Wireless Irrigation System

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OUR TEAM

Grant

Anantajit

Jay

Agenda

- Introduction
- Original Design
- Power Subsystem
- Control Subsystem
- Final Build
- PCB Review
- Tests
- Conclusions

The Problem

- Traditional: central control → solenoid valves
- Wires carry control + power to valves
- Valves require over/underground pathing
  - Limits installation locations
  - Increases costs
  - Wasteful watering
  - Damage prone

Our Solution

- Control valve operation wirelessly with Bluetooth
- Eliminate power wires by using battery power
- Recharge battery while water is flowing (during watering cycles)

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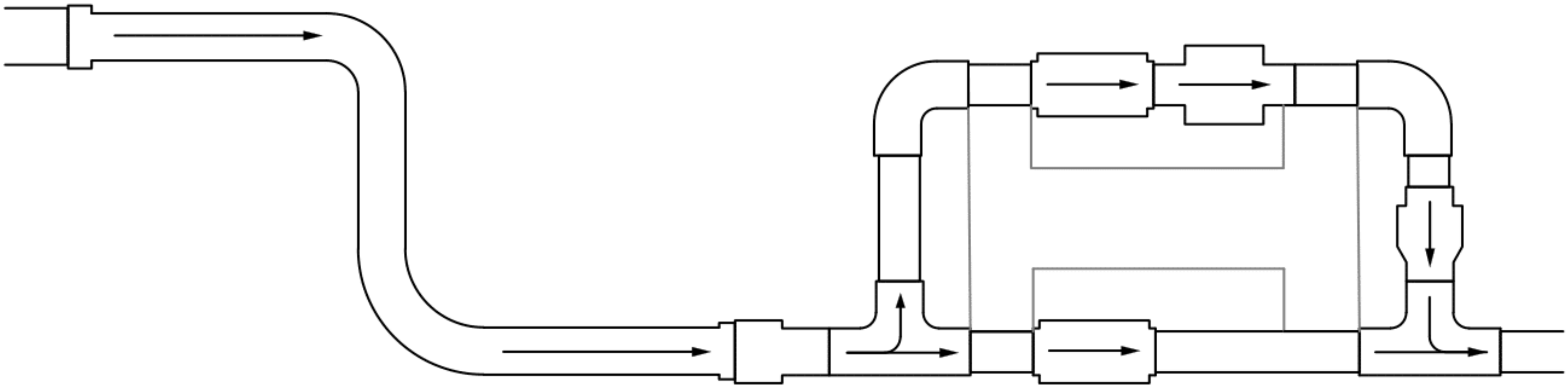
Problem: turbine limits water flow

Our Solution

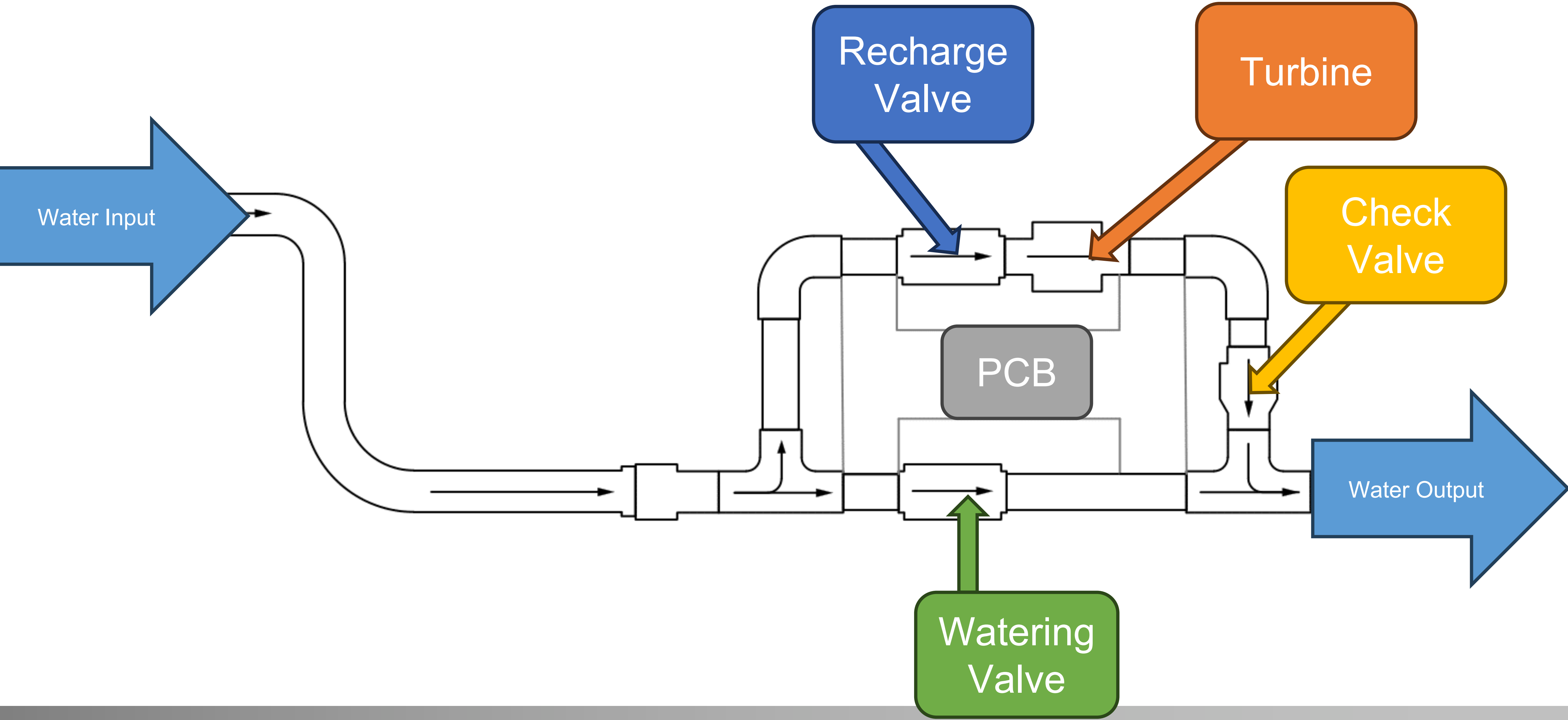
Solution: add a turbine bypass valve

- Increase water flow rate ⇒ open the watering valve
- Begin charging ⇒ open only the recharge valve
- Check valve protects turbine from driving backwards

Our Solution



Our Solution



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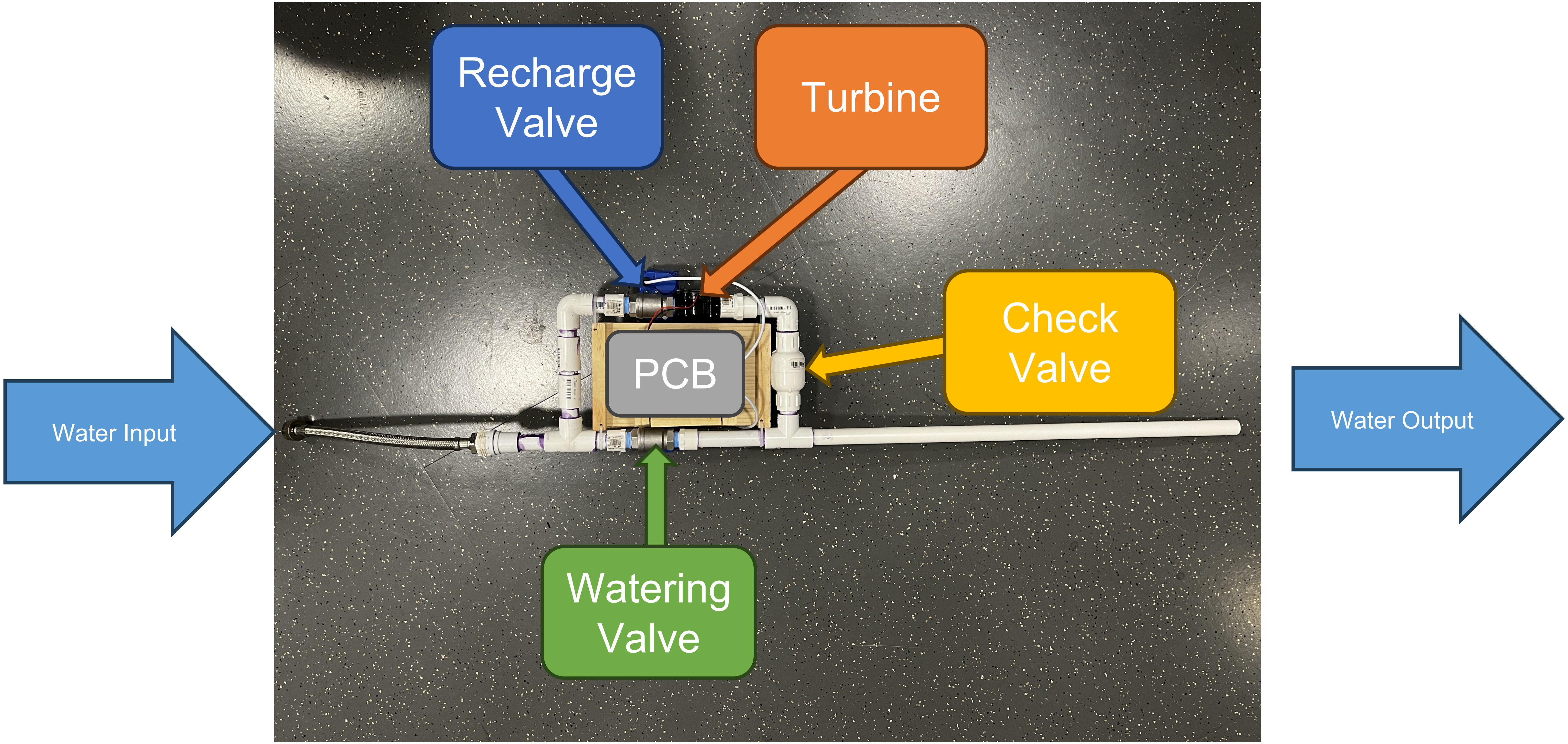
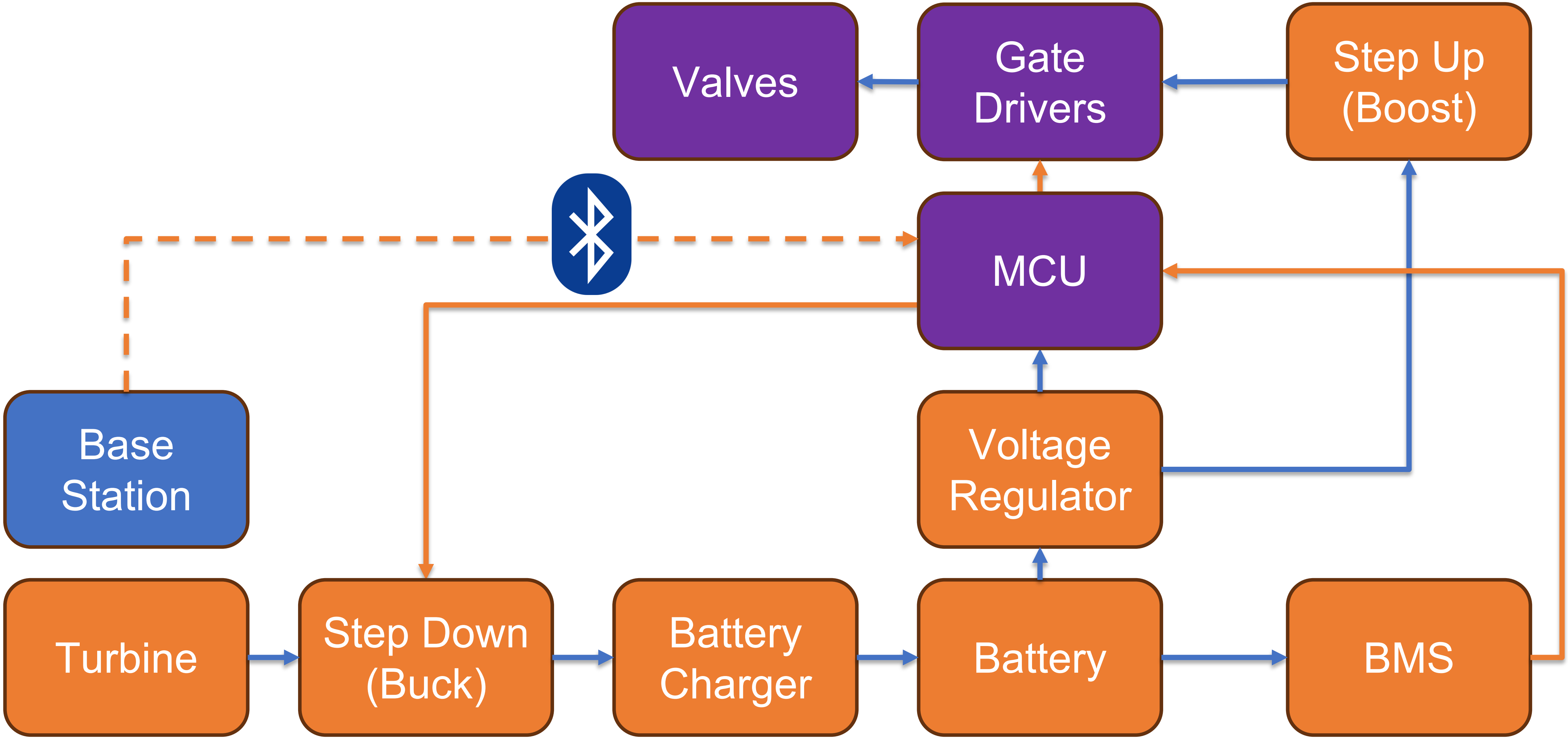


Open/close valves based on remotely-issued commands

Recharge the battery using water flow during water cycles

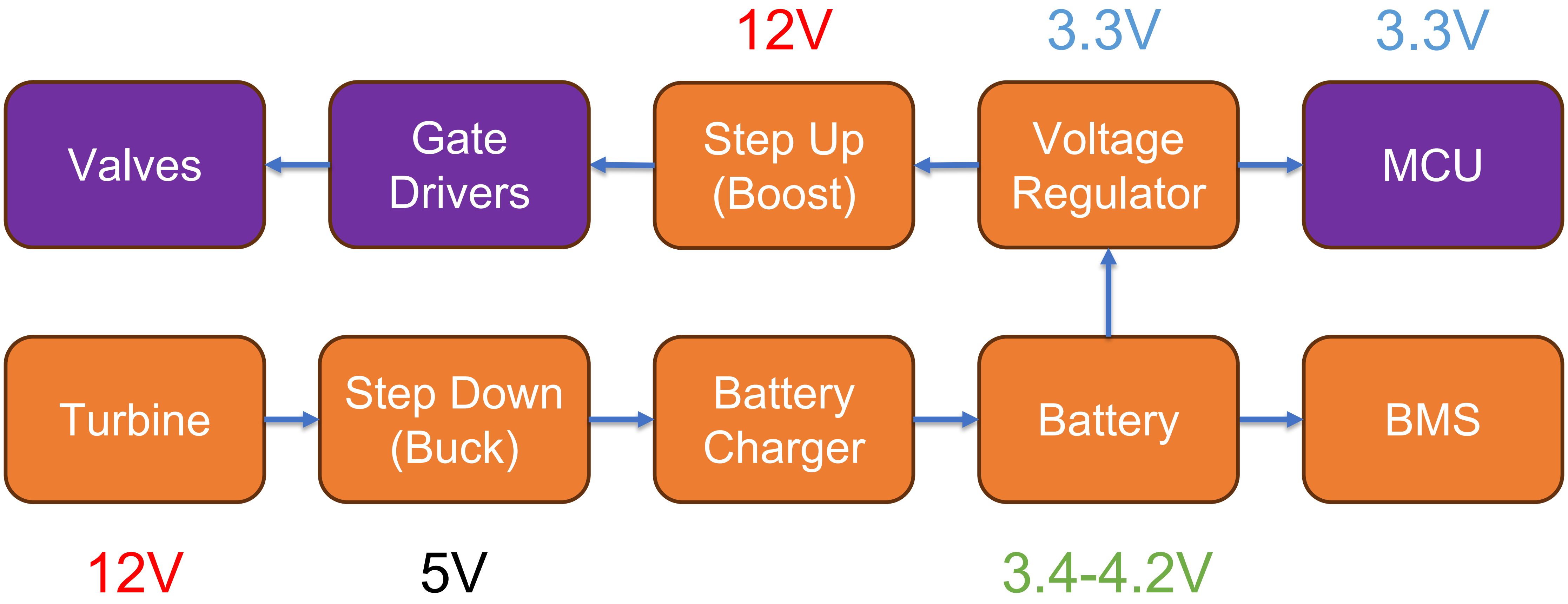
Battery capacity measurement capability (goal: 48+ hours on a single charge)

Original Design

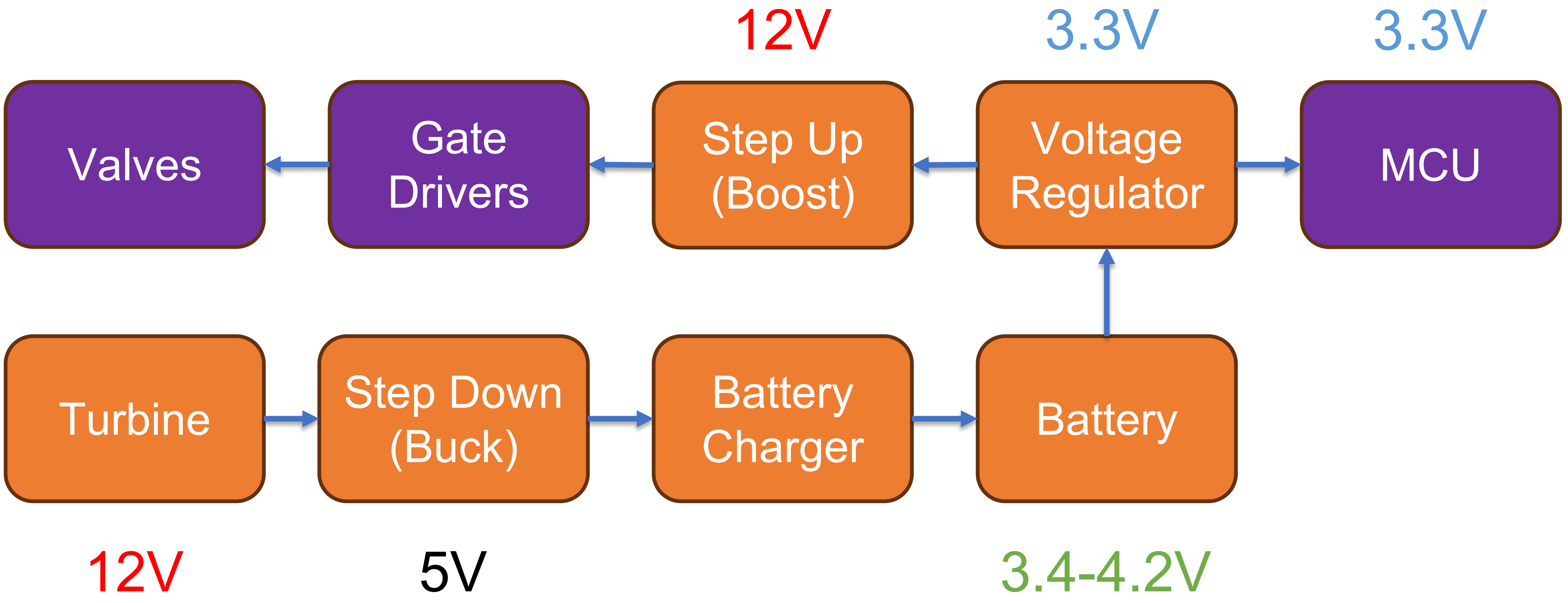

Valves
Gate Drivers
Step Up (Boost)
MCU
Base Station
Voltage Regulator
Turbine
Step Down (Buck)
Battery Charger
Battery
BMS

Power Subsystem

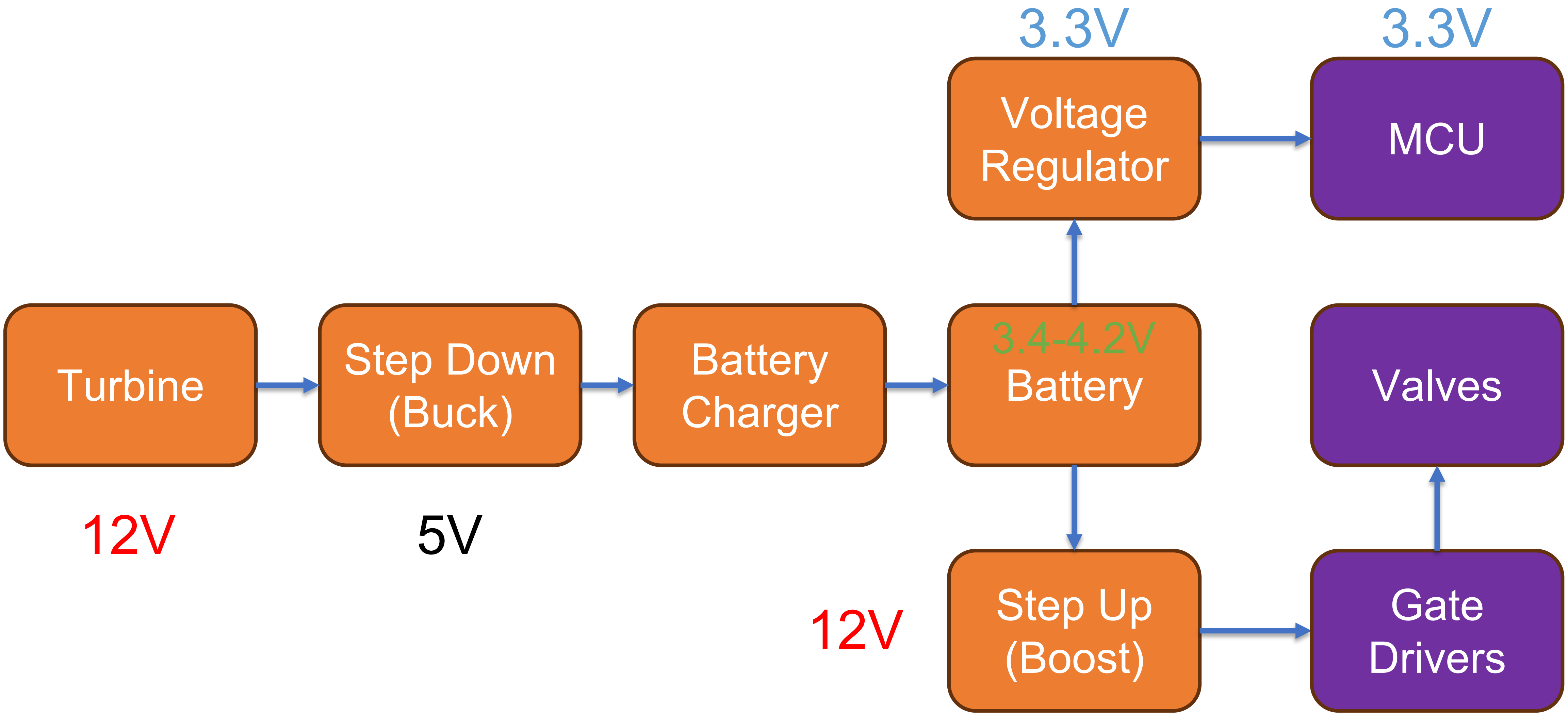
Power Subsystem Original Design



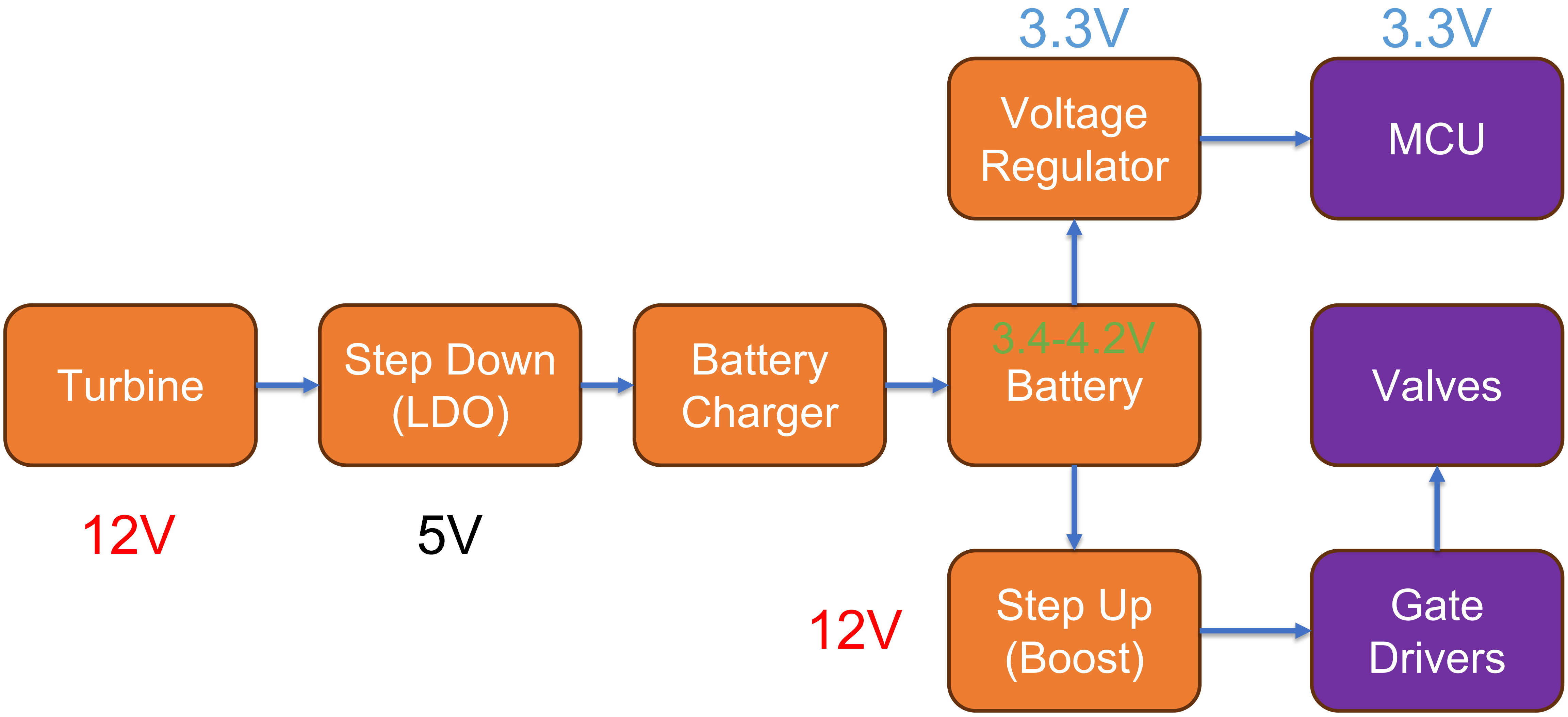
Power Subsystem Modifications



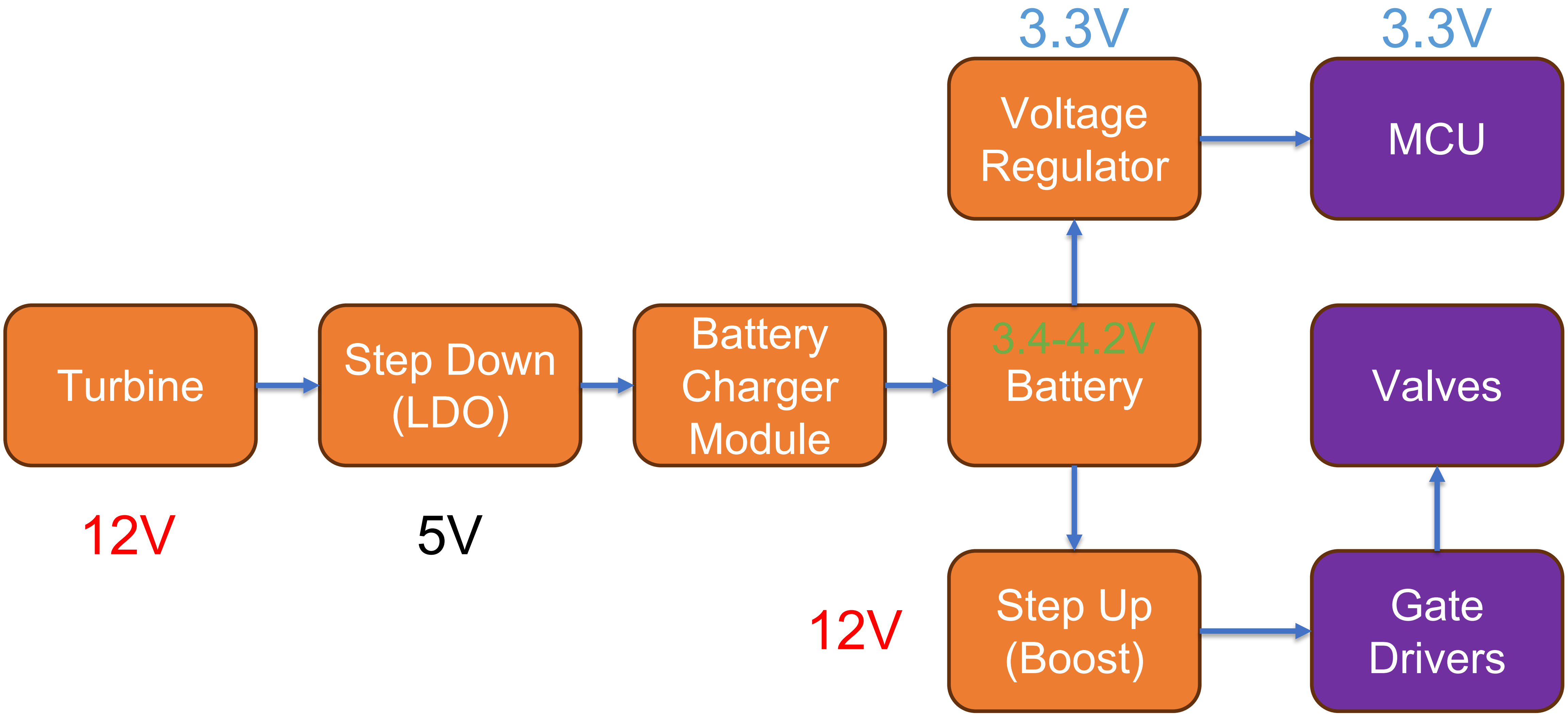
Power Subsystem Modifications



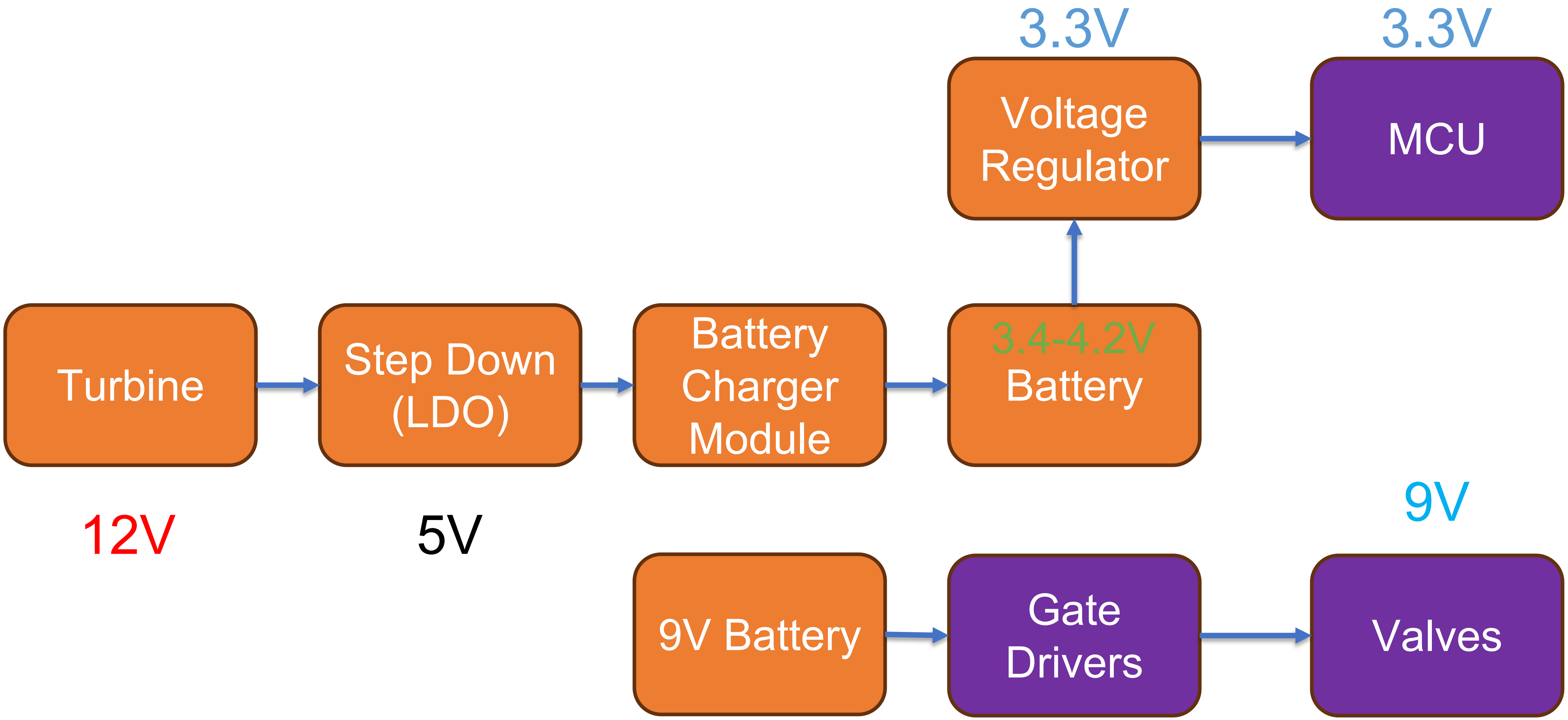
Power Subsystem Final



Power Subsystem Final

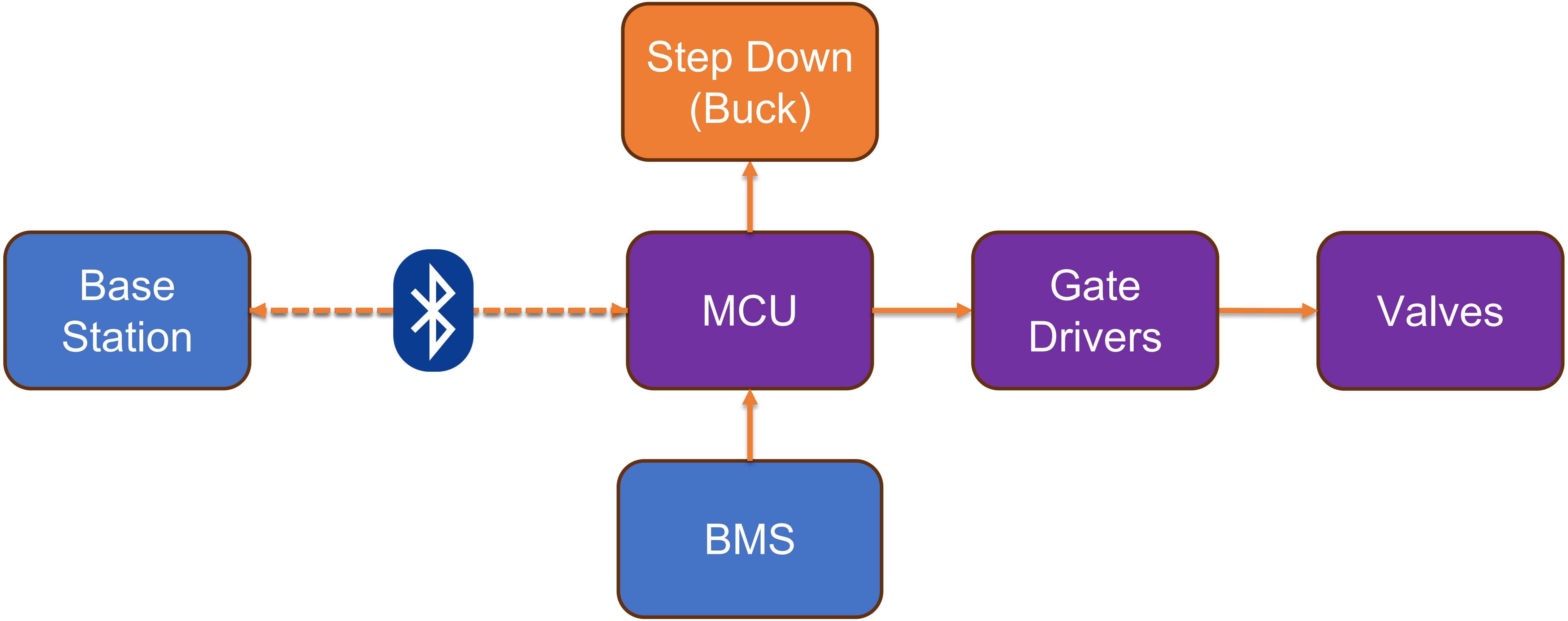


Power Subsystem Final

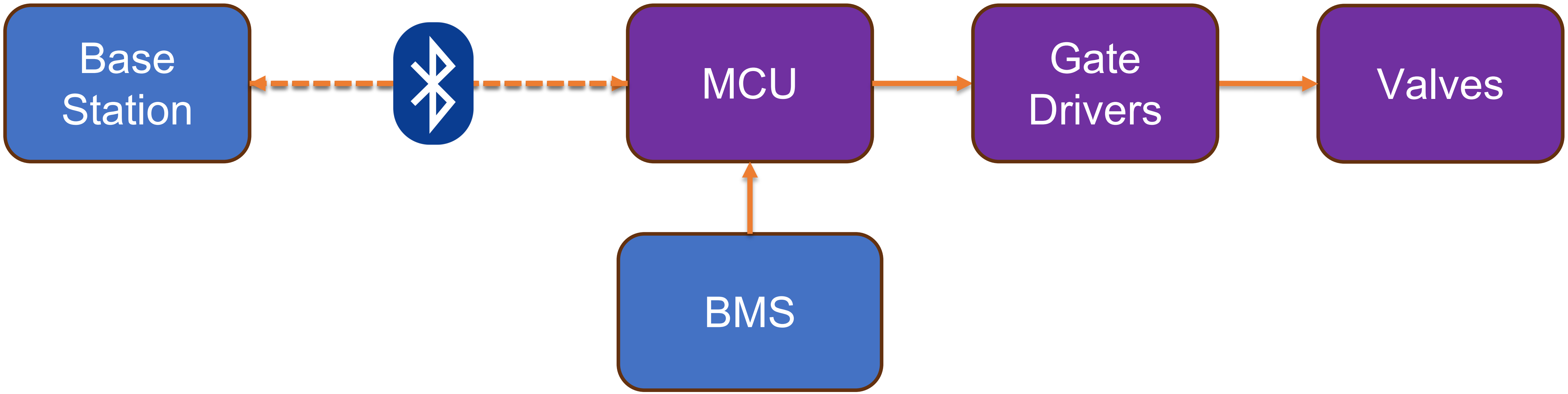


Control Subsystem

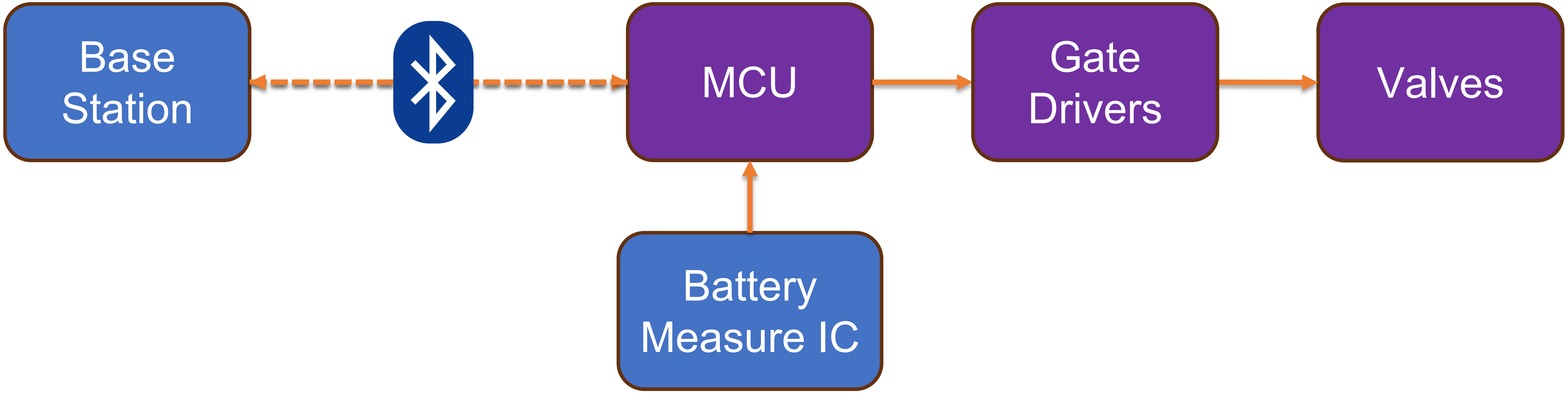
Control Subsystem Original Design



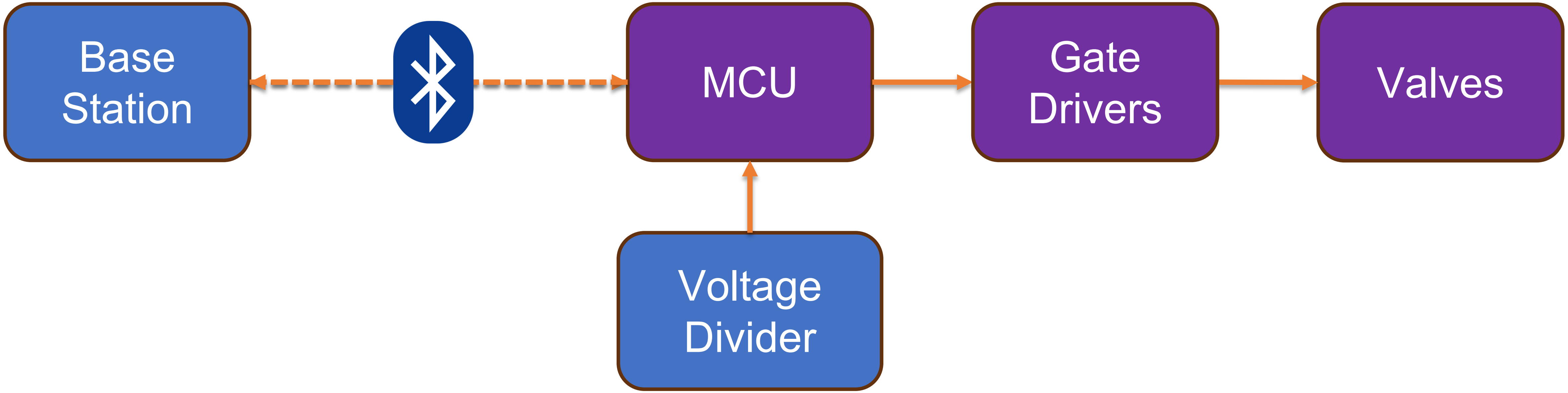
Control Subsystem Original Design



Control Subsystem Modifications

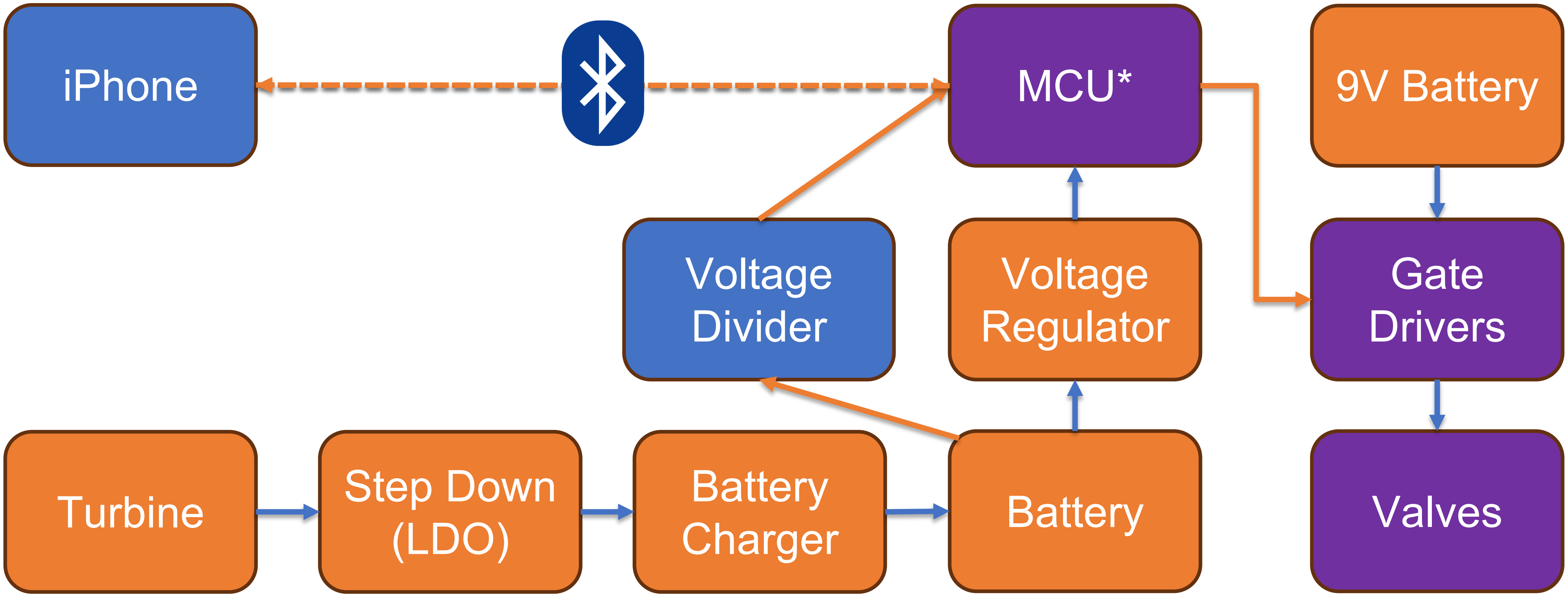


Control Subsystem Final

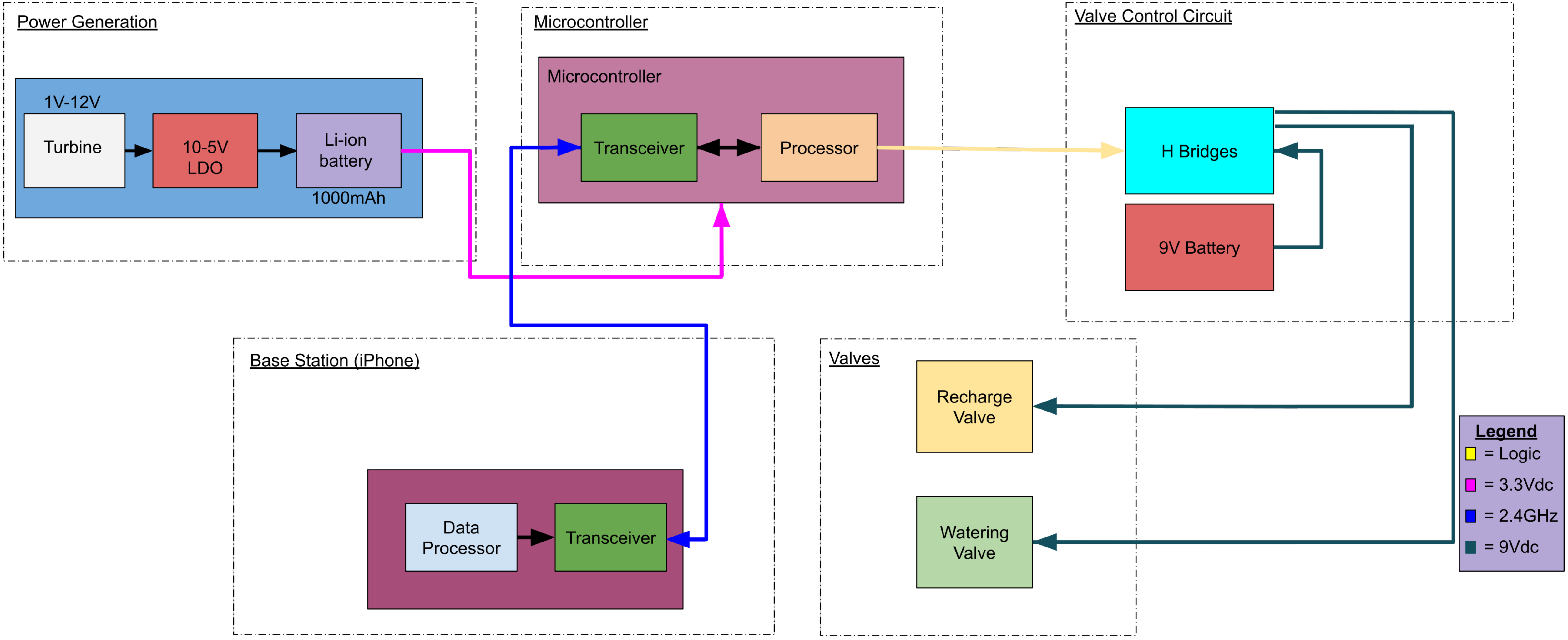


Final Build

Final Design

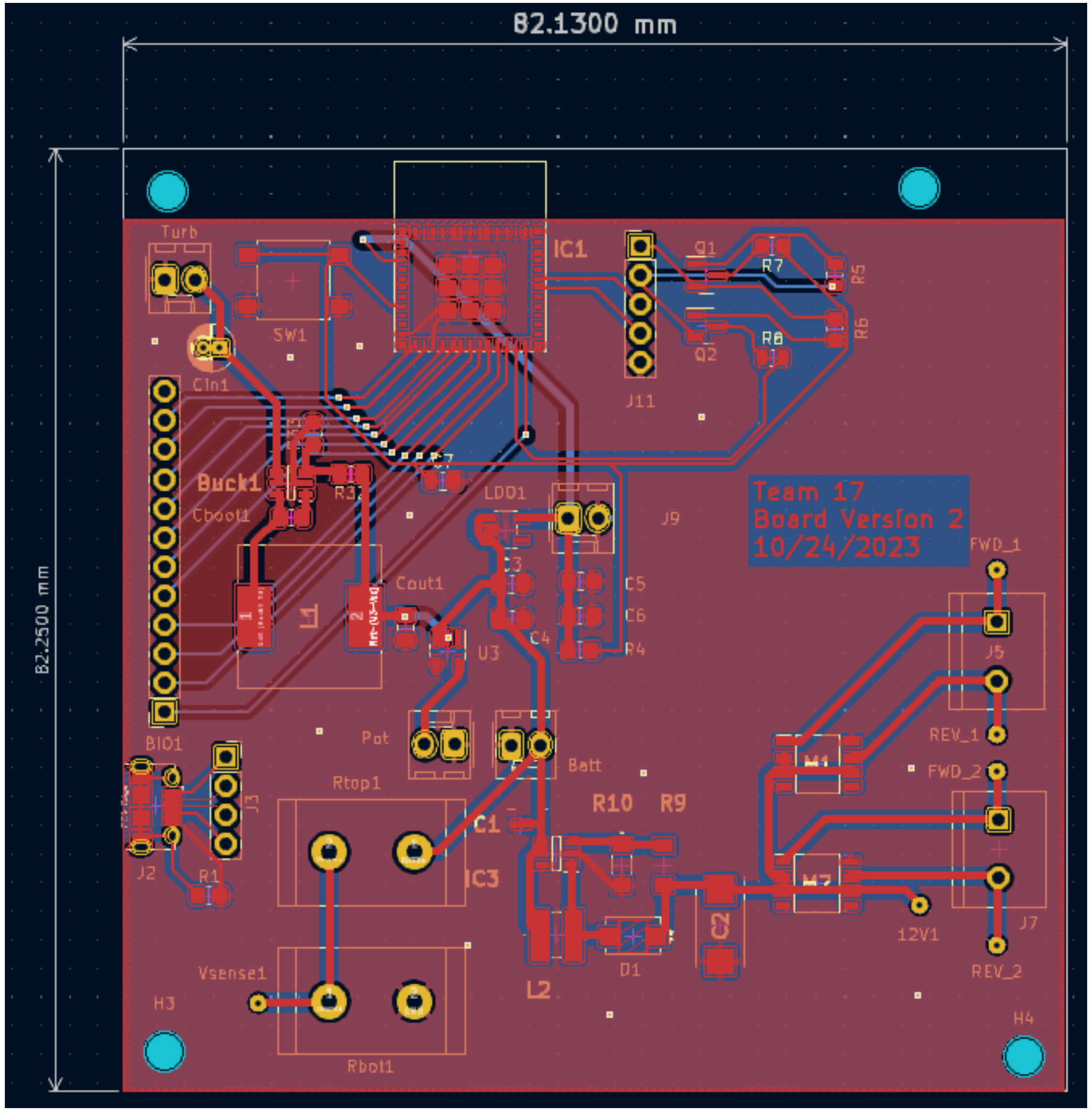


Final Block Diagram With Voltages



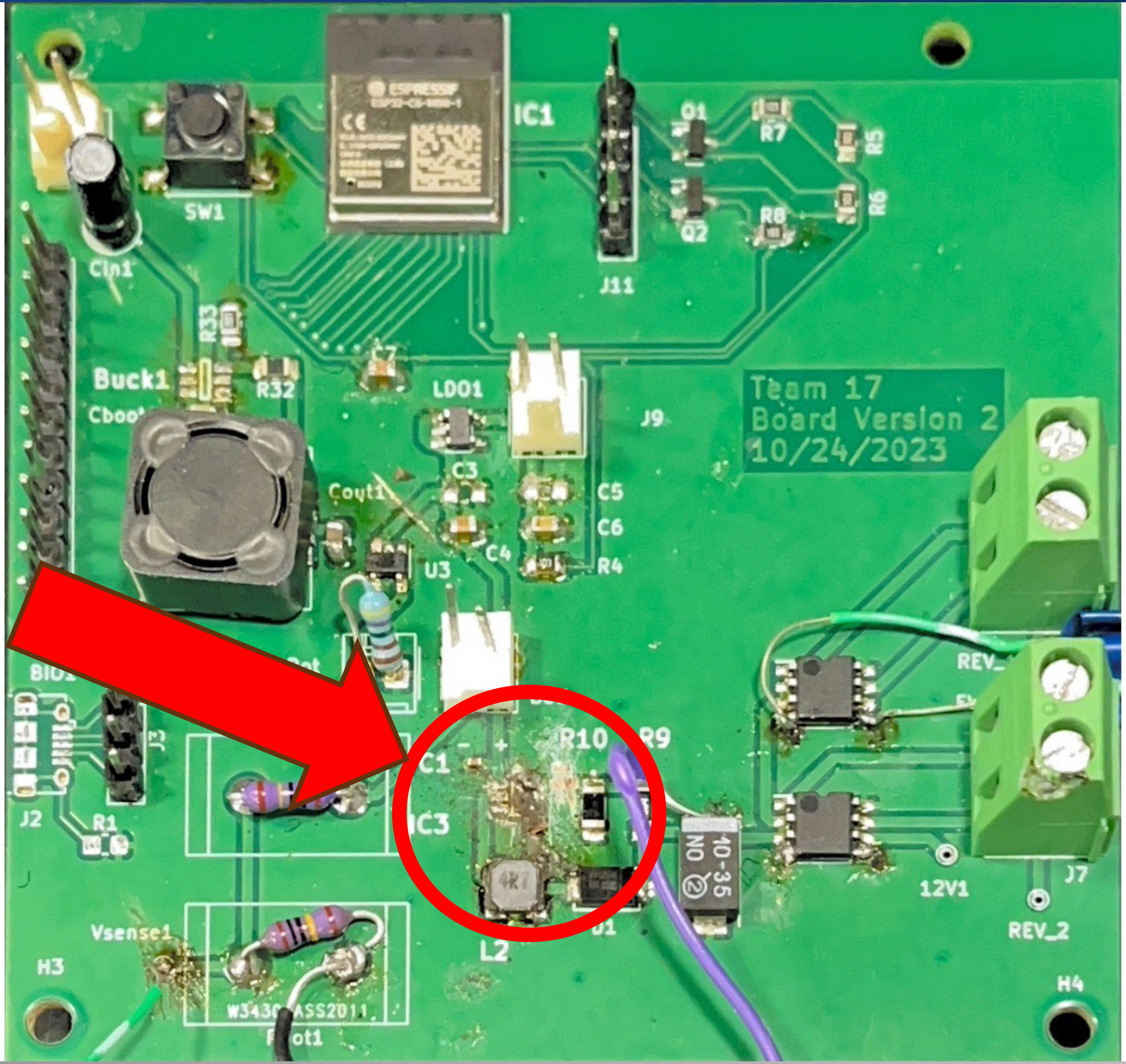
PCB Review

PCB Design

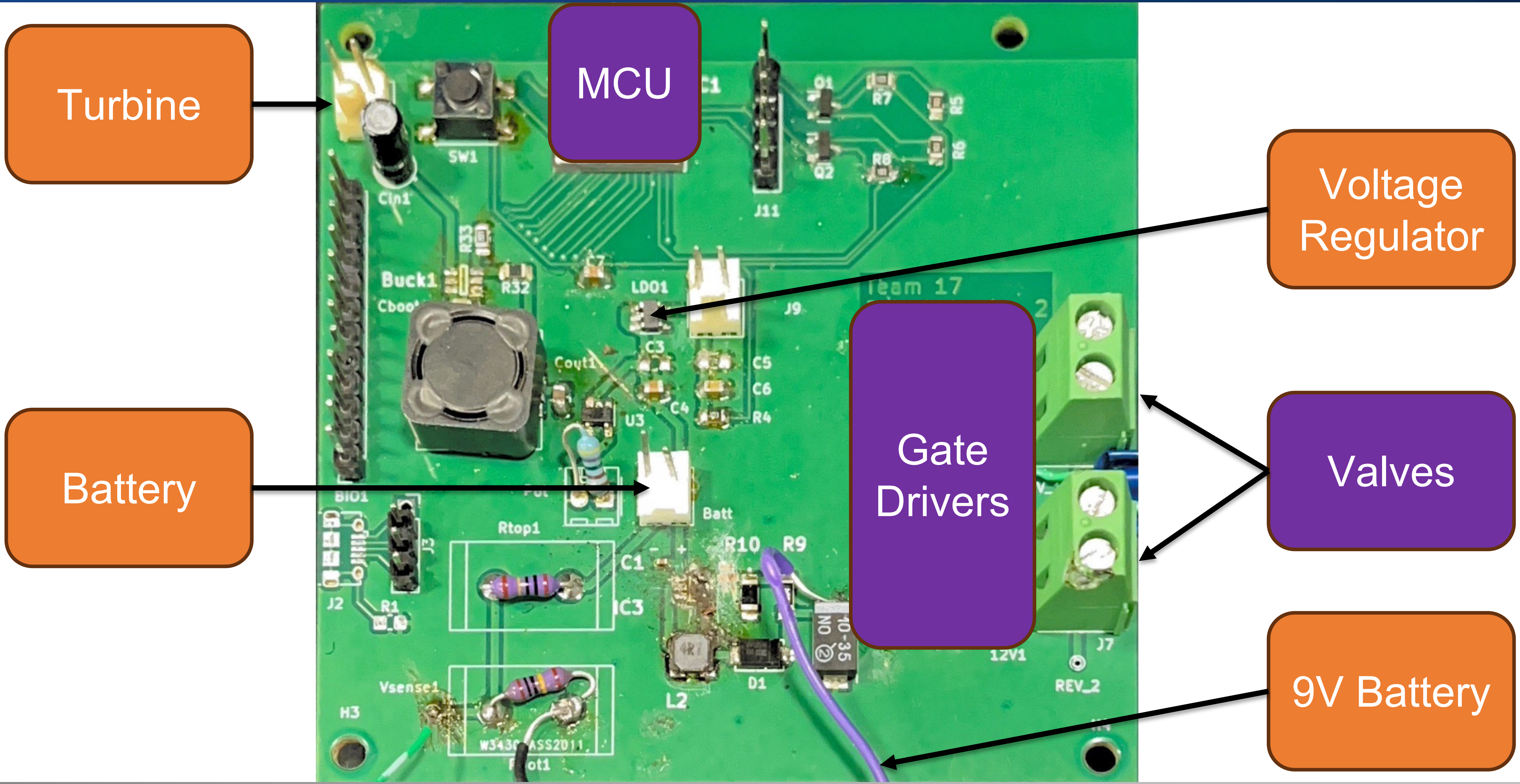


82.1300 mm
82.2500 mm
Team 17
Board Version 2
10/24/2023
IC1
J11
Q1
Q2
R5
R6
R7
R8
Turb
SW1
Cin1
Buck1
Cboot1
R3
L1
LDO1
J9
C3
C4
C5
C6
R4
Cout1
U3
FWD_1
J5
REV_1
FWD_2
J7
REV_2
12V1
BIO1
Pot
Batt
Rtop1
R10
R9
C1
IC3
J2
J3
R1
C2
D1
L2
Vsense1
H3
H4
Rbot1

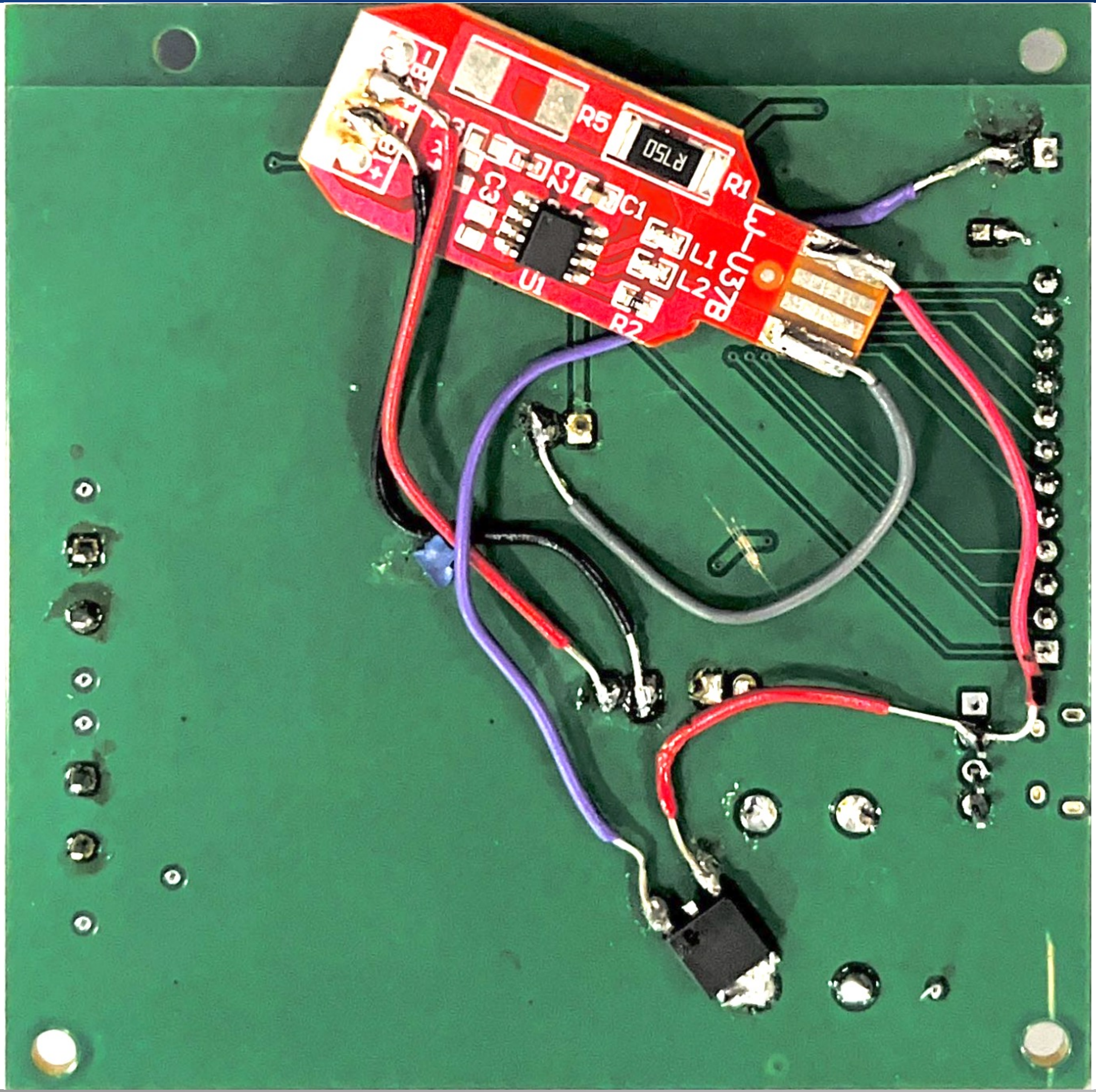
Final PCB (Front)



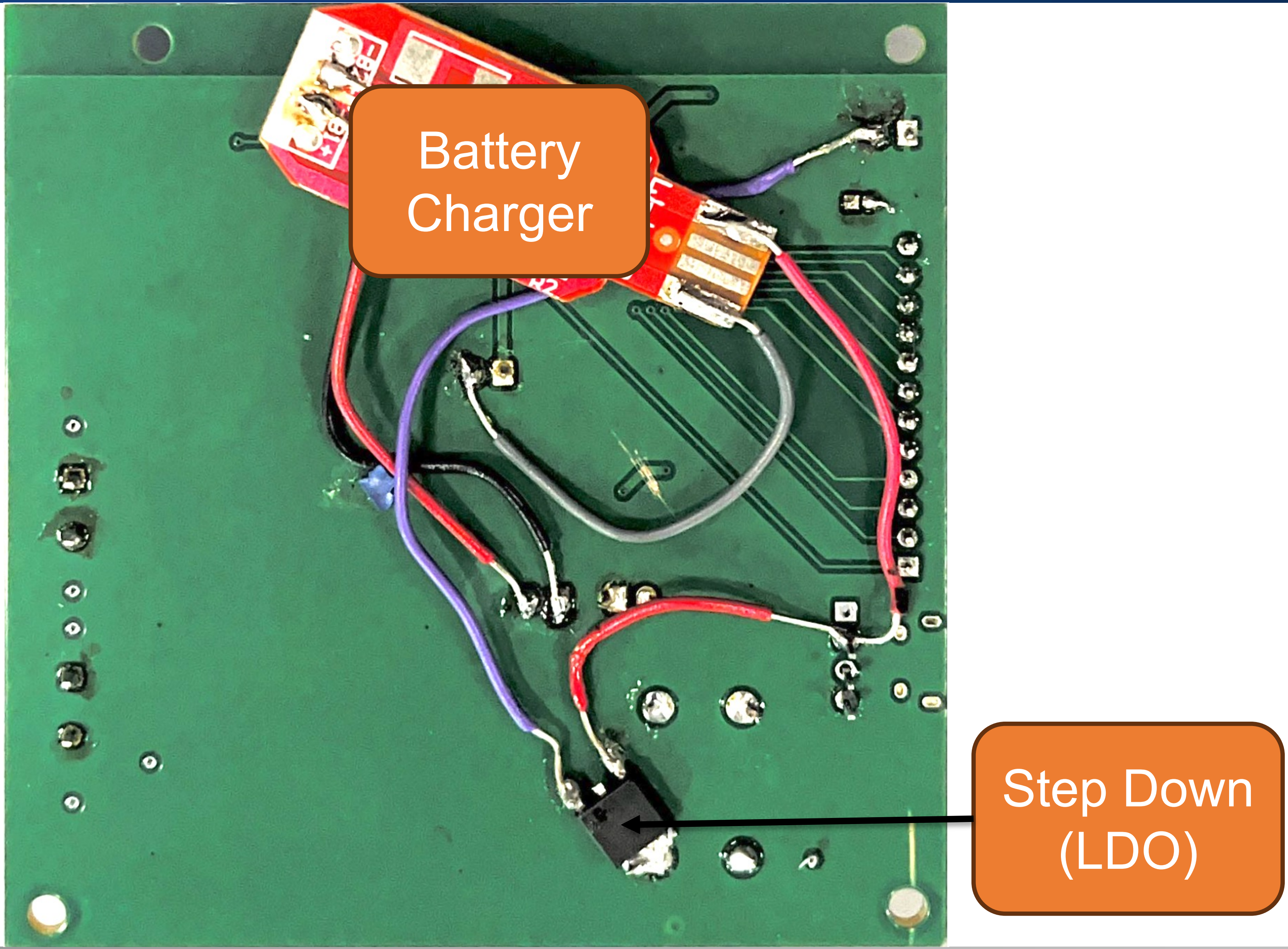
Final PCB (Front)



Final PCB (Reverse)



Final PCB (Reverse)



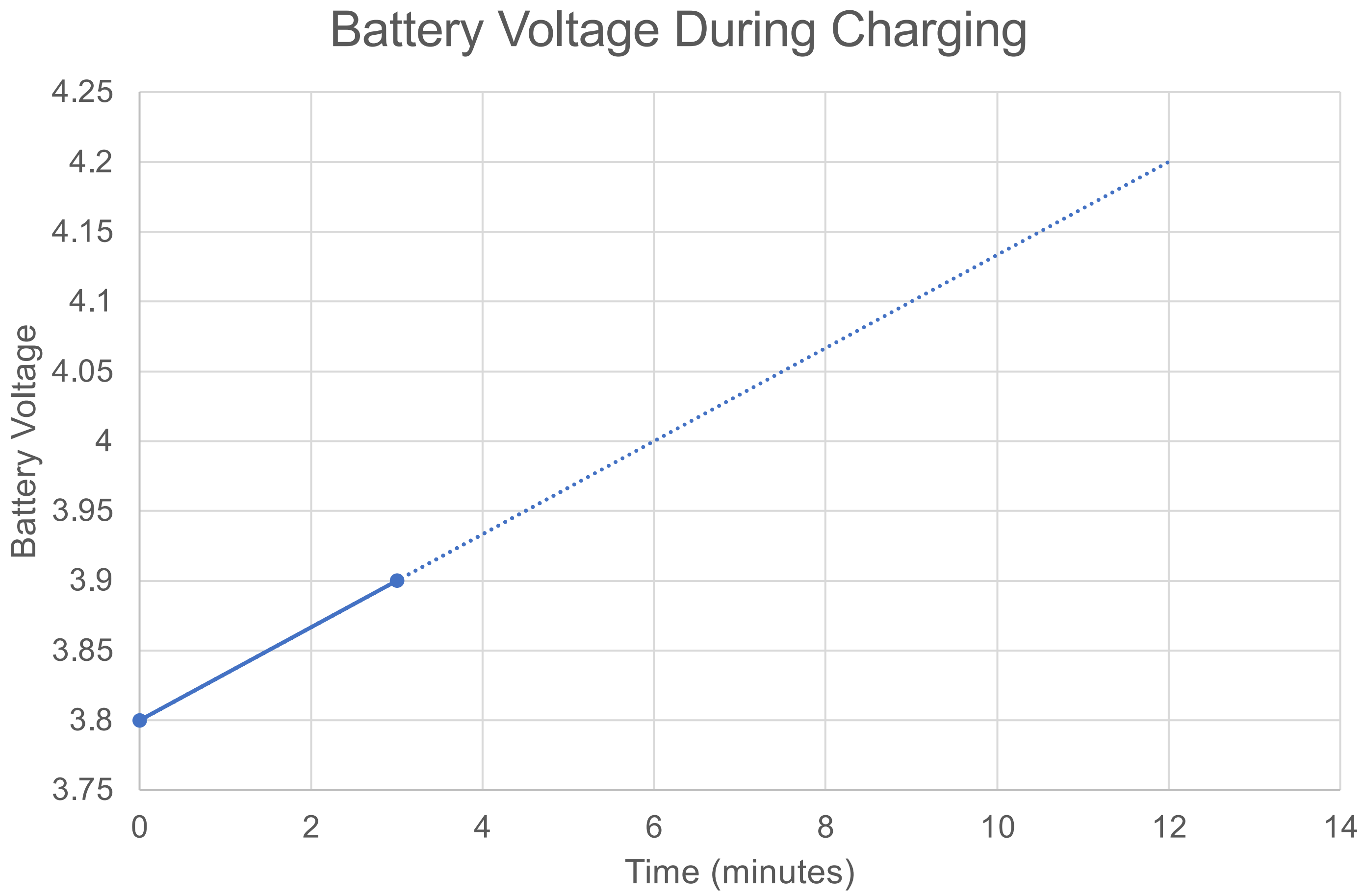
Testing

Power Consumption Testing

Valve Testing	Recharge Valve		Watering Valve	
Voltage	+12V	-12V	+12V	-12V
Avg Actuation Time (s)	4	4	3.8	3.84
Avg Current (mA)	40	42	40	40
Avg Power (mW)	480	480	476	480
Avg Energy (J)	1.92	1.92	1.81	1.845

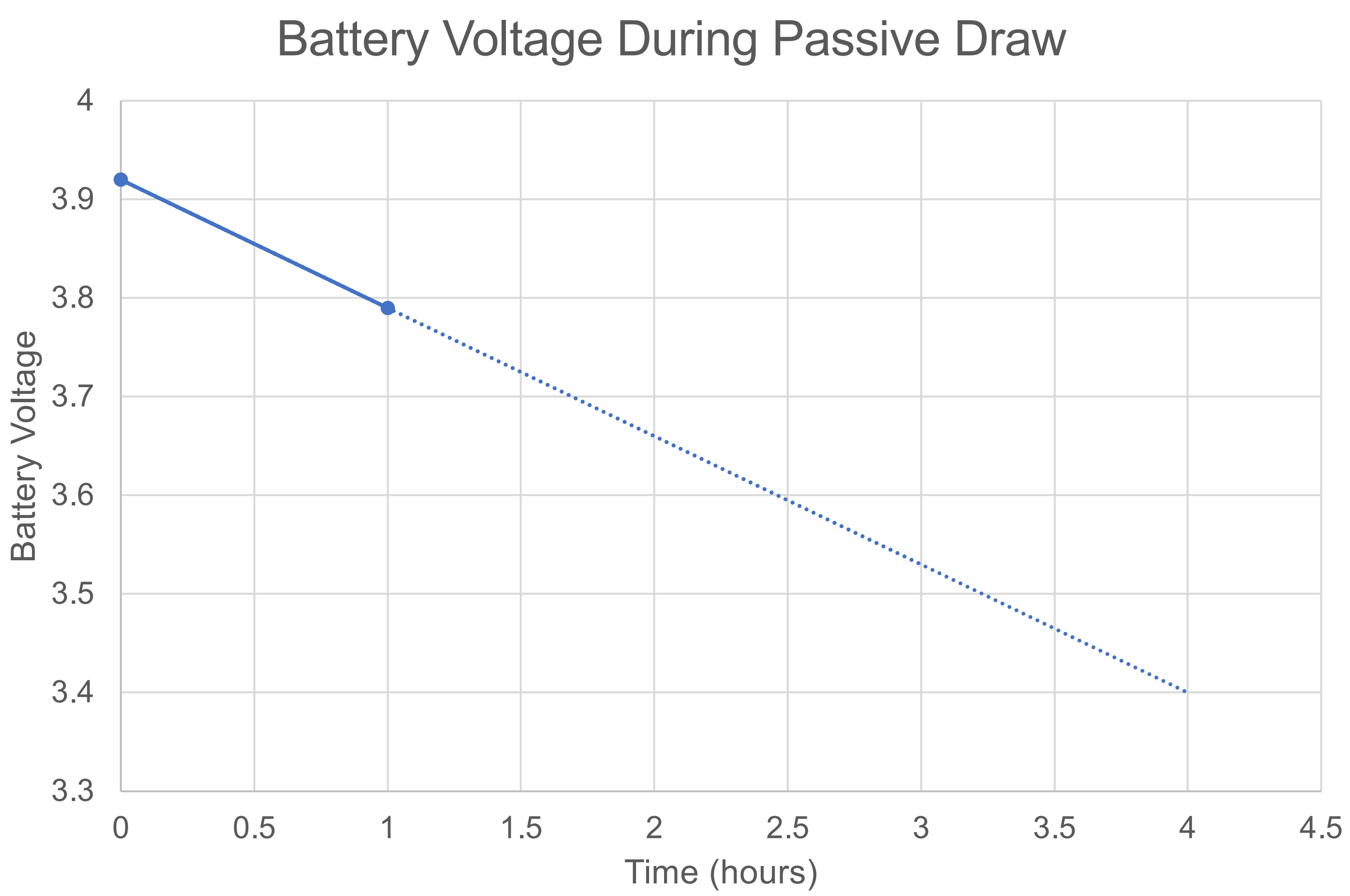
- Valve Test: Initial Vbat = 3.87V
  - Opened and then closed both valves
  - Vbat = 3.85V (<10% loss)

Battery Testing



- Initial Vbat = 3.8V
- 12V Bench, 500mA draw
- Final Vbat = 3.9V after 3 minutes
- 24 minutes to charge dead battery (3.4V) to full (4.2V)

Battery Testing



- Initial Vbat = 3.92V
- Final Vbat = 3.79V after 1 hour
- Approx 6.15 hours of battery capacity

•System Passive Power: 129mA @ 3.7V

  - Passive battery power ~ 477mW

•Turbine: 50mA @ 12V

  - Battery power = 0.3W-0.477W=-0.177W

Conclusions

High Level Requirements

Open/close valves based on remotely-issued commands

Recharge the battery using water flow during water cycles

Battery capacity measurement capability (goal: 48+ hours on a single charge)

Lessons

Timely unit testing before integration

Modular PCB design for final iteration

Careful testing to avoid IC damage

Communication while ordering parts

Recommendations for Further Work

Near Future

- Waterproof circuit enclosure
- Integrate microcontroller onto the PCB
- Increase conversion efficiencies so battery can charge

Down the line

- Communication between multiple valves
- Smaller form factor
- Smart monitoring conditions

Questions?

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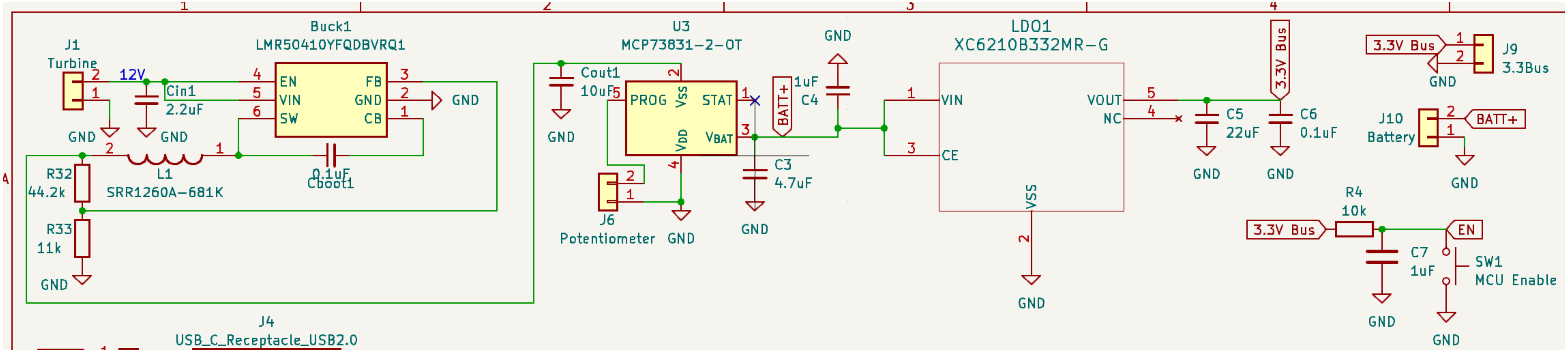
PCB Schematic - Power



PCB Schematic - Control

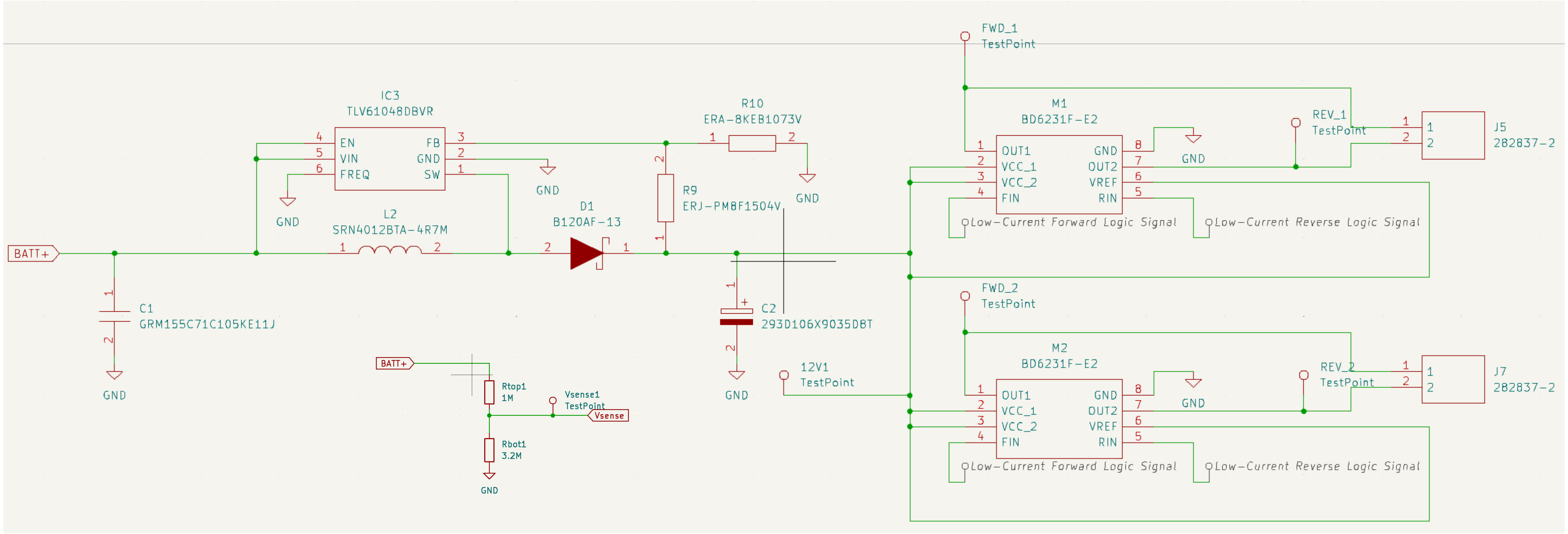


Table 8: Power Subsystem Requirements

Requirements	Verification
All power conversion must be more than 85% efficient and design puts efficiency above all else.	1. Measure the input and output power at either side of every converter using a DMM and calculate efficiencies 2. Read all input and output waveforms of every converter to make sure smooth waveforms are maintained using an oscilloscope
If the battery is fully charged (4.2V ±0.1V, then stop charging	1. Place a charged battery (4.2V ±0.1V) into device right before a watering cycle 2. Monitor voltage and current to battery charging circuit with a DMM over a period of 2 minutes and make sure that battery does not get charged (voltage does not increase by more than 0.3V) 3. Measure to see if the ”Battery Charged” signal is high when placing fully charged battery into device with a DMM

Continued on next page

Requirements	Verification
If the battery is going to die (3.4V ±0.1V), then close both valves	1. Place a close to dead battery into the device (3.4V ±0.1V) and observe that both valves close from an open state 2. Monitor "Low Battery" signal from battery charging circuit using a DMM and observe signal going high when dead battery is placed into device
Full battery can power all background processes for at least 5 days	1. Place a full battery (around 4.2V) into the system with valves closed and no water source 2. Observe how long the system can be powered until the "Low Battery" signal comes on 3. Record the voltage of the battery every hour and tabulate into a graph
Turbine valve shuts off when battery is fully charged.	1. Set both valves to "open" 2. Put a fully charged battery into the device 3. Observe the PWM waveform going to valve using an oscilloscope and record 4. Observe the turbine valve physically shutting

Requirements	Verification
The power supply to the battery charger circuit must provide a voltage in the range of 4.7-5.5V for a current load up to 300mA when the turbine is generating power.	1. While the turbine valve is open and power is being generated from the flow of water, measure the current and voltage at the input to the battery charger circuit using a DMM to verify that the voltage is between 4.7V-5.5V through the whole watering cycle (20 minutes) 2. Take notes on the voltage and current every 30 seconds and tabulate the data into a graph 3. Note whenever the voltage or current drops below this threshold and record for how long

Table 9: Microcontroller Subsystem Requirements

Requirements	**Verification**
The device must be able to pair with a base station prior to physical installation.	1. Initiate this test with a fully-charged on-board battery. 2. Use a cable to connect a laptop to the device (disconnected from the water supply). 3. The laptop will display confirmation that the connection between the devices is successful and will initiate the key exchange process. 4. Once the key exchange is completed successfully, the base station will communicate this to the user that the device can be unplugged. This is a pass/fail test.

Requirements	Verification
The device must be able to maintain a wireless connection with the base station. Furthermore, the base station should be able to send/receive data based on user input with a maximum latency of 10 seconds.	1. Start the test with the device having a fully charged battery (4.2V), and with the device pairing process completed. 2. Power on the base station (wired power source). 3. Send a 'ping' packet to the device. 4. The device should briefly enter a active mode, and send a 'ack' packet to the base station in response. 5. If the base station does not receive an 'ack' packet, it should notify the user that the device is suffering from connectivity issues. 6. For performance benchmarking, we will run this 'ping' test 100 times, and count the number of successful transactions which occured. 7. Record the number of successful transactions which occured for the final report.

Requirements	Verification
The device's wireless component must be able to remain in the idle state (no valve operations, no wireless data received/-transmitted) for at least seven days time. Note that it is ok for the device to be in a fully-discharged state at the end of this 1 week period.	1. Due to the time constraints of the demo time, we will be unable to wait three days to demo this component. 2. Instead, we will measure power consumption for a smaller interval of time, and extrapolate to estimate the battery life of the device. 3. We will initiate this test over a 10 minute time window, and computing the difference in battery percentage. 4. We can then compute a $\frac{\text{minutes}}{\text{Battery }\%}$, and get our idle-time battery estimate. 5. Record this battery estimate ($100 \times \frac{\text{minutes}}{\text{Battery }\%}$) in the final report.

Requirements	Verification
The device must be able to transition from idle state to active state if it receives a packet from the base station. After entering the active state for some amount of time (depending on the task given by the base station), the device returns to the idle state.	1. Initiate this test by starting the device in the idle state. 2. Then, have the base station send a wake signal to the device. 3. After sending the wake signal, initiate the ping test. 4. Note that it is ok for these steps to be combined into a single step. 5. After passing the ping test, then wait for the device to enter the idle state (we will pre-program this to happen instantly). 6. Then conduct the idle power consumption test. 7. If both tests pass, then the idle-active-idle transition requirement is met. This is a pass/fail test.

Requirements	Verification
The device must be able to control valves by outputting digital signals, based on commands from the base station. Note that the valve subsystem circuitry will handle the conversion of these digital signals, and our assumption is that the valve subsystem circuitry will function as per the valve subsystem specifications.	1. Initiate this test with a nearly-fully charged battery (4.2V), and the device in the idle state. 2. Initiate a 5 minute watering cycle command from the base station. 3. The device should begin by opening the "recharge" valve. 4. Once the valve is open, the device should open the "primary watering" valve. 5. Once both valves are open, the base station should receive a confirmation that the watering cycle is active. 6. After five minutes (with no base station invervention), the device should shut off the primary watering valve within 10 seconds, then the recharge valve within 10 seconds. 7. It should then communicate that the watering cycle is completed to the base station. This is a pass/fail test.

Requirements	Verification
While in the idle state, if the battery enters the "low battery" state (as defined in the Power Subsystem), the device will transmit a packet to the base station. The base station should then display this result to the user.	To conduct this test, we will need a lab setup. 1. We will spoof the battery circuitry by using a bench function generator. 2. We will initiate the device in the idle state. 3. We will then sweep from the maximum battery voltage (4.2V) down to the discharged battery voltage (3.4V) over a 10 minute time period. 4. Once the battery is below the 'low battery' threshold, the base station should receive a packet alerting that the device is low on battery. This is a pass/fail test.

Table 10: Valve Subsystem Requirements

Requirements	Verification
The turbine valve must open, close, and maintain state depending on the signals transmitted to the valve subsystem.	1. First, test the turbine valve opening by setting up the system so the battery is low and starting a water cycle. We should see the turbine valve open. 2. Then, test the turbine valve closing in two situations. First test that when the battery is fully charged and the water cycle is still going, the turbine valve closes. 3. Then, test that when the battery is not fully charged but the water cycle ends, the turbine valve closes. 4. Lastly, test that if none of the above conditions are met, the turbine valve remains idle and neither opens nor closes.
The non-turbine valve must open, close, and stay idle depending on the signals transmitted to the valve subsystem.	1. First, test the non-turbine valve opening by starting a water cycle. We should see the non-turbine valve open. 2. Then, test the turbine valve closing in two situations. First test that when a water cycle ends, the non-turbine valve closes. Then, test that when the battery is low, the non-turbine valve closes. 3. Lastly, test that if none of the above conditions are met, the non-turbine valve remains idle and neither opens nor closes.

Requirements	**Verification**
Make sure the battery consumption each time a valve opens or closes is less than 10% of the total battery capacity.	1. Test the energy consumption by opening or closing an individual valve. 2. Then check the net battery percentage before and after and to see whether less than 10% of the battery capacity was used.