UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN
ECE 445: SENIOR DESIGN

Covid-19 Convenience Locker

Project Proposal

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1.**Introduction**

1.1 Objective

COVID has affected students' lives for around a year and has caused tremendous inconvenience to us. It is likely that the COVID pandemic will continue for a long time. Here at U of I, we are required to take saliva tests day by day at specific locations. This will make our life inconvenient since we need to move to the Illini Union and somewhere else to take tests. Some students may live far away from these test locations and it is difficult for them to go to these test locations day by day. On the other hand, too many students presenting at the test locations at the same time may also cause potential infections. While we think it is feasible to arrange some lockers around student's apartments which will make it easier to access the testing tube and then store them.

We propose a locker with testing tubes inside locating at each large student apartment. The students are required to access the testing tube every other day and then store it inside the locker before a specific time. The testing staff should pick up the tubes each day. Our objective is to design a machine that can use mechanical structure to distribute and store the testing tubes. To identify the tester information, we would try qr-code verification to print identity labels. A mechanical component should be designed for each user to pick up and store exactly one testing tube, for example, mechanical FIFO or rotation distribution design. We also expect there is an energy saver module which could let the whole locker in sleep mode when there is no person accessing the locker. To avoid possible contamination by COVID virus, we also propose a liquid pump which will dispense alcohol spray after someone has used the locker. A temperature sensor and a cooling fan are also designed to avoid high temperature inside the locker when it is in summer. A thermal printer will be used to print labels while the students should stick it onto the testing tube.

1.2 Background

Since the spread of COVID-19, COVID testing has become a necessary part of everyone's life. In U of I, all students have to take saliva tests twice per week to gain access to buildings. According to the statistics of SHIELD, there are totally 1,387,056 tests taken on campus by now. Economically speaking, a large amount of testing will bring huge cost and utilize many resources. For example, every testing location has to be assigned a certain number of people to help distribute and collect testing tubes. In addition, for testers, it is probable that some of them have to spend much time going to the test location, which makes it inconvenient in daily life. For safety, although the distance between people is strictly controlled in the testing location, it is still possible to cause potential infection when many people take tests in the same place and same time. Because of these three reasons, we decided to design a convenience locker to help reduce the cost and trouble for testers. There is no need for human resources any more because the locker itself can distribute and collect tubes by internal rotator. For each community area, we can place several lockers there so there is no need for residents to go outside and take the test. Since people can get a tube and go back home to take the test and then return the tube, the situation of many people taking tests in the same place at same time will not happen any more, which decreases the potentiality of infection.

1.3 Visual Aid

Inspired by the convenience of vending machine design, this project aims to automate the covid-19 testing process. Utilizing the electrical hardware and mechanical design, the team is able to design the programmable testing tube distribution system. A visualization is shown in Fig. x.

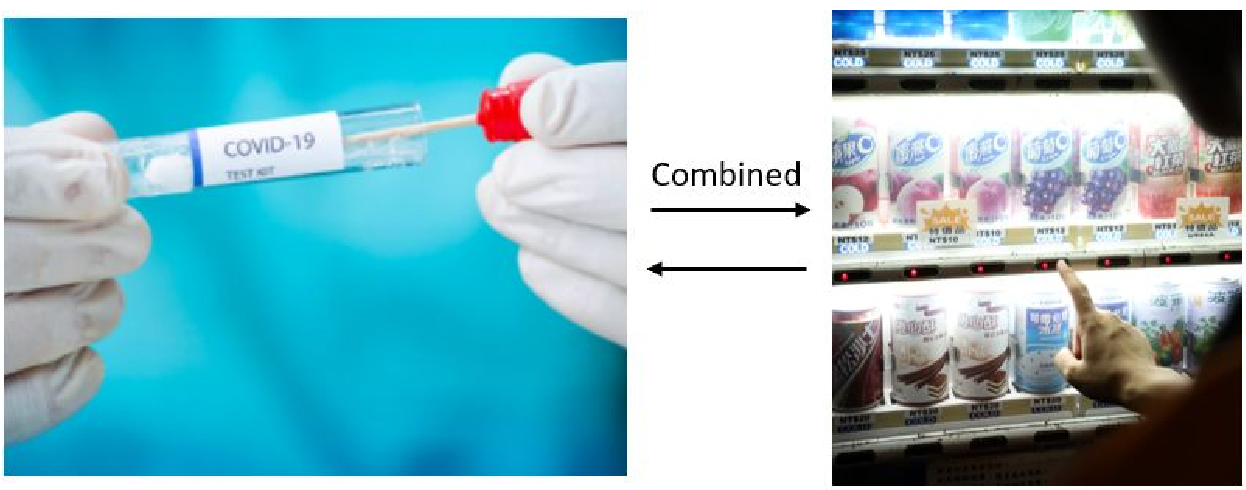

Figure x. Visualization the goal of ECE445 Covid-19 Convenience Locker [1]

1.4 High-level Requirements List

- The internal rotator must be able to rotate 45° each step to distribute and collect 8 testing tubes through servo motors.
- Student's I-card can be detected by RFID with accuracy above 90% and the identity information will be printed via thermal printer.
- LCD must be able to display temperature and humidity of the environment of testing tubes collected by temperature and humidity sensors.

2.Design

2.1 Block Diagram

The success of this project relies on the successful operation of 6 modules: power unit, mechanical system, processing module, environment control module, identification module, and display module. The power module will handle the voltage conversion and continuously provide power to the other modules. The mechanical system will distribute and receive only 1 testing tube per test. The process unit will communicate with all the other electric modules. The environment control module will guarantee the storage temperature is below 30°C. The identification unit will identify UIUC i-card under 125kHz with above 90% accuracy and print the tube label with corresponding student's information. The display section will report the locker's temperature and student's information. If temperature is above threshold temperature, the LED will turn on and notify the students the locker is unavailable. The detailed block diagram is attached as Fig x.

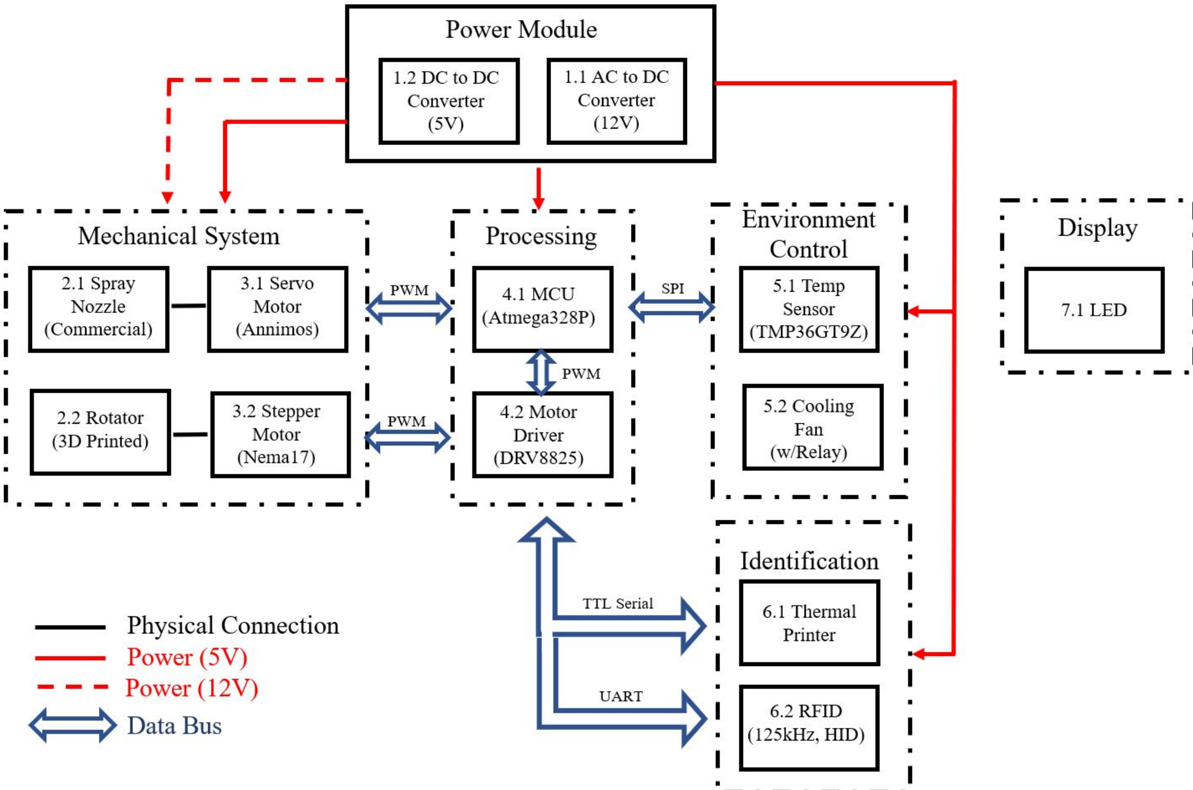

Figure x. Block diagram of Covid-19 Convenience Locker

2.2 Physical Design

The detailed CAD assembly of covid-19 convenience locker is shown in Fig x. The connection between electronic devices is not shown in the figure.

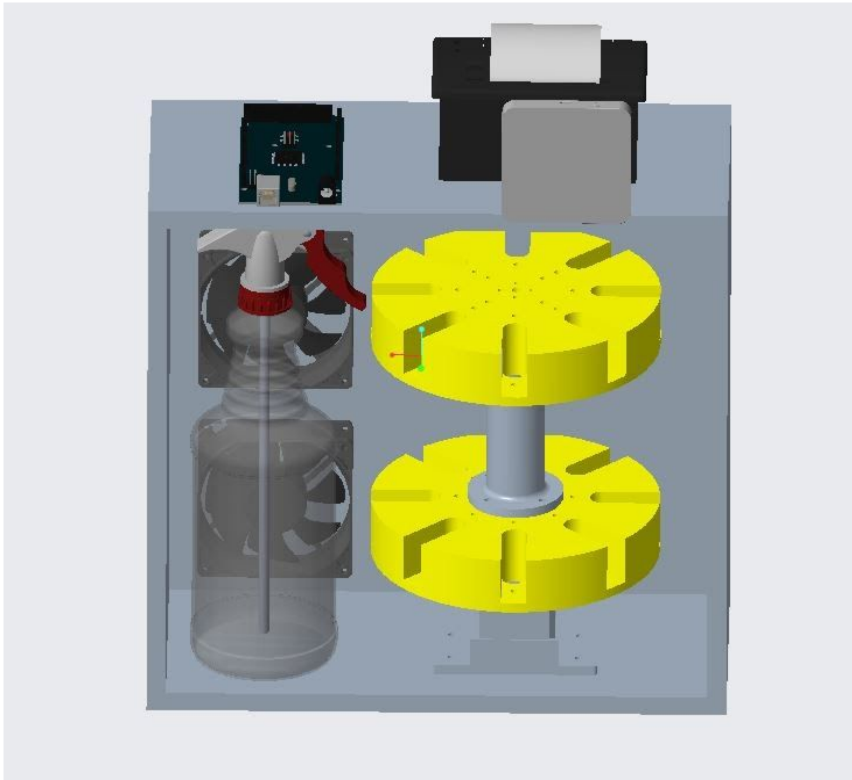

Figure x. CAD assembly of Covid-19 Convenience Locker

2.2.1 Power Module

The power module takes 120VAC from the wall outlet as input power, and output 12VDC and 5VDC to our system. Since we assume that all the students' apartments have outlets inside the building, the battery (requires charging frequently) is not considered in this project. Our power budget is ~12.6W, which is mainly consumed by Nema17 servo motors(12V,0.35A), thermal printer(5V,1.5A), 2 x cooling fans(5V,0.18A).

2.2.1.A AC to DC Converter (12V)

Since the team is planning to directly use the US standard outlet as the main power source, AC to DC converter is important to continuously provide 12VDC power into the PCB. Because the female socket connected to the power source could only handle the current smaller than 3A, the team needs to make sure the current draw from the power source never exceeds this threshold current. Also. The team needs to make sure the peak operating temperature (hotspot) is smaller than 120°C (typical PCB operational temperature)

Requirement	Verification
1.) Current drawing from the power source should be smaller than 3A. 2.) Local temperature of hotspot during operation should be smaller than 120°C.	1.) Sweep the electronic components and test the peak current. 2.) Utilize a temperature sensor to measure the PCB temperature near the input power source.

2.2.1.B DC to DC Converter(5V)

Except the 12VDC power used by a servo motor, other electronic devices operate at 5VDC signal. P78A-0500 linear regular is used in this project. P78A-0500 requires input voltage from 7-28 VDC, and will output dc voltage 5V ($\pm 3\%$). Also, the max current limit for P78A-0500 is 500mA. Since the final device is targeted to operate in the Illinois area, the device should be able to function at -20°C area.

Requirement	Verification
1.)The device can output dc voltage 5V ($\pm 3\%$). 2.) The device is able to operate normally at low temperature (-20°C).	1.) Use a high-accuracy oscilloscope to determine the output voltage accuracy. 2.) Check the functionality during the low temperature condition (for example on a cooling plate)

2.2.2 Mechanical System

The mechanical system is related to the success of distributing/receiving testing tubes and sanitizing the interior area. The small servo motor is attached directly to the spray bottle to automate the sanitizing process, while a larger servo motor is connected to the tube rotator system to distribute and receive the testing tubes.

2.2.2.A Servo Motor(Annimos)

The servo motor must be quick enough(large acceleration) to initiate enough pressure difference within the spray bottle. The approximation acceleration could be calculated using Bernoulli Equation. Assume no energy loss, for a spray bottle with height $\sim 20cm$, the required pressure difference is approximately $1.54 \cdot 10^{-4}$ Pa. Given the mechanism configuration of the motor, the required acceleration is about 0.038 m/s^2 . To make sure the spreading area is large enough to cover all the testing tubes, the servo motor should be able to press the spray multiple times within short time duration($\Delta t \leq 1s$).

Requirement	**Verification**
1.)The arm of the servo motor should be able to accelerate with 0.038 m/s^2 . 2.) The servo motor should be able to spray multiple times within short time duration($\Delta t \leq 1s$).	1.) Use a high speed camera to capture the motion of the servo motor, and characterize the dynamic information. 2.) Measure the continuous operating performance via a timer.

2.2.2.B Stepper Motor (Nema17)

The PID 324 Stepper Motor - NEMA-17 has 200 steps per revolution which gives 1.8 degrees per step. NEMA-17 has an operating voltage ranging at 12V. It should be directly connected to the power supply. There are 8 testing tubes in the whole system. So, the stepper motor should rotate 45 degree each time which is 25 steps. The holding torque for the stepper motor is 1.6kg/cm which is above what we need for the locker. The stepper locker also needs to be connected to the motor driver to receive the rotating signal.

Requirement	**Verification**
1.)The stepper motor could rotate 45 degree each time and distribute the testing cube correctly. 2.) The servo motor should be able to rotate without being stuck.	1.) Test the step motor separately to see whether it could rotate in the locker 2.) Write the program into the motor driver and complete around 50s~ rotation to check.

2.2.3 Processing

2.2.3.A Micro-controller (Atmega328P)

The Atmega328P is the central controller of the whole system. Every command should be sent from Atmega328P. The Atmega328P has an operating voltage ranging from 1.8V to 5.5V. A DC controller will help to transfer the 12V input voltage to the proper voltage range. The temperature range for the Atmega328P is from -40 Celsius to 85 Celsius. This could be easily satisfied. Power Consumption at 1MHz, 1.8V, 25°C for the Atmega328P is 0.2mA at active mode. By P=UI, we can get the power is 0.36 mW. We would write programs for each part separately and test them through the Atmega328P.

Requirement	**Verification**
1.) The micro controller should be able to send signals to each part and receive data from each part.	1.) We would test our program one by one. Every time we wrote a program in, we would use an oscilloscope to test the behavior of each part to prove we are doing the right thing.

2.2.3.B Motor Driver(DRV8825)

The DRV8825 is designed to control the NEMA17 since it requires 12V input. The DRV8825 has a 8.2V to 45V operating supply voltage. We would connect it to the 12V DC supply. The DRV8825 will give a 12V supply and 350mA current supply to the Nema17.

Requirement	**Verification**
1.)DRV8825 should be receive signal from the Atmega328 2)DRV8825 should be able to control the Nema17 after it receive signal from Atmega328	1.) We would test whether DRV8825 could function properly after we wrote a program into the Atmega328 2)If the above is correct, we will connect it to the Nema17 and test the functionality of Nema17.

2.2.4 Environment Control

2.2.4.A Temperature Sensor(TMP36GT9Z)

The TMP36 is the temperature sensor in our design. When the temperature is too hot, it should send commands to the Atmega328P and the Atmega328P will send commands to the cooling fan. The TMP36GT9Z has an operating voltage ranging from 2.7V to 5.5V. A DC controller will help to transfer the 12V input voltage to the proper voltage range. The self-heating of the temperature sensor is as low as 0.1 Celsius in the air. The temperature sensor could provide typical accuracies of ±1°C at +25°C and ±2°C over the −40°C to +125°C. The TMP36 we used has a 10 mV/°C scale factor and it provides a 750 mV output at 25°C.

Requirement	**Verification**
1.) The TMP36 correctly output 750mv at 25°C 2.) We could detect a 10 mV/°C scale factor when the temperature changes.	1.) Test the TMP36 in a air-conditioned room at 25°C 2.) Change the temperature to 15°C and test the output.

2.2.4.B Cooling Fans(w/Relay)

We would use 2 USB DC fans as the cooling component. The operating voltage is 5V and we would use the Atmega328P to control the fans. When the temperature sensor sends a high signal, the Atmega328P should enable the voltage.

Requirement	**Verification**
1.) The fan should start when it is 35°C.	1.) Test the fan is working first 2.) Change the temperature to 35°C and test whether the fan is working

2.2.5 Identification

2.2.5.A Thermal Printer

The ADA597 will be used as a thermal printer. The ADA597 has an operating voltage ranging from 5V to 9V and an operating current of 1.5A. We would use a DC converter to reach this goal. This printer uses common 2.25" wide thermal paper which is widely available.

Requirement	**Verification**
1.) The printer should print correctly according to the Atmega328	1.) Test the printer to make sure it is running and the connection is right 2.) Test the code in the Atmega328P and test

	the printer on correct printing

2.2.5.B RFID Reader

The HID 5455BkN00 will be used as a RFID reader. The average operating voltage and operating current is 25 mA at 5 V. The operating temperature is -30°C to 65°C. The size is 127mm*127mm so it could perfectly fit into our locker. The RFID frequency range for the reader is 125KHz, which fits our i-card.

Requirement	**Verification**
1.) The RFID reader could read the correct the information and sent to the Atmega328	1.) We would connect it to the Atmega328 and test whether it could read the correct information. 2) We should test whether the input voltage is correct.

2.2.6 Display

2.2.6.A LED(WP7113ID)

The WP7113ID can emit high efficiency red light. The operating voltage is 1.5V for this diode at 25°C. The red light should be on when the temperature is above the threshold temperature. It will receive signal from the Atemaga328P and turn on.

Requirement	**Verification**
1.) The red light should be on when the temperature is above the threshold temperature.	1.) We would first test it is working under a certain voltage 2) We should test whether the input voltage is correct when the temperature is above the threshold and test whether it emits red light.

2.3 PCB Design

2.3.1 Schematic

Power Module

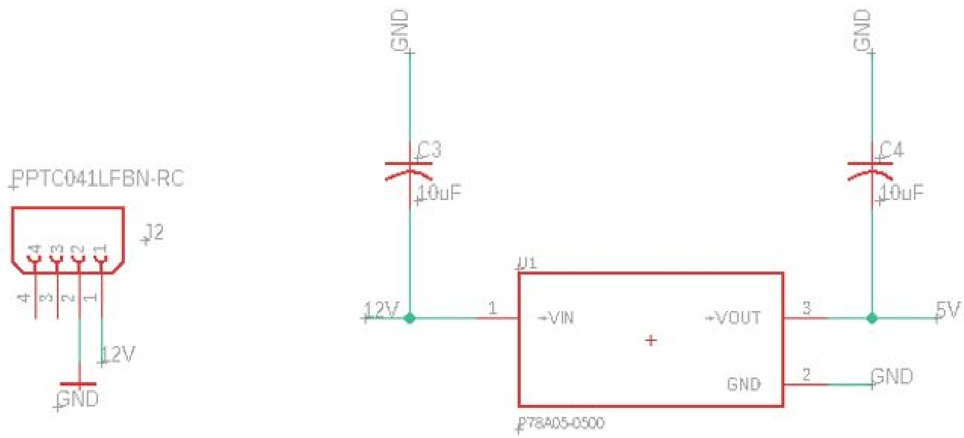

Fig x. PCB Schematic of Power Module

MCU

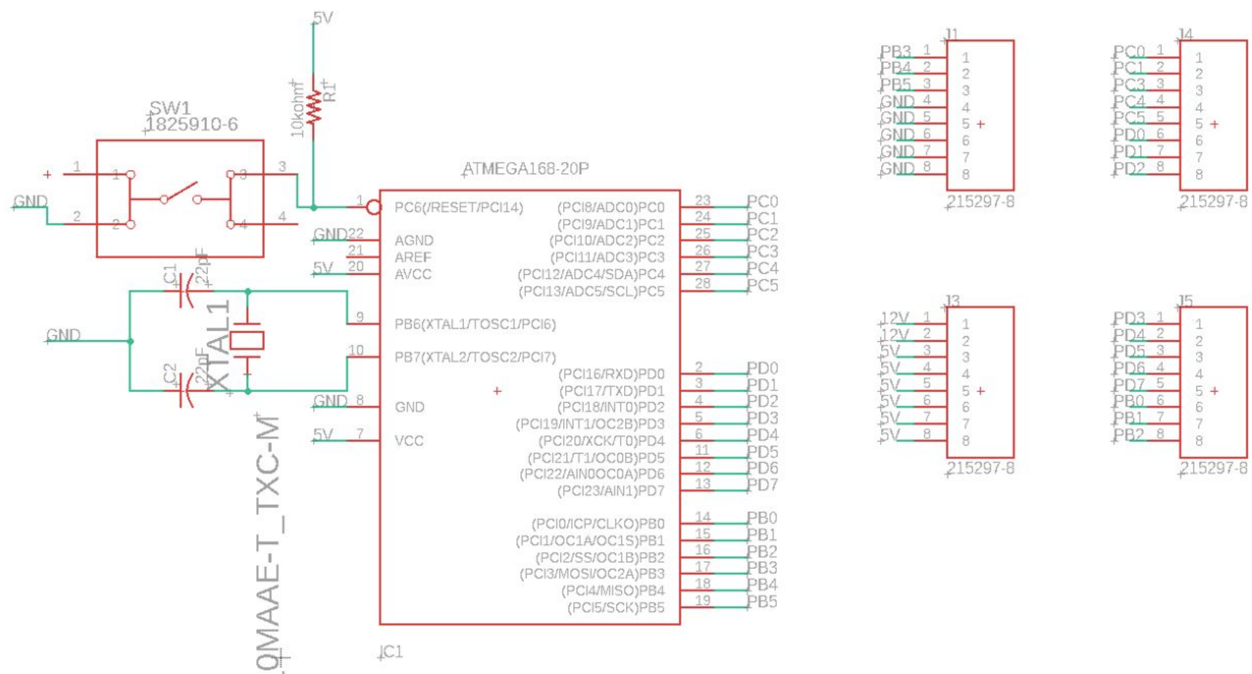

Fig x. PCB Schematic of Microcontroller Module

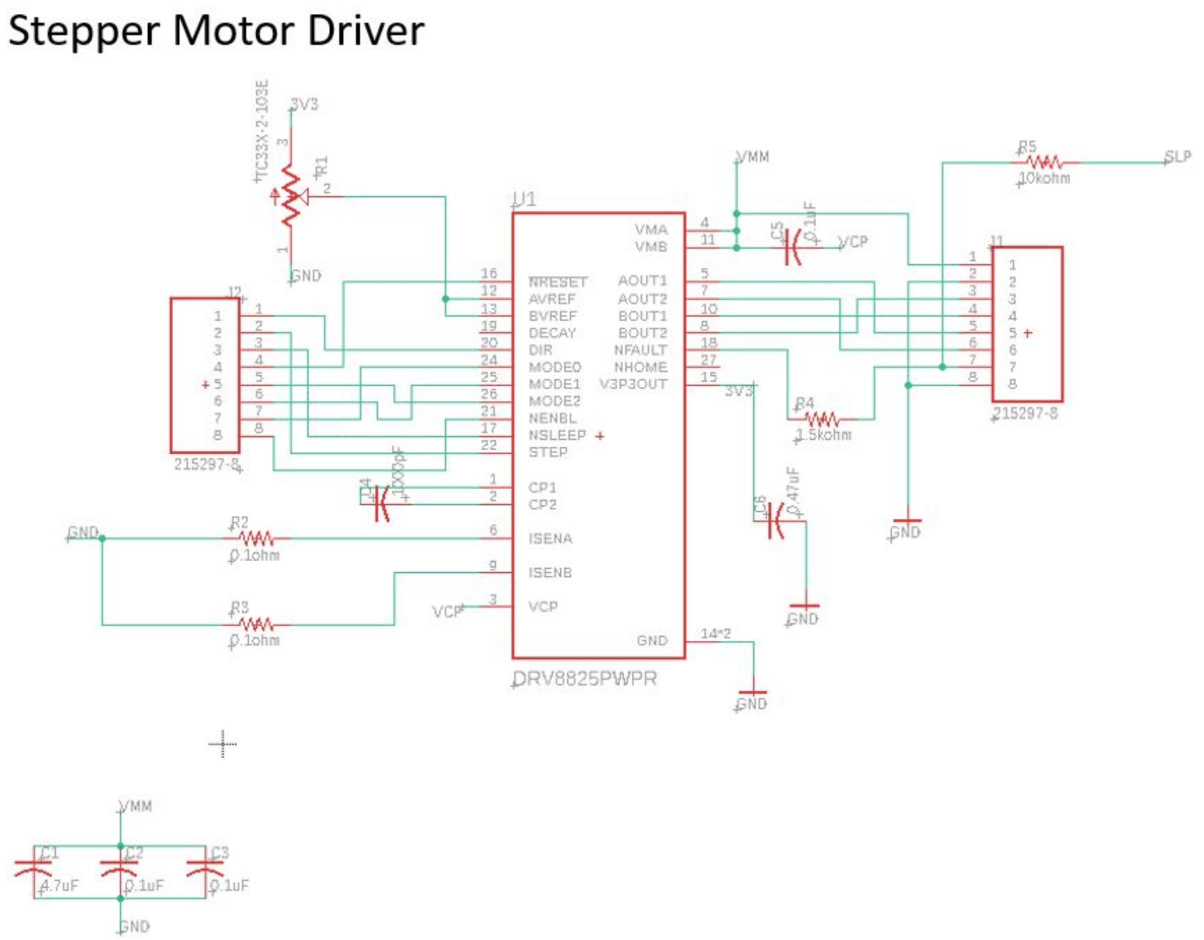

Fig x. PCB Schematic of Stepper Motor Driver Module

2.3.2 PCB Layout

3. **Cost and Schedule**

3.1 Cost Analysis

3.2 Schedule

4.**Discussion of Ethics and Safety**

5. Citations

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