CAI/AEC 2025
Programming

Solar Energy Control System

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Meet the Team

Lauren Daigle
Project Manager

Matthew Hutchinson
Data Acquisition
and Debugging

Liam MacLennan
Networking Lead

Colby White
Mechatronics Lead

Background

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- In the face of climate change, **deep decarbonization** is necessary to satisfy **increasing energy demands**.
- Solar and wind are **low-cost solutions,** however**, wind is unpredictable**
- Solar is more reliable, and work can be done to **optimize the energy output**

Problem Statement

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Participants must design a **client-server application** to **monitor and control** the operations of a **solar power plant** equipped with motorized photovoltaic panels and safety mechanisms. The system must include:

1. **Data monitoring and storing**
2. **Control mechanisms**
3. **Wireless communication**

Requirements

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1. Data Monitoring and Storing

a. **Collect data** from sensors to **calculate the power generated**.

b. **User interface** - display the collected data.

2. Control Mechanisms

a. **Adjust the angle** of solar panels **manually** and **automatically**.

b. **Emergency shutdown** to remotely cut off the current flow to the grid.

3. Wireless Communication

a. **Store** and **display** data sent from **client** (ESP32) to **server**.

b. Errors – server must manage and reconnect.

Constraints

1. Hardware

- Only the assigned hardware can be used (ESP32 for sensor and Raspberry Pi for server) and cannot be modified.

2. System Network

- The system must be wireless and communicate through Wi-Fi. The network must be a hotspot hosted by a computer.

Specific Objectives

1 | **Read and Display Data**

-Voltage, Current, Angle

2 | **Interface Hardware**

-Manually adjust panel angle with an interface

-Fault checking (button)

-Fault LED

3 | **Automation**

-Shut off servo upon a fault and re-enable once resolved.

-Automatically track the sun angle

Specific Objectives cntd.

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4 | **Wireless Data Acquisition**

-Wirelessly communicate with Pi Server

-Notify on disconnect, attempt to resolve and reconnect

5 | **Web Based Interface**

-Website interface

-Graph real-time data (no refreshing)

-Interface scales to mobile devices and desktop

Design Process

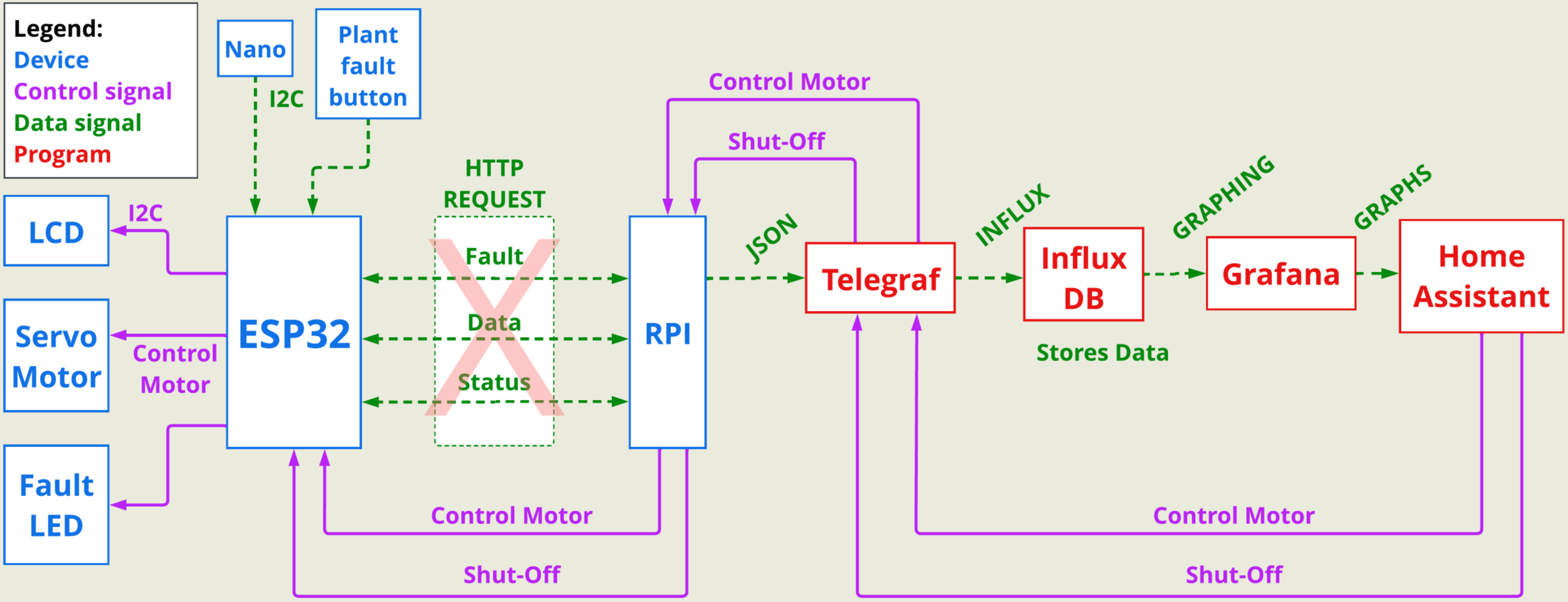
1 — Problem Definition
- Defined requirements based on prior knowledge and skills

2 — Preliminary Design
- Divided tasks based on strengths for concurrent engineering
- Scheduled check-ins to manage time and maximize productivity

3 — Iterative Design
- Prototyped and tested design
- Iterated on server communication methods

4 — Final Design
- Improved functional components

Solution



Legend:
Device
Control signal
Data signal
Program
Nano
I2C
Plant fault button
LCD
I2C
ESP32
Servo Motor
Control Motor
Fault LED
HTTP REQUEST
Fault
Data
Status
RPI
Control Motor
Shut-Off
JSON
Telegraf
INFLUX
Influx DB
Stores Data
GRAPHING
Grafana
GRAPHS
Home Assistant
Control Motor
Shut-Off
Control Motor
Shut-Off

S. Objective 1

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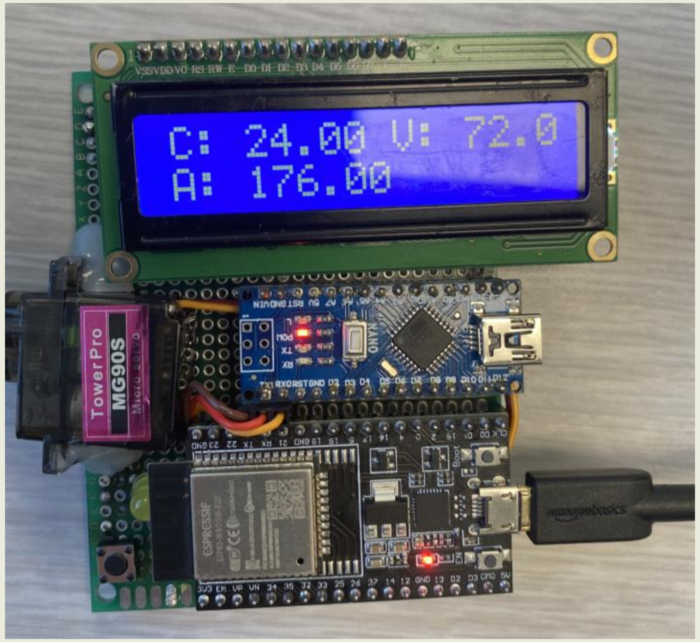
1 | Read and Display Data

-Voltage, Current, Angle



Utilized the LiquidCrystal I2C library by Frank de Barbander [1]
And the Wire library by Expressif Systems [4]

-Previous experience

-Confidence in a successful outcome

```
//read I2C data from nano for voltage, current, and angle
void readI2CData() {
  Wire.requestFrom(0x55, 32); // Request 32 bytes from I2C address 0x55
  jsonData = "";
  while (Wire.available()) {
    char c = Wire.read();
    if (c == 0xFF) break; // End of data
    jsonData += c;
  }
```

S. Objective 2

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2 | **Interface Hardware**

-Manually adjust panel angle with an interface

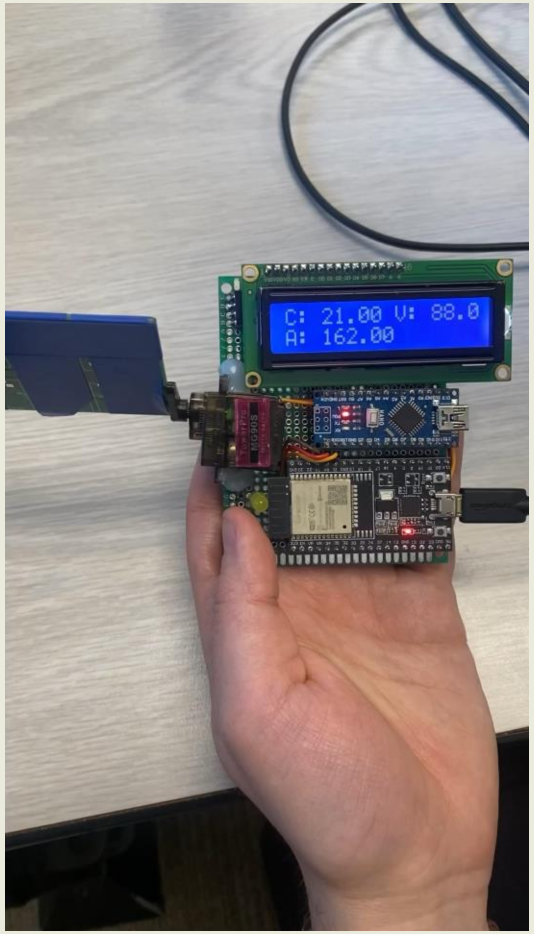
-Fault checking (button)

-Fault LED

```
int importedUserAngle = 0; // from the website
```

```
void manualControl(int userAngle) {
  //This function will take in the user's input and move the servo to that angle
  if (userAngle < minAngle) {
    myservo.write(minAngle);
  } else if (userAngle > maxAngle) {
    myservo.write(maxAngle);
  } else {
  myservo.write(userAngle);
  }
}
```

Used ESP32Servo library from Kevin Harrington and John K. Bennett [2]



S. Objective 3

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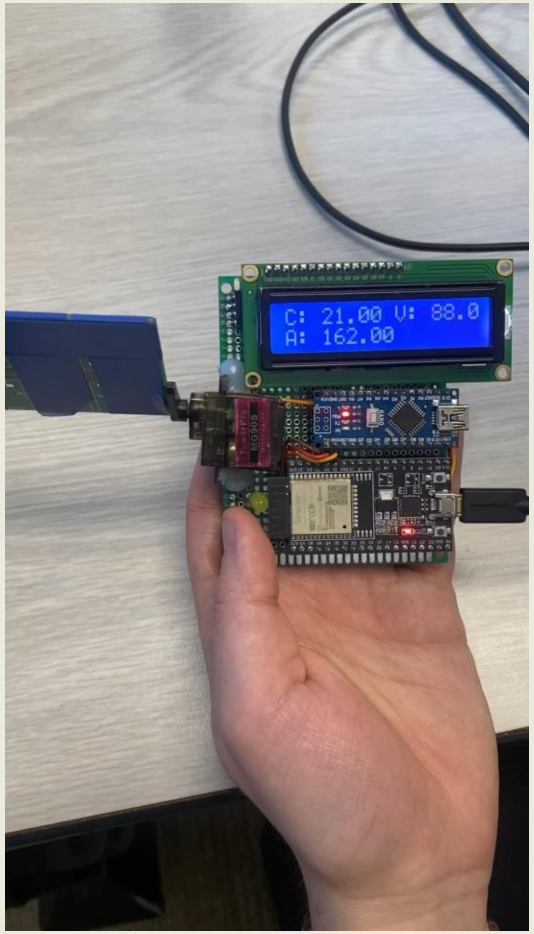
3 | **Automation**

-Shut off servo upon a fault and re-enable once resolved.

-Automatically track the sun angle

```
// Check fault status from server
void checkFaultStatus() {
  if (WiFi.status() == WL_CONNECTED) {
    HTTPClient http;
    http.begin("http://pi.com/plant1/fault");

    int httpCode = http.GET();
    if (httpCode > 0) {
      String payload = http.getString();
      StaticJsonDocument<200> doc;
      DeserializationError error = deserializeJson(doc, payload);
      if (error) {
        Serial.print(F("deserializeJson() failed: "));
        Serial.println(error.f_str());
        return;
      }
      fault = doc["fault"];
    } else {
      Serial.println("Error on HTTP GET request for fault status: " + String(httpCode));
    }
    http.end();
  } else {
    Serial.println("WiFi not connected");
  }
}
```



S. Objective 4

4 | Wireless Data Acquisition

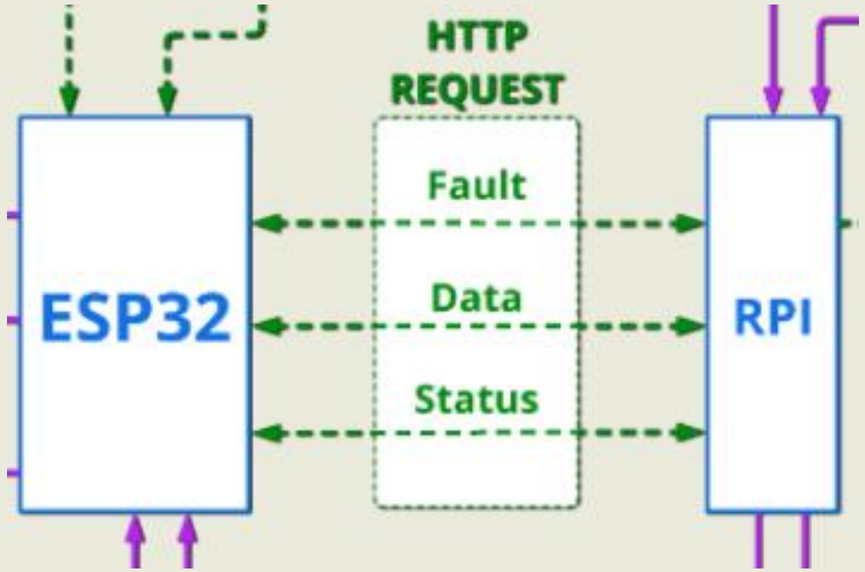
-Wirelessly communicate with Pi Server

-Notify on disconnect, attempt to resolve and reconnect

Originally focused on MQTT communication due to its flexibility in IOT applications.

Moved to HTTP/S upon discovery of Raspberry Pi Backend Issues

Unable to resolve connection issues



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S. Objective 5

5 | **Web Based Interface**

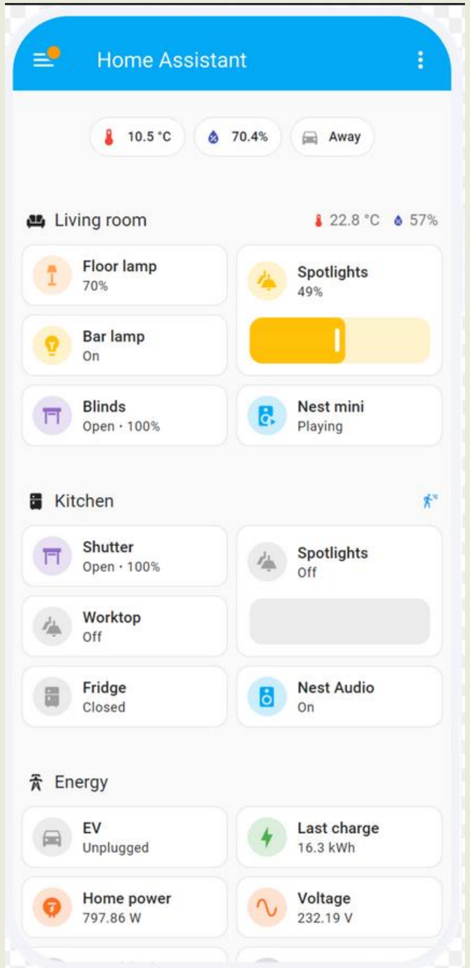
-Website interface

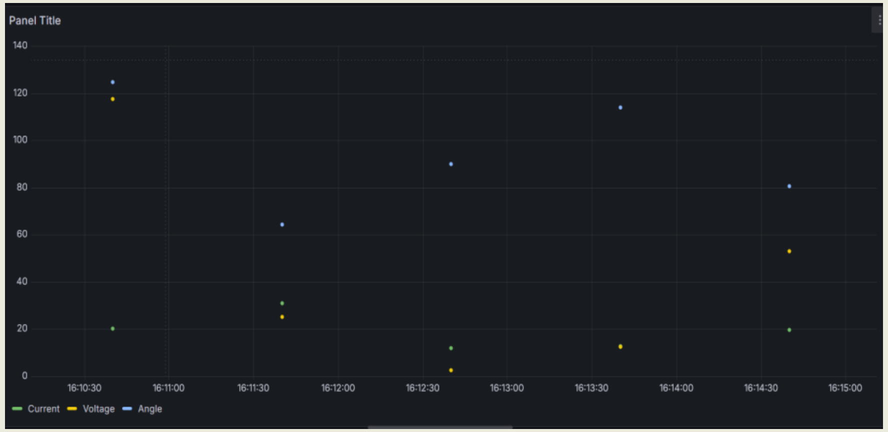
-Graph real-time data (no refreshing)

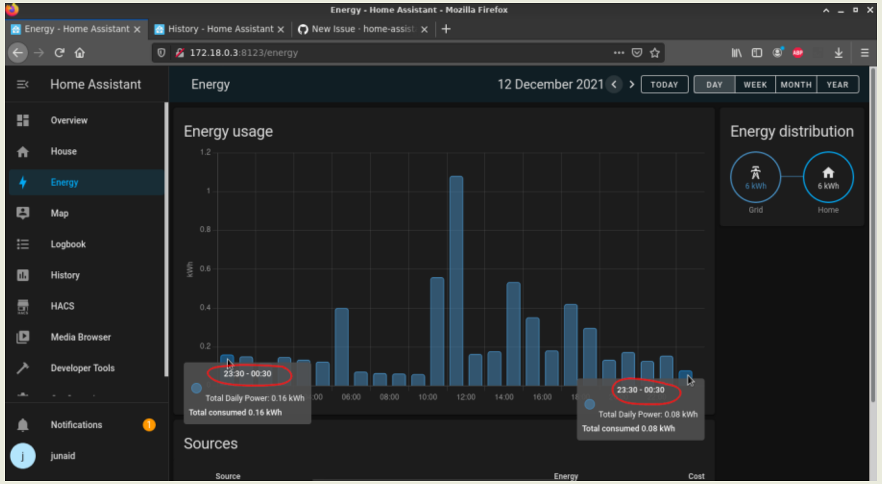
-Interface scales to mobile devices and desktop

Home Assistant

- Scales to either web clients or mobile devices
- Allows for real-time visualization of graphed data
- Allows for an all-in-one platform for data visualization and monitoring







Testing

- Tried out the data reading, LCD display, and motor control. Minor adjustments to limits corrected their functionality
- Attempted multiple connection strategies, encountering persistent errors throughout. Explored various methods to successfully broadcast the data, but challenges persisted.
- Generated random test data for database validation and visualization within the platform

Errors and Critiques

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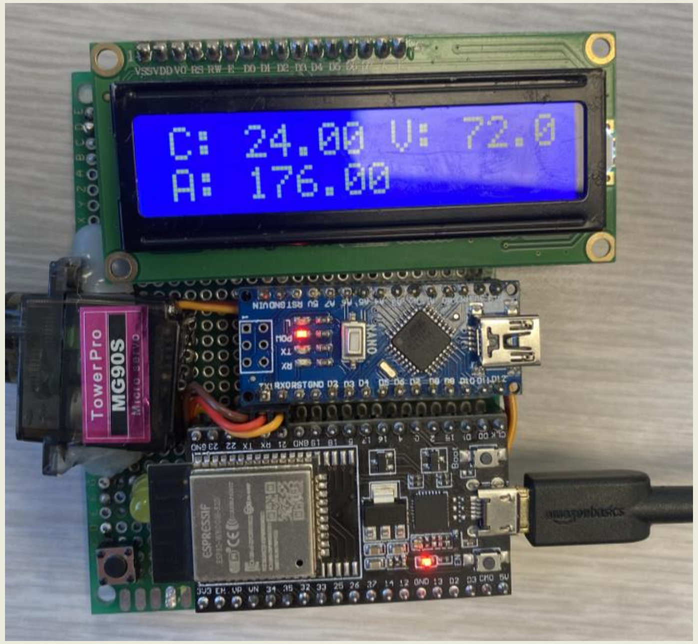
Server side (Raspberry Pi):

- Unable to resolve peer connection refusal by telegraf
- Unable to implement front end graphing of real-time data
- Unable to implement front-end fault reset and manual override from front end.



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References

[1] LiquidCrystal_I2C: https://github.com/johnrickman/LiquidCrystal_I2C (Author: johnrickman)

[2] ESP32Servo: https://github.com/madhephaestus/ESP32Servo (Author: madhephaestus)

[3] ArduinoJson: https://github.com/bblanchon/ArduinoJson (Author: Benoît Blanchon)

[4] Wire: https://github.com/espressif/arduino-esp32/tree/master/libraries/Wire (Author: Espressif Systems)

[5] WiFi: https://github.com/espressif/arduino-esp32/tree/master/libraries/WiFi (Author: Espressif Systems)

[6] HTTPClient: https://github.com/espressif/arduino-esp32/tree/master/libraries/HTTPClient (Author: Espressif Systems)

[7] WiFiClientSecure: https://github.com/espressif/arduino-esp32/tree/master/libraries/WiFiClientSecure (Author: Espressif Systems)

[8] GitHub Copilot: Used for autocompletion assistance