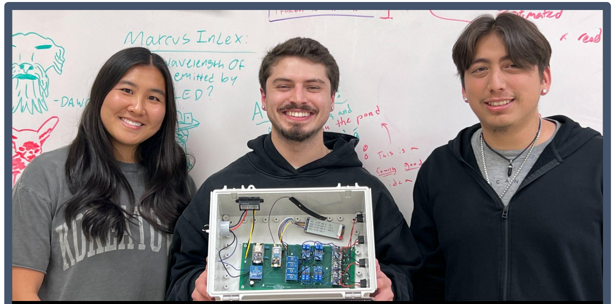
SONOMA STATE UNIVERSITY | BACHELOR OF SCIENCE ELECTRICAL ENGINEERING

R.E.A.C.H

Remote Energy Access and Control Hub



Kamryn Juan Jair

Senior Design Project Proposal

Jair Pacheco, Kamryn Shigemoto, Juan Jimenez
Sonoma State University Department of Engineering Science
Advisors: Farid Farahmand
Client: Zac Robinson

shigemotok@sonoma.edu
pachecoja@sonoma.edu
jimenezjua@sonoma.edu

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Overview

- Background
- Problem Statement
- Existing Solutions
- Proposed Solution
- Value Proposition
- System Overview
  - High Level Diagram and Physical Description
- Challenges and Risks
- Marketing and Engineering Requirements
- Alternative Design Matrix
- Tests
- Estimated Budget
- Schedule
- Future Development
- Supporting Courses

Background

Existing Setups and Requirements in Vineyards:

- Sensors and field devices (soil moisture monitors, and automated valves)
- Power comes from the grid, power over ethernet (PoE), and batteries (require changes)
    - Cable runs along existing vineyard rows to connect devices
- Devices need reliable power and communication
    - Ex) Weather data needs be available 100% of the time ⟶ used to trigger frost alarms.

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Problem Statement

Remote and rural locations, such as ranches, farms, vineyards, and nature preserves, rely on field devices like sensors, actuators, and cameras.

- These devices often run on solar or other remote power systems, but existing solutions do not provide reliable ways to monitor device status, manage power usage, or control loads from a distance.
- As a result → operational downtime, limited visibility into system health, and increased maintenance trips

Existing Solutions

Temank MPPT Solar Charge Controller RUNNER-60A DC150V LCD Display ($229.00)

- MPPT single panel
- Power management modes
- RS485 connectivity

Anker SOLIX C200 DC Solar Generator + 60W Solar Panel ($299.99)

- 5 charging ports
- Built in protection to prevent overcharge and over-current
- Recharge with solar panels

Morningstar TS-60M TriStar Solar Charge Controller with Meter ($393.00)

- RS-232 communication
- 7 different digital presets
- Diversion regulation

SABRENT 10-Port 60W USB 3.0 Hub (HB-BU10) ($49.99)

- Manual connection
- Step down conversion
- Power control through individual power switches

Existing Solutions

<u>R.E.A.C.H.'s Features</u>	Temank	Anker SOLIX	Morningstar TS-60M TriStar	Sabrent 10-port USB hub	REACH
Provides Power Management	✅	✅	✅	❌	✅
Provides Scheduling Capabilities	❌	❌	❌	❌	✅
Maintain Historical Data for Data Analysis	❌	❌	❌	❌	✅
Remote Website Dashboard Interface and Monitoring	❌	❌	❌	❌	✅

Proposed Solution

REACH is an external module that seamlessly integrates with existing solar power systems to provide **connectivity**, advanced **remote power management**, and **monitoring** over connected loads in remote locations.

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Value Proposition

REACH works seamlessly with existing remote power systems and enhances customer experience by:

- **Power management** allows control over power usage through assigned outlet priority in the event of low power availability
- **Scheduled** real time programming for hands-off control
- Access to online website for **remote monitoring** and long-term data analysis
- **Reduce** downtime, maintenance trips, and operational uncertainties
- Local **WiFi hotspot** for connectivity and access to simple control website

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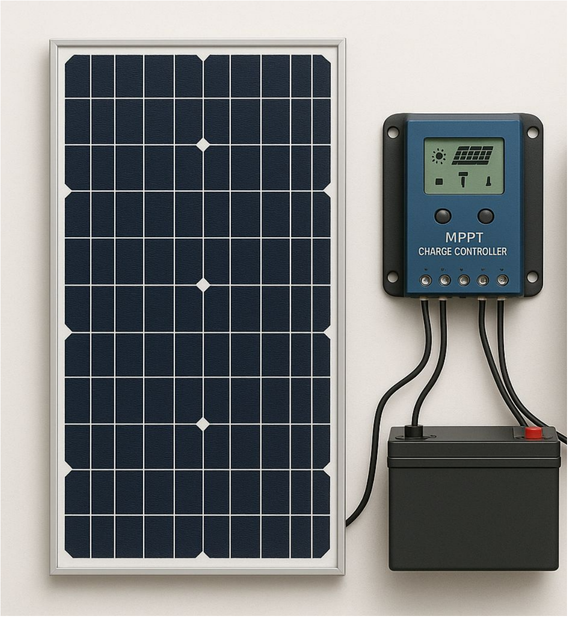
Value Proposition



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Marketing Requirements

MR1. The system shall provide control over remote field devices using multiple DC power outlets.
MR2. The system shall allow remote scheduling and load management to optimize power usage.
MR3. The system shall support LTE connectivity for remote monitoring and control via a cloud-based dashboard.
MR4. The system shall include a local display that presents clear, easy-to-understand information.
MR5. The system shall easily connect to typical existing solar power systems, including off-the-shelf solar panels, solar charge controllers, and standard DC batteries.
MR6. The system shall monitor and log voltage, current, and power metrics for solar input, battery state, and output ports.
MR7. The system shall include appropriate circuit protection before delivering power to USB/DC outlets.
MR8. The system shall be lightweight, transportable, and easy to install in field locations.
MR9. The system shall be water resistant for outdoor deployment.
MR10. The system shall provide wireless connectivity in remote locations through a built-in WiFi hotspot.

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Engineering Requirements

ER1. 4 USB outlets, 5V @ 900mA max for each line, with local and remote control. **(MR1)**

ER2. Scheduled on/off control and load prioritization via dashboard, ≤ 60s execution latency. **(MR2)**

ER3. The dashboard shall display the latest system metrics (outlet voltage/current, outlet status) with a resolution of ±0.1V and ±0.01A. **(MR3)**

ER4. The local display shall present outlet status, estimated charge/discharge time and allow local outlet control. Displayed information shall refresh at least every 5 seconds. **(MR4)**

ER5. The system shall operate using a solar panel rated for 12V and provide between 30W to 50W, and sustain functionality for at least 5 hours without solar input. **(MR5)**

ER6. The internal system (excluding USB outlets) shall consume no more than 5W during typical operation to maximize runtime on battery. **(MR5)**

Engineering Requirements

ER7. The system shall measure and log voltage, current, and power for solar input, battery, and each output port with an accuracy of ±0.2V and ±0.01A, and synchronize logs with the cloud dashboard every 10 minutes. **(MR6)**

ER8. All output ports shall include protection via manually resettable fuses rated ≤ 1A.**(MR7)**

ER9.The entire system, including enclosure, outlets, and display, shall weigh ≤ 10 lbs and fit within a container size of 15 x 15 x 35 cm. **(MR8)**

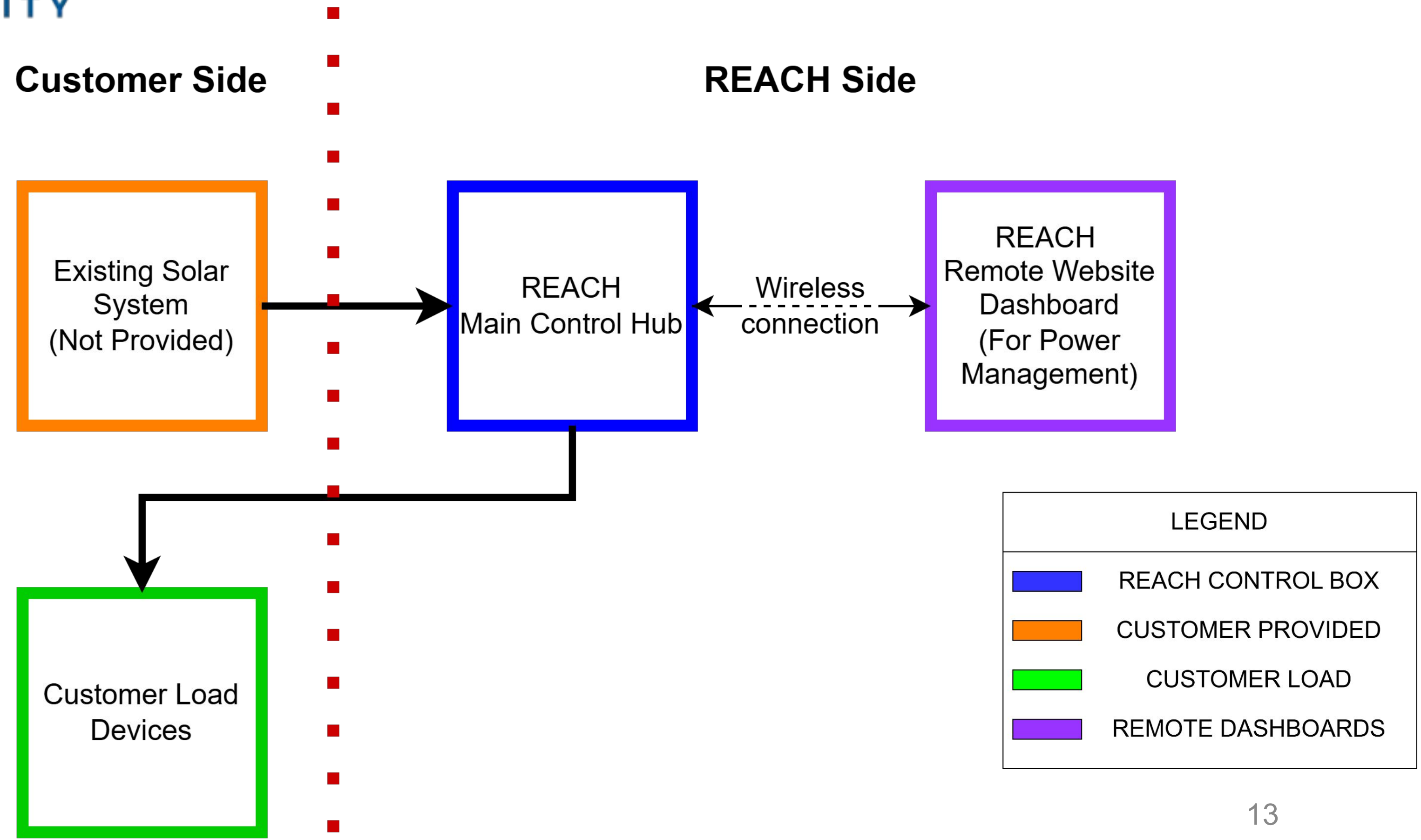
ER10. The enclosure and all external components shall meet the IP65 standard for water and dust resistance suitable for outdoor deployment. **(MR9)**

ER11.The system shall create a local WiFi hotspot supporting at least 4 simultaneous connections with the local control webpage loading within 5 seconds of connection. **(MR10)**

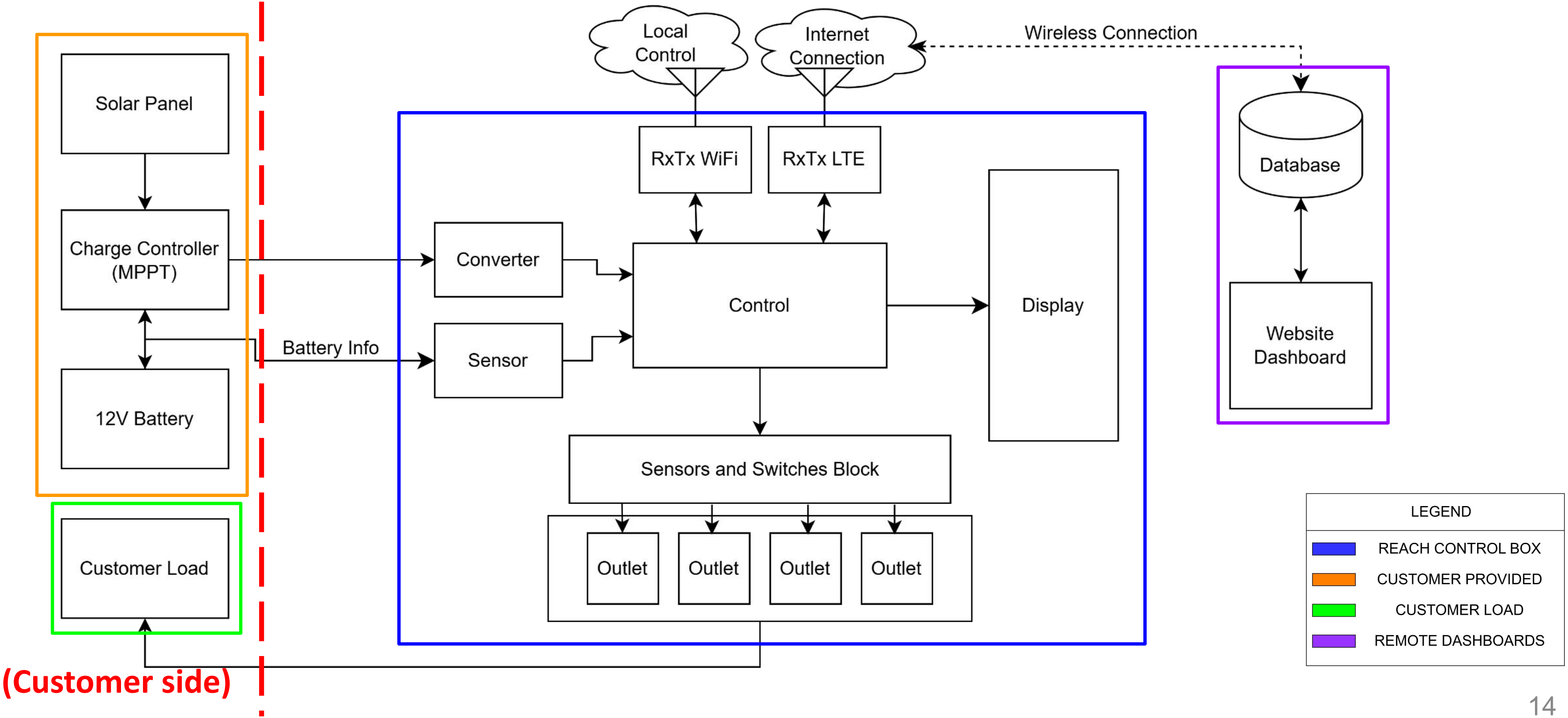
ER12. The system shall execute user-defined schedules for each output port using an onboard RTC with a timing accuracy of ±1 minute, independent of cloud connectivity. **(MR2)**

ER13. The system shall receive 95% of telemetry data and scheduling data and log it to the database. **(MR3)**

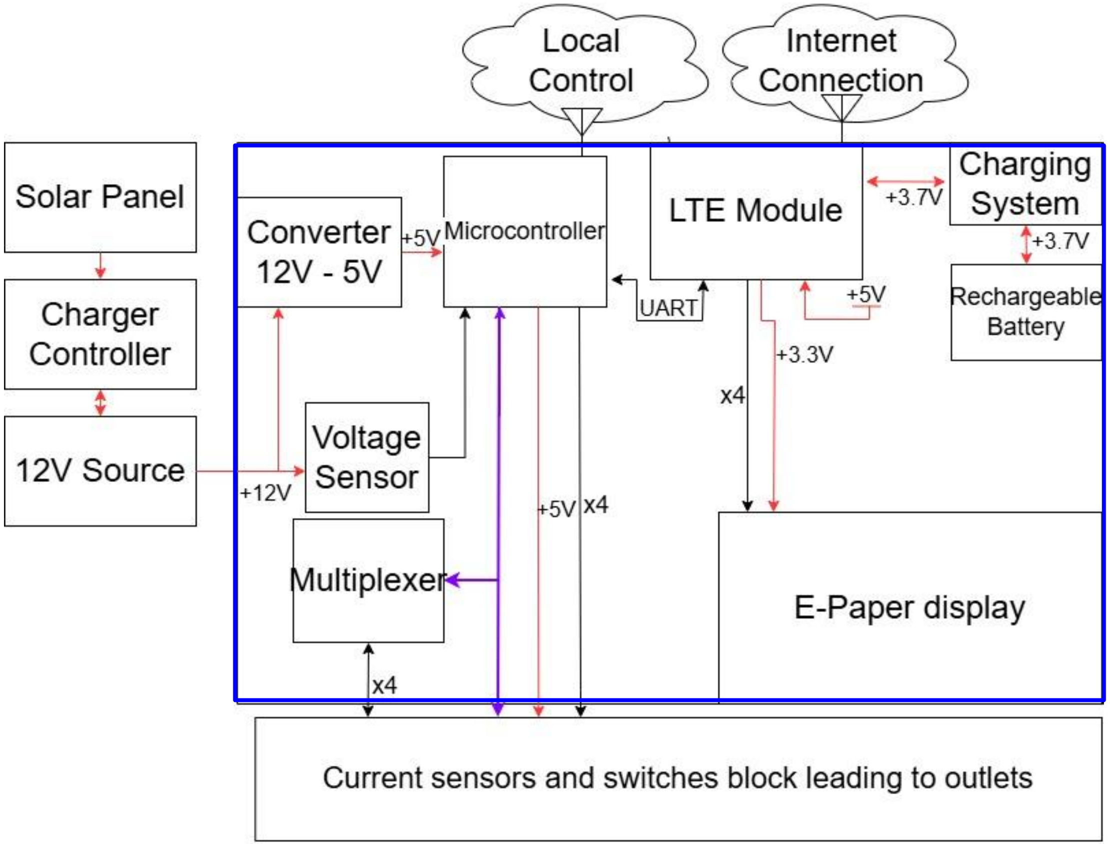
High Level System Diagram

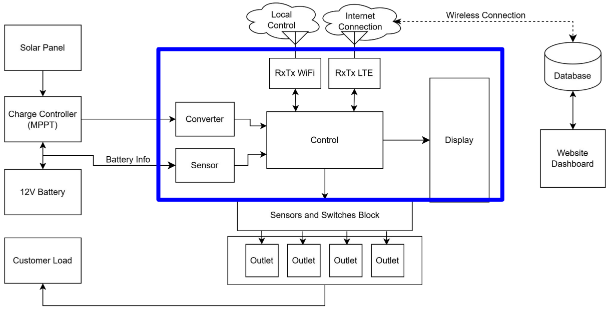


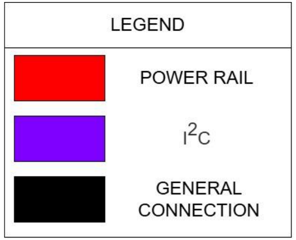
High Level Diagram



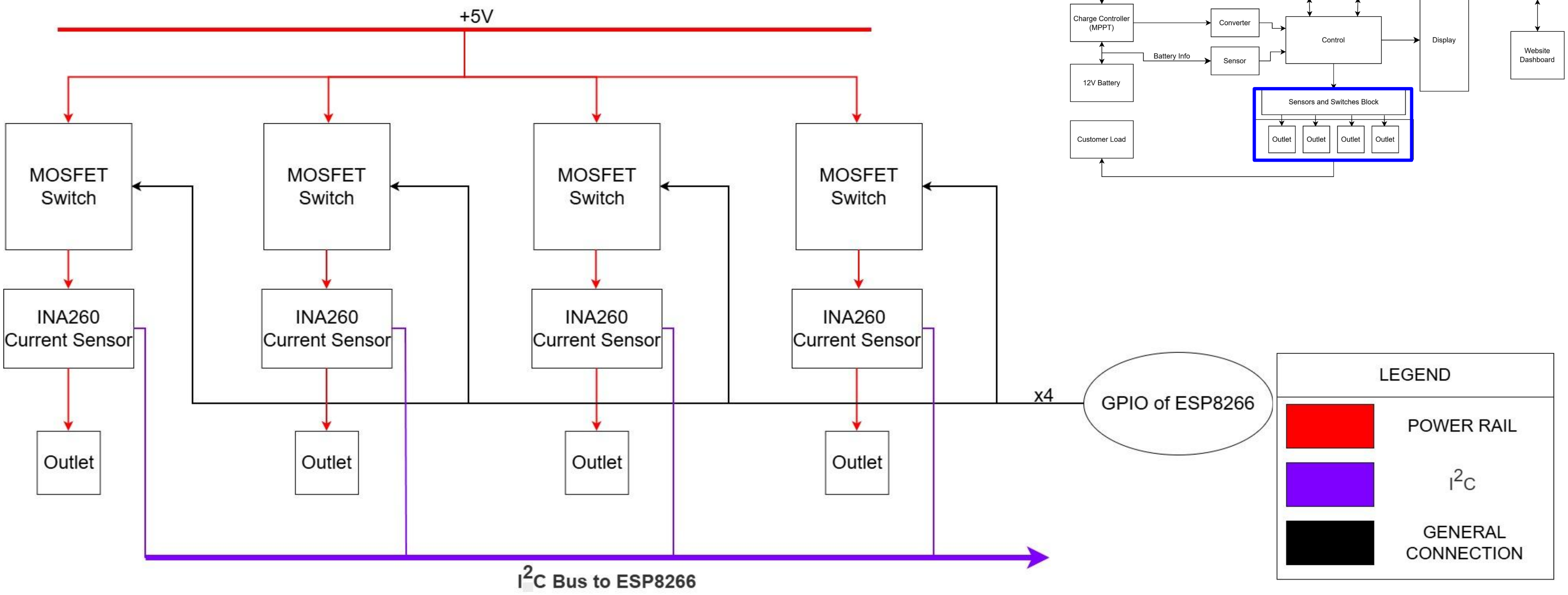
High Level Diagram: Control Hub

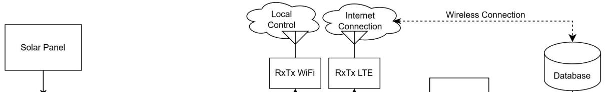




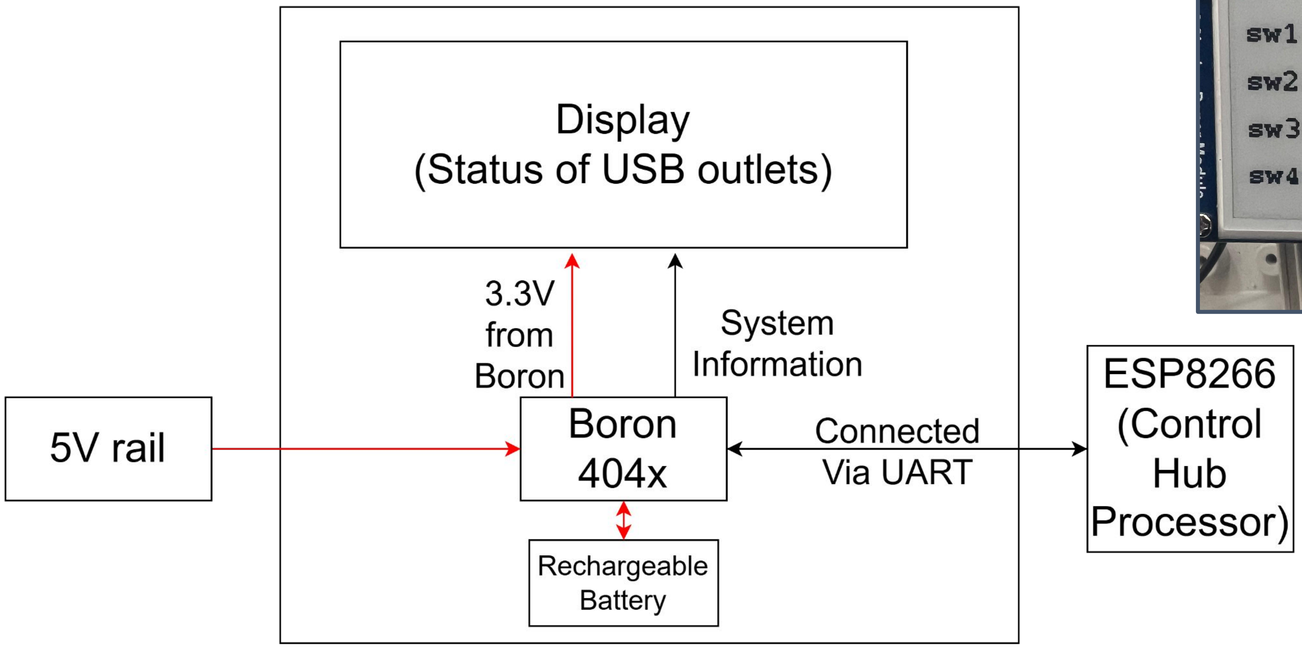


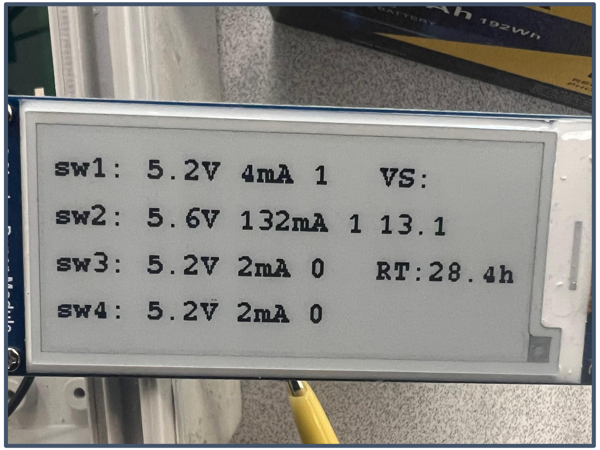
High Level Diagram: Control Hub





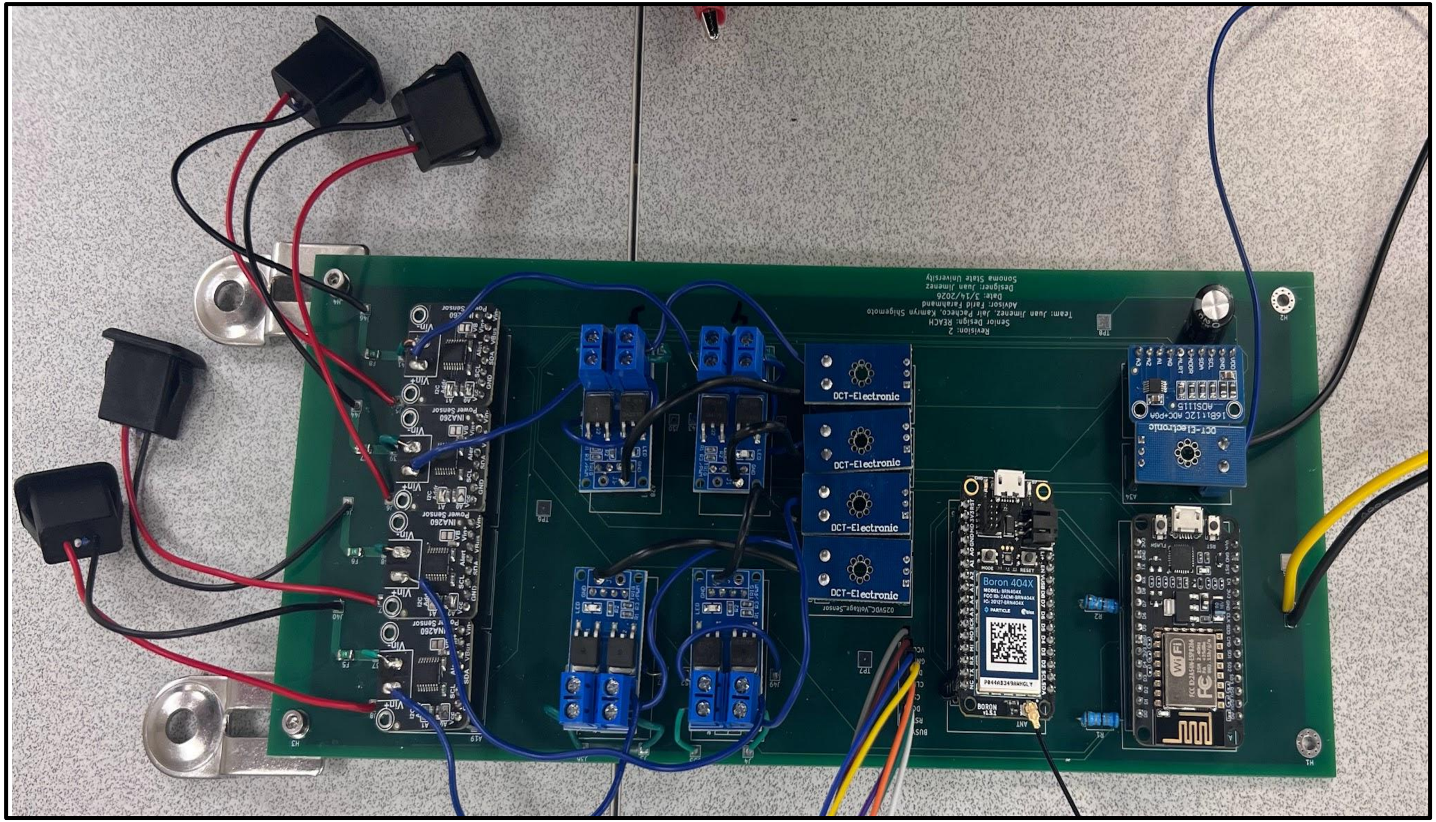
Display Panel Diagram



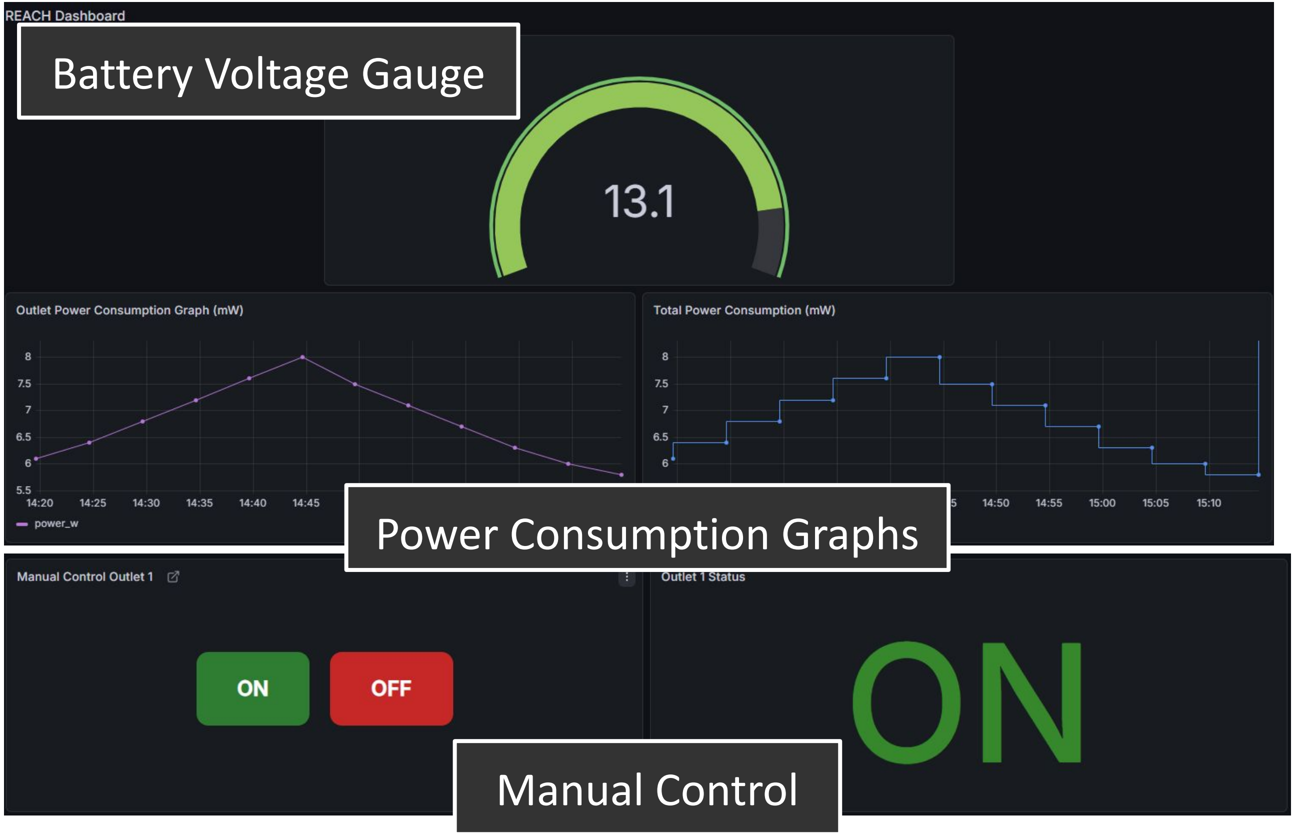


296x198 pixel Epaper
(E-Ink Display)

Assembled System



Remote Website Dashboard (DB)



- System Sensor readings
- Manual Control
- System Runtime
- Load Priority
- Scheduling

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DB: System Runtime Algorithm

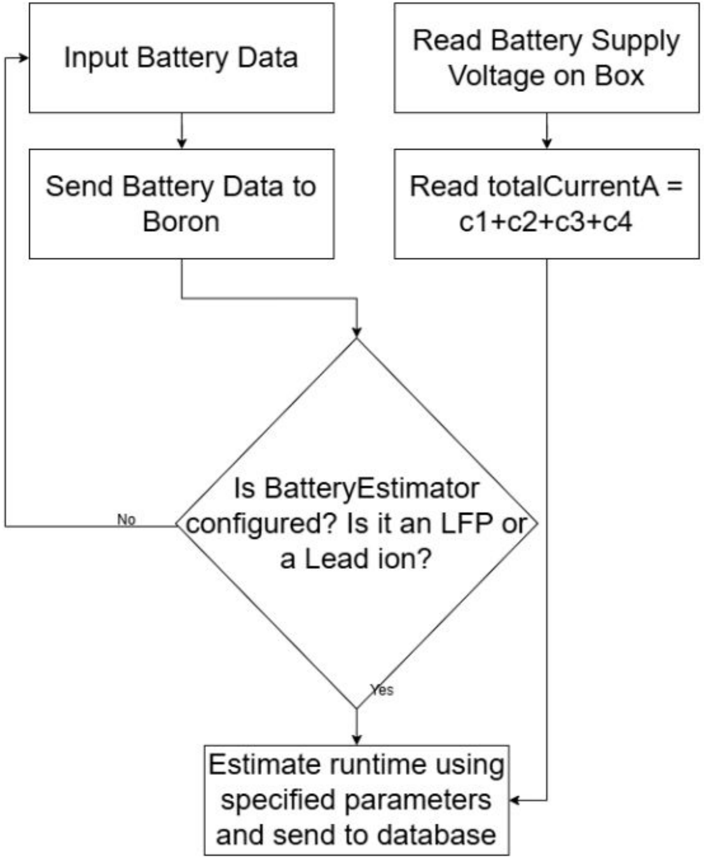
Current Battery Configuration

Battery Capacity (Amp-Hours)	Battery Chemistry ↓	Nominal Voltage
15	LFP	12.8

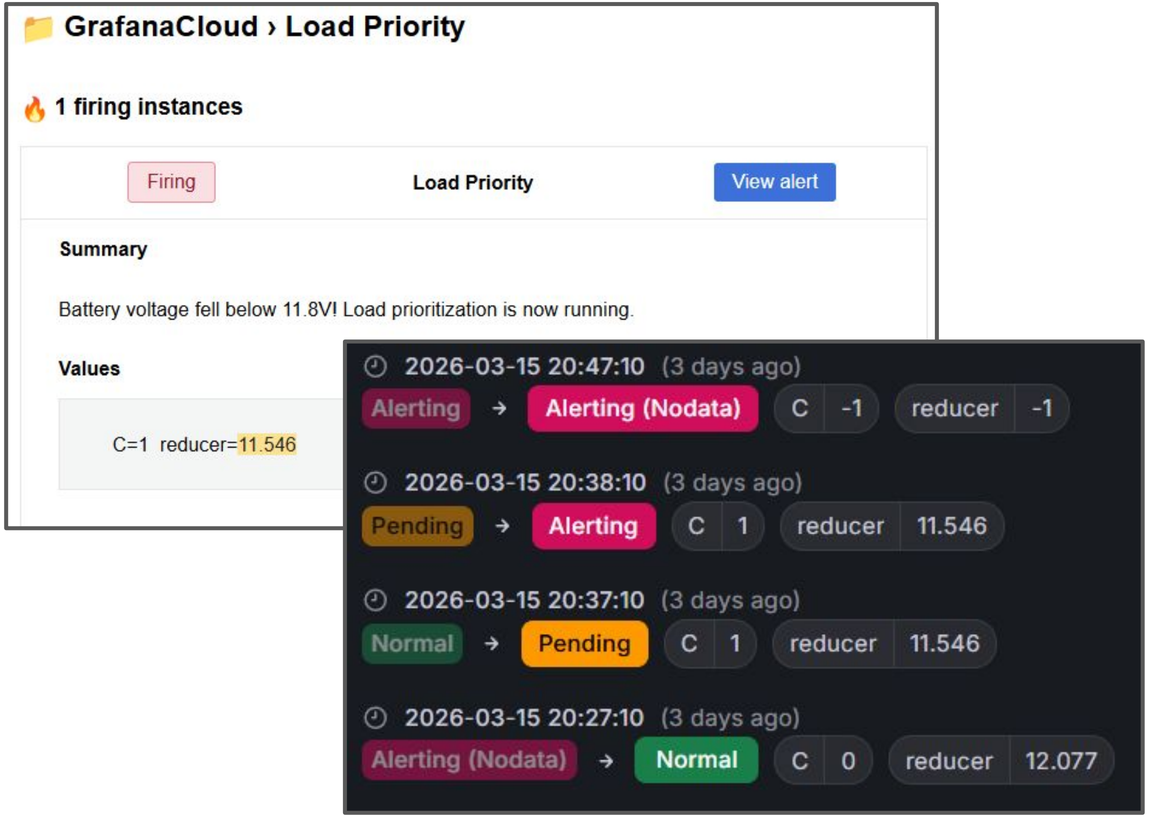
Update Battery Configurations

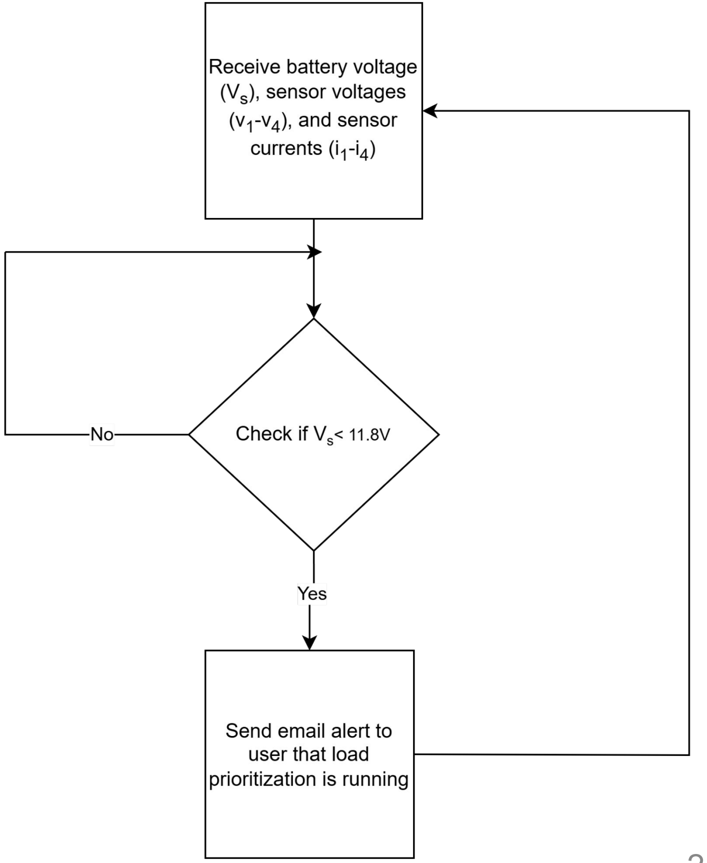
Battery Capacity (Amp-Hours)	0
Battery Chemistry	Choose
Nominal Voltage	0

Submit



DB: Load Priority Algorithm





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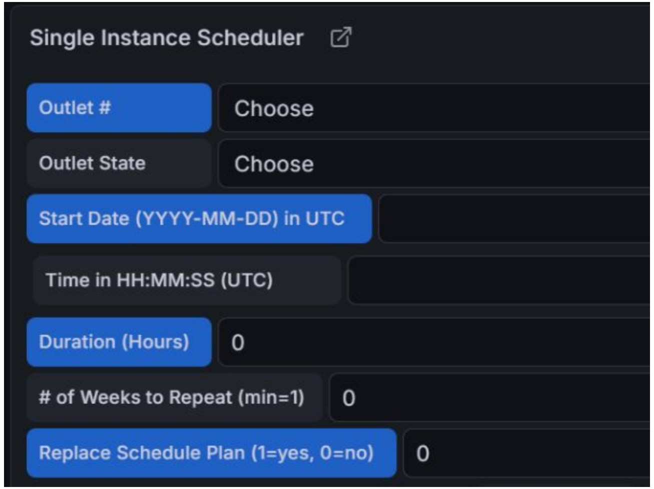
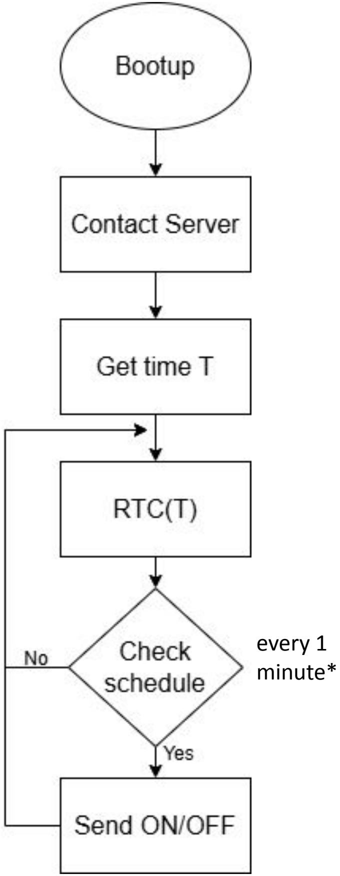
DB: Schedule Algorithm



Created At	Start Time	End Time	Enabled	Target State	Outlet ID
2026-04-10 1:50:47	2026-04-10 1:51:00	2026-04-10 1:58:30	1	1	2
2026-03-13 18:15:41	2026-03-13 19:46:10	2026-03-13 20:01:10	1	0	4
2026-03-13 18:15:39	2026-03-13 19:46:10	2026-03-13 20:01:10	1	0	3
2026-03-13 18:15:36	2026-03-13 19:46:10	2026-03-13 20:01:10	1	0	2
2026-03-13 18:15:31	2026-03-13 19:46:10	2026-03-13 20:01:10	1	0	1



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Power Calculations

Conditions	ESP8266	Particle Boron	Mosfet Switch	INA260	DCT-Voltage	Epaper	ADS1115	Total Current (mA)	battery current (mA)	mW
Peak Current (HB)	250	490.0	2	10	2.4	8	10	772.4	209.6	3577.4
Peak Current (LB)	170	120.0	0	0.4	2.4	8	10	310.8	84.3	1439.5
Active (HB)	120	207.0	2	0.4	2.4	8	10	349.8	94.9	1620.1
Active (LB)	70	63.9	0	0.4	2.4	8	10	154.7	42.0	716.5

Total Power Consumption (P_T) = Sum of Total Current (I_T) * (Operating Voltage/(Battery Voltage * Buck Converter Efficiency))

Power Calculations (Theory)

Total Power Consumption (P_T) = Total Current (I_T) * (Operating Voltage/(Battery Voltage * Buck Converter Efficiency))

Total Current = all module current conditions

In Our Case: P_T = Total Current * (3.3V/ (12.8 * η))
@ operating conditions (12-13.5 V)
η = 0.75
Therefore the total power consumption ranges from 0.716 to 3.577 W

Alternative Design Matrix

Main MCU:

Criteria	Weight	PIC18F47K42	ESP8266	Raspberry Pi	ESP32S3
Cost	0.2	0.29	0.30	0.15	0.26
Processing Power	0.05	0.10	0.30	0.40	0.20
Availability	0.05	0.02	0.01	0.96	0.06
Familiarity	0.3	0.22	0.32	0.17	0.30
Clock Speed	0.1	0.04	0.09	0.83	0.04
Power consumption	0.3	0.31	0.33	0.06	0.30
Score		0.23	0.28	0.25	0.25

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Alternative Design Matrix

Transceiver MCU:

Criteria	Weight	Particle Boron	ESP32 S3	Raspberry Pi	ESP8266
Cost	0.2	0.2	0.32	0.12	0.36
Type of Transmission	0.3	0.33	0.27	0.17	0.23
Ease of Use	0.2	0.25	0.15	0.3	0.3
Support	0.1	0.26	0.22	0.3	0.22
Transmission Rate	0.1	0.18	0.23	0.27	0.32
Power Consumption	0.3	0.45	0.2	0.1	0.25
Score	1	0.37	0.28	0.22	0.33

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Alternative Design Matrix

Transistors for switching:

Criteria	weight	Dual Mosfet PWM Switch	AO3400A surface mount	IRLZ44N surface mount
Loss	0.2	0.33	0.34	0.33
Cost	0.25	0.36	0.29	0.35
Availability	0.15	0.33	0.33	0.33
Temperature Resistance	0.1	0.43	0.14	0.43
High-Side Simplicity	0.3	0.63	0.25	0.13
Score	1	0.44	0.28	0.28

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Alternative Design Matrix

Type of Transmission

Criteria	Weight	LTE	LoRa	WiFi	Zigbee
Range	0.15	4	5	2	2
Data Rate	0.35	5	1	5	2
Latency	0.2	4	1	5	3
Cost	0.1	2	5	4	3
Scalability	0.1	5	4	3	4
Power Consumption	0.1	3	5	2	4
	1	0.31	0.2	0.29	0.2

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Estimated Budget

Component	Quantity	Individual Price	Costs	Description
ESP8266	1	7.99	7.99	Used to control the main power hub
Particle Boron 404x	1	49.95	49.95	Used for long range transmission
YRDZXG [Buck converter]	1	9.99	9.99	Used to step down the voltage from 12V to 5V
ADS1115 [Multiplexer]	1	3.96	11.89	Allows the ESP to interface with multiple analog sensors
INA260	4	17.99	71.96	Used to measure current
DCT-Electronics [Voltage sensor]	5	1.18	5.89	Used to measure voltage
Female USB	4	2.50	10.00	Outlets used to deliver power
Dual MOSFET PWM Switches	4	1.29	12.99	Used to shut off power to outlet
Waveshare E-INK	1	21.99	21.99	Used to display outlet states and power metrics
Total Cost			211.65	

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Tests

Test #	Objective	Related ER	Status	Notes
FT.1	Test basic two-way communication between ESP and Particle Boron	ER1, ER2, ER3	Complete	Continue to test more advancements
FT.2	Test control of website through WiFi connection	ER11	Complete	Successfully changed status of output over WiFi
FT.3	Test current and voltage readings from INA219	ER7	Complete	Looking to optimize IC accuracy or look for another
FT.4	Test range of communication using ESP network	ER11	Incomplete	Looking into antennas to extend range
ST.1	Measure power consumption of the system	ER6	Incomplete	Power calculations completed

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Tests

Test #	Objective	Related ER	Status	Notes
FT.5	Test functionality of optical relays to turn outlet ON/OFF	ER1, ER2	Incomplete	Compare with FETs, switching speed, power consumption
FT.6	Test accuracy of current and sensor readings using ACS712 Hall Effect sensor	ER3, ER4, ER7	Incomplete	Compare with INA219, measure power consumption
FT.7	Dashboard functionality: Send status of outlets and scheduling to ESP and local display, receive sensor readings and status of outlets	ER2, ER3, ER7	Incomplete	Dashboard should have simple user interface, measure power consumption during data transmission
FT.8	Bit Error Rate: Send known bit patterns from ESP to Boron to LTE and checking for bit errors or dropped packets	ER7	Incomplete	Calculate bit error rate and find solution for any dropped packets
FT.9	Test that scheduling features are synched with real time clock implementation	ER2, ER7	Incomplete	Measure power consumption and any delays

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Tests

Test #	Objective	Related ER	Status	Notes
FT.5	Test scheduling functionality for all 4 outlets for single instances in one day	ER2, ER12	Pass	Successfully able to run scheduled for all 4 outlets multiple times in a day
FT.6	Testing ESP reliability	ER3, ER7	Pass	Successfully able to prove ESP reliability, telemetry data was received by dashboard and database
FT.7	Testing the email alert system for load prioritization	ER2	Pass	Successfully able to send email alerts to user when load prioritization is enabled
ST.2	Testing power consumption of the built system under normal operation	ER6	Pass	Successfully operated well below the engineering requirement
FT.8	Testing current readings from the INA260	ER7	Pass	Successfully measured the current accurately and precisely
FT.9	Testing voltage readings from the DCT-Electronic 5:1 voltage sensors	ER7	Pass	Successfully measured the voltage precisely and accurately
FT.10	Load Prioritization Test	ER2	Pass	Successfully shut off low priority lines while leaving high intact

START OF NEW TEST

FT.10 - Load Prioritization Test

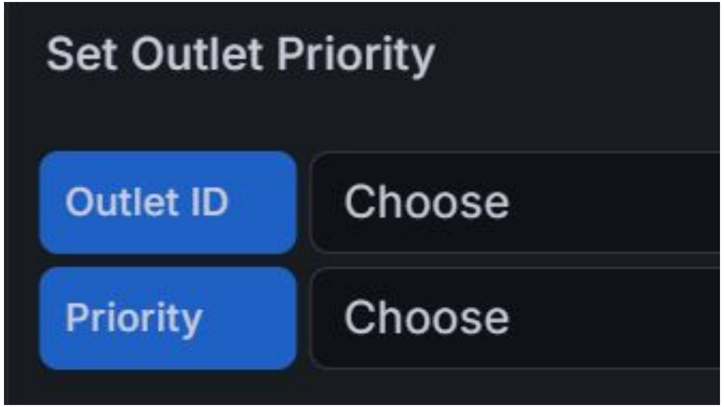
Goal:

- Test to see if load prioritization works with varying loads
- The low priority lines should turn off at threshold voltage
- High priority should never turn off (while system active)
- Similar draw lines (low priority) should both turn off
- ER2

FT.10 - Load Prioritization Test

Setup:

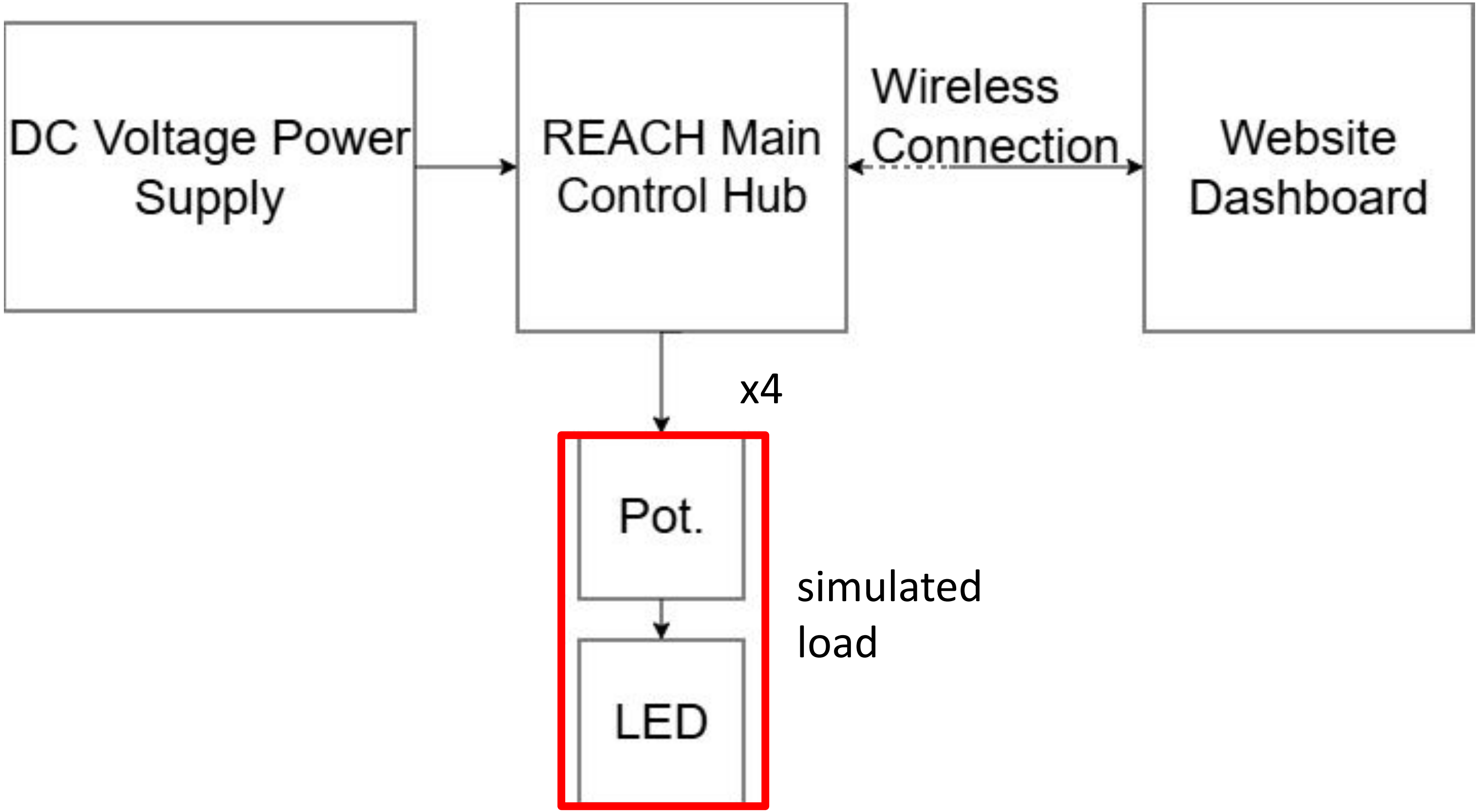
CASE 1: High priority high draw load
CASE 2: 2 equal(in current) low priority loads



Outlet ID	Priority	Last Shed (UTC)	Reason	Time Updated
1	High			2026-03-16 0:59:38
2	Low			2026-03-16 1:55:53
3	Low			2026-03-16 1:55:58
4	Low			2026-03-16 1:56:03

FT.10 - Load Prioritization Test

Setup:



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FT.10 - Load Prioritization Test

Results: [CASE 1] High Priority High Draw Load

Default Set Up:

Time Received	Outlet ID	Battery Voltage (V)	Power Consumption (mW)	Sensor Current (mA)	Sensor Voltage (V)
2026-03-15 19:30:49	3	12.1	0	0	5.0
2026-03-15 19:30:49	1	12.1	321	63	5.1
2026-03-15 19:30:49	2	12.1	30.6	6	5.1
2026-03-15 19:30:49	4	12.1	0	0	5.0

After Voltage Supply Drops:

Time Received	Outlet ID	Battery Voltage (V)	Power Consumption (mW)	Sensor Current (mA)	Sensor Voltage (V)
2026-03-15 19:40:52	3	11.6	0	0	5.0
2026-03-15 19:40:52	1	11.6	265	52	5.1
2026-03-15 19:40:52	2	11.6	0	0	5.0
2026-03-15 19:40:52	4	11.6	0	0	5.0

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FT.10 - Load Prioritization Test

Results: [CASE 2] 2 equal (in current) low priority loads

Default Set Up:

Time Received	Outlet ID	Battery Voltage (V)	Power Consumption (mW)	Sensor Current (mA)	Sensor Voltage (V)
2026-03-15 20:26:11	2	12.1	71.4	14	5.1
2026-03-15 20:26:11	1	12.1	76.5	15	5.1
2026-03-15 20:26:11	3	12.1	66.3	13	5.1
2026-03-15 20:26:11	4	12.1	25	5	5.0

After Voltage Supply Drops:

Time Received	Outlet ID	Battery Voltage (V)	Power Consumption (mW)	Sensor Current (mA)	Sensor Voltage (V)
2026-03-15 20:36:13	4	11.5	30	6	5.0
2026-03-15 20:36:13	3	11.5	0	0	5.0
2026-03-15 20:36:13	2	11.5	0	0	5.1
2026-03-15 20:36:13	1	11.5	81.6	16	5.1

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FT.10 - Load Prioritization Test

Conclusion:

- Successfully able to keep high priority lines ON
- Highest draw low priority lines dropped at threshold voltage
- If 2 low priority lines are close in current draw and the highest, they both shut OFF

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FT.6 - Link Reliability Test

Goal:

- Testing ESP reliability
- Make sure that when the circuit is powered on, data values are sent to the database in a timely manner without bogus values
- ER13

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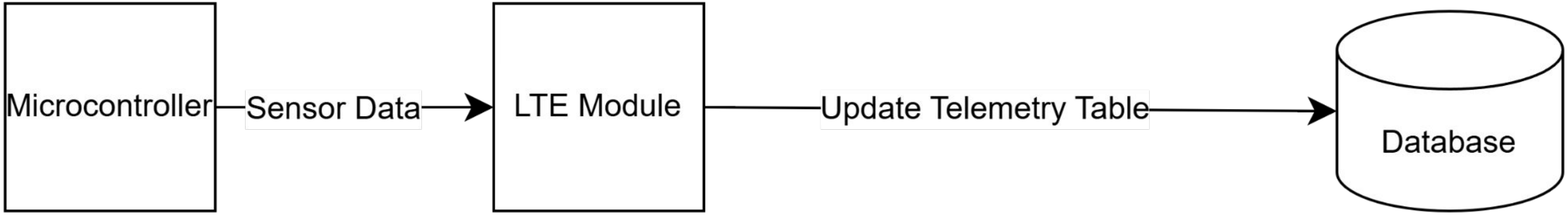
FT.6 - Link Reliability Test

Setup:

- Looked at data on March 7, 2026 over a span of 13 hours, data wasn't continuously being sent the whole time
- Data was sent 57 times that day, expected to see 57 data points for each outlet



FT.6 - Link Reliability Test

Results:

Start Time:

id	ts	outlet_id	battery_v	power_w	current_a	sensor_v
355	2026-03-07 10:17:57	4	12.1	0	0	4.7
356	2026-03-07 10:17:57	1	12.1	97.3	20	4.9
357	2026-03-07 10:17:57	2	12.1	0	0	4.8
358	2026-03-07 10:17:57	3	12.1	0	0	4.8

End Time:

id	ts	outlet_id	battery_v	power_w	current_a	sensor_v
578	2026-03-07 23:48:33	2	12.1	0	0	4.8
579	2026-03-07 23:48:33	1	12.1	0	0	0
580	2026-03-07 23:48:33	3	12.1	0	0	4.8
581	2026-03-07 23:48:33	4	12.1	0	0	4.8

FT.6 - Link Reliability Test

Conclusion:

- Only one data point was dropped (outlet 4)
- Link reliability proved to be reliable
  - Expected to receive telemetry data 57 times
  - Received 98.2% of telemetry data (56/57)
- Timing proved to be accurate (±1 min), data sent in 10 minute intervals when system was powered on
- Dashboard received and displayed the latest system metrics (within a specific accuracy) and synchronized every 10 minutes

START OF NEW TEST

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FT.5 - Scheduling Reliability Over Time Test

Goal:

- Test to see if single instance scheduling works throughout one day
- Make sure outlets turn on at scheduled start time
- Make sure outlets stay on for assigned duration
- ER2, ER12, ER13

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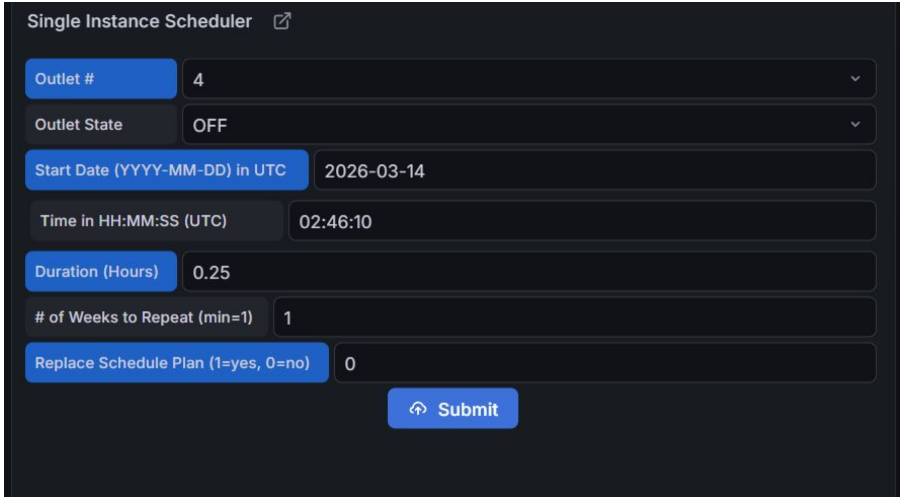
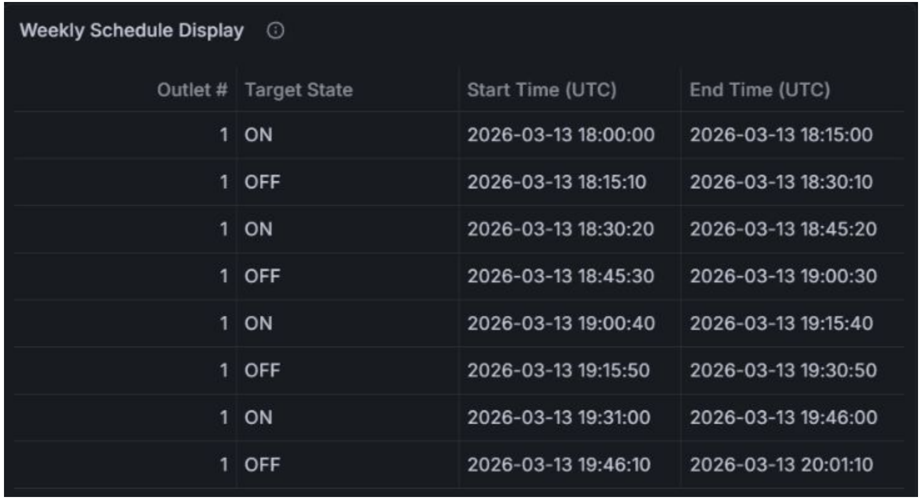
FT.5 - Scheduling Reliability Over Time Test

Setup:

Tested scheduling for all 4 outlets, 3x ON/OFF in one day

- All 4 outlets stayed on or off for ~15 minutes (the scheduled duration)



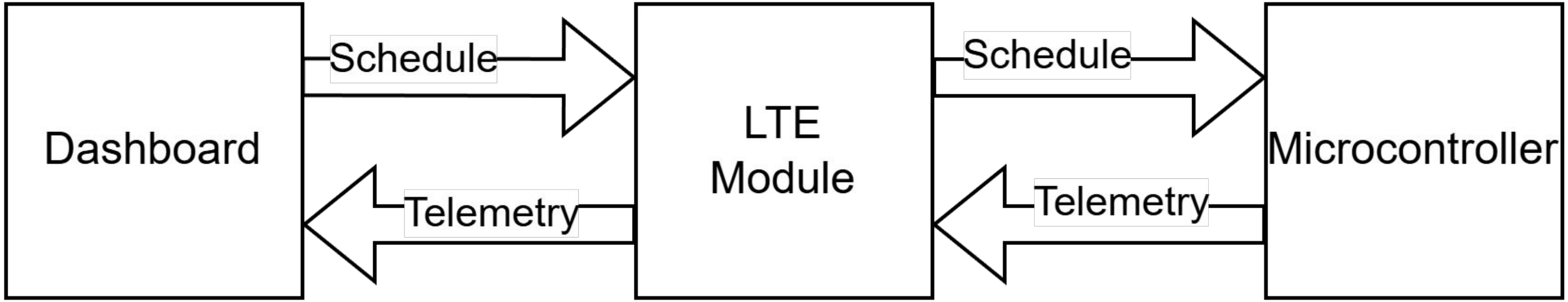


Weekly Schedule Display

Outlet #	Target State	Start Time (UTC)	End Time (UTC)
1	ON	2026-03-13 18:00:00	2026-03-13 18:15:00
1	OFF	2026-03-13 18:15:10	2026-03-13 18:30:10
1	ON	2026-03-13 18:30:20	2026-03-13 18:45:20
1	OFF	2026-03-13 18:45:30	2026-03-13 19:00:30
1	ON	2026-03-13 19:00:40	2026-03-13 19:15:40
1	OFF	2026-03-13 19:15:50	2026-03-13 19:30:50
1	ON	2026-03-13 19:31:00	2026-03-13 19:46:00
1	OFF	2026-03-13 19:46:10	2026-03-13 20:01:10

FT.5 - Scheduling Reliability Over Time Test

Setup:



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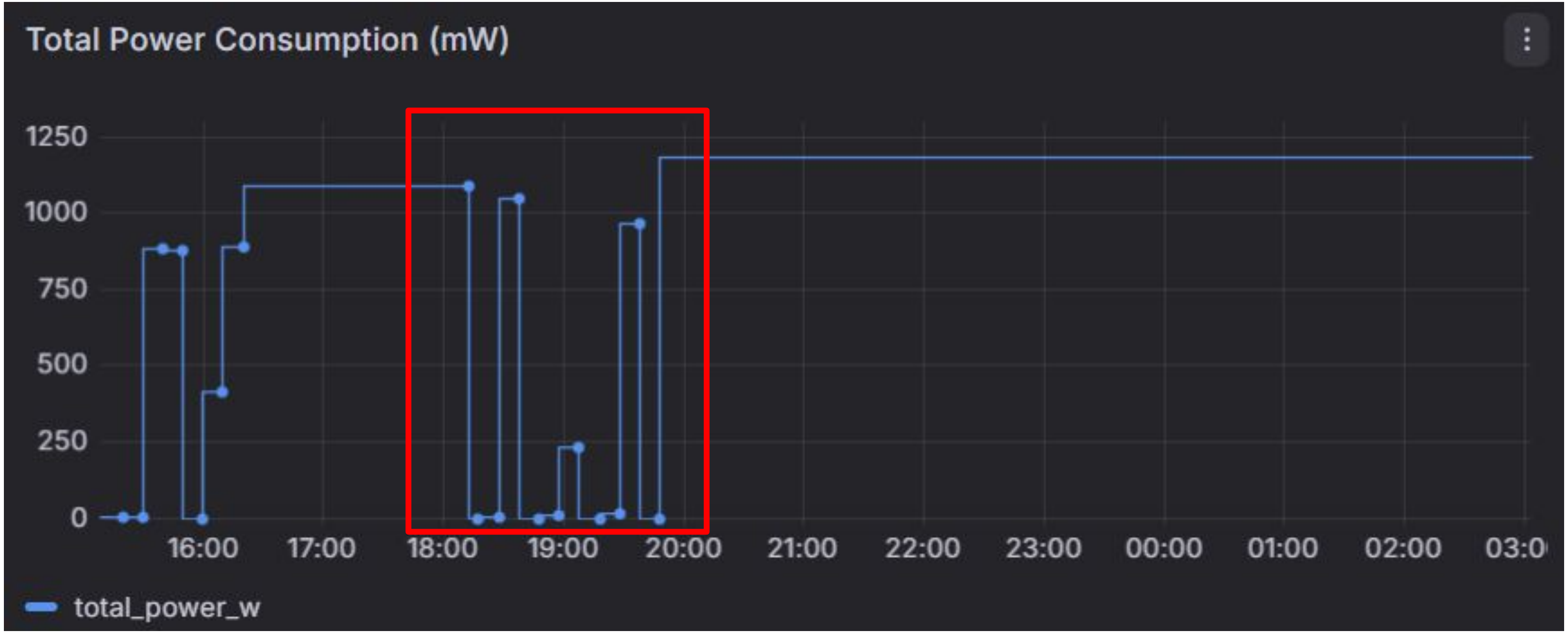
FT.5 - Scheduling Reliability Over Time Test

Results:

Instance	Date	Outlet State	Start Time	Scheduled Duration	Outlet 1 Current (mA)	Outlet 2 Current (mA)	Outlet 3 Current (mA)	Outlet 4 Current (mA)
1	03/13/26	OFF	6:15 PM	15 mins	1	0	0	0
2	03/13/26	ON	6:30 PM	15 mins	87	18	20	86
3	03/13/26	OFF	6:45 PM	15 mins	0	0	0	0
4	03/13/26	ON	7:00 PM	15 mins	11	13	23	—
5	03/13/26	OFF	7:15 PM	15 mins	0	0	0	0
6	03/13/26	ON	7:31 PM	15 mins	80	13	21	81
7	03/13/26	OFF	7:46:00 PM	15 mins	0	0	0	0

FT.5 - Scheduling Reliability Over Time Test

Results:



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FT.5 - Scheduling Reliability Over Time Test

Conclusion:

- Successfully able to schedule all 4 outlets for one day using the dashboard with very little latency when Boron polled for schedules (every 1 min)
- All 4 outlets started at the correct scheduled time (within ±1 minute) using RTC
- Most of the data points were successfully sent over to the database, one data point was lost in transmission
    - Received 100% of schedules, 96.4% of the telemetry data

START OF NEW TEST

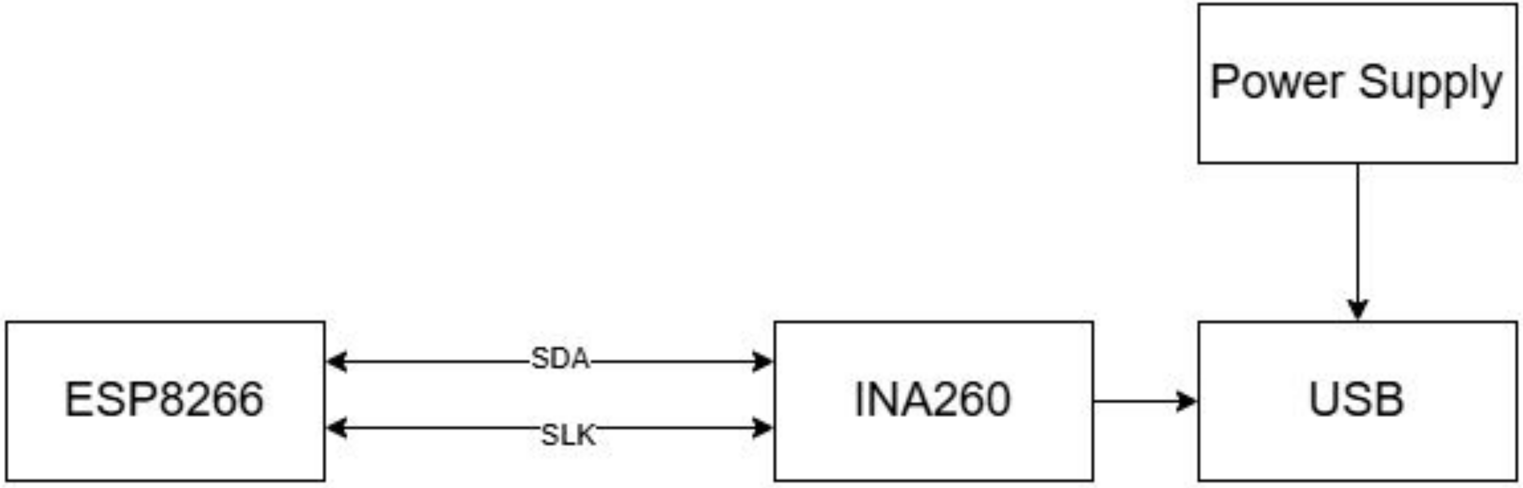
FT.8 - Current Sensor Test

Goal:

- Establish accurate and consistent readings with the INA260 power sensor
- Ammeter used is HY3005D power supply (+/- 2% current accuracy)
- ER7

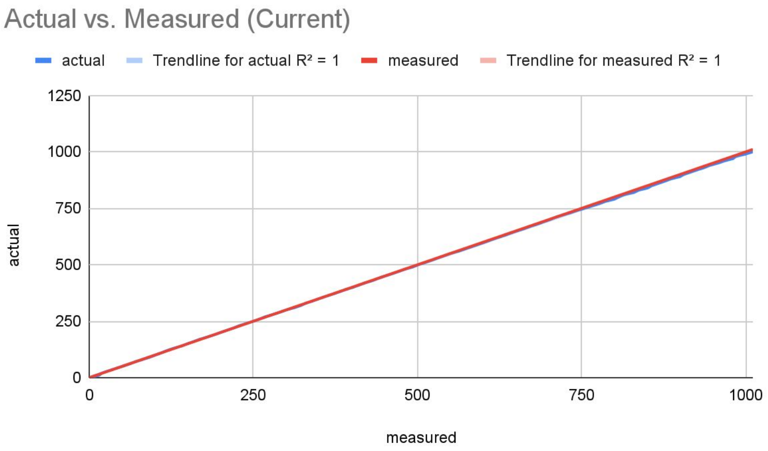
FT.8 - Current Sensor Test

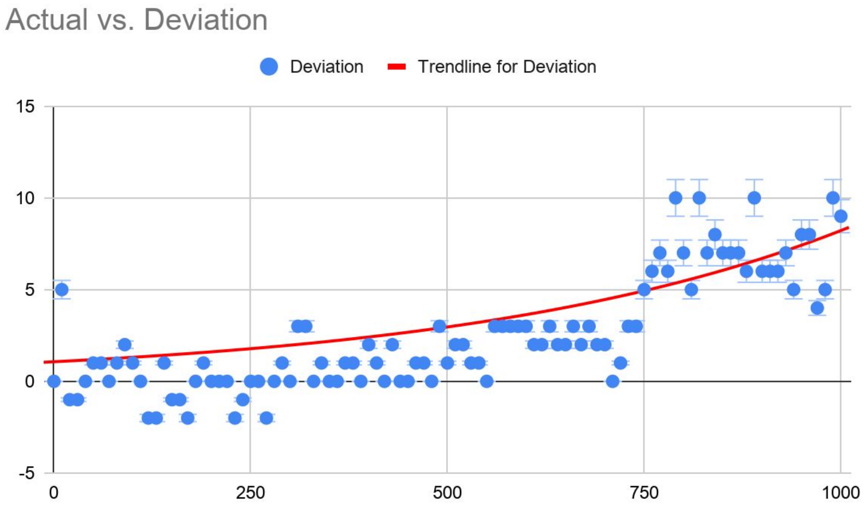
Setup:



FT.8 - Current Sensor Test

Results:





measured	0	19	29	40	200	210	220	228	239	250	260	268	280	291	300	603	612	622	633	642	652	663	672	692	702
actual	0	20	30	40	200	210	220	230	240	250	260	270	280	290	300	600	610	620	630	640	650	660	670	690	700

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FT.8 - Current Sensor Test

Conclusion:

- All four current-sensor channels showed highly linear, accurate readings across the tested range, confirming that the current sensing system is well-calibrated to measure within +/-.01A and meets engineering accuracy requirements.

START OF NEW TEST

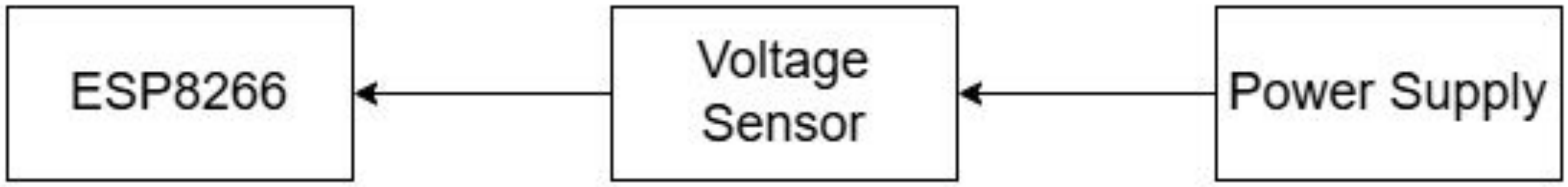
FT.9 - Voltage Sensor Test

Goal:

- Establish accurate and consistent readings with the Voltage Sensor
- Voltmeter used is HY3005D power supply (±1% voltage accuracy)
- ER7

FT.9 - Voltage Sensor Test

Setup:



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FT.9 - Voltage Sensor Test

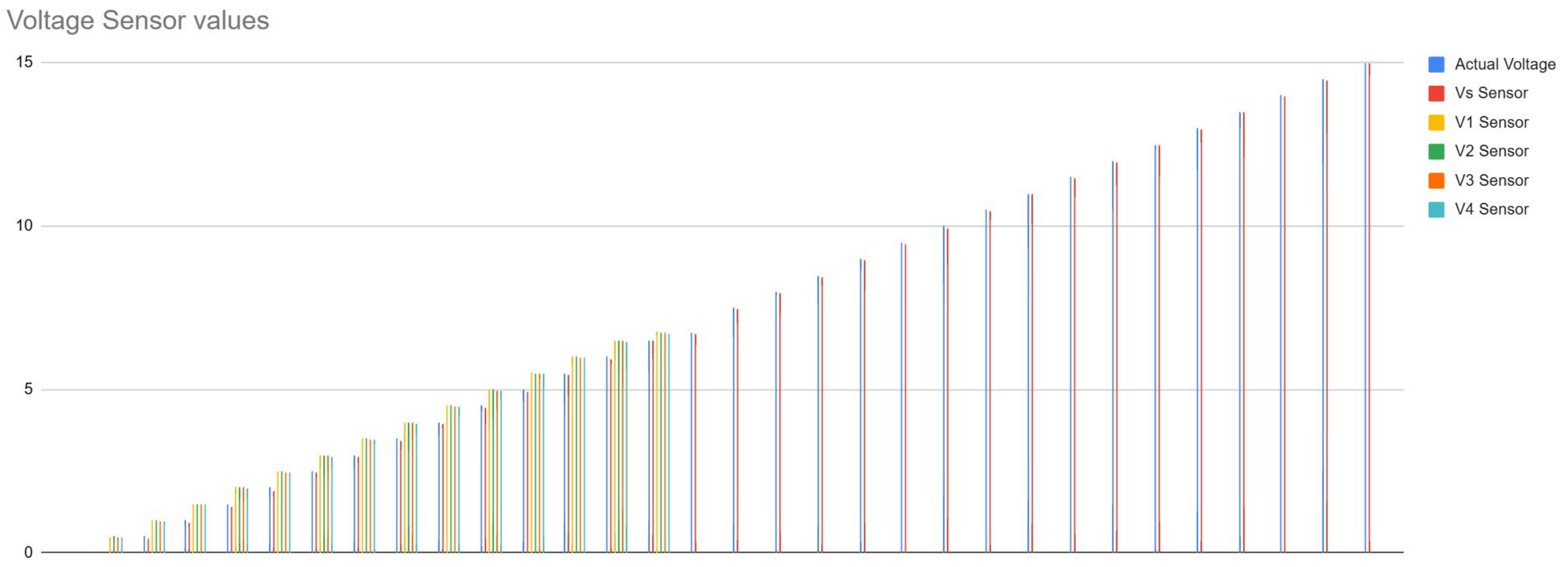
Results:

Actual Voltage	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	6.75	7.5
V1	0	0.49	1	1.5	2	2.51	3	3.5	4.01	4.51	5.01	5.51	6.01	6.51	6.77	N/A
V2	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	6.75	N/A
V3	0	0.47	0.97	1.48	2	2.47	2.98	3.48	3.98	4.48	4.98	5.48	5.98	6.48	6.73	N/A
V4	0	0.47	0.97	1.47	1.97	2.47	2.96	3.47	3.96	4.46	4.97	5.47	5.96	6.45	6.72	N/A
VS	0	0.45	0.91	1.41	1.91	2.45	2.94	3.44	3.94	4.42	4.92	5.44	5.921	6.5	6.71	7.45

8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7.96	8.46	8.95	9.45	9.95	10.45	11	11.47	11.97	12.48	12.97	13.49	13.97	14.47	14.98

FT.9 - Voltage Sensor Test

Results:



FT.9 - Voltage Sensor Test

Conclusion:

- Sensors calibrated and measures within ± 0.2V of the actual voltage measurement

START OF NEW TEST

ST.2 - Power Consumption Test

Goal:

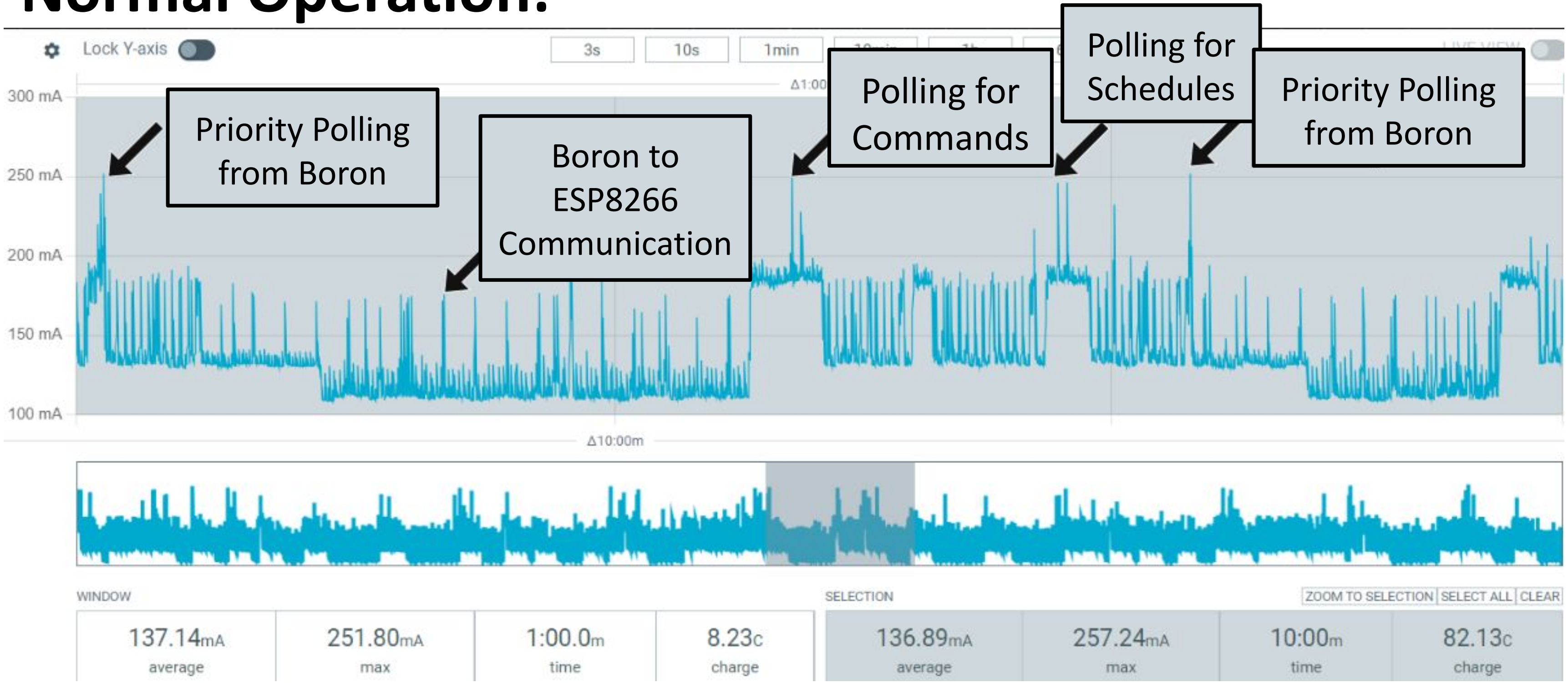
- Use the NORDIC Power Profiler Kit ii to measure how much power the internal system consumes under normal circumstances (accuracy 10% at 50-1000mA)
- ensure power measurements are within suspected power consumption calculations
- ER5, ER6

S1.2 - Power Consumption Test

Setup:

S1.2 - Power Consumption Test

Normal Operation:



ST.2 - Power Consumption Test

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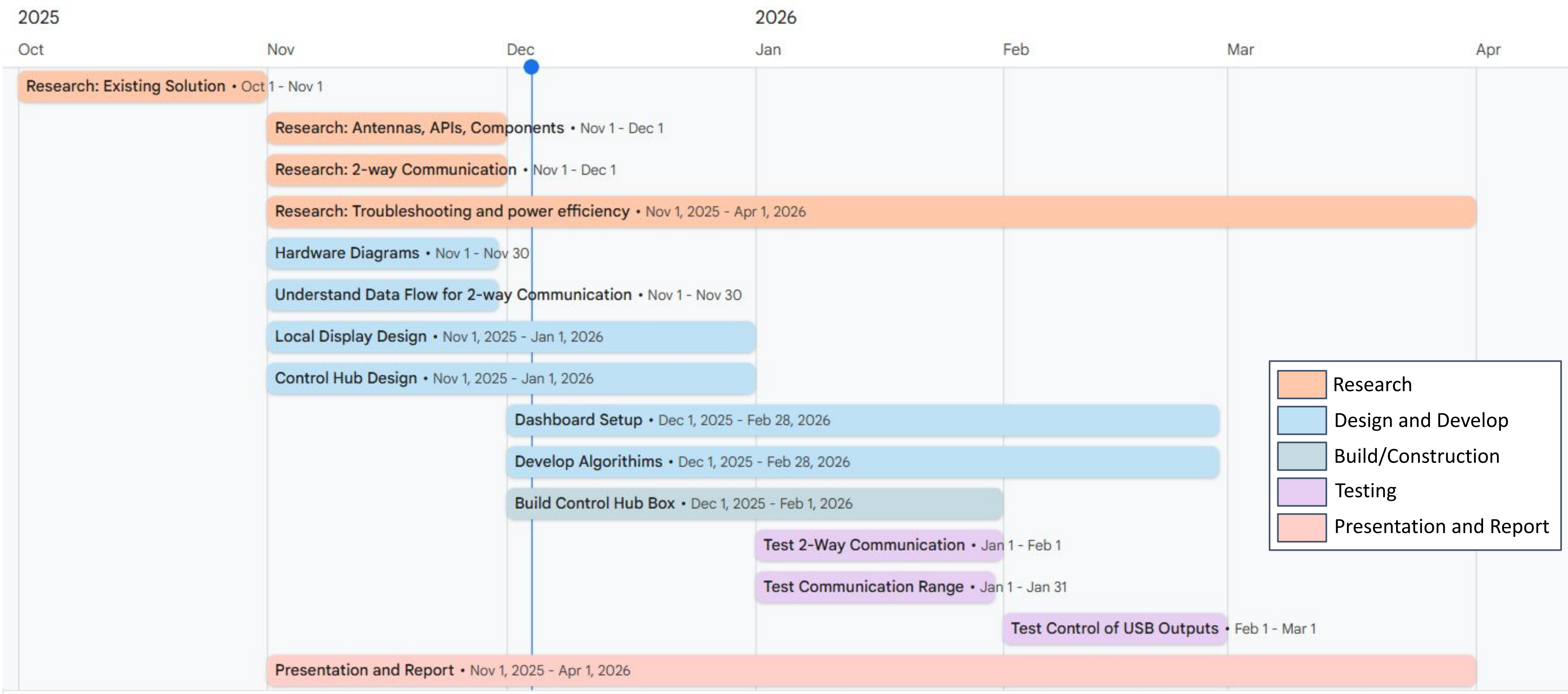
Conclusion:

- Normal operation draws an average current of about 137 mA, with peaks around 250 mA
- Test lasted 13 hours off of battery
- Power consumption internally is less than 5W
  - @ Peak operation, max consumption is 1.31W
  - @ Average operation, consumption is 0.717 W
- Estimated consumption was 0.716 W to 3.577W

Challenges and Risks

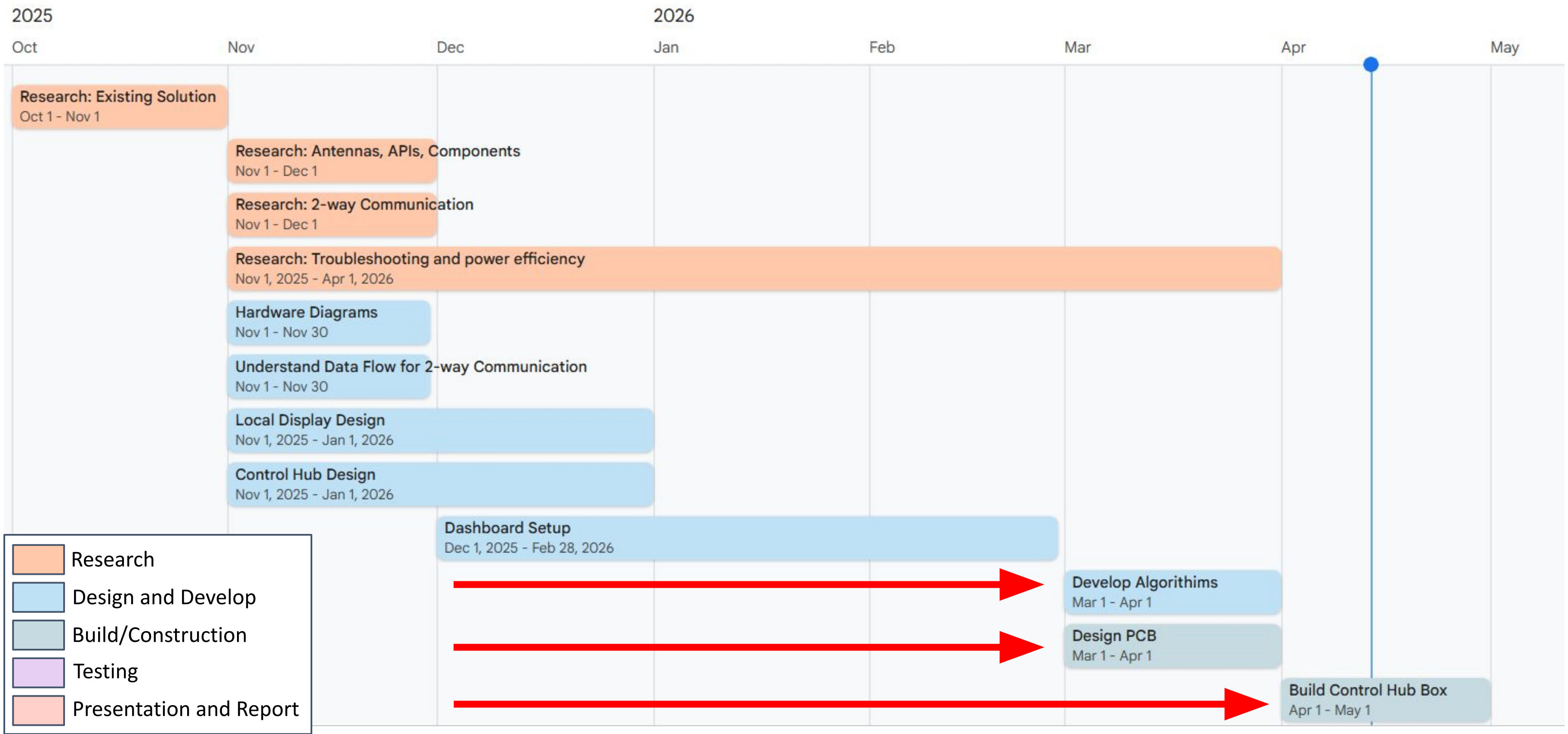
- USB outputs draw more current than expected
  - Likely to occur and result in major consequences
  - Solution: Implement fuses to protect the circuit
  - Solution: Implement IC that can control current going to the USB outlet
- Several days without sun to charge battery
  - Almost certain to occur with moderate consequences
  - Solution: Low power consumption mode (ex: send less frequent updates to dashboard)
  - Solution: Make system as power efficient as possible
- LTE Drops connection
  - Likely to occur with moderate consequences
  - Solution: Find suitable antenna for Particle Boron to extend range

Gantt Chart

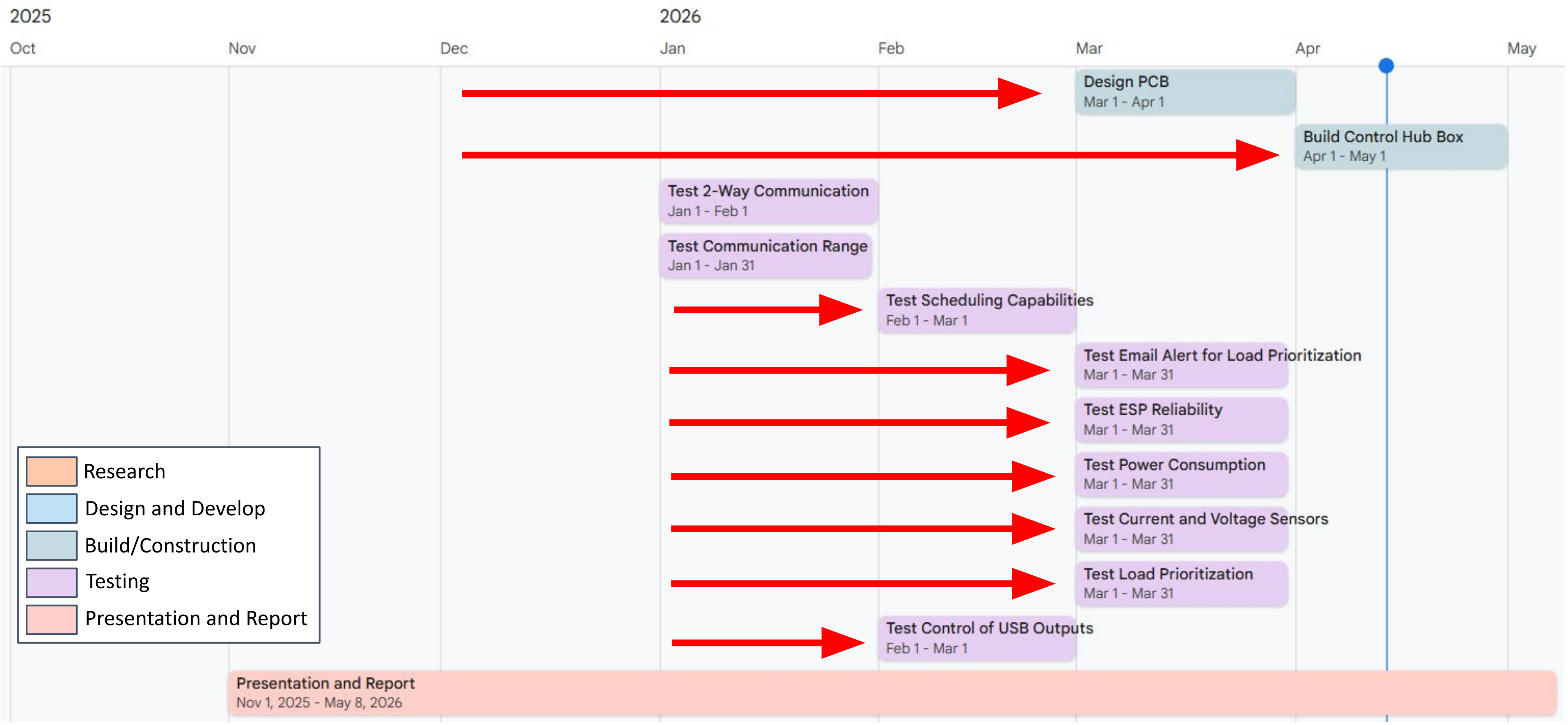


2025
2026
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Research: Existing Solution • Oct 1 - Nov 1
Research: Antennas, APIs, Components • Nov 1 - Dec 1
Research: 2-way Communication • Nov 1 - Dec 1
Research: Troubleshooting and power efficiency • Nov 1, 2025 - Apr 1, 2026
Hardware Diagrams • Nov 1 - Nov 30
Understand Data Flow for 2-way Communication • Nov 1 - Nov 30
Local Display Design • Nov 1, 2025 - Jan 1, 2026
Control Hub Design • Nov 1, 2025 - Jan 1, 2026
Dashboard Setup • Dec 1, 2025 - Feb 28, 2026
Develop Algorithims • Dec 1, 2025 - Feb 28, 2026
Build Control Hub Box • Dec 1, 2025 - Feb 1, 2026
Test 2-Way Communication • Jan 1 - Feb 1
Test Communication Range • Jan 1 - Jan 31
Test Control of USB Outputs • Feb 1 - Mar 1
Presentation and Report • Nov 1, 2025 - Apr 1, 2026
Research
Design and Develop
Build/Construction
Testing
Presentation and Report

Revised Gantt Chart



Revised Gantt Chart



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Schedule

- Research
  - Existing solutions (November)
  - Antennas, APIs, and components (December)
  - 2-way communication (November)
  - Troubleshooting and power efficiency (Always)
- Design
  - Hardware diagrams (November)
  - Data Flow for 2-way communication (November)
  - System box design (January)
  - Dashboard setup (March)
  - Develop algorithm for scheduling feature (March)
- Building
  - System box (April)
- Testing
  - 2-way communication (February)
  - Communication Range (January)
  - Control over USB outputs (February)
- Presentation and Report
  - Continuous improvement until final presentation

Division of Labor (Proposed):

- Kamryn: ESP network and Display
- Juan: Power efficiency and Hardware
- Jair: Boron communication and dashboard

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Project Milestones

Important Takeaways:

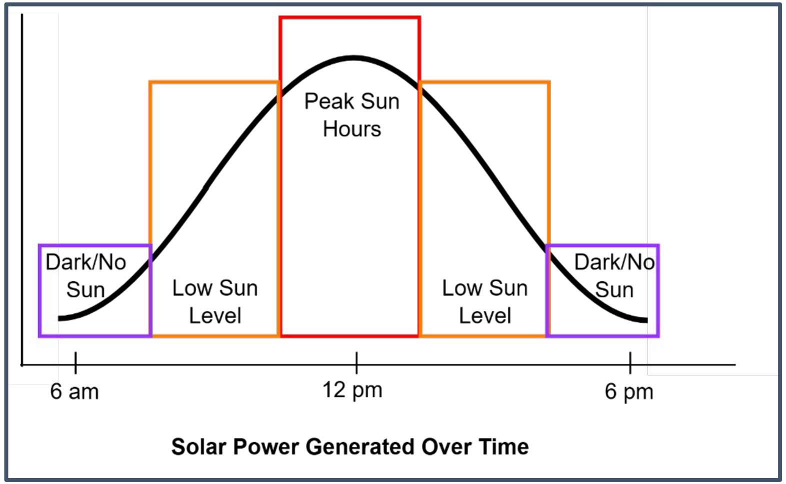
- Learning how to design and test the PCB
- Using the Nordic Power Profiler for power consumption testing
- Accepting shortcomings and going through several rounds of revisions
- Attention to detail in design, programming, and documentation
- Importance of documentation and testing

Task	**Projected finish date**
Dashboard and API Research	January
Testing IC (Power Measurements)	December
Two way communication	November
Power management algorithm	February

Further Developments

Proposed ideas for future revisions and developments of REACH:

- Power balancing at the outlets (USB ports)
- Work with higher voltage loads (110V and inverter)
- Hotspot functionality
- Incorporating AI
  - Weather prediction and scheduling
- Message Queuing Telemetry Transport (MQTT) to lower power consumption
- System temperature regulation for batteries in the remote locations

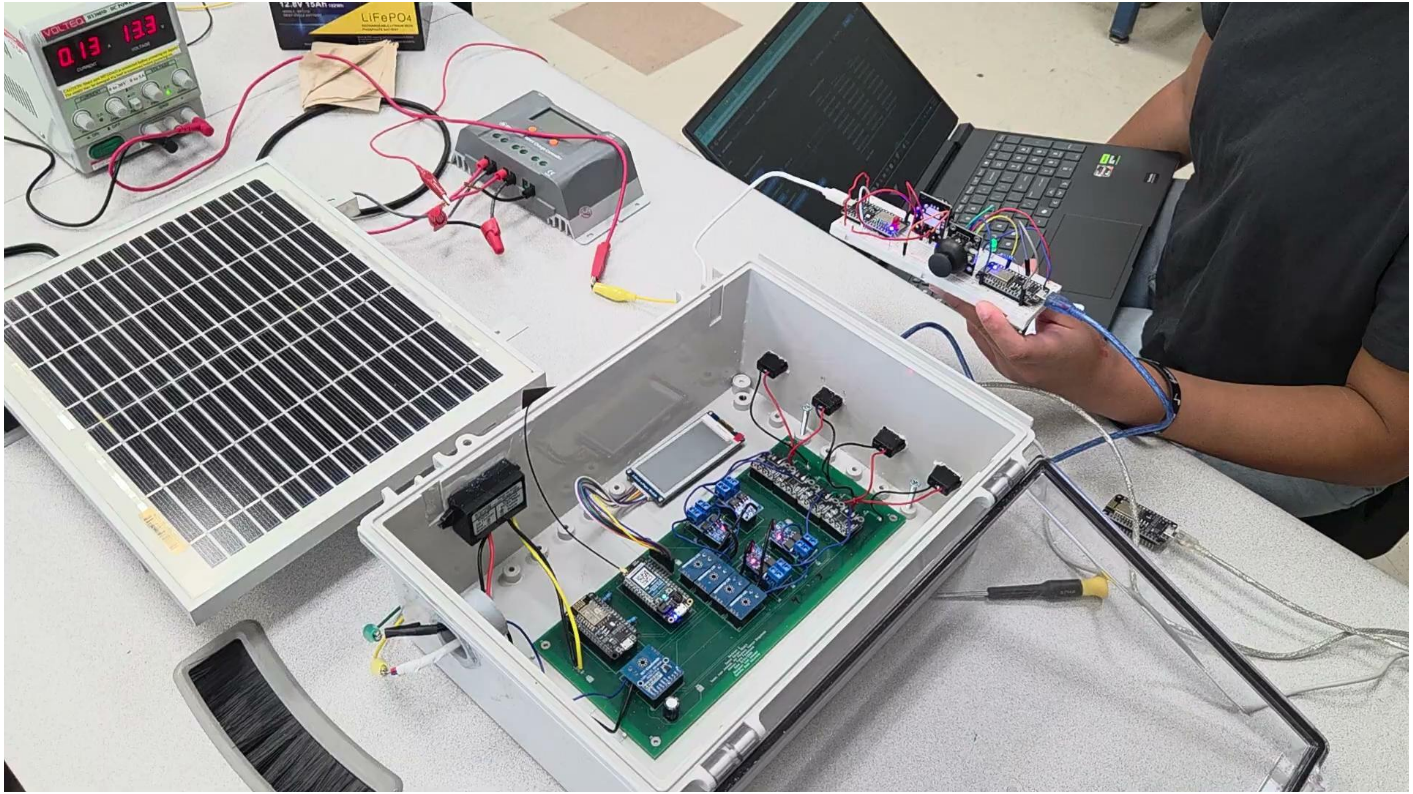


Supporting Courses

- EE220: Circuits
- EE310: Microprocessor and System Design
- EE470: Internet of Things
- EE465: Networking and Networking Management

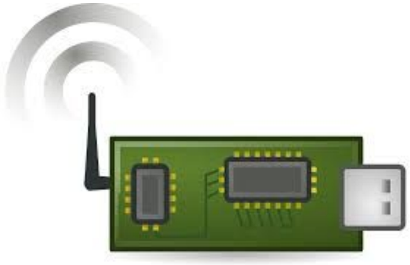
Questions/Comments

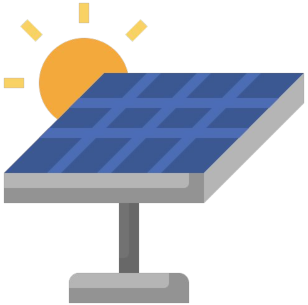
Demo Video



Proposed Solution

REACH is a power management system that utilizes **solar energy** to simultaneously **provide power** and control services for multiple low-power field devices. Each USB power outlet can be **managed and monitored** for device health, power usage, and fault detection. REACH also provides connectivity to these devices through remote access from **a local display panel** and a **web dashboard**. Users can minimize on-site maintenance and maximize productivity by monitoring power levels, controlling device use, and enabling system alerts.





Physical Description

Physical Description

- Box enclosure suitable for outdoor use
  - Antenna attachment (extend connectivity: WiFi hotspot and LTE)
  - Door to access components inside
- Inside the box
  - 4 USB outlets
  - Transceiver Module
  - Switches and sensors hub
- Local Display Panel
  - Display screen
  - Buttons for control over outlets

Proposed Solution: REACH

REACH is a compact, off-grid IoT connectivity and power-management platform designed for rural and remote locations. It provides:

- Seamless integration with existing local power sources
- WiFi connectivity for low-power devices in off-grid environments
- Intelligent power management, load control, and scheduling features
- Remote monitoring and remote control of all connected devices
- A locally hosted configuration website ???? IS IT TRUE?
- A cloud-based dashboard with remote access and maintained historical data

REACH
POWER SOLUTIONS

Connect Seamlessly to Your Energy and Internet Needs

Empower Your Power System Efficiently

SEAMLESS INTEGRATION WITH EXISTING LOCAL POWER SOURCES

Intelligent power management, load control, and scheduling features

Proposed Solution

Key Features of REACH:

- **Rechargeable Battery:** Recharge with solar energy and provides continuous power when sunlight isn't available (night/bad weather)
- **Solar Power:** Sustainable power source allows off-grid operation
- **Handheld Device:** Users can monitor and control system locally
- **Web-Based Dashboard:** Real-time remote monitoring and control of the REACH system
- **Multiple Power Outlets:** Simultaneously power and individually control each outlet, connect multiple low-power field devices (ex: camera, sensors, actuators)
- **Connectivity:** Connects user to their remote devices through WiFi/communication network
- **Scalable Architecture:** Expandable structure allows for future high power developments and advanced connectivity options

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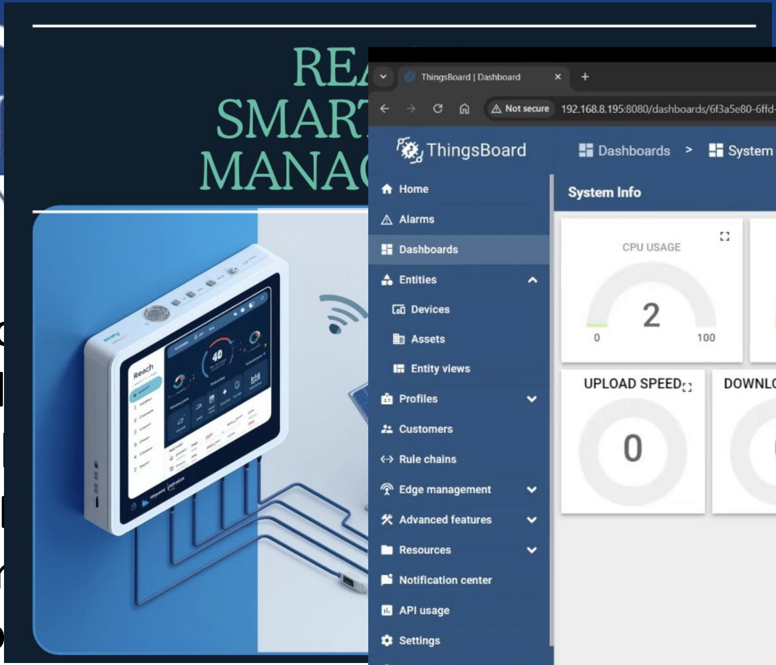

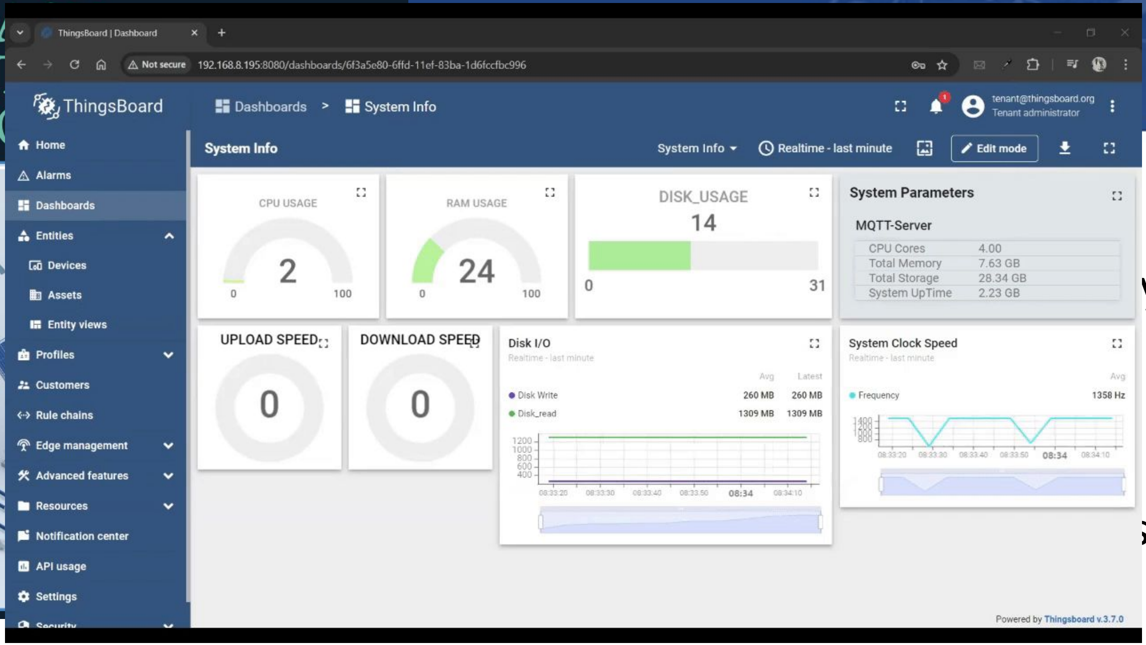

REACH can effortlessly connect to existing off-grid power systems. It provides intelligent remote management and scheduling for optimal power usage, while enabling real-time monitoring, remote control, and long-term data access for field devices. This reduces labor, downtime, and operational uncertainty.

Value Proposition

REACH can effortlessly connect to existing off-grid power systems. It provides intelligent remote management and scheduling for optimal power usage, while enabling real-time monitoring, remote control, and long-term data access for field devices. This reduces labor, downtime, and operational uncertainty.

New Suggested Marketing Requirements

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MR1. The system shall provide control over multiple USB/DC outlets for remote field devices, including the ability to toggle power status, manage load prioritization, and receive status feedback locally and remotely.

MR2. The system shall support remote scheduling, load management, and event-based control to optimize energy efficiency and ensure prioritized delivery to critical devices.

MR3. The system shall support LTE connectivity for remote access to a cloud-based dashboard that displays outlet status, system alerts, voltage/current metrics, historical data visualization, and control functionality.

MR4. The system shall include a local display panel showing outlet status, battery SOC, estimated charge/discharge time, and offer control via buttons including emergency shutoff functionality.

MR5. The system shall easily connect to typical existing solar power systems, including off-the-shelf solar panels, solar charge controllers, and standard DC batteries.

New Suggested Marketing Requirements

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MR6. The system shall monitor, log, and display voltage, current, power usage, and SOC metrics for battery and each individual output port, with data accessible both locally and remotely.

MR7. The system shall include circuit protection for USB/DC outlets, including current limiting and surge protection, to prevent damage to connected devices.

MR8. The system shall be lightweight and portable for easy transport to field locations.

MR9. The system shall be water resistant for outdoor deployment.

MR10. The system shall provide wireless connectivity in off-grid environments via a built-in WiFi hotspot, supporting local access to the configuration web page and control interface.

Suggested Engineering Requirements

ER1. The system shall provide 4 USB outlets outputting 5V ± 0.1V at up to 900mA (4.5W max per outlet), with on/off control via both local and remote dashboard interface, with a command execution delay of ≤ 5 seconds. **(MR1)**

ER2. The system shall support scheduled on/off control and load prioritization of outlets through the dashboard interface, with execution latency not exceeding 30 seconds from the scheduled time under normal conditions. **(MR2)**

ER3. The dashboard shall display the latest system metrics (SOC, outlet voltage/current, outlet status) with a data update frequency of 1 data set per 60 seconds, and a value accuracy of ±0.4V and ±0.1A. **(MR6)**

ER4. The system shall detect and log alerts for low SOC, overcurrent, or outlet faults, and transmit them to the dashboard with a maximum delay of 1 minute. (**MR7**)

Suggested Engineering Requirements

ER5. The local display shall present outlet status, SOC (±10% accuracy), and estimated charge/discharge time. Display shall refresh every 10 seconds, and allow local outlet control and emergency shutoff via physical buttons. **(MR4)**

ER6. The system shall operate using a 12V DC input from solar panels providing ≥ 30W, and sustain functionality for at least 5 hours without solar input using a 12V/7.5Ah battery. **(MR5)**

ER7. The system shall measure and log voltage, current, and power for solar input, battery, and each output port with a resolution of 0.1V and 0.1A, and synchronize logs with the cloud dashboard every 10 minutes. **(MR6)**

ER8 All output ports shall include protection via resettable fuses rated ≤ 1A, and support over-voltage protection up to 6V to prevent damage to connected devices. **(MR7)**

ER9 The entire system, including enclosure, outlets, and display, shall weigh ≤ 10 lbs and fit within a form factor of 15 x 15 x 35 cm. **(MR8)**

Suggested Engineering Requirements

ER10. The enclosure and all external components shall meet the IP65 standard for water and dust resistance suitable for outdoor deployment. **(MR9)**

ER11. The system shall create a local WiFi hotspot supporting at least 4 simultaneous connections within a 10-meter radius, with the local control webpage loading within 5 seconds of connection. **(MR10)**

ER12. The internal system (excluding USB outlets) shall consume no more than 9W during typical operation to maximize runtime on battery. **(MR5, MR7)**

Dashboard Simulation

Goal:

- Simulate and develop a user friendly interface to switch through 4 options of outlets to display the available power, power consumption, and current draws going through each outlet through a series of graphs, while also showing the load profile of the system

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Dashboard Simulation (Theory)

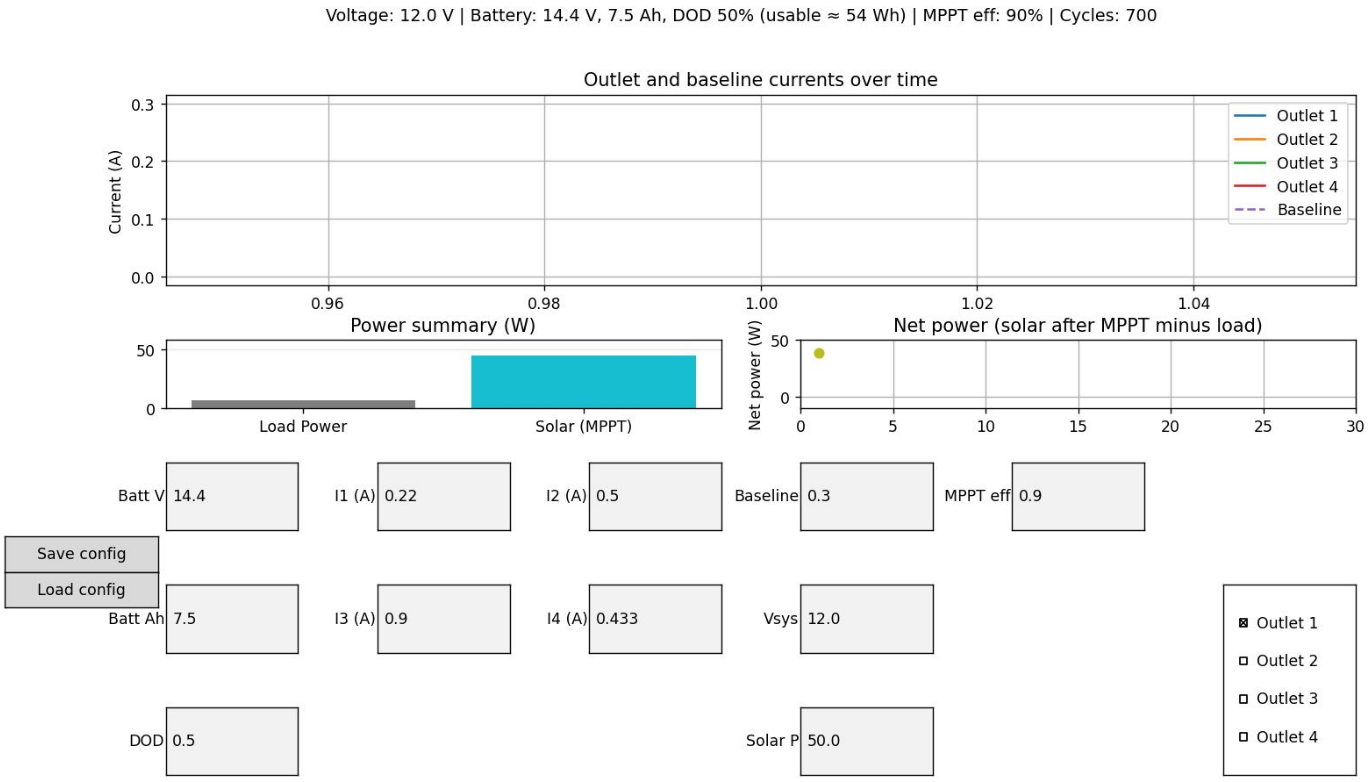
Setup:

3 variations of simulation:

O2 on O1 off

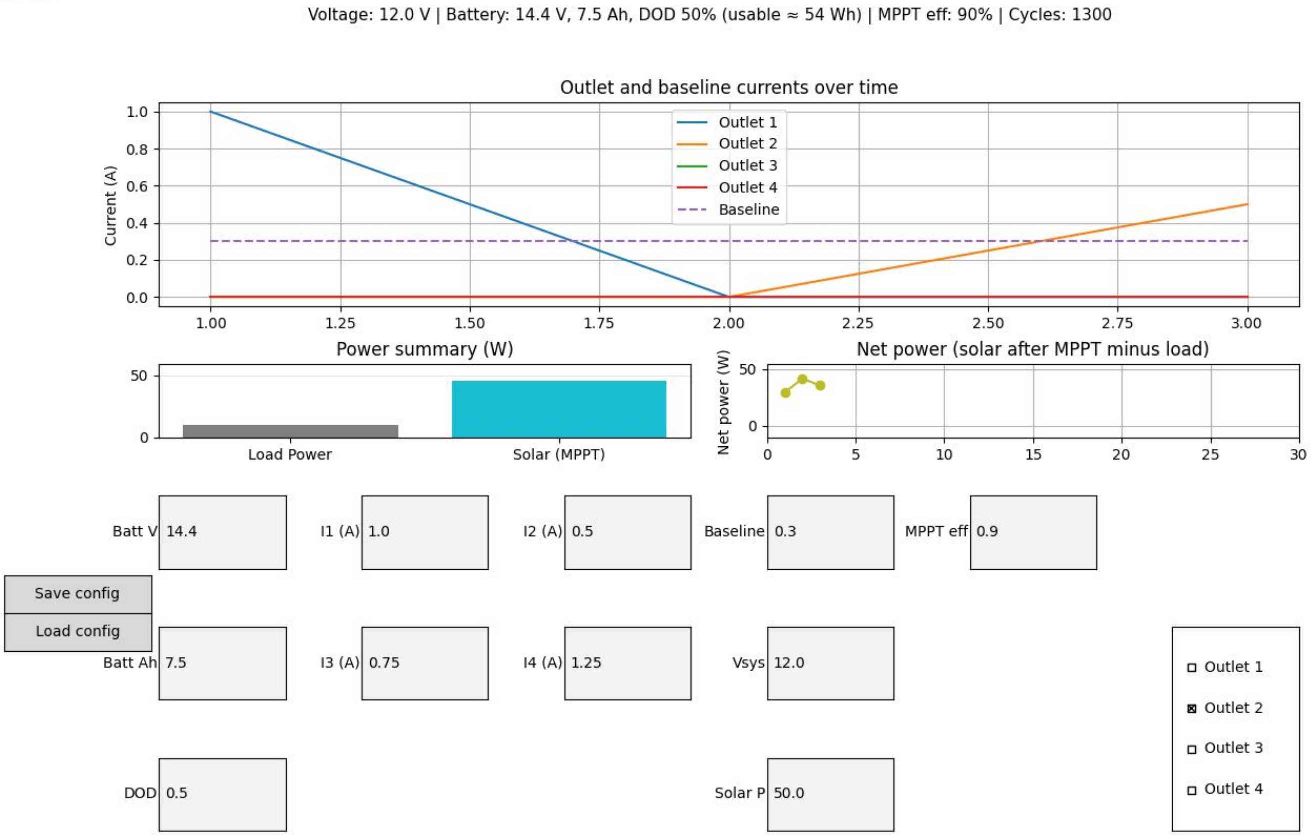
O4 on O3 O2 O1 off

All Outlets on



Dashboard Simulation (Theory)

Results: O2 on O1 off



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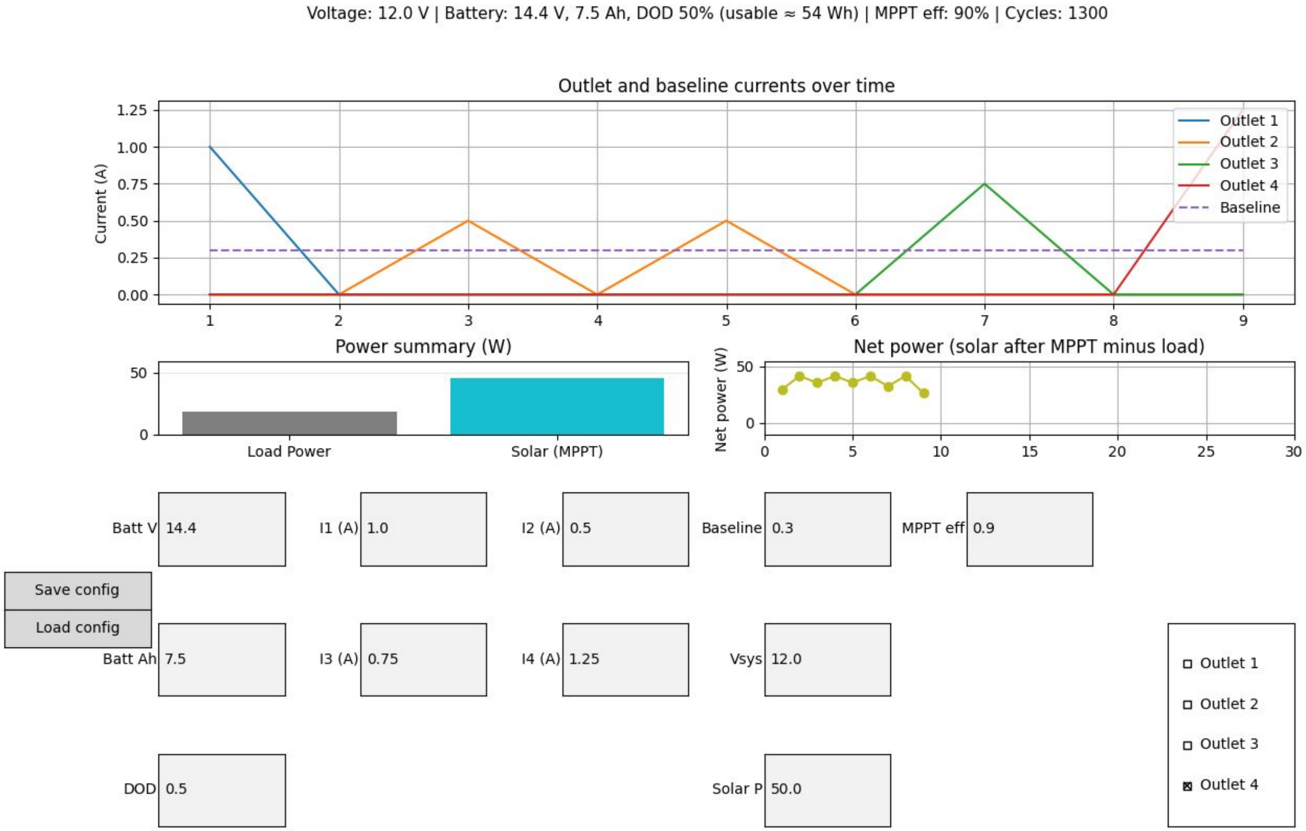
Dashboard Simulation (Theory)

Results:

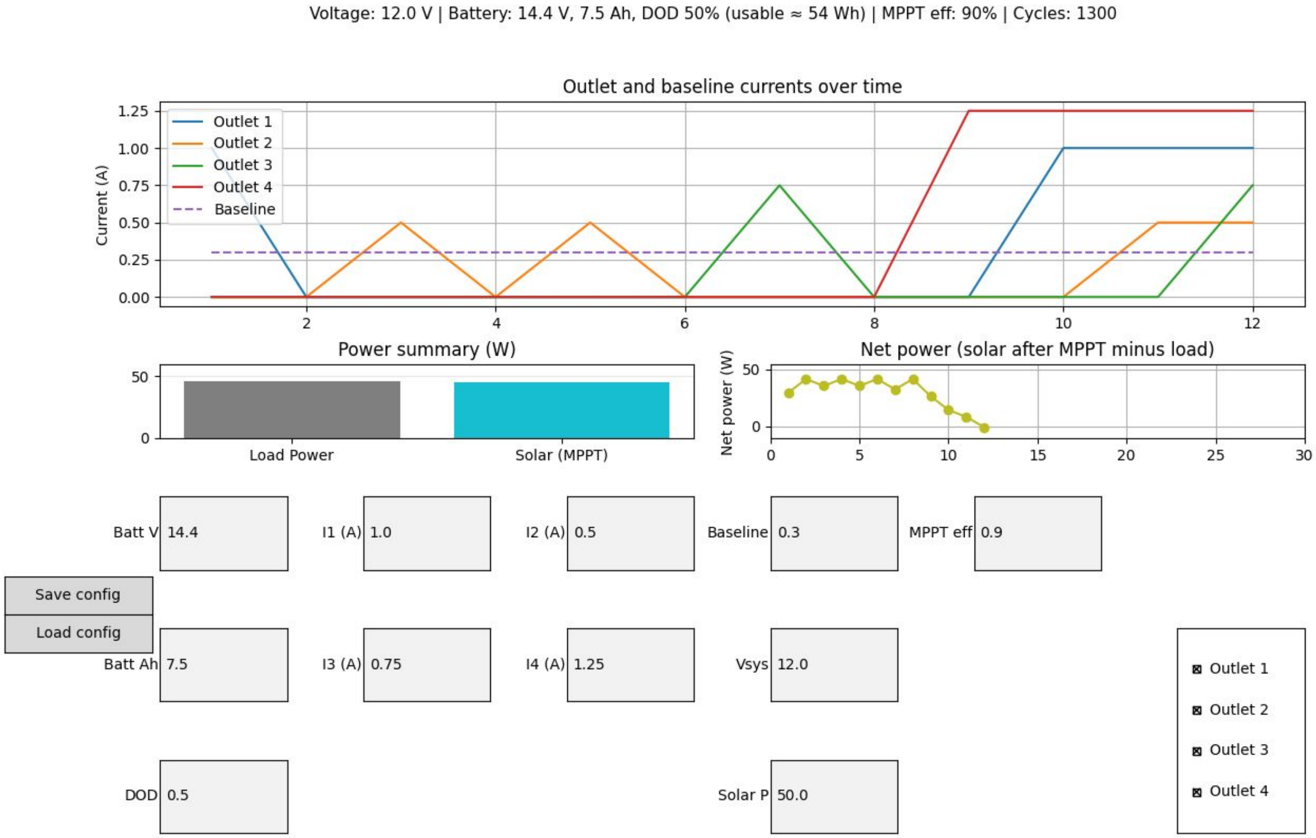
O4 on O3

O2 O1



Dashboard Simulation (Theory)

Results: All Outlets



Conclusion:

The simulation was successful in running at low quality and having the user input the specifications manually, while displaying the overall load profile. In future development, I would like to implement a more accurate graphical display, while also connecting this algorithm to receive data from the microcontroller for accurate data processing.

Solar System Algorithm (Theory)

Goal:

- Create an algorithm that customers can use for calculations regarding the solar powered charging system
- Be able to output how much power is provided from the customer’s solar charging system
- Allow customers to input the specs for their solar panel, battery, and solar charger

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Solar System Algorithm (Theory)

Setup:

- Inputs:
    - Solar panel (W), battery (V), battery capacity (Ah), peak discharge (A), hours of full sun (hr), battery SoC, charge rate, etc
- Outputs:
    - Total battery capacity (Wh), energy provided by battery (Wh), daily load consumption of REACH (Wh/day), solar energy provided per day (Wh/day), etc

Solar System Algorithm (Theory)

Results:

```
----- REACH Solar System Calculation Tool -----

Solar panel wattage (W): 12
Battery voltage (V): 12
Battery capacity (Ah): 7.5
Battery peak discharge current (A): 108
Battery State of Charge (ex: 20% = 0.2): 0.2
CC/CV Efficiency (ex: 0.95): 0.95
Charge rate/C-rate (ex: 0.5 for 0.5C): 0.5
Solar Charger Efficiency (ex: 95% = 0.95): 0.95
Average REACH system load (W): 9.95
Estimated peak/full sun hours per day: 5.9
Use simplified model just using peak sun hours (Option A) or approximated sunrise/sunset curve (Option B)? [Select A or B]: A

----- Calculated Results -----
Total battery capacity: 90.0 Wh
Maximum battery discharge power: 1296.0 W
Energy provided by battery until shut off (no solar panel): 72.0 Wh
Solar energy provided per day: 67.3 Wh/day
Daily load (REACH) consumption: 238.8 Wh/day
Daily energy balance (solar - load): -171.5 Wh/day
Time to recharge battery: 1.68 hours
Runtime with no sun available: 0.30 days
Hours of effective sun to recharge battery from cutoff with load ON: 49.66 hours.
```

Solar System Algorithm (Theory)

Conclusion:

- Successfully able to make solar calculations that will be helpful for user
- Some of the data that is outputted can be used in the other algorithm
- Work on fine-tuning some of the calculations, like the energy provided based on sun hours

LTE Connectivity Test

Conclusion:

- Successfully transmitted data created by sensor connected to ESP8266
- Event driven transmission is not only good for testing but could be implemented in final design
- UART can be used to allow both devices to communicate with each other

LTE Connectivity Test

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Results:

ESP measurements (sent to boron)

```
node_name=node-1&temperature=21.2&humidity=60.7
node_name=node-1&temperature=21.2&humidity=60.8
node_name=node-1&temperature=21.1&humidity=60.8
node_name=node-1&temperature=21.2&humidity=60.8
node_name=node-1&temperature=21.2&humidity=60.8
node_name=node-1&temperature=21.1&humidity=60.8
```

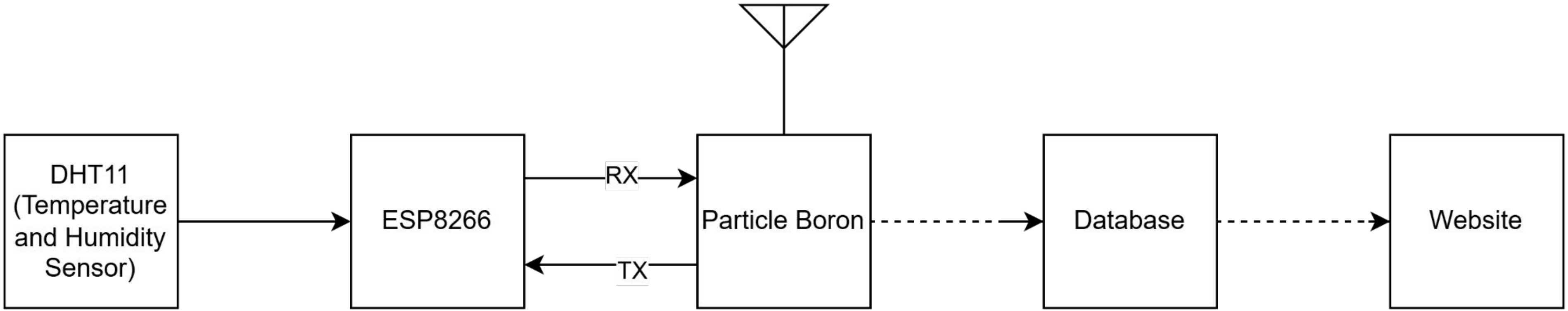
Boron data transmitted

```
PS C:\Users\jairp\OneDrive\Documents\ParticleWorkbench\UARTCONNECT> particle serial monitor
Opening serial monitor for com port: " COM6 "
Serial monitor opened successfully:
Published (button press): node_name=node-1&tempnode_name=node-1&temperature=21.0&humidity=62.1
Published (button press): node_name=node-1&temperature=21.0&humidity=62.2
```

node-1	2025-11-10 23:38:13	22	64
node-1	2025-11-10 23:51:12	22	63
node-1	2025-11-10 23:51:13	22	66
node-1	2025-11-11 22:29:28	21	62

LTE Connectivity Test

Setup:



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LTE Connectivity Test

Goal:

- Transmit data via LTE
- Have the values be inserted to database
- Utilize UART transmission type to send data from ESP8266 to Particle Boron 404x

START OF NEW TEST

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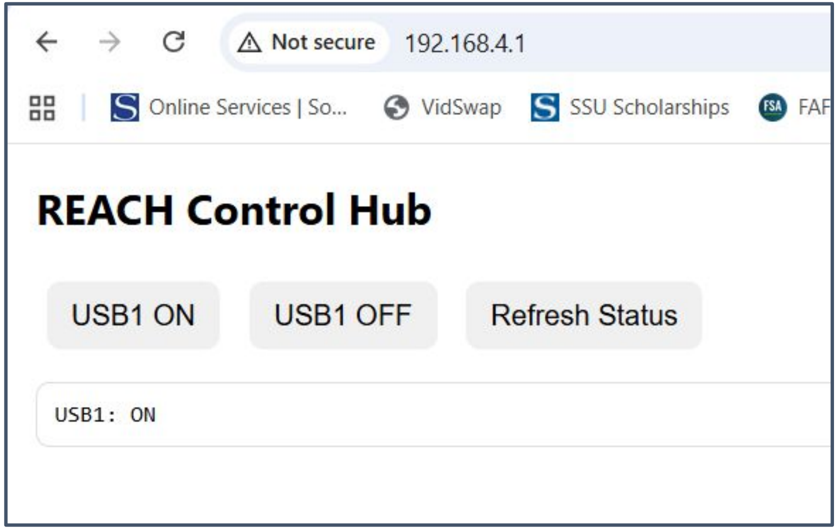
WiFi Control Test

Conclusion:

- Successfully able to create local WiFi network from ESP8266
- Successfully able to create locally hosted web page to change status of an outlet
  - Buttons, curl, URL
- Successfully able to connect devices to network and access web page

WiFi Control Test

Results:

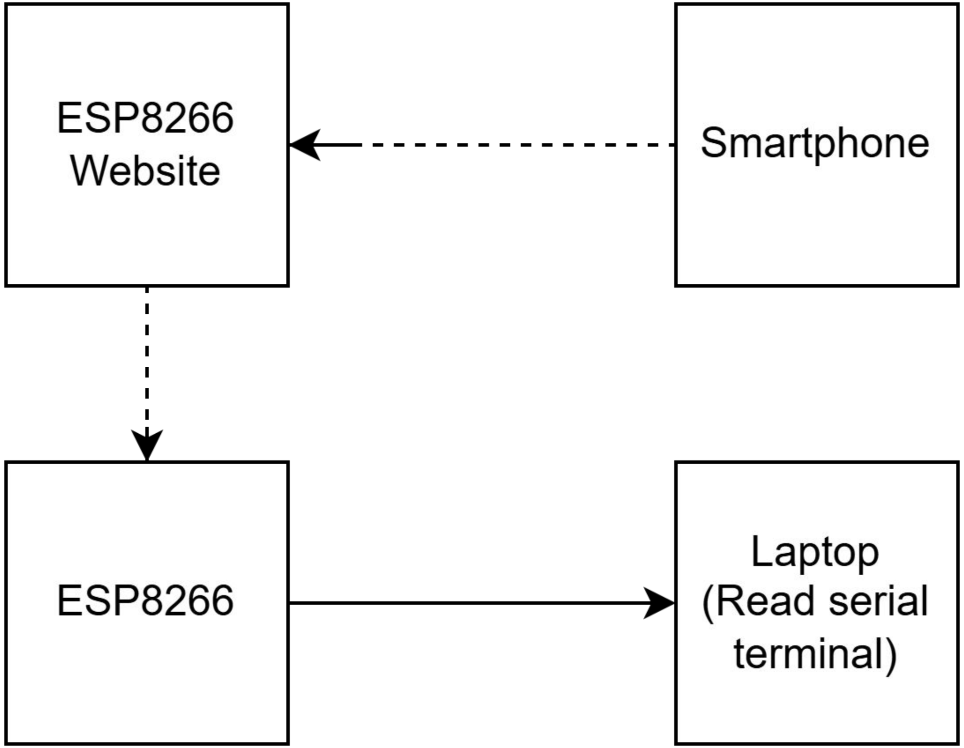



```
ESP8266 AP IP Address: 192.168.4.1
ESP8266 Network Available
Connect to the Wi-Fi network: esp8266_hotspot

Open this URL in your browser:
    http://192.168.4.1/
REACH HTTP server started
Connected clients: 0
Connected clients: 0
Connected clients: 0
Connected clients: 1
```

WiFi Control Test

Setup:



WiFi Control Test

Goal:

- Setup WiFi network on ESP8266 to provide connectivity
- Create simple web page that's locally hosted on ESP8266
- Connect devices to local network and make changes to website

START OF NEW TEST

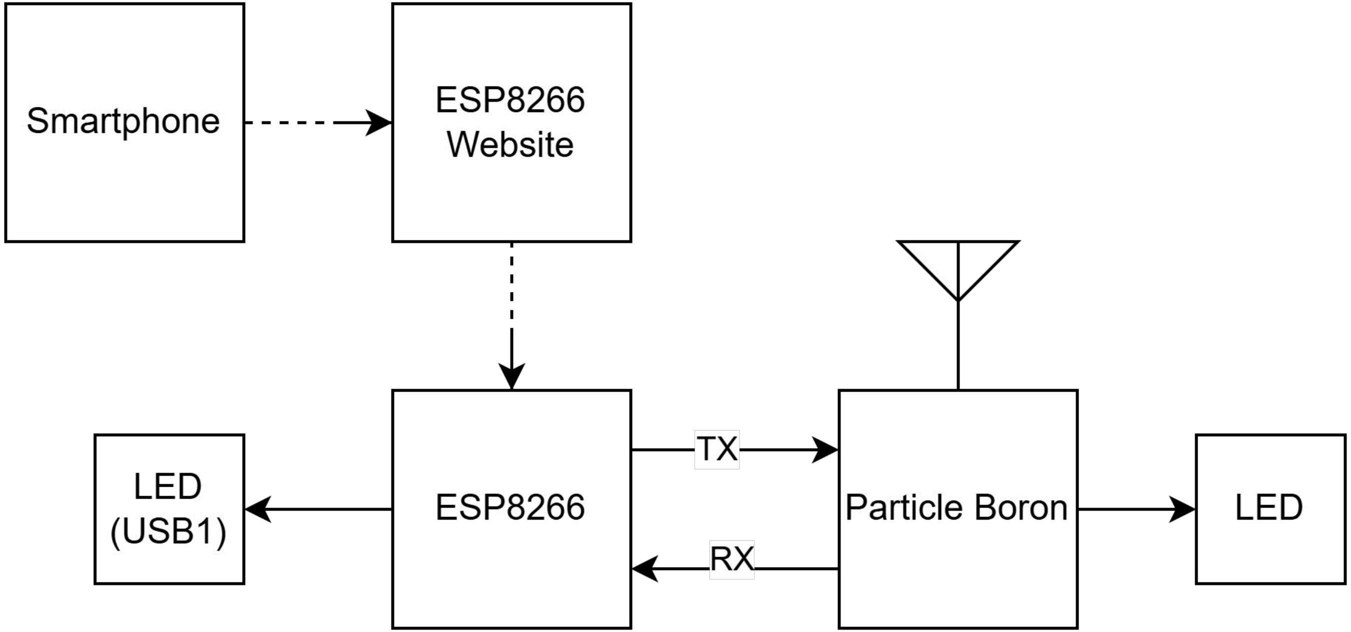
2-Way Communication Test

Goal:

- Establish basic 2-way communication using the Particle Boron and ESP8266
- See the messages being sent and received in the terminals
- Control some sort of output (ex: relay, LED)

2-Way Communication Test

Setup:



2-Way Communication Test

Results:

```
Received from Boron: USB1=OFF
Connected clients: 0
Sent to Boron: ESP status: USB1=OFF
Received from Boron: USB1=ON
Connected clients: 0
Received from Boron: USB1=OFF
Connected clients: 0
Sent to Boron: ESP status: USB1=OFF
Received from Boron: USB1=ON
Connected clients: 0
Received from Boron: USB1=OFF
Connected clients: 0
Sent to Boron: ESP status: USB1=OFF
Received from Boron: USB1=ON
```

ESP Terminal

```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL

Sent to ESP: USB1=OFF
Sent to ESP: USB1=ON
Received from ESP: ESP status: USB1=ON
Sent to ESP: USB1=OFF
Sent to ESP: USB1=ON
Received from ESP: ESP status: USB1=ON
Sent to ESP: USB1=OFF
Sent to ESP: USB1=ON
Received from ESP: ESP status: USB1=ON
Sent to ESP: USB1=OFF
Sent to ESP: USB1=ON
Received from ESP: ESP status: USB1=ON
```

Boron Terminal

2-Way Communication Test

Conclusion:

- Successfully able to establish 2-way communication between the two microcontrollers
- Successfully able to see when messages were sent and received between the Boron and ESP8266
- Successfully able to turn an LED on and off using commands from the Boron, ESP, and local website

START OF NEW TEST

INA219 Current and Voltage Accuracy Test

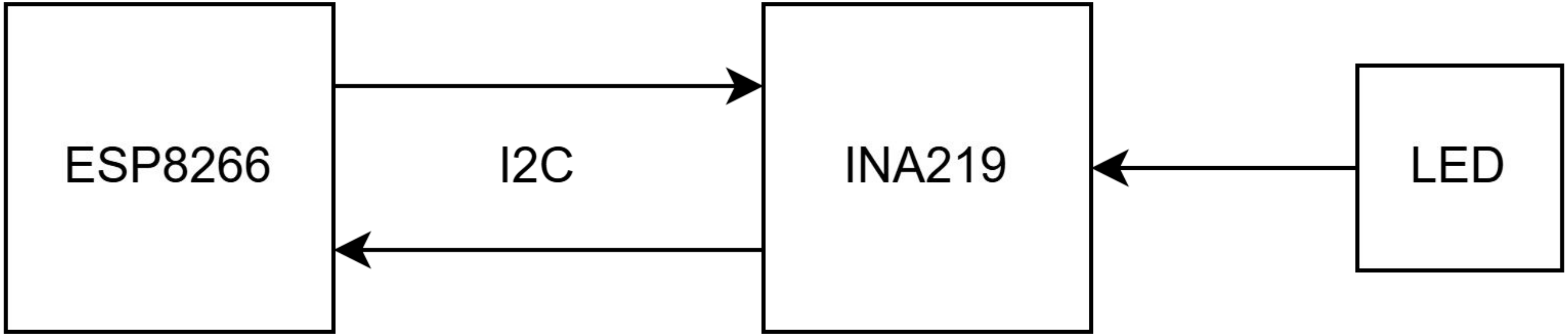
Goal:

- INA219 is used for measuring current and voltage, and in this application, will be used for measuring the outlet current and voltage.
- See if component is viable for system

INA219 Current and Voltage Accuracy Test

Setup:

INA219, which connected to an ESP8266 via I2C



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INA219 Current and Voltage Accuracy Test

Results:

```
Bus (V-):         0.936
Load Voltage:     0.938
Current (mA):     18.000
Power (mW):       16.000
```

Tested (V)	Actual load (V)	% error
0	0	0
1	0.976	2.4
5	4.2	16

```
Bus (V-):         0.948
Load Voltage:     0.949
Current (mA):     9.300
Power (mW):       8.000
```

Tested (A)	Actual (A)	% error
0	0.0	0
0.012	0.013	8.3
0.021	0.018	14.2

INA219 Current and Voltage Accuracy Test

Conclusion:

- Look for new IC’s, we conclude there is drift when current gets too high, and different IC’s will be required

Problem Statement

Remote and rural locations, such as ranches, farms, vineyards, and nature preserves, rely on field devices like sensors, actuators, and cameras.

- Although power generators and remote power systems exist, they lack reliable connectivity and remote power management over the devices.
- As a result → Difficult to manage these field devices and monitor their status or health

Project Milestones

Task	Projected finish date
Dashboard and API Research	January
Testing IC (Power Measurements)	December
Two way communication	November
Power management algorithm	February

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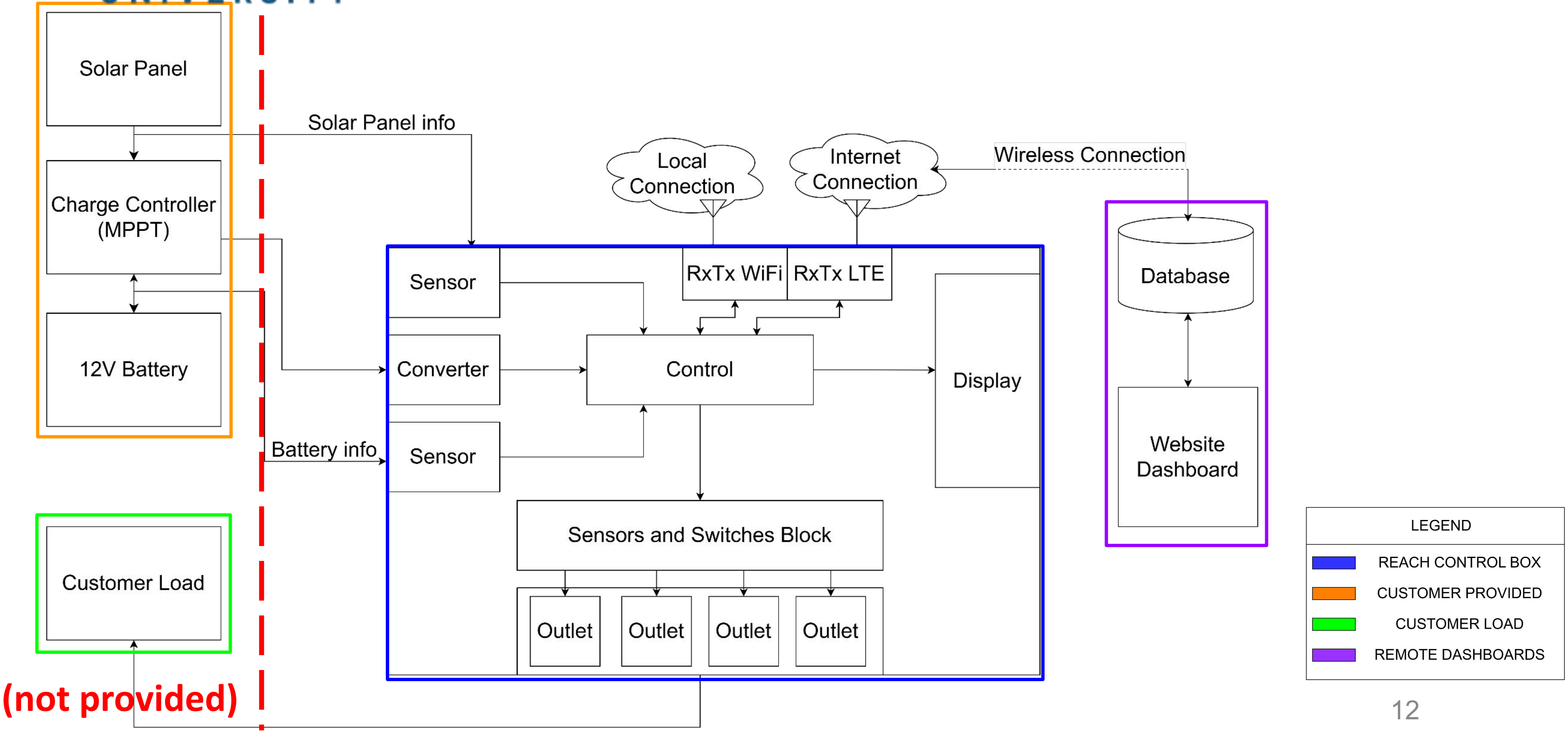
High Level Diagram



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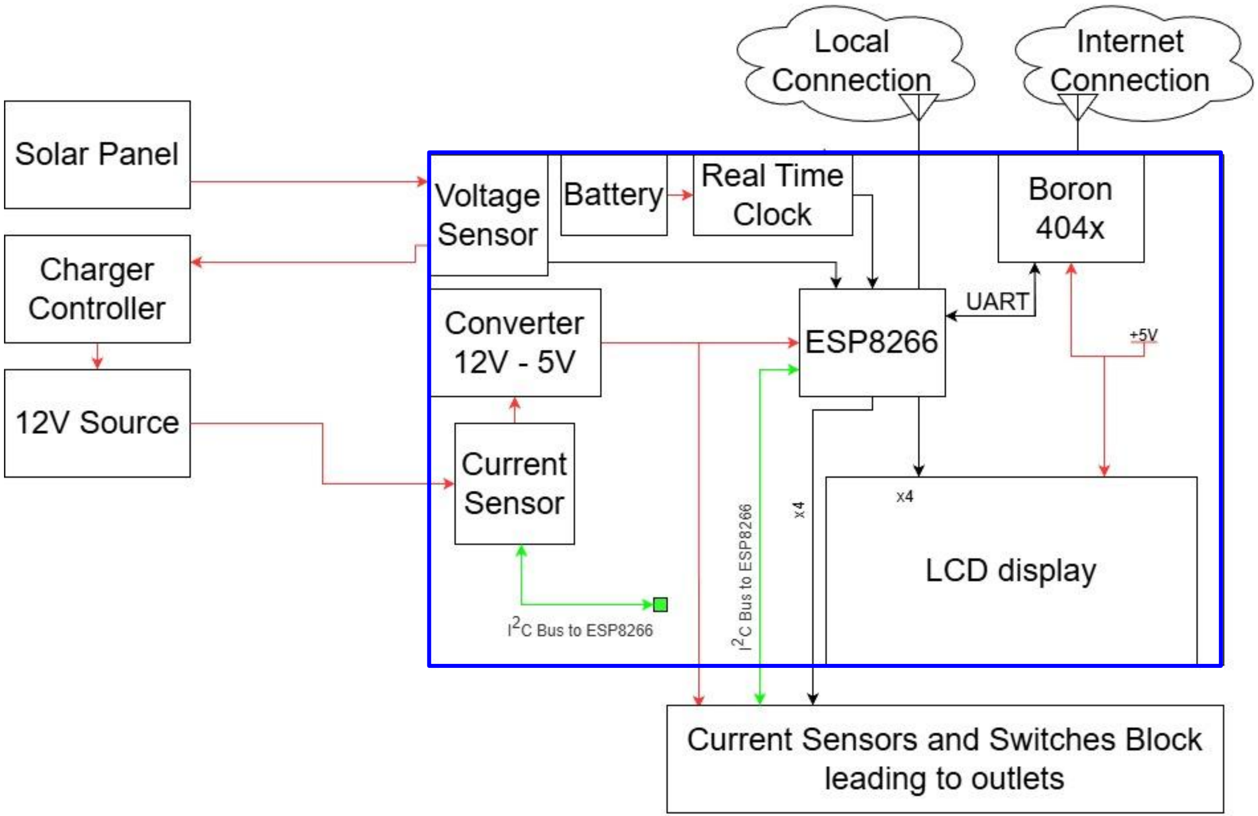
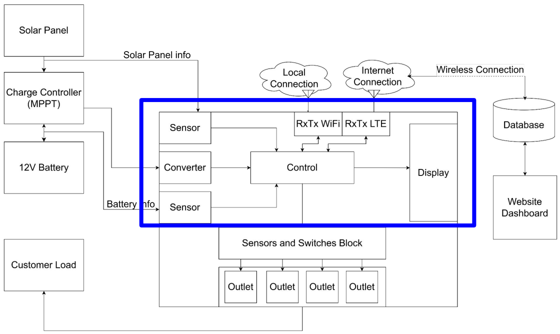
High Level Diagram: Control Hub





LEGEND
REACH CONTROL BOX
CUSTOMER PROVIDED
CUSTOMER LOAD
REMOTE DASHBOARDS

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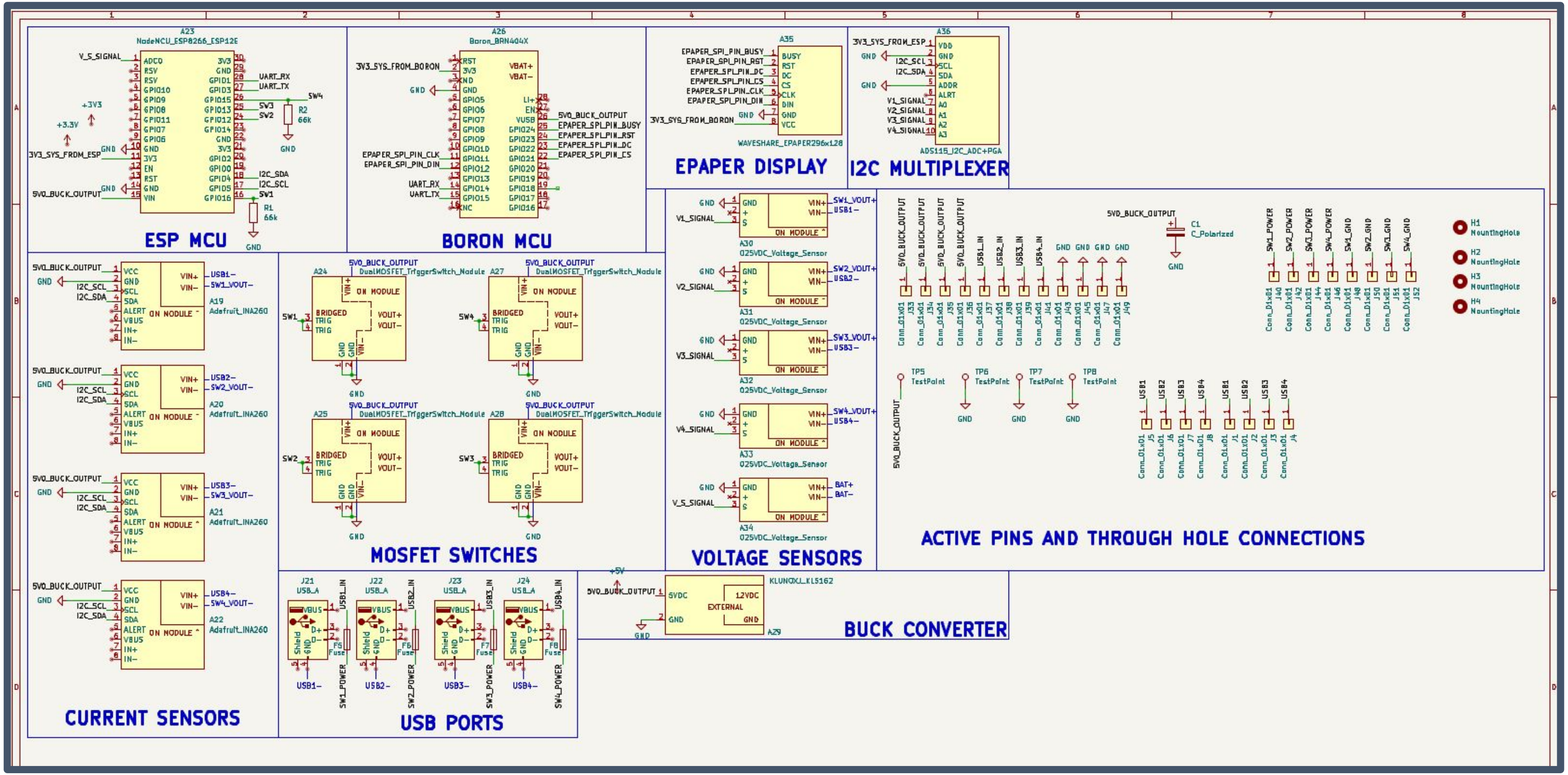
Circuit Diagram



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Circuit Diagram