ShowerSync

ECE 445 Project Proposal

Team 21:

Reet Tiwary - rtiwary2

Edward Xiong - exiong2

Keshav Dandu - kdandu2

TA: Nikhil Arora

February 8th, 2024

1. Introduction

- **Problem:**

Imagine running late for something. You are not only scrambling to finish last minute work, but you also still need to shower. Now you have to wait on your water getting just to the right temperature, but also waste a ton of water in the process of it all, altogether causing you to just show up late and increasing your water bill.

With this type of situation, there are already products in the market that can adjust temperatures beforehand and have it as a preset. For example, smart showers are nice in that way because users can have a chance to control their desired water temperature, allowing time for the water to reach the desired preference all through a mobile application with Bluetooth included. But not everyone can afford a smart shower as it is expensive and requires a whole shower/bath renovation process. Additionally, how can we come up with the solution of not wasting water and being able to reuse it for alternative purposes while also being cost-effective?

- **Solution:**

A high-level idea of our solution is to create a convenient and efficient self-adjusting shower knob/pin system with a compartment to store and reuse any water outside of the desired temperature. This would aim towards cost-effectiveness, a user-friendly interaction, a simple installation, and an environmental-friendly approach to a convenient shower process. How we would implement this solution would be broken into system compartments/parts.

The system comprises a temperature sensor, a motorized knob mechanism that can be

easily attached to various shower knobs and faucet pins using a two-piece design, and finally a removable container located near the faucet which stores any water outside of the desired temperature through a tubing system into the container to be reused. When the sensor is able to detect the correct temperature through the faucet, the faucet pin is pulled through the linear actuator system, allowing the accurate water temperature to be dispersed through the shower nozzle and saving the user's time as well as their showering process.

The temperature sensor accurately gauges the water temperature passing through the faucet system, while the motorized knob system ensures that the shower knob is adjusted to match a predefined temperature setting and that the faucet pin is pulled when the desired temperature is reached, indicating to the user that the shower is ready. When the desired temperature has not been reached, the faucet has a tubing system that stores any water outside of the desired temperature into a container which can be removed and reused for other household purposes.

The entire system is controlled by a microcontroller, and to enhance user experience, we plan to incorporate wireless communication using a Bluetooth module. This wireless capability allows users to remotely adjust the shower temperature without the need to physically interact with the knob and pin, so the shower is ready to go.

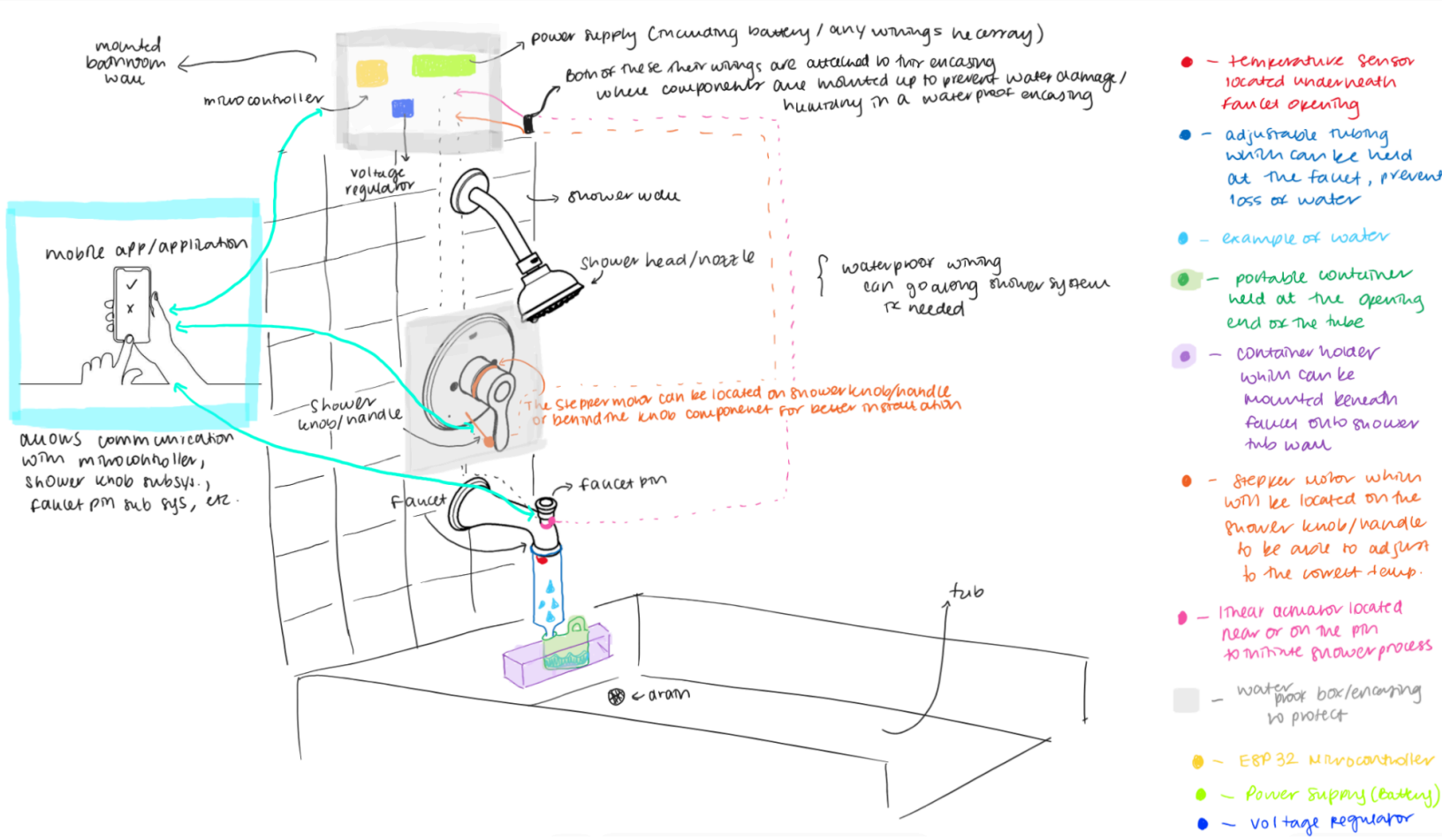
The self-adjusting shower knob/pin system and the faucet tubing system provide comfort and convenience but also minimizes water wastage by precisely regulating the desired water temperature and saves any water outside of temperature regulation into a usable container for

alternative purposes.

Finally additional features, such as a user-friendly mobile app interface and real-time temperature feedback, can be integrated for an enhanced and customizable showering experience while also being cost-effective.

- **Visual Aid:**

Rough Sketch of the visual aid for ShowerSync which uses a temperature sensor located underneath the faucet to preset the user's desired water temperature signaling the shower knob to find the right temperature and finally signaling the faucet pin to allow water through the nozzle. Any water outside of the desired temperature will be kept in a portable container.



1) The faucet as shown in the visual aid shows how the water temperature sensor will be located underneath the faucet as it needs to detect the temperature of the water for verification that the desired temperature has been acquired.
2) The faucet also has a tubing system set up to initiate the water-saving aspect for this project to prevent any loss of water. Beneath the faucet we will have a tubing system that will not expose the opening of the faucet to the rest of the tub. The tube is adjustable and it will allow water to flow into the portable container which is beneath the faucet held by a container holder which can be easily mounted.
3) The shower knob/handle communicates with the temperature sensor in that it should be able to find the temperature desired. We will utilize a stepper motor that moves the knob/handle where the desired temperature may be. To waterproof the shower knob/handle, we will encase it since the user does not have to manually touch the knob/handle at all. To encase it we will either use a waterproof clear encasing or whichever may be suitable.
4) The faucet-pin will use a linear actuator which will be pulled up once the user confirms that they are ready to begin the shower process. Otherwise, we will need to determine how long the linear actuator can wait to lift up. When the user has completed their showering process, the linear actuator will allow the faucet-pin to drop down, once the knob/handle is back to rest.
5) The mobile application communicates with the faucet to set and find the user's desired temperature, then it will communicate again with the entire shower system when the knob/handle locates the temperature (angle wise), notifying to the user that desired temperature has been reached and whether they want to proceed with

showering or not. This will communicate with the faucet-pin to either be lifted to allow the water to pass through the shower head and the showering process begins or to wait until the user is ready. Finally, the mobile application will send a signal to the shower knob/handle to return to rest and return the faucet pin back to rest as well.

- **High-Level Requirements List:**

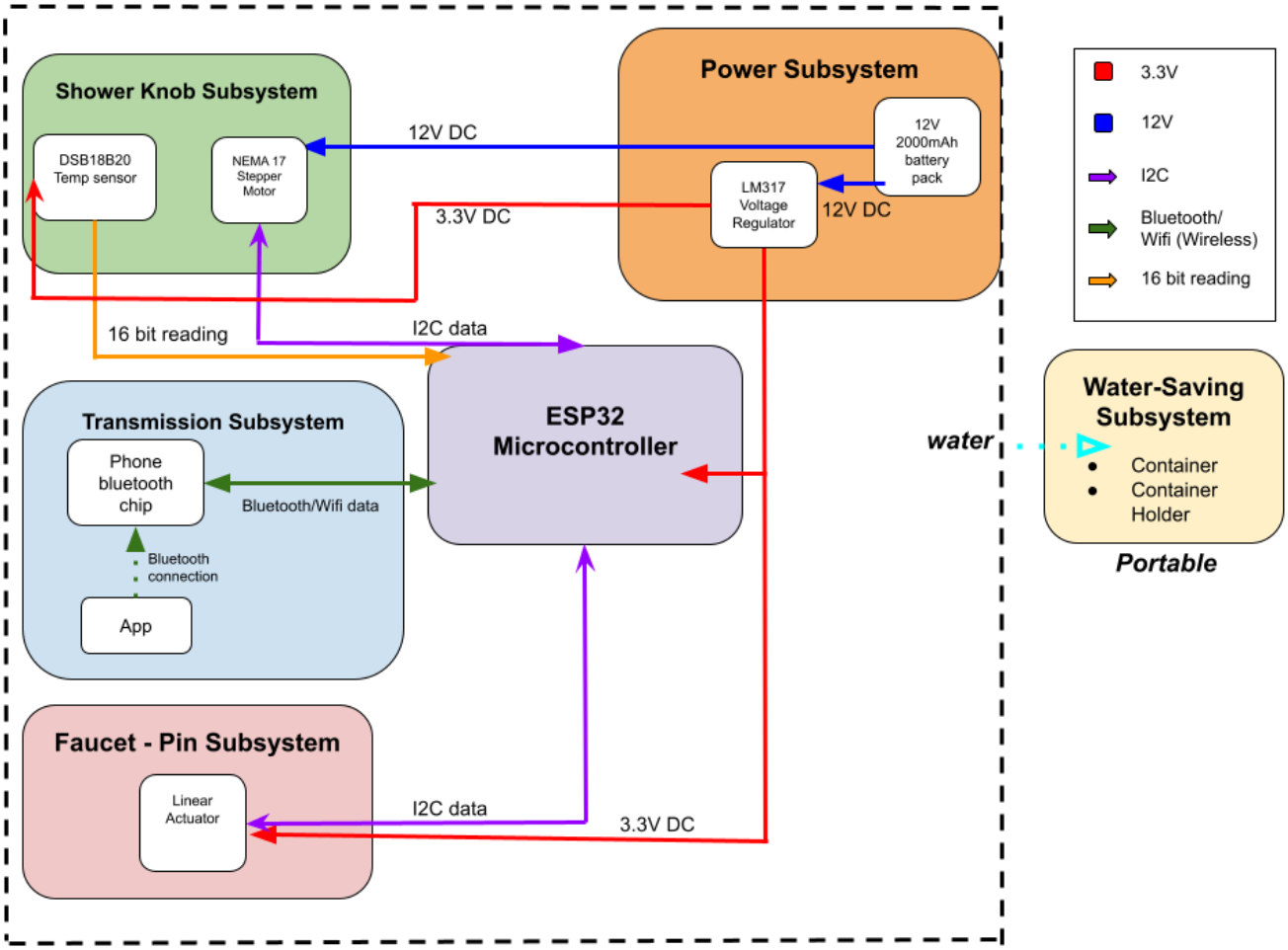
1. When activated by the user, the ShowerSync system should automatically turn on the faucet and redirect the water to a separate storage until the matching user temperature is reached (i.e. 80 degrees). The temperature should be **accurate to an error of 6 degrees**.

2. Once the shower knob/handle has acquired the desired temperature, the shower system should be able to notify the user to begin the shower process by initiating the faucet-pin subsystem. The time between when the desired temperature is reached and when the pin is pulled should be **no more than 25 seconds.**

3. The device should be able to react to remotely-issued commands. The entire device should be able to respond and **begin the entire process within 10 seconds** of the remotely-issued command.

2. Design

- **Block Diagram:**



- **Subsystem Overview:**

1) **Shower Knob Subsystem:**

The Shower Knob Subsystem contains the temperature sensor and a stepper motor for the shower knob/handle. How it connects to other subsystems is that the ESP32 microcontroller will receive preset information from the user and send it toward the shower knob subsystem. The shower knob subsystem will take in the data and set the temperature accordingly with the sensor and use the motorized mechanism to find the correct temperature. Once the desired temperature has been achieved, the microcontroller communicates the fact that the desired temperature has been received and the mobile application notifies the user about this. Once the user is prompted to begin their shower, this will initiate the faucet-pin subsystem which will allow the shower process through the nozzle/shower head. Any water that is outside of the desired temperature will automatically go into the water-saving subsystem which just stores water outside of user preference for external use.

With the components, the DS18B20 temperature sensor (5V) is a sensor that is specifically designed to be used for reading water temperature. We chose this sensor due to it being designed specifically with similar applications in mind and since it is cost-effective. The N17 stepper motor (12V) is the motor we plan to use to rotate the shower knob. It would be configured to do a pushing or pulling motion based on the temperature reading. Due to our system being in a shower and likely having water get all over it, we have begun looking into ways to waterproof the system beginning with the electrical components. We found waterproof wiring that we would likely use between the

sensor to the PCB and the PCB to the motor. We also have to consider water getting onto pieces such as the motor so we are also looking into the possibility of a 3D printing material that would be waterproof so that we could create perfect structures to encase the motor and other delicate components in. If this is not feasible the next option we would consider is waterproof encasing that are premade and are made of a material similar to silicon.

2) **Faucet-Pin Subsystem:**

The Faucet-Pin Subsystem connects to other subsystems in that once the the ESP32 microcontroller receives the sensing from the temperature sensor that the user's desired temperature has been reached, this will send the data to the transmission subsystem which will prompt the user if they are ready to start their shower process. User will either select "ready" which will send the data to the microcontroller which will send the data to the faucet-pin subsystem where the faucet pin will utilize a linear actuator mechanism to lift the pin up, allowing the water to go through the shower head/nozzle. If the user selects "no" then the faucet-pin subsystem will not be initiated. When the user is finished with their shower, they can select "done" which will allow the microcontroller to send the data to the shower knob subsystem to go back to resting position and once the shower knob subsystem goes back to rest, then the microcontroller will signal the faucet-pin subsystem that the shower-knob has been returned to its original state and allow the linear actuator to drop the faucet pin down to rest as well, switching off/ closing off any water flow.

The faucet-pin subsystem would use a servo-based setup similar to the shower

knob subsystem which would pull the pin that would switch the water from coming out of the faucet to coming out of the shower head. We would likely use the N17 stepper motor for simplicity instead of trying to figure out how to use a second type of motor. We will also use the waterproofing solutions from the shower knob system to find ways to protect the electronics in this subsystem.

3) **Water-Saving Subsystem:**

The Water-Saving Subsystem contains a water tubing configuration that will be attached to the faucet and have the other end connected to the portable container which stores any water outside of the desired temperature. The container is held by a container holder which will be mounted underneath the faucet on the side of the tub to allow the portable container to be held. The portable container will be removable by the user to use any water stored in it for external use.

How the water-saving subsystem works with the other subsystems is that while it does not need to use any electronic device in its configuration, once the shower knob subsystem receives the desired temperature the user has requested (from transmission subsystem to microcontroller to the shower knob subsystem), then while the shower knob is adjusting itself to reach the user's desired temperature, the faucet is basically opening allowing any water that is not reaching the desired temperature to be wasted. Rather than being wasted with the tubing system in place, any water outside of the desired preferences will automatically store into the portable container and altogether save any water to be wasted externally into the tub drain. The portable container will be big enough to store enough water outside of desired temperatures and the container holder

should be able to hold it up based on how much water is being carried over. This subsystem interacts with all of the subsystems altogether since it is storing the water and at the end the user can use the portable container for other external uses.

With the components, the faucet tube is adaptable and can be adjusted from our side to keep the water flowing into the water container/storage which can be held on the bathroom shower wall beneath the faucet in a straight manner allowing the flow of the water to enter into the container. The mounting strips mount the container holder where we can place the water container in and users can move the container in and out of the holder easily and use it for other household purposes.

4) **Transmission Subsystem:**

The Transmission Subsystem contains a mobile application where the user can set a temperature request, start the shower process and end the shower process with ease.

How it connects to other subsystems is that it will signal to the ESP32 microcontroller to deliver the preset information. ESP32 will receive preset information from the user and send it toward the shower knob subsystem. The shower knob subsystem will take in the data and set the temperature accordingly with the sensor and use the motorized mechanism to find the correct temperature. Once the desired temperature has been achieved, the microcontroller communicates the fact that the desired temperature has been received and the mobile application notifies the user about this. Once the user is prompted to begin their shower, this will initiate the faucet-pin subsystem which will allow the shower process through the nozzle/shower head. Any water that is outside of the desired temperature will automatically go into the

water-saving subsystem which just stores water outside of user preference for external use. After the shower process is complete, the transmission subsystem will take in the user's "done" indicating that he/she is finished with the shower which will allow the microcontroller to indicate to the shower-knob system to return the knob/handle back to rest, which will allow the microcontroller to indicate to the faucet-pin subsystem to drop the faucet pin down to rest, switching/closing off all water and completing the shower as a whole.

With the components, the HC-05 transceiver is a very cost-effective receiver that would be compatible with our board. We currently are planning on using Bluetooth connectivity in our app to connect with our system or doing it over a WIFI network. In either case, the transceiver would be able to do the job. The ST7735R is a component in the case that we decide to pivot from the original idea of using a phone application and instead opt for a system where we would implement buttons or connect some kind of remote to control the temperature. It is unlikely that we choose to go in that direction but we have gone ahead and found this component as a starting point just in case.

5) **Microcontroller Subsystem:**

The Microcontroller Subsystem is perhaps the second most crucial part of the project aside from the power subsystem. How the ESP32 microcontroller connects to other subsystems is that it will receive preset information from the user which is from the transmission subsystem and send the data toward the shower knob subsystem. The shower knob subsystem will take in the data and set the temperature accordingly with the sensor and use the motorized mechanism to find the correct temperature. Once the desired temperature has been achieved, the microcontroller communicates the fact that

the desired temperature has been received and the mobile application notifies the user about this. Once the user is prompted to begin their shower, this will initiate the faucet-pin subsystem which will allow the shower process through the nozzle/shower head. Any water that is outside of the desired temperature will automatically go into the water-saving subsystem which just stores water outside of user preference for external use. After the shower process is complete, the transmission subsystem will take in the user's "done" indicating that he/she is finished with the shower which will allow the microcontroller subsystem to indicate to the shower-knob system to return the knob/handle back to rest, which will allow the microcontroller subsystem to indicate to the faucet-pin subsystem to drop the faucet pin down to rest, switching/closing off all water and completing the shower as a whole.

Component-wise, the ESP32 WROOM board is very powerful with a dual-core processor and Bluetooth and WIFI connectivity which is specifically useful to make our transmission subsystem. It is also compatible with Arduino DOIT which could simplify work down the line. It is also very compact and has a very low power consumption while having a wide range of pins which would be useful in our case since we would want to make it as small as possible since it would make waterproofing or making a waterproof encasing easier.

6) **Power Subsystem:**

The power subsystem is an important part of this entire project as it supplies everything to work the way it may need to (other subsystems will not be able to communicate with each other without this). We will encase the power supply to be safe from water, details regarding this are further discussed in this proposal.

- **Subsystem Requirements:**

REQUIREMENTS:	VERIFICATION:
Shower Knob Subsystem:	
• Must be able to move the shower knob as necessary effectively within the range of motion (about 60-90 degrees).	• The motor should be able to turn the knob in both directions to turn the water on and off. We should be able to measure the change in the angle of the shower knob handle using a simple measurement from something such as a protractor.
• Should be able to communicate effectively with the microcontroller relaying the temperature.	• Microcontroller should be able to effectively control the motor based on readings and create the intended motion.
• Should be able to give readings of the temperature within three degrees of the actual temperature.	• If another temperature sensor is used it should give a reading within the same range. This can be tested using cups of water at different heats and comparing readings.
• Would require 6 V to power the motor from the power subsystems, and a 3.3 V for the temperature sensor.	• Effectively provide voltage to the motor as necessary. This can be verified by using a multimeter to read the voltage going into the component.

Faucet-Pin Subsystem:	
• Must be able to effectively switch between the shower head and the faucet at the bottom based on the microcontroller. • Must be able to work on multiple instances back-to-back without manual intervention being required. • Would require 3.3 V supplied by the power subsystem to power the motor.	• When the user is ready to shower it goes to the shower head and when the user is finished with their shower it goes back to the faucet. • Upon use for one shower, it should not mess with the setup or require a person to go and adjust the motor to function a second time. • Effectively provide voltage to the motor as necessary. This can be verified by using a multimeter to read the voltage going into the component.
Water Saving Subsystem:	
• Must effectively hold excess water as the water is heating up and be able to store all the water. • Should not require any voltage and include preliminary precautions to avoid safety risks.	• Extra water during the process of the water heating up should all be stored in some form of container. That is convenient for users to remove and use as they choose to later. • No components should be able to be or within 10 inches of electrical components to avoid contact between electricity and water for safety.

Transmission Subsystem: ● Must accurately receive information from the User via an application and send it to the microcontroller. ● Must allow the user to control certain parameters such as temperature and notify the user when the water is ready.	● Must be able to see clear interaction of data between microcontroller and application where they can see information from each other. ● When users set parameters or inputs such as temperature there should be effective communication to the user when the water is at that temperature.
Power Subsystem: ● Must be able to consistently maintain and regulate voltage levels for each of the subsystems. ● Supplies 3.3 V to Shower Knob Subsystem, Transmission Subsystem, Micro-Controller Subsystem and Faucet-Pin Subsystem. ● Supplies 6 V to Shower Knob Subsystem.	● We should be able to monitor the voltage being passed throughout different components and consistently see effective regulation without noticeable fluctuation. ● If monitored using a multimeter, we should be able to effectively see that the anticipated voltages are sent to each individual component as planned.

Microcontroller Subsystem:	
• Must be able to effectively communicate with the other subsystems. Relaying data to and from every subsystem as intended.	Must be able to do the following: 1. Receive readings from the temperature sensor and instruct the shower knob subsystem's motor. 2. Be able to send information to and receive information from the application and be able to see them correctly on both sides. 3. Be able to instruct the motor in the faucet-pin subsystem based on inputs from the transmission subsystem.
• Would require 3.3 V supplied by the power subsystem to power the ESP32 Microcontroller.	• Effectively provide voltage to the motor as necessary. This can be verified by using a multimeter to read the voltage going into the component.

Tolerance Analysis:

1) **Power Analysis**

A factor that we have to consider is how much power our system needs to be able to operate. If we do not choose a correctly-rated battery/power system, then we are unable to power all the parts successfully. Initially, we were thinking of using a typical six-cylinder 5V battery that would provide us around 550 mAh. Additionally, we would regulate the voltage to match the necessary voltages we would need for our parts. Unfortunately, many of our parts did not provide a clear measurement of the power consumption, so we had to create an educated guess on what the power consumption would be based on similar parts.

The N17 stepper motor we plan on using did provide a power consumption of 120mA at a nominal voltage of 12V. Since we are not using a 12V power source, we estimate that the motor would take about 150mA. The ESP32 microcontroller we plan on using does not provide a power rating but it is mentioned in the description that it is an ultra-low power consumption board. As such, we give a generous estimate of around 200 mA for the microcontroller. Since we plan on using an app to connect with our Bluetooth/wifi transceiver, we will not need to power a remote for our project. The only remaining part that we have to power is the DS18B20 temperature sensor, but sensors like these consume little power, so we can assume it takes 1mA.

With all the parts accounted for, we can calculate the necessary power supply we need. First, let's assume we use a 550mAh battery. To account for potential losses to heat and voltage variation, we assume that only 70% of the 550mAh is available to use.

$$0.7 \times 550mAh = 385mAh$$

Our total power consumption needed from all our parts can be calculated as follows:

$$150mA + 100mA + 1mA = 251mA$$

To calculate how many hours of use we get, we divide the two numbers:

$$385mAh/251mA \ = \ 1.53\,h$$

This value of 1.53 hours is fairly low considering that we want the battery to last for numerous showers before having to replace it. As such, we decided to look into batteries with a higher power rating. We eventually found a 5V battery that could provide 2500mAh to our system. By doing the same calculations again, we can find the number of hours our device lasts again.

$$0.7 \times 2500mAh \ = \ 1750mAh$$

$$1750mAh/251mA \ = \ 6.97\,h$$

This estimate of 6.97 hours is much higher than our initial 1.53 hour estimate. Assuming the average user takes 10 minute showers, we reach a usage of around 41 showers. Although this number is not as ideal as we hoped for, it is still a reasonable amount of showers for the price of one battery.

2) Voltage Regulation

To regulate the different voltages we need for our project, we plan on using a LM317 voltage regulator. As such, we need to analyze the temperature it operates on to ensure that we don't have any issues with the regulator. To start we know that the max temperature the LM317 can operate regularly at is 150 C. To calculate the max temperature we may encounter, we use the following equation.

$$T \ = \ i\,out \ * \ (V\,in \ - \ V\,out\,) \ * \ (\Theta\,ja\,) \ + \ T\,a$$

Next, we need to find all the unknowns in this equation. We know our Vin is 5V and the lowest Vout we have is 3.3V, so we can substitute those numbers immediately. From the datasheet, we

also know that $\Theta\, ja$ is 100C/W and Ta is 40 C. To calculate i out, we can assume that i in = i out and calculate the current within our system. From the ESP-32 WROOM1 datasheet, we see that there is a current draw of 165 mA on average and 211 mA in the worst case. For our purpose, we assume the worst case. Our DSB18B20 temperature sensor only has a current draw of 1mA. Finally, our motor has a current draw of 120 mA. Adding these up, we get a current of around 332 mA. Now, we can plug into the equation.

$$T = 332mA * (5 - 3.3) * 100 + 40 = 96.44C$$

As we can see, this value is much lower than the 150 C threshold provided by the datasheet, so we know it is safe for us to apply the voltage regulator on our design.

3. Ethics and Safety

The main IEEE ethical dilemma we are facing with ShowerSync is the safety aspect of water with all of the components and materials we will be utilizing. A lot of our safety features regarding ShowerSync will have the involvement of water and how to prevent the aspect of electrocution. As we are using a waterproof-based temperature sensor, which will interact directly with the water, we also need to make sure that anything that we are using to mount any of the motorized-based components with the various subsystems is also waterproof.

Additionally, we need to take into consideration the power source of ShowerSync and how that can be affected by any interaction of the water if it so happens. We will not have a battery near any water because that will be dangerous and will pose a risk factor. However, we plan on keeping any of the components out of reach from the water by mounting them in an encasing near the wall above the shower head tub configuration and allow water proof based wirings to help serve as the motor based systems and anything we may need to connect our divide too. By encasing the power source, using waterproof-based encasing and waterproof wirings whilst also being mounted above the shower head where it would be attached to the wall of the building, there can be a guarantee that water will not disrupt the system and neither will humidity.

Our solution approach supports Section 1.1 of the IEEE Code of Ethics which states “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment” (IEEE Code of Ethics). It is important to have safety considered in ShowerSync because we need to protect not only the user, but also the components and materials we will be utilizing to create the interaction with water as

safely as possible. This will also allow us to focus on the device's design from the perspective of how we can achieve our goals whilst also remaining safe and use materials that will allow the user to be safe while delivering its purpose.

By mounting the waterproof encasing/box which will contain the batter and controller and use waterproof wiring and waterproof wiring for the motor system this will allow any prevention of water disrupting the device. The waterproof temperature sensor will be placed inside of the faucet, since it is waterproof and sensing just the water temperature, we believe that it should be fine if the enclosing of it is also waterproof. We would need an encasing or box based material which will be impermeable to water and can withstand any pressure or impact that it may receive if it does.

Moreover, it will be critical for ShowerSync to provide instructions to users on how to use the device properly so that there are no issues with any short circuiting, and to prevent bigger issues like hazardous fires starting. This supports the ACM Code of Ethics Section 2.7 because we are "foster[ing] public awareness and understanding of computing, related technologies, and their consequences" (ACM Code of Ethics). With this, ShowerSync will highlight the importance of keeping the features waterproof and dry so materials are not malfunctioning either. If there is damage to the wirings, there will be information on how to handle the device and who to contact if there are any issues.

Lastly, the IEEE's Code of Ethics and ACM's Code of Ethics both explain the duties that engineers must adhere to in their professional careers. Section 2.2 of IEEE states to "support colleagues and co-workers[,] to strive to ensure the code is upheld, and to not retaliate against individuals reporting a violation" (IEEE Code of Ethics). With ShowerSync being a project where a device is being created to help user's with an end goal, it is important that the users'

safety and welfare come first. With reference to ACM's Code of Ethics Section 3.7, "[we need to] recognize and take special care of systems that become integrated into the infrastructure of society" (ACM Code of Ethics), implying to us that it is also important that we as engineers are truthful in our job and do not engage in any areas of unethical based actions as well as conflicts, by doing this we will uphold the value and standards of engineers and ShowerSync's standards as well as safety concerns.

References:

"ACM Code of Ethics." *Code of Ethics*, www.acm.org/code-of-ethics. Accessed 21 Feb. 2024.

"IEEE Code of Ethics." *IEEE*, www.ieee.org/about/corporate/governance/p7-8.html. Accessed 20 Feb. 2024.