Small Equipment Checkout System

Design Document

Sdmay19 - 13
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List of Definitions

- **A-Track system:** It is a powerful database that manages ISU students' personal information.
- **CRUD:** An acronym for Create Read Update Delete. This acronym is typically used to describe software functionality.
- **ETG:** An acronym for Electronics and Technology Group.
- **ECpE:** Electrical and Computer Engineering department of Iowa State University
- **OWFS:** An acronym for 1-Wire Filesystem.
- **1-Wire® Device:** 1-Wire is a device communications bus system that provides low-speed data, signaling, and power over a single conductor. It is designed by the Dallas Semiconductor Corp and trademarked by Maxim.
- **PCB**: An acronym for Printed Circuit Board
- **ISU:** An acronym for Iowa State University
- **Identity Provider:** An identity provider is a system entity that creates, maintains, and manages identity information while providing authentication services to applications.
- **Shibboleth:** Shibboleth is a single sign-on system for computer networks and the internet. It allows people to sign in using just one identity to various systems run by federations of different organizations or institutions.

1 Introduction

1.1 Acknowledgement

This senior design team, sdmay19-13, would like to thank Iowa State University(ISU), and college of Electrical and Computer Engineering(ECpE) for providing the excellent opportunity for students to form teams and to work on the professional design process. Especially, we want to thank the Electronic Technology Group(ETG), and our client and advisor, Lee Harker, for all the guidance and technical support. We have also appreciated all the contribution from the team, sdmay18-01, who has worked on this project before. Their design shows us many possibilities for this project.

1.2 Problem and Project Statement

Electrical and Computer Engineering are subjects rely heavily on experimental experience, and students will utilize various components and equipment throughout their learning process. Currently, the most common way for students to checkout equipment is borrow directly from Electronic and Technology Group (ETG)'s part shop. However, this checkout procedure has its own limitations in working time and efficiency.

The current checkout system requires ETG faculty spending time in part shop to process students' requirement, preparing equipment, and recording manually. This is not just inefficient in time, but also a waste in human resource. Also, many students likely to do the experiments after school or during weekends. In this situation, the ETG's limited working time, which is weekdays from 7am to 5pm, becomes a hinder for students to get necessary resources.

Overall, the final goal of this project is designing a feasible and reliable equipment checkout system that can solve the problems listed above by simplifying faculty's maintain process, and providing more availability for students.

1.3 Operational Environment

The accomplished design will be placed outside the ETG's part shop in Coover Hall. The whole system is supposed to work under room temperature for all times. The system can be divided into two parts, one is the shelf with boxes that used for storing equipment, the other one is a touch screen for user's interface. The shelf is made by metal and will be fixed to the wall, so its stability is the most important concern and will be tested carefully. The touch screen should have quick and accurate feedbacks to user's operations. Since the system will be place in public environment, the locker in each box should be able to protect the box from steals and slight damages. And some students may forget to close the doors of locker units. Therefore, it is necessary to have a function for our system to detect if the doors are closed after use

1.4 Intended Users and Uses

There are two kinds of intended users, students and administrators. Students should be currently enrolled at Iowa State University(ISU), so, they will have authentication credentials to ISU's Shibboleth Identity Provider, and be permitted to access the system. Administrators should be employed at ISU under the ETG department to have authenticated access to the checkout system's website.

In order to have needed equipment in time, plenty of students have to schedule their experiences during weekdays, and this may cause the shortage in both laboratory space and equipment. Small Equipment Checkout System will allow students to borrow equipment by all day and all hours. As the result, students will have more flexible studying time by using this system.

This system will only require administrators to do the maintenance at a very specific time, so administrators will be released from fixed daily office hour. Then, they can focus more on technical support for the ECpE department and improving our lab experience.

1.5 Assumptions and Limitations

Assumptions:

- All ISU students and ETG staffs will have authentication credentials to Iowa State University's Identity Provider, Shibboleth.
- The checkout system's website will not be able to be accessed outside of Iowa State University's Internet.
- Students and administrators will be able to use a touchscreen attached to the locker to interact with the checkout system.
- The system can be used all the time except it is in maintenance.
- The system will be displayed in the English language.
- One locker unit will be used to store the Raspberry Pi.

Limitations:

- There will be 34 locker units in the checkout system.
- The size of PCB should be smaller than 3.2cm*2.5cm*1.2cm (Appendix 1).
- The output voltage of Raspberry Pi's pin is 3.3V(Clifford, Paul.).

- ISU staffs who are in other departments cannot access the administrator website.

1.6 Expected End Product and Deliverables

The Small Equipment Checkout System can be divided into software and hardware system. And the project delivery will include prototype and final product.

1. Prototype - December 3, 2018
At the end of the first semester, we should have at least one locker with circuit successfully controlled by the software.
   - Hardware
     We should design a new circuit to control the lock in the box. The circuit should be powered and connected to Raspberry Pi, and can be controlled through the website. A sensor should also be placed on the circuit to check if the door is closed after use, or the alarm will be activated.
   - Software
     The software includes website application, 1-Wire® System, MySQL database and Android application. For the prototype, the website application should be able to have the ability to control 1-Wire® System and manage data in the MySQL database.

2. Final product - April 28, 2019
At the end of the second semester, we should have a perfect and functional small equipment checkout system for the ECpE students and ETG staffs to use in a real operating environment.
   - Integrated System
     For the final product, all of the aimed functionalities that we need should be achieved. The locks and LEDs inside boxes are able to control by the software system. All locker units have corresponding PCB implemented. The PCB implemented in the locker units should be wired to the Raspberry PI. The web application should be able to control all units of the locker.
   - Final Design Document
     The final delivery should include the detailed design documents. Followed the documents, ETG staffs should be able to maintain and manage the checkout system.
   - Code
     Both frontend and backend code should be available for ETG to access in ISU’s GItlab.
   - Software Manual

This manual will serve as a guide to the checkout system's software implementation. It will be available for ETG to access in ISU's Gitlab.

- Hardware Manual
  This manual will serve as a guide to the checkout system's hardware implementation. It will be available for ETG to access in ISU's Gitlab.

2. Specifications and Analysis

2.1 Proposed Design

The picture below is our proposed design for the whole project. Based on that, we will design new and smaller PCBs to control the communication between locker units and 1 wire device. What's more, we will extend the current web application to control all 34 locker units and be able to send email reminders to students

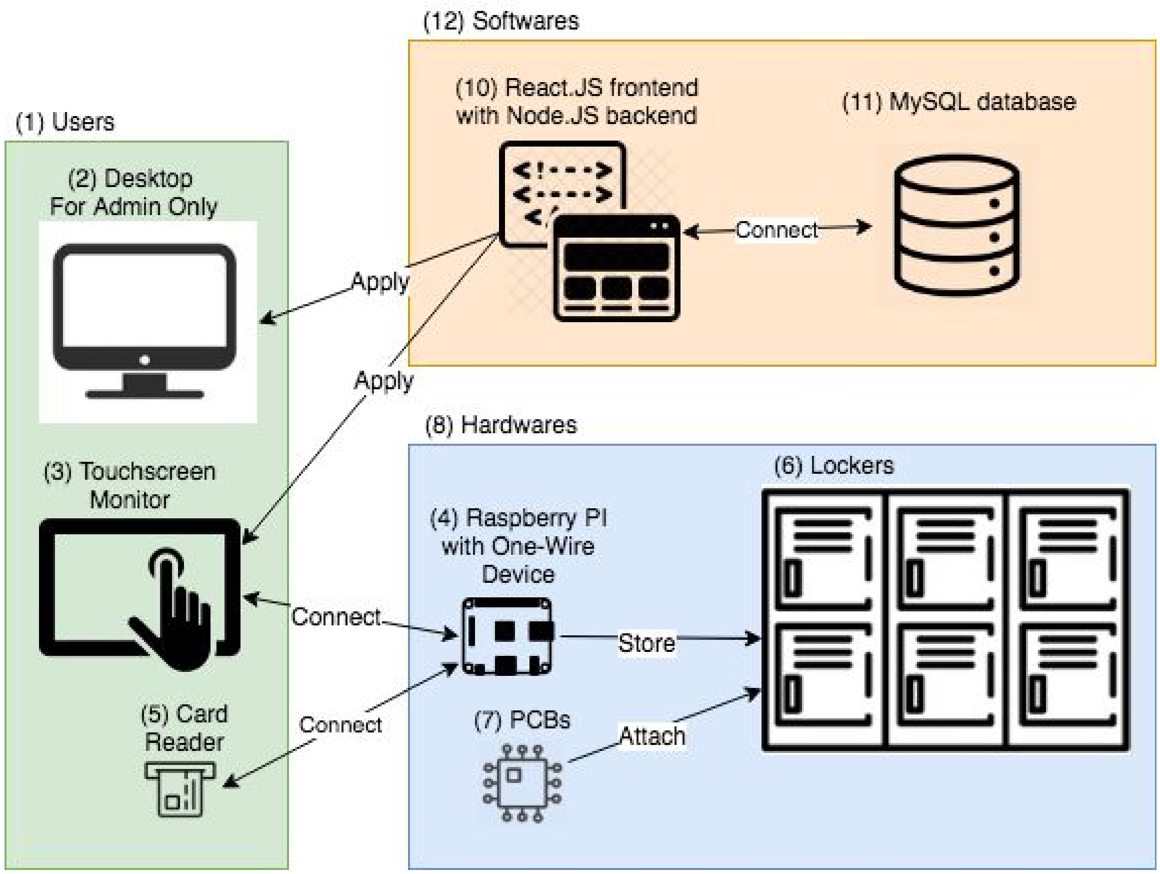

Figure 1: Proposed system design

The system should have 3 major components, users (1), software(12), hardware(8). For the users (1) part, it has a Touchscreen(3) for borrowers to operate. It has a card reader (5), which will be used when borrowers want to check out or return equipment. It will read ISU ID from ISU card to identify the borrowers and check if he/she is an ISU student or an ETG staff through the A-track system which is our university's self-designed attendance tracking system. The ETG staffs can access the checkout system through any computers(2) which connected to the ISU network.

For the software(12), we have a web application which has a frontend implemented by React.JS, a backend implemented by Node.JS(10) and a MySQL database(11).

For the hardware(8), we will have the main control board with a Raspberry Pi and a One-Wire master device(4) on it. The Raspberry Pi is a microcontroller, and we will install Raspbian on it as the operating system. The One-Wire device will be used to connect Raspberry Pi and all PCBs(7) in locker units(6). The PCB(7) will have a one-wire chip, which assigns a unique address for each locker, and can control the electromagnetic lock and the LED. PCB(7) will also have a buzzer to make noise when the sensor detected the door is not closed for a long time. In the locker(6), each unit will have an item for borrow. In order to make the wiring of whole system tidy and clear, we need to resize the PCB so it can fit in an plastic cover and fix on box's door. We plan to use the surface-mount, double-sided PCB to save the area.

Functional Requirements

For students:

- Log in and out
- View available equipment
- Select an equipment item to checkout
- Turn on the LED to check equipment
- Determine checkout duration
- View currently checked out equipment (personal)
- Return equipment, close checkout record
- Report system misuse or broken items
- Receive Email Reminder

For Administrators:

- Log in and out
- CRUD available equipment
- Determine max checkout durations for items
- CRUD student users, records, and user privileges
- Receive email status reports
- Create update, remove locker units
- Add new Administrators

Non-functional requirements

- Maintainability:

Our product could be maintained by ETG for future usage. ETG will have documents and resources to access the whole system and add more locker units.

- Security:
  Our web application has the access restriction for people outside of ISU to prevent our checkout system from unnecessary data losing.

2.2 Design Analysis

Hardware-

1. lock circuit:

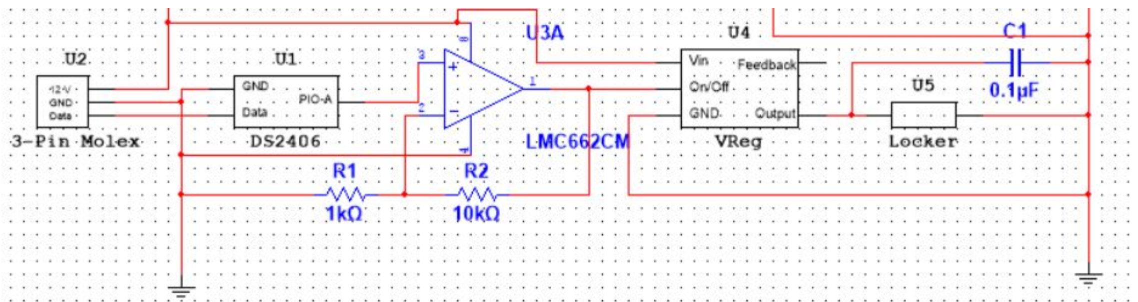

Figure 2: Lock Control Circuit

For the locker circuit, we used a single PIO pin one-wire slave device, DS2406. The connector of 3-pin Molex provides a 12 volts voltage and receives data signal. When the Slave Device receives the signal, it generates a 0.24 volts voltage on PIO-A. The small volts buffed by op amplifier to 10 times. That voltage is strong enough to trigger the on/off pin on voltage regulator. When the status is on, output voltage equals to Vin which is 12 volts power supply. The lock opens when it receives 12 volts voltage.

The previous group had made a prototype with the switch controlled by PMOS. But we found there is an interference between 12 volts power supply and Slave Device. When the power supply turns on, the OWFS is not able to find the address of our Slave Device. Otherwise, there is no connection problem between OWFS and Slave Device. Therefore, we choose LM2575T voltage regulator instead. The circuit voltage becomes more stable, because voltage regulator can supply constant voltage level. Also, the problem of interference is solved.

2. Door detecting circuit:

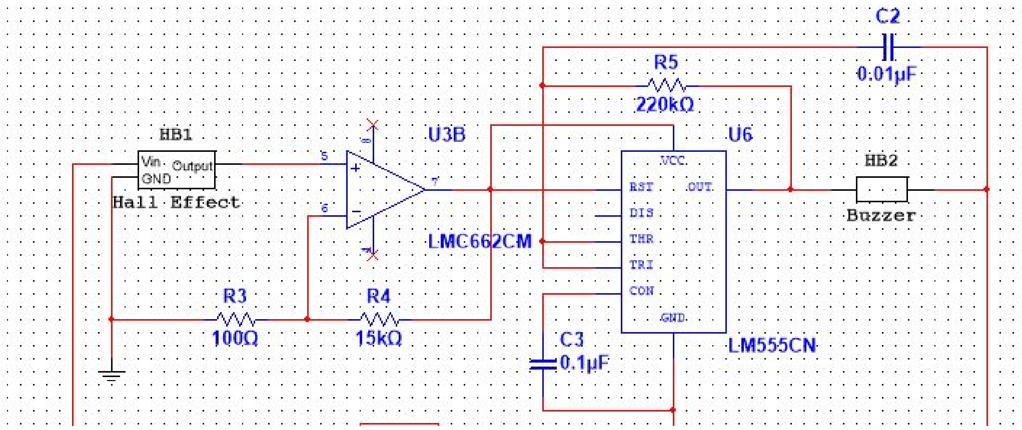

Figure 3: Door Detecting Circuit

For the door detecting circuit, the major component is the Hall Effect Sensor, DRV5023. This sensor can switch its output status between high and low based on magnetic flux density. According to our test, when a magnet is closed enough to turn off the sensor, the output is 0V. When the magnet is far enough to turn on the sensor, its output increase to 76mV. The Hall Effect Sensor we used is unipolar, so the result is independent with magnet types. Next, we used a non-inverting op-amplifier with a voltage gain of 151 to boost the sensor's output to 11.45V when it's on. The supply voltage of amplifier and hall effect sensor is 12V coming from raspberry.

For the alarm part of door detecting circuit, we used a buzzer without build-in oscillator. So, we built a square-wave generator with the timer, LM555CN, to power the buzzer. The reset of LM555CN is low triggered. We connect the voltage supply and reset of LM555CN to the amplifier's output, so, when the door is closed, the magnet is close to the hall effect sensor and the output of sensor is 0V, which is unable to turn on the timer, then the buzzer is off. When the door is open, the magnet is away from the sensor, and the boosted output voltage can reach 11.45V, which can turn on the timer and produce a square wave to power the buzzer, then the buzzer can make noise.

As for details of timer, we chose the value of resistor and capacitor so that the frequency of output square wave is 300 Hz. The equation is shown below.

$$f = \frac{1}{0.693 * 2R * C}\ Hz$$

In our final product, we plan to use a buzzer with a built-in oscillator, so we can save one timer. Also, the current design can only make noise immediately when door is open.

With the saved timer, we can design a delay switch so the buzzer will start making noise after door has been opened for 5 seconds.

Software-

Currently, for the software portion, there are two kinds of software applications are under construction. The first one is the web application that has already implemented the major functionality by the previous team. The second one is Android App which is designed and created by ourselves.

1. Web application

- What we have finished

  We have successfully run the React.JS frontend and Node.JS backend of the web application implemented by the previous team and enabled it to communicate with the OWFS. What's more, we have obtained the database access of previous team's web application. Furthermore, the OWFS has been set up to communicate with the hardware portion designed by hardware team.

- Strength and weakness of current software design and how will we fix the weakness

  The strength of the current web application is that it includes all of the basic functionality that the client of the checkout system required such as students and ETG staffs can log in and log out the checkout system by swiping their ISU ID in the card reader. What's more, students could check out and return the equipment through control the touchscreen monitor. Furthermore, ETG staffs could manage the record of the checkout system not only through the touchscreen monitor but also through the website in their our computer if they have a card reader with them. What's more, they have set up restriction for people to access the web application by Shibboleth Identity Provider and A-track system.

  There are a couple of weakness in the current web application that we have.

  a. Database

     Figure 1 is the data schema of the current database. Based on our current observation of that, the database does not include the deleting locker units address function. Because sometimes the locker units may break by accident and the maintenance worker may need to replace the PCB attached on them. After replacement, the locker units will be assigned to a new address. Therefore, we need to add this function in the future implement.

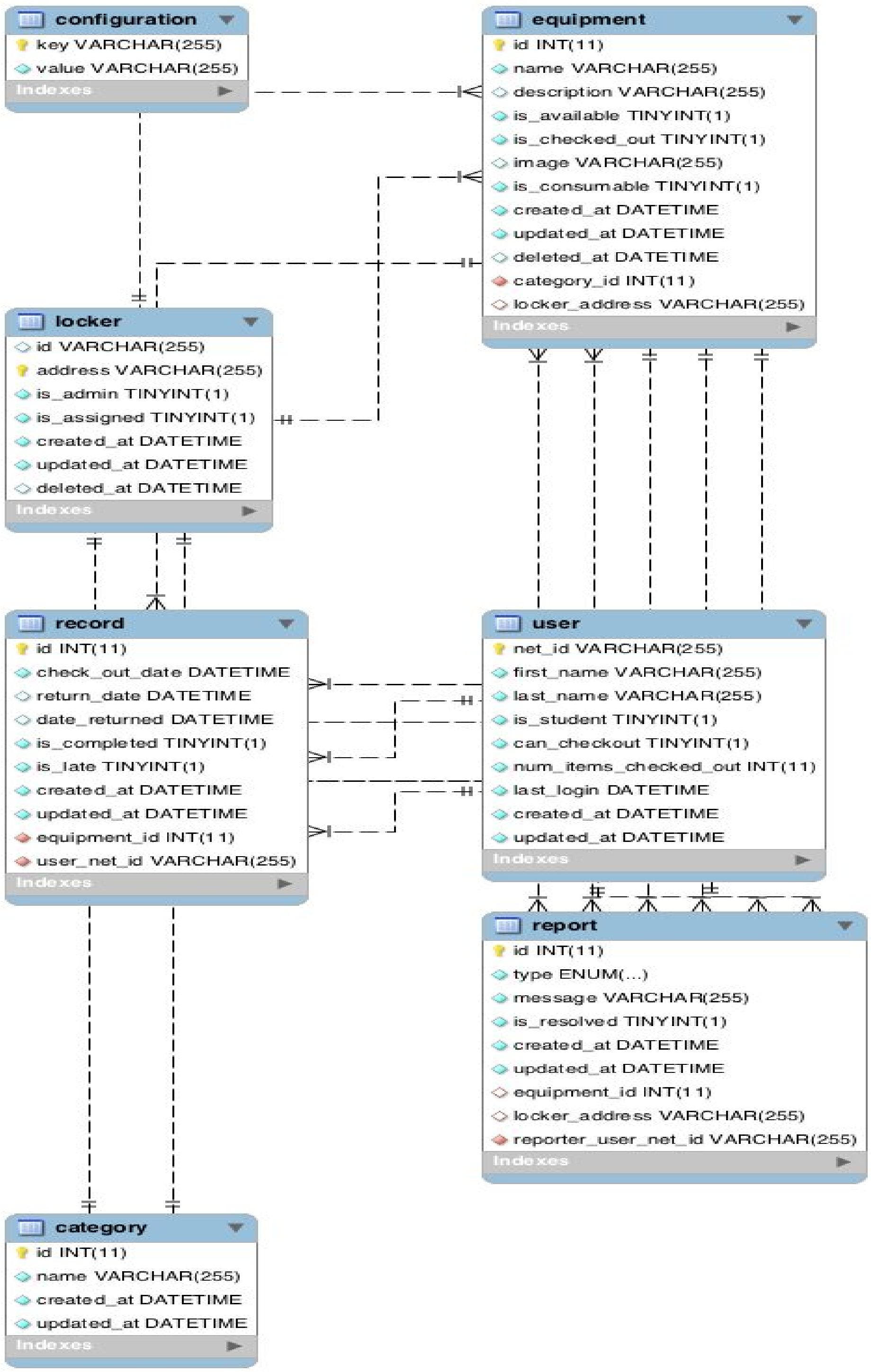

Figure 4: Database Schema of current web application database

b. Check out and return process

Based on the requirement of our client, he would like to obtain the check out and return procedure into a new process shown as Figure 5 below. Therefore, we have to implement this in the web application as well.

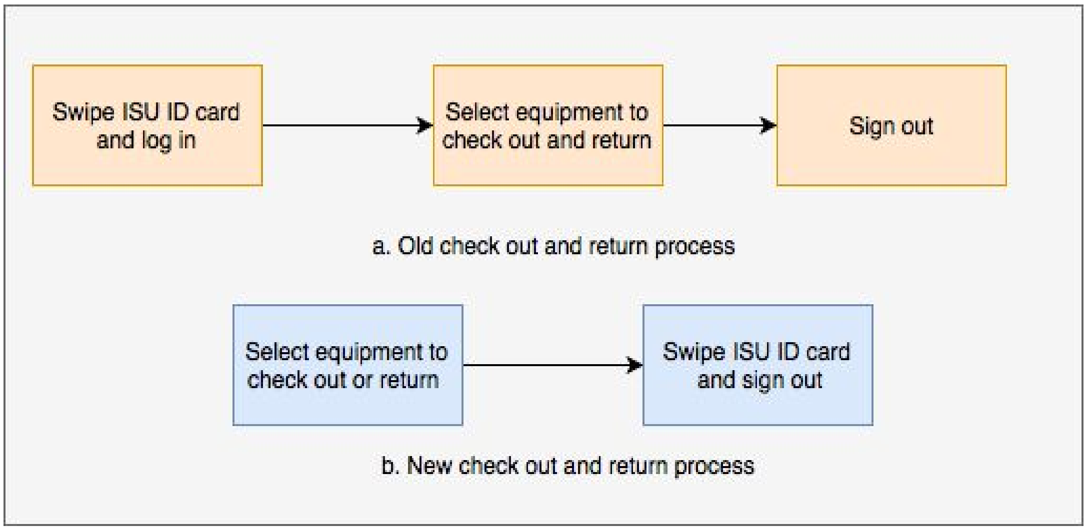

Figure 5: Desired check out and return process

c. Communicate with all 34 locker units

The current web application only can communicate with three locker units, which is obvious not satisfied the requirement for the whole checkout system to run appropriately. Therefore, we will implement this function into the web application cooperated with some extra configuration in the OWFS.

2. Android APP

- What we have finished

For now, the Android has a Home page where user can browse all lockers, and the locker on the homepage is at the same position where real locker is on the shelf. On the right top, there is a button for administrator login. When user clicks one of them, it goes to the detail page. User can also make a checkout on this page. If user chooses checkout, it asks user to enter ISU ID, it will warn user to check if the item is missing. If it is missing, user can click “Item is missing” button. When user wants to make a return, it will ask the user to enter ISU ID and check if it is the same one on record. When a administrator wants to log in, it will go to a login page. After the administrator logged in, it will list four options, “All Lockers”, "Records", "Change Password", "Initialize". For "All Lockers", it will list all lockers just like the home page, when the administrator clicks one locker, it goes to the detail page, on this page, administrator can edit item's information and status. For "Records", it lists all checkouts and returns records, each record has a type, date, borrower. For "Initialize", administrator can change the size of the shelf. For "Change Password", it allows administrator to change the login password.

- Strength and weakness of current software design

  Android has the **strength** that it is the most popular platform in the world, and in the future, we can open this APP to students so they can check stock and make a reservation on their phone. And our team members are already familiar with Java. However, it still has a **weakness** that Android Virtual Machine on Raspberry Pi will take lots system resources.

3 Testing and Implementation

In the beginning, we are going to test the hardware section and software section separately. Once both the hardware section and software section pass the test, we will connect them together and test the whole system to make sure the software can control the hardware.

3.1 Interface Specifications

There are two main parts for this project. First, the check in and out system should read the student ID and let the user choose either borrow or return the component. Then, the computer will send the signal to the raspberry Pi. Then, the raspberry Pi will process the signal and send the signal to the locker box by one-wire system.

3.2 Hardware and Software

Hardware:

- D2482S-100+T&R One-wire chip to connect Raspberry Pi and locker.
- Raspberry Pi used as microcontroller.
- Electric lock To unlock and lock the individual doors.
- DRV5023 Hall Effect Sensor on door detecting circuit
- Non-inverting Amplifier on door detecting circuit
- LM555CN Square-wave generator
- PS1240 Buzzer

Software:

The software that we are going to use in our checkout system is a web application. For students, It will give students the information of items in each locker unit and the record information about the equipment that he or she has checked out before and let students choose which equipment he or she wants to check out or return. Then, it will ask students to input personal information by swiping their ISU ID card and finish the sign out process. For ETG staffs, it will allow them to check the record of equipment in the checkout system and do editing to them. What's more, they can open the locker units if the checkout system is in error state.

3.3 Functional Testing

- ECPE students and staffs can make a checkout.
    - User can open the locker they choose, and system can generates a

record for this return/checkout, it will be a successful test.

- User can see what item is inside each box.
  - A user chooses a locker, it will be considered as a success if the LED in that locker is turned on, so the user can check if the item is missing in that locker.
- Door will alarm when it’s not closed after a use
  - We will simulate the situation that the door is not closed, we will first open the door widely if the alarm starts, then the test is successful.
  - Then we will just leave a slight gap between door and locker, if the alarm starts, then test succeeds.
- Administrators can edit item information.
  - We will simulate a administrator edit an item information for a locker, when he opens this locker’s detail page, the description should be same as what the administrator just entered.
- Administrators can browse checkout records.
  - We will simulate some checkouts and returns, then go to records page see if every operation is recorded. We will check the operation type, date, borrower for each record see if they are correct.

3.4 Non-functional Testing

- Maintanabilty

We will let some EcpE students to revise the documents that we are going to give to ETG and ask them to give feedback to it. If the majority of students can understand our documents easily, then it passed the test. Otherwise, we need to improve our documents.

- Security

We will ask some ISEAGE members to try to attack our system. If they attack our system successfully, we will improve our checkout system based on the successfully attacking methods that they have used to break our checkout system.

3.5 Process

The Figure 6 is showing the testing process of our whole checkout system.

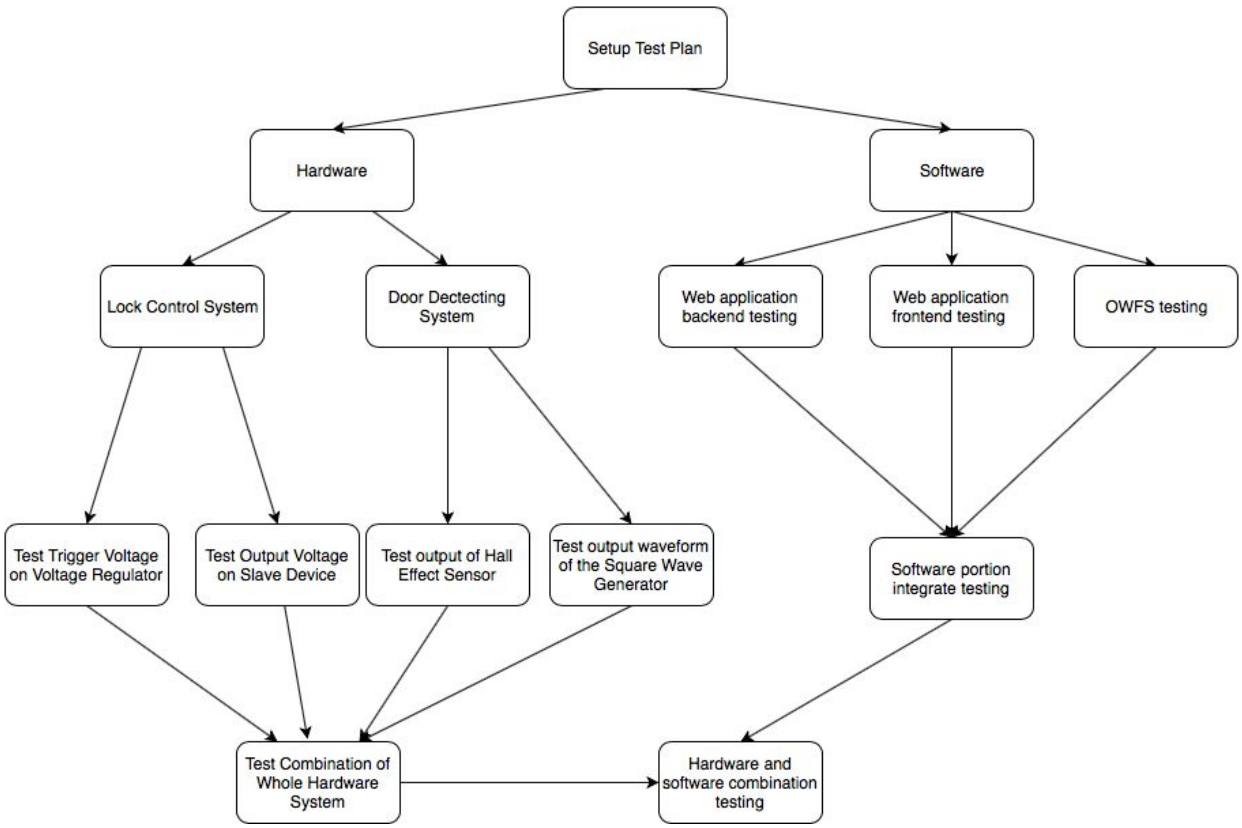

Figure 6: Testing process

3.6 Results

Hardware

- Lock control system

  The trigger voltage of PMOS that change from Cutoff to Saturation Region is 0.4V.

  The out voltage output pin on Slave Device when it receives the data from Master device is 0.24V.

  The lowest trigger voltage of LM2575T voltage regulator is 1.6V.

The gain of non-inverting op amplifier is 1+ 10k/1k = 11. It is strong enough to boost the voltage from output pin on Slave Device to trigger the on/off status of LM2575T voltage regulator.

- Door detecting system

  The output of Hall Effect Sensor is: 75mV at high status, 0V at low status.

  The output of the non-inverting amplifier: 11.45V

  The frequency of square wave generated by the LM555CN: 300 Hz

Figure 6: Test result of square wave generator

Software

Since we have not completed the whole system yet, we just tested some separate parts. Below are the tests we did and passed.

1. We can open the locker through our website.
2. We tested alarm function on a banana board, we put a magnet near the sensor, the speaker made noise.

3. When we made a checkout, a record was generated by the system, the information in the record is correct.

We have faced many challenges during the testing.

Both of our software group members were not familiar with web design which includes Javascript, SQL, HTML Layout, etc. It’s very complex, our members meet unexpected difficulty during the learning process.
In this project, we need to design and produce our own PCB. If there are some bugs we don’t find before production or we break our PCB, it will take a long time to make a new one. So, we need to apply very detailed tests to our circuit and PCB design documents.

4 Closing Material

4.1 Conclusion

Because our group was required to continue the previous group's work, our goal is improving the old design and adding new functions to the current system, and finally achieve an all-time, self-service checkout system.After fully test and analysis on the old design, our hardware team have rebuilt lock control circuit and added a door detecting circuit. For the software part, we have improved the web application. Beside, we have developed a new Android App which had the same function as online web application. At end of the first semester, we successfully connected one locker unit to the software and passed the functional test. For the next semester, our hardware section is going to create and test PCBs and place them in all 34 lockers. At the same time, our software team is planning to improve the check-out process so that users can choose the circuit components first, then, sweep the ISU ID card to open the locker. At the end of next semester, our hardware part and software part should form a integrated system which can control all 34 locker units together.

4.2 References

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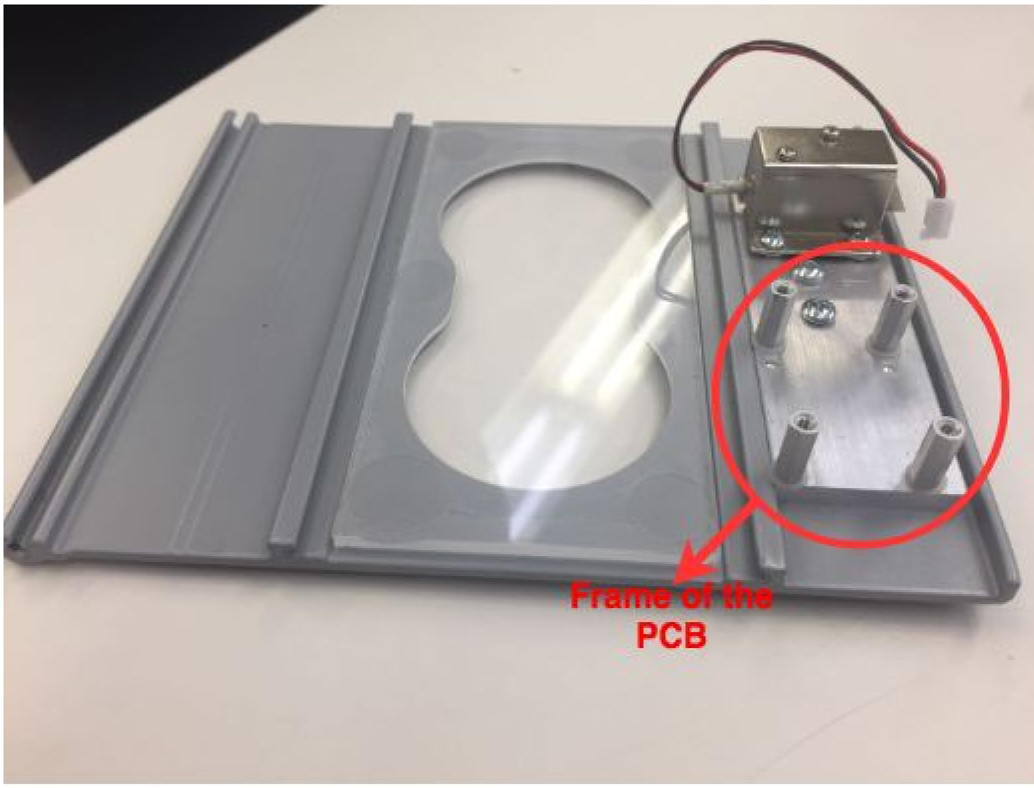
4.3 Appendices

1. The locker unit's door:



The measurement of the frame of the PCB is 3.2cm*2.5cm*1.2cm.