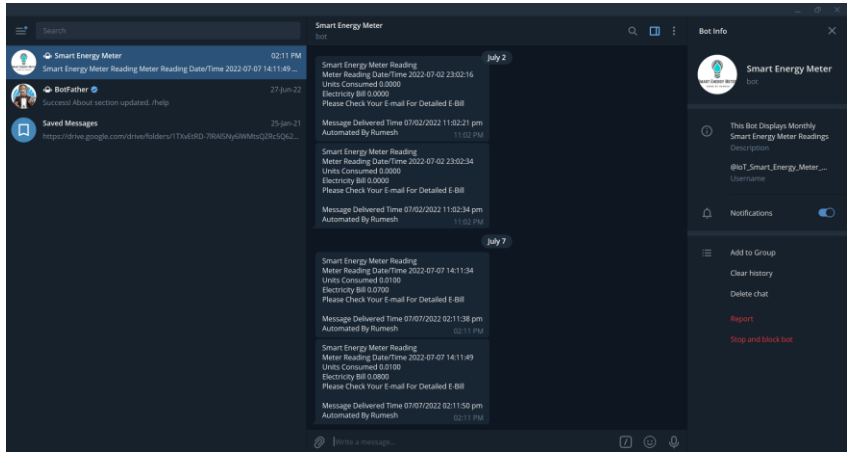


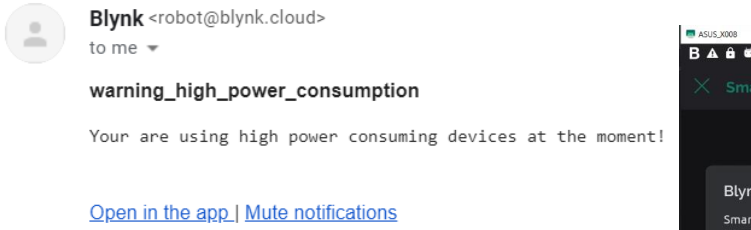
2 Layer PCB with 9 vias, 10 x 10 cm Area

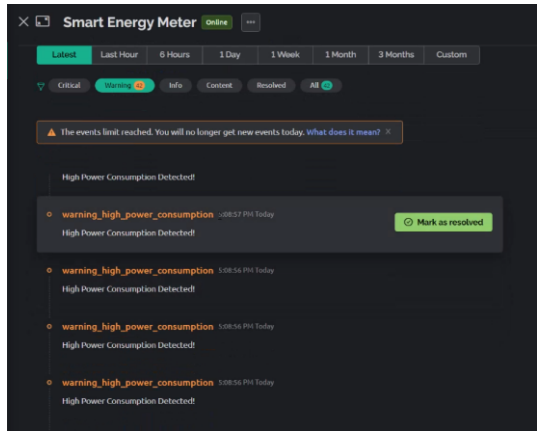
Features of Smart Energy Meter

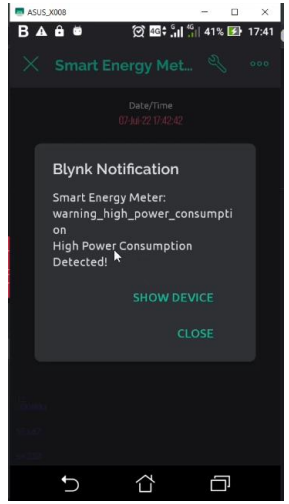


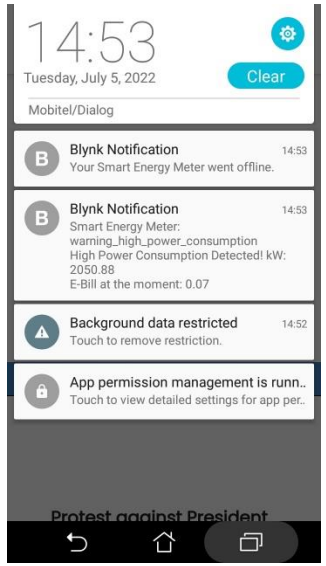










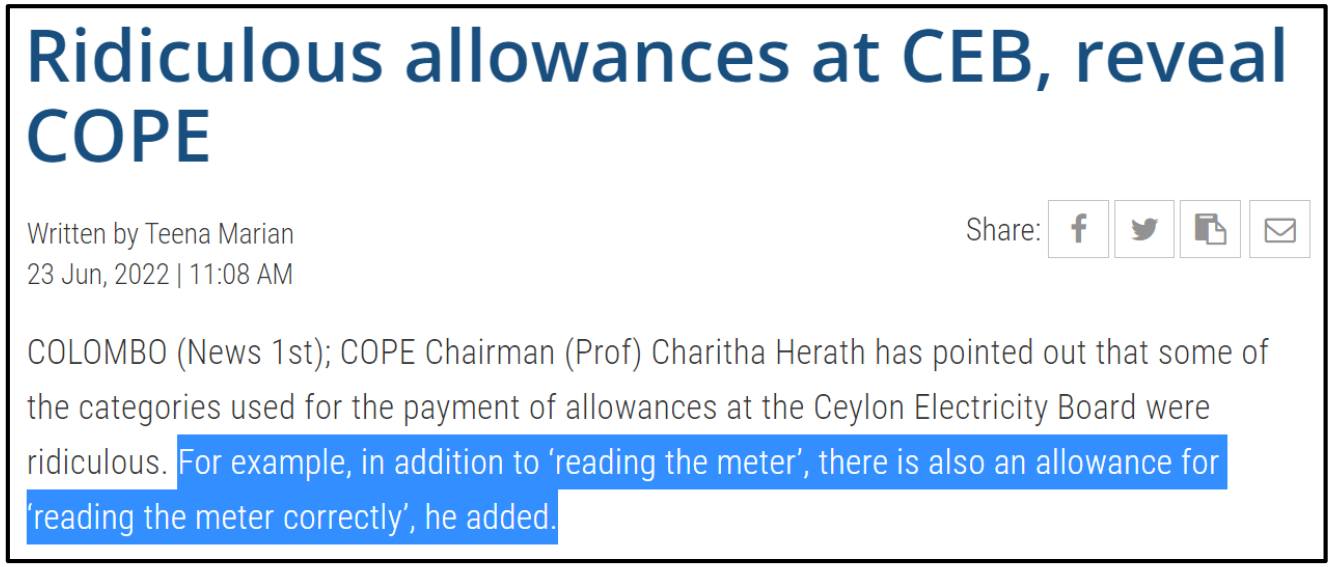


- ✓ Web Dashboard & Mobile App
  - ✓ Alert Email
  - ✓ App/Web notification
- ✓ AMR + Bill Generation + E-mail
- ✓ E-Bill as Telegram message
- ✓ Firmware Update via OTA

Errors & Pros & Improvements

Errors

- Brownout Error
- HTTP port conflict
- Firewall
- PHP/Apache/MySQL Configurations



Ridiculous allowances at CEB, reveal COPE

Written by Teena Marian
23 Jun, 2022 | 11:08 AM

Share:

COLOMBO (News 1st); COPE Chairman (Prof) Charitha Herath has pointed out that some of the categories used for the payment of allowances at the Ceylon Electricity Board were ridiculous. For example, in addition to 'reading the meter', there is also an allowance for 'reading the meter correctly', he added.

Pros

- Meter Reader Job no needed
- No paper based Electricity bill
- Can integrate API to provide more features. (eg. QR code based usage check/ Bill Pay)
- Plug and Play

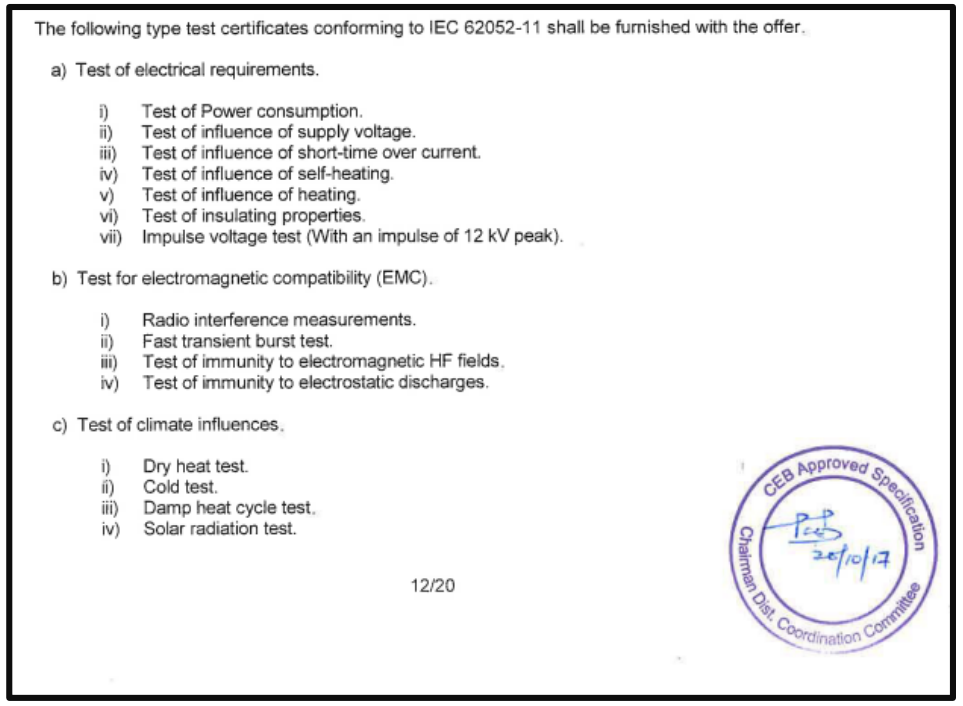
Improvements

- Energy Meter for 3 phase Supply, Integrating Solar panel with Smart Energy Meter
- Inclusion of Time of Use (TOU) tariff system
- Detecting and notifying tamper alerts
- SD Card Module ➔ Data backup
- Stable internet connection ➔ 4G Sim module (eg. Malduino)

News Source: https://www.newsfirst.lk/2022/06/23/ridiculous-allowances-at-ceb-reveal-cope/

Challenges

- **Calibration of Smart Energy Meter**
- Integrating voltage sensors – Need to break the circuit
- Communication latency & Data update latency
- Blynk doesn't run on Windows Phones, Blackberries and other old platforms.
- Tests to be performed – Vibration test, Immunity to temperature rise, Immunity to EMI, Influence to short time overcurrent



The following type test certificates conforming to IEC 62052-11 shall be furnished with the offer.

a) Test of electrical requirements.

i) Test of Power consumption.
ii) Test of influence of supply voltage.
iii) Test of influence of short-time over current.
iv) Test of influence of self-heating.
v) Test of influence of heating.
vi) Test of insulating properties.
vii) Impulse voltage test (With an impulse of 12 kV peak).

b) Test for electromagnetic compatibility (EMC).

i) Radio interference measurements.
ii) Fast transient burst test.
iii) Test of immunity to electromagnetic HF fields.
iv) Test of immunity to electrostatic discharges.

c) Test of climate influences.

i) Dry heat test.
ii) Cold test.
iii) Damp heat cycle test.
iv) Solar radiation test.

12/20

CEB Approved Specification
20/10/17
Chairman Dist. Coordination Committee

Source: CEB Specification Programmable Direct Connected Static Energy Meter

References

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- https://techiesms.com/iot-projects/nodemcu-projects