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Electrical Engineering

R.E.A.C.H

Remote Energy Access and Control Hub

Senior Design Project Proposal
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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.

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

Existing Solutions

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

- MPPT single panel
- high efficiency
- 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

Reach Features	Temank	Anker SOLIX	Morningstar TS-60M TriStar	Sabrent 10-port USB hub
Provides Power Management	✅	✅	✅	❌
Provides Scheduling Capabilities	❌	❌	❌	❌
Maintain Historical Data for Data Analysis	❌	❌	❌	❌
Remote Website Dashboard Interface and Monitoring	❌	❌	❌	❌
Provides Local Hotspot Connectivity	❌	❌	❌	❌

Proposed Solution

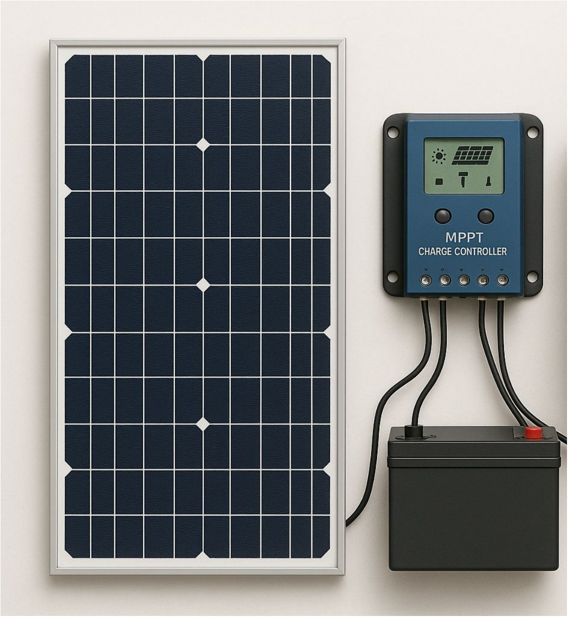
REACH is an external module that seamlessly integrates with existing solar power systems to provide advanced **local power management**, **remote monitoring** over connected field devices, and **distributed connectivity** in remote locations.

Value Proposition

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

- **Power management:** 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

Value Proposition



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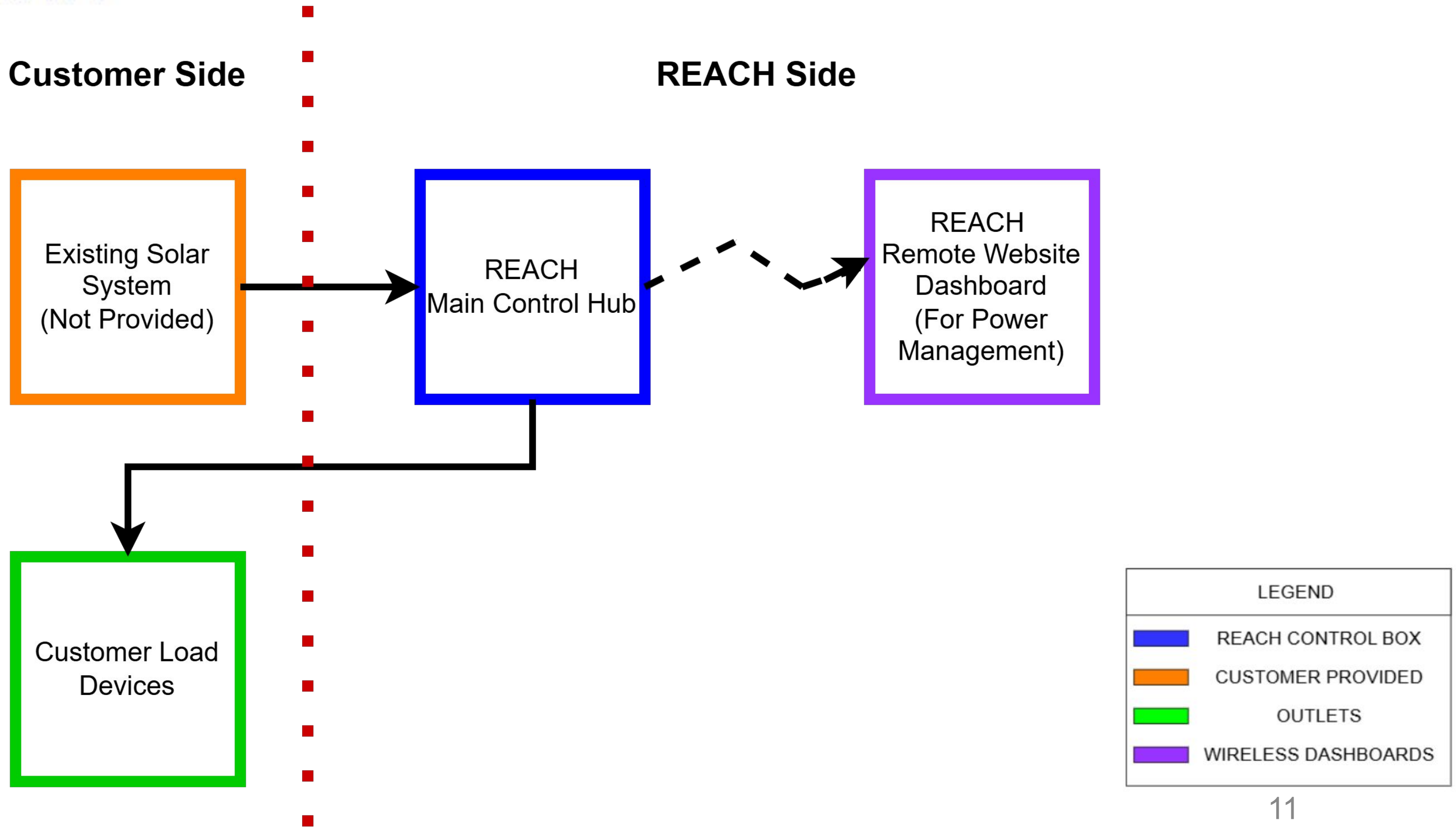
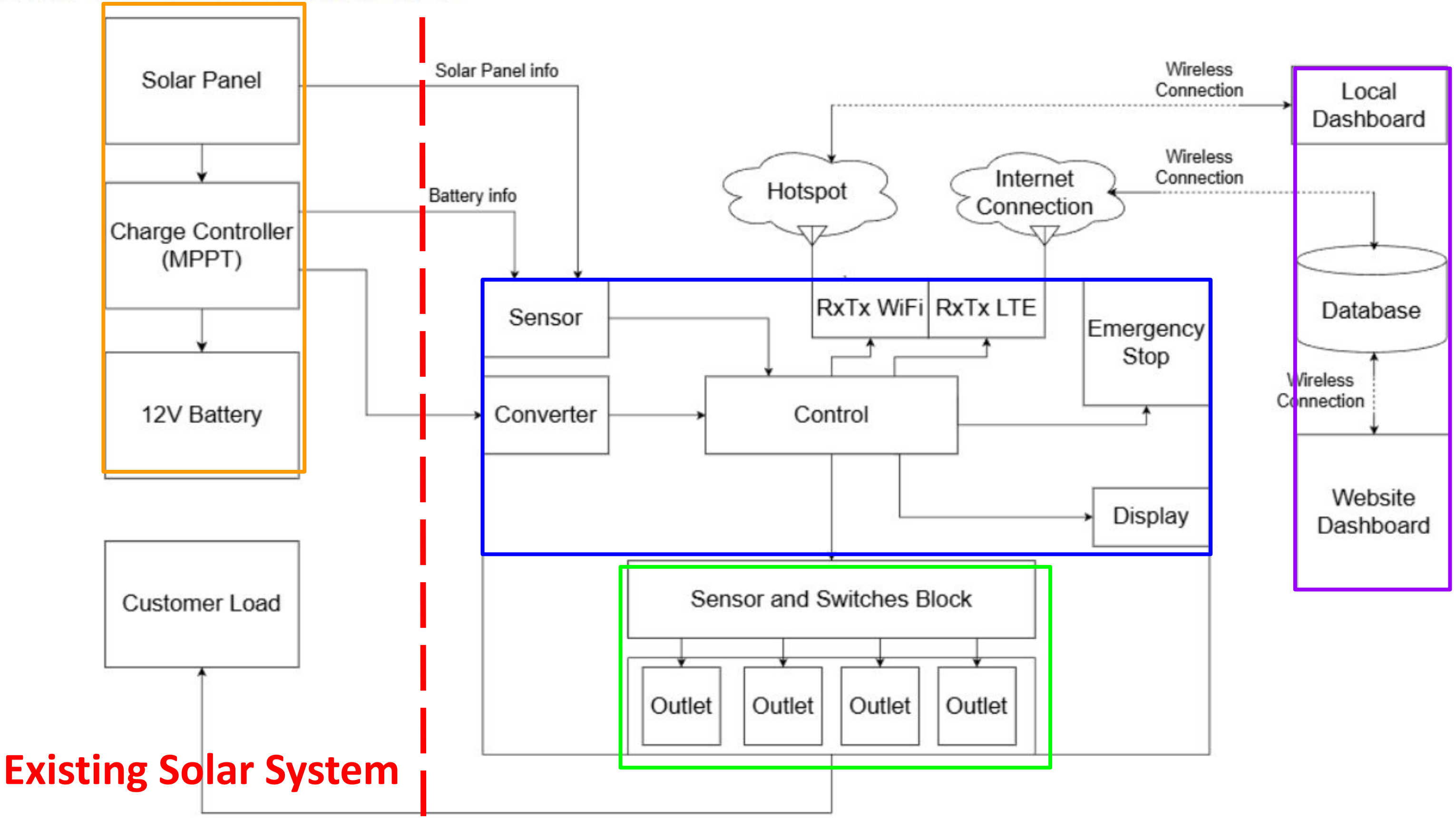
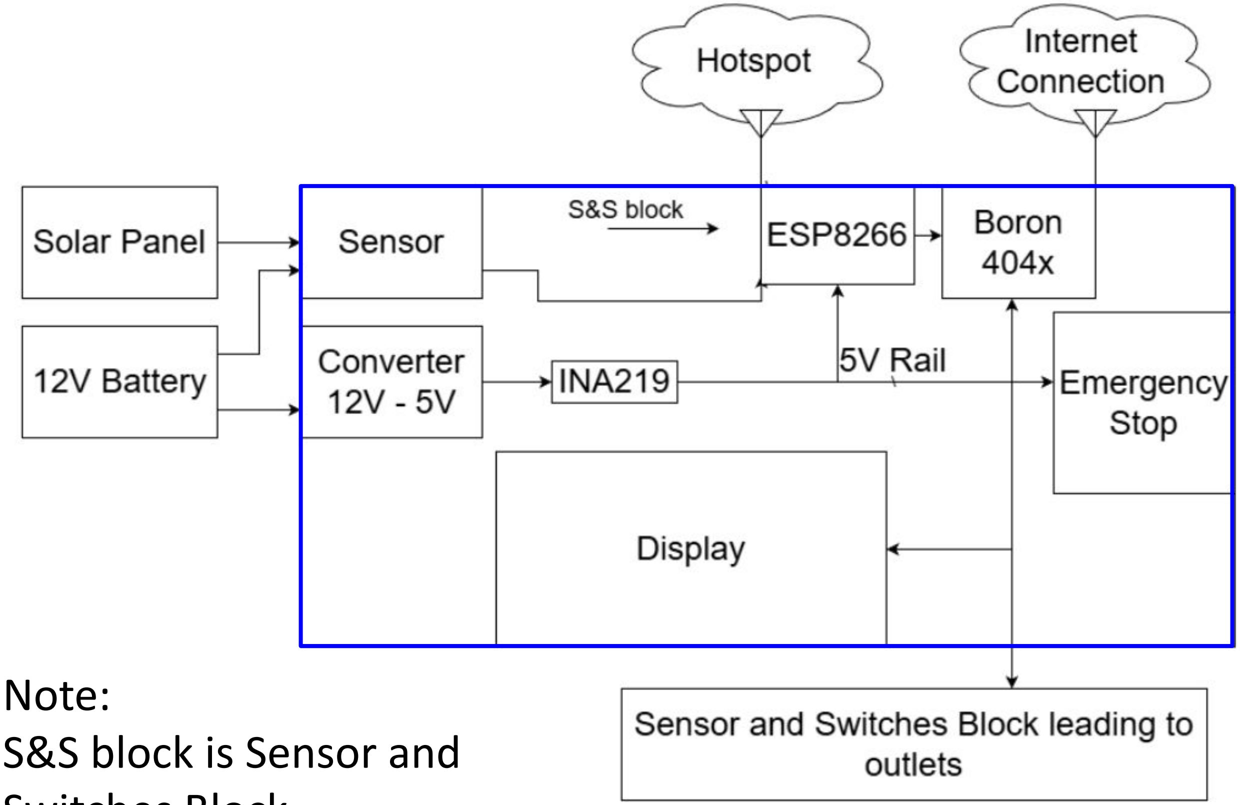
High Level System Diagram

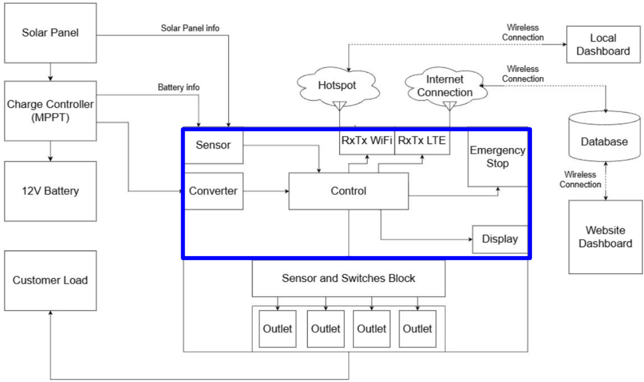


High Level Diagram



High Level Diagram: Control Hub



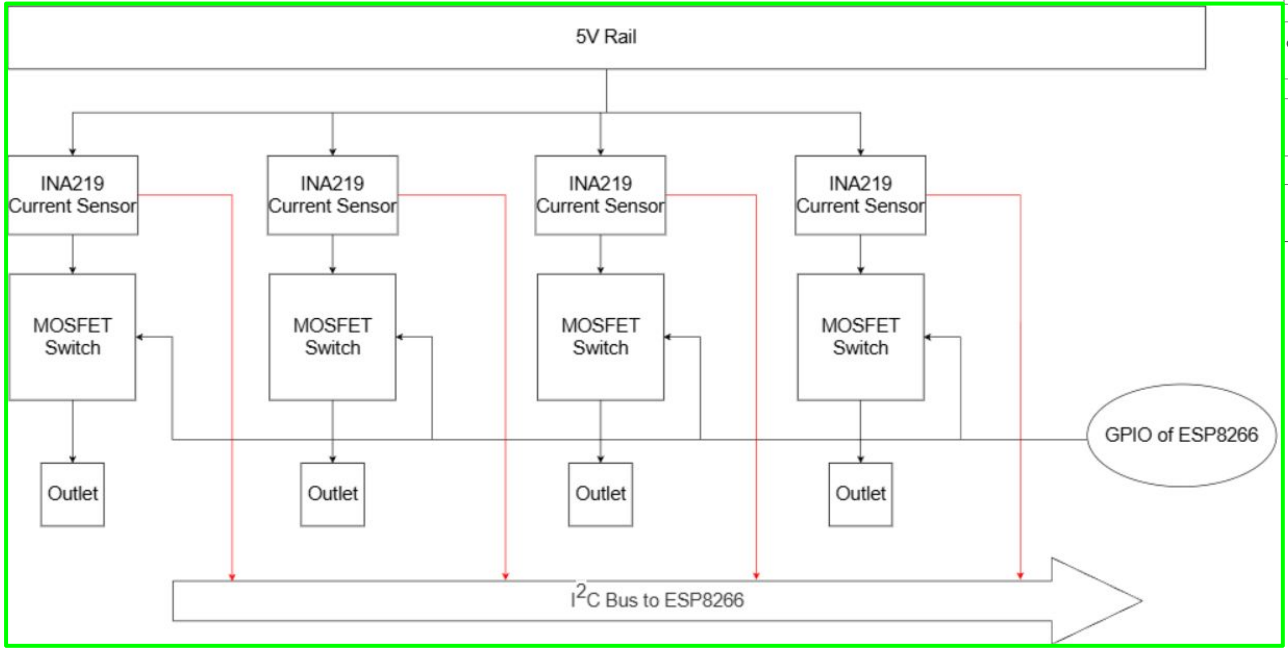


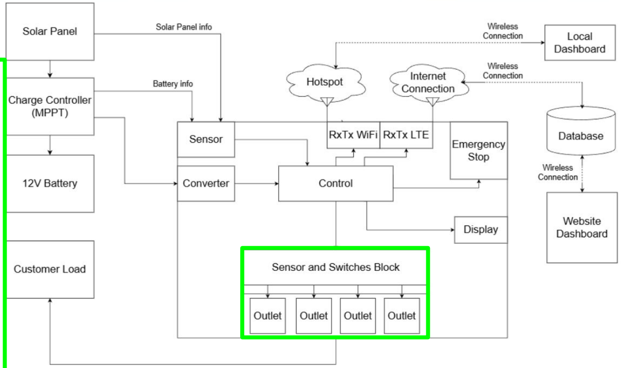
LEGEND

- REACH CONTROL BOX
- CUSTOMER PROVIDED
- OUTLETS
- WIRELESS DASHBOARDS

Note:
S&S block is Sensor and Switches Block

High Level Diagram: Control Hub





LEGEND

- REACH CONTROL BOX
- CUSTOMER PROVIDED
- OUTLETS
- WIRELESS DASHBOARDS

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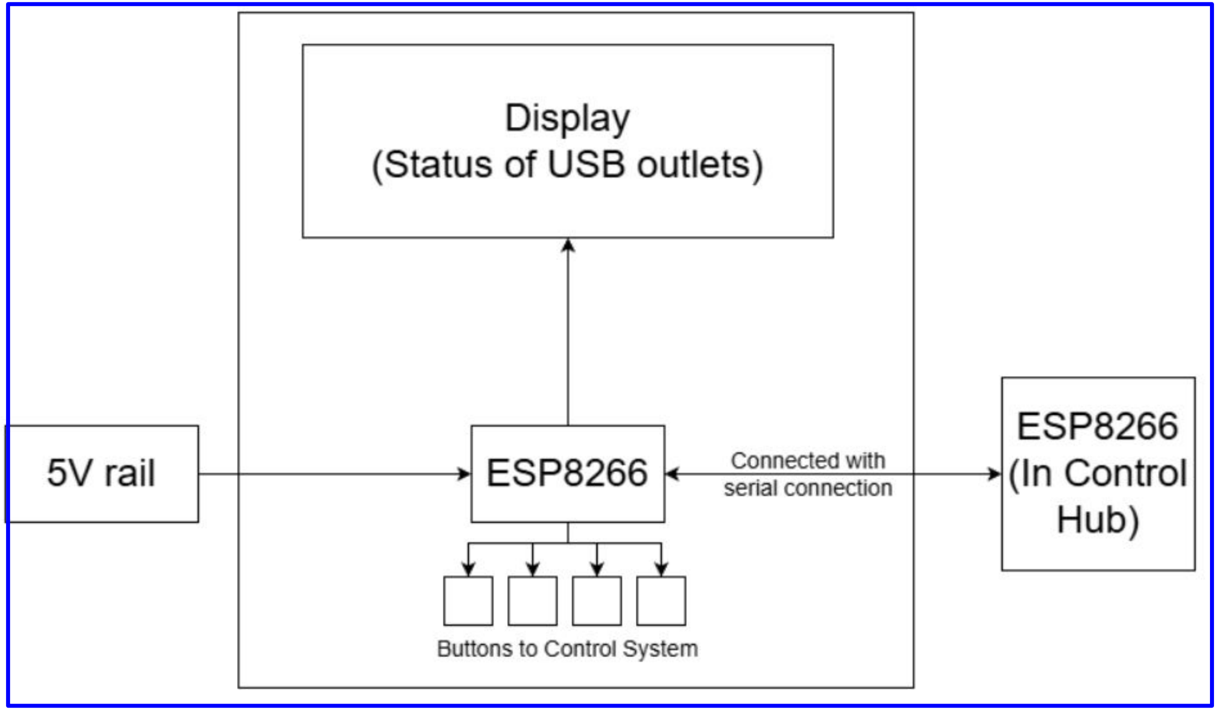
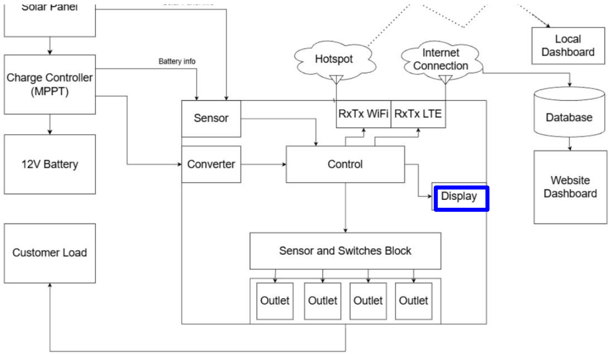
Display Panel Diagram





LEGEND

REACH CONTROL BOX

CUSTOMER PROVIDED

OUTLETS

WIRELESS DASHBOARDS

Software Diagram

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, and emergency shut off.
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.

Engineering Requirements

ER1. 4 USB outlets, 5V ± 0.1V @ 900mA max, 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 (state of charge (SoC), outlet voltage/current, outlet status) with a resolution of ±0.1V and ±0.1A. **(MR3)**

ER4. The local display shall present outlet status, SoC (±10% accuracy), and estimated charge/discharge time and allow local outlet control and emergency shutoff. **(MR4)**

ER5. The system shall operate using a solar panel rated for 12V and provide ≥ 30W, 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 ±0.4V and ±0.1A, 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)**

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

Alternative Design Matrix

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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	0.368	0.28	0.222	0.33

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Alternative Design Matrix

Transistors for switching:

Criteria	weight	NDP6020P	AO3400A	IRLZ44N
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
temp 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

Estimated Budget

Component	Quantity	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
INA219	5	4.10	20.50	used to measure power
Female USB	4	2.50	10.00	outlets used to deliver power
NDP6020P	4	1.70	6.80	Used to shut off power to outlet
Fuses	4	0.20	9.00	Used to protect circuits
Waterproof Box	1	39.99	39.99	Used to house our components

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	Connect devices to ESP’s Wifi network	ER11	Complete	Successfully connected multiple devices to the WiFi network
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

START OF NEW TEST

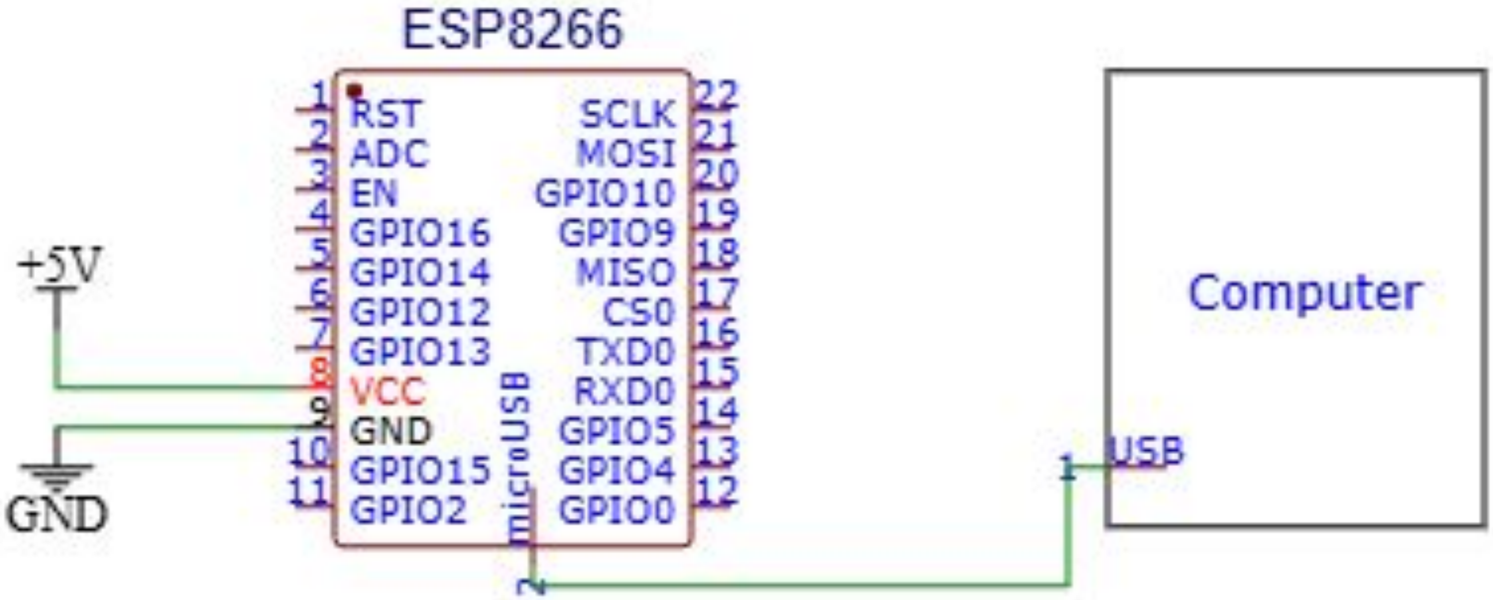
WiFi Hotspot Test

Goal:

- Setup hotspot 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

WiFi Hotspot Test

Setup:



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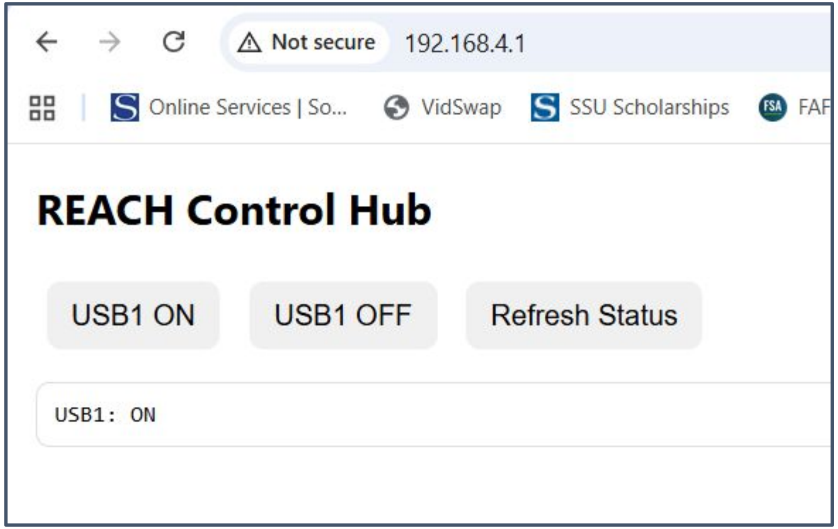
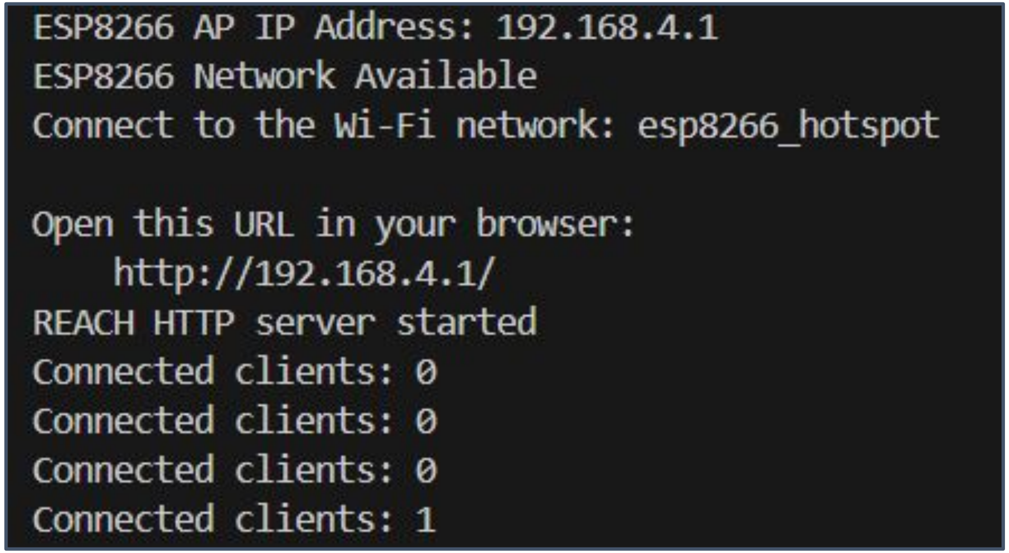
WiFi Hotspot Test

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 Hotspot 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

START OF NEW TEST

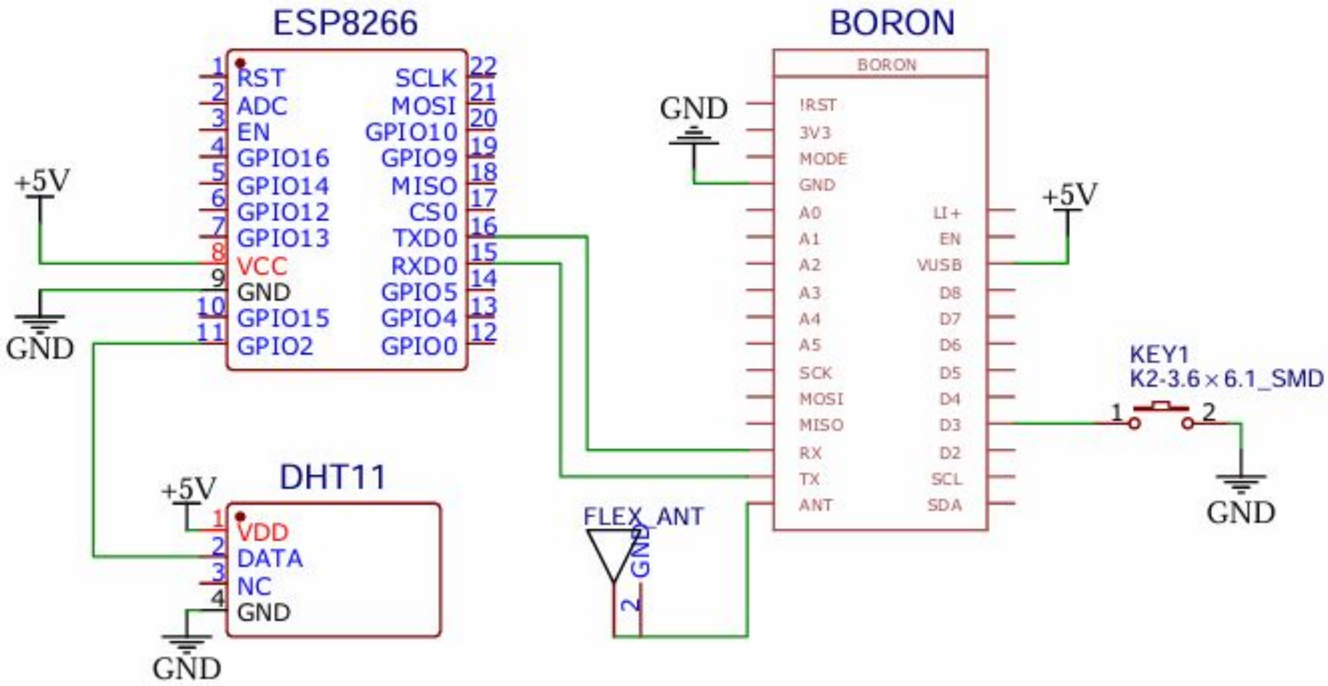
Boron Functionality Test

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

Boron Functionality Test

Setup:



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Boron Functionality Test

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

Boron Functionality 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

START OF NEW TEST

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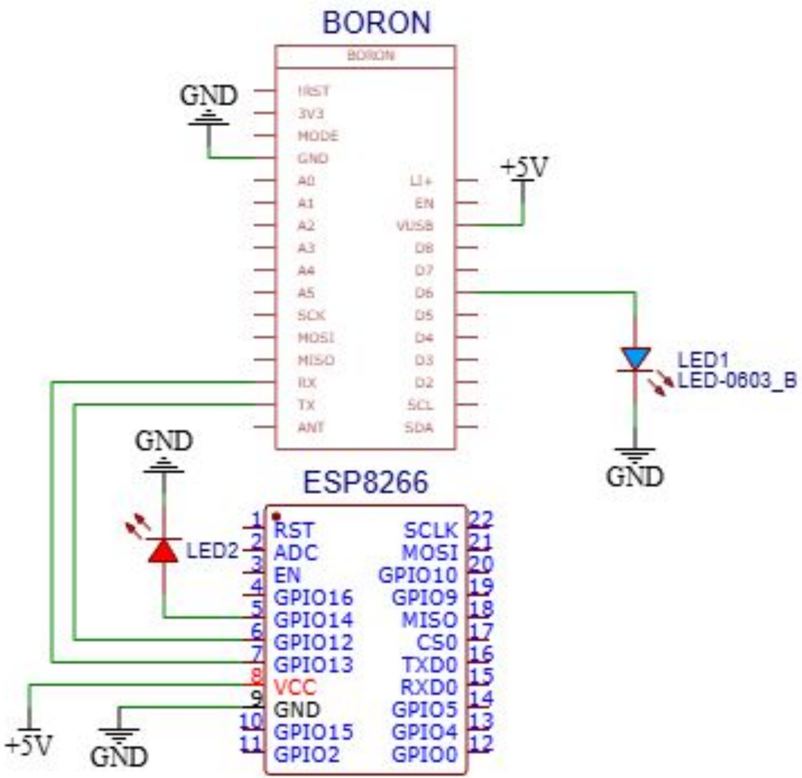
2-Way Communication Test

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 Sensor Test

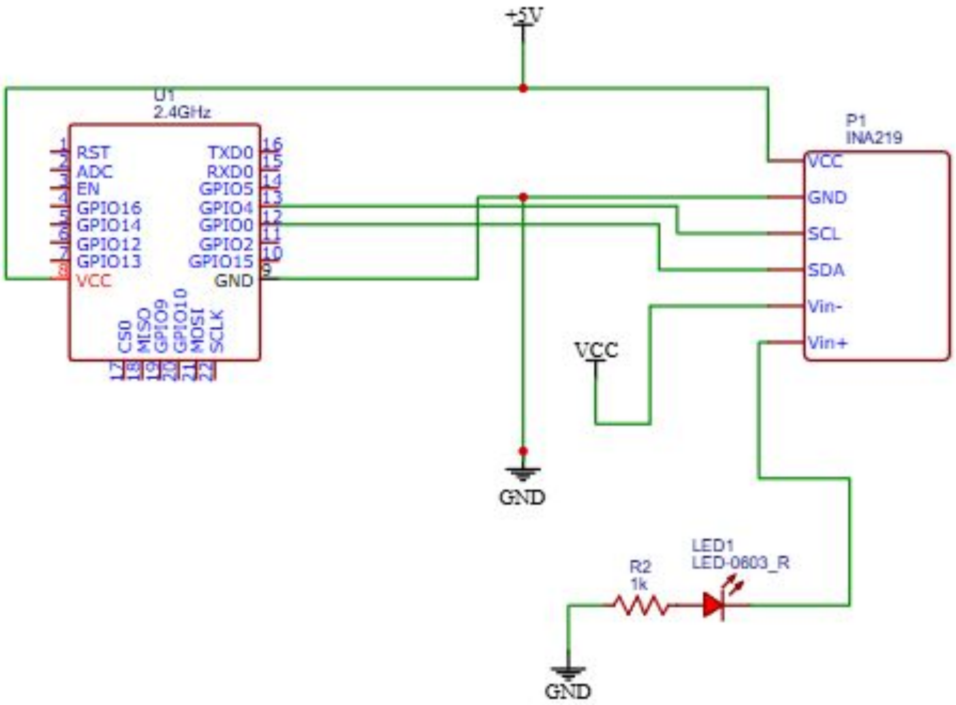
Goal:

- INA219 is used for measuring current and voltage, and in this application, will be used for measuring the outlet current and voltage.

INA219 Sensor Test

Setup:

INA219, which connected to an ESP8266 via I2C



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INA219 Sensor 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
```

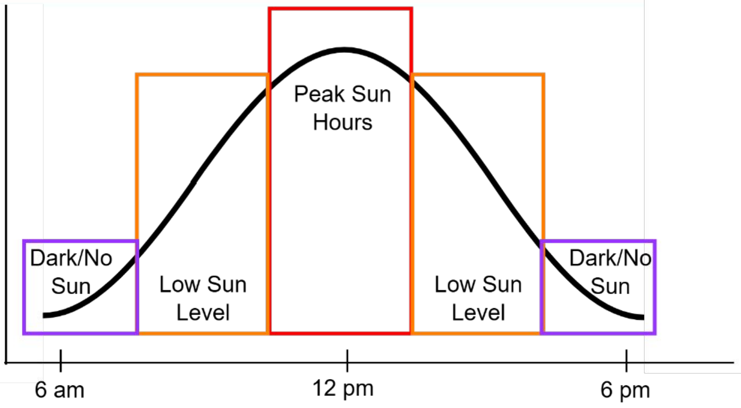
Tested (A)	Actual (A)	% error
0	0.0	0
0.012	0.013	8.3
0.021	0.018	14.2

INA219 Sensor Test

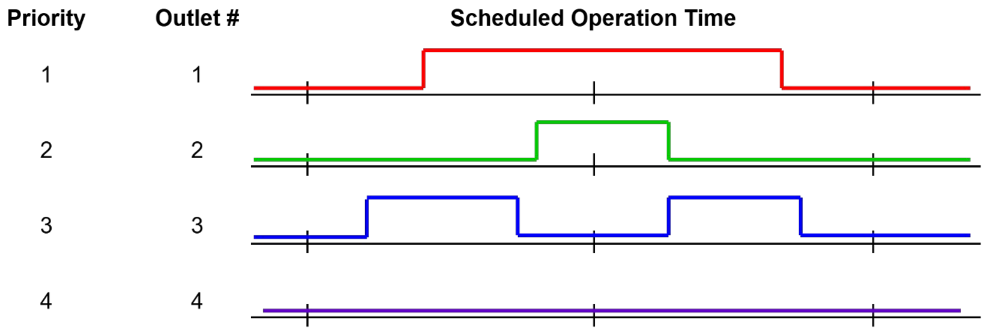
Conclusion:

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

Scheduling Feature (Theory)



Solar Power Generated Over Time



Power Calculations (Theory)

Assuming battery used is the SigmasTek 12V/7.5Ah, @12V 2.25A input, the buck converts 12V- 5V with 95% = η

- 5V rail (devices/η = 4.39 W)
  - ESP consumes: 2.97W
  - Boron consumes: 1.98W
  - INA219 consumes: 0.003W
  - Display consumes: 0.1W
  - transistor circuit consumes: .02W
- Total power consumption = 18W + 4.39W = 22.4W

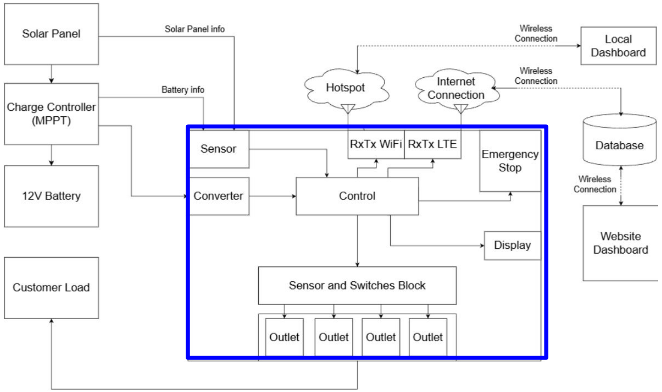
Runtime: 90Wh/22.4W

- runtime = 4.017 hours

Power Calculations (Theory)

Assuming SigmasTek 12V/7.5Ah battery connected to solar panel:
@12V and 2.25A of input, buck converts to 5V with 95%= η, MPPT charger has 90% = η

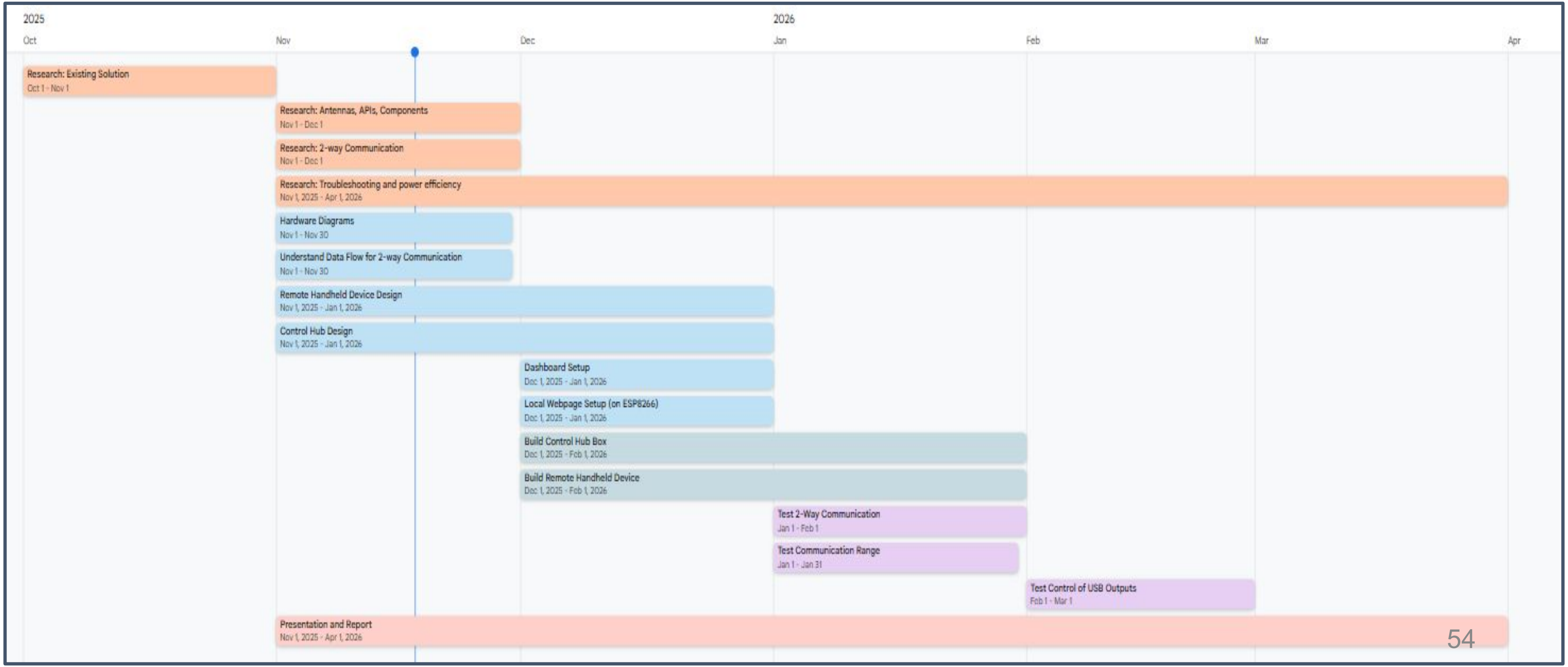
- Energy per 24 hour cycle = 22.4 * 24 = 537.6Wh
- around 26.2W ave per 24 hrs
- Solar Panel upper bounds = 50W/12V



Challenges and Risks

- USB outputs draw more current than expected
  - Likelihood=4 (likely), Consequences=4 (major), Total=16 (extreme)
  - 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
  - Likelihood=5 (almost certain), Consequences=3 (moderate), Total=15 (extreme)
  - Solution: Low power consumption mode (ex: send less frequent updates to dashboard)
  - Solution: Make system as power efficient as possible
- Limited connectivity because of connection range
  - Likelihood=4 (likely), Consequences=2 (minor), Total=8 (high)
  - Solution: Find suitable antenna for ESP and 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
Remote Handheld Device Design
Nov 1, 2025 - Jan 1, 2026
Control Hub Design
Nov 1, 2025 - Jan 1, 2026
Dashboard Setup
Dec 1, 2025 - Jan 1, 2026
Local Webpage Setup (on ESP8266)
Dec 1, 2025 - Jan 1, 2026
Build Control Hub Box
Dec 1, 2025 - Feb 1, 2026
Build Remote Handheld Device
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

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)
  - Figure out handheld design (January)
  - System box design (January)
  - Dashboard setup (February)
  - Local Webpage setup (February)
- Building
  - System box (February)
  - System Display (February)
- 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
- Jair: Boron communication and dashboard

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Project Milestones

Task	Projected finish date
API Research	December
Testing IC (Power Measurements)	December
Two way communication	November
Ordering Components	December
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
- Backup power
  - Using smooth power module and connecting to the grid
- System temperature regulation for batteries in the remote locations

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Supporting Courses

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

Questions

Questions/Comments