Automatic Water Bottle Filler

ECE 445 Project Proposal
Team #21
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I. Introduction

I.A Problem

Water bottle filling stations have saved millions of plastic bottles from being wasted and have started to become common in most buildings we see. While they are effective in public spaces where many people have access to them, there are not many applications in homes or small businesses. Since these devices require the attention of the user at all times during use, the traditional built-in refrigerator water dispensers are sufficient for most people, as there is no real advantage over the current method. These home devices also require user attention for tens of seconds while bottles fill up, and must be manually started and stopped.

Public water bottle fillers require constant user attention and also cost upwards of $2500 per installation. Thus, they are not an attractive solution for small buildings and homes. Additionally, home fridge water dispensers add over $200 to the cost of the refrigerator. Busy parents with large families and people with large water bottles spend precious time filling bottles each day, when they could use that time to perform other daily tasks in the meantime. Users are unable to multitask while filling up a water bottle because of the risk of spilling water.

I.B Solution

Our solution is to create a cost effective water dispenser with an automatic stop and start feature that detects when a bottle is present and stops filling when the bottle is almost full. It offers a hands-free attention-free solution to homeowners and small businesses. Additionally, the device will have a feature for gyms to dispense pre-workout to gym-goers and can be used to mix and dispense other concentrated drinks as well. This device will save people time and money, and will create an easy selling point for gyms instead of distributing pre-packaged pre-workout drinks.

In our device, the user will select between types of liquid dispensed, and will select either “full fill” or “half fill”. The device will use a sensor to determine the height of the top lip of the bottle/container, and will dispense liquid. The device will also actively monitor the level of liquid in the container through an ultrasonic sensor. The device will stop filling up the bottle/container when the desired liquid level is reached. For concentrated drinks such as pre-workout, a predefined volume of liquid concentrate will first be dispensed followed by water.

I.C Visual Representation

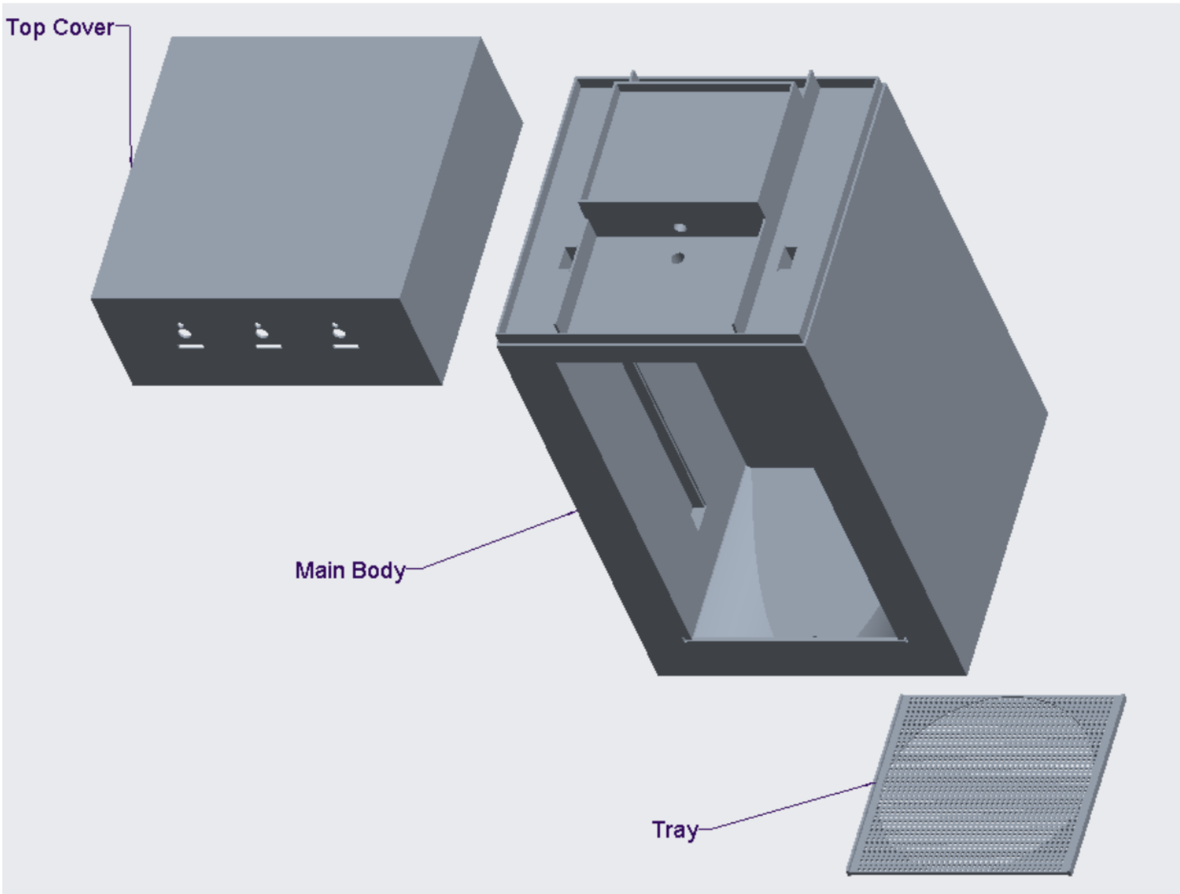


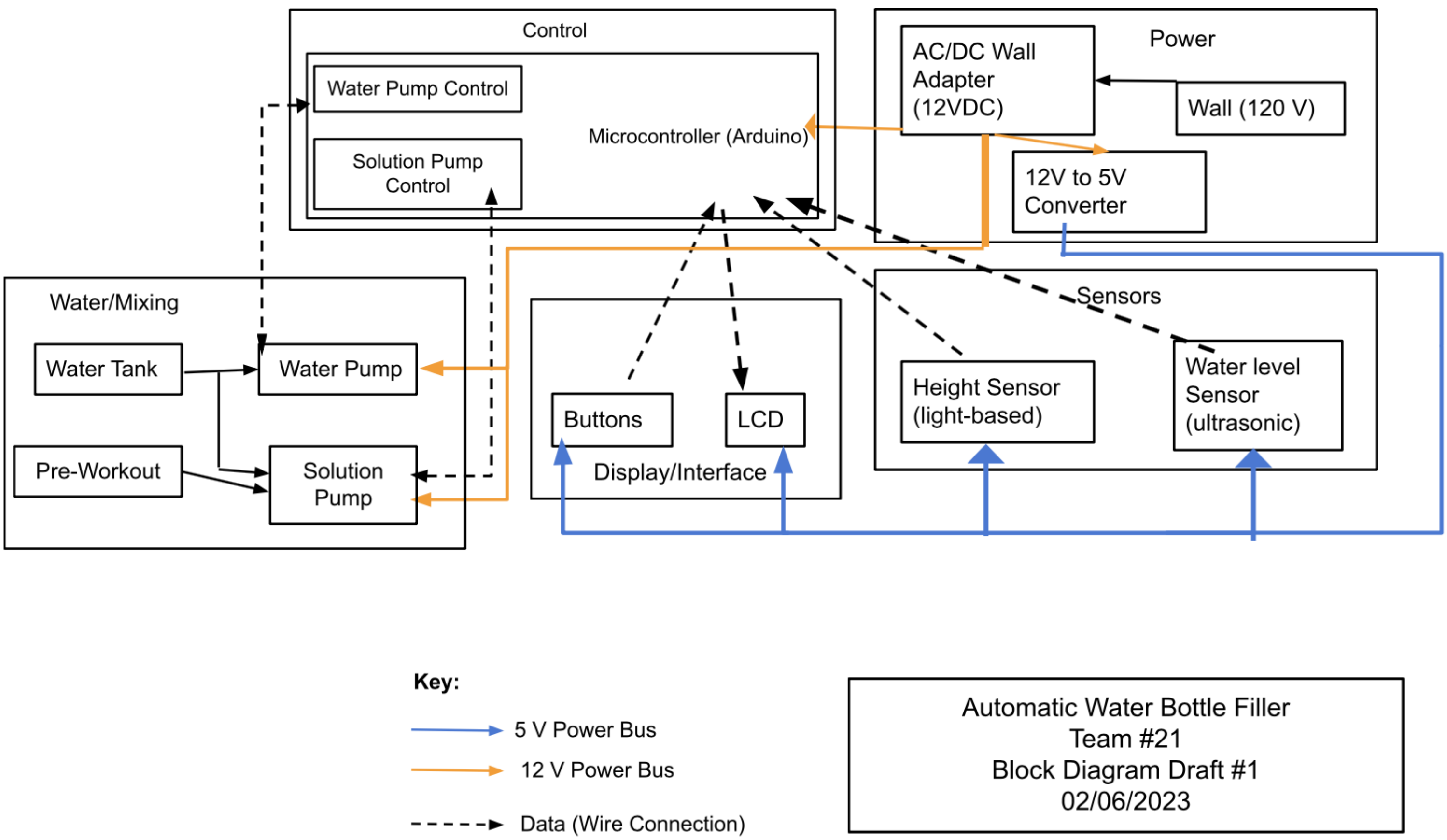
Figure 1: Automatic Water Bottle Filler Drawing

I.D High-Level Requirements

- Sensors determine the height of the bottle and monitor the level of water in the container accurately within 20 cm, no overflows occur.
- Controller can automatically turn on/off the pump based on sensor values of water level and bottle height.
- Users can select between different drink types and can select a desired fractional volume of their bottle/container (eg. ⅓, ½, 1 etc.). Users can leave the device unattended as it operates.

II. Design

II.A Block Diagram:



II.B Subsystems:

II.B.i Power Subsystem:

The power subsystem is utilized to power the entire device. For user convenience, the device will be wall-powered. In order to stay within voltage ratings for the different components receiving power, we'll utilize two separate power buses, one 12V bus (to the pumps and microcontroller), and one 5V bus (to the various sensors, buttons, and LCD). To accomplish this in the most efficient way possible, we plan to utilize a basic 12V AC-DC wall adapter, which provides our 12V bus, then get the 5V bus utilizing a basic buck converter module in our PCB. 12V will be sent to the pumps and microcontroller, and 5V will be sent to the sensors, buttons, and LCD display.

- *Requirement #1: The wall + charger combination delivers 12 V +/- .5% (necessary to stay within voltage ratings)*
- *Requirement #2: The subsystem delivers power to the entire device from the single outlet plug-in alone*

II.B.ii Display/Interface Subsystem:

The interface subsystem is how the user communicates with the device. It will allow the user to choose if they want pre-workout or regular water, if they want their bottle completely filled or only half filled, manually dispense water (similar to a traditional water fountain), and start the automatic dispensing. Finally, there will be a manual on/off switch to supply power to the device. This subsystem will consist of 3 switches (power on/off, preworkout/water, 50%/100%) and 2 buttons (manual dispense, start). The buttons relay back to the microcontroller.

- *Requirement #1: Water or pre-workout is dispensed when the manual dispense buttons are pressed*
- *Requirement #2: The on/off switch controls the delivery of power to the device - if the switch is off, even if the device is plugged in, no power is delivered*

II.B.iii Control Subsystem:

The control subsystem is what connects all of the different subsystems together. The microcontroller receives information from the interface that tells it to begin pumping and the desired capacity fill of the pumping. The microcontroller will then receive the information on the height of the container using the height sensor and the current water level using the ultrasonic sensor. The microcontroller will then drive the Water Pump Control and the Solution Pump Control. This will be a high low signal that will then connect to the desired pumps to signal whether a pump should start working and when it should turn off. The constant updating data reception from the ultrasonic sensor will be the determining factor of when each given pump should be turned off. The microcontroller will be receiving a 12V power supply from the power subsystem.

- *Requirement #1: When a button is pressed, runs the functionality corresponding to that button. EX: If manual dispense water is pressed, turns the water pump on.*
- *Requirement #2: Receives water bottle height and current water level data from sensors within +/- 5 cm.*
- *Requirement #3: Calculates the "full" water level within +/- 1 cm, shuts off the pumps when the current water level reaches the "full" level determined.*

II.B.iv Sensor Subsystem:

The sensor subsystem consists of an Ultrasonic/Laser proximity (water level) sensor and an LED-phototransistor (height) sensor. The water level sensor will monitor the water level of the bottle from the top of the device and will accurately relay the water level to the control unit through I2C or a Trigger/Echo digital signal. The LED height sensing system will flash lights along the height of the bottle and will send photodiode data to the microcontroller. The LEDs will be powered with 12V, while the photoresistors and ultrasonic/proximity sensor will be powered with 5V.

From the Microcontroller, the LED/Phototransistor sensor will be enabled and disabled using digital signals to the MOSFET and BJT. The Ultrasonic/proximity sensor will be constantly powered due to low power consumption. These connectors will be wired to the sensors which will be mounted on the enclosure.

For the height measurement, we will be building our own custom sensor. The circuit will be soldered onto protoboards with a waterproof face plate with the diodes and transistors protruding through. During operation, The LED's will be simultaneously turned on during the height sensing period. Each LED will be positioned across a phototransistor on the other side of the water bottle. Phototransistors in the path of light will increase in current flow, increasing the voltage across the 1k Ohm resistor. These analog voltages will be read by the Microcontroller through the analog pins. The height of the bottle will be estimated based on trigonometric calculations using average water bottle size and maximum light angle from the highest LED and the gradient of Photodiode currents. LED Color will be determined during testing to see which color has the highest sensitivity. Hardware has been designed for LED's with threshold voltage up to 2.4V. Brightness will be adjusted with series resistor values.

For the water level sensor, we will be attempting two different approaches. The first approach uses an ultrasonic Time of Flight sensor which will be positioned pointed at the surface of water. It will send and receive an ultrasonic beam and calculate the time difference between transmitter and receiver. The second approach will be using a Laser based proximity sensor. It uses the same Time of Flight approach, but with much better accuracy and narrow transmission radius. We will test to see if the ultrasonic sensor meets our performance requirements, as it is a cheaper sensor than the Laser proximity sensor. The hardware has been designed so both sensors can be used with the same connector. Both sensors operate with 5V input voltage and have two digital communication pins. The ultrasonic sensor uses Trigger/Echo based communication while the Laser sensor uses I2C.

- *Requirement #1: Determines the water bottle's height accurately (within +/- 5 cm)*
- *Requirement #2: Determines the current water level (within +/- 5 cm)*

II.B.v Water Subsystem:

The water subsystem consists of 1 water tank, 1 pre workout concentrate tank, and 2 pumps. The pumps are powered by 12V from the power subsystem. The pumps receive instructions for when they are able to be on from their respected pump control in the control subsystem. The pumps will directly draw liquid from the desired container and pour into the water bottle.

- *Requirement #1: Pumps draw liquid from the desired tank and turns on and off when instructed by the microcontroller*
- *Requirement #2: Tanks and pumps remain leak free, keeping liquid away from electronics.*

II.C Risk Analysis:

The block that poses the greatest difficulty to implement is the sensor block. The sensor block is the most difficult because there are many intricate parts that are involved. First off, we need to make sure that the height measuring sensors are able to give us an accurate value for the height of the given input bottle. Having many different sizes, shapes, and materials increases the level of difficulty for the height sensor. Finding the method to implement the laser sensor will also pose a challenge. Identifying the method that has the best mixture of cost effectiveness and functionality is critical. A few methods we've thought of for implementing the height (laser) sensor include a mechanical lift to move the sensor up and another on the side to lift up a receptor (stopping when the sensor connects). Another possible method of implementing this sensor is to have multiple sensors at different heights and we can check the highest sensor that doesn't hit its target. As you can see this method is less accurate but will not have a complex mechanical component. Exploring and thinking of a few more methods of implementing this sensor will be very important in the success of this project.

The ultrasonic sensor poses challenges because we need to find a small enough sensor that can be near the output source of the liquid. This sensor's unique challenge is that it is the sensor that needs the most casing on the outside and inside of the device. Making sure that we craft a clever plan to keep the user and device safe will be very important for this sensor.

The last big challenge that we need to take into account with the project as whole but specifically with sensors is the fact that we are creating a device that uses liquids in close proximity to electricity. This increases the difficulty of implementing the sensors because we need to make sure that we seal the devices in such a way that they can't be damaged by liquids but are also working with the level of precision that we need. This is very important as safety is the number one priority and we also pride ourselves on the fact that our device has a high level of precision. Finding the best solution will take time experimenting with sensors and different materials to make sure we do not hinder a sensor's ability to work.

III. Ethics and Safety

The main ethical/safety concern for this project is the use of both water and electricity. A malfunctioning device or misuse of the device (whether intentional or accidental) could result in electric shocks. Referring to the IEEE code of ethics 7.8.I.1 "to hold paramount the safety, health, and welfare of the public … and to disclose promptly factors that might endanger the public or the environment" [1], we are obligated to ensure that the circuitry is protected from any possible contact with water, as well as include warning of electrical shock on the device. To ensure that water and electrical components never come into contact, we plan to do the following:

1. Keep the water storage element completely sealed other than the pump tubing in order to prevent splashing.
2. Apply a water-resistant coating (such as urethane or acrylic lacquer) to all circuitry.
3. Create a hard-plastic housing for all electrical components as an added measure of safety.

Finally, we'll include a small shock warning label (similar to the ones present on devices like hairdryers, lamps, etc.) to ensure the public is aware of potential shock dangers. During the construction of this project, we'll ensure to follow good laboratory practices involving shocks, especially the "one hand rule" (keeping one hand off electric components at all times to prevent creating an avenue for current).

While the water shock concern is the main safety concern, IEEE 7.8.I.5 "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others" [1] applies as well. This essentially means that we will treat our TA, peers, and other course staff with respect, and openly accept constructive criticism in order to ensure the best possible outcome for our project.

As far as the final product is concerned, there are a few ethical standards we'll have to include in the user manual. Specifically with the drink concentrates, they must be changed before the "use by" date. This means that each container of concentrate should be changed once every 75 days, if it doesn't run out before that [2]. Finally, the water being dispensed must be within EPA regulations, specifically below the maximum contaminant levels and within treatment regulations. Since the local water utility is responsible for ensuring water quality, this should not be a concern, but a note will be included in the user manual.

IV. Appendix

[1] IEEE, "IEEE Code of Ethics," *ieee.org*, Jun. 2020. https://www.ieee.org/about/corporate/governance/p7-8.html

[2] "Syrup Quality Guidelines." Available: https://www.cokesolutions.com/content/dam/cokesolutions/us/documents/foodservice-quality/foodservice-quality-syrup-quality.pdf