MEDICAL KIT DISPENSER

ECE 445 Design Document

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February 24, 2022

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1. Introduction

1.1 Problem

There have been instances during which medical necessities have been in need but are inaccessible, either due to how far the closest drug store is or the time of day during which such necessities are needed. For example, cold medicine is something that you often do not have at home and will only need when you are having a severe case of the sniffles––but circumstances are that you likely would not get such drugs if they are not relatively immediately available. Another scenario is when sometimes, the straps in our mask would snap off. Most people do not carry around a spare mask in their bag, which requires them to get another one from a store. In the era that we are currently in, addressing our illnesses and the safety of others as soon and as effectively as possible is out of everybody's best interest.

1.2 Solution

What we would like to do to address such issues is to build a modular vending machine that is targeted towards UIUC students and can be placed around campus. Our implementation of this machine is unlike any other vending machine that you can find either at ECEB or anywhere else for that matter. We would like to make it modular so that it can be as small (so that it can be placed in low-traffic areas) or as large (conversely, in high traffic areas) as it needs to be. A consequence of the modular design is that the trays that store inventory can be expanded vertically or horizontally to accommodate for every product size––a feature that is not found in any vending machine.

In addition, as this product is intended to serve the user more than to benefit the owner, the design of such device will be focused on ensuring that the user is able to obtain whatever product it is that they have ordered through a series of motion detectors. The vending machine is intended to provide goods that current students are able to obtain for free, either from McKinley or otherwise; however, such goods are often distributed to students on a quota. That is, students are able to dispense certain goods after some time period has elapsed. The software related to this device will thus serve two purposes: to track the user's past transactions to ensure that they are eligible to dispense a certain product, and to track inventory of the machine. Due to the required internet connection, an Arduino or Raspberry Pi will be used to make implementing the database-to-machine connection feasible for this project; however, the implementation of the actual machinery and any failsafe system will require at least 2 PCB boards; one to unify the BUS that connects to all the dispensing trays, the motion sensor, and the arduino so that the machine functions as intended, and the other to ensure that the individual trays dispenses an item when commanded.

Due to the modularity of the design and the implementation of the software, this machine can also serve as an all-in-one distribution center for goods that are often handed over to students as needed. While this machine is initially intended for distributing necessities, it can also be stocked with other items depending on where they are. For example, a machine at the ARC can also be used to vend sanitation wipes or some injury-related remedies.

1.3 Visual Aid

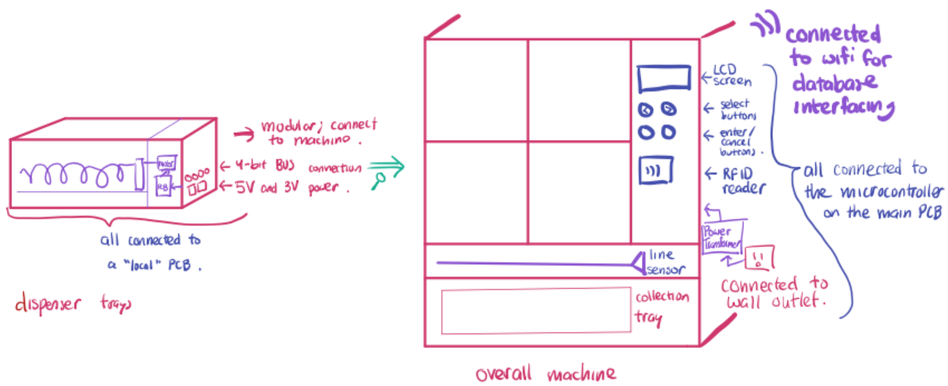


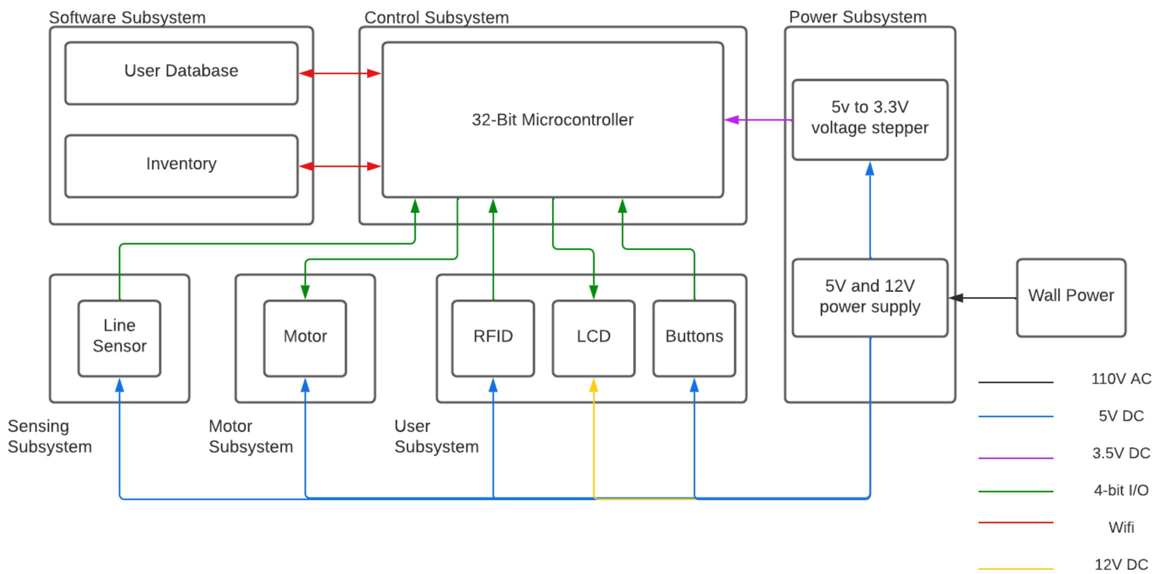
Figure 1. Physical Design of Medical Kit Dispenser

1.4 High-Level Requirements List

- ☐ The motion sensor should be able to detect if an item is dispensed by checking that the signal sent will be high, and should send a signal to the control module PCB. It should then update the user and inventory databases after it successfully dispenses a product but before dispensing the next product.
- ☐ The microcontroller should be able to read a user's identification using the RFID and successfully interpret the user ID, which prompts the LCD screen to show what the user can dispense; the user should be able to choose the product using the four buttons.
- ☐ When a product is chosen, the correct signal should be sent by the microcontroller to the BUS, and the corresponding module should activate the motor to dispense a product for five seconds before repeating up to three times.

2. Design

2.1 Block Diagram



(*) All our user I/O components will communicate with the 32-bit controller using generic I/O handling.

Figure 2. Block Diagram of Medical Kit Dispenser

For the project to be successful, the Medical Kit Dispenser will require two components: a hardware and a software component. The components board will be divided into five main units: controlling subsystem, motor subsystem, sensing subsystem, user subsystem, and the power subsystem. The control unit will consist of a 32-bit microcontroller. The power subsystem consists of a 5v power supply and a stepper that will power the control, sensing, motor and user subsystem. The user interface unit will consist of an RFID, LCD, buttons, and a line sensor. The RFID, LCD, buttons and line sensor will be connected to the 32-bit microcontroller in the control unit through wires to be connected to the PCB. The dispensing unit will consist of a motor through a 4-bit BUS. The software components will consist of two items: user database and inventory. They both will be connected to the 32-bit microcontroller in the control unit through wires and connected to the internet through wifi.

2.2 Physical Design

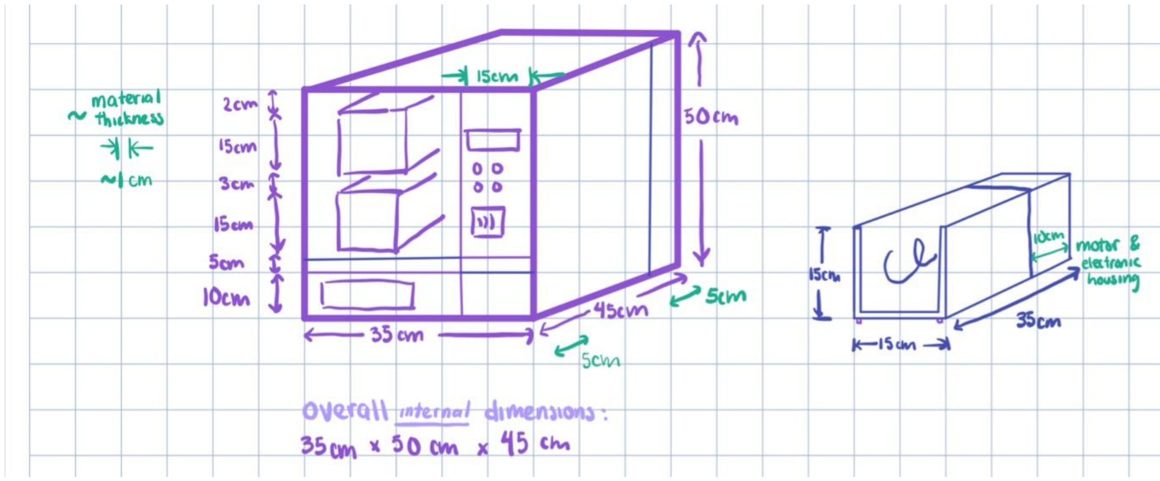
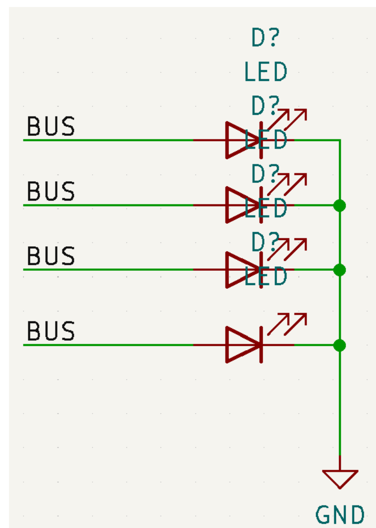


Figure 3. Physical Dimension and Design of Medical Kit Dispenser

2.3 Subsystem Requirements

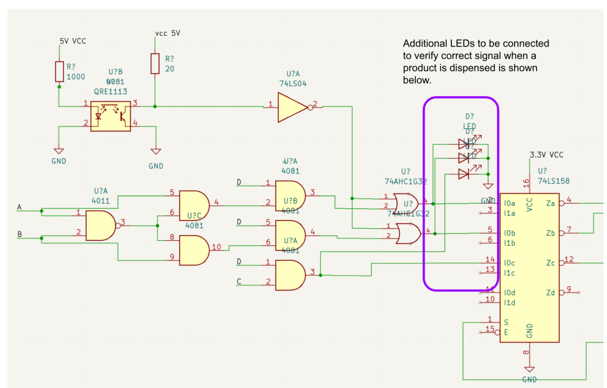
2.3.1 Control Subsystem

This is the primary subsystem that ensures that the whole machine functions as intended. The microcontroller ensures that when a valid RFID signal is received, the user is able to select and receive products that they are eligible to dispense. This involves accessing the user database (subsystem 2.2.6) to ensure eligibility, and to display the eligible entries to the LCD screen (subsystem 2.2.4). When a valid input signal is received, a BUS signal is sent to the motors (subsystem 2.2.3) through a BUS, and when a signal is registered from the sensing modules (subsystem 2.2.2), the whole cycle repeats.

Requirement	Verification
1. The correct BUS signal should be emitted when a product is chosen; 2. The correct products should be displayed to the LCD screen; 3. An RFID signal should be received and correctly interpreted by the microcontroller. 4. When a product is dispensed or indispensable, the microcontroller should update the inventory and user database correspondingly.	1. Connecting leads from the BUS to a series of LEDs on a breadboard and configuring the LED's the different motors for the different products and testing if sending the correct signal will light up the LED corresponding to the correct motor.  2. Tapping an ID card and adding various items to the inventory (both dispensable and indispensable) verifying that the correct product is shown on the LED screen. 3. Scan an id-card through the RFID signal, dispensing an object and verifying that the database for the correct user is being updated. 4. Put in a fake entry into the inventory database assigned to a non-existent tray. An attempt to dispense that item should fail after three attempts, and the inventory should be cleared.

2.3.2 Sensing Subsystem

The sensing subsystem will compromise all the sensors used. These sensors will detect whether an item has been properly dispensed. If an item has been properly dispensed, the object will pass through the line sensor and notify the microcontroller that the object has been dispensed, if not the microcontroller will know to retry.

<table>
<tr><th>Requirement</th><th>Verification</th></tr>
<tr><td>1. When motion is detected by the sensor, an active signal should be sent to the microcontroller.</td><td>1. Try to dispense an object and verify that the inventory of the object is being updated. To test the circuitry if the correct signal is being dispensed, consider below; attach 3 LEDs to the input of the MUX as shown. If the correct signal is being transmitted, the LED should signal 0 1 1 from top to bottom, where 0 is “off” and 1 is “on.”

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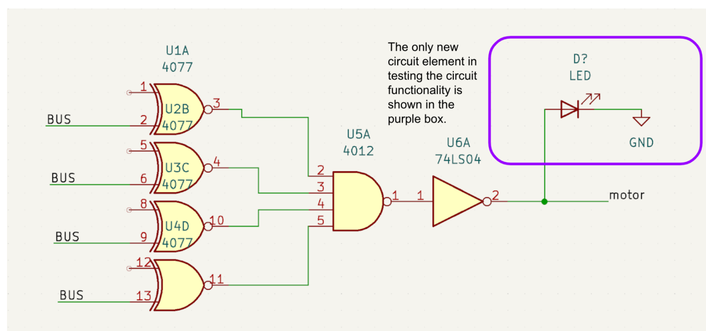
2.3.3 Motor Subsystem

The motor subsystem is in charge of dispensing items. A signal will be sent by the microcontroller through the bus to the motor and will push the object down for dispensing.

<table>
<tr><th>Requirement</th><th>Verification</th></tr>
<tr><td>1. When the correct signal is delivered across the BUS, the motor should activate for exactly one cycle on a rising edge.</td><td>1. One can artificially send a BUS signal by connecting leads to the BUS entry ports of the dispenser module and either connecting it to 3V power or to ground to represent a “1” or “0” bit. Then, attach an LED to the wires connected to the motor; if the LED illuminates upon the correct signal being transmitted across the BUS, the device is deemed to be functional.



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2.3.4 User Subsystem

The user subsystem comprises all the parts that the user will interact with including the LED screen, RFID and buttons. The LED screen is used so that users will be able to see what items they are able to dispense or choose what items to be dispensed. The buttons will be used for users to interact with the LED screen and choose which product they would like to be dispensed. The RFID module will be used to read the i-cards of users to identify who they are.

Requirement	Verification
1. The correct products should be displayed to the LCD screen 2. An RFID signal should be received and correctly interpreted by the microcontroller	1. Adding products to the inventory and verifying that the correct product is shown on the LED screen 2. Scan an id-card through the RFID signal, try to dispense an object through that account and verify through the database if it labels that account as having dispense the object.

2.3.5 Power Subsystem

The power subsystem will be plugged into a standard wall plug and convert it to a 5V DC power supply. This will be used to power the user subsystem, the sensing subsystem and also the motor subsystem. From there the 5V power supply will be stepped down to 3V to power the 32-bit microcontroller.

Requirement	Verification
1. The power system must take in 120V and output a 5V DC current to the PCB 2. The power system must transform the 5V DC current and step it down to a 3.3V DC current	1. Use a voltmeter to detect the output voltage from the power system and verify if it is 5V 2. Use a voltmeter to detect the output voltage from the step-down power converter and verify that it is 3.3V

2.3.6 Software Subsystem

The software subsystem will compromise two parts: inventory and user database. The inventory component will track the current items in the dispenser and will inform the microcontroller of what items are currently available so it will be able to display the correct information on the LED screen. The user database is to be used to identify users who are currently using the dispenser and inform the microcontroller to display what items each user is able to dispense based on the quota they have on the item.

Requirement	Verification
1. When a product is dispensed or indispensable, the microcontroller should update the inventory and user database correspondingly.	1. Scan an id-card, try to dispense an object and see if the database gets updated correctly.

2.3.7 Supporting Figures and Descriptions

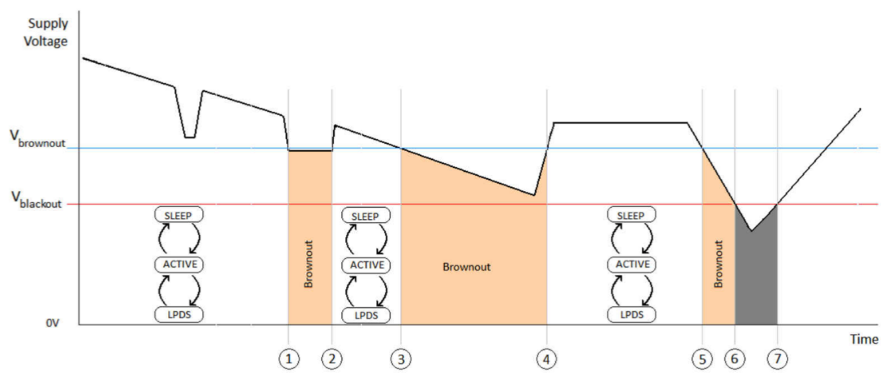

Figure 4. Brownout and Blackout Conditions of Microcontroller[2]

The supplied voltage must be above 2.1V but below 5V at all times to prevent brownout and blackout operation; as live data transmission is required for our device, it is imperative that the device does not enter the two aforementioned conditions.

Table 15: Electrical Characteristics Of LD1117#30C (refer to the test circuits, T_J = -40 to 125°C, C_O = 10 μF unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_O	Output Voltage	V_{in} = 5 V I_O = 10 mA T_J = 25°C	2.94	3	3.06	V
V_O	Output Voltage	I_O = 0 to 800 mA V_{in} = 4.5 to 10 V	2.88		3.12	V
ΔV_O	Line Regulation	V_{in} = 4.5 to 12 V I_O = 0 mA		1	30	mV
ΔV_O	Load Regulation	V_{in} = 4.5 V I_O = 0 to 800 mA		1	30	mV
ΔV_O	Temperature Stability			0.5		%
ΔV_O	Long Term Stability	1000 hrs, T_J = 125°C		0.3		%
V_{in}	Operating Input Voltage	I_O = 100 mA			15	V
I_d	Quiescent Current	$V_{in} \leq$ 12 V		5	10	mA
I_O	Output Current	V_{in} = 8 V T_J = 25°C	800	950	1300	mA
eN	Output Noise Voltage	B =10Hz to 10KHz T_J = 25°C		100		µV
SVR	Supply Voltage Rejection	I_O = 40 mA f = 120Hz T_J = 25°C V_{in} = 6 V V_{ripple} = 1 V_{PP}	60	75		dB
V_d	Dropout Voltage	I_O = 100 mA T_J = 0 to 125°C		1	1.1	V
		I_O = 500 mA T_J = 0 to 125°C		1.05	1.15	
		I_O = 800 mA T_J = 0 to 125°C		1.10	1.2	
V_d	Dropout Voltage	I_O = 100 mA			1.1	V
		I_O = 500 mA			1.2	
		I_O = 800 mA			1.3	
	Thermal Regulation	T_a = 25°C 30ms Pulse		0.01	0.1	%/W

Figure 5. Electrical Characteristics of the 5V to 3.3V stepper[4]

The stepper is able to output a stable voltage of above 3V under a 5V input voltage. Assuming proper functionality, this ensures that the microcontroller is always active.

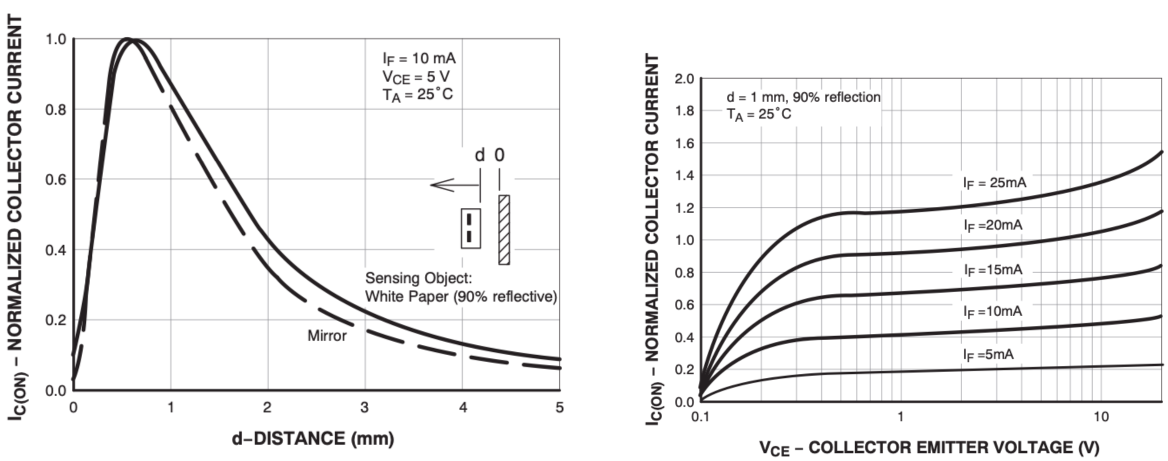

Figure 6. IV Curves of the Line Sensor as a function of distance and V_{CE}[3]

The line sensor will be designed to be active low; that is, it will have a “high” output when no item is dispensed and “low” when otherwise. As the device operates using a phototransistor, it will detect an object by an instantaneous lack of reflectivity that causes the photocurrent to decrease. The current can be passed through a resistor and connected to the microcontroller to probe a “high” or “low” state.

2.5 Circuit Diagram

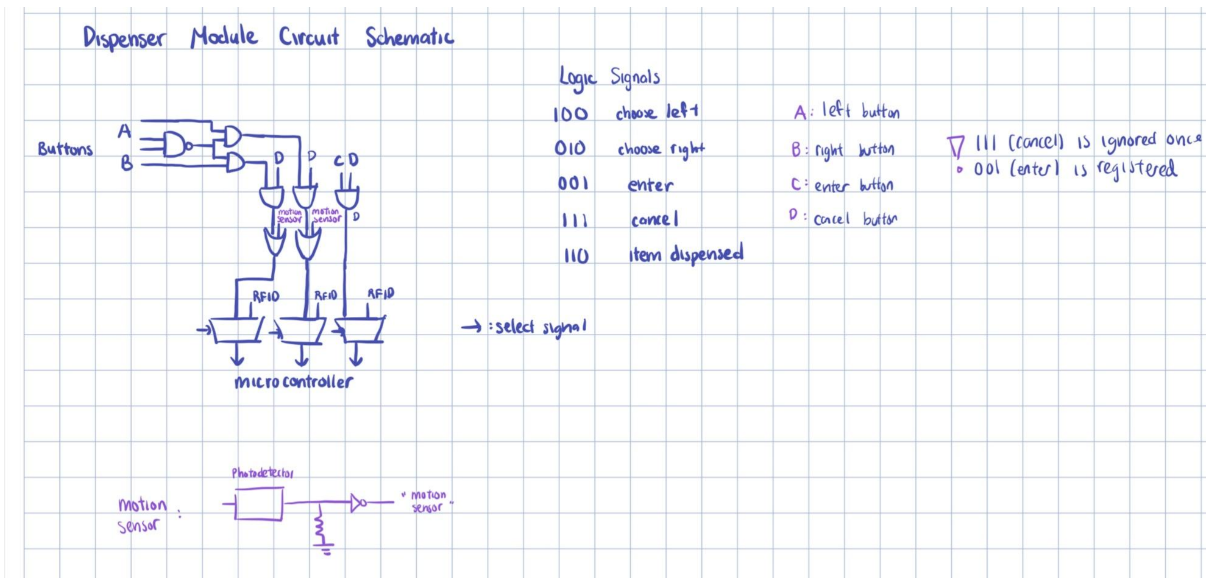

Figure 7: Circuit Diagram of Relevant Electronic Components Requiring Logic Design

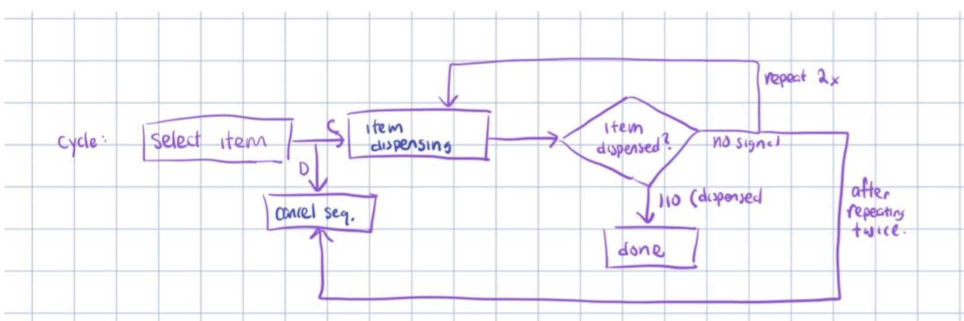

Figure 8: Functional Block Diagram of Circuit in Figure 7

Figure 7 shows the logic implementation required for our device; our microcontroller has 24 general I/O pins, and 16 pins will be dedicated to the LCD screen and four pins to the BUS. Consequently, we have four pins to drive the remaining logic; therefore, a series of states will be used to break down the signals from each device. The circuit diagram in Figure 7 shows how three input pins and one output select pin is sufficient to drive the remaining logic, which involves the input from the RFID sensor, the buttons, and the motion sensor, as facilitated by a series of multiplexers and logic gates. We will be implementing an I2C protocol for communications between the RFID module and the microcontroller, and the pins compatible for such communication have been assigned as such.

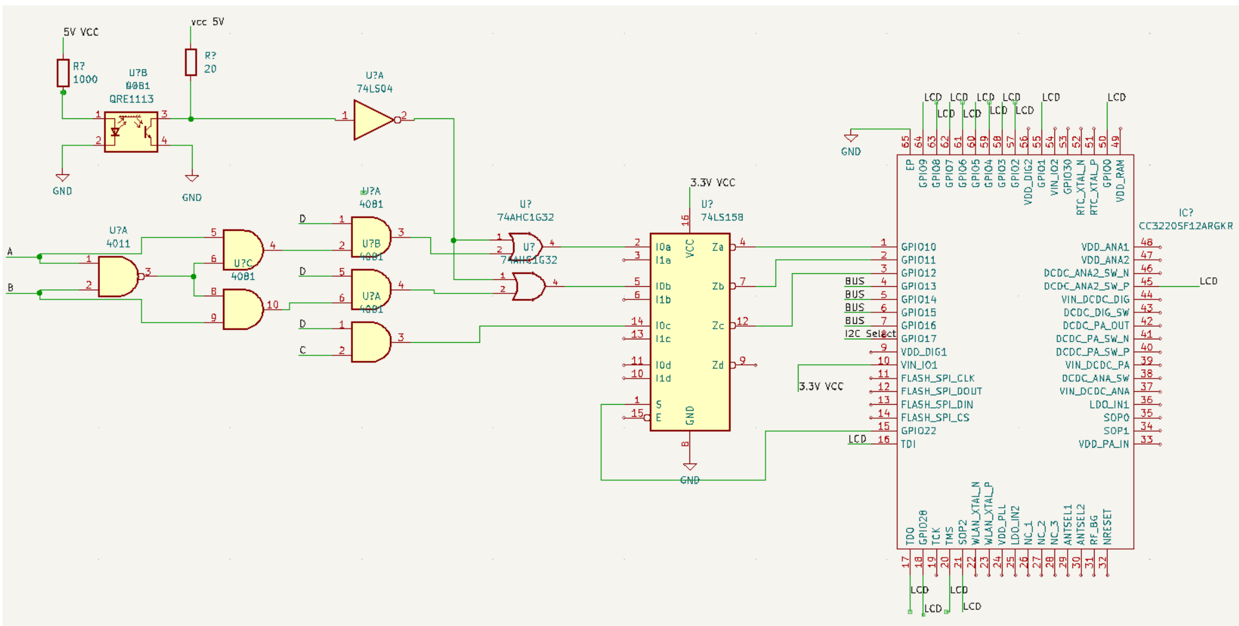

Figure 9: Circuit Diagram of Controller Module; Implementation and Integration of Circuit in Figure 7

The circuitry required to implement the dispenser module and activating the motors is relatively simple; if the appropriate signal is being transmitted across the BUS, then a series of NXOR gates should transmit a 1 signal; if all four signals are active, then the motor should detect a high signal and run for one cycle, which will be directly clocked by the 32-bit microcontroller across the BUS.

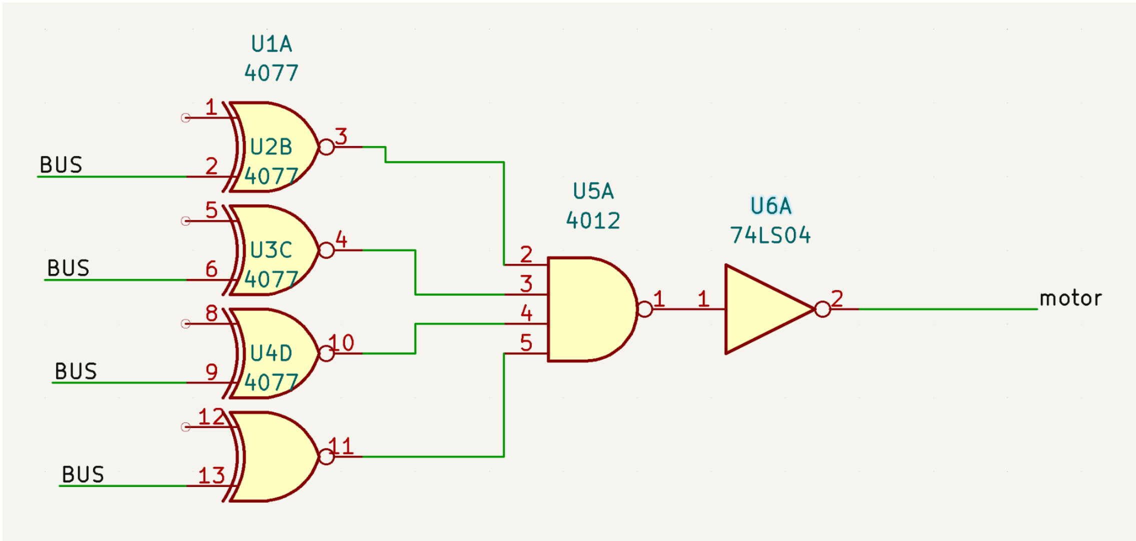

Figure 10: Circuit Diagram of the Dispenser Module

2.5 Tolerance Analysis

There are several areas where errors can occur, and the origins can be generally attributed to software and hardware. The most prominent software issues will likely be errors in communication between the machine's microcontroller and an online database; an example would be an unsuccessful update of the inventory database and the user database. However, as the reliability of the internet connection that the device will rely on to communicate with the online database is out of our control, our tolerance analysis will simply be that an update to inventory and the user information will be done prior to the next dispensing cycle.

The most significant source of error from a hardware point of view would be from the voltage response of the line motion sensor as it is a function of reflectivity, which itself is a function of the distance between the object and the sensor, and of the material being dispensed. The V_{CE} of the phototransistor saturates at 0.3V; as such, assume that the target voltage entering the photoresistor is 0.5V during the "on" state. To that end, as we are using a 20 Ohm resistor to pin down the voltage under flowing current, and as shown in Figure 6, choose the collector voltage to be 0.2A. When the reflectivity is measured to be low, assume that the reflectivity can yield a normalized current within the range of $I_n \in [0, 0.3]$, implying a current of $I \in [0, 0.06]\,A$ when an item is sensed

to have dispensed.[3] Therefore, during the "low" state of the motion sensor, the voltage being transmitted to the logic will be calculated below:
By design, choose V_C = 5V and R = 20 Ohms. Assume that I = 0.06A as the upper current limit during the off state and I = 0.2A during the on state. Then using V = IR, during the on state, the voltage should be V = 5 - (20*0.2) = 1V, and during the off state V = 5 - (20 * 0.2 * 0.3) = 3.8V. The trigger voltage for the AND gates is 3V, meaning that the logic gates are able to differentiate between ON and OFF states well within our tolerance ranges. [5]

There can also exist a time delay in communication between the hardware components that are difficult to determine ahead of time. For example, the time required for the RFID reader to completely read an ID card and transmit the time to the microcontroller is a function of clocking speed, the size of data to be transmitted, and processing time by both the microcontroller and the RFID reader. As such, while we are predicting that the operation should take five seconds, we will need to determine the total processing time; the processing time should be consistent and we expect that the variance should be in a range of +/- 1 second.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Assume that an electrical engineer responsible for designing and assembling the circuitry and electronics of this project is paid $45/hour in compensation. A reasonable time estimate for the construction and assembly of this implementation of this machine is 3 hours. Furthermore, the PCB design and assembly of this machine, which includes compatibility testing and simulations, will likely take 12 hours per partner. The software design component will likely take 48 hours to implement and debug, and that integrating the microcontroller with the software will take 24 hours. It is expected that it should take around 2 hours of labor for the machine shop to create the housing for the dispensing machine; it is reasonable to assume that they are paid $40/hour in compensation.

3.1.2 Parts

The hardware components that will be used for this project, along with the associated costs, is outlined below:

Item (linked)	Quantity	Cost (USD)
Microcontroller	1	10
RFID Module	1	40
Metal Pushbutton	4	20
120V to 12 and 5V Transformer	1	20
5V to 3.3V Stepper	1	2
16x2 LCD Screen	1	10
Object Reflection Sensor	1	2
12V DC Motor	1	17
Vending Machine Spirals	1	8
Spiral Adapter	1	2
Purchasing Total (assuming 10% tax)		131 (144)
Labor		4980
Grand Total		5124

3.2 Schedule

Week	Josh Leeman	Dylan Hartato	Matthew Chung
1	Design Document. Design the PCB for the Module.	Design Document. Design the PCB for the Control Module.	Design Document. Design the idea and skeleton for the backend software.
2	Design Document is Due. Get the PCB design approved so that it can start.	Design Document is Due. Get the PCB design approved so that it can start. Try to start	Design Document is Due. Fill out Google form to place an order, so that we can start early.
3	Spring Break	Spring Break	Spring Break
4	Complete the PCB to work and Make it work together with the Motors	Complete the PCB to work and Make it work together with the Motors	Complete Software Code to work with Backend. When finished, help assemble the housing and slots
5	Make the Multiple Subsystem work together and test for errors	Make the Multiple Subsystem work together and test for errors	Make the Multiple Subsystem work together and test for errors
6	Make the different subsystems work and debug the problems	Make the different subsystems work and debug the problems	Make the different subsystems work and debug the problems

	(anticipating most of the problems to be the different parts working together properly.	(anticipating most of the problems to be the different parts working together properly.	(anticipating most of the problems to be the different parts working together properly.
7	Finish up and make sure everything works for the Mock Demo. Try to keep on testing. This week is generally kept empty just in case something happens and extra time is needed.	Finish up and make sure everything works for the Mock Demo. Try to keep on testing. This week is generally kept empty just in case something happens and extra time is needed.	Finish up and make sure everything works for the Mock Demo. Try to keep on testing. This week is generally kept empty just in case something happens and extra time is needed.
8	Mock Demo	Mock Demo	Mock Demo
9	Final Demonstration. Work on presentation and Final Paper.	Final Demonstration. Work on presentation and Final Paper.	Final Demonstration. Work on presentation and Final Paper.
10	Final Demonstration and Final Paper Due	Final Demonstration and Final Paper Due	Final Demonstration and Final Paper Due

4. Ethics and Safety

Every piece of technology has its risks, and such risks can range from abuse of collected information or risk of injury to the user from unintentional misuse. While the implementation of our device requires us to collect some data regarding the user's vending history, none of the information should be considered sensitive. However, user information should not be divulged unless absolutely necessary to ensure privacy, and as such the user information database and inventory database should be implemented independently to ensure that those who have access to inventory are not able to access user information without proper credentials.

The primary safety concern is primarily electrical; the machine will house a 120v to 5v and 12v stepper, and a lower 5v to 3.3v stepper. To ensure that high voltage electrical hazards are minimized, the 120v stepper is enclosed and will be isolated from the majority of the electronics and human-to-machine contact points. In addition, the wattage of the whole machine is sufficiently low (~120W) such that the likelihood of a fire hazard from a malfunction of the transformer is very low.

Any wiring carrying the 12V voltage will run in the back of the machine from the transformers to the modules and then the motors, and thus the risk posed to the user is very small. The user interfaces are all going to be made from insulating material (such as plastics) to prevent any electrical injuries from occurring to the users. The 5v and 3.3v electronics will be primarily housed on the PCB board, which itself is isolated from the buttons and screen that the user may touch; even so, the voltage is sufficiently low that it does not pose a significant hazard to the user.

In regards to the IEEE code of ethics, we are ensuring that we are going to follow the code of conduct, specifically in Article I, number 1 [1]. Our device is going to keep the privacy of others because we are going to only collect when a certain person has dispensed an item. Each user is going to be stored as an ID, not by their names, so user information is going to be ambiguous. Furthermore, the information is going to be held in the database, which is not accessible by anyone. Another article that we will follow is on the idea that we are not going to discriminate against others as stated in Article II number 7 [1]. We are following this by ensuring that we are not going to purposely hand out more supplies to certain individuals. Since we are ensuring that everyone will have a quota on supplies, no one is going to have more than the others, at least purposefully.

5. References

[1] “IEEE code of ethics,” IEEE, Jun-2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 10-Feb-2022].

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