RFID Anti-Theft Door Lock

ECE 445 Design Document

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1. Introduction

● Objective

For most people, home is both the start and the end of their days. Home is also the place where people spend the most time staying in. However, home is also a private place; nobody is happy if everyone can enter his or her home without any limits. Therefore, most people install locks on their doors to prevent others to easily get inside. Nevertheless, the traditional door lock has become undependable. Sometimes, the key or the lock might be corrosive, and the lock becomes very hard to open. Many people have the experience that they plug in the key and spin it clockwise, but the door does not open. Then, they spin it counterclockwise, but it still does not open. Then, they try to spin it clockwise again, and the door finally opens. This process is absolutely annoying. Besides that, some people even meet the situation in which the keys are broken and parts of the keys are stuck inside the door. More importantly, those traditional locks do not have any anti-theft function. Burglars who master the skills of opening the locks can easily enter people's houses. Some people may think that there are so many families, so the percentage that they encounter burglaries is low. This opinion is imprudent. If they did not encounter burglaries, that would be perfect. However, if burglaries did occur and they did not have a reliable lock, the property loss could not be eliminated. Even their life safety could not be guaranteed.

Our goal is to design an RFID anti-theft door lock. This lock utilizes an RFID tag to open, so it is much more convenient than the traditional lock. It only takes less than one second to open the door, and people does not need to worry about the direction to spin. Also, this lock offers two protections, both during the burglary and after the burglary. This lock contains a crime alarm and camera. If a burglar attempted to open the lock without the tag or destroy the lock, the alarm would ring to notice the surrounding people and the burglar might leave immediately. If the intruder came at night and the house owners had already fell asleep, the alarm would wake up the house owners. This is the protection during the process of a burglary. Moreover, The camera would also take a photo of the burglar so as to help the police to apprehend the criminal. The house owners and the police could arrest the criminal and retrieve their properties. This is the protection after the burglary.

● Background

The United States has the most burglary crime in the world. In 2014, the amount of burglaries was 1.71 million, which was about four times of that in Germany, the second top country [1]. Currently, most people still use the traditional door locks. They install door locks only because they think that they need locks. They subliminally consider that all kinds of locks have the same security level, so they are unwitting that their locks cannot effectively impede burglars. Therefore, many people's houses are actually in danger, but they are not aware of this fact.

In the past, the traditional lock was economical and reliable in some degree, but the technology is now able to provide higher security and protection for people.

- High-level Requirements List
- The RFID lock must be convenient and reliable to be opened.
- The lock must be solid enough so that the intruder is unable to easily destroy it.
- The buzzer must be loud enough to make the surrounding people vigilant.
- The camera must be able to capture a clear photo of the intruder.

2. Design

- Block Diagram

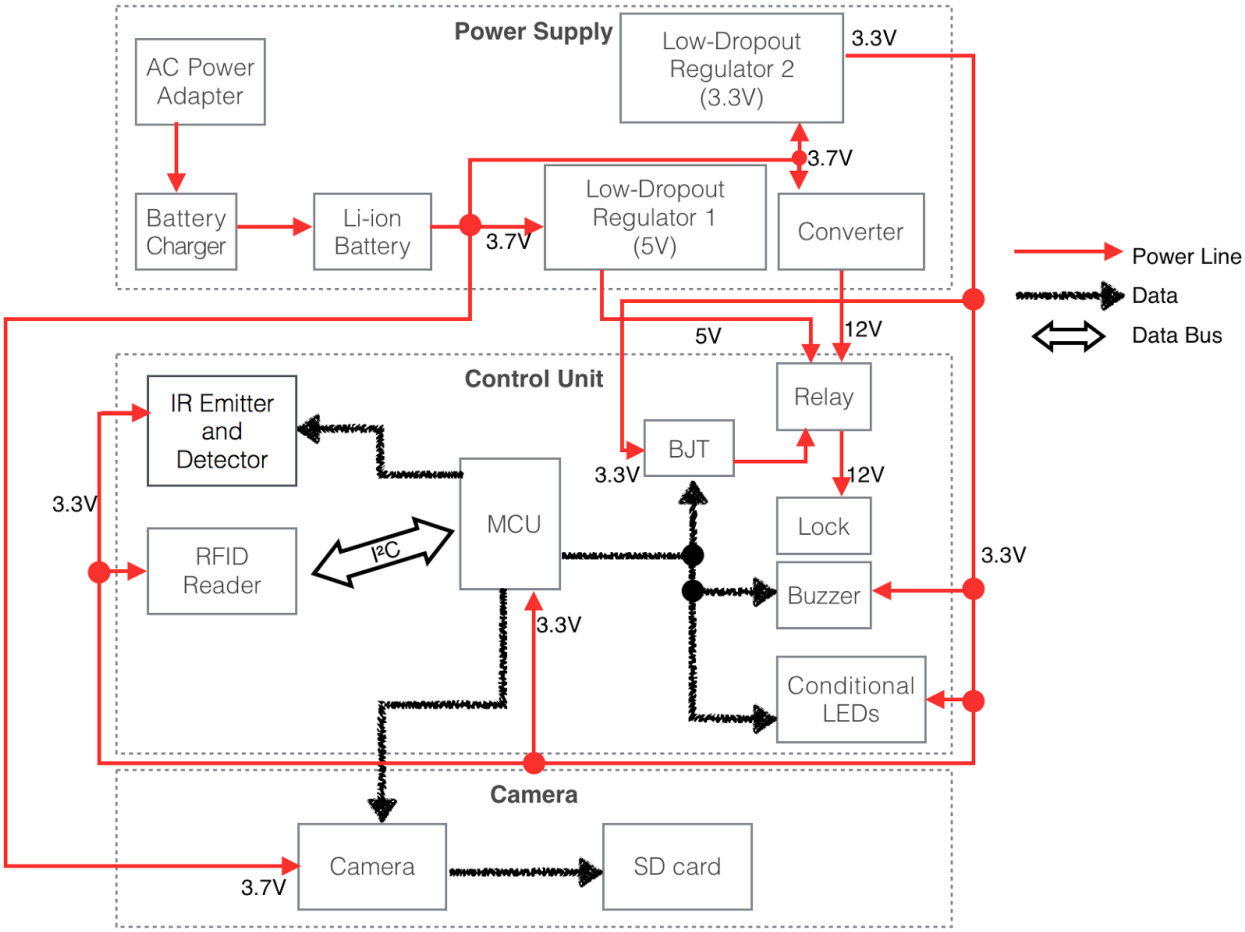

Fig. 1. Block Diagram

- Physical Design

On the front surface of our lock, there is a camera, a buzzer, the RFID reading area, and a handle. We place the camera on the top of the lock so that the view would not be impeded by

the handle. We place the electronic lock, power supply unit, and the control unit inside of the lock.

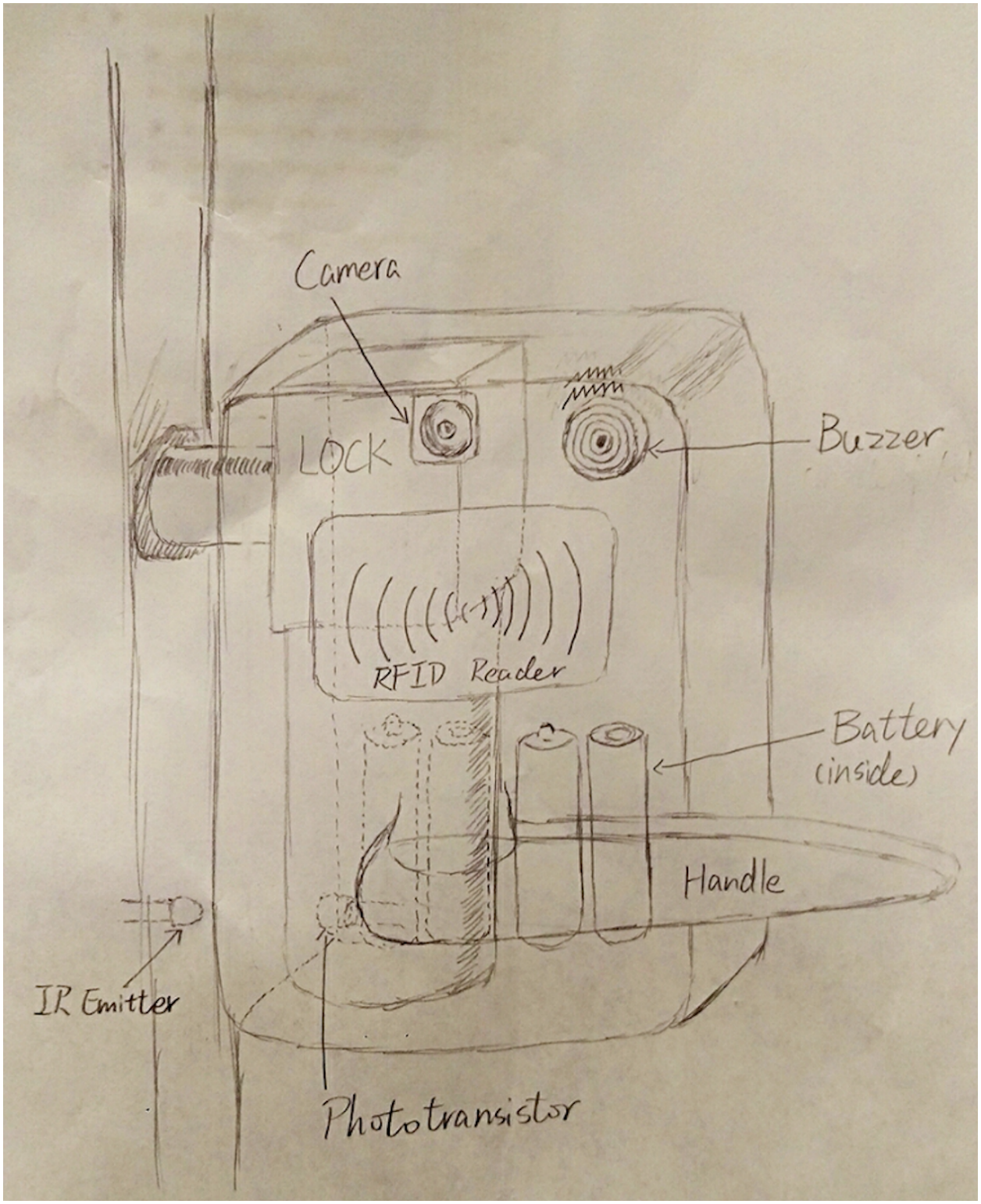

Fig. 2. Physical Design

- Block Design

1) Power Supply

The power supply has to assure that the lock works 24/7. We do not want people to be locked out of their houses due to a lock without power.

AC Adapter: SoulBay 12W Universal Multi-Voltage AC/DC Adapter

Our lock requires a reliable power supply, so we choose the power outlet.

Requirements	Verification
1. Must be able to convert AC input voltages from 100V to 240V. 2. The output voltage must be 5V VDC.	1. A. Swap the input voltage from 100V to 240V. B. Test the output voltage change when an 100 ohm resistor is the load.

Battery Charger: BQ24040

This is used to charge those Li-ion batteries.

Requirements	Verification
1. Li-ion battery charges to 4.16-4.23V when a continuous 5V input voltage is applied. 2. Charging at maximum current and voltage can be sustained below 50°C.	1. A. Discharge a li-ion battery to 3.7V cell voltage. B. Charge the battery at the output of the charger without limiting current. C. At the termination of the charge cycle, use a voltmeter to check the voltage of the battery. 2. A. Throughout the charging cycle, observe the temperature. Use an IR thermometer to ensure that the temperature is below 50°C.

Battery: YKS Universal Li-ion Rechargeable Batteries

The battery is used when a power cut occurs in the house. The battery must be safe and ready to work 24/7.

Requirements	Verification
1. Must be able to provide power for the system for at least 48 hours without power outlet.	1. A. Calculate the total current consumption B. Calculate the total mAh of batteries C. Divide the total mAh by the total current consumption to make sure that the duration is longer than 48 hours.

LDO1 (low dropout voltage regulator): TLV704

This LDO is used to provide power for the relay.

Requirements	Verification
1. The output voltage has to be 5V ±2% when the current is 40mA and the input voltage is 3.6V to 4.2V	1. A. Connect a 100Ω resistor to the output pin. B. Connect the input to the power supply C. Measure the voltage of the resistor with a voltmeter. Swap the input voltage from 3.6V to 4.2V. Measure the output voltage,

LDO2 (low dropout voltage regulator): TLV704

This LDO is used to provide power for the buzzer, conditional LEDs, MCU, RFID reader, IR emitter, and IR detector.

Requirements	Verification
2. The output voltage has to be 3.3V ±2% when the load current is 150mA and the input voltage is 3.6V to 4.2V	1. A. Connect a 22Ω resistor to the output pin. B. Connect the input to the power supply C. Measure the voltage of the resistor with a voltmeter. Swap the input voltage from 3.6V to 4.2V. Measure the output voltage,

DCDC Converter: PTN04050C

Since the voltage input of the lock is 12V, we need a converter to convert 3.7V voltage to 12V voltage.

Requirements	Verification
1. When the input is from 4.2 V to 3.6 V the output voltage has to be 12V±5% when the load current is at least 450mA.	1. A. Connect the input of the converter to the power supply and the load of the converter is 25 Ohm resistor. B. Swap the input voltage from 3.6V to 4.2V and measure the output voltage.

2) Control Unit

The control unit is to accomplish the main functions of this lock. It contains a micro control unit to send data to the lock, buzzer, and LED.

MCU: MSP430FR2310

The micro control unit is used to process all the data. It receives data from the IR detector and RFID reader and tells the lock, buzzer, and the LED what to do. We decide to use MSP430FR2310 made by Texas Instruments.

Requirements	Verification
1. The Responding time from the RFID starting the reading to the lock or camera trigger IO change has to be less than 100ms	1. Connect the RFID to MCU. 2. Connect the SDA pin and Trigger IO pin to the oscilloscope and measure the time between two signal change.

IR Emitter and Phototransistor: WP3A10SF4BT and QSD122

The IR emitter is placed on the door and makes the phototransistor know that the door is closed. The phototransistor is used to detect if the door is open. If the phototransistor cannot detect the IR, that means the door is open.

Requirements	Verification
1. The phototransistor must be able to detect the IR emitter within 10cm. 2. The phototransistor must be able to detect the emitter at up to 40°C.	1. A. Power up the IR emitter with a 1.5V voltage source. B. Place the phototransistor 10cm away from the emitter. C. Use the phototransistor to detect the IR. C. Measure the voltage of the phototransistor. Ensure that there is voltage across the phototransistor. 2. A. Before performing the verification in 1, use a hair dryer to heat the emitter. B. Use a thermometer to measure the surrounding temperature.

	C. When the temperature reaches 40°C, turn off the hair dryer and perform the verification in 1.

RFID Reader: RC522 RFID Reader

The RFID reader is used to detect the tag in order to open the door. The reading distance of our RFID reader has to be short. Otherwise, people may unintentionally open the door when they just walk by.

Requirements	Verification
1. The reading distance must be less than 10 cm. 2. The operating voltage must be 3.3V±2%.	1. A. Perform the reading in the distance from 2cm to 20cm in 2cm step. Find how far the RFID reader could read. 2. A. Swap the input voltage of RFID reader from 2.8V to 3.4V. Check whether it works properly

Lock: Electric Drop Door Lock Z9W0

We use an electronic lock since it is easy to control. Also, it is appropriate for diverse doors and has an anti residual magnetism design. The lock we choose is made from durable and high aluminium alloy material and durable for use. The lock is powered with the converter, which has a 2.4A output current.

Requirements	Verification
1. The working current has to be less than 2.4A. 2. Must be quickly unlocked when the power is cut.	1. A. Use a current generator to apply 450mA(based on the description) to ensure the lock works. 2. A. Stop the power supply. B. Ensure that it is unlocked immediately.

Buzzer: Uxcell Electronics Buzzer LZQ-3022

If someone tries to intrude, the buzzer will ring to notice the surrounding people. In most cases, the burglar will choose to leave immediately. Also, if the burglar comes at night, the buzzer has to be loud enough to wake up the house owner.

Requirements	Verification
1. The noise must be at least 80 db at 20m away from the buzzer.	1. A. Connect the buzzer to a 3.3V voltage source. B. Use a decibel meter to measure the decibel at 20m away from the buzzer. Ensure that the noise is above 80 db.

Conditional LED: LED Light Emitting Diodes

When a proper tag is detected, the LED is green. When an incorrect tag is detected, the LED is red.

Requirements	Verification
1. Must have green light and red light.	1. A. Connect those LEDs to a 3.3V voltage source. B. Ensure that there are green and red LEDs.

Relay: Omron G6D-1A

The relay is used to control the lock. Lock with power and unlock without power.

Requirements	Verification
1. Must be able to control 12V voltage, which is the requirement of the lock.	1. A. Power up the relay with 5V voltage. B. Connect a 100Ω resistor to the output pin. C. Connect the relay to a 12V voltage source. D. Send a signal to the relay. E. Use a voltmeter to measure the voltage across the resistor. Ensure the voltage is 12V.

3) Camera

When the lock detects a person who attempt to intrude, the camera will take a photo for that person. The house owners and the police can use the photo to arrest the intruder.

Camera: Mini Spy Trigger Camera for Photo or Video

If a person tries to intrude, his or her face is usually closed to the lock, so we can simply install the camera in the lock, instead of the place closing to the peephole. However, capturing the face of the person is not our only concern. Sometimes, the camera might fail to capture the face due to some factors, such as light. If the camera could capture some details of the person's clothes or accessories, that would be considerably helpful. Therefore, the resolution has to be relatively high.

Requirements	Verification
1. The photo resolution has to be at least 1280x720 to capture enough details.	1. A. Connect the red wire to a 3.7V Li-ion battery and connect the black wire to the ground B. Connect the white wire to the battery for less than 1 second to take a photo C. Check the photo on a laptop to ensure that the resolution is 1280x720.

SD card: SanDisk 8GB Class 4 MicroSDHC Card

The SD card is used to store the photos taken by the camera. Since the camera is not often used, the storage can be relatively small.

Requirements	Verification
1. The storage must be at least 512 MB.	1. A. Plug the microSD card into a laptop to check the storage.

4) Circuit Schematics

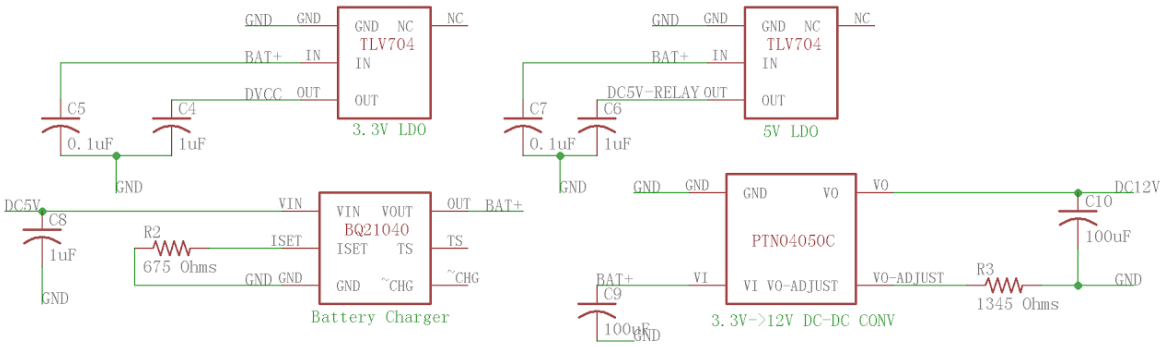

Fig. 3. Power Supply Unit

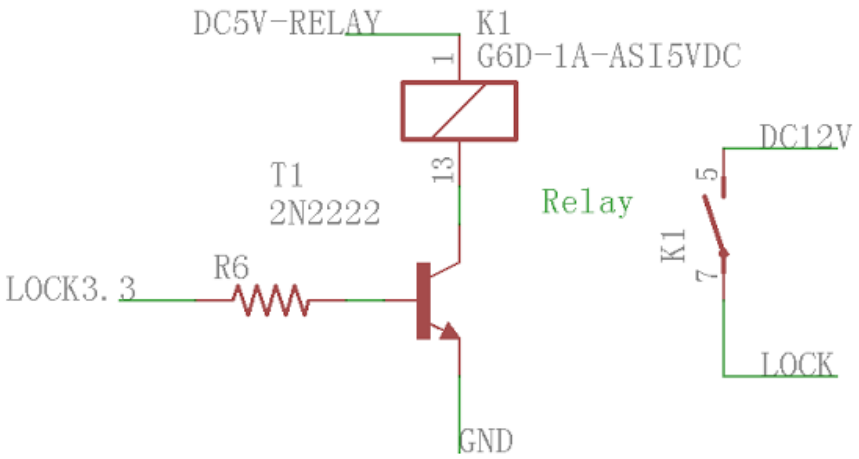

Fig. 4. Lock Unit

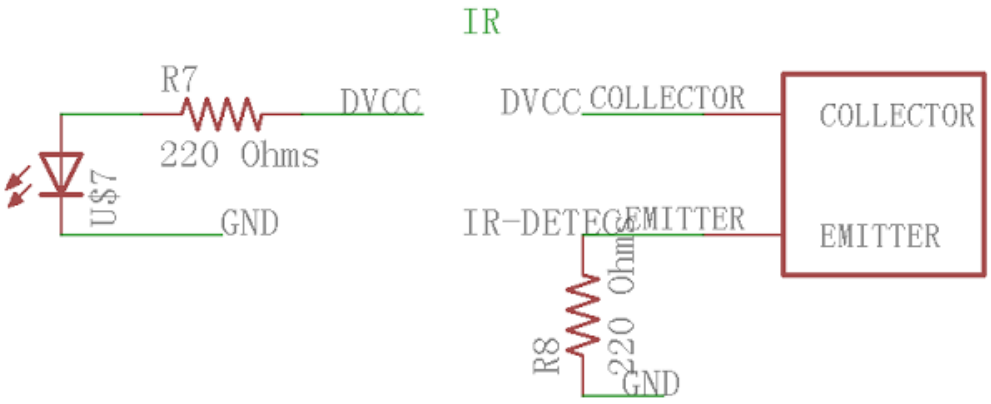

Fig. 5. IR Unit

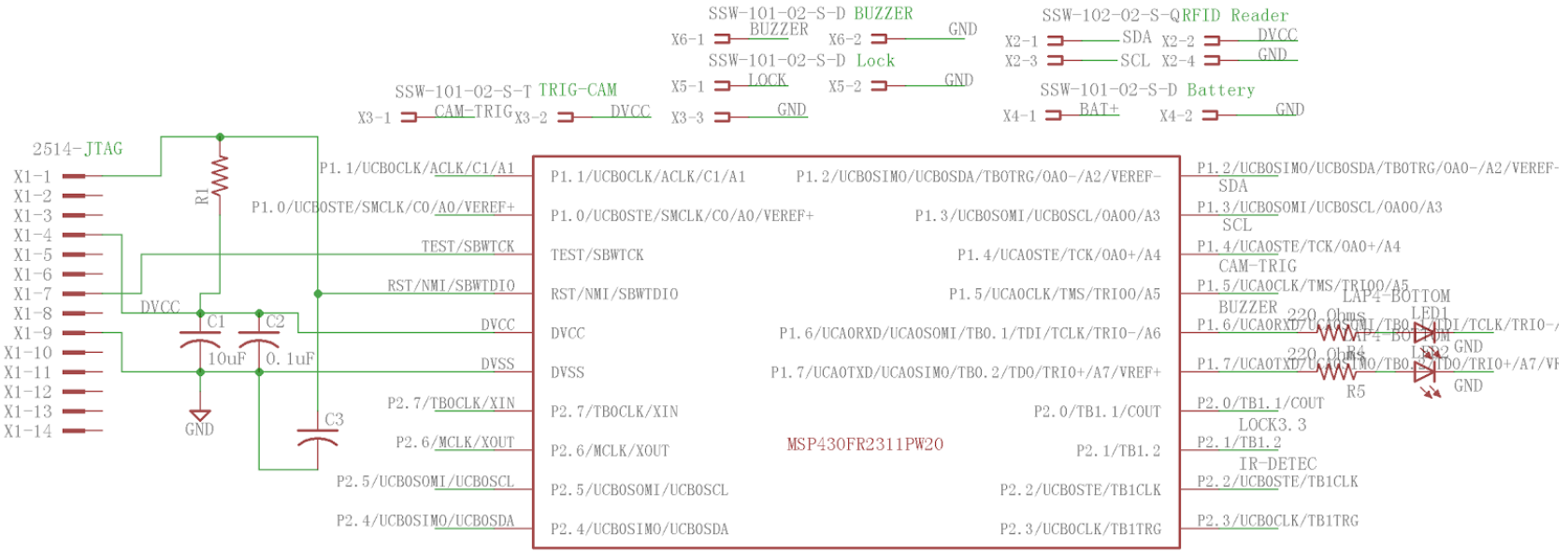

Fig. 6. Control Unit

5) Calculations

The following chart is the components powered by the LDO2. Toe total current consumed by these components must be less than the output current of LDO2.

Devices connected to LDO2 (3.3V)	Current
MCU	2.432mA
Buzzer	50mA
LEDs	40mA (20mA each)
IR Emitter	20mA
Phototransistor	6mA
RFID Reader	20mA
TOTAL	138.432mA

The maximum current output of the LDO is 150mA, so this design is feasible.

Based on our plan, the duration of batteries should be at least 48 hours in case there is a power cut in the house. We first need to calculate the current consumptions of LDO1, LDO2, converter, and camera to get the total current consumption.

Current input of LDO1 = 138.432mA x 3.3V ÷ 3.7V = 123.5mA Eq.1

Current input of LDO2 = 40mA(current of Relay) x 5V ÷ 3.7V = 54.1mA Eq.2

Current input of Converter = current of lock = 450mA Eq.3

Current input of Camera = 80mA Eq.4

Total current consumption=707.6mA Eq.5

Duration of batteries = 4 x 9800mAh ÷ 707.6mA ≈ 55 hours Eq.6

The calculated duration is about 55 hours, which satisfies our plan.

6) Door and Alarm Logic Flow Charts

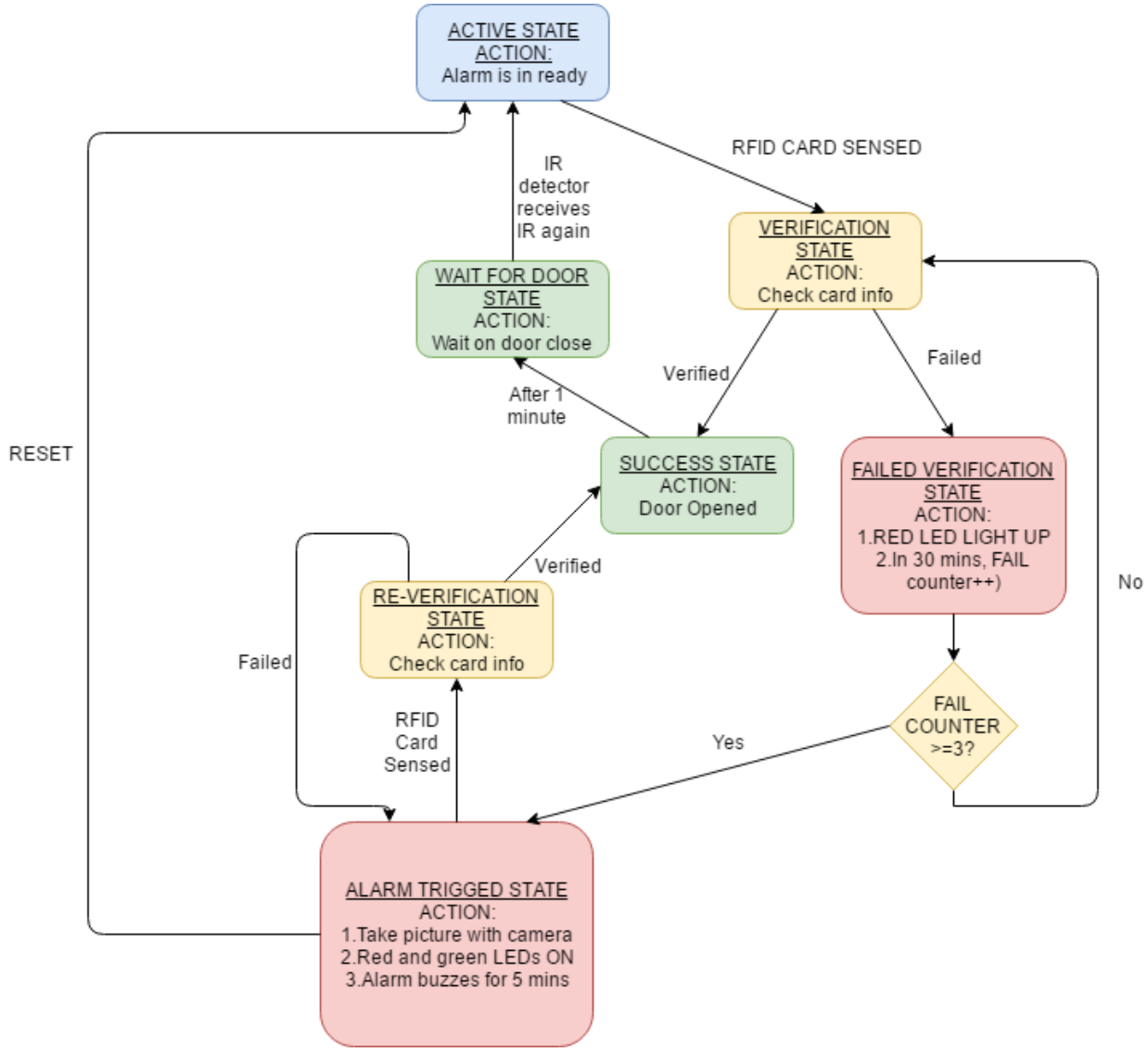

Fig. 7. Door and Alarm Logic Flow Chart

- Tolerance Analysis

One important tolerance we must maintain is that the phototransistor matches to the IR emitter because these two components are used to detect whether the door is open or closed. If these two components did not work properly, the anti-theft function would not exist. The wavelength of our IR emitter is 880nm, so the phototransistor must detect this wavelength no matter what.

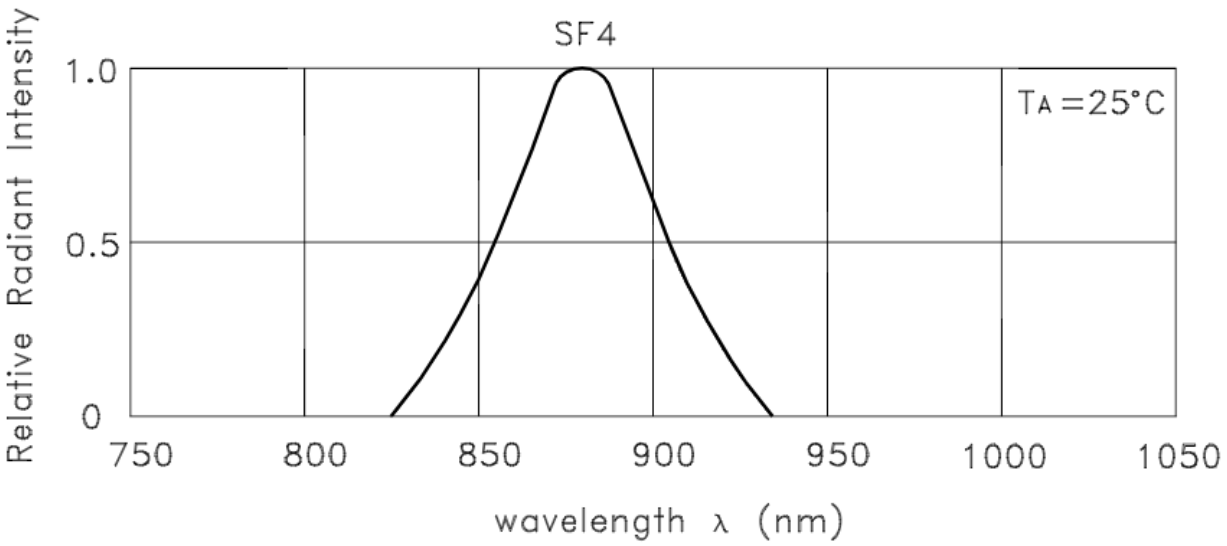

Fig. 8. Relative Intensity Vs. Wavelength of the IR Emitter [2]

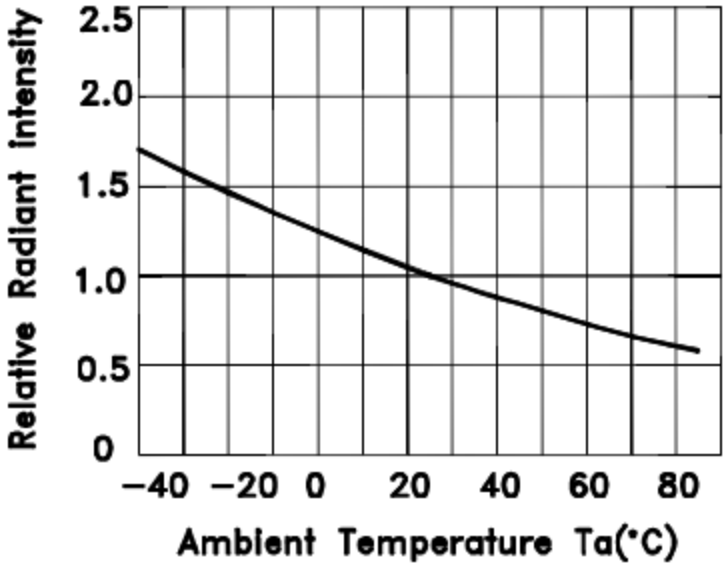

Fig. 9. Relative Intensity Vs. Ambient Temperature of the IR Emitter[2]

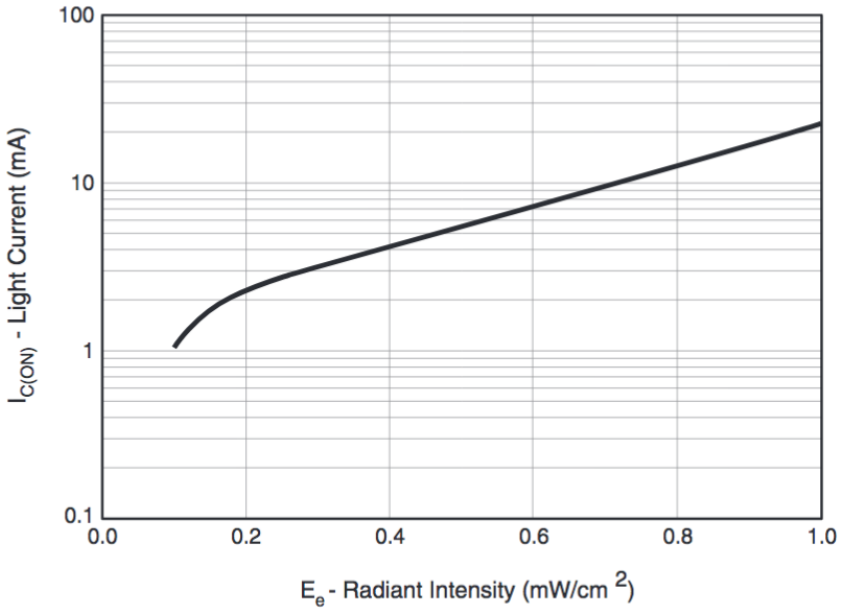

Fig. 10. Light Current vs. Radiant Intensity of the Phototransistor[3]

This phototransistor is designed to detect the wave with wavelength=880 nm. For the IR emitter, the relative radiant intensity of 880 nm is the highest at any ambient temperature. The normal operating temperature of our lock is from -20°C to 35°C. As the temperature drops, the radiant intensity of the IR emitter increases, so we do not need to worry about those cold days. Moreover, even in some very hot days, with temperature approaching 40°C, the relative radiant intensity can still be approximately 0.8 mW/cm². When the intensity is 0.8 mW/cm², the light current of the phototransistor is about 12mA, which is enough for the system to work.
Another tolerance we need to concern is that the operating voltage of the electronic lock is 12V. The lock is powered by the DCDC converter, so the converter must provide stable 12V voltage for the lock. The total output voltage variation of the converter is 3%, which means that for 12V output voltage, it varies from 11.64V to 12.36V [4]. Currently, we do not know the input voltage tolerance of the lock. If the tolerance was ±5%, this lock would be functional. After we get the lock, we will measure the accurate input voltage range of the lock to make sure that it can work properly with the converter.

3. Cost and Schedule

- Cost Analysis

1) Labor

Name	Hourly Rate	Hours	Total	Total x 2.5
Zhengchang Kou	$25	300	$7500	$18750
Stanley Yang	$25	300	$7500	$18750

Xinyi Zhang	$25	300	$7500	$18750
Total				$56250

2) Parts

Block	Part	Quantity	Cost/unit	Manufacturer	Vendor	Total Cost
AC Adapter	SoulBay 12W Universal Multi-Voltage AC/DC Adapter	1	$10.97	SoulBay	Amazon	$10.97
Battery Charger	BQ24040	1	$1.12	Texas Instruments	Texas Instruments	$1.12
Li-ion Battery	YKS Universal Li-ion Rechargeable Batteries	4	$1.50	YKS	Newegg	$6.00
DCDC Converter	PTN04050C	1	$0.77	Texas Instruments	Texas Instruments	$0.77
Low-Dropout Regulator	TLV704	2	$0.77	Texas Instruments	Texas Instruments	$1.54
MCU	MSP430FR2310	1	$1.60	Texas Instruments	Texas Instruments	$1.60
IR Emitter	WP3A10SF4BT	1	$0.52	Kingbright	Mouse Electronics	$0.52
Phototransistor	QSD122	1	$0.40	Fairchild	Mouse Electronics	$0.40

RFID Reader	RC522 RFID Reader	1	$5.28	Sunfounder	Ebay	$5.28
Lock	Electric Drop Door Lock Z9W0	1	$17.82	Unbranded	eBay	$17.82
Buzzer	Uxcell Electronics Buzzer LZQ-3022	1	$9.08	Uxcell	eBay	$9.08
Conditional LED	Round LED Light Bulb Emitting Diode Lamp	2	$0.02	n/a	eBay	$0.04
BJT	2N2222	1	$1.55	Farnell	American Microsemiconductor	$1.55
Relay	G6D-1A-ASI-NP DC24	1	$6.39	Omron	Mouse Electronics	$6.39
Camera	Mini Spy Trigger Camera for Photo or Video	1	$12.50	Adafruit	Adafruit.com	$12.50
SD Card	SanDisk 8GB Class 4 MicroSDHC Card	1	$6.99	SanDisk	Amazon	$6.99
Total						$82.48

3) Grand Total

Section	Total
Labor	$56250
Parts	$82.48
Grand Total	$56332.48

- ## Schedule(* Bolded Task means official task.)

Week	Task	Responsibility
10/2	**Design Document Due(Thurs)**	All
	Research on Parts	
10/9	**Preparation of Design Review(Tues)**	All
10/16	**Soldering Assignment Due(Fri)**	All
	Design Logic Flows	Stanley
	Parts Purchasing and Acquiring	Zhengchang + Xinyi
10/23	**1st Round PCBway Orders(Thurs)**	All
	Certified PCB layout	
11/16	**Individual Progress Reports Due(Mon)**	All
	Final ROund PCBway Orders(Thurs)	
	Fix Any Problems Found in 1st Round	

11/13	Implementing Logics on Chips	Stanley
	Help with Implementation and assemble components on board	Zhengchang + Xinyi
11/20	Test Corner Cases(Tried to Find Bugs)	Xinyi + Zhengchang
	Debug and Fix Corner Cases for Project	Stanley
11/27	**Mock Demo(All week)**	All
	Demo,Mock Presentation,Presentation Sign Up(Mon)	
	Fix any problems encountered in Mock Demo and Create Presentation	
12/4	**Demo**	All
	Mock Presentation	
	Start Working on Final Papers	
12/11	**Presentation**	All
	Final Papers(Wed)	
	Lab Notebook Due(Thurs)	

4. Discussion of Ethics and Safety

Our lock contains a Li-ion battery, so we have to pay attention to the safety of the battery. If the battery is placed in an extreme temperature, there is a possibility of explosion [5]. Most houses are not located in places with extremely high temperature, so the air temperature is not a big deal. However, if the lock is under direct sunlight, the temperature of the battery may become much higher than the air temperature, which will be hazardous. The lock is a half outdoor and half indoor device, so we plan to place the battery in the indoor part to avoid the direct sunlight.

The ACM code of ethics mentions that engineers are required to respect the privacy of others [6]. In fact, this is also the main goal of our project. For most people, their houses are the most important place, and they absolute want to protect the privacy in a considerably high level. Our RFID anti-theft lock is able to accomplish this desire for people.

Moreover, the basic function of our lock is to protect people and their properties. Therefore, we have to consider any situations that might happen in order to make sure that our lock is considerably reliable. For example, we have to make sure that the reading range of the RFID reader is very short. Less than 10 cm would be acceptable. If the reading range is 5m, the door might be opened when the house owners just walk by their house without the intention of opening the door. That would be a huge security risk. We have to pay attention to all details as it is our duty to build a high-quality product.

Finally, based on the IEEE code of ethics, engineers should “improve the understanding of technology; its appropriate application, and potential consequences [7]”. Many people knows the necessity of protecting their houses; they just do not know the appropriate approach. We design this lock not only to provide convenience and high-level protection, but also to make people realize the reliable approach to protect their privacy and property.

5. References

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