G2G Automated Token Exchanger

ECE 445 Design Document – Spring 2022

Project # 38

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1 Introduction

1.1 Problem

Good2Go (G2G) containers are used all throughout dining halls at U of I for individuals wanting to take their food to go. The program allows you to trade in an old container for a redeemable wooden token, where that token can then be used to trade for a new container. The current process for exchanging containers for tokens and tokens for new containers lacks a unified system across campus, and relies on human supervision and interaction. Also, the current state of G2G is that a person wanting to get a G2G container will have to wait in the same line as other people who just want to eat in the dining hall. This results in longer waiting time for students while requiring unnecessary human to human interactions. This proves to be a hassle for both parties that handle the process since it is too simple to have any one person be assigned to it, but occurs often and spontaneously enough to become bothersome.

1.2 Solution

Our solution involves an automated token and container exchange machine that will serve two key functions. One is to have a digital token that upon a deposit returns a clean container. Second is generating a token or a clean container after accepting a used container. The goal here is to make the process semi-autonomous by removing the human to human interaction and also allow users to directly swap old containers with new ones without the need of exchanging them for tokens. This will improve the efficiency, simplicity, and performance speed of the Good2Go container system.

To do so, the system will require sensors to detect validity of the containers and the tokens. It will also have a screen display and buttons to receive user input. Lastly the microcontroller and motors will be used to process the internal state of the machine and execute the actions necessary to receive old containers, output new ones and generate a token.

The sensors are the main replacement of human to human interaction, as they are responsible for authenticating valid containers and tokens. Each container has its QR code scanned and weight measured; containers that are overweight or are missing valid QR codes are rejected. Wooden tokens will be replaced with virtualized tokens stored in a magnetic swipe card. A card reader identifies each user. A screen display and a series of buttons are used to inform the machine of the user input. Once a user deposits an old container, they will be able to select to receive a new container or a token. The microcontroller will then take this input from the user and will activate the motors to dispense and receive Good2Go containers. The motors will be placed to allow accurate delivery of only a single container at a time, which is further described in the diagram below as well as under the Subsystem Overview.

1.3 Visual Aid

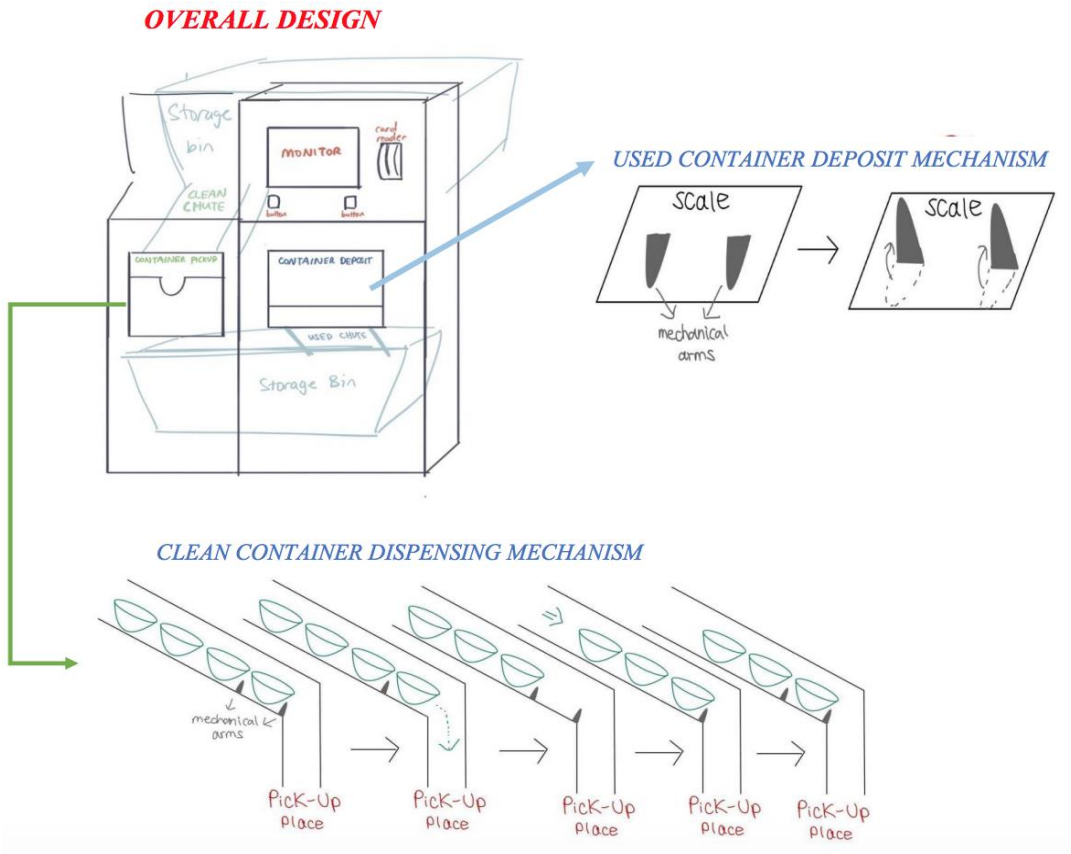


Figure 1: Overall Design of the G2G Token Exchanger

1.4 High-level Requirements List

To consider our project successful, the following requirements must be met:

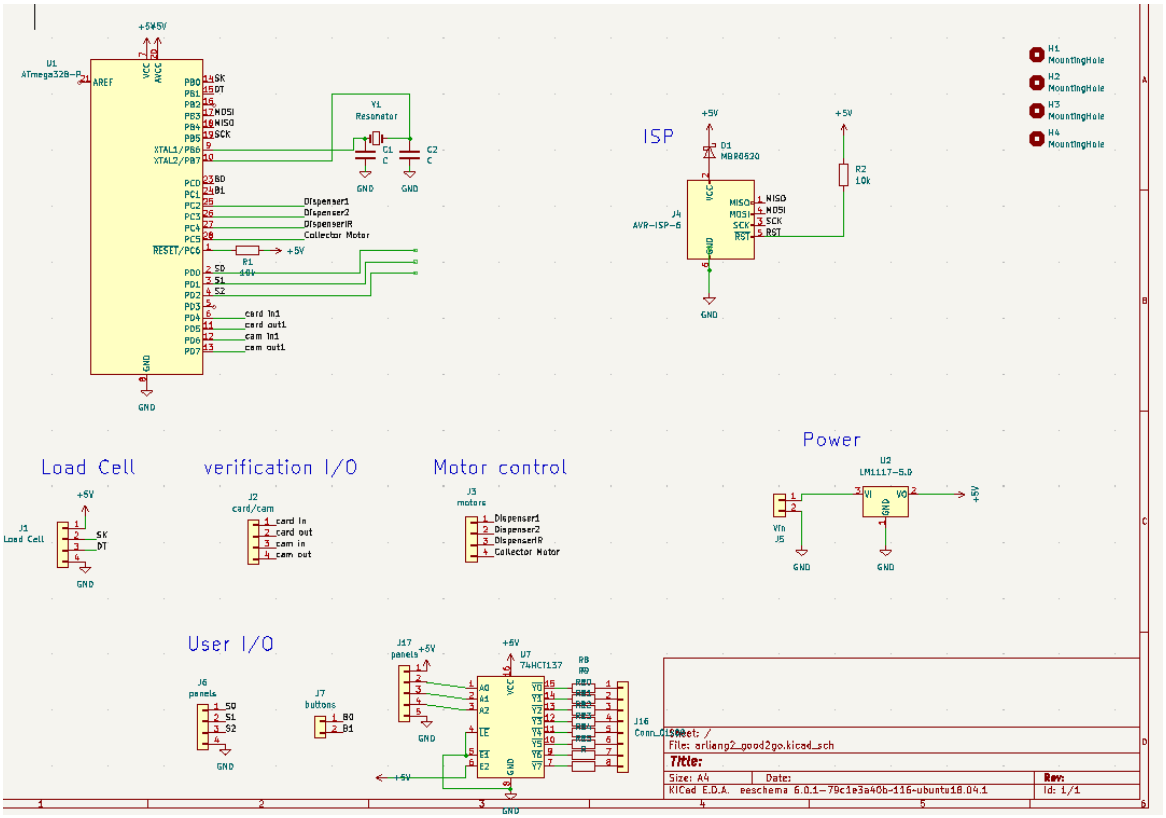
1. Deliver the entire process (from receiving container/token to dispensing a new one) in less than 15 seconds. This time is calculated assuming 0 delay in user's action. Thus, the time taken from receiving a container to dispensing a new one or updating token from the machine's side should be less than 15 seconds.

2. Dispense exactly one new container at a time indefinitely without any jamming. The system should never allow more than one container to be dispensed upon a single request.

3. Correctly detect invalid G2G containers using QR code through image recognition algorithm to read binary data and using weight threshold (30 grams + base weight) to reject containers holding too much food waste.

2 Design

2.1 Circuit Schematic



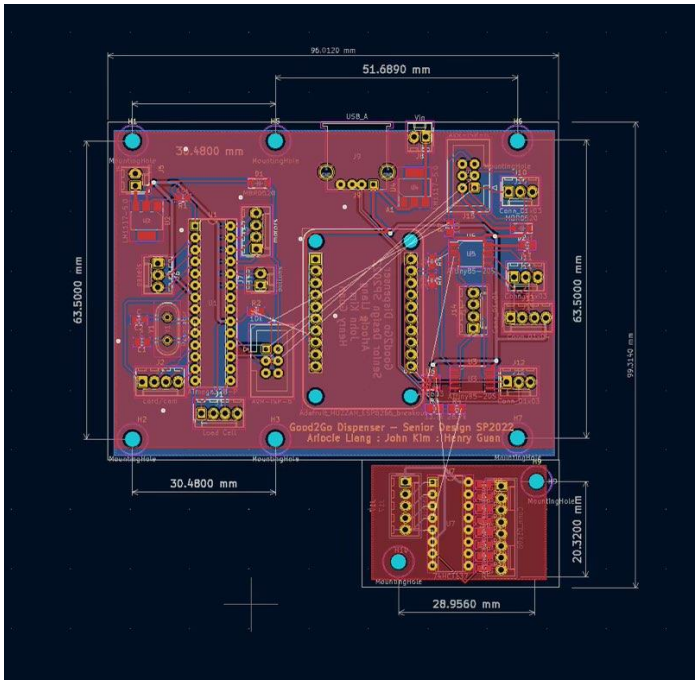


Figure 2: Automated G2G Token Exchanger PCB Circuit Schematic

2.2 Block Diagram

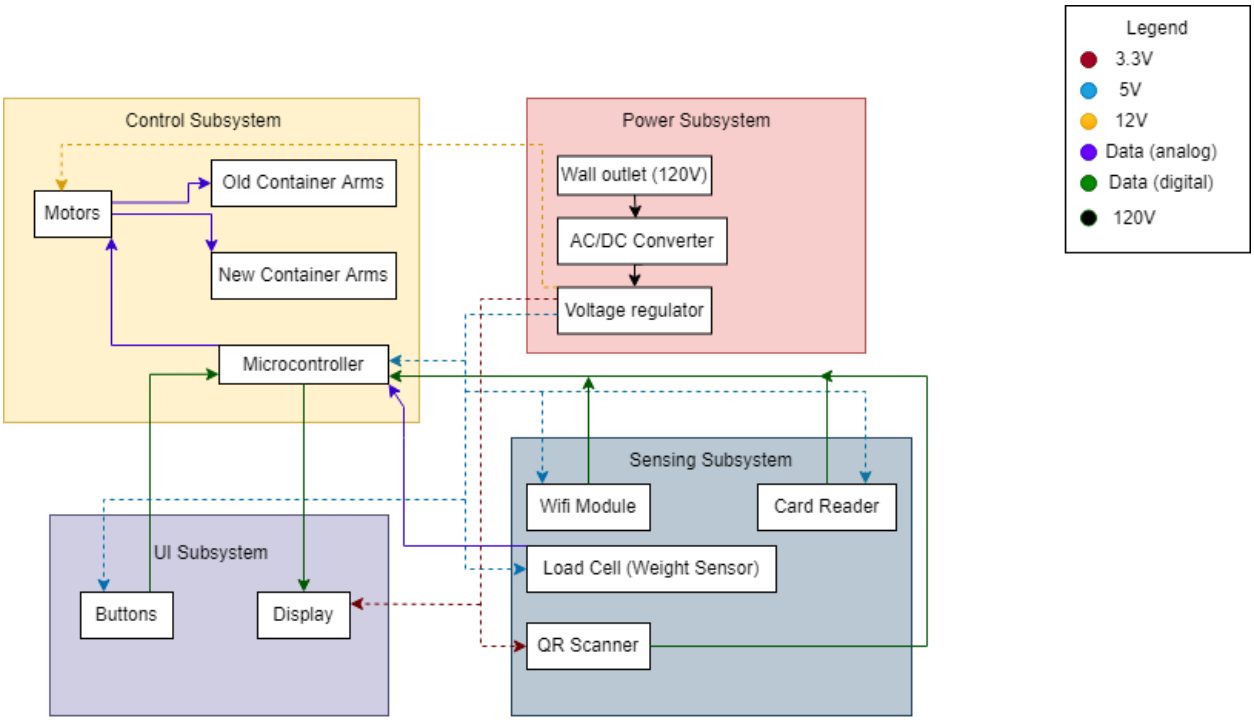


Figure 3: Automated G2G Token Exchanger Block Diagram

2.3 Functional Overview & Block Diagram Requirements

2.3.1 Sensing Subsystem

The sensing subsystem is responsible for checking for valid users and valid containers as well as updating the token count per card swipe. The QR scanner is used to identify valid containers by reading the food container ID and a wifi module to send it over to the microcontroller. If it is an invalid ID, the machine returns to its initial state. Otherwise, the machine will dispense either a {new container} or generate a {token}. The scale is used to measure weight so that once it exceeds {container weight + 30 grams}, the machine will not accept the container and will return to its initial state. If the weight is within the threshold, the machine will dispense either a {new container} or generate a {token}. Lastly, the card swipe is used to process digital coins instead of physical ones. Each card will hold information of the

number of tokens and will get updated for every swipe. If a card swipe is read from the initial state, the machine will dispense a new container

Table 1: Sensing Subsystem – Requirements & Verification

Requirements	**Verification**
• Can scan QR code on transparent G2G containers.	• Check if the white sticker backening ensures correct QR scan by having it placed on a transparent glass with transmittance greater than 70%.
• Execute action (whether dispensing or receiving) only for valid G2G containers.	• Run different test cases for both valid and invalid containers. Invalid container runs will include {valid G2G containers with too much waste (> 50 grams)} and {containers with no QR code}. The machine should not execute any action for at least 5 seconds or until a valid container is placed. For valid containers, the machine should carry out an action such as dispensing or receiving in less than 5 seconds.

2.3.3 Control Subsystem

The control subsystem is mainly responsible for handling the machine's state transitions and activating motors. An ATMega328 microcontroller will in addition read data from the scale, card swipe as well as from the QR scan. From the initial state (old container, token), if the user inputs an old container, the microcontroller will take input from the scale and activate the motor to receive the returned old container, and then wait for further user input for {new container} or a {token}. Otherwise if the user

selects a token, the microcontroller will process the token and activate the motors to dispense a new container.

Motors will be wired to a pair of arms near the opening of where the user can place an old container. It will be placed on the same surface as the scale (on the bottom of the old container) so that once the motors are activated, it lifts up and acts as the pushing mechanism to deposit the old containers. A different set of motors wired to two arms (spaced for a single container) will also be used to dispense new containers. Only a single container will be preloaded in between the arms, with the rest being loaded behind this single container at an angle. Upon the activation of the motors, the first arm closest to the drop chute will open first, dispensing the container. That arm will then close, followed by the second arm opening, allowing one container through. That barrier will then close, completing the process of preloading another container that's ready to dispense.

Table 2: Control Subsystem – Requirements & Verification

Requirements	**Verification**
• Container should receive old container in less than 9 seconds and dispense a new container in less than 6 seconds.	• Conduct 10 repetitive tests, timing the receiving starting when the user places an old container. The timing of dispensing is taken right after the receiving to ensure total time taken is less than 15 seconds.
• Dispense exactly one new container upon a single request without any mechanical faults such as jamming.	• Conduct 10 repetitive tests and compare the distance of the arms to their original position, ensuring it is less than 0.5mm to show it can be done indefinitely.

2.3.3 UI Subsystem

The display screen along with the button is used to guide the user into selecting one of the two options. The first selection is {old container} and {token} which is used to inform the machine what it's supposed to expect from the user. In the case of the {token}, the machine will read from the card swipe. The next option that will be displayed is {new container} and {token} which occurs in the event the user returns an old container. Based on the input, the machine will return either a new container or update the token info from the swiped card.

Table 3: UI Subsystem – Requirements & Verification

Requirements	**Verification**
• Correctly keep track of the number of tokens per user.	• Insert 4 old containers and convert them to tokens. Assume 4 tokens are correctly stored. Then using the same user card, convert the tokens to new containers until no tokens are left. Ensure the number of new containers received equals the number of old containers put in.

2.3.4 Power Subsystem

The power subsystem is responsible for powering all the necessary components without burning or damaging the components by supplying a consistent voltage within range. The machine takes in power from a conventional wall outlet that goes through an AC/DC converter and regulator to produce a regulated voltage specified in our design to properly power all components.

Table 4: Power Subsystem – Requirements & Verification

Requirements	**Verification**
• Power all the components with constant voltage in accordance with the voltage ratings in the block diagram.	• Test the voltage running through each component with an oscilloscope and observe if the voltage supplied exceeds a 5% variance.

2.4 Tolerance Analysis

The mechanical aspect of the dispensing and retrieval system is one of the most critical components of our project. The main functionality of the machine highly depends on accurate and correct retrieval of old containers to be thrown into the storage bin. This action is executed by a pair of 5cm arms powered by a stepper motor with a 1.8 degree step angle with 200 steps per revolution. Since the placement of the G2G container on the scale may vary in position, the arms need to provide enough slant and force to retrieve the container without having the container collide with any side of the walls.

To ensure such performance, it will be tested with different angles for the arm ranging from 45 to 90 degrees with a step size of 5 degrees. The control variable will be the number of pulses ranging from 25 to 50 with a step size of approximately 2.8 given the motor rotation equation below. The placement of the pair of arms will be spaced to maintain a distance of 15cm to ensure no containers can slip through. The speed of the motor will be calculated as follows to enable the retrieval mechanism:

$$\text{Motor rotation } (^\circ) = \text{step angle } (^\circ/\text{step}) \times \text{number of pulses}$$

$$\text{Motor speed (r/min)} = \text{step angle } (^\circ/\text{step}) \div 360\ (^\circ) \times \text{pulse rate (Hz)} \times 60$$

If the constant velocity motion profile for the stepper motor does not generate enough force to throw back the old containers, the acceleration profile can be used with acceleration torque and a constant rate of pulses. For the dispensing system, we will incorporate a 1 second delay between when both actuate so that the first arm can allow a container to be dispensed, which will then allow for the next container to preload itself via the second arm dropping. The upper bound on the dispensing is 9 seconds with motors for each mechanical arm having 1 second motion for the up and down movements. Thus the 1 second delay is calculated using the bound below where ‘a’ is the first mechanical arm and ‘b’ is the second:

$$\text{a down (1s)} + \text{wait (2s)} + \text{a up (1s)} + \text{delay (1s)} + \text{b down (1s)} + \text{wait (2s)} + \text{b up (1s)} \leq 9\text{s}$$

3 Cost & Schedule

3.1 Cost Analysis

The total cost for parts as seen in Figure x before shipping is $150.08. 10% shipping cost adds another $15.01 and 10.5% sales tax adds another $15.75. We can expect a salary of $25/hr x 3 hr x 60 = $4500 per team member, which would be $13,500 in labor costs for a team of three. The grand total comes out to be $13,680.84.

Table 5: Cost Analysis of All Components

Description	Manufacturer	Quantity	Extended Price	Link
Load Cell Amplifier - HX711	SparkFun	1	$10.95	Link
ATmega328 Microcontroller Bootloader Uno	Atmel	1	$5.87	Link
Adafruit WiFi / 802.11 Development Tools ESP8266	Adafruit	1	$12.08	Link
HID OMNIKEY 3121 R31210320-01 Smart Card Reader - USB 3.0 - Gray	HID	1	$17.09	Link
30-2 Grayhill Pushbutton Switch	Mouser	2	$10.50	Link

ARDUCAM 5MP PLUS OV5642 MINI CAM	Digikey	1	$45.60	Link
SLE 4442 Chip Pearl White Cards	Generic	1	$12.99	Link
10 Inch IPS LCD Panel (1024x600 resolution)	ODM	1	$35.00	Link

3.2 Schedule

Table 6: Weekly Schedule

Week	Task	Person
February 27 - March 5	Begin PCB design, incorporate TA feedback for PCB	Everyone
March 6 - March 12	Order parts for prototyping, complete design with machine shop ORDER PCB March 8	Everyone
March 13 - March 19	Spring break	Everyone
March 20 - March 26	Test machine shop prototype and make revisions if necessary, and begin board assembly	Everyone

March 27 - April 2	Complete board assembly, program microcontroller @ 3.3V, test PCB power delivery with an oscilloscope Revisions to PCB design if necessary ORDER PCB March 29	Everyone
April 3 - April 9	Integrate weight sensing and test with mechanical arms, followed by testing with containers	Everyone
April 10 - April 16	Integrate all subsystems together and test	Everyone
April 17 - April 23	Fix any remaining minor bugs	Everyone
April 25	Demo	Everyone

4 Discussion of Ethics and Safety

This project has potential pitfalls with ethics and safety issues that can conflict with the IEEE Code of Ethics and the ACM Code of Ethics, with safety and privacy of the user being two standout issues (ACM, IEEE, 2022). Namely, the user could get their finger stuck in the motor area with the chutes for dispensing and accepting containers, which is a safety concern. Additionally, with our database of user info associated with each RFID card, the user could be prone to a data leak, which is a big concern for privacy, especially in current times where data is extremely valuable (ACM, 2022).

It is our utmost priority to ensure that people's privacy is protected and they are aware of safety concerns (ACM, 2022). As noted in the IEEE and ACM Code of Ethics, we will treat all persons fairly and not discriminate against people based on race, age, disability, gender, national origin, gender identity, or gender expression (ACM, IEEE, 2022). We will also not engage in harassment of any form, including sexual harassment or bullying behavior (ACM, IEEE, 2022). Additionally, we will also accept honest criticism of our project as well as properly credit contributions by others (IEEE, 2022).

5 Citations

[1] *IEEE Code of Ethics*. IEEE. (n.d.). Retrieved February 20, 2022, from https://www.ieee.org/about/corporate/governance/p7-8.html

[2] *ACM Code of Ethics and Professional Conduct*. Code of Ethics. (n.d.). Retrieved February 20, 2022, from https://www.acm.org/code-of-ethics

[3] Admin, and Michael S says: "Barcode/QR Code Reader Using Arduino & QR Scanner Module." *How To Electronics*, 28 Feb. 2022, https://how2electronics.com/barcode-qr-code-reader-using-arduino-qr scanner-module/#What_is_QR_Code_038_how_it_works.