SPSL (Solar Powered Smart Lock)

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***Abstract* — The Purpose of this project is to build a smart lock, which uses Solar Energy as a power source. The smart lock has several features to lock/unlock it such as RF (Radio Frequency), keypad, fingerprint scanner and an android app. The first phase of the project is research, which lasts around a semester. During the first phase we looked into different technologies of smart locks and the best and cheapest way to build it. The second Phase of the project involved designing circuits and building the smart lock according to the specifications that we have decided in phase one.**

***Index Terms* — Access Control, Data Transfer, Microcontrollers, Motion Detection, Programmable Logic Arrays, Solar Panels, Voltage Control.**

I. Introduction

SPSL (Solar Powered Smart Lock) is unique product. It is the only smart lock that uses renewable energy as a power source instead of replaceable batteries. It also gives more than one access point to use and cost much less than the similar products in the market. To consume a very low power so the battery can last for a long time we will be using a motion sensor that will trigger the lock to wake up once a person is detected in front of the door. Then an LCD screen will provide the different options to the user, so he/she can choose how to access the door. The MCU will analyze the data coming from the device that being used by the user and determine whether to grant user an access or not. The user will choose between entering a password, scanning fingerprint or using an RFID card to enter the door. The Project also includes an android App that can be used to unlock the door using the Internet. The big advantage of that is the lock owner can unlock the door from anywhere if he does not want to give the password to the person trying to enter his home.

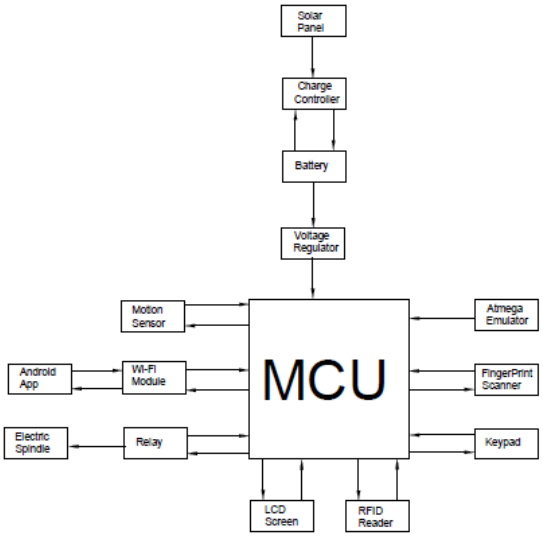
II. SYSTEM Overview

When designing the solar powered smart lock, there was a specific set of criteria or the group members determined specification requirements. These requirements were meant to serve as an evaluation or guideline as to how successful our design approach was. Having guidelines allows us to tune and specify the components to meet these standards. The overall project requirements to meet these standards. The overall project requirement specifications that were set were:

- Lock Size : 9 x 4.5 inches
- Battery Life span: 6 years
- Unit Weight: 7 lbs.
- Motion Detector Range Distance: 3 to 6 m.

III. Subsystems

In this section each subsystem and its components will be further discussed in order to provide a deeper understanding into why certain designs were made and how these designs affect the design performance. The analysis of each individual system will also provide a clear picture into how these subsystems come together to form the backbone of the Solar Powered Smart Lock.



A. The Power of the System

The power system of the solar powered smart lock was one of the main challenges in the project. The minimum power used is essential for the project to maximize the battery life of the smart lock. To power the entire system a variety of different solar panel, charge controller, battery, voltage regulator, relay options were tested.

Solar Panel

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 still provides 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 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.

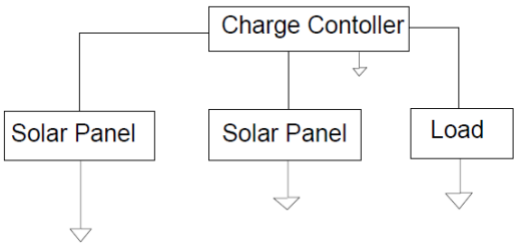
Monocrystalline (Mono-Si) and Polycrystalline (P-Si) solar panels consider as PV solar panels. Both of them are built using silicon. Since they are built with Silicon that mean both can be doped with different materials to form p-type or n-type if needed. Even though both are formed from Silicon, two 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. The AOSHIKE 5V 60MA Epoxy Solar Cell for Solar Battery Charger was chosen for the project because of its high efficiency output. It has an excellent low light effect and it is very powerful. One of the main reasons for us to do this project because we were not able to find any similar technology using a solar panel as a power source for smart lock.

Charge Controller

A solar charge controller manages the power going into the battery bank from the solar array. It ensures that the deed cycle batteries are not overcharged during the day, and that

the power does not run backwards to the solar panels overnight and drain the batteries. Some charge controllers are available with additional capabilities, like lighting and load control, but managing the power is its primary job.



A solar charge controller is available in two different technologies such as PWM and MPPT. An MPPT charge controller is more expensive than a PWM charge controller, and it is often worth it to pay the extra money.

A PWM solar charge controller stands for 'Pulse Width Modulation.' These operate by making a connection directly from the solar array to the battery bank. During bulk charging, when there is a continuous connection from the array to the battery bank, the array output voltage is 'pulled down' to the battery voltage. As the battery charges, the voltage of the battery rises, so the voltage output of the solar panel rises as well, using more of the solar power as it charges. As a result, it is very important to make sure the nominal voltage of the solar array and the voltage of the battery bank are matched.

An MPPT solar charger controller stands for ' Maximum Power Point Tracking.' It will measure the Vmp voltage of the panel, and down-converts the PV voltage to the battery voltage. Because power into the charge controller equals power out of the charge controller, when the voltage is dropped to match the battery bank, the current is raised. So, you are using more of the available power from the panel.

The TP4056 charge controller was selected for our project. The TP4056 is a complete constant-current /constant-voltage linear charger for single cell lithium-ion batteries. The SOP package and low external component count make the TP4056 ideally suited for portable applications. The TP4056 has an excellent feature such as: Programmable Charge Current up to 1A, Constant-Current/Constant-Voltage, and

Automatic Recharge.

Battery

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)

Also, we are using another 3.7V battery as a backup, which is EBL 18650. This battery has a capacity of 3000 mA, with a diameter of 18mm, and 65mm height. Base on our research, this battery takes longer to drain and it does not contain Hg/Cd/Pb, so it classify as clean energy source since it would not pollute the environment.

Voltage Regulators

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.

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Motion Sensor System

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 enough 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.

Many sensor types were reviewed and looked upon such as Passive infrared (PIR) sensors, Microwave sensor, tomographic motion detector systems, photo-sensors, and dual-technology motion detection sensors.

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.

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.

Microcontroller (Atmega2560)

The microcontroller is the most important part of the project. In other words, it is the brain of the whole project. It drives the hardware and allows it to do all the functionality that is implemented. The microcontroller is used for most of the task in the project. It controls the motion detection through a motion sensor. It does the locking and unlocking mechanism using the electric spindle and the input from the finger print scanner, keypad, RFID module, and Wi-Fi module. Since the microcontroller (MCU) is the backbone of the project, it was important to select one that is easy to program and implement. MSP430 and Atmega chip were the most popular ones. Eventually the Atmega2560 was chosen for our project. Atmega2560 is easy to program, easy to implement electronically, and powerful enough to handle the entire task in the project.

Unlocking systems

RFID reader Access

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 can 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.

Fingerprint Access

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.

The one biometrics that was chosen was fingerprint. 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.

Passcode Access (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.

Application access

The mobile application will allow for remote control of the smart lock device. The mobile development portion of the project was programmed for Android devices to be specific by using UDP protocol connection we will be able to send a high signal to the relay, so we can open the lock. the application is written using android studio and it does support a minimum SDK version of 19 being KitKat

WIFI access

For the WIFI is used a TI chip called CC3220,I wrote the server using Energeia IDE ,I used UDP socket to the send the signal from ping 62 to the relay and open the lock from there, I also connect the whole system using my iPhone hotspot

Electric Spindle

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.

In our case we are using the T5200 Electric spindle, which is a very great device that allow the inside latch to work like normal. While the handle on the outside have to be electrically operated. From the outside if it was not energizing, once you pop the handle it would move freely nothing would happen. However, when power being applies to the spindle, the outside part will be engaged then the handle will be able to operate the latch. Which can also described as a fail-secure lock.

Fail-secure locks are most commonly used in electronic locking devices for high security situations, because their default state is to remain locked. The type of lock we have is a fail secure, which keep the door locks and can unlock it only when power is applied to the spindle. The default state for the lock is to be locked until power is applied to grant people access. Which mean when enter the right password, or when the right ID tag is being used the relay will triggered then send the right power to the lock, with that power the lock will be able to open the door.

Since our main goal was to make the ultimate lock that would protect the house at all cost, we could not use a fail-safe electric spindle. 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.

IV. PROTOTYPE DESIGN

Wood is the material chosen for the prototype. It was easy to build and manipulate that we designed on paper first then we designed it on solid works in order to have it cut by using the laser machine. Furthermore, we assembled all the pieces and clued the product together to make up the shell for the lock.

IV. PROJECT OPERATION PROCEDURE

The solar powered smart lock aims to provide the user different options to unlock and easy access their home doors. Making the life of our users easy is the priority. The user will have four different access options such as

fingerprint access, app access, passcode access, and key tag access. The solar powered smart lock is user friendly and secured. Once the user approach the door, the systems will wake up and give the user access options and choose one access and door is unlocked. For the android app, the user will need to download the app. And the app is user friendly as well. Once the app is downloaded, to unlock the door is only one click away. We faced some extreme challenges on the way of making the success of the project. There are still some implementations that will need to be revised for now we are happy of what we have because we have learned a lot making this project.

IV. BIOGRAPHY

Livenghtston Cius is currently a senior at the University of Central Florida and will be graduating with a Bachelor of Science in Electrical Engineering in December 2018. After graduation, his goal is to pursue a career in systems engineering for deep space mission.

Wikender Alcius is a senior electrical engineer at the University of Central Florida. Currently, he is interning with Interplan LLC as an Electrical designer. After graduation his goal is to pursue his goal as a PE electrical engineer and own his own business.

VII. Conclusion

To sum up, going to a four-year institution is not only the masterpiece. However, getting the privilege to put together what we have been learning for the past four year combine, and use our knowledge to create the Solar Powered Smart Lock, which will help improve the safety in our house.

Also getting to do this project, as a group is really helpful in teaching us the importance of teamwork. Every single member of the group was responsible in other to get the work done. We also had to intertwine with one another, even though everyone had a specific task; we all help each other and collaborate with one goal to move forward.

Acknowledgement

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