The Smart Water Faucet

Senior Design Proposal
Spring 2025

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Conner McAuliffe,
& Zachary Carlier

Supervised by:
Prof. Masood Ejaz

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Meet the Team

Zachary Carlier

- Pursuing a B.S. in Electrical & Computer Engineering Technology – Electrical (Fall 2025 Graduation)
- Chief Production Manager at Harris Aerial LLC.

Conner McAuliffe

- Pursuing a B.S. in Electrical & Computer Engineering Technology – Electrical (Summer 2025 Graduation)
- LPR Intern at Jenoptik Smart Mobility Solutions.

Premnauth Persaud

- Pursuing a B.S. in Electrical & Computer Engineering Technology – Electrical (Summer 2025 Graduation)
- AutoTech installer at Best Buy.

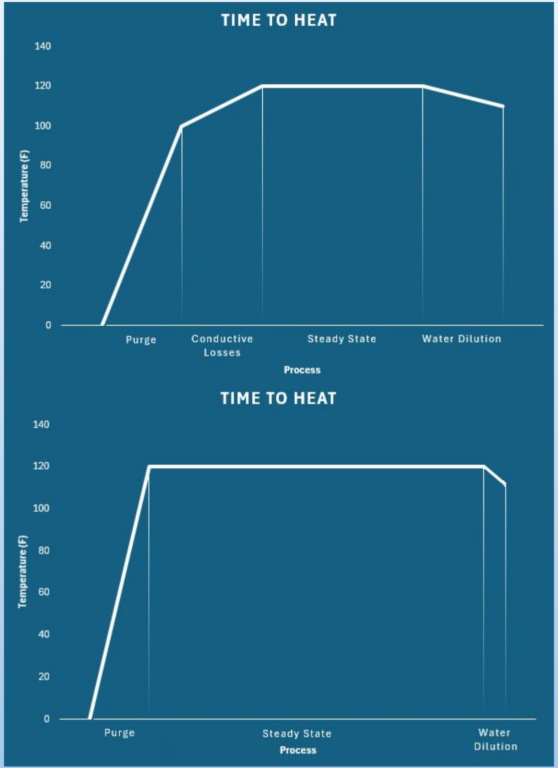
Problem & Solution

Problem

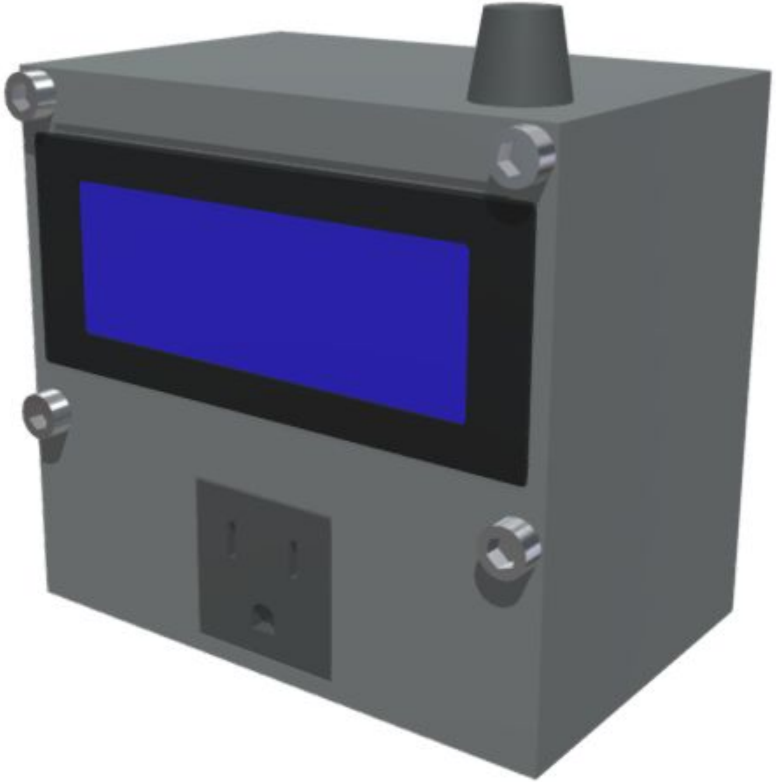
- The centralized heated water systems used in the United States are efficient but have many barriers to consistent water temperature, requiring frequent user intervention.

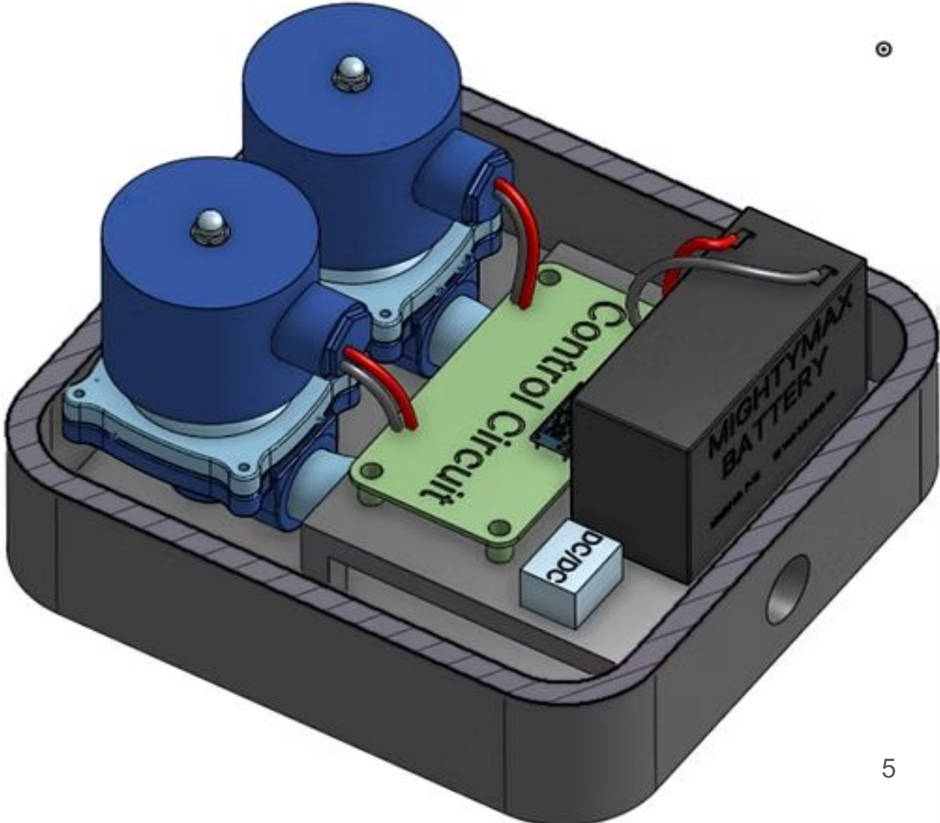
Solution

- The Smart Water faucet serves to automate this process and allow the user to customize their experience with minimal obstructions to convenience.



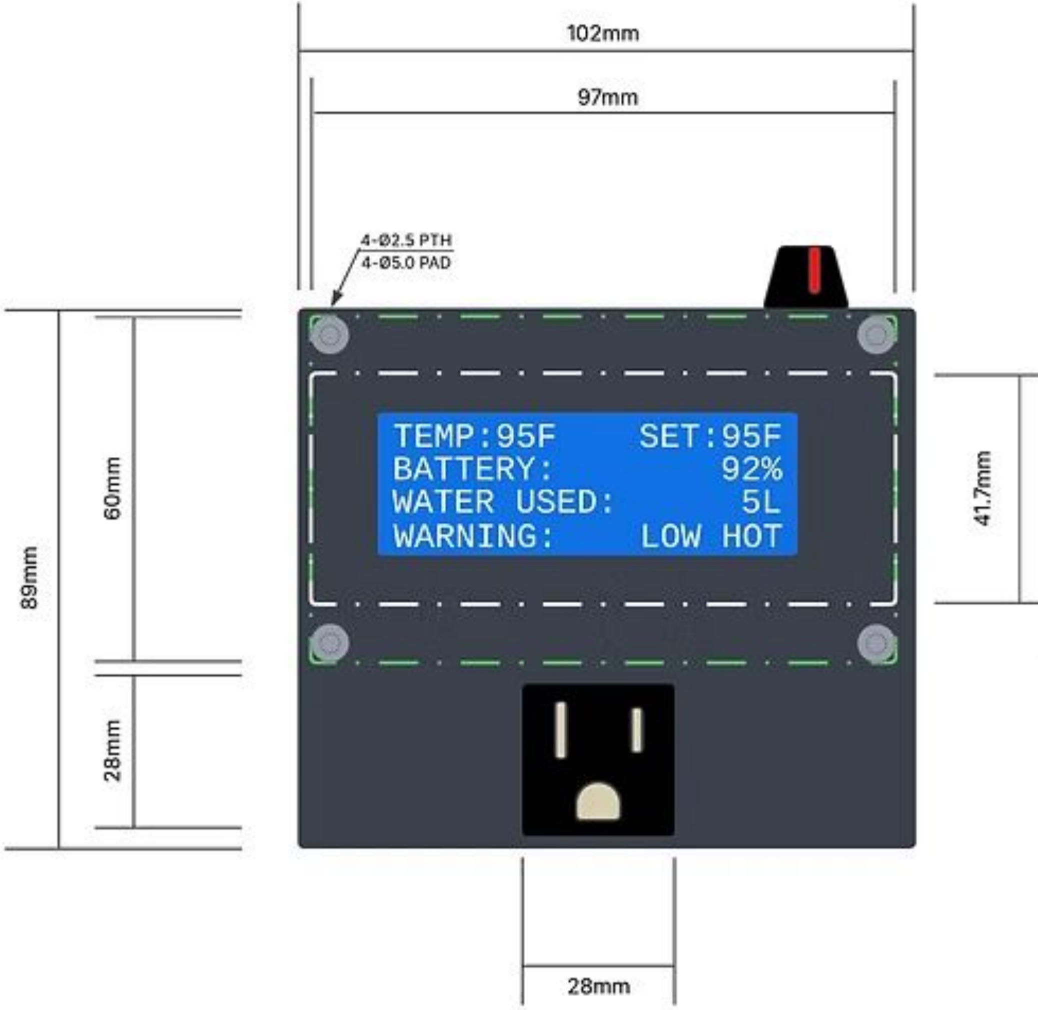
Proposed Design





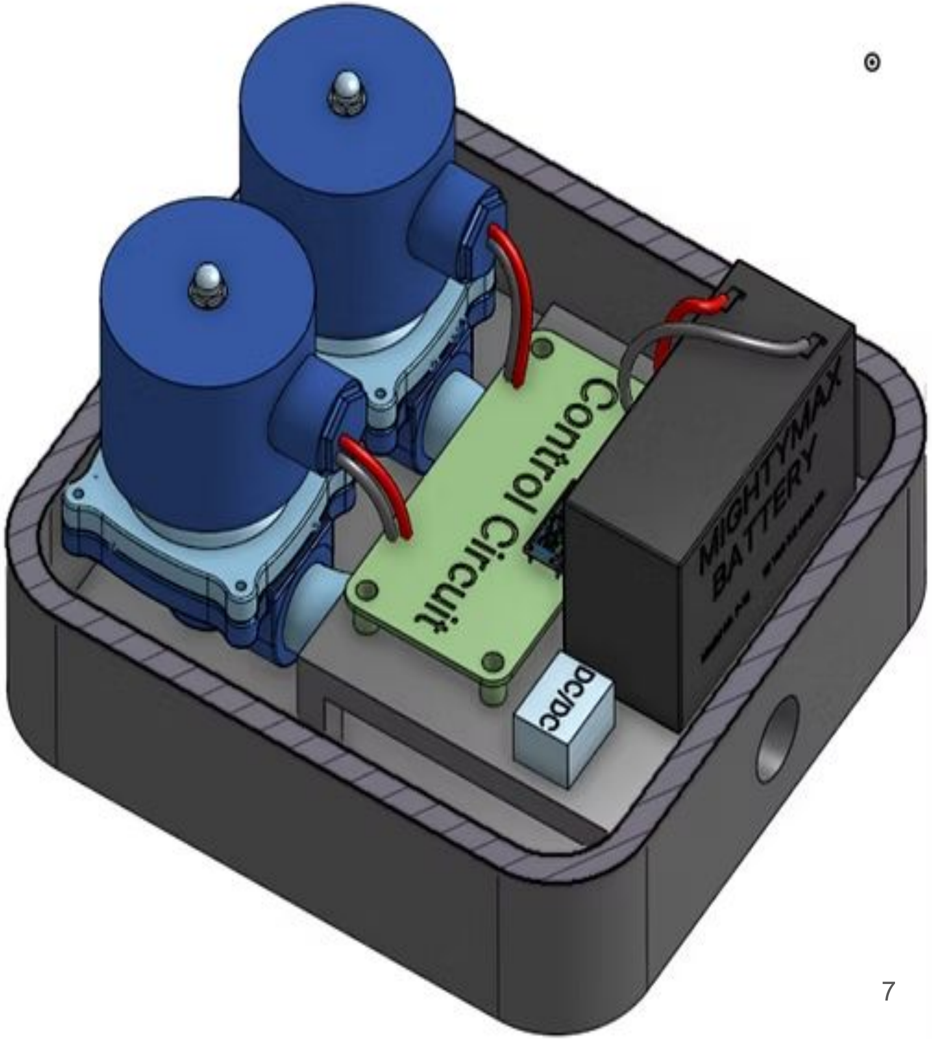
Thermostat

- ●Temperature is adjusted by turning a knob. The resulting voltage output is translated into a temperature and sent to the valve enclosure Microcontroller (MCU).
- ●The MCU receives transmitted data from the Valve Enclosure's sensors, and displays corresponding information on the Liquid-Crystal Display (LCD).
- ●Included is a 3-prong plug that allows the unit to be powered by the nearest wall outlet, and a tamper-proof AC outlet for convenience.
- ●Communication is provided through Bluetooth Low Energy 5.
- ●Dimensions: 102mm length x 89mm height x 68mm depth



Valve Regulator

- When the faucet is active, the temperature and flow sensor send data to the MCU.
- The desired temperature is received from the thermostat and sent to the logic controller with the current temperature.
- The logic controller will open and close the hot and cold valves to precisely adjust water temperature.
- Sensor data is sent to thermostat for display.
- Dimensions: 325mm length x 225mm height x 345 depth



Similar Products

BathSelect Trio [1]

Table 1.1 - Comparable Products				
Feature	**Smart Water Faucet**	**BathSelect Trio**	**Fontana**	**Thermostatic Mixing Valve**
Automatic Temperature Control	Yes	No, requires additional parts.	Limited	Yes
LCD Display	Yes	Yes	No	No
Temperature Feedback	Yes	Yes	No	No
Self-Powered	Yes (Valve Enclosure Only)	No	No	No
Touchless Operation	TBD	Yes	Yes, Optional.	No
Requires Professional Installation	No	Yes	Yes	No
Over Temp Protection	Yes, with warning.	Yes, with warning.	Yes, mechanical.	Yes, mechanical.
Leak Detection	Yes	No	No	No
Water Consumption Data	Yes	No	No	No
Power Requirements	12VDC / 110VAC	6VDC / 220VAC	6VDC / 110-220VAC	None
Price	$212.52	$783.91 - $833.63	$652.22 - $828.43	$30.99
Primary Application	Universal	Commercial	Commercial	Universal

Similar Products

Fontana [2]

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Similar Products

Thermostatic Mixing Valve [3]

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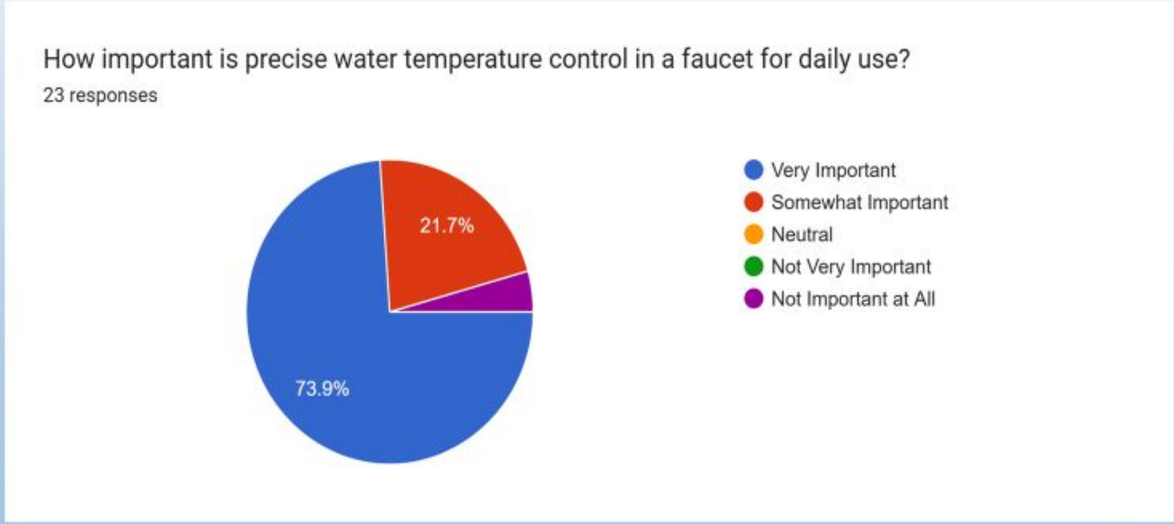
Survey & Results

- Respondents value temperature control

- Reduction of water waste

- 78.3% of respondents are likely to purchase

- Respondents would spend <$200



Valve Regulator Engineering Requirements

Valve Regulator		
Priority	Requirement (the system shall ...)	Verification & Success Criteria
1	use the temperature set by the user on the thermostat to regulate water temperature.	Multiple trials will be run with the prototype, and the set water temperature will be tracked for accuracy while artificially modulating the water input temperature to verify valves continuously adapt to dynamic conditions.
2	electrically sustain most or all of its operation via a built in turbine generator.	Systems will be subjected to multiple operating conditions, and valve activity will be tracked and/or reduced to validate or maintain sustainability.
3	be able to detect leaks and close both valves in addition to sending leak messages to thermostat to protect against property damage.	A Minimum amount of water will be introduced into the system to trigger the moisture sensor. Valves should immediately close and thermostat should display error messages.
4	have a waterproof enclosure for electrical components to prevent internal malfunction.	Enclosure for electrical components will be subjected to IPX-7 testing criteria (1 meter for 30 minutes) and checked for water intrusion.
5	continuously send water temperature, flow rate, and battery voltage data to the thermostat wirelessly.	These variables will be cross referenced with external measurements against the thermostat while running.
6	be completely contained, with only 4 connections for the faucet.	System will be modeled, and flush mount connections will be integrated into design to attach to valves and sensors.
7	have the ability to be externally charged in cases of battery exhaustion.	System battery will be artificially drained, and state of charge will be tracked via voltage & current to validate rapid and safe charging.

Thermostat Engineering Requirements

Thermostat		
Priority	Requirement (the system shall ...)	Verification & Success Criteria
1	accept temperature request from user & send to valve regulator	Potentiometer will be validated to linearly control displayed & transmitted temperature value from 0-150F.
2	display requested temperature, water temperature, water consumption, leak detection & battery state of charge on an LCD screen	These variables will be cross referenced with external measurements against the thermostat while running.
3	minimize power consumption when not in use.	MCU current will be measured to make sure it goes into sleep mode once the faucet has been turned off.

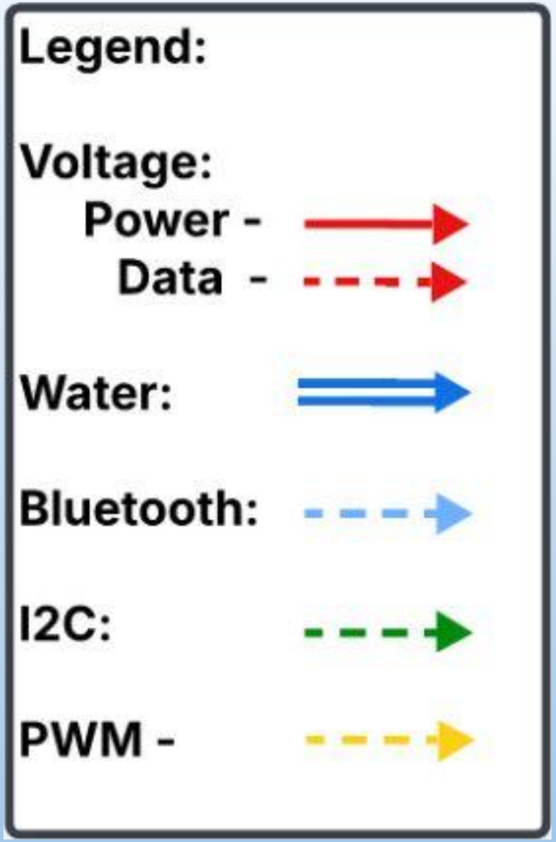
Product Engineering Requirements

Product		
Priority	Requirement (the system shall …)	Verification & Success Criteria
1	Include an installation and operator's manual.	The manual should be concise and clear, providing a detailed explanation on how the system will be installed and how to operate it with illustrations, procedures, and parts and tools needed.

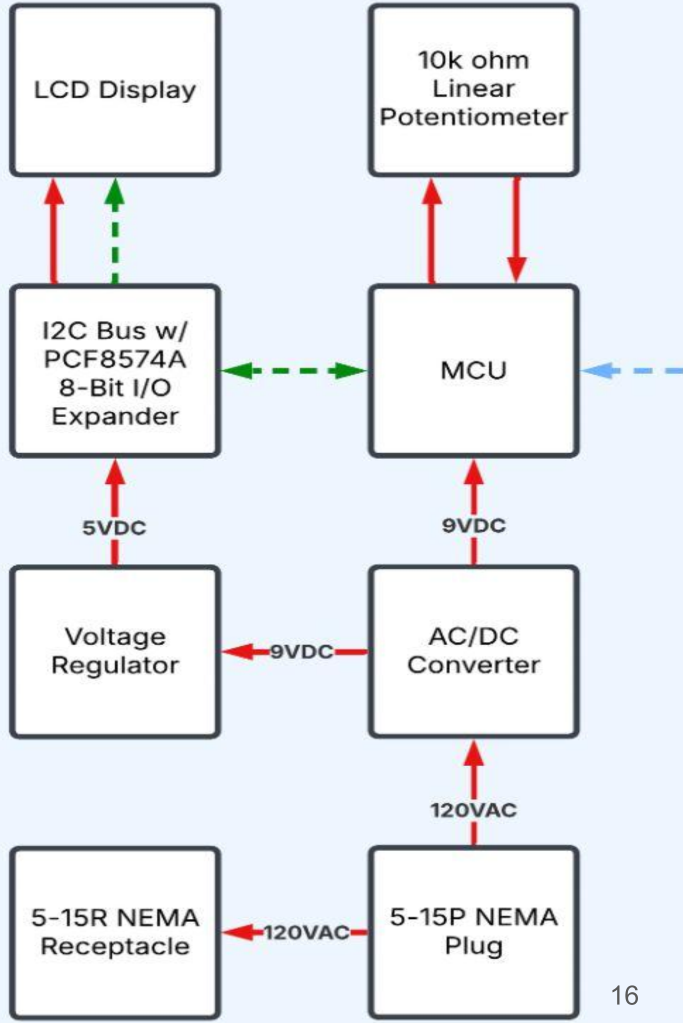
Limitations

1. May need to be charged periodically depending on usage scenario
2. May reduce water flow rate and available pressure due to sensors and turbine
3. Cannot compensate for insufficient hot water
4. Requires initial installation from user

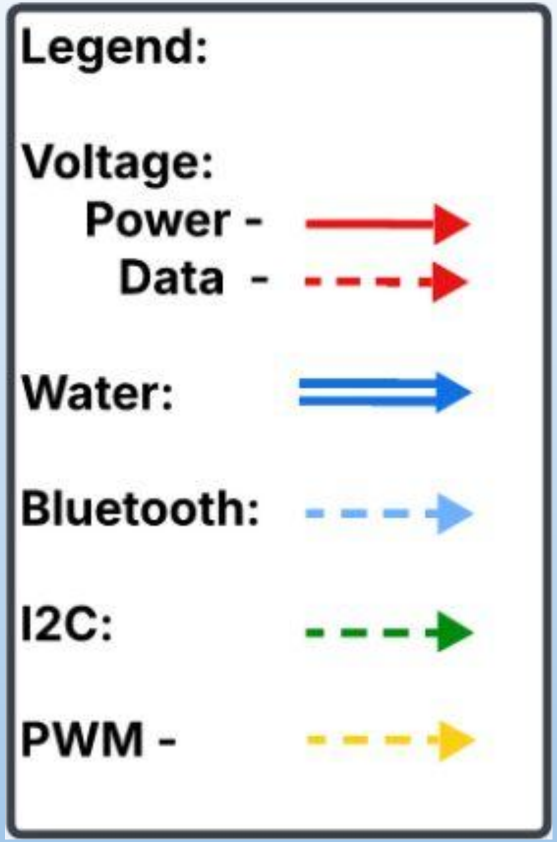
Hardware Block Diagrams



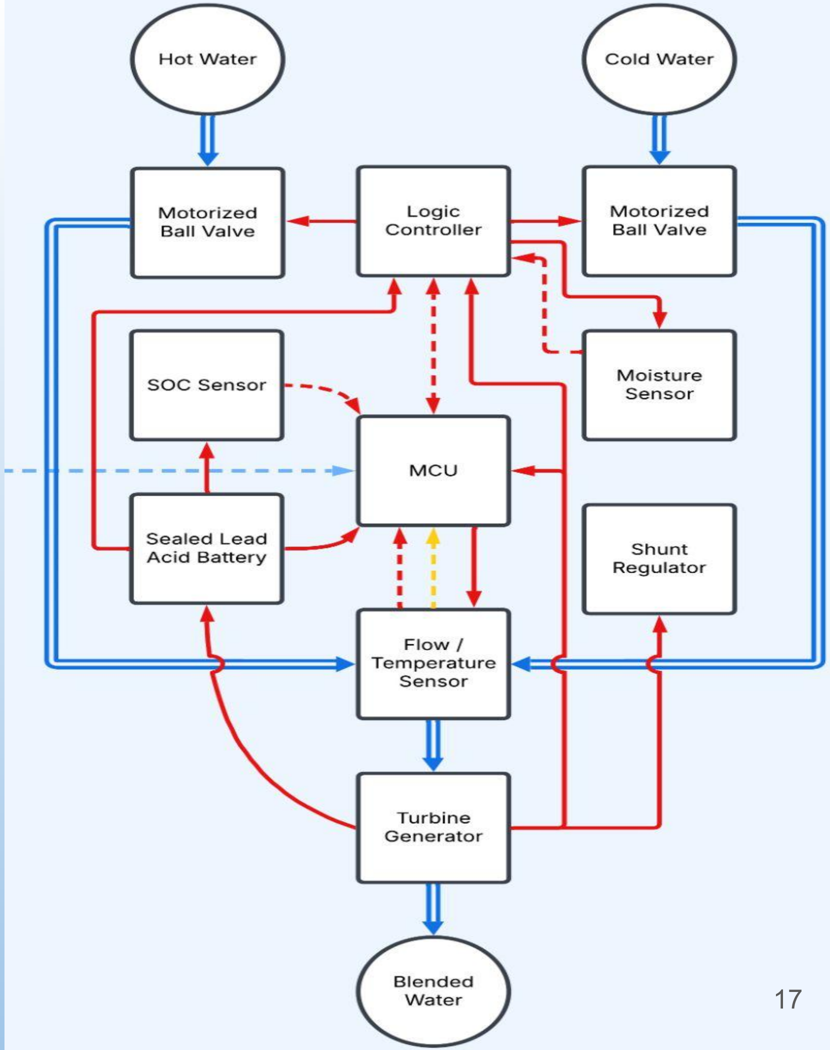
Thermostat



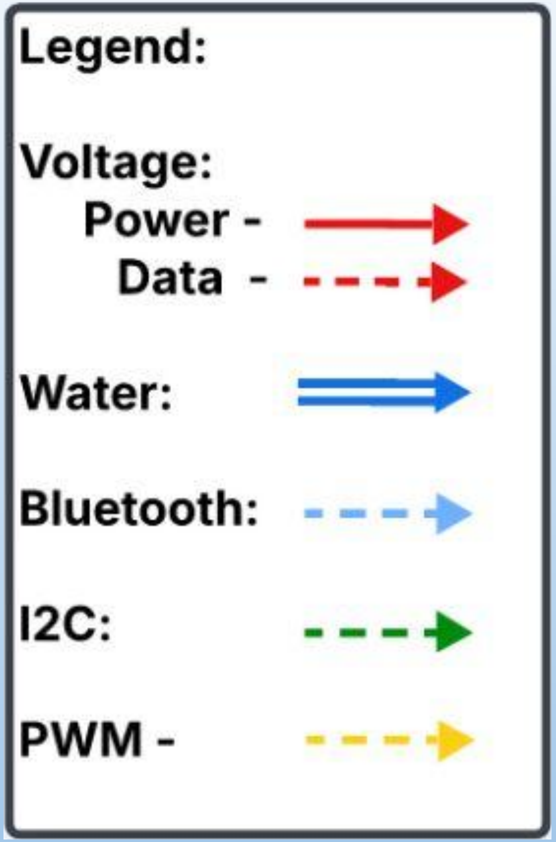
Hardware Block Diagrams



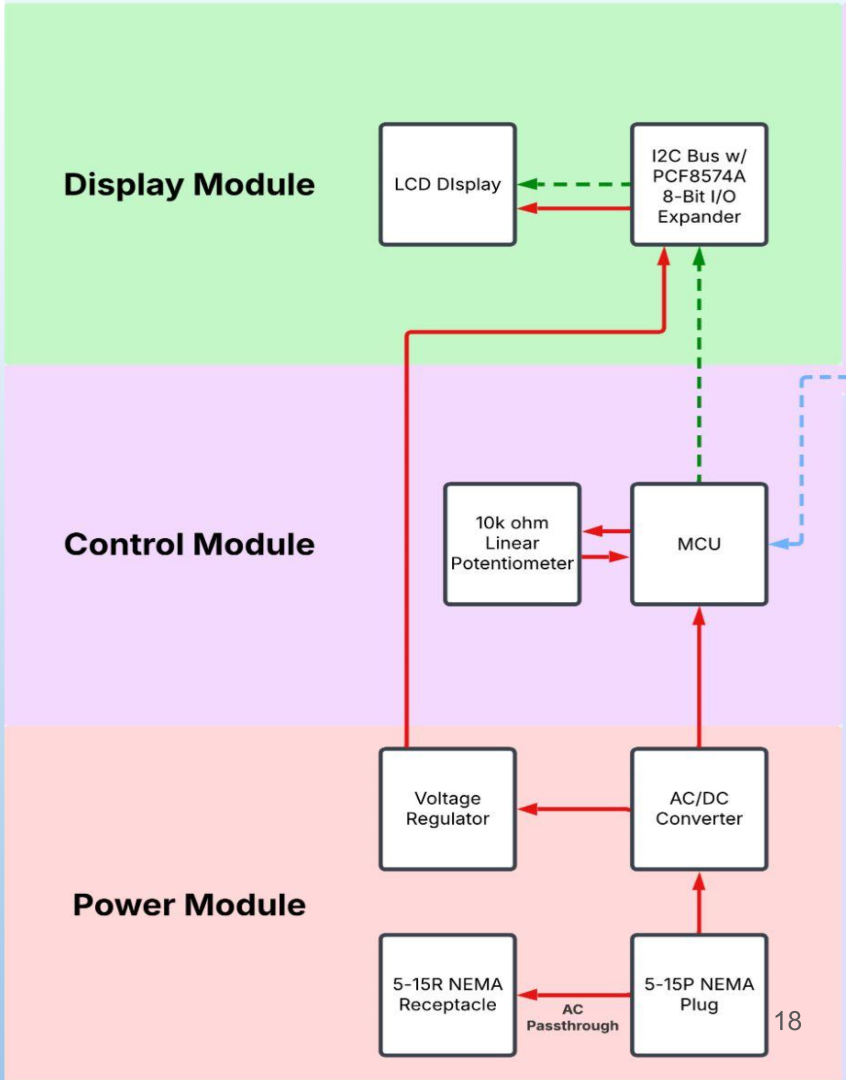
Valve Regulator



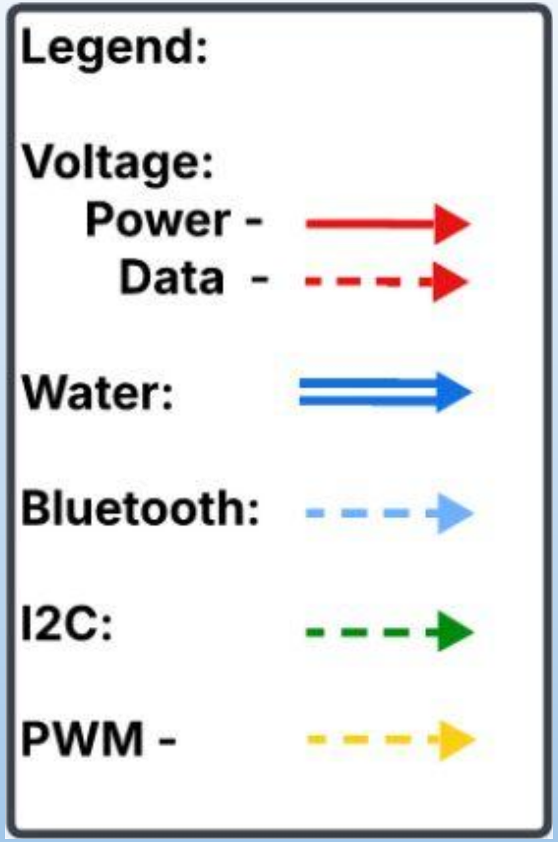
Modular Block Diagrams



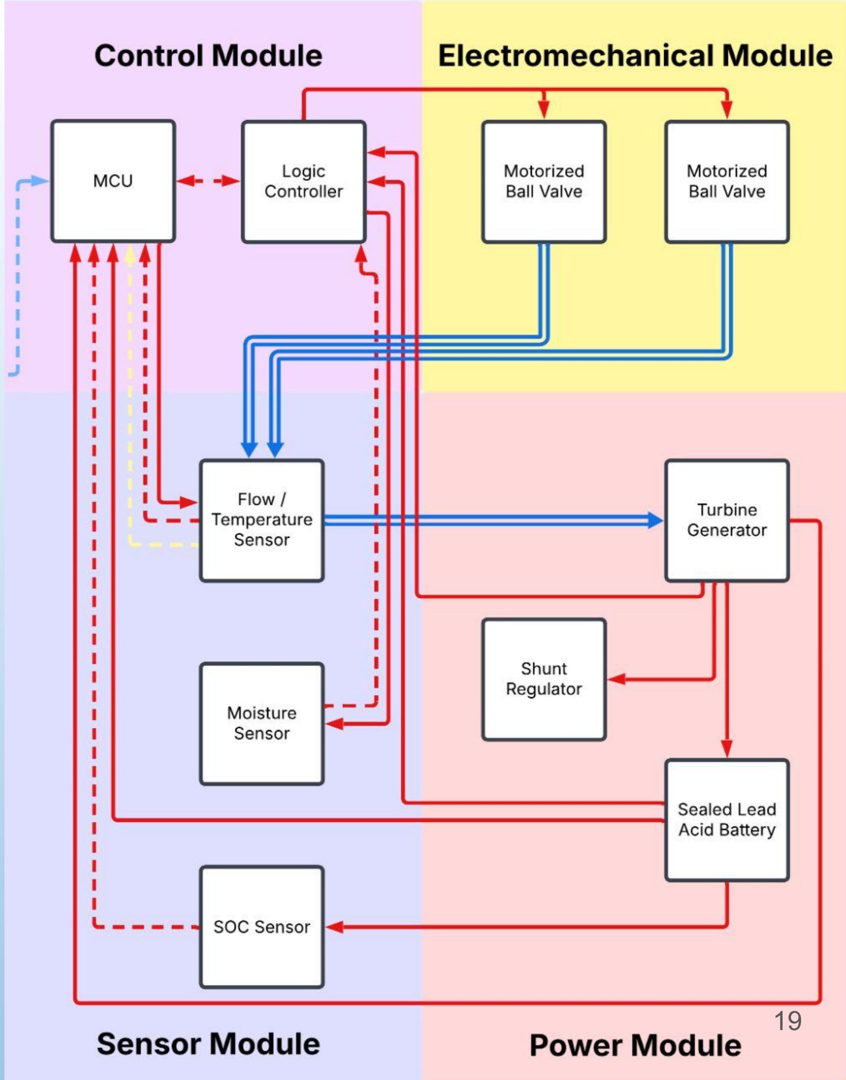
Thermostat



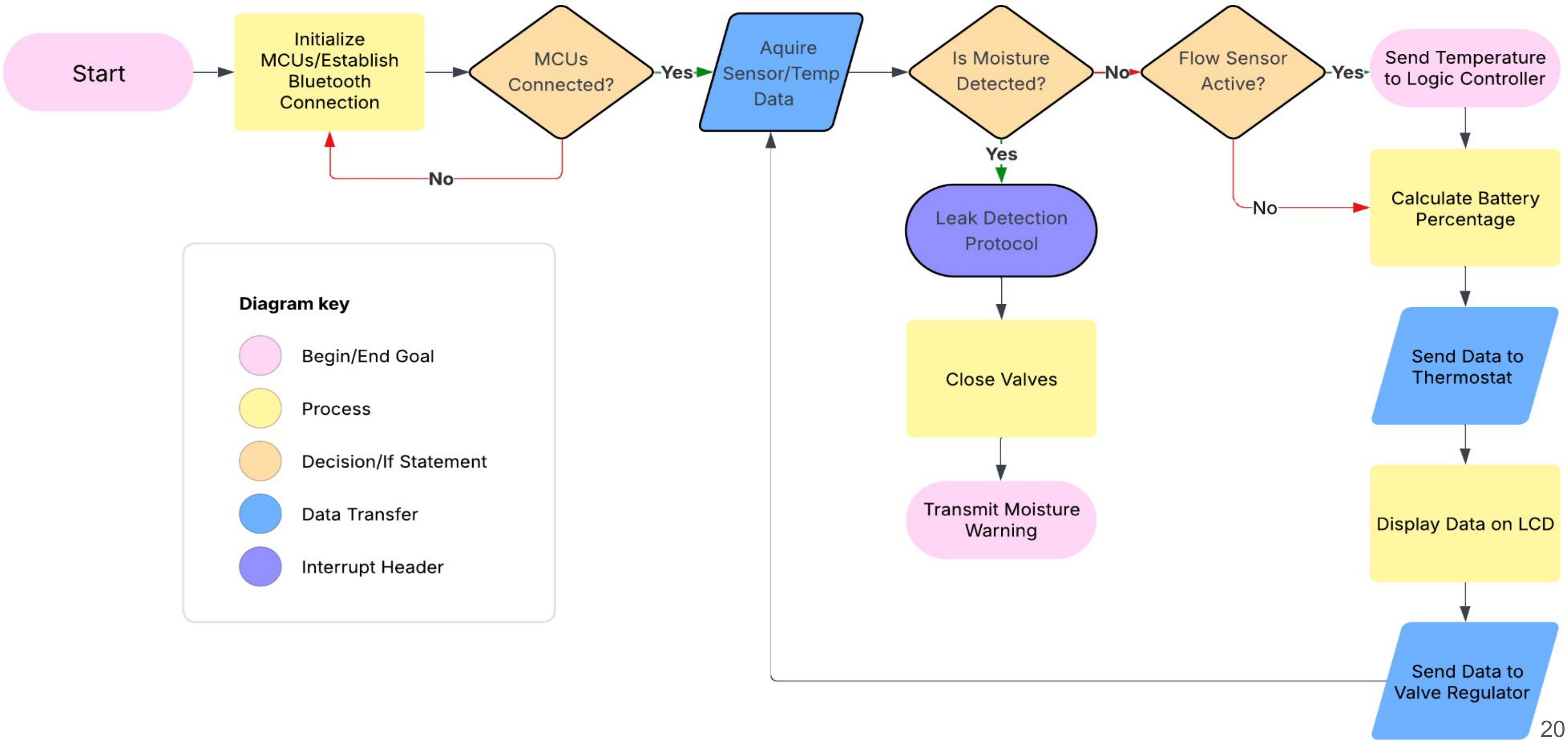
Modular Block Diagrams



Valve Regulator



Software Flowchart



Valve Regulator Engineering Specifications

Valve Regulator			
Module	**Component**	**Engineering Specifications (must …)**	**Justification**
Power Module	Sealed Lead Acid Battery	provide at least 9V at 0.9A	Removes the need to interface with AC voltage or replace batteries
	Turbine Generator	have 1/2' fitting & provide at least 12.9V at 200mA	Required to charge 12V battery
	Shunt Regulator	provide up to 200mA of sustained current dissipation above calibration voltage	Allows for passive voltage protection
Electromechanical Module	Motorized Ball Valves	have 1/2" fitting and be able to have full control over water pressure down to 0 PSI	Allows for manipulation of final output temperature
Control Module	Logic Controller	dynamically switch voltage & polarity of valves	Allows for dynamic valve adjustment
	MCU 1	have BT capability, at least 2 onboard ADC & DAC outputs, & 4 GPIO pins	Data must be acquired and encoded to communicate with the thermostat
Sensor Module	Temperature Sensor	have a temperature range of 0-150F & 1/2" fitting	Water temperature needs to be sampled constantly to control valve position
	Flow Sensor	have flow rate of 0-30 L/min & 1/2" fitting	Tracking water consumption adds value to the product by making the user aware of cumulative water use per cycle
	Moisture Sensor	be able to detect at least one drop of liquid or excess condensation	Unit will be subjected to constant water pressure. If a leak develops in any of the connections, the product and its environment will become damaged by water.
	SOC Sensor	reduce battery voltage down to MCU ADC range (13V to 3.3V)	Allows for digital sampling of battery SOC to send to thermostat display

Thermostat Engineering Specifications

Thermostat			
Module	**Component**	**Engineering Specifications (must ...)**	**Justification**
Control Module	MCU 2	have at least one 3.3V output and capable of receiving an input voltage from 7 - 12VDC.	Most sensors/peripherals require either 3.3VDC or 5VDC for operation.
		be capable of supporting I2C communication.	I2C reduces the need for excess GPIO pin usage.
		be capable of Bluetooth 5 low energy communication.	Data will be transmitted to and/or received from the valve regulator MCU.
		have at least two analog GPIO pins.	Temperature configuration will be read via analog signal.
		have at least one digital GPIO pin.	LCD Backlight can be controlled using high or low signal and transistor for current regulation.
	Potentiometer	be 10k ohms, linear, and panel mounted.	Set temperature configuration will be controlled via analog components.

Module	**Component**	**Engineering Specifications (must ...)**	**Justification**
Display Module	LCD Screen	be 3.3V - 5V compatible	3.3V LCD can be powered via MCU, or else 5V through voltage regulation.
		have an adjustable backlight	reduced power consumption possible if backlight is toggled off when not in use.
		be within thermostat size constraints: 101mm (L) / 89mm (W).	selection of an LCD module that is capable of displaying all necessary information without being larger than the enclosure.
		capable of being controlled via I2C	communication via I2C reduces the need for excess wiring.
	I2C Bus	have 16 bidirectional I/O pins, an 8-bit expander, and capable of interfacing with LCD backlight.	I2C communication sends bits of data every clock pulse, with an 8-bit expander data can be transmitted more efficiently.
		capable of I2C communication at 100kbps	Standard I2C communication is 100kbps.

Thermostat Engineering Specifications

Module	Component	Engineering Specifications (must …)	Justification
Power Module	AC/DC Converter	be capable of outputting 9VDC from 110VAC at a minimum of 3W.	Thermostat components will require DC power for operation.
	AC Pass-Through	comply with NEC / NFPA 70 standards and tamper-proof.	Household wiring and electronics are required to meet certain compliance measures for fire safety.
	Multi-Voltage Regulator	Regulate 9V supply down to 5V (constant) & 3.3V (switched).	MCU operates best above 5V, but LCD requires 5V & backlight requires 3.3V.
	AC/DC Converter	be capable of outputting 9VDC from 110VAC at a minimum of 3W.	Thermostat components will require DC power for operation.
	AC Pass-Through	comply with NEC / NFPA 70 standards and tamper-proof.	Household wiring and electronics are required to meet certain compliance measures for fire safety.

Valve Regulator Power Module

- Power Module Consists of a Turbine Generator and 12V Lead Acid Battery
    - Beduan 1/2” 12V Turbine Generator [4]
        - Allows for installation of valve enclosure without interfacing with AC voltage.
    - 12 7.2Ah Sealed Lead Acid Battery [5]
        - Sustains transient power demands and sleep mode operations.
        - Stores any excess power produced.
        - Reasons for Chemistry type.
            - Tolerates unregulated charging well.
            - Ideal for standby power applications.
            - Generic specifications allows for low replacement costs and high availability.

Valve Regulator Electromechanical Module

- Water temperature with be controlled by 2 1/2” 3 wire electric ball valves. [6]
- Advantages
    - Minimal power requirements (0.4A at 12V) vs solenoid valves (1.2A).
    - Can be parked in any position.
        - No power consumption during steady-state.
        - Allows valves to be staged for purge cycle during sleep.
    - Disadvantages
        - No ability to track position of valves.
            - Can be partially counteracted by monitoring current consumption to determine maximum actuation points.
        - Higher number of outputs required from regulator.

Valve Regulator Sensor Module

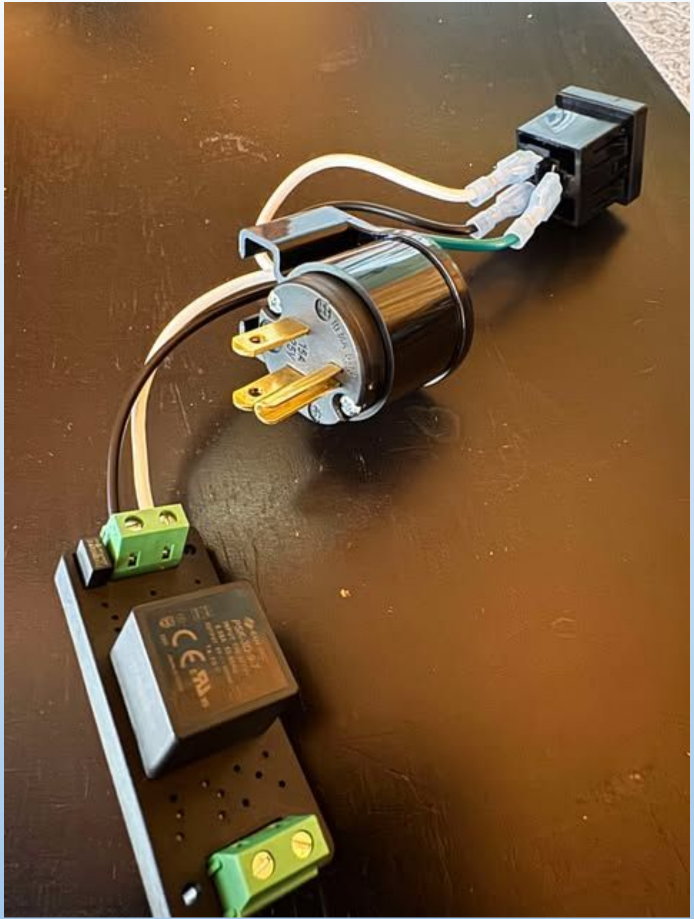
- GREDIA ½" Male Thread Water Flow Sensor (with temperature sensor) [7]
  - 1-25L/Min
  - 0-80℃ (0-176℉)

- HiLetgo Raindrop Sensor [8]
  - Sends signal with water activation

Valve Regulator & Thermostat Control Module

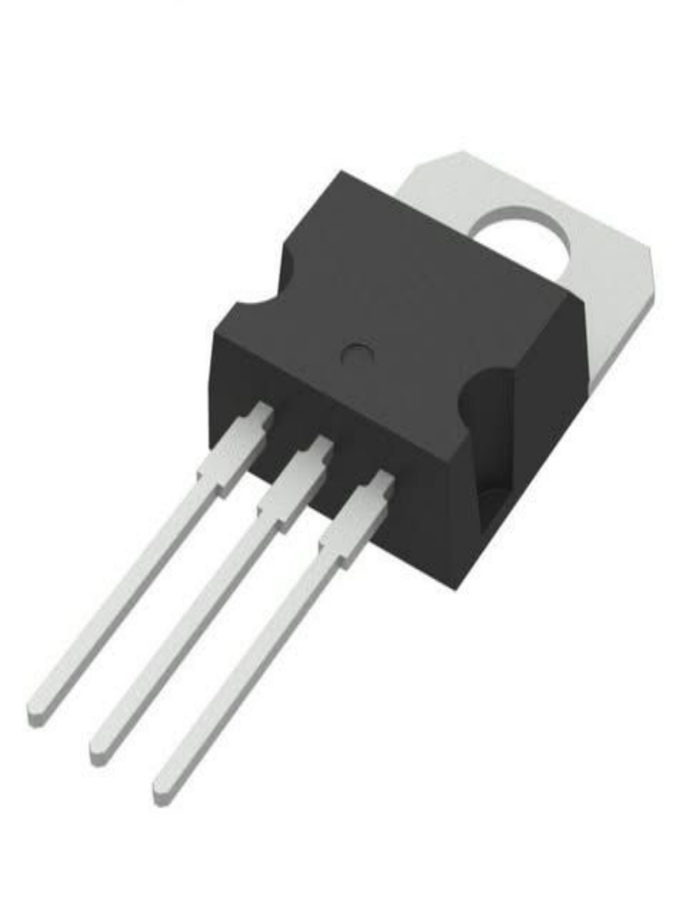
- Arduino Nano 33 BLE rev. 2 [9]
- Small Form Factor
- Bluetooth Capability

Thermostat Power Module



- CUI Inc. PSK-3D-9-T AC-DC Converter.
- Qualtek Tamper-Proof NEMA 5-15R Outlet.
- Qualtek NEMA 5-15P Plug.
- 14 AWG Thermoplastic High-Heat Nylon wire.

Thermostat Power Module



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- Qualtek Tamper-Proof NEMA 5-15R Outlet.
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- 14 AWG Thermoplastic High-Heat Nylon wire.
- L7805 Voltage Regulator. [10]

Thermostat Display Module

- SunFounder LCD2004 80 Character Screen. [11]

- PCF8574 based I2C Bus With contrast knob. [11]

Power Budget

Table 2.3a - Valve Regulator Power Budget				
Component	**Voltage (VDC)**	**Current (mA)**	**Power (W)**	**Comment**
Generator	12	200	1.86	Maximum
Battery	12	0	0	Should only sustain transients or absorb excess power
Valve 1	12	-360	-0.54	At 25% Duty Cycle
Valve 2	12	-360	-0.45	At 25% Duty Cycle
MCU 1	12	-0.004	-0.05	MCU Maximum Power Consumption + BLE + Converter Losses
Logic Controller	12	-0.004	-0.05	Initial Estimation
Net			0.68	
Generator	12	0	0	
Battery	12	360	4.32	20 hour rated discharge rate
Valve 1	12	0	0	
Valve 2	12	0	0	
MCU 1	12	-2.8E-09	-3.36E-11	Sleep mode with BLE on
Logic Controller	12	-45	-0.5	Initial Estimation
Net			3.78	
Estimated Standby Time (hours)			160	

Table 2.3b- Thermostat Power Budget				
Component	**Voltage (VDC)**	**Current (mA)**	**Power (W)**	**Comment**
AC/DC Converter	9	333	3	Maximum
LCD Screen	5	-10	-0.09	Screen + Logic + Converter Losses
LCD Backlight	3.3	-30	-0.27	Backlight + Converter Losses
I2C Bus (PCF8574)	5	-0.1	-9E-4	
MCU 2	9	-0.011	-9.9E-5	MCU Maximum Power Consumption + BLE + Converter Losses
Net			2.64	
AC/DC Converter	9	333	3	Maximum
LCD Screen	5	-10	-0.09	Screen + Logic + Converter Losses
LCD Backlight	3.3	0	0	
I2C Bus (PCF8574)	5	-0.1	-9E-4	
MCU 2	9	-2.8E-09	-2.52E-11	Sleep mode with BLE on
Net			2.91	

Monetary Budget

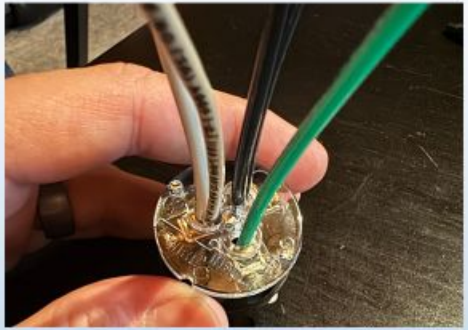
Table 3.1 - Monetary Budget			
Quantity	**Description**	**Supplier**	**Price**
2	1/2" Stainless Steel Electric Ball Valve	U.S. Solid	76.36
1	12V 7.2 AH Rechargeable SLA Battery	Mighty Max	20.24
3	Small form factor BLE MCU	Arduino	86.01
1	G1/2" Water Flow Sensor with Temperature Sensor	GREDIA	15.54
1	Micro Water Turbine	Beduan	12.77
1	2004 I2C LCD	SunFounder	14.16
1	Tamper Resistant NEMA 5-15R Snap	Qualtek	1.61
1	15A 125VAC NEMA 5-15P Angled Str	Qualtek	9.92
1	Panel Mount 10K potentiometer - 10K Linear	Adafruit	1.01
1	Potentiometer Knob - Soft Touch T18 - Red	Adafruit	0.53
1	Chassis Mount 9V Internal AC-DC Power Supply	CUI Inc.	12.92
1	3-Way Thermostatic Mixing Valve	Fyeer	28.74
1	3/4" to 1/2" Threaded Female Adapter	Proline	9.78
3	Rain Drop Sensor	HiLetgo	20.73
	Miscellaneous		100
	TOTAL		**$ 410.32**

Health & Safety

- Low voltage design.
- National Electrical Code (NEC) / National Fire Protection Agency (NFPA) & Underwriters Laboratories (UL) compliance conscious design.
- Warning System.
- Food-Safe Plumbing Fixtures.

Preliminary Work - Thermostat Power Module

- NEMA 5-15 plug and receptacle wiring installed.
- Circuit protection with various recommended elements.
- Multi-stage voltage regulation.

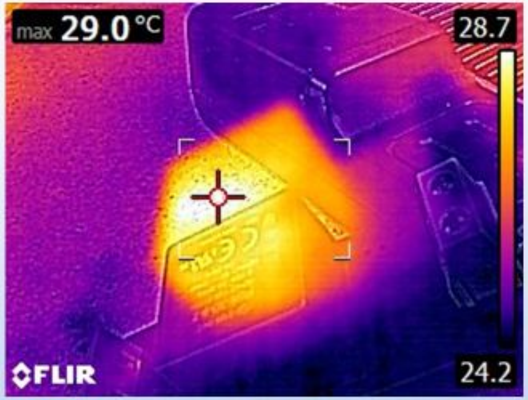


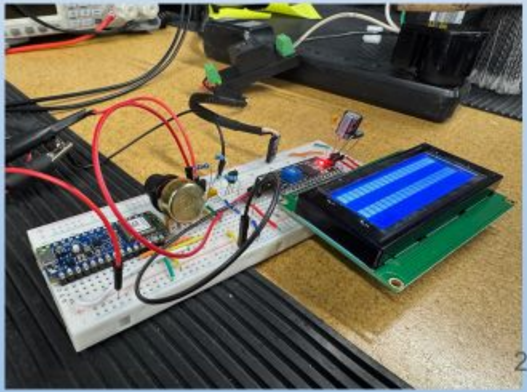
Preliminary Work - Thermostat Power Module

- Load and thermal testing performed to determine if cooling would be necessary.

- Component operation verified with a multimeter & oscilloscope.

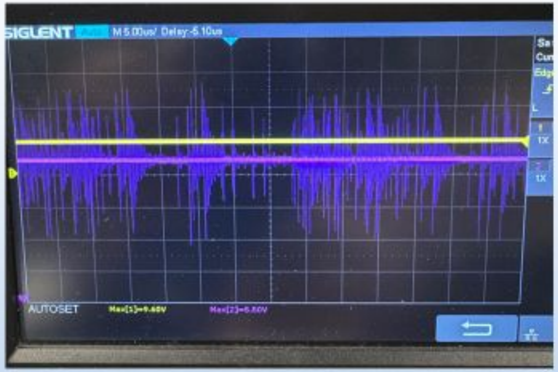
- Trialed different methods for backlight control.





Preliminary Work - Thermostat Power Module

- Decision to use LM317 or L7805 voltage regulator.
- LM317 requires careful consideration when selecting resistors and capacitors, limited part selection resulted in higher voltage.
- L7805 provided stable voltage within specifications listed on its datasheet at 5.02V and provides additional voltage protection from surges.



Preliminary Work - Generator Output Characteristics

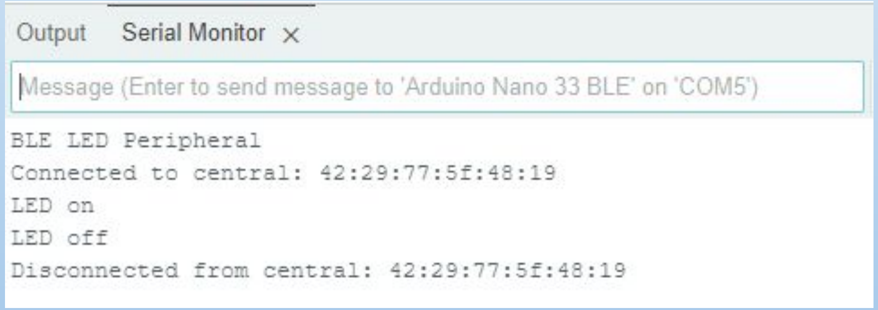
- Limited & Contradictory Power Ratings
  - No regulator specifications.
  - Rated for 10W, but only 220mA.
- Regulator Observations
  - 7812 linear regulator paired with zener diode.
  - Accurate but inefficient and does not allow battery to be charged (requires at least 12.9V).
- Output Observations
  - 3 phase generator which produces 46V open circuit and 161mA short circuit.
  - Yields a maximum output power of 1.86W at 285 ohms.
  - Internal regulator will be disabled and replaced with passive shunt regulation to decrease losses through regulator (no dropout voltage) and higher charging voltage at low loads.

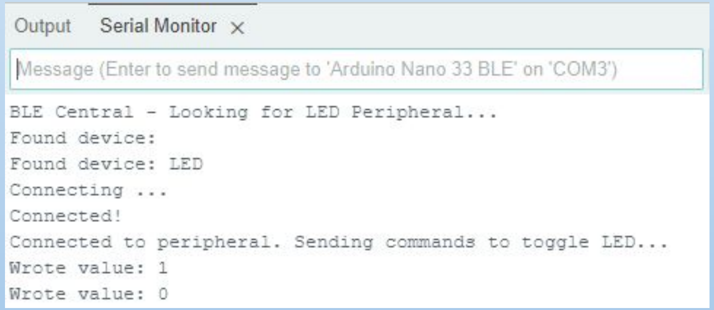
Preliminary Work - Valve Testing

- A ball valve was purchased and tested to gauge its accuracy, power consumption, and tolerances.
- The valve takes approximately 5 seconds to fully actuate from either position to the other.
- If power is removed during actuation, it will pause at the same position almost immediately.
- Attempts to reduced the valve operation at lower voltages (to increase precision) yields poor results, with it ceasing to function completely below 9V instead of slowing down.
- This poses possible limitations to precision, which is its main disadvantage against solenoid valves.

Preliminary Work - Bluetooth Software

- Thermostat and valve regulator must communicate between each other.
- Arduino Nano 33 BLE selected for Bluetooth capabilities.
- Central & Peripheral





Project Timeline

Month	MARCH			APRIL				MAY				JUNE				JULY			
Week	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23	Week 24	Week 25	Week 26	Week 27	Week 28
Date / Task	3/13/2025	3/20/2025	3/27/2025	4/3/2025	4/10/2025	4/17/2025	4/24/2025	5/8/2025	5/15/2025	5/22/2025	5/29/2025	6/5/2025	6/12/2025	6/19/2025	6/26/2025	7/3/2025	7/10/2025	7/17/2025	7/24/2025
Order Supplies	■	■	■	■															
Create Schematics		■	■	■	■														
Project Building			■	■	■	■	■	■	■	■	■								
Project Testing				■	■	■	■	■	■	■	■	■	■	■	■				
Troubleshooting				■	■	■	■	■	■	■	■	■	■	■	■				
Prototype Thermostat															■	■	■		
Prototype Valve Regulator															■	■	■		
Report		■	■	■	■										■	■	■	■	
Powerpoint				■	■	■											■	■	■
Rehersal					■	■												■	■
Presentation						■													■

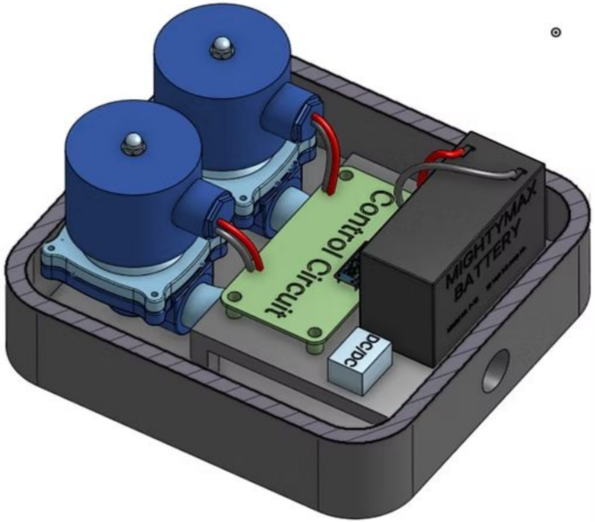
Responsibilities & Coordination

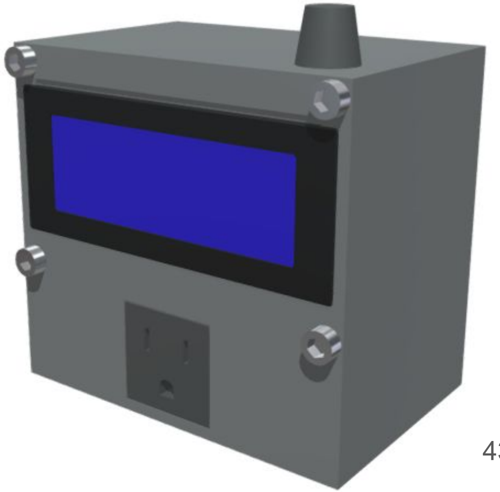
Product	System	Component	Responsibility
Valve Regulator	Logic Controller	Valve Logic & Actuation	Prem
		Leak Detection & Valve Shutoff	
		OFF State Valve Return	
	Power Management	Wake & Sleep Detection	
		Active Charger Circuit (User Input)	
		Passive Overcharge Protection (Generator)	
	MCU 1	Wireless Communication Protocol & General Programming	Conner
		Temperature & Flow Rate	
		Battery SOC	
		Leak Notification	
	Enclosure	Design & Depictions	
		Enclosure Fabrication & Assembly	Group
		Troubleshooting & Diagnostics	
Thermostat	Power Management	AC/DC Conversion	Zach
		Multi-Stage Voltage Regulation	
	MCU 2	General Programming	
		LCD Screen & Backlight Control	
		Potentiometer Integration	
	Enclosure	Design & Depictions	Group
		Enclosure Fabrication & Assembly	
		Troubleshooting & Diagnostics	
		Passive Outlet Integration	Zach

Future Improvements

- Battery backup for thermostat for usage during power outages.
- More specialized generator to reduce or remove battery requirements to further reduce required maintenance.
- Higher level of feedback to user (voice or chime notifications).
- Preset user modes for different applications and usage scenarios.
- Separate heater module to increase comfort features without a reduction in compatibility.

Summary & Conclusion





Questions

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