AUTOMATIC WATER BOTTLE FILLER

ECE 445 DESIGN DOCUMENT - SPRING 2023

Project #21
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February 24th, 2023

Abstract:

This document is intended to provide a detailed summary of the design process and planned implementation for our project - an automatic water/pre-workout dispensing system. This document will detail the components we intend to use, individual subsystems and specifications, analyses of safety, cost, and tolerance, as well as the project schedule.

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1 Introduction

1.1 Problem

Water bottle filling stations have saved millions of plastic bottles from being wasted and have started to become common in most public buildings. While they are effective in public spaces where many people have access to them, they are not useful 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 of the separate dispenser. 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, so they are not an attractive solution for small buildings and homes. The only alternative for at-home use is a built in fridge water dispenser, but these features add over $200 to the cost of the refrigerator. Busy parents with large families and people with large water bottles spend significant time filling bottles each day, usually when they are busy or tight on time. Parents getting their kids ready for school and working professionals who go to work early are unable to multitask while filling up a water bottle because of the risk of spilling water.

1.2 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 "100% fill" or "50% fill". The device will use a sensor to determine the height of the bottle/container and will dispense until the bottle is full. The device will also actively monitor the level of liquid in the container through a time-of-flight based 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.

1.3 Visual Aid

The initial inspiration for this project came from observing the pros and cons of different water bottle filling systems in campus buildings and recreation facilities. Below are two options students currently have for filling their water bottles:

Figure 1: ECEB Water Bottle Filling Station

Figure 2: MEB Water Bottle Filling Station

Observing these two systems, there are clear benefits and drawbacks to both. The ECEB station [Figure 1] requires the user to hold the lever down the entire duration of the filling process, but no water is wasted assuming that the user is paying attention. However, this system requires constant user interaction and attention. The MEB station [Figure 2] automatically turns on when it detects an object, but does not turn off until the object is removed. There is a delay between the object being removed and when the water stops dispensing that results in wasted water. While this water waste may seem negligible, these stations fill hundreds of bottles per day and this waste water accumulates quickly. Furthermore, the MEB system has no option for manual filling. In the event that the sensor system malfunction'/s or maintenance is required, users must fill their bottles from the water fountain mouthpiece, which is difficult and slow. We incorporate elements from both of these stations into our device's design: the manual fill feature from Figure 1 and the general shape and usage of sensors from Figure 2. Our goal is that our final device looks similar to Figure 2, but provides more functionality and less waste. Below is an exploded view of our physical design:

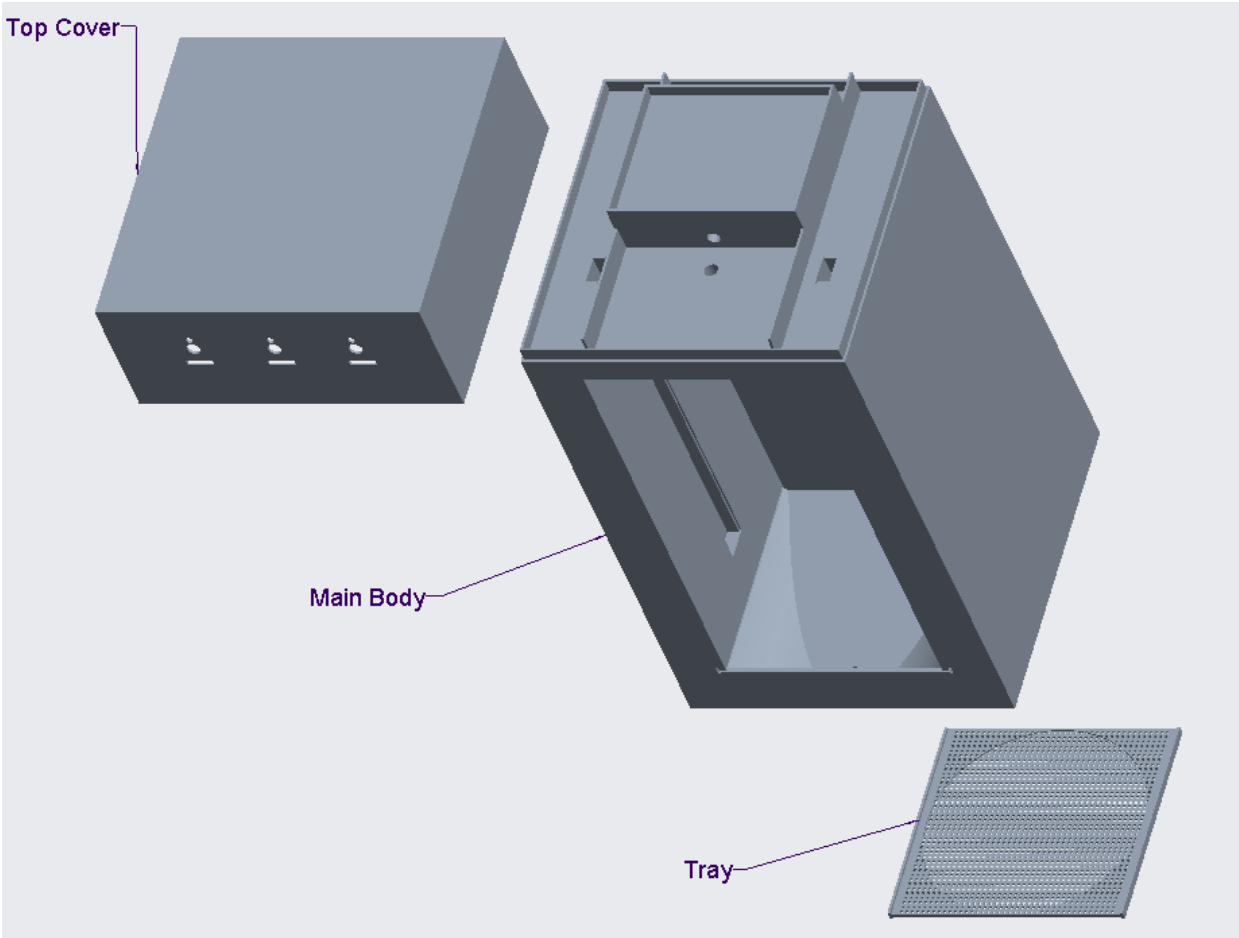

Figure 3: Design Overview - Visual Aid

1.4 High-Level Requirements

To ensure a successful project, our design will need to achieve the following:

1. Sensors determine the height of the bottle and actively monitor the level of water in the container within +/- 2 cm.
2. Controller can automatically turn on/off the pump based on sensor values of water level and bottle height.
3. Users can select between different drink types and can select a desired fractional volume of their bottle/container (eg. ½, 1 etc.). Users can safely leave the device unattended as it operates.

2 Design

2.1 Physical Design

At its most basic level, our design will consist of water pumps, tubing, a PCB, and two sensors. These components, as well as our interface (switches and buttons) will all be contained in the enclosure modeled below:

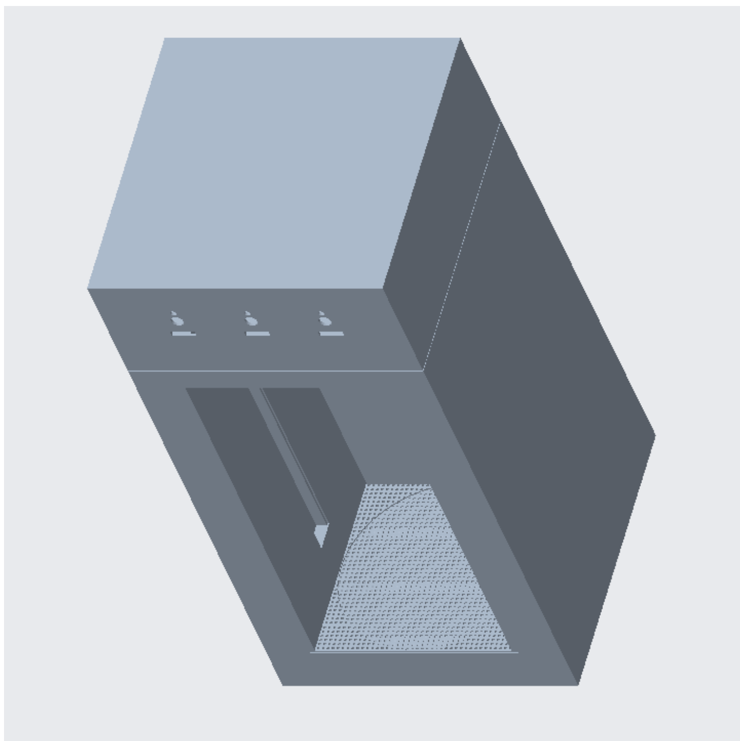

Figure 4: Top/Front View of Device Enclosure

In the final design, there will be a series of LEDs (approximately 12 inches long) on one side of the housing, and a series of phototransistors the same length on the opposite side. These LED-photoresistor pairs make up our height sensor. Our device will be able to measure and fill containers between 4 inches and 12 inches in height. A more detailed drawing of our enclosure is shown below:

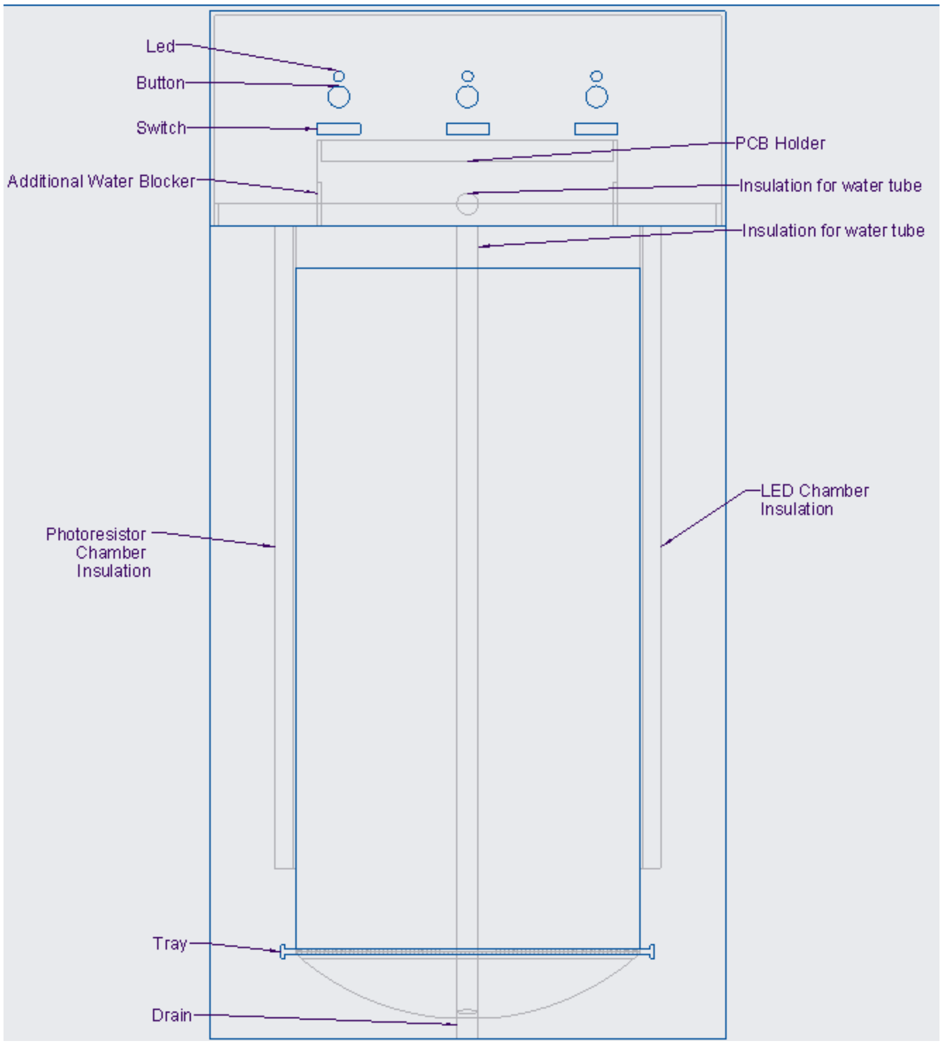

Figure 5: Detailed Enclosure Design

In any design involving electricity and water, safety is of utmost importance. One measure we've taken to ensure electrical safety is in the housing itself - the PCB and user interface electronics will be a part of their own separate housing at the top of the unit, and the water tubing will have insulation as an added measure of safety.

2.2 Block Diagram

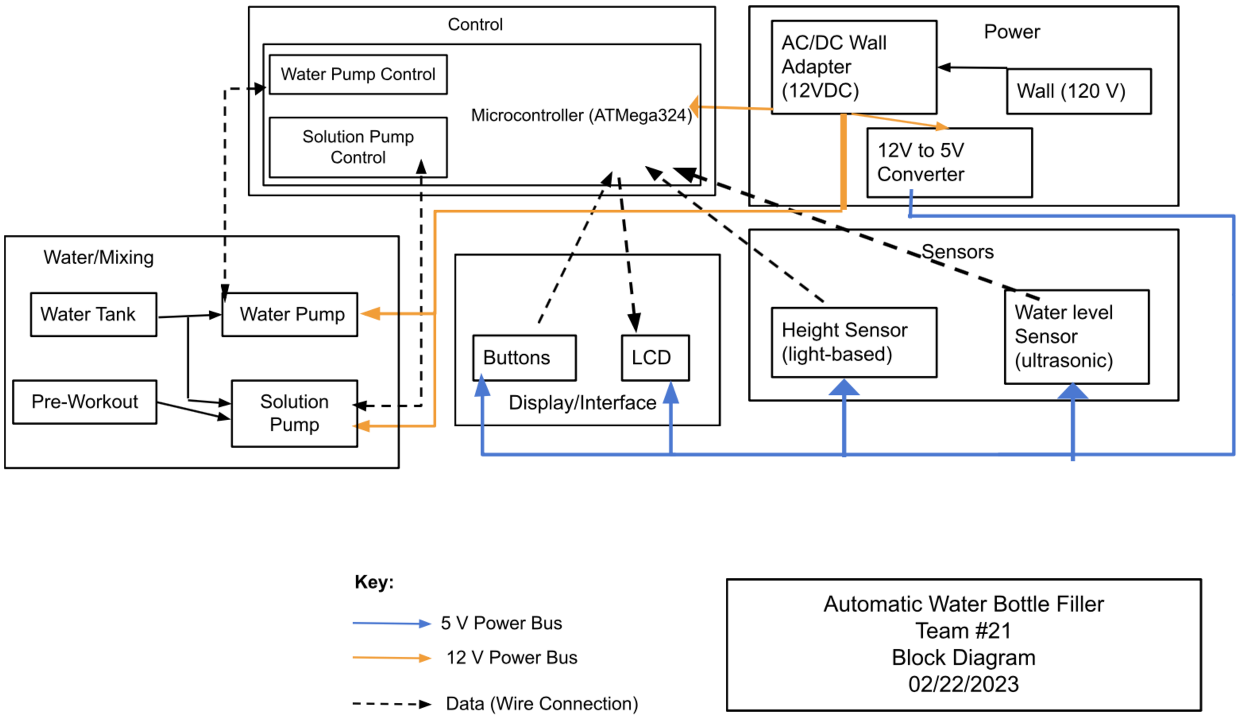

Figure 6: Block Diagram

As shown on the block diagram, our system consists of five subsystems (control, power, liquid, display/interface, and sensors), as well as a specially designed enclosure.

2.3 Functional Overview & Subsystems

2.3.1 Power Subsystem

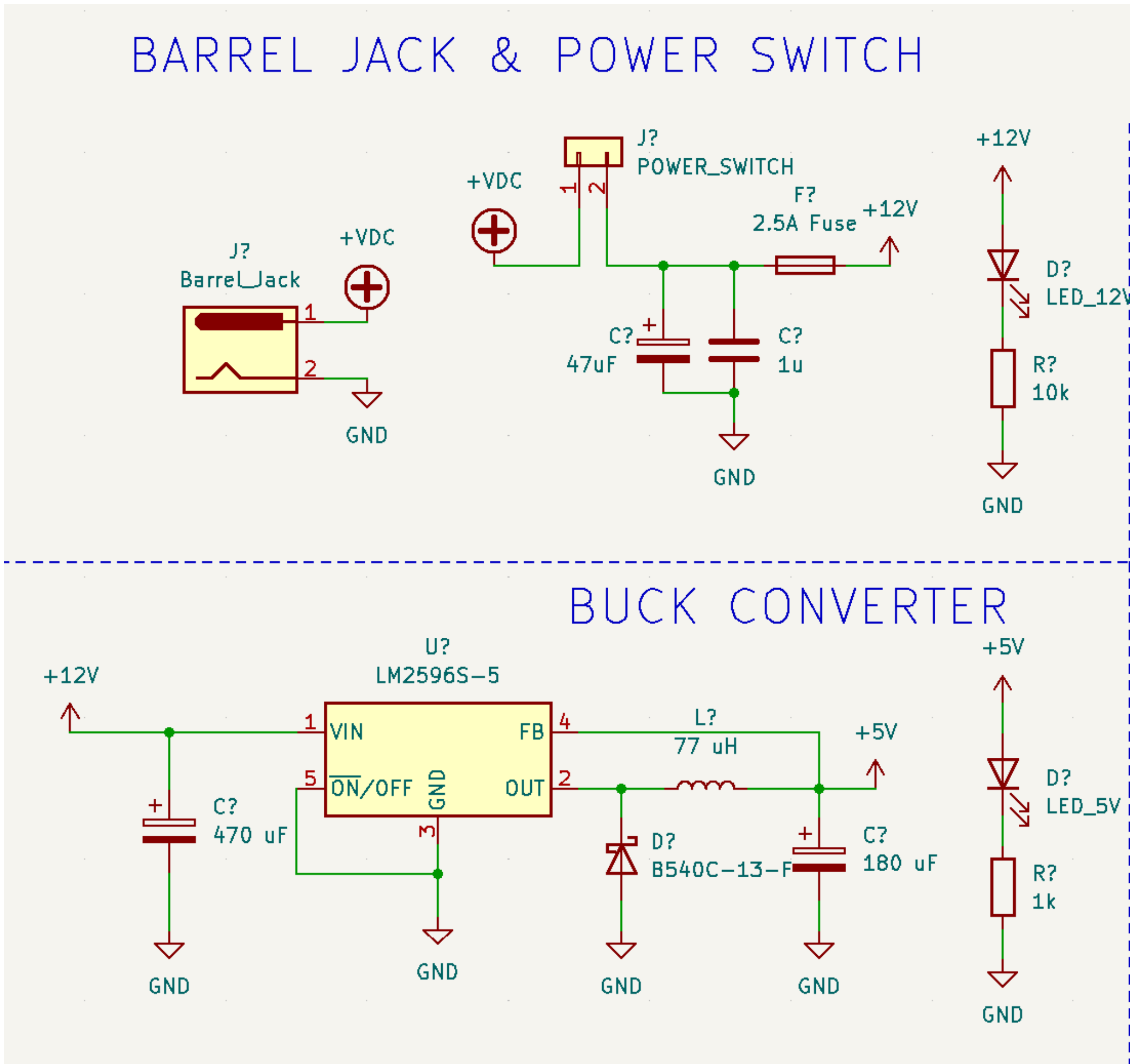

Figure 7: Schematic for Barrel Jack, Power Switch, and Buck Converter

The power subsystem handles efficient power delivery to the entire device. For user convenience and simplicity, 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 rails, one 12V rail (to the pumps and LED's), and one 5V rail (to the various sensors, buttons, switches, and microcontroller). To accomplish this in the most efficient way possible, we plan to utilize a basic 12V AC-DC wall adapter along with a LM2596S-5 buck converter. There is also a main power switch which will act as an emergency shutoff switch turning off power to the entire device. 12V will be sent to the pumps and LED sensor, and 5V will be sent to the microcontroller, sensors, switches, buttons, and phototransistors. The power input is rated for 12V and a maximum of 2.5A with a fuse.

Requirement #1
● The wall adapter delivers 12 V +/- .5% (necessary to stay within voltage ratings) throughout operation of the device, the buck converter delivers 5 V +/- 5%
Verification
● Power on the device. ● Place voltage probes on the 12V and 5V rails. ● Run the device through the sensing/dispensing process. Verify that the voltage across the rails does not deviate from the desired voltage by more than 0.5% and 5% respectively.
Requirement #2
● The subsystem delivers up to 2.5A of current while maintaining voltage levels.
Verification
● Connect a 5 Ohm resistor across 12V and ground, and place a voltage probe on the 12V rail to verify voltage stays within the desired range. ● Connect a 2 Ohm resistor across 12V and ground, and repeat the previous step.

2.3.2 User Interface Subsystem

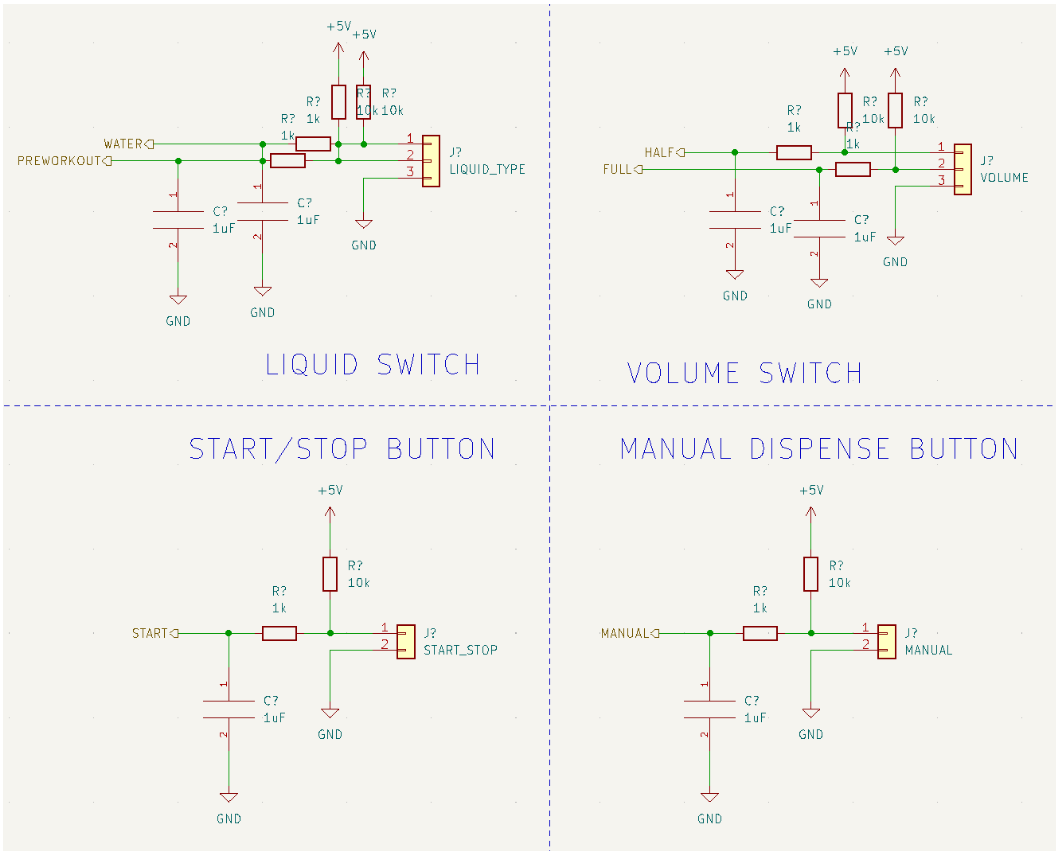

Figure 8: Schematic for Buttons and Switches

The user interface subsystem will handle user inputs and preferences. It will allow the user to select pre-workout or regular water, completely filled or half filled, automatic dispensing (start/stop), and manually dispense water (similar to a traditional water fountain). Finally, there will be a main 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, automatic start). The buttons communicate with the microcontroller. Additionally, debounce circuits are included to allow for interrupts in the software registering a single press or flip. All switches and buttons are IP67 waterproof rated, and will be mounted on the enclosure.

Requirement #1

- The user interface must relay the user inputs to the device and perform the task selected by the user

Verification
● Plug in the device to the wall, then turn on the main power switch. Set switches to 100% full and water initially. ● Push the "manual dispense" button. Verify that water is dispensed while the button is pressed. ● Push the "auto start" button. Verify that the device begins sensing and dispenses water until the water bottle's height is reached. ● Flip %full switch to 50% and hit "auto start". Verify that the device stops dispensing water when the bottle is half full. ● Flip preworkout/water switch to preworkout and press manual dispense. Verify that preworkout, not water, is dispensed.
Requirement #2
● The On/Off switch allows no power to flow when Off, and powers the device when On.
Verification
● Plug in the device, with the power switch flipped to "off". ● Press the manual dispense button. Nothing should happen. ● Flip the power switch to "on". ● Press the manual dispense button. Water should be dispensed.

2.3.3 Control Subsystem

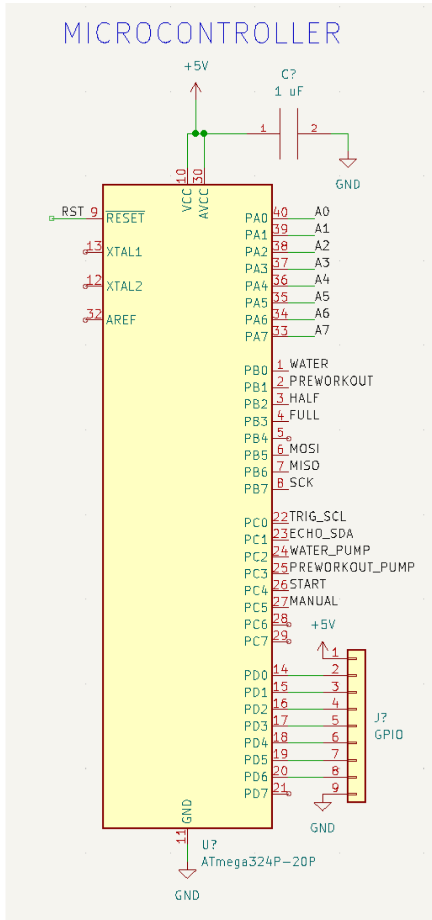

Figure 9: Schematic for Microcontroller

The control subsystem will accept user and sensor inputs and will drive the pumps. The microcontroller (ATMega324P) receives settings and start/stop commands from the user interface. The microcontroller will then drive the height sensor and calculate the height of the container (water bottle). Then, the device will enable the correct pump to dispense liquid while reading from the water level sensor. When the microcontroller determines the correct amount of liquid has been dispensed, it will shut off the pump and wait for the next user input.

The microcontroller enables the pumps through N-channel MOSFET's due to the microcontroller's I/O pin current and voltage limit. The analog ADC pins will be used for the phototransistor height sensor, and the GPIO breakout connector will be used for testing of new features in the future. All sensors and buttons/switches are routed to I/O pins on the ATmega324P.

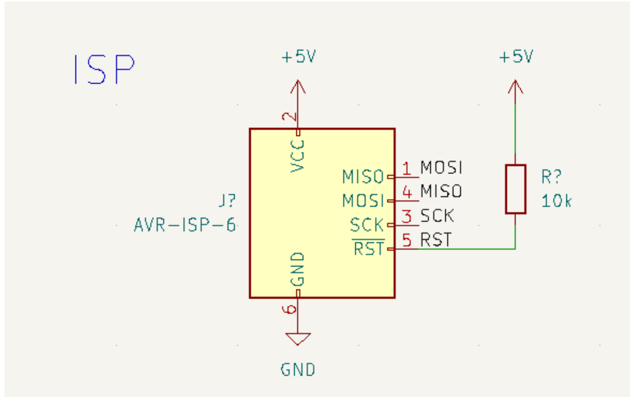

Figure 8: Schematic for ISP

The microcontroller will be programmed using ISP. The reset pin has a pullup resistor due to it being active low.

Requirement #1
• When a button is pressed, the controller runs the functionality corresponding to that button. EX: If manual dispense water is pressed, the controller turns the water pump on.
Verification
• Plug in the device and hold down the manual dispense water button, the pump should turn on and water should be dispensed. When the button is released, the pump should stop and water should stop being dispensed.
Requirement #2
• Receives water bottle height and current water level data from sensors within +/- 1 cm.
Verification
• Measure the water bottle height with a ruler. • Look at the value recorded in the controller, compare the actual water bottle height with this value. Is it within +/- 1 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.

Verification

- Measure the water bottle height, then calculate 80% of that height (“full” level).
- Run the water dispenser, measure the final height of the water dispensed. Is it within 1 cm of the “full” level calculated?

2.3.4 Sensor Subsystem

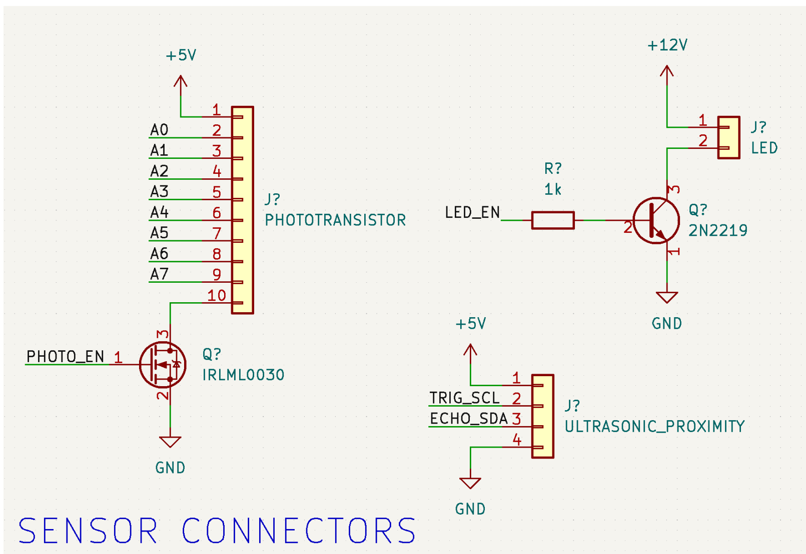

Figure 8: Schematic for ISP

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.

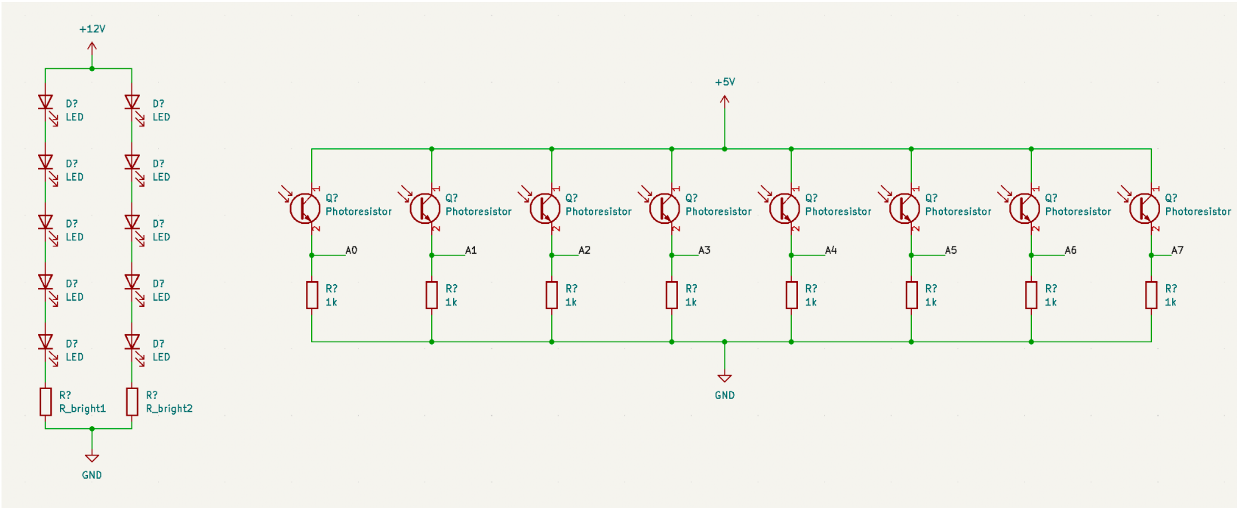

Figure 10: Schematic for LED and Phototransistor Sensor.

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.

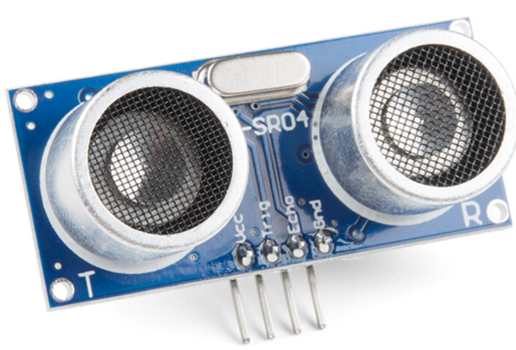

Figure 9: HC-SR04 Ultrasonic Sensor

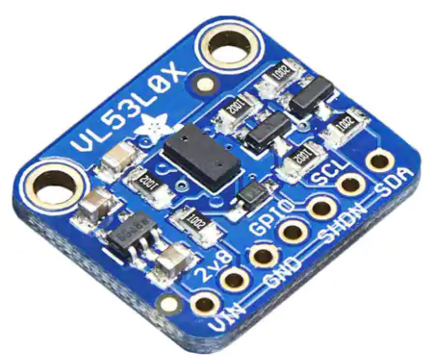

Figure 10: VL53L0X Proximity Sensor

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 +/- 1 cm).
Verification
• Measure water bottle height with a ruler. • Measure the value the sensors determine. Is it within +/- 1 cm?
Requirement #2
• Determines the current water level (within +/- 1 cm).
Verification
• Place a cup with some random amount of water on the tray, with a ruler held near it (allows observation of water level in real time). • Monitor the value recorded in the controller, compare the actual water height with this value. Is it within 1 cm?
Requirement #3
• Stops filling bottle if bottle is removed
Verification
• Place a bottle under the dispenser and select automatic dispensing mode. • Before dispensing is finished, remove the bottle. • Does the pump stop within 1 second?

2.3.5 Liquid Subsystem

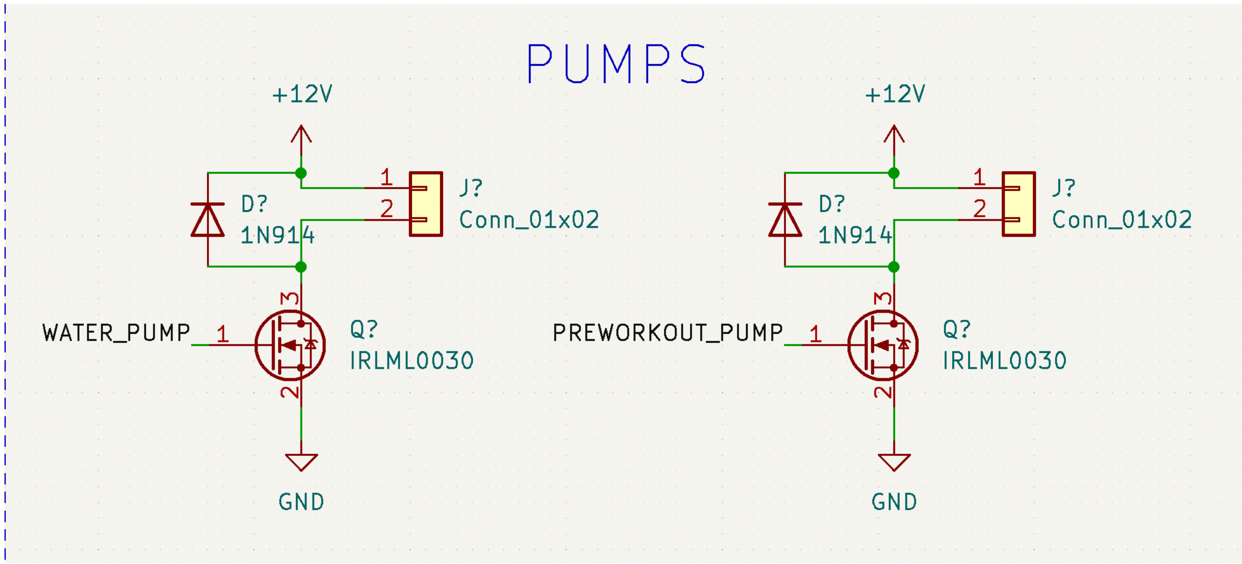

Figure 11: Schematic for Pump driver

The water subsystem consists of 1 water tank, 1 pre workout tank, and 2 pumps. The pumps are 12V brushless DC pumps with max power draw of 3.6 W. An enable signal from the microcontroller turns on MOSFET which allows conduction to the correct pump. Since these are inductive machines, a freewheeling diode is placed across the pumps to avoid stress on the MOSFET. The pumps will be located in the enclosure with wires connecting to the PCB. The pumps will draw liquid from the external tank, and will pump to the outlet nozzle.

Requirement #1
• Pumps draw liquid from the desired tank and turn on and off when instructed by the microcontroller
Verification
• Toggle switch to “preworkout” and click dispense. Preworkout should dispense. • Toggle switch to “water” and click dispense. Water should dispense. • Liquid should stop dispensing when instructed by the control system. There should be no residual liquid dispensing afterwards.
Requirement #2
• Tanks and pumps remain leak free, keeping liquid away from electronics.

Verification

- Observe the device over time of use. There should be no leaking water inside the enclosure, and there should be no splashing water around the working area of the device.

2.4 Hardware Design

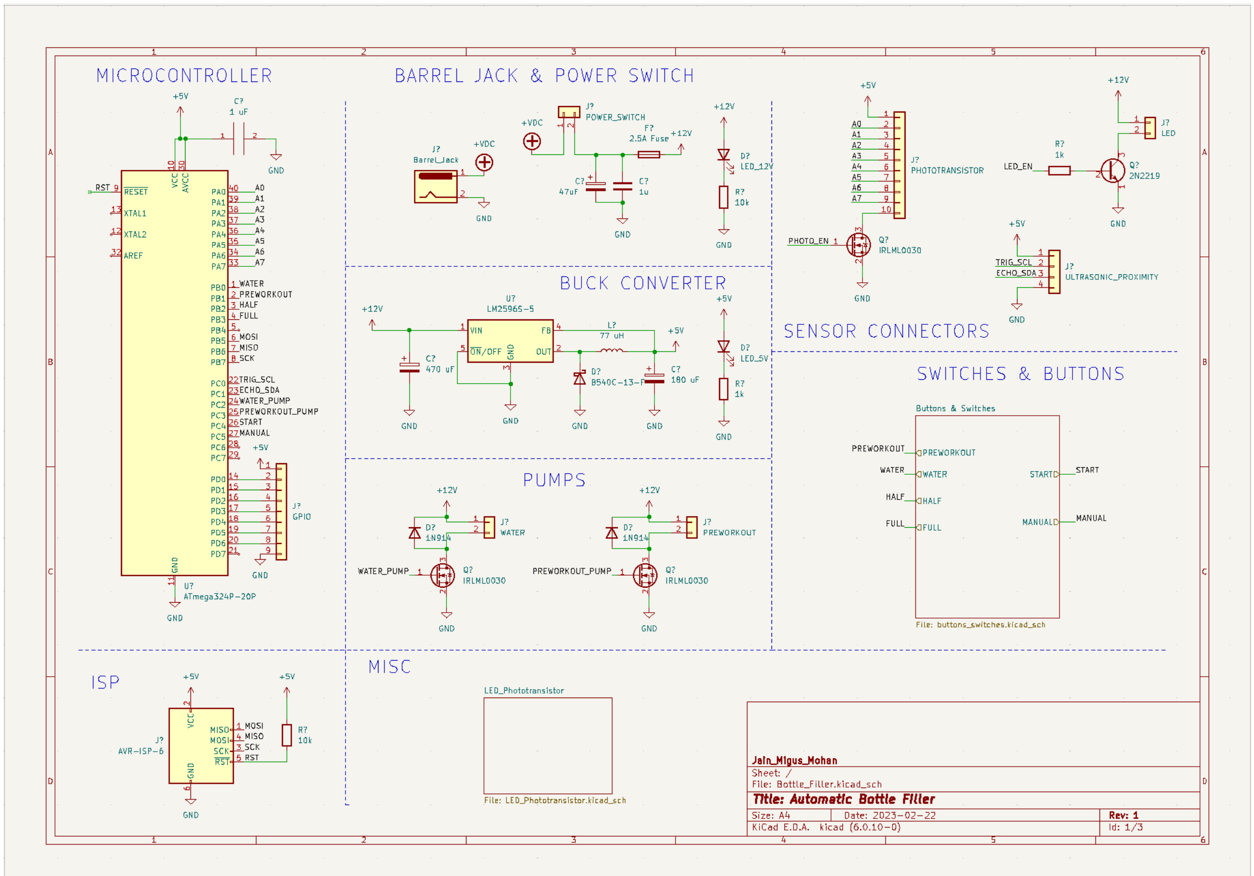

Figure 11: Full Schematic

Design Decisions

1. Power Subsystem: Many design decisions were made regarding the Power system. Supplying power from an external wall adapter was chosen for user simplicity and simplicity of circuitry. Keeping an AC/DC converter off our PCB will lead to lower EMI concerns and unwanted transient behavior. Because our device is intended to be stationary, using a wall power source is ideal rather than using battery power and a charger. A main power switch was used in order to have an electrical emergency shutoff as well as in order to save power when not in use. A 2.5 A fuse was used especially for

water and electrical safety. In the case of a short caused by water, the 2.5 A fuse will blow, preventing water from causing additional damage to the circuit. A buck converter was chosen over a LDO for the improved efficiency although the switching of the converter would create more electrical noise vulnerabilities.

2. User Interface Subsystem: In order to keep the device simple to use, we opted for buttons and switches instead of a touch screen or LCD display. This simple user interface is easy to understand for anybody and is robust and durable for water use.
3. Control Subsystem: When choosing a microcontroller, the number of I/O pins as well as the number of Analog pins was key. With many sensors, buttons, switches, and moving parts, several I/O pins are needed. We chose a microcontroller with 32 I/O pins with 8 Analog pins.
4. Sensor Subsystem: For the height sensor, many options of sensing were explored. Instead of having a moving laser emitter and detector which moves upwards to measure height, we opted for a stationary sensor with electrical variations rather than mechanical. Less moving parts lowers weight and reduces the number of points of vulnerability. Additionally, by designing our own height measuring sensor, we can make adjustments as needed during testing, and we can calibrate the sensor for our application under a wide range of ambient light conditions. We will be testing LED/Phototransistor and IR emitter/detector as possible options for this sensor. For the water level sensor, we designed the circuit in order to accommodate multiple possible sensors. We will decide which sensor to use after testing, but our open ended design allows for multiple different solutions. Using a Laser sensor is accurate and low profile, while using an ultrasonic sensor is cheaper. We will test both options with many different water bottle materials and heights.
5. Liquid Subsystem: Using separate pumps for both liquid types allows us to avoid contamination. We considered using a mixing tank for water and pre-workout concentrate, but decided it would be safest to avoid additional moving parts and either use a pre-mixed solution or to dispense one liquid at a time. Additionally, we chose small pumps that could be enclosed in the device with inlet ports on the outside of the device in order to simplify the operation and design of the product. Lastly, we chose to use MOSFETs as power switches for the pumps for the power savings.

2.5 Software Design

For software design we'll be using an ATmega324 microcontroller which runs at 20MHz and can be programmed in either Assembly or C (we'll be using C). Our microcontroller needs to receive instructions from the user interface and sensors, and then execute the desired functionality based on the inputs. The microcontroller also needs to compute the desired level of water, then continuously monitor the water level, shutting off the pump when the water level hits the desired level. We have a few simple states, detailed below:

- <u>START</u>: Send power to the buttons, switches, and sensors, enabling the microcontroller to receive instructions from the user interface and data from the sensors.
- <u>DISPENSE WATER</u>: Turn on the water pump.
- <u>DISPENSE PREWORKOUT</u>: Turn on the preworkout pump.
- <u>STOP</u>: Stop power to pumps.

Our general algorithm is shown below:

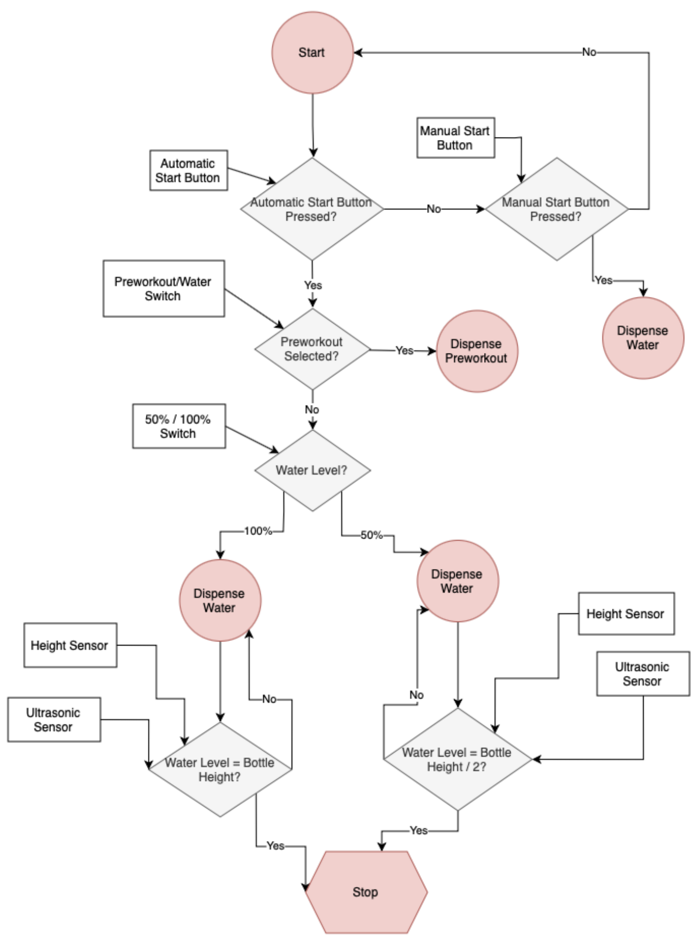

Figure 12: Basic Algorithm for Dispensing Circuit

2.6 Tolerance Analysis

One of the most critical aspects of our design is the overheating on the buck converter. To help with overheating we want to keep the current at 2.5A with a fuse. We will receive 12V +/- 0.5% input into the LM2596S-5 buck converter. This gives us a voltage range of [11.94V, 12.06V]. Knowing this range we can find the load resistance needed to have a maximum current of 2.5A. The LM2596S-5 datasheet [5] specifies that the output is 5v +/- 5% which is [4.75V, 5.25V].

$$R_{Load} = \frac{(V_{inMax} - V_{outMin})}{I_{Max}} \tag{1}$$

$$R_{Load} = \frac{(12.06 - 4.75)}{2.5}$$

$$R_{Load} = 2.924\ \Omega$$

Our result from Equation 1 shows us that we need a resistance load of a minimum 2.94 Ω to stay below our maximum current of 2.5A.

The LM2596S has an 80% efficiency at 3A load, so limiting the current to 2.5A will keep the efficiency higher. It has a thermal resistance of 2 degrees per watt.

2.7 Risk Analysis

The ultrasonic sensor creates risk because of exposed electronics near the output source of the liquid. This sensor will require the most waterproofing 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. Using hot glue, waterproofing spray, and silicone sealant will help keep water away from electronics.

In general, the main risk of our product is keeping liquid away from electronics. When looking for our buttons and switches, we selected parts that comply with the IP67 waterproofing standards. For other close-proximity sensors, we will use the mechanical housing as well as sealant to waterproof. We also designed our product in a way to keep electrical wires and water isolated to have multiple barriers of protection. We also designed a location for our PCB above the max height that the water gets carried.

Safety is of the utmost importance when dealing with liquid and electronics, so we will be exploring multiple options for waterproofing and safety. We have implemented a main power fuse as well as some mechanical waterproofing methods and have selected parts with waterproof ratings. In the event of a short from water, our device has a main power switch as well as a 2.5A fuse.

3 Cost and Schedule

3.1 Cost Analysis

Description	Manufacturer	Part Number	Quantity	Price Per Unit	Total Price
AC-DC 12V Adapter		WKY-1203000	1	$0.00	$0.00
Buck Converter	Texas Instruments	LM2596SX-5.0/NOPB	1	$6.73	$6.73
Buck Inductor	Pulse Electronics	PE-54038SNLT	1	$3.98	$3.98
Buck Input Cap	Panasonic	EEU-FR1H471	1	$1.43	$1.43
Buck Output Cap	Panasonic	EEU-FR1V181B	1	$0.68	$0.68
Buck Diode	Diodes Incorporated	B540C-13-F	1	$0.52	$0.52
Microcontroller	Microchip Technology	ATMEGA324P-20PU	1	$7.03	$7.03
Ultrasonic Sensor	SparkFun Electronics	HC-SR04	1	$4.50	$4.50
Proximity sensor	Adafruit	3317	1	$15.25	$15.25
Water Pump	Amazon	N/A	2	$10.24	$20.48
LED Mixed Pack	SparkFun Electronics		16	$0.00	$0.00
Phototransistor	Vishay	BPW85A	8	$0.70	$5.60
Toggle Switch	NKK Switches	M2013SD3W01	2	$5.57	$11.14
Push button	CIT Relay and Switch	EH12NMB3ZX	2	$4.48	$8.96
Power Switch	NKK Switches	JWMW11RA1A	1	$9.27	$9.27
Barrel Jack Connecter	Wurth	694106301002	1	$1.02	$1.02
Diode	Diodes Incorporated	1N4148WSF-7	2	$0.18	$0.36
BJT for LED's	onsemi	BCW33LT3G	1	$0.22	$0.22
MOSFET	UWM	IRLML2502	3	$0.51	$1.53
47uF Aluminum Electrolytic Capacitor	Panasonic	EEU-FR1E470B	1	$0.44	$0.44
1k Ohm Resistor	Panasonic	ERJ-3EKF1001V	7	$0.10	$0.70
10k Ohm Resistor	Panasonic	ERJ-3GEYJ103V	7	$0.10	$0.70
1uF Ceramic Capacitor	YAGEO	CC0603JRX7R7BB105	8	$0.24	$1.92
Silicone Spray Sealant	LED Supply	9013-07	1	$15.99	$15.99
Proto-boards	Adafruit	4783	6	$2.25	$13.50
Total Cost:					**$131.95**

Table 13: Cost Analysis

There are two basic costs for this project: parts/equipment and labor. From the final parts list above, we expect our parts cost to be \$131.95 before shipping and taxes. Factoring in a tax rate of 10% (adds \$13.20) and a shipping rate of 5% (adds \$6.60), the total cost for the materials comes out to \$151.74. For labor costs we expect a base pay of \$35/hr, and each team member plans to spend 10 hrs/week on the project for 15 weeks, and finally an overhead factor of 3.

$$Labor\ Cost\ =\ \#\,Team\ Members\ *\ Pay\ Rate\ *\ \#\,hrs/wk\ *\ \#wks\ *\ overhead$$
$$Labor\ Cost\ =\ 3\ *\ \$35/hr\ *\ 10\ hrs/wk\ *\ 15\ wks\ *\ 3$$
$$Labor\ Cost\ =\ \$47,250$$

From these calculations, the projected total cost will be:

$$Total\ Cost\ =\ Parts\ Cost\ +\ Labor\ Cost$$
$$Total\ Cost\ =\ \$131.95\ +\ \$47,250$$
$$=\ \$47,381.95$$

Finally, as we look forward to our device's hypothetical functionality, we note that the sensor-based water bottle filling stations already in use (such as the Elkay EZH2O) typically retail for upwards of \$1,400 each [4]. Our device, which costs \$124.88 in parts and approximately \$200 to assemble, can save a potential buyer up to \$1,075, and therefore makes our product highly marketable.

3.2 Schedule

Week	Task	Team Member
2/19 - 2/26	CAD Model	Jakub
	PCB Design 1st Draft	Priyank
	Design Document + Proposal Revisions	Abby (+ All)
	Design Document Due 2/23	All
2/26 - 3/5	Design Review Prep	All
	PCB Adjustments/Review	Priyank + Abby
	Parts Ordering	Jakub
	Design Review 2/28 11:00 am	All

3/5 - 3/12	Finalize PCB/Electric design	Priyank
	Microcontroller Code Drafting	Jakub
	LED System Assembly	Abby
	1st Round PCB Order 3/7	All
3/12 - 3/19	Spring Break	All
3/19 - 3/26	Initial PCB Assembly + Soldering	Priyank
	Sensor/Diode Testing	Abby
	Microcontroller Code Drafting	Jakub
3/26 - 4/2	Housing Construction	Jakub
	Sensor/Diode Subsystem Assembly	Abby
	Pump Testing + Assembly	Priyank
	2nd Round PCB Order 3/28	All
4/2 - 4/9	Individual Subsystem Testing	All
	Assembly + Testing	All
	Final Presentation + Paper Drafting	All
4/9 - 4/16	Debug	All
4/16 - 4/23	Mock Demo Prep	All
	Debug (as needed)	All
	Presentation Draft	
	Final Demo	All

4/23 - 4/30	Mock Presentation	All
	Final Paper Draft	All
4/30 - 5/7	Final Presentation	All
	Final Paper Due 5/3	All
	Lab Checkout 5/4	All

4 Ethics and Safety

4.1 Ethics Analysis

As engineers, we are obligated to behave in an ethical manner, and ensure that anything we design reflects these values. More specifically, we are bound by the Institute for Electrical and Electronics Engineers (IEEE)'s Code of Ethics. 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, and significant harm to the user. 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.

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.

4.2 Safety Analysis

Ensuring user safety is particularly relevant for this project due to the electric shock potential. In the event that powered components and water come into contact, the user could be shocked, electrical fires could start within the housing, and the entire system could become a hazard. We have incorporated safety into every element of our design. In the housing, all electric components are in a separate enclosure above the water system. The tubing used to carry water through the system will also be encased in its own housing, so even if there are leaks, the water wouldn't reach the electrical components. Furthermore, the water storage element will be completely sealed off to prevent leaks or splashing. Finally, circuitry will be coated with a waterproof coating (such as urethane or acrylic lacquer). We'll include a small shock warning label (similar to the ones present on devices like hairdryers, lamps, etc.) to the cord, and a shock warning label on the user interface of the device (such as the one shown below) to ensure that the public is aware of potential dangers.

Figure 14: Shock Label [3]

As far as the final product is concerned, there are a few consumer safety standards we'll have to include in the user manual. Specifically the drink concentrates 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.

References:

[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

[3] “C8002-30WHYF-Warning - Electric Shock Hazard,” *Safety Label Solutions*. https://www.safetylabelsolutions.com/Warning--Electric-Shock-Hazard_p_468.html (accessed Feb. 22, 2023).

[4] “Elkay EZH2O Enhanced Wall Mounted Water Bottle Refilling Station, Filtered, Light Gray,” *www.globalindustrial.com*. https://www.globalindustrial.com/p/elkay-ezh2o-lzs8wslp-next-generation-water-bottle-refilling-station-wall-mount-gray?infoParam.campaignId=T9F&gclid=CjwKCAiA9NGfBhBvEiwAq5vSyxEEj8tDfP3LoiNkCLjFMynFxnp1qLHNcXlYZXI7ZDsf-y7xndoBDBoCziQQAvD_BwE (accessed Feb. 22, 2023).

[5] “LM2596 Simple Switcher Power Converter 150-KHz 3-a Step-down Voltage Regulator” *www.ti.com*. https://www.ti.com/lit/ds/symlink/lm2596.pdf?HQS=dis-mous-null-mousermode-dsf-pf-null-wwe&ts=1620718466883.(accessed Feb. 22, 2023).