Automatic Beverage bottle sorting bin

ECE 445 Design Document - Fall 2023

Project #5

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1. Introduction

1.1 Problem and Solution

Problem:

Garbage bins for bottles are typically placed near vending machines. These bins often feature separate holes: one for metal cans and one for plastic bottles. However, due to the unclear of the instructions, many individuals do not adhere to these sorting instructions, resulting in misplaced items. This results in a waste of the labor force for garbage sorting.

Solution:

To address the waste, we propose an advanced garbage bin equipped with an automatic sorting system. In general, the sorting system should be fully autonomous with no need for extra human instruction. In our design, this bin will have a singular entrance where users deposit bottles. The system will then automatically determine whether the object inserted is a bottle, and whether the bottle is made of plastic or metal by metal and optical sensor. The input object will then be classified into metal, plastic bottles, or others and sorted into three separate bins.

1.2 Visual Aid

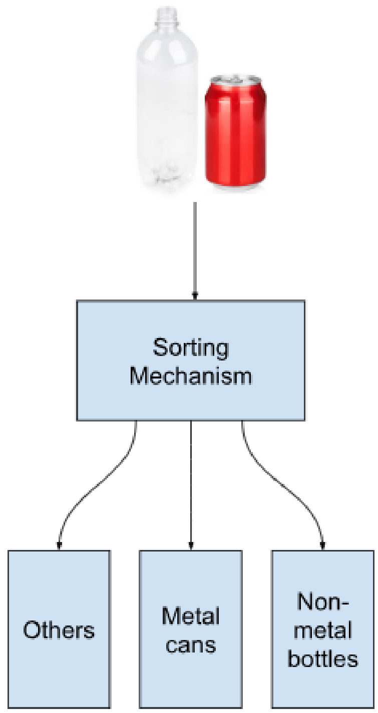


Figure 1: Visual Aid

1.3 High-level requirements list

1. A successful bottle sorting bin should allow bottles to exit the sorting systems only after an object is inserted and metal detector and laser diodes have finished analysis on its size and component. The whole process should take less than 40 seconds.
2. Our scaled down model should sort objects that are less than 5 centimeters in diameter and 10 centimeters in length into a different bin.
3. It should correctly sort plastic bottles, metal cans, and others into three different bins.

2. Design

2.1 Block Diagram

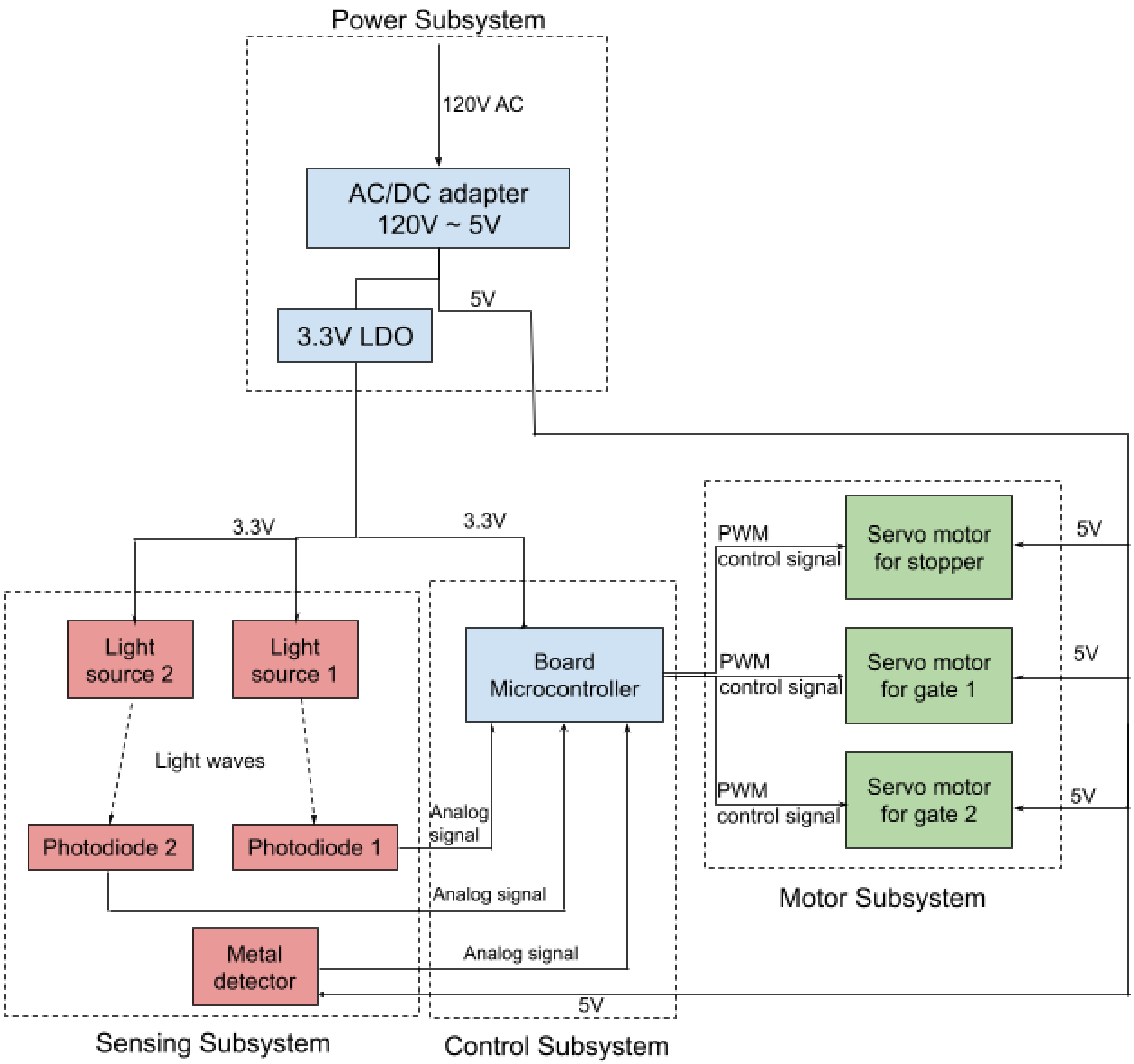


Figure 2: Block Diagram for Bottle Sorting Machine

2.2 Physical Design

For this project, due to size limitations, we are going to build a scaled down model of the actual machine that we planned to do in the first place.

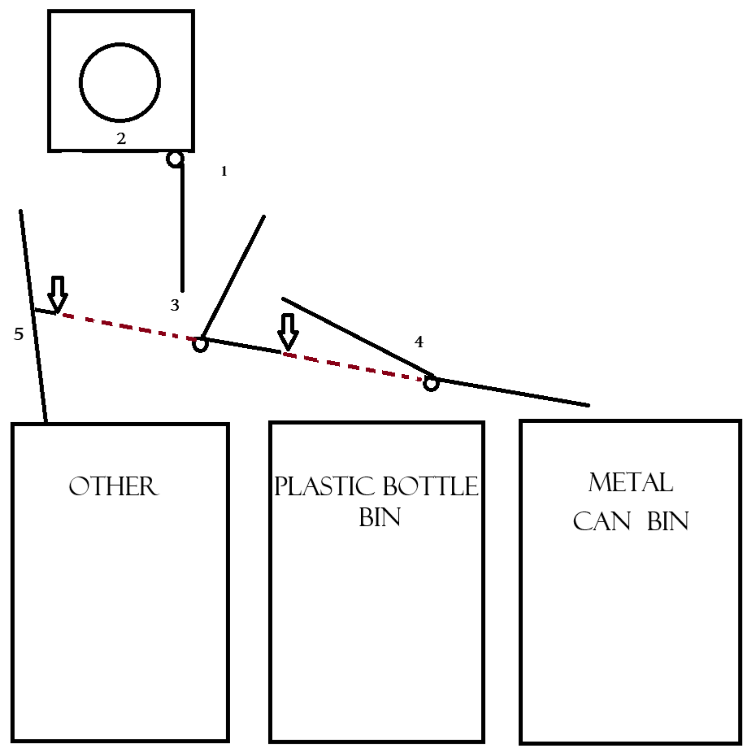


Figure 3. Front view of Bottle Sorter

1. Servo motor for hold and release bottle in sorting chamber.
2. Sorting chamber with light detecting system and metal sensing system inside.
3. Servo motor which controls opening the bin when the object is others
4. Servo motor which controls opening the bin when the object is plastic.
5. Wall to make sure bottles go into the bins.

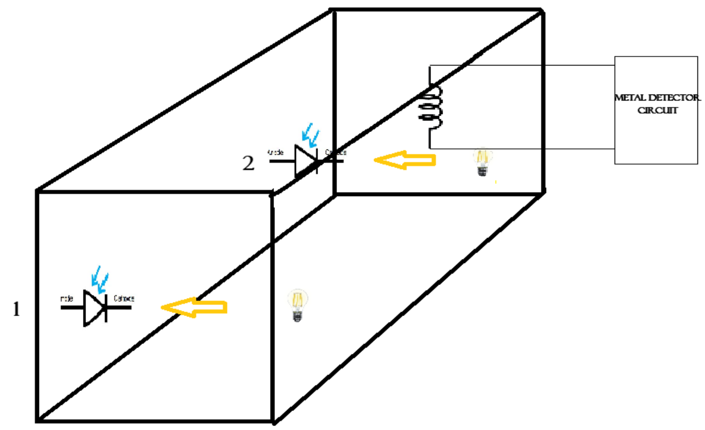


Figure 4: Chamber

1. First set of photo diodes and laser diodes.

2. Second set of photo diodes and laser diodes.

These two set of light sensors will measure the size of the object inserted

3. Metal detector is placed on the back of the chamber.

2.3 Power Subsystem

Power subsystem includes an AC DC converter and one regulator. AC DC converter converts 120V AC from the wall plug to a DC voltage in order to power the regulator. The regulator then provides 3.3 VDC to control the system and sensing system. We will use LDO and adjust the feedback factor for the feedback voltage from output to input(Vadj) in order to obtain different current.

Table 1: Power Subsystem Requirements and Verification

Requirements	**Verification**
A 3.3 VDC regulator should provide 3.3 VDC +/- 0.1 V with at most 1.5A of current to power the microcontroller and the laser diodes [4]	First connect LDO circuit's VDD to AC-DC converter and connect test load resistors. Then, measure the output voltage value at different current levels. Analyze the result to see if the output voltage is in the 3.3 +/- 0.1 V range.
AC/DC converter takes120 VAC as input and outputs 5VDC +/- 0.2V with 3 A current to power the 3.3V LDO, motors, and metal detector.	First connect the AC/DC converter to the wall plug and connect test load circuits (metal detector and motors). Then, measure the output voltage at different current levels. Analyze the result to see if the output voltage is in the 5 +/- 0.2 V range.

2.4 Sensing Subsystem

Laser diode-photodiode sensing is composed of 650nm laser diodes and photodiodes with absorption peak at 650 (± 50) nm. Photodiodes will be aligned with the laser diode. When the laser is blocked by plastic bottles or metal cans the light received by photodiodes will decrease, causing the current generated by photo diodes to decrease.

The metal detector is an oscillation circuit with a big inductor. When metal is present near the inductor it will change the inductance of the oscillation circuit, thus causing a change in the frequency. The output will be fed into a signal mixer and then fed into a low pass filter to make the shift in frequency more significant.

Table 2: Sensing Subsystem Requirements and Verification

Requirements	Verification
Light sensing system should have at least 5mV change in its output voltage when blocked by plastic bottles. The lowest resolution for the ADC of our microcontroller is 0.56mV. [6][7]	Assemble the sorting chamber and install the light sensing system in. Directly connect the voltage output of the light sensing system to a voltmeter. Measure the voltage with and without the bottle in the chamber.
The highest output frequency for our metal detector should be lower than 30 Khz and lowest frequency not higher than 1Khz. Since the maximum sample rate for Our ADC is 2Mhz.	Assemble the whole sorting system and install the metal detector. Connect the metal detector output to an oscillation scope. Measure the output frequency when the chamber is empty and when a metal can is inserted into the chamber.

2.5 Control Subsystem

We plan to use ESP32-S3 as our micro controller. The control system should be able to process three analog signals from a photo diode and metal detector and output three analog signals to the servo motor. It should also be able to provide the PWM signals to motors and supply voltage to sensors

Table 3: Control Subsystem Requirements and Verification

Requirements	Verification
It should give the correct output signal to three motors based on input signal to the sensors.	We will provide simulated analog input to the microprocessor using a waveform generator and check whether the motor can move to the right position.

2.6 Motor Subsystem

Motor subsystem consists of 3 servo motors, and it should receive control signals and power supply from the control subsystem. The torque requirement will be set after further discussion with the machine shop.

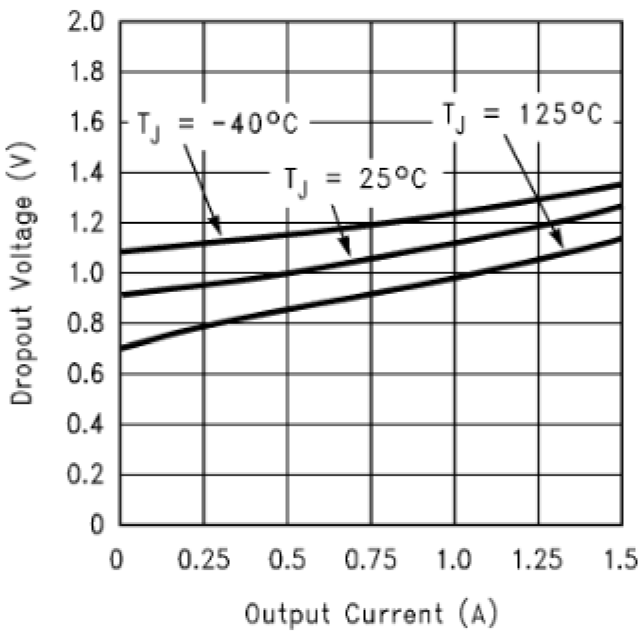
Table 4: Motor Subsystem Requirements and Verification

Requirements	Verification
The motor should rotate for 85 degrees within 5 seconds. [8]	Connect the motor to control system and power supply and attach the load to the motor. Test how many seconds it takes for the motor to complete the motion.

2.7 Tolerance Analysis

The use of photodiode for sensing the size of object may produce inaccurate results Especially when the optical component gets misaligned or a transparent object is inserted.. In addition the fluctuation from power supply to the photodiode may also cause wrong measurement. For transparent bottles, we can make measurements of change in light intensity before and after the bottle is inserted and choose the right photodiode with enough sensitivity.
In order to get rid of the noise from the sensor we can integrate the value from the light sensor for a few seconds and take the average value as our measure value.
The sensitivity of the metal detector may also cause problems for our project. It may sense metal in the bin component or metal outside the bin. We should measure the signal amplitude when the chamber is empty and decide the threshold according to that value. The sorting chamber should also be set far away from the metal can bin inorder to reduce interference.

Power supply:



[4]Figure 5: Dropout Voltage vs Output current

	THERMAL METRIC[(1)]	LM1086			UNIT
		KTT	NDE	NGN	
		3 PINS	3 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	40.8	23.0	35.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	42.3	16.1	24.2	
$R_{\theta JB}$	Junction-to-board thermal resistance	23.3	4.5	13.2	
ψ_{JT}	Junction-to-top characterization parameter	10.2	2.4	0.2	
ψ_{JB}	Junction-to-board characterization parameter	22.3	2.5	13.3	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance: Control Section/Output Section	1.5/4.0	1.5/4.0	2.9	

[4]Figure 6: Thermal Metric for LDO

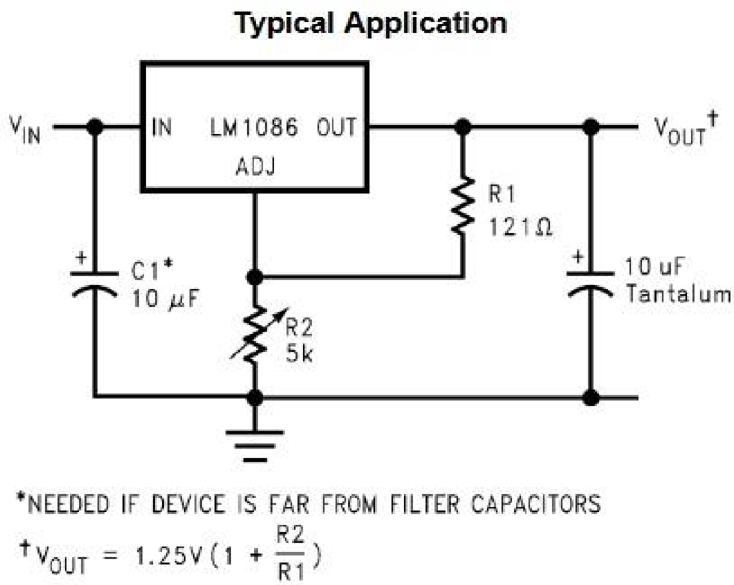
The maximum operating temperature for our LDO is 125 °C.

P_D = 1.5 A * (7.2-5) = 3.3 W

$T_J = R_{\theta JA} * P_D + T_C$ = 105.9 °C < 125 °C

Therefore, we can conclude that our LDO will not exceed maximum operating temperature.

LDO:



[4]Figure 7: LDO Circuit

For 5 V LDO, R1 = 121Ω, R2 = 411.4Ω

Let R1 = r1 ± n*r1

R2 = r2 ± m*r2 (m,n are tolerance)

R2/R1 = (r2/r1)*[(1±m)/(1±n)]

∴ΔR2/R1 = ±3.4 (m/n) for 5V LDO

Same calculation can be done with 3.3V LDO, the results are shown as following:

ΔR2/R1 = ±2.64 (m/n) for 3.3V LDO

3. Cost and Schedule

3.1 Cost Analysis

Table 5: Hardware cost analysis

Component name	Manufacturer	Quantity	Price ($)
AC/DC converter, LNK564DN-TL	Power Integrations	1	0.78

LDO, LM1086	Texas Instruments	2	4.52
Laser diode, VLM-650-04 LPA	Quarton Inc.	2	26.74
Photodiode, BPW34S	Vishay	2	2.32
Microcontroller, ESP32-S3	Espressif Systems	1	1.85
Metal detector, coil	Shanrya	1	6.24
Servo motor, HS-318	Hi-Tec	3	40.62
			Total: 82.29

We expect an hourly salary of $ 35. We expect to work 15 hours per week for 10 weeks. Therefore, the labor cost of our group is 35*15*10*3 = $15750

The total cost is estimated to be: 15750 + 82.29 =$ 15832.29

3.2 Schedule

Table 6: Schedule

Week	Team goals	Jingjie	Jiajun	Tianyu
9/25	Design Document	Design Document/ Start PCB layout	Design Document/ Finalize sensors	Design Document/ Finalize motors and power hardwares
10/2	Design Review/ PCB Review	PCB Layout	Build & test sensors	PCB layout/ Build & test sensors
10/9	1st PCB Orders/ Teamwork Evaluation 1/ Machine shop	Teamwork Evaluation/ PCB Layout/ Microcontroller Code	Teamwork Evaluation/ Finalize with machine shop	Teamwork Evaluation/ Finalize with machine shop

10/16	2nd PCB Orders	Assemble & edit PCB/ Microcontroller Code	Assemble & edit PCB/ Microcontroller Code	Assemble & edit PCB/ Microcontroller Code
10/23	3rd PCB Orders/ Individual progress reports	Individual progress reports	Individual progress reports	Individual progress reports
10/30	Software & hardware debug	Software debug	Hardware debug	Hardware debug
11/6	Wrap up	Demo Preparation	Demo Preparation	Demo Preparation
11/13	Mock demo	Test all functionalities	Test all functionalities	Test all functionalities
11/20	Fall Break			
11/27	Final Demo	Prepare for Final presentation	Prepare for Final presentation	Prepare for Final presentation
12/4	Final Presentation/ Final Papers	Final Paper	Final Paper	Final Paper

4. Discussion of Ethics and Safety

To be a static garbage sorting system, our project has few Ethics & Safety regards:

According to the IEEE code of Ethics 1[1], we need to maintain its public effects, so the shape of the system and the decoration of the machine should not contain malicious intent, including but not limited to discrimination and harmful content. For design purposes, we choose to contain no elements of discrimination, so it avoids potential negative social effects.

While maintaining a high ethical principle, we should also regard the safety guidelines. The dangers of our system mainly come from two aspects, one is the usage of the laser beam, and another is the exposure of the wire with the danger of electric shock.

Since we use laser beams to detect objects, it is crucial that human eyes and skins are not directly exposed to the beam. According to OSHA, the laser beam should be inspected with optical aids to be classified as non-hazardous[2]. Our sorting system works in a black box environment where laser beams are not directly observable, so it should be considered safe in normal cases. However, we should also warn users to avoid making direct contact with laser beams, like mistakenly inserting their arms into the sorting machine, which may lead to a higher hazardous level.

Besides beams, another risk comes from the exposure of wire elements. The electric shock can be caused by contact with the energy sources, such as wires with AC current[3]. In our metal detector, we need a coil to sense the change in magnetic field, which has AC current flow that may lead to an electric shock under mistake operation such as touching the coil directly by hands. To address the problem, we flipped the coil part so the plastic cover would protect users from direct contact with the coils. In this way, we address all the related ethical and safety issues with our project.

Justification: With sufficient caring with ethical elements and safety regard, our design strictly follows the correlated requirements and specifications. The system contains without any discriminating and hazardous elements to public space for ethical regard. We also designed the detection box carefully so the exposure of coil and laser would not threaten the user in safety concerns.

5. Citations

[1]*IEEE code of Ethics*. IEEE. (n.d.). https://www.ieee.org/about/corporate/governance/p7-8.html

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[7]Silicon Pin photodiode - vishay intertechnology. (n.d.-d). https://www.vishay.com/docs/81521/bpw34.pdf

[8]*HS-318 servo-stock rotation*. ServoCity. (n.d.). https://www.servocity.com/hs-318-servo/