Laundry Machine Availability Tracker

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ECE 445 Design Document - Spring 2020
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1. INTRODUCTION

1.1 Objective

A popular amenity that apartments have is the addition of in unit laundry. Many apartments, however, do not come with in unit laundry and there is usually a communal laundry room that is shared by the apartment's tenants. This is similar to university dorm laundry in which students living in the same dorm share several dorm laundry rooms that they must bring their laundry to. The problem many people encounter with a communal laundry room is finding an available unit when they are sharing with so many others. This can lead to several trips to and from your unit to the laundry room waiting for an available washing unit to open. There is also not an efficient system to manage the who waited the longest other than physically waiting in the laundry room for someone's laundry to finish and claiming it on a first come first serve basis.

Our solution to this problem is an app that users can download which would be connected to each laundry machine unit in the room to track the laundry status. The app will include a queue system so that multiple users can sign up to use the laundry machines in turns. We will also implement a locking system that will lock the lid of the laundry machine until a code is input to an attached keypad. The code will be provided to the user that is currently using the machine and will be changed when the it is the next user's turn. A vibration sensor will be attached to each laundry machine to monitor the status of each machine. When the vibration sensor no longer senses vibrations for a period of time, that signifies that the machine has completed its cycle. The current user will be notified via the app to retrieve their clothes and after a set time the machine will be marked as available. Once a laundry machine is available, the next user will be notified via the app that a machine is available to use.

1.2 Background

Similar solutions have been implemented in universities, and even our own university has a system that tracks washing machine availability [1]. The university laundryview system has a timer for each individual machine in use and also tells the user which machine is available. This system is fine if multiple machines are available at once but the problem arises when only a few or no machines are available. The problem with this system is that it only tracks the status of the machines itself and still relies on a first come first serve basis for who uses the available unit. From personal experiences living in the university dorms we have seen during busy laundry days in which students would be waiting in the dorm room for the next available unit to open. Impatient users would also take out the laundry if the previous user did not retrieve their clothes in time due to the locks on the machine unlocking automatically once the timer ran out. Our system is an upgrade to the university system since we will have a lock and queue subsystem that puts users in a line for the next available machine guaranteeing them a laundry machine for use once it is their turn.

1.3 Visual Aid

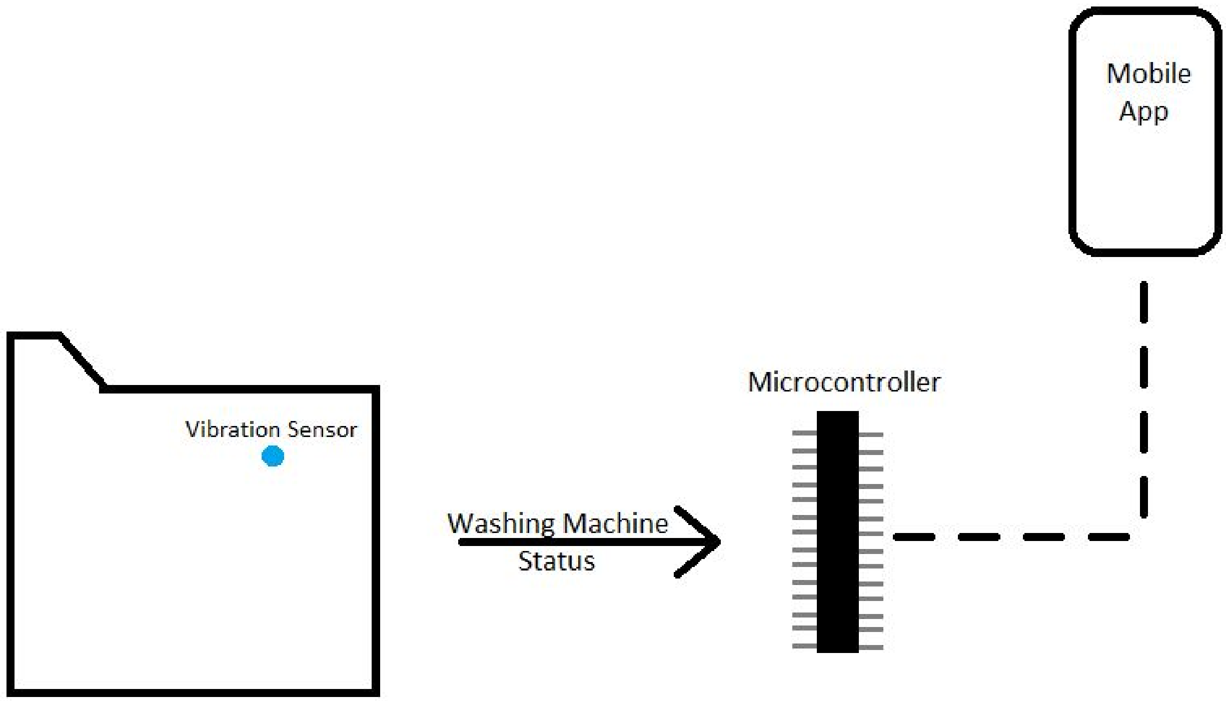


Figure 1: Visual Aid

1.4 High Level Requirements

1. Vibration sensor must be able to accurately tell the microcontroller when vibrations are coming from the laundry machine.
2. Locking mechanism must work together with the attached keypad to allow the lid to be opened only when the correct code is put in by the user.
3. Application accurately states the status of the laundry machine based on readings from vibration sensor and allows users to queue up to use the machine.

2. DESIGN

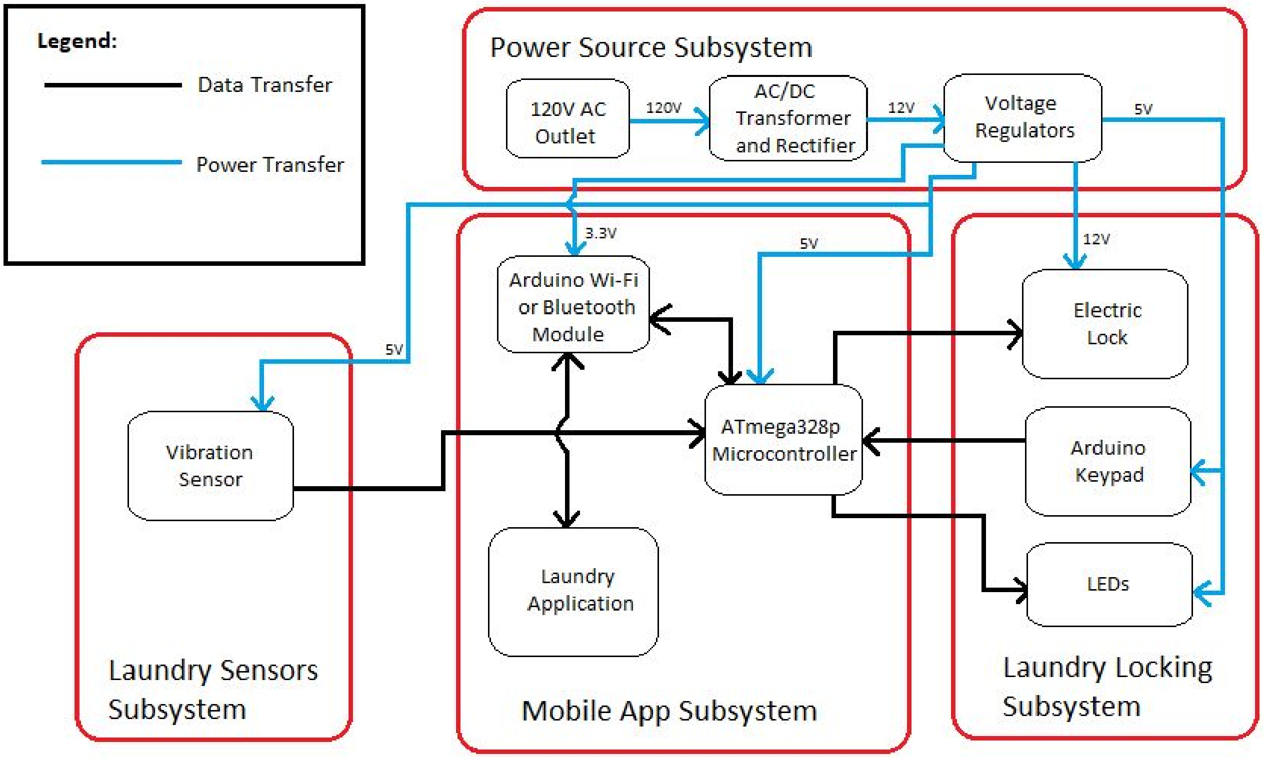


Figure 2: Block Diagram

A combination of four different subsystems is needed for our solution to function as intended. The power subsystem will allow us to step down and convert the 120V AC voltage from a wall outlet into 12V DC for our solenoid lock, 5V for our microcontroller, vibration sensor, and keypad, and 3.3V for our Wi-Fi module. In order to check the status of our laundry machine, we will use the output vibration sensor contained in our laundry sensor subsystem to decide whether or not the laundry machine has finished its cycle. The laundry locking subsystem will allow us to keep the machine lid locked to people aside from the current user of the machine through the use of a randomly generated code given to the current user that will unlock the machine if inputted into the keypad. Our mobile app subsystem is what will allow the microcontroller to send the status of the laundry machine as well as the code for the keypad to users through the use of a Wi-Fi module.

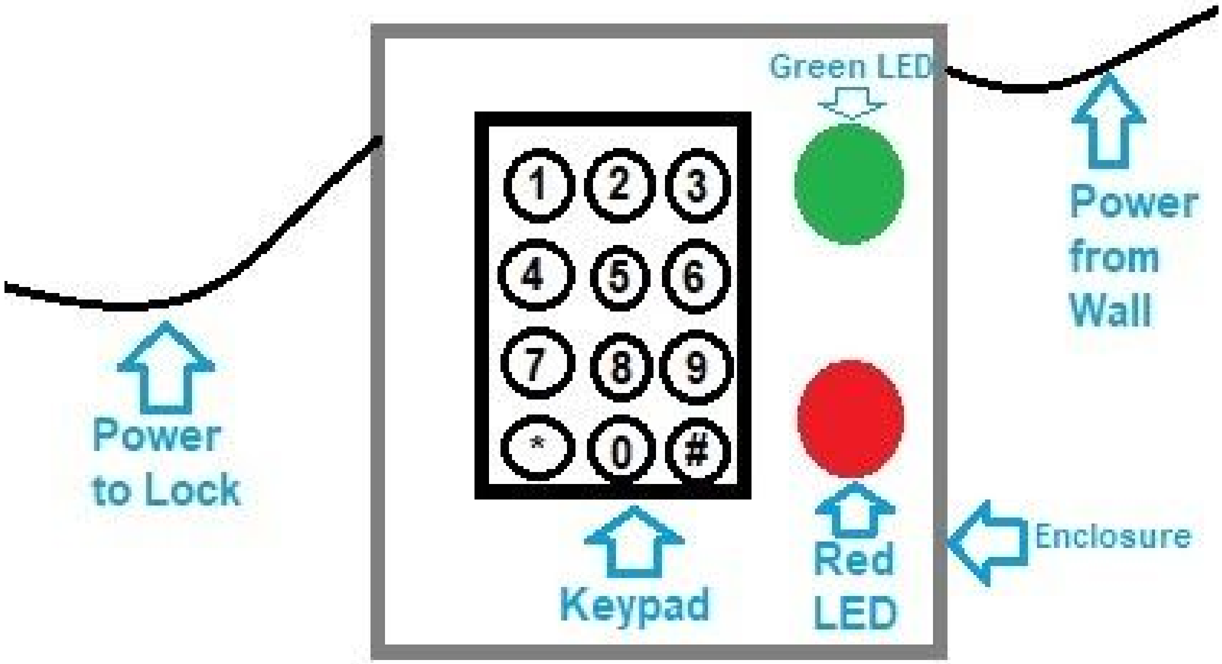


Figure 3: Physical Design Box Outside

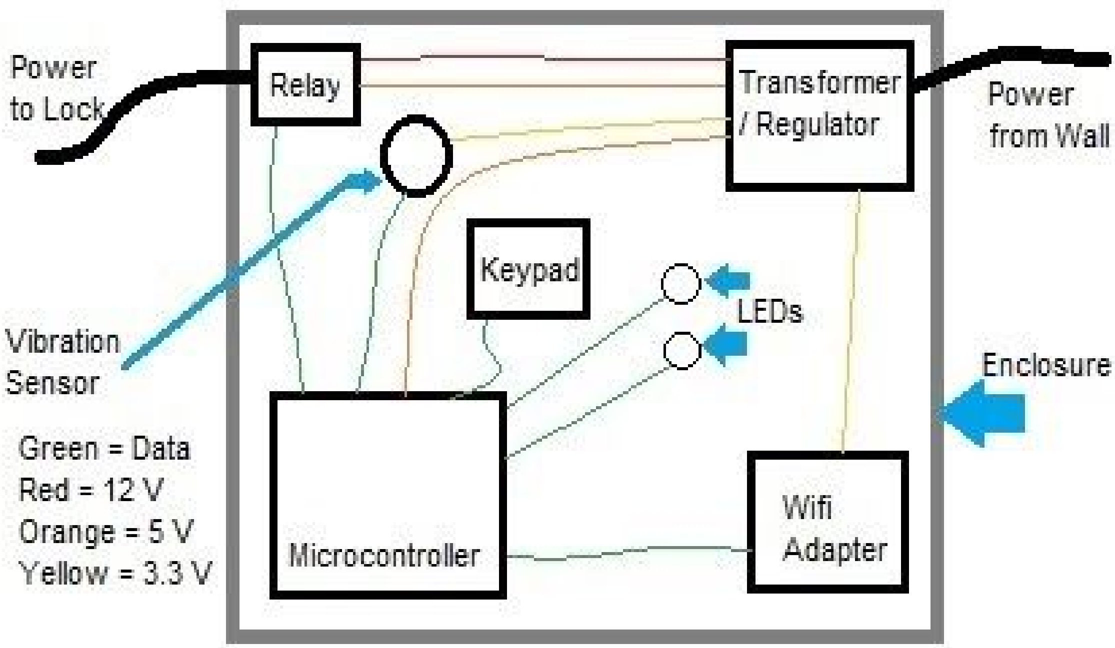


Figure 4: Physical Design Box Inside

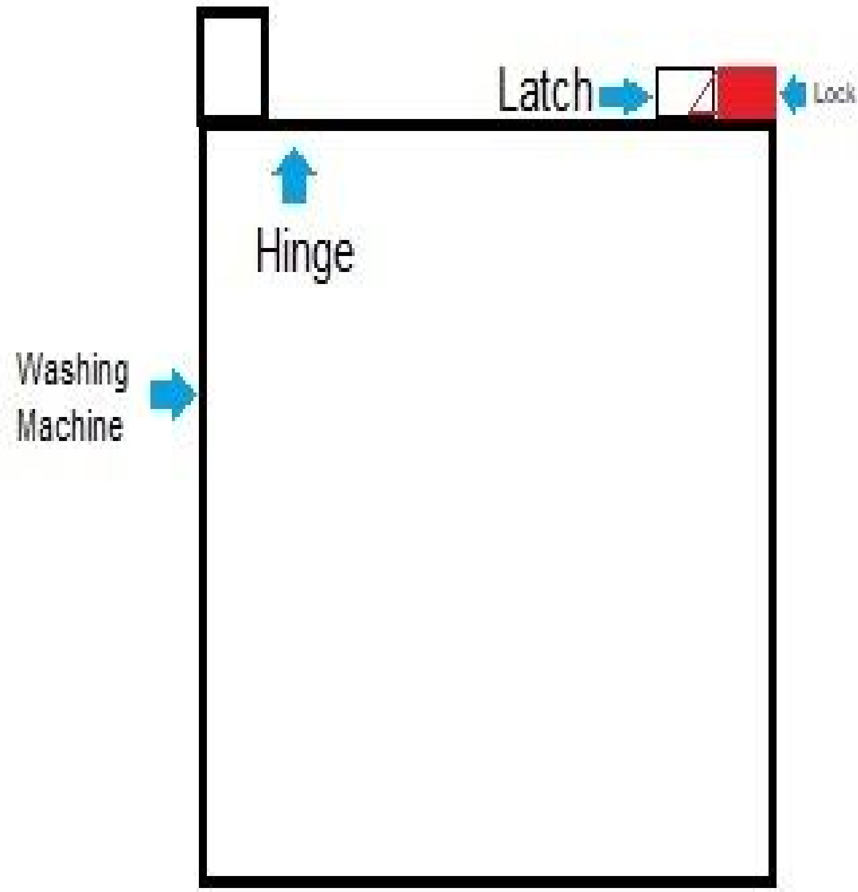


Figure 5: Physical Design Washing Machine Locking System

The microcontroller will sit in a box attached to the washing machine with the vibration sensor. Placed on the outside of the box for user access will be the keypad for unlocking the laundry machine lid along with a red LED and green LED to indicate whether or not the code inputted into the keypad is the correct code for unlocking the lid. The lock itself will be placed next to the lid in such a way that while the lock is not being provided sufficient voltage, the lock will be over the edge of the lid, preventing it from opening.

2.1 Power Source Subsystem

The 120V AC voltage from a wall outlet is not suitable to power our system. Thus we need to use an AC/DC transformer and rectifier to bring the voltage down to 12V DC for our electric lock and 5V DC for our microcontroller, vibration sensor, and keypad. An additional regulator is needed for the Wi-Fi module in order to supply it with the required 3.3V. We have a predicted current draw of about 700mA for our system, thus the transformer must give us an output current of about 0.8A to 1A.

2.1.1 AC/DC Transformer and Rectifier

This will change the voltage from the wall supply to 12V DC which is required to power the electric lock.

Requirement	Verification
1. Takes in the 120V AC from the wall outlet and provides an output of 12 V DC (+/- 5%).	1. Connect a resistor to the output of the converter and measure the voltage across the resistor using an oscilloscope.

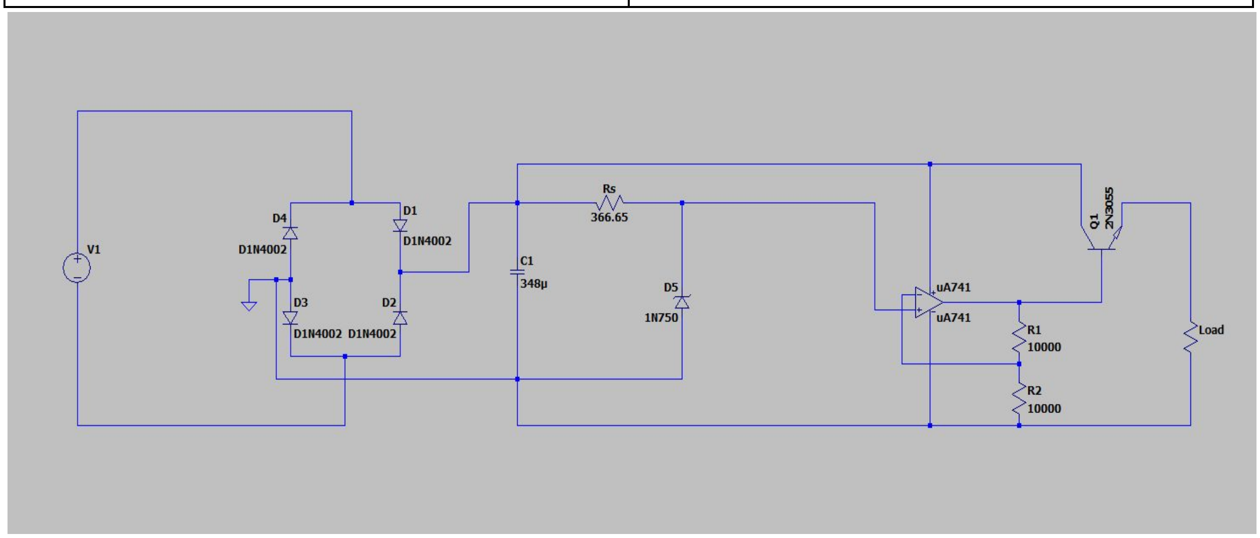


Figure 6 : Circuit Schematic of Transformer/ Rectifier

2.1.2 DC-DC Regulator

This is used to step down the 12V DC output of the Transformer to 5V DC which is used to power the Vibration sensor, the microcontroller, and the keypad.

Requirement	Verification
1. The regulator will convert the 12V DC to 5V (+/-5%) DC output	1. A. Connect a resistor as a load and measure the voltage output.

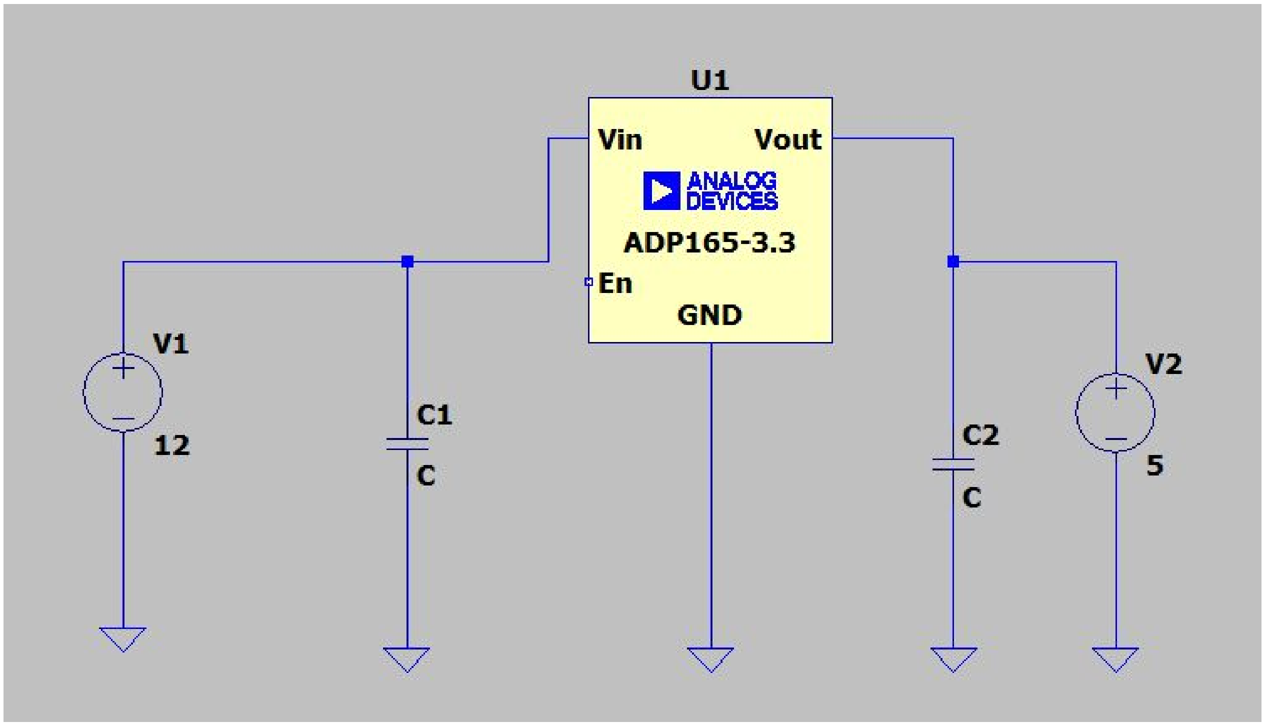


Figure 7: Circuit Schematic of voltage regulator

2.1.3 DC-DC Regulator

This regulator is used to step down the 5V DC output of the above regulator to 3.3V DC in order to power the WiFi Module.

Requirement	Verification
1. The regulator will convert the 5V DC (+/-5%) input to a 3.3V DC(+/-5%) output.	1. A. Connect a resistor as a load and use the oscilloscope to measure the output to verify the correct voltage

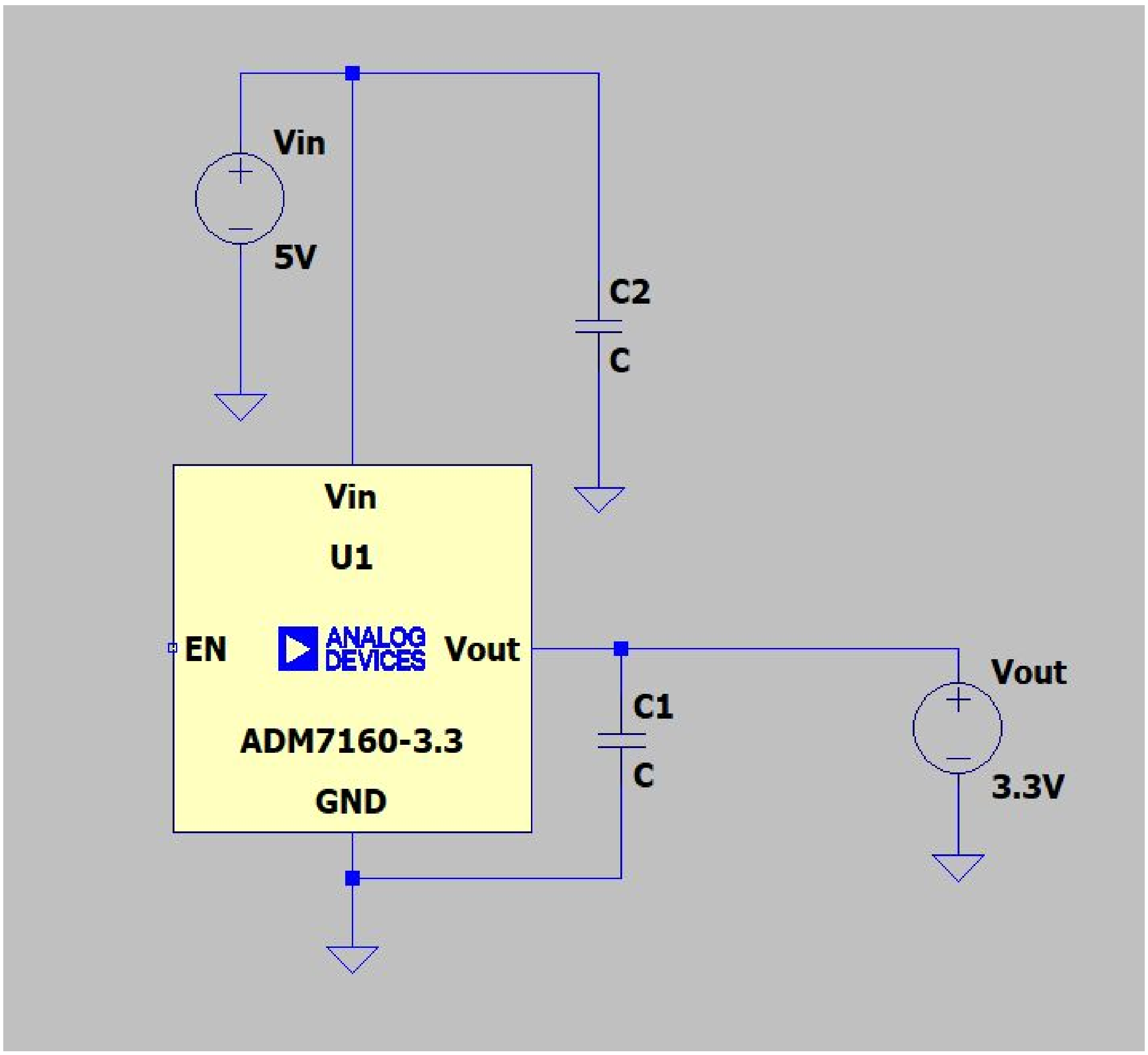


Figure 8: Circuit Schematic of voltage regulator

2.2 Laundry Sensor Subsystem

This subsystem is comprised solely of the vibration sensor. We have decided to use a piezoelectric sensor that outputs a range of voltages depending on the strength and intensity of the vibration. It will be mounted onto the face of the laundry machine itself, and communicate its information directly to the microcontroller in the mobile app subsystem. The necessary voltage for the vibration sensor to operate will be provided in the form of 3.3V to 5.0V from the power supply subsystem. The state of the laundry machine will be decided based on the voltage outputs received from the vibration sensor as shown in Figure 5.

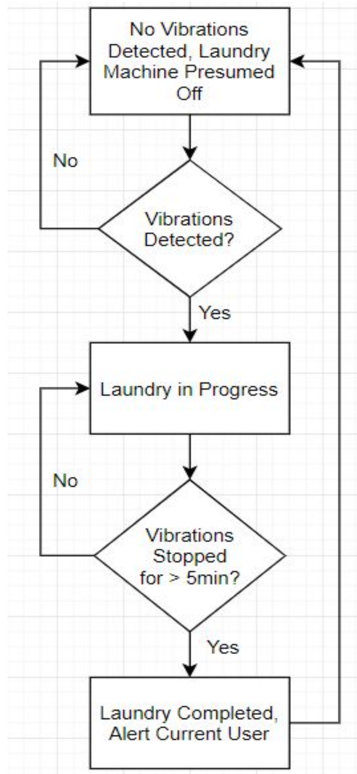


Figure 9: Vibration Sensor Software Flowchart

2.2.1 Vibration Sensor

The vibration sensor will provide an analog output of voltage change corresponding to the presence and intensity of vibrations from the object it is attached to.

Requirement	Verification
1. Senses vibrations at the various points of a wash or dry cycle, differentiated from the ambient vibration of the machine or from nearby machines.	1. A. Hook vibration sensor up to Arduino Mega B. Place vibration sensor on running in-unit washer/dryer C. Utilize Arduino data to chart cycles of the machines D. Determine ambient vibration and times of intermittent vibration

2.3 Laundry Locking Subsystem

The laundry locking subsystem will control the electric solenoid lock placed across the edge of the laundry machine lid, allowing us to keep the laundry machine locked from people who are not the current user. The mobile app subsystem's microcontroller will choose a random code that will be required to be typed into the keypad in order to provide the necessary voltage to unlock our solenoid lock. LEDs will be used to inform the user as to whether or not the code they typed into the keypad was the correct code or not. The code will be provided to the current user of the laundry machine via the app. A new code is generated when the lock is unlocked by the correct code. The solenoid lock will be powered by 12V ± 5% from the power supply subsystem while the keypad and LEDs will be powered by a range of 3.3V to 5.0V from the same subsystem.

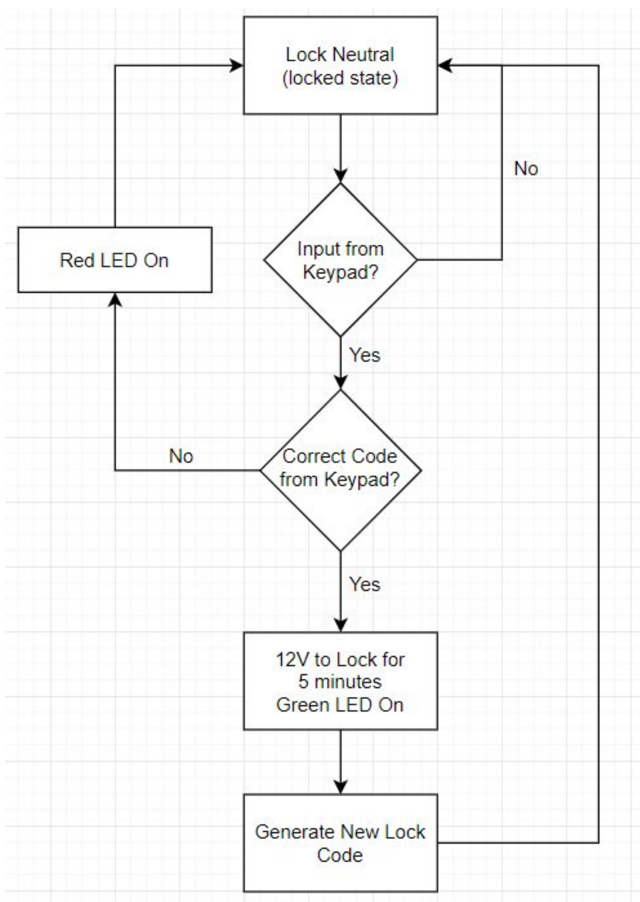


Figure 10: Locking Subsystem Software Flowchart

2.3.1 Electric Lock

This part will hang over the laundry machine lid, restricting it from opening while the lock is extended. When provided with sufficient voltage the solenoid lock will retract and the laundry machine lid will no longer be obstructed, allowing the lid to be opened.

Requirement	Verification
1. Electronic solenoid lock retracts when continuous 12V ± 5% input voltage is applied	1. A. Provide 12V to the solenoid lock from power supply subsystem B. If lock retracts, part is working as intended.

2.3.2 Keypad

This part will contain buttons corresponding to the numbers 0 through 9, similar to a phone's number pad, allowing us to choose a random code made of numbers within a specified range, ie. up to four digits. The key pressed is found by checking the HIGH or LOW status of two pins of the matrix keypad.

Requirement	Verification
1. Each numerical keypad input (0-9) is correctly read by Arduino	1. A. Write code for Arduino to read the input provided by the keypad into a variable B. Print value of that variable to terminal C. If the value matches what was typed into keypad, keypad input is properly being read by Arduino

2.3.3 Red and Green LEDs

These LEDs will simply be used to indicate whether or not the code typed into the keypad is the correct code for unlocking the solenoid lock. If correct, the green LED will light up, if incorrect the red LED will light up.

Requirement	Verification
1. LED is able to be powered by and withstand 3.3V power supply	1. A. Construct circuit providing 3.3V ± 5% along with a calculated resistance to protect the LED B. Connect multimeter to circuit to measure current through LED C. Ensure current being provided is within operational range of LED

2.4 Mobile App Subsystem

The app we plan to build will allow users to check the current status of a laundry machine (running or available). Multiple users will be able to queue up to use the laundry machine in a first come first served order. When signing up for the queue, a user will be required to select how many loads of laundry they plan to do up to a maximum of 3. Three loads of laundry will equate to being queued for using the machine 3 times in a row. If the user is currently queued up, they are not allowed to sign up for the queue. They may not dequeue from the system if they are the user that is currently using the laundry machine (machine must be running) to prevent glitchy situations. The user currently using the machine will be able to press a button to receive the current code required to unlock the lid lock. The microcontroller will be supplied with 5V from the power supply subsystem while the Wi-Fi module will be provided with 3.3V. The microcontroller will also receive information from the vibration sensor in laundry sensors subsystem pertaining to the status of the laundry machine. It will control the voltage given to the solenoid lock and actions of the LEDs in the laundry locking subsystem based on input from the keypad in that subsystem.

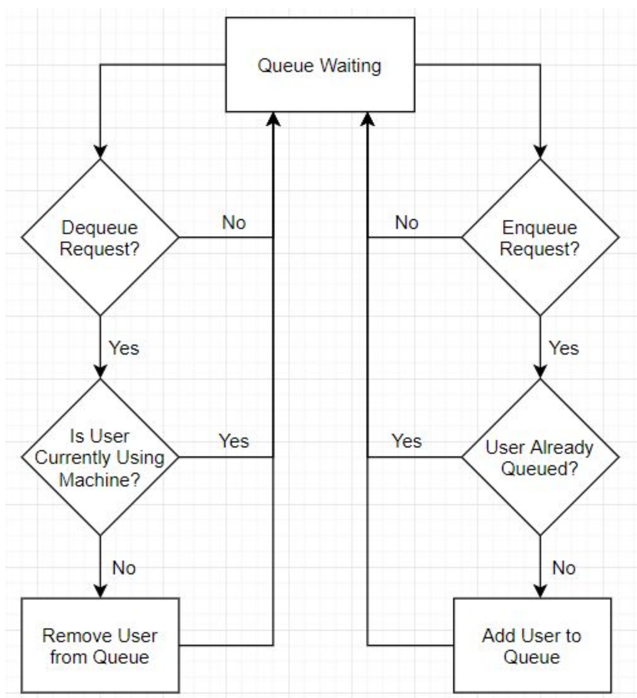


Figure 11: Queue Subsystem Flowchart

2.4.1 Microcontroller

The brain of the system that receives the output from the vibration sensor and decides whether or not the laundry machine has started and whether or not its cycle has ended. Also receives input from the keypad to check if it matches an internally, randomly generated code to decide whether or not to allow 12V to be given to the solenoid lock and which of the LEDs to turn on. We will also add a 16MHz crystal oscillator to help adjust the microcontroller's clock frequency.

Requirements	Verification
1. The microcontroller will need to be able to send and receive data from the other modules it is connected to (vibration sensor and keypad) 2. Microcontroller can communicate with UART at rate of 50kbps	1. A. Write simple code to store data output from vibration sensor into a variable and data input from keypad into a variable B. Print variables onto terminal and ensure they match the expected results 2. A. Establish connection between microcontroller and Putty B. Set terminal to baud rate of 50kbd C. Send and echo back 50 characters D. Ensure all characters echoed back match those that were sent

2.4.2 ESP8266 Wi-Fi Module

Facilitates communication between the microcontroller and our mobile app. Module will allow the microcontroller to send information through it to the mobile app and information from the mobile app to flow through it to the microcontroller.

Requirements	Verification
1. Module must successfully communicate data from microcontroller to server/app	1. A. Write necessary code to connect module to Wi-Fi network B. Type IP address of Wi-Fi module into browser and connect to the module using Putty C. Type into the putty console and the characters should be printed onto the web browser

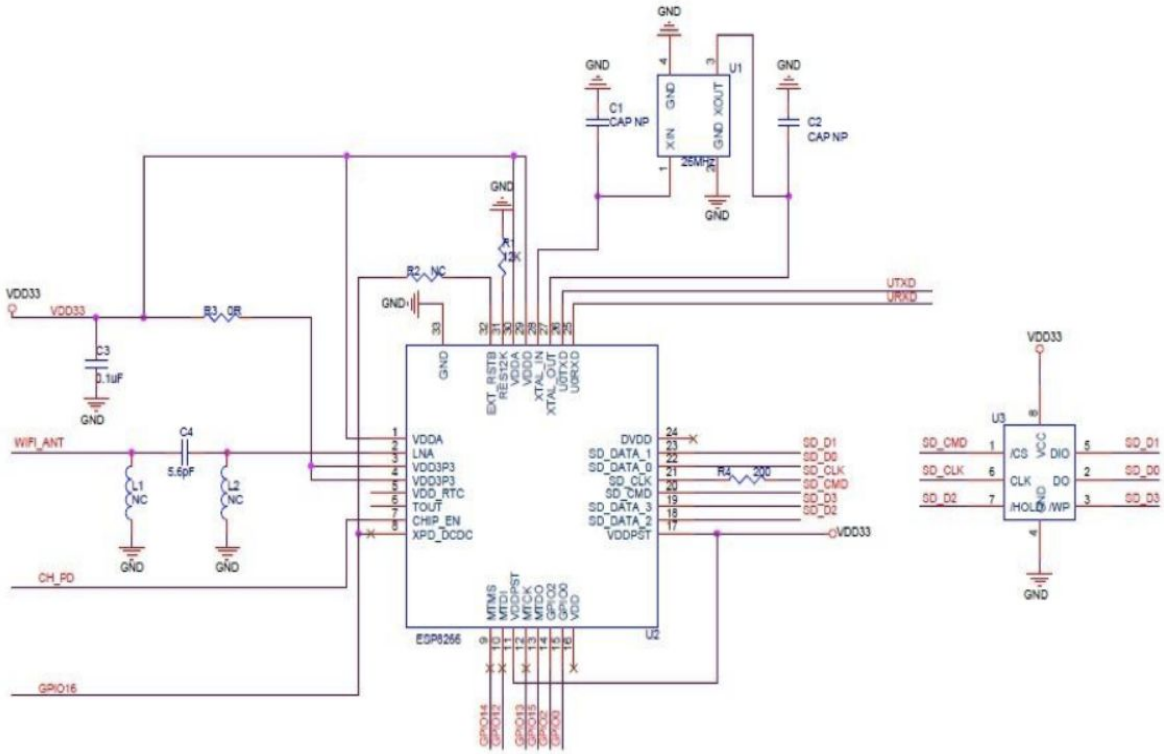


Figure 12: Circuit Schematic of Wifi Module

2.4.4 Washing Machine App

The app will be the primary module users will interface with. This will contain the queue system the users can sign up for as well as the status of the laundry machine being tracked. The user will be able to view the code for the lock associated with their washing machine by pressing a button if they are the one currently using the machine. User will be able to enqueue and dequeue as they please as long as they follow the rules described earlier.

Requirements	Verification
1. Distributes the appropriate keypad code to the next in line user 2. Queue progresses with first come, first serve priority 3. Queue has back out function 4. App displays time left in current cycle 5. App notifies user that they have use of the current washing machine 6. Queue updates as users finish their washing/back out 7. App has emergency unlock button	1. A. Use app to sign up for laundry on two phones B. Check phone screen for receipt of first keypad code C. Run or simulate running of laundry cycle. D. Check second phone screen for receipt of second code.

8. App prevents user from monopolizing queue 9. App allows for multiple loads	2. A. Use app to sign up for laundry first on one phone, then on a second phone B. Simulate laundry being finished C. Check first phone to confirm receipt of code D. Check second phone to confirm no receipt of code 3. A. Use app to sign up for laundry on one phone, then on a second phone. B. Use back out function on first phone C. Verify that second phone moves up in queue 4. A. Use app to sign up for laundry on phone B. Simulate start of laundry cycle C. Check "Time Remaining" function 5. A. Repeat tests in step 3 B. Confirm notification received 6. A. Repeat tests in step 3 7. A. Use app to sign up for laundry on phone B. Simulate start of laundry cycle C. Press emergency stop button D. Confirm emergency stop 8. A. Use app to sign up for laundry B. Confirm inability to sign up for more than 3 consecutive loads 9. A. Use app to sign up for laundry B. Enter in load amount C. Simulate laundry D. Confirm receipt of next code(s)

Calculations

Current Draw Calculations:

Transformer Current Provided: 3000 mA

- Arduino Operation Power: 25mA
- Relay Trigger Power: 5 mA
- Lock Power: 430 mA
- Vibration Sensor Power: 1 mA
- Wifi Module Power: 215 mA

= Spare Current: 2324 mA

This spare current will be used up by whatever programs and code we need to run on our microcontroller to accomplish our design. The spare current will also be consumed by the LED's, so we need to make sure we choose appropriate LED's and associated resistors to limit the current draw. These include interfacing with the keypad, generating new lock combinations, opening and closing the lock, and communication with the app through wifi.

2.5 Tolerance Analysis

Through discussions with your TA, identify the block or interface critical to the success of your project that poses the most challenging requirement. Analyze it mathematically and show that it can be feasibly implemented and meet its requirements. See the Tolerance Analysis guide for further guidance.

It was obvious to us from the start that the most critical block to the success of our project is our Mobile App. Since it is very difficult to analyze quantitatively, we will analyze the potential issues and pitfalls qualitatively. The App contains half of what we consider to be especially unique to our system: the queue. The queue organizes the order that we intend to impose on the community laundry rooms, and makes sure that all of the users have the time they need to do their laundry. If we do not ensure that the queue proceeds smoothly, we could possibly have many issues.

The user must be able to back out of the queue, in case they have other obligations that would prevent them from doing laundry, and they must also be able to stop the queue in case they need access to their clothes for a variety of reasons (such as leaving a phone or wallet in a pants pocket). If the busy user is not able to leave the queue, other users' laundry will be unnecessarily backed up, and if the user needs access to their laundry and can't get it, there is a possibility for their property to be damaged by the machine. Also, the app must be able to account for users that want to do multiple loads at a time, while preventing the queue from being monopolized by one or a select few users. If we do not allow multiple loads, it could be difficult for users to get all of their laundry done at once, and if we do not install prevention against queue monopolization, it will be difficult for users to get any laundry done in the first place. Even in normal operation of the queue, we need to ensure that we install the proper time limits for loading and unloading of laundry so that the next user doesn't have to wait too long for their laundry, as well as removing the past user from the queue.

The App also needs a way to determine one user from the other, so that the individual people trying to do laundry can be sent the appropriate code at the appropriate time, depending on their position in the queue. The app must also implement a timer that lets the user know how much time they have left until their laundry is done.

Our App has a lot of features and design aspects to account for, and for that reason, is the most likely of our subsystems to have difficulties or issues. Therefore, we have to start its development early and troubleshoot and debug over the course of the semester.

3. COST AND SCHEDULE

3.1.1 Cost Analysis

Part	**Vendor**	**Cost**
Arduino MEGA 2560 REV3	Amazon	$44.95
LE Power Adapter	Amazon	$24.99
BINZET DC Converter Step Down Regulator	Amazon	$7.59
Logic Level Converter - Bi-Directional	Sparkfun	2.95
HiLetgo Relay Switch	Amazon	5.79
WiFi Module - ESP8266	Sparkfun	6.95
Membrane 3x4 Matrix Keypad	Adafruit	$3.95
Atoplee Electric Lock Assembly Solenoid	Amazon	$23.13
WINGONEER Analog Ceramic Piezo Vibration Sensor Module	Amazon	$6.99

3.1.2 Labor

We have assumed a $35/hr salary working 10 hours a week for the 16 week semester for each member.

($35/hour) x 2.5 x 10(hrs/week) x 16 (weeks) x 3 = $42000

3.1.3 Grand Total

Our total costs are the costs of the parts added with the cost of labor which comes out to a grand total of $42197.29

3.2 Schedule

Include a time-table showing when each step in the expected sequence of design and construction work will be completed (general, by week), and how the tasks will be shared between the team members. (i.e. Select architecture, Design this, Design that, Buy parts, Assemble this, Assemble that, Prepare mock-up, Integrate prototype, Refine prototype, Test integrated system).

Week	**Mike**	**Chris**	**Rob**
#7 (3/2 - 3/8)	Begin work on algorithms for cycle detection, queue, LED’s	Begin PCB Design, order parts	Begin PCB Design, prepare specs for Pseudo Laundry Machine
#8 (3/9 - 3/13)	Test Vibration Sensor, investigate and decide on communication protocols between microcontroller and wifi module	Finalize First PCB Design, Test component specs	Finalize specs for Enclosure, First PCB Design, Lock Mechanism
#9 (3/23 - 3/29)	Integrate Keypad	Get Relay Working, LED’s	Finalize Pseudo Laundry Machine design
#10 (3/30 - 4/5)	Begin Working on App, Solder PCB	Finalize End PCB Design, Test power system specs	Finalize End PCB Design,
#11 (4/6 - 4/12)	Connect to Wifi, move from Arduino to Microcontroller and PCB	Audit wifi connection, facilitate change between Arduino and PCB	Audit wifi connection, facilitate change between Arduino and PCB
#12 (4/13 - 4/19)	Work on App, Test on real washing machine	Assemble enclosure with components	Assemble backup components
#13 (4/20 - 4/26)	Finalize app functionality	Prepare Mock-Up Demo	Prepare Mock-Up Demo
#14 (4/27 - 5/3)	Prepare Presentation	Prepare Presentation	Prepare Presentation
#15 (5/4 - 5/6)	Complete Report	Complete Report	Complete Report

4. DISCUSSION OF ETHICS AND SAFETY

1. Ethics and Safety Issues

Thankfully, the fact that we are working with something as innocuous as laundry machines means that there are relatively few ethical concerns. However, there are still some aspects of our design that could be intentionally abused. First of all, one user could use a single device or multiple devices to reserve the laundry machines for extremely long durations of time, preventing others from moving up in the queue and thereby from using the laundry machines. This could have unintended consequences, such as someone not being able to have clean clothes available for important things like dates, work, interviews, and other important occasions. Someone could also abuse the queue system in order to charge for someone to use laundry, since only the person abusing the system would have the code for the next several hours. Someone with time constraints on doing their laundry would be forced to submit to this abuser, or else not be able to do their laundry.

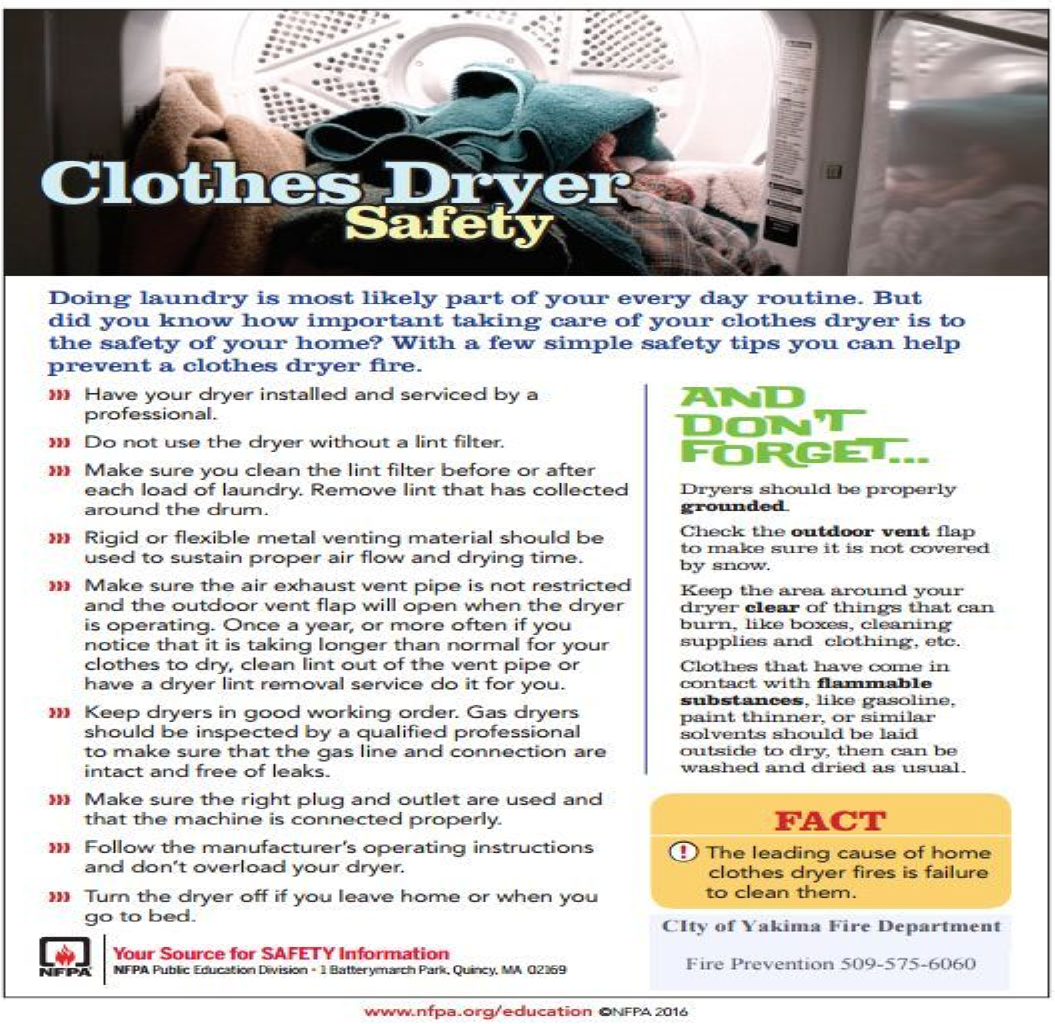
Despite the lack of ethical concerns, there are some safety issues with our project. Firstly, the user could possibly get their finger lodged in between the washer/dryer door and the locking system. If the user isn't careful, they could also accidentally leave their phone or other valuable electronics or other item in the washer/dryer, and not be able to access the machine to pull it back out in time to save their valuables. In accordance with item 1 of the IEEE Code of Ethics [2], we will make certain that our design "holds paramount the safety, health, and welfare of the public". We will take all precautions to ensure that our 120V-12V step down transformer, perhaps the most dangerous part of our project, is both safe, well built, and lasts. In this way, we will protect the health of the consumer from any possible electrical shock from connecting or disconnecting power from our product.

2. **Precautions**

We have chosen our components specifically for safety and reliability purposes. We understand that there are many risks when dealing with electricity, especially around water and flammable materials like lint, so we are taking the utmost care in order to ensure that there is minimal risk for accident or injury. We will also securely insulate our wires and all of our electrical connections in order to decrease the risks of shock or fire. Listed below are fire and electrical safety documents.

Electrical:
https://www.nist.gov/system/files/documents/el/isd/mmc/high_voltage_rules_revised.pdf

Fire:



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