Project Green Can

Team 1

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9th February 2022

ECE 445: Senior Project Design

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1. Objectives and Background

1.1 Problem

According to an article written by the National Association of Convenience Stores (the Value of Can and Bottle Recycling), crushing cans before recycling saves space, provides more recyclable material per container and making transportation more efficient.

However, the average person's means of crushing cans before recycling neither has a system to prevent the crushing of non-empty nor a safety guard for its users– what happens if a hand gets stuck in front of the crushing surface or if some metal shards fly around during the crushing? These concerns are some of the many outlined by some concerned threads in a discussion forum (Health and Safety Tips).

So the problem is apparent: improving our current system of recycling cans with safety in mind.

1.2 Solution

We intend to make an Aluminum can recycling machine that prevents the recycling of non-empty Aluminum cans and keeps track of how many cans have been recycled for documentation purposes at larger organizations. This solution encourages large-scale recycling through a user-safe system that prevents the recycling of non-empty and/or pressurized cans.

The machine will use a latch sensor (similar to those used to turn the light on or off in refrigerators) to tell when the can-crushing enclosure's door is shut and a load cell to tell when an empty aluminum can (weighing from 12g to 16g) has been inserted into the machine. When, in addition to the previous two conditions, there is no overload of cans detected in the collection system (i.e., as long as there are not too many cans in the machine's collection bin), and the start button is also pressed, a PCB will send a signal to the motor, which will crush the can. The motor will proceed to crush the can until a potentiometer attached to the motor indicates to the PCB that they can have been crushed to the point where, if the motor retracts, it will fall into the can disposal chute. If, before this point, the current monitor attached to the motor indicates that an irregular amount of current is being exerted to crush the can, the motor will be retracted immediately to prevent damage to the machine. Assuming the can is sufficiently crushed, it will be allowed to fall into the disposal chute by the retracting motor, breaking the beam of an IR sensor placed at the bottom of the chute and sending a signal to the PCB. The can will proceed to fall into the disposal bin below the device, while the PCB will internally increment its count of the number of cans recycled and display the current number on a small display.

To ensure only empty cans are crushed, our system will monitor two values: the weight of cans placed into the crushing cubicle and the current drawn from the motor. If its weight exceeds the weight of an empty can or the current crosses an experimentally determined threshold, a red LED will glow (indicating to the user that the machine will not crush the can be placed inside, sending the machine into a do not accept state). There will be a collection bin for the crushed cans.

At any point in time, the system is one of four internal states: A start state (which it will be frozen in temporarily if it detects an invalid can on the load cell, a can blocking the disposal chute due to a full disposal bin, or an open door to the can insertion area) where the machine can be asked to crush a can, a crush state (which will only be triggered from the start state if none of the freezing conditions are true and if the go button is pressed) where, assuming no problems are detected, the can will be crushed by extending the crushing piston and retracting it once the can has been crushed small enough to fall into the disposal chute, a retraction state (which only occurs to immediately retract the piston if the door is suddenly opened or if the current is detected to be to unsafe) to implement safety measures during crushing, or an increment state (which occurs after the crush state assuming a can is detected by the disposal chute as the piston is retracted) to increment the recorded number of cans crushed and continue retracting the piston. The current state of the machine, including which of the four internal states it is in, and the presence of problematic signals (too much weight, too much current, too many cans, can door open) might also be indicated by a set of LEDs.

1.3 Goals and Benefits

- Provides a user-safe method of can-crushing for recycling by shielding users from metal shards and stopping the can-crushing platform if the protective covering is removed.
- Collects can-recycling data for study when employed as a communal amenity.
- Encourages can-recycling in areas where people do not have can-crushers at home.
- Prevents recycling of non-empty cans.

1.4 High-level requirements

- The system crushes only non-pressurized empty cans when they are inserted into the can-crushing space.
- The crushed cans are collected in the collector until it is full/ the collection duct is obstructed (in this case, the machine goes into a mode where it must be serviced to continue operation)
- The system keeps track of how many cans have been crushed in between service cycles.

2. Design

2.1 Visual Aid

As shown below, our project is designed to lay down with a can disposal chute facing a collection bin. It comprises four main subsystems: a power, can-crushing, collection, and control system.

The can-crushing system revolves around the motor: controlled by the PCB, it moves a can-crushing surface that pushes a can (initially placed on a load cell that detects its weight to ensure that the can is empty and valid for crushing) against the opposite surface effectively crushing it which makes it small enough to go through the disposal chute into the collection system which increments the crushed can count by 1 via the IR sensor and the PCB and updates total cans crushed internally and displays this number via the Arduino serial display. As seen from the top view, there is also a door for an entry which serves as a safety component to prevent people from accidentally placing their hands in the machine while a can is being crushed and getting hurt. This door comes with a door sensor that communicates with the PCB indicating when the door is shut and safe for the commencement of crushing.

For the internals of both the top and side view, a linear motor piston is seen with a crushing block mounted to its head which is key in the process of crushing the can. We also see a can detection IR beam for the purpose of detecting when a can has been placed on the crushing platform which houses the load cell.

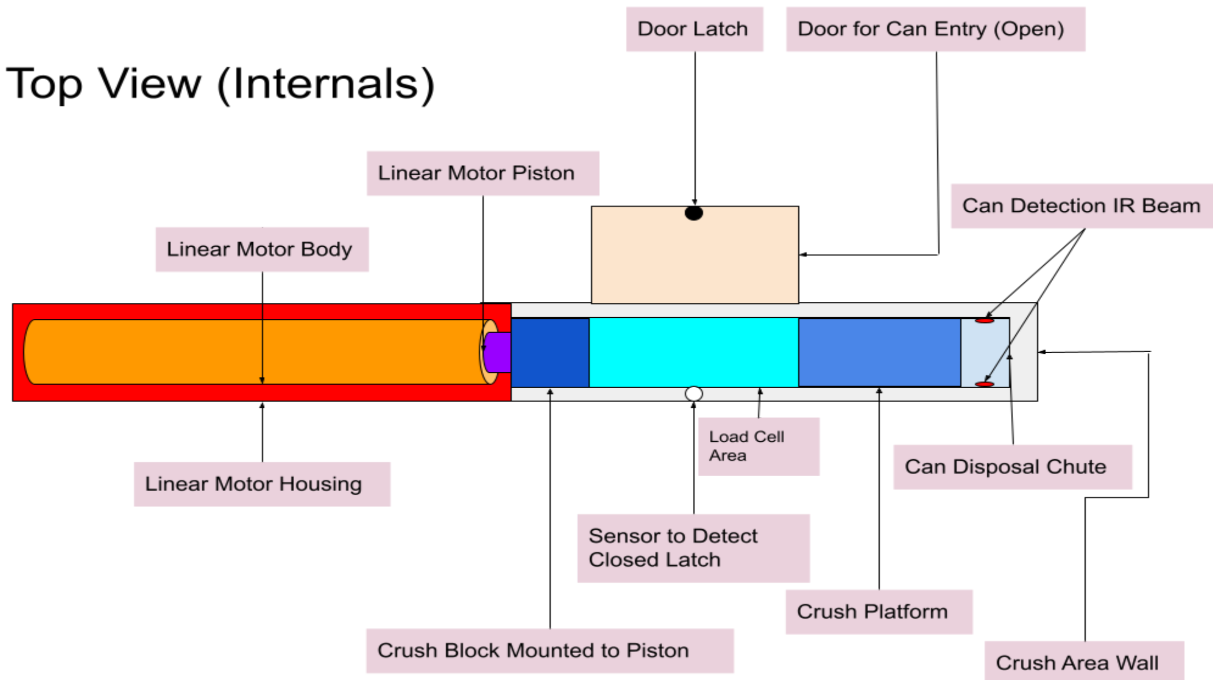

Figure 1: Top View (Internals)

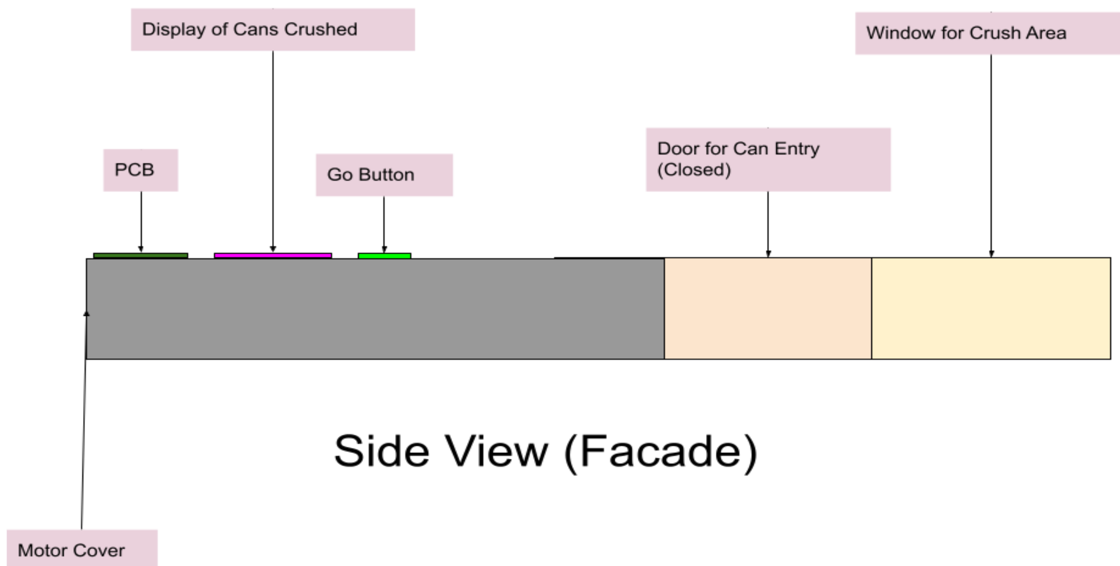

Figure 2: Side View (Facade)

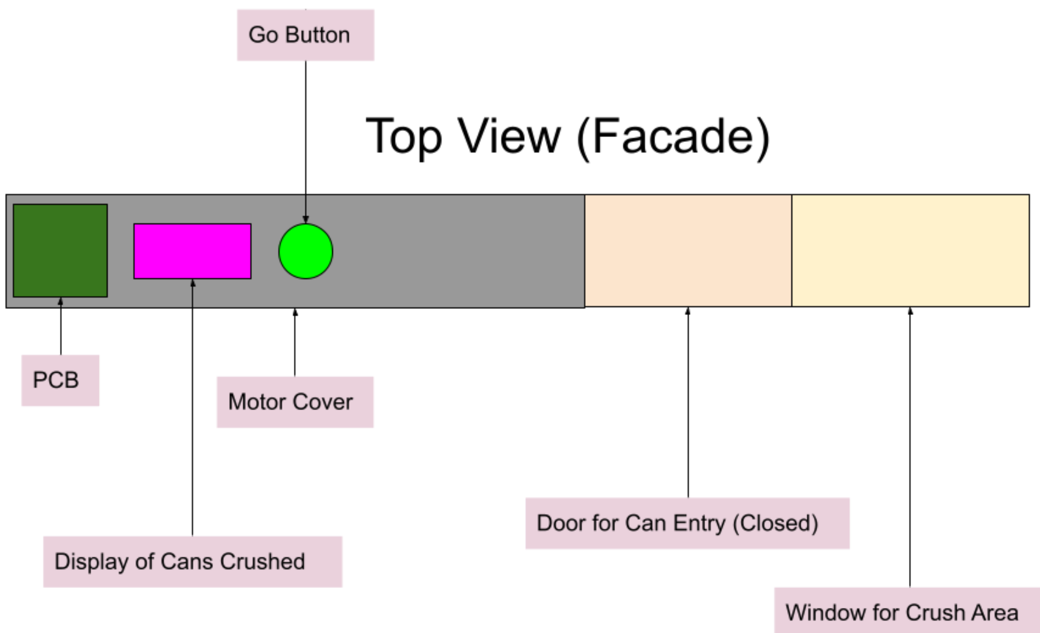

Figure 3: Top View (Facade)

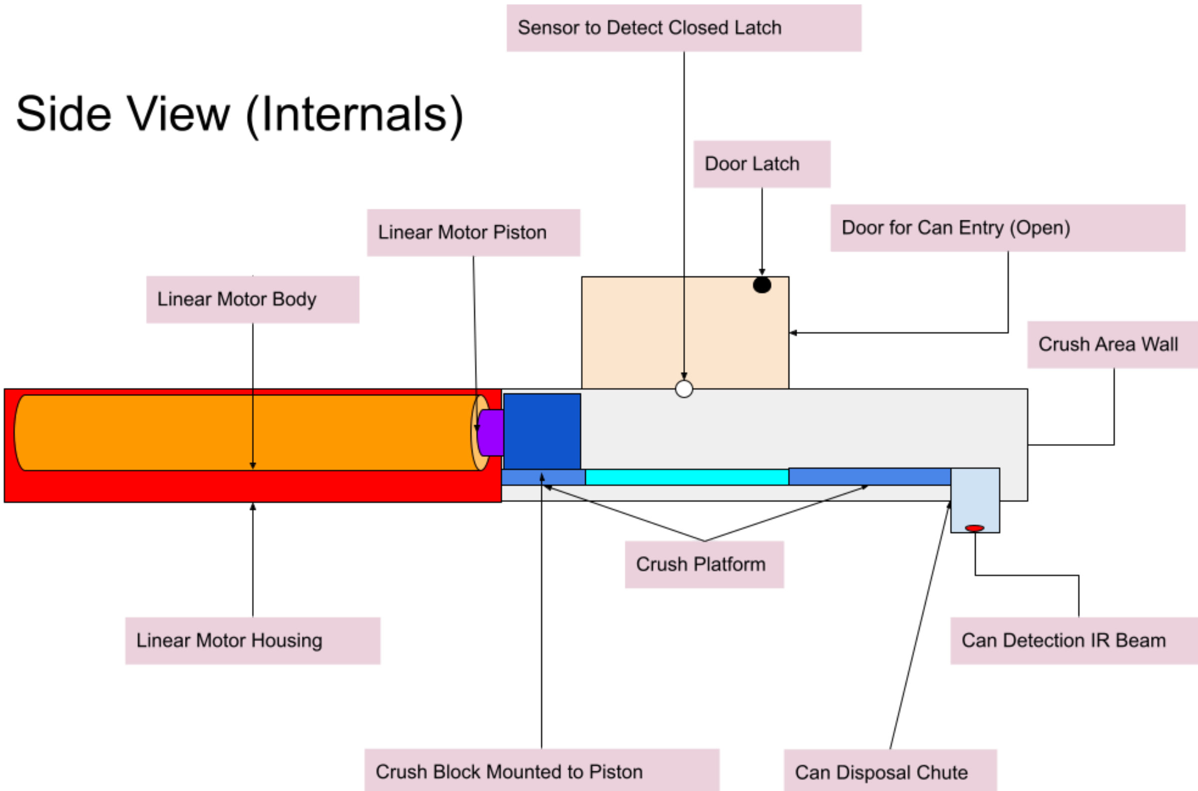

Figure 4: Side View (Internals)

2.2 Block Diagram

The block diagram contains the 3 main systems for the machine; the can-crushing system, the control system (PCB), and the collection system. The can-crushing system contains multiple subsystems, which include the door sensor, which communicates to the PCB the status of the door, either opened or closed, which the PCB uses to decide if it is safe to begin the can-crushing process, so that subsystem is solely to promote safety. The load cell resides on the crushing platform and communicates to the PCB the weight of a can be placed on this platform to help the PCB realize that this can is empty and is ready to get crushed and recycled. The linear motor has 12V supplied to it and contains the potentiometer (with 5V supplied to it) as well as the current monitor, which communicates current readings to the PCB, which the PCB uses to send back retract/extend signals to the motor in order to use just enough force to crush the can and not too much or too little.

The control system (PCB) contains the state machine, which uses the signals from the subsystems mentioned above in the can-crushing system. This state machine is displayed via LEDs. The PCB also takes the signal from the IR sensor in the can collection system and increments the internally kept number of cans crushed, and sends this number to the can collection system to be displayed on the Arduino display.

The can collection system contains an IR sensor to detect when a can has been crushed and collected through the disposal chute into the collector. This IR sensor then sends a signal to the PCB indicating that a can have been collected so that the PCB increases the number of cans crushed internally. The can collection also contains the Arduino display to display the number of cans crushed as communicated by the PCB.

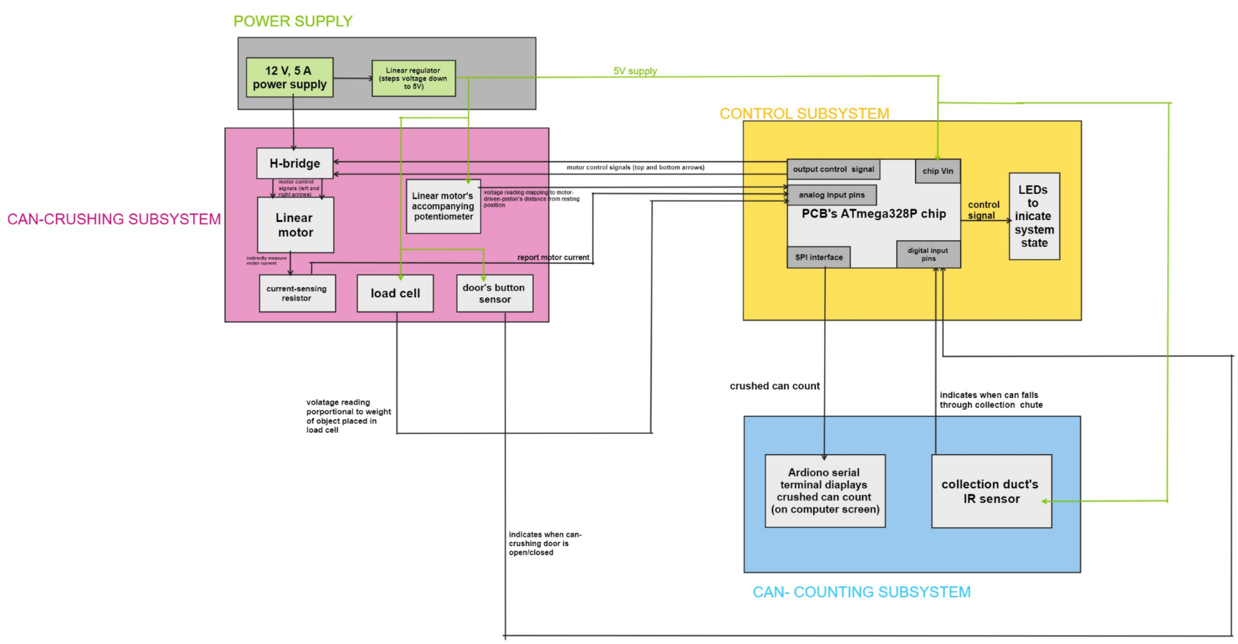

Figure 4: Block Diagram

2.3 Subsystem Overview

- **Can-Crushing System with built-in protection from recycling full cans**

Once in the can-crushing state, the opening through which one places the can must remain shut unless the motor stops moving the can-crushing platform (there is a button the door should hold down to tell if the door remains shut). The motor will also only move the piston to crush the inserted can if the weight sensor beneath the can does not sense that the can weigh outside the acceptable 12 to 16 g range. Once crushed, gravity pulls the crushed can through an open chute which leads to the collector subsystem.

The motor's potentiometer reports the piston's location to the PCB, which, in turn, sends back control signals to the motor.

For safety reasons, the motor's current is also reported to the PCB. If the motor stalls for any reason (for example, squishing a small animal that crawled into the can-crushing space, crushing a human body part if the door was opened and the button's feedback to the control system is too late, or the motor is trying to crush an empty to pressurized can which could explode under compression, etc.) this creates a spike in the current drawn by a motor (stall current). This spike is noticed by the control system, which reverses the direction of the motor.

- **Collector subsystem**

The collector chute has an IR sensor that monitors when crushed cans fall into the collector below. If, for some reason, the chute becomes blocked (this could happen when the crushed cans pile too high or a crushed can does not fit down to the chute properly), a signal is sent to the control subsystem, which puts the system in a state where no more cans will be accepted until the system in service. Additionally, the IR sensor acts as a counter for the can-counting done by the PCB in the control subsystem.

- **Control subsystem**

This comprises the PCB and the Arduino serial output terminal. Using inputs from the can-crushing subsystem (load cell weight, motor potentiometer, and the motor current readings), the PCB outputs control signals to control the direction of the motor. The button under the door of the can-crushing area also sends a signal to the PCB to stop the motos if the door is opening during can-crushing.

The PCB, upon receiving a signal from the collector chute's IR sensor, increments the can count and displays this using the Arduino's serial output terminal.

- **Power Subsystem**

Because our design effectively requires two different sources of power, 5V for the majority of our components and 12V for our actual motor, and also requires that we be able to switch the polarity of the device, we require an extra subsystem specifically to properly power our project. This uses three components in total: a 12V and 5A supply which can be plugged into a wall socket, an H-bridge to switch the polarity of the 12V, and a linear regulator which can step the 12V and 5A of the original source down to 5V and 1mA. The 5V and 1mA are used for all components which are not the linear motor itself, and the H-bridge is used to supply 12V and 5A to the motor. However, the H-bridge will only supply the 12V and 5A to the motor if it receives a signal to run the motor from the control units, and it will switch the polarity of the 12V based on another signal from the control unit to either move the motor forward or backward, assuming it is being turned on by the control unit.

2.4 Subsystem Requirements

- Can-Crushing System with built-in protection from recycling full cans
  - Motor drives can-crushing platform to crush can
  - Only empty cans are crushed
  - Opening the door stops the motor from its crushing motion

- Collector subsystem
  - Blockages in the collector chute are reported to the control system as a flag to stop accepting cans till the blockage is removed.
  - Sends can-count increment signal to PCB every time a can is crushed and sent down the chute.

- Control subsystem
  - Stop the motor when it is stalling.
  - Keeps count of how many cans have been crushed.
  - Does not allow the motor to run if the load cell detects overweight/underweight entities in can-crushing space.

- Power subsystem
  - Supply H-bridge with a 12 V signal.
  - Supply 5V to the motor’s potentiometer, load cell, PCB’s processing chip, door button sensor, and collection chute’s IR sensor.

2.5 Software Design

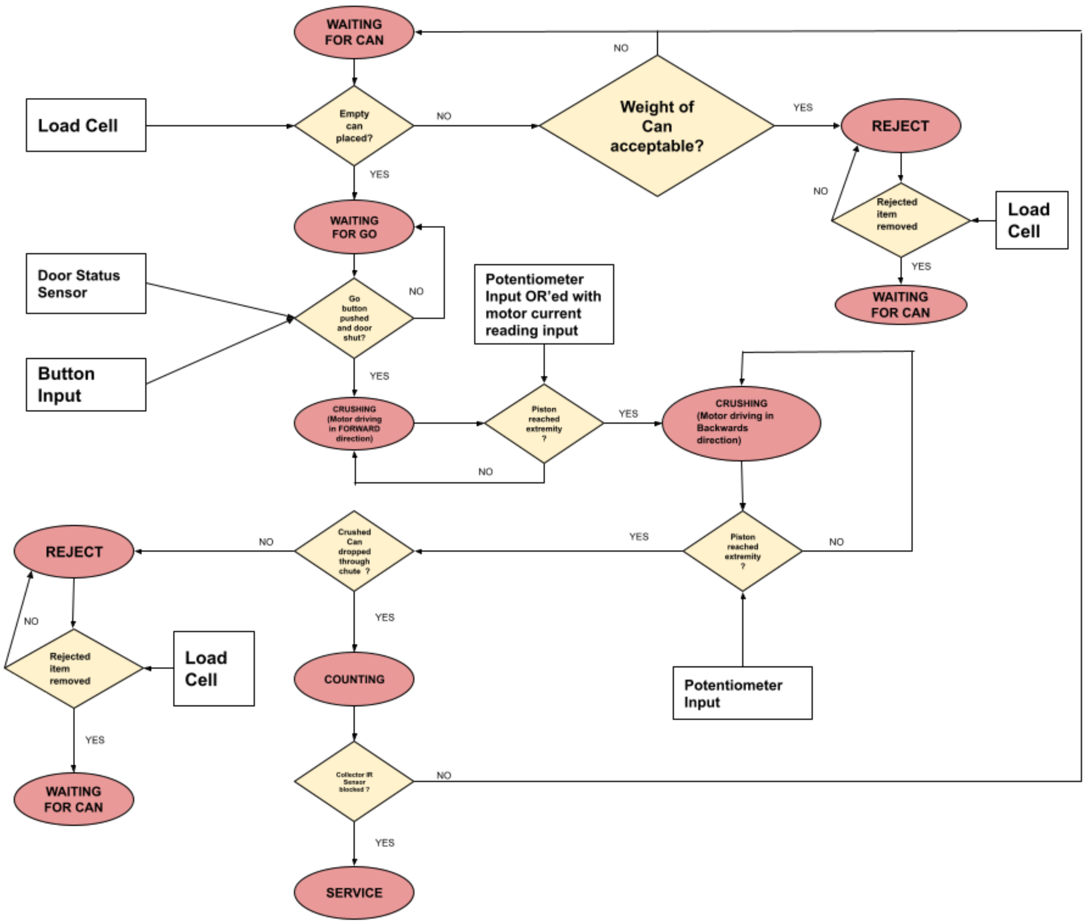

Figure 10

The PCB microchip will run a program that keeps the system in one of seven states at every point in time. These states will be indicated by LEDs on the machine and are outlined below:

- WAITING FOR CAN: The initial starting state of the system. The motor is kept off, and the piston is kept reeled in. When the Load cell reads in voltage corresponding to an item weighing between 12 and 16 grams, the system progresses to the WAITING FOR GO state. If the item placed is beyond 16 grams, the system goes into REJECT state. Although this is not shown in Figure 10, items weighing below 12 grams leave the system in the WAITING FOR CAN state.

- REJECT: When items weighing over 16 g are fed into the machine, this state is reached. This is to ensure items like rocks and non-empty cans are not recycled by the machines and later delivered to recycling centers. Once the overweight items are removed, the system goes into the WAITING FOR CAN state.

- WAITING TO GO: this state serves as a safety mechanism as we do not want the can-crushing platform being driven forward by the motor while a user's hand is still in its path of motion. To proceed with can crushing, users press a go button.

- CRUSHING (MOTOR GOING IN FORWARD DIRECTION): at the start of the can-crushing process, the motor drives the can-crushing platform forward. To know when the extremity is reached (whether the can-crushing platform is pressing against a hard surface or the piston has been extended to its full extent), the PCB's program monitors the motor's potentiometer's reading and the V_m of the motor (V_m is explained in the Hardware Design section).

- CRUSHING(MOTOR GOING IN BACKWARD DIRECTION): the second part of the crushing process is after the piston's direction is swapped when it has reached the extremity, the motor drives the can-crushing platform backward. When the piston reaches the extremity a second time, and the can is thoroughly crushed and falls into the collector chute as detected by an IR sensor, the system goes into the COUNTING state. If, however, the collector's IR sensor did not sense a can dropping through the collection chute, the system progresses to the REJECT state.

- COUNTING: in this state, the system internally increases the number of cans it has crushed. Also, the system checks if the collector's IR sensor has been blocked for too long. If this is the case, the system goes into the SERVICE state; if not, the system goes back to the WAITING FOR CAN state.

- SERVICE: in this state, the humans would interact with the collector bin in an attempt to unblock the IR sensor. The block could result from the collector bin being too full and overflowing with crushed cans, or a can could just be positioned to block the IR sensor.

3. Tolerance Analysis

We have ensured that our system is a closed loop: assuming what is likely empty, non-pressurized can is placed into the can-crushing container (detected by the load cell, which feeds into the control subsystem), the control subsystem PCB microchip program sends out a control signal which drives the motor to crush it; the motor then retracts (when its potentiometer indicates the piston has been fully extended or V_m indicates a motor stall in the PCB microchip program) and, as the crushed can slip through a collection chute, the system increases the can count and either go into SERVICE state (if there is now an obstruction in the collection chute) or returns to the initial WAITING FOR CANS state.

One major point of concern is the control of the motor– what happens if it pushes the crushing platform too far?

We choose to discuss this part of the project as its correct operation is crucial to the successful operation of the project. Without a successfully crushed can, nothing goes down our collection chute, no can count is kept, and our control subsystem stays in the initial state indefinitely.

It is due to its importance that we ensure, through simulation, we will achieve acceptable fault tolerance from the motor: in the worst case, the motor's forward driving signal from the control subsystem is slightly too powerful. This could damage the load cell or crush the can too quickly (prematurely triggering the collection chute's IR sensor in a state where its input is not considered by the PCB).

By monitoring the current of the motor, we ensure the PCB reels the motor back to its original position before the can is crushed too thinly (causing the second issue mentioned in the preceding paragraph). By separating the load cell from the actual can-crushing platform (as shown in the visual aid), we avoid the first issue mentioned in the preceding paragraph.

This ensures our high-level requirements are met because, by preventing the damage of our load cell, cans outside the allowed weight range can be rejected in future uses of our system and, by preventing premature triggerings of the collector chute's IR sensor, its readings will be available in states when they are used in can-counting and obstruction detection. Additionally, monitoring the motor's current prevents the motor from attempting to crush items that are not empty non-pressurized cans (such as hollow rocks and human parts) which may bypass the load cell's weight restrictions.

Other points of concern are the progression of machine states. They are outlined in the Software Development section, and we have taken time to ensure the system is not stuck in any state indefinitely:

WAITING FOR CAN progresses to WAITING FOR GO once an item 12 g to 16 g is detected. Any item under 12 g keeps the system in the WAITING FOR CAN state, and any item over 16 g sends the system into REJECT state when placed on the load cell.

WAITING FOR GO progresses to CRUSHING (MOTOR GOING IN FORWARD DIRECTION) once the go button is pressed, and the crushing door must remain shut (monitored by a button the door must hold down) during either of the CRUSHING states unless the system will go into REJECT state.

CRUSHING (MOTOR GOING IN FORWARD DIRECTION) progresses to CRUSHING (MOTOR GOING IN BACKWARD DIRECTION) once the motor potentiometer indicates the crushing piston has been fully extended or V_m indicates the motor has stalled.

CRUSHING (MOTOR GOING IN BACKWARD DIRECTION) progresses to COUNTING once the motor has fully retracted and the collector chute IR sensor signals a crushed can have fallen through the collection chute. If, however, the collector's IR sensor did not sense a can dropping through the collection chute, the system progresses to the REJECT state.

COUNTING progresses to WAITING FOR CAN if the IR sensor does not indicate a blockage in the collection chute. Else, it progresses to the SERVICE state until the can is removed– this will be indicated by the IR sensor readings– allowing the system to finally progress to the WAITING FOR CAN state.

The REJECT state also loops back to the start state: once the load cell senses the rejected item has been removed, the system progresses to the WAITING FOR CAN state.

4. Ethics and Safety

Our project is straightforward from an ethics and safety perspective. For one thing, ethically speaking this is a device designed to make recycling cans easier and safer and to encourage recycling by showing how many cans have been recycled in it, so it could generally be considered a social good. Meanwhile, from a safety perspective, the main feature of our project aside from counting cans is that it takes multiple safety countermeasures, including preventing people from injuring themselves or the machine through intentional or unintentional misuse.

During the project, we may be working with reasonably high currents to effectively crush the cans, and also will not have implemented all the safety features before building the basic crushing mechanism, so we will need to be careful that none of us injure ourselves during the testing process. This includes not accidentally crushing our hands or accidentally crushing things that shouldn't be crushed while testing the can rejection system After the project. As far as intentional misuse of our finished project goes, there are some things we won't be able to prevent, like someone putting a mouse in the can crushing machine, but for the most part our project protects against most forms of misuse.

The IEEE and ACM ethical guidelines, while important, are not particularly relevant to our project. That being said, I am very certain that our group members have upheld, continue to uphold, and will continue to uphold these codes in their academic and professional careers. The only two principles which I think are specifically useful to our project are 1.1 and 1.2 of the ACM ethical guidelines. By making recycling easier, we are contributing to society and human well-being, as recycling is a key part of both making society cleaner and more efficient, and thereby more pleasant for human beings to live in.

The best way to avoid ethical breaches is to ensure that people are familiar with why they need to avoid them. There are numerous ways to do this, including making people aware of negative consequences for them practically or from a long-term awareness of what they'll be missing out of through not being ethical. What we believe will, in particular, ensure the cooperation of our with ethical standards team is the fact that we are all too hard working and ernest to ever resort to underhanded or dishonest tactics. This is demonstrably true given our effort to complete all assignments as soon as they have come out, and consistently stay ahead of schedule. Simply put, we have no need to be dishonest or unethical. We are also strong proponents of personal accountability, and will continue to make sure that we stay on a good track.

The United States Department of Labor's Occupational Safety and Health Administration (OSHA), lists moving parts and unexpected machine startup as two of the three leading issues for workers in the recycling of metals, the third being lead, which is not relevant to this project, given that we intend to recycle aluminum cans, and a lead can most likely be so heavy that it would trip our system anyway. Plainly, OSHA considers amputation from errors in machine use paired with unintuitive machine functions to be significant concerns for its recycling process, meaning that if anything, our project will be an asset towards popularizing recycling.

We could not find any relevant federal regulations for our project. We checked the website of the Environmental Protection Agency (EPA) to find that there were no significant concerns surrounding the disposal of crushed aluminum cans. As long as the aluminum is sent to a scrapyard or collection center after being harvested, there should be no concerns surrounding weighting, crushing, and then counting the cans.

As far as industry standards are concerned, we could also not find any which were particularly relevant, even after consulting the website of The Aluminum Association. The main knowledge we gained is that recycling aluminum saves almost all of the energy spent making new aluminum, 95% to be exact, and that if all aluminum soda cans were recycled instead of going to landfills, we could save almost a billion dollars for the US economy. This also helps to support our current Aluminum production, as only 20% of the aluminum already produced isn't recycled aluminum, so if we could just recycle a little more we could have 0 net aluminum waste.

For campus policy, we checked the website for the Facilities and Services (F&S) Waste Management Department, to be informed the aluminum cans are highly recyclable by a facility we have on campus, meaning that the addition of production quality GreenCan units, to various school buildings or campus areas would probably be a great idea that would positively impact the school's reputation as a net 0 campus.

Given that our project is primarily based around ensuring safety, it is unlikely that our end product will present significant safety concerns. However, the safety concerns regarding the moving motor possibly hurting users is handled by our system since an IR sensor detects if the door closing the can-crushing state can stop the moving motor.

5. Citations

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