Senior Design 2
Project: Solar powered Smart Lock

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Final Project and Group Document

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1.0 Executive Summary

According to FBI: UCR (Uniform Crime Reporting) in 2016 there were 1.5 million burglaries in the US. The number of burglaries has been dropping around 40%(percent) in the last 10 years. Security experts relate the drops to many different reasons like unemployment rate dropping and the economic growth. However, one of the suggested reasons is that many people started using high-tech home security systems in their homes. Some experts claim that having a home security system decreases the chances of the house getting robbed by at least 30% (percent), however these studies are controversial as they are done by experts who usually works for security companies that uses these studies to advertise their home security products.

There is no doubt that the advancing in technology bring a lot of good benefits and have a major impact onto our life, as well as it makes our life more secured. For example, in some major cities security cameras has been install to help fight crimes and some major incidents. There are cameras located in every corner for surveillance and with this wonderful innovation; many criminals were caught using these security cameras. Furthermore, cars as well become more secure nowadays, as the engine would not turn on if the key were not inside of it, also cameras and sensor have been used in many cars to help with some safety hazard. The same thing goes for homes as well. House innovation plays a major role into today's society. To help increase the safety of our home, many thing were created, like digital keys, occupancy light, cameras and sensors to help capture intruders.

Our senior design project, which is a "Solar Powered Smart Lock", is going to be in home security systems specifically in door locking and unlocking. The door lock represents the first obstacle to the unwanted person who the lock owner wants to keep out of his place. While working in this project, we took in consideration how a smart lock will recognize if the person is authorized or not authorized to get access and how it will respond to unusual access attempts. The door will only be open, if a person is authorized to enter the house, otherwise the lock will not give him/her an access to get on the other side of the door. However, if the person is persisting and keep trying to open the door without consent to do so, the lock would be able to take the necessary precaution and get into actions to prevent the unlawful things to happen, such as burglary. To prevent such things from happening the lock will be able to alarm and send a snapshot of the activity to the homeowner. The notification will warn the owner about the incident and the owner will choose to call the police if it is an unusual face or suspicious activity.

2.0 Project Description

Here, for our project descriptions, we will introduce the reasons that motivated us to create a solar smart lock for our senior design project. In order to address every concerns and details, we will introduce our project section by section, as it will show below; In the first section, we will discuss about the motivation and the goals for the project. Second, we will address the objectives for the project. The third section will cover the requirements specifications for the project, which will also cover each and everyone responsibilities and roles. Last but not least, we will present the quality of house analysis as well as the budget for this project, which will cover all our financial goals as follow in the sections below.

2.1 Project Motivation and Goals

Obsessive students need goals in order to be motivated throughout life and work at the extreme to achieve success. However, to get those goals achieved, an educational background will be one the best support toward these dreams. An advanced educational can have many impact on oneself, especially professionally and personally, which will affect his or her community professionally and economically by creating jobs, a safer and better environment. Electrical engineers typically do the following: […] [d]esign new ways to use electrical power to develop or improve products, […] [d]o detailed calculations to compute manufacturing, construction, and installation standards and specifications [and] […] [d]irect manufacturing, installing, and testing to ensure that the product as built meets specifications and codes. The educational training that we received during our time here at the great University of Central Florida has so many impacts in our life. It affects us especially, teaching and giving us a good amount of knowledge to be able to maneuver and create our own invention with the amount of skills and knowledge required to get the design done and to function properly.

As Group 8 is fascinated about technology, home innovation and their security, we think that having a smart lock is one of the best and easy way access a house and make it secure at the same time. Imagine what can happen if you lock yourself out while cooking some delicious meal? Your meal is on the stove, while you know it is on high. There is no way to access the house without a key. At that moment all type of panics begin, not able to open up the door or break the key in the worst case scenario to turn off the stove or bring down the volume. Anything could happen to both, the house and the food, it is either the food gets burn or the house gets caught on fire, which would lead to a definitely wrong way. With this Solar Powered Smart Lock, there is no need to worry about that anymore. This Solar Powered Smart Lock is the best, most advantages and ultimate smart lock. No need for a key if you accidently lock yourself out. No needs

to keep replacing batteries every now and then, and no need to worry about getting your house burn, ruin your food, or any thing worse that could happen while you are outside.

Since security and home innovation has a major impact in our daily life, digital smart locks have become an important part of those systems, and play a major role it. Digital smart lock is one of the best invention for the future technology. This Smart Lock will be the first in the world to use solar powered source and a rechargeable battery that will be reliable and efficient. As we all know each side of the house get at least two hours of direct sunlight daily, this solar powered smart lock will have enough energy from the sun to be charged and function. This smart lock will be affordable for all the amazing features it will provide to the user, since it will very easy to program, it will be user friendly smart lock at the same time will be very hard to hack into or change the passcode without the admin permission. Once it is programed, only the admin will be able to change the combination or mess around with it. The goal of this smart lock project is to help people protect their home and control the security around the house in an easier way by using the latest technology as solar power feature and an occupation sensor detector, as well as a snapshot notification that will be sent to the owner's telephone every time someone enter the wrong passcode three times or more, as a fraud protection. Misplacing keys, nor losing keys will not be a problem anymore because the smart locks will give you the chance and opportunity to open your door in many different ways such as keypad, facial recognition, telephone application, as well as finger print. Our team hopes that this project will make the home security monitoring much easier and safer to use. Also it will save the owner from a lot of the troubles, such as losing their keys or misplace them. The "Solar powered smart lock" brings solution to those problems.

According to "Vector Security", house keys are among the most commonly misplaced items. One minute the person will have his/her keys handy, the next minute the person has no clue on where the key is located and he or she has some important stuff to take care of. However, having the idea to incorporate smart locks into our homes gives us many benefits as well as added security, increase convenience, connectivity to our house, also it will help prevent lockouts. Smart lock gives oneself the ability to combine multiple keys into one; as well one will be able to carry his or her keys digitally. Smart locks help to eliminate the needs of physical keys and not concern about misplacing it, especially if it is a single key, which is very small and untraceable. Many people get late to meetings, schools, work and some other important places due to misplacing there keys, they do not want to leave the house without locking the doors. On the other hand, some have to do an unwanted U-turn, just to go back to the house and double check and make sure that he or she locks the door before leaving the house.

Seeing and experiencing those problems during our daily lives motivate us to help put an end into this madness. With a single smartphone or any other devices we are dedicated and motivated to bring all your keys into one and place it into your smartphone by using an application that gives the customer the availability to lock and unlock the door remotely anywhere and anytime. Also as monitoring if the door lock after leaving the house as well as knowing when someone access the house. If the owner has a guest and he or she is not at home, there will be no need to leave the important stuffs that he or she is doing just to go and open the door, the smart lock will give the option send a one time passcode just to get in, while the original passcode that was set on the lock would not have to be changed. This one time passcode will be entered on the keypad, and it will be expired as soon as it is enter, or after a set amount of hours unused it will be expired. That way, the owner would not have to give is administrator passcode to his guess. This temporary passcode will only be available for a certain period of time. This feature will also be useful for businesses. In case a business owner or a company would like to use our lock, it will give them the opportunity to create a unique access code for the employees in order to monitor who enters the building, at what time they enter the building as well as which entrance did they enter the building from.

To ensure more security, we will incorporate a biometric feature system to lock and unlock the door using fingerprints. This biometric fingerprint will be very simple and easy to activate and install, at the same time it will be very hard to hack into, since it will be a solid system. Biometrics are known to be one of the toughest features to hack, because they are lasers that no one would be able to get copy of them. Another beneficial feature about the biometric is that, it gives ever user the most unique access to the lock, in case the passcode has been forgotten, the fingerprint will always be there, which is one of the safest, easiest and most unique way to unlock the door by just placing the assigned finger on the scanner.

To sum up, smart locks offer many benefits to homeowners who are looking to better safeguard and manage their homes. Having not to worry about misplacing keys is one of the best feelings one can experience. The entire mechanical key set will be handling in one place with a smartphone application and it assure convenience.

2.2 Objectives

The main objectives for this project are to design and build one of the most interesting and unique smart locks that ever existed. With the solar power capability, we can say thus far this is the most unique project of its kind so far on the market. In order to have our project to stand out from the others, we would like to achieve multiple objectives that will bring our knowledge and understanding to the test. We want to be inexpensive, to

be very efficient, to have a light weighted, Solar powered, easy to use, and easy to install compare to other similar smart locks in the market.

2.2.1 Cost

One of the goals is to focus on building the project with a reasonable cost. It is true that spending more by getting always the best parts in the market will give us the best result, however we want to compete with other smart locks that are on the market. That is why we have a budget that does not exceed $200. It can be done basically by comparing parts and choose the one that will do the needed task with minimum cost. For example, we have many motors to choose from so we will choose the cheapest one bear in mind it does not consume too much power. Refer to (table 2.1) that shows the project cost estimate.

Part	Range of Cost ($)
Keypad	10 - 50
Motion Sensor	2 - 20
Fingerprint Scanner	30 – 50
Electrified lock	10 - 400
Micro Solar Panel	5 - 20
Lithium Battery	8 - 15
Microcontroller	10 - 35
Camera	20 - 40
PCB	20 - 30
Other parts	20
Total Cost	112 - 680

Table. 2.1 Project parts cost

We can see that the most expensive part in the project is the electrified lock. The reason is there are many types of electronic locks and as expensive it gets the more secure and reliable it is. To save as much as we can in this section we plan to get a broken lock and get the electronic parts to use it in our project. By using the strategy of combining the lock parts from different sources we believe that we can save money and stay on budget.

By other parts we mean the small parts that will go on the PCB between the parts like Voltage regulators, relays, charge controller, etc. There is a big gap between the minimum and maximum cost due to the electric lock price range. However, based on this initial estimate and the strategy we are taking we should be able to finish the project with our estimated budget

2.2.2 Efficiency

As we all know that cost play a major role when it come to build an efficient project or an invention. The more money someone put down for a project the higher and better chance for efficiency that will be rewarded at the end of tis project. However, our objective for this project is to diminish the cost, while we increase the efficiency level for the smart lock. Even though we know that would be a tough pair to work with and have them go in the best way for us as well as the customers, we are dedicated to work beyond measure to achieve this objective. The first challenge will be the solar panel that we need to be compatible and well efficient to charge the reserved battery whenever there is a lack of energy from the sun. We might need to get the power supply equipment form the same manufacture to make sure we get the best efficiency and compatibility .by saying power supply parts we mean solar power panel, charger control and battery form the same manufacture. As well to conserve energy and keep if safe, we will have an occupancy sensor in the lock that will only power on the circuit during the presence of an individual. We will program the sensor to send a signal to the servo in less than one minute when there is no one in front of the door; the sensor will transmit the message to the servo, and then the microcontroller will switch the circuit off and stay into an idle mode until someone else come to the door. This feature will also be a good security feature; in case the owner unlock the door accidently with his or her cellphone using the application provided, the door will not be unlock as long as there is no movement in front of it. Another efficient key factor that we will include in this project will be an alert that will be send to the application whenever someone enter the wrong passcode more than three time. The camera provided will automatically take a picture of the person entering the code at the moment and send it to the user. If it is an unexpected and unusual activity or person, the owner can choose to notify police to prevent break-in or theft. Our objectives are for the efficiency of the system to be super high in order to compete with the other smart lock on the market.

2.2.3 Weight

The smart lock will be small enough to carry and will be very lightweight. Once we get all the parts on hand we plan to measure the parts individually and add an approximate weight for the case. Overall we have a marketing equipment to have less than 10 lbs. for our design.

2.2.4 Solar Powered

The solar panel will be small enough to fit on the lock. We will have a mini solar panel on the lower side of the lock that will collect enough energy to charge the battery as well as powering the circuit without any problem. We believe that any little amount of sun that will be collected will be more than enough to keep the battery going for more than seven days, since the lock will not be in use every second during the day. In order to mange the power and to ensure that there is enough power to use the lock when there is no sun, we will use a relay that that will trigger and allow current to flow to the circuit only when someone is close to it. The microcontroller will control this feature to switch the board into idle mode when it is not in use.

2.3 Requirements Specifications

Before we move ahead with our project, we must got some requirement under control and make sure we meet all the necessary requirement in order to get project done successfully. We have to get some research done in order to meet the full capabilities that it will take accomplish the goal for this project. Below are the list of the material that we must get under control to attend the objectives.

- The main source of energy that will be provided to the smart lock will come from the sun. The sun will provide the energy to the battery, charge it up and then it will run to the circuit. The circuit can use both energy directly from the sun and energy from the battery while charging. The smart lock will have a microcontroller that will keep the power flow steady, if there is no primary energy source from the sun, which may cause by any type of disturbance, such as, clouds, weather, and dusk or any type of residues. The battery will use the conserved energy to provide power to the circuit.
- The microcontroller will have an occupancy sensor that will send signal to a relay to switch on whenever a user if in front of it and switch off whenever it sense there is no one using it, t will go to idle mode in order to save and conserve energy.
- The 5 Volt solar panel will need help from a stepped up via a Direct Current (DC) boost converter will increase the voltage provided to around 12 volts, which will be enough to power the circuit and charge the battery faster. Also, it will have a charge controller that will prevent the battery from over charging, it will know to charge the battery when it is low and on demand.

- This smart lock will have one camera, which will handle the image processing. We still debating to see if we will use the camera for facial recognition, or for safety hazard. During facial recognition, the owner would be able to open the door by placing his or her face in front of the camera, then the camera will detect all the 80 different nodal points in the face, if it's the correct user it will open it and a green LED will indicate, if not the red LED will indicate that is a wrong face. On the other hand, we thinking about using the camera for security hazard, which will take a snapshot of the user if he or she enters the wrong passcode three times or more. This feature will take the snapshot and sent it to the owner's application. In case of breakage, the owner can notify police as soon as possible.
- A telephone application that will provide access to the entire feature in the smart lock. The owner just has to simply connect it to the key using Bluetooth or wireless. The application will give access to a digital key that will be able to lock and unlock the key anywhere and anytime. The owner can also use the application to set up the key that will be needed to unlock the key using the keypad. The application will give access to receive notifications such as pictures and other required maintenance.
- The smart lock will have a digital encryption technology that cannot be copied or broken. Also it will be a highly intelligent lock that cans only switch keys and codes in favor of sensors and recognition software, such as the telephone application. This generation of lock will help the user to carry a digital wireless key stored in his or her smartphone. It will be very convenient and it will lessen the weight carrying around, and the feeling of key lost and no access into the house will be over, since everything will be on the door and the phone. Since it is very easy to make a key copy if leaving it down for couple of minute, now there will not be any need to worry about that.
- A six to eight digit passcode that can be enter using the lock keyboard. Once the owner set it the first time, it will be asked to enter the same passcode twice in order to save it and make sure the owner is aware of the passcode for security purposes. If the passcode is needed to be change, the user must have the original passcode in order to override it and put a new passcode. As well a notification will be send to the application so the owner could be accept the change if he or she is the one changing it or not. As well the passcode can be change using the application.
- A raspberry pi will be using as the microcontroller because it has more processing power than any other microcontroller in the market and the fact that we are trying to use image processing in our project to control the camera in which raspberry pi microcontroller can handle it easier and faster, it will also provide the best service possible that will be needed to get our project done successfully, it also has capabilities and ports not found on other microcontrollers such as 4 USB port, an

audio adapter, Bluetooth and BLE, however the bad part about the raspberry pi is its power consumption, The Raspberry Pi can consume up to 2.1 amps (only under some circumstances, which amounts to 10.5 watts), resulting in a battery life of only 1 hour which is not good compare to other microcontrollers in the market

- With all these great and important features that the smart lock will be provided to the customers, it will be a life changing experience. Based on the problems people face due to losing or misplacing keys, and also how easy is it to stole a key and make a copy key in the hardware store. We decided to lessen those types of problems in any ways that we can. The objective is to make this Smart Lock will be much better and safer than the ones that are currently on the market. I will be amazing because of its security protocol and the service it will provide to the user.

2.4 Quality of House Analysis

In order to deliver the best quality product to our customers for our project, there are some marketing requirements and some Engineering Requirement that must be compatible to give a better idea on which approach to take. To meet the customer's requirements, we use the house of quality as a graphical representation of the useful information for the project to keep the efficiency and the cost balanced, which will be easier to understand and to meet all the needs, necessary. Moreover, providing the best quality service, to keep the customer happy and satisfied. According to (figure 2.1), which is the house of quality that refers to the engineering requirements as well as the customer's requirements. We must follow the picture below, which is the house of quality that we worked on as a guideline to make sure that we meet the customer's requirements as well as the market requirement.

		Weight	Dimensions	Power Input	Setup Time	Operate
		–	–	–	–	–
Durability	+	↑	↓	↑		↑
Low Cost	–	↑	↓	↑		↑
Easy to Install	+	↑	↓	↑	↑	↑
Battery Life	+	↑		↑		↑
Easy to Customize	+	↑	↓	↑	↓	↓
Easy to Use	+	↑		↑	↑	↑
Target for Engineering Requirement		< 10 lbs	3*7.5 inches	5V	<5 mins	<$200

House of Quality

Correlations:
++ Strong Positive
 + Positive
- - Strong Negative
 - Negative

↑ Positive correlation
↓ Negative correlation

Figure 2.1 Quality of House Analysis

As it shows in (figure 2.1) above, these measure that we took are qualitative, as well they focus on the elements of this project, which help us determine the marketability of the product to ensure that the product is well presented and super efficient and to be inexpensive. We are trying to reduce the price, as much as we can to offer the best product to the customer and make it affordable so more customer could want it. We make sure that everyone would love to use our smart lock, and make sure that we listed everything and make sure that the project is well documented from a nontechnical point of view.

The engineering measurement that we agreed on in the table above provides the most accurate information on the structural integrity of the smart lock. For example, we put a plus sign in front of durability and a minus sign in front of cost that means we want the smart lock to be durable as well as cheap at the same time. Easy to install have a plus sign, since our objective is that for the smart lock to be under friendly, so the owner can program it easily and safe.

2.4.1 Project Block Diagram

According to (figure 2.2) below, we divided the work equally among us section by section to make sure that everyone has a specific task to do. However we make sure to intertwine, to help around when help is needed and to fulfill the weak spots in order to get the project accomplish.
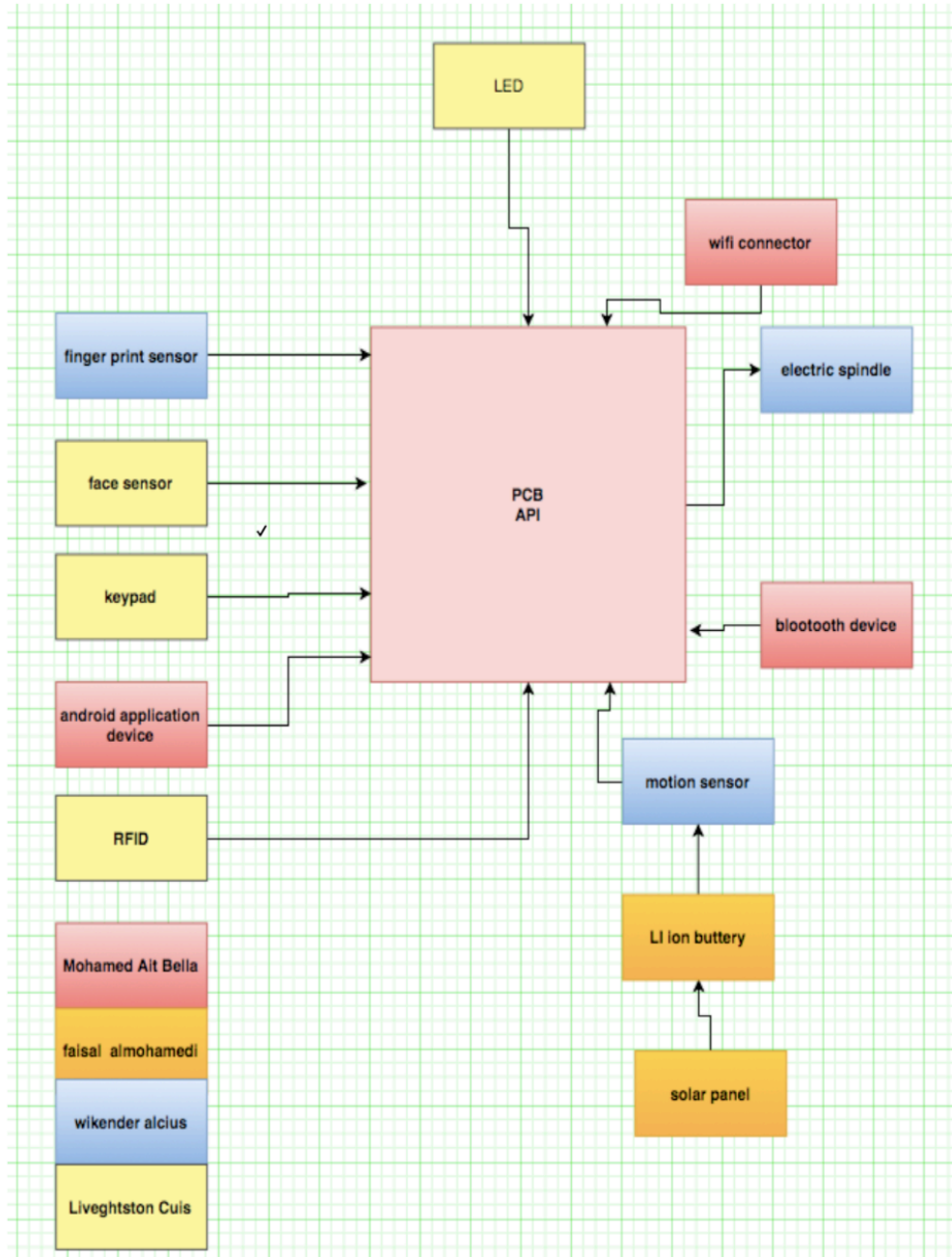
Figure 2.2 Project Block Diagram

Project Block Diagram Status:

- Each block is currently being researched
- All the blocks are currently I design process
- None of the blocks have been purchased or acquired
- None of the blocks are being prototyped

2.4.2 Block Diagram Illustration

In order for current run through the circuit, the occupancy sensor has to pickup a certain type of movement from a user to as he or she approaches the door. The motion sensor will send signal to activate the microcontroller exactly once someone is at the door. The person will have many options to unlock the door as it shows in (figure 2.3) below:

o   Using a card with RFID.
o   Using facial recognition.
o   Using a keypad to enter a passcode.
o   Using his fingerprint.
o   Using an app on a phone.
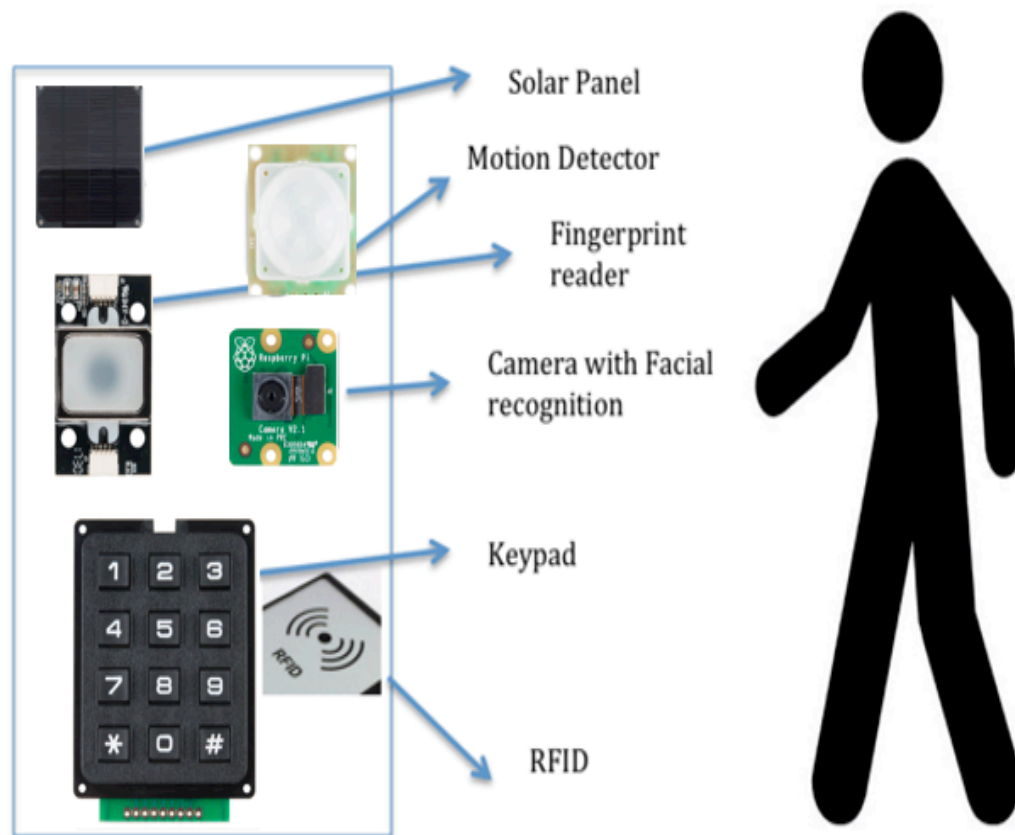
Figure 2.3 Block Diagram Illustration

2.5 Realistic Design Constraints

In every engineering design there are some limits that should be taken into consideration. There are different types of limits that we must follow

such as; time constraints, economic constraints, ethical constraints, social constraints, and finally safety constraints. In the following sections we will approach these different type constraints and give more details about each of them.

2.5.1 Time constraints

Since we are taking senior design class in summer time became our biggest concern. The semester is only 11 weeks long and it took us almost 3 weeks to finally agree on a project idea which gave us 8 weeks to work on 120 pages project description. Having other responsibilities as well that needed our attention like work, other classes and family took a lot of our time. It was also hard for us to find a good time when all of us are free to meet to discuss the project progress and divide responsibilities. We decided to meet every Sunday even though it supposed to be a day for rest from the responsibilities. We also created a mile stone so we can check our progress over the time to make sure we will be able to deliver the project on time.

2.5.2 Economic Constraints

In most projects the problem is that the group members cannot finance a project if it cost too much. In our design we are facing an opposite situation, we are trying to stick with a budget to maintain the marketing requirement. We have done some researchers by looking at different smart locks and their marketing price. The best smart locks in the market do not exceed a price of $270. Even though our design will have more functions than these other smart locks plus it will run on solar power, the other lock still maintain the highest standards so it will make no sense if the project cost us more than $250.

2.5.3 Ethical Constraints

Ethical is also considered as constraint for us in this project. We have to be sure that our design cannot be used in a wrong way. Our design at the end is going to function as a door lock. The lock purpose is to give access to some people and deny access to others. Our responsibility is to do the best as we can to make sure there is no way that we know about might give an unwanted person an access to the building. For example we are using RFID as one of the methods to unlock the door so we need to be sure that the RFID system we are using is secure and not vulnerable based on our best knowledge. Another example is since the door could be unlocked using an app that we are developing. We need to make sure that the app is secured, and no one could use the app beside the owner of the lock. That might lead to have some constraints on where we are getting all the software and hardware involved in the project.

2.5.4 Social Constraint

Somehow the social constraint for us is related to the time constraint. We just got to know each other, so we did not socialize with each other before taking this class. Our personalities were unknown to each other, which placed some constraint on us when we had to choose our. Each one has different potentials and we had a short time to know them and think how we going to implement them. And there was a time when we were not able to fully trust each other. That made hard to divide tasks between us, because we were afraid that a person may not be able to finish his task on time and jeopardize the whole project. We also have a totally different backgrounds as we originally from different countries. That means we do not share the same culture so one thing that might be important for one of us will be redundant for another.

2.5.5 Safety constraints

Safety is an important factor especially when we work with a rechargeable lithium ion. If the battery heat rose to a high level we might have fire. Another concern is that the battery may explode which in both cases the surrounding equipment and the circuit will get affected. According to Battery University that those cases are usually caused by using non-certified lithium ion batteries. So to avoid this situation we will get a reliable high quality battery

To be ready for any unpredictable events, we will build our project in a well safe environment like a lab. We will also take all the precautions of wearing gloves and make sure there is always a distinguisher nearby in case of fire.

2.5.6 Volume and weight Constraints

At the end of the project the lock has to be installed on a door. There will be a constraint on its volume. There is no standards on how big the whole lock system should be, but it has to be in a reasonable size and weight. Otherwise the lock system may conflict with its marketing requirements. In other words we need to make sure that there is enough space for all the equipment, which will be placed inside the system. We may have to change some arraignments or place some parts outside the box when it is necessary. These changes if they had to be done will make sure that our lock does not exceed the volume or weight constraint.

2.5.7 Power source constraint

We have decided to put this constraint on our self, as it what makes our project unique and different from others. Almost all smart locks in the

markets use replaceable AA batteries. We want our design to function on a built-in lithium ion battery that will be recharged using a small size solar panel.

2.5.8 Standards Constraints

As we plan to combine different parts from different manufactures together, we need to take into consideration if those parts are compatible with each other's. We probably will not have any problems combining the electrical parts as we can always get the required power supply by using step-up or step-down voltage. However it is the mechanical parts that we need to be careful with. There are many different standards for the door lock components and we will discuss them in details in section five. The best way to get all the components (whole lock system) from one manufacture to be sure they follow the same standard. If one or two parts need to be manipulated to achieve one of the project goals then we need to make sure it follows the same standard as the other parts.

2.5.9 RoHS Compliance

RoHS stands for Restriction of Hazardous Substances. Since there is a chance for our product to hit the market we want it to be RoHS compliant. It was originated in EU in 2002 and by 2007 all electronics product has to RoHS compliance. To achieve that our product should not exceed the maximum level of the following 10 substances:

- Lead (Pb): < 1000 ppm
- Mercury (Hg): < 100 ppm
- Cadmium (Cd): < 100 ppm
- Hexavalent Chromium: (Cr VI) < 1000 ppm
- Polybrominated Biphenyls (PBB): < 1000 ppm
- Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm
- Bis (2-Ethylhexyl) phthalate (DEHP): < 1000 ppm
- Benzyl butyl phthalate (BBP): < 1000 ppm
- Dibutyl phthalate (DBP): < 1000 ppm
- Diisobutyl phthalate (DIBP): < 1000 ppm

Based on our knowledge, we should have no problems getting the RoHS compliance to our project. Which could help us in marketing this product around the world

3.0 Existing Similar Projects and Products

As the project go through, the goal is to design a smart luck that will open a house door in many way, this smart luck system will be using a solar

panel to charge the main circuit board increases. This approach is not a new technology and other companies have either developed a similar product or are currently working in the process of developing such a project.

3.1 August Connect

August lock has a WIFI connection as an option add on select model, it is connected to a power outlet and has a Bluetooth connection between itself and your home WIFI network which help you control your lock from anywhere, while this lock doesn't require a third-party hub it could add significant value to a once-Bluetooth-only product, depending on your need for remote lock access.one of the good side of this kind of locks is when your WIFI home goes down the lock uses 4 AA batteries, so it will be running in any circumstance. Also, an App will alert you once the batteries get low. in addition, august lock has a Discreet installation which means no wiring is required. All you need is to replace the interior part of your existing door lock. Exterior door hardware remains the same, so technically you'll still be able to use your old door lock. However, the setbacks about this lock are when looking at the August smart lock it is nearly impossible to tell if your door is locked or unlocked. Even though you are using an App to figure it out, still get confusing, it only shows the color (green or red) but doesn't say anything about the door being actually locked or unlocked. So, does the green color mean that your home is safely protected or that guests are welcome. Also, the installation is a not a smooth process bending the back plate will increase the resistance on the smart lock so when you finally attach the August smart lock to the plate, it won't function. But there is actually a way out by bending the plate back or have August send you a new one. Other issues that august smart lock faces are the frequent loss of connection due to sometimes the app can't find your lock, which makes you need an actual key to open the door. Same stuff happens with Auto-Unlock feature. It works when it wants to, but normally it's not in the mood to work. The third problem august lock has is the slow time the app takes to connect to the lock.

3.2 Lockitron's Bolt

This smart lock has most the things we would like to have in a smart lock for much more less money than any other lock in the market also this lock will surprise you about his impressive performance and range of options this machine has. we can install it as a deadbolt conversion or a complete replacement, and while none of its three unlock modes quite match the Kevo's tap-to-unlock system, they're pretty close for a lot less. However, the mean thing I like about this like is the look, in addition, his mechanical components are very satisfying compare to other locks in the market. We can also enable remote access and notifications by requiring an addition

Bridge, which is a flash-drive-sized wireless gateway that communicates between the Bolt and your WIFI router for an additional charge. Finally, the only backside that people experience with this lock is the hiccups with the Bolt which is more than with our other picks, which along with the relative lack of experience of Lockitron dropped it from contention for one of our top spots but still perform good and even better with the software update people gets.

3.3 Array Smart Lock

This the closest product to our project, changing a batteries is always a hassle for any machine, but this company called Brink's Home Security figure out a way to solve this problem by developing an array of smart lock using a cloud and an app that enabled the internet of things using a device called (IOT) which home owners can use without adding separate hubs or accessories. ARRAY connects to the cloud using a home's existing WiFi router, and its advanced rechargeable power system that use solar panel to eliminates the need to replace and discard batteries. It is compatible with iOS, Android, and Amazon Alexa-enabled devices. First, this system includes lots of features such as eliminates the need for a gateway hub. Second, the high-capacity power system includes a removable lithium battery that can be quickly recharged via micro-USB cable or ARRAY's onboard photovoltaic panel. Third, this system works with iOS and Android systems to ensure that almost any smartphone user can operate the lock. Also, they have ARRAY's intuitive smartphone app enables consumers to operate the lock remotely, schedule user access, issue e-Keys and keypad codes, and enable push notifications when users lock or unlock the door. Finally, the system is able to use Apple and Android Wear smartwatch users that can two-tap lock or unlock their doors, Amazon Echo devices that can lock the door and perform other functions.

3.4 Poly-Control's Danalock

In addition to providing support for both Bluetooth and Z-wave which is a hallmark of most Poly-Control locks, the Poly-Control V2 provides support for both Wi-Fi, and Harmony. Which means it can be compatible with home-automation systems or remote door access, not many locks can rival the performance of the Danalock V2. Also, Danalock Z-wave has been provided with a lock-state sensor, which helps recognize whenever a dead bolt state is in the proximity, conducting in an easy installation process and an improved user experience. more importantly when it comes to communication protocol this smart lock offers the broadest range, while using Bluetooth signal recognition to find your smart phone, it uses also a z-waves to connect your smart lock with home automation system, you can also lock or unlock your door remotely using a WIFI integration in the lock and your phone.

The backside of Danalock is the fact that it comes only in two colors black and anodized aluminum, so comparing to other smart locks in the market whom offers at least three styles it's not giving the customers many option weather or not to like it and it won't match your house décor much less the hardware of your door. Other than that, this lock won't require you to change your existing deadbolt the Danalock V2 has three mounting plates which match most deadbolt layouts out there. Also, four-cylinder adapters give the V2 the freedom to switch the locking mechanism between Z-wave, Wi-Fi, and Bluetooth.as far as battery Danalocks claims to have a battery that can less you for 12 months on average because the lock is using CR123A lithium batteries which are known for their durability and performance. Beside all the good things we said about the Danalocks, we didn't talk much about how secure the lock is, as we know the biggest strength of the lock is the deadbolt it's also its biggest weakness, if we make the deadbolt strong the Danalock V2 can withstand the toughest of onslaughts. Make it weak, and your worse imaginations might come true.to solve this problem you need to spend little extra money to replace your existing deadbolt by an ANSI/BHMA Grade 1 deadbolt. So, you can be sure that the deadbolt will complement the efforts of the lock to secure your house. Finally, Danalocks has many features. First of all, the Danalock V2 uses a technology called DanaBridge to give you a remote access and control over itself. By taking advantage from existing technologies in your home such as a tablet which uses BLE or Wi-Fi or an old smart phone, the app turns them into a bridge, making it easy and cost-effective for you to remotely manage your smart lock. Second, V2 will give you notifications throughout the day. For instance, if you want to be reminded when your children come home from school, it will remind you with a notification. Thirdly, V2 has an auto-lock feature which will lock the door after it has remained open for a specific time period. You'd be in charge to decide after how much time the door should relock once someone has left or entered the home. Fourth and the one feature I like most is the fact that V2 has a Geo location feature which will constantly search for any of your smartphone. If you activate this feature, it will unlock your front door once you are within 100-200 yards. So, if you are returning from shopping with hands full of shopping bags, you may want to activate this feature while still in your car.

3.5 kwikset kevo

Kwikset kevo is a great smart lock that is at least as secure as a traditional deadbolt and a lot more convenient to use in order to justify the price to buy it. The Kevo's unique mechanism to trigger the lock you simply tap the deadbolt's exterior housing with your finger is nearly as fast as using a key but far more convenient, making it the best method we've seen for everyday smart lock use.Kevo also uses Bluetooth-based close range

authentication system which is more secure than the geofence based auto unlocking features employed by many locks. The fact that you can control the Kevo with a standard key, a wireless key fob, or a smartphone app also makes it the most versatile option compare to other options in the market. It does also have Kevo app that makes it easy to administer the lock and share keys, which allow guests to lock and unlock your door. And if you have the Kevo Plus upgrade you can control and monitor your lock when you're away from home.

3.6 table best smart locks in the market

According to the (table 3.1) below, we do some researches and summarize the description above to compare different characteristic of smart locks that is available in the market.

product	August Smart Lock HomeKit Enabled	Schlage Sense	Kwikset Kevo	Poly-Control Danalock V3 BTZU	Schlage Century Touchscreen Deadbolt Lock
Connectivity	Bluetooth, Wi-Fi	Bluetooth	Bluetooth	Bluetooth, Z-Wave	Z-Wave
Integration	Amazon Alexa, Apple HomeKit, IFTTT, Nest	Apple HomeKit	Nest	Amazon Alexa, IFTTT	N/A
Installation	Interior Escutcheon	Exterior Escutcheon, Interior Escutcheon	Exterior Escutcheon, Interior Escutcheon	Interior Escutcheon	Exterior Escutcheon, Interior Escutcheon
App	Mobile, Web	Mobile	Mobile	Mobile	N/A
Notifications	Email, Push	N/A	Push	N/A	N/A

Table 3.1 best smart locks in the market

4.0 Strategic Components and Technology behind it

In our world today, one of the general relevant technologies is to digitalize everything around us which means integrating CPUs in everything, so they can operate on their own such as a water pumps station, mechanical machines, and house door lock. Our project is to improve the digitalization of private house doors, which is mainly the smart lock of the door.

A smart lock is an electronic and electromechanical lock, which is designed to perform locking and unlocking operations on a door when it receives such instruction from an authorized device using a wireless protocol or a cryptographic key to execute the authorization procedures. It also monitors access and sends notifications for the different events it monitors, and some other critical events related to the device. Smart locks can be considered part of a smart home.

As stated above a smart lock is an electronic and electromechanical lock that is in engineering, electro mechanics combines processes and procedures drawn from electrical and mechanical engineering. The electronic smart lock has become popular and useful this day and has developed many features through a micro controller unit chip, which allows it to do smart thing. Electro mechanics focuses on the interaction of electrical and mechanical systems and how the two systems interact with each other. This process is especially prominent in energy production systems such as those of Dc machines, which can be designed and operated to generate power from a mechanical process such as generator or use to power a mechanical effect such as motor. Electrical engineering in this context also encompasses electronics engineering that is the reason an electronic smart lock is considered as electromechanical device.

Electromechanical devices are the ones, which have both electrical and mechanical processes. Typically, a manually operated switch is an electromechanical component due to the mechanical movement causing an electrical output. The term is usually understood to refer to devices, which involve an electrical signal. Often involving electromagnetic principles such as in relays, which allow a voltage or current to control another, usually isolated circuit voltage or current by mechanically switching sets of contacts, and solenoids, by which a voltage can actuate a moving linkage as in solenoids valves. The electric typewriters, teleprinters, clocks, initial televisions systems, and the very early electromechanical digital computers are the examples of modern electronics and electromechanical devices. Today we are using the same idea to create smart lock and improving it every day to make it more and more convenient to access our home.

Now to perform the mechanical locking and unlocking operations, a wireless signal or a cryptographic key can be provided. Wireless communication, or sometimes simply wireless, is the transfer of information or power between two or more points that are not connected by an electrical conductor. The most common wireless technologies used today are radio waves. With radio waves, distances can be short such as a few meters for Bluetooth or as far as millions of kilometers for deep-space radio communications. It encompasses various types of fixed, mobile, and portable applications, including two-way radios, cellular telephones, personal digital assistants (PDAs), and wireless networks. Other examples of applications of radio wireless technology include GPS units, garage door openers, wireless computer mice, keyboards and headsets, headphones, radio receivers, satellite television, broadcast television, cordless telephones, and of course smart lock. Somewhat less common methods of achieving wireless communications include the use of other electromagnetic wireless technologies, such as light, magnetic, or electric fields or the use of sound.

And the other function is cryptographic key, which is another option to lock and unlock a door that is upgraded with a smart lock. In cryptography, a key is a piece of information (IA parameter) that determines the functional output of a cryptographic algorithm. For encryption algorithms, a key specifies the transformation of plaintext into cipher text, and vice versa for decryption algorithms. Keys also specify transformations in other cryptographic algorithms, such as digital signature schemes and message authentication codes. As the smart lock is designed to have easier access to our homes; at the same time there is a need for secrecy. In designing security systems, it is wise to assume that the details of the cryptographic algorithm are already available to the attacker. This is known as Kirchhoff's principle – "only secrecy of the key provides security", or, reformulated as Shannon's maxim, "the enemy knows the system. "The history of cryptography provides evidence that it can be very difficult to keep the details of a widely used algorithm secret. A key is often easier to protect than an encryption algorithm, and easier to change if compromised. Thus, the security of an encryption system in most cases relies on some key being kept secret.

Trying to keep keys secret is one of the most difficult problems in practical cryptography. An attacker who obtains the key for example theft, extortion, dumpster diving, assault, torture, or social engineering; can recover the original message from the encrypted data, and issue signatures. To have a big picture, smart lock played a big part in home automation also known as smart home or smart house. A home automation system will control lighting, climate, entertainment, and appliances. It may also include home security such as access control and alarm systems. However, when connected to the internet, home devices are an important constituent of

the Internet of Things. So, we cannot talk about smart lock door without talking about smart home or house or simply home automation.

A home automation system typically connects controlled devices such as TV, Computers, and appliances to a central hub or "gateway". The user interface for control of the system uses wall-mounted terminals, tablet or desktop computers, or a mobile phone application, or a web interface, that may also be accessible off-site through the internet. Most smart locks are installed on mechanical locks and they physically upgrade the ordinary lock. It has not been a long time since they got into the markets. Smart locks, like the traditional locks, need two main parts to work: the lock and the key. Simple as it sounds but very complicated task to achieve. In the case of these electronic locks, the key is not a physical key but a smart lock or a special key fob configured explicitly for this purpose, which wirelessly performs the authentication needed to automatically unlock the door.

Smart lock allows users to grant access to a third party by the means of a virtual key through the means of a microcontroller unit chip. This key can be sent to the recipient smartphone over standard messaging protocols such as e-mail or SMS. Once this key is received, the recipient will be able to unlock the smart lock during the time specified previously by the sender. Smart lock is capable to grant or deny access remotely via a mobile app. Our smart locks which include a built-in Wi-Fi connection that allows for monitoring features such as access notifications or cameras using a raspberry pi to show the person requesting access allow the user to access the door through face recognition. Our solar smart lock also allows the owner to see who and when someone is at the door.

According to (figure 4.1), the schematic below is a reflection of the blocks of the smart lock that we are building. Each block may have two or more components of the smart lock. It is a simpler version of the real schematic that will explain in detail the project prototype. With this block diagram, it is easier to show and explain how everything come together and how important each component is within the project. One always said, a picture is worth ten thousand words. With that being said, let us talk about the first part of the project such as the human machine interface.
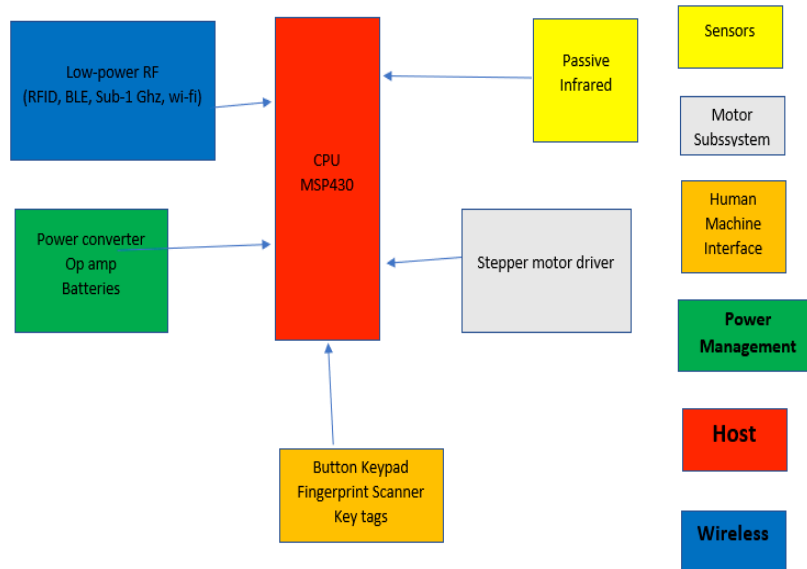
Figure 4.1: Reflection of Block Diagram

4.1 Human Machine Interface

The human machine interface (HMI) provides a method for the user to interact with the system or to view a response from the e-lock. Our smart lock human machine interface may include a keypad, backlight, LEDs, speaker, fingerprint scanner, pixy camera or even a microphone. The HMI of our solar smart lock will be designed on a PCB that may be physically separated from the rest of the system. TI's MSP430 microcontroller (MCU) with a highly technological intergrade module can be designed for adding a dedicated HMI controller to our e-lock. For example, a Wireless connectivity enables part of the HMI functionality, such as the keypad, to be handled on a remote device such as a smartphone or tablet by creating a remote app.

4.1.1 Keypad

A keypad is typically a set of buttons arranged in a block or pad. Those buttons can be digits, symbols, or alphabetical letters. The pads that contain only numbers are called numeric pads. Numeric keypads are typically found on calculators, push-button telephones, vending machines, ATMs, point of sale devices, combinations locks, and digital door locks Perhaps the most common form of electronic lock uses a keypad to enter a numerical code or password for accessing the device. Keypads are divided into alphabetical pads, symbolic pads, and numeric pad. However, all those types of keypad create one keypad in almost every electronic device. There are different types of keypads like Membrane, Dome-Switch, Scissor-Switch and capacitive keypad.

Membrane Keypad consists of three layers: a top layer that has the labels, a space layer between the top and back layer and a back layer that features conductive stripes. This type can be distinguished from the other types as its symbols printed on a flat, flexible surface.

Dome-Switch keypad is a combination of a flat-panel membrane and a mechanical-switch keypad. It is a silicone keypad with dome-shaped switches that have two circuits board embedded under each switch.

The scissor-switch key contains of two separate plastic layers that lock together in a similar way to a scissor. This type is very close to the Dome-Switch but the scissor-switch improves functionality by keeping the keys connected together.

Capacitive keypads detects key pressing by using capacitance technology. When a key is pressed down, it chances the capacitance of the capacitor pads. In terms of functionality it is the same as any standard keypad. However due to its internal structure, it is quicker and more reliable than the standard ones.

4.1.2 Biometrics

Biometrics has become the technical term for body measurements and calculations. It refers to a certain technical body part measurement unit related to human characteristics. Biometrics validation is used in computer science and electrical engineering as a form of identification and access control. It is also used through public camera to identify individuals in groups that are under surveillance. Biometric identifiers such as fingerprint, face recognition and so on are the distinctive, measurable characteristics used to label, describe, and specify individuals. Biometric identifiers are often classified as physiological versus behavioral characteristics. Physiological characteristics depict the shape of the body such as fingerprint, palm veins, face recognition, DNA, palm print, hand geometry, iris recognition, retina, and odor or scent.

A fingerprint is the trace or mark left by the friction ridges of a human finger. With the development of technology, Human fingerprints are found to be very detailed, nearly unique if not to say 100 percent unique. The blue print of the human finger is difficult to alter, and durable over the life span of an individual, making them suitable as long-term identifiers for human identification.

A facial recognition system is also one of the newest technologies out there that has the ability to identify or to verify a person from a digital image or a video frame from a video source. Multiples methods have been found in the facial recognition area in which facial recognition systems

work, however in general, the one method that is highly being used is by comparing selected facial features from a given image within a database using machine learning. While initially a form of computer application, it has seen wider uses in recent times on mobile platforms and in other forms of technology such as robotics. With the development of machine learning, many computer application, mobile app, some other form of technology in robotics are enabled to utilize facial recognition through the method of comparison.

4.1.3 Backlight (LCD screen)

A backlight is a light source that is placed behind an actor, object, or scene to create a highlight that separates the subject from the background. These days, backlight has become one of the best features of liquid crystal displays (LCD). The backlight represents that light source of LCDs and enables the screen to have a visible image. The backlights are highly utilized in small displays to boost readability in low light conditions. For example, a smart wrist watches with low light conditions, which are always exposed, outside requires a backlight to have a readable image. Backlights are very popular these days, they are found in almost every device such as smart phones, computer displays, and LCD televisions.

4.1.4 LED

After the breakthrough of light-emitting diode (LED), it has become a great feature in human machine interface. An LED is a two-lead semiconductor light which is typically a p-n-p junction that emits light when it is activated by the switching voltage or current. The electrons are able to recombine with electron holes within the diodes when the required voltage or current which allows the energy to be released in the form of photons. The manifestation, which is being done in the LED, called electroluminescence and the energy band gap of the semiconductor determine the energy of the photon. LED initially was used for calculators, clocks, and indicator lights. Today, it is being used in big screens concert, televisions, and remote control to send signals.

4.2 Host controller

The host controller is the brain of the project, which control everything in the project. That is, it is responsible for processing inputs from the user and from sensors. It also generates responses by actuating the physical locking mechanism or providing feedback through the human machine interface. The host controller is a high technical module micro controller unit. There are several types of micro controller such as MSP430, Raspberry pi, CC3000.

4.2.1 MSP430

The MSP430 chip is one of the most popular microcontroller in the world, which comes from the Texas instruments family. It is a mixed-signal microcontroller. The MSP430 microchip can operate with a current of less than one milliamp that is its power consumption is very low. The one reason why MSP430 uses low power consumption is the fact that it has capability of wake-up times below one microsecond, which allows the microcontroller to stay in, sleep mode longer which minimizes the average current consumption. There are some very used full peripherals such as internal oscillator, timer, watchdog, USART, and I2C. MSP430 typically does not have an external memory bus. It is limited to its on-chip memory. "The MSP430 incorporates a 16-bit RISC CPU, peripherals, and a flexible clock system that interconnect using a von-Neumann common memory address bus (MAB) and memory data bus (MDB). Partnering a modern CPU with modular memory-mapped analog and digital peripherals, the MSP30 offers solutions for demanding mixed-signal applications." (MSP430x2xx) The MSP430 has a lot of great features that some microcontrollers do not have such as:

- Ultralow-power which extends battery life
- High-performance analog ideal for precision measurement
- Extensive vectored-interrupt capability
- Optimized for modern high-level programming
- Permits flexible code changes, field upgrades and data logging in system programmable Flash

Today modern process control system has become increasingly more complex and so does the requirement for embedded processing with individual sensor units. MSP430 is used in almost every embedded system such as industrial sensing and communications to control and monitor sensors within in digital communication, energy harvesting (renewable energy) to reduce peak and average current consumption, building automation (access control and security) to have the internet of things to be connected with the house, and RFID for door lock which is highly supported. Referring to (figure 4.2) below the block diagram shows a typical architecture of a basic MSP430.
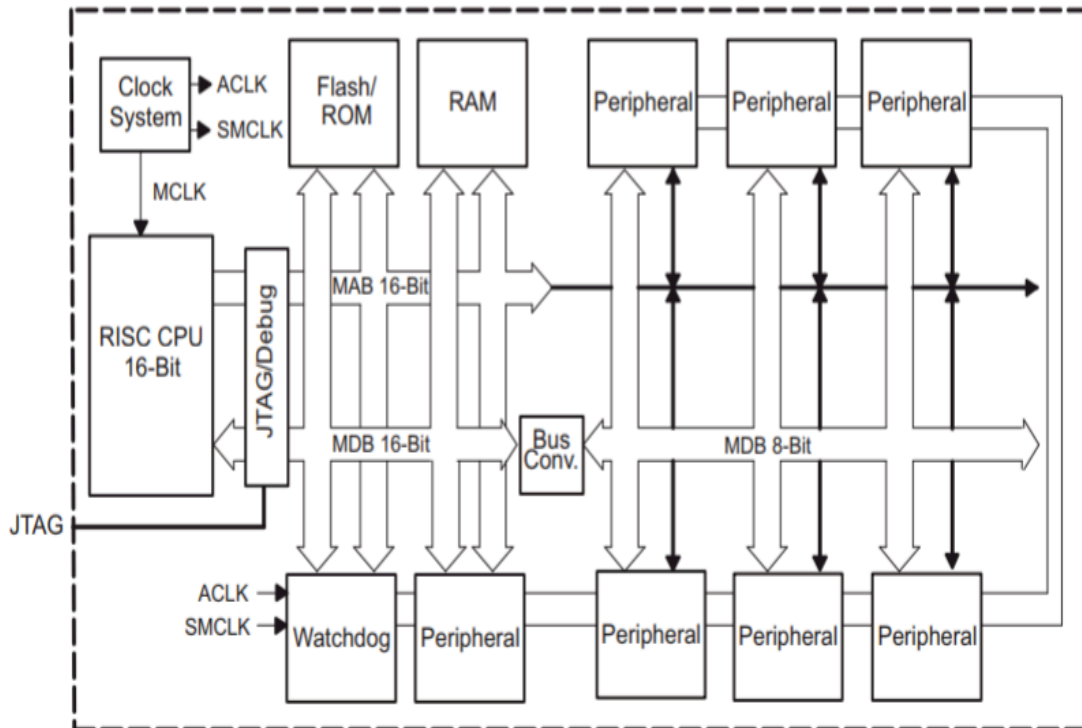
Figure 4.2 Architecture of a basic MSP430

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4.2.2 CC3XXX

The cc3000 is wireless micro controller unit (MCU) that consists of Wi-Fi, Bluetooth low energy, sub-1 GHz and internal MCU which all use a common development environment with a single core software. The idea of creating the complex CC3xxx module micro controller unit (MCU) is for the Internet of things, which has become very popular when it comes to home automation. Having cc3xxx module in our project would enable the smart lock to be connected within the Internet of things of the house.

4.2.3 Raspberry Pi

The raspberry pi is a small and affordable computer, and single-board microcomputers that is being used today to learn and to teach basic programming. The raspberry pi is known for more processing power than nearly all microcontrollers due to its power consumption. It lacks the hardware control and other peripherals found in microcontrollers. The micro controllers such as msp430 family are well known of peripherals for reading sensors, controlling hardware, and facilitating low-power communication. Though the raspberry pi may process information faster, but the micro controllers consume way less power, which makes it very accessible for low-energy electronic devices.

4.3 Wireless

Wireless connectivity such as Wi-Fi, Bluetooth low energy, sub_ 1 Ghz, or RFID adds an additional data interface to the lock. This interface can be used for various purposes including wireless authentication of the user, remote control and monitoring, wireless transfer of software updates, or communication with networked sensors. In some cases, the addition of a wireless interface allows for part of the HMI functionality to be handed by remote device such as a smart phone or tablet.

4.3.1 Wi-fi

Wi-fi is a wireless technology, which plays an important role in our society today due to its used. It is a technology that is based on the local area networking for devices using radio waves. This technology allows devices such as personal computers, smartphones, smart television, printers, video games, and so on to connect to the internet. This technology also just has improved so much and now we have a new term, which is called "Internet of Things". The Internet of Things allows devices to be connected in one local network like a hub, so they can communicate with each other base on how they are being programmed. Those devices mention above have the capability to be connected wirelessly with the Wi-Fi technology. The Wi-Fi device that is sending the signals can be up to about 50 meters away which is can be referred to as hotspot.

4.3.2 Bluetooth

Bluetooth is a similar radio-wave technology, but it's mainly designed for communicating over short distances less than about 10m or 30ft. Typically, you might use it to download photos from a digital camera to a PC, to hook up a wireless mouse to a laptop, to link a hands-free headset to your cellphone so you can talk and drive safely at the same time, or to connect your phone with a home smart lock so you can be able to open your front door. Therefore, electronic gadgets that work this way have built in radio antennas (transmitters and receivers) so they can simultaneously send and receive wireless signals to other Bluetooth gadgets. All these technologies involve sending information back and forth not along copper cables but in radio waves buzzing invisibly through the air.

Bluetooth is also a wireless technology standard for exchanging data using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz. It can be done for example between mobile devices and personal area networks (PANs). Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 30 000-member companies in the areas of telecommunication, computing, networking, and

consumer electronics. The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and projects the trademarks. A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device. A network of patents applies to the technologies, which are licensed to individual qualifying devices.

Bluetooth Low Energy is also known as Bluetooth LE or BLE, formerly marketed as Bluetooth Smart is a wireless personal area network technology designed and marketed by the Bluetooth Special Interest Group aimed at novel applications in the healthcare, fitness, beacons, security, and home entertainment industries. Compared to classic Bluetooth, Bluetooth Low Energy is intended to provide considerably reduced power consumption and cost while maintaining a similar communication range. Mobile operating systems including IOS, Android, Windows phone and BlackBerry, as well as macOS, Linux, Windows 8 and Windows 10, natively support Bluetooth Low Energy. The Bluetooth SIG predicts that by 2018 more than 90 percent of Bluetooth-enabled smartphones will support Bluetooth Low Energy.

4.3.3 Sub-1 GHz

Sub-1 GHz RF operates in the ISM spectrum bands below sub-1 GHz which runs in between 769 – 935 MHz that is the 315 MHz or the 468 MHz frequency range. This spectrum band below 1Ghz is particularly useful for radio frequency of the Internet od Things applications. The applications for Internet of Things (IoT) are typically low power. The Sub-1 GHz offers several advantages over the 2.4 GHz spectrums for such IoT applications.

Range of Sub-1 GHz wireless offers more range than the 2.4 GHz. The range is an important criterion for our project and the Sub-1 GHz happens to be a better choice. Sub-1 GHz wireless transmission offers 1.5-2 times more distance coverage than the 2.4 GHz spectrums. Also, the sub-1 GHz wireless spectrum has a long-range mode that can have more than 100 km coverage for our project, which will have the capability of using the internet of things. Wireless Sub-1 GHz radio frequency needs a lower power signal from the transceiver compared to the 2.4 GHz spectrums to get the same output power signal at the receiver. This makes the sub-1 GHz radio frequency a great choice for battery operated in the internet of things sensor devices. The other quality that the sub-1 has is the interference.

The ideal radio frequencies of the Internet of things are wireless applications for sub-1 GHz includes smart metering and industrial lighting. These Internet of Things applications typically cover harsh environments.

The long range and the lower interference features of the Sub-1GHz spectrum band make it a perfect fit for these Interne of Things applications.

The Internet of Things sensor products using wireless sub-1 GHz spectrum can handle the interference better. This is because they operate on a lower frequency with fewer existing applications using that spectrum. Also, the lower frequencies with ISM bands enable the sub-1 GHz transmissions to weave between buildings in an urban environment better. The superior range of sub-1 GHz is probably the best feature of this spectrum band. Typically, many wireless applications fail only because all the nodes cannot be reached by the existing protocol. By spanning a larger range, especially at lower baud rates, sub-1 GHz is becoming the preferred alternative vs 2.4 GHz.

4.3.4 RFID

The radio-frequency identification (RFID) is one of the features, which is including in our solar smart lock project. It uses the technology of electromagnetic fields to identify and track tags that are being attached to objects. It has the ability to track the tags because they have electronically information's that are stored in the tags. There exist two different tags such as passive and active tags. Passive tags gain energy from the nearby radio frequency reader radio waves. And the active tags contain a local power source. The power source can be a battery and has the ability to function from hundreds of meters from the radiofrequency identification reader. The tag has a better feature comparing with a bar code which is there is no need to be within the line of sight of the reader. It just needs to be attached to the object. RFID is highly used in the industry field such as government, healthcare, manufacturing and aerospace industries.

RFID systems use different frequencies to communicate: low frequency (LF), high frequency (HF) and ultra-high frequency (UHF). The size of the radio changes depending on the frequency band as the radio behaves differently to each of these frequencies bands. There are some pros and cons when using any of these bands. When using low frequencies the radio will have slower information read rate, but the effect of any metal or fluid surfaces interferences will be limited. However in the high frequency bands it's the other way around. The read rate will increase while any nearby metals effects will be limited.

LF band covers frequencies from 30 KHz to 300 KHz. This band has a short read range of around 10 cm, and has slower read rate comparing to HF. With these features LF is widely used in an access control applications similar to our project.

HF band covers frequencies from 3 MHz to 30 MHz. This band has a higher reading range that can reach up to 1 m and very high reading rate. Based on these features HF mainly used in information exchange applications like a very familiar example SunPass car tags.

UHF band covers frequencies from 300 MHz to 3 GHz. This band has a read range that can reach up to 12 m. With these high frequencies it is hard to exchange information as any impedance can affect UHF easily. That why a technique involved using labeled antenna, which will give a higher range, on both sides had to be used. Based on the extremely high data exchange in UHF it is used in wireless devices and items tagging.

Passive tags and Active tags are two types of RFID tags. Passive tags collect energy from a nearby RFID reader's interrogating radio waves that can be read by the reader. As passive system is restricted, by the power of the tag's sign reflected back, they are normally less than 10 m in range. Since this type of tags contains only a chip and antenna, it is less expensive comparing to active tags.

Active tags have a local power source such as a battery and may operate hundreds of meters from the RFID reader. Since there is an antenna involved this type is usually used with UHF frequencies. There are two fundamental sorts of active tags: transponders and reference points. Transponders work only after receiving a radio sign from a reader. After that it will turn on transmits a sign back.

4.4 Sensors

Various sensors can be used in an e-lock to detect the state of the lock and the door. For example, an accelerometer or inertial measurement unit (IMU) to know when a door is open, closed, or during the presence of a user. And another type of sensor is a passive infrared (PIR) sensor for proximity detection.

A motion detector is a device that detects moving objects, particularly people. Such a device is often integrated as a component of a system that automatically performs a task or alerts a user of motion in an area. They form a vital component of security, automated lighting control, home control, energy sufficiency, and other useful systems. The electronic motion detector contains an optical, microwave, or acoustic sensor, and in many cases a transmitter for illumination. However, a passive sensor senses a signature only from the moving object via emission or reflection. For example, it can be emitted by the object, or by some ambient emitter such as the sun or radio station of sufficient strength. Changes in the optical, microwave, or acoustic field in the device's proximity are interpreted by the electronics based on one of the technologies listed

below. Most low-cost motion detectors can detect up to distances of at last 15 feet or 4.6 meters. Specialized systems cost more but have much longer ranges. Tomographic motion detection systems can cover much larger areas because the radio waves are at frequencies which penetrate most walls and obstructions, and are detected in multiple locations, not only at the location of the transmitter.

Motion detectors have found wide use in domestic and commercial applications. One common application is activating automatic door openers in businesses and public buildings. Motion sensors are also widely used in lieu of a true occupancy sensor in activating streetlights or indoor lights in walkways such as lobbies and staircases. In such smart lighting systems, energy is conserved by only powering the lights for the duration of a timer, after which the person has presumably left the area. A motion detector may be among the sensors of a burglar or thief alarm that is used to alert the homeowner or security service when it detects the motion of a possible intruder. Such a detector may also trigger a security camera to record the possible intrusion. Several types of motion detection are in wide use such as the followings.

Passive infrared (PIR) sensors are sensitive to a person's skin temperature through emitted black body radiation at mid-infrared wavelengths, in contrast to background objects at room temperature. No energy is emitted from the sensor; this is how the name passive infrared came about. This distinguishes it from the electric eye for instance not usually considered a motion detector, in which the crossing of a person or vehicle interrupts a visible or infrared beam.

Microwave sensor detects motion through the principle of Doppler radar and is like a radar speed gun. A continuous wave of microwave radiation is emitted and phase shifts in the reflected microwaves due to motion of an object toward or away from the receiver result in a heterodyne signal at a low audio frequency.

An ultrasonic transducer emits an ultrasonic wave that sounds at a frequency higher than a human ear can hear, and receiver's reflections from nearby objects. Just like in Doppler radar, heterodyne detection of the received field indicates motion. The detected Doppler shift is also at low audio frequencies for walking speed since the ultrasonic wavelength of around a centimeter is like the wavelength used in microwave motion detectors. One potential drawback of ultrasonic sensors is that the sensor can be sensitive to motion in areas where coverage is undesired, for instance, due to reflections of sound waves around corners. Such extended coverage may be desirable for lighting control, where the goal is detection of any occupancy in an area. But for the opening an automatic

door, for example a sensor selective to traffic in the path toward the door is superior.

The tomographic motion detector systems are a fundamentally new form of motion detection technology, which provides a full complete area hidden from view because it is not just a line of sight technology. The tomographic motion detector systems sense disturbances to radio waves as they pass from node to node of a mesh network. They can detect over large areas completely because they can sense through walls and other obstructions. It works by encircling or in other words by surrounding an area with several nodes that communicate with each other through radio waves and fabricating what you would call a mesh network. Each network of that mesh contains one processing unit (PU), which is normally a closed contact for enabling integration with any standard panel.

The tomographic motion detector systems have some distinct and interesting advantages over many existing motion sensing technologies. First and for most important, it has a very low false alarm rate. It does not rely on line of site, which means that it cannot be blocked by objects moved in front of the nodes in the network. It offers a full complete coverage of areas up to 5000 square feet. And most of all, tomographic motion sensor can be completely hidden from view.

The video camera software has become very popular these days, which can play a big role in the sensor area. With the proliferation of low-cost digital cameras that can shoot video, it is possible to use the output of such a camera to detect motion in its field of view using software. This solution is particularly attractive when the intent is to record video triggered by motion detection, as no hardware beyond the camera and computer is needed. Since the observed field may be normally illuminated, this may be considered another passive technology. However, it can also be used together with infrared illumination to detect motion in the dark, that is, with the illumination at a wavelength undetectable by a human eye.

Photo-detectors are also known as photo-sensors, are sensors of light or other electromagnetic radiation. The way it works is by a p-n junction that converts light photons into current. Photodiodes and phototransistors are a few examples of photo detectors. From measuring power from picowatt to several hundred mill watts, it is usually measured by sensors based on the semiconductor photodiodes. They have a very fast response with a time range of nanoseconds to microseconds however typically it takes to about 0.2 seconds with the processing involved. Photo detectors are very sensitive. It is so fast that much attenuation needs to be done to make it fall under a certain range so that it is useful and practical.

There are three main types of photodiode sensors highly used in many embedded systems. Silicon photo sensors are for the visible and near infrared spectral range. Power consumption goes up to 300 mill watts. Then there are germanium photo diodes near infrared that is out to 1800 nm. Then there are Indium Gallium Arsenide or IngaAs photo diodes, which are for near infrared out to 1700nm, which are mainly for telecommunication applications.

The dual-technology motion detectors have become very efficient lately due to the reduction of used energy. Many modern motion detectors use combinations of different technologies. While combining multiple sensing technologies into one detector can help reduce false triggering. It does so at the expense of reduced detection probabilities and increased vulnerability. For example, many dual-technology sensors bring together both a PIR sensor and a microwave sensor into one unit. For motion to be detected, both sensors must sense the object at the same time. This decreases the probability of a false alarm. For example, since heat and light changes may trigger the PIR but not the microwave or moving tree branches may trigger the microwave but not the PIR. If an intruder can fool either the PIR or microwave, however, the sensor will not detect it.

Passive Infrared technology is often paired with another model to maximize accuracy and reduce energy use. PIR draws less energy than emissive microwave detection, and so many sensors calibrated so that when the PIR sensor is triggered, it activates a microwave sensor. If the latter also picks up an intruder, then the alarm is sounded.

4.5 Motor subsystem

The motor subsystem includes both the motor driver and the motor used to actuate the locking mechanism. E-locks commonly use brushed DC or stepper motors to move the locking mechanism. These types of motors can be driven using low-voltage, single H-bridge, or dual Hybridge motor drivers, such as the DRV8833, DRV8833C, DRV8837, and DRV8837C devices.

"The DRV8886AT is a stepper motor driver for industrial and consumer end equipment applications. The device is fully integrated with two N-channel power MOSFET H-bridge drivers, a micro stepping indexer, and integrated current sensing. The DRV8886AT can drive up to 2 A full scale or 1.4-A rms output current (24-V and T_A=25 degree Celsius, dependent on PCB design). The DRV8886AT uses internal current sense architecture to eliminate the need for two external power sense resistors saving PCB area and system cost. The DRV8886AT uses an internal PWM current regulation scheme adjustable between Autotune adaptive decay technology, slow, and mixed decay options. Autotune adaptive decay

technology automatically adjusts for optimal current regulation performance and compensates for motor variation and aging effects. A simple STEP/DIR interface allows an external controller to manage the direction and step rate of the stepper motor. The device can be configured in different step modes ranging from full-step to 1/16 micro stepping. A low-power sleep mode is provided for very low standby quiescent standby current using a dedicated sleep pin." (DRV8886AT)

4.6 Power components

Electronic locks are usually powered by using four AA batteries. The various lock subsystems may operate at different voltages, which create a need for voltage regulators in the system. A designer must carefully select the appropriate regulators to use because this choice has a direct impact on the battery life achieved by the system.

4.6.1 Batteries

In this part of the project, various types of batteries will be discussed and researched so that we choose the right battery type for our project. We look forward to having a battery that can store enough energy and it has a quality of life span. Below are the different types of batteries that we have found:

Lithium-ion batteries are well known for a high-power density battery. The lithium-ion batteries came in smaller size and they are used in a multitude of devices such as cell phones, calculators, pacemakers, electric cars, power storage. There are six different types of lithium-ion batteries that are being used in the world market today.

Lithium-ion cobalt batteries are made from lithium carbonate and cobalt. They have very high capacity and are used in small electronics. According to investingnews.com "This type of battery has some drawbacks, including a shorter lifespan and limited specific power." which means that devices that use these batteries require relatively frequent charging – as smartphone owners can attest." (Kay)

Lithium manganese batteries contain a low internal resistance and improved current handling which enables fast charging and high currents discharging. According to Battery University, some specifications on lithium manganese batteries are as follow "Li-manganese can be discharged at currents of 20 to 30 amp with moderate heat buildup. It is also possible to apply one-second load pulses of up to 50 amps." (BU-205) Due to the high current level that these batteries can produce, they are used today in power tools, hybrid and electric vehicles, and medical equipment.

Lithium nickel manganese cobalt oxide batteries are also often as NMC batteries which "can tailored to serve as energy cells or power cells. For example, NMC in an 18650 cell for moderate load condition has a capacity of about 2800 mAh and can deliver 4 A to 5A; NMC in the same cell optimized for specific power has a capacity of only about 2000 mAh but delivers a continuous discharge current of 20A. NMC has a good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate." (BU-205)

"Lithium nickel cobalt aluminum oxide batteries are also called NCA batteries and are becoming increasingly important in electric powertrains and in grid storage. NCA batteries are not common in the consumer industry but are promising for the automotive industry. NCA batteries provide a high-energy option with a good lifespan, but they are not as safe as they could be and are quite costly." (Kay)

"LTO is also known as Li4Ti5012 has advantages over the conventional cobalt-blended Li-ion with graphite anode by attaining zero-strain property, no SEI film formation and no lithium plating when fast charging and charging at low temperature. Thermal stability under high temperature is also better than other li-ion systems. However, the battery is expansive. At only 65 Wh/kg, the specific energy is low, rivalling that of NiCd. Li-titanate charges to 2.80V/cell, and the end of discharge is 1.80 V/cell. Typical uses are electric powertrains, UPS and solar-powered street lighting." (BU-205)

"Nickel-Cadmium batteries are also known as NiCd, which was invented in 1899 by Waldemar Junger. It was the only other rechargeable batteries at that time beside lead acid batteries "For many years, NiCd was the preferred battery choice for two-way radios, emergency medical equipment, professional video cameras and power tools. In the late 1980s the ultra-high capacity NiCd rocked the world with capacities that were up to 60 percent higher than the standard Ni Cd. Packing more active material into the cell achieved this, but the gain was shadowed by higher internal resistance and reduce cycle count. "NiCd also suffer from the memory effect if not allowed to fully discharge then the battery will only discharge up to the previous value." (BU-205)

"Nickel Metal Hydride also known as NiMH was being researched in the late 1960s however did not become available until 1980 when researcher was able to provide NiMH batteries that had 40 percent higher specific energy than NiCd. "NiMH has become one of the most readily available rechargeable batteries for consumer use. Battery manufacturers, such as Panasonic, energizer, Duracell and Rayovac, have recognized the need for a durable and low-cost rechargeable battery and offer NiMH in AA,

AAA and other sizes. The battery manufacturers want to lure buyers away from disposable alkaline to rechargeable batteries." (BU-205)

According to (table 4.1 and 4.2) below we do a basic comparison of many different types of battery.

Battery	Price/kWh	Weight of 1 battery	Model number
Lithium Manganese	$1.11	< 1lb	Energizer
Lithium Iron	$0.8688	3.03 lb	LFX21L6-BS12
Lithium Iron Phosphate	$0.879	1.2 lb	Deltran
Lithium Cobalt	$0.468	1.75	Panasonic

Table 4.1 Battery basic comparisons

Battery Technology Comparison

Specifications	Lead-Acid	NiCd	NiMH	Li-Ion		
				Cobalt	Manganese	Phosphate
Specific energy density (Wh/kg)	30 – 50	45 – 80	60 – 120	150 – 190	100 – 135	90 – 120
Internal resistance (mΩ/V)	<8.3	17 – 33	33 – 50	21 – 42	6.6 – 20	7.6 – 15.0
Cycle life (80% discharge)	200 – 300	1,000	300 – 500	500 – 1,000	500 – 1,000	1,000 – 2,000
Fast-charge time (hrs.)	8 – 16	1 typical	2 – 4	2 – 4	1 or less	1 or less
Overcharge tolerance	High	Moderate	Low	Low	Low	Low
Self-discharge/month (room temp.)	5 – 15%	20%	30%	<5%	<5%	<5%
Cell voltage	2.0	1.2	1.2	3.6	3.8	3.3
Charge cutoff voltage (V/cell)	2.40 (2.25 float)	Full charge indicated by voltage signature	Full charge indicated by voltage signature	4.2	4.2	3.6
Discharge cutoff volts (V/cell, 1C*)	1.75	1	1	2.5 – 3.0	2.5 – 3.0	2.8
Peak load current**	5C	20C	5C	> 3C	> 30C	> 30C
Peak load current* (best result)	0.2C	1C	0.5C	<1C	< 10C	< 10C
Charge temperature	-20 – 50°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C
Discharge temperature	-20 – 50°C	-20 – 65°C	-20 – 65°C	-20 – 60°C	-20 – 60°C	-20 – 60°C
Maintenance requirement	3 – 6 months (equalization)	30 – 60 days (discharge)	60 – 90 days (discharge)	None	None	None
Safety requirements	Thermally stable	Thermally stable, fuses common		Protection circuit mandatory		
Time durability				>10 years	>10 years	>10 years
In use since	1881	1950	1990	1991	1996	1999
Toxicity	High	High	Low	Low	Low	Low

Source: batteryuniversity.com. The table values are generic, specific batteries may differ.

**"C" refers to battery capacity, and this unit is used when specifying charge or discharge rates. For example: 0.5C for a 100 Ah battery = 50 A.

**Peak load current = maximum possible momentary discharge current, which could permanently damage a battery.

Table 4.2 Battery technology comparison (Lithium)

4.6.1.1 Batteries in portable electronics

Today's Li-ion battery technology is driven by consumer demands for applications that have more computing power and come in thinner, smaller packages. In response, design engineers and components manufacturers must continue to find a creative solution that conforms to these requirements. Which brings us to the evolution of Latium ion batteries technology, which is direct, tied to the miniaturization of small devices such as a smart lock. As the portable devices get smaller the battery cells and packs that power them have shrunk accordingly. According to a report by the research company Navigant, revenue generated by the sales of all advanced batteries for portable power applications will top $7.1 billion in 2013 and grow to over $12.4 billion by 2023.

4.6.2 Solar Panels

One amazing fact about solar energy is that in just two minutes of sun there is enough power to cover a year's usage of humanity (Kader). We were also able to conclude from what we have learned in power management class that the sun is the ultimate source of energy. All forms of energies can be tracked back to the sun. This assumption was made based on the law of conservation of energy as it states that the energy cannot be created or destroyed, but can change its initial form to many different forms like: chemical, electrical, mechanical, etc.

Being an ultimate source of energy gave this type of energy a great advantage when it is compared with any other form of energy. However, solar energy has many more advantages with few disadvantages that are mentioned below.

Advantages:

- It is pollution free, so it doesn't harm the environment and cause pollution that may harm living creatures.
- In terms of economic it is a return of investment as it reduces the consumer utility bill.
- There is no maintenance for the solar panel unlike the regular generator motor.
- Being able to live off the grid in places where transmission lines cannot reach.
- The efficiency in solar power is improving every day as the panel get smaller and cheaper while it is still provide the same amount of power.

There are also some disadvantages of using solar panel as a source of energy, however many of them can be solved using some different techniques. For example, solar panel do not provide any energy at night or a very low energy on cloudy days, but this problem can be solved by using batteries to store the energy and use it when it needed. Based on that, we can be certain when we say that the pros of using solar energy overweight the cons.

There are many types of solar panels like Monocrystalline, Polycrystalline, Amorphous Silicon, Cadmium and PV (Photovoltaic). The most known and used one is photovoltaic cells, with an efficiency of 40%, and the way it works is by converting solar energy into electrical energy through the photoelectric effect. The photoelectric effect essentially states that when photons strike the surface of certain materials, electrons would use this energy to break free. This is a useful property and when implemented onto a semiconductor doped with electron and holes, the electrons would flow

40

in one direction due to the internal electric field in the semiconductor. It used in a closed circuit, this would lead to current flow along with a small voltage. Since the voltage is usually too low to serve any practical use, these photovoltaic cells or solar cells are connected in series to raise the voltage and increase the power output. Photovoltaic cells can be found in calculators, satellites, rooftops, solar farms, electric door lock, and various other devices.

Monocrystalline (Mono-Si) and Polycrystalline (P-Si) solar panels consider as PV solar panels. Both of them are built using silicon. Since they are built with Silicon that mean both can be doped with different materials to form p-type or n-type if needed. Even though both are formed from Silicon, two different methods are used to create these two types. In Monocrystalline the silicon is formed into bars than it got cut to wafers. On the other hand, the Polycrystalline is made by melting fragments of Silicon together to form a wafer ('Mono'). Anyone should be able to distinguish between these two types as the Mono-SI is black colored, while P-Si is blue colored. By comparing them together we found that the difference between them is just that Monocrystalline is more expensive and more efficient. However based on just these two different many factors come to play. Since Monocrystalline is more efficient that means it will be able to deliver the same amount of power as Polycrystalline will but in a smaller area. However, it is going to cost us more money than Polycrystalline.

Overall, using solar panel as a power source in new project is very popular. As the world is heading to a green power and antipollution technologies we will be seeing more usage of solar panel. Actually one of the main reason for us to do this project because we were not able to find any similar technology using a solar panel as a power source

4.6.3 Voltage regulator

A voltage regulator is an electronic circuit that provides a stable DC voltage independent of the load current, temperature, and AC line voltage variations. A voltage regulator may use a simple feed-forward design or may include negative feedback. It may use an electromechanically mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

A voltage regulator is used to regulate voltage level. When a steady, reliable voltage is needed, then voltage regulator is the preferred device. It generates a fixed output voltage that remains constant for any changes in an input voltage or load conditions. It acts as a buffer for protecting components from damages. A voltage regulator is a device with a simple feed-forward design and it uses negative feedback control loops. There

are mainly two types of voltage regulators such as linear voltage regulators and switching voltage regulators.

According to (figure 4.3) below the circuit typically consists of following four parts: Reference voltage circuit, error amplifier, series pass transistor, and feedback network. The blocks diagram below gives an idea about the linear voltage regulator circuit.
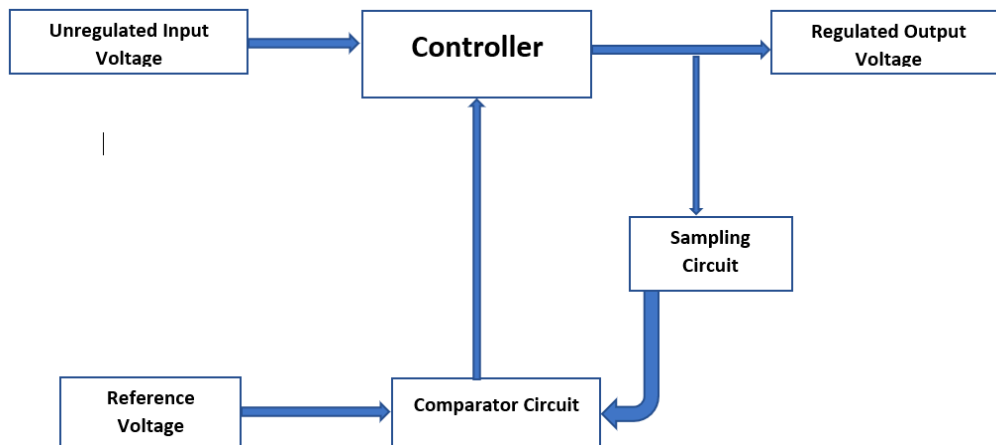
Figure 4.3 Linear voltage regulators

The advantage of linear voltage regulator

- Gives a low output ripple voltage
- Fast response time to load or line changes
- Low electromagnetic interference and less noise

Disadvantages of linear voltage regulator

- Efficiency is very low
- Requires large space – heatsink is needed
- Voltage above the input cannot be increased

Linear regulator acts like a voltage divider. In ohmic region, it uses FET. The resistance of the voltage regulator varies with load resulting inconstant output voltage. And there are two types of linear voltage regulators such as series and shunt.

A series voltage regulator shown in (figure 4.4) uses a variable element placed in series with the load. By changing the resistance of that series element, the voltage dropped across it, can be changed. And the voltage across the load remains constant. The amount of current drawn used by the load, which is the main advantage of the series voltage regulator. Even when the load does not require any current, the series regulator is considerably more efficient than shunt voltage regulator.
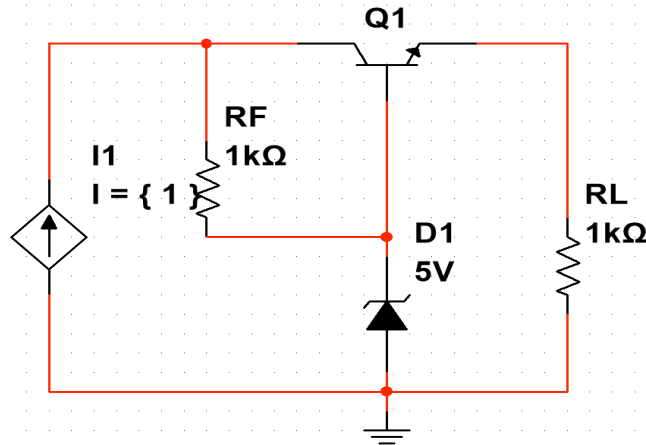
Figure 4.4: series Voltage regulator basic schematic

A shunt voltage regulator works by providing a path from the supply voltage to ground through a variable resistance. The current through the shunt regulator is diverted away from the load and flows uselessly to the ground, making this form usually less efficient than the series regulator. It is, however, simpler, sometimes consisting of just a voltage-reference diode, and is used in very low-powered circuits wherein the wasted current is too small to be of concern. This form is very common for voltage reference circuits. Shunt regulators can usually only sink (absorb) current as shown in (figure 4.5).
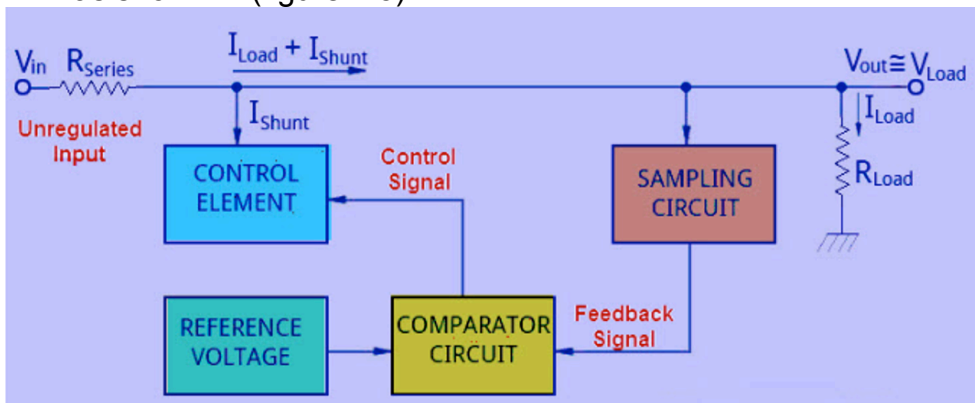
Figure 4.5: Series voltage regulator (copyright alphron)

4.6.3.1 Applications of shunt regulators

Shunt regulators are used in:

- Low output voltage switching power supplies
- Current source and sink circuits
- Error amplifiers
- Adjustable voltage or current linear and switching power supplies
- Voltage monitoring
- Analog and digital circuits that require precision references
- Precision current limiters

A switching voltage regulator rapidly switches a series device on and off. The switch's duty cycle sets the amount of charge transferred to the load. This is controlled by a feedback mechanism similar to that of a linear regulator. Switching regulators are efficient because the series element is either fully conducting or switched off because it dissipates almost no power. Switching regulators are able to generate output voltages that are higher than the input voltage or have opposite polarity, unlike linear regulators as shown in (figure 4.6).
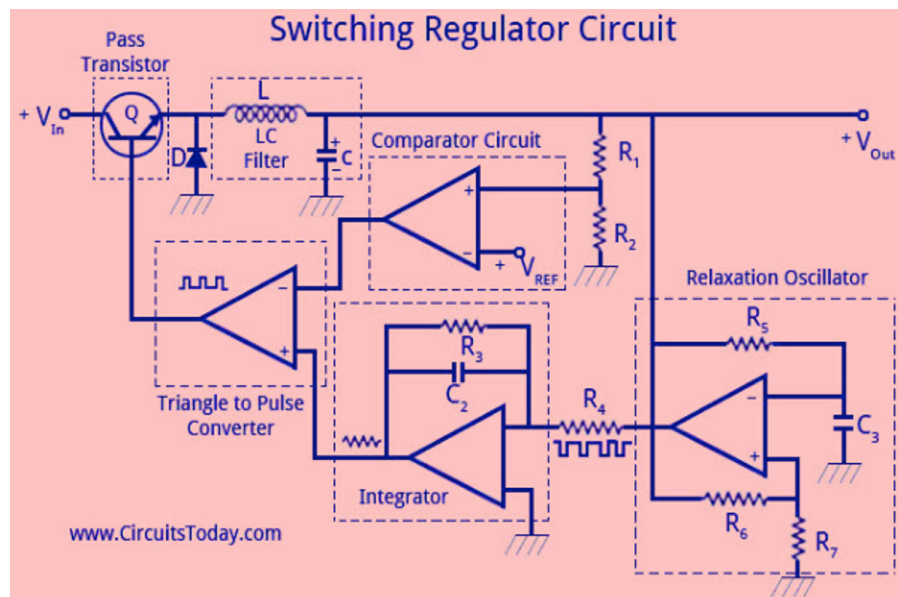
Figure 4.6: switching voltage regulator (Alphron copyright)

4.6.3.2 Advantages of switching voltage regulators

The main advantages of a switching power supply are efficiency, size, and weight. It is also a more complex design, which is capable of handling higher power efficiency. Switching voltage regulator can provide output, which is greater than or less than or that inverts the input voltage.

Disadvantage of switching voltage regulator:

- Higher output ripple voltage
- Slower transient recovery time
- EMI produces very noisy output
- Very expensive

There are three types of switching voltage regulators: Step up, step down and inverter voltage regulators. Step-up voltage regulators are also known as boost switching regulators provides a higher voltage output by raising the input voltage. The output voltage is regulated, as long as the power drawn is within the output power specification of the circuit. For driving strings of LEDs, step up switching voltage regulator is used.

Step down voltage regulators are also known as buck switching regulators, which reduce an input voltage to a lower and regulated voltage much more efficiently than linear regulators. For example, a step-down buck switching regulator ICs and buck switching controller ICs offer typical input voltage capability from less than two volts to 100 volts.

Inverter voltage regulators are also known as dc-to-dc inverting switch regulators, which are specifically designed to invert input voltages to negative output voltages.

The electric voltage regulators are found in devices such as computer power supplies where they stabilize the DC voltages used by the processor and other elements. They are found in automobile alternators and central power station generator plants, which control the output voltage. They are also found in electric power distribution system. For example, step up voltage regulator will be used in our project to increase the voltage for the stepper motor driver in the deadbolt of the smart lock.

4.7 Types of Electronic Door's Lock

With the advancing of High-tech security technology users became able to open or close locks in many different ways, automatically, remotely or keyless. By saying automatic locks we mean that it can be programmed to lock and unlock without human intervention. Remotely is by using an IR (Infrared signal) to open the door and it most common use is in car's

garage door. Other ways are by using a keypad, fingerprint or an RFID card, which defined as keyless. In our project, we had to research different types of electronic locks and compare them with each other to find the most suitable one.

4.7.1 Electric Deadbolt Lock

Electronic door locks has a part that called the actuator. This part function is to connect the bolt to a small motor. Once the right amount of voltage is applied across the actuator's terminal, it will convert the signal's energy to a mechanical motion that will push or pull the deadbolt to the desired position. There are many ways to trigger the actuator like using an RFID card reader for example.

4.7.2 Electromagnetic Lock

Known also by Maglock or Magnetic lock, this kind of locks works on the basic concepts of electromagnetism. When a current pass through a loop of wire (solenoid) it produces a magnetic field. To make this field useful so it can be used in locking a door, the solenoid is wrapped around a piece of iron. The effect of the field is greatly amplified which will cause it to attract any nearby conductors. This basic concept is used to keep a door lock or unlock for a certain time by applying current through the solenoid when it needed.

4.7.3 Fail-Safe and Fail-Secure

By using these techniques, we can get two different types of locks fail-secure and fail-safe. In fail-safe the door's default state is open or unlocked. When it needed to be in locked state a power will be applied. Then as long as the power is applied the door will stay locked. In fail-secure is the other way around. The default state for the lock is to be locked until power is applied to grant people access.

4.7.3.1 Fail-Safe and Fail-Secure Usages

Fail-safe locks most common usage is in life safety situations such as fire exit doors, or stairwell. Because in emergency situations usually power is lost, so people will be able to access any door that uses fail-safe mode. However, from a different point of view, when the power is lost. The doors using fail-safe will be accessible by anyone that is why all the entry points need to be secured. Fail-secure locks are most commonly used in electronic locking devices for high security situations, because their default state is to remain locked.

4.8 possible architectures and related diagram

In the following sections we are discussing different types and approaches of PCB designs.

4.8.1 PCB design

PCB or printed circuit board which we can also called printed wiring board used to mechanically connects electronic components using conductive tracks, pads, and other features etched from copper sheets laminated onto a non-conductive substrate.it also support an electrical connect between different component on the PCB where Conductive pathways are etched or "printed" onto board, connecting different components on the PCB, such as transistors, resistors, and integrated circuits. A printed circuit board has a predesign copper tracks on a conducting sheet which helps us to reduce the wiring therefore reduce the faults arising due to a loose connection, so we can simply place the components on the PCB a solder them.

The construction of the PCB can be done in three ways, namely single sided, double sided and multi layered. However, to connect the component on the PCB we use two different ways called a hole technology and surface mount. In hole technology we mount a process by which component leads are placed into the drilled holes of a bare printed circuit board (PCB) and soldered to the pads on the opposite side. This can be done using manual assembly or automated insertion mount machines. In surface mount technology the components are mounted or placed directly onto the surface of printed circuit boards (PCBs),also J-shaped or L- shaped terminals on every component get in touch with the PCB directly. A solder paste includes a glue, solder and flux are applied at the contact point to grip the components in position until the solder is liquefied. PCBs have copper tracks to connect the holes where the various components are located they are specially designed for each and every circuit and build construction very easy. Though, making the PCB necessitates special tools. The different types of printed circuit boards mainly include the following

- Single Sided PCBs
- Double Sided PCBs
- Multilayer PCBs
- Rigid PCBs
- Flex PCBs
- Rigid-Flex PCBs
- Aluminum-Backed PCBs

4.8.2 Single Sided PCBs

Single Sided PCBs contain only one layer of conductive material and are best suited for low-density designs. Their printed circuit boards are easily designed and quickly manufactured. They serve as the most cost-effective platform in the industry. Also, in single-sided PCB circuit boards, electronic components of interconnection between relied on wire directly connected. And now, just as an effective tool of experimental circuit panel and exist; Printed circuit board in the electronics industry has occupied a position of absolute rule. This technique is only recommended for low-frequency circuitry.in addition, this type of design is extremely susceptible to radiated noise. It is harder to design a board of this type, because of the many things can go wrong. Many complex designs have been successfully implemented with this technique, but they require a lot of forethought.

4.8.3 Double Sided PCBs

 First of all, double sided PCB is the same as single sided PCB.The only difference between both is that a single sided board has copper on one side of the board. Technically speaking, a single-sided board will not have copper plated in the drilled holes either. Second, double sided PCB allows for closer routing traces by alternating between a top and bottom layer using vias. Today, double sided printed circuit board technology is perhaps the most popular type of PCB in the industry. Also, the advantages of double sided PCB are the fact that as designers it will gives us more flexibility, increase of the circuit density with a lower cost.

4.8.4 Multilayer PCB

Unlike a Double-Sided PCB, which only has two conductive layers of material, all multilayer PCBs must have *at least three* layers of conductive material, which are buried, in the center of the material. The way we made them is by Alternating layers of prepeg and core materials are laminated together under high temperature and pressure to produce Multilayer PCBs. This process ensures that air isn't trapped between layers, conductors are completely encapsulated by resin, and the adhesive that holds the layers together are properly melted and cured. The range of material combinations is extensive from basic epoxy glass to exotic ceramic or Teflon materials.

4.8.5 Rigid PCBs

Rigid PCBs are printed circuit boards that are made out of a solid substrate material that prevents the board from twisting. Possibly the most common example of a rigid PCB is a computer motherboard. Rigid PCBs make up perhaps the largest number of PCBs manufactured. These PCBs

are used anywhere that there is a need for the PCB itself to be set up in one shape and remain that way for the remainder of the device's lifespan. Also, rigid PCBs can be anything from a simple single-layer PCB all the way up to an eight or ten-layer multi-layer PCB, which makes them, share the same application.

4.8.6 Flex PCBs

 Flexible PCBs are made of materials that can flex and move, such as plastic. Like rigid PCBs, flexible PCBs come in single, double or multilayer formats. As they need to be printed on a flexible material, they tend to cost more for fabrication. Because of their flexibility they tend to save us money and weight, since they can be used to cover areas that might take multiple rigid PCBs. Flexible PCBs can also be used in areas that might be subject to environmental hazards. To do so, they are simply built using materials that might be waterproof, shockproof, corrosion-resistant or resistant to high-temperature oils an option that traditional rigid PCBs may not have.

4.8.7 Flexible-Rigid PCB

Flex-rigid PCBs combine the best of both worlds when it comes to the two most important overarching types of PCB boards. Flex-rigid boards consist of multiple layers of flexible PCBs attached to a number of rigid PCB layers. Flex-rigid PCBs have many advantages over just using rigid or flexible PCBs for certain applications. For one, rigid-flex boards have a lower parts count than traditional rigid or flexible boards because the wiring options for both can be combined into a single board. The combination of rigid and flexible boards into a single rigid-flex board also allows for a more streamlined design, reducing the overall board size and package weight.

4.8.8 Aluminum-Backed PCBs

Aluminum-backed PCBs are designed in much the same way as their copper-backed counterparts. However, instead of the usual fiberglass used in most PCB board types, aluminum-backed PCBs make use of aluminum or copper substrate board. The aluminum backing is lined with thermally insulating material that is designed to have a low thermal resistance; meaning less heat is transferred from the insulating material to the backing. Once the insulation is applied, a circuit layer of copper, ranging in thickness from one ounce to ten, is applied.

Aluminum-backed PCBs have many advantages:

● Low cost
● Environmentally friendly

- Heat Dissipation
- Material durability

4.8.9 PCBs Manufacturers

In this section my group will have to choose the amount for PCB layers that will be enough and fit our design. To be honest we didn't make a decision yet, however I had had researched multiple different manufacturers and sorted the information in the tables below. Because we don't have enough time and financial resources we may take on consideration the cheapest PCB which is either single and double layers boards, in flowing tables it shows as different types of single layers PCB's and their price as well as their manufacture names as shown in (table 4.3 and 4.4)

Manufacturer	Type of PCB	Cost ($)	Total Days
PCBWay	Single	102.24	8
EasyEDA	Single	57.90	9
ALLPCB	Single	77.09	5
Elecrow	Single	77.96	10
PCBWay	Single	103.31	8
U&I(quickturnpcb)	Single	125.60	8
Eurocircuits	Single	126.87	9
Smart Prototyping	Single	130.30	9
Bay Area Circuits	Single	151.62	10
ShenZhen2U	Single	166.13	10
Bittele (7pcb)	Single	198.73	5
PCB Zone	Single	200.16	8
Aisler	Single	272.32	9
Accutrace PCB4U	Single	289.55	8
ExpressPCB	Single	326.13	4
Advanced Circuits	Single	374.24	8

Table 4.3. PCB brands and prices tables (single layer)

Manufacturer	Type of PCB	Cost ($)	Total Days
PCBWay	2 Layer	122.47	8
EasyEDA	2 Layer	57.90	9
ALLPCB	2 Layer	96.10	5
Elecrow	2 Layer	77.96	10
PCBWay	2 Layer	123.54	8
U&I(quickturnpcb)	2 Layer	125.60	8
Eurocircuits	2 Layer	126.87	9
Smart Prototyping	2 Layer	130.30	9
Bay Area Circuits	2 Layer	151.62	10
ShenZhen2U	2 Layer	178.04	10
Bittele (7pcb)	2 Layer	198.73	5
PCB Zone	2 Layer	200.16	8
Aisler	2 Layer	272.32	9
Accutrace PCB4U	2 Layer	289.55	8
ExpressPCB	2 Layer	326.13	4
Advanced Circuits	2 Layer	374.24	8

Table 4.4. PCB brands and prices table (double layer)

As we see from both tables there is no big difference when it comes to the price, since we are doing our own project without sponsor help, our budget is limited so there an equation with two variables to solve here cheap price an fast time frame that makes us choose probably a PCB layers price between 57.90$ and 100$, depending on the time constraint we probably can receive it as little as 8 days. Which is a fair time when it comes to the total time we have to finish the project.

4.8.10 Power Distribution for Two-Layer Boards

- Single-Point vs Multipoint Distribution

In a true single-point power-distribution system, each active component has its own separate power and ground, and these traces would remain

separate until they meet at a single reference point. In multipoint systems, the connections are made in a daisy-chain fashion, so there are multiple 0-V reference points. It is clear that multipoint systems have the potential for common impedance coupling. While implementing a single-point system may be impossible, a combination of single point for devices generating RF and multipoint for everything else serves to reduce noise. The best scheme possible has a single point that ties together the regulator ground, microcomputer ground, battery negative, and chassis or shield.

- Star Distribution

Star distribution is much like single point. It looks like all points reference the same fixed point, which is located centrally, by about the same length of traces. Additionally, that same reference point may be attached, via a large single trace, to its source, which is not centrally located. Therefore, the major differences to single point are:

➢ The single reference point on a star can be a longer trace, instead of a point
➢ The point where the separate traces begin is near the center of the board, and each trace goes in its own direction, with the resulting trace length equal to that of all the others.
➢ The star is best applied to something like a system clock in a high-speed computer board. The signal originates on the edge connector and proceeds to the center of the board, where it then splits and goes to each place it is needed. Since it effectively originates at the center of the board, the delay in the signal from one area of the board to another is minimal. The name star sometimes is used to refer to single point, making the above clarification necessary.

The power and signal efficiency distribution for to layer board as shown below in (table 4.5).

	Trace Type	
	Power	**Signal**
Single Point	Best	O.K.
Star	O.K.	Best
Multipoint	Worst	Worst

Table 4.5. Power distribution

- Gridding to Create Planes

Gridding is the most critical design technique for two-layer boards. Much like a power utility grid, gridding is a network of orthogonal connections between traces carrying ground. It effectively creates a ground plane, which provides the same noise reduction as on four-layer boards. It serves two purposes:

- Emulates the ground plane of a four-layer board by providing a ground return path under each of the signal traces
- Lowers the impedance between the microcomputer and the voltage regulation

The (figure 4.7) below explains how to design the Gridding Power Traces on Two-Layer Boards
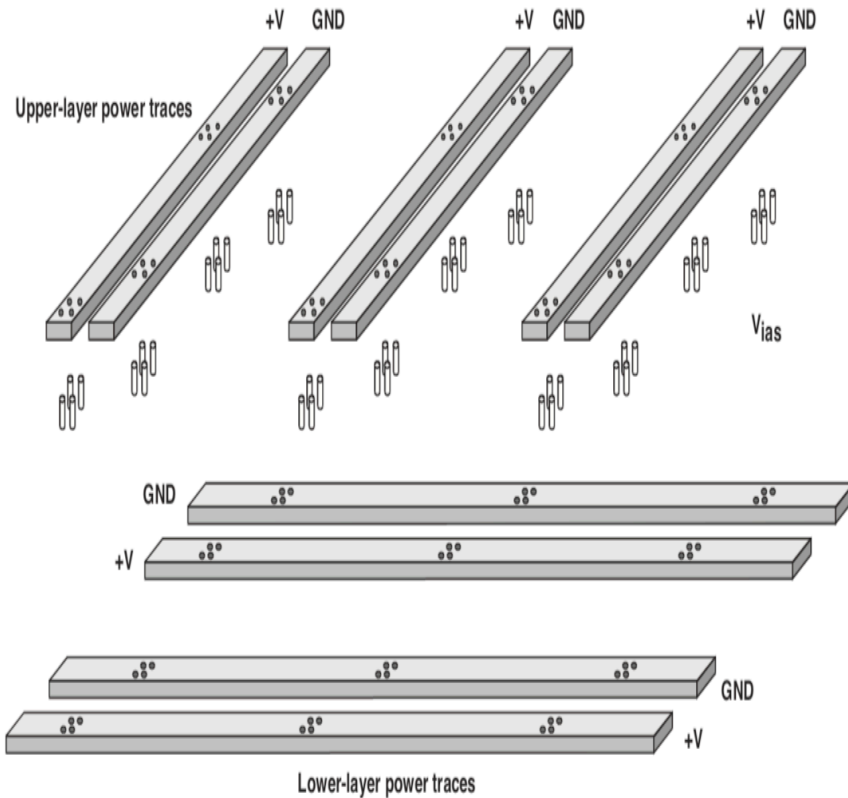
Figure 4.7 Gridding Power Traces on Two-Layer Boards

4.9 Password Based Door Lock System using 8051 Microcontroller

Password Based Door Lock System using 8051 Microcontroller is a simple technology where a secure password will replace the traditional locks system which uses a mechanical lock a and key mechanism, which is being replaced by new advanced techniques of locking system. These techniques are an integration of mechanical and electronic devices and are highly intelligent. One of the prominent features of these innovative lock systems is their simplicity and high efficiency. Such an automatic lock system consists of electronic control assembly, which controls the output load through a password. This output load can be a motor or a lamp or any other mechanical or electrical load.

5.0 Standards

Standards are used in every thing around us and if something is unique then a new standard will be written just for it. Standards are extremely

important in our project because we are designing a smart lock that any person should be able to use easily. ANSI/BHMA (American National Standards Institute Builders Hardware Manufactures Association) organization is the source for door lock standards. However, as this project is consisting of different parts that use different technologies to lock/unlock the door. There will be other standards when dealing with each technology by itself and the way that all the parts communicate with each other.

5.1 Door lock standards

The lock system is consists of many parts like spindle, latch and deadbolt and all of them have some standards to follow. Some of these standards are important to us, as we are going to build our project by manipulating some of these parts as shown in (figure 5.1).
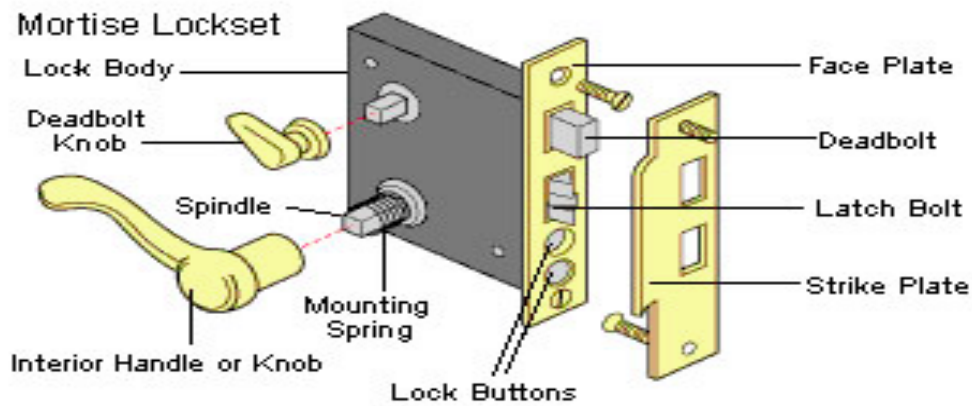
Figure 5.1 Door Lock Components

5.1.1 Bore Hole and cross bore

The hole where the doorknob is going to be in the door is called borehole or boor hole. The standard size for a borehole is 2 – 1/8" in diameter. Another hole with 1" in diameter extends from the edge of the door through the borehole. This hole is called cross bore and it is where the latch is installed.

5.1.2 Latch

The latch task is to maintain the door in closed position. There are many types of latches like Deadbolt latch, spring latches, slam latch and toggle

latch. There is a fascinating physics behind how the latch works by joining two objects and allows them to separate when needed. The latch should fit into the cross bore leaving a 1inx2-1/4in rectangular on the edge of the door.

5.1.3 Spindle

There are two handles on every door. What connects these handles together is a square metal bar, called the spindle. There is no one standard for this part as every manufacture are making them to meet their preference. For example, Yale Lock are using 3/8" -20 threads per inch for their spindles. While Sargent Lock are using 3/8"-16 threads per inch for their spindles. Lockwood, which is one of the most known companies, are using 3/8"- 18 threads per inch for theirs. In some smart locks the spindle is an electronic device where one side could be moved without the other. We couldn't find any standards for electronic spindles.

5.1.4 Deadbolt

While the latch moves by rotating the handle, the deadbolt moves only when a key or a knob rotates through a cylinder. Another difference between the latch and the deadbolt, the latch depends on a spring to get back to its original position while in the dead bolt does not making it hard to move it by any object as someone tries to break in. deadbolt should fit in a standard borehole (2-1/8" in diameter). However, another measurement is important when installing a deadbolt, which is known as backset. Backset is the distance from the edge of the door to the center of the borehole. For residential door, there are two backsets standards: 2 3/8 inches and 2 3/4 inches.

5.2 ANSI/BHMA Grade level

ANSI/BHMA has classified all locks to three grade levels based on it performance under different circumstances. The standards references are:

Grade one: The highest level (Heavy Duty) usually used for commercial security. In order for the lock to receive this grade this grade the knob must withstand 800,000 cycles, six door strikes and a 360 lb. weight test. The dead bolt must withstand 250,000 cycles and 10 strikes with a hammer. ("BHMA Standards.")

Grade two: used for residential security in homes and apartment. The knob in this grade must withstand 400,000 cycles and the dead bolt must withstand 150,000 cycles and 10 strikes with a hammer. ("BHMA Standards.")

Grade three: lowest and weakest however that doesn't mean bad quality. Not recommended to be used in main entry point. ("BHMA Standards.")

Our main goal in this project is to combine technology and power consumption rather than having a secure heavy-duty lock. This means getting certified grade lock might increase the project's budget, as we will need to provide the best materials to build the lock. We would like to get a grade certification for our project but it is not our main concern as it is taking us away from our field as electrical engineers.

5.2.1 Electric strikes - ANSI/BHMA A156.31

We might use an electric strike as a lock mechanism in our project. ANSI does specify the dimensions for the body of a lock, however, there is no standard in how the latch bolt, dead latch and deadbolt are to be arranged on the lock. That means the manufacturers companies have the free choice to design their locks in different configurations. Based on that we have to choose which lockset manufacturer we are going to use before we choose the electric strike to be sure that it will function perfectly.

Electric strike comes in 12 or 24 volts and it also fall under the same ANSI/BHMA product grading. As we are using micro solar power as power source we want the electric strike to use the minimum possible power so we will work with 12 volts. It is going to be a challenge for us to maintain a standard body lock dimensions that will host a 12 volts battery inside of it.

5.3 communications standards

In our project there will be some communications made between the microprocessor and different applications. Applications like RFID, WIFI, Bluetooth, fingerprint and a keypad should be able to communicate efficiently with the microprocessor. The microprocessor then will unlock or lock the door based on these communications.

5.3.1 RFID (Radio Frequency Identification) Standards

As RFID systems became widely used in different areas like payment systems, tracking goods and contactless smart cards the need of well-established standards was necessary. ISO (International Organization for Standardization) has created standards that deal with RFID systems. In this project we are working with contactless smart cards that is going to be one of the methods to unlock the door.

5.3.1.1 Communications standards for UHF Calss1 Gen2 – ISO 18000

Iso18000 defines three parts of reader-tag communication. How the exchanged data are coded, modulated and which anti-collision protocol is used. In terms of ISO18000 standard all UHF passive systems should use PIE (Pulse Interval Encoding) for coding, ASK (Amplitude-Shift Keying) for modulation and Q-Algorithm as an anti-collision protocol.

5.3.1.2 Standards for Vicinity cards – ISO 15693

Vicinity cards are cards, which can be read from distance like RFID cards. This standard applies only one passive RFID tags, as it has no power source. ISO 15693 systems operate at 13.56 MHz and have a reading range distance of 1 m to 1.5 m.

The communication between the reader and the card in this standard should use ASK with 10% or 100% modulation index. The coding data is 1 out of 4 PPM (Pulse position Modulation) with LSB (Least significant bit) sent first. Or 1 out of 265 PPM

The communication with the reader can be done in two ways: ASK or FSK (Frequency Shift Keying). When using ASK the modulation index is 100% and the subcarrier frequency is 423.75 KHz. The data rate is either low with 6.62 Kbits/Sec or high with 26.48 Kbits/Sec. To get a logic zero the transmission begins with eight pulses of 423.75 KHz followed by unmodulated time of 18.88 microseconds. To get logic one it just the other way around, starts with unmodulated time then eight pulses. When using FSK the sub carrier switches its value between 423.75 and 484.25 KHz. The data rate is low and high with the same value as ASK. To get a logic zero the transmission begins with eight pulses with a frequency of 423.75 KHz followed by nine pulses with a frequency of 484.28 KHz. While the logic one is the other way around.

5.3.1.3 Air Interface Protocol - ISO 11785

Air Interface Protocol standards is the way that a communication is done between the tag and the reader. It also specify how the data has to be organized and in which format in the tag. ISO has approved 2 protocols to use between the tag and the reader known as Half Duplex and Full Duplex as shown in (table 5.1).

Protocol	Full Duplex	Half Duplex
Modulation	ASK	FSK
Frequency	129-133.2 KHz 135.2-139.4 KHz	124.2 KHz 1 134.2 KHz 0
Channel code	DBP (Differential Biphase)	NA
Symbol time	0.23845 ms	0.1288 ms 1 0.1192 ms 0
Telegram	128 bits	112 bits

Table 5.1 Half and Full Duplex Comparsion

5.3.1.4 Contactless integrated circuit cards - ISO 14443

For an RFID system to be certified it has to use a frequency of 13.56 MHz to communicate. The card contains microchip, transmitter and communicates with the reader provides the microchip with its power so it will be able to transmit data as shown in (figure 5.2). There are 2 different types of protocols for this process A and B. Type A is more common than type B and it is also called memory cards and type B is called microprocessor cards.

There is no big difference between these two types. And the lack of resources on this field we only found that the main difference between the two types is that for some historic reasons type B is often used in the francophone regions of the world. While type A is used in the rest of the world.
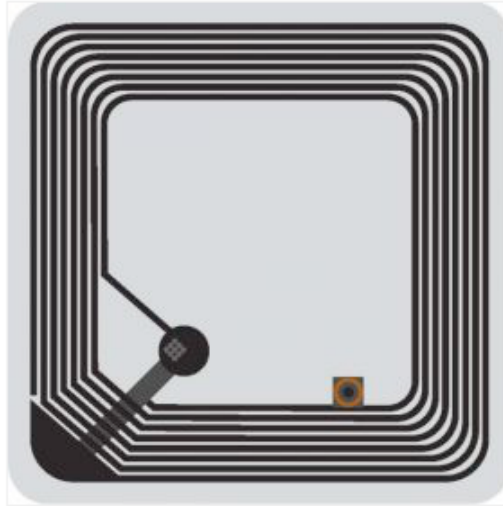
Figure 5.2 RFID Tag

5.3.2 WIFI IEEE 802.11 family of standards

WIFI communication is going to be used in our project, as the android application communicates with the microprocessor. The most known and common standard for WIFI communication is IEEE 802.11. This standard was developed by WI-FI Alliance since 1997 and the family was growing since then. There are many standards belong to this family like 802.11a, 802.11b, 802.11n, 802.11ac and 802.11ad.

Most common home used standards are IEEE 802.11ac and IEEE 802.11n. By compassion we found that IEEE 802.11ac is 3 times faster than IEEE 802.11n. It is capable of exchanging data in rate of 1300 Mbps while the 802.11n speed is 450 Mbps. That why in our project we will be working with IEEE 802.11ac standard. This standard operates in a frequency of 5 GHz and 80/160 MHz channel width. It also uses up to 8 antennas MMI (multiple input, multiple output) that reduce error, boost speed, and consume less power.

802.11 in General are the products that implement 802.11 standards and are referred to as "Wi-Fi certified." In the section below we go in details about each type of the 802.11 family members.

802.11a concepts are:

- Specifies a PHY that operates in the 5 GHz U-NII band in the US - initially 5.15-5.35 AND 5.725-5.85 - since expanded to additional frequencies
- Uses Orthogonal Frequency-Division Multiplexing

- Enhanced data speed to 54 Mbps

802.11b concepts are:

- Enhancement to 802.11 that added higher data rate modes to the DSSS (Direct Sequence Spread Spectrum) already defined in the original 802.11 standard
- Boosted data speed to 11 Mbps
- 22 MHz Bandwidth yields 3 non-overlapping channels in the frequency range of 2.400 GHz to 2.4835 GHz
- Beacons at 1 Mbps, falls back to 5.5, 2, or 1 Mbps from 11 Mbps max.

802.11d concepts are:

- Enhancement to 802.11a and 802.11b that allows for global roaming
- Particulars can be set at Media Access Control (MAC) layer
- 802.11e concepts are:
- Enhancement to 802.11 that includes quality of service (QoS) features
- Facilitates prioritization of data, voice, and video transmissions

802.11g concepts are:

- Extends the maximum data rate of WLAN devices that operate in the 2.4 GHz band, in a fashion that permits interoperation with 802.11b devices
- Uses OFDM Modulation (Orthogonal FDM)
- Operates at up to 54 megabits per second (Mbps), with fallback speeds that include the "b" speeds

802.11h concepts are:

- Enhancement to 802.11a that resolves interference issues
- Dynamic frequency selection (DFS)
- Transmit power control (TPC)

802.11i concepts are:

- Enhancement to 802.11 that offers additional security for WLAN applications
- Defines more robust encryption, authentication, and key exchange, as well as options for key caching and pre-authentication

802.11j concepts are:

- Japanese regulatory extensions to 802.11a specification
- Frequency range 4.9 GHz to 5.0 GHz

802.11k concepts is just the using the radio resource measurements

for networks using 802.11 family specifications

802.11m concepts are:

- Maintenance of 802.11 family specifications
- Corrections and amendments to existing documentation

802.11n concepts are:

- Higher-speed standards
- Several competing and non-compatible technologies; often called "pre-n"
- Top speeds claimed of 108, 240, and 350+ MHz
- Competing proposals come from the groups, EWC, TGn Sync, and WWiSE and are all variations based on MIMO(multiple input, multiple output)

5.3.3 Bluetooth Standard

The core specification for Bluetooth is developed by SIG (Special Interest Group) and they are responsible for updating and enhancing it. There are different types of cores where each one has many layers in it that describe the Bluetooth protocol architecture.

5.3.3.1 Basic Rate Core Configuration

This is the first version of Bluetooth (Bluetooth 1.0). It was rarely used due to its low speed of only 1Mbps and the difficulty of pairing. In this core the Host required to have five layers L2CAP (Logical Link Control and Adaptation Protocol), SDP (Service Discovery Protocols), ATT (Attribute Protocol), GATT (Generic Attribute Profile) and GAP (Generic Access Profile). On the other hand the controller requires to have three layers which are RF (Radio Specification), BB (Base band) and LMP (Link Manager Protocol). (Bluetooth)

5.3.3.2 Enhanced Data Rate Configurations

EDR (Enhanced Data Rate) is also known as Bluetooth 2.0. Improved in both pairing and speed rate which became 3 Mbps triple times the first version (basic rate). There are three categories needs to be met in transport requirements to claim support for EDR they are shown in (table 5.2)

Category	Transport Requirements	Controller Part
		LMP Features **Supported**
1	EDR for asynchronous Transports (single slot)	Enhanced Data Rate ACL 2 Mb/s mode (25) AND Enhanced Data Rate ACL 3 Mb/s mode (26)
2	EDR for asynchronous Transports (multi-slot)	3-slot Enhanced Data Rate ACL packets (39) AND 5-slot Enhanced Data Rate ACL packets (40)
3	EDR for synchronous transports	Enhanced Data Rate eSCO 2 Mb/s mode (45)

Table 5.2. EDR Configuration requirements (Bluetooth)

5.3.3.3 High Speed Core Configuration

HS core has a high data rate speed similar to the one in IEEE 802.11. However, it consumes too much power. For an implementation to claim support of HS it has to satisfy the following requirements.

In the host part the L2CAP layer has to have an enhanced retransmission mode and fixed channel for AMP. While the controller part should have an 802.11 PAL layer.

5.3.3.4 Low Energy Core configuration

This is the most know and used version of Bluetooth being used these days known as Bluetooth 4.0. The idea behind it is using a sensor to start collection data form low rate devices. This feature made it possible to use Bluetooth on low power consumption devices such as smart watches. To claim support for this core configurations the fallowing standard has in (table 5.3 and table 5.4) have to met on both the host and controller part.

Layer	Feature
L2CAP	If the GAP Peripheral or Central role is supported, L2CAP LE Signaling Channel (CID 0x0005) and all mandatory features associated with it
GAP	All mandatory features for at least one of the LE GAP roles
ATT	If the GAP Peripheral or Central role is supported, all mandatory features
GATT	GATT is mandatory when ATT is supported. When supported, all mandatory features
SM (Security Manager)	If the GAP Peripheral or Central role is supported, all mandatory features

Table 5.3 LE Core Configuration Host requirements (Bluetooth)

Layer	Feature
PHY (Physical)	All mandatory features
LL (Link)	All mandatory features

Table 5.4 LE Core Configuration Controller requirements (Bluetooth)

*The mandatory features are specified in Bluetooth core specification v5.0

5.4 Fingerprint Identification standards

Biometric definition is the measuring of biological features. The main use for it is to verify an individual's identity from his/her fingerprint, face, voice …etc. The use of biometrics evolved dramatically around the world with the spread of technology. Over the time agencies needed to exchange these sensitive data with each other, that's when a standard for saving and exchanging biometric records was necessary.

NIST (National Institute of Standards and Technology) have being working with federal agencies, academic institutions and industry partners for a long time to improve human identification systems. Any new biometric system must have two components, message format and image quality. The message must have a type1 (transaction record), type2 and one more type of seven other records.

Type1 by itself has a total of 15 fields that hold different types of information like software version number, file content, type of transaction, date, time, recipient info and other information.

Type2 is called user-defined descriptive text record. This record holds information about the subject's physical characteristics, demographic and the criminal history.

Type3 has the fingerprint information in a greyscale low-resolution image. The fields will have information regard the fingerprint like finger position, image scanning resolution, horizontal line length, vertical line length and image data.

5.5 PIR sensor Standards

PIR stands for Passive Infrared Sensor, which detect any motion by using thermal detectors. There are two slots in any PIR motion detector. As long as the room is empty both detectors will absorb an equal amount of heat, in this case the sensor in an idle mode. However, when a warm body is walking a cross the room then one of the slots will absorbs more heat than the other, which will result in an electrical signal. There are two types of motions that a sensor detects, minor and major motion. The definitions for both motions according to NEMA (National Electrical Manufactures Association) is the movement of a person sitting at an office desk reaching for a telephone, turning pages, picking up a coffee, etc. Major motion is the movement of a person walking into or through an area.

5.5.1 Manufacture responsibility

NEMA is the source for any standards regarding PIR motion detector. Therefore any manufacture claiming to have tested NEMA WD-7 standard should provide the following information on their products.

- Mounting height.
- Maximum horizontal coverage angel.
- Dimensions of coverage area.
- Dimensions of room
- Floor surface material

The manufacture should also provide an illustration of the horizontal or vertical field in the following format.

- Grid pattern, with a maximum 3x3 ft. cell size.
- Crosshatched cells where major motion is detected
- Shaded or solid cells, where minor motion is detected.

5.5.2 PIR Testing

Regardless whether the sensor is going to be placed indoors or outdoors, it has to go for an operating condition for coverage area test. The test is called environment test and it runs as following and shown if (Figure 5.3)

- The room shall be divided into square grid with cell dimensions of 3x3 ft.
- The room should be larger than the test area
- The temperature should be measured at the sensor if it is mounted over 10 ft. and 70 F for all other sensors.
- The humidity of the room needs to be recorded.
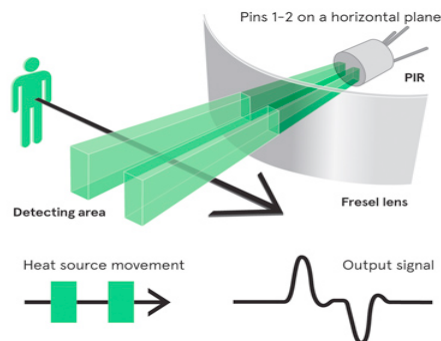
Figure 5.3 PIR motion detector

5.5.2.1 Major Motion Test

The test subject height has to be 5ft 7in +-4in and weight 170ib +-20. The person has to walk from a cell to cell with two stops at the edge of every cell. If the sensor was able to detect the movement the cell should be crosshatched in a drawing template. If the movement was not detected the cell should left blank at the template.

5.5.2.2 Minor Motion Test

For the minor motion test, a robotic arm mounted at a height of 36 in +-1 with dimensions 3x3x15 in has to be used. The arm needs to move to a four different angels 0, 90, 180, 270. The arm then will be moved from cell to cell to test the sensor detection. If the sensor detected any of the four 90 degrees sweep motions, then the cell should be shaded in the drawing template.

At the end of both tests, the template has to be compared with one provided by NEMA WD-7 (Figure 5.4). If the template matches the illustration format of NEMA WD-7 then the sensor is compatible with their standard.
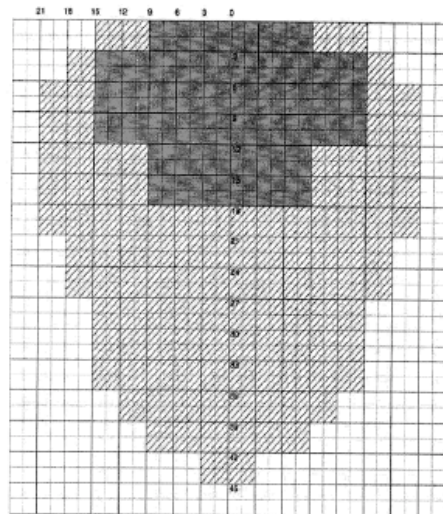
Figure 5.4 NEMA WD-7 wall switch PIR pattern (Occupancy)

5.6 Solar panel standard

Solar panels come in different sizes as every brand has its own standard. However, every solar panel has a number of PV (photovoltaic) cells. The cell has a standard size of 156 square mm. the number of cells vary

depends on whether it is a residential or commercial panel. (Table 5.5) gives a compassion between the residential and commercial used Solar Panels.

	Residential	Commercial
Number of cells	60	72
Dimensions	65x39 inches	78x39 inches
Weight	Depends on the manufacture brand	Depends on the manufacture brand

Table 5.5. Residential and Commercial solar panel

5.7 LED light standard

There are many types of LED (Eight emitting Diode) lights. Some examples of these types are LED Die, LED Package, LED Bulb and LED Array. We will focus on the LED Die, as it is probably the one will be used in our design. According to EPA Energy star LED Die defined as a small block of light-emitting semi-conducting material on which a functional LED circuit is fabricated.

There are many reasons of having standards for LED light. One of the reasons to make sure that the LED product is safe. Another reason is to define its performance related characteristics. An important reason as well is to determine whether the product qualifies for energy saving.

ANSI works with many professional associations like IEEE and IESNA (Illuminations Engineering Society North America) to develop tests and standards for LEDs. For example, ANSI/IES RP-16-10 standard purpose is to establish definitions for solid-state lightning devices. While ANSI C78.377 standard is for SSL indoor products color characteristics to communicate efficiently with their producers and users.

5.8 Keypad standard – E.161

This is an ITU-T (ITU Telecommunication Standardization Sector) that assign the basic 26 Latin letters (A to Z) to a <u>keypad</u>. Based on this standard, whenever letters or digits appear on a key, the recommended relationships between them are shown in the (Figure 5.5) below.

1	2 ABC	3 DEF
4 GHI	5 JKL	6 MNO
7 PQRS	8 TUV	9 WXYZ
	0	

Figure 5.5 Relationship between numbers and letters in a keypad (E.161)

This is known as standard 4 x 3 array. There are two other arrays which can be used as well 6 x 2 and 2 x 6 arrays. The number and symbols order in these arrays are shown in the (figure 5.6)below

Standard 4 × 3 array

1	2	3
4	5	6
7	8	9
*	0	#

6 × 2 array

1	2
3	4
5	6
7	8
9	0
*	#

2 × 6 array

1	2	3	4	5	*
6	7	8	9	0	#

Figure 5.6 Button arrangements in different arrays (E.161)

Based on E.161 standard, extensive research has shown that these arrangements lead to shorter entry times and lower error rates than other arrangements.

Two more buttons can be added to the previous ten giving a total of twelve buttons. The star button (*), which is immediately to the left of the button zero, is used to transmit the frequency pair 941 Hz and 1209 Hz. The button square (#), which is immediately to the right of the button zero, is used to transmit the frequency pair 941 Hz and 1477 Hz. Once these buttons are added the keypad is using what is called as dual mode.

According to this standard, it is recommended that the button holding number five be marked with a tactile identifier. This is done to assist Blind and visually impaired people to identify the numbers they are dialing. It will also help people to dial in other situations as well like low light conditions.

5.9 Standards Impacts

Sometimes implementing the standards can affect a design. While working on our project there are some standards that we should consider their impacts on our project.

5.9.1 Door lock standards impact

As we have no experience in building a door lock from scratch, we need to know the standard for that. One of our goals is that our lock can be easily installed in any door, which cannot be done without using the standards.

5.9.2 Communications standards impact

We also want some communication between an android application and the microprocessor inside the lock. This communications will tell the lock whether to lock or unlock the door, beside some other features that can be added. By knowing the standards for the Bluetooth and WIFI, it will help us in choosing the right router and Bluetooth version. These standards are also needed when designing the app to make sure the communications will be done in the right way.

5.9.3 PIR sensor standard Impact

By looking at PIR motion detector standards we should be able to choose the right one for our design. For example, in our design we do not really care about any minor motion detection. By ignoring this feature, we should be able to get a cheaper and smaller PIR motion detector. That will help us to achieve some of our engineering and marketing goals.

5.9.4 Biometric fingerprint ID standard impact

This standard made it so clear how a fingerprint ID data are so sensitive information. In our design we need to be sure that the data will be secured and compatible with the NIST standard. This will show the user of the product that his information is secured and cannot be used or transferred without his/her knowledge.

6.0 Parts selection

To provide the best product to our customers and to make sure that they get the best quality service, we had to select some well-qualified parts to build our project. We had to find the best part with the cheapest price. As a result we will meet the engineering requirements as well as the customer's requirements.

6.1 Electric Deadbolt

In physics, we have learnt about the electromagnetic field theory how it is formed and how it can be created for human resources. It has become a major component in the electronic devices world. For example, the deadbolt of a smart lock uses the electromagnetic field effect to create movements for the lock and unlock mechanism. "Solenoids are basically electromagnets: they are made of a big coil of copper wire with an armature in the middle; so, when the coil is energized, the armature or the slug is pulled into the center of the coil." (adafruit) The solenoid has the capability to lock and unlock the door using the electromagnetic field concept.

This specific solenoid that we are using in our project of the solar smart lock is really strong, and it has a slug with a slanted cut and a good mounting bracket, according to adafruit website. The electronic deadbolt lock shown the diagram below is designed for any door and it is safe. When the door is locked, there is no energy being consumed. As explained in the paragraph above, this electronic lock consumes power only when it is being unlocked. "When 9-12-volt DC is applied, the slug pulls in, so it does not stick out anymore and the door can be opened." (adafruit) and the other amazing flexibility that this electronic door lock has is the capability to rotate the slug from 90, 180, or 270 degrees so it can match the place where it is being used.

Those are the technical details about the electronic deadbolt lock as shown in (figure 6.1):

- 12VDC (9-12 DC volts can be used to do the locking and unlocking mechanism however, lowers voltage results in weaker/slower operation)
- Draws 650mA at 12V, 500 mA at 9V when activated
- Designed for 1-10 seconds long activation time
- Max Dimensions: 41.85mm / 1.64" x 53.57mm / 2.1" x 27.59mm / 1.08"
- Dimensions: 23.57mm / 0.92" x 67.47mm / 2.65" x 27.59mm / 1.08"
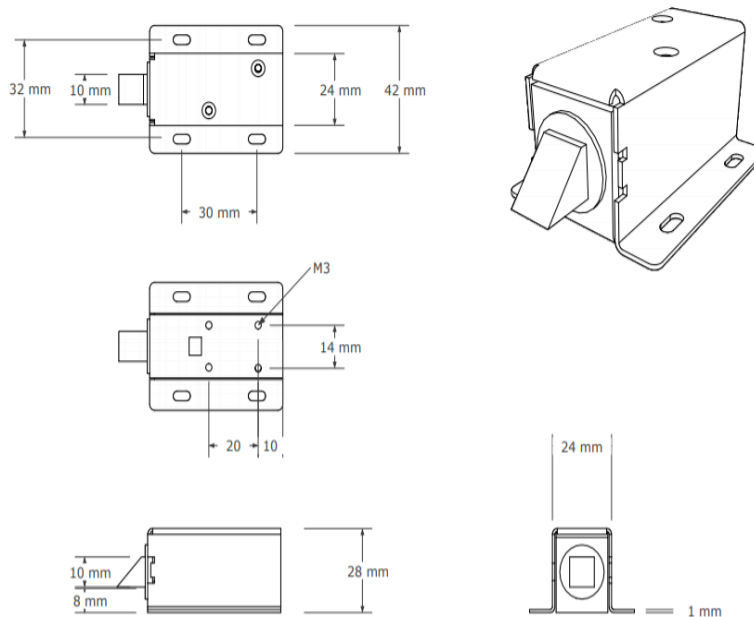- Wire length: 222.25mm / 8.75"

Figure 6.1: Electronic deadbolt lock diagram (adafruit copyright)

6.1.1 Electric Spindle

Another choice that we are still considering is to use an electric spindle instead of an electric deadbolt. This product is quite rare in the market and we were able to find it only with one provider in the United Kingdom (Locksonline.co.uk). The reason why we are letting this to be a secondary choice is because it takes a long time for it to arrive to the US. This part has a low power consumption of 6 – 12 volts. Making it the best choice in terms of power consumption. It is attached to a spindle with 8mm in diameter. It is important to know that in UK and Europe they use a different standards for their locks. Luckily the spindle diameter is available in US lock as well so we should have no problem with it.

6.2 Wi-Fi Module ESP6288

Today, almost every electronic device has the capability to connect to the internet. We have selected the Wi-Fi module ESP8266 for our project so not only it has the capability to connect to the internet using Wi-Fi but it also has the capability to be part of the internet of things. "ESP8266 offers a complete and self-contained Wi-Fi networking solution, allowing it to either host the application or to offload all Wi-Fi networking functions from another application processor". (Espressif) Knowing that this module is be

self-contained and can either host the application or offload Wi-Fi networking application to other processor gives us a couple of options to work with when building the solar smart lock project. This means we can either let the module host the Wi-Fi connectivity or let the micro controller unit (MCU) processor host the connectivity.

 "When ESP8266 hosts the application, and it is the only application processor in the device, it is able to boot up directly from an external flash. It has integrated each to improve the performance of the system in such applications, and to minimize the memory requirements. Alternatively, serving as a Wi-Fi adapter, wireless internet access can be added to any microcontroller-base design with simple connectivity through UART interface or the CPU AHB bridge interface." (Espressif)

There will be a motion sensor detector in our project to allow easy flexibility to the access to the door. So, it is necessary to have a wi-fi module that can connect to the sensor, so this specific part of the project can be done in a easily manner possible. "ESP8266 on-board processing and storage capabilities allow it to be integrated with the sensors and other application specific devices through its GPIO, with minimal development up-front and minimal loading during run time. With its high degree of on-chip integration, which includes the antenna switch balun, power management converters, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area. Sophisticated system-level features include fast sleep; wake context switching for energy efficient VoIP, adaptive radio biasing for low-power operation, advance signal processing, and spur cancellation and radio co-existence features for common cellular, Bluetooth, DDR, LVDS, LCD interference mitigation." (espressif) The feature or specifications of the wi-fi module is as follow:

- 802.11b/g/n protocol
- Wi-Fi Direct (P2P), soft-AP
- Integrated TCP/ IP protocol stack
- Integrated PLL, regulators, and power management units
- +19.5 dBm output power in 802.11b mode
- Integrated temperature sensor
- Supports antenna diversity
- Power down leakage current of < 10uA
- Integrate low power 32-bit CPU could be used as application processor
- SDIO 2.0, SPI, UART
- STBC, 1X1 MIMO, 2X1 MIMO
- A-MPDU & A-MSDU aggregation & 0.4 millisecond guard interval
- Wake up and transmit packets in <2ms
- Standby power consumption of < 1.0mW (DTIM3)

"ESP8266 has been designed for mobile, wearable electronics and Internet of Things applications with the aim of achieving the lowest power consumption with a combination of several proprietary techniques. The power saving architecture operates in 3 modes: active mode, sleep mode, and deep sleep mode. By using advance power management techniques and logic to power-down functions not required and to control switching between sleep and active modes, ESP8266 consumes less than 12uA in sleep mode and less than 1.0mW (DTIM=3) or less than 0.5mW (DTIM=10) to stay connected to the access point." (espressif)

"When in deep mode, only the calibrated real-time clock and watchdog remains active. The real-time clock can be programmed to wake up the ESP8266 at any required interval. The ESP8266 can be programmed to wake up when a specified condition is detected. This minimal wake up time feature of the ESP8266 can be utilized by mobile device SOCs, allowing them to remain in the low-power standby mode until Wi-Fi is needed. In order to satisfy the power demand of mobile and wearable electronics, ESP8266 can be programmed to reduce the output power of the PA to fit various application profiles, by trading off range for power consumption. By integrating the costliest components such as power management unit, TR switch, RF balun, high power PA capable of delivering +25dBm (peak), EsP8266 ensures that the BOM cost is the lowest possible, and ease of integration into any system. With ESP8266, the only external BOM are resistors, capacitors, and crystal. The ESP8266 has so many applications such as smart power plugs, home automation, mesh network, industrial wireless control, baby monitors, IP cameras, sensor network, wearable electronics, Wi-Fi location-aware devices, security ID tags, and Wi-Fi position system beacons." (espressif)

The current consumption and Radio frequency performance of the WI-FI module are discussed as shown in (table 6.1 and 6.2) below.

Mode	Typical	Unit
Transmit 802.11b, CCK1Mbps, P_{out}=+19.5 dBm	215	mA
Transmit 802.11b, CCK1Mbps, P_{out}=+19.5 dBm	197	mA
Transmit 802.11b, CCK1Mbps, P_{out}=+19.5 dBm	145	mA
Transmit 802.11b, CCK1Mbps, P_{out}=+19.5 dBm	135	mA
Receive 802.11b, packet length=1024 byte, -80 dBm	60	mA
Receive 802.11b, packet length=1024 byte, -80 dBm	60	mA
Receive 802.11b, packet length=1024 byte, -80 dBm	62	mA
Standby	0.9	mA
Deep sleep	10	mA
Power save mode DTIM 1	1.2	mA
Power save mode DTIM 3	0.86	mA
Total shutdowm	0.5	mA

Table 6.1: Current consumption (Espressif)

Description	Minimum	Typical	Maximum	Unit
Input frequency	2412		2484	MHz
Input Impedance		50		Ohm
Input reflection			-10	dB
Output power of PA for 72.2Mbps	14	15	16	dBm
Output power of PA for 11b mode	17.5	18.5	19.5	dBm
Sensitivity				
CCK, 1Mbps		-98		dBm
CCK, 11Mbps		-91		dBm
6Mbps(1/2 BPSK)		-93		dBm
54 Mbps (3/4 64-QAM)		-75		dBm
HT20, MCS7 (65 Mbps, 72.2Mbps		-71		dBm
Adjacent Channel Rejection				
OFDM, 6Mbps		37		dB
OFDM, 54Mbps		21		dB
HT20, MCs0		37		dB
HT20, MCs7		20		dB

Table 6.2: Radio frequency performance under room temperature (espressif)

The ESP8266 module (chip) embeds an ultra-low power Micro 32-bit CPU, with 16-bit thumb mode. This CPU can be interfaced using: code RAM/ROM interface (iBus) that goes to the memory controller which can also be used to access external flash memory, or using data RAM interface (dBus), which also goes to the memory controller, or using AHB interface for register access and JTAG interface for debugging. The memory controller contains ROM, and SRAM. It is accessed by the CPU using the iBus, dBus, and AHB interface. Any of these interfaces can request access to the ROM or RAM modules, and the memory controller arbiters serve these three interfaces on a first-come-first-serve basis. The AHB blocks perform the function of an arbiter, controls the AHB interfaces from the MAC, SDIO (host) and CPU. Depending on the address, the AHB data requests can go into one of the two slaves such as APB block or flash controller (usually for standalone application). Data request to the memory controller are usually high-speed requests, and requests to the APB block are usually register access. The APB block acts as a decoder. It is meant only for access to programmable registers within ESP8266's main blocks. Depending on the address, the APB request can go to the radio, SI/SPI. SDIO (host), GPIO, UART, real-time clock (RTC), MAC or digital baseband.

Below, in (figure 6.2) we show how the schematic diagram of the Wi-Fi module been drawn.
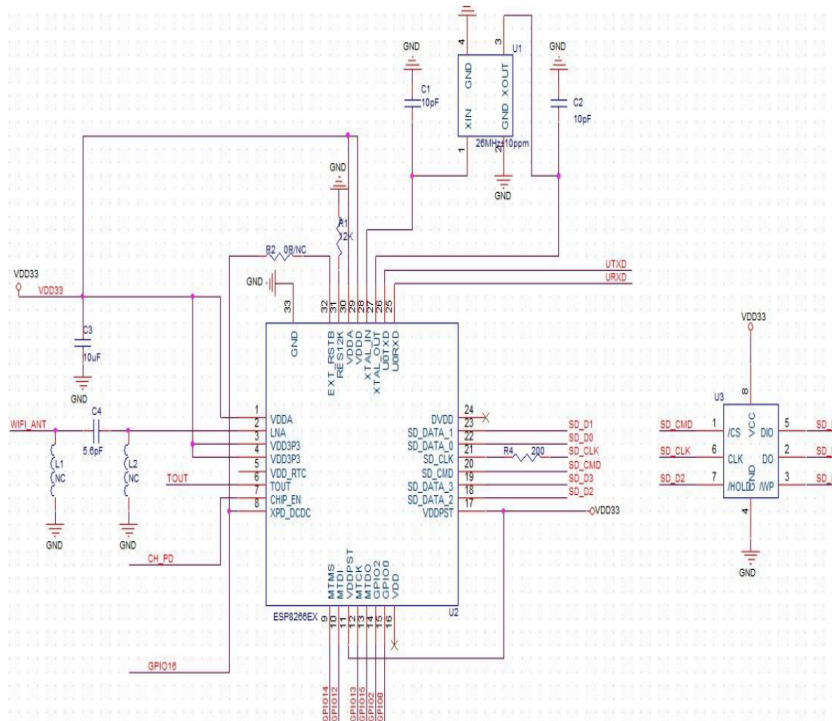

Figure 6.2: WI-FI module esp3266 schematic (adafruit copyright)

The minimum and maximum input or output that the module can handle are shown in (table 6.3) below

Parameter	Minimum	Max	Unit
Input low voltage	-0.3	$0.26 \times V_{IO}$	V
Input high voltage	0.75xVIO	3.6	V
Input leakage current		50	nA
Output low voltage		$0.1 \times V_{IO}$	V
Output high voltage	0.8xVIO		V
Input pin capacitance		2	pF
VDDIO	1.7	3.6	V
Maximum drive capability		12	mA
Temperature	-20	100	Degree Celsius

Table 6.3: Parameters of input and output (espressif)

6.2.1 CC3220MODA

After reaching Senior Design2 we started working on how to create communication between the WiFi module and the relay to unlock the door. We were able to find more resources on how to use and program the CC3220MODA. We also got the Launchpad for free from the Ti lab and the facuilty gave us all the help that we need on how to get this module and have it on our PCB. Below is some feauters for the CC3220MODA.

- o Include an Integral Antenna for Easy Integration Into the Host System.
- o Supports: UART, SPI and I2C.
- o IP Addressing: Static, LLA and DHCPv4.
- o 1.27-mm Pitch QFM package for easy assembly and Low-cost PCB design.
- o Voltage Supply: 2.3 – 3.6 V.
- o Low power mode.

6.3 Bluetooth module (HM-13 dual, EDR 4.0 & BLE 4.0)

"The Bluetooth HM-13 module is the next evolution in our line of serial Bluetooth modules. This board is equipped with an HM-13 module which supports both Serial Port Profile (SPP) and Bluetooth low-energy (BLE) Bluetooth profiles via Bluetooth 4.0. The HM-13's support for BLE means it is compatible with any smartphone. Or it can be connected to any computer via the old standard (SPP) and can used as a transparent Bluetooth data gateway. It can even be used in dual-mode, which means that it can be connected to a pair of devices simultaneously. The board includes all of the voltage regulating and level shifting that is needed to interface either 5 volts or 3.3-volt microcontrollers with the Bluetooth module." (Bluetooth)

"Communication with the HM-13 is performed through a serial UART, and an AT-command structure is used to configure it. In addition to the power-indicator LED, there is a green 'CON' LED. When the module is disconnected, this LED will blink at 1Hz and when it is connected, the LED will be on. The HM-13 provide many amazing features such as the voltage level-shifting supports both 5 volt and 3.3-volt systems, it is designed to interface directly to Arduino Pro's, it uses simple UART interface (4800-230400 baud), it has expansive AT command set, The BLE and SPP Bluetooth profile are supported, it has a built-in antenna, it is low power consumption, and so on. Below there is a picture of the internal connection and a schematic taken from the spark fun website as shown in (figure 6.3 and 6.4)." (Bluetooth)
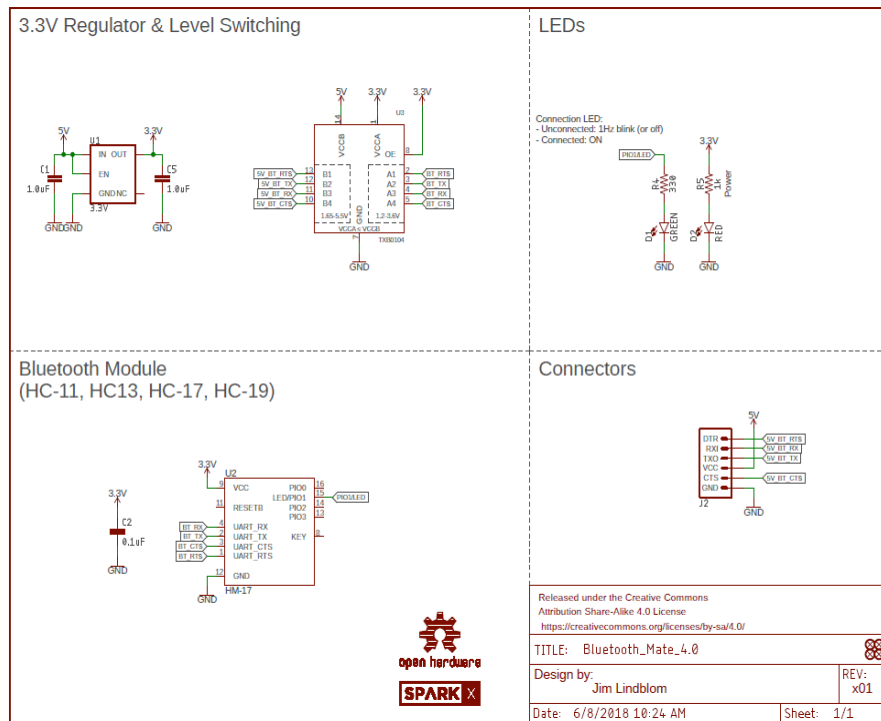

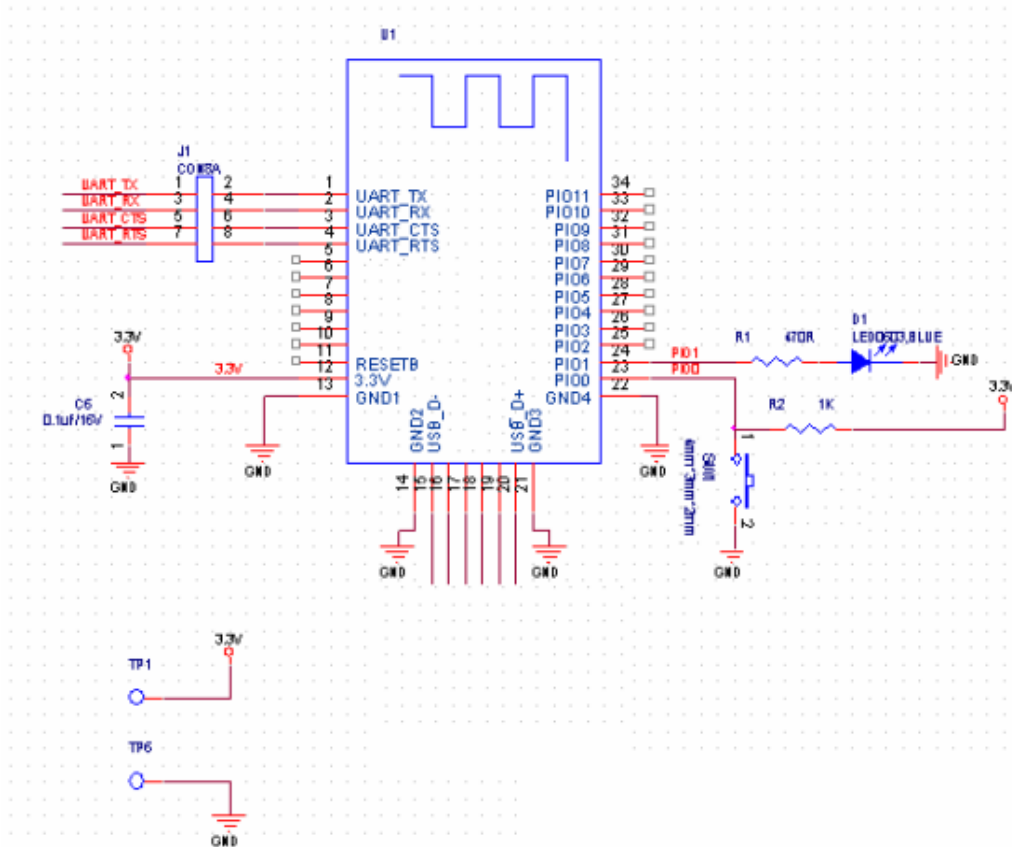Figure 6.3: connecting parts of Bluetooth module (MH-13 dual)

Figure 6.4: Bluetooth module (MH-13 dual) schematic (sparkfun.com copyright)

6.4 Fingerprint Scanner – TTL (GT-521F32)

"The GT-521FX2 is high performance fingerprint module that is able to be awakening by a finger touching the metal frame of sensor. It is one chip fingerprint module designed for integration into products with UART interface. It configure as USB mass storage device so that it does not need additional effort to handle the driver. The active area allows stable imaging and ability to cope with mass-market applications in need of both security and convenience. The reader within the MCU device is high performance; low power consumption 32-bit microcontrollers based around an ARM Cortex -M3 processor core and the fingerprint algorithm is processed on it." (Fingerprint)
"The fingerprint scanner- TTL (GT-521F32) has a lot of amazing features, which allow it to be easily in the Internet of Things. For example it has the simple UART & USB communication protocol. It complies with USB 2.0 full-speed (12Mbps) specification. It also has Ultra-thin Optical Sensor, Resolution 450 DPI, and wake up on finger function, and a finger print storage. It also works well with dry, moist or rough fingerprints. It has an

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anti-scratch with surface high hardness >5H, 1:1 verification, 1: N identification, high-accuracy and high-speed fingerprint identification technology, and convenient and safe and facilitation. In (table 6.4) below, the specification of the scanner reader module will be found."(Fingerprint)

Item	GT-521FX2
CPU	ARM Cortex M3 Core
Sensor	Optical Sensor
Window (mm)	16.9 x 12.9
Effective area of the sensor(mm)	14 x12.9
Image Size	258 x 202 pixels
Resolution	450 dpi
The maximum number of fingerprints	200/3000 fingerprints
Matching Mode	1:1:1: N
The size of template	496 Bytes (template) +2 Bytes
Communication Interface	UART, default baud rate = 9600bps after power on USB ver2.0, Full speed
False Acceptance Rate (FAR)	<0.001%
False Rejection Rate (FRR)	<0.1%
Enrollment Time	<3 sec (3 fingerprints)
Identification Time	<1.5 sec
Operating Voltage (V)	DC 3.3 to 6V
Operating Current (mA)	<130

Table 6.4: specification of the scanner reader module (fingerprint)

The diagram (Figure 6.5) below is related to the fingerprint scanner reader.
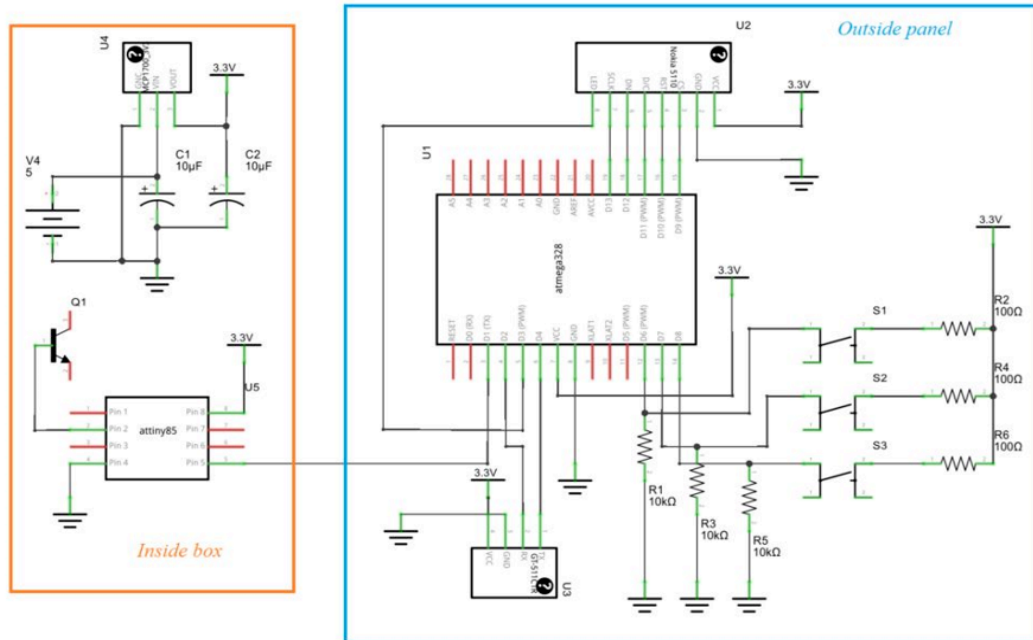
Figure 6.5: Related schematics to fingerprint scanner reader

6.5 Solar panel

In our project we will be using an AOSHIKE 5V 60MA Epoxy solar panel (7261349). This solar panel has a dimension of 2.67 x 1.45 inches that will be small enough to fit on the lock. This mini solar panel has a high conversion rate, even though there is a low light effect, it will provide a high efficiency output. It also has a unique process to make components beautiful and strong anti-snow, for the customers that leave up-North snow would not be a problem to power the lock. In addition, this process of solar panels has a surface, excellent transmission, light weight about 3.2 ounces, with a thin thickness shape, which will be very easy to install.

6.6 SparkFun RFID USB Reader

This is a USB to serial unit based on FTDI chip (figure 6.6). It has a read LED and a buzzer that will turn on or make a sound when a tag is being read. The USB-to-serial IC function is to convert the module's TTL (Transistor-Transistor logic) serial output to USB. For this unit to function probably it will needs one of the following readers:
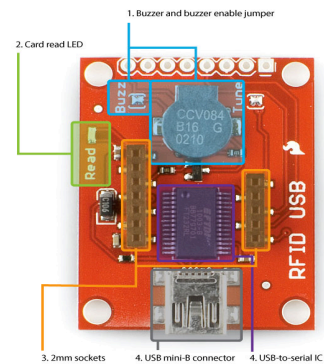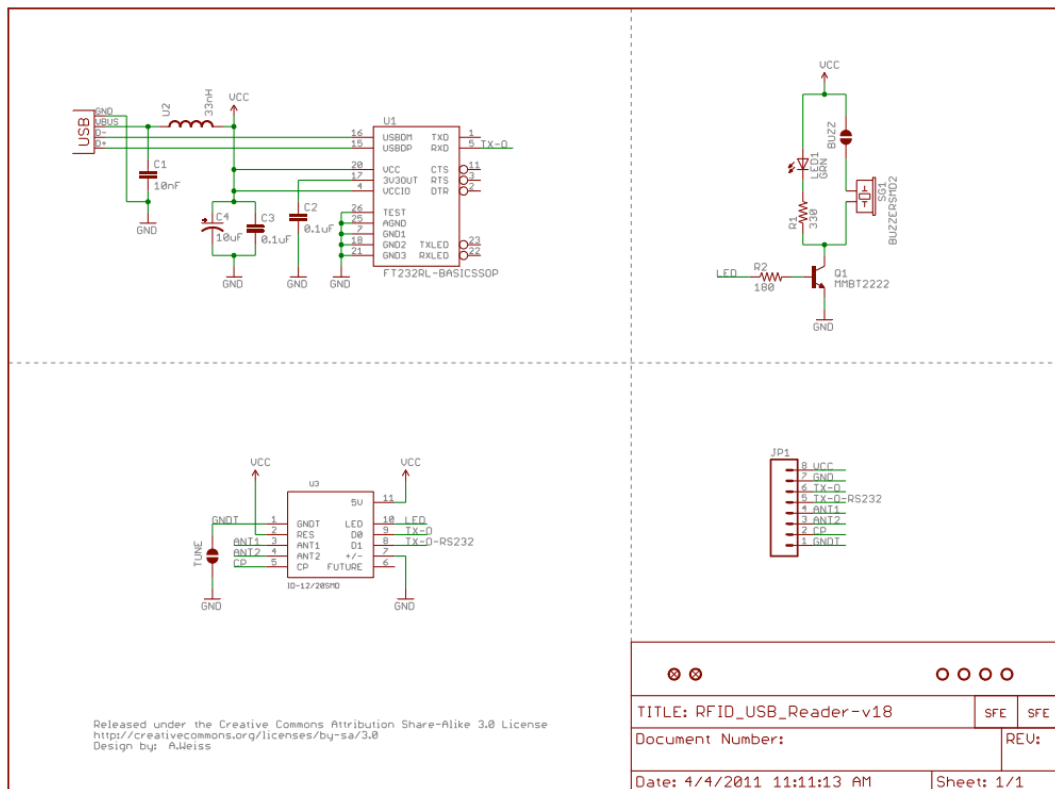
Figure 6.6: RFID USB Reader-SEN-

- ID-3LA
- ID-12LA
- ID-20LA

These readers work only with 125 kHz ID tags. After the chosen reader is plugged into the headers. The unit can be programmed with any terminal program that uses 9600bps 8N1.

6.6.1 Schematic for the USB Reader

Below in (figure 6.7) is the schematic for the USB reader. This circuit diagram will be combined with other component's circuit diagram to build the PCB.

Figure 6.7: RFID_USB_reader schematic

6.7 RFID ID-12LA Reader (125 kHz)-SEN-11827

This is a small footprint reader that supports ASCII, Wiegand26 and Magnetic ABA Track2 data formats. This reader task is to identify and track Data on tags or cards that uses RFID. It has a built-in antenna that can power up a 125 kHz tags or cards and get a serial string output that contains the unique ID.

ID-12LA features:

- 2.8 - 5V supply
- 125kHz read frequency
- EM4001 64-bit RFID tag compatible
- 9600bps TTL and RS232 output
- Magnetic stripe emulation output
- 120mm read range
- 25x26mm

6.7.1 RFID ID-12LA Pins out

There are a total of 11 Pins on the ID-12LA reader refer to (figure 6.8 and table 6.5) for layout and pin description.

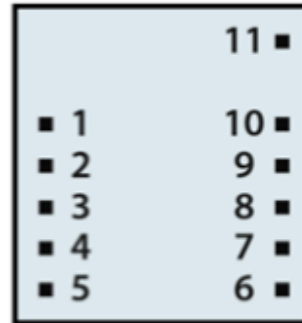| Pin #	Description
1	GND (Ground)
2	RES (Reset)
3	No connection
4	No connection
5	CP(Card present)
6	Tag in Range
7	Format Selector
8	Data 1
9	Data 0
10	Read (LED/Beeper)
11	2.8 – 5 input Voltage

Table 6.5: ID 12's Pin Function

Figure 6.8: ID 12's Pins Layout

- Pin2 should be strapped to Pin 11 all the times.
- Pin 5 is used when the output format is set to Magnetic Emulation.
- Pin 6 is set to VDD when a tag is in range otherwise it is set to 0 Voltage.

- Pin 7 selects one of the three formats based on the terminal it is connected to:
  - o GND: ASCII.
  - o Pin 10: Magnetic Emulation.
  - o 5 Volts: Wiegand26
- Pin 8 is the clock output for the Magnetic Emulation output format or the output data for the ASCII format. It can be also used to connect to a computer RS232 input.
- Pin 9 is active in ASCII format and it output the inverse of the data in Pin 8. This pin can be used to connect to a UART.

6.7.2 Schematic for ID-12LA Reader

Figure 6.9 illustrates the circuit diagram for the ID-12LA reader. The components values are given in (table 6.6).

Part #	Value	Part #	Value
R1	100R	C2	1000 uF
R2	4K7	C3	100 nF
R3	2K2	Q1	BC457
C1	10 uF	B1	2.7 – 3kHz, 5v pkpk

Table 6.6: ID-12LA's Components values
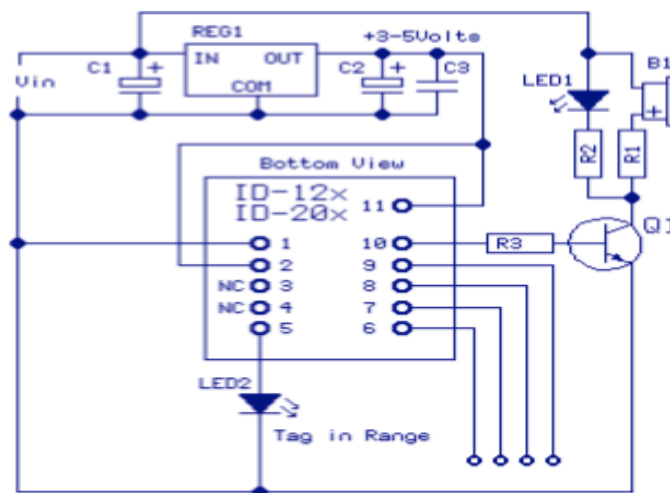
Figure 6.9: ID-12LA Reader

6.8 RFID Tag

In our project we are using two basic passive RFID tags with a unique 32-bit ID that works in the 125 kHz range. Passive tag does not contain a battery as the power being supplied by the reader. It is not reprogrammable (read only), as programming a tag will take us to a different field of study. In this project the tag is only used as a mean to access the door so a passive RFID is the best choice.

6.9 12-button Keypad-COM-14662

Basic 12 button keypad in a matrix format. It has a 7 output pins, which a microcontroller has to scan to figure out which button is being pressed. That means we need to create a program that analysis any code and based on that code an action will be taken.

6.9.1 Keypad Schematic

Figure 6.10 illustrates the schematic for a basic 12 button keypad with a 7 pin output.
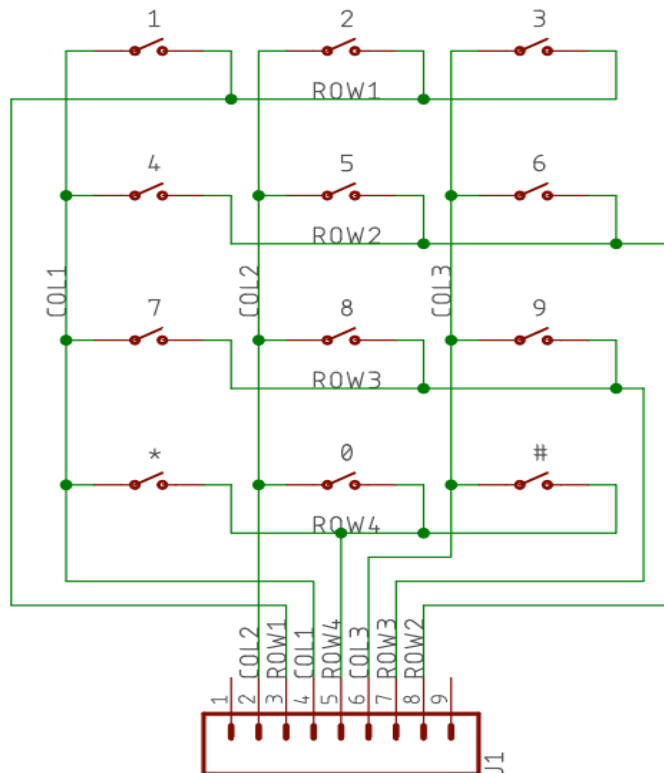
Figure 6.10: Basic keypad's schematic

6.9.2 Understanding the principle of keypad Matrix

In order to write a program code for the keypad so it will function probably in our design it is important to understand how it works. By looking back at Fig we can see that the keypad is divided into four rows and three columns. From these three and four we get our seven output pins (2, 3, 4, 5, 6, 7 and 8). By looking at the circuit again we can see that all the circuits are open circuits initially. That will make all the seven outputs to be zero when no button is pressed.

However, when a button is pressed two of the seven outputs will be activated. For example, when button five is pressed the second row and the second column will pass current. That will make pins two and eight to activate. Table 6.7 was created defining the pins associated with each number.

Button #	Pins #
1	3,4
2	2,3
3	3,6
4	4,8
5	2,8
6	6,8
7	4,7
8	2,7
9	6,7
*	4,5
0	2,5
#	5,6

Table 6.7: Pins Vs. Numbers relation

6.10 PIR Motion Sensor (JST)-SEN-13285

We bought our motion sensor from Sparkfun.com as they provide many details regarding their products and very clear instructions on how to setup the equipment and make it work. This motion sensor needs a voltage supply of 5 – 12 volts. However, if a jumper wire is used to past the 5 volts

regulators on the board, then it only needs 3.3 volts. There are 3 wires coming out of the motion sensor colored as Red, White and black.

The red on with sign (+) is the power supply, 3.3 or 5-15 volts as discussed earlier. The Black one labeled as (AL), is the alarm, this pin can be connected directly to an input pin as it is designed as an open collector. The white should be grounded.

When the PIR motion sensor in its active mode it will keep sensing for any motion or activity. Once a motion is detected the alarm pin will get pulled low. That's why the alarm output should be pulled high to 5V to avoid any false positive. Most microcontrollers have internal pull-up resistors on their I/O pins, which can easily accomplish that task.

As we are planning to put the PIR sensor outdoors it was important to take its temperature operation into consideration. The operation temperature for this PIR is -10 – 40 C, which should be fine as, according to many weather experts, the highest it can get in Orlando area is 38 C. The range for most PIR motion sensors varies from 5 – 12 meters. The range was not specified for this PIR so we will need to find out ourselves by testing it.

6.10.1 SparkFun OpenPIR

After reaching Senior Design2, we decided to change our motion sensor to another one. The main reaon was that all the parts on our circuits worked on 3.3V except the motion sensor that was working on 5V. so instead of building another voltage regulator just for it we replaced with another one. The new one costs us only $5 more, but it has more features. It consumes less power in standby mode and we can also adjust the detection distance manually.

6.11 MSP430P401R

The MSP432401R is an ideal micro-controller unit for real-time operating systems. The MSP432401R is an ultra-low power 32-bit ARM Cortex M4 that runs at up to 48MHZ. It consumes approximately 95 micro amps per MHz, so at its top speed it only requires only about 14 mW of power. It has a standby power level of only 850nA. The Msp432P401R is an impressive device. It has a 1Msps 14-bit ADC, a DSP Engine, an IEEE754 compliant floating-point unit. It also has full support for the Thumd-2 mixed 16-bit and 32-bit instruction set, along with a DSP extension instruction set. "the simpleLink MSP432P401R microcontrollers (MCUs) are optimized wireless host MCUs which allows developers to add high-precision analog and memory extension to applications based on simplelink wireless connectivity solutions. The micro chip controller unit also contains wi-fi, Bluetooth low energy, sub-1 GHz, and host MCUs." (MSP430P401R)

The MSP432P401R is powered at between 1.65V and 3.7V MAX. The specifications on external capacitors and inductors that are required if you are using the MSP432P401R on its own. The maximum voltage that can be applied at any pin is -0.3 V to Vcc +0.3V, so at 3.3 V that is 3.6 V. The maximum voltage of the MSP432P401R is 4.17 volt regardless of the VCC. The maximum current that can be sourced or sinked to any pin is +/-2mA. "The CPU and all of the peripherals in the device interact with each other through a common AHB matrix. In some cases, there are bridges between the AHB ports and the peripherals." (MSP430P401R)

The MSP430P401R micro controller is supported by a comprehensive ecosystem of tool and software (IDE) which is easy to use. The micro controller has some other great feature such as advanced Low-Power Analog, memories, Ultra-Low-Power Operating Modes, Flexible Clocking, Code Security, built-in System, Timing and control, Serial Communication, Flexible I/O. The MSP430P401R are well used in many applications such as industrial and automation, metering, test and measurement, heath and fitness, and consumer electronics.

6.11.1 ATmega2560

After getting to Senior Design2 we started facing problem with coding. Especially with the Fingerprint as all the codes related to the device like enrolling a new fingerprint or checking if the fingerprint matches any saved one. We tried to write similar codes using msp430 libraries, but it was too hard and complicated. As this problem derived us away from our project and let us to learn more about translating the code we decided to use ATmega2560 to make it easier for us.

Below are some features of ATmega2560 that goes along with our project.

- Four 16-bit Timer/Counter.
- Supports: USART, SPI and I2C.
- Interrupt and Wake-up on pin change.
- Six sleep modes.
- Low power consumption: active mode: 1MHz, 1.8V: 500µA, Power-down Mode: 0.1µA at 1.8V.

6.12 Raspberry PI 3 model B

Raspberry PI 3 model B is the latest version of the raspberry Pi microcontroller, what we can benefit from a raspberry Pi microcontroller is the fact that it has the same computer shipboard a pc or a computer has but in a much smaller size. In addition we can use the Pi 3 as budget desktop, media center, a retro games console or a router for a starters but

it's also used in a thousand of project people had build where people used it to build tablet, laptops, phones and robots. The Pi by itself is a just normal bare board; we also need a power supply a monitor and a mouse also a keyboard to play with it. Once we have all the tools to control the PI we need to download the NOOBS (new out of box software) installer, once we finish this step the Onstaller will make sample for us to set up various operating system. However, the best one to use for raspberry PI 3 is the official OS Raspberrian operating system.

Raspberry pi 3 has a faster quad-core processor more than any other predecessor Pi. It has 60 %better performance in 32 bit more than PI-2 and 10 time faster than the original single core PI. In addition, compare to the single core PI the real world applications will see an increase of 2.5 time for single thread application and 20 time faster when it comes to video game performance .The board is also capable of playing 1080p MP4 videos at 60 frame per second which will boost the media center credential. Also, PI 3 supports wireless and Bluetooth connection. While, the Raseberrian is the best operating system to use with the PI-3, the Pi-3 encourage people to learn how the hardware and software works, the OS is stacked with software we can learn such as java python and for piecing everything the internet of things appliances using nodes. Finally raspberry Pi 3 has a 1G SDRAM you can at least how fast the Pi will computing data compered to its previous one.

6.13 SparkFun 20x4 SerLCD - Black on RGB 3.3V

We were looking for a quite bid LCD since it is a major component in our project. Most of the LCDs out there are 5V and 2 lines only. We needed a 3.3V and 4 lines so it goes along with the rest of the parts in the projects. We found what we were looking for on SparkFun. The price for this LCD is little bit high compared to other, but it has all the features that we were looking for.

- 20x4, Black on RGB Display
- Three communication options: Serial, I^2C and SPI
- Adjustable I^2C address controlled via software special commands (0x72 default)
- Emergency reset to factory settings
- Operational backspace character
- Incoming buffer stores up to 80 characters
- Pulse width modulation of backlight allows direct control of backlight brightness and current consumption
- Open-sourced firmware and Arduino-compatible bootloader enables updates via the Arduino IDE

7.0 Software design

In order to give the user, the best experience using the smart lock, he should be able to control it from anywhere let's say you are working and someone from your family lost his key and needs you to open the door for him you should be able to that without being forced to be close to the lock. You can also be able to check to status of your lock and if you forgot to lock your door you should be able to do it remotely as shown in (figure 7.1).

SERVER

internet

WIFI

open
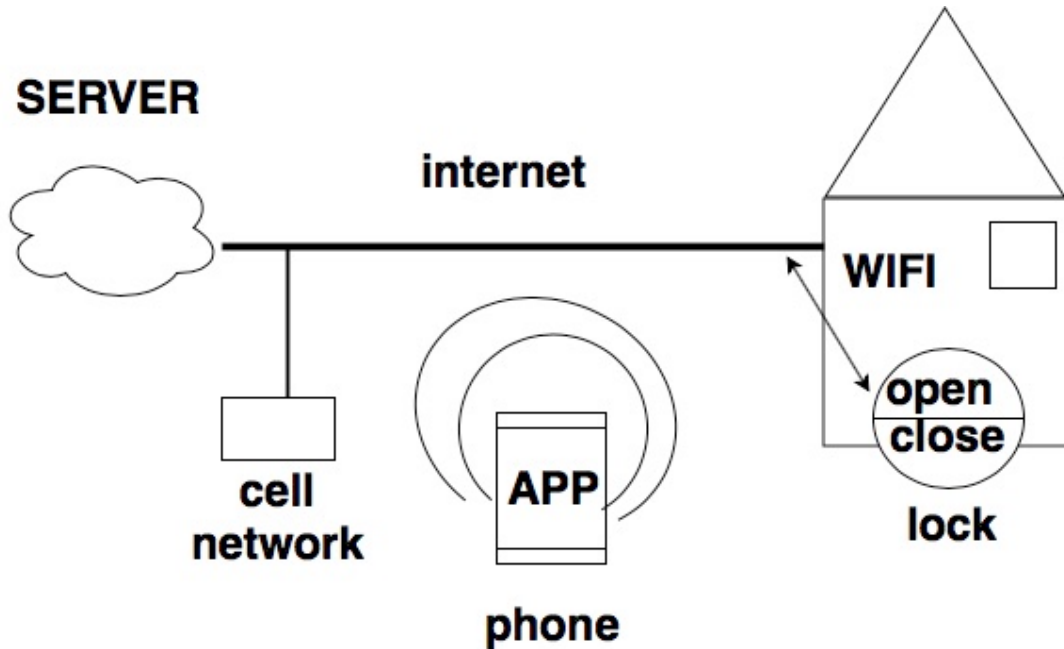close

cell
network

APP

lock

phone

Figure 7.1: Application overview

To make sure the customer has a great experience with app, we have to divide the app to two sides the backend application which is connected to the servers and the frontend which react with the users and run on the mobile device.in addition talking about mobile device we are referring to a wireless machine who contain always a cellular or a WIFI connection which should always be able to access the internet, the backend application should be able to talk to both the frontend application as well as the server which sends a signal to the microcontroller which in return sends the same signal to open the lock. The extent of this division is shown in the graph above.

7.1 Application servers

An application server is It basically a regular server, the only difference is that it is not meant to talk with other computers, but instead, it was built to talk specifically with a single Mobile App (actually it is talking with the

user's mobile device, based on interactions with the mobile app). We can reach the server using both the backend and the frontend of the app. The mobile application server will contain both a server operating system and server hardware. These function simultaneously to allow the server to provide remote access and services to apps, which can include authentication, updates, and security features. In this system, the mobile application server communicates with the client component, which operates on the mobile device to receive apps, and follows the commands of the server. The application will connect to the server using an API, which we need to create, the server will have a database with many keys and will gate a Jason call from the app after that it will send a call to the hardware server to open the lock.

7.1.1 Backend

The backend is a mix of the server, Database, API and operating system that powers the app frontend, the way it works is by accessing the program interface API for the frontend customer and the operating system to communicate with. This server-side application directly interacts with the database via an application-programming interface (API), which pulls, saves, or changes data. Then, the data are returned and converted into front-end code a user interacts with such as filling out a form, creating a profile, shopping online. In general, anything you see on a site is made possible by back-end code, which exists on, is powered by a server as shown in (figure 7.2).
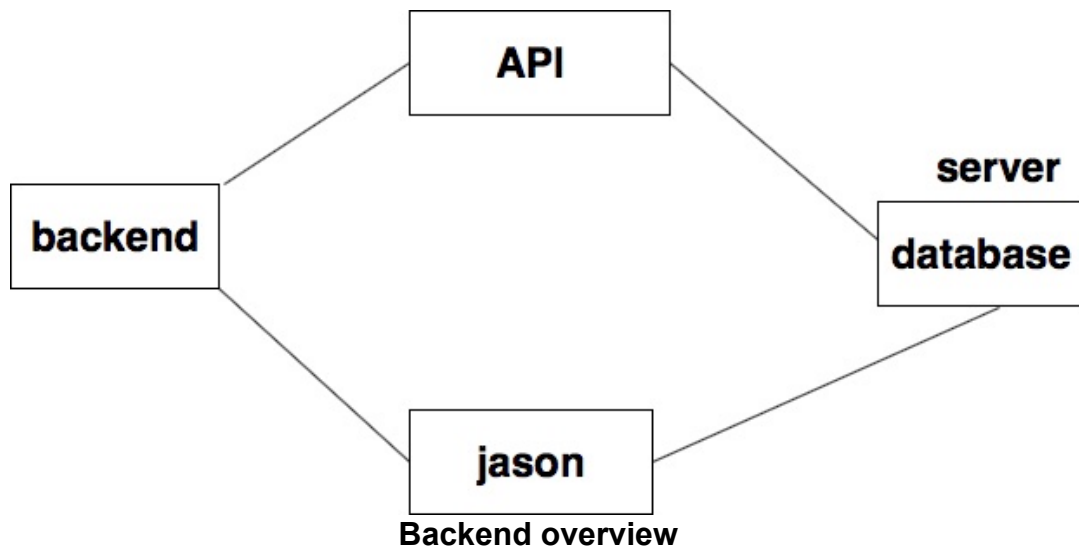

Backend overview

Figure 7.2: backend overview

7.1.2 API design

In order to design a good working API that will be easy to use by the client-side application, it will be architecture in a state transfer (REST) way, which has the following characteristics:

- **Simplicity:** The way to interact with API resources is well-defined and strict: you have a clear and simple path to follow concerning what you can and cannot do. Interaction is stateless: requests have all data needed to move resources to the next state.

- **Client-server:** to be able to share data across clients in Realtime much easier, clients do not store long term data (only current stateful data). Since the server doesn't render content for the client and only provides data, it allows the server to more easily scale

- **Stateless:** Make all client-server interaction stateless. Server will not store anything about latest HTTP request client made. It will treat each and every request as new. No session, no history.it also makes client hold their own state and get their information from the server as needed for update.

- **Cacheable:** the API can be cashed when accessed in order to brings performance improvement for client side, and better scope for scalability for server because load has reduced.

Since our application will be built using JavaScript and Android studio we are going to need to use Jason formatting to do an API call since it's a native format for their runtime.

Example of Jason format:

```
var myJSON = '{
"name":"John","age":31,"city":"NewYork"}';
var myObj= JSON.parse(myJSON);
document.getElementById("demo").innerHTML = myObj.name;}
```

As you can see Jason is a lightweight data interchange format human can read and write it's also easy for machines to pars it and compile it, Jason is always built of two structure a collection of names and value pairs and also an order of list values. We can find JSON libraries in all languages libraries. Since JSON is now the most widely used API format. By using RESTful JSON API, our customer will have easy time running the side frontend application, and it will be able to run separately from the backend. Node JS will be compiled and ran under a restricted user account on each cloud instance. This will ensure that vulnerability in our software does not

compromise the entire server instance. Our backend service will be deployed to the cloud servers using GIT, which is a version control system for software development. In the GIT code repository for our backend NodeJS application, we are going to list the dependencies for the codebase in a Node Package Manager (NPM) "package. JSON" file, which when deployed will automatically install all dependencies to run the application.
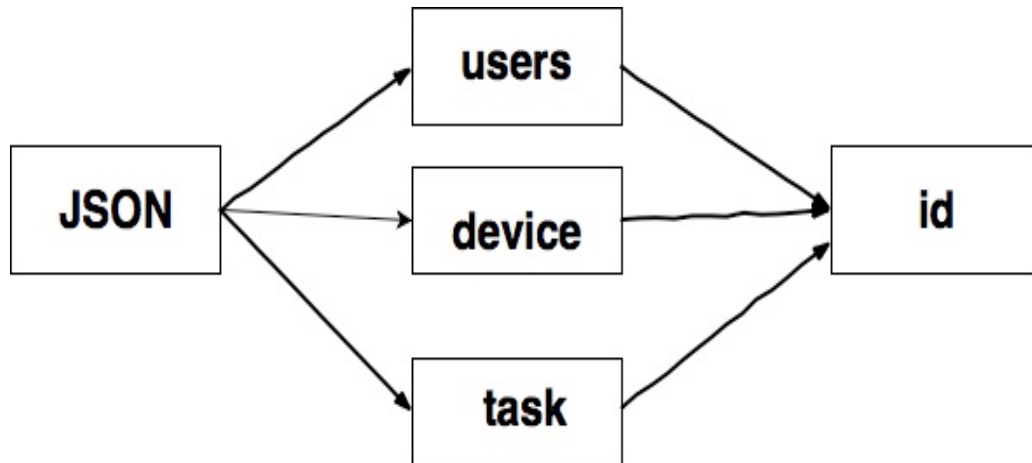

Figure 7.3: Route Path Progression

As shown in the (figure 7.3) above, the codebase mainframe will consist of Express JS library, which is a web application routing framework. This will help us creating RESTful API by generating multistage routes, for each we will have a special key to manipulate it. By using the key, we can retrieve and modify data easily. We also notice from the figure above a list of the API data models that will be integrated for our API, which each one of the items in the data supported HTTP verbs as well as the resource endpoint it can be accessible from. In the endpoint, brackets are optional, and parameters are prefixed with a colon as shown in (table 7.1) below.

Attribute	Type	Meaning
id	String	Identifies the unique ID of a resource.
href	String	Identifies the URL of the current resource.
link	Object	Identifies a relationship for a resource. This attribute is itself an object and has "rel" "href" attributes.

Table 7.1: REST metadata: [2]

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To create the HTTP API we are going to need four common actions (view, create, edit, and delete) map directly to HTTP verbs that are already implemented, the way this verbs works is most of the time when I am clicking around in my browser I'm using the get HTTP method which makes this method used when getting resources from the internet, also when I'm submitting something I'm using the post method to post data back to the app, As for the other methods, some browsers don't even implement them all. However, for our uses, that doesn't matter. What matter is that we have a bunch of "verbs" to choose from which help to describe the actions we are taking. We will be using client libraries which already knows how to use the different HTTP methods.in other hand to create a user I need to send an HTTP post to the endpoint which create a body request that has for example a user name and a password the users need to use to log in, we also need to encrypt the password by using hashing encryption to secure the password storage. Also, an API token will be return after a successful login, which is going to help as well new users to sign up in the app by creating a new account. We can update a user by using HTTP put requests, which can be sent to the endpoint containing update fields of the data. Same if we want to delete user information we use an HTTP delete to send a request to the endpoint.

7.1.3 Android Selection

We had the choices of multiple mobile operating systems to choose from for our mobile operating system. We narrowed our choices down to android to be selected because; from our research we find out that android apps run in 70% of the phones in the world. And obviously we are trying to reach as much market as we can to get the maximum benefits. We created comparative benchmarks to help us decide which mobile operating system was going to be the best for us between the android and iOS.
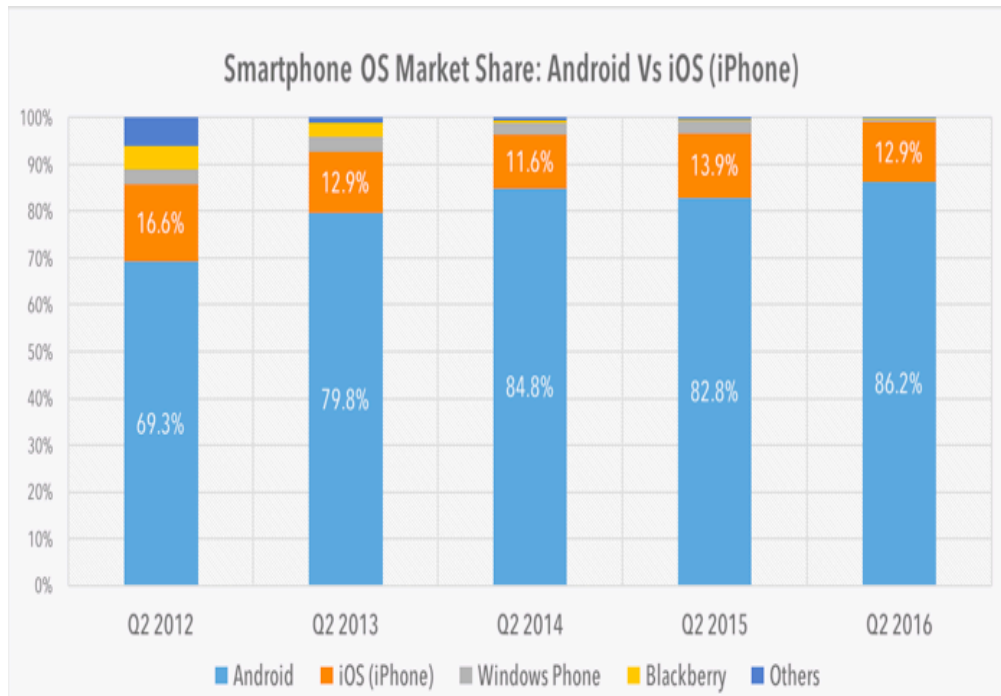
Figure 7.4: popularity of use IOS vs Android Graph [3]

From the (figure 7.4) above we can see that android operating system control almost 86% of the market while OS come second by 12% of the market, which prove that our choice for Android was based on the fact that it has most of the international market. Even though android lead the market in most of the third world country still has a huge part of the market including china the second biggest market in the world. In addition, android has lower crash rate than iOS which will help us avoiding errors in the future. Finally, android is more customizable which will make it easy for us when it comes to make changes in the design of our application.

7.1.4 Android application design

In addition of choosing android as the operating system for us to create an application, I have chosen android studio as an IDE to develop my mobile application. I'm going to be creating lots of information to create a fully functional application. One of the most valuable aspect of android studio is the fact that it will help you organize your work by making you store your code into packages, project files, also, the design aspect in android studio is much easier compare to other IDEs, you can create your buttons layouts text by dragging them from an existing library, so you don't need to program them, the code is already written for you ready to be used. Android studio has lots of debugging tools to help us figure out mistakes or bugs, which takes lots of time to do in other IDEs, in addition, android studio has an emulator ready for you, so you can compile and run your

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code to see how it will look like in the mobile device. Android studio will allow us to easily to organize each part of the code such us variables, functions name, classes, return values, so it will be easy for other people to read and debug our code. Finally, and most importantly is the fact that creating layout in android studio is so easy, which make the conception of your application much easier so if you want to add any elements to our design without mistakenly putting the element in the top of each other.

7.1.5 application design logic

to start designing the application we need to start by designing the plan for how we can implement our coding, this will help us to have a general idea of how the application will look like and which functionality will give to it such as the functionality after you click a button or the signing functionality. After that, we can start designing the basics of the application by creating the layouts and the button, then we can start making each part talk to each other by creating the ActionListener to make the button do an actual thing. We can use a flowchart to explain the design logic of our application. First of all, we need to design the home screen of the application that user will see when entering the application, then will move to more complex stuff, in this part we will have the most computation of the application which make it important to understand the design logic before starting this part. Finally, we will start designing the control button logic, which will show us the effectiveness of our application.
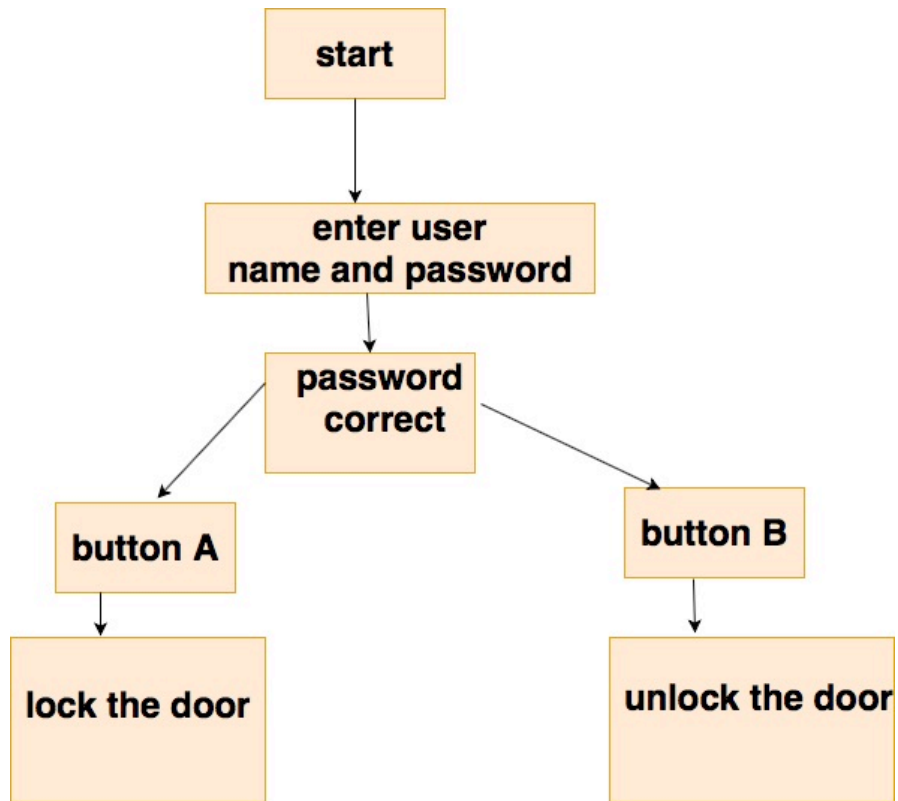
Figure 7.5: Application Design Logic Flowchart

In our application design as you see in (Figure 7.5) a flowchart above it will be sample we have two signing buttons, once the system verifies the correctness of the user name and password you 'll go to the next page which will chow you two buttons, the first one will open the lock the second one will lock the door. I can add to that a sign-up table to help new users to put their information.

7.2 Database design

Database design is very crucial aspect for mobile applications. For our application I'm going to use The MySQL software which is software consists of the MySQL server, several utility programs that assist in the administration of MySQL databases, and some supporting software that the MySQL server needs (but you don't need to know about). The heart of the system is the MySQL server. The MySQL server then creates a subdirectory in its data directory, names the new subdirectory new data, and puts the necessary files with the required format into the new data subdirectory. In the same manner, to add data to that database, you send a message to the MySQL server, giving it the data and telling it where you want the data to be added. Before passing any instructions to MySQL server, it must be running and waiting for the request. The way the

program is set up is usually start when the computer starts and continue running all the time. Also, MySQL is known to be the most secure and reliable database management system in a popular mobile application including Facebook and tweeter. The data security and support for transactional processing that accompany the recent version of MySQL can greatly benefit any business, especially if it is an eCommerce business that involves frequent money transfers. In addition, MySQL offers unmatched scalability to ease the management of embedded apps using a smaller footprint. Also, when it comes to performance, MySQL features a distinct storage-engine framework that facilitates system administrators to configure the MySQL database server for a flawless performance since we will be receiving a million queries every single day or a high speed transactional operating system, MySQL is designed to meet even the most demanding applications while ensuring optimum speed, full-text indexes and unique memory caches for enhanced performance. All the fears and worries that arise in an open-source solution can be brought to an end with MySQL's round-the-clock support and enterprise indemnification. The secure processing and trusted software of MySQL combine to provide effective transactions for large-volume projects. It makes maintenance, debugging and upgrades fast and easy while enhancing the end-user experience. [4]

7.2.1 Database models

.User model: it will contain the user information, to be specific it will contain the user unique id, so we can use it to be able to reference the user object in other models such as user email, name and password. This will help us to set up the sign up and sign in task. User ids will be resolved within references of other models and email addresses will be used for logging in.

.Device model: the device model will contain the device unique ID plus any of the settings the device will have since the smart lock will be supporting an android operating system. Other than that, we need to make sure that the device back the infrared option because we may use that as well to open the lock, going back to the database we need to, have an index id for the device model add to that the user id that we can use to update the device information within other models. Also, the API will be responsible to select one values available to configurate the device basis.

.Account settings mode: The account setting model will give us the ability to update the user information such as name, email, and password. It will also allow users to add or delete their account.As you see in the (Figure 7.6) at bottom we explained all the models and what etch model will contain as attributes. Also, there is a quite relationship between some of this model because some of them share the same attribute.
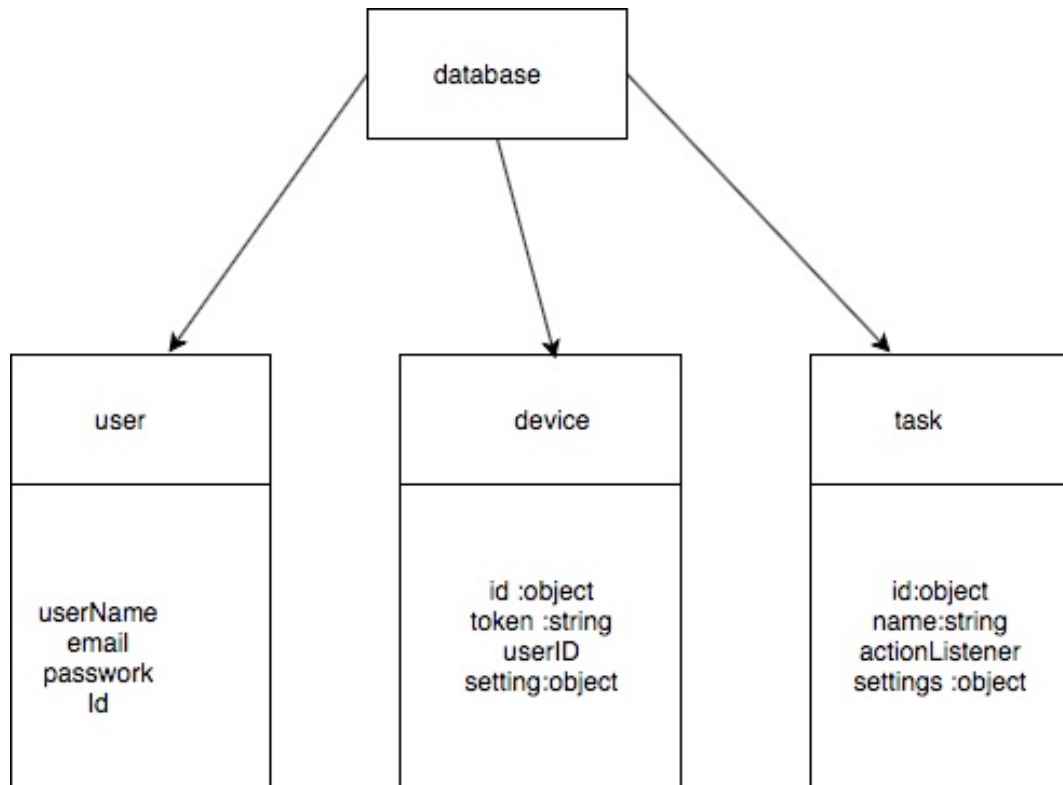
Figure 7.6: database interaction graph

7.3 Image Processing

In our project we need to make sure that one of the options is to open the door using face recognition for that we will have a camera that can scan the face by using image-processing technology. The way the technology works is HD camera captures the photo and then the application developed detects the face out of the image and crops it out and sends it over to the app Face API interfaced cloud set up. The face is identified and recognized from a pre-saved database of facial images on cloud. If the face is matched user the microcontroller will send a signal to open the lock.to be able to do this we need to add the images to the database of images over the cloud from which the face will be recognized. The device will function with an application and will have an interactive UI, which will let the application call the APIs to access the hardware and do the desired functions and also display the result. The application's front end is deployed on Microsoft Visual Studio and the API(s) are called through it.

7.4 Open CV

In the first part on object detection, using deep learning we'll discuss Single Shot Detectors and MobileNets. when combined together these methods can be used for super-fast, real-time object detection on resource constrained devices including the Raspberry Pi, smartphones, etc. From there we'll discover how to use OpenCV's module to load a pre-trained object detection network. This will enable us to pass input images through the network and obtain the output bounding box (x, y)-coordinates of each object in the image. Finally, we'll look at the results of applying the MobileNet Single Shot Detector to example input images.Also, OpenCV uses machine learning algorithms to search for faces within a picture. Because faces are so complicated, there isn't one simple test that will tell you if it found a face or not. Instead, there are thousands of small patterns and features that must be matched. The algorithms break the task of identifying the face into thousands of smaller, bite-sized tasks, each of which is easy to solve. These tasks are also called. For something like a face, you might have 6,000 or more classifiers, all of which must match for a face to be detected (within error limits, of course). But therein lies the problem: for face detection, the algorithm starts at the top left of a picture and moves down across small blocks of data, looking at each block, constantly asking, "Is this a face? Is this a face?" Since there are 6,000 or more tests per block, you might have millions of calculations to do, which will grind your computer to a halt.

8.0 Project Prototype construction and coding

In order to build our project, there are some prototypes that we have to get right before we put everything into places. For example, we have to make sure we meet the exact specification for the power that needs to be distributed in the circuit. However, this is not our final prototype. I believe our prototyping will keep going through the end of the semester and will continue through the next semester during our Senior Design II. We use the prototyping process to implement our component one by one in a timely manner in order to verify and make sure that our design work. On the other hand, when it comes to hardware prototyping, we use breadboard to do the connections and the hands on experience. In contrast we use computer software to do all the software prototyping to debug the respective components. In the following paragraphs, we will talk about the voltage regulator, the charge controller and the power distribution.

8.1 Power distribution

Solar energy is unevenly distributed throughout the planet, some area will get more sun than others, and also it inconsistent less solar energy is

collected on cloudy days on cloudy days and at night. So a total reliance would require an effective storage of energy with efficient ways to supply electricity to the circuit during nighttime and cloudy days. Therefore, we have to design a good and efficient way to collect energy and distribute it throughout the smart lock. As a result, a reliable power supply is required to charge the battery and provide power to the rest of smart lock.

The solar powered smart lock will collect it main energy from the sun. However the amount of energy and power collected from the sun can be varied greatly from times to times and obstacle that can happens, such as cloud and residues. In order to reduce the circuit dependency on the solar energy, a rechargeable battery will be install that can serve as energy storage whenever the energy from the sun is not available. The battery will increase the time period that the system will be able to function without the solar energy. The steps it takes to power up the system will be listed in the following paragraph.

### 8.1.1 Integrated Renewable Power System Controller

A charge controller or charge regulator which is going to manages the power going into the battery bank from the solar array, and also, It ensures that the deep cycle batteries are not overcharged during the day, and that the power doesn't run backwards to the solar panels overnight and drain the batteries. Most of the solar panels have more voltage than batteries. If the voltage left unregulated batteries will be damaged from overcharging.

8.1.2 12V DC-to-DC step-up Voltage Regulator

A 3.7 volts battery and a 5 volts solar panel will not be enough to feed energy to the smart lock. Therefore, we would need an output voltage that is greater than the source voltage. In order to supply enough voltage to our circuit, a 12 volts step-up voltage regulator is required to keep the energy balanced as well as to empower the energy source. The role of this micro step-up voltage will basically serve as a boost, it will take any input voltage as low as 2.5 volts and then efficiently bring it up and keep it steady at 12 volts, which is the exact amount of voltage that will be required for our project. The step-up voltage regulator will steps up the voltage, at the same time it will step-down the current. The boost converter will basically take the 5V DC from the solar panel and the 3.7V DC from the battery then bring them up to a different voltage that is 12V DC, this change is called DC to DC conversion.

The things that make the voltage regulators more efficient are their transfer function, which can be defined as the output voltage divided by the input voltage (Voltage out/Voltage in). As we all know Power is equal

to voltage times current (P=VI), the power must be conserved, since the delivered current is lower than the provided current. This measurement is very important to protect the battery. As we know heat is a major concern when it comes to charging a battery, transfer function will help protects the battery from getting heat as well to protect the battery life. According to the graph efficiency VS output current below, the 12 volts booster has a pretty good efficiency level; the average is around 80 to 90 percent efficiency, as shown in (Figure 8.1) below.
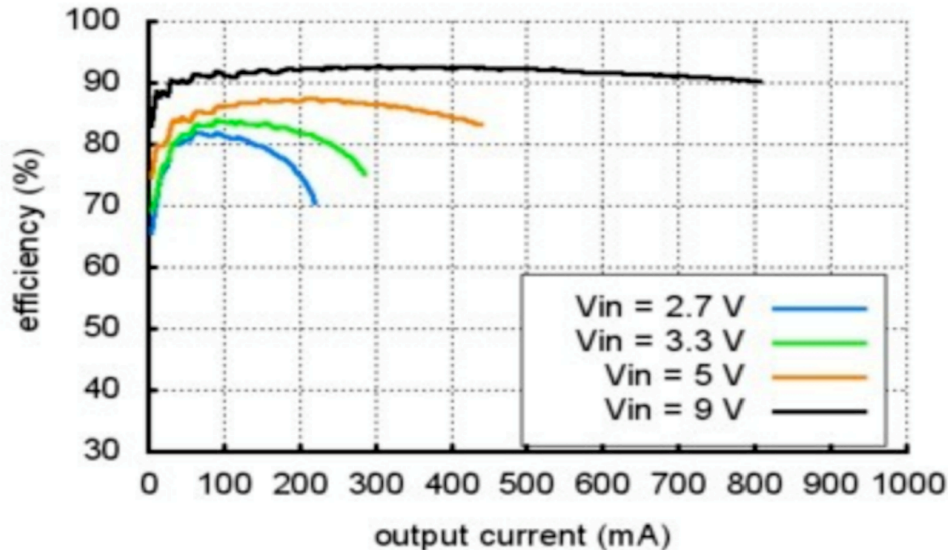
Figure 8.1: efficiency VS output current

In order to build a step-up voltage, a LM2577 mouser is needed with the help of an inductor, as well as a couple of resistors and capacitors. The inductor plays a very important role when it comes to stepping up the DC-to-DC voltage. The inductor creates a magnetic field whenever current goes through it. As soon as the voltage that passed through the inductor changes, the inductor's magnetic field will start to collapse. Inducing current through the inductor as it creates a voltage spike as the magnetic field collapses. Since the voltage from the inductor is higher than the input voltage, it will lead to a much lower output current than the input current. Therefore the main purpose of the inductor is to step up the voltage. With the help of the zener diode, it prevents the current to flow back from the capacitor to the input voltage. Then the capacitor stores the voltage that goes trough and distribute it to the output voltage. Below in (Figure 8.2) is the picture of the schematic of the voltage booster that shows how the connections are made to form the step-up voltage regulator.
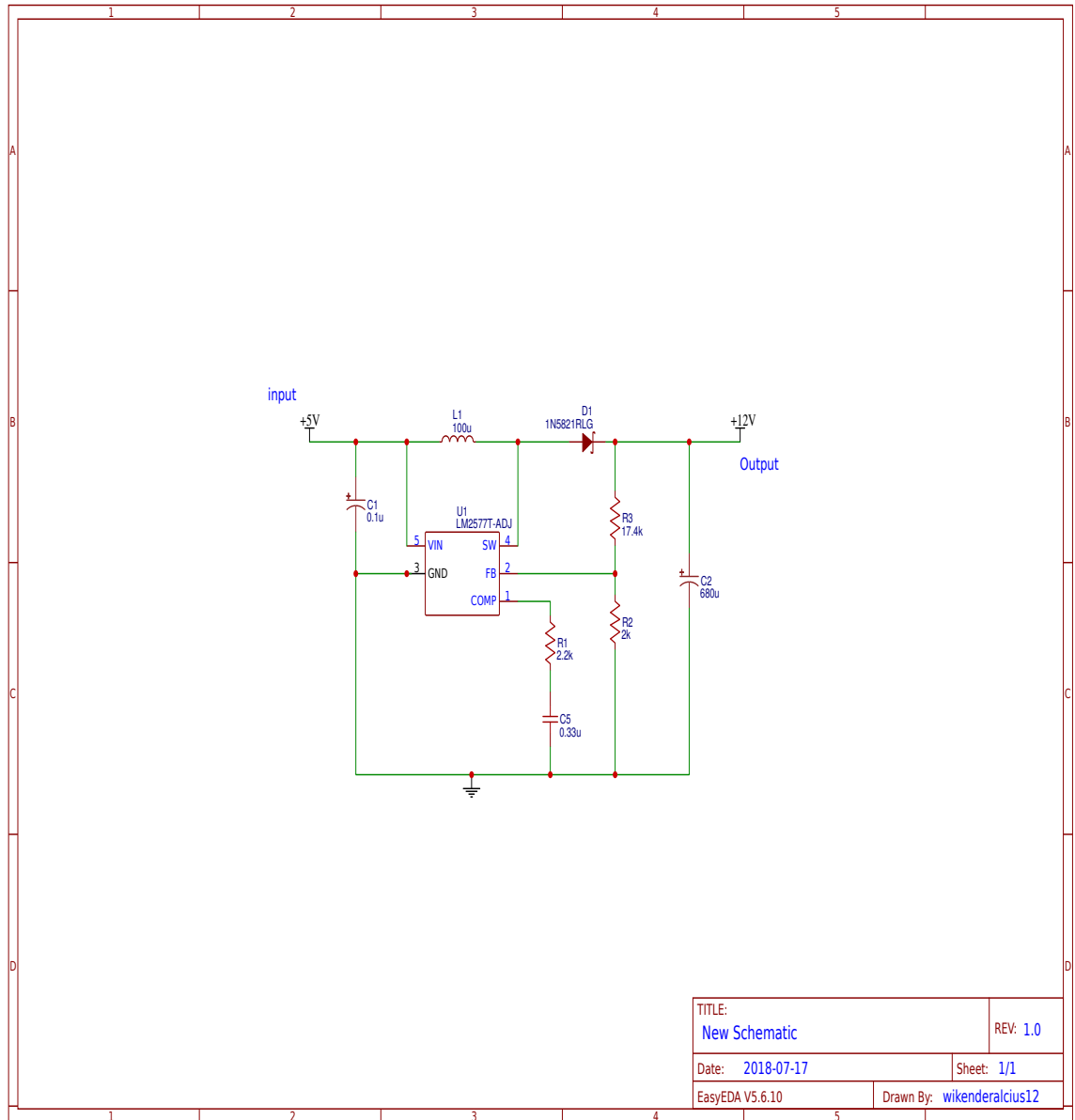
Figure 8.2: voltage booster/ step-up voltage

8.1.3 Charge Controller

First of all, the minute that the solar panel receive the photon from the light then the electrons are connected by thin metal fingers at the top of the cell from there they flow to the external circuit to do the electrical work to charge the battery. Before sending the power directly to the battery, we have to place a solar charge controller in between the solar panel and the battery. The charge controller is an important component in the battery base system, the primary role of this charge controller is to manage charging the battery and prevent it from over charge. Also it will control the rate of the current and voltage at which it charges. The charge controller

will also have load control, in which we will connect the DC load to the charge controller. It will turn on base on the voltage of the battery, when the battery is low on charge the load will flow to the battery and let it charges and slow down flow when close to full. However, when it is full it will send a trickle charge to keep it topped off. When the battery is full, the charge controller will allow current to flow only one way. Electricity flows from high voltage to low, during clouds and at night, the voltage of the battery is higher than the voltage of solar panel it is connected to, which will give it the tendency to flow out of the battery without a charge controller. Below in (Figure 8.3) is a picture of the schematic for the charge controller:
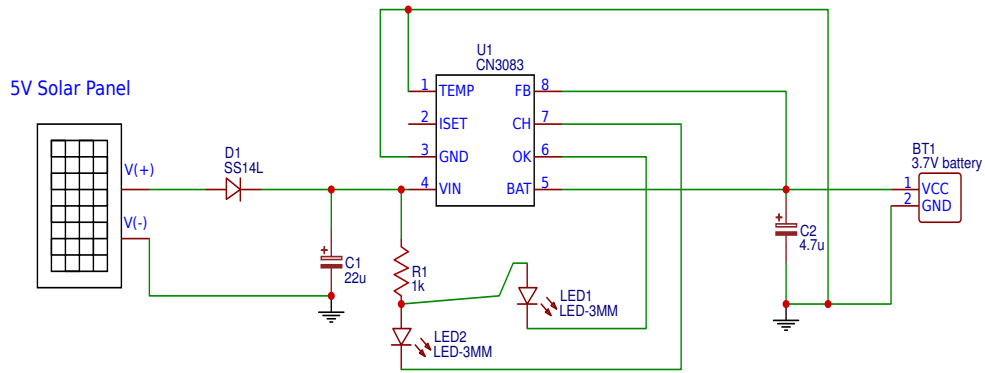

Figure 8.3: charge controller

Secondly, we will need about two step-up voltages to trigger up the voltage provided by the battery as well as by the solar panel. One boost converter will be place after the solar to take the 5V provided and turn it into 12V in order to send out the amount of voltage required keeping the smart lock working. On the other hand, another boost converter will be place after the battery to take the 3.7V and then convert it into 12V, to keep it as efficient as possible to keep the smart lock powered on when needed. Then a relay will be place at the gate to control which power that will go into the circuit and when will it be distributed. The way this relay will operate is it will received a signal from the occupancy sensor that will tell when there is a person in front of the door, it is okay to let the electricity to flow through the circuit and it will power on, so it could save the charge from the battery when it is on idle mode.

The occupancy sensor that will be on the lock will have a range about two to three feet distance from the door. A range of five to six feet for the height, last but not least about a two feet width. As soon as the occupancy sensor sense and feels like someone is approaching the door, it send the message to the microcontroller. The microcontroller will the send the message to the relay in less than a second. As the relay received the message it will be open it to let the current flow and powered on the circuit. Since the circuit is powered on, it will be ready for the user to open the lock in anyways that he or she wants to. The user can open the door, either by punching in the right passcode, using his or her finger on the biometric, or by using the application on the cellphone.

8.2 Approach to the Full Schematic Prototype

Below in (Figure 8.4) is an approach to the full schematic, in order to have a better idea on how our smart lock will function. Base of this approach we will be able to fix and update the parts that do not meet our requirement.
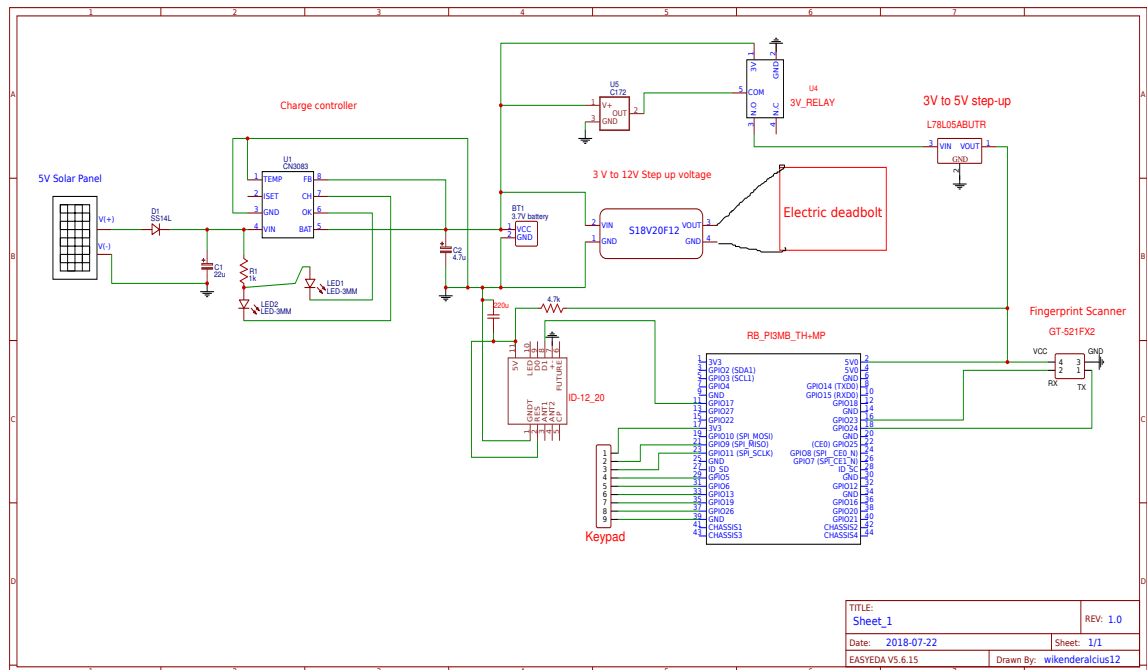

Figure 8.4: Approach to the full schematic

8.2.1 Voltage Booster

In order to get our project to work in the best possible ways, we first have to get the prototype to work and get feedback from it. Based on the feedback that we receive, we were able to make some changes. As we go along the way, we will notice the issues that may cause problems while we

building our project. All the problems encounter during the steps in the prototype will lead us to the best part before we finalize our project. We expect to have couple more changes in the future just to make sure that we present the best product to the customer.

Secondly the other problem that we encounter was the step-up voltage regulators that we choose at first. The "S18V20F12" 3V to 12V DC to DC step up voltage that would connect directly from the battery, we thought would be the right component to power up the deadbolt would not be efficient enough. The same goes for "L7805ABUTR" 3V to 5V booster that would be placed after the relay, which will send power when the relay is open to the rest of the circuit, would not be the perfect match for it and it is a linear voltage booster, as a result we cannot use this type of step voltage. The best match that we get so far for our boost converter is the "MT3608", which is a DC-to-DC step voltage regulator with an input voltage of 2-24V and an adjustable output voltage from 5V up to 28V, with a peak current output up to 2Amp. In order to adjust the output voltage, one just needs to adjust the potentiometer. It also comes with a build-in automatic pulse frequency modulation mode at light load. The best thing about this voltage booster is that it has efficiency up to 97%. Below in (figure 8.5) is a graph that compares the efficiency of the system vs. its output current.
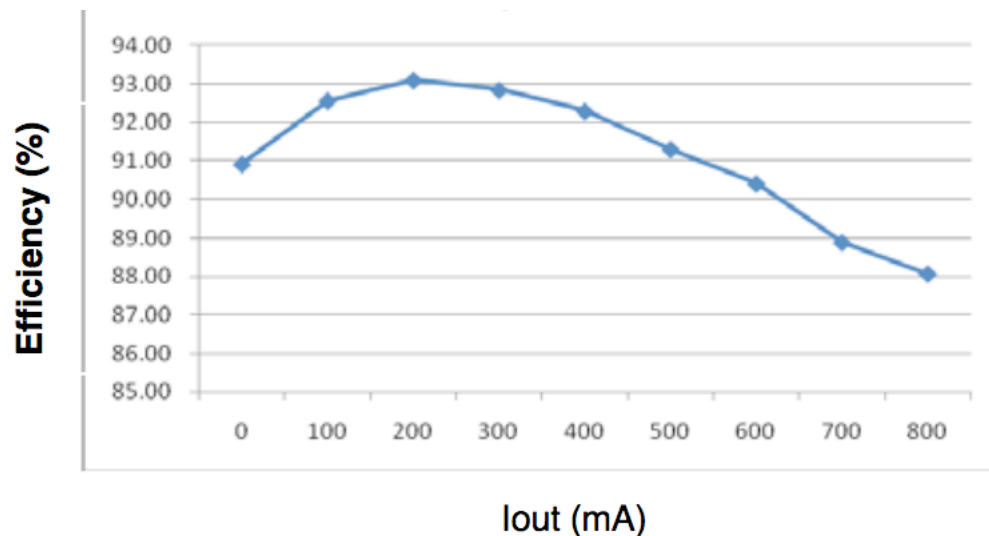
Figure 8.5: Efficiency Vs. Output current

8.2.2 Solar Charge Controller

As it shown in the picture above, this is a complete approach to get our project together. Having a 5V solar connected to a "SS14L diode" and a 22U farad capacitor, which is parallel to a 1 kilo-ohms resistor that form

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the input voltage of a "CN3083 charger" to form the charge controller that will keep the battery from over charged and prevent it from over heating. However, this was not the most efficient solar charge controller. First of all, a "SS14L diode" was not needed in this circuit; the same goes as well for the LEDs, since our goal is to keep our printed circuit board as small as possible and cheap. We did some more research and a better and more compatible solar charge controller, which is "SM72442" this Maximum Power Point Tracking (MPPT) can be programed to control up four devices and it has an efficiency up to 99.5%.

8.2.3 Microcontroller

Last but not least, a microcontroller is needed to take and send command back and forth to the rest of the circuit. Even though we are using a Raspberry pi 3 model B, it would not sufficient enough to do all the desired work. However, the main purpose of the Raspberry pi is for controlling the Pixycam camera that will do the facial recognition, in which it will compare the 80 nodal points on a human face to see if it matches the one that is programmed to do the unlocking. If the face matches, it will open the door; on the other hand, if it does not match it will give an alert to try again. Moreover, the raspberry pi 3 will also be used to receive wireless signals. In order to control the circuit we will use a "MSP432P401R" as the brain of our project. This microcontroller has up to 256KB of flash memory, which is super fast and give the option to read and program multiple programs at the same time. Moreover, when comparing to program words individually, the flash memory provides a supported burst write mode that take a very little amount of time. Also the good thing about this controller that meet our requirement is that it has an ultra low power modes, with a wide range of supply voltage; from 1.62 V to 3.7V and a high performance MCU with a build-in wireless connectivity options. The power efficiency of this microcontroller gives the access for software to program many and large blocks of data at one time.

8.3 PCB Vendors and Assembly

To our parts together, we had to buy and order our part from many different vendors. First we find the part that we need, and then find the datasheet for each part in order to read about the specific part selection and to see if it will be compatible, or if it is the best choice that will meet our requirement. After getting enough information on the specific part, we compare the websites for availabilities, price and reliability. We choose each part from the website that is cheaper for us an convenient to get us the product in a timely manner. The faster we get the product for a cheaper price is the better it is for us.

For example, Amazon and Sparkfun play a huge role in helping us saving money toward buying parts. The best deal we find for the solar panel was a set of 10 pieces on Amazon for $15.87. Also the adjustable step up voltage was found on Amazon, a set of five pieces for eight dollars. When it comes to the microcontroller, we had to get the raspberry pi 3 model B for forty dollars. Thanks to Amazon prime they were delivered to us on that same day. On the other hand, the majority of the rest of the components were ordered through Sparkfun, such as the keypad, the battery and the RFID kit were ordered from their website. For example, we ordered the RFID for $45 and it takes about a week to be delivered.

When it comes to our PCB vendor, we had to use as much resources as possible in order to deliver the best quality product our customers. To draw our schematics, first we use multism to do the most simple circuit testing, to see if the circuit conducts electricity very well and to check if there are no shorts in the circuit. For example, for our step voltage we draw the schematic on multism to measure the efficiency and how much voltage it can produce at the output. However, we use a 3.7V DC as the input voltage, and then to measure the output voltage, we connect a voltmeter in parallel to the last capacitor, and we obtain 12V as the output voltage. As we obtain our expected value, we can draw the conclusion that our step up voltage work fine as expected. We also use the Eagle software to draw our Printed Circuit Board (PCB), to do the draft and see how it will come out, Eagle provide a really cool feature in which it will auto wired the circuit. However, when auto wired is used to draw the PCB, it could look like a complete mess, and there would be no way to interpret our read the direction of each wire, since they would be all scrambled together.

However, for our complete design, we used EasyEDA to draw our schematic, and also to do the PCB. The cool thing about EasyEDA is that it is a free online software, one can access it from anywhere and anytime, from any computer. As long the user as an account, it can be access at any location. As well, it is very user friendly. It is very easy to look for part, as they have a very huge library, all the user had to is to write the part name or part number, it will help find the right parts. As it was recommend to us by a friend, it did not take long to get used to it, less than one hour was more than enough to be familiar with it and to complete our searches. The main reason we choose this online software to draw our final schematic and PCB is that they also sell the part on their website as we select as specific part to be on our PCB, we can choose to buy it from them at the same time. As a matter of fact, we do not have to worry about having the right component to fit our PCB and matching size, since it is the same as the show online on the schematic.

8.3.1 Final PCB

Our PCB plan went the way we planned it to be. We created a 2 layers PCB that holds all the parts and connections needed in the project. We found that is more efficient to build the PCB on Eagle instead of EasyEda. It is true that EasyEda has more libraries however Eagle holds more full designs that we were able to use and adjust to work with our design. (Figure 8.6) shows our PCB that was used in this project.
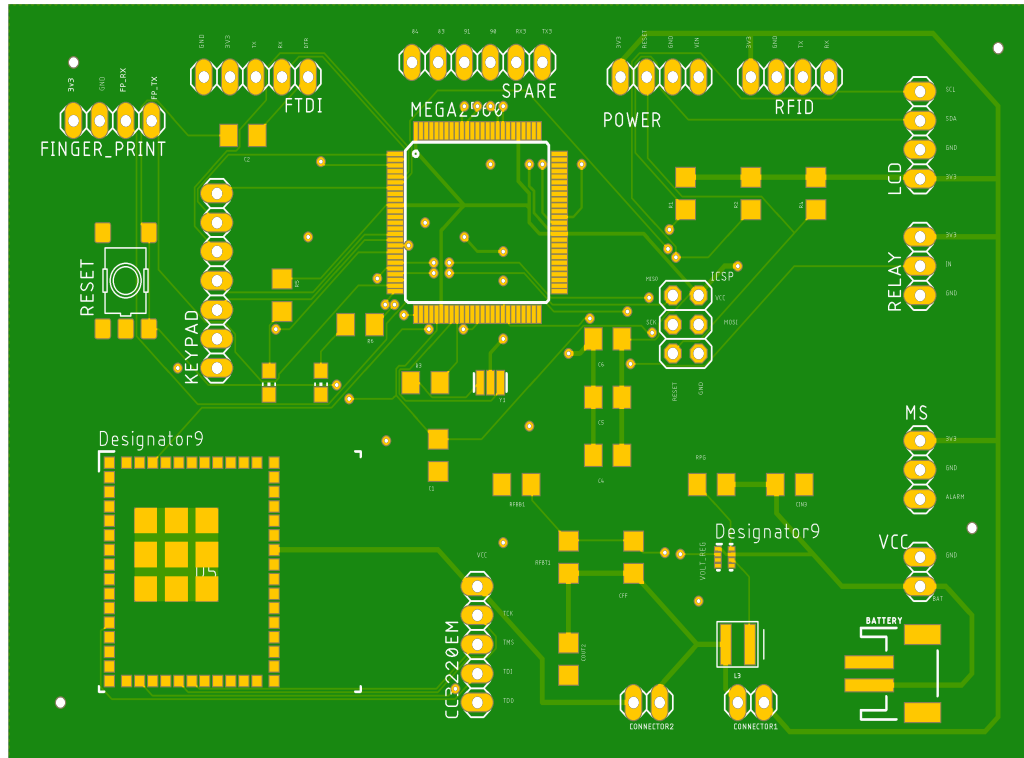

Figure 8.6 Final PCB

8.4 Initial Schematic

Prototyping was one of the best things that we could have done. It gives us a lot more ideas on how to approach the project and update any part that was not compatible with the project. Below, (figure 8.7) shows the final Smart Lock's schematic in which there are many parts that have been replace and update. As we found out while prototyping in the previous sections, the voltage regulators were not compatible with the project as we were not able to use a linear step-up voltage. First we had to use a different charge controller, which is SM72442 a Programmable Maximum Power Point Tracking Controller for Photovoltaic Solar Panels that comes with overvoltage protection as well as over current protection. Second, we replace the voltage booster by the MT3608 step-up voltage, which is the best voltage booster so far; it has an input voltage as low as 2V and can be adjusted up to 24V safely.

On the other hand, we added an extra microcontroller to control the whole circuit. The microcontroller that we chose is the MSP432P401r, which is the latest version of that, has been release from Texas Instrument (TI). The main reason that we choose this microcontroller is that; not only it is the latest version, it is also really fast. This microcontroller provides the access to run many program at the same. Also, it comes with a build-in Wi-Fi as well as Bluetooth. While the MSP432P401r is responsible to do the main tasks, such as, receiving commands, execute data, and compile them to send and transmit the desired command. The Raspberry pi control the image processing, which will be programmed to identify the 80 nodal points from a person. The preset face will be saved on there to be used as a prototype. Whenever a user tries to use the facial recognition mode, the Raspberry Pi will capture the image and compare it to the preset in the prototype, if the faces match, the door will be opened successfully. However, if it is a different face, that have not set and save in the memory, the door will not be open, and an error message will be displayed.

Finally, we kept all the other parts from the beginning as shown in the approached to the schematic. We connect everything together, in order to see how it is connected and make sure that our Smart Lock is working. To be sure and certain that it is working, we had to test it using a breadboard. We follow the schematic below to build it and take notes of anything that is not going to be used in this project and replace them according to the plan.
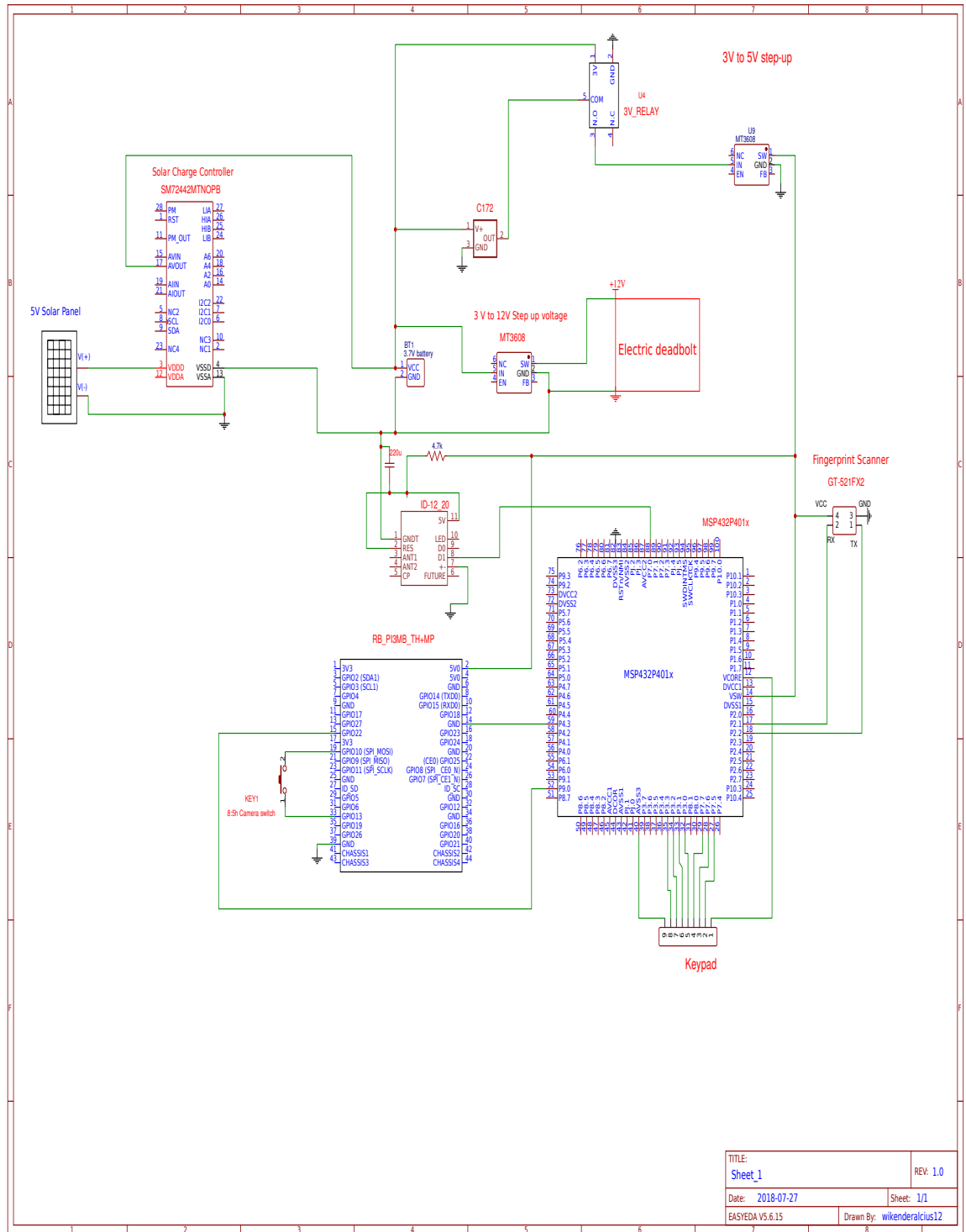
Figure 8.7 Smart Lock Initial Schematic

8.4.1 Final Schematic

The previous schematic was updated as we moved through Senior Design2. We figured out many mistakes and corrected them refer to (Figure 8.8 and Figure 8.9). Examples for some of the things we changed.

- Using a relay channel to be able to trigger the relay with a GPIO pin.
- Updating the MCU to ATmega2560.
- Using the right pins that support the required type of communication.
- Designed a voltage regulator using TiWebBench.
- Putting JTAG to be able to program the MCU and the Wi-Fi module.
- Placing some LEDs so we can know the status of our PCB.
- Placing a Reset button.
- Using decoupled capacitors so we can upload the code to the MCU.
- Using a 16MHz external o'clock.

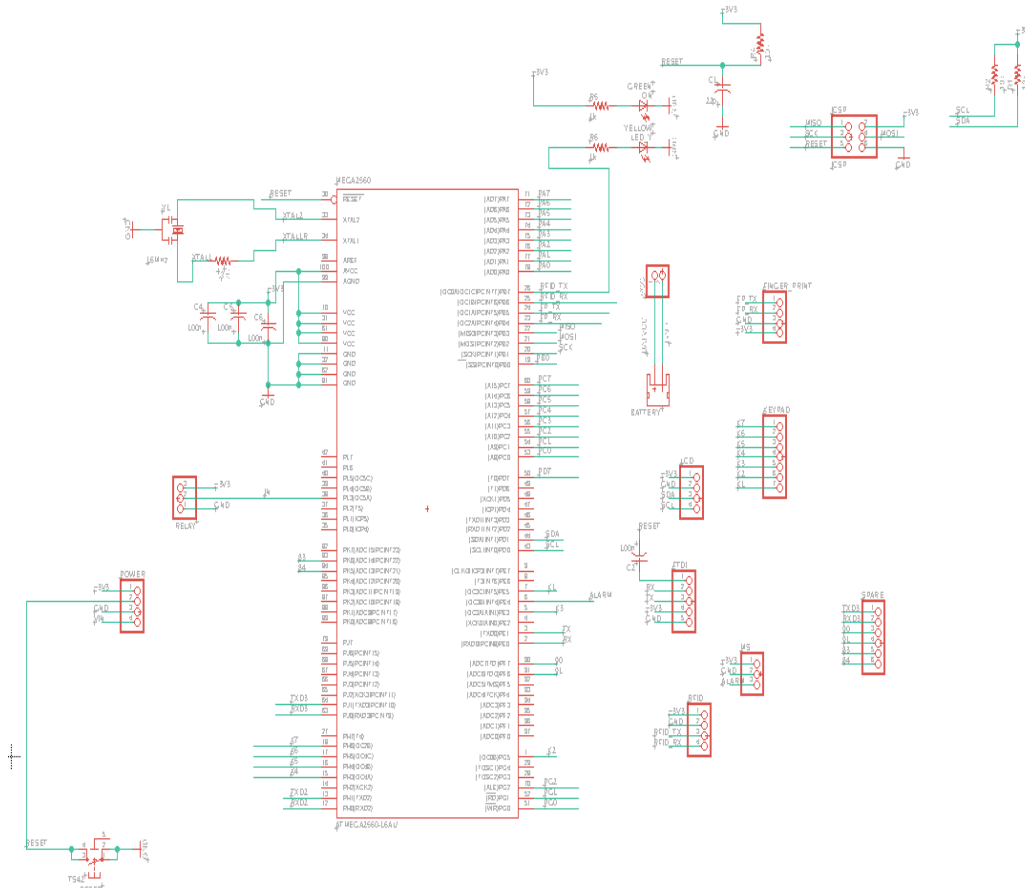Figure 8.8 Final Schematic (Voltage Regulator and CC3220MODA)

Figure 8.9 (ATmega2560 with its connections)

8.5 Initial Coding Plan

Our plan for coding is to set up a number of application programs and try to implement each part of it to make the prototype to work, once we make sure each part of program is working and doing its job then we start the process of bringing each part of the project together in a single peace.by prototyping each part of the application in a separate project will help our developer to write and test the API in different environment where we can test all kind of dirty code for it and be able to be familiar with the API. After that we can import the final cleanest code to be used with the final project with the most efficient algorithm possible.

When we start the project, a skeleton will be set up including all the methods and all the classes that we use for the project as whole. Then after making sure each individual works with the prototype we will transfer each one them to the skeleton application we created for this purpose this will help us to focus on each task while making sure they all work together which help us avoiding any problems we can face putting all the task together, so we can organize the developers work. Also, by putting all the methods in the skeleton it will be easy for us to know what each class do

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in the code, so we only have to worry about implementing the correct information behind the interface already been placed in the skeleton.

One of the most important aspects in our project is image recognition this will be an aspect to deal with early in the project because we need to figure out how the open CV's works and all the problem who comes with it such us the size of the object you are trying the scan and the amount of light in the area also the Height of the project and if that the height is in the interval scan of the camera. Implementing all this stuff in the software construction will help us to process the flow easier than working in all aspects in the same time.

The coding will be performed using an android studio IDE for project, this is a good IDE to build apps because it offers bunch of tools to be able to design easily, it also offers a good library to search for any code you like and keep track of all issues we faced, you can find a bug easy you can also forget about it easy later on if you don't keep truck of it efficiently. For now, I'm not sure which bug trucker will be used in our project. However, we will try to find one that can work with android studio to simplify the process of finding and trucking bugs. In addition, we are going to need debug tracker software to help us search and fix all the bugs in our codes. Also, we need to use a source control for the project, so we decided to use GitHub because it allows web-based source control, which allows all users to work from their home and push the code from anywhere as long as they have Internet.

8.5.1 Final Code

When we started coding our project in Senior Design2, we discovered that there is a lack of coding knowledge in our group. As we don't have a programmer in our group it was a hard task for us to come up with a final code. We changed our MCU to make it easier for us so we can use some provided libraries. Using interrupts and timer to wake up our system and make it go to standby mode was a challenge for us as well. We had to spend some time looking for help from many different resources. At the end our hard work paid off.

Our Final code was written using Arduino IDE. We got our examples codes from SparkFun along with the parts that we bought. Then we basically used the keypad with case functions to call the function that needs to be used. Figure 8.9 shows how we did that with the LCD.
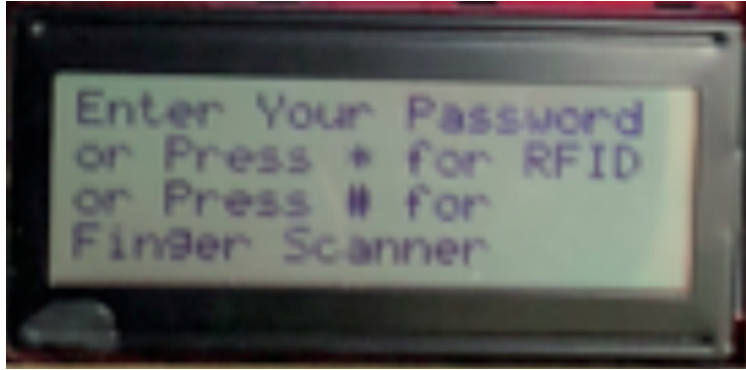
Figure 8.10 Using the Keypad to access different functions

9.0 Project Prototype Testing Plan

In order to ensure that our hardware are in good quality, to make sure that they work perfectly and that they are within engineering specification, we had to conduct a hardware testing plan. This plan helps us saving time, by preventing from using any type of faulty equipment that may cause a problem in the future. We had to test each individual component separately to make sure that they are operating adequately for the smart lock to work at its finest.

9.1 Hardware Test Environment

One of the main components that we make sure that we test in the first place was the voltage boost converter, which is the MT3680. To assure that we don't use too much voltage and get our circuit burn, we must test the regulator and make sure it provide the necessary amount of power to the smart lock. To do the testing, we used the 3.7V battery as the input voltage, use a voltmeter to measure the voltage coming out of the regulator, as we adjust it, we obtain a voltage as low as 5V and when we adjust it clockwise using a flat screw driver, we get a voltage up to 28V, which would be too much for the smart lock and burn down circuit. As result, we control the output voltage while doing the testing and make sure that we keep it about 11.5 to 12 volts as the highest to keep it safe. Since our deadbolt consumes the most power, which is 12V, we only have to send 12V to the deadbolt. However, for the rest of the circuit we will use another step-up voltage regulator to provide 5V for the other components.

9.2 Hardware Specific Testing

For a specific testing, we used a solar panel and the solar charge controller to get the accurate measurement that we needed. We use a 3-hour time frame just to conduct a small experiment and to see it everything works as it is says in the datasheet. First we solder two pieces of wire on the back of the solar panel and then connect it parallel to the

battery in order to charge it, we keep on monitoring and measuring the voltage as we go along with the process. When we measure the voltage of the battery at the beginning is was super low, the voltage of the battery was about 0.3V. When he come back after approximately 2 hours, the battery was full of charge, which is 3.59V and it was not heated. Then we came back to check it after 30 minutes it was about the same with a little voltage gain that was added and brought it up to 3.60V. For the last 30 minutes, we did another voltage check it was just increasing little by little, it barely sent out power to charge the battery. We came up to conclusion that as it get closer and closer to the maximum charging capacity, the charge controller release less and less current, then stop charging the battery to prevent it from over charging and as well it is served as a heat monitor to prevent it from over heating.

9.2.1 RFID Kit Test

To test out RFID test we going to need the following:
- RFID Kit (Reader, USB reader and a tag)
- Terminal program
- Arduino (best choice for testing only)

First thing we need to do is to place the RFID reader on the FRID USB reader. This will allow the USB reader to transmit the data from the reader to the terminal. After that, we will need to plug the USB to the computer and we may also need to install an FTDI (Future Technology Devices International) driver. Next step is to open a terminal program, as it will show the tag ID later on. Then by using Arduino IDE's built-in serial monitor we just follow these steps:

- Go to Tools > Port and select the RFID reader's port.
- Go to Tools > Serial Monitor. The default terminal settings (9600 baud, no line ending) are fine. The monitor should be blank.

After that the reader suppose to be in a in full function mode and it is just waiting for a tag to be scanned. So we will just have to wave a card over the reader and then we will hear a beep and see the tag ID on the screen.

9.2.2 PIR Motion Sensor Test

To run this test we will need the PIR sensor and an Arduino. The PIR sensor has only three wires red (Power), white (Ground) and black (Alarm). The power and ground wires will be connected to the 5V and GND pins on Arduino. The alarm wire will go to pin 3 for example. Since this Sensor is in low active mode, then whenever the sensor is inactive, the pin should read high. And whenever motion is detected the sensor will pull D2 (internal pull-up resistor) low.

9.2.3 Battery Test

Testing the battery can be done using simple methods. Since we are using 3.7V and 2Ah battery, then these are the two features that we need to test. At the beginning we have to be sure that the battery is fully charged. Then to check for the supplied voltage we just need to use a multimeter. To test if we can really get 2 Amps for an hour, we just need a load with a known power consumption rate. Based on that and the time it took for the battery to die we can find out if the battery can provide this amount of current during one hour.

9.3 Software Test Plan

The starting testing will confirm that we won't have any bug on our system before implementing it, the first test will help to see the flaws with smart lock and help us to improve the code if it's necessary. Finally, GitHub will help us to put the whole code together for the android application we are making and making easy for us to combine each part of the code together. Then we will have two testing process after that both done by group members the first test will be testing each feature the lock will do separately. Second, it will be a prototype test that test all the features combined together to see how the features affect each other and if they do what they supposed to do, and the lock provide the right functionality. The environment of this testing will be the same as the live condition for the lock woks conditions.

We will have a document that keep trucks of the bugs we faced in our code, this will help us to fix them if run into them again, one of us will find the bug another person will help fixing it, someone else will run a test to see if the fix did its job or not and ensure they is no new bugs to fix, as testing progress we will also have a testing document of all the test we performed during the time frame of our project this will allow us to run a multiple test after every set of bugs we fixed to make sure when we face a new bug that it's not been seeing before. We can also rate the bugs from 1 to 10 it depends of how critical the bug to our system, when it comes to breaking our system partially or entirely in the main while we will keep removing each time we face them to produce a polished finished code product.

9.4 Software Specific Testing

During the development and the testing periods, our smart lock functionality was constantly tested using the debugs features with the debug software we were using in order to build an application who runs our system properly. The majority of the testing was performed in our local machines since compiling and building the project in our local machines is

much faster than remotely deploying into the smart lock prototype. However, we compile the project to the smart lock if necessary in order to evaluate the progress of the UI to be able to make any adjustment if necessary. Once we finish the development and all the test case, we finally performed on the actual smart lock to confirm proper functionality by the users.

9.5 Computer Vision Test

The objective of this test is to make sure that the camera we are using for is recognized and connected to the raspberry Pi, this very important because we have to change the firmware of the camera will be changed to run the proper algorithm, we apply this test to see if the camera still connecting and communicating with the Pi after the firmware changes.

9.5.1 Line Detection Test

The objective of this test is to see if the camera is able to detect a line and send the information back to the MCU, which is a Raspberry PI 3 Model B in our project. The best way to do that is by using an Arduino as it is easier to use and it will show us whether the camera is able to detect a line or not. The way to do that is just by connecting the output of the camera to the input of Arduino using a video signal splitter. The video signal splitter task is to identify the signal that coming from the camera and analysis it. Then just by using a debug that illustrates the output of the camera on the screen in binary representation. Then we test the camera by just looking at the monitor while we move the camera along a line to the left and right. After that we should be able to see whether the camera is able to detect a line by looking at the binary numbers representation. For example if the representation is like 011100000 that indicates that the line is to the left of the screen.

9.5.2 Database Test

To test the database and the server, we need to apply classical system testing process: We need to check the response time for executing the transaction of multiple remote users. With normal transaction we should we should include one editable transaction to check the performance of the database of this type of transaction. We also need to check the time taken to fetch specific records. Also, we need to apply a stress testing by doing a performance to identify a break point such as when the application is loading in such way the system fails at one point we call this this point a breakpoint of database system which called also a fatigue system. In addition, we need to apply a functions testing by testing each function correctness in the program of the server application, example a function that makes a button perform an action listener with accuracy, in general

tables update program consist of three basic programs which is update row insert row, so we need to make sure that each table has a foreign key relate in a proper way to their parent table. We also need to increment the key; we can do that using MySQL.

9.5.3 Server and Mobile App Test

We need to run the application and compare the data shown with the data stored in the database. Then apply an acceptance test, which act like we are a certain type of customer that receiving an unknown solution and will test it for functionality

9.5.4 Create a User and Log in Tes

To create a User a log in test, we have to make the Application is completely done and working properly without crashing. The minute that a user login successfully the application should display a welcome message. To do such thing, we have to create the welcome message under activities. As we select an empty activity, we give it a name as login successfully. We want the application to display the user name as well, in a large and bold text. We will write the program into java to declare some variables; first of all we would have the main one as the login button, as the password, then to specify each server URL. We need to check if all the steps to create a user are working properly make sure that the user data get stored at the database. When we try to login without entering a user name and password, it should display a message that say to enter a valid user name and password. We also need to perform a login test by entering a user name and a password and try to log in and log out couple time and make sure the system keeps track of the user information

9.6 The Project's Parts

These are the parts that we plan to use in our Solar Powered Smart Lock, as shown in (figure 9.1 and figure 9.2).
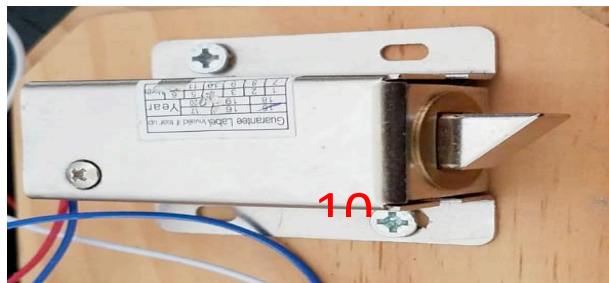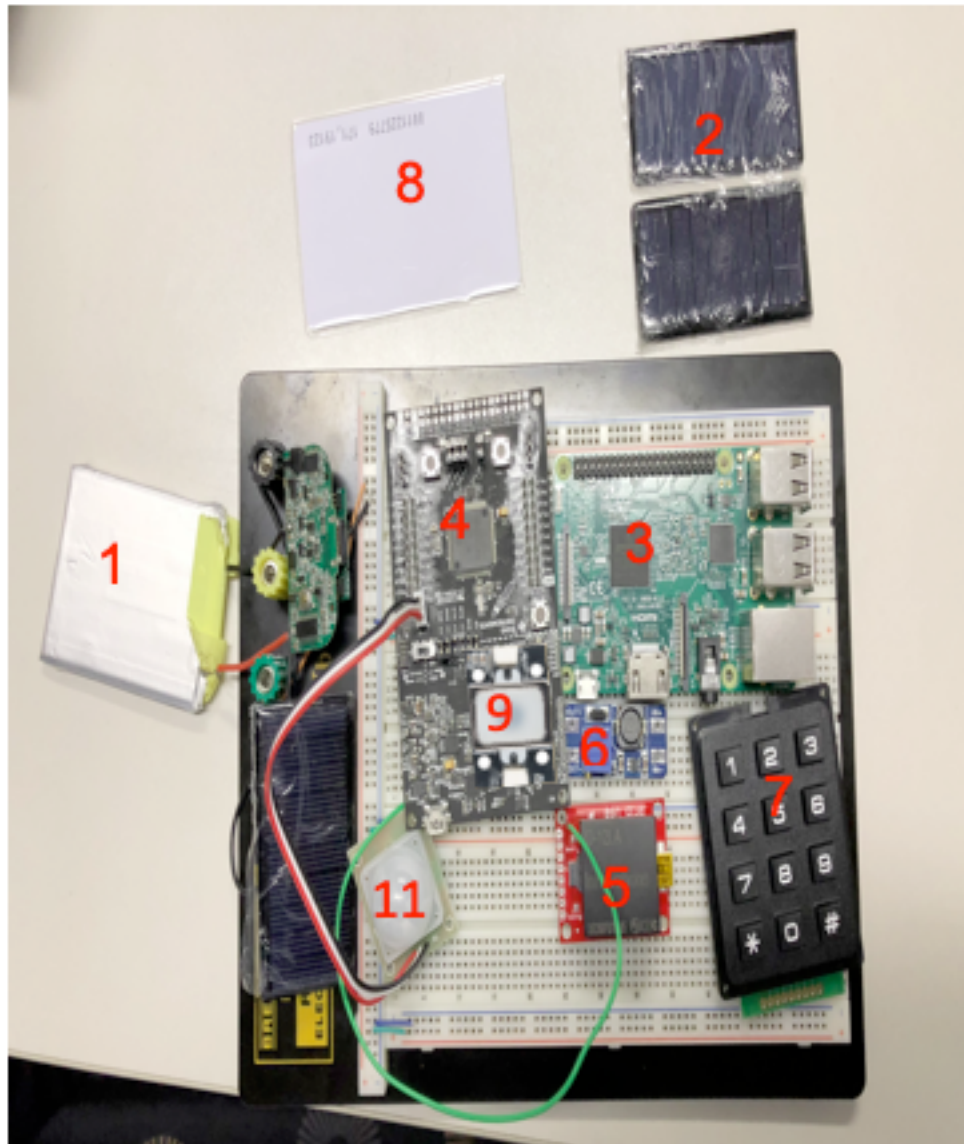

Figure 9.1: Electric Deadbolt

Figure 9.2: Project parts combined

The parts that we have in hand right now are
1. 3.7V Li Battery
2. 5V Solar Panel
3. 3 Raspberry Pi 3 Model B
4. MSP432 MCU
5. RFID Kit
6. Voltage Step-up
7. Keypad
8. RFID Tag
9. Fingerprint Scanner

10. Electric Deadbolt
11. Motion Sensor

The parts that we are expecting to arrive within a week from now:

1. Small LCD screen
2. Camera that compatible with the Raspberry pi
3. Electric Spindle (Spare part)

However, we might still have to order and replace some other parts base on how our project come out after receiving the Printed Circuit Board. Also if the parts do not fit the actual board we will have to adjust them by ordering the right size.

1. Relays
2. Solar charge controller
3. LED light
4. Capacitors
5. Resistors
6. Diodes
7. Inductors

9.7 Prototype Design

After we finished testing the PCB along with all the parts and saw that we don't have any problem with the software or the hardware, we started building the box that will hold all the parts and will be placed on the door. We used SolidWorks to create each side of the box then we assembled them using a wood glue. The final design is shown in (figure 9.3). The top side of the box has an angel of 45 degree to get the best chance for the solar panel to get a direct contact with the sun. The fingerprint scanner was placed on the top panel as well with the exact right dimensions. The LCD is located on the bottom facing upward as well so the person who is interacting with the smart lock can easily read the instructions. The motion sensor was placed on the front panel were it can detects any movements and the keypad is just next to it. We also created small holes for the RFID reader just to be sure that the wood wont block the signal.
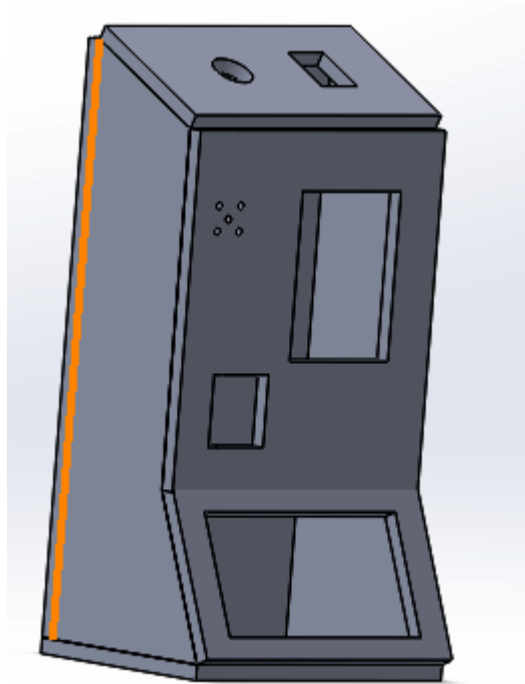
Figure 9.3 Prototype Design

10.0 Initial Project milestone for both semesters

It is very important to plan ahead of time to get everything done on the right time. This is why a project milestone is very important in Senior Design classes. The milestone has many benefits like:

- Get each assignment done on time.
- Helping us to be consistent.
- Help us choosing the right time to meet and work on the project.
- Help us individually in time management.
- Helping us to be organized.
- As we know ahead of time in which days we going to work hard, we can prepare ourselves mentally and socially.

Table 10.1 shows our plan to finish the 120-page project document on time. We were able to plan this semester in details, as we know all the deadlines that we need to meet on time. However, we still don't know any deadlines related to the next semester we still do some planning as we do for our Senior Design I class in order to get our stuff done in a timely manner. That is the reason why the Table 10.2 missing a lot of details for now. Once the next semester starts we will update the table to stay on track just as we did in Senior Design one. Our first step as the semester start will be; to test our final schematic on the breadboard to make sure that every component work together respectively. The project should work on the breadboard as it would do on the Printed Circuit Board, if there is a

mistake, we would be able to fix it easily, since there would be any solder or unsoldering needed to get this task done.

When the breadboard is fully done and work perfectly, we will go ahead and convert the schematic into PCB format. One of our major challenges will be the routing of the circuit, because when we try to do the routing automatically, it comes out all messy. Therefore we have to do all the routing manually to make sure that they do not interfere with one another. We have to leave a fair amount of space between each line, and to know how thick or thin a wire would be. If the wires are to close to each other, it might be a problem when it is printed out, and that may create some short in the circuit. As a result, we would have to redo everything, which would be a time constraint, since we project for everything to be done at a specific time and date.

Senior design 1		
Description	**Duration**	**Date**
Brainstorming	1 weeks	May14 - May 21
Project selection	1 week	May22 - May 29
Research and writing the initial document	1 week	June 1 – June 7
Submit the Initial Project 10 pages document	1 Day	June 10
Update the initial Project document after getting the project approved	2 Days	June 13 - June 15
Start doing researches and writing the first 60 pages of the final document	3 Weeks	June 15- July 4
Create Table of contents, List of Figures, List of tables and combine the group work in one file	1 Day	July 5
Submit 60 Pages Draft	1 Day	July 6
Parts Selection	4 Days	July 10
Doing researches and writing the next 40 pages of the final document	1 Week	July 11 – July 18
Update the Table of contents, List of Figures, List of tables and combine the group work in one file	1 Day	July 19
Submit 100 Pages Draft	1 Day	July 20
Doing researches and write the last 20 pages of the final document	5 Days	July 21– July 26
Research and design PCB	2 days	July 26 – July 28
Finalizing the Project	1 Day	July 29
Final document	1 Day	July 30

Table 10.1: Senior Design1 Milestone

Senior design 2		
Description	Duration	Date
Breadboard Test	1 week	Aug 20 – Aug 26
Update From breadboard	1 week	Aug 27- Sep 1
Order and Receive Parts	1 week	Sep 3 – Sep 9
Start Building the prototype	1 week	Sep 10 – Sep 16
Testing & redesign	1 week	Sep 17 – Sep 24
Finalizing the PCB	1 week	Sep 25 – Oct 1
Make the PCB	3 Weeks	Oct 2 – Oct 23
Test the Prototype and fix any errors we face	2 weeks	Oct 24 – Nov 10
Peer Presentation		TBA
Update the project based on the notes from the presentation		TBA
Final report		TBA Dec
Final presentation		TBA Dec

Table 10.2 Senior Design 2 Milestone

As we were working on the project in Senior Design2 we faced some problems and couldn't stick to the initial milestone. We had to order 4 PCBs in total as we changed our plan and fixed some issues we were facing. At the end we were able to finish the project just on time. That is why we recommend that we assume that the deadline is a month earlier than what it really is. That will give an efficient time to work on the project and fix all the issues before it is too late.

10.1 Conclusion

To conclude, getting the privilege to put together what we have been learning for four years and to combine it into two semesters and make something out of it was one of the best things that we could have experience in our career. Our senior design project, which is a "Solar Powered Smart Lock", is going to be in home security systems specifically in door locking and unlocking. "Senior Design I" teaches us a lot of thing that we did not expected, it shows us how to put together what we have learned in the past into practice for the future. It teaches us how to work as a team, despite many circumstances we have to walk together, side by side and carry each other across the finish line. Even though there are many challenges that we faced during Senior Design I, they did not stop us from moving forward. We used these challenges as roadblock; however, they made us stronger to overcome those obstacles. These challenges push us beyond measure to do a lot of self-teaching, as a result, these challenges offered tremendous insight and knowledge that will be useful in the future.

As we set our goals at the beginning of the semester, to be successful throughout Senior Design I, we had to meet almost everyday, not to procrastinate to get everything done on time. I was very difficult to beat these goals. However, nothing is impossible. To overcome those challenges, we had to change the due dates and make the rest of the team believe the project is due a week in advance, as a result, we have more time to finish it and make sure that everything is in place. Even though it was not 100% complete, but we had an extra week to finalized the document. We try our best to create time and start as early as we can; to get this goal accomplished our main every member of the team had to be responsible, every member of the team is consider as the group leader. Friendship plays a really important role when it come to get this project done, we support one another and joke around in order to keep the team from arguing. Time management was the biggest challenge for us, as we wrote it down at the beginning of the semester, we made sure to keep that at the summit of the group, which we put as our core value.

One of the best characteristic about our group is that we intertwine with one another, even though everyone chose a specific task to do, we as a group supervise each other to make sure that the individual task do not affect the group. We are really proud of the group effort, every single member did a tremendous job in order to get this project accomplished. All members of the group get their feet in the water to perform their respective task as well as to involve in the others works just to make sure that we stay balanced. We were able to solve the challenges by working as a team instead of letting one person to do the job. The ability to rely one each other makes us strong and walks together to achieve success.

Finally, As Christopher Pike, Sati said, "A true teacher would never tell you what to do. But he would give you the knowledge with which you could decide what would be best for you to do." During our four years studying Electrical Engineering here at the great University of Central Florida, we have learned a tremendous amount of stuff that will last us a lifetime and walk with us through our career. Knowledge is the best gift that someone can receive for his or her entire life; As a result we decide to do the "Solar Powered Smart Lock

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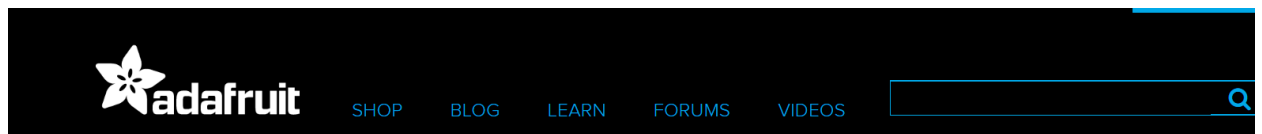
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