Smart Water Faucet

Senior Design Project
Summer 2025

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Table of Contents

Meet the Team

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

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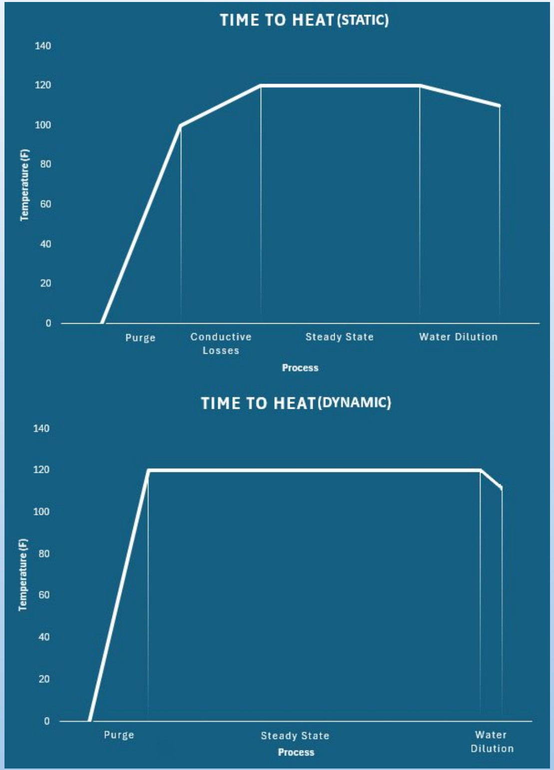
- Completing a B.S. in Electrical & Computer Engineering Technology – Electrical (Summer 2025 Graduation)
- AutoTech installer at Best Buy.

Conner McAuliffe

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

Motivation

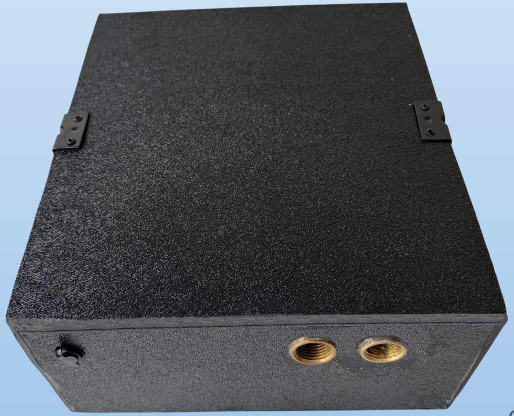
- Counteract the negative effects of centralized heated water systems.
    - Stale water it hot lines.
    - Conductive losses through pipes.
    - Water heater dilution.
- Increase precision and accuracy of water regulation.
- Provide more insight and feedback to users.



Smart Water Faucet

Product Overview

- Consists of two separate products.
  - Thermostat
    - Mounts to closest outlet, and displays water conditions on the liquid crystal display. Accepts temperature requests from the user and sends to the valve regulator using Bluetooth Low Energy 5.
  - Valve Regulator
    - Is located under sink, and uses temperature request from thermostat to regulate final water temperature while transmitting water output temperature and consumption back to thermostat.



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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Thermostatic Mixing Valve [3]

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Engineering Requirements & Limitations

Valve Regulator Engineering Requirements

Valve Regulator		
#	Requirements (the system shall ...)	Verification & Success Criteria
1	use the temperature requested by the user on the thermostat to preemptively set and maintain water temperature.	Trials will be run with the product, and the set water temperature will be tracked for accuracy. This data will be compared against a thermostatic valve to validate performance.
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 3 or 4 connections for the faucet.	The 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		
#	Requirements (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 60-120F.
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		
#	Requirements (the system shall ...)	Verification & Success Criteria
1	Include an installation and operator's manual.	The manual will 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

- Valve Regulator will need to be periodically charged.
- Initial installation is required.
  - User installation manual will be provided.
- Cannot generate its own heated water.
  - Contains a recirculation pump to purge hot line in sleep mode.

Hardware Block Diagrams & Modular Block Diagrams

Hardware Block Diagrams

Legend:

Voltage:
- **Power -**
- **Data -**

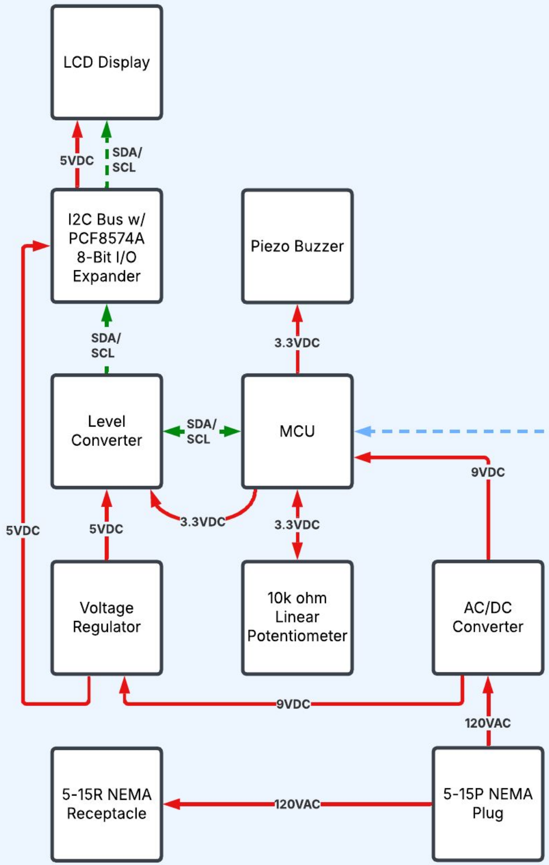
Water:

Bluetooth:

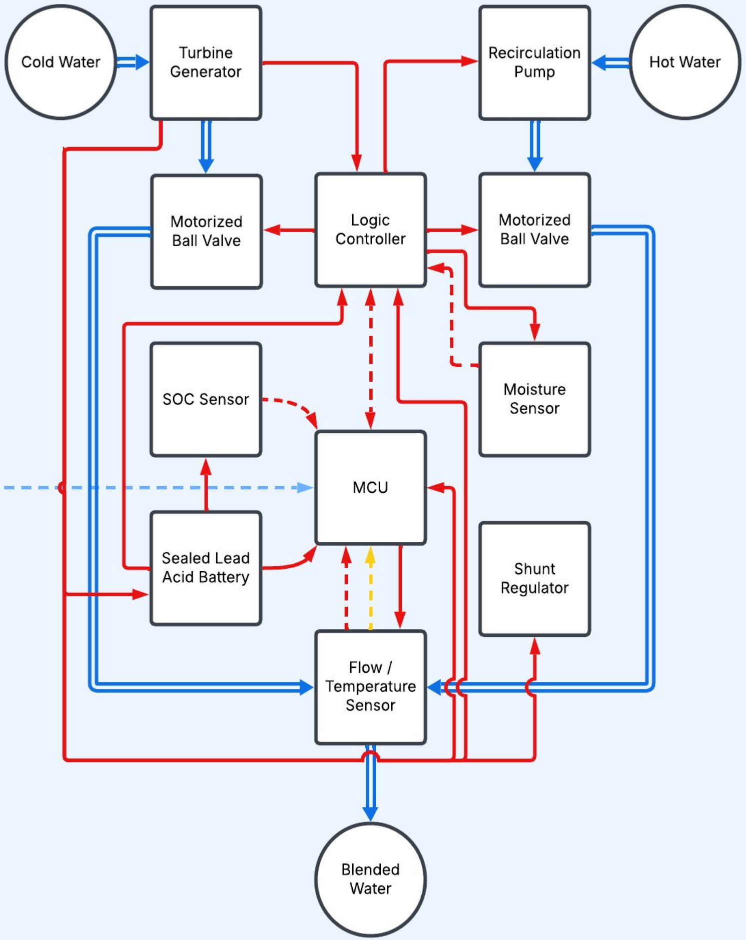
I2C:

PWM -

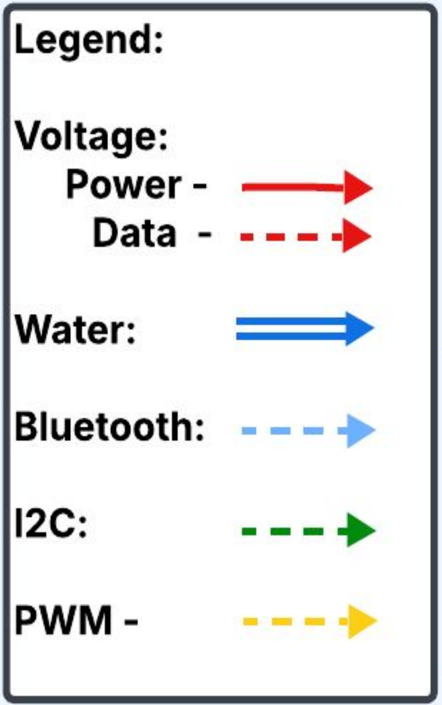
Thermostat Hardware Block Diagram

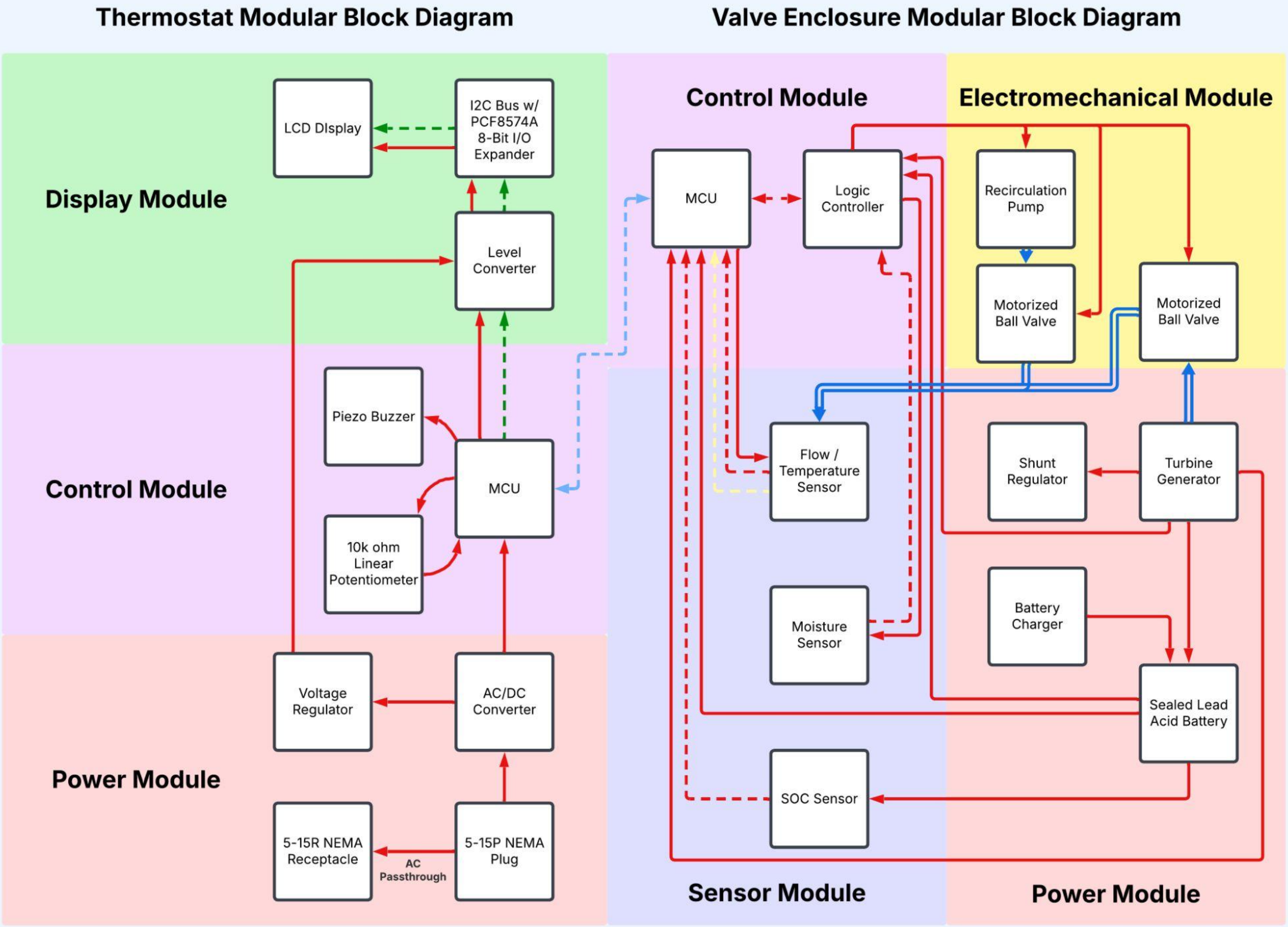


Valve Enclosure Hardware Block Diagram



Modular Block Diagrams





Engineering Specifications & Hardware

Valve Regulator Power Module

- The Power Module consists of a 12V Lead Acid Battery, Turbine Generator, and 12V 3A Smart Battery Charger.
    - 12V 7.2Ah Sealed Lead Acid Battery [4].
        - Provides power for enclosure .
    - 1/2” 12V Turbine Generator [5].
        - Supplements 12V battery.
    - 12V 3A Smart Battery Charger [6].
        - Charges battery quickly and effectively.
        - Output was modified to a barrel connector for convenience.

Valve Regulator Electromechanical Module

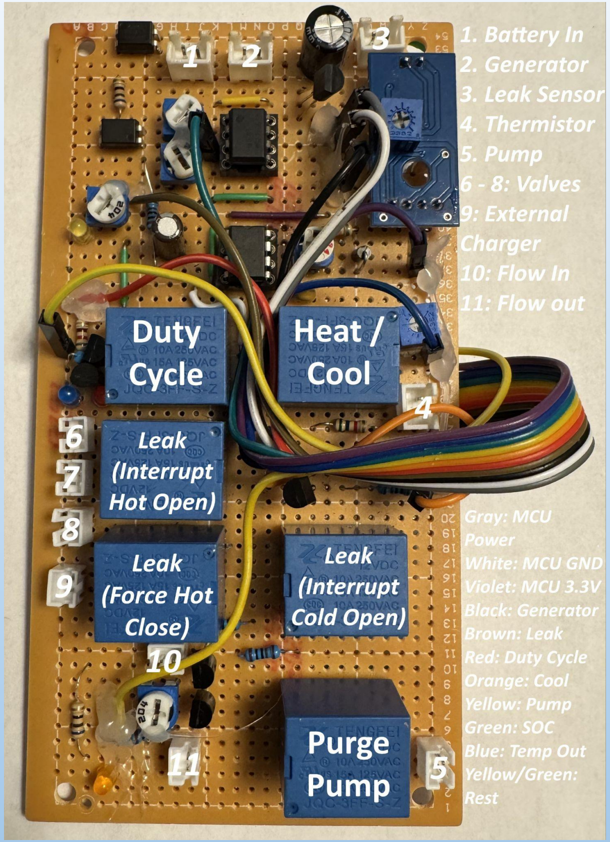
- Consists of 2 1/2” 3 wire electric ball valves[7] and one 12V 1/2” Circulation Pump.
    - Ball Valves: Required for temperature regulation.
        - Low Power Requirements and can be parked in any position but offers less precision & feedback in addition to higher number of outputs required from logic controller.
    - Circulation Pump: Required for preheating function during sleep mode.
        - Adds additional convenience features to product, but adds complexity to valve system and reduces product runtime.

Valve Regulator (Sensor Modules)

- Gredia G1/2” Water Flow & Temperature Sensor[8]
  - 50K ohm NTC Thermistor
  - Generates a 50% duty cycle square wave that varies its frequency based on flow rate
  - 1-25L/Min
  - 0-80℃ (0-176℉)
- HiLetgo LM393 Rain Drop Sensor[9]
  - Grounds its output whenever the moisture sensor impedance drops below a certain value

Valve Regulator Control Module

- Logic Controller.
  - Conditions and calibrates sensor data for MCU (leak, thermistor, flow, generator).
  - Controls valves based on requested state & mode or during pump requests.
  - Shuts off valves manually during leak protocol.
  - Has two states and three modes of operation.
    - Heat/Cool State.
    - Full/Trim/Rest Mode.
      - Full: 100% Duty Cycle.
      - Trim: 3% Duty Cycle.
      - Rest: 0% Duty Cycle.
- Arduino Nano 33 BLE rev. 2.
  - Communicates wirelessly to thermostat and samples sensor data.



Thermostat Control Module

- Arduino Nano 33 BLE rev. 2 [10]
- Bluetooth Low Energy 5
- Small Form Factor
- 22 Programmable GPIO Pins

Thermostat Specifications – Power Module

- CUI Inc. PSK-3D-9-T AC-DC Converter.
    - Capable of providing 9VDC from 110VAC at 3W.
- Qualtek Tamper-Proof NEMA 5-15 receptacle and NEMA 5-15 Plug.
    - UL Listed components wired with NEC compliant THHN wire.
- L78l05 Voltage Regulator. [11]
    - TO-92 – 5V / 100mA voltage regulator

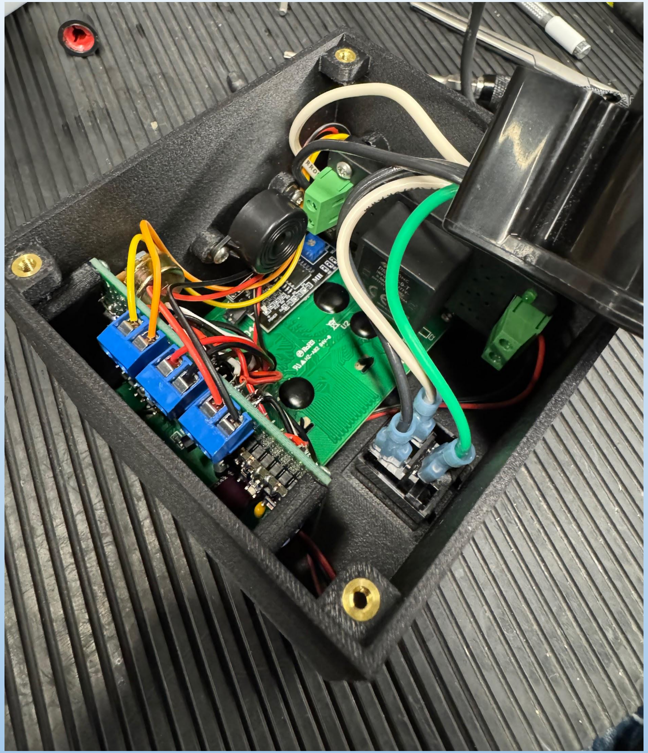
Thermostat Specifications – Display Module

- SunFounder LCD2004 80 Character Screen. [12]
  - 5VDC, with an adjustable backlight, and capable of I2C communication protocol.
- PCF8574 based I2C Bus With contrast knob. [12]
  - 16 I/O pins interface directly into LCD with backlight control capabilities.
- HiLetGo I2C Logic Level Converter.[13]
  - Capable of converting 3.3V I2C signals into 5V I2C signals.

Project Contributions

Thermostat Contribution - Hardware

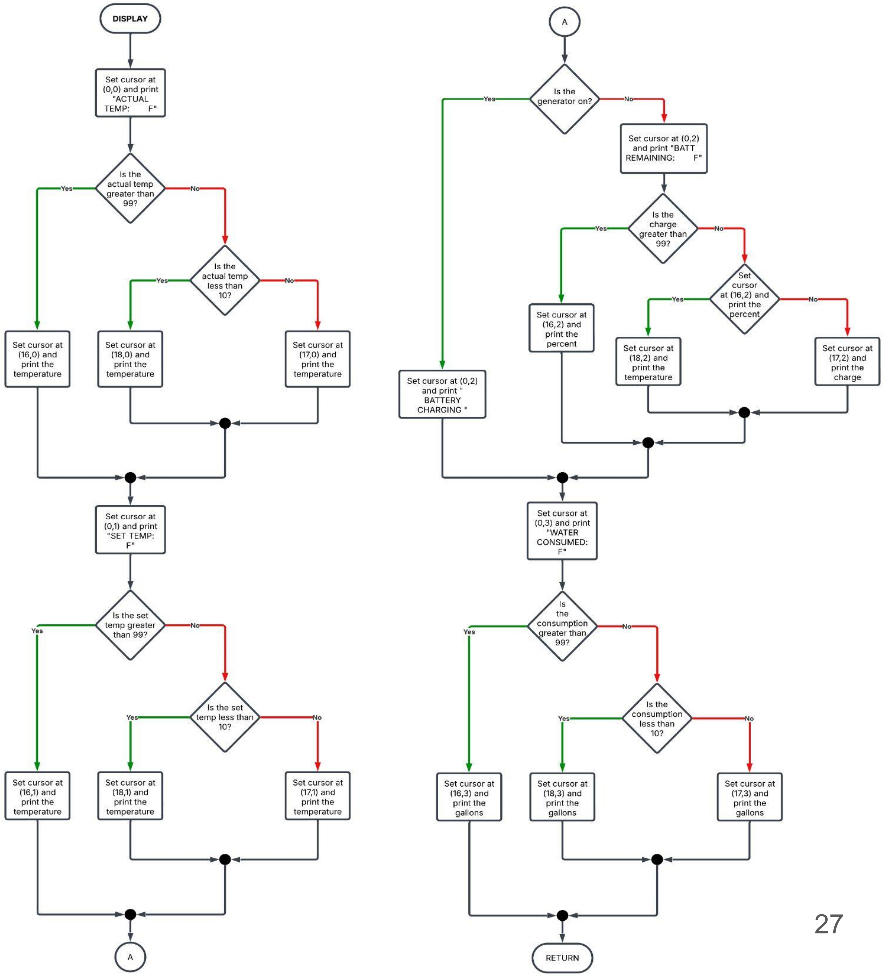
- Prototype PC board used to contain circuit elements, includes circuit protection, filtering, and multi-stage voltage regulation for various components.
- UL and NEC / NFPA Compliant Wiring and Design Considerations.
- Compact design with mounting points for hardware.
- Inclusion of buzzer for warning chimes.
- Liquid crystal display with power saving features, warning messages, and information.
- Passive AC receptacle pass-through for added convenience.



Thermostat Contribution – Software: Display

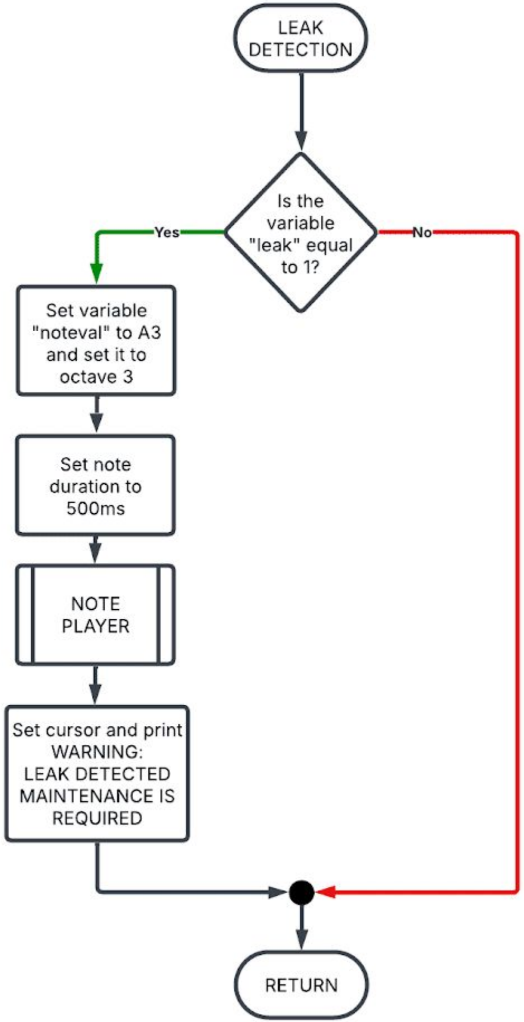
- Information displayed is controlled using conditional statements with inequalities.
- Data shifts its position on screen based on value size.
- Warning's are performed in separate functions using similar logic.

DISPLAY FLOWCHART



Thermostat Contribution – Software: Warnings

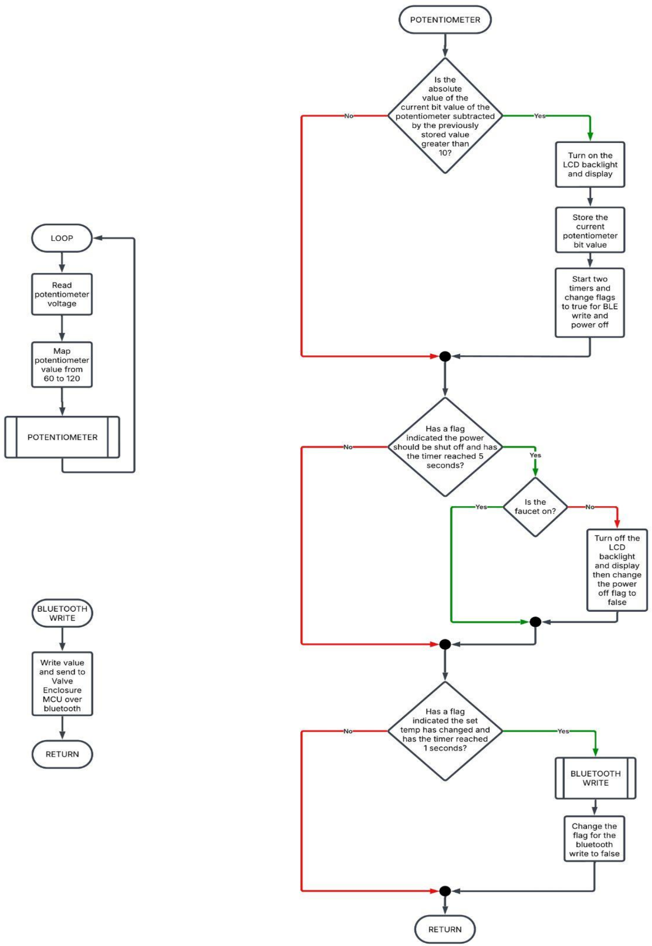
- Each warning is activated by conditions set in the valve regulator.
- These conditions determine if a value for each warning is false (0) or true (1).
- Each warning has a unique message and buzzer alert sound.



Thermostat Contribution — Software: Potentiometer, Backlight, and BLE Write

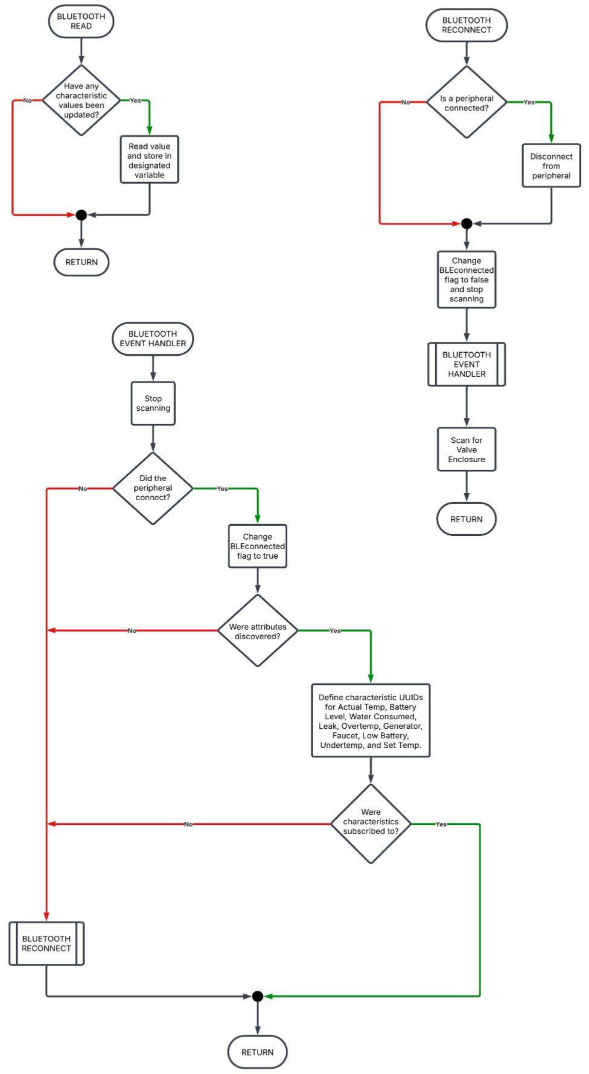
- The potentiometer controls the value of the set temperature using Arduino ADC.
- Backlight control is implemented based on use of faucet (always on) or thermostat knob (5 seconds on).
- Bluetooth write delay of one second to prevent spamming.

POTENTIOMETER, BACKLIGHT, AND BLUETOOTH WRITE FLOWCHART

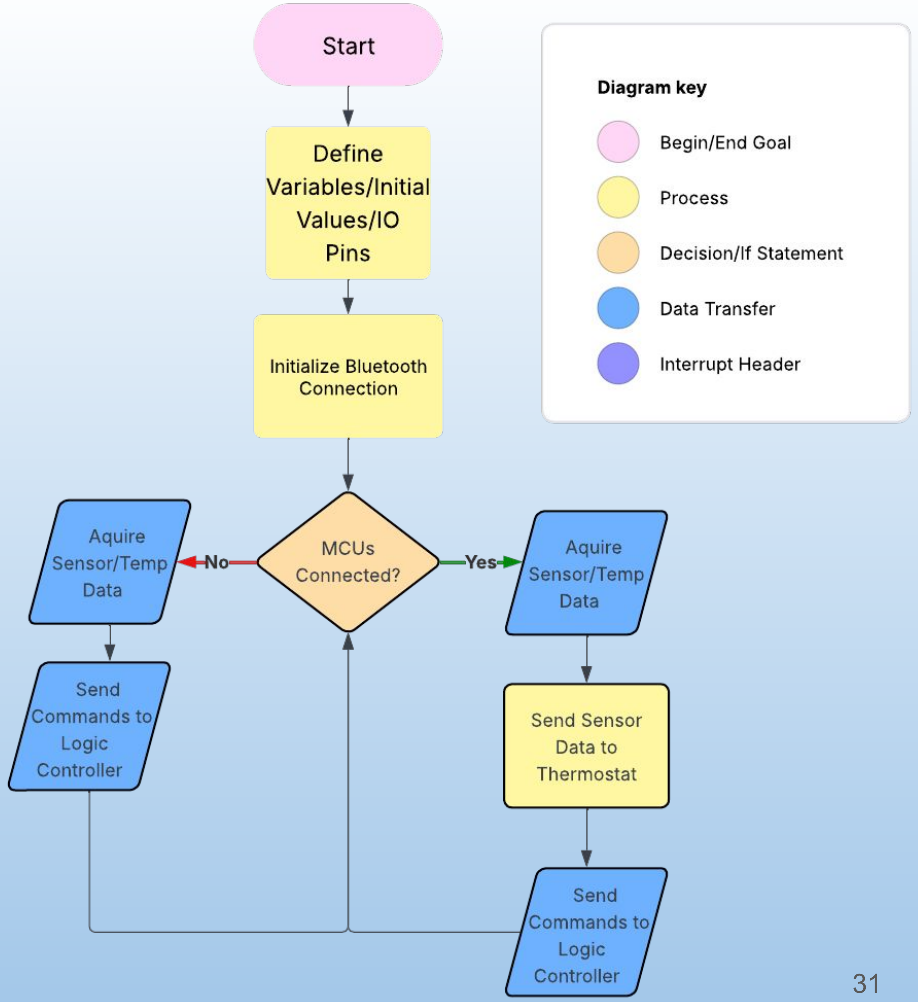


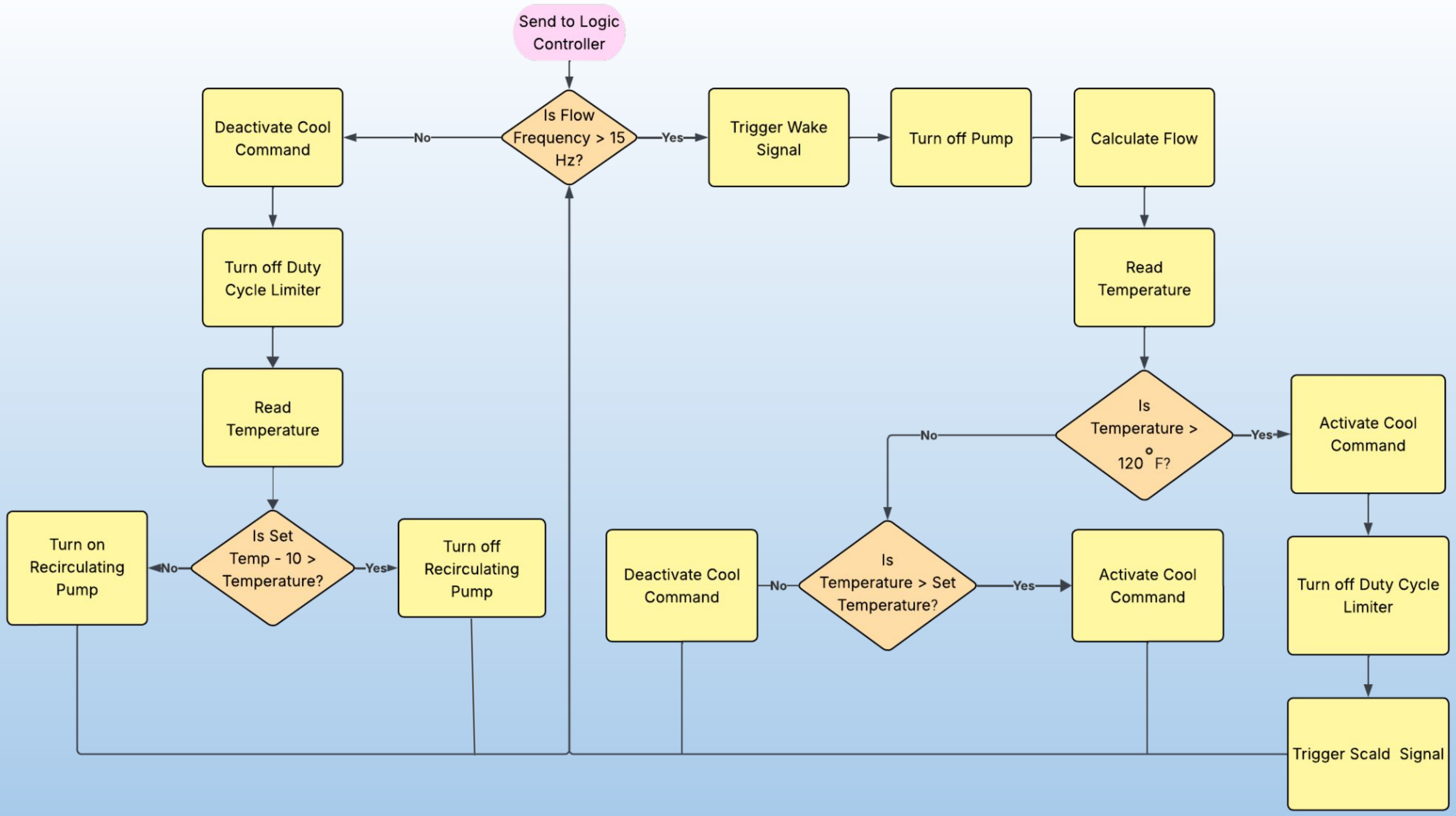
Thermostat Contribution – Software: Bluetooth

- Bluetooth Event Handler allows for connection to peripheral and discovery of attributes.
- Characteristics were set to Read | Notify or Write based on needs. Notify allows values to be read and updated whenever a change occurs.
- Code includes bullet-proof bluetooth reconnection in the event of power outage or low battery SoC in the valve regulator.

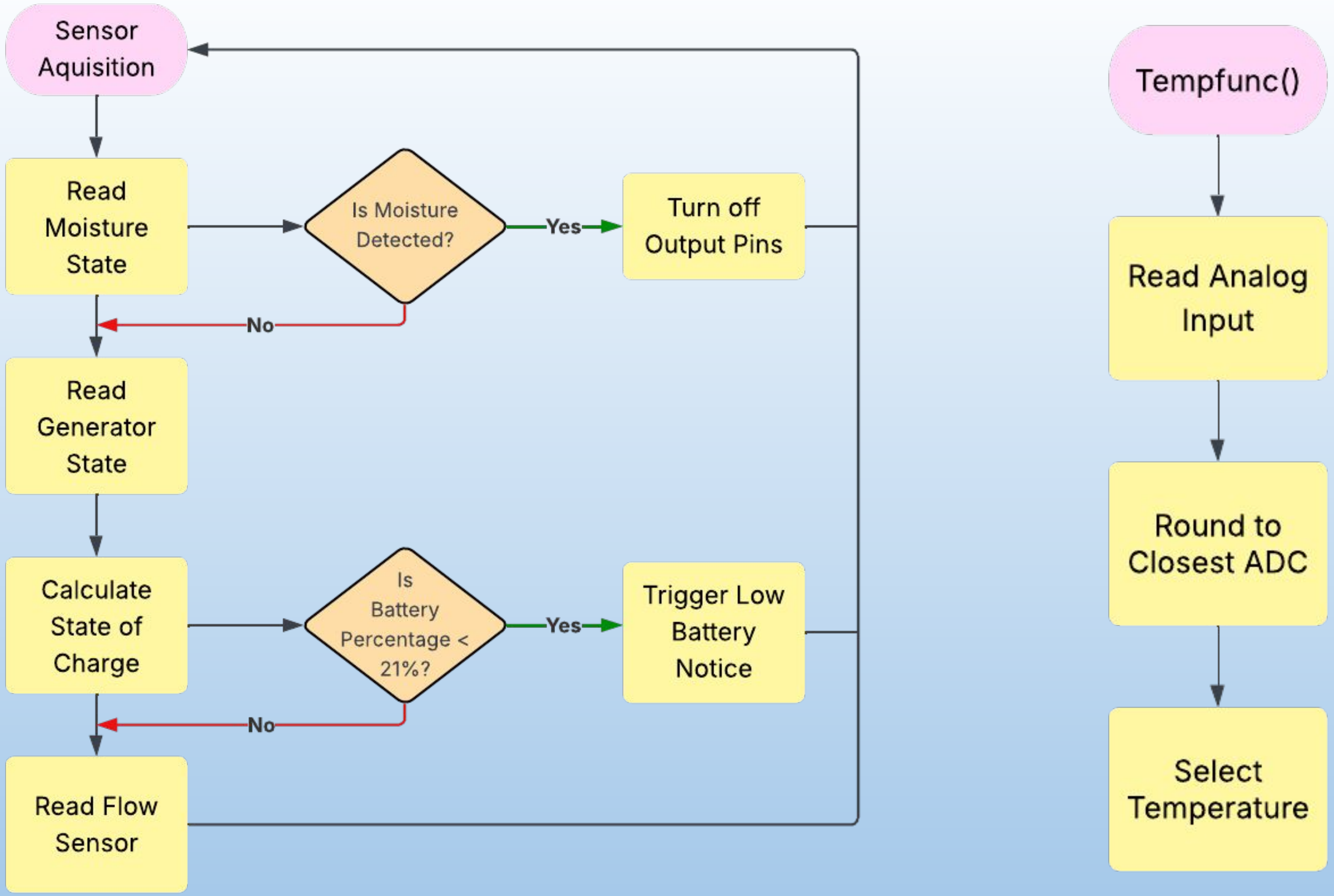


Valve Regulator Contribution - Software



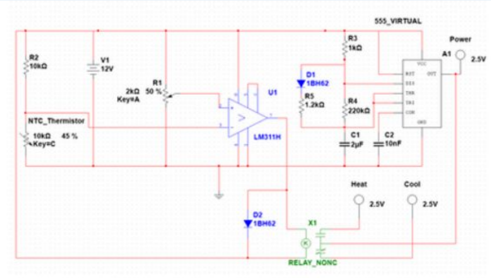


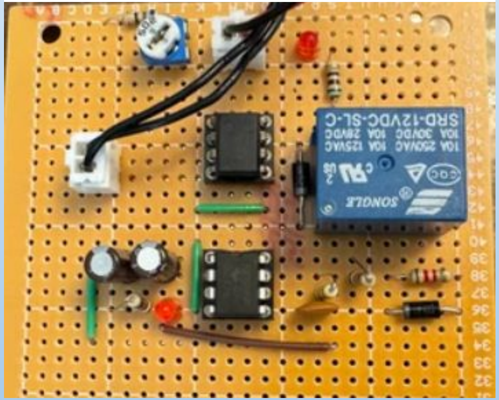
Send to Logic Controller
Is Flow Frequency > 15 Hz?
No
Yes
Deactivate Cool Command
Turn off Duty Cycle Limiter
Read Temperature
Is Set Temp - 10 > Temperature?
No
Yes
Turn on Recirculating Pump
Turn off Recirculating Pump
Trigger Wake Signal
Turn off Pump
Calculate Flow
Read Temperature
Is Temperature > 120 °F?
No
Yes
Activate Cool Command
Turn off Duty Cycle Limiter
Trigger Scald Signal
Is Temperature > Set Temperature?
No
Yes
Deactivate Cool Command
Activate Cool Command


Sensor Aquisition
Read Moisture State
Is Moisture Detected?
Yes
Turn off Output Pins
No
Read Generator State
Calculate State of Charge
Is Battery Percentage < 21%?
Yes
Trigger Low Battery Notice
No
Read Flow Sensor
Tempfunc()
Read Analog Input
Round to Closest ADC
Select Temperature

Valve Regulator Contribution - Duty Cycle Limiter

- Initial Testing of the ball valve performance with an analog comparator yielded extremely poor regulation capabilities because they were far too rapid to regulate water in any meaningful way.
- Attempts at limiting voltage or current lead to malfunction.
- Final solution was to create a low duty cycle pulse generator to drive them.
- To the right is an early adoption of the pulse generator circuit.



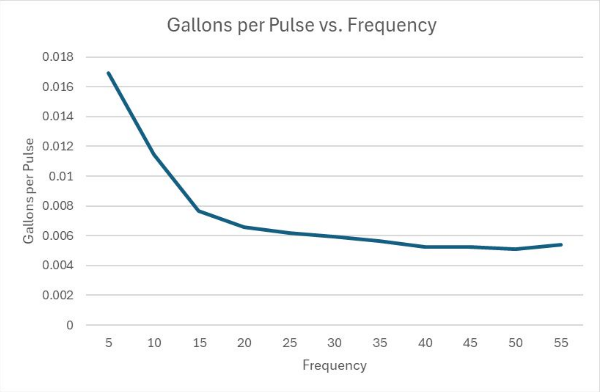


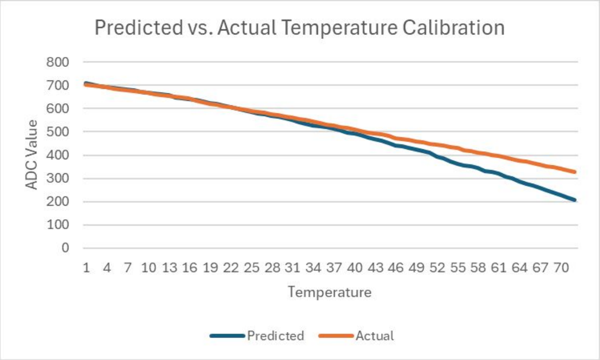
Valve Regulator Contribution - Pump Integration

- A 12V ½” Impeller pump was chosen and tested to validate its capabilities as a recirculation pump.
- The key success to this pump's operation was the low water pressure differential between the hot and cold lines, which allowed it to achieve its intended purpose with minimal power usage.
- This pump is only activated in sleep mode, and only under certain conditions.
- To keep the water lines isolated when the pump is not needed, the cold water valve is forced open (hot is naturally open during sleep mode) to temporarily bridge the two water lines whenever the pump runs.

Valve Regulator Contribution - Sensor Calibration

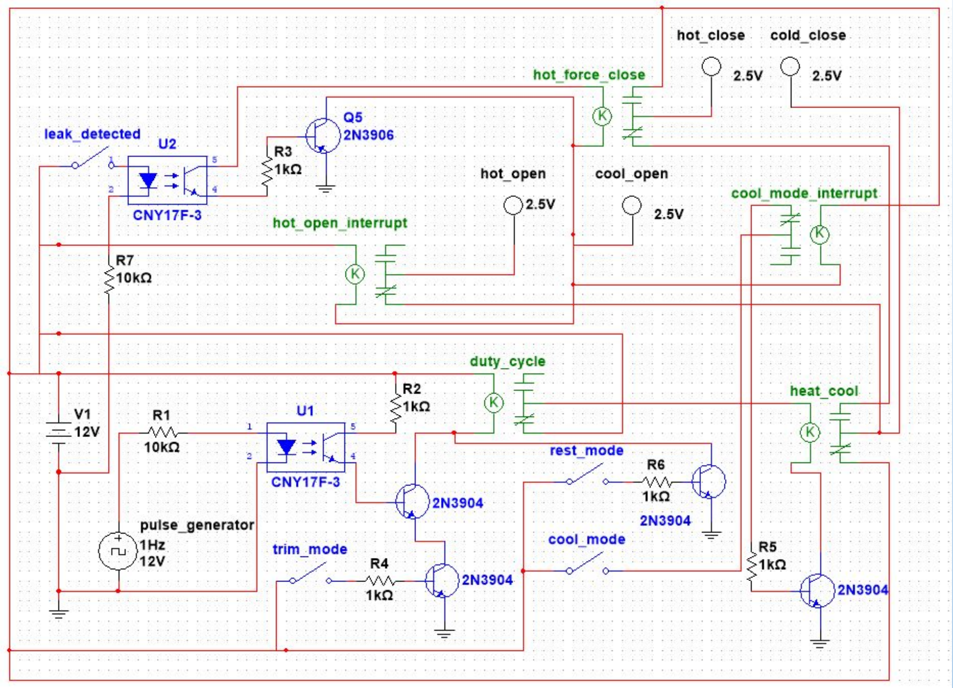
- Flow Sensor
  - The flow sensor was calibrated by finding out how long it takes to fill a container at different frequencies. This was used to generate a Gallons Per Pulse vs. Frequency chart which signifies the accuracy of the sensor at different frequencies.
  - The sensor deviated substantially below 15 Hz so these results were discarded, and the rest were average to generate an average of 5.88milli gallons per pulse which was used for the water consumption tracking.
- Thermistor
  - The output table of the NTC thermistor were used to generate an initial calibrated voltage and ADC bit value at different temperatures.
  - This provided measurements that were only accurate at lower temperatures.
  - Final calibration was only achieved by manually tuning the ADC at every temperature against the output of a thermistor that was directly coupled to the sensor.





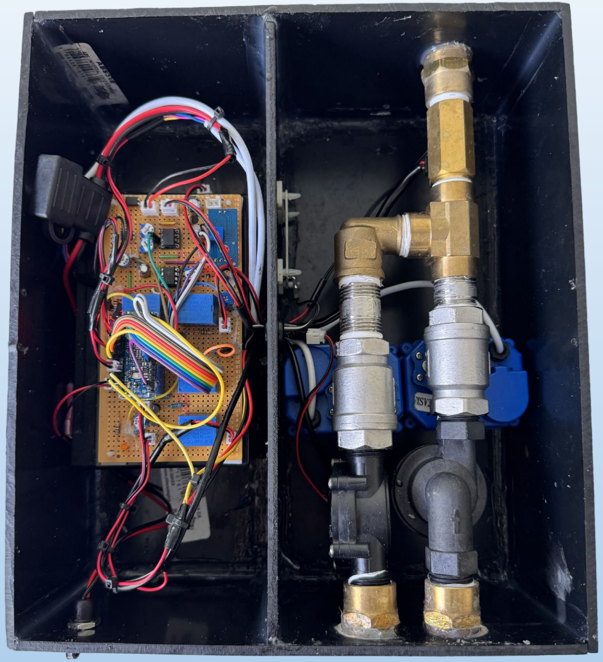
Valve Regulator Contribution - Leak Detection Protocol

- Unless a cool command is received by the MCU, the system rests in a “heating” state, with the hot valve received an open command and the cold valve receive a close command.
- This meant that during leak protocol, three actions need to occur.
    - Close hot valve.
        - Cut heat open signal.
        - Manually generate heat close signal.
    - Ignore “cool command” to keep cold valve closed.
- These were achieved through the use of three relays, which are driven directly by the leak detection circuit.
- This allows the logic controller to close the valves during a leak, even if the MCU malfunctions or gets damaged.
- This system also naturally ignores trim and rest commands.



Valve Regulator Contribution - Enclosure Design

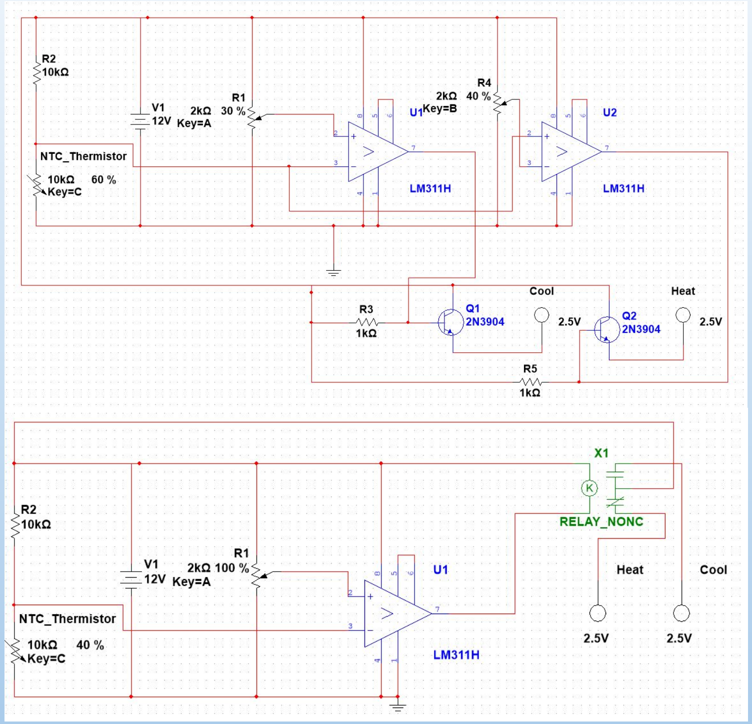
- The system is divided into two sealed compartments.
- All electronic components are housed in one compartment, while all water-interfacing components are isolated in the other.
- Waterproof sealant is applied to all interior joints to ensure moisture resistance.
- The top lid is removable for serviceability and is sealed with a gasket to maintain enclosure integrity.
- Panels were cut individually from ABS plastic and were secured with epoxy.



Troubleshooting

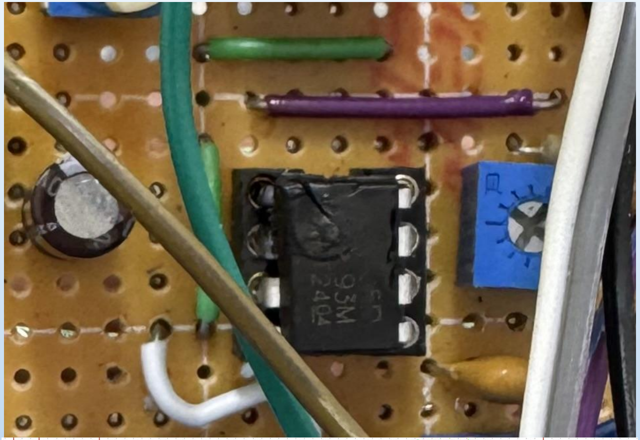
Troubleshooting - Valve Malfunction

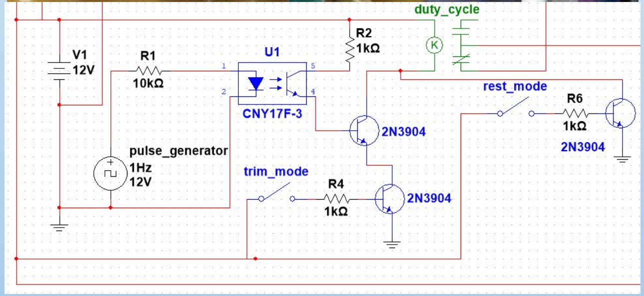
- The valves malfunctioned constantly during initial attempts at controlling them.
- After exhaustive testing, it was determined that during actuation, inactive wire HAD to be disconnected for it to interpret the active one.
- This resulted in the use of an SPDT relay instead of BJTs, which ended up being very useful by producing resting states and simplifying the logic output.
- The two diagrams to the right show the circuit before (top) and after (bottom) this modification.



Troubleshooting - Pulse Generator Isolation

- Although the pulse generator greatly increased the precision of the valves, throughout testing it would periodically fail, sometimes quite dramatically with smoke and collateral damage.
- This was narrowed down to inappropriate actuation of the duty cycle limiter, which exposed the timer to voltage when certain functions were activated (pump, leak).
- As stated previously, the valves did not work properly with BJTs, so the final solution was to use the pulse to drive a relay to periodically interrupt the valve power.
- This also lead to increased utility, because this same relay was then used to create the third “rest” mode by continuously driving it to turn off the valves.
- To provide resistance to further damage, the timer output was also buffered with an optocoupler.





Troubleshooting - Thermostat

- An incompatibility was discovered early on that caused no information to display on the LCD screen.
- Originally planned to use a BJT as a switch, but this resulted in current leakage which kept the screen on.
- To improve connectivity, a clean up of bluetooth scan function calls was needed. Using BLE.scan() too often results in an overloaded stack. A reconnect function was implemented that disconnects BLE entirely and retries reducing the usage of excessive re-scans.

Troubleshooting - Flow Sensor Input

- Libraries are available to automatically read the flow sensor wavelength using pulseIn().
- PulseIn() and BLE functionality heavily rely on Timer2.
- An interrupt was implemented to manually read the wavelength and convert to flow rate.

Final Testing
&
Summary of Results

Final Testing & Results

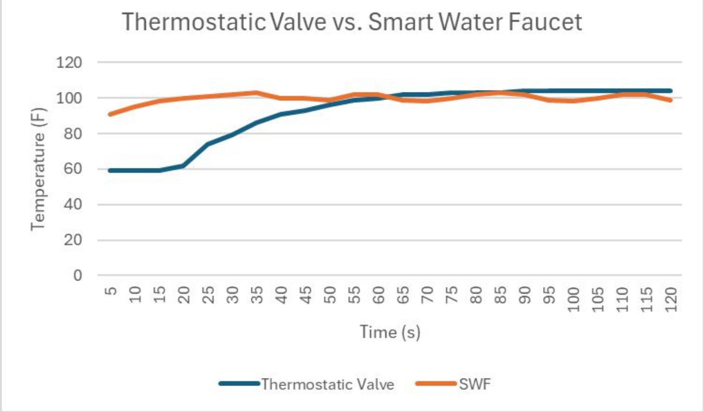
Requirement 1: Valve Regulator

“The Smart Water Faucet shall… use temperature set by the user on the thermostat to preemptively regulate water temperature.”

Testing: A thermostatic valve was used as the baseline for comparison of the Smart Water Faucet, and they were both tested with a goal of 100°F.

Results: Due to the circulation pump, the Smart Water Faucet achieved the goal temperature faster, and got closer to the final temperature, but could not achieve steady state. This requirement was met, but it is clear that actions need to be taken to stabilize steady state output.

The Thermostatic valve achieved a much more stable steady-state, but targeted a temperature of 105°F instead.



Final Testing & Results

Requirement # 2: Valve Regulator

“The Smart Water Faucet shall… electrically sustain most or all of its operation via a built-in turbine generator.”

This requirement was <u>not met</u> because the addition of the circulation pump dramatically increased the power budget, and lead to a compromise of placing the turbine generator on the cold line, which means power can only be generated if sufficient amounts of cold water are required for final mixing.

Due to this result, the power budget was repurposed to a runtime estimate, and a larger investment was made to the external charger to increase charging convenience.

Final Testing & Results

Engineering Requirement #3: Valve Regulator

"The Smart Water Faucet shall... be able to detect leaks and close both valves in addition to sending a leak message to the thermostat to protect against property damage."

This was achieved by pouring a bottle of water into the valve compartment, and observing the system behavior.

This test was passed successfully, however, it should be noted that the system will not stop leaks that occur before the valves.

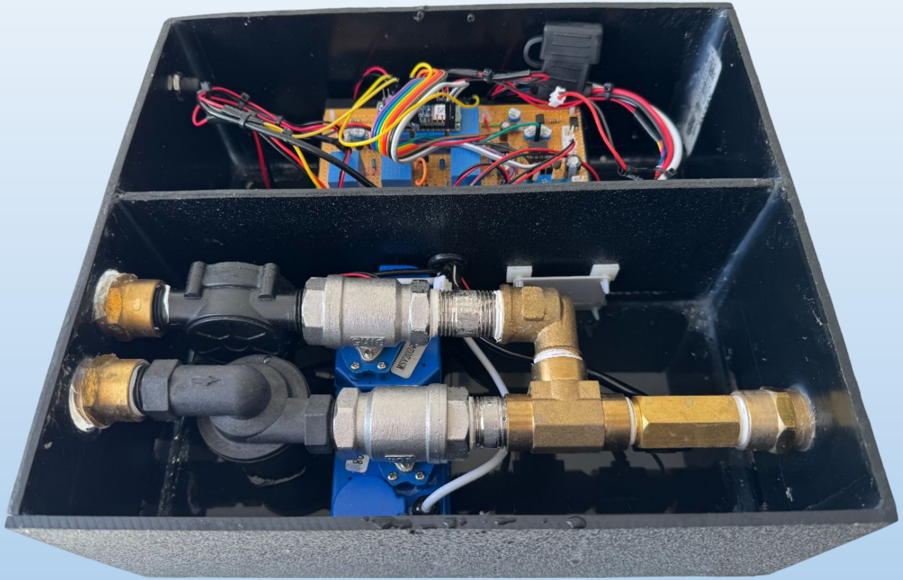
Final Testing & Results

Requirement #4: Valve Regulator

“The Smart Water Faucet shall…have a waterproof enclosure for electrical components to prevent internal malfunction.”

For this requirement, water was placed in the valve compartment, and it was held overnight to see if there were any detectable leaks. This test was successful, and the unit was also tilted 15 degrees in every direction to validate the angle requirements of IPX2. This was further validated by the fact that the electronic components did not incur any detectable water damage during final testing.

It should be noted that the initial design goals were IPX7, but this was proved to be an excessive requirement due to the rigorous testing criteria required, the number of wires traveling through the compartments, and requiring access to the product for maintenance.



Final Testing & Results

Requirement #5: Valve Regulator

“The Smart Water Faucet shall...continuously send water temperature, flow rate, and battery voltage data to thermostat wirelessly.”

The success of this requirement was contingent on the bluetooth communication between the MCUs as well as the valve regulator’s ability to collect data.

The requirement was tested by operating the Smart Water Faucet as a user would and observing the thermostat as data was updated. The user adjusted the dial to set 95°F, the valves opened/closed to accept the change, and the temperature began to rise as the water consumption incremented. With these values updating in real time as well as an accurate display of battery percentage, this requirement was deemed a success.

Final Testing & Results

Engineering Requirement #6: Valve Regulator

“The Smart Water Faucet shall…be completely contained, with only 3 or 4 connections for the faucet.”

This requirement was met, with the only changes made to the product design being to remove the requirement for a splitter and just opting to cap the unused faucet handle instead.

Final Testing & Results

Engineering Requirement #7: Valve Regulator

"The Smart Water Faucet shall...have the ability to be externally charged in cases of battery depletion."

This requirement was successfully met by charging the product right before final testing and tracking the observed battery performance. The battery was around 60% charged at this point, and after being charged, maintained full charge throughout final testing.

Final Testing & Results

Engineering Requirement #8: Thermostat

"The Smart Water Faucet shall... accept temperature request from user & send to valve regulator."

This requirement was met and verified using the serial monitor of the valve regulators MCU to monitor if a value had been received over Bluetooth. Further verification was performed to confirm that a change in set temperature resulted in an activation of the valve's cooling or heating routine.

Final Testing & Results

Engineering Requirement #9: Thermostat

"The Smart Water Faucet shall… display requested temperature, water temperature, water consumption, leak detection & battery state of charge on an LCD screen."

This requirement was met first by extensive testing with the LightBlue app and in final testing with temperature tracking, battery state of charge, water consumption, and leak detection warnings.

Final Testing & Results

Engineering Requirement #10: Thermostat

"The Smart Water Faucet shall... minimize power consumption when not in use.

This requirement was met before the prototype of the thermostat was built. Current was measured from the 9VDC source to determine the total decrease in power consumption when the backlight and display turned off.

Power consumption during normal operation is ~387 mW, and drops to ~110 mW.

Final Testing & Results

Engineering Requirement #11: Product

"The Smart Water Faucet shall… include an installation and operator's manual."

This requirement was met and can be viewed on our website and in our report.

Summary of Results

#	System Requirements	Pass / Fail
1	"The Smart Water Faucet shall... use temperature set by the user on the thermostat to preemptively regulate water temperature."	Pass
2	"The Smart Water Faucet shall... electrically sustain most or all of its operation via a built-in turbine generator."	Fail
3	"The Smart Water Faucet shall... be able to detect leaks and close both valves in addition to sending a leak message to the thermostat to protect against property damage."	Pass
4	"The Smart Water Faucet shall...have a waterproof enclosure for electrical components to prevent internal malfunction."	Pass
5	"The Smart Water Faucet shall...continuously send water temperature, flow rate, and battery voltage data to thermostat wirelessly."	Pass
6	"The Smart Water Faucet shall...be completely contained, with only 3 or 4 connections for the faucet."	Pass
7	"The Smart Water Faucet shall...have the ability to be externally charged in cases of battery exhaustion."	Pass
8	"The Smart Water Faucet shall... accept temperature request from user & send to valve regulator"	Pass
9	"The Smart Water Faucet shall... display requested temperature, water temperature, water consumption, leak detection & battery state of charge on an LCD screen."	Pass
10	"The Smart Water Faucet shall... minimize power consumption when not in use."	Pass
11	"The Smart Water Faucet shall... include an installation and operator's manual."	Pass

Non-Technical Information

Health & Safety

- Regulatory Compliance standards prioritized throughout the design.
- Low voltage design that removes the need for 110VAC near plumbing fixtures.
- Warning System that warns of leaks, scalding risks, and low battery.
- Food-Safe Plumbing Fixtures.

Code	Component
NSF, REACH	U.S. Solid 1/2" Stainless Steel Motorized Ball Valve
ROHS, REACH	Gredia G1/2" Water Flow Sensor with Temperature Sensor
REACH	Beduan Micro Water Turbine
UPC, NSF, CSA	Threaded Female Mount Adapter
UPC, NSF, CSA	BYT-7A014 DC Circulation Pump
UPC, NSF, CSA	1/2" Threaded Cap Fitting
UPC, NSF, CSA	Series 1/2" Threaded Street Elbow
UPC, NSF, CSA	Series 1/2" Tee
UPC, NSF, CSA	Series 1/2" 2" Brass Nipple
UPC, NSF, CSA	Series 1/2" 2.5" Brass Nipple
UPC, NSF, CSA	2pcs Brass Coupling
ROHS, UL, CE, UKCA, IEC 62368, IEC 61558, IEC 60335	CUI Inc. 9V Power Supply
ISED/IC, MIC, ROHS, CE, FCC, UKCA, REACH, WEEE	Arduino Nano 33 BLE Rev. 2
ROHS, UKCA, CE	HiLetGo I2C Logic Level Converter
CE, FCC	HiLetGo HD44780 2004 LCD 20x4
UL, cUL	Qualtek NEMA 5-15 Receptacle
UL, cUL	Qualtek NEMA 5-15 Plug
NEC (NFPA 70)	14 AWG THHN Wire

Power Specifications

Thermostat Power Specifications				
Component	**Voltage (VDC)**	**Current (mA)**	**Power (W)**	**Comment**
Maximum				
AC/DC Converter	9	333	3.00	Maximum
LCD Screen	5	-5.7	-0.03	Screen + Logic + Converter losses
LCD Backlight	5	-31.5	-0.16	When the faucet is on.
I2C Bus (PCF8574)	5	-0.1	0.00	Power consumption is minimal
Potentiometer	3.3	-3.3	-0.01	Assuming lowest temperature is set
Piezo Buzzer	3.3	-0.7	0.00	Current draw only when active
MCU 2	9	-7.7	-0.07	Measured during normal operation
Net			2.73	
With LCD backlight off and buzzer inactive				
AC/DC Converter	9	333	3.00	Maximum
LCD Screen	5	-5.7	-0.03	Screen + Logic + Converter losses
LCD Backlight	5	0	0.00	When the faucet is off
I2C Bus (PCF8574)	5	-0.1	0.00	Power consumption is minimal
Potentiometer	3.3	-3.3	-0.01	Assuming lowest temperature is set
Piezo Buzzer	3.3	0	0.00	Typical operating expectations
MCU 2	9	-7.7	-0.07	Measured during normal operation
Net			2.89	

Valve Regulator Runtime Estimate				
Component	**Voltage (VDC)**	**Current (mA)**	**Power (Wh)**	**Comment**
Generator	12	-78	0.31	0.93 watts generated over 20 minutes
Recirculation Pump	12	700	-0.22	Power consumed if pump runs for 30 seconds every 45 minutes
Valves	12	147	-1.76	25 seconds for wake/sleep transition plus 20 minutes at 3% duty cycle
Logic Controller Board	12	54	-15.6	Continuous power consumption (MCU is included in this figure)
Net			-17.27	Power Use Every Day
Estimated Standby Time			120 hours	Battery Capacity of 86.4Wh divided by a daily power consumption of 15.6Wh

Proposed and Final Costs Comparison

Proposed Monetary Budget			
Quantity	**Description**	**Supplier**	**Price**
2	1/2" Stainless Steel Electric Ball Valve	U.S. Solid	$77
1	12V 7.2 AH Rechargeable SLA Battery	Mighty Max	$20
3	Small form factor BLE MCU	Arduino	$86
1	G1/2" Water Flow Sensor with Temperature Sensor	GREDIA	$16
1	Micro Water Turbine	Beduan	$13
1	2004 I2C LCD	SunFounder	$14
1	Tamper Resistant NEMA 5-15R Snap	Qualtek	$2
1	15A 125VAC NEMA 5-15P Angled Str	Qualtek	$10
1	Panel Mount 10K potentiometer - 10K Linear	Adafruit	$1
1	Potentiometer Knob - Soft Touch T18 - Red	Adafruit	$1
1	Chassis Mount 9V Internal AC-DC Power Supply	CUI Inc.	$13
1	3-Way Thermostatic Mixing Valve	Fyeer	$29
1	3/4" to 1/2" Threaded Female Adapter	Proline	$10
3	Rain Drop Sensor	HiLetgo	$21
	Miscellaneous		$100
	TOTAL		**$413**

Final Project Cost			
Quantity	**Description**	**Supplier**	**Price**
2	U.S. Solid 1/2" Stainless Steel Motorized Ball Valve	U.S. Solid	$76
1	Mighty Max 12V 7.2 AH Rechargeable SLA Battery	Mighty Max	$20
2	Arduino Small form factor BLE MCU	Arduino	$57
5	Sensors	GREDIA	$18
1	Beduan Micro Water Turbine	Beduan	$13
1	NEMA Rcpt 738W-X2/35	Qualtek	$2
1	NEMA Plug Q-710-RA	Qualtek	$10
18	Electronic Components	BoJack	$46
1	PSK-3D-9-T	CUI Inc.	$13
1	20x4 LCD	SunFounder	$14
1	I2c LCD Converter Module	HiLetGo	$3
1	120pc Dupont Wire	ELEGOO	$4
1	HD44780 20x4 LCD	HiLetGo	$11
1	3D Printed Enclosure - Printed with Bambu Labs	N/A	$4
1	Adapters & Fittings	Luorng	$98
1	10 Micro JST Connectors	Daier	$5
1	6pcs DC 12V SPDT Relay	Tnisesm	$9
1	BYT-7A014 DC Circulation Pump	Bayite	$21
1	3A Automotive Battery Charger	Everstart	$25
4	Epoxy Resin	Gorilla Glue	$24
1	Waterproof Caulk & Seal	Gorilla Glue	$7
1	Female Power Jack	Luorng	$2
	TOTAL		$464

Actual Expenses

Table 4.2 - Actual Project Expenses			
Quantity	**Description**	**Supplier**	**Price**
2	U.S. Solid 1/2" Stainless Steel Motorized Ball Valve	U.S. Solid	$76
1	Mighty Max 12V 7.2 AH Rechargeable SLA Battery	Mighty Max	$20
5	Arduino Small form factor BLE MCU	Arduino	$143
1	Gredia G1/2" Water Flow Sensor with Temperature Sensor	GREDIA	$16
1	Beduan Micro Water Turbine	Beduan	$13
1	3-Way Thermostatic Mixing Valve	Fyeer	$29
1	3/4" to 1/2" Threaded Female Adapter	Proline	$10
3	Rain Drop Sensor	HiLetgo	$7
1	NEMA Rcpt 738W-X2/35	Qualtek	$2
1	NEMA Plug Q-710-RA	Qualtek	$10
1	Potentiometer	Adafruit	$1
1	Potentiometer Knob	Adafruit	$1
10	LM317 IC Reg Linear Pos Adj 1.5A to220	Luminax	$4
20	2N3904 Transistor NPN 40V 0.2A TO-92	Luminax	$1
1	Resistor Kit (Unintended Purchase)	Luminax	$13
2	PSK-S3-5-T	CUI Inc.	$34
5	1uF Capacitor	Kemet	$3
5	150uF Capacitor	Nichicon	$3
5	SA7.0A TVS Diode 7VWM 12VC	Littlefuse Inc	$2
2	PSK-3D-9-T	CUI Inc.	$26
5	120uF Capacitor	Nichicon	$3
5	SA12A TVS Diode 12VWM 19.9VC	Littlefuse Inc	$2
2	Breadboard / Jumper Wire Kit	AYPZUKE	$22
1	20x4 LCD	SunFounder	$14
1	20x4 LCD (2-pack)	SunFounder	$18
1	220V to 5V ACDC converter	EC Buying	$11
1	I2c LCD Converter Module (3-pack)	HiLetGo	$9
1	LM317 TO-92	Brigold	$7
1	Electronic Component Kit	MOGAOPI	$23
1	2600pc Resistor Kit	MOGAOPI	$20
1	650pc Capacitor Kit	BOJACK	$16
2	120pc Dupont Wire	ELEGOO	$7
1	174pc PCB Prototype Kit	HEHIPLE	$18
1	50pc Voltage Regulator Kit	BOJACK	$15
1	Piezo Buzzer 3-pcs	HiLetGo	$7
1	Level Converter (10 pc)	HiLetGo	$8
1	HD44780 20x4 LCD	HiLetGo	$11
1	978L05 Voltage Regulator (50 pack)	QSKAII	$7
3	Motion Sensor	HiLetGo	$9
4	3D Printed Enclosure - Printed with Bambu Labs	N/A	$14
1	Threaded Female Mount Adapter	Luorng	$10
1	1/2" NPT Brass Coupling	T Tanya	$11
1	100pcs PCB Spacer	Marsrut	$10
1	3.3V Buck Regulator	ANMBEST	$7
1	63-37 Tin Lead Rosin Core Solder	MAIYUM	$10
1	Micro JST Connector Set (20 pack)	Daier	$9
1	100pcs 1 ohm resistor	Edgelec	$6
1	100pcs 1K ohm resistor	Edgelec	$6
1	100pcs 1.5K ohm resistors	Edgelec	$6
1	100pcs 2.2 ohm resistors	Edgelec	$6
6	DC 12V SPDT Relay	Tnisesm	$9
1	BYT-7A014 DC Circulation Pump	Bayite	$21
50	NE555 Timer IC	BKJACK	$7
100	Pack O-Rings	RecDec	$7
200	2N3904 + 2N3906 TO-92 Transistors	Bridgold	$9
1	1/2" Threaded Cap Fitting	Proline	$8
1	Series 1/2" Threaded Street Elbow	Proline	$12
1	Series 1/2" Tee	Proline	$10
3	Series 1/2" 2" Brass Nipple	Proline	$19
3	Series 1/2" 2.5" Brass Nipple	Proline	$32
4	1/2" Braided Stainless steel Faucet supply line	Reliabilt	$40
1	3A Automotive Battery Charger	Everstart	$25
4	Epoxy Resin	Gorilla Glue	$24
1	Waterproof Caulk & Seal	Gorilla Glue	$7
5	Female Power Jack	Luorng	$10
4	Brass Coupling	TANYA	$20
1	100pcs Nylon PCB Spacer	Marstrut	$98
1	50pcs PC817 Optocoupler	BOJACK	$9
	TOTAL		**$1029**

Project Timeline Comparison

Table 4.4 – Proposed GANTT Timeline																			
Design Proposal																			
Month	MARCH			APRIL				MAY				JUNE				JULY			
Week	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
Date / Task	3/13	3/20	3/27	4/3	4/10	4/17	4/24	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24
Order Supplies																			
Create Schematics																			
Project Building																			
Project Testing																			
Trouble-shooting																			
Prototype Thermostat																			
Prototype Valve Regulator																			
Report																			
Powerpoint																			
Rehearsal																			
Presentation																			

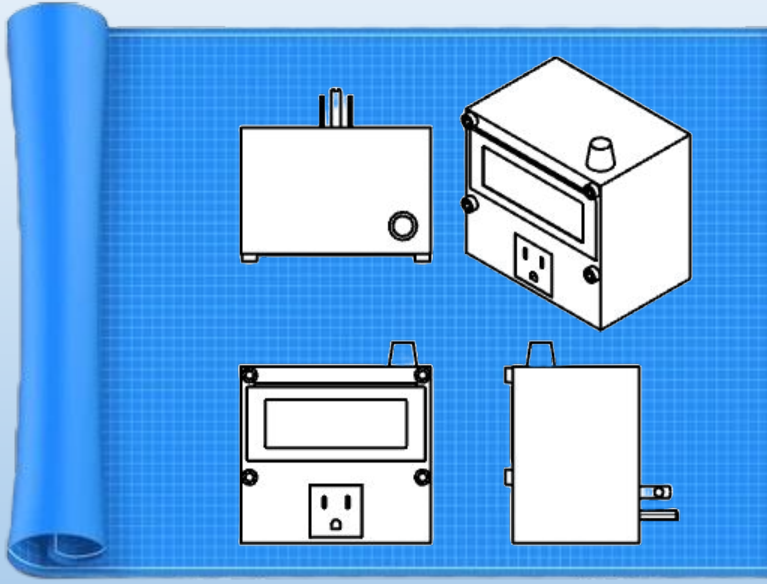
Table 4.5 – Actual GANTT Timeline																			
Design Project																			
Month	MARCH			APRIL				MAY				JUNE				JULY			
Week	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
Date / Task	3/13	3/20	3/27	4/3	4/10	4/17	4/24	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24
Order Supplies																			
Create Schematics																			
Project Building																			
Project Testing																			
Trouble-shooting																			
Prototype Thermostat																			
Prototype Valve Regulator																			
Report																			
Powerpoint																			
Rehearsal																			
Presentation																			

Final Task Distribution

<table>
<tr><th>Product</th><th>System</th><th>Component</th><th>Responsibility</th></tr>
<tr><td rowspan="13">Valve Regulator</td><td rowspan="4">Logic Controller</td><td>Valve Actuation Logic & Duty Cycle Control</td><td rowspan="6">Prem</td></tr>
<tr><td>Leak Detection & Valve Shutoff</td></tr>
<tr><td>Sleep Mode Valve Parking</td></tr>
<tr><td>Sensor Calibration & Conditioning (Battery, Temperature, Flow, Generator)</td></tr>
<tr><td rowspan="2">Power Management</td><td>Active Charger (User Input)</td></tr>
<tr><td>Passive Charge Protection (Generator)</td></tr>
<tr><td rowspan="4">MCU 1</td><td>General Programming & BLE comm.</td><td>Conner & Zach</td></tr>
<tr><td>Output Triggers (Valve, Pump, Duty Cycle)</td><td rowspan="4">Conner</td></tr>
<tr><td>Sensor Sampling & Processing (Battery, Temperature, Flow)</td></tr>
<tr><td>Wake & Sleep Detection</td></tr>
<tr><td rowspan="3">Enclosure</td><td>Product Depictions</td></tr>
<tr><td>Enclosure Design & Assembly</td><td rowspan="2">Prem</td></tr>
<tr><td>Troubleshooting & Diagnostics</td></tr>
<tr><td rowspan="10">Thermostat</td><td rowspan="2">Power Management</td><td>AC/DC Conversion</td><td rowspan="6">Zach</td></tr>
<tr><td>Multi-Stage Voltage Regulation</td></tr>
<tr><td rowspan="4">MCU 2</td><td>BLE Comm. & General Programming</td></tr>
<tr><td>Warning System & Chime Notifications</td></tr>
<tr><td>LCD Screen & Backlight Control</td></tr>
<tr><td>Potentiometer Integration</td></tr>
<tr><td rowspan="4">Enclosure</td><td>Product Depictions</td><td>Zach & Conner</td></tr>
<tr><td>Enclosure Design & Assembly</td><td rowspan="4">Zach</td></tr>
<tr><td>Troubleshooting & Diagnostics</td></tr>
<tr><td>Passive Outlet Integration</td></tr>
<tr><td rowspan="4">Administrative Tasks</td><td>User Manual</td><td>Preparation, Formatting, and Development</td></tr>
<tr><td>Tables</td><td>Formatting and Maintenance</td><td>Prem</td></tr>
<tr><td>Report & Website</td><td>Formatting and Maintenance</td><td>Group</td></tr>
<tr><td>Flow Charts</td><td>Creation & Revisions</td><td>Zach & Conner</td></tr>
</table>

Future Improvements

- Implement Project in a Shower
- More Efficient Temperature Regulation
- More Accurate Data Acquisition
- Increased Product Runtime



Summary & Conclusion

Questions

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