UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

AUTOMATIC WATER BOTTLE FILLER

Electrical & Computer Engineering

Team 21

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The Problem

Water bottle filling stations have saved millions of plastic water bottles from ending up in landfills. However, since they require active user attention and cost upwards of $2,000, they are not applicable for smaller businesses, gyms, etc.

The Solution

Our solution was to design a cost-effective water dispenser with automatic stop capabilities. The device will detect when a water bottle is present, dispense water until the bottle is nearly full, then shut off.

Agenda

Proposed & Executed Design Overview (Successes and Failures)

Critical Components

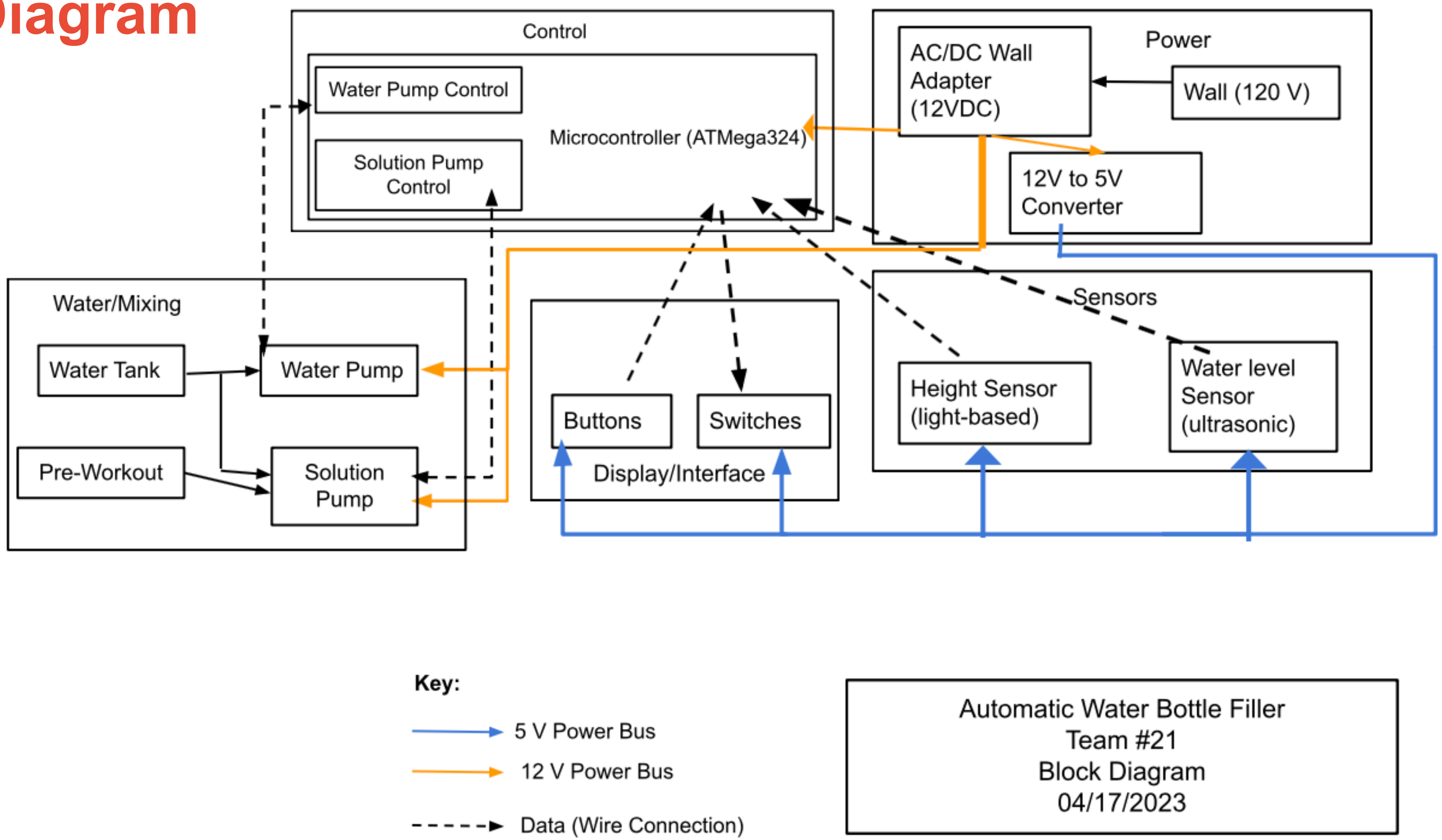
Subsystems RV’s & Testing

Conclusions – Lessons Learned & Recommendations for Further Work

High – Level Requirements

- Sensors determine the height of a bottle and actively monitor the level of water in the container within +/- 2 cm.
- 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/cup (eg. ½, 1 etc.). Users can safely leave the device unattended as it operates.

Block Diagram



Final Design

50% / 100% Full Switch

Water Level Sensor

Preworkout/ Water Switch

Automatic Start Button

Manual Dispense Button

Power Switch

Preworkout Output

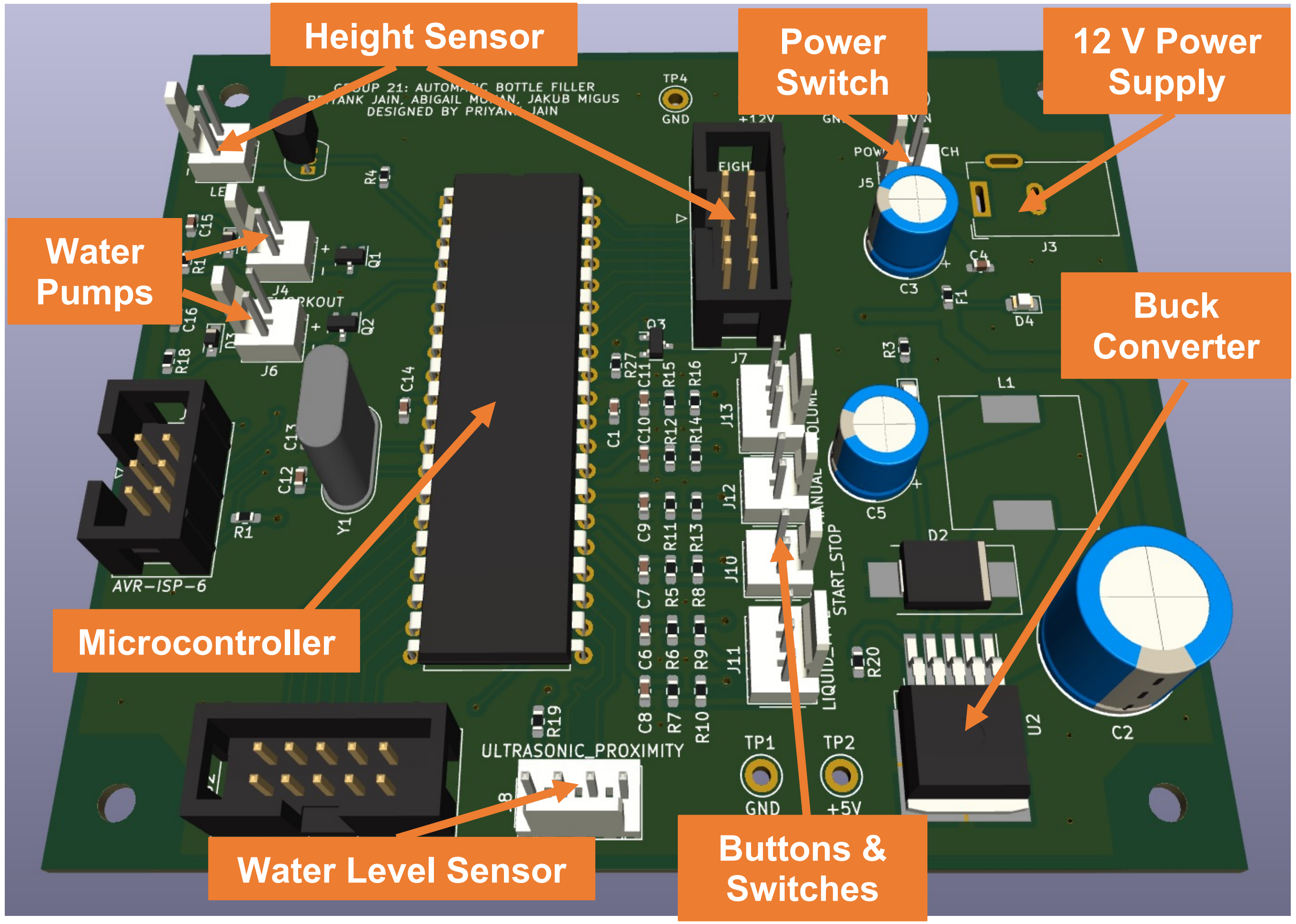
Water Output

Photodiode Array

LED Array

Project Results – Video Demonstration

Critical Components - PCB

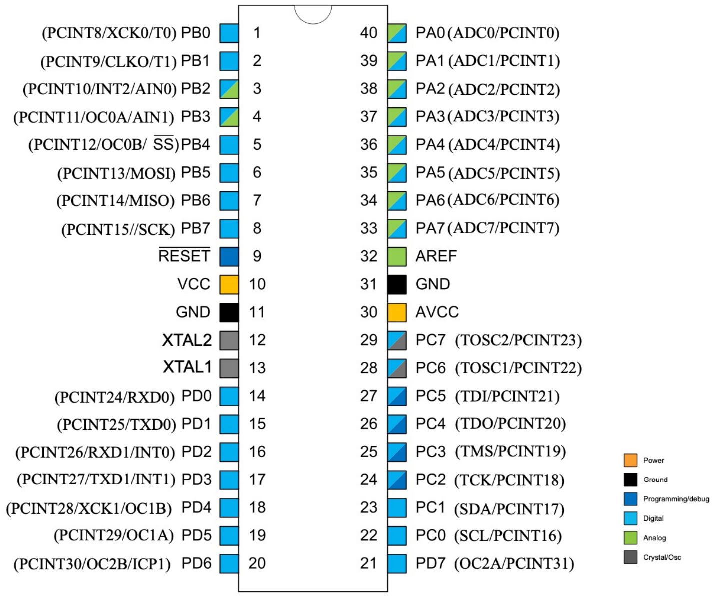


The PCB

The PCB contains the electrical connections for all subsystems. It houses the:

- 12V Input, 12V to 5V Buck Converter
- Button & Switch connections
- Microcontroller (ATmega324P)
- Water Pump Supply
- Control electronics
- Sensor Connections

Critical Components



Microcontroller – ATmega324P

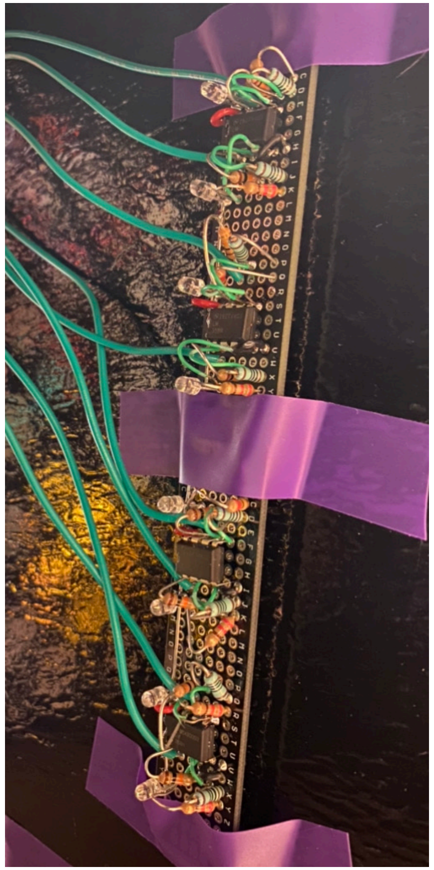
- Selected for its high number of I/O pins including 8 Analog pins
- Can be programmed using In-system Programming (ISP) and can be wired to relay serial data through UART
- Operates on 5V, so it complies with our voltage rails

Water Level Sensor – VL53L0X Adafruit Time of Flight Sensor

- Selected because it offers far more accuracy than the Ultrasonic HC-SR04 in a narrower measurement field
- Uses a 940 nm Laser VCSEL emitter and detector and measures Time of Flight (ToF) to measure distance up to 2m
- Communicates over I2C

Critical Components

LED Array



Phototransistor Array

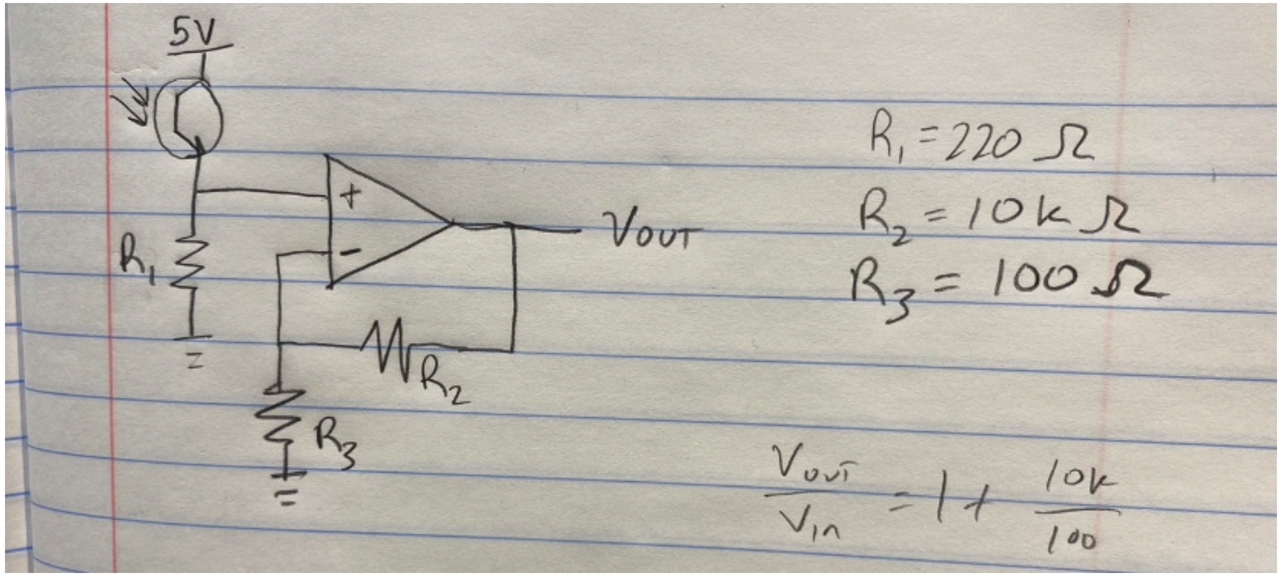
Bottle Height Sensor

LED Array

- 10-LED light array
- Blue LED circuit designed for 20mA through each LED

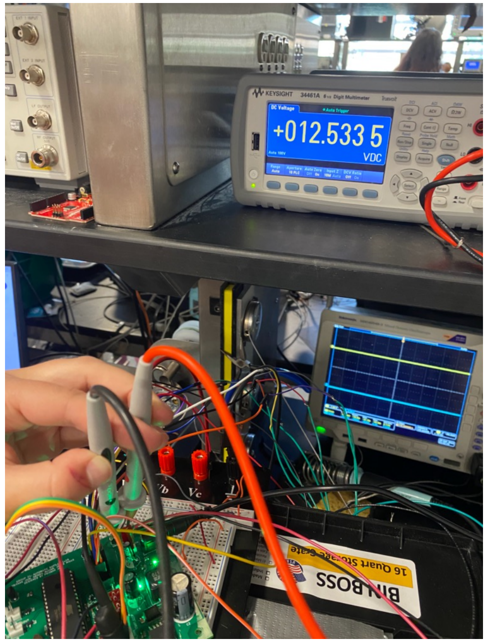
Phototransistor Array

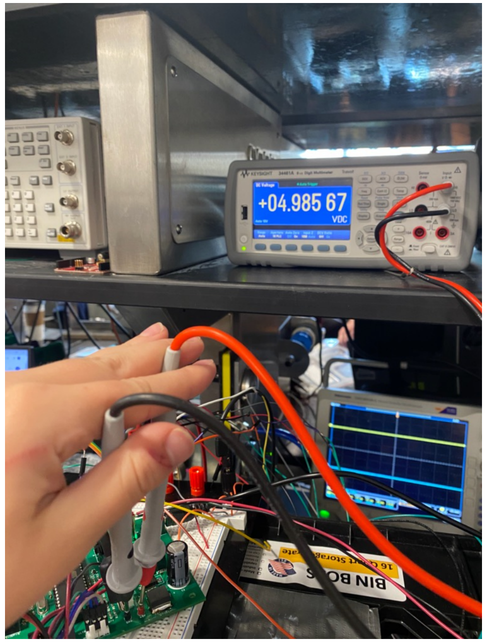
- Phototransistors are each fed into an OpAmp Non-Inverting amplifier for an output range of 0 - 3.6V



Subsystem Requirements and Verifications

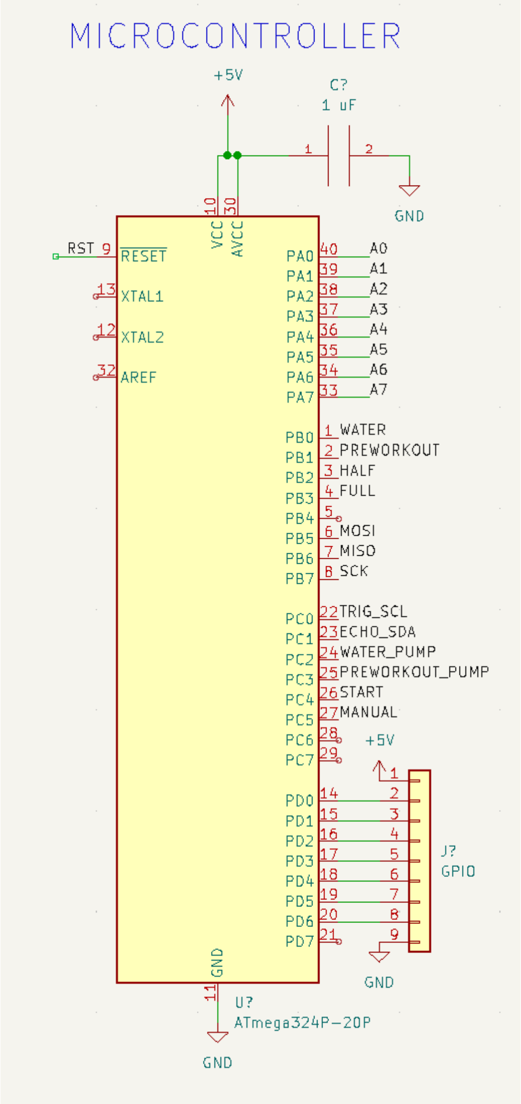
Subsystem	Requirement	Met?
Power	The wall adapter delivers 12 V +/- .5% (necessary to stay within voltage ratings) throughout operation of the device, the buck converter delivers 5 V +/- 5%	~
Power	The subsystem delivers up to 2.5A of current while maintaining voltage levels.	✓
User Interface	The user interface must relay the user inputs to the device and perform the task selected by the user.	✓
User Interface	The On/Off switch allows no power to flow when Off, and powers the device when On.	✓





Subsystem Requirements and Verifications

Subsystem	Requirement	Met?
Control	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.	✓
Control	Receives water bottle height and current water level data from sensors within +/- 1 cm	✓
Control	Calculates the "full" water level within +/- 1 cm, shuts off the pumps when the current water level reaches the "full" level determined.	✓



Subsystem Requirements and Verifications

Subsystem	**Requirement**	**Met?**
Liquid	Tanks and pumps remain leak free, keeping liquid away from electronics.	✓
Liquid	Pumps draw liquid from the desired tank and turn on and off when instructed by the microcontroller	✓

Pump Delay Testing

One concern was the delays in turning on/off the pumps. We determined an average turn-on delay of 1.41s and determined that turn off delay was negligible.

Subsystem Requirements and Verifications

Subsystem	Requirement	Met?
Sensing	Determines the water bottle's height accurately (within +/- 1 cm).	✓
Sensing	Determines the current water level (within +/- 1 cm).	✓
Sensing	Stops filling bottle if bottle is removed	✓

Height Sensor Characterization

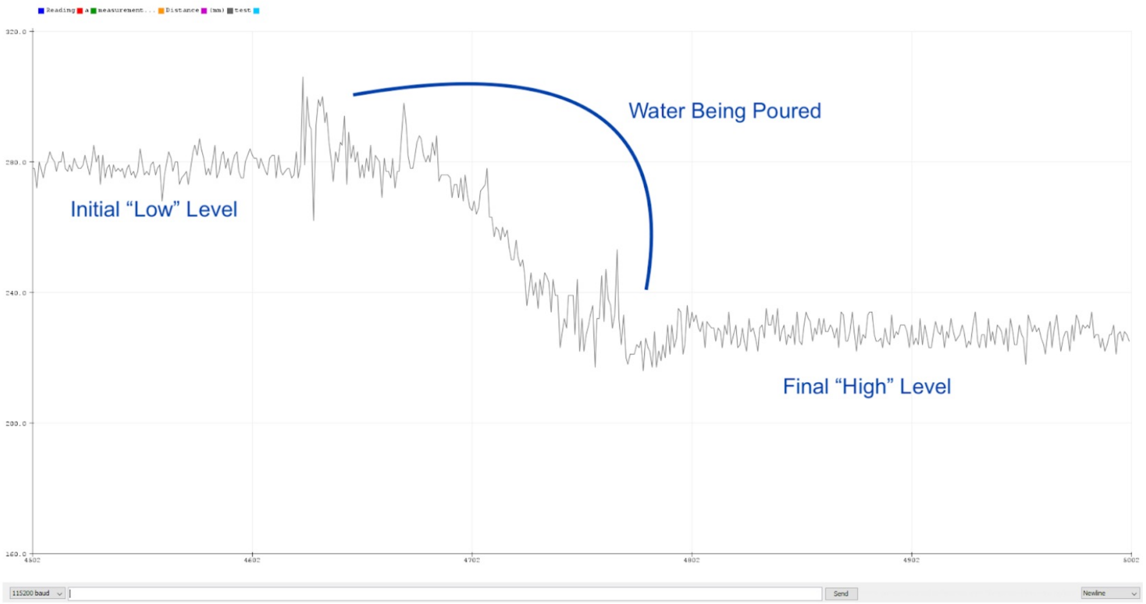
Raised the height of the bottle by .1875" (~.25 of the distance between photodiodes) and determined expected values for each photodiode.

This increases our accuracy from the original plan, which was simply to see which diodes were blocked or not.

Proximity Sensor Testing

To test the proximity sensor, we set up the sensor to an Arduino's serial monitor, determining how accurate it is for different bottle heights/actions

When testing at steady state, every measurement was within 1 cm of actual heights.


Water Being Poured
Initial "Low" Level
Final "High" Level

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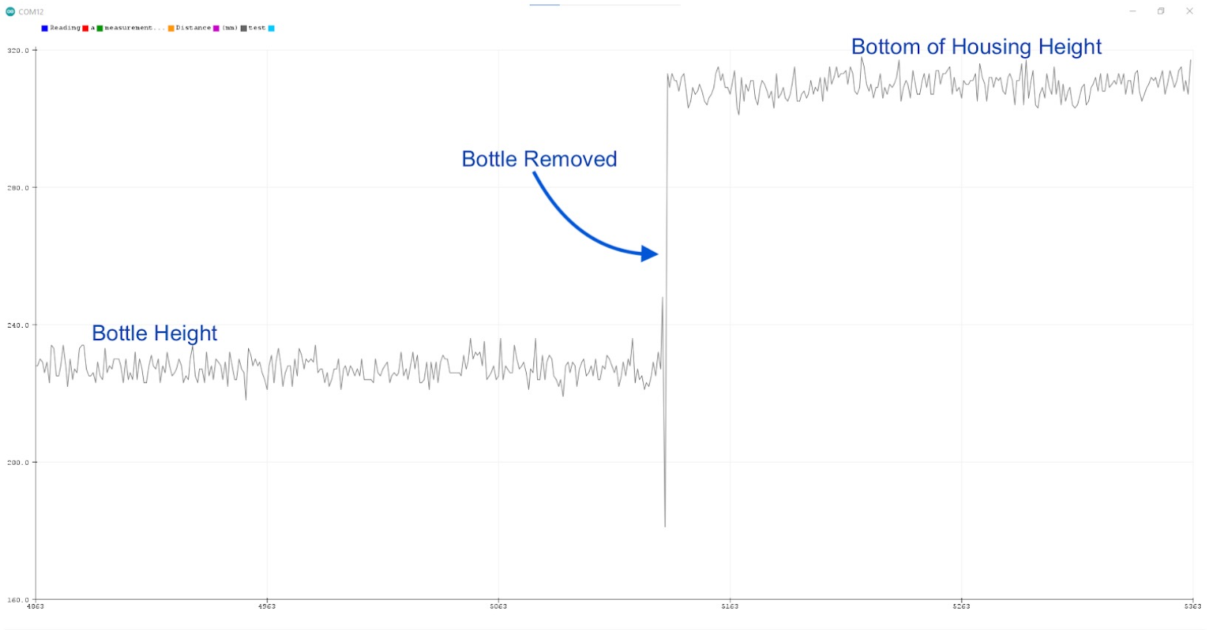

Bottom of Housing Height
Bottle Removed
Bottle Height

Changes Made during Design

- User interface evolved the most from initial to final design; because we were limited by the number of I/O pins on the microcontroller, we needed to scale back our design from an LCD screen and LEDs to some simple buttons and switches
- Sensing was also actively evolving
  - Abandoned original plan to use ultrasonic sensor in favor of a more complex TOF sensor, to guarantee the most accuracy possible
  - Utilizing a load sensor was suggested but ultimately not chosen because it did not accommodate a variety of water bottle shapes/sizes/materials and ultimately made the required calculations more complex
- Because the pumps had to be submersible, we changed the liquid subsystems design to an open bucket

Conclusions & Lessons Learned

Conclusions

- Our design is effective as a low-cost, automatic alternative to currently available sensor-based water dispensing systems.
- By using two sensors (a height sensor and a water level sensor), we are able to achieve a “smarter” functionality than anything else currently on the market.

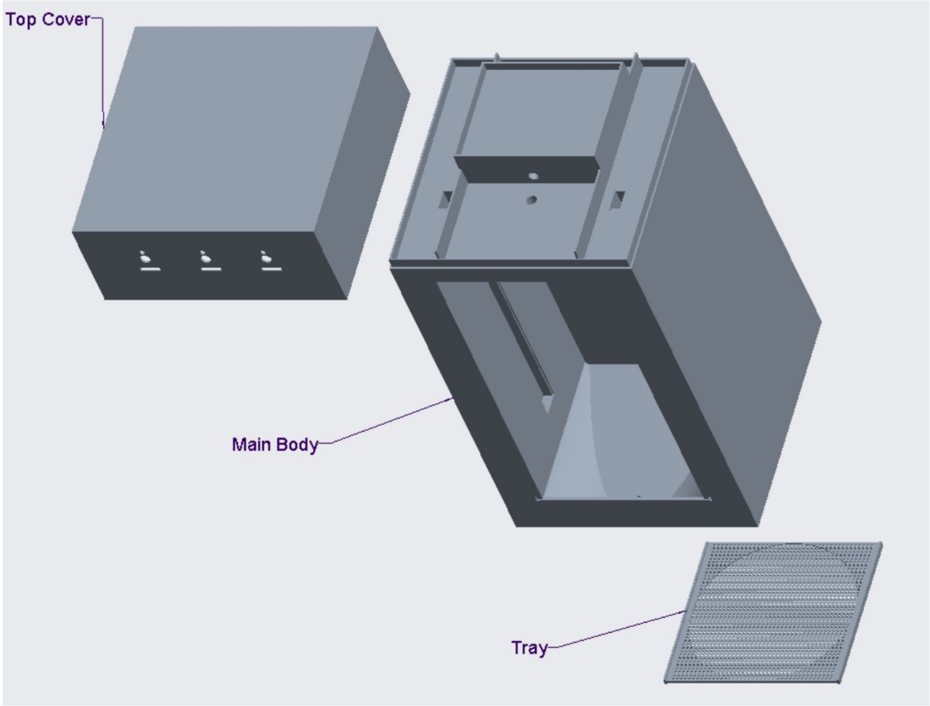
Lessons Learned

- Modular testing is critical. Our final assembly required significantly less debugging than expected because we tested the individual components so extensively.
- When working in a group, assigning tasks based on individual strengths and weaknesses is extremely beneficial to the final product.
- When working with an off-the shelf product such as our Time of Flight sensor, make sure to test it extensively as if you built it, and use ALL documentation that comes with (data sheets, sample code, etc.)

Recommendations for Further Work

- **Housing:** Our original planned housing was too complex for us to execute given budget and time constraints, to make the product more marketable we could implement the designed housing.

- **Waterproofing:** In order to expand past our simple “proof of concept” prototype into a marketable device, we must significantly expand on our waterproofing to make it user-safe.



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