Small Equipment Checkout System

Final Project Report

Sdmay19 - 13
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0. Executive Summary

0.1 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.

0.2 Problem Statement

Electrical and Computer Engineering 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 check out equipment is borrowing 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 the part shop to process students' requirement, preparing demanding equipment, and recording manually. This is not just inefficient in time, but also a waste in human resource. Also, many students likely to do experiments after school or during weekends. In this situation, the ETG's limited working time, which is weekdays from 7 am to 5 pm, becomes a hinder for students to get the 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.

0.3 Operating 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 locker used for storing equipment, the other one is a touchscreen monitor for users to interact with. The shelf is made of metal and will be fixed to the wall, so its stability is the most important concern and will be tested carefully. The touchscreen monitor should have quick and accurate feedback on the user's operations.

Since the system will be placed in the public environment, 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.

0.4 Intended Users and Intended 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 a shortage in both laboratory space and equipment. Small Equipment Checkout System will allow students to borrow equipment by all day and all hours. As a 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 a fixed daily office hour. Then, they can focus more on technical support for the ECpE department and improving our lab experience.

0.5 Assumptions and Limitations

0.5.1 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.

0.5.2 Limitations:

- The size of the PCB should be 4.8cm*2.1cm*0.5cm.
- The voltage of the data output pin on the Raspberry Pi is 3.3V(Clifford, Paul.).
- ISU staffs who are in other departments cannot access the administrator website.

1. Requirements specification

1.1 Functional Requirements

1.1.1 For students:

- Users can check the availability of each item on the front page.
- After Selecting an item to check out, the LED in the corresponding unit will be turned on for checking purpose.
- The system will ask users to sweep the ID card to open the lock.
- Users can review the currently checked out equipment (personal).
- Users can return equipment and close checkout record.
- Report any damaged item to ETG.

1.1.2 For Administrators:

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

1.2 Non-Functional Requirements

1. The size of the PCB should be designed carefully so it can fit into the plastic cover, which will be attached on the locker's door
2. The hardware should be able to work stably for 24/7.
3. All the control PCBs in lockers should be connected through a single bus line, so the number of units can be extended easily.
4. Administrators can add more units by connecting more PCBs and updating the database, without modifying the circuit design.

2. System Design & Development

The picture below is our proposed design for the whole project. New and smaller PCBs will be designed to communicate between locker units and 1 wire device.

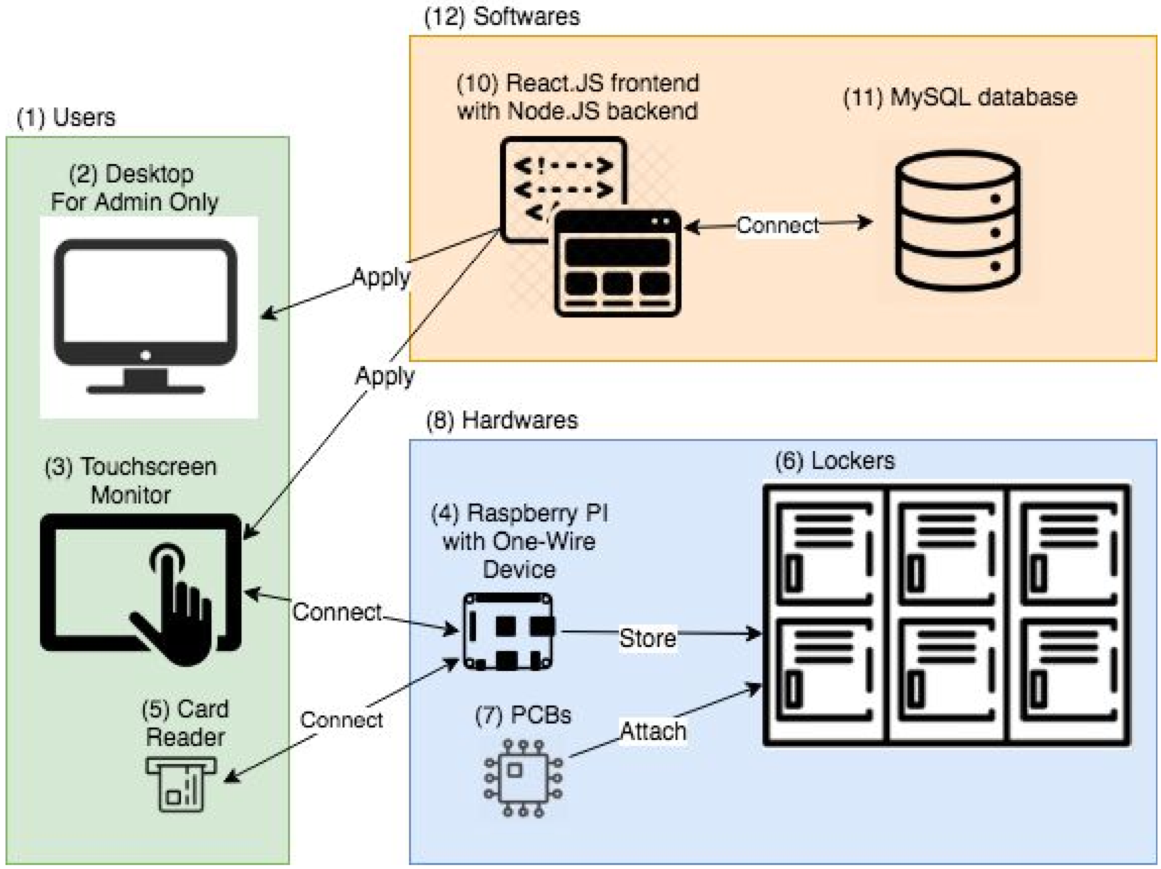

Figure 1: Proposed system design

The system should have 3 major components, users (1), software (12), and hardwares (8). For the users (1) part, it has a Touchscreen(3) for users to browse and operate. It has a card reader (5), which will be used when users want to check out or return equipment. It will read ISU ID from ISU card to identify the users 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.

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 lockers (6). The PCB(7) will contain a one-wire slave device, which assigns a unique address for each locker and can control the electromagnetic lock and the LED. PCB(7) will also have a hall effect sensor to detect if the door is closed after using. In the locker(6), each unit will have an item for borrow. In order to make the wiring of the whole system tidy and clear, we need to design a very compact PCB so it can fit in a plastic cover and attach on locker's door. We plan to use the surface-mount PCB to save the area.

The appearance of the whole project is shown in the figure 2. All locker units will be used to store items and PCBs. Users can use the the touching screen to operate the system.

The figure 3 shows the locker unit that will be used to store the Raspberry Pi and the PCB with master device. This unit is non-transparent and can only be opened by administrators with key.

The figure 4 shows the locker unit that will be used to store items and slave PCBs. All the other units are same as this one expect the unit shown in figure 3. This unit has a hole covered by the transparent plastics in the center, when users are at the step of checking the item, the LED in the unit will turn on and users can look through this hole to check the item. There is no key hole on this unit, the latch will be controlled by the slave circuit.

Figure 2: Appearance of the whole project

Figure 3: Locker unit for Raspberry Pi and master PCB

Figure 4: Locker unit for item and slave PCB

3. Implementation

3.1 Hardware

The small PCBs with DS2408 slave device are placed in each locker. By changing the output status of DS2408's PIO 0 and PIO 1, the slave device can control the latch and LED. All slave PCBs are connected to the master device through one bus line. When users change the condition of the latch or LED in any locker, the PIO status in OWFS will be changed. The master device will send the data change to the specific slave device by calling its address.

Master Circuit

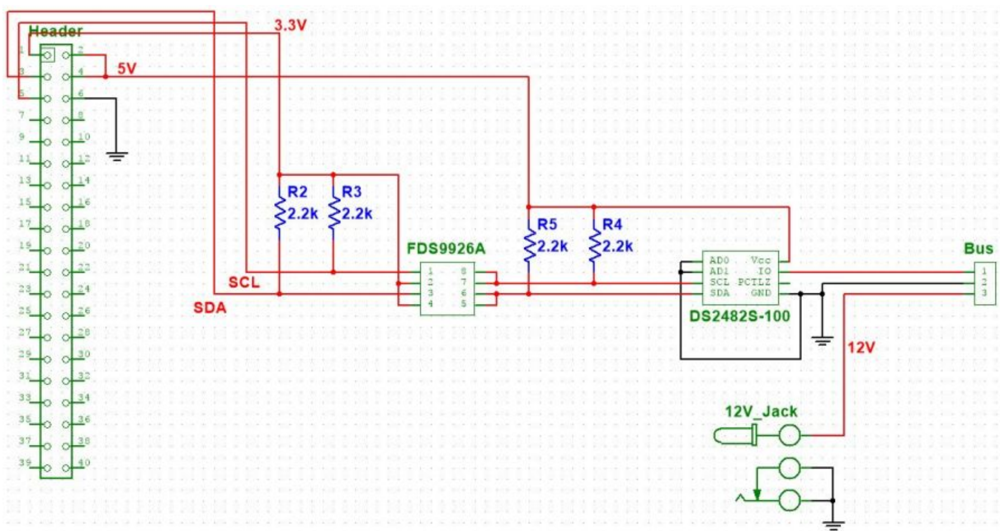

Figure 5: Master Circuit Diagram

This master circuit is designed by the previous senior design team, sdmay18-01. This circuit is attached to the Raspberry Pi by connecting the GPIO that supply the 1-wire function to the 1-wire master device. The master device can control any specific PIO on each slave device.

Manufacturer Part Number	Description	Unit Cost	Quantity
FDS9926A	MOSFET 2N-CH 20V 6.5A 8SOIC	$0.68	1
DS2482S-100+	IC BRIDGE I2C TO 1-WIRE 8-SOIC	$1.93	1
PJ-102A	CONN PWR JACK 2X5.5MM SOLDER	$0.67	1
Raspberry Pi header extender	0.1" 2x20-pin Strip Dual Male Header for Raspberry Pi	$7.99	1
3-pin Bus Connector	Bus Connector	$0.11	1
CRG0805F2K2	RES SMD 2.2K OHM 1% 1/8W 0805	$0.10	4

Figure 6: Table of cost for master circuit

Slave Circuit

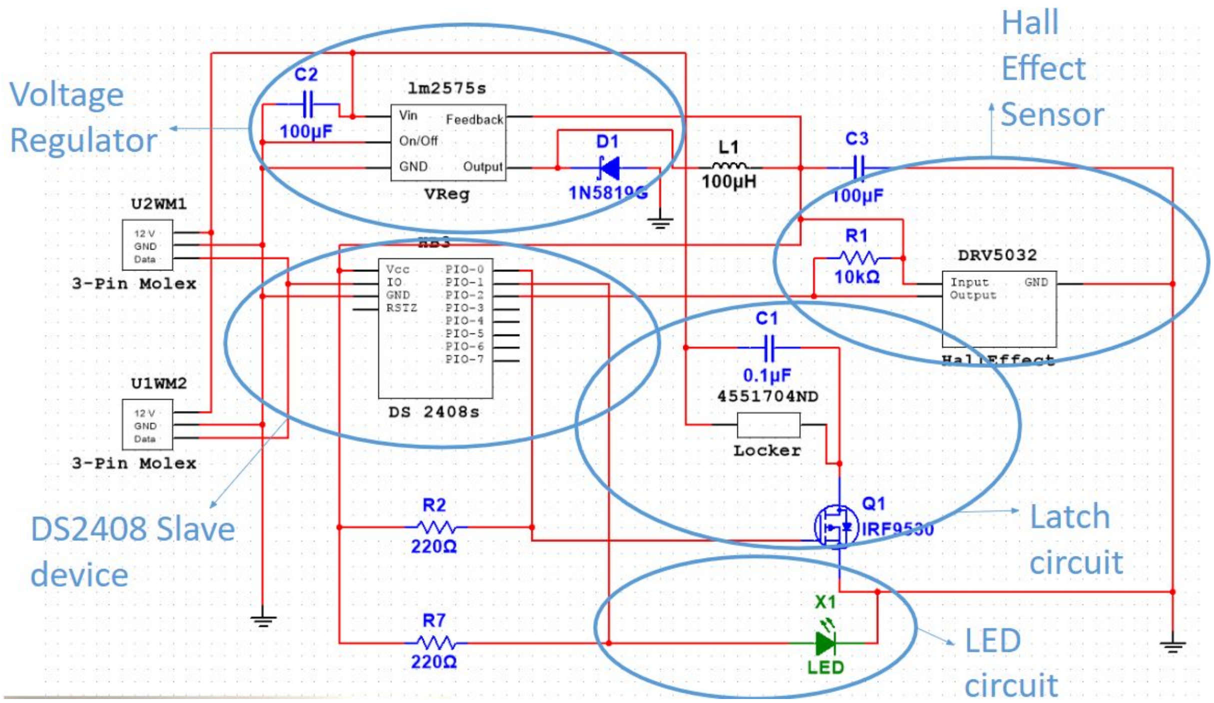

Figure 7: Slave Circuit Diagram

Voltage Regulator: This part of the circuit takes in a 12V voltage coming from the master circuit, and convert it to a 5V voltage to supply the DS2408 slave Device.
DS2408 Slave Devices: Each DS 2408 can assign an unique address for each PCB and control 8 programmable PIOs.
Latch circuit: The latch circuit has a NMOS which its gate is connected to the PIO 0 of DS2408. A 12 V voltage powers the latch and connected to the drain of NMOS, the source of the NMOS connects to the ground. When the PIO 0 of DS2408 is set to high, the NMOS turns on and the latch will open. When the PIO 0 is set to low, the NMOS turns off and the latch will close. A 220-ohm pull-up resistor is also connected to the PIO 0 to boost the output and ensure the NMOS can fully turn on.
LED circuit: A 220-ohm pull-up resistor is connected to the PIO 1 to boost the output so it can power the LED. The circuit can turn the LED on and off based on different PIO output.
Hall Effect Sensor: A hall effect sensor is connected to the PIO 2 of DS2408. The sensor will change the output status according to the magnetic flux density. When the sensor is close enough to the magnet on the door, the output will be low and the software can know that the door is closed, otherwise, an alarm will be triggered.

Manufacturer Part Number	Description	Unit Cost	Quantity
DF3A-3P-2DS	CONN HEADER R/A 3POS 2MM	$0.19	2
DS2408S+T&R	IC SWITCH 8-CHAN ADDRESS 16 SOIC	$5.89	1
DRV5032FCDBZT	SENSOR MAG SWTCH OMNI SOT-23-3(open drain)	$0.89	1
LM2575S-5.0	IC REG BUCK 5V 1A TO263-5	$4.69	1
B2B-PH-K-S(LF)(SN)	CONN HEADER VERT 2POS 2MM	$0.17	1
RR1220P-103-D	RES SMD 10K OHM 0.5% 1/10W 0805	$0.11	1
C0805X104K5RACTU	CAP CER 0.1UF 50V X7R 0805	$0.40	1
SME2014UWDN05	LED Lighting SM2014 White, Warm 3985K 3.2V 150mA 110° 0805 (2015 Metric)	$2.91	1
CC1210MKX5R7BB107	CAP CER 100UF 16V X5R 1210	$4.41	1
VLS6045AF-101M	FIXED IND 100UH 1A 527MOHM SMD	$0.58	1
1N5819HW-7-F	DIODE SCHOTTKY 40V 1A SOD123	$0.50	1
CRGP0805F220R	CRGP 0805 220R 1%	$0.22	2
DF3-3S-2C	CONN RECEPT HOUSING 3POS 2MM	$0.11	2
AOD454A	MOSFET N-CH 40V 20A TO252	$0.64	1

Figure 8: Table of cost for slave circuit

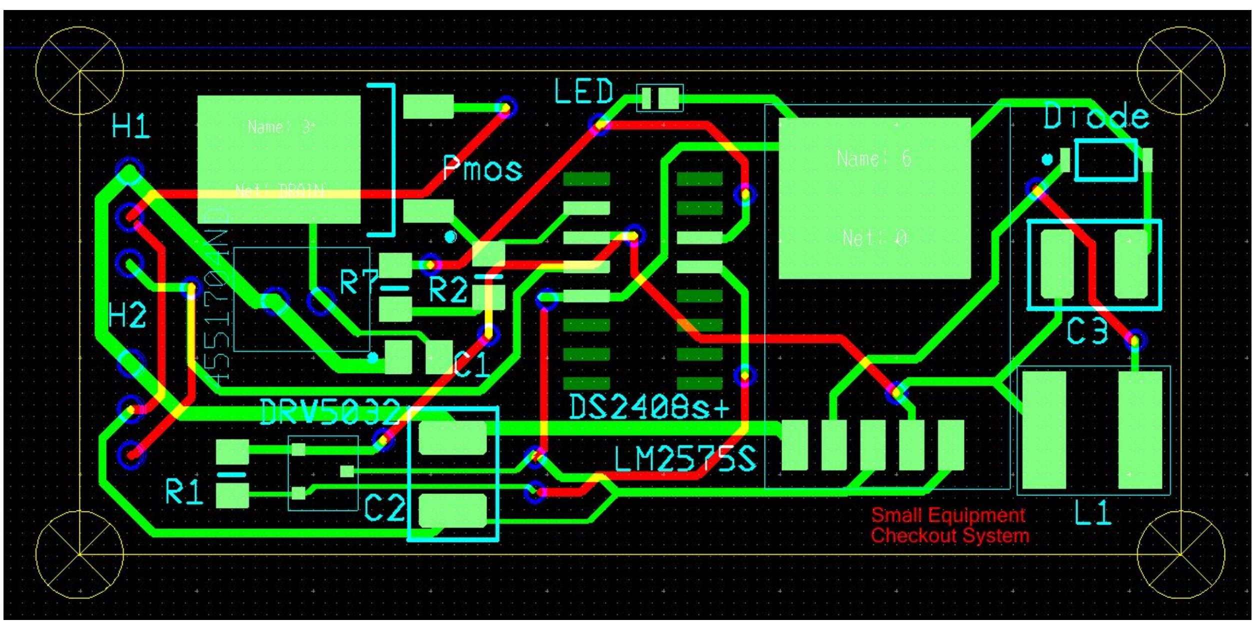

Figure 9: Slave PCB design

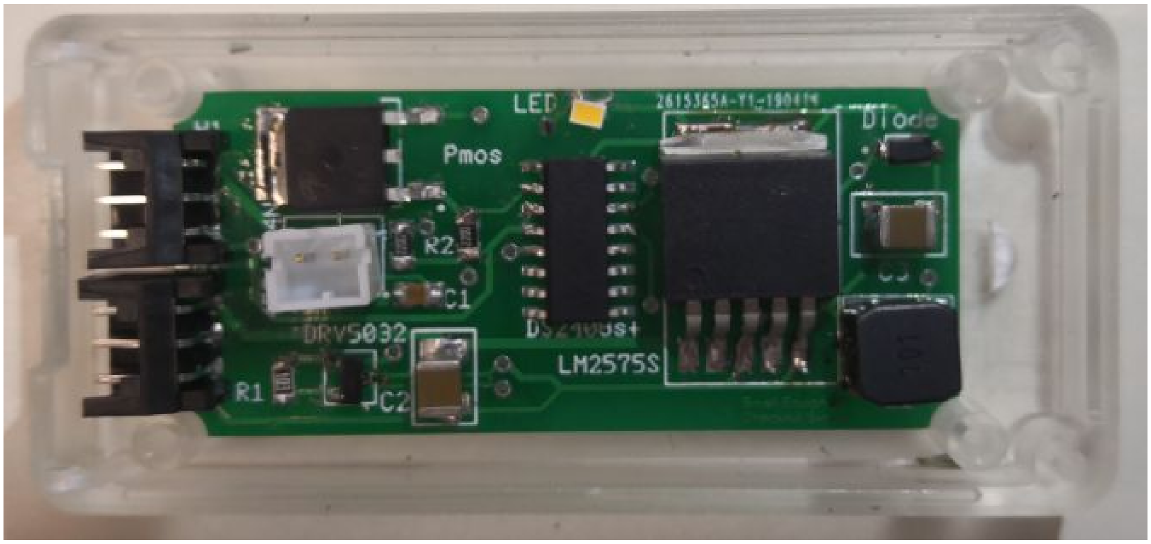

Figure 10: Slave PCB Final Product

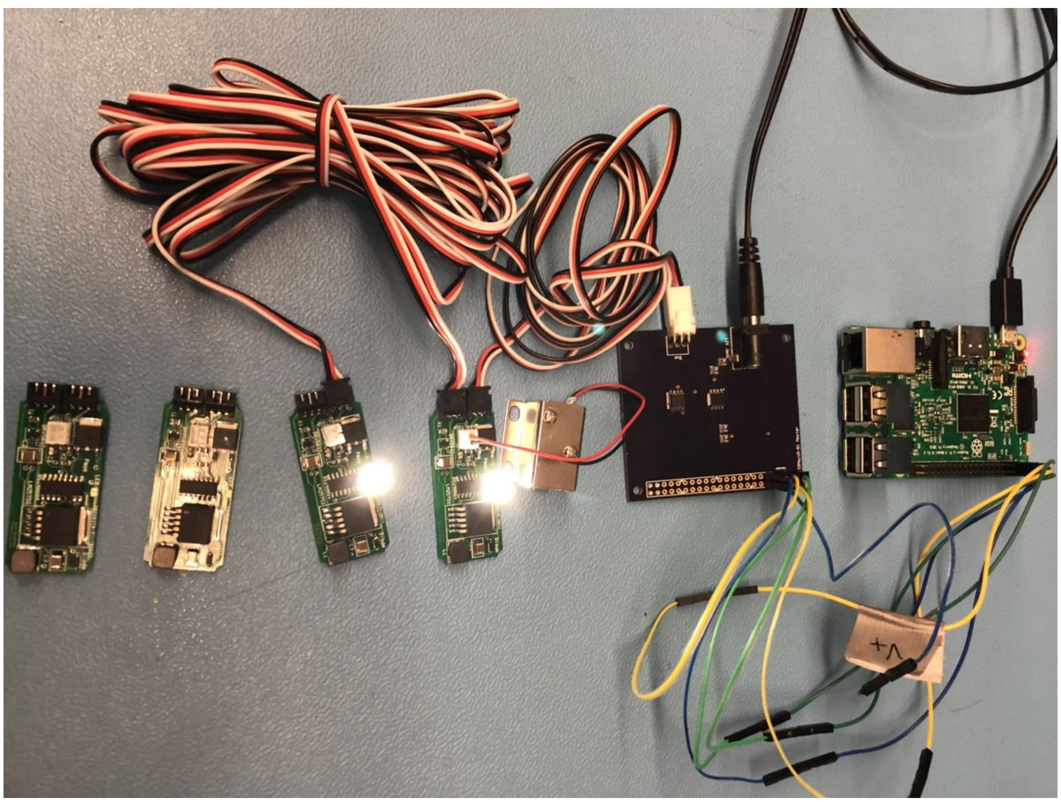

Figure 11: Completed hardware system

3.2 Software

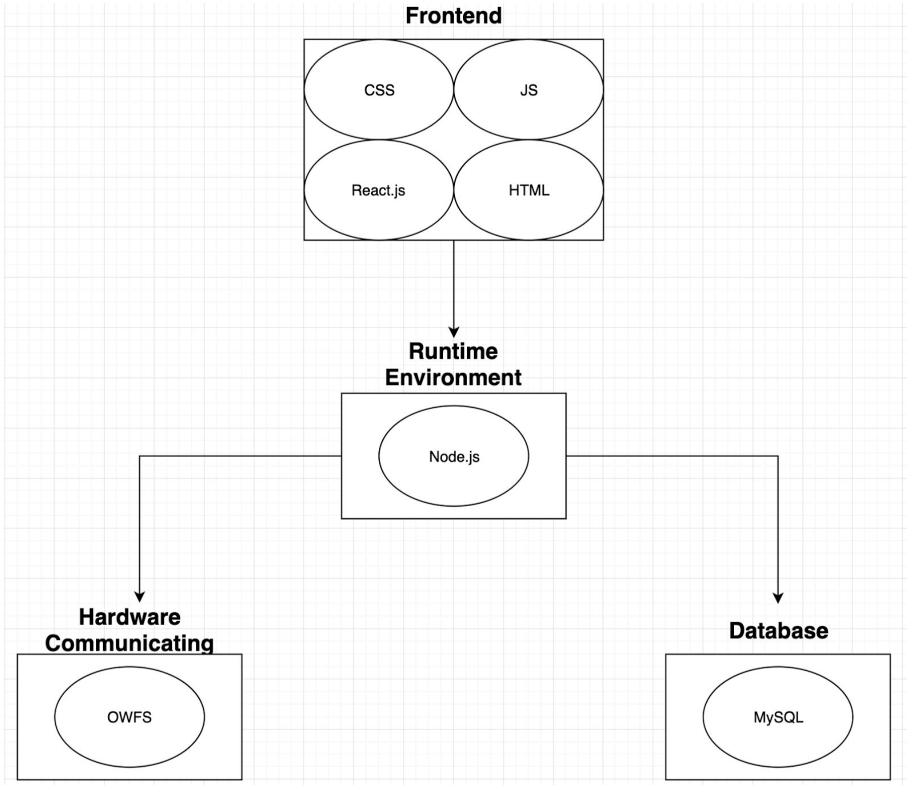

Figure 12: Software design

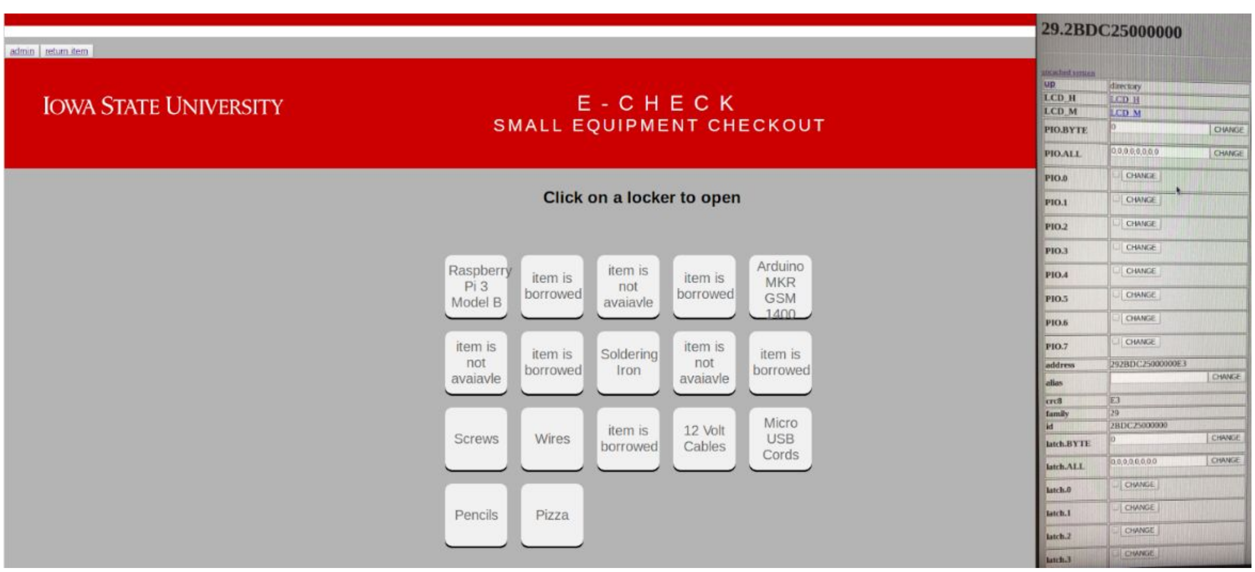

Figure 13: Website homepage & OWFS address page

For the software design, we mainly used react.js and node.js, we also used MySQL as our database and OWFS.server to communicate with the hardware.

Frontend: we used HTML for structuring web page and CSS for styling and formatting. We used react.js as for building user interfaces. It handles user's action and sends the request to the server for fetching and changing data.

Backend: we used node.js as our runtime environment. It has different Models which matches the tables in the MySQL database. It has controllers for each Model to get all elements from the corresponding table in the database.

OWFS: OWFS runs a localhost server, users can switch the PIO status on this server between 0 and 1 to change the hardware state. In the backend, we use "READ" to get the output voltage of Hall Effect Sensor PIO from OWFS server to determine the door is closed or not. We use "WRITE" to change the status of the latch and LED PIOs on OWFS server.

Database: we used MySQL as our database, it contains category, configuration, equipment, locker, record, report, and user tables. Each table has different columns for detail information. For example, the locker table has the id, address, is_admin, etc columns.

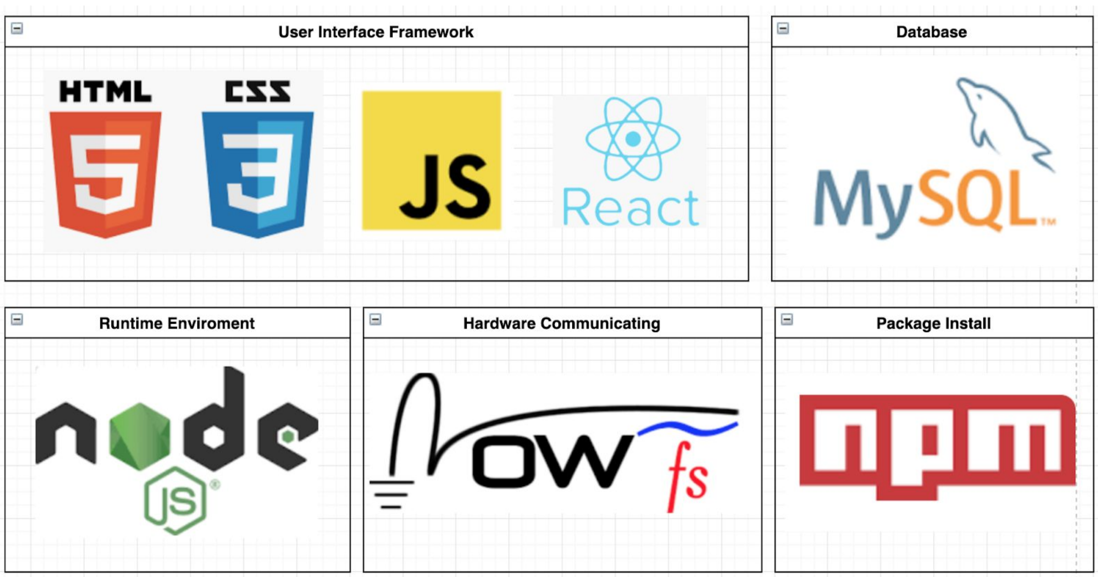

Figure 14: Software implementation applications

We chose react.js for our front end development is that it has interactive, stateful and reusable UI components and the development of web applications which can change data without reloading the page. The node.js offers easy scalability on different devices, it also handles the concurrent request more efficient. Besides, both of react.js and node.js use JavaScript as their coding language which is supported by all web browser and easy to learn. OWFS offers a simple solution to communicate between hardware and software. MySQL is a secure and reliable database management system, it is being globally renowned and used in the popular web applications like WordPress, Drupal, Joomla, Facebook, and Twitter. It also offers high-speed data accessing and changing.

4. Testing, Validation, and Evaluation

In the beginning, the test will be separated into the hardware section and software section. 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.

4.1 Test Plan

Hardware:

The hardware testing is mainly measurements of voltage at some specific net of our circuit. The following test will be applied to check if each part works.

- Measuring the input voltage of the voltage regulator to check if the master circuit can delivery 12V voltage to the slave circuit.
- For the voltage regulator testing, measuring the output voltage of the voltage regulator to ensure that it can convert 12V to 5V voltage.
- When testing the latch circuit, with a pull-up resistance equal to 220-ohm, measuring the output voltage of PIO 0 at both high and low status. Then, comparing the result to the datasheet of NMOS ensuring that under the high/low status, the output is larger/lower than the threshold voltage, so the NMOS can turn fully on/off.
- When testing the LED circuit, with a pull-up resistance equal to 220-ohm, measuring the output voltage of PIO 1 at both high and low status, and comparing the result to the datasheet to ensure that the LED can work properly.
- For the door detecting circuit, the distance between the hall effect sensor and the magnet will be adjusted, then the output should be low to 0 V when the magnet is close enough, and increase to around 5 V when the magnet is far enough.

Software:

- All buttons, elements, and boxes on the website should achieve their functionality. All possible actions of users will be tested.
- The home page should list all lockers and each locker should be labeled with the item's status.
- The item page should list the item's detailed information.
- On the "item check" page, if users choose "No", the system should create an item missing report and change the item status to missing. If users choose "Yes", the website should go to the checkout page.
- If users successfully make a checkout, the system should create a checkout record and change the item status to borrowed.
- If a user successfully makes a return, the system should create a return record and change the item status to available.
- When users are trying to login to the manager page, non-administrator users should be blocked.

- After a user updates locker an item’s information, the data in the database should also be updated.

Combined

- When users are at the “item check” page, the LED in the corresponding locker should turn on.
- After users swept their ID card at borrow or return page, the corresponding door should open.
- When the door is left open after using, the alarm should be triggered.

4.2 Process

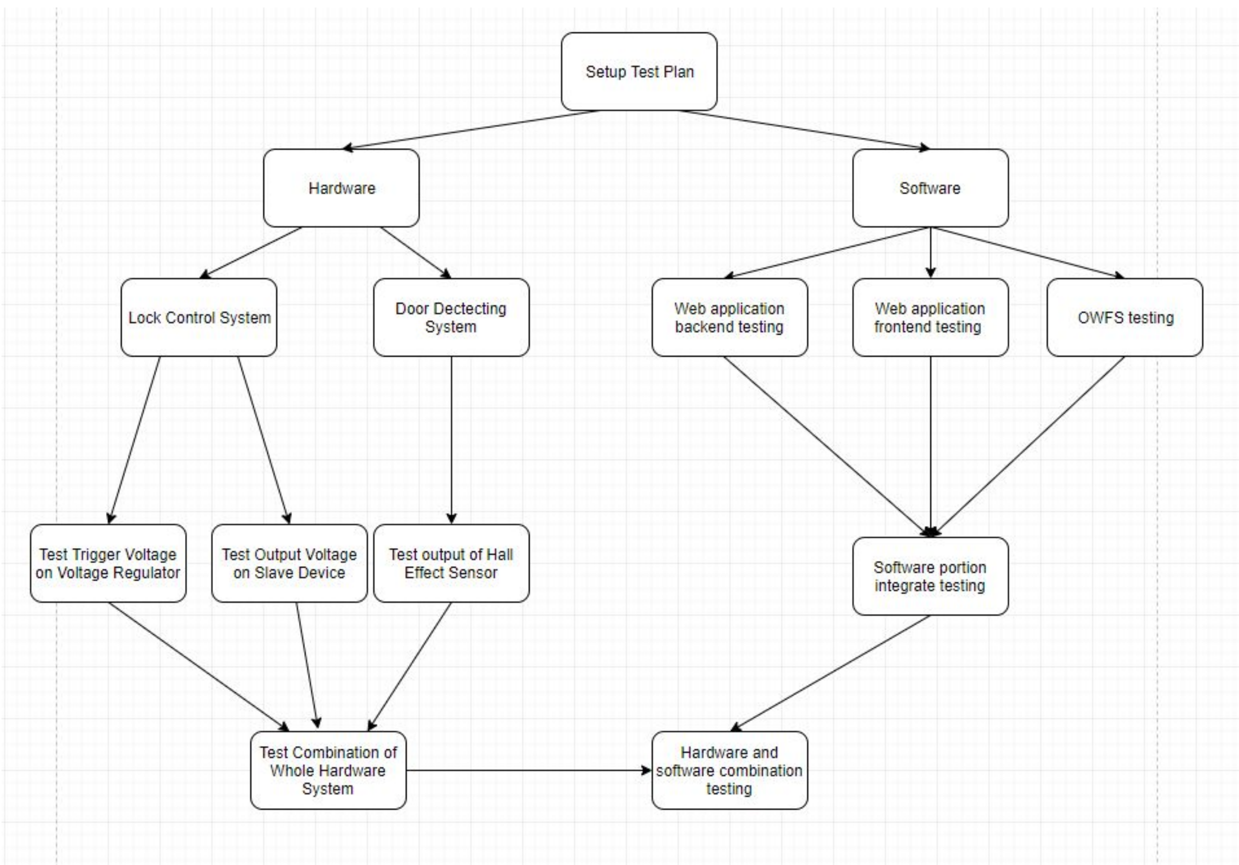

Figure 15: Testing process of the whole checkout system

4.3 Results

Hardware

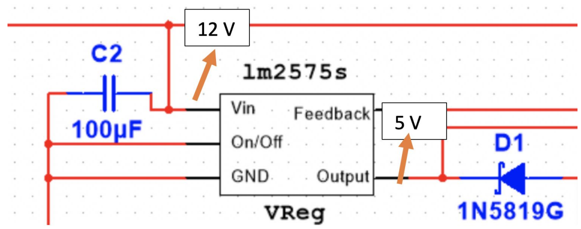

Figure 16: Testing result of the voltage regulator

- The measurements show that the input of the voltage regulator is 12 V and the output is 5 V. That means the voltage regulator is functional.

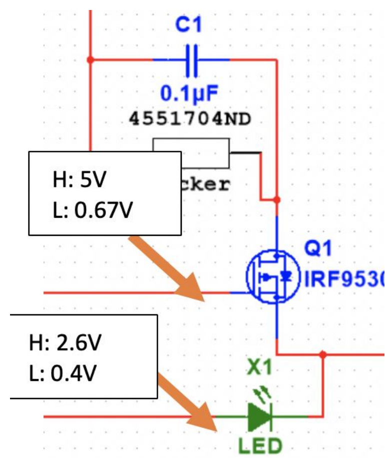

Figure 17: Testing result of the PIO 0 and PIO 1

- The measurement of PIO 0, which connects to the NMOS gate, was 5 V at high output and 0.67 V at low status. The datasheet of the NMOS shows that the threshold voltage is 3.3 V, so, the test result confirmed that the NMOS can fully turn on/off at high/low status.
- The measurement of PIO 1, which is connected to the LED, was 2.6 V at the high status and 0.4 V at the low status. This voltage is enough to light up the LED.

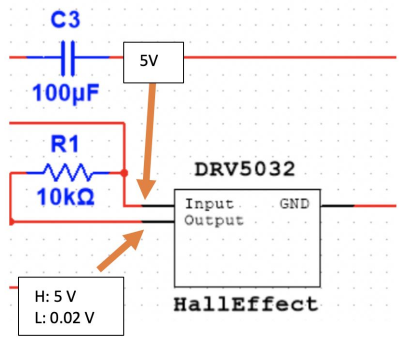

Figure 18: Testing result of the PIO 2

- The hall effect sensor is powered by a 5 V voltage coming from the voltage regulator. When the magnet was close to the sensor, the output was 0.02 V. When the magnet was far, the output increased to 5V.

Software

All buttons, elements, and boxes on the website act correctly, they lead to correct pages. All the actions listed in the software section of the test plan had been tested and meet the expectation.

Combined

After combining the software and hardware sections together, we applied the test for the whole system.

When users were at the “item check” page, the LED can turn on. After confirmed that the item is in the locker and swept ID card, the corresponding door opened. The test result showed that the system is unable to read the output of the hall effect sensor, so the door detecting sub-system need more configurations in the backend to be functional.

5. Project and Risk Management

5.1 Actual Risk

During the slave circuit testing, the master circuit is burned because of the misconnection between master and slave circuit. Since the data, 12 V, and ground pins are very close and in the same shape, it is very easy to misconnect when using the jumper wire. To avoid this risk, we used 2 mm 3 pin connect header and cable, which can only connect in one direction, to make sure the order of connection is correct.

5.2 Potential Risk

- Because the system needs to collect student ID information, there is a possibility that this information will be leaked under cyber attack.
- The Raspberry Pi is placed in a box without a cooling system and will work for 24/7. It is possible to become overheated.

5.3 Project timeline

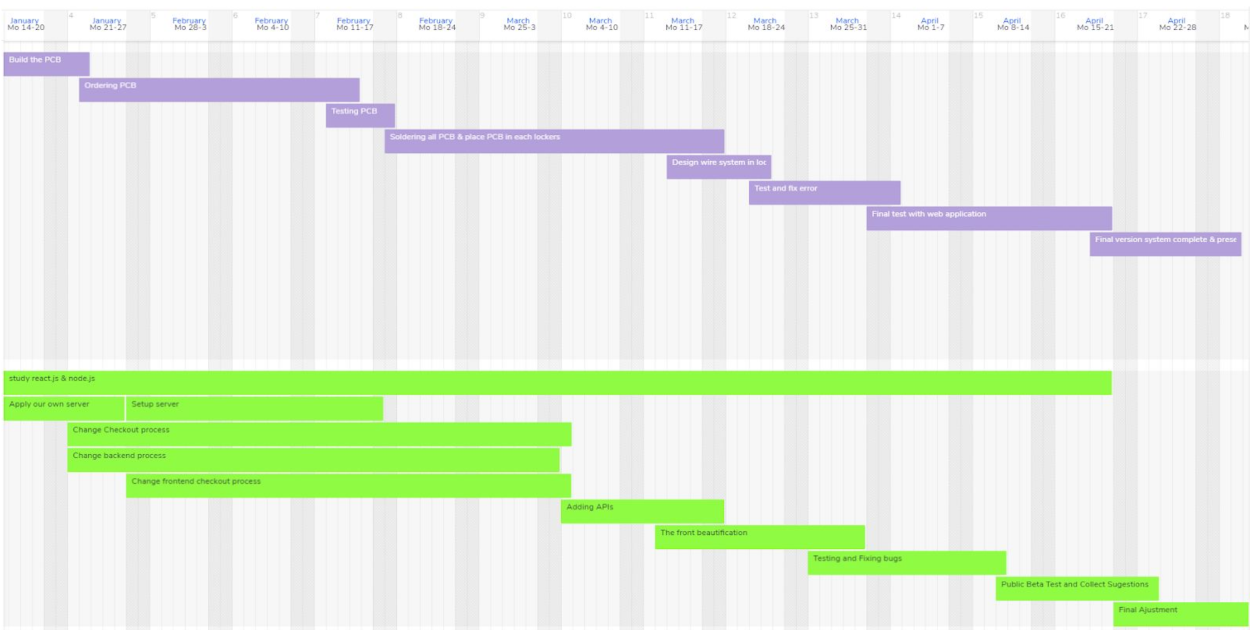

Figure 19: Proposed Timeline

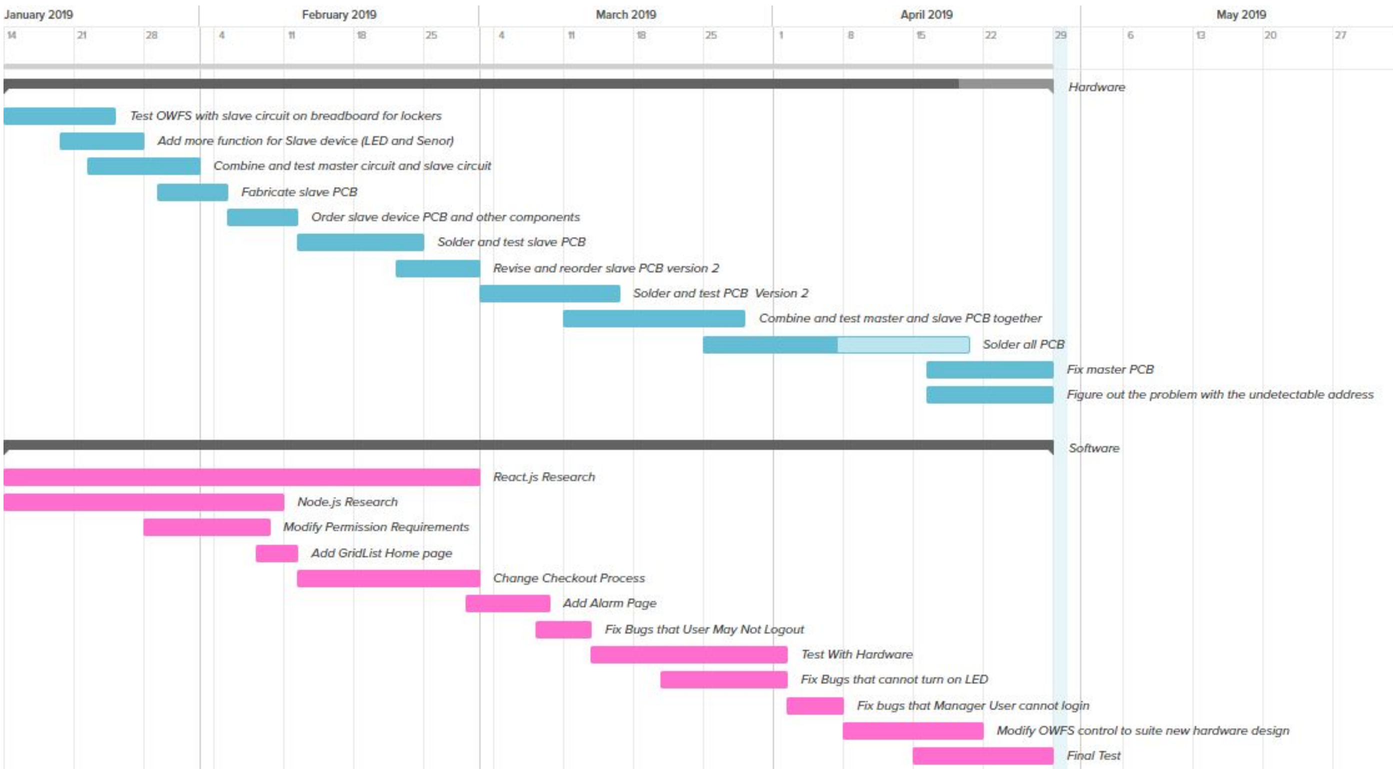

Figure 20: Actual Timeline

5.4 Cost

Manufacturer Part Number	Description	Unit Cost	#	Total
DF3A-3P-2DS	CONN HEADER R/A 3POS 2MM	$0.19	68	12.92
DS2408S+T&R	IC SWITCH 8-CHAN ADDRESS 16SOIC	$5.89	34	200.26
DRV5032FCDBZT	SENSOR MAG SWTCH OMNI SOT-23-3(open drain)	$0.89	34	30.26
LM2575S-5.0	IC REG BUCK 5V 1A TO263-5	$4.69	34	159.46
B2B-PH-K-S(LF)(SN)	CONN HEADER VERT 2POS 2MM	$0.17	34	5.78
RR1220P-103-D	RES SMD 10K OHM 0.5% 1/10W 0805	$0.11	34	3.74
C0805X104K5RACTU	CAP CER 0.1UF 50V X7R 0805	$0.40	34	13.6
SME2014UWDN05	LED Lighting SM2014 White, Warm 3985K 3.2V 150mA 110° 0805 (2015 Metric)	$2.91	34	98.94
CC1210MKX5R7BB107	CAP CER 100UF 16V X5R 1210	$4.41	34	149.94
VLS6045AF-101M	FIXED IND 100UH 1A 527MOHM SMD	$0.58	34	19.72
1N5819HW-7-F	DIODE SCHOTTKY 40V 1A SOD123	$0.50	34	17
CRGP0805F220R	CRGP 0805 220R 1%	$0.22	68	14.96
DF3-3S-2C	CONN RECEPT HOUSING 3POS 2MM	$0.11	68	7.48
AOD454A	MOSFET N-CH 40V 20A TO252	$0.64	34	21.76
795891442205	Mini Electromagnetic Electric Control Door Cabinet Drawer Lockers Lock	$2.69	34	91.46
1528-2233-ND	Jumper Wires	$1.95	34	66.3
RASPBERRY PI B	Resberry Pi	$29.95	1	29.95
2197	HDMI FLAT CABLE - 1 FOOT / 30CM	$3.95	1	3.95
U050-003	USB 2.0 A TO MICRO-USB B CABL 3'	$4.65	1	4.65
	PCB	$0.40	34	13.6
Total				$965.73

Figure 21: Table of cost for whole system

6. Conclusion

6.1 Closing Remarks

Even though the completion of the system is still in progress, the hardware design is fully completed. Our circuit can successfully control the latch and LED in lockers, and the door detecting circuit can output different voltage based on the distance to the magnet in the locker. The frontend of the website has all the required functions, grid list of lockers, alarm page, etc. The part that still needs to be improved is the OWFS configuration of the newly added PIO 2 (door detecting circuit), and the controller of this PIO in the backend. Unlike the latch circuit and LED circuit, the door detecting circuit will output voltage instead of take in voltage, which need to configure differently in the backend. And the new function that can read the input from PIO 2 also need to be added in the script. Until these steps are completed, the alert cannot be triggered as we expect.

6.2 Future work

1. Complete the door detecting system.
    - Hardware is complete.
    - Need to add new functions in frontend and backend.
2. Add more locker units to the whole checkout system.
    - Slave circuit and PCB design documents can be downloaded from group website. All slave PCB are the dame and can connect to the master PCB through one bus line.
    - Design the manual about how to modify the database and website when adding more units with different items.
3. Design and implement the cooling solution for the unit that stores the Raspberry Pi and master PCB.
    - Drill a hole in the back of the locker and install a fan.
    - The power supply can be provided by the master PCB, then the circuit need to re-designed.

List of References

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Team Information

Yimin Wang

Major: Electrical Engineering

Team Role: Project Manager

Technical Role: Hardware Team

Jiaxin Li

Major: Electrical Engineering

Team Role: Treasurer

Technical Role: Hardware Team

Fengnan Yang

Major: Electrical Engineering

Team Role: Reporter & Meeting manager

Technical Role: Hardware Team

Caining Wang

Major: Computer Engineering

Team Role: Software Developer & Secretary

Technical Role: Software Team