1. Introduction

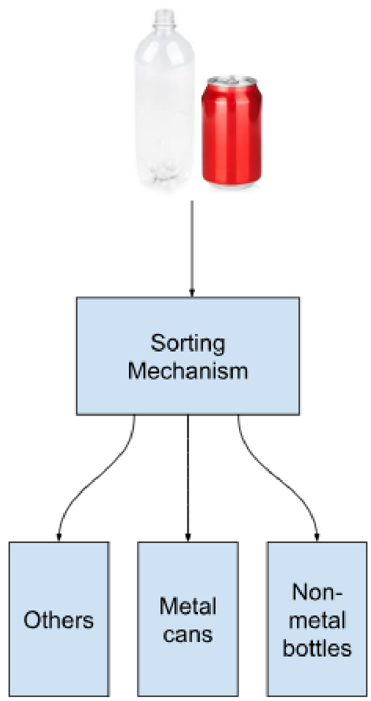
Problem:

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.

Visual Aid:

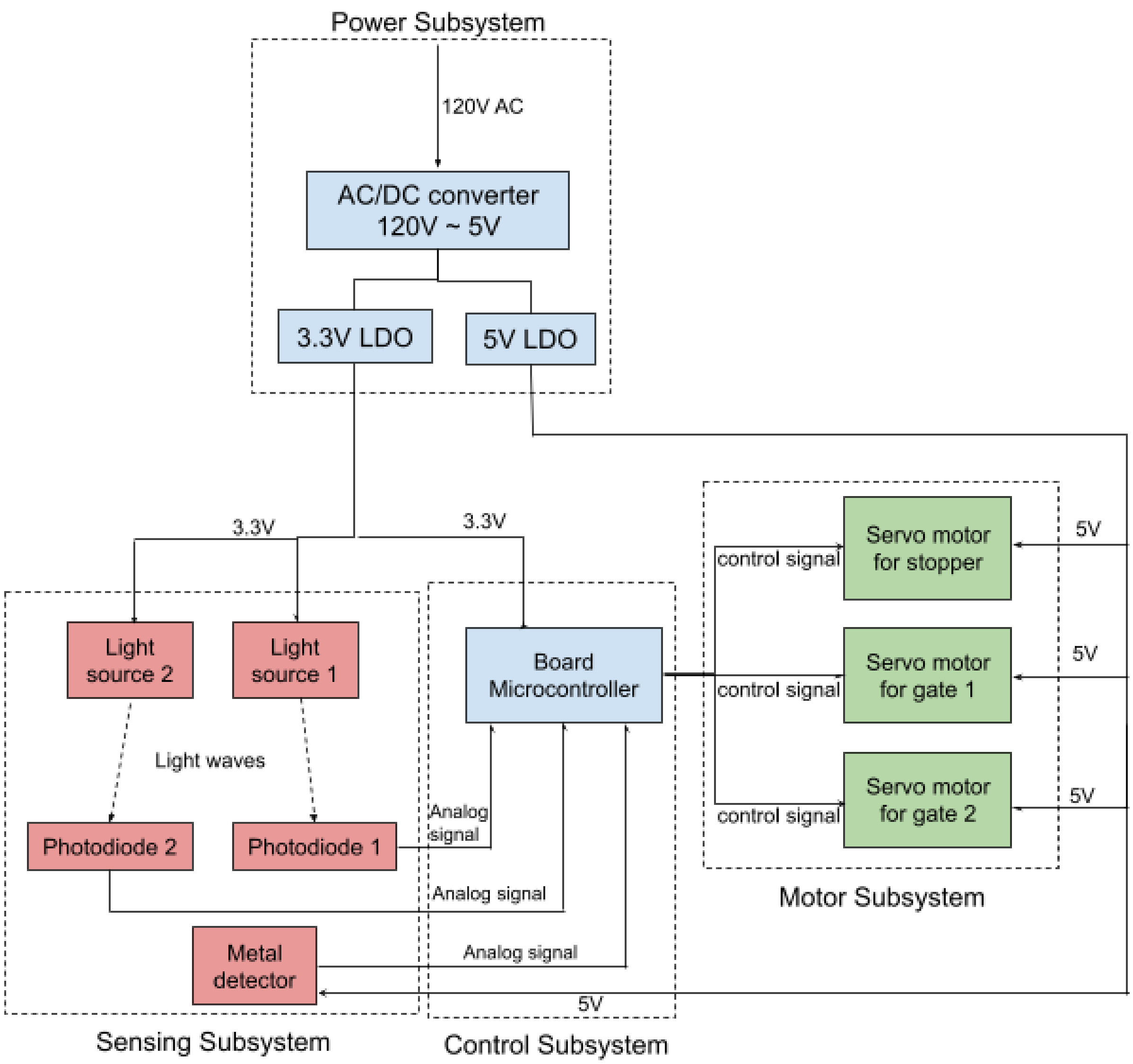


High-level requirement list:

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. For the analysis process, the two laser diodes would determine the input size and input status. After the input size and input status are determined, the garbage would be classified into bottles or not. Afterward, the metal detector would further classify it to plastic or metal. 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

Block diagram:



Subsystem Overview:

Power subsystem:

Converts 120V AC from the wall plug to 5V DC that is used to power the control and sensing system.

Sensing Subsystem:

Light sources and metal detectors are powered by 5V DC. Photodiodes will receive light from the light source and change the current produced which is sent to the control subsystem. Metal detector will use EM waves to determine the property of the object inserted. Signal received by metal detector is sent to the control subsystem for analysis.

Control Subsystem:

Control subsystem is powered by the power subsystem. It receives signals from the sensing system, after analyzing, it outputs control signals to the motors subsystem.

Motor Subsystem:

Motor subsystem is powered by the board and receives control signals from the board. The servo motor then turns to open and close gates.

Subsystem Requirements:

Power subsystem:

Power subsystem includes an AC DC converter and two regulators. AC DC converter converts 120V AC from the wall plug to a DC voltage in order to power two regulators. Two regulators then provide 5 VDC and 3.3 VDC separately 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.

Sensing Subsystem:

The sensing subsystem gathers the data on the shape and material of the object inserted which will help to sort it into the correct bin. Light sources and photodiodes together will determine the size of the object, and the metal detector will determine if the object is metal. Photodiodes draw 400μA of quiescent current and supplied by a 2.25-5V DC voltage. It will produce 0.47A of current for every watt of light received. Metal detector is supplied by 3-5V DC voltage, and will send signals to the control system if metal is present within 60mm of the coils (The closer the metal, the stronger the signal is).

Control Subsystem:

The control subsystem consists of a ESP32-s3-wroom-1-n16r2 chip and other circuits that ensures the functionality and programmability of the chip. The control system should be able to process three analog signals from the two photodiodes and metal detector and output three PWM signals to control the servo motor. If both photodiodes are blocked, and no metal is detected, the control subsystem should control the servo motors should open gates that orient the bottle to the plastic bin. If both photodiodes are blocked, and metal is detected, the servo motors should open gates that orient the bottle to the metal bin. If only one photodiode is detected, the servo motors should open gates that orient the bottle to the other bin.

Motor Subsystem:

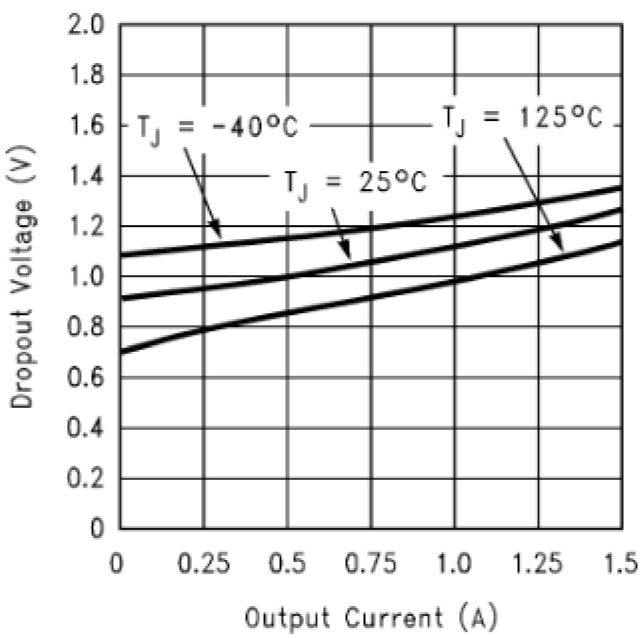
Motor subsystem consists of 3 servo motors. Each motor has three connections: one line is 5 V power supply, one line is PWM signal that is generated from the control subsystem, and the last line is ground. The torque requirement will be set after further discussion with the machine shop.

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 KTT 3 PINS	LM1086 NDE 3 PINS	LM1086 NGN 8 PINS	UNIT
$R_{\theta JA}$	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

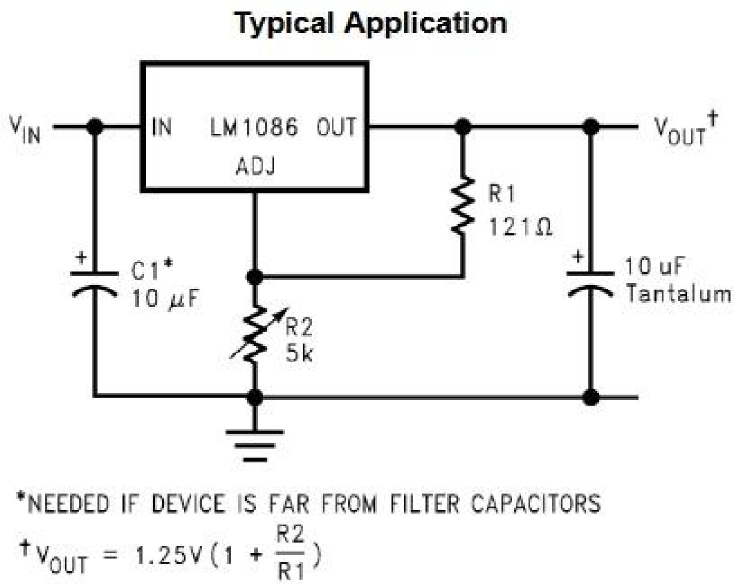
The maximum operating temperature for our LDO is 125 °C.

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 $R1 = r1 \pm n*r1$

$R2 = r2 \pm m*r2$ (m,n are tolerance)

$R2/R1 = (r2/r1)*[(1\pm m)/(1\pm n)]$

$\therefore \Delta R2/R1 = \pm 3.4\ (m/n)$ for 5V LDO

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

$\Delta R2/R1 = \pm 2.64\ (m/n)$ for 3.3V LDO

3. 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

[2]*Laser Hazards - Hazards*. Occupational Safety and Health Administration. (n.d.). https://www.osha.gov/laser-hazards/hazards

[3]WebMD. (n.d.). *Minor electric shocks and Burns: Symptoms, causes, and treatments*. WebMD. https://www.webmd.com/first-aid/electric-shock

[4]LM1086 1.5-a low dropout positive voltage regulators datasheet (rev. J). (n.d.-b). https://www.ti.com/lit/ds/symlink/lm1086.pdf?HQS=dis-mous-null-mousermode-dsf-pf-null-wwe&ts=1694226213634&ref_url=https%253A%252F%252Fwww.mouser.cn%252F