University of
Central
Florida

# Solar Powered Window Blinds

Group 11

Artis Coleman - Computer Engineer
Sean Diamond - Optical Engineer
Dakota Jordan - Computer Engineer
Stephen Walsh - Electrical Engineer

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## Table of Contents

**Appendices**

# 1.0 Executive Summary

This capstone design project will be an adaptation of the traditional window blinds, with its main feature being the collection of solar energy. Most electricity that powers the world today comes from the consumption of fossil fuels, a non-renewable resource. While it is not a current necessity, the world will need to find alternative methods of electricity generation before our limited resources run out.

This project will introduce just one of many envisioned products that will be commonly found in residential homes in the future which will collect energy to be stored in a central power storage unit which will power the entire residence. These central electricity storage units are essentially large rechargeable batteries, prototypes of which are already emerging in our current economy (i.e. Tesla's Powerwall).

To this end, our project will modify the traditional residential window blinds. They will be easy to install and operate, and provide a relatively low-cost energy collector to complement an energy-efficient residence.

# 2.0 Project Description

## 2.1 Project Motivation and Goals

Since the main focus of this project is to provide additional natural energy to a residence, it is only logical that it should maximize the energy it collects by minimizing the energy it consumes while still providing features that a consumer expects from a technologically-advanced product. To this end, the blinds will aim to be lightweight, relatively low cost, and use minimal energy to perform basic operations such as opening and closing.

The current state of technological development is seeing an increasing amount of products developed for the "Internet of Things". These blinds aim to be a member of this category of products by being interconnected wirelessly with the user’s mobile device to allow for greater control over their home. Motor operation for these blinds opens up the ability to extend our focus to making the device easy to operate for the elderly or disabled who may not be able to use manual operation of traditional blinds.

## 2.2 Objectives

The main objective of this project is to provide a supplementary power source for an energy-conscious home. The operation of the product itself will be self-powered so that it will not use up disposable batteries or require external electricity. Additionally, the excess energy gained through the solar cells can be stored in a battery for use in other areas of the home. A USB charge port is included on the product as the only provided interface for accessing this excess energy. However, if a central home battery storage device is used, it is assumed that it will have additional interface ports to utilize the energy provided. Multiple installations of this product can provide a significant boost in the home's electricity reserves.

Secondary objectives include convenient operation of the blinds and external thermometer. With the ability to open and close the blinds with the push of a button, this allows for more convenient use of the product. This is an especially useful feature for disabled persons who may not be able to open and close the blinds manually. Also, with the use of the mobile application, even less effort is required. Information from the external thermometer will be displayed on a screen on the product itself, as well as transmitted to the user's phone.

## 2.3 Requirements Specifications

### 2.3.1 Hardware Specifications

A list of hardware specifications has been established in order to clearly define the product and assist in design of the hardware. These specifications, listed in Table 1, must be met in order for this project to be considered complete.

| # | Description |
|---|---|
| 1 | As many solar cells as possible mounted to the housing |
| 2 | Install additional cells on the light-blocking material of the blinds if possible |
| 3 | Fit window with width of at least 30 inches |
| 4 | Ability to recharge an external battery source |
| 5 | Draw energy from either external battery source or directly from solar cells |
| 6 | Operation of motor from both buttons and mobile application |
| 7 | USB port to act as charging station for USB-compatible devices |
| 8 | External thermometer |
| 9 | Display screen for thermometer and battery life |
| 10 | Communicate wirelessly with mobile phone app |
| 11 | Battery source will be interchangeable and not internal |
| 12 | Adjustable height to work with multiple window sizes. |

**Table 1** - Hardware Specifications

### 2.3.2 Software Specifications

A list of software specifications has been established in order to clearly define the product and assist in design of the software. These specifications, listed in Table 2, must be met in order for this project to be considered complete.

| # | Description |
|---|---|
| 1 | Mobile application to work in Android environment |
| 2 | Controls opening and closing of blinds |
| 3 | Displays the battery's current charge and % of maximum |
| 4 | Displays temperature read by the external thermal sensor |
| 5 | If battery is expending more energy than it's charging, display time remaining until battery is empty if current rate is maintained |
| 6 | Should be able to interact with the blinds from at least 25 feet away |
| 7 | Includes secure "sync" option to associate your blinds with your device |
| 8 | Track and display charging/discharging statistics |
| 9 | Display the rate of battery charging from the solar cells |
| 10 | Display time until battery is fully charged |
| 11 | Display dollar amount saved based on local energy rates daily and cumulatively |
| 12 | Compatible with at least 3 most recent API versions of Android |

**Table 2** - Software Specifications

# 3.0 Research Related to Project Definition

## 3.1 Existing Similar Projects and Products

### 3.1.1 Similar Products: Motorized Window Blinds

Biochemtronics has an article titled "Automatic Window Blinds Controller (PICAXE)" published on instructables.com [1]. The project involves adding a microcontroller-powered motor to a regular set of window blinds. Motorized window blinds are available for sale at home improvement stores; however, they are usually quite expensive. An inexpensive PICAXE Micro Controller is used for this project and the total cost of the project is only about $20.00. Biochemtronics used a light dependent resistor (LDR) to activate the motor and open the blinds when a pre-set level of light is present on the window. This feature will not be useful in our project because we want the blinds to be closed when sunlight is present; however, the overall design of the blind controller is similar to what we want to achieve in our project. The parts list for this project is shown in Table 3.

| Part | Manufacturer | Cost |
|---|---|---|
| PICAXE -08M Micro Controller | Spark Fun Electronics | $2.95 |
| ULN2003A Darlington Array | BG Micro #ICSULN2003 | $0.59 |
| DPDT 5.0V Relay | BG Micro # REL1106 | $1.29 |
| Solarbotics GM3 Gear Motor, 224:1 6V | Solarbotics | $5.50 |
| 3.5mm Stereo Jack | BG Micro #AUDCA017 | $0.36 |
| 4 X 1.5V AA Battery Holder | BG Micro #BAT1068 | $0.79 |
| Battery Snap (9V style) | BG Micro #BAT1033 | $0.25 |
| LM7805T 5.0V, 1A, Regulator | BG Micro #REG7805T | $0.40 |
| Small Project Box | BG Micro #ACS1157 | $1.95 |
| Small Proto Board (2 3/8) | BG Micro #ACS1433 | $0.89 |
| 8 Pin Dip Socket | BG Micro #SOC1036 | $0.10 |
| (2) 16 Pin Dip Sockets | BG Micro #SOC1038 | $0.08 |
| Light Dependent Resistor | Radio Shack #276-1657 (5 pk) | $2.99 |
| (2) SPST Switches | BG Micro #SWT1043 | $0.20 |

**Table 3 -** Biochemtronics Automatic Window Blinds Controller BOM

The PICAXE -08M serves as the brain for the controller. This chip is an 8 pin DIP that features several inputs and outputs, analog to digital converters, a pulse width modulator, and an IR transceiver. It was originally designed for educational use and is easy to program. It is also more affordable than other microcontrollers because it runs on freeware. The LDR attaches to the analog to digital converter (ADC) input of the PICAXE to monitor the light level outside. The ADC sets a variable to a value between 0 and 255 based on the intensity of the light on the LDR. This variable is used to set the light level at which the PICAXE outputs will turn on and open or close the blinds. The Darlington Array is used to amplify the low current of the PICAXE outputs so that they can switch the high currents required by the relay and motor. The Darlington Array also protects the rest of the circuit from voltage spikes caused by the inductive loads. The 5 V DPDT relay is used to reverse the polarity of the motor so that the blinds can both open and close. The pulse width modulator of the PICAXE can be used to control the motor speed; however, this is not required when using the Solarbotics gear motor. The circuit diagram for the controller is shown in Figure 1, printed with permission from Biochemtronics.

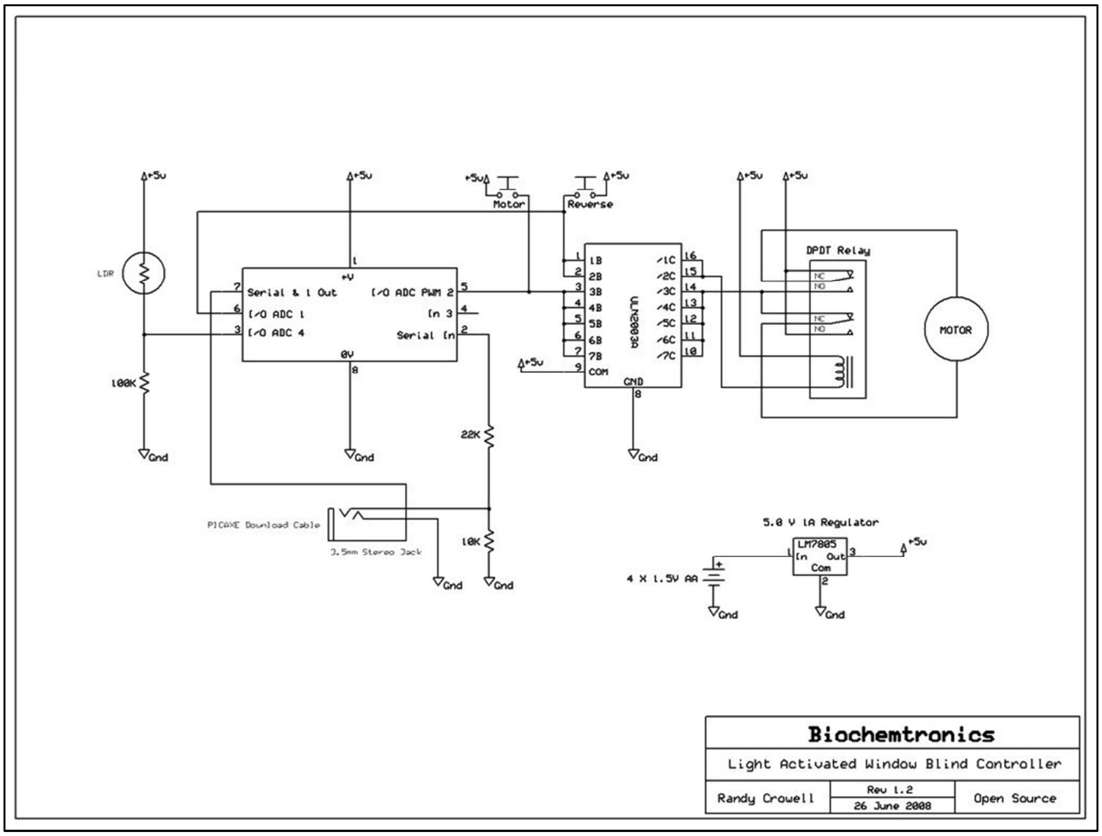


**Figure 1 -** Biochemtronics Light Activated Window Blind Controller

In order for the motor to open and close the blinds a small hole needs to be drilled in the motor shaft. After removing the rod from the blinds the small hook at the top of the rod used to open the blinds can be put through the hole that was drilled in the motor shaft. When the motor is activated it will cause the hook to spin and open and close the blinds. Position adjustment switches can be added to the circuit in order to manually open and close the blinds. A 360  servo or stepper motor could be used in place of the gear motor to increase the position accuracy; however, this would increase the cost of the project.

Once the circuit is constructed the PICAXE needs to be programmed. The code reads the outside light level from the ADC and defines the levels at which the blinds will open and close. Code is also included in order to keep the blinds from trying to open again once they are already open and from trying to close once they are already closed. The open and close position needs to be adjusted so that the motor will not under or over-rotate. Connecting a computer to the controller that is mounted to the blinds allows the variables in the code to be fine-tuned. If the controller gets off track over time the adjustment buttons can be used to tweak the blinds back to the desired position. A picture of the completed project is shown in Figure 2, printed with permission from Biochemtronics. The battery pack is attached to the top of the project box so that the batteries can be easily replaced or recharged.

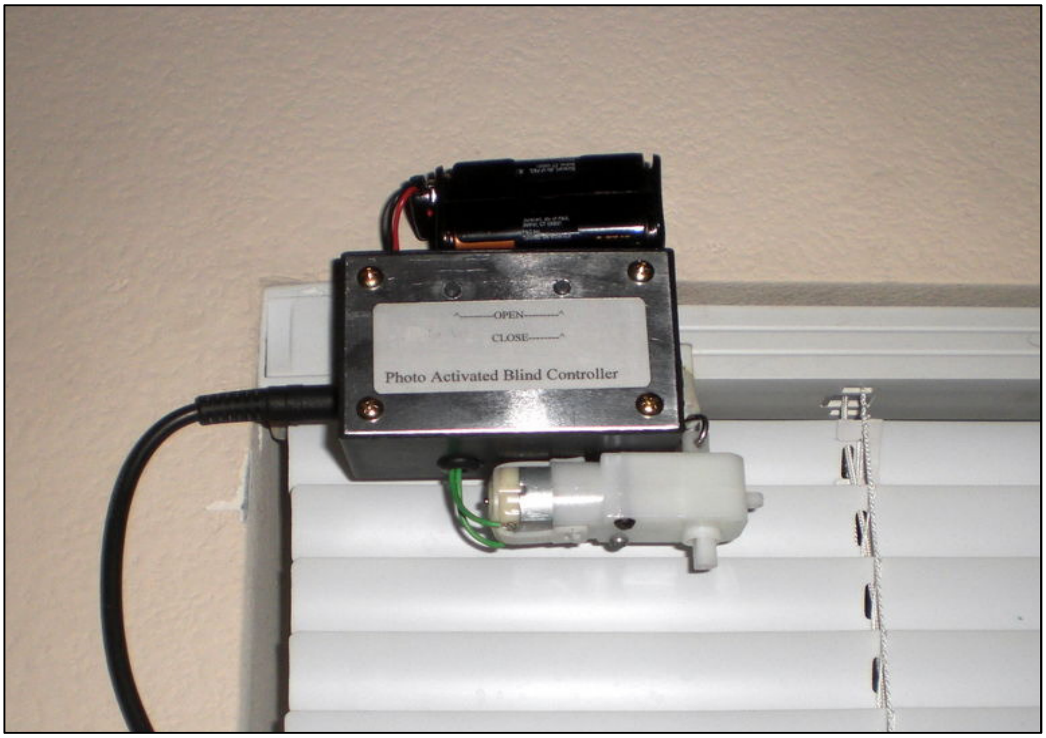


**Figure 2** - Completed Biochemtronics Project

This project provides a good example of how a simple microcontroller and inexpensive motor can be used to motorize blinds. There are several adjustments that need to be made in order for this design to be incorporated in our project. The main difference between this project and our design is the blind type. We want to use a roller shade system instead of a conventional blind system with slats. Using a roller blind will allow a large, bendable solar panel to be attached to the shade. The solar power collected by the shade could then be used to power the motor as well as the microcontroller and a built in USB charger. Another feature that we want to incorporate in our project is remote controllability. This will allow the user to control the blinds using a smart phone application. The LDR could be repurposed to monitor light levels over a certain period of time. This will allow a mobile user to monitor the best times for collecting solar energy.

### 3.1.2 Solar Powered USB Charger

Honus has an article titled “How to make a solar iPod/iPhone charger –aka MightyMintyBoost” published on instructables.com [2]. The project involves converting an Adafruit MintyBoost charger, which usually runs off of AA batteries, to a solar powered charger that recharges a lithium polymer battery. The MintyBoost kit ($19.50) includes the following parts:

- 5V boost
- converter
- 8-pin socket
- 220uF
- power supply capacitors
- 0.1uF bypass capacitors
- 3.3kΩ, 75kΩ, and 49.9kΩ resistors
- 1N5818 Schottky diode
- 10uH power inductor
- USB type A female jack
- 2 x AA battery
- holder
- PCB

The Mintyboost is designed to provide a 500mA charge rate to the USB chargeable device. The 49.9k and 75k resistors are used in order to adjust the bias on the four pins of the USB so that iPhone charging is supported. Many USB devices that do not require data transfer will charge with pins 2 and 3 of the USB floating; however, the iPhone requires these pins to be biased at 2 V to attain a 500mA charge rate. The circuit diagram of the Mintyboost's USB pin configuration is shown below in Figure 3, printed with permission from Honus.

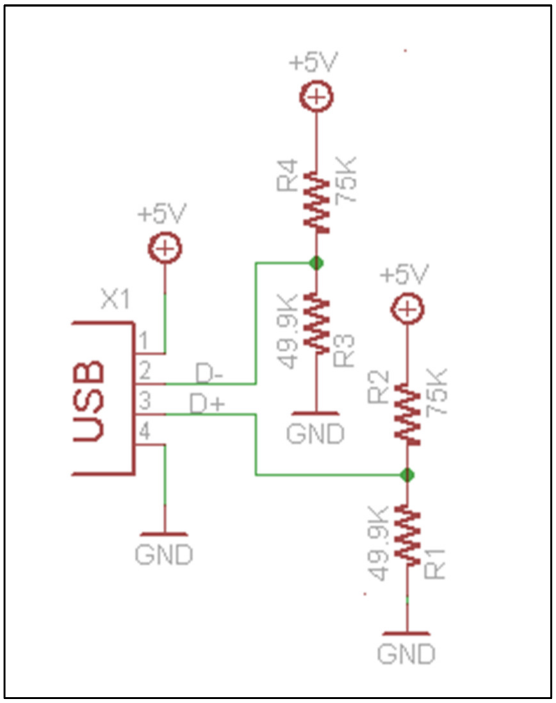


**Figure 3 -** Mintyboost USB Pin Configuration

The 3.3k resistor is used to improve the high current capability of the boost converter chip. One of the ceramic capacitors is used in order to stabilize the output voltage as well as filter out high frequency noise. The other capacitor is used to stabilize the internal reference of the boost converter chip. The Schottky diode is used to ensure energy is transferred in only one direction from the battery to the USB port. The boost (or step-up) converter chip is a DC/DC power converter that has an output voltage greater than the input voltage. The IC socket protects the boost converter chip and can easily be replaced if there are any problems with the circuit. The power inductor is used by the DC/DC converter chip to store and convert power from low to high voltages. The electrolytic capacitors are used to stabilize the input and output voltages during up-conversion. They also act to filter low frequency noise. The circuit diagram for the MintyBoost v3.0 is shown below in Figure 4, printed with permission from Honus.

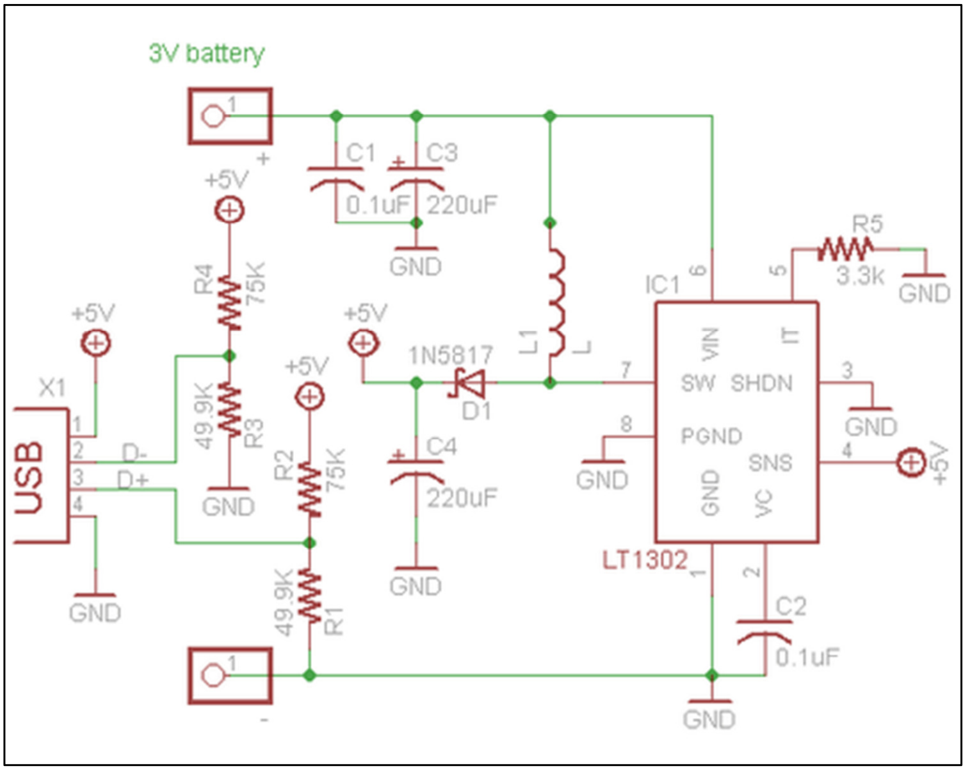


**Figure 4 -** Mintyboost Circuit Diagram

Once the MintyBoost kit is assembled a 2-pin JST cable can be soldered to the PCB in place of where the AA battery holder would normally be attached. Figure 5, printed with permission from Honus, shows the MintyBoost circuit with the added JST cable. The JST can then be connected to the load output port of the Adafruit USB LiPoly Charger ($17.50), which was specially designed for solar use. If a regular charger were used the efficiency would be poor due to the charger constantly turning on and off in varying light conditions. The MCP73871 Voltage Proportional Charge Control chip is used to draw as much current as possible while maintaining a constant voltage point. Resistors are used in order to set the voltage point and a large capacitor is used to stabilize the rapid voltage collapse of the panel. In addition, a Schottky diode charges the capacitor from the panel and prevents the capacitor from draining back into the panel. If the amount of power generated by the solar panel where larger a Max Power Point Tracker (MPPT) circuit would be needed. This circuit uses a DC/DC converter to keep the charger operating at the maximum power. Since adding the DC/DC converter is expensive and only increases the efficiency by 30% for small panels a linear converter is the right choice for this application.

**Figure 5 -** MintyBoost Circuit with Added JST Connector

An additional feature offered by the MCP73871 chip is load sharing. When the panel is producing power the load current goes directly from the input voltage to the output. The lipoly battery will supply up to 1.8 A if the current required by the load is higher than what is provided by the panel. An extra USB mini-B and DC jack are included on the board so that the battery can be charged when solar energy is not available. Three indicator LEDs allow the user to easily monitor the status of the charger. The red LED indicates that there is power connected to the charger, the orange LED indicates when the battery is being charged, and the green LED indicates when the battery is fully charged.

The last step for this project is to connect the 3.7 V 2.5 Ah Adafruit LiPoly Battery ($14.95) and the Adafruit 6 V 3.4 W solar panel ($44.95). A 2.1mm terminal block adapter can be used to connect the panel to the DC jack on the charger. This panel is made of monocrystalline silicon and has a cell efficiency of 17%. It outputs 6V at 530 mA and is waterproof, scratch resistant and UV resistant. The lipoly battery can be connected to the battery port on the charger by a 2-pin JST cable. The output ranges from 4.2V to 3.7V and has a capacity of 2.5 Ah for a total of about 10 Wh. Protection circuitry is built in to the battery, which prevents over-charging, over-use, and output shorts. A 10k Precision Epoxy Thermistor ($4.00) can be added on to the board in order to monitor the temperature of the battery and shut down charging if the battery becomes too hot. This is useful if the battery will be used outside. Figure 6 shows how the LiPoly battery and USB charger connect to the charge controller and Figure 7 shows the completed project with the solar panel, both figures 4 and 5 printed with permission from Honus.

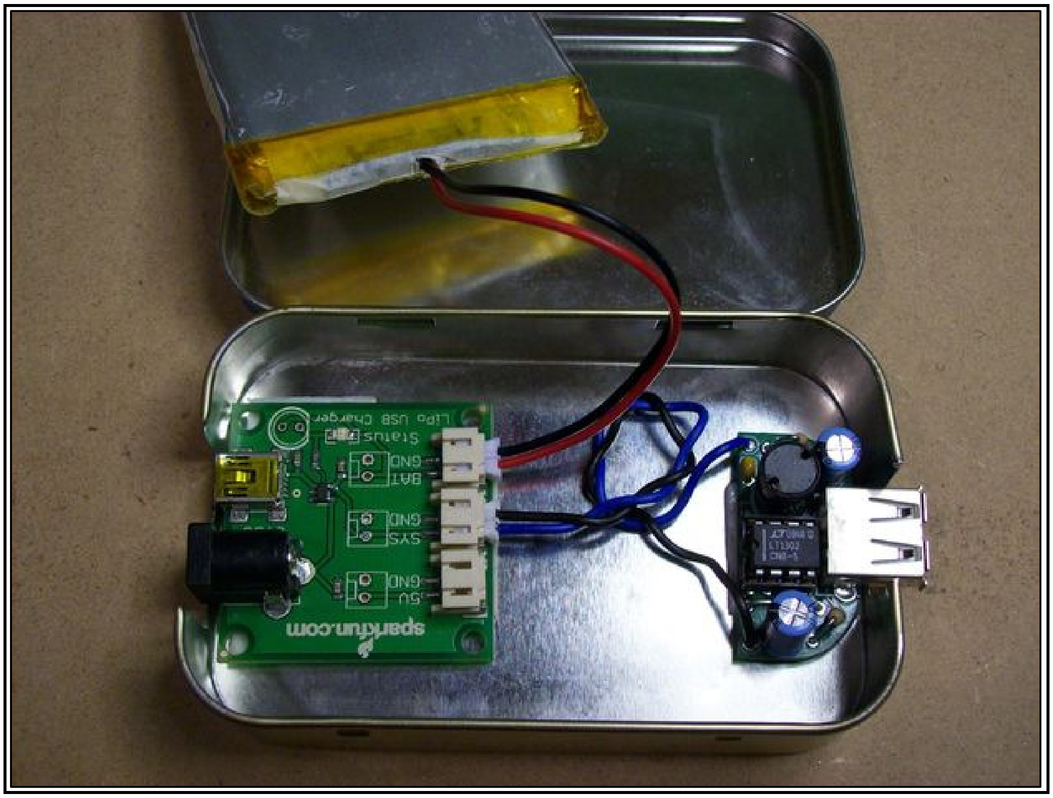


**Figure 6 -** Battery and USB Charger Connected to Charge Controller

**Figure 7 -** Completed Solar USB Charger

This DIY project provides good insight into the kind of circuitry that is needed in order to construct a solar power USB charger. The parts list for this project is shown in Table4. The total cost for this project is $100.90. A larger solar panel and battery could be used in order to scale this project so that more solar energy could be captured and stored.

This system would require an MPPT charge controller in order to maximize the amount of energy transmitted from the solar panel to the battery. A lead acid battery could be used instead of a LiPoly battery in order to reduce cost.

| Part | Manufacturer | Cost |
|---|---|---|
| MintyBoost Kit v3.0 | Adafruit | $19.50 |
| USB/DC/Solar Lithium Ion/Polymer Charger v2 | Adafruit | $17.50 |
| Lithium Ion Polymer Battery – 3.7v 2500mAh | Adafruit | $14.95 |
| Large 6V 3.4W Solar Panel – 3.4 W | Adafruit | $44.95 |
| 10K Precision Epoxy Thermistor | Adafruit | $4.00 |
| | Total | $100.90 |

**Table 4 -** Solar USB Charger Parts List

## 3.2 Relevant Technologies

### 3.2.1 Solar Cells

#### *3.2.1.1 Photovoltaic Technology Considerations*

There are a variety of solar cell technologies to choose from when designing an application that will use solar energy for power. One of the most important characteristics to assess is the efficiency of the cells. The efficiency of a solar cell refers to the ratio of incident light energy to the converted electrical energy. The spectrum of incident light, semiconductor material used, and device structure all have an effect on the efficiency of the cells [3]. The most efficient photovoltaic technology should be chosen so that the most energy can be collected; however, the efficiency is often limited by cost.

Most solar cells are silicon based because the manufacturing process to produce silicon wafers is mature [3]. Cells that are made with other materials that are rare to earth, such as tellurium, can be much more expensive. When selecting a photovoltaic technology, a tradeoff between efficiency and cost should be considered. The size and shape of the photovoltaic should also be considered. Certain photovoltaic technologies use semiconductor wafers, which are very thick compared to alternative thin-film devices, which can be flexible. Thinner cells may be suitable for applications where space and weight limitations are present.

#### *3.2.1.2 Crystalline Silicon Photovoltaics*

Crystalline silicon photovoltaics are currently the most widely used photovoltaic cells on the market. This technology represents about 90% of the world total photovoltaic cell production [4]. These cells have high efficiency and can be connected together under high transmittance glass to produce reliable, weather resistant photovoltaics. Monocrystalline and polycrystalline silicon are two technologies used to produce the silicon wafers for these photovoltaics. Figure 8 shows a monocrystalline cell on the left and a polycrystalline cell on the right.

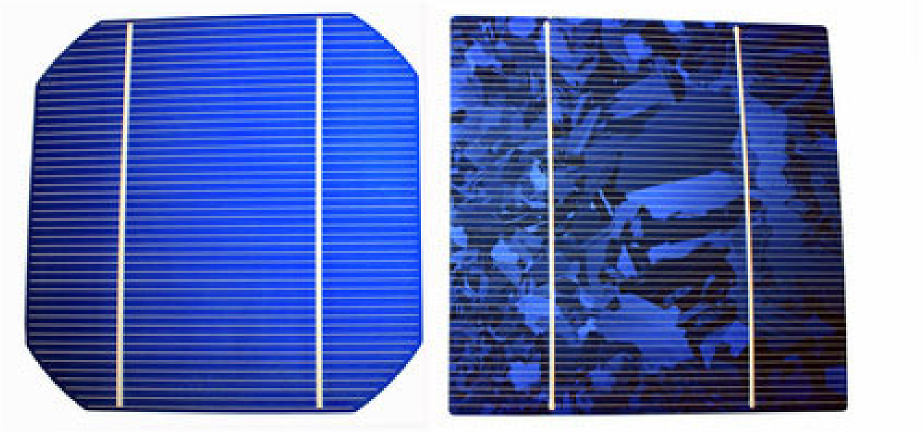


**Figure 8 -** Monocrystalline (left) and Polycrystalline (right) Solar Cells

Monocrystalline silicon solar cells yield the highest efficiencies, but are also more expensive than other photovoltaic technologies. Standard industrial cells yield efficiencies ranging from 16-18% and high-efficiency cells are capable of efficiencies greater than 20% [4]. The best research cells are currently capable of 25% efficiency levels, though the manufacturing technologies needed to create these cells are expensive and time consuming because specialized equipment is needed. The Czochralski process is typically used to grow the crystals and the silicon wafers are cut from cylindrical ingots.

Polycrystalline, or multicrystalline, silicon solar cells are more common than monocrystalline cells because they are less expensive. Standard industrial cells yield efficiencies ranging from 15-17% and currently make up about 48% of the world photovoltaic market [4]. They are produced from metallurgical grade silicon by a chemical purification process called Siemens process and the wafers are cut from square ingots. The efficiency of these cells is less than that of monocrystalline cells due to the presence of grain boundaries, which reduces the overall minority carrier lifetime for the material [5].

Cell module efficiencies for both technologies are about 14%. This is due to the fact that the square polycrystalline cells have a higher packing factor than the pseudo-square monocrystalline cells. Wafers for both technologies range in thickness between 160 and 240 $\mu m$. Cell modules containing crystalline silicon cells are relatively thick because of the thickness of the wafer and the glass casing.

### *3.2.1.3 Thin-Film Photovoltaics*

Thin-film photovoltaics are the thinnest and least expensive photovoltaics produced. Unfortunately, they are also less efficient than traditional crystalline silicon photovoltaics. These devices are made by depositing thin layers of photovoltaic material on a substrate. The thickness of the film varies from the nanometer range to the micrometer range. This is much thinner than the silicon wafers used in crystalline silicon photovoltaics. When deposited on a flexible substrate, such as plastic, the photovoltaics can be applied to curved surfaces. Figure 9 shows a thin-film cell that has been deposited on a flexible plastic substrate.

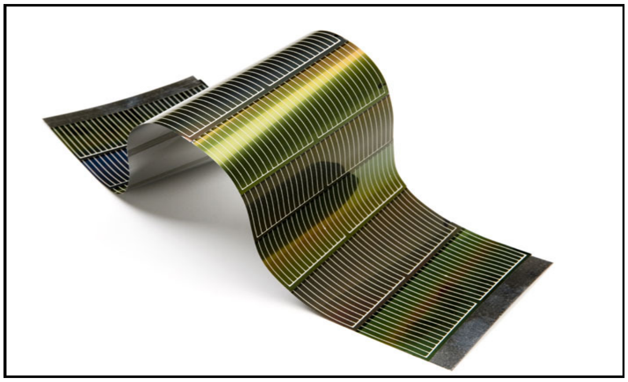


**Figure 9 -** Flexible Thin-Film Cell

Amorphous silicon photovoltaics were the first thin-film solar cells to be made commercially available. They are made by vapor-depositing a 1 $\mu m$ thick layer of silicon on a plastic, glass, or metal substrate [6]. Unfortunately, these cells suffer from the Staebler-Wronski effect which describes the degradation in photoconductivity with prolonged exposure to intense light [7]. This causes the efficiency of these cells to decrease over time until a stabilized efficiency is reached. Typical efficiencies for amorphous silicon modules drop from 10% to 7% due to the Staebler-Wronski effect [6]. Although the efficiencies of these cells are limited, they are still competitive due to their affordability and flexibility.

Cadmium telluride photovoltaics are another kind of thin-film solar cells that solve the efficiency problem present in the amorphous silicon technology. First Solar recently reported its average commercial module efficiency to be 14.7% [8]. This is competitive with the 14% efficiencies found in polycrystalline silicon modules. Cadmium telluride cells currently represent 7% of the world photovoltaic market [8]. Although these cells yield high efficiencies at a low cost, there are concerns about both the scarcity of tellurium and the toxicity of cadmium. Since this technology is newer and somewhat controversial, it is not as available as amorphous silicon photovoltaics.

### 3.2.2 Display Screens

Due to the fact that our project will require the use of a display screen to provide a visual source to output data we must make an analysis of different relevant technologies. There are currently two major types of display screen technology. First there is CRT, cathode ray tube, and technology. This is used mostly in older TV models apparent in the 1980s through 1990s. Over the past few years a newer type of TV emerged and quickly taken controlled of the display screen market. This technology is called flat panel displays [12]. This analysis will go over the advantages and disadvantages in each of the possible display screen technologies.

The first option for a display screen would be a cathode ray tube TV. Even though the technology used in this device is fairly outdated the price to acquire these devices is extremely cheap and fairly accessible. However actually using this technology would bring a lot of disadvantages. Major disadvantages would be its size, weight, and energy consumption is all considerably large. Building a solar powered blinds project requires optimization in all of these fields.

The next type of display screen would be using flat panel display technology. Flat panel displays are the newer of the two technologies and can be found pretty commonly now. Different models of flat panels exists LCDs, LED, and E-Paper displays are all examples of a few types of flat panel displays [14]. Using a flat panel display have many advantages over CRT for example they can be found in various sizes readily, the energy consumption in flat displays is substantially less, and the weight is much lighter so they can be easily mounted to the blinds structure.

LCD and LED display screens would be very ideal if the output we choose to display has constantly changing data. This data would need to be changing every few seconds to minutes to really benefit from the screens low power consumptions. For instance, if we displayed the time on the blinds having an LCD or LED screen would be very useful for energy consumption. Reasons why we would need to consider displaying images or data that is constantly changing is because LCD and LED screens all have a normally high refresh rate. This refresh rate is used to update the images on the display. For an example let's consider that a screen is operating at a 60Hz refresh rate. That’s means the display is attempting to refresh the screen 60 times per seconds. Which if the images are not changing is a complete waste of energy. So the previous statement holds that this type of display would be useful if the display is constantly outputting a different variety of data. Another option of LED screens would be to use a segmented display but this would limit what we can output as visual data [13].

A new and very appealing technology to use is electronic paper displays. These e-paper displays allow data to be retained on screens even after the power sources are turned off completely. This feature is called “bistable” which in practice the display is truing consuming power only when the display is active (changing). So in contrast to using a LCD/LED screen where even non changing screens require a refresh rate of even 30 times a second minimal, the e-paper display will be refreshing at a far slower rate and conserving even more energy. Adding times when we know the images are worth changing, we could consider even turning of the power to the display utilizing the bistable feature [9]. A visual representation of the technology can be seen in Figures 10 and 11, reprinted with permission from Persuasive Displays INC [10].

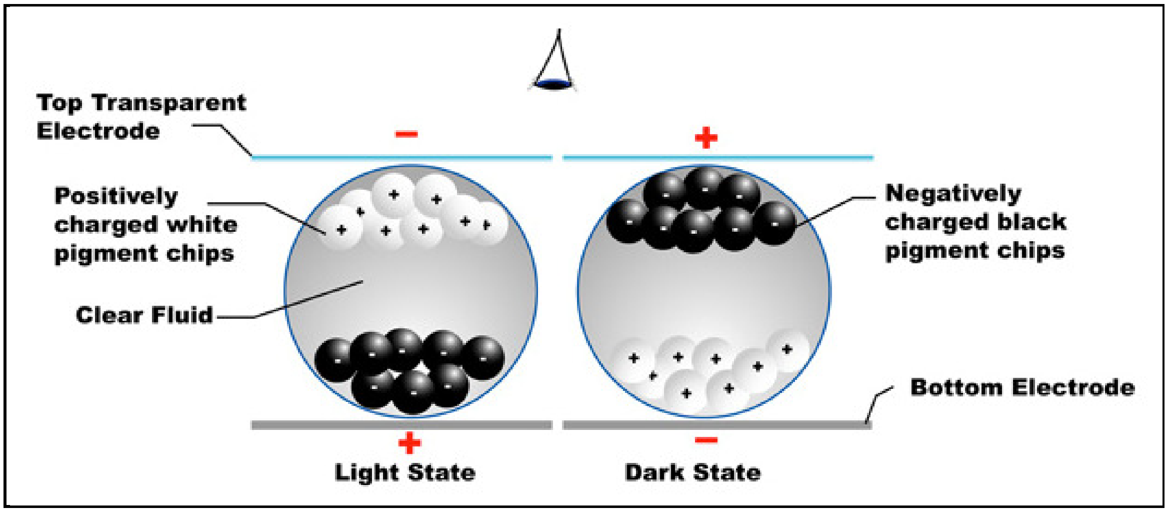


**Figure 10 -** Two Pigment Ink System

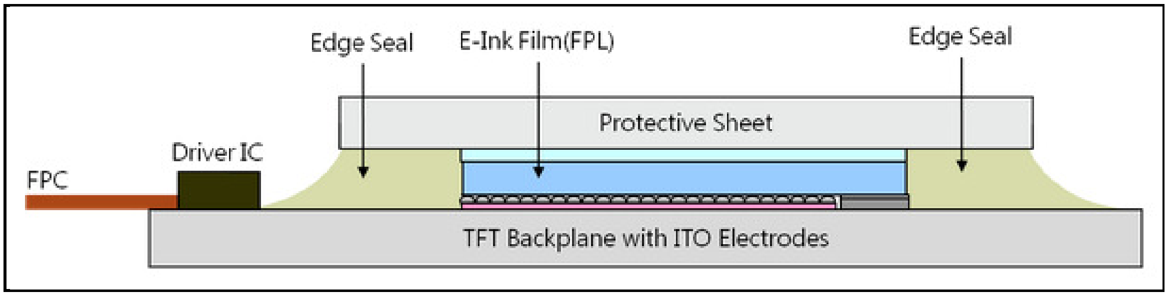
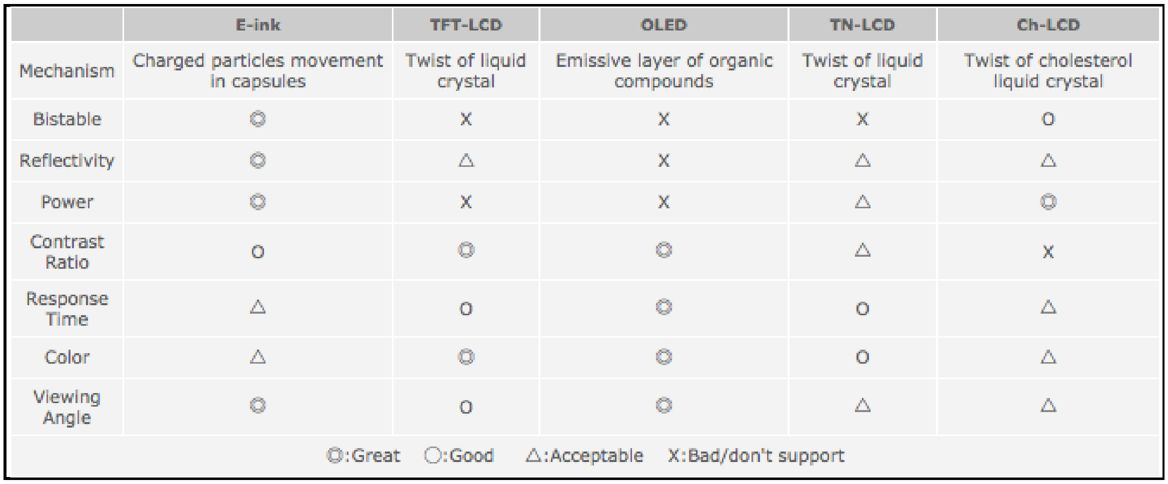


**Figure 11 -** E-Paper Module Components

In our project let's say for an example we would like to display the charging battery icon, weather status, and temperature status most of the time these images will not need to be updated a substantial amount of times. Using an e-paper display would drastically reduce the energy drain on the system unlike a LCD/LED. The only downside to actually using an e-paper display is there is a slight increase and price, especially if we wanted to consider getting a multi-colored display model. Being that it’s a newer technology the average price is higher than something of similar standards like an LCD/LED.

A comparison of various electronic display technologies can be seen in the chart in Figure 12, reprinted with permission from Persuasive Displays INC.



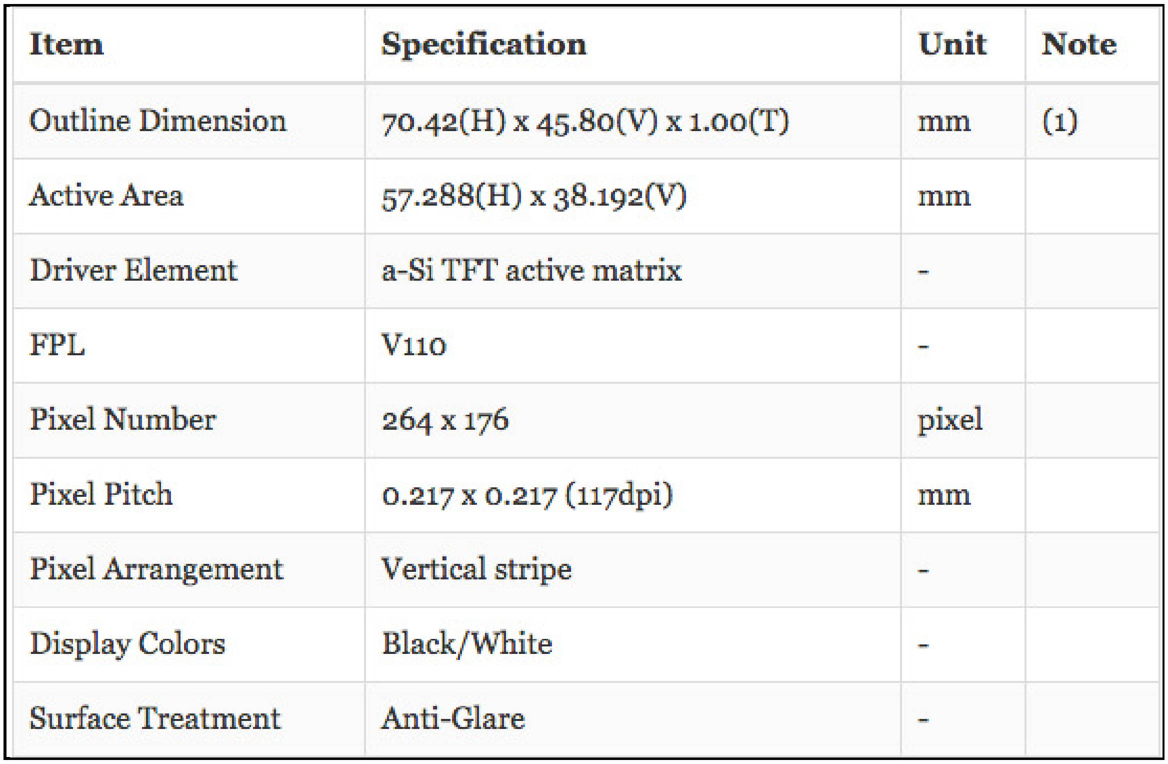
| | E-ink | TFT-LCD | OLED | TN-LCD | Ch-LCD |
|---|---|---|---|---|---|
| Mechanism | Charged particles movement in capsules | Twist of liquid crystal | Emissive layer of organic compounds | Twist of liquid crystal | Twist of cholesterol liquid crystal |
| Bistable | ◎ | X | X | X | O |
| Reflectivity | ◎ | △ | X | △ | △ |
| Power | ◎ | X | X | △ | ◎ |
| Contrast Ratio | O | ◎ | ◎ | △ | X |
| Response Time | △ | O | ◎ | O | △ |
| Color | △ | ◎ | ◎ | O | △ |
| Viewing Angle | ◎ | O | ◎ | △ | △ |

◎:Great ○:Good △:Acceptable X:Bad/don't support

**Figure 12 -** Comparison Table of Display Technologies

For this project we decided to go with an e-paper display for practical reasons that the overall goal of this project is to converse energy and provide an alternate renewable energy source. The specific e-paper display we are getting will be Persuasive Displays 2.7 E-Paper display. The specific Digikey part number is E1270CS021-ND and its price before tax is $21.72 [11].

Persuasive Display's 2.7 E-Paper display specifications are shown below in Figure 13, reprinted with permission from Persuasive Display INC.



| Item | Specification | Unit | Note |
|---|---|---|---|
| Outline Dimension | 70.42(H) x 45.80(V) x 1.00(T) | mm | (1) |
| Active Area | 57.288(H) x 38.192(V) | mm | |
| Driver Element | a-Si TFT active matrix | - | |
| FPL | V110 | - | |
| Pixel Number | 264 x 176 | pixel | |
| Pixel Pitch | 0.217 x 0.217 (117dpi) | mm | |
| Pixel Arrangement | Vertical stripe | - | |
| Display Colors | Black/White | - | |
| Surface Treatment | Anti-Glare | - | |

**Figure 13 -** General Specifications

## 3.2.3 Motors

### *3.2.3.1 Motors Overview*

We have been looking for used motorized blinds to see if there is a way to take the motor out of an old pair and use them for our project. The reason for this is because I assumed it would be much cheaper to just take apart an old pair of blinds and use the motor, then pay for a brand new motor. However, as I have been searching through the internet, it seems that they are approximately the same price and can be quite expensive. The roller blind motor seems to be the most commonly used motor and seems to be the most inexpensive. This motor however, only has one point that rotates that could be used for either opening or closing the blinds. There is no mechanism to connect to that would allow for the blinds to rotate to open first, and then be opened or closed. This poses a problem for us because we are trying to do both of these things. This brings up the idea then, of creating another gear that the motor would crank, that would adjust the rotation of the blinds as they are being opened or closed. So instead of doing these two actions separately, they could be done simultaneously and controlled by a basic blind motor.

These motors seem to range in price anywhere from 70 to over a 100 dollars. This seems to be a bit expensive for a motor when you could just buy the whole assembly for about 120 dollars. The motor kits that they are selling as well online are about a total of 115 dollars to make and install your own motor.

Originally, we had theorized that a vertical slat design would be the easiest and most effective to implement for our project. A concept rendering of this design can be seen in Figure 14, courtesy of BlindsParts.

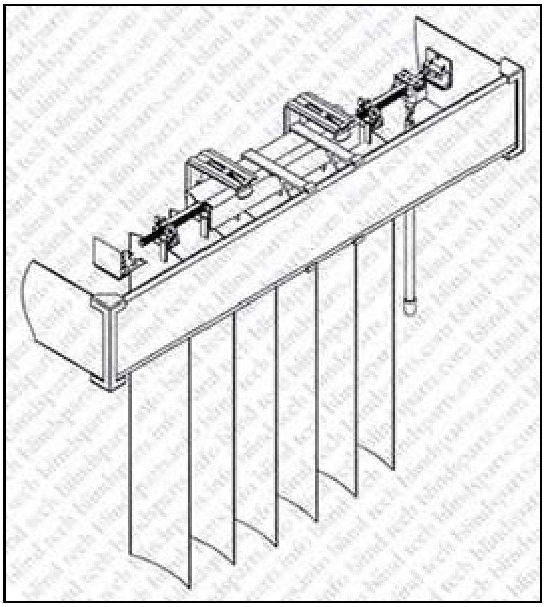


**Figure 14 -** Vertical Blinds Concept

The simplest solution that I have found through research, is to just get two separate small D/C motors, that are pretty inexpensive and will have enough torque to turn the blinds and then enough to open the blinds all the way. One of the D/C motors will be to spin the blinds to open the slats. The second motor will be to draw the blinds open all the way. The motors will have a limit switch that will let the motor spin a certain amount to stop the blinds from overturning or trying to open them too far.

Just about as we had decided on the blind and motor layout, we saw another architecture that seems to be the most plausible way to go. This architecture uses a pull down blind shade which can be automated by a single motor. This will significantly simplify the process of attaching the motor and it will cut the rice in half as we will only have to use a single motor instead of two. The shade will still be automated, but it will only have to be rolled up and down. It will not have to turn and then have to be drawn open. It also takes away from more potential points of failure as well as cutting the power that will be needed to open these blinds. Figure 15 depicts a sample of the assembly we are anticipating of having for our project design.

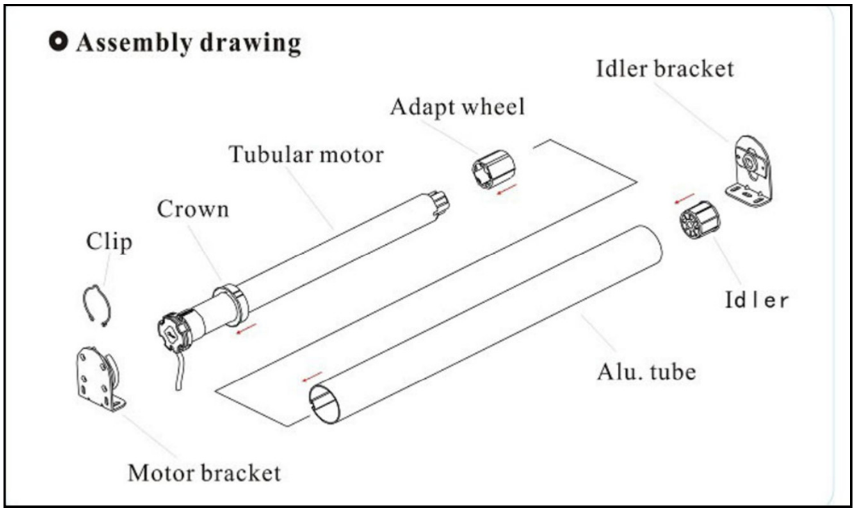


**Figure 15 -** Motor for Rolling Shades Architecture

As shown in the figure above, after we have obtained the motor, we will also need to have the mounting brackets. These will be custom fitted for the window that the system will be installed into. The housing we will use will have to be a small form fitting enclosure which means that our PCB will have to be a smaller PCB and the amount of components we can hide in the enclosure is limited. Most importantly we will have to make sure that the mounting brackets are installed correctly and securely so that the blinds will not fall out of the wall. This is a major deal because we can't have any safety issues and we don't want the system to fall and get damaged from the wall.

### *3.2.3.2 Servo Motors*

Looking into the option of using a servo motor, it seemed to be a bit of overkill. The price for this motor seemed financially unaffordable. This motor is retailed at six hundred and twenty dollars. This is very high compared to some other options. The motor is definitely more than enough to get the job done though. It has enough power to turn the blinds and to open the blinds all of the way.

The motor has the some of the following specs. The power that is used to run this motor seems to be way too unattainable. It requires four hundred watts of power to run. The rated voltage for this part is one hundred and fifty volts. This motor has a rated speed of five thousand revolutions per minute. This is more than enough for this project especially with a peak speed of eight thousand revolutions per second. The torque is much more than believed to be needed at twenty inch pounds [15].

The motor seems to be a bit heavier than what would be desired. It weighs in at a little bit over three and a half pounds. This is a little too heavy since there will be two of the motors in these blinds, as one would be motor to turn the blinds, and one would be to open the blinds all of the way. The motors need to be mounted in a fixture on the wall which means that a lighter motor would be desired as to not stress the fixture mounted in the wall.

After looking at all of these specs on this servo motor, it is apparent that it is not the right motor for this project. It is too big and bulky and is very unaffordable and uses too much power for our solar powered power supply.

### *3.2.3.3 DC Motors: Leeson Motors DC Motor-.05 - .1HP, 12-24V, 1750-4200RPM, TENV, Sq. flange*

This next motor is a D/C motor that seemed to be a bit more affordable than the servo motor that was previously looked at. This motor is priced at approximately one hundred and thirty five dollars. This motor also offers a square mounting surface on the sides of it that make it much easier to mount inside of a housing. This motor has a horsepower of one half to approximately one. This is once again, more than enough to do the job we need it to in our project. The revolutions per minute are seventeen hundred and fifty [16]. This is still overkill on the blinds. The blinds can open much slower if needed to. The working voltage is also much more attainable because the voltage required to run this is in the range of twelve to twenty four volts. A drawback on this motor that was the same as the servo motor is that the motor weighs four pounds. So adding eight pounds into the fixture hanging from the wall is going to loosen the mounting mechanism overtime much faster than a lighter motor.

This motor is also very large. It is almost half of a foot. This is another drawback because we do not want the fixture on the wall to be too bulky. This motor having been still too expensive, too large, and weighing too much will not be a motor that will be used to work with our project. This motor can be seen in Figure 16, courtesy of Leeson Motors.

**Figure 16 -** Leeson Motors's DC Motor

### *3.2.3.4 DC Motor – 13800 RPM 3VDC 350mA*

This motor seems to have a lot more promise than the previous motors that have been looked into. This motor is much more affordable to say the least. This motor is retailed at only a dollar thirty nine. The only issue that may be ran into with this motor is that the motor may not have enough torque, but this will have to be determined later on in the testing procedure.

### *3.2.3.5 12V Motor with Drive Shaft*

This motor seems to be the closest to what we have been looking for. It is a motor that is designed specifically for motorized blinds and is used to roll up the blind shade. The housing on the motor is long like a tube and it is a relatively low-profile housing for this motor. It seems to be pretty easy to install and looks like it will get the job done. It is a twelve volt low powered motor too, which is exactly what we were looking for since we are running our entire project off of our battery. The smaller than amount of power used is, the better. Also, this motor is rated to pull up a load of up to six pounds.

This seems to be way more than enough for a thin blind shade with a solar panel that just has a film on it. The torque rating on the motor is .7 nm which seems to be a perfect amount for this project. It is also able to rotate at thirty four revolutions per minute. The standby current for the motor is eighteen milliamps and the most current it can possibly draw is twelve hundred milliamps which is when it stalls [17]. The normal current draw when in operation is approximately eight hundred milliamps. This is definitely viable since we will have a battery that is sixty watt hours. The tube length for the motor comes in any size from twelve inches to anything larger. This definitely seems to be the right motor for us and our needs for this project. A breakdown of parts for this motor can be seen in Figure 17.

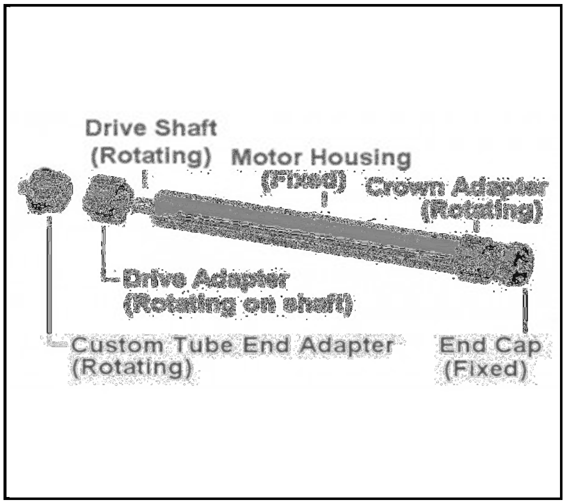


**Figure 17 -** Drive Shaft Motor

## 3.2.4 Remote Connectivity

A wireless connection will be required to communicate between our device and a mobile phone equipped with the corresponding application. There are several different options available to us to accomplish this goal: Wi-Fi, Bluetooth, or Zigbee [18]. While power consumption is an important focus of the product, we will not require an "always-on" connection so this may not be the defining factor for which connection method we choose to take. Because of this, we will also need to take into account other metrics in addition to power consumption such as range, interference, security, and bandwidth. These metrics have been gathered and compiled into Table 5 for easy comparison [19].

| Connect Method | Active Power Consumption | Idle Power Consumption | Max Range | Security | Interference | Bandwidth |
|---|---|---|---|---|---|---|
| **Wi-Fi** | 750 mW | negligible | 32-95 m | WPA2 | Minimal at 2.4 GHz | 54 Mb/s |
| **Bluetooth** | 100 mW | negligible | 10 m | CRC | Minimal at 2.4 GHz | 1 Mb/s |
| **Zigbee** | 80 mW | negligible | 10 m | AES & CTR with CTM | Minimal at 2.4 GHz | 250 kb/s |

**Table 5 -** Comparison of RF Specifications

### *3.2.4.1 Wi-Fi*

Common Wi-Fi frequency ranges are around 2.4 GHz and 5 GHz. The main benefit in the 2.4 GHz system is that it has a longer wavelength meaning it can bend around corners a little better than its 5GHz equivalent. This makes it good for large homes or apartment buildings. However, since the 2.4 GHz standard is more common, it is prone to interference it here are multiple other routers using the same frequency within a certain proximity. It is also prone to interference from other devices such as cell phones.

If we choose to use a Wi-Fi chip on our microcontroller, it will require the user to purchase and set up their own wireless router. Also, it would take significantly more power to operate than either Bluetooth or Zigbee options. It also takes additional steps to set up through a router. The main benefit of this is the significantly longer range. If it's connected to a router, it can potentially be accessible from anywhere that has a wireless connection. However, the power drain from Wi-Fi does not make this a good option.

### *3.2.4.2 Bluetooth and Zigbee*

Bluetooth and Zigbee are both very similar in terms of power consumption, range, and security protocols. However, with Zigbee being the newest standard to enter the remote connectivity lineup, there are still problems to be worked out. Some of these problems include interoperability [20] and a lack of development resources.

Bluetooth has a new standard they refer to as Bluetooth Low Energy (BLE). BLE has a bit lower range and bandwidth than traditional Bluetooth technology, but we will not be requiring frequent or large data transfer between the MCU and mobile application. We also expect it to be used from within the same room as the blinds. Additionally, Bluetooth technology has been around for many years, so there are ample resources available on the web to assist us in software development. For all of these reasons, we will choose to go with a Bluetooth connection for convenience and power consumption.

### *3.2.4.3 RFID*

Our project will require a "sync" feature that will allow the user to register the device with their mobile phone in order to control operation of the blinds with the mobile application. One of the methods being considered for this synchronization is a radio frequency identification (RFID) chip. The RFID tag would be located inside the control housing for the blinds and the phone would act as the RFID reader.

A product that uses RFID to connect to smart phones is Assa Abloy Hospitality Mobile Access (formerly VingCard Elsafe). This technology allows the user to make a reservation at a participating hotel location through their mobile app. When the user arrives at the hotel, they can just go straight to their room where an RFID-compatible locking mechanism is installed on the door. The user simply has to put the phone in proximity to the door to unlock the door and the check-in process is completed automatically [23].

The main focus for us in Assa Abloy's product is its compatibility with RFID technology. Specifically, it uses near-field communication (NFC) which utilizes the high frequency band of RFID [21]. This requires very close proximity between the tag and the reader, approximately 4 inches. Additionally, NFC communication can go both ways since either device can act as a tag or reader. This may allow us to display a "synced" notification on the integrated display screen on the blinds.

Additionally, smart phones that are NFC compatible can be used as electronic wallets as well. There is an increasing number of retail checkout card scanners that support the use of NFC cards to pay for products. This is usually indicated by a prompt similar to, “Tap or swipe your card”. The “tap” portion of this is enabled through the use of NFC built into a chip on certain credit cards. The technology in compatible smart phones can be used in the same manner.

Compatibility might be a problem for using NFC technology with our mobile phones. However, cell phones from most major manufacturers such as Acer, BlackBerry, HTC, LG, Motorola, Nokia, and Samsung have come equipped with NFC capabilities for several years now [22]. One notable exception to this are that all iPhones older than the iPhone 6. This is not a major setback for us since we are currently only planning to support Android devices with our mobile application. Also, NFC is supported after Android 2.3.3, SDK version 10, which was released on February 9, 2011. As we can see in Figure 1, the amount of people that would not be able to use this feature is only 0.3% (Froyo) of Android users (as of June 1, 2015) [24].

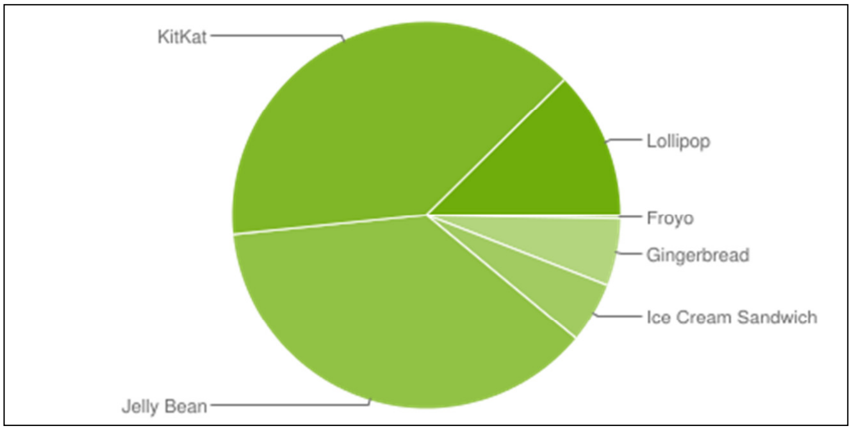


**Figure 18 -** Android API Distribution as of June 1, 2015

One feature of the Android API is that a setting can be specified to only allow Google Play to display the application to users with NFC-compatible phones. However, we will still keep it in Google Play even for non-compatible phones for publicity.

## 3.3 Possible Architectures and Related Diagrams

### 3.3.1 Microcontroller Units Architecture

There are several possibilities when deciding on a microcontroller unit. The first consideration is the type of architecture to use. At the highest level, the possible MCU architectures we have to consider are the Von Neumann architecture and the Harvard architecture, with Von Neumann being the older of the two. The main difference is the way the memory is set up [26].

Getting more specific, some common MCUs are MSP430, 8051, PIC, AVR, and ARM. We want to use the newer Harvard architecture for this project because it is the more popular of the two in modern microcontrollers, and it would provide us with more relevant experience for future projects. MSP430 uses Von Neumann architecture, so we will rule that out as one of our possibilities. Older ARM units use Von Neumann as well [24]. This leaves us with 8051, PIC, AVR, and newer ARM processors.

Out of these four remaining architectures, AVR and ARM are the newest. As a result, they are generally faster than the 8051 and PIC MCUs [28]. Additionally, 8051 and PIC have small stack space and can be a bit challenging for C programming [29]. Assembly programming is still viable, but would take a bit more time.

Focusing on AVR and ARM, we can see that both are very good options. There are multiple free compilers available for both, and they're both very widely used in modern applications. However, AVR is designed specifically for use with video codecs and for use in devices such as Apple's iPod. ARM on the other hand, has a wide range of uses and is heavily used in smart phones. As a very flexible and powerful option, we choose to go with an ARM MCU. Also, since ARM processors are used in a wider variety of products in the current economy, this would provide us with good experience which is highly probable to be used in future applications.

The ARM processor has more processing capabilities than we require for this project. If we were developing this product for actual marketing for a company, I would probably not use the ARM because of the (slightly) extra power consumption and additional cost. However, we want the learn how to use the ARM processor to allow us to explore future opportunities and careers.

### 3.3.2 Motors Architecture

Eagle and LtSpice will be the programs that we will be using to design our schematic for our board. Each part will have its own library with its own package, device and schematic symbol. We will be aiming to use 603’s as much as possible because the cavity in the blind housing is relatively small, so we will try to make the board as small as possible. There will not be very many parts on the physical PCB layout since we will be using a battery controller externally to charge the battery from the solar energy. The only circuits on the board itself will be the regulation circuit from the battery to the necessary voltage to operate the micro and to charge any USB device that will be plugged in as well as operate the motor.

### 3.3.3 Power Distribution Architecture

The basic power distribution layout is shown below in Figure 19. The solar module is the only power input into the battery. A solar charge controller will be necessary in order to maximize the amount of power being input into the battery and also to provide protection circuitry for the solar module input and load outputs. The loads include the roller blind motor, microcontroller, USB charger, and e-paper display. Appropriate circuitry will be required to deliver the correct amount of power to each sub-system and to protect each load from receiving too much power. Since the solar module will only charge the battery during the day, the loads should be chosen to draw as little power as possible while still accomplishing the desired function.

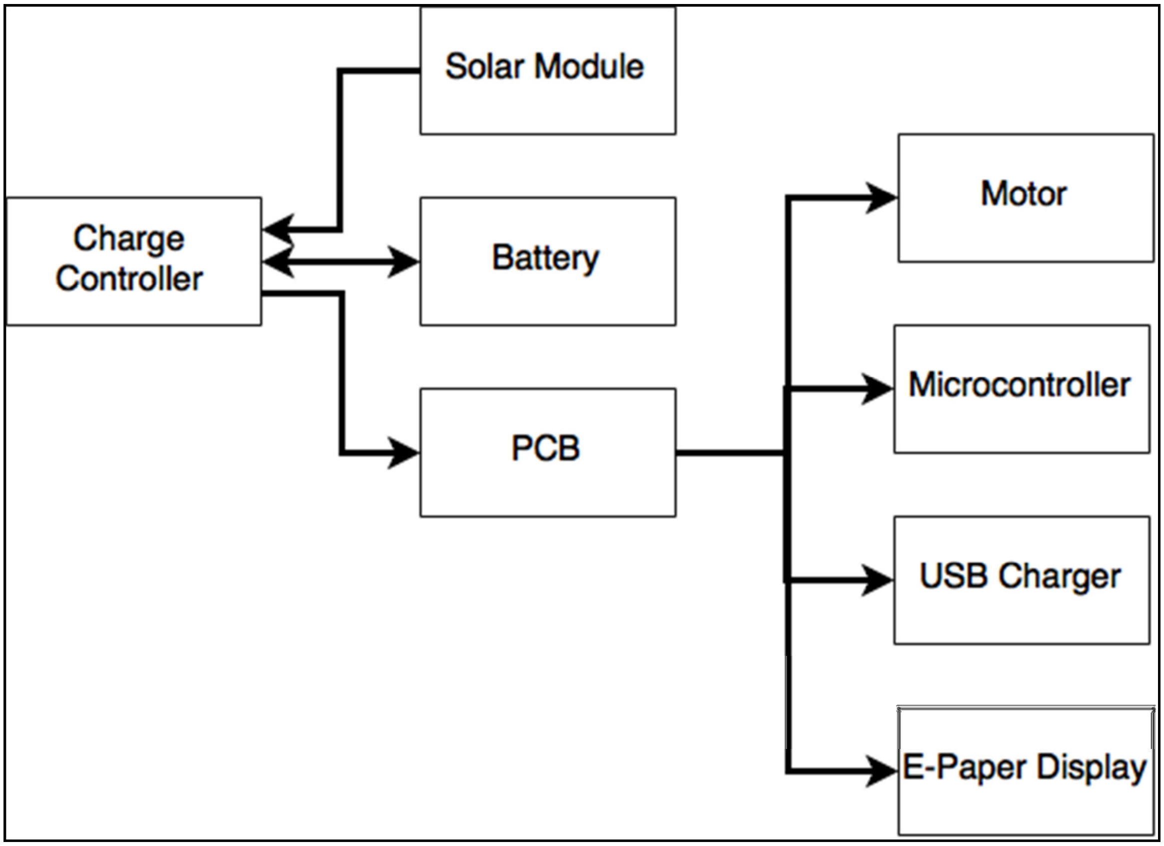


**Figure 19 -** Power Dissipation Architecture

### 3.3.4 Power Input

#### *3.3.4.1 Solar Module Options*

There are a variety of solar cell technologies to choose from when designing an application that will collect solar energy. These include monocrystalline silicon, polycrystalline silicon, and amorphous silicon photovoltaics. Crystalline silicon photovoltaics are non-flexible and would need to be installed to blinds having large vertical or horizontal slats. The advantage to using crystalline silicon photovoltaics is that they yield higher efficiencies. This means they will provide more power to the battery for every hour of incident sunlight using the same amount of space. The size of each module would need to match the size of each slat. The modules could be connected in series or in parallel in order to increase the output voltage or current of the system. Amorphous silicon photovoltaics are flexible and can be attached to roller shades, but are less efficient than crystalline photovoltaics. Several larger modules could be used and attached directly to the back of the shade. This would reduce the complex wiring necessary when using crystalline photovoltaics.

ML Solar carries a set of 40 3”x6” polycrystalline photovoltaics for $33.95. These cells are shown below in Figure 20, printed with permission from ML Solar. Each cell has an average power of 1.8 W operating at a maximum voltage of 0.5 V and a maximum current of 3.6 A. These cells can be connected in series in order to achieve the higher voltage necessary for charging a 12 V lead acid battery. A voltage of 13.5 to 13.8 V is recommended for charging a 12V lead acid battery; however, the charge controller will regulate the voltage to match that of the battery if the voltage of the solar module exceeds that of the battery. Using 30 of these cells connected in series will provide a total average power of 54 W operating at a maximum voltage of 15V and a maximum current of 3.6A.

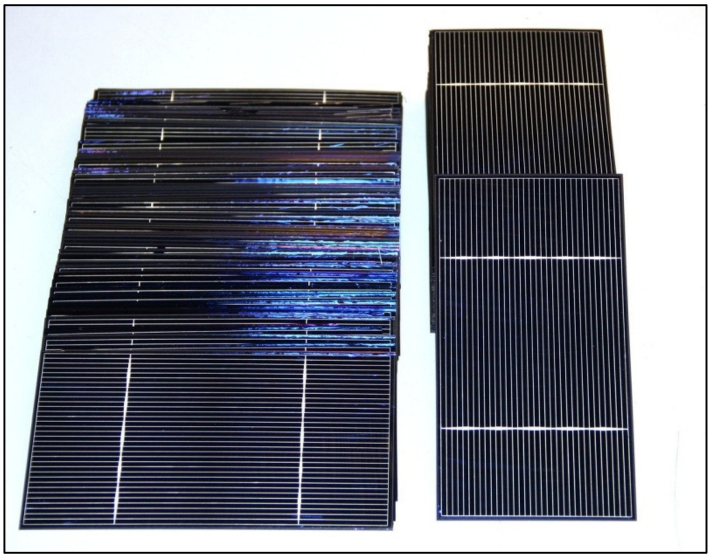


**Figure 20 -** ML Solar 3”x6” Polycrystalline Cells

Blocking diodes will need to be used in order to keep the current flowing in the correct direction. Bypass diodes will also be needed in order to bypass a cell that is shaded. Figure 21 shows how the cells can be connected in series when using the blocking and bypass diodes.

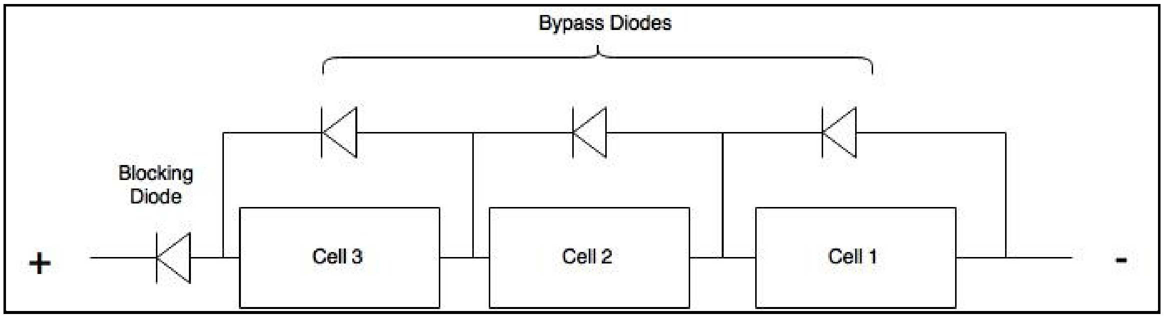


**Figure 21 -** Connecting Solar Cells in Series

Five cells can be connected in series on each of six vertical 6” slats. This will create six 9W modules that can be connected in series to form the final 54 W module. This module will be capable of capturing the amount of energy capable of being stored by the 60Wh battery in about 1.1 hours under ideal lighting conditions. While the amount of power capable of being captured by these cells far exceeds that of the amorphous silicon cells, the wiring required would be more intricate and blinds with large slats would need to be used.

Sunpower carries a set of 20 6”x6” monocrystalline photovoltaics for $89.99. These cells are shown below in Figure 22, printed with permission from cicibizhk (eBay). Each cell has an average power of 3.3 W operating at a maximum voltage of 0.58 V and a maximum current of 5.93 A. Similar to the polycrystalline cells, these cells can be connected in series in order to achieve the higher voltage necessary for charging a 12 V lead acid battery. Using 18 of these cells connected in series will provide a total average power of 59.4 W operating at a maximum voltage of 10.4 V and a maximum current of 5.93 A. The charge controller will need to be able to boost the voltage and drop the current in order to safely charge the battery.  Three cells can be connected in series on each of the six vertical 6” slats. This will create six 9.9 W modules which can be connected in series to form the final 59.4 W module. This module will be capable of capturing the amount of energy capable of being stored by the 60Wh battery in one hour under ideal lighting conditions.

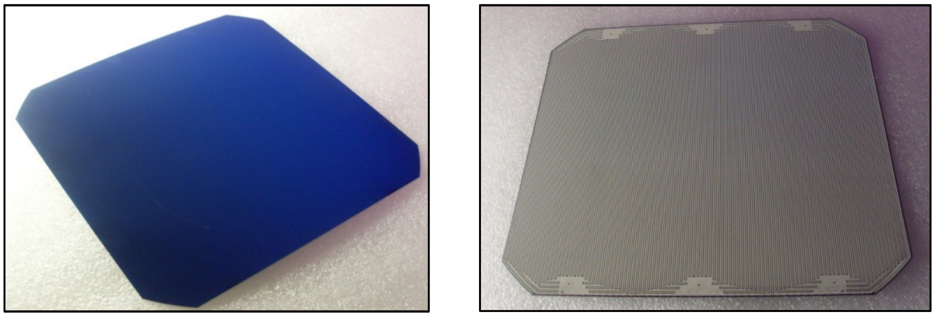


**Figure 22 -** Sunpower 6”x6” Monocrystalline Cells

Powerfilm makes a series of rollable, amorphous silicon panels, which come in a variety of sizes. They are made using a proprietary roll process, which makes them much more flexible then other thin film technologies. The R-14 model is 14.5”x42” and costs $185.99. This panel is shown in Figure 23, printed with permission from FlexSolarCells. The panel has a total average power of 14 W operating at a maximum voltage of 15.4 V and a maximum current of 900 mA. A blocking diode is built into the unit to prevent back charging. If more power is desired, panels can be connected in parallel to achieve a higher current. The voltage of the panel is ideal for charging the 12 V lead acid battery being used to store energy. This module will be capable of capturing the amount of energy capable of being stored by the 60Wh battery in 4.29 hours under ideal lighting conditions. Although the panel is more expensive and less efficient than the crystalline silicon modules, the rollable nature of the product would allow for it to be easily attached to a roller shade. This would drastically reduce the amount of solder connections needed, which reduces the amount of failure points in the system. The panel also weighs 0.98 lbs, which will not put much stress on the motor used to roll the shade.

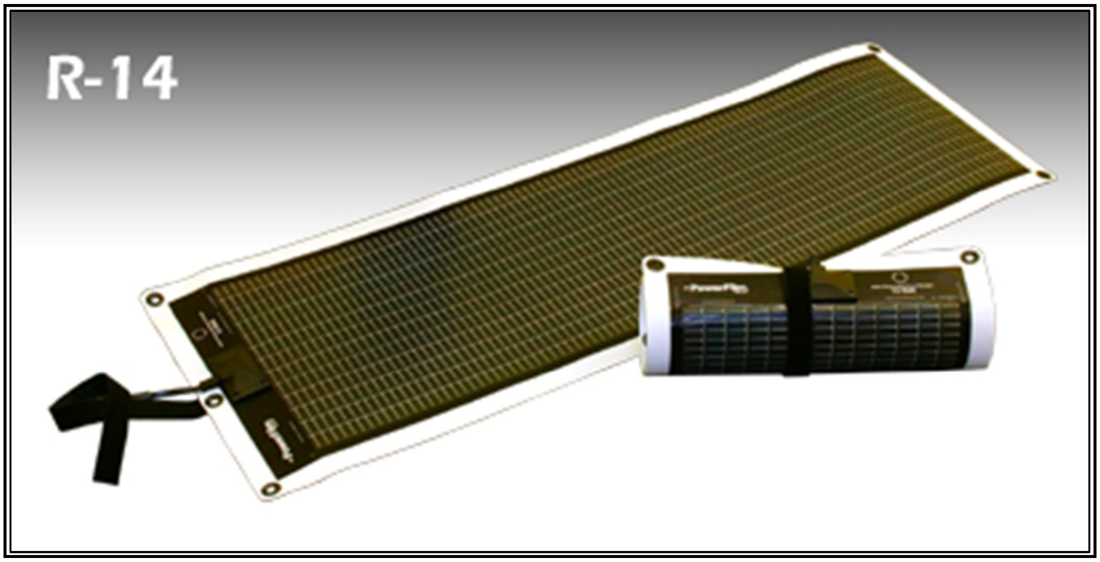


**Figure 23 -** Powerfilm R-14

In order to maximize the power capable of being captured by the system while maintaining the roller shade design, a combination of crystalline solar cells and amorphous silicon solar panels can be used. The 3.3 W 6”x6” monocrystalline photovoltaics can be attached to the back of the 6”x6”x36” housing unit used to store the battery and circuit boards. Connecting six of the cells in series would produce 20.6 W operating at a maximum voltage of 3.48 V and a maximum current of 5.93 A. Adding the 14 W amorphous silicon rollable solar panel brings the total power of the system to 34.6 W. This system will be capable of capturing the amount of energy capable of being stored by the 60Wh battery in 1.73 hours under ideal lighting conditions. A diagram of the system described is shown in Figure 24.

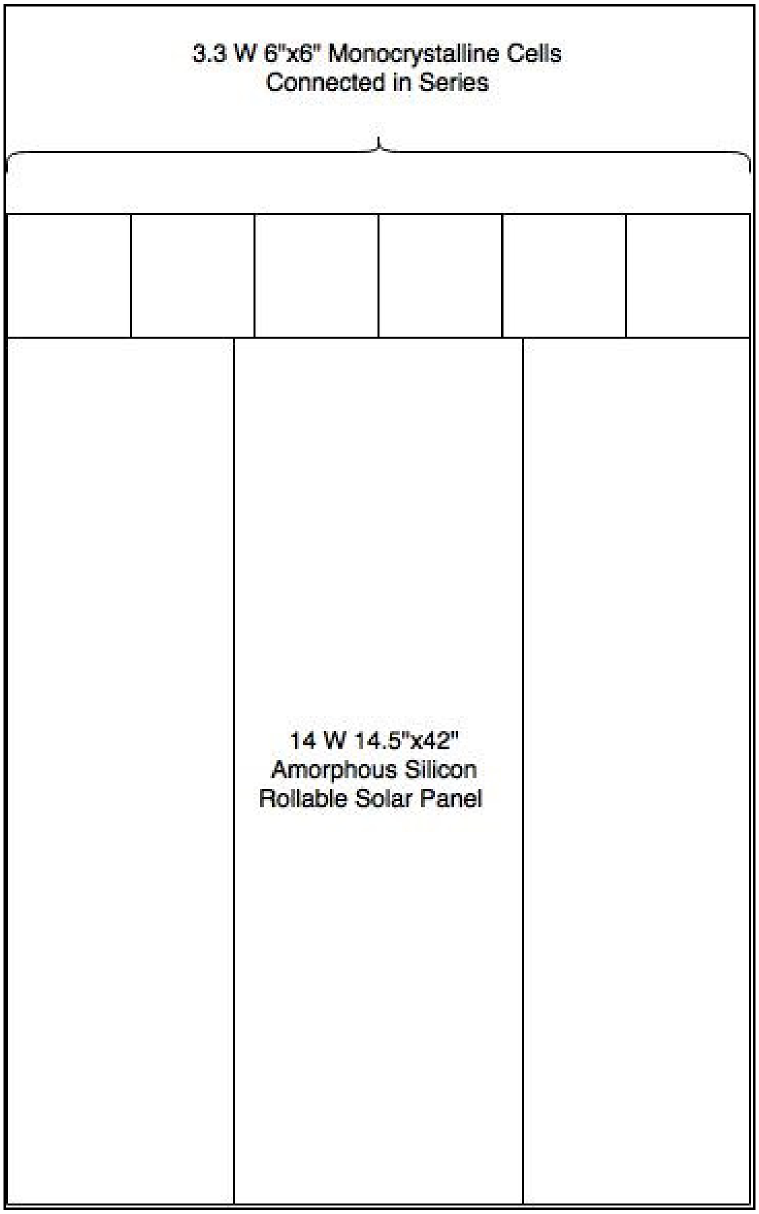


**Figure 24 -** Crystalline and Amorphous Silicon Design

### *3.3.4.2 Maximum Power Point Tracking*

Maximum Power Point Tracking (MPPT) compares the output voltage of the solar module to the terminal voltage of the battery. From this information, the maximum power that can be output by the solar module into the battery is calculated. The optimized voltage is then selected in order to maximize the current flowing into the battery. The efficiency is increased most when temperatures are below average. A 20-45% power gain in winter and a 10-15% power gain in summer can be achieved when an MMPT is used [30].

The MMPT circuit is a high frequency DC-to-DC converter. It takes the DC input from the solar modules and converts it to high frequency AC signal. It then runs the AC signal through a transformer and a rectifier to convert it back to a different DC voltage and current that matches the battery voltage. Since light and temperature conditions vary continuously throughout the day most MMPT charge controllers are now digital microprocessor controlled devices. Several companies make MPPT charge controllers with varying costs, peak efficiencies, speeds, max panel voltages, battery voltages, and max load currents.

The Genasun GV-5 is a 65W 5A MPPT solar charge controller for lead-acid batteries. An image of this controller is shown in Figure 25, printed with permission from Genasun. The controller costs $75.00 and has a maximum recommended panel power of 65 W. Inputs include a 27 V maximum panel voltage input, a 12 V battery input and a load input with a continuous rated load current of 5 A. Although it is rated for 27 V, a 22 V maximum panel voltage is recommended under standard operating conditions. The minimum battery voltage for normal operation is 7.2 V and the maximum input current is 9A. A computer controlled four-stage battery charging profile is used in order to increase the battery life and maximize capacity. This includes an absorption voltage of 14.2 V, a float voltage of 13.8 V, and a load disconnect voltage ranging from 11.4 to 12.5 V. A battery temperature compensator is also included which adjusts the voltage at a rate of -28mV/°C. The controller utilizes an MPPT tracking speed of 15 Hz in order to adapt quickly to changing light conditions. This results in an electrical efficiency of 96%-99.85% and a tracking efficiency of 99+%. The controller uses ceramic components instead of electrolytic components in order to increase the product lifetime. A 10-year warranty is included with purchase. The GV-5 consumes 0.150 mA when operating and 0.125 when asleep. It weighs only 2.8 ounces and has dimensions of 4.3”x2.2”x0.9”. A built-in electronic protection circuit cuts power when a short circuit is detected. This will protect the controller from damage if the polarity of any of the inputs is mistakenly reversed.

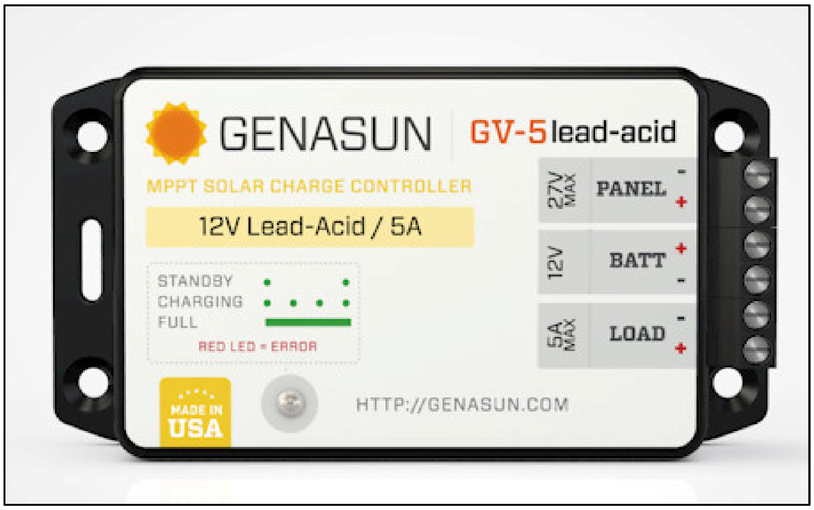


**Figure 25 -** Genasun GV-5

Genasun also makes the GV-4 and the GV-10, which are similar controllers that are designed for smaller and larger panel powers respectively. The GV-4 costs $65.00 and has a maximum recommended panel power of 50 W. The GV-10 costs $109.00 and has a maximum recommended panel power of 140 W. Inputs include a 27 V maximum panel voltage input and a 12 V battery input. There is no load input on either of these controllers. The warranties on the GV-4 and GV-10 are five years, which is half the warranty of the GV-5. All of the other characteristics of these charge controllers are identical to those of the GV-5 [31].

#### *3.3.4.3 Pulse Width Modulation*

A pulse width modulation (PWM) charge controller is less expensive than an MPPT controller and is more ideal for small systems. It can be used if the solar module voltage is matched to that of the battery under normal operating conditions. Unlike the MPPT controller, which operates at above the battery voltage, the PWM operates at the battery voltage. It performs best in warm weather and when the battery is near full [32].

In PWM charging method the charge controller sends out a short charging pulse of energy to the battery. The controller then checks the state of the battery to determine if more pulses should be sent and how wide the pulses should be. If the battery is fully discharged the controller will send out longer pulses at a steady rate. When the battery is nearly full the pulses will become shorter and shorter. The controller checks the charge of the battery between pulses and adjusts the pulse accordingly.

The Morningstar SS-6L-12V is a 12 V 6 A PMW solar charge controller. An image of this controller is shown in Figure 26, printed with permission from MorningStar. The controller costs $45.00 and has a maximum recommended panel power of 72 W. Inputs include a 30 V maximum panel voltage input, a 12 V battery input, and a load input with a continuous rated load current of 6 A. The controller consumes 8 mA when operating which is many times more than the MMPT controller. The minimum battery voltage for normal operation is 1 V and the load in-rush capability is 45A. A four-stage battery charging profile is used in order to increase the battery life and maximize capacity. This includes an absorption voltage of 14.1 V, a load disconnect voltage of 11.5 V and a load reconnect voltage of 12.6. A battery temperature compensator is also included which adjusts the voltage at a rate of -30mV/℃. A 5-year warranty is included with purchase. It weighs 8 oz. and measures 6”x2.2”x01.3”. A built-in electronic protection circuit protects the controller from overload, short-circuit, and high voltages from the solar and load inputs as well as high voltages from the battery.

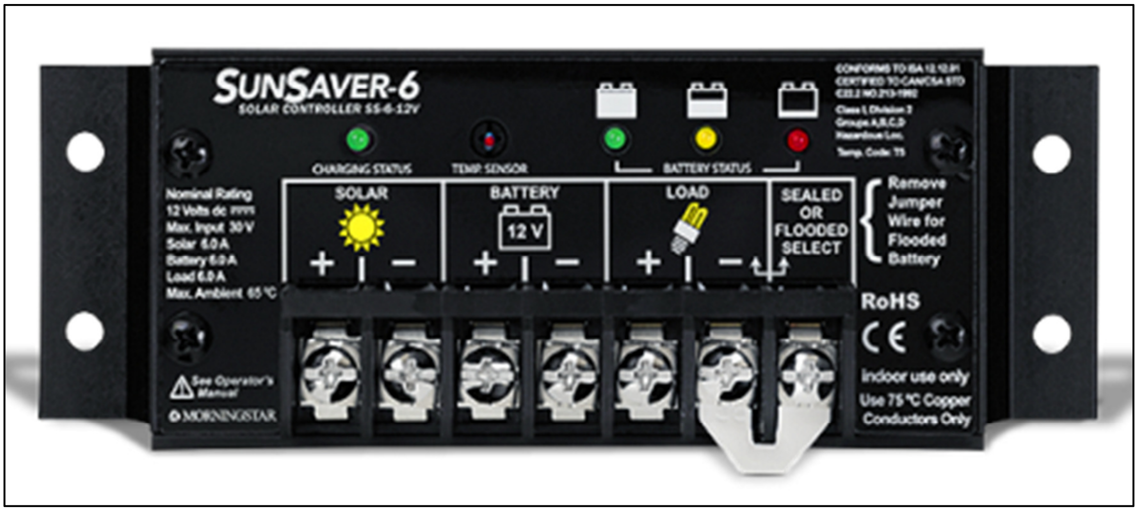


**Figure 26 -** Moringstar SunSaver-6

Morningstar also makes the SS-10L-12V, which is a similar controllers that is designed for larger panel powers. This controller costs $55.00 and has a maximum recommended panel power of 120 W. Inputs include a 30 V maximum panel voltage input, a 12 V battery input, and a load input with a continuous rated load current of 10 A. The controller consumes 8 mA when operating which is many times more than the MMPT controller. The minimum battery voltage for normal operation is 1 V and the load in-rush capability is 65A. All of the other characteristics of these charge controllers are identical to those of the SS-6L-12V.

### 3.3.5 Battery Options

When selecting a battery to use for solar energy storage it is important to consider the cost, lifetime, size, environmental impact, and reliability of the different technologies available. A deep cycle battery is required for applications where the battery will be regularly discharged at a low rate over several hours. This is in contrast with a shallow cycle, or starter, battery, which delivers a high power pulse over a short period of time. The battery selected for this project will have to be a deep cycle battery because USB charging will require the battery to be discharged at a low rate. Two battery chemistries that are commonly used for solar energy storage are lead acid and lithium-ion. Lead acid batteries are the best option when working with a limited budget because they are more affordable than lithium-ion batteries.

Lead acid batteries can be divided into two main types: flooded and sealed. Flooded lead acid batteries are more affordable than sealed lead acid (SLA) batteries; however, they require upright orientation to prevent leakage, a ventilated environment, and routine maintenance. SLA batteries can be further divided into GEL and absorbed glass mat (AGM) categories. AGM batteries are more common because they offer higher current rates and display long life cycles when discharged less than 60% between recharges [33]. They are also less expensive than GEL batteries. GEL batteries have longer life cycles than AGM and perform better in higher temperature environments. Lithium-ion batteries are the best option when a high life cycle is desired. They are more expensive than lead acid batteries; however, they are lightweight and less sensitive to variations in temperature.

The Powerizer 12 V 5Ah LiFePO4 rechargeable battery costs $79.95. This battery has a built in PCB to protect it from being overcharged (>15.6 V), over discharged (<8.8 V), or over drained (>40~60 A). An LED indicator is also built in which shows the capacity status. The battery is rated to have a cycle life of greater than 1000 cycles. The maximum charging rate is 2.5 A and the maximum discharging rate is 10 A. The battery measures 3.5”x2.8”x3.98” and weighs 1.48 lbs. It has T1 terminal connectors.

The Universal Power Group UB250 12 V 5Ah SLA AGM rechargeable battery costs $9.93. The battery is rated to have a cycle life of 200 cycles when the battery is discharged 100%, 500 cycles when the battery is discharged 50%, and over 1200 when the battery is discharged 30% before recharging. The lifetime for this battery is shown graphically in Figure 27, printed with permission from UPG. The battery measures 3.54”x2.76”x3.98” and weighs 3 lbs. It has F1 terminal connectors.

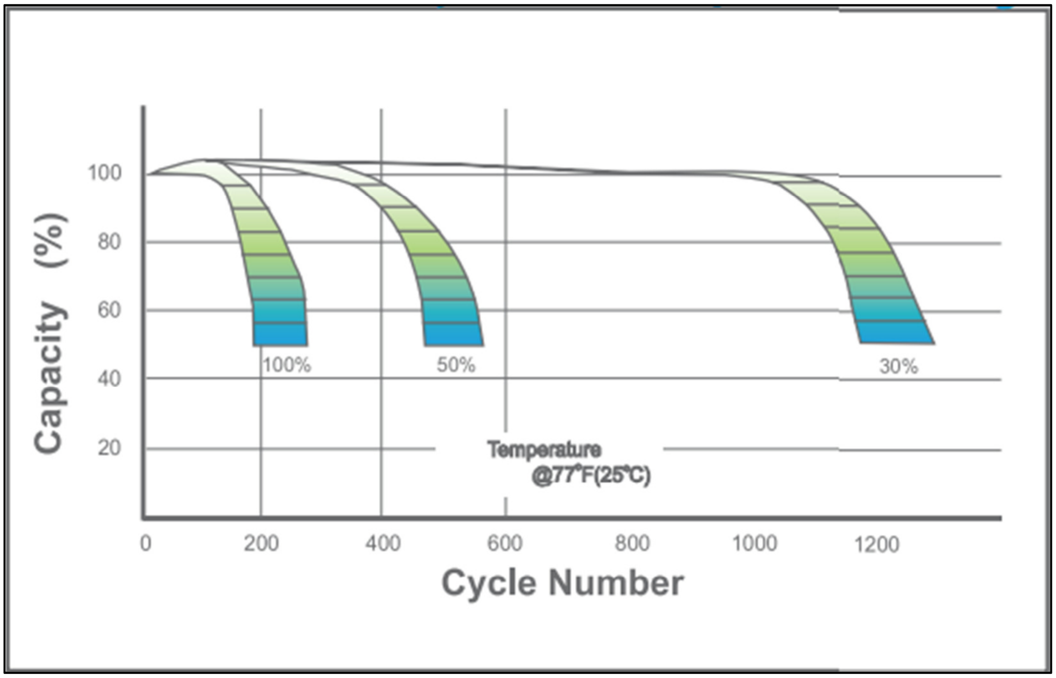


**Figure 27 -** Cycle Life vs Depth of Discharge for UB250 Battery

The lithium-ion battery is about eight times more expensive than the lead acid battery with similar specifications; however, there are several safety features that are built in to the lithium-ion battery that are not included in the lead acid battery. Since a solar charge controller will be used regardless of the battery chemistry the added circuitry of the lithium-ion battery that provides protection from overcharging, over discharging, and over draining is unnecessary. There is no indicator on the lead acid battery to show the capacity status; however, a simple battery monitor chip could be implemented such as the Maxim DS2438 Smart Battery Monitor. The 8-pin DS2438 is shown in Figure 28, courtesy of Maxim, and costs less than $5.00. It features a battery temperature sensor, battery voltage and current meters, and an integrated current accumulator. The voltage meter can be used for defining the end-of-charge and end-of-discharge voltages. The current accumulator keeps a running total of all current going into and out of the battery [34].

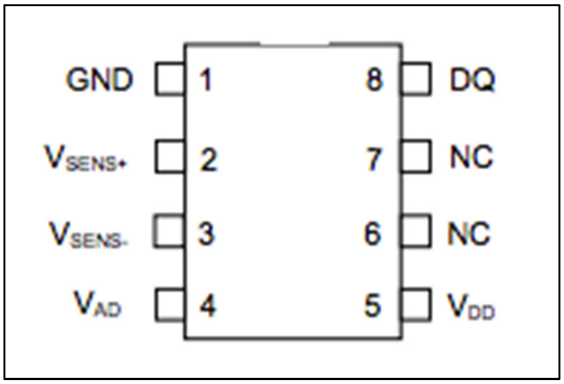


**Figure 28 -** Maxim DS2438

The cycle life for the lithium-ion battery is about twice that of the lead acid battery when the battery is discharged 50% before it is recharged. If the lead acid battery is only discharged 30% before it is recharged then the lifetime is about the same as the lithium-ion battery. If the battery will be discharged completely every night then it would be most beneficial to spend more upfront on the lithium-ion battery. If the battery will be discharged less than 50% before it is recharged then the lead acid is a much more affordable option. Even if the lead acid battery needed to be replaced up to seven times in the time that it would take the lithium-ion battery to retire it would still be the more economical option; however, it would have a larger environmental impact. It is important to correctly recycle batteries of all chemistries in order to reduce the environmental impact.

### 3.3.6 Power Output

The load output of the charge controller will be connected to the PCB which will be designed to deliver a specified amount of power to each of the loads. The loads include the roller blind motor, the microcontroller, the USB charger, and the e-paper display.

#### *3.3.6.1 Roller Blind Motor*

Roller blind motors operate at 12 V and draw around 1 A of current when operating. The standby current for the motors is around 20 mA. Higher standby currents are typical for motors with radio controllers. Since the motors operate at 12 V there is no need to convert the voltage for this load. A resistor will need to be used in order to limit the amount of current that is required for the motor to work when the radio control is activated. The value of this resistor will depend on which roller blind motor is chosen.

#### *3.3.6.2 Microcontroller*

The Atmel SAM3N00A is one of the low power options available by Atmel. Normal operation requires 1.62-3.6 Volts, with a power consumption of 3 $\mu A$ in backup mode and 5-15 $\mu A$ in wait mode.  Table 6 shows the active power consumption of the remote connectivity options available.

| **Remote Connectivity Technology** | **Active Power Consumption** |
|---|---|
| Wi-Fi | 750 mW |
| Bluetooth | 100 mW |
| Zigbee | 80 mW |

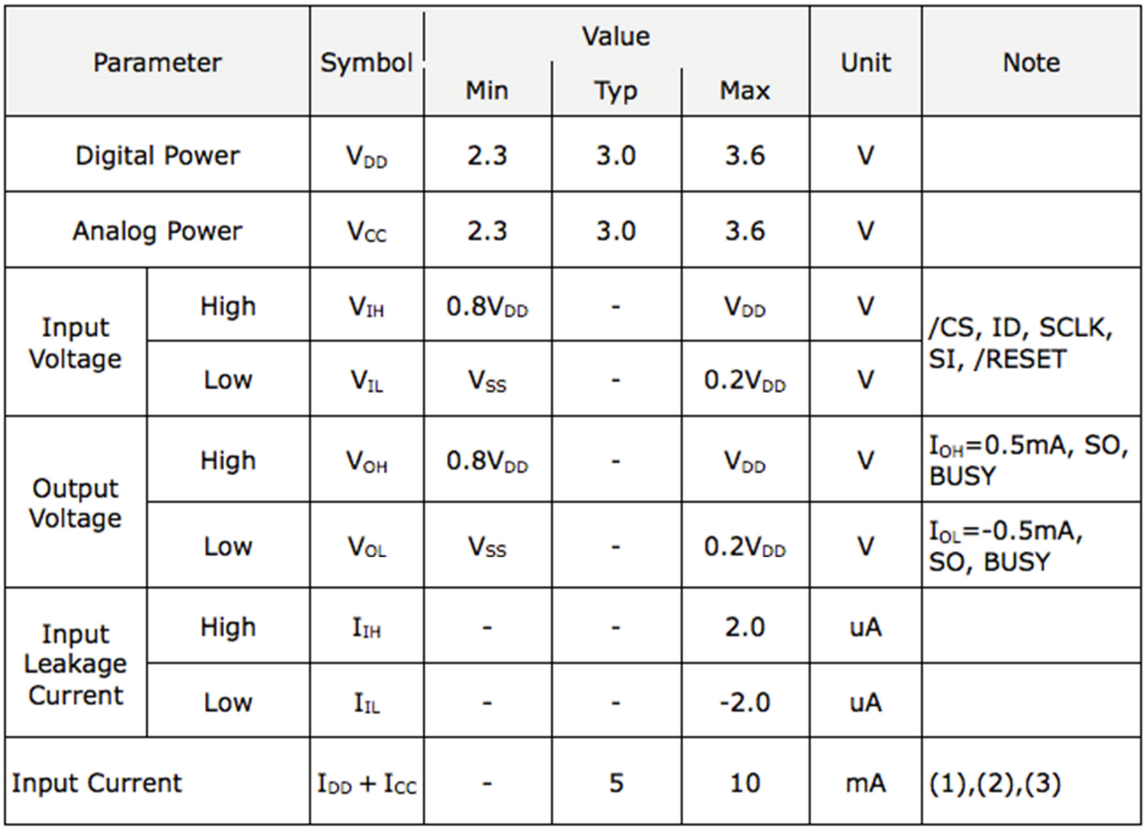
**Table 6 -** Remote Connectivity Power Consumption

#### *3.3.6.3 USB Charger*

The biasing of the four USB pins is important when deciding on what kind of devices will be capable of charging. Pin 1 is defined as Vcc and is always biased at 5V. A 5V voltage regulator will be needed in order to reduce the 12 V battery voltages to 5 V. The TI L7805 voltage regulator will maintain a fixed output voltage of 5V with a maximum output current of 1.5 A. Pin 4 is defined as ground and is always connected to ground. The charging port of a USB chargeable device contains hardware that detects when a charger is connected. Traditional USB ports have a maximum output of 0.5A; however, newer devices are capable of using higher currents, which results in faster charging times. Pins 2 and 3 are defined as the data pins. Pin 2 is the negative data pin and pin 3 is the positive data pin. If the data pins of a charger are left floating then the device will default to the traditional 0.5 A rate. If the data pins are shorted then the device will be capable of drawing larger currents. This current will depend on the resistors used.

#### *3.3.6.4 E-Paper Display*

Figure 29 shows the recommended operational conditions for the Pervasive Displays 2.7 inch E-paper display. This is a bit higher than expected, but the statistics themselves are a bit misleading. The reason we chose to go with the e-paper display over some other options is that it only requires power to change the display. All figures displayed on the screen will persist even without any power. This is perfect for our project because the only time we need to update the screen is when there is a temperature change or a significant change in the battery charge.



| Parameter | | Symbol | Value | | | Unit | Note |
|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | | |
| Digital Power | | $V_{DD}$ | 2.3 | 3.0 | 3.6 | V | |
| Analog Power | | $V_{CC}$ | 2.3 | 3.0 | 3.6 | V | |
| Input Voltage | High | $V_{IH}$ | $0.8V_{DD}$ | - | $V_{DD}$ | V | /CS, ID, SCLK, SI, /RESET |
| | Low | $V_{IL}$ | $V_{SS}$ | - | $0.2V_{DD}$ | V | |
| Output Voltage | High | $V_{OH}$ | $0.8V_{DD}$ | - | $V_{DD}$ | V | $I_{OH}$=0.5mA, SO, BUSY |
| | Low | $V_{OL}$ | $V_{SS}$ | - | $0.2V_{DD}$ | V | $I_{OL}$=-0.5mA, SO, BUSY |
| Input Leakage Current | High | $I_{IH}$ | - | - | 2.0 | uA | |
| | Low | $I_{IL}$ | - | - | -2.0 | uA | |
| Input Current | | $I_{DD} + I_{CC}$ | - | 5 | 10 | mA | (1),(2),(3) |

**Figure 29 -** Operational Conditions for E-paper Display

## 3.4 Possible Software Development Environments

### 3.4.1 Embedded Microchip Environments

Since we will be using an ARM microcontroller unit, we will need development software that is compatible. First, we will need to find out what language would be best to use. There are several languages we could use such as assembly, C, C++, Pascal, Basic, Java, and some others. However, when developing for an MCU, we will want to focus on assembly or C for portability and efficiency reasons. With C being a more intuitive language than assembly, we will go with that language instead. Most modern compilers can translate C language to the MCU almost as efficiently as writing optimal assembly code directly. The only reason to ever really program an MCU with assembly anymore is if the response time of the application needs to be as real-time as possible, such as with some devices used in the medical field or the military.

Now that we have decided to use the C software language, we will need an IDE that supports both C and ARM. There are many choices, but we will consider the following:

- Code Composer Studio
- Crossworks
- DS-5 (Eclipse plugin)

- Keil MDK

Code Composer Studio has limitations on its free software, and still requires an annoying download and setup process for it. Crossworks does not appear to be very user-friendly. Keil MDK appears to function well and without much of a learning curve. DS-5 has a free community version, which is a plugin for the Eclipse IDE. This is an alluring option because we have used the Eclipse IDE for Java development during previous courses using Java.

We decided to go with the Code Composer Studio for our embedded software development. At first, the DS-5 plugin seemed like a good option, but upon reflection it seemed that it might cause more complications. The risk of delaying our project development is not worth the convenience and familiarity it may give. Since Code Composer Studio is specifically geared toward MCU programming, it should handle any of our requirements without any unforeseen complications. We have also used it in previous courses, but to a lesser extent and not as recently. Even so, even a limit experience with the program should help to ease the transition to a new IDE and help the development process go more smoothly.

### 3.4.2 Mobile Application Environments

The mobile application for this project will be developed for Android devices. The core programming language we decided to use is either Java or C#. With this in mind a few software development platforms can be considered.

First on the list is Google’s recently revamped Android Studio. This would serve as the best ideal development program if we would choose Java as the primary application development. Reason being it supports the development of android apps, has a vast amount of resources and guides to help prevent problems, and is directly related with android’s creators. With Android Studio’s built in features like intelligent code editor, GitHub integration, multi screen app development, virtual devices, and Android builds. Having all of these features in one platform can save the developers the trouble of exporting code and upload the different builds [36].

Another considerable software development platform for the mobile application would be Xamarin. Xamarin is another platform developed and managed by a software company called Oracle. This platform utilizes C# as the core programming language instead of common languages like Java, Objective C, and Swift used in most other mobile application development platforms. Other features in Xamarin are built in user interfaces, API Access, and the Xamarin Test Cloud. If we were to choose Xamarin the developers would be required to learn and use C#. This is not a bad thing but can set them back as they would need to have experience and knowledge. Not having this experience can create a possible learning curve but the developers will have an opportunity to both learn and use a new programming language and platform [35].

Another benefit of Xamarin would be the increase in accessibility of the mobile application. This is because Xamarin allows iOS development readily unlike Android Studio. The disadvantage is that it cost money to actually place the application on Apple's Appstore. This is just a consideration though since we actually have no planned to develop or even place on the Appstore. So this is more so a feature that is only nice to have.

The last option for a mobile development platform is Eclipse IDE. This one would require the most behind the scenes setup to get started but allows many of the same features as the other two platforms.

For our mobile platform since we are planning to use Xamarin we will have an abundance amount of resources fully at our disposal.

## 4.0 Related Standards

Standards greatly affect how new technologies are spread in the United States. The purpose of forming standards is to simplify product development and to ensure safety in the development and use of new products. Standards make products more interoperable, which can lead to faster development and cost reduction. Many standards will be utilized in our project including safety standards, reliability standards, communication standards, programming language standards, connector standards, and battery standards. Some of these standards will be pre-established by organizations such as IEEE, ANSI and UL and others will be project specific. Below are a few of the standards that will be used in our project.

### 4.1 Safety Standards

Table 7 lists the safety standards relevant to our project. As always, safety is a primary concern in any project. Our project does not involve any hazardous materials or sharp objects, but safety should always be considered when working with electrical parts. For example, the housing in which the electronics and the rolled up canvas will be housed will possibly reach high temperatures since it will be in direct contact with the window, at least on one sight. We have to consider the fact that this may pose a fire hazard.

| Standard | Description |
|---|---|
| IEC 61508 | Functional safety of electronic and programmable safety-related systems. |
| NFPA 70 | National Electrical Code that specifies safe electrical design, installation, and inspection to protect people and property from electrical hazards. |
| UL 50 | Performance requirements for enclosures to provide a degree of protection to personnel against incidental contact with enclosed equipment |
| UL 62109-1 | Describes standard for safety of power converters used in photovoltaic power systems. |

**Table 7** - Safety Standards

### 4.2 Reliability Standards

Table 8 lists the reliability standards relevant to our project. The purpose of a project would be meaningless if the product is not designed to be reliable. In this case, our largest reliability risk will be the solar cells we use to absorb energy from the sun. We will need to know the exact characteristics of our cells in order to properly utilize them and ensure maximum performance and, therefore, reliability.

| Standard | Description |
|---|---|
| UL 61215 | States requirements for testing crystalline silicon photovoltaic modules to determine the electrical and thermal characteristics, which are used to determine if the module is capable of withstanding prolonged exposure to a specified climate. |
| UL 61646 | States requirements for testing thin-film photovoltaic modules to determine the electrical and thermal characteristics, which are used to determine if the module is capable of withstanding prolonged exposure to a specified climate. |

**Table 8 -** Reliability Standards

### 4.3 Communications Standards

Table 9 lists the standards for communications. The three possible protocols we would be using are either Wi-Fi or Bluetooth, as well as RFID.

| Standard | Description |
|---|---|
| IEEE 802.11b | Defines wireless-networking specifications up to 11 Mbits/s using a 2.4GHz band (Wi-Fi). |
| IEEE 802.15.1 | Defines wireless medium access control and physical layer specifications for wireless personal area networks (Bluetooth). |
| IEEE 802.15.4f | Defines protocol for active RFID and sensor applications |

**Table 9 -** Communications Standards

### 4.4 Programming Language Standards

In reference to the standards of the programming languages we are following many of the standardizations of ISO/IEC 9899:2011 also known C11. However for personal preferences below are some case specific guidelines the developers will be responsible for following at all times.

#### 4.4.1 Version Control

In order to handle the version control of the mobile application development the developers plan to integrate a code collaboration tool into the development cycle. There are quite a few collaboration tools to choose from but we are going to limit the choices to the following four tools only: Beanstalk App, Cloud9, GitHub, and Jira [37]. This following discussion will analyze the advantages, disadvantages, and the overall cost association with using these tools.

A distributed software company called Wildbit makes the Beanstalk App. This company's focus is to improve the way web apps are built, ran, and deployed. The overall ideal behind the beanstalk app is to create a hosting service that can offer and all GitHub and SVN version control, developer collaboration tools, and deployment tools. Beanstalk is also packed full with multiple useful features designed to help developers track code changes, error tracking, and deploy working code [38].

Beanstalk's pricing plans varies depending on the needs of the projects and developers. However they do offer a free plan that is available for the first two weeks of a subscription. The prices for continuing use after the end of the two weeks go for $15 per month up to 200 per month. There are also two different levels of pricing plans. One being made for freelancers and startups that as the prices increase the only changes in the plans are to the total storage space, repositories, users, and servers. The other level is made for businesses and enterprises that add more features altogether to the plans. These features are bonuses like added security tools, priority support, and custom backups. For our projects development this added features may be a little bit extreme in terms of what we actually plan to build for the mobile application [39].

Overall Beanstalk is a great tool the developers can use to code and work together. With features like version control, code editing using their built in editors, and many more. The only downside is that the tool costs money monthly to use during the development phase.

The next tool for discussion is called Cloud9. This code collaboration tool differs from the other tools by the fact that it is more so like a cloud based IDE. This feature also makes Cloud9 have the ability to have real time coding and chatting unlike most of the other tools [43]. Cloud9 is able to do this by actually creating developer environments that can support a variety of languages we will b using to Cloud9 offer a free account with limited features and at max one premium workspace. The developers may be able to function completely with just a free account alone. However if not the pricing for Cloud9 base plans start at $9 per month going up to $79 per month for large plans [44]. This base plan will offer enough resources for sure to operate with minimum efficiency.

One of the most popular if not the most popular collaboration software tool available is GitHub. With the ability to work with the tool almost anywhere GitHub possesses a huge amount of advantages over its competition. Built as an open source platform so many companies have also built on add-ons or even integrated GitHub's services into their own products. With powerful collaboration tools, ability to perform code reviews along with code management, issue tracking, and completely free access to the entire feature without a paid plan GitHub may be the best pick as far as an all-in-one collaboration tool. The only disadvantage to using GitHub is the free plan limits the developers to a public repository. This means anyone can access the project to view our files of even use our code and work. The only way to gain access to a private repository is if we choose an upgraded plan starting at $7 per month. All of their plans each offer unlimited collaborators and public repositories. The only things that change as the prices increase is the total amount of private repositories available to the collaborators. The plan we intend to purchase would be the micro level plan that offers 5 private repositories. Also GitHub offers education discounts to even reduce the monthly costs even more [42].

Last but not least is Jira. Jira is a project management software product for collaborative development. It is made by a company called Atlassian, which specializes in making an assortment of products for developers trying to work together. The purpose of using Jira in contrast with some of the other collaboration tools is that it's great for planning, tracking, and reporting progress of the developers [40]. This is a great product for the developers who plan to use agile methodologies. The features built into Jira are knowledge management, development workflow, continuous integration, and real-time collaboration. Jira offers a free 7 days then prices vary depending on if you choose to be a cloud based or server based system. Cloud based systems range from $10 to $1,000 per month while server based systems range from $10 to $24,000 per month. The prices increases are as more users join your team it costs more monthly. All of the other features do not change. For the amount of developers for our project we would only need a plan costing $10 per month if we were to proceed and use Jira as a program management tool [41].

After considering all of the tools we decided that we would be using GitHub to handle our version control needs. We will be using the micro plan level. This plan will cost us normally $7 per month. However one of the developers in our project already owns an upgraded plan and has an extra private repository that we can use for this project. In doing so, we will be able to save us the cost of paying $7 per month in our project budget. Additionally, since we will be able to use a private repository, we can ensure that our intellectual property will not be vulnerable to others. It is important to protect the privacy of our work to avoid potential plagiarism claims if another group of people decide to steal our research and claim us as the violators.

### 4.4.2 Version Control Standards

The following list contains all of the version control coding preferences the developers must adhere too.

- The naming convention to keep track of forks in the repositories is as follows:
    - Ex: [1.00]ClassName.filetype
- A scenario of every time we upload a file with new changes, we will increment the version count of the name of the file. If the original file name is

[1.01]ClassName.filetype. After commiting code changes we would then upgrade the version count of the file to [1.02]ClassName.filetype.
  - Ex: Original = [1.01]ClassName.filetype
    New = [1.02]ClassName.filetype

- In order to avoid working on the same files at the same time we will follow this rule in certain scenarios. If we ever have to switch over the file we're working on, we'll formalize everything to the next version. So instead of [1.XX], we'll push it to [2.XX] so we don't have conflicting changes in the same file.

### 4.4.3 Embedded Language Standards

The developers are to abide by these standards set below at all times for the purpose of standardizing all code in the C language for embedded programming of the projects hardware applications.

#### *4.4.3.1 Naming Conventions Standards (Embedded Programming)*

Follow these naming conventions to ensure the developers know what the variable scope is along whether it's a function of file being used.

- Constants will use all caps.
  - Ex: int CAPS = 1000;
- Constants will use underscores to replace the spaces in the name.
  - Ex: int ALL_CAPS = 1000;
- Functions will use camel case with the first word always lowercase.
  - Ex: functionNamesLikeThis();
- File names will be camel case with the first word always uppercase.
  - Ex: FileNameLikeThis();
- Variable names will be all lowercase.
  - Ex: int lemons = 0;
- Variable names will use underscores to replace the spaces in the name.
  - Ex: int num_of_lemons = 0;
- All names should be descriptive enough to leave no ambiguousness to the other developers when reviewing code during a code review.

#### *4.4.3.2 Blank lines Standards (Embedded Programming)*

The use of blanks line should be standardize in a way the developers can easily scan the code to search and find what they are looking for. These rules should always be used in the following cases to ensure that the minimum extra white space will be in the code.

- Three lines inclusive should be in between sections in order to help separate the two areas of code.
  - Ex: After a method and before a new method there should be blank lines.
- One line break may be used to separate code inside of a function or method whenever it would improve readability.
  - Ex: Immediately after variable declarations and conditional statements
- All return statements will be separated from the code by a line break.
  - Ex: A code sample is shown below

    ```
    int main(){
            printf("Hi");
            return 0;
    }
    ```
- In all other cases there should be no line breaks unless it falls into one of the categories listed above.

*4.4.3.3 Function Formatting Standards (Embedded Programming)*

All functions in the code are to be standardized by the following rules.

- Immediately after naming or declaring a function an open bracket is to follow. Then an immediate line break wit the content of the function starting one indent inside of the previous indent mark. The closing bracket will be placed on a new line with the same indentation level as the original indentation at the beginning of the function.
  - Ex: A code sample is shown below

    ```
    private double functionNameHere(int some, int variable){
            printf("Group: ");   // Some example code
            printf("11");   // Indented like this
            return 0;
    }   // The closing brackets will always be on a newline.
    ```

*4.4.3.4 Comments Standards (Embedded Programming)*

The developers should avoid using multi line comments and follow these standards in regards to comments

- Each file will have multiple section headers (done with the built-in commenting syntax) in the following format:
  - Ex. A code sample is shown below

```
//**********************************************************
//*   Title of section, e.g. Header, Constants, Main Loop, or Functions    *
//*               Up to two lines of text inside - Centered                *
//*                                                                        *
```

```
//*********************************************************
```

- Every function will have a description of what it does, as well as a short description of each input and output (avoid using global variables besides constants), pass all inputs and outputs to/from the main loop with function calls and returns:
    - Ex: A code sample is shown below
      ```
      // Prints text to the screen
      // x: The text that is to be printed
      void printToScreen(String x) {
              printf("%s\n", x);
      }
      ```
- Besides the section headers and the function headers, all other developer comments will be end-of-line comments. First apply three spaces after the code. Then “//” followed by a space. Then immediately after the space you can type the details you wanted to address in the comment.
    - Ex: A code sample is shown below
      ```
      printf(“Hello World”);   // Print statement for Hello world
      ```

#### *4.4.3.5 Conditional Statements Standards (Embedded Programming)*

All types of statements and loops should be written as follows.

- First the type of statement or loop should be written. Then a space will follow separating the type from the opening parentheses. After the comparison statements are made a closing parentheses should be placed. Then a space will be in between the closing parentheses and the opening bracket.
    - Ex: A code sample is shown below
      ```
      for (i = 1; i < 10; i++) {
              printf("i = %d",i);
      }
      ```
- If statements, for loops, and while loops along with any other types shall be written with a space in between each of the elements and the operator inside of the parentheses.
    - Ex: A code sample is shown below
      ```
      if (a = b) {
              a++;
      }
      ```
- If they use brackets the open bracket should follow the closing parentheses with a space in between them. They closing bracket should be on a newline lined up with the beginning conditional statement indentation.

### *4.4.3.6 Miscellaneous Standards (Embedded Programming)*

These are miscellaneous standards for embedded programming that did not fit into any other specific areas.

- Try to avoid lines longer than 100 characters. This standard depends on the IDE we choose. Also this character count does not include comments.
- General progression: header > libraries > global variable declaration > main loop > function calls

## 4.4.4 Object-Oriented Language Standards

The developers are to abide by these standards set below at all times for the purpose of standardizing all code in the object-oriented language for mobile programming of the projects software applications.

### *4.4.4.1 Naming Conventions Standards (in object-oriented language)*

Follow these naming conventions to ensure the developers know what the variable scope is along with whether or not it is a function or file being used.

- Constants will use all caps.
    - Ex: int CAPS = 1000;
- Constants will use underscores to replace the spaces in the name.
    - Ex: int ALL_CAPS = 1000;
- Methods will use camel case with the first word always lowercase.
    - Ex: methodNamesLikeThis();
- Class names will be camel case with the first word always uppercase.
    - Ex: FileNameLikeThis();
- Variable names will be all lowercase.
    - Ex: int lemons = 0;
- Variable names will use underscores to replace the spaces in the name.
    - Ex: int num_of_lemons = 0;
- All names should be descriptive enough to leave no ambiguousness to the other developers when reviewing code during a code review.

### *4.4.4.2 Blank lines Standards (in object-oriented language)*

The use of blanks line should be standardized in a way the developers can easily scan the code to search and find what they are looking for. These rules should always be used in the following cases to ensure that the minimum extra white space will be in the code.

- Three lines inclusive should be in between sections in order to help separate the two areas of code.
    - Ex: After a method and before a new method there should be blank lines. One line break may be used to separate code inside of a function or method whenever it would improve readability.
    - Ex: Immediately after variable declarations and conditional statements
- All return statements will be separated from the code by a line break.
    - Ex: A code sample is shown below

      ```
      int main(){
              printf(“Hi”);
              return 0;
      }
      ```
- In all other cases there should be no line breaks unless it falls into one of the categories listed above.

### *4.4.4.3 Method Formatting Standards (in object-oriented language)*

All functions in the code are to be standardized by the following rules.

- Immediately after naming or declaring a method an open bracket is to follow. Then an immediate line break with the content of the method starting one indent inside of the previous indent mark. The closing bracket will be placed on a new line with the same indentation level as the original indentation at the beginning of the method.
    - Ex: A code sample is shown below

      ```
      private double methodNameHere(int some, int variable){
              printf(“Group: “);   // Some example code
              printf(“11“);   // Indented like this
              return 0;
      }   // The closing brackets will always be on a newline.
      ```

### *4.4.4.4 Comments Standards (in object-oriented language)*

All types of statements and loops should be written as follows.

- Each file will have multiple section headers (done with the built-in commenting syntax) in the following format:
    - Ex. A code sample is shown below

```
//***********************************************************
//*     Title of section, e.g. Header, Constants, Main Loop, or Functions       *
//*                     Up to two lines of text inside - Centered                        *
//*                                                                                                  *
//***********************************************************
```

- Every function will have a description of what it does, as well as a short description of each input and output (avoid using global variables besides constants), pass all inputs and outputs to/from the main loop with function calls and returns:
    - Ex: A code sample is shown below

```
// Prints text to the screen
// x: The text that is to be printed
void printToScreen(String x) {
        printf("%s\n", x);
}
```

- Besides the section headers and the function headers, all other developer comments will be end-of-line comments. First apply three spaces after the code. Then “//” followed by a space. Then immediately after the space you can type the details you wanted to address in the comment.
    - Ex: A code sample is shown below

```
printf(“Hello World”);   // Print statement for Hello world
```

### *4.4.4.5 Conditional Statements Standards (in object-oriented language)*

All types of statements and loops should be written as follows.

- First the type of statement or loop should be written. Then a space will follow separating the type from the opening parentheses. After the comparison statements are made a closing parentheses should be placed. Then a space will be in between the closing parentheses and the opening bracket.
    - Ex: A code sample is shown below

```
for (i = 1; i < 10; i++) {
        printf("i = %d",i);
}
```

- If statements, for loops, and while loops along with any other types shall be written with a space in between each of the elements and the operator inside of the parentheses.
    - Ex: A code sample is shown below

```
if (a = b) {
        a++;
}
```

- If they use brackets the open bracket should follow the closing parentheses with a space in between them. They closing bracket should be on a newline lined up with the beginning conditional statement indentation.

### *4.4.4.6 Miscellaneous Standards (in object-oriented language)*

These are miscellaneous standards for embedded programming that did not fit into any other specific areas.

- Try to avoid lines longer than 100 characters. This standard depends on the IDE we choose. Also this character count does not include comments.
- If you have to break up a method call to multiple lines, indent up to the start of the function call + 8 spaces (not an indent). Also this character count does not include comments.
- General progression: header > libraries > global variable declaration > main loop > function calls
- Avoid using multi-line comment notations
    - Ex: A code sample is shown below

```
/*
* Avoid using this format if possible. This commenting notation is not
* standardized between all languages and IDEs
*/
```

- Always use end of the line comments or refer back to the top of the list.

## 4.5 Connector Standards

### 4.5.1 USB Standards

Table 10, below, shows a list of relevant standards for the Universal Serial Bus.

| Standard | Description |
|---|---|
| UL 6703 | Outline of Investigation for Connectors for Use in Photovoltaic Systems |
| ANSI C119.6-2011 | Standard for electrical connectors used in non-sealed, multiport connector systems rated 600 V or less for aluminum and copper conductors. |
| USB Battery Charging 1.2 Compliance Plan | Defines standards used for USB chargers. |

**Table 10 -** USB Standards

### 4.5.2 Battery Connector Standards

Table 11, below, shows a list of relevant standards for the battery connector.

| Standard | Description |
|---|---|
| IEEE 937-2007 | Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems |
| IEEE 1013-2007 | Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems |
| IEEE 1361-2014 | Guide for Selecting, Charging, Testing, and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems |
| IEEE 1526-2003 | Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems |

**Table 11 -** Battery Connector Standards

## 4.6 Battery Standards

Table 12, below, contains IEEE standards are relevant to our project regarding batteries.

| Standard | Description |
|---|---|
| IEEE 937-2007 | Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems |
| IEEE 937-2007 | Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems |
| IEEE 1013-2007 | Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems |
| IEEE 1361-2014 | Guide for Selecting, Charging, Testing, and Evaluating Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems |
| IEEE 1526-2003 | Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems |

**Table 12 -** Battery Standards

## 4.7 Design Impact of Relevant Standards

Implementing the standards listed above will make the project safer to the end user.

Using products that are compliant with the NFPA 70 standard will ensure the electronics will not introduce any hazardous conditions that could result in fire.

The UL 50 will be considered when selecting the 6”x6”x36” enclosure that the electronics will be stored in. This will ensure that users are protected when incidentally coming into contact with the enclosure.

The UL 62109-1 standard will be considered when selecting boost converters, the charge controller, and other power converters used in the solar module sub-system.

UL 61215 and UL 61646 will be used when selecting the photovoltaics for the project. This will ensure that any crystalline silicon or thin-film photovoltaics will be able to provide reliable power in the specified installed environment.

The Wi-fi and Bluetooth standards will be used in order to determine which remote connectivity method is most suitable for the project. Additionally, the RFID standard will be used when designing the security sub-system for the project.

UL 6703 will be used in order to choose compliant connectors used in the solar module sub-system. This includes the connections from the solar module to the charge controller, the charge controller to the battery, and from the charge controller to the PCB.

The USB Battery Charging 1.2 Compliance Plan will be used in order to choose the pin assignment for the USB charger so that it operates in accordance with the standard. The battery standards will be used as a guide for selecting the appropriate battery size for the project, charging the battery, and testing the battery to ensure it is performing well.

# 5.0 Realistic Design Constraints

## 5.1 Economic Constraints

There are some economic issues to take into account when designing the product for this project. We currently do not have any sponsorship for this project, so all expenses will be paid by members of the team. The electronic pieces do not seem to be much of an issue, but the solar cells will be the largest expense that we will have to take into consideration.

One way we have been able to lower the cost of the solar cells is to use less of the flexible strips and more of the solid crystalline ones. The crystalline cells are much cheaper, but the only place we can fit them into our design is on the housing, which has limited exposure to the window. If we use only the crystalline strips, we estimate that it would not be able to gather enough energy on its own to meet our requirements. As a result, we have decided to use a combination of the two architectures to maximize the energy gathering while trying to minimize cost.

Another effect of economic constraints can be seen in our choice of blinds. We had originally decided to use a vertical blind design that would operate with two motors, one to rotate the blinds open and another to pull them to the side. We discovered that it would be cheaper, not to mention easier to implement, to use a rolling shade instead. The rolling shade operates only on one motor and has a more simple design, which will reduce the overall cost of our project.

Financial constraints have also affected our software design decisions as well. We had originally conceived of this product to be a complement to the Apple HomeKit [45]. However, to develop mobile applications for Apple, you have to get a license which costs $99 per year [46]. This is a decent price if you are a very active developer and will be producing multiple applications annually. However, we would only have plans to use the license for this project and the cost was a big detriment to developing the application on Apple’s platform. Android, on the other hand, is free to develop as long as it is not distributed through the Google Play store. If we wish to put the application on Google Play it is only a $25 one-time registration fee [47]. Because of this, among other reasons, we have decided to develop the mobile application for Android.

## 5.2 Time Constraints

The time constraint is also a large factor in our design choices. We only have one semester to build this product. This means we have to build/buy the canvas, housing, and motor. We also have to acquire all the parts for our PCB and have it all integrated into the board. We also have to attach and wire all the solar cells to the blinds and get the charge controller working properly. We also expect some possible complications with the USB charger being able to charge at appropriate speeds across different phone models.

All of those physical requirements must be met within our completion milestone of November 30th. In addition to that, we will have software development going on concurrently. We will need to program the microcontroller to handle all the mechanical operations, and also to process commands from the mobile application. We will also have to develop the mobile application itself.

These requirements and our time constraints have compounded into affecting our design decisions in order to meet our deadline with a finished product. Instead of building everything from scratch, we will most likely buy a do-it-yourself roller blinds kit which will include the housing and motor. We may still need to replace the motor to fit our needs. Instead of soldering the parts to the PCB ourselves, we will also be sending out the parts to a third party to integrate them all for us (at additional cost). We also considered the fact that a data link may be required for the USB charger to determine the optimal current to maximize charge time for a cell phone, but due to time constraints we may have to use a set current for all devices and just ground the data pins.

As far as the software development goes, it has been affected by the time constraints as well. We hope to be able to include additional features in our program such as pulling weather reports from the internet to determine optimal sun exposure at different times and dates. We also would like to be able to display the rate at which the battery is charging at any point in time, and hopefully be able to display a graph for up to a month of charging history. However, these are superfluous features, and we must first get basic operations working first. Given enough time, this product could turn out to be very impressive.

The limited time given to complete this project has also affected our chances to learn more about new technology. We are fortunate to be able to learn about e-paper and get more hands-on experience with RFID, but we had hoped to be able to expand our skill set more than that with this project. We had hoped to be able to learn a different object-oriented language to use in the development of the mobile application, preferably C#, but we may end up having to do the development with Java just because we are already familiar with that language.

### 5.3 Ethical, Health, and Safety Constraints

This project contains risks that must be handled and taken with major consideration. This portion of the document will analyze the ethical, health and safety risks associated with the operation of Solar Blinds.

To answer the question why we decided to pursue such a device as Solar Blinds is because we along with everyone else see that the demand for a new fuel source is at an all time high. Seeing that the issues on air pollution and the ozone layer disappearing are always on the news. It's quite alarming that nothing can really be down about it until a new easily accessible resource is found. Therefore the overall goals of this present a device that can be used to reclaim some of the nature resources and turn them into an energy source we can use at our own disposal.

This product will be designed to operate on a small scale most likely for a normal everyday house. It can easily be converted into a project that will work will what large company skyscrapers that face the sun most of the day but since very few of them exist where we are located we will limit the project to everyday households.

The only health risks associated with the development of this device are the use of batteries for storing the information. In the section describing the use of batteries will elaborate more on how we decided to counteract this design constraint.

Safety to the user is something that must not be taken lightly. To handle this design constraint we plan to adhere to the standards described by professionals when we actually begin building and coding the hardware and software applications. We must also ensure that the parts that we have out sourced to be developed also adhere to the same engineering standards to ensure the proper requirements are met.

# 6.0 Project Hardware and Software Design Details

## 6.1 Electrical Hardware

Figure 30 is a diagram displaying how all the different components of the project will be connected. As we can see, everything goes directly through the PCB. The PCB is the heart of our project, so it is important that we design it properly and that it is completed as soon as possible. This will be a potential bottleneck in our development, so it is something we will have to give special attention as we go into the next semester working on this project.

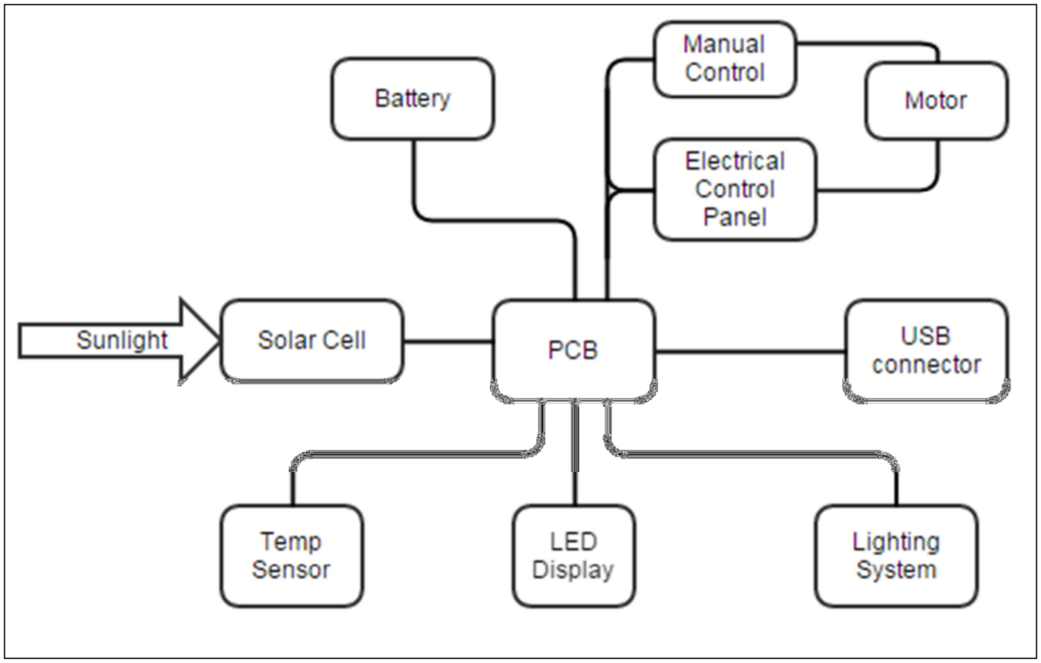


**Figure 30** - Hardware Block Diagram

### 6.1.1 Charging Circuit

When the sunlight hits our solar panel and begins to send a voltage across these terminals, we will need to regulate the current and voltage that will be running through the battery at any given time. This voltage will be fluctuating throughout the day and can reach voltages much higher than the batteries and can harm the battery if it is not regulated correctly. We have considered many different options to charge our battery correctly and safely.

One of the ways we have considered is buying an aftermarket, already built battery charger from solar cells to a lithium battery. This will eliminate any errors that we could make by designing a circuit ourselves that will be quite complicated to ensure maximum power efficiency. Also given the short time that we have to design, build and test this project, it is much easier going with an already made battery controller that eliminates a lot of time to build and test. We have decided to go with the Gena Sun Gv-5 65W 5A Solar Charge Controller with MPPT, which can be seen in Figure 31. This controller monitors the voltage fifteen times per second and continues to keep a steady output voltage and current [48].

**Figure 31 -** Genasun Solar Charge Controller

### 6.1.2 PCB

Eagle is the medium we will be using to create our PCB Layout and create all of our gerbers to send out to the manufacturers for our PCB board. We will design all of the individual parts of the components into separate libraries with their own package, symbol and device names. We can then take these parts and drop them into a schematic that will look like our previously laid out schematic in LtSpice. This will drop all of our components on a PCB board and then we will have to place them and route each part. The PCB board will be as small as possible to reduce cost and be able to fit in the housing we need it to fit into. We will delete out many of the layers from Eagle as we will not need all of these layers that they give us. Also, we will not need to do a panel drawing for our boards because we will not be ordering our boards by panel, but if this ever went into mass production, there would have to be a panel layout made as well as just the board layout.

The program we will be using to prototype our board is LtSpice. This program has you design in parts into different files and then allows you to bring them together and build schematics. This allows us to build an accurate model of our schematic and assign the necessary pins and voltages to all of the different components that we will need in our PCB and our project design. You can also run mock circuits and simulate how the circuit will work when completed and put together.

### 6.1.3 Microprocessor

The first part that was designed in is the CC2640. This is a microprocessor that supports bluetooth and has enough I/O pins to complete the job that we need it to complete. This micro will have a crystal hooked up to it, as well as a voltage of three volts to power the micro. This voltage will regulated down from twelve volts to three through a linear voltage regulator. There will also be a motor hooked up to this micro that will spin in two different directions depending on which pin of the motor is pulled high or low. Also attached to this micro will be a display that is called an e-paper. This is a display that uses very low amount of power because it only updates when told to, and it will hold the display for hours without having to use barely any power at all. The display resembles something of an etch-a-sketch. This is the display that will be showing the temperature outside. The temperature pin will also be hooked up to the micro and there will be a regulated five volts on the e-paper as well. The pinout for the CC2640 is shown in Figure 32 [49].

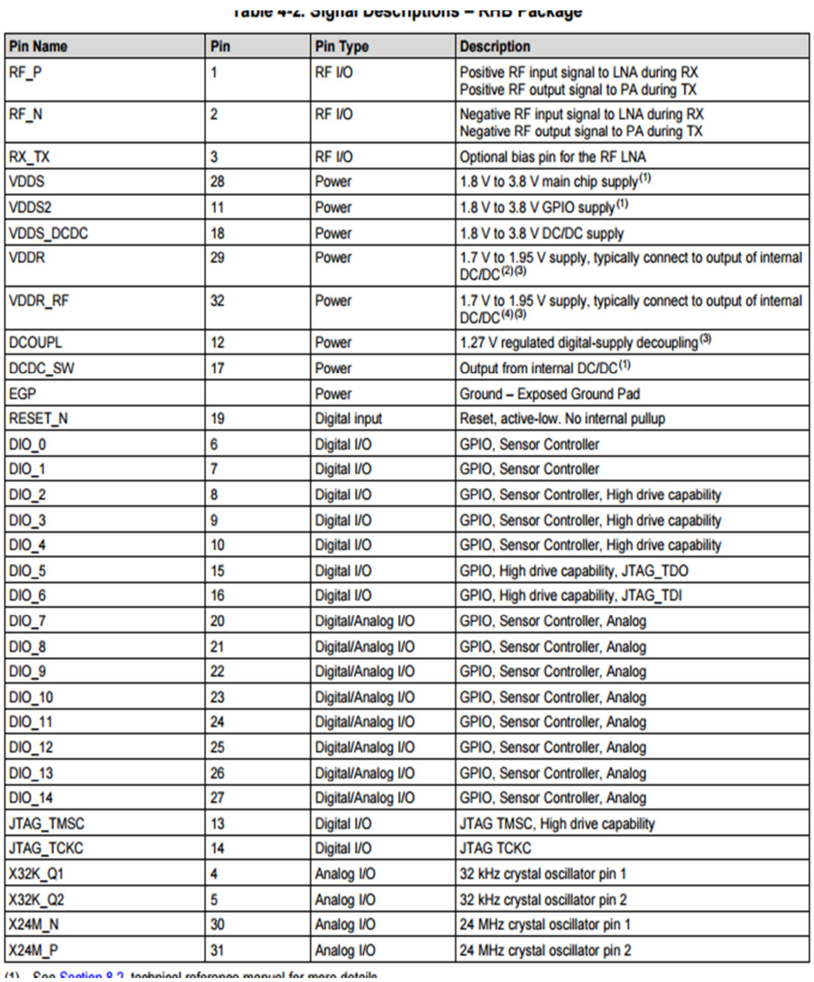


Table 4-2. Signal Descriptions – RHB Package

| Pin Name | Pin | Pin Type | Description |
|---|---|---|---|
| RF_P | 1 | RF I/O | Positive RF input signal to LNA during RX<br>Positive RF output signal to PA during TX |
| RF_N | 2 | RF I/O | Negative RF input signal to LNA during RX<br>Negative RF output signal to PA during TX |
| RX_TX | 3 | RF I/O | Optional bias pin for the RF LNA |
| VDDS | 28 | Power | 1.8 V to 3.8 V main chip supply(1) |
| VDDS2 | 11 | Power | 1.8 V to 3.8 V GPIO supply(1) |
| VDDS_DCDC | 18 | Power | 1.8 V to 3.8 V DC/DC supply |
| VDDR | 29 | Power | 1.7 V to 1.95 V supply, typically connect to output of internal DC/DC(2)(3) |
| VDDR_RF | 32 | Power | 1.7 V to 1.95 V supply, typically connect to output of internal DC/DC(4)(3) |
| DCOUPL | 12 | Power | 1.27 V regulated digital-supply decoupling(3) |
| DCDC_SW | 17 | Power | Output from internal DC/DC(1) |
| EGP | | Power | Ground – Exposed Ground Pad |
| RESET_N | 19 | Digital input | Reset, active-low. No internal pullup |
| DIO_0 | 6 | Digital I/O | GPIO, Sensor Controller |
| DIO_1 | 7 | Digital I/O | GPIO, Sensor Controller |
| DIO_2 | 8 | Digital I/O | GPIO, Sensor Controller, High drive capability |
| DIO_3 | 9 | Digital I/O | GPIO, Sensor Controller, High drive capability |
| DIO_4 | 10 | Digital I/O | GPIO, Sensor Controller, High drive capability |
| DIO_5 | 15 | Digital I/O | GPIO, High drive capability, JTAG_TDO |
| DIO_6 | 16 | Digital I/O | GPIO, High drive capability, JTAG_TDI |
| DIO_7 | 20 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_8 | 21 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_9 | 22 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_10 | 23 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_11 | 24 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_12 | 25 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_13 | 26 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| DIO_14 | 27 | Digital/Analog I/O | GPIO, Sensor Controller, Analog |
| JTAG_TMSC | 13 | Digital I/O | JTAG TMSC, High drive capability |
| JTAG_TCKC | 14 | Digital I/O | JTAG TCKC |
| X32K_Q1 | 4 | Analog I/O | 32 kHz crystal oscillator pin 1 |
| X32K_Q2 | 5 | Analog I/O | 32 kHz crystal oscillator pin 2 |
| X24M_N | 30 | Analog I/O | 24 MHz crystal oscillator pin 1 |
| X24M_P | 31 | Analog I/O | 24 MHz crystal oscillator pin 2 |

(1) See Section 8.2, technical reference manual for more details

**Figure 32 -** CC2640 Pinouts

This micro has more than enough digital and analog I/O pins to get the job done. The micro also has a ARM Core processor in it which seems to be a bit overkill, but it is good experience to learn how to code. This micro also needs a twenty four mega-hertz crystal to operate. Usually microcontrollerss need some external capacitors but this specific micro has internal capacitors to tune the crystal. In the LtSpice design for this part, there is the outline of the part which is a square and there are the 32 pins that are attached to them. The pins are all named the same as the pinout above. The spice model is depicted in Figure 33.

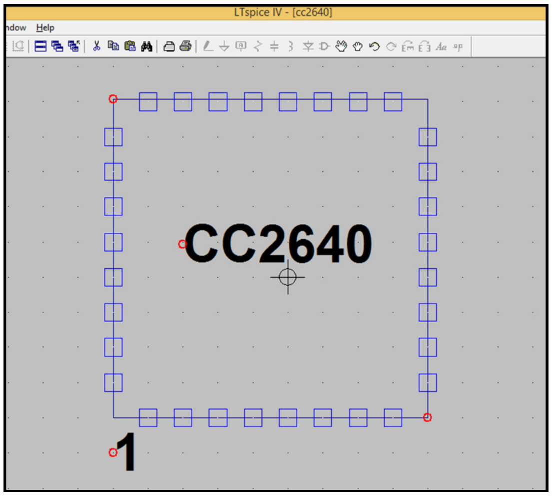


**Figure 33 -** LTSpice Pinout of CC2640

Designing this part into Eagle isn't as simple as most parts are to draw into Eagle. This part, since it is a microprocessor, has a much smaller pitch than most parts and the pads were shaped oddly. They were not your standard looking rectangular pads. The pads looked like a rectangle with a rounded top as shown in Figure 34. Also, another specification that made this part a bit more involved into creating into eagle is that the package has a ground pad directly under it and has a pattern of vias that need to be followed. This pattern is crucial for the correct heat sinking of the part.

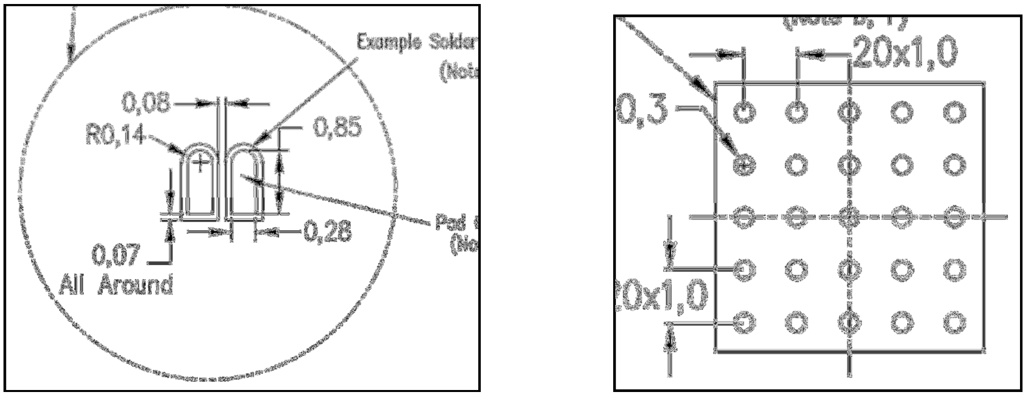


**Figure 34 -** Eagle CC2640 pins

Figure 35 is the actual package drawn into the eagle libraries so we can use it on the PCB board itself. The pins and all the package design was created by following the datasheet as closely as possible.

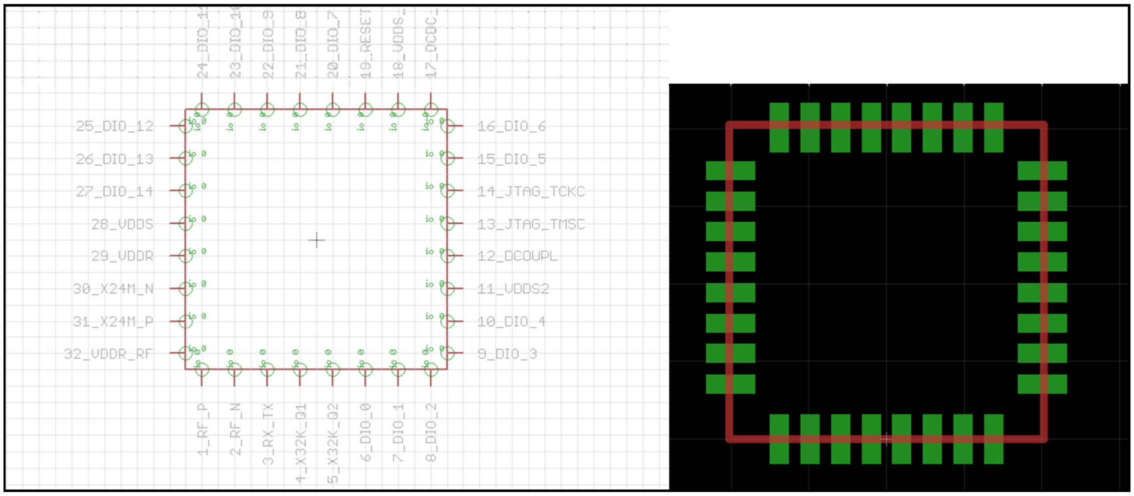


**Figure 35 -** Eagle PCB Board

### 6.1.4 Motor

The next part that was designed into the library in LtSpice was the motor. A screenshot of the motor as represented by LtSpice can be seen in Figure 36. This motor is operated by applying a high voltage from the micro on one of the I/O pins to turn the motor on and either spin the motor clockwise or counterclockwise as labeled below in the picture of the motor.

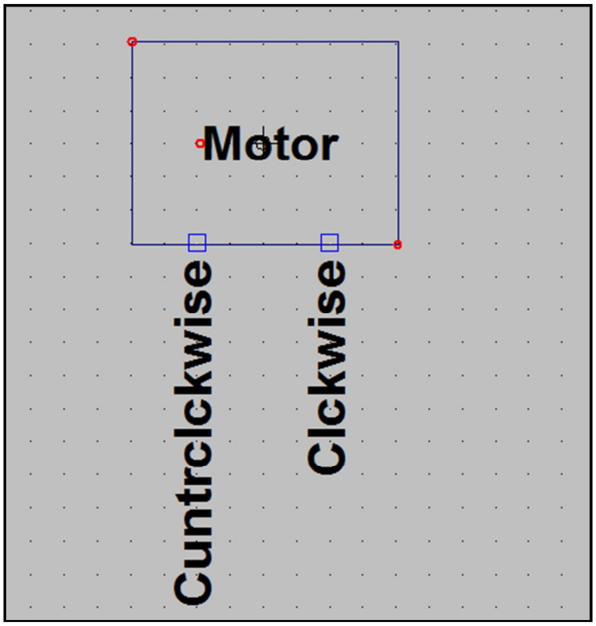


**Figure 36 -** LTSpice Motor Representation

These pins were hooked up to the I/O pins labeled eight and nine in the schematic of the CC2640. These are just digital I/O pins to either supply a high or a low.

### 6.1.5 E-Paper

This was the next complicated to design into the LtSpice model next to the microprocessor. This element of our project will be used to tell the current temperature of the outside air and also display the charge of the battery from time to time. This display works very uniquely compared to many other displays. This will use significantly less power than other displays because it doesn't need constant current like a seven segment display to keep the LED's lit. This display writes only when told to and can hold the image that has been written for a long period of time after being written to without having to be updated for awhile. This keeps power consumption down on this display and this is a major advantage seeing that we are using a battery operated controller.

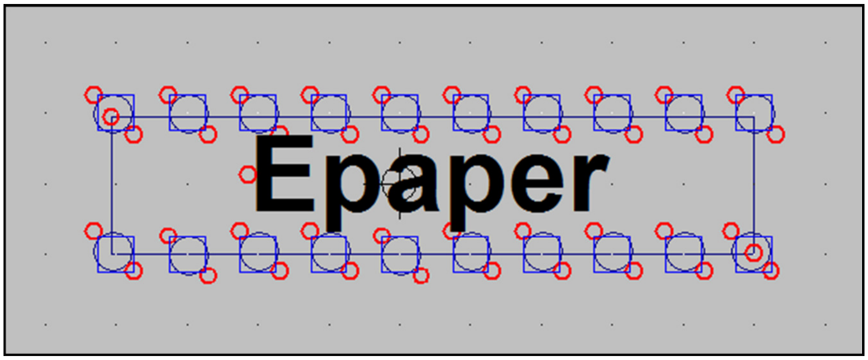
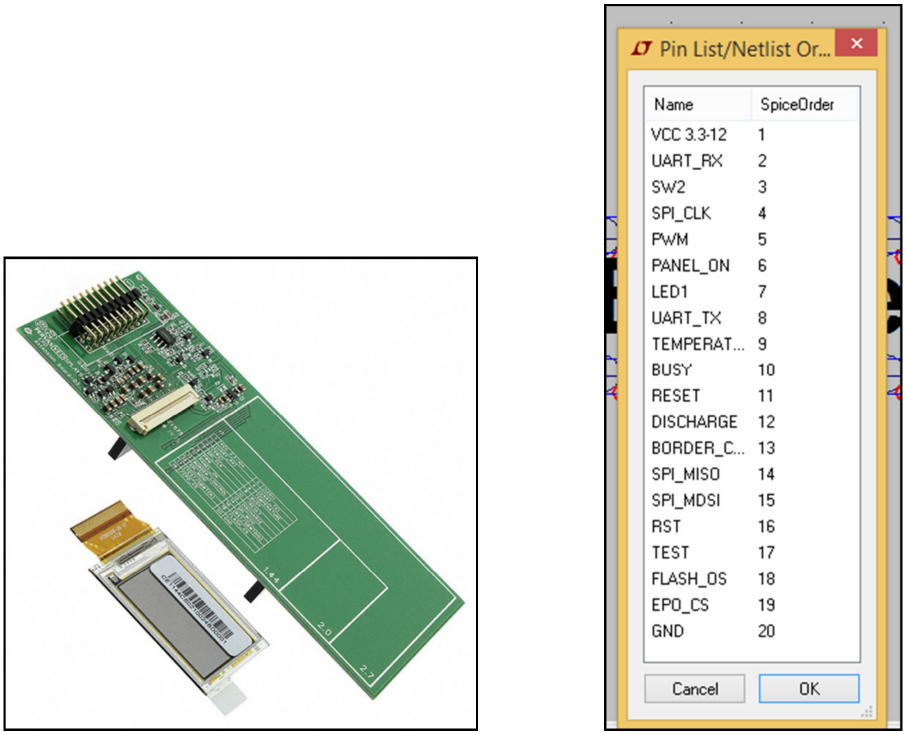


**Figure 37 -** LTSpice E-Paper Representation

This schematic symbol in Figure 37 represents the twenty pins on e-paper sub board. The e-paper plugs into a PCB sub board, shown in Figure 38, which has pin outs that will be connected to the micro on our PCB board. The pinouts for the sub board are also included in Figure 38.



| Name | SpiceOrder |
|---|---|
| VCC 3.3-12 | 1 |
| UART_RX | 2 |
| SW2 | 3 |
| SPI_CLK | 4 |
| PWM | 5 |
| PANEL_ON | 6 |
| LED1 | 7 |
| UART_TX | 8 |
| TEMPERAT... | 9 |
| BUSY | 10 |
| RESET | 11 |
| DISCHARGE | 12 |
| BORDER_C... | 13 |
| SPI_MISO | 14 |
| SPI_MDSI | 15 |
| RST | 16 |
| TEST | 17 |
| FLASH_OS | 18 |
| EPO_CS | 19 |
| GND | 20 |

**Figure 38 -** PCB Sub Board and Pinouts
http://www.digikey.com/product-detail/en/S1144CS021/S1144CS021-ND/5046794

### 6.1.6 USB Charger

We have designed in a Universal Serial Bus into LtSpice, as can be seen in Figure 39, and have assigned it the necessary pins s a typical USB device. This USB is the charger to charge any non-apple phone. The only pins that are connected in the schematic are the Voltage pin and the Ground pin. This will allow phones to charge but at a slower rate as to not drain the battery too fast.

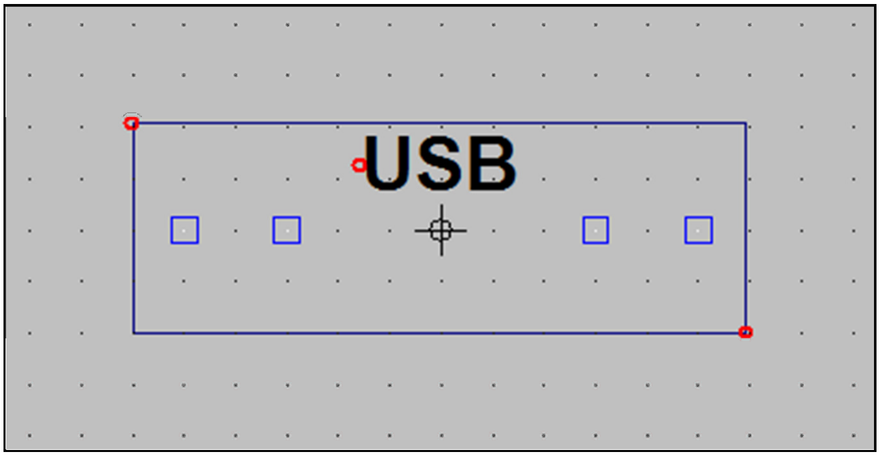


**Figure 39 -** LTSpice USB Charger Representation

There is another option we have explored instead of buying a battery charging controller. This is designing our own circuit that will regulate the voltage of the solar panel and keep the battery charging at a constant current. The challenge would be doing this the most efficient way. The best way to design the circuit ourselves would be to use a current limiting diode and a Zener diode. The current limiter diode would be in series with the solar panel voltage and it would drop the necessary voltage across the diode to supply a constant rated current to charge the battery at a constant current no matter what the solar panel voltage is at. The Zener diode would be connected in parallel with the battery that will be charging because it will keep the voltage in check that the battery is charging too as to make sure it doesn't over charge the battery. The battery will continue to charge until it hits the voltage of the Zener diode and then it will allow the current to run through the Zener diode and keep the battery from overcharging.

In Figure 40, we can see the diode that keeps the current constant. It does so by dropping the necessary voltage across it. This will continue to regulate the current until it hits a threshold that it will not be able to regulate the current anymore.

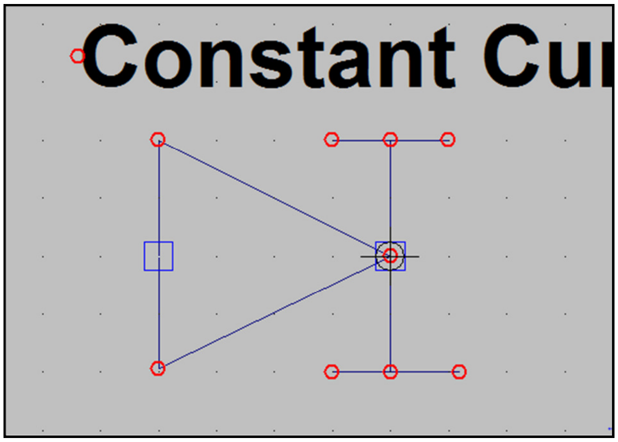


**Figure 40** - LTSpice Current Stabilizing Diode

Figure 41 shows the schematic that could be used to charge the battery at a constant current and protect the battery from overcharging. The constant current diode as previously described will keep the correct current to charge the battery no matter the voltage across the solar panel. The zener diode takes care of protecting the battery from overcharging and damaging the cells in the battery.

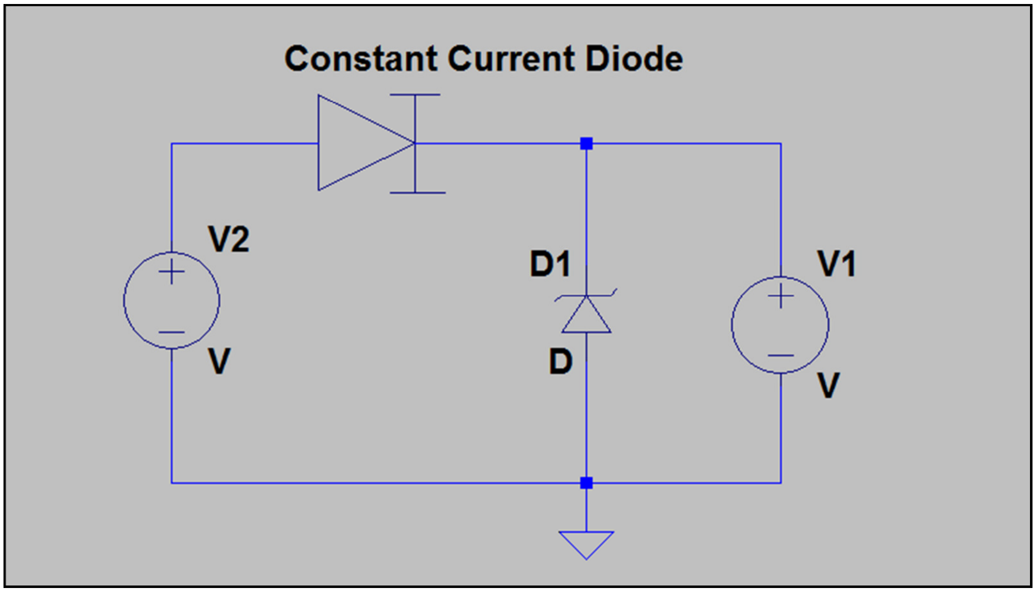


**Figure 41** - LTSpice Current Stabilizing Circuit

Figure 42 is a USB jack which is a connector for the USB charger that we will be adding to our circuit. This will most likely have its own PCB board because it will be attached off board so it is easily accessible for the user to plug their phone in and access the phone while it is charging. This part is a through hole part that is also attached at a ninety degree angle. This will make it easier to plug into and have the USB board condescended easier in its own separate little housing.

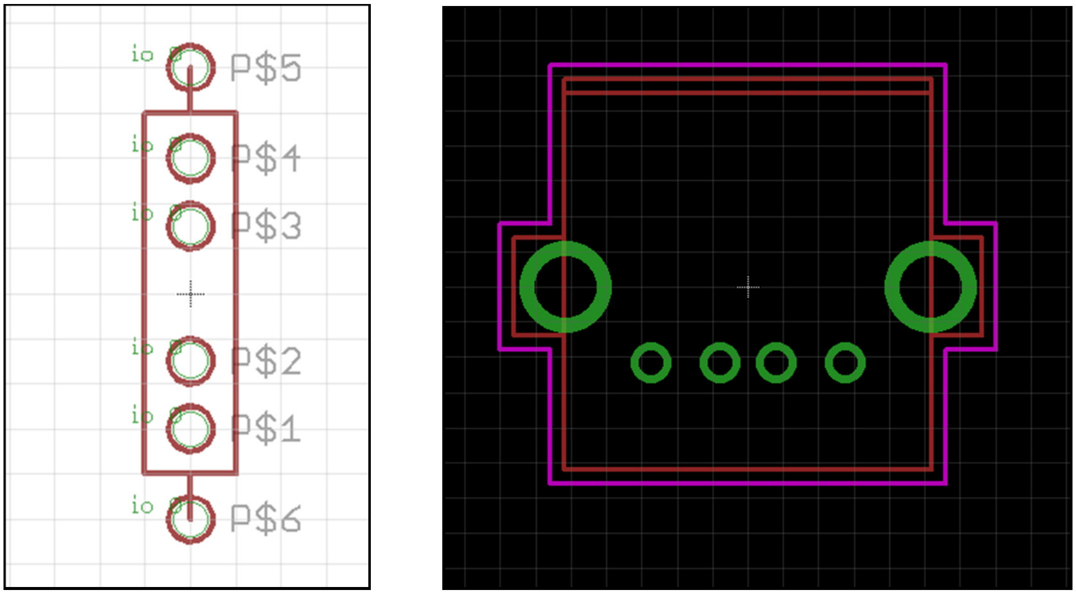


**Figure 42 -** Eagle USB Charge Port

### 6.1.7 Crystal (24 MHz)

The 24 MHz crystal is hooked up to our micro via the two inputs for the twenty megahertz crystal. The LtSpice representation of this part is displayed in Figure 43. Usually a crystal needs to have some capacitors hooked up to it to let it oscillate correctly, but this micro has internal capacitors so there is no need to connect external capacitors.

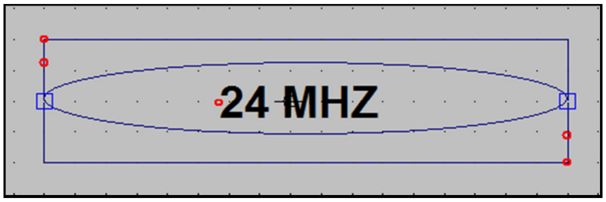


**Figure 43 -** Eagle 24 MHz Crystal

This is the crystal that we will be using for the micro to operate with. The schematic symbol is one that we drew up to represent the crystal and separate it from the other parts. It uses a Y to designate the crystal because there is no other part that uses this prefix and it is a commonly used notation for the crystal on many types of PCB boards.

The package that we are using for the crystal can be seen in Figure 44. It is the same for all the different values of crystals from the supplier we are purchasing it from. The micro itself can also be ran off of a 32 KHZ crystal, but we have not yet gotten to do any testing so we don’t know if this is a better choice or not. But it will be a very easy thing to fix if we need to swap crystal values.

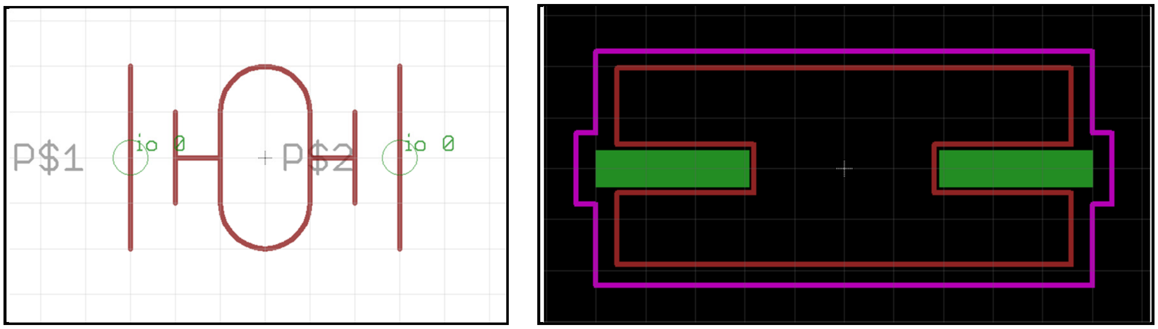


**Figure 44 -** Eagle 32 KHz Crystal

### 6.1.8 Voltage Regulator

The last element that was designed into LtSpice to complete the schematic was the MCP 1702 Linear Voltage regulator, shown in Figure 45. There were two different linear regulators that had to be added to the schematic. One of the linear regulators was a twelve volt to 3 volt regulator to power the micro itself. The second linear regulator that was added was the twelve volt to five volt regulator. This regulator is used to regulate the five volts to power our USB and power our e-paper display.

The packages for the two regulators are the same as well as the same pin out, they just are ordered with different part numbers to get the two different desired outputs. Pin one is the ground, while pin two is the Voltage in pin and Pin three is the Voltage out pin. So in the case of the three volt regulator, the Voltage out pin would have the desired three volt output [50].

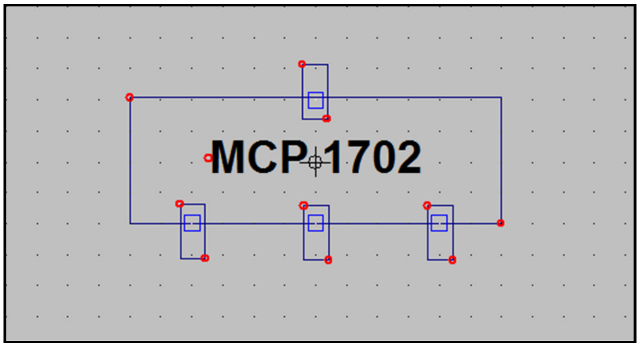


**Figure 45 -** Eagle's Representation of MCP 1702 Pins

The diagram in Figure 46 is a layout of the regulators pins and the package.

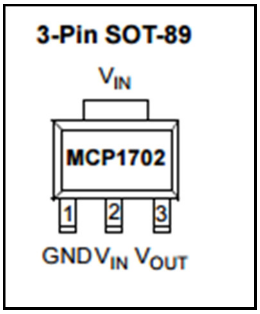


**Figure 46 -** Voltage Regulator Pins and Package

The MCP 1702 is another component that had to be added into our library. We were able to draw it up in Eagle, as can be seen in Figure 47. This component is going to have two different devices that will have the same symbol for the schematic and the same layout for the PCB.

There are two different values of the regulators which is the reason why there will be two different devices. The first device will be the version of the MCP 1702 that will be a linear regulator that regulates from twelve volts to three volts. The second device will be another version of the MCP 1702 that will regulate the twelve volts to five volts. The packages will be the same for each of these.

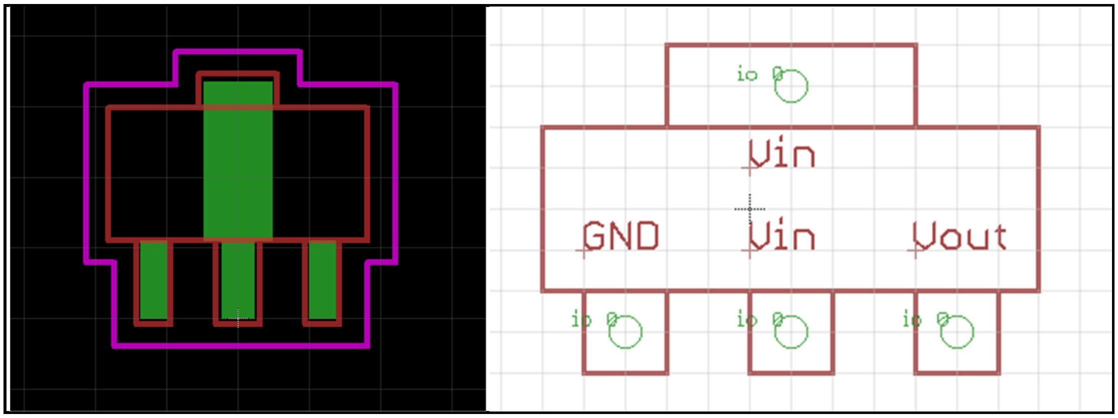


**Figure 47 -** Eagle Representation of MCP 1702

6.1.9 Antenna Circuit

The diagram in Figure 48 shows different options for the circuit that can be used for the different antenna schemes.  We have looked into the different ones, but we are not sure which one we are going to use for our current design.  We have ordered an evaluation board to test the schemes of the antenna circuit setup, so after we have gotten our hands on it and can test the different types of ways to hook up the antenna, then we will finalize our decision on which circuit to use.

The first type of antenna circuit we can choose from is the Differential Operation circuit. This type of circuit is the most favored because it is the best performance wise, but it requires external biasing which can take up more board space and may be a bit more costly.  The Single-ended Operation is another option we have to consider and it is biased internally and has the lowest power consumption which seems like something that we want the most.  This seems to be the option that most suits our needs because it uses the least amount of power to run, but once again we will need to wait to test the different schemes because since it uses less power, it may not have the same range as the other option and we made need the range depending on how far the Bluetooth reaches [51].

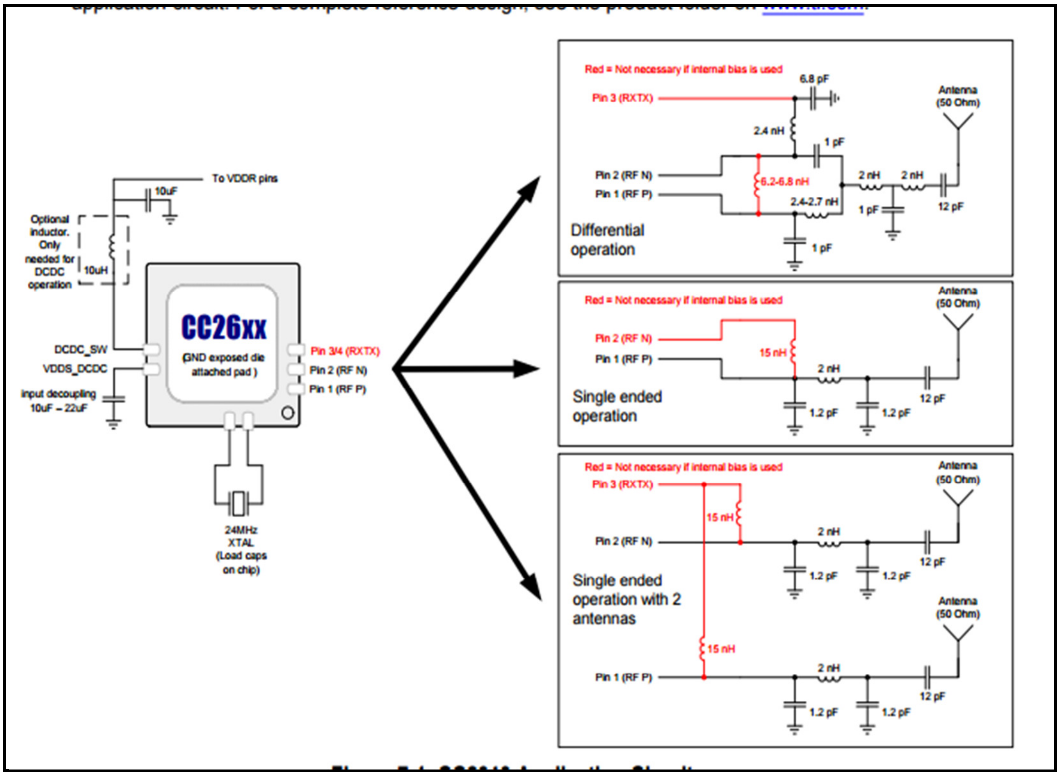


**Figure 48 -** Antenna Configurations

## 6.1.10 Complete Schematic

The schematic in Figure 49 shows all of the required connections from all of the previous components that were designed into this LtSpice Schematic. Together, this schematic should be able to do all of the functions that we were hoping to complete correctly and most efficiently. The only parts that will have to be tested to add to this schematic is the antenna circuit which we will have to experiment with to see which one we would like to choose, and a few different connections to the e-paper display.

The pinouts were displayed on Digikey on the sub board [52], but there was no documentation as to what pins need to be hooked up where and what pins do what other than the one word descriptions of the pins function. So once again, when we get our hands on these boards and can test some of the functions of these pins, then we will be to finish all of the connections to the micro to have it operate correctly and be able to be written to from the code in the micro.

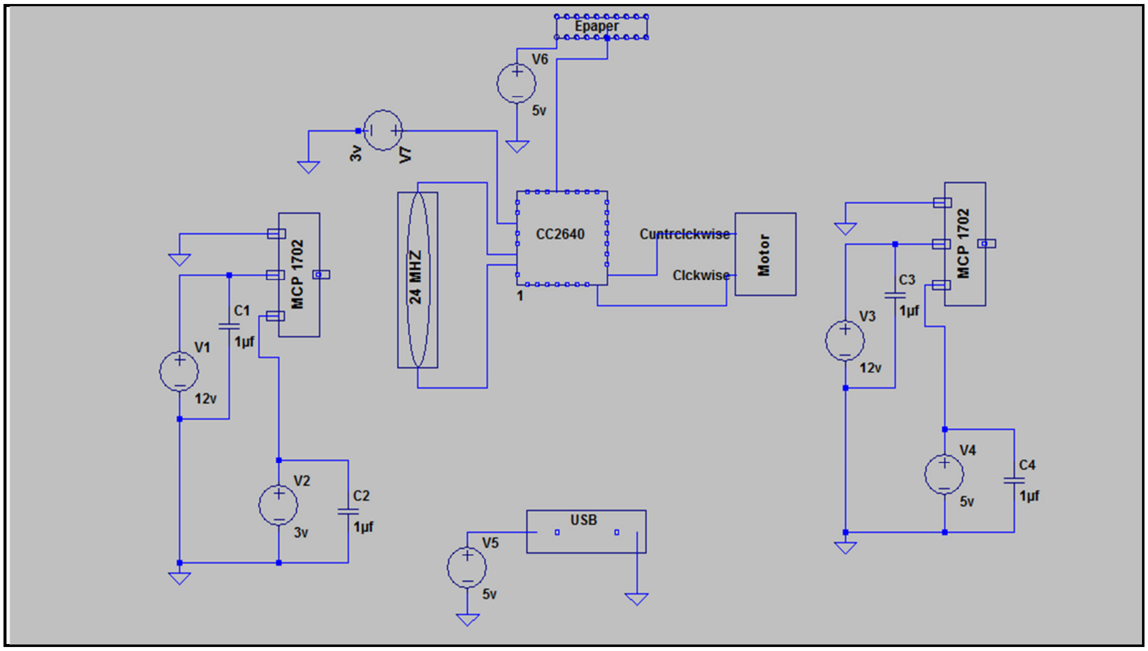


**Figure 49 -** Complete Schematic Represented in Eagle

The Eagle Schematic is being built and all the parts we need for the schematic have been designed in. The only parts we are waiting to put into the library is the e-paper display because there is still a lot of testing that has to be done to know what needs to be connected on it to operate correctly. We will only be using a header though for the schematic and PCB layout because the e-paper display uses a ribbon cable to connect the display to the board. The header will then be hooked up to the micro correctly once we find which functions we will need to hook up from the display. The PCB has not yet been assembled for this reason nor has the finished and completed schematic. We still have a lot of testing to do before we finalized the PCB layout and the schematic itself but this is a pretty good start.

### 6.2 Solar Technologies

In order to maximize the power capable of being captured by the system while maintaining the roller shade design, a combination of crystalline solar cells and amorphous silicon solar cells will be used. The crystalline solar cells The total power of the system will be 34.6 W.

Sunpower 3.3 W 6”x6” monocrystalline photovoltaics will be attached to the back of the 6”x6”x36” project box used to store the battery and circuit boards. A set of 10 of these cells can be purchased on eBay for $46.99. Connecting six of the cells in series produces a 20.6 W solar module operating at a maximum voltage of 3.48 V and a maximum current of 5.93 A. The cells will need to be tabbed using 2mm x 0.15mm tabbing wire (MISOL 10m: $6.28 on Amazon), a rosin flux pen (MG Chemicals 835-P: $8.95 on Amazon), and lead-free silver solder (Trakpower Rosin Core Lead Free Silver Solder:

$11.93 on Amazon). A DC-DC boost converter will be needed in order to step up the voltage of the solar module to match that of the amorphous silicon solar module. This will allow the two modules to be connected in parallel without suffering significant power losses. The DC-DC LTC1871 step up module will work well for this conversion. The circuit costs $10.04 and allows a user to select the input and output voltages. Table 13 shows the specifications of this device.

| Measure | Value |
|---|---|
| Input voltage | 3.5 – 30 V |
| Maximum output power | 100 W |
| Output voltage | 3.5 – 30 V |
| Maximum input current | 10 A |
| Power consumption | 15 mA |

**Table 13 -** LTC1871 Specifications

The output of the LTC1871 will have a maximum voltage of 15.4 V and a maximum current of 1.34 A. Figure 50 shows the complete diagram of the monocrystalline solar module including the boost converter.

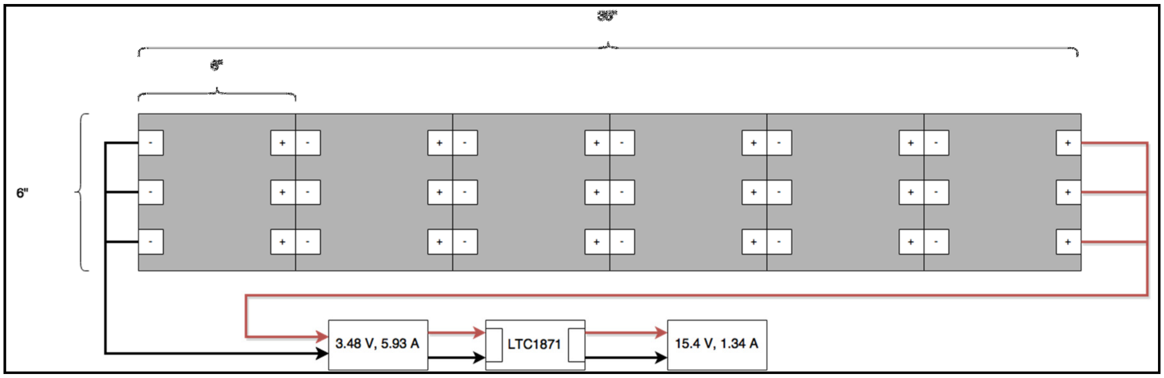


**Figure 50 -** Monocrystalline Solar Module

The Powerfilm R-14 rollable amorphous silicon solar module measures 14.5”x42” and costs $185.99. The panel has a total average power of 14 W operating at a maximum voltage of 15.4 V and a maximum current of 900 mA. Adding the 14 W amorphous silicon rollable solar panel brings the total power of the system to 34.6 W. Connecting the modules in series provides a maximum voltage of 15.4 V and a maximum current of 2.24 A. A diagram of the system described is shown in Figure 51.

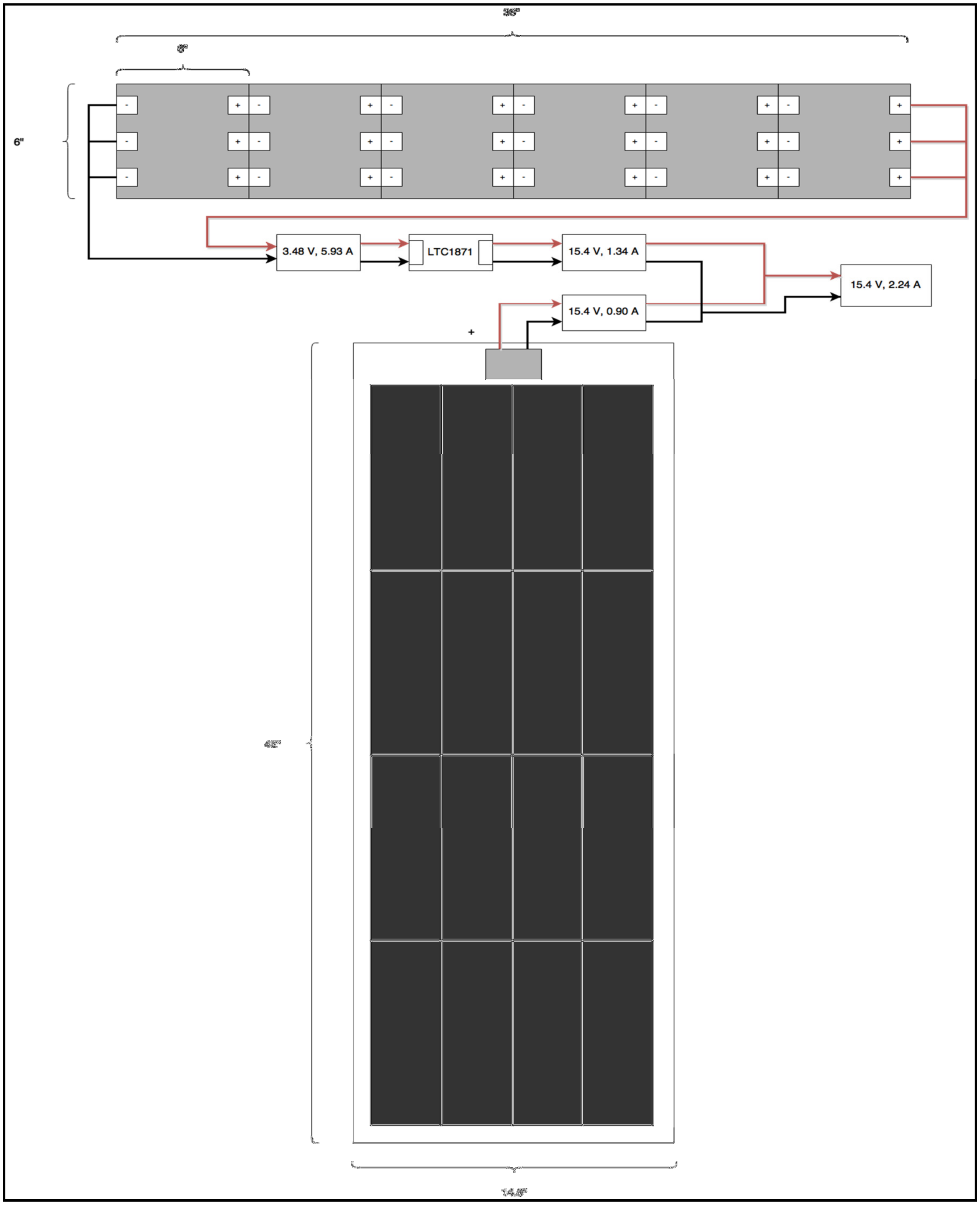


**Figure 51** - Combined Solar Module

This system will be capable of capturing the amount of energy capable of being stored by the 60Wh battery in 1.73 hours under ideal lighting conditions. The Universal Power Group UB250 12 V 5 Ah SLA AGM rechargeable battery will be used for the project. The battery costs only $9.93 which is much more affordable than the equivalent lithium-ion batteries on the market. The battery is rated to have a cycle life of 200 cycles when the battery is discharged 100%, 500 cycles when the battery is discharged 50%, and over 1200 when the battery is discharged 30% before recharging. Assuming the battery is discharged to 50% every night and recharged to 100% of its capacity each day, the battery should last about 500 days before it needs to be replaced. Although the lifetime of the lithium-ion battery would be about twice as long, it costs eight times as much as the lead acid battery. Thus, the lead acid battery is the more economic choice. The nominal capacity of the battery varies with the discharge current. Figure 52 shows this relationship graphically. If the loads require a constant high current then the battery will perform much worse than 5 Ah.

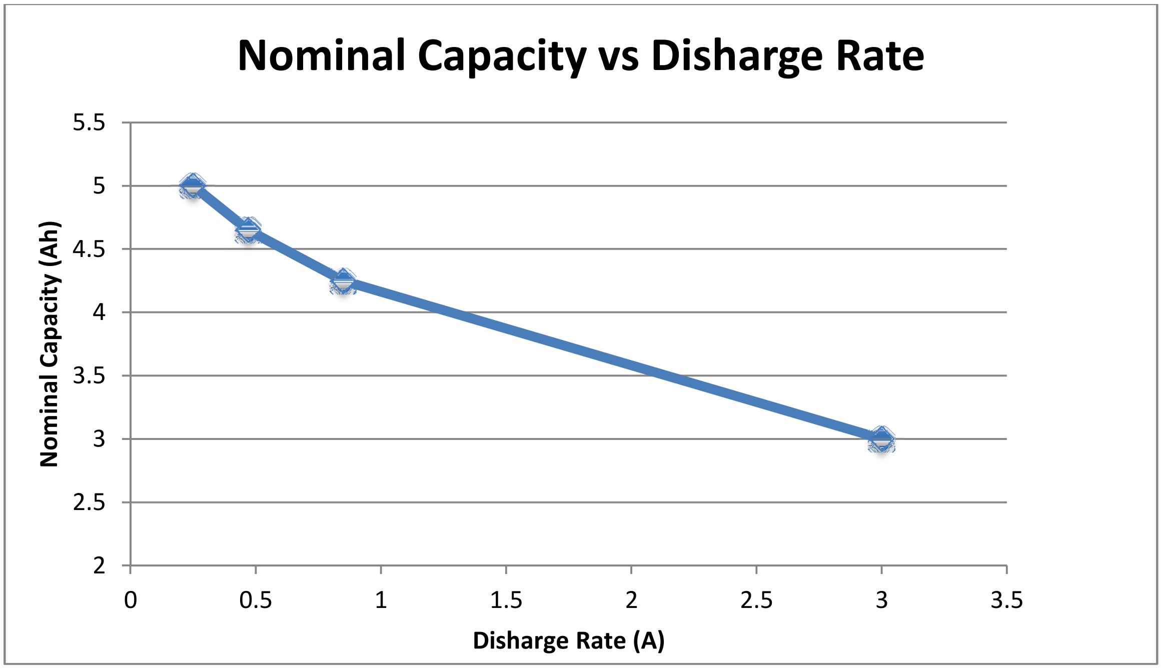


**Figure 52 -** Nominal Capacity vs Discharge Rate for SLA Battery

The battery measures 3.54”x2.76”x3.98” and weighs 3 lbs, which will fit well in the 6”x6”x36” project box. The maximum charge current for the battery is 0.35C where C is the number of cells in the battery. A 12 V SLA has six cells, so the maximum charge current for this battery is 2.1 A. This is slightly less than the 2.24 A maximum output current of the solar module. The charge controller will need to be designed to limit the output current of the solar module so that the maximum charge current of the battery is not exceeded.

The Genasun GV-5 65W 5A MPPT solar charge controller for lead-acid batteries will be used. The controller costs $75.00 and has a maximum recommended panel power of 65 W. Inputs include a 27 V maximum panel voltage input, a 12 V battery input and a load input with a continuous rated load current of 5 A. Although it is rated for 27 V, a 22 V maximum panel voltage is recommended under standard operating conditions. This is well above the 15.4 V designed output voltage of the solar module. The minimum battery voltage for normal operation is 7.2 V. The maximum input current is 9A which is well above the 2.24A maximum output current of the solar module. A computer controlled four-stage battery charging profile is used in order to increase the battery life and maximize capacity. This includes an absorption voltage of 14.2 V, a float voltage of 13.8 V, and a load disconnect voltage ranging from 11.4 to 12.5 V. A battery temperature compensator is also included which adjusts the voltage at a rate of -28mV/℃. The controller utilizes an MPPT tracking speed of 15 Hz in order to adapt quickly to changing light conditions. This results in an electrical efficiency of 96%-99.85% and a tracking efficiency of 99+%. The controller uses ceramic components instead of electrolytic components in order to increase the product lifetime. A 10-year warranty is included with purchase. The GV-5 consumes 0.150 mA when operating and 0.125 when asleep. It weighs only 2.8 oz. and measures 4.3”x2.2”x0.9”. A built-in electronic protection circuit cuts power when a short circuit is detected.  This will protect the controller from damage if the polarities of any of the inputs are accidentally reversed.

Table 14 shows the bill of materials for the complete solar sub-system.

| Manufacturer | Item | Seller | Price |
|---|---|---|---|
| Sunpower | 3.3 W 6”x6” Monocrystalline Solar Cells (10) | eBay | $46.99 |
| MISOL | 2mm x 0.15mm Tabbing Wire (10 m) | Amazon | $6.29 |
| MG Chemicals | 835-P Rosin Flux Pen | Amazon | $8.95 |
| Trakpower | Rosin Core Lead-Free Silver Solder | Amazon | $11.93 |
| DROK | DC-DC LTC1871 Step Up Module | GearBest | $10.04 |
| Powerfilm | R-14 Rollable Solar Module | FlexSolarCells | $185.99 |
| Universal Power Group | UB250 12 V 5 Ah SLA AGM Battery | 1000Bulbs | $9.93 |
| Genasun | GV-5 MPPT Charge Controleller | Genasun | $75.00 |
| Total | | | $355.12 |

**Table 14 -** Solar Sub-System Bill of Materials

Figure 53 shows the diagram of the complete solar sub-system. This connects all of the solar cells together and with the housing.

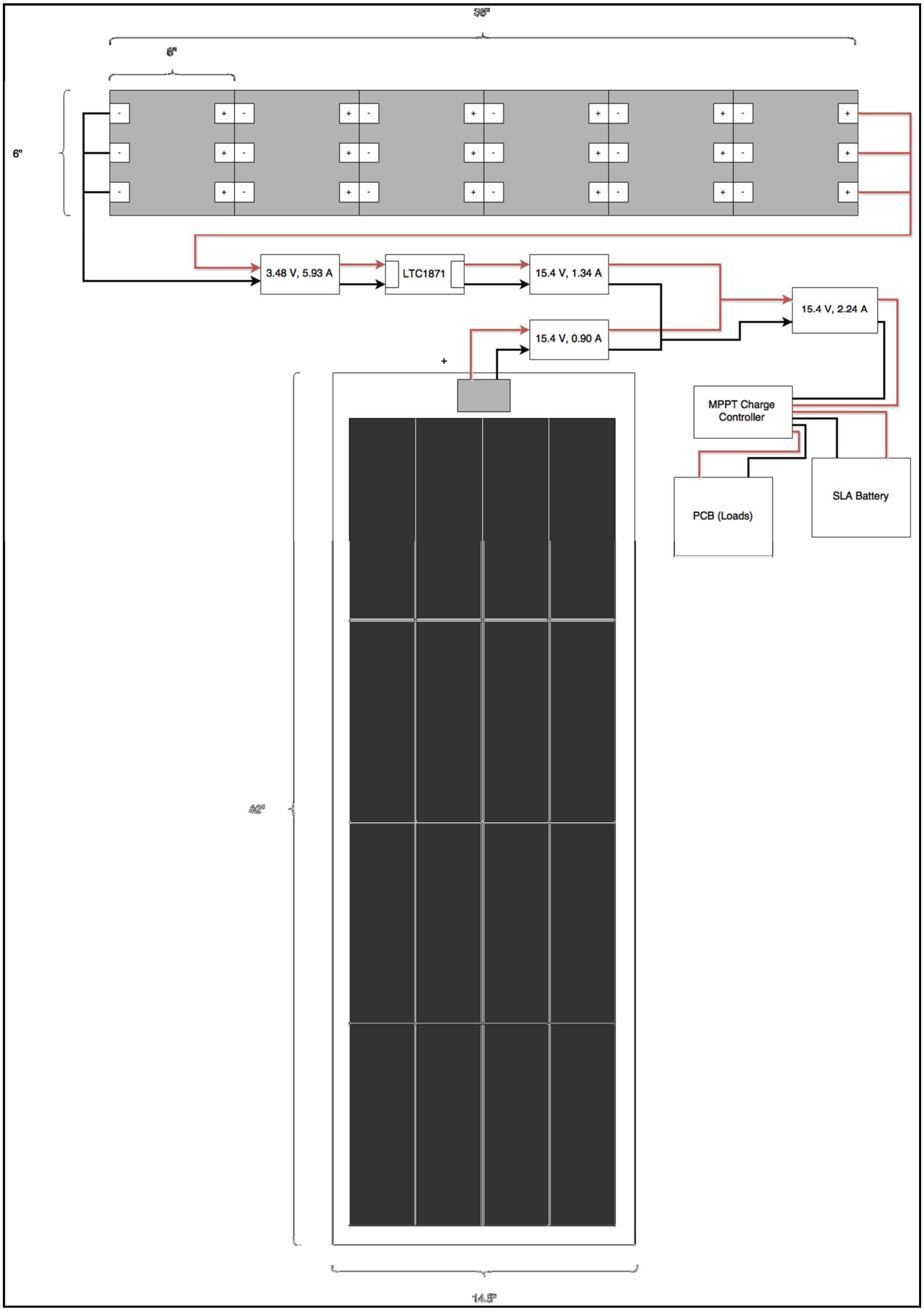
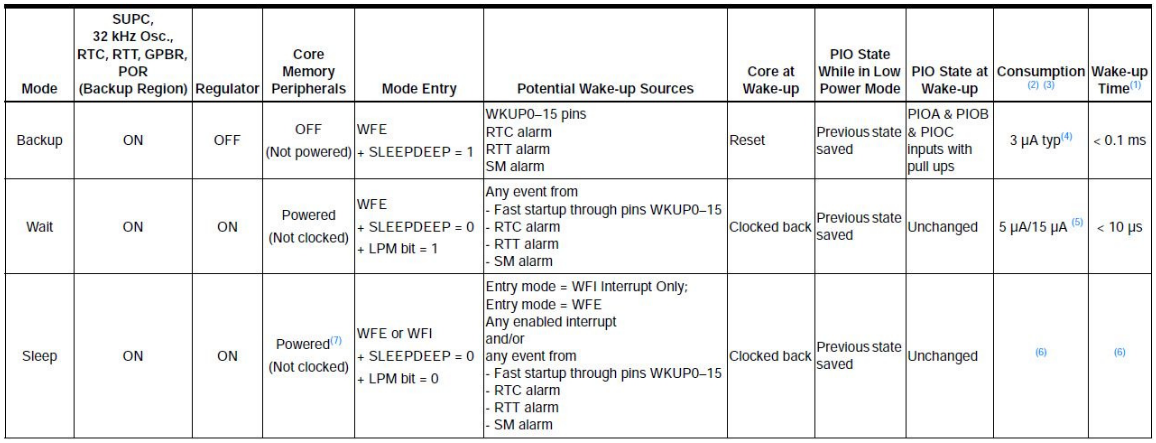


**Figure 53 -** Complete Solar Sub-System

## 6.3 Embedded Hardware

As discussed previously, in section 3.4.1, we decided to use ARM architecture. With one of the main goals of this project focusing on energy efficiency and power conservation, these will need to be large factors into our decision on a MCU. In addition to an MCU, we also know that we will need remote connection capability.

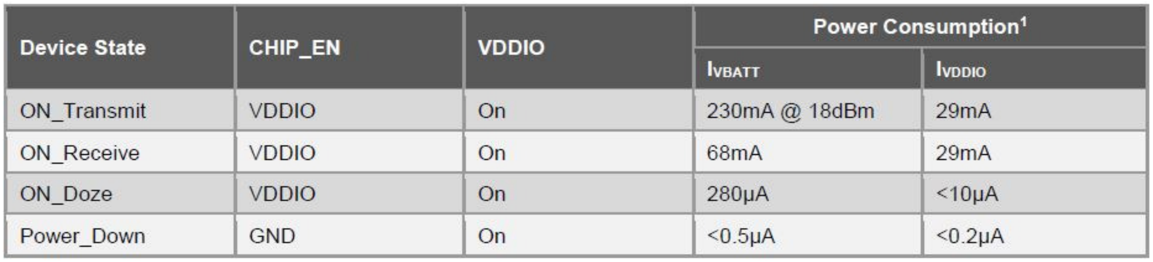
A good energy-efficient option presented itself in the Atmel SAM3N00A. This utilizes the ARM Cortex-M3 architecture, which falls into the category of Harvard architectures used by ARM. It is also one of the low power options available by Atmel. Normal operation requires 1.62-3.6 Volts, with power consumption shown in Figure 54, courtesy of Atmel.



| Mode | SUPC, 32 kHz Osc., RTC, RTT, GPBR, POR (Backup Region) | Regulator | Core Memory Peripherals | Mode Entry | Potential Wake-up Sources | Core at Wake-up | PIO State While in Low Power Mode | PIO State at Wake-up | Consumption (2) (3) | Wake-up Time(1) |
|---|---|---|---|---|---|---|---|---|---|---|
| Backup | ON | OFF | OFF<br>(Not powered) | WFE<br>+ SLEEPDEEP = 1 | WKUP0–15 pins<br>RTC alarm<br>RTT alarm<br>SM alarm | Reset | Previous state saved | PIOA & PIOB & PIOC inputs with pull ups | 3 µA typ(4) | < 0.1 ms |
| Wait | ON | ON | Powered<br>(Not clocked) | WFE<br>+ SLEEPDEEP = 0<br>+ LPM bit = 1 | Any event from<br>- Fast startup through pins WKUP0–15<br>- RTC alarm<br>- RTT alarm<br>- SM alarm | Clocked back | Previous state saved | Unchanged | 5 µA/15 µA (5) | < 10 µs |
| Sleep | ON | ON | Powered(7)<br>(Not clocked) | WFE or WFI<br>+ SLEEPDEEP = 0<br>+ LPM bit = 0 | Entry mode = WFI Interrupt Only;<br>Entry mode = WFE<br>Any enabled interrupt<br>and/or<br>any event from<br>- Fast startup through pins WKUP0–15<br>- RTC alarm<br>- RTT alarm<br>- SM alarm | Clocked back | Previous state saved | Unchanged | (6) | (6) |

**Figure 54 -** SAM3N00A Power Consumption

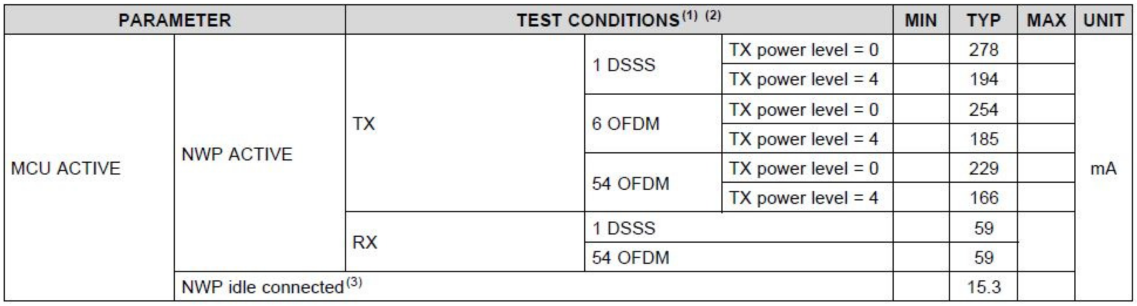
The SAM3N00A does not have remote connection capability. In order to achieve this, we will require an additional module to supply this functionality. Atmel has several chips available for this. The most energy-efficient Wi-Fi module by Atmel is the ATWILC1000, whose power consumption can be seen in Figure 55, courtesy of Atmel.



| Device State | CHIP_EN | VDDIO | Power Consumption¹ | |
|---|---|---|---|---|
| | | | $I_{VBATT}$ | $I_{VDDIO}$ |
| ON_Transmit | VDDIO | On | 230mA @ 18dBm | 29mA |
| ON_Receive | VDDIO | On | 68mA | 29mA |
| ON_Doze | VDDIO | On | 280µA | <10µA |
| Power_Down | GND | On | <0.5µA | <0.2µA |

**Figure 55 -** ATWILC1000 Power Consumption

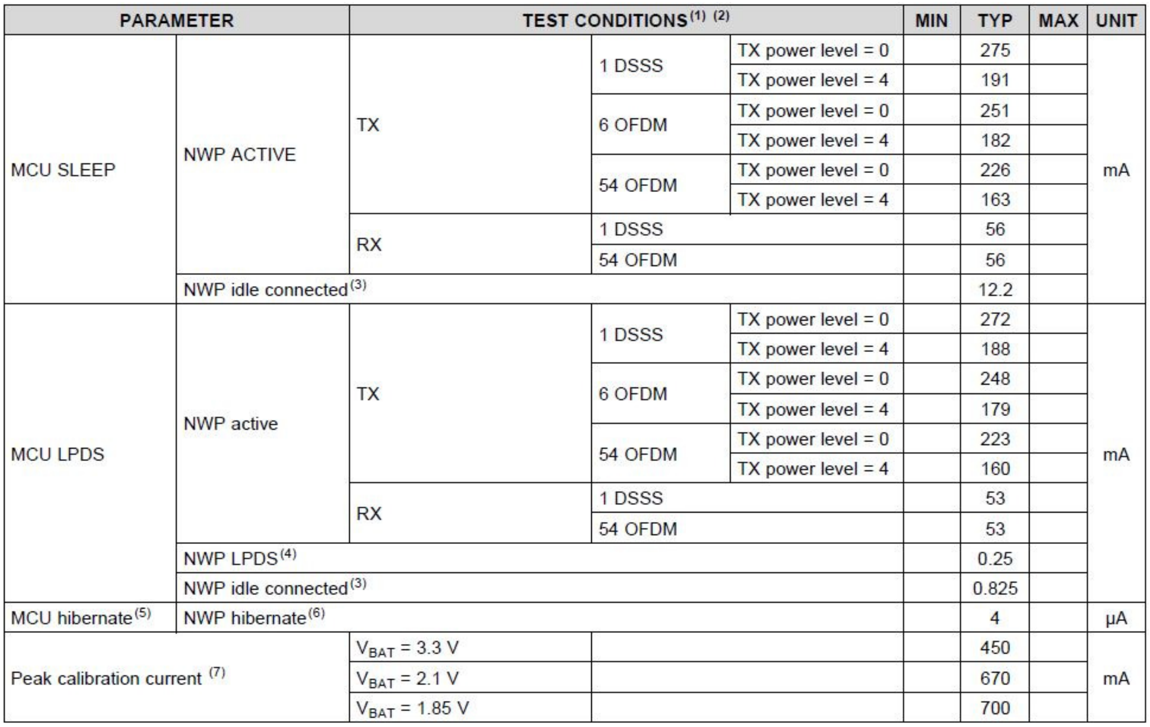
An alternative to the Atmel MCU is the CC3200 made by Texas Instruments. The CC3200 uses an ARM Cortex-M4 core. The main advantage of this chip over Atmel's is that it has a built-in WiFi module. This would significantly reduce the time and effort required for installation of the MCU and setup of WiFi. The tradeoff with this chip is that it uses more power than the Atmel. The active power consumption for the CC3200 can be seen in Figure 56, courtesy of Texas Instruments.



| PARAMETER | | TEST CONDITIONS[1] [2] | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| MCU ACTIVE | NWP ACTIVE | TX | 1 DSSS | TX power level = 0 | | 278 | | mA |
| | | | | TX power level = 4 | | 194 | | |
| | | | 6 OFDM | TX power level = 0 | | 254 | | |
| | | | | TX power level = 4 | | 185 | | |
| | | | 54 OFDM | TX power level = 0 | | 229 | | |
| | | | | TX power level = 4 | | 166 | | |
| | | RX | 1 DSSS | | | 59 | | |
| | | | 54 OFDM | | | 59 | | |
| | NWP idle connected[3] | | | | | 15.3 | | |

**Figure 56 -** CC3200 Active Power Consumption

As we can see, the current can reach pretty high values while the chip is active. The power consumption for the CC3200 while in sleep mode can be seen in Figure 57, courtesy of Texas Instruments.



| PARAMETER | | TEST CONDITIONS[1] [2] | | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| MCU SLEEP | NWP ACTIVE | TX | 1 DSSS | TX power level = 0 | | 275 | | mA |
| | | | | TX power level = 4 | | 191 | | |
| | | | 6 OFDM | TX power level = 0 | | 251 | | |
| | | | | TX power level = 4 | | 182 | | |
| | | | 54 OFDM | TX power level = 0 | | 226 | | |
| | | | | TX power level = 4 | | 163 | | |
| | | RX | 1 DSSS | | | 56 | | |
| | | | 54 OFDM | | | 56 | | |
| | NWP idle connected[3] | | | | | 12.2 | | |
| MCU LPDS | NWP active | TX | 1 DSSS | TX power level = 0 | | 272 | | mA |
| | | | | TX power level = 4 | | 188 | | |
| | | | 6 OFDM | TX power level = 0 | | 248 | | |
| | | | | TX power level = 4 | | 179 | | |
| | | | 54 OFDM | TX power level = 0 | | 223 | | |
| | | | | TX power level = 4 | | 160 | | |
| | | RX | 1 DSSS | | | 53 | | |
| | | | 54 OFDM | | | 53 | | |
| | NWP LPDS[4] | | | | | 0.25 | | |
| | NWP idle connected[3] | | | | | 0.825 | | |
| MCU hibernate[5] | NWP hibernate[6] | | | | | 4 | | µA |
| Peak calibration current [7] | | $V_{BAT}$ = 3.3 V | | | | 450 | | mA |
| | | $V_{BAT}$ = 2.1 V | | | | 670 | | |
| | | $V_{BAT}$ = 1.85 V | | | | 700 | | |

**Figure 57 -** CC3200 Sleep Power Consumption

For Wi-Fi Options, the Atmel is the better choice as far as power-consumption is concerned. However, for Bluetooth options, Atmel does not have any Bluetooth modules to connect to its MCUs. However, Texas Instruments has six wireless MCUs with Bluetooth capability built-in. Of these six chips, the lowest-power option is the CC2640 which is marketed as "ultra-low power wireless MCU for Bluetooth Smart". The current usage of the CC2640 can be seen in Table 15, courtesy of Texas Instruments.

| Active | Idle | Standby | Shutdown | Reset Held |
|---|---|---|---|---|
| 1.45 mA<br>+ 31 µA/MHz | 550 µA | 1 µA | 0.15 µA | 0.1 µA |

**Table 15 -** CC2640 Power Consumption

Clearly, the Bluetooth MCU is hundreds of times more power-efficient than the Wi-Fi option. We will be using the CC2640 for our project, more specifically, the CC2640F128RHBR because it is the cheapest model at the sacrifice of a few pins. With a remaining 32 pins, we should not run into any problems.

## 6.4 Mobile Application

This section of the report will establish the concepts of operation for the Solar Blinds mobile application. Described below are the design details and processes in the mobile application design. We will be discussing which coding language is used and environment it will be built in, the high level architecture, and the specific features and functionality of the mobile application at a low level.

### 6.4.1 Coding language

For our mobile application system the developers choose to pursue the development of the Solar Blinds application using C# as the primary language. If time constraints are going to be too strict then we will have to fall back to using Java since we are more familiar with it.

Mobile applications are normally developed in an object-oriented language, and we feel that expanding our experience into a new programming language will be a great benefit to us. Up until now, we have only been taught MIPS assembly, C programming, and Java programming as part of our standard curriculum. Although C# may not be much different from Java, it is used for many different uses and potential employers would be happy to see that we have prior experience in this language.

### 6.4.2 Build Environment

The build environment of the mobile application will be attempted in the free version of Xamarin Studio. This environment allows the developers to use C# as their primary language which that choose to work with. All source code and any other files will be managed using Xamarin Studio and preexisting folder structure since it is able to readily deploy code into working app bundles.

### 6.4.3 High Level Architecture

For our application's high level architecture we will be using a mix of layering and repository styles. The layering style representation is used because the data will have to go through multiple layers and processed individually at each specific layer. Upon reaching the lowest layer, the I/O, Bluetooth, NFC, and RFID Management components will begin to interface with the actual mobile device and Solar Blinds. When the information is finally processed it will go to the user layer which can branch out into many differ states depending on the option screens selected. Using a GUI an assortment of screens will be used to display the different menu items the users can select from the home screen.

This makes the GUI one of the highest levels the data will reach. This is because the opening screen actually will be displaying the data to the user but it will not allow users options to make changes to the solar blinds data internally. The data will only be represented in these screens. The user will use the GUI to send signals to get or push data to the Solar Blinds. The only options the user will have on the opening screen is to enter the app or double press the back button to close the app. At the menu layer the scheme will become linear in manner since its starts to act a repository for the differ types of data being pass to and from many different classes. The diagram in Figure 58 shows how all of the interaction between the mobile application and the physical components will take place.

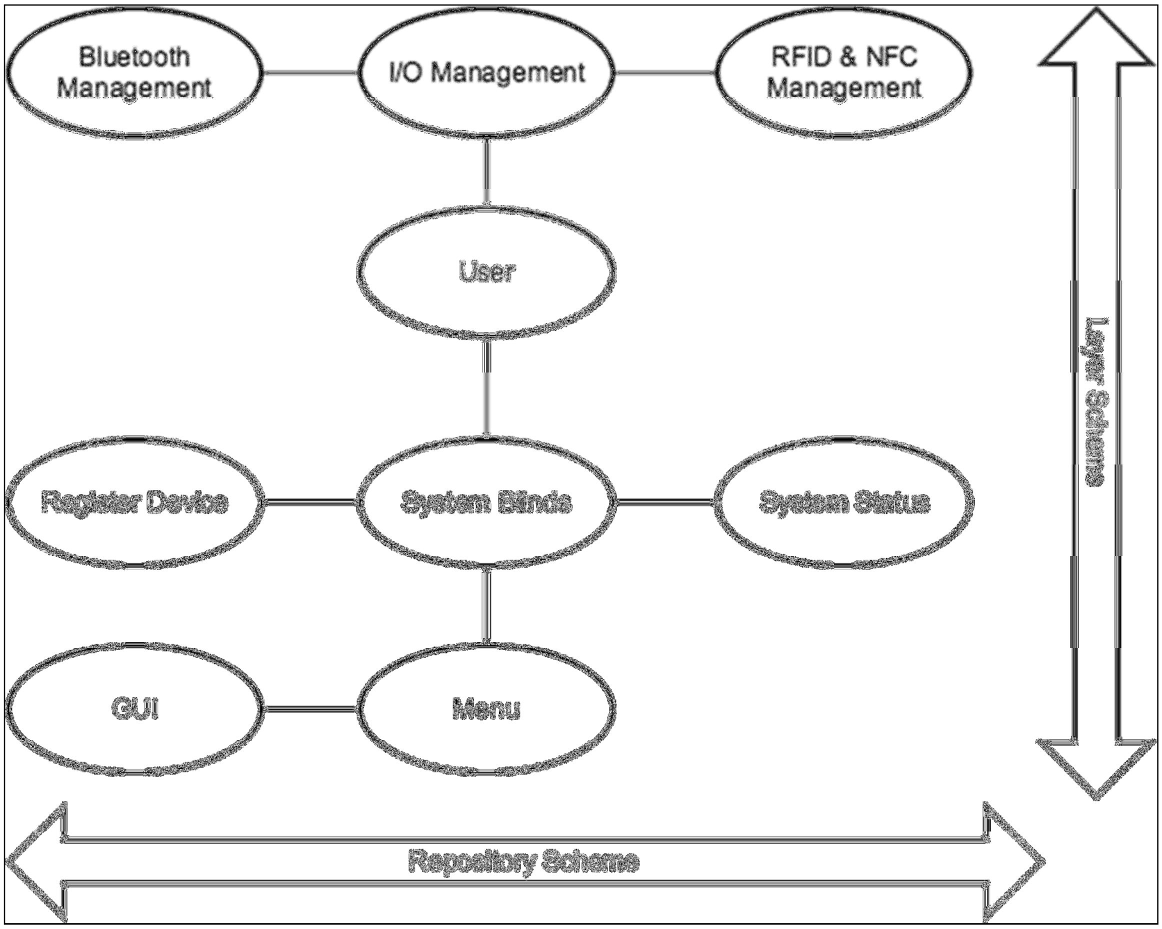


**Figure 58 -** Major Components and System Interfaces

### 6.4.4 Activity Descriptions

The activity diagram shows all of the user's actions they are able to accomplish using the mobile application and the Solar Blinds together are shown in Figure 59. These actions also represent the requirements needed to take this action and scenarios when the actions are available to be used by the user. If the user attempts any unpermitted actions the mobile application will inform the user that there is an error and show the steps that are needed to fix this.

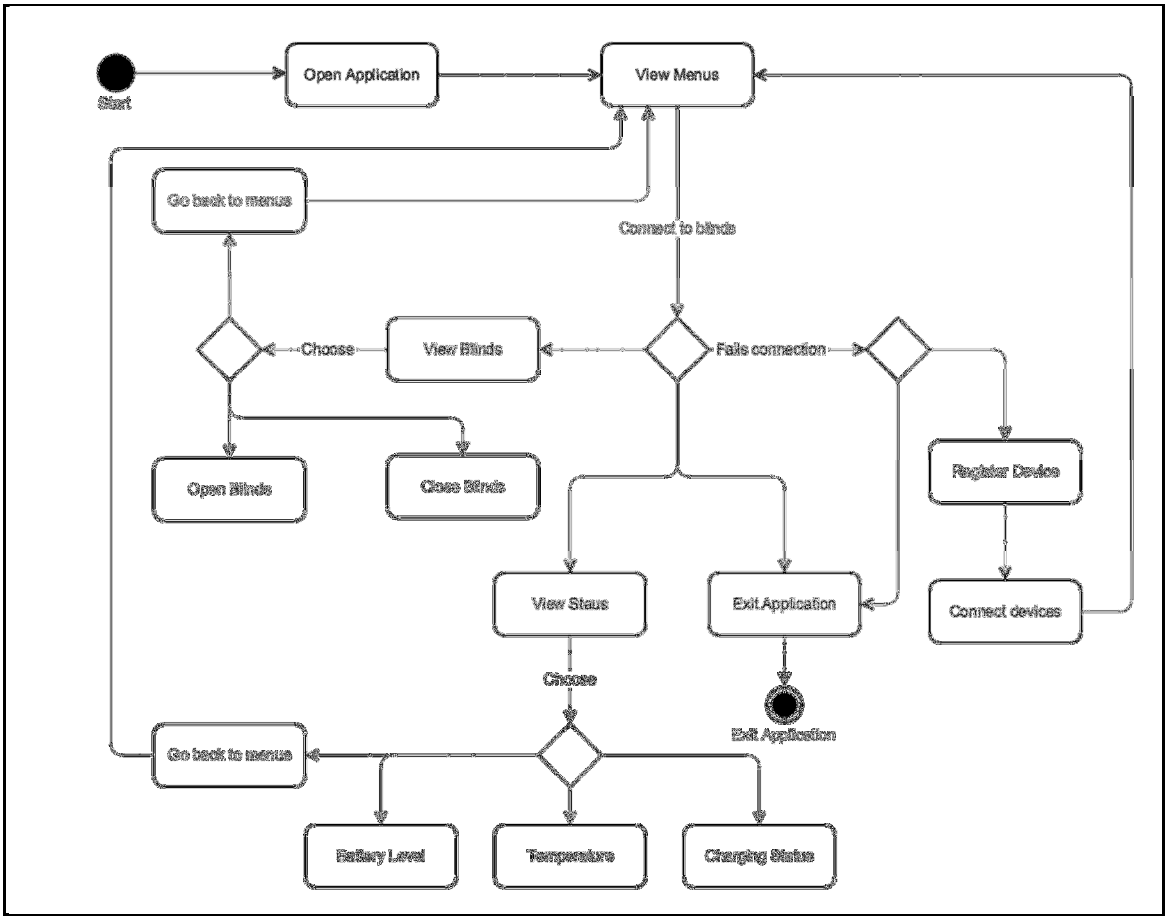


**Figure 59 -** Activity Diagram of the Mobile Application

6.4.5 Use Case Descriptions

This system will allow a user to operate directly with the Solar Blinds via our mobile application. In order to do this, the user must maintain certain requirements and cannot alter these specified procedures. Any user can access the mobile application by simply opening it up and view the menus. However if the user attempts to do anything besides just viewing the menu the action will fail. This is because in the use case the user can open the application and view menu but when they do those tasks they must connect the device. This is to prevent anyone from randomly controlling the Solar Blinds without proper authorization. When registering the device the user will have two options they can either select connect their device or disconnect their device. Remember though in order to actually operate the blinds the user must be connected to the Solar Blinds. This is why in the use case diagram in Figure 60 includes "connect device" for any action that will either operate or show the internal data of the Solar Blinds.

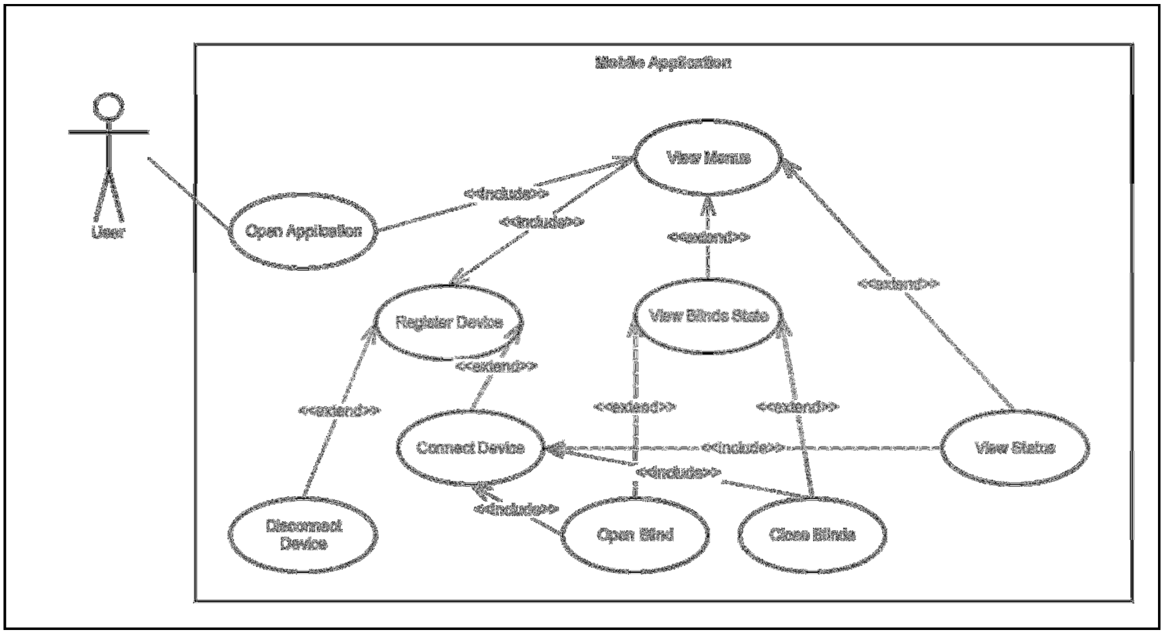


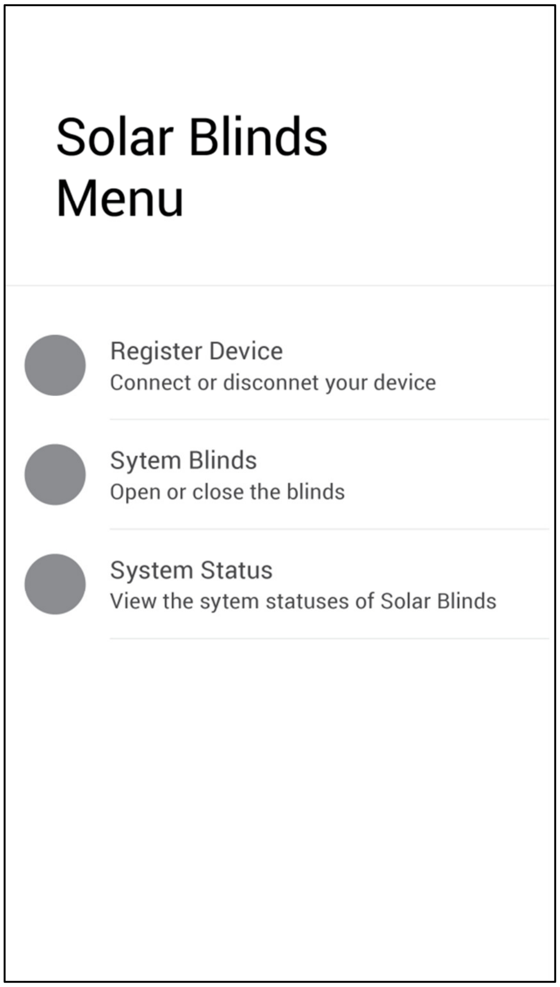
**Figure 60 -** Use Case Diagram of the Mobile Application

## 6.4.6 Mobile Application Screen

### *6.4.6.1 Menu Screen*

After showing the app cover screen the user will be taken directly to the menu screen without the need of user input. The menu screen shown in Figure 61 will act as the GUI navigation point to reach all of the other features of the mobile application. All of the buttons will feature a normal state and an active. The buttons shown on the menu screen will be:

- Register Device
- System Blinds
- System Status



Solar Blinds
Menu

Register Device
Connect or disconnet your device

Sytem Blinds
Open or close the blinds

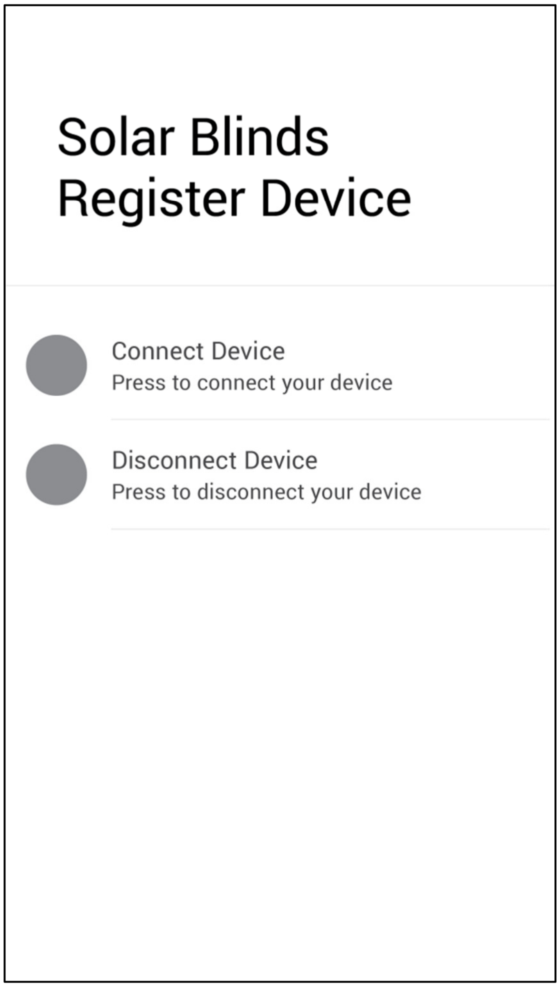
System Status
View the sytem statuses of Solar Blinds

**Figure 61 -** Menu Screen Concept

### *6.4.6.2 Register Device Screen*

This screen, shown in Figure 62 will allow the user the ability to register the Solar Blinds device and mobile application with their mobile phone in order to view the output information and to send data back to the Solar Blinds with their mobile device. Using NFC and Bluetooth technology pressing on the buttons will initiate the mobile application to begin sending signals via Bluetooth to the Solar Blinds. The buttons shown on the register device screen will be:

- Connect Device
- Disconnect Device



Solar Blinds
Register Device

Connect Device
Press to connect your device

Disconnect Device
Press to disconnect your device

**Figure 62 -** Device Sync Screen Concept

### *6.4.6.3 System Blinds Screen*

This screen, shown in Figure 63, will be used to actually control the blinds from your mobile application. When the mobile application is connected to the Solar Blinds the screen will indicate the current status of the blinds with a green dot (shown in the appendix). Pressing the button will switch between the two possible states. If the Solar Blinds are already in the open state pressing the open button again will do nothing. This is to prevent malfunction on the motors. The buttons shown on the system blinds screen will be:

- Open Blinds
- Close Blinds

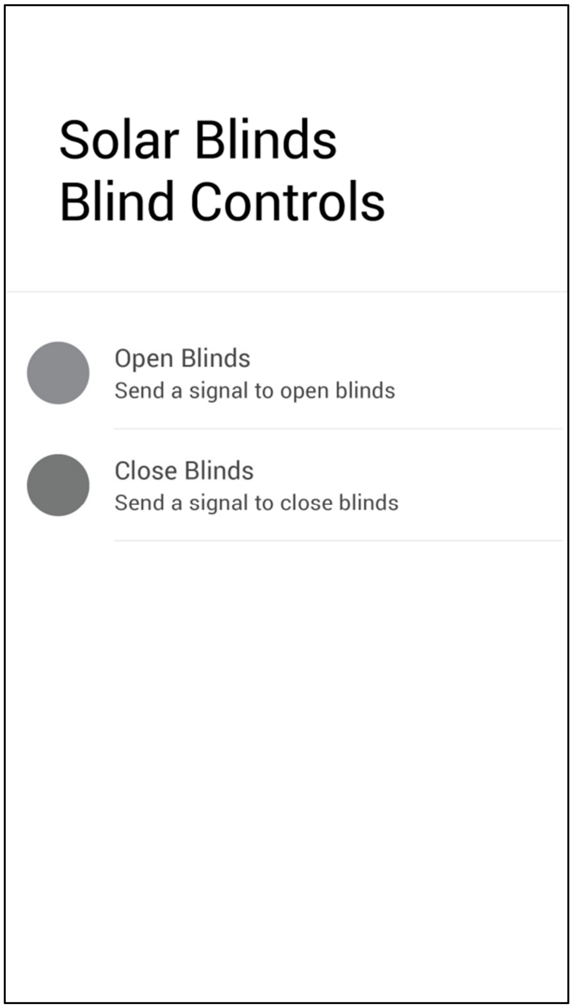
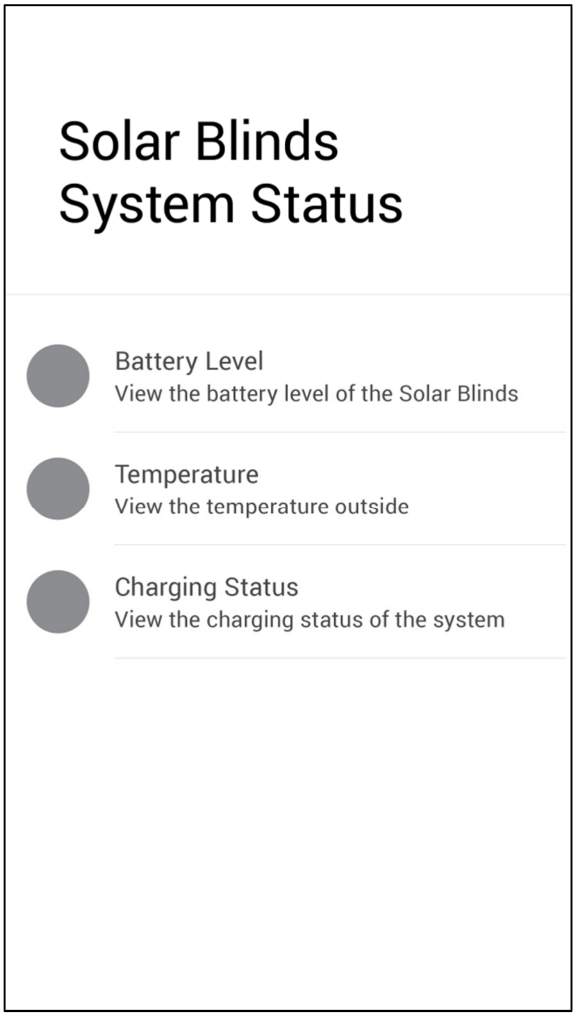


**Figure 63 -** Solar Blinds Screen Concept

### *6.4.6.4 System Status Screen*

This screen, shown in Figure 64, will be used to display the status of the internal components of the Solar Blinds system. The user would not be truly interacting directly with the Solar Blinds device at this point because the mobile application will only be receiving data as opposed to before when it was doing both. The buttons shown on the system blinds screen will be:

- Battery Level
- Temperature
- Charging Status



Solar Blinds
System Status

Battery Level
View the battery level of the Solar Blinds

Temperature
View the temperature outside

Charging Status
View the charging status of the system

**Figure 64 -** System Status Screen Concept

## 6.4.7 Low Level Design

### *6.4.7.1 Graphic User Interface*

This handles all of the graphics displayed. The different screens were broken down more in depth above please reference them to see more information about them. The input, output, attributes and actions associated are:

- Inputs: Sensors (touchscreen technology), Solar Blinds Statuses
- Outputs: Graphics of the Solar Blinds data and statuses
- Attributes: The different screens
- Actions: Display all of the graphic data onto the mobile application screens

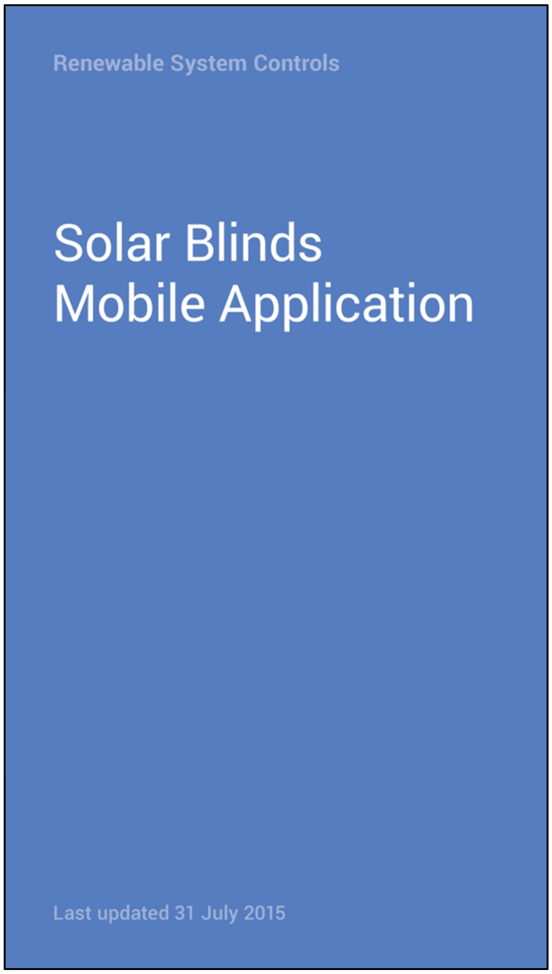
### *6.4.7.2 Input/Output*

This handles the raw data collection and sends it to the other components in the system. Like for an example the touchscreen sending information to the Solar Blinds when the user presses the close blinds button on the System Blinds screen. The input, output, attributes and actions associated are:

- Inputs: Data from the device in regards to the touch screen, Bluetooth, RFID and NFC
- Outputs: The data in form of graphic representation and forms to be transferred via Bluetooth, RFID, and NFC
- Attributes: Touch sensor
- Actions: Get the data from the device and send to the read of the system

#### *6.4.7.3 Mobile Application Prototype*

This section contains a graphical overview of the potential design for the Solar Blinds mobile application. This prototype includes images of the mobile application along with the screens representing the active state buttons (toggled on) on each of the buttons that can be used to take the user to another screen or even cause an interaction signal to be sent to the Solar Blinds or the mobile application. All of these screens are discussed in detail in the 9.2 Software Operation section of the report.

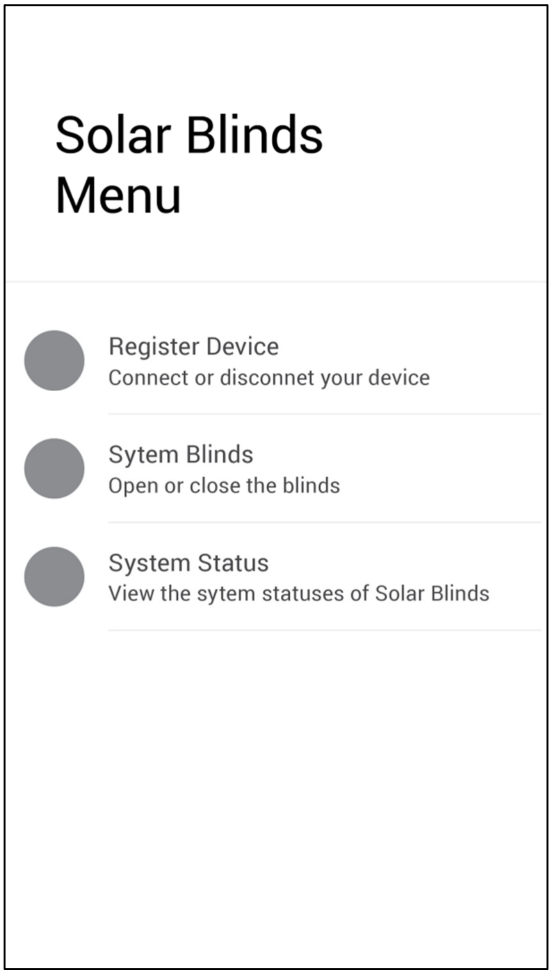


Renewable System Controls

Solar Blinds
Mobile Application

Last updated 31 July 2015

**Figure 65 -** App Cover/Intro Screen



Solar Blinds
Menu

Register Device
Connect or disconnet your device

Sytem Blinds
Open or close the blinds

System Status
View the sytem statuses of Solar Blinds

**Figure 66 -** Main Menu

The mobile application's cover screen is shown in Figure 65. This will be displayed when the app starts and is displayed until the application loads.

In Figure 66, next to the cover screen, is a concept of the main menu. The menu screen of the mobile application provides a GUI for the main navigation of the mobile application.

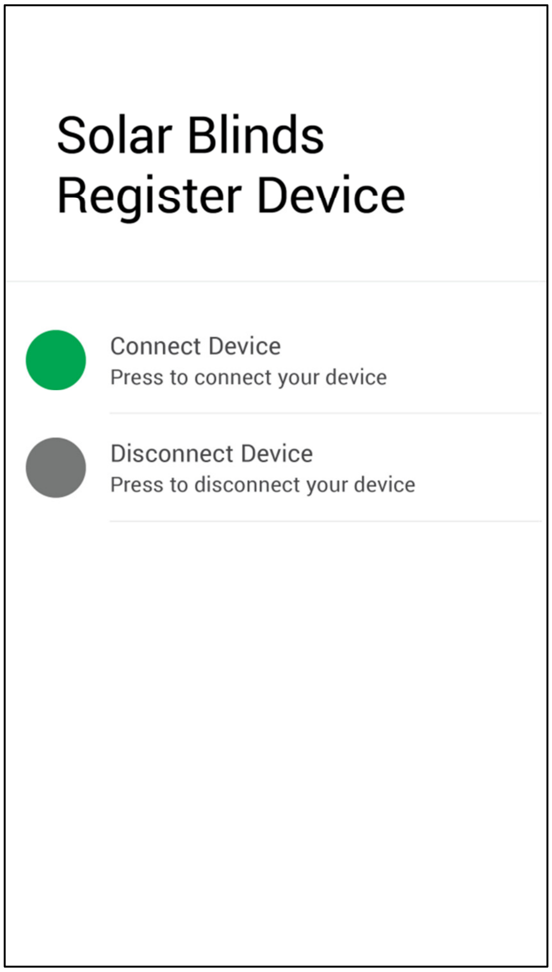


**Figure 67 -** Sync Screen

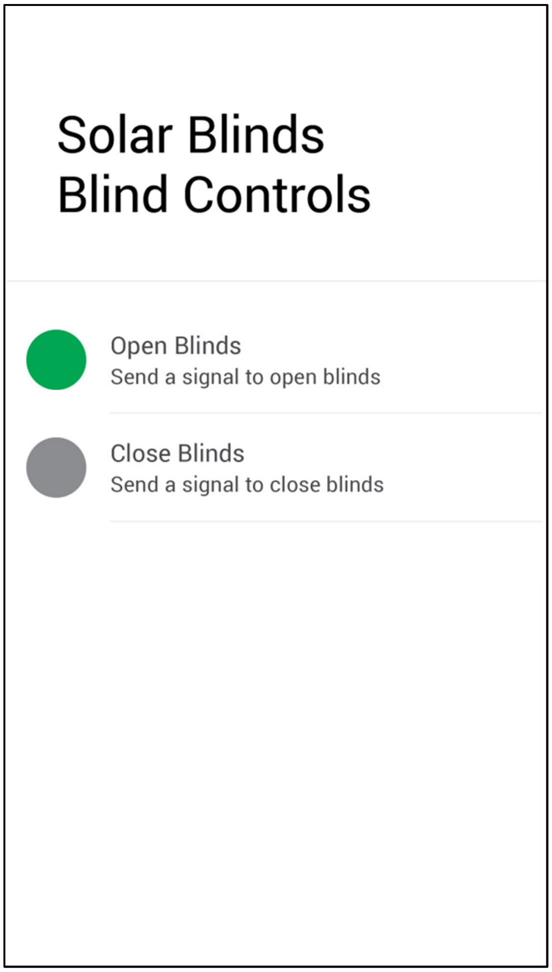
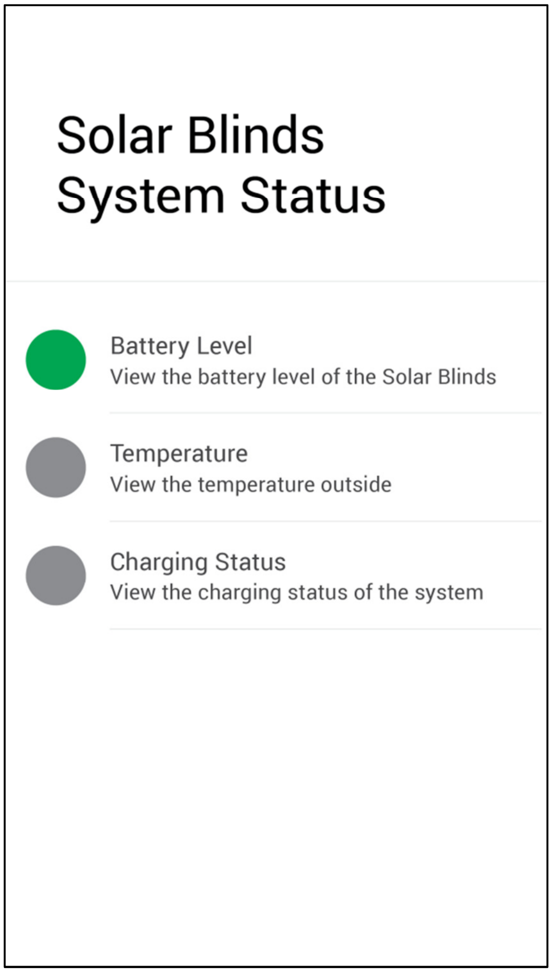


**Figure 68 -** Blind Control Menu

The register device screen in Figure 67 is used to connect or disconnect the user's mobile device. The green button represents that the button is currently being pressed.

The system blinds screen in Figure 68 is where the user will go to open and close the blinds. Likewise here, the green button represents it is being pressed.



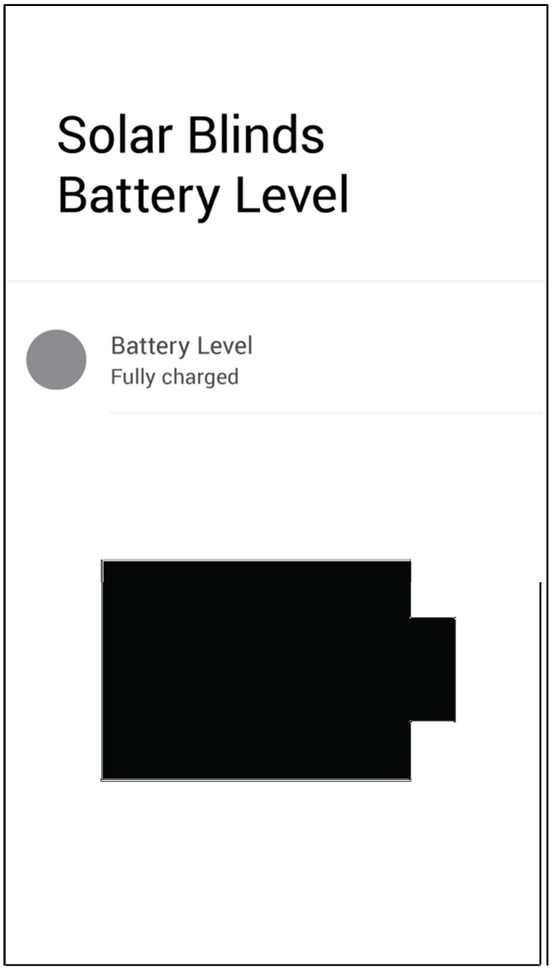
Solar Blinds
System Status

● Battery Level
View the battery level of the Solar Blinds

● Temperature
View the temperature outside

● Charging Status
View the charging status of the system

**Figure 69 -** System Status Menu



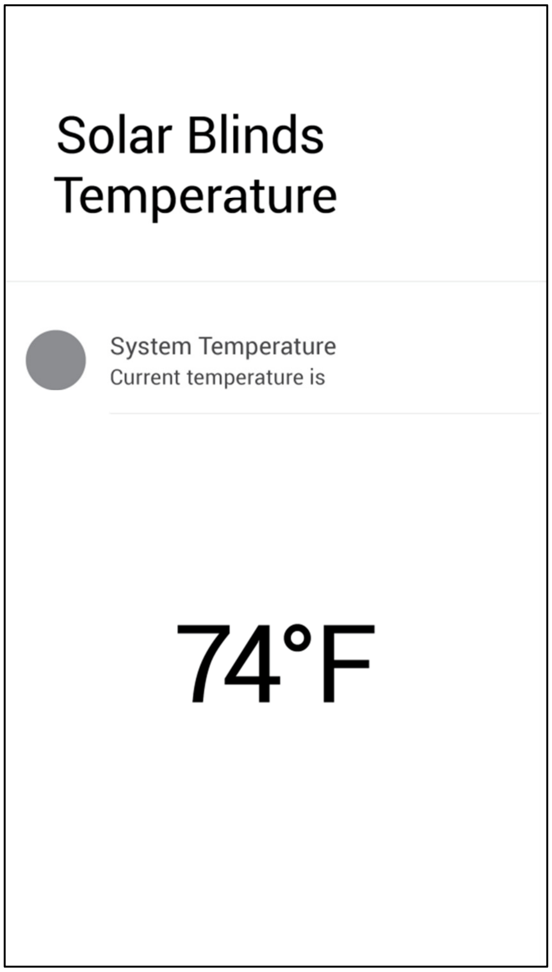
Solar Blinds
Battery Level

● Battery Level
Fully charged

**Figure 70 -** Battery Menu

The system status screen in Figure 69 provides the user with navigation button to the battery level, temperature, and charging status of the mobile application. The green button represents that it is being pressed.

The battery level screen in Figure 70 shows the current battery level of the solar blinds system. The battery has 5 states that can be shown to the user. The state displayed here represents a fully charged battery.

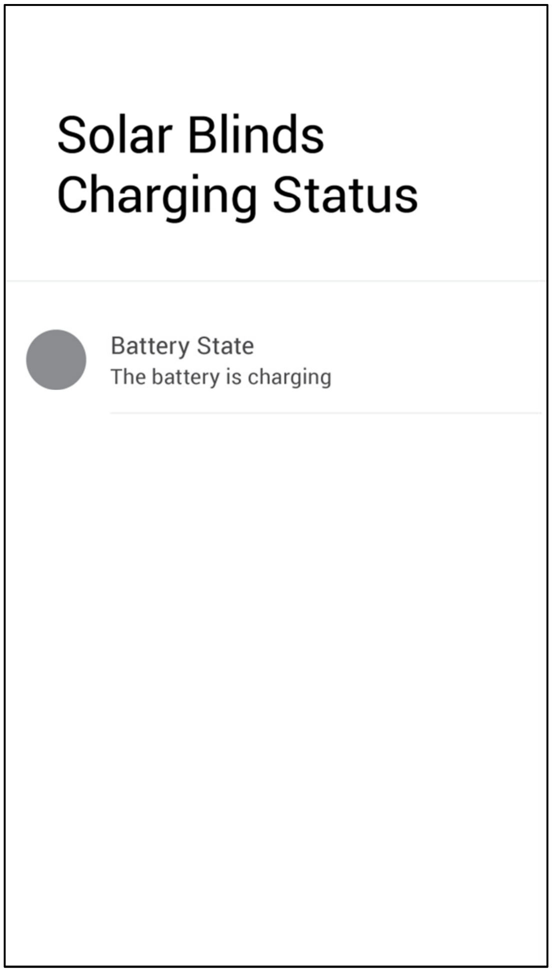


Solar Blinds Temperature

System Temperature

Current temperature is

74°F



Solar Blinds Charging Status

Battery State

The battery is charging

**Figure 71 -** Temperature Menu

**Figure 72 -** Battery State Menu

Figure 71 shows the temperature screen. This screen will show the user the current outside temperature. We would also like to implement real-time weather updates from the internet if time permits.

The charging status screen in Figure 72 shows the user if the blinds are currently charging or discharging energy. The battery would be discharging energy if there is less power incoming from the solar cells than is being expended to power the various functions. While a phone or other electronic device may be charged through the USB port, the battery of the blinds will display as discharging here.

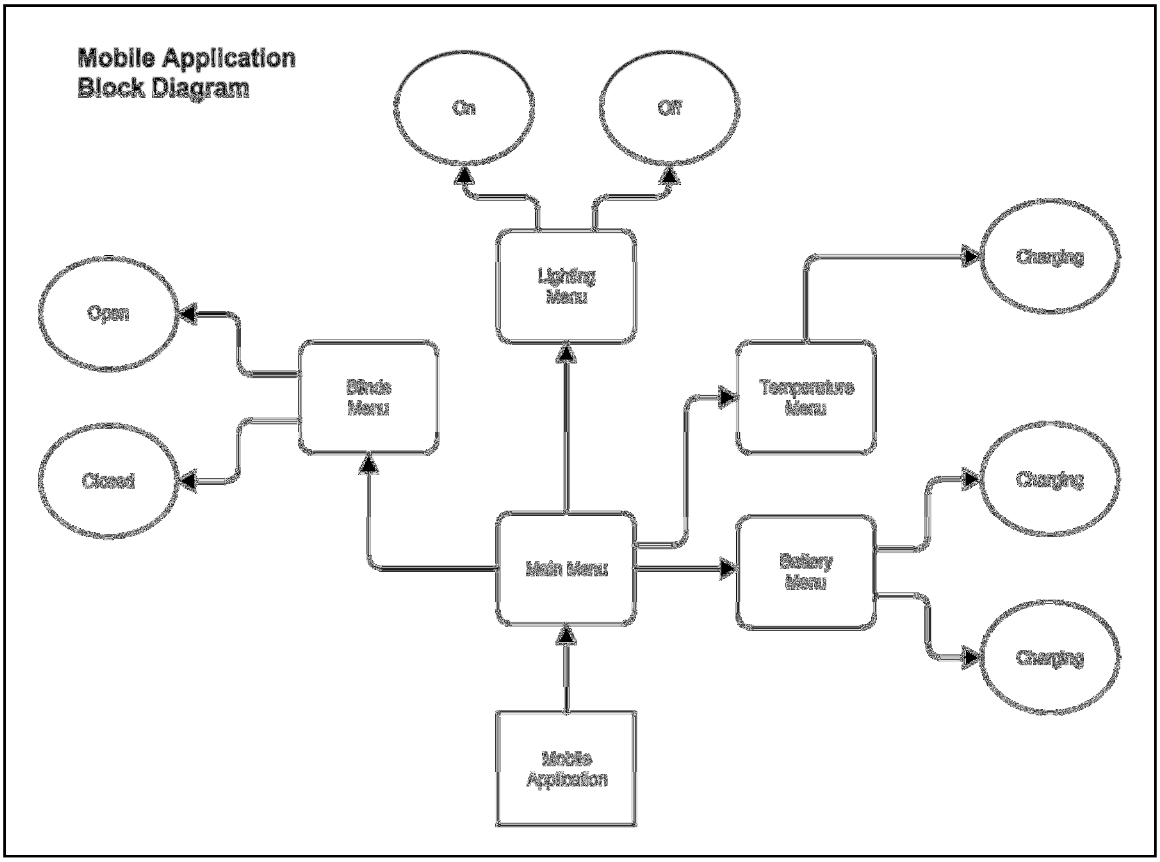


**Figure 73 -** Mobile Application Block Diagram

In Figure 73, we have a block diagram which shows the basic configuration of the entire mobile application. This is a visual representation of the connections between the various screens in the application and their various functions.

Table 16 is a list of responsibilities for each portion of development for the application. The work will be divided between our two computer engineers, but much collaboration is anticipated.

| Block Name | Responsible member | Input / Output |
|---|---|---|
| Main Menu | Dakota | Input - Touch input from a touch screen<br>Output - A success or fail message and changing the application screen to the next menu |
| Battery Menu | Dakota | Input - Not Applicable<br>Output - Status of the battery |
| Blinds Menu | Artis | Input - A button toggle on a touchscreen device that can switch between open and close.<br>Output - A success or fail message and the physical device (solar blinds) opening or closing the blinds. |
| Lighting Menu | Artis | Input - A button toggle on a touchscreen device that can switch between on and off.<br>Output - A success or fail message and the physical device (solar blinds) turning on or off the lights. |
| Temperature Menu | Dakota | Input - Not Applicable<br>Output - Status of the temperature sensor |

**Table 16 -** Mobile Application Software Development Assignments

# 7.0 Project Prototype Construction and Coding

## 7.1 Parts Acquisition and Bill of Materials

Shown below in Table 17 is the bill of materials for this project. This consists of all of the costs and parts that will be used in the production of our design.

| Part | Manufacturer | Cost |
|---|---|---|
| 3.3 W 6”x6” Monocrystalline Solar Cells (10) | Sunpower | $ 46.99 |
| 2mm x 0.15mm Tabbing Wire (10 m) | MISOL | $ 6.29 |
| 835-P Rosin Flux Pen | MG Chemicals | $ 8.95 |
| Rosin Core Lead-Free Silver Solder | Trakpower | $ 11.93 |
| DC-DC LTC1871 Step Up Module | DROK | $ 10.04 |
| R-14 Rollable Solar Module | Powerfilm | $ 185.99 |
| UB250 12 V 5 Ah SLA AGM Battery | Universal Power Group | $ 9.93 |
| GV-5 MPPT Charge Controller | Genasun | $ 75.00 |
| PCB Assembly | OSH Park | $ 30.00 |
| Microcontroller CC2640F128RHBR | Texas Instruments | $ 13.08 |
| Bluetooth Module (on MCU) | Texas Instruments | $ --- |
| Wiring | Retailer | $ 10.00 |
| MintyBoost USB Charger | Adafruit | $ 19.50 |
| E-paper Display | | $ 21.72 |
| | **Total**: | $ 449.42 |

**Table 17 -** Bill of Materials and Manufacturers

## 7.2 PCB Vendor and Assembly

We have been considering many different options on what to do to order and populate our PCB board. We will be using Eagle to design our schematic and PCB layout. As far as vendors go for sending out the PCB board to be made, here are some of the vendors we are considering: Sunstone, Avanti Circuits, OSH Park, PCB Pool, Olimex, and PCB Train. Each of these vendors all make PCB prototype boards but some do at much higher cost and some make them at much longer lead times.

Sunstone seems to be a bit pricey with a cost for two boards that are zero to nine square inches being about a hundred dollars, but the lead time of these boards are only a week. Avanti doesn’t provide a price until the actual board has been submitted, but the standard lead time on these boards is about two weeks.

OSH Park seems to be a reasonably priced option as well, even though the lead time seems like it will be over two week. OSH Park says that the boards will ship under twelve days of receiving the order. This means that all though they may ship within twelve days, there is still added time for the delivery. The cost for these boards though for two layers is only five dollars per square inch which is much cheaper than the other options we have seen thus far.

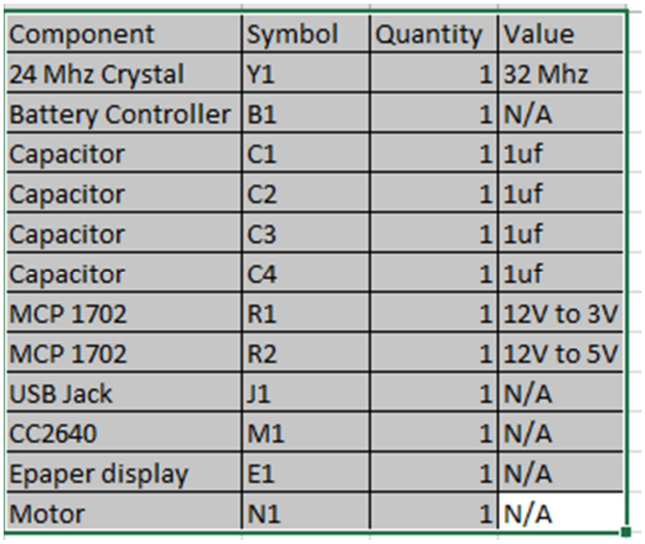
PCB Pool offers four two by two PCB boards for a total price of eighty dollars. This doesn't seem too bad if we need multiple boards which would be nice for testing in case something goes wrong and we need more boards. The lead time for these boards is about the average of what I have been finding as it is about two weeks.

Olimex seems like it would've been a good company to have used, but if you try to go to their website, it is down. They seem to only operate during certain months out of the year.

PCB Train seems to be the most expensive. The cost of manufacturing PCB boards starts at two hundred euros as a baseline price. This in American dollars is about two hundred and twenty one dollars. This seems much more expensive than our other options unless we were creating a board that was much more intricate than this.

It seems as of right now, the best option as far as lead times and price will be OSH Park. This will be the company that we will be sending our PCB out to.

Figure 74 is the list of the components that we will need for the PCB Assembly. They were put into an excel spreadsheet and have the attached symbols that will appear on the actual PCB boards Silkscreen Layer.



| Component | Symbol | Quantity | Value |
|---|---|---|---|
| 24 Mhz Crystal | Y1 | 1 | 32 Mhz |
| Battery Controller | B1 | 1 | N/A |
| Capacitor | C1 | 1 | 1uf |
| Capacitor | C2 | 1 | 1uf |
| Capacitor | C3 | 1 | 1uf |
| Capacitor | C4 | 1 | 1uf |
| MCP 1702 | R1 | 1 | 12V to 3V |
| MCP 1702 | R2 | 1 | 12V to 5V |
| USB Jack | J1 | 1 | N/A |
| CC2640 | M1 | 1 | N/A |
| Epaper display | E1 | 1 | N/A |
| Motor | N1 | 1 | N/A |

**Figure 74 -** PCB Components List

### 7.3 Final Coding Plan

Table 18 in this section will outline the calendar for the completion of different parts of the mobile application. The developers will be responsible for ensuring that they meet all of the following deadlines in order to provide ample amount of time for code reviews, testing, debugging, and optimization.

Since we will be using agile methods for development as the developers are coding they will also be testing and verifying the mobile application both virtually and physically. In case any issues arise during development is can be addressed and alterations can be made then and there if deemed necessary. This way the mobile application will be full testing by the end of November.

| Week | Task | Due Date |
|---|---|---|
| 1 | Finalize design prototype | 8/28 |
| 2 | Complete navigation screen | 9/4 |
| 3 | Complete the toggle states for the buttons along with how they are to be implemented | 9/11 |
| 4 | Complete the android device connection setup | 9/18 |
| 5 | Analysis report go back and ensure completion of tasks | 9/25 |
| 6 | Complete the setup for opening and closing the blinds | 10/2 |
| 7 | Complete the setup to pull in data from the Solar Blinds | 10/9 |
| 8 | Analysis report go back and ensure completion of tasks | 10/16 |
| 9 | Ensure all tasks are in testing complete. If tasks are not in that state reassign them to developers. | 10/23 |
| 10 | Refractor and optimize the code | 10/30 |

**Table 18 -** Final Coding Plan

# 8.0 Project Prototype Testing

Once our project has been completed, there will be a necessary procedure that needs to be followed to make sure all aspects are working right. There are many parts to this project and if any individual ones fail, the whole project will not work correctly.

## 8.1 Hardware Test Environment

A 3’x4’ model window will be built using two-by-fours and a pane of glass. The solar shade unit will be mounted to the inside of the glass. This will allow the unit to be moved around and tested under various light conditions. The following environments will be used to test the window.

- Window facing east
- Window facing west
- Window facing north
- Window facing south
- Window facing directly up
- Window angled at 30 relative to the ground
- Window angled at 45 relative to the ground
- Window angled at 60 relative to the ground
- Window angled at 90 relative to the ground
- Glass pane on
- Glass pane removed

A battery capacity meter will be used to measure the amount of energy that is added to the battery under each test condition. A two-hour time window will be used for each test condition. The quality of available light should be the same for each test. The data captured in each of these tests can be compared in order to find which environment is most effective for capturing light. When the window is facing east it will capture energy earlier in the day and when the window is facing west it will capture energy later in the day. When the window is facing north or south the light will not be as intense in the morning or in the evening, but should be more consistent throughout the day. By testing the window at different angles relative to the ground we will be able to calculate the loss in solar panel efficiency as a function of angle. The solar panel will perform best when it is facing directly up because the angle of incidence to the sun is 90°. As the angle is increased relative to the ground the efficiency should decrease. The final test is comparing the efficiency of the solar panel when the glass pane is on to when the glass pane is removed. The solar panel should yield higher efficiencies when the glass pane is removed because some of the incident light will be reflected when the glass pane is on.

## 8.2 Hardware Specific Testing

The Hardware test effort is a critical to ensure the project is running at optimum performance. Our testing efforts will also ensure the project will not malfunction and cause harm to anyone that is using the product in a real life scenario. This portion of the report will be describing our projects test environment and procedures for testing the Solar Blinds hardware systems. We are going to be describing the objective for each hardware activity and what’s expected to be accomplished from it. The hardware code will be programed in Code Composer. After completion of the testing we will compile a list of all of the bugs and flaws that we have found throughout the code for the software application testing. The details listed below will show what we expect will occur in the software.

### 8.2.1 Stopping Criteria

The testing procedures must be continued non-stop unless a specific problem occurs that hinders further testing. These stopping criteria may be either functionality wise or cosmetic. Once the bugs or issues are isolated the tester should make well-documented notes about what exactly occurred, when they occurred and there best assumption as to why they are happening. Before moving on to the next the tester should consult with a developers or the builder to make sure the issue is not a simple fix. If it is have the developer or the builders fix the issue and redeploy the code or hardware.

Once all of the test cases are passed the code and hardware will be considered deliverable. This state means that there are no known bugs or issues to our knowledge and all of the system is fully working.

### 8.2.2 Hardware Test Cases

This section will provide a step-by-step procedure for each test case that will occur during the software testing activity. The test cases format will all be standardized into the following format.

| |
|---|
| **Test Objective:** Define the test case’s goal. |
| **Test Description:** Define the step-by-step guidelines. |
| **Test Conditions:** Define any specific conditions that should be applied to the environment when testing. |
| **Expected Results:** Define the resulting actions that should be seen by the tester. |

**Table 19 -** Example Table of a Test Case

Following the format of Table 19, the following Tables 20-24 describe the various test cases which we will explore in order to test that our device's hardware functions properly. This testing will be done at the end of all hardware development toward the end of October 2015. See the milestones in section 10.1 for more details.

| |
|---|
| **Test Objective:** Ensure the Solar Blinds turn on |
| **Test Description:**<br>Using solar energy make the Solar Blinds turn on |
| **Test Conditions:** See test environment |
| **Expected Results:** The Solar Blinds should turn on. |

**Table 20 -** Test Case: Power On

| |
|---|
| **Test Objective:** Make sure the Solar Blinds display screen turns on and functions |
| **Test Description:**<br>• After the Solar Blinds turns on ensure the Solar Blinds display screen is functioning<br>• Ensure the screen displays all of the correct details |
| **Test Conditions:** See test environment |
| **Expected Results:** The application cover screen will be displayed. |

**Table 21 -** Test Case: Display Screen Functions

| |
|---|
| **Test Objective:** Verify the USB charger functions and capabilities |
| **Test Description:**<br>• Check and make sure the USB charger is outputting the correct amount of the energy<br>• Ensure the charger is able to charge a device |
| **Test Conditions:** See test environment |
| **Expected Results:** The USB charger is supposed to be able to power a small device via a USB cable. |

**Table 22 -** Test Case: USB Charger Functions

| |
|---|
| **Test Objective:** Ensure that motors are able to fully open the blinds |
| **Test Description:**<br>• Used the mobile application to send a signal to the Solar Blinds to open them.<br>• Used the manual option to send a signal to the motors to open the blinds. |
| **Test Conditions:** See test environment |
| **Expected Results:** The Solar Blinds motors should be able to open the blinds |

**Table 23 -** Test Case: Retracting the Blinds

| |
|---|
| **Test Objective:** Ensure that motors are able to fully close the blinds |
| **Test Description:**<br>• Used the mobile application to send a signal to the Solar Blinds to close them.<br>• Used the manual option to send a signal to the motors to close the blinds. |
| **Test Conditions:** See test environment |
| **Expected Results:** The Solar Blinds motors should be able to close the blinds |

**Table 24 -** Test Case: Lowering the Blinds

### 8.2.3 Battery and Controller Testing

To test that the battery controller is charging the battery correctly, we will need to leave the solar panel film out in the sun for an extended period of time and have it hooked up to the battery controller which is in turn supposed to be charging the battery. We can let it continue to charge for some time, and as it is charging, we can use a voltmeter and make sure that it is charging correctly and that the battery controller and the battery itself is working right.

### 8.2.4 Voltage Regulation

After the battery and the controller have been verified to be working correctly, we need to net move to the regulation part of the circuit on the board itself. We need to make sure that everywhere specified in the schematic, there is the correct voltage on each node there. Once this has all been verified and we know that there is enough voltage being applied to each node, then we will move on to test the motor.

### 8.2.5 Motor Test

First, we need to check the motor by itself. We should see that if we just apply the voltage correctly the D/C motor should spin one way continually until it either hit the limit switch or we disconnect the voltage being applied to it. Next, we need to apply the voltage in the opposite direction, and see if the motor itself spins the opposite way. Once all this has been verified, then we know that the motor itself is working correctly so anything else that goes wrong with the motor later on in the project, we know isn't caused from the motor itself not functioning correctly. We will wait until later to check to see if the motor is correctly operated by the micro.

### 8.2.6 LED Test

The next section of our project that there is to test is the LED lights that will illuminate and draw steady current from our battery source. We need to test the LED’s individually first to make sure that they were all put in correctly and that none were put in backwards. This is a common mistake and the LED will never light if the LED is put in backwards. To test this, we will have to apply a voltage to the strip of LED's we are going to use and power. This will allow us to see the LED's all lit up. Once we have tested these by themselves, we know that there are no physical defects in the LED's themselves. Later on in the testing procedure, we will use the micro to turn these LED's on and off.

### 8.2.7 USB Charger

The next step in the testing procedure is to test the USB charger itself. This is going to be the number one power consumer in our project. It is going to use 5V and draw about 1 A to charge phones at a quicker rate. This can be tested by checking the voltage on the USB header itself and making sure that it is five volts. Also, we can make sure that a phone or iPad or any device that is plugged in is charging. Also, we need to make sure as we are charging any device that is plugged into the USB slot, that the battery isn't draining to fast. We need to make sure that our battery is large enough and has enough capacity that it can supply the correct current and voltage needed to charge any of the devices plugged into that port.

### 8.2.8 Microprocessor Testing

This is the most complicated and extensive testing that will be done in our project. The micro is the heart of the whole project. First, we need to make sure that the I/O pins we are working with are functioning correctly and are doing exactly what we are telling them to do. A way for us to check this, is to tell the micro to put a high or a low on a certain pin, and making sure we see the pin itself go high or low using a multimeter. This will ensure that the pins that we think we are talking to, are indeed the correct pins we are talking to. This is important because we can be telling the micro to pull the wrong pin low and we can do something we didn't intend to do, or we can actually hurt the circuit itself.

After we have verified that we can correctly target the pins that we need to assert a high and a low on, then we can start testing the pins that the motor is hooked up to. We need to make sure that we can assert a high on the right pins to turn the motor on in the direction we want it to spin to either rotate the blind open or closed. Once we have verified that we can assert highs and lows on our motor in the spots that we need to and can have it turning the blinds, we need to check the second motor and make sure that the motor is going to act the same way for drawing the blinds open and closed. This all comes before we are able to start testing the motors with the limit switch capability. Either we will need to test the limit switch so once the blinds rotate or open enough, they stop, or we will need to timeout how long it takes and assert a high or a low on that pin for however long.

Once all of that is verified and working correctly, we need to verify that the LED strip can be turned on and off as well. This will be tested by seeing if we can apply a high or a low depending on the design and seeing the LED's turn on or off. If this is successful, we will have successfully tested our micro and all of its processes.

### 8.2.9 Final Test

For the final testing after all of the individual parts have been tested, we will test the project as a whole. We will take the blinds and install them in a window in one of our houses. After they have been installed, we will let the blinds sit for one full day. This will allow us to see how much energy we can expect on a random day. After the day has past, then we will measure the amount of charge we have gathered in our battery. After we have checked the charge, we will begin trying to drain it. We will operate the blinds open and closed, and see how much charge is left. Then, we will charge one of our phones. After this has been accomplished, we will see how much charge once again is left in the battery. At the end of this test, we will also light the LED's and see how much capacity is left unused in the battery. This will give us a ballpark of what to expect from a random day of sun and how much capacity it takes to run each part of our project.

We will continue this test over multiple days as to capture the amount of charge that will be gathered from various weather conditions. Some days will be cloudier than others and some days will be sunnier than others. Also, the heat may also play a role in how much charge is lost to thermal energy. This will all be tested over a week or so and the results will help us learn the limits of our creation.

## 8.3 Software Test Environment

Using agile methodologies the developers will be coding the mobile application and testing the functionality of the code as they progress through the development of code. Initially most of the testing may be done via Xamarin Cloud. Xamarin Cloud allows us the ability to test the functionality of the mobile application on multiple different android operating systems easily even if with do not have the physical devices ourselves. For the testing with physical devices we have the following devices readily available:

- Samsung Galaxy Note 4
- Sony Xperia Z3V
- Access to test models from Verizon

Additionally, we can use Genymotion as another platform for testing our application. Xamarin includes the capability of virtual testing on multiple platforms, but it does so through a cloud server system. This may introduce some potential complications related to typical internet latency which would skew test results. Genymotion can be installed locally so latency is not an issue.

Regardless of which software we use, we will be able to thoroughly test the compatibility of our application on multiple devices. This will allow us to see any critical flaws that may be related to API that has been deprecated, as well as the scalability of our GUI.

## 8.4 Software Specific Testing

The software test effort is a crucial part of the projects software development process. Testing our software will ensure the mobile application is functioning correctly. This portion of the report will be describing our projects test environment and procedures for testing the Solar Blinds mobile application. We are going to be describing the objective for each software activity and what’s expected to be accomplished in our application. The mobile application will be specifically for the Android mobile operating system only since we will only be deploying the application for Android. After completion of the testing we will compile a list of all of the bugs and flaws that we have found throughout the code for the software application testing. The details listed below will show what we expect will occur in the software.

### 8.4.1 Stopping Criteria

The testing procedures must be continued non-stop unless a specific problem occurs that hinders further testing. These stopping criteria may be either functionality wise or cosmetic. Once the bugs or issues are isolated the tester should make well-documented notes about what exactly occurred, when they occurred and their best assumption as to why they are happening. Before moving on to the next the tester should consult with a developer to make sure the issue is not a simple fix. If it is have the developer fix the issue and redeploy the application.

Once all of the test cases are passed the code will be considered deliverable. This state means that there are no known bugs or issues to our knowledge and all of the application is fully working.

### 8.4.2 Software Test Cases

This section will provide a step-by-step procedure for each test case that will occur during the software testing activity. The test cases format will all be standardized into the following format.

| |
|---|
| **Test Objective:** Define the test case's goal. |
| **Test Description:** Define the step-by-step guidelines. |
| **Test Conditions:** Define any specific conditions that should be applied to the environment when testing. |
| **Expected Results:** Define the resulting actions that should be seen by the tester. |

**Table 25 -** Example Table of a Test Case

Following the format of Table 25, the following Tables 26-52 describe the various test cases which we will explore in order to test that our device functions properly. This testing will be done at the very end of all development toward the end of November 2015. See the milestones in section 10.1 for more details.

| |
|---|
| **Test Objective:** Click on the application icon on the android device. |
| **Test Description:**<br>Using a virtual or physical android device click on the application icon |
| **Test Conditions:** See test environment |
| **Expected Results:** The android device should open the Solar Blinds Application. |

**Table 26 -** Test Case: Opening the Application

| |
|---|
| **Test Objective:** Make sure the application cover screen appears when the application start. |
| **Test Description:**<br>After clicking on the application icon the application cover screen should appear automatically. |
| **Test Conditions:** See test environment |
| **Expected Results:** The application cover screen will be displayed. |

**Table 27 -** Test Case: View the Application Cover

| |
|---|
| **Test Objective:** View the menu screen of the Solar Blinds mobile application. |
| **Test Description:**<br>After the cover screen the mobile application should display the Solar Blinds menu screen automatically. |
| **Test Conditions:** See test environment |
| **Expected Results:** The Solar Blinds menu screen should be displayed automatically. |

**Table 28 -** Test Case: View the Menu Screen

| |
|---|
| **Test Objective:** Ensure that double pressing the back button from the view menu screen exits the application. |
| **Test Description:**<br>Double press the device's back button to exit the application from the view menu screen |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application should close after the double press. |

**Table 29 -** Test Case: Exit Application

| |
|---|
| **Test Objective:** Confirm that the application transitions to the correct screens |
| **Test Description:**<br>Click on the view menu screen in the following order:<br>Case 1)<br>• Register Device<br>• System Blinds<br>• System Status<br>Case 2)<br>• System Blinds<br>• Register Device<br>• System Status<br>Case 3)<br>• System Blinds<br>• System Status<br>• Register Device |
| **Test Conditions:** See test environment |
| **Expected Results:** The screens should always change to and display the correct screens. |

**Table 30 -** Test Case: Transition Between Screens

**Test Objective:** Ensure clicking on the System Status button takes the user to the sub screens.

**Test Description:**

1. Click on the System Status button.
2. Verify the mobile application displays the sub screens
    a. Battery Level
    b. Temperature
    c. Charging Status
3. Click on each of the previously listed screens in the following order:

Case 1)

- Battery Level
- Temperature
- Charging Status

Case 2)

- Temperature
- Battery Level
- Charging Status

Case 3)

- Temperature
- Charging Status
- Battery Level

Case 4)

- Charging Status
- Temperature
- Battery Level

Case 5)

- Charging Status
- Battery Level
- Temperature

4. Verify that clicking on each button activates the button toggle.

**Test Conditions:** See test environment

**Expected Results:** The user will be able to navigate to each of the listed sub system status screen. On each button press the button should be displayed in the active state.

**Table 31 -** Test Case: Navigate through System Status Submenus

| |
|---|
| **Test Objective:** When the user presses on a button the button should toggle to the active state. |
| **Test Description:**<br>Press on the buttons of different menus to see the buttons change state.<br>Check the buttons on the following screens to verify the states.<br>• Menu<br>• Register Device<br>• System Blinds<br>• System Status |
| **Test Conditions:** See test environment |
| **Expected Results:** Verify the buttons change to a to a green button on press. |

**Table 32 -** Test Case: Verify the Toggle Buttons

| |
|---|
| **Test Objective:** The users device should connect directly to the Solar Blinds system |
| **Test Description:**<br>• Navigate to the Register Device screen by following this path:<br>o Menu > Register Device<br>• On the Register Device screen click on the Connect Device button<br>• Verify the button toggle and the Connect Device button displays its active state<br>• Verify that a success message is giving when the devices sync |
| **Test Conditions:** See test environment |
| **Expected Results:** The devices should connect with each other. The connect device button should display the active state button when toggled. |

**Table 33 -** Test Case: Register Device Successfully Syncs

| |
|---|
| **Test Objective:** The users device should disconnect directly to the Solar Blinds system |
| **Test Description:**<br>• Navigate to the Register Device screen by following this path:<br>o Menu > Register Device<br>• On the Register Device screen click on the Disconnect Device button<br>• Verify the button toggle and the Disconnect Device button displays its active state<br>• Verify that a success message is giving when the devices disconnects. |
| **Test Conditions:** See test environment |
| **Expected Results:** The devices should disconnect with each other. The disconnect device button should display the active state button when toggled. |

**Table 34 -** Test Case: Register Device Successfully Disconnects

| |
|---|
| **Test Objective:** The users device should receive a success message from connecting a device. |
| **Test Description:**<br>Once the mobile application receives the success signal from the Solar Blinds it should display "The Solar Blinds and your mobile device are now connected". |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a success message from connecting a device. |

**Table 35 -** Test Case: Success Message from Connecting Device

| |
|---|
| **Test Objective:** Device should receive a success message from disconnecting a device. |
| **Test Description:**<br>Once the mobile application receives the success signal from the Solar Blinds it should display "The Solar Blinds and your mobile device are now disconnected". |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a success message from disconnecting a device. |

**Table 36 -** Test Case: Success Message from Disconnecting Device

| |
|---|
| **Test Objective:** The users device should receive a fail message from connecting a device if the following scenarios are present. |
| **Test Description:**<br>• The device NFC technology is not turned on or not available.<br>• The device Bluetooth technology is not turned or not available.<br>• The devices are too far apart.<br>• There is an error sending the signal |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a fail message from connecting a device if the listed scenarios are present. |

**Table 37 -** Test Case: Fail Message from Connecting Device

| |
|---|
| **Test Objective:** The users device should receive a fail message from disconnecting a device if the following scenarios are present. |
| **Test Description:**<br>• There is an error dropping the connection.<br>• If the device is in the following scenario it will automatically be disconnected.<br>o Bluetooth technology is turned off or not available<br>o The devices are two far apart |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a fail message from disconnecting a device if the listed scenarios are present. |

**Table 38 -** Test Case: Fail Message from Disconnecting Device

| |
|---|
| **Test Objective:** The users device should receive a success message from opening the blinds. |
| **Test Description:**<br>Once the mobile application receives the success signal from the Solar Blinds it should display “The Solar Blinds have been successfully opened. Enjoy the sunlight”. |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a success message from opening the blinds. |

**Table 39 -** Test Case: Verify the Success Message from Opening Blinds

| |
|---|
| **Test Objective:** The users device should receive a success message from closing the blinds. |
| **Test Description:**<br>Once the mobile application receives the success signal from the Solar Blinds it should display “The Solar Blinds have been successfully closed. Welcome to the dark side”. |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a success message from closing the blinds. |

**Table 40 -** Test Case: Verify the Success Message from Closing Blinds

| |
|---|
| **Test Objective:** The users device should receive a fail message from opening the blinds if the following scenarios are present. |
| **Test Description:**<br>• The device NFC technology is not turned on or not available.<br>• The device Bluetooth technology is not turned or not available.<br>• The devices are too far apart.<br>• There is an error sending the signal |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a fail message from opening the blinds if the listed scenarios are present. |

**Table 41 -** Test Case: Verify the Fail Message from Opening Blinds

| |
|---|
| **Test Objective:** The users device should receive a fail message from closing the blinds if the following scenarios are present. |
| **Test Description:**<br>• The device NFC technology is not turned on or not available.<br>• The device Bluetooth technology is not turned or not available.<br>• The devices are too far apart.<br>• There is an error sending the signal |
| **Test Conditions:** See test environment |
| **Expected Results:** The users device should receive a fail message from closing the blinds if the listed scenarios are present. |

**Table 42 -** Test Case: Verify the Fail Message from Closing Blinds

| |
|---|
| **Test Objective:** Use the mobile application to open the Solar blinds |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Blinds<br>• On the System Blinds screen click on the Open Blinds button<br>• Verify the button toggle and the Open Blinds button displays its active state<br>• Verify that a success message is giving when the Solar Blinds recognizes the signal and they begin to open. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application and the Solar Blinds should connect and a signal is transmitted between them. The mobile application will display a success message when the signal is confirmed and the Solar Blinds will begin opening. The Open Blinds button should display the active state button when toggled. |

**Table 43 -** Test Case: Opening the Solar Blinds

| |
|---|
| **Test Objective:** Use the mobile application to close the Solar Blinds |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Blinds<br>• On the System Blinds screen click on the Close Blinds button<br>• Verify the button toggle and the Close Blinds button displays its active state<br>• Verify that a success message is giving when the Solar Blinds recognizes the signal and they begin to close. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application and the Solar Blinds should connect and a signal is transmitted between them. The mobile application will display a success message when the signal is confirmed and the Solar Blinds will begin opening. The Open Blinds button should display the active state button when toggled. |

**Table 44 -** Test Case: Closing the Solar Blinds

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system battery levels |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed. The options in battery levels are:<br>o Full<br>o Almost Full<br>o Half Full<br>o Almost Empty<br>o Empty<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 45 -** Test Case: View the System's Battery Level

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system full battery level. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed when the battery level is reading in between 100% - 80%.<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 46 -** Test Case: View the Full Battery Level

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system almost full battery level. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed when the battery level is reading in between 79% - 60%.<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 47 -** Test Case: View the Almost Full Battery Level

| |
|---|
| **Test Objective:** To view the Solar Blinds system half full battery level. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed when the battery level is reading in between 59% - 40%.<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 48 -** Test Case: View the Half Full Battery Level

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system almost empty battery level. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed when the battery level is reading in between 39% - 20%.<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 49 -** Test Case: View the Almost Empty Battery Level

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system empty battery level. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Battery Level<br>• Verify the correct battery levels are being displayed when the battery level is reading in between 19% - 0%.<br>• Verify the words match the image of the battery being displayed respectively. |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application will display the correct battery levels in reference to the systems current battery levels |

**Table 50 -** Test Case: View the Empty Battery Level

| |
|---|
| **Test Objective:** Use the mobile application to view the Solar Blinds system temperature reading levels |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Temperature<br>• Verify the correct readings are being displayed.<br>• The mobile application should display only reading in Fahrenheit degrees.<br>• Verify the display is standardized to look like the following:<br>o **74**°F |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application should display the Solar blinds temperature reading in Fahrenheit degrees. |

**Table 51 -** Test Case: View the System's Temperature Reading

| |
|---|
| **Test Objective:** Use the mobile application to view the Charging Status of the Solar blinds system. |
| **Test Description:**<br>• Navigate to the System Blinds screen by following this path:<br>o Menu > System Status > Charging Status<br>• Verify the correct charging statuses are being displayed.<br>• When the system is charging the charging status should say:<br>o The battery is charging<br>• When the system is discharging the charging status should say:<br>o The battery is discharging |
| **Test Conditions:** See test environment |
| **Expected Results:** The mobile application should display the Solar blinds charging status correctly for the charging state and the discharging state. |

**Table 52 -** Test Case: View the System's Charging Status

# 9.0 Project Operation

## 9.1 Hardware Operation

The way this project will work is quite simple. The user will take their phone and have it sync to the blinds if they have a NFC chip in their phone and it will be linked to the automated blinds. This can then be connected through the Bluetooth chip and be controlled through an app on the phone. Once the phone has connected to the Bluetooth chip, you will be able to open and close the blinds with a simple push of a button. This will either open or retract the blinds based on the position of the blinds at the point of activation when the button is pushed. When the button is pushed, it will send a signal to the Bluetooth chip and this will send a signal to the microprocessor. This then will be translated to the microprocessor that a button was pushed. Depending on which button was pushed on the app, this will send a signal to the micro that will either tell the motor to spin clockwise or counterclockwise. The micro will put a high on the right side of the motor that will tell t to open or close the blinds. The motor will then run and complete its task.

Also, there will be other functions of these blinds. The blinds will also come equipped with its own USB charger to charge any non-Apple device. It will pull approximately five hundred milliamps and have a voltage of five volts across it. This is more than sufficient to charge any device, even if it takes a bit longer than desired. There will also be another part of the project that will have a display attached to the micro.

This display comes with its own temperature gauge as well as a display that can be written to and display what is desired. The temperature gauge will read the current outside temperature and it will send the results to the micro. We can then update the display to show what the current temperature is outside. The display is also a special type of display that will be able to hold whatever has been written to it for a long period of time. It is said to supposedly be able to hold the written display for a few hours without drawing barely any current which is ideal for our situation for using a battery operated circuit.

We will have the display take a temperature reading every few hours as to use the least amount current possible so we will keep the battery usage as low as possible. We will also want to display the current charge of the battery at various times throughout the day as well. This will be achieved by the micro reading the current voltage of the battery on one of its pins and displaying the current battery charge.

## 9.2 Software Operation

The operation of the mobile application will be simple and fluent enough for the user to not require a tutorial and allow easy understanding of what each control accomplishes and how to access them. The mobile application can be downloaded from the play store for free with little dependencies of the resources of your mobile device.

After downloading the mobile application you can open the application by simply clicking on the application icon in the application tray. Once the icon has been clicked the mobile application's cover screen will appear. This image will be displayed until all of the application is loaded and ready for interaction of 3 seconds has passed. Once this screen is gone the user will be presented with the view menu screen and here they will be presented with the view menu screen and here they will able to navigate to all of the following sub screens. The buttons listed will each have its own toggle states to inform the user the mobile application recognizes the users touch input. The active states for all of the buttons will be that the normal button color changes. The available buttons on the menu screen are register device, system blinds, and system status.

In order the truly operate and interact with the mobile application and the Solar Blinds the user must connect their mobile device to the Solar Blinds. To do this the user must navigate to the register device screen by pressing on the respective button. Once on the screen the user can choose to connect their device or disconnect it. Pressing connect device will initiate the mobile devices NFC and Bluetooth technology to establish a direct connection with the two devices will communicate via Bluetooth. Once the devices are successfully connected the mobile application will display a informational alert saying that the procedure was a success. Pressing on the disconnect device button will initiate the dropping of the active connections between the mobile device and the Solar Blinds thus disconnecting the two.

The next possible software operation the user can interact with the mobile application is to control the Solar Blinds via the application. The user must click on the System Blinds button on the menu screen to be taken to the respective sub screen. On the System Blinds screen the user will be able to select either open blinds or close blinds. The mobile application will be developed to not allow the user the option to send multiple open signals or multiple close signals when the Solar Blinds are already in the respective states. This prevents the mobile application from potentially cause damage to the motors and structure of the Solar Blinds. Once one of the buttons is pressed the application will display the active states for the button and begin to send the signal via Bluetooth to the Solar Blinds. This signal will get the current state of the blinds and verify that the state is not in the state the mobile application is trying to make it enter. If the states do not make the blinds motors will activate and either open or close the blinds. After finishing the Solar Blinds will send a response signal stating the blinds are fully open or close. Then the mobile application will display a success alert saying that the procedure was a success. If the states do match then the Solar Blinds will do nothing and send a fail signal back to the mobile application. When the mobile application receives this signal it will alert the user that the blinds may be already in the suggested state or there was an error sending the signal.

The system status screen will mainly provide data details of the Solar Blinds instead of providing direct user interact. The system status will have the following options the user can select to view; battery level, temperature, and charging status. Clicking on the battery level option will transition the screen to display the current Solar Blinds battery level from being charged by the solar energy. There are 5 different states of the battery level. The first state is full. This is where the battery level is completely charged. The mobile application will display this state for the battery if it’s in between the range 100% - 80% and it will show a full battery icon. The next state is the almost full state. This state will be displayed if the battery is in between 79% - 60% and it will show a semi full (75%) battery icon. The next state after that is the half full state. This state will be displayed if the battery is in between 59% -40% and it will show a 50% full battery icon. The next state is the almost empty state. This state will be displayed if the battery is in between 39% - 20% and it will show an almost empty (25%) battery icon. The last state is the empty state. This state will be displayed if the battery is in between 19% - 0% and it will show an empty (0%) battery icon. When the battery icon is in the empty state some of the functionality of the Solar Blinds may be operational due to the low power reserves.

Viewing the temperature is also another part of the mobile application were the user has very minimal direct action on the Solar Blinds. Once the transition to this screen the mobile application will display in Fahrenheit degrees the temperature outside. If possible we would like to consider adding a weather forecast to this screen along with some more functionality but those are going to be extra features we would be adding if we have extra time.

Lastly, the last part of the operational software is viewing the charging status of the blinds. This screen informs the user on whether or not the Solar Blinds are actually absorbing solar energy and charging the battery. This screen can be found as the last button under the system status buttons.

# 10.0 Administrative Content

## 10.1 Milestones

Our group has set a list of milestones for us to achieve in order to stay on track in our project development. By completing the sections described by the dates listed, we will be able to ensure completion and thoroughness of our project by the dates due.

These milestones have been divided by month for legibility. The milestones for documentation are set for June 2015 to August 2015 in Tables 53 through 55.

| June 2015 | |
|---|---|
| **Section** | **Complete By** |
| Executive Summary | 06/14/2015 |
| Project Motivation and Goals | 06/14/2015 |
| Objectives | 06/14/2015 |
| Requirements Specifications | 06/14/2015 |
| Existing Similar Projects and Products | 06/21/2015 |
| Relevant Technologies: Solar Cells | 06/21/2015 |
| Relevant Technologies: Display Screens | 06/21/2015 |
| Relevant Technologies: Motors | 06/21/2015 |
| Relevant Technologies: Remote Connectivity | 06/21/2015 |
| Relevant Technologies: Microchip Processors | 06/30/2015 |
| Relevant Technologies: Motors | 06/30/2015 |
| Relevant Technologies: Power Distribution | 06/30/2015 |
| Relevant Technologies: Embedded | 06/30/2015 |
| Relevant Technologies: Mobile App | 06/30/2015 |
| Standards: Safety | 06/30/2015 |
| Standards: Reliability | 06/30/2015 |
| Standards: Communications | 06/30/2015 |
| Standards: Programming Languages | 06/30/2015 |
| Standards: Connectors | 06/30/2015 |
| Standards: Battery | 06/30/2015 |
| Standards: Design Impacts | 06/30/2015 |

**Table 53 -** June 2015 Milestones

| July 2015 | |
|---|---|
| **Section** | **Complete By** |
| Design Constraints: Economic & Time | 07/07/2015 |
| Design Constraints: Ethical, Health, Safety | 07/07/2015 |
| Design Details: Electrical Hardware | 07/21/2015 |
| Design Details: Mechanical Hardware | 07/21/2015 |
| Design Details: Solar Technologies | 07/21/2015 |
| Design Details: Embedded Software | 07/21/2015 |
| Design Details: Mobile Application | 07/21/2015 |
| Prototype: Hardware Test Environment | 07/31/2015 |
| Prototype: Hardware Specific Testing | 07/31/2015 |
| Prototype: Software Test Environment | 07/31/2015 |
| Prototype: Software Specific Testing | 07/31/2015 |
| Milestones | 07/31/2015 |
| Budget & Financing | 07/31/2015 |

**Table 54 -** July 2015 Milestones

| August 2015 | |
|---|---|
| **Section** | **Complete By** |
| Competency & Completeness Review | 08/01/2015 |
| Finalize Citations | 08/02/2015 |
| Finalize Formatting | 08/03/2015 |
| Documentation Binding | 08/05/2015 |

**Table 55 -** August 2015 Milestones

Here, at the beginning of August, we will be ending our work on the documentation and beginning the work on actually creating our device. This lists of milestones for development are displayed in Tables 56-58, and only include deadlines by which we must accomplish various goals. However, it is implied that we will also begin working on the next section at the due date of the previous section. For example, below we can see that the battery status display screen of the mobile application will be completed by September 18th, and starting around that same time will be the development for the data communication with the MCU.

Since we have four members in our group, we will have a lot of concurrent work going on in order to complete the project within the time allotted to us (one semester). Because of this, a lot of the due dates are all intermingled among the different facets of our group. We have Sean and Stephen working on the "hardware" sections, and Artis and Dakota will evenly divide the "embedded" and "mobile app" sections, and then whoever is free at the time will be responsible for the "general" categories. The different sections have been color-coded for easy reference.

| September 2015 | | |
|---|---|---|
| **Category** | **Section** | **Complete By** |
| Mobile App | Basic menu operation functional | 09/01/2015 |
| General | All hardware acquired | 09/01/2015 |
| Mobile App | RFID sync functional | 09/04/2015 |
| Hardware | Motor installed into blinds | 09/04/2015 |
| Hardware | Solar cells mounted | 09/04/2015 |
| Mobile App | Menus optimized | 09/11/2015 |
| Hardware | PCB Finished | 09/11/2015 |
| Hardware | Temperature gauge installed | 09/11/2015 |
| Hardware | Buttons mounted | 09/11/2015 |
| Mobile App | Battery status display complete | 09/18/2015 |
| Embedded | Battery charging operational | 09/18/2015 |
| Embedded | Manual operation functional (buttons) | 09/18/2015 |
| Hardware | Charging systems complete | 09/18/2015 |
| Mobile App | Send/receive data to/from MCU operational | 09/25/2015 |
| Embedded | Bluetooth connection to phone functional | 09/25/2015 |
| Hardware | Components wired (temp, buttons, e-paper) | 09/25/2015 |
| Hardware | E-paper display mounted and wired | 09/25/2015 |

**Table 56 -** September 2015 Milestones

After the end of September, we have enough of the hardware completed that we can start focusing more on the software development. We needed the PCB to be assembled before we can do much with the embedded programming, and we can only do so much with the mobile application without having a data link with the MCU.

| October 2015 | | |
|---|---|---|
| **Category** | **Section** | **Complete By** |
| Mobile App | Motor functions controllable | 10/02/2015 |
| Embedded | E-paper display operational | 10/02/2015 |

| | | |
|---|---|---|
| Hardware | USB charge port installed, wired, and powered | 10/02/2015 |
| Mobile App | Battery screen complete | 10/09/2015 |
| Embedded | E-paper displaying battery and temperature info | 10/09/2015 |
| Hardware | Phone holder mounted to housing | 10/09/2015 |
| Mobile App | Temperature screen complete | 10/16/2015 |
| Embedded | USB charge port operational | 10/16/2015 |
| Hardware | Wooden testing frame assembled | 10/16/2015 |
| Mobile App | Support for multiple blinds RFID registration | 10/23/2015 |
| Embedded | Reflect USB connection status on e-paper | 10/23/2015 |
| Hardware | Blinds able to mount into test frame | 10/23/2015 |

**Table 57 -** October 2015 Milestones

| November 2015 | | |
|---|---|---|
| **Category** | **Section** | **Complete By** |
| Mobile App | Battery statistics added based on past history info | 11/06/2015 |
| Hardware | Battery charge efficiency tests | 11/06/2015 |
| Mobile App | Import weather info from internet to temperature screen | 11/13/2015 |
| Mobile App | UI compatibility across devices achieved | 11/13/2015 |
| Hardware | Phone charge efficiency via USB tests | 11/13/2015 |
| Mobile App | Optimizations | 11/20/2015 |
| General | Demonstration/presentation material compiled | 11/20/2015 |
| Mobile App | Final software systems test | 11/27/2015 |
| General | Presentation material completed | 11/30/2015 |

**Table 58 -** November 2015 Milestones

Unfortunately, we must admit that not all milestones for the research and documentation portion were completed by the set deadlines. However, this is true for most projects. We still had all milestones for August complete by the final deadline of the report submission. We have set additional milestones to help ourselves stay on track of the actual development of the product with the goal of keeping a tighter schedule than we did for the research and writing of this report.

We have decided that it would be best to have a finalized product, both in hardware and software, by the end of November. Although we have not yet received a deadline for project completion at the end of next semester, we feel that a deadline of November 30th will give us adequate time for thorough testing and any necessary modifications before submission and presentation is due. We are confident that we can meet all of these milestones without undue strain on our schedules or abilities.

### 10.2 Budget and Finance Discussion

We decided as a group that our total budget for this project would be $500, but with a goal of $300 or less. We have no sponsors so we will be paying out of pocket for this project. However, we also believe that anything worth doing should be done right, so we will not unnecessarily sacrifice quality for no other reason than expense.

After the final bill of materials was realized, it appears that we did not meet our $300 goal, at least in planning. Fortunately, we were able to keep the cost under the $500 limit which we had set originally. This cost will be divided among the members of the team. Afterward, one member may buy out the project from the others so they may keep the final product for their own personal use. We have two members interested in purchasing the product after completion. This will help to mitigate cost of the project.

Additionally, we may find ways to save on these parts as well. It has been mentioned that the USB charge kit we have on the bill of materials can be constructed from more basic parts for a fraction of the cost. We were also unable to find the specific wiring we would need to connect the various components to the PCB, so only an estimate was used here. We also believe all of the soldering supplies may not be necessary, as long as the required equipment is available in the design lab at the university.

# Appendices

## Appendix A: Copyright Permissions

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http://genasun.com/all-products/solar-charge-controllers/for-lead/gv-5-pb-5a-solar-charge-controller/
http://www.ti.com/lit/ds/symlink/cc2640.pdf
https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcR2C40O_XyoI_K9CtqM0xEoa0mp2ZMvp5lXEVkblk-zeSmlUsHo1D15KE8
http://www.ctscorp.com/components/Datasheets/008-0309-0.pdf
http://www.digikey.com/product-detail/en/S1144CS021/S1144CS021-ND/5046794
http://ww1.microchip.com/downloads/en/DeviceDoc/22008E.pdf

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ML Solar

**From:** <sales@mlsolar.com>
**Subject: RE: 'diamonds@knights.ucf.edu' submitted the form from your 'Contact Us' page**
**Date:** August 3, 2015 at 12:09:57 PM EDT
**To:** <diamonds@knights.ucf.edu>

Hi Sean.
Yes. Feel free to use our images for your school design project. If you have any other questions please let us know.

ML Solar
Danny
408 583 8101

> -------- Original Message --------
> Subject: 'diamonds@knights.ucf.edu' submitted the form from your 'Contact Us' page
> From: "Contact Form" <contactform@bigcommerce.com>
> Date: Sun, August 02, 2015 3:03 pm
> To: sales@mlsolar.com
>
> **Full Name:** Sean Diamond
> Hello,
> I am a senior engineering student at the University of Central Florida and I am working on my senior design project. I would like to use a picture of the 3x6 solar cells from your website in my paper and I wanted to ask to make sure it was okay. This paper is for a design class and will not be published or used to make money.
>
> Thank you,
> Sean Diamond

---

Morningstar

Sean,

Thank you for contacting Morningstar with your inquiry. You can use any pictures from our website, but we would appreciate it if you noted that the pictures are courtesy of Morningstar in your work.

Please let me know if you have any other questions.

Thanks,

Patrick Smith
Technical Sales Engineer, Morningstar Corporation

P: 215-321-4457
E: psmith@morningstarcorp.com

---

Flex Solar Cells

Sean,

Sure. Just send me a copy of the final report. I'd love to read it.

Best Regards,
Fritz Meitzen
Sales Director
Electrical Engineer

FlexSolarCells.com
P: (512) 680-7034
fritzm@flexsolarcells.com

On Aug 2, 2015, at 5:30 PM, Sean Diamond <diamonds@knights.ucf.edu> wrote:
Hello,
I am a senior engineering student at the University of Central Florida and I am working on my senior design project. I would like to use a picture of the R-14 model from your website in my paper and I wanted to ask to make sure it was okay. This paper is for a design class and will not be published or used to make money.

Thank you,
Sean Diamond

---

## Battery Space

Hi Sean,
Yes, it is ok, please indicate the picture is from BatterySpace.com
Best regards,
Jasmine Sun
Batteryspace.com/AA Portable Power

825 S.19th St.
Richmond, CA 94804
Tel: +1-510-525-2328
Fax: +1-510-439-2808
Email: sales@batteryspace.com
Site: http://www.batteryspace.com

We can now provide UN38.3 / IEC 62133 / UL 2054 / CE Test service.
By accepting our order, you agreed to our Sales Agreement

On Sun, Aug 2, 2015 at 3:56 PM, Sean Diamond <diamonds@knights.ucf.edu> wrote:
Hello,

I am a senior engineering student at the University of Central Florida and I am working on my senior design project. I would like to use a picture of the Powerizer 12 V 5 Ah LiFePO4 battery from your website in my paper and I wanted to ask to make sure it was okay. This paper is for a design class and will not be published or used to make money.

Thank you,
Sean Diamond

---

## Pervasive Displays Inc.

---------- Forwarded message ----------
From: "Soren Jorgensen" <soren_jorgensen@pervasivedisplays.com>
Date: Aug 3, 2015 8:55 PM
Subject: Greetings from Pervasive Displays
To: <artiscolemanjr@gmail.com>
Cc:

Hello Artis,

Thank you for reaching out to us. Which university do you go to?

Please consider this email as permission to use material we have posted on our website or on repaper.org as long as the source is credited.

I would personally be interested in reading the report and hope to receive a copy.

Best regards,
Soren Jorgensen

| Soren Jorgensen | Pervasive Displays | Business Development |Portland, OR |
| +1917.553.6304 | Soren_Jorgensen@PervasiveDisplays.com| sjn_chidisp (Skype) |

## Appendix B: Abbreviations

Below is a list of abbreviations used in this document and their full meanings.

| Abbreviation | Meaning |
|---|---|
| DIY | Do It Yourself |
| PCB | Printed Circuit Board |
| USB | Universal Serial Bus |
| Wi-Fi | Wireless Internet for Frequent Interface |
| LED | Light-Emitting Diode |
| MCU | Microcontroller Unit |
| BOM | Bill of Materials |
| BLE | Bluetooth Low Energy |
| RFID | Radio Frequency Identification |
| NFC | Near Field Communications, a subset of RFID |
| GUI | Graphic User Interface |

## Appendix C: References

[1] Instructables.com, 'Automatic Window Blinds Controller (PICAXE)', 2015. [Online]. Available: http://www.instructables.com/id/Build-A-Motorized-Window-Blinds-Controller-For-Les/. [Accessed: 05- Aug- 2015].

[2] Instructables.com, 'How to make a solar iPod/iPhone charger -aka MightyMintyBoost', 2015. [Online]. Available: http://www.instructables.com/id/How-to-make-a-solar-iPodiPhone-charger-aka-Might/. [Accessed: 05- Aug- 2015].

[3]S. Kasap, *Optoelectronics and photonics*. Boston: Pearson, 2013.

[4]T. Saga, 'Advances in crystalline silicon solar cell technology for industrial mass production', *NPG Asia Materials*, vol. 2, no. 3, pp. 96-102, 2010.

[5] Pveducation.org, 'Multi Crystalline Silicon | PVEducation', 2015. [Online]. Available: http://www.pveducation.org/pvcdrom/manufacturing/multi-crystalline-silicon. [Accessed: 05- Aug- 2015].

[6] Solar-facts-and-advice.com, 'Amorphous silicon solar cells: Solar Facts and Advice', 2015. [Online]. Available: http://www.solar-facts-and-advice.com/amorphous-silicon.html. [Accessed: 05- Aug- 2015].

[7]'Staebler-Wronski Effect in Amorphous Silicon and Its Alloys', *OPTO-ELECTRONICS REVIEW*, pp. 21-34, 2004.

[8] Energy.gov, 'Cadmium Telluride | Department of Energy', 2015. [Online]. Available: http://energy.gov/eere/sunshot/cadmium-telluride. [Accessed: 05- Aug- 2015].

[9] Eink.com, 'E Ink: Technology: Electrophoretic Techology', 2015. [Online]. Available: http://www.eink.com/technology.html. [Accessed: 05- Aug- 2015].

[10] Pervasivedisplays.com, 'Pervasive Displays - Why ePaper (EPD)', 2015. [Online]. Available: http://www.pervasivedisplays.com/technology/home. [Accessed: 05- Aug- 2015].

[11]P. Displays, 'E1271CS021 Pervasive Displays | E1271CS021-ND | DigiKey', *Digikey.com*, 2015. [Online]. Available: http://www.digikey.com/product-detail/en/E1270CS021/E1270CS021-ND/5046793. [Accessed: 05- Aug- 2015].

[12] Desktop Class - Online Classroom, 'Discuss Different Types Of Display Screens', 2011. [Online]. Available: http://www.desktopclass.com/education/computer-it/discuss-different-types-of-display-screens.html. [Accessed: 05- Aug- 2015].

[13] PCMAG, 'How to Buy an LCD Monitor', 2015. [Online]. Available: http://www.pcmag.com/article2/0,2817,2362048,00.asp. [Accessed: 05- Aug- 2015].

[14] HubPages, 'Screen Displays and Types', 2015. [Online]. Available: http://sdrahcir8.hubpages.com/hub/Screen-Displays-and-Types. [Accessed: 05- Aug- 2015].

[15] Applied-motion.com, 'V0400-211-C-000 | Applied Motion', 2015. [Online]. Available: http://www.applied-motion.com/products/servo-motors/v0400-211-c-000?gclid=CjwKEAjwiZitBRCy0pb3rIbG9XwSJACmuvvzQzOH6cBfJrGSHhzrXfUBWESLlE1E2sY2EzAUOLeb_RoCUMjw_wcB. [Accessed: 05- Aug- 2015].

[16]S. Leeson Motors DC Motor-.05 - .1HP, 'Leeson Motors DC Motor-.05 - .1HP, 12-24V, 1750-4200RPM, TENV, Sq. flange', *Global Industrial*, 2015. [Online]. Available:

http://www.globalindustrial.com/p/motors/ac-motors-2-phase/dc-motors/motor-25-tenv-1750-4200rpm-536f?infoParam.campaignId=T9F&gclid=CjwKEAjwiZitBRCy0pb3rIbG9XwSJACmuvvzwfAkcTsO3eZcoxMyUIgHq3r4EB38stGEwMGzNFVCghoC7Mvw_wcB. [Accessed: 05- Aug- 2015].

[17] Rollertrol.com, '12v DC Tubular Motors with Built-in Remote Control', 2015. [Online]. Available: http://rollertrol.com/store/en/tubular-motors/33-window-blind-motor.html. [Accessed: 05- Aug- 2015].

[18] Diffen.com, 'Bluetooth vs Wi-Fi - Difference and Comparison | Diffen', 2015. [Online]. Available: http://www.diffen.com/difference/Bluetooth_vs_Wifi. [Accessed: 05- Aug- 2015].

[19] Msdn.microsoft.com, 'Wi-Fi power management for connected standby platforms (Windows Drivers)', 2015. [Online]. Available: https://msdn.microsoft.com/en-us/library/windows/hardware/dn757332(v=vs.85).aspx. [Accessed: 05- Aug- 2015].

[20]S.  Higginbotham, 'ZigBee wants to be the Bluetooth of the internet of things. Too bad everyone hates it.', *Gigaom.com*, 2013. [Online]. Available: https://gigaom.com/2013/08/30/zigbee-wants-to-be-the-bluetooth-of-the-internet-of-things-too-bad-everyone-hates-it/. [Accessed: 05- Aug- 2015].

[21]J.  Thrasher, 'RFID versus NFC: What's the difference between NFC and RFID?', *RFID insider*, 2013. [Online]. Available: http://blog.atlasrfidstore.com/rfid-vs-nfc. [Accessed: 05- Aug- 2015].

[22] NFC World+, 'List of NFC phones', 2015. [Online]. Available: http://www.nfcworld.com/nfc-phones-list/. [Accessed: 05- Aug- 2015].

[23] Hospitality Net, 'Hospitality Net - ASSA ABLOY Hospitality Revolutionizes Hotel Security and Convenience with Industryâ€™s Premier Mobile Access Solution', 2015. [Online]. Available: http://www.hospitalitynet.org/news/4070162.html. [Accessed: 05- Aug- 2015].

[24] Developer.android.com, 'Dashboards | Android Developers', 2015. [Online]. Available: https://developer.android.com/about/dashboards/index.html?utm_source=suzunone. [Accessed: 05- Aug- 2015].

[25]2015. [Online]. Available: https://web.eecs.umich.edu/~prabal/teaching/eecs373-f10/readings/ARM_Architecture_Overview.pdf. [Accessed: 05- Aug- 2015].

[26]2015. [Online]. Available: http://konstantin.solnushkin.org/teaching_reports/intro_to_hpc/2007/harvard_architecture.pdf. [Accessed: 05- Aug- 2015].

[27]M.  Verle, *PIC Microcontrollers*. Beograd: Mikroelektronika, 2008.

[28] Ladyada.net, 'PIC vs. AVR smackdown', 2015. [Online]. Available: http://www.ladyada.net/library/picvsavr.html. [Accessed: 05- Aug- 2015].

[29] Quora.com, 'What is the difference between 8051, PIC, AVR and ARM? - Quora', 2015. [Online]. Available: http://www.quora.com/What-is-the-difference-between-8051-PIC-AVR-and-ARM. [Accessed: 05- Aug- 2015].

[30] Solar-electric.com, 'What is Maximum Power Point Tracking (MPPT)', 2015. [Online]. Available: http://www.solar-electric.com/mppt-solar-charge-

controllers.html. [Accessed: 05- Aug- 2015].

[31] Genasun.com, 'Genasun MPPT Controllers for Lead-Acid Batteries | GenasunGenasun', 2015. [Online]. Available: https://genasun.com/products-store/mppt-solar-charge-controllers/mppt-for-lead-acid/. [Accessed: 05- Aug- 2015].

[32]I. Solarcraft, 'PWM vs MPPT Solar Charge Controllers | Solarcraft', *Solarcraft.net*, 2015. [Online]. Available: http://solarcraft.net/articles/comparing-pwm-and-mppt-charge-controllers/. [Accessed: 05- Aug- 2015].

[33] Altenergymag.com, 'A Comparison of Lead Acid to Lithium-ion in Stationary Storage Applications | AltEnergyMag', 2015. [Online]. Available: http://www.altenergymag.com/content.php?post_type=1884. [Accessed: 05- Aug- 2015].

[34]2015. [Online]. Available: http://datasheets.maximintegrated.com/en/ds/DS2438.pdf. [Accessed: 05- Aug- 2015].

[35] Xamarin.com, 'How do I share code across platforms with Xamarin? and other FAQs - Xamarin', 2015. [Online]. Available: http://xamarin.com/faq. [Accessed: 05- Aug- 2015].

[36]A. Overview, 'Android Studio Overview | Android Developers', *Developer.android.com*, 2015. [Online]. Available: http://developer.android.com/tools/studio/index.html. [Accessed: 05- Aug- 2015].

[37]A. Gajani, '4 Online Collaboration Tools for Developers', *Blog.monitor.us*, 2015. [Online]. Available: http://blog.monitor.us/2013/05/cc-in-review-4-online-collaboration-tools-for-developers/. [Accessed: 05- Aug- 2015].

[38]L. Wildbit, 'Wildbit â€“ We create web products to help business collaborate and communicate more effectively', *Wildbit.com*, 2015. [Online]. Available: http://wildbit.com/. [Accessed: 05- Aug- 2015].

[39]L. Wildbit, 'Beanstalk Plans & Pricing', *Beanstalkapp.com*, 2015. [Online]. Available: http://beanstalkapp.com/pricing. [Accessed: 05- Aug- 2015].

[40] Atlassian, 'JIRA - Issue & Project Tracking Software | Atlassian', 2015. [Online]. Available: https://www.atlassian.com/software/jira. [Accessed: 05- Aug- 2015].

[41] Atlassian, 'Pricing | Atlassian JIRA', 2015. [Online]. Available: https://www.atlassian.com/software/jira/pricing. [Accessed: 05- Aug- 2015].

[42] GitHub, 'Build software better, together', 2015. [Online]. Available: https://github.com/pricing. [Accessed: 05- Aug- 2015].

[43] C9.io, 'Cloud9 - Your development environment, in the cloud', 2015. [Online]. Available: https://c9.io/. [Accessed: 05- Aug- 2015].

[44] C9.io, 'Cloud9 - Plans and Pricing', 2015. [Online]. Available: https://c9.io/web/site/pricing. [Accessed: 05- Aug- 2015].

[45] Developer.apple.com, 'HomeKit - Apple Developer', 2015. [Online]. Available: https://developer.apple.com/homekit/. [Accessed: 05- Aug- 2015].

[46] Developer.apple.com, 'Choosing a Membership - Support - Apple Developer', 2015. [Online]. Available: https://developer.apple.com/support/compare-memberships/. [Accessed: 05- Aug- 2015].

[47]G.  Publishing, 'Get Started with Publishing | Android Developers', *Developer.android.com*, 2015. [Online]. Available: http://developer.android.com/distribute/googleplay/start.html. [Accessed: 05- Aug- 2015].

[48] Genasun.com, 'Genasun GV-5 65W 5A Solar Charge Controller with MPPTGenasun', 2015. [Online]. Available: http://genasun.com/all-products/solar-charge-controllers/for-lead/gv-5-pb-5a-solar-charge-controller/. [Accessed: 05- Aug- 2015].

[49] Ti.com, 'CC2640 | Bluetooth / Bluetooth Low Energy | Wireless Connectivity | Description & parametrics', 2015. [Online]. Available: http://www.ti.com/product/cc2640. [Accessed: 05- Aug- 2015].

[50]2015. [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/22008E.pdf. [Accessed: 05- Aug- 2015].

[51]2015. [Online]. Available: http://www.ti.com/lit/ds/symlink/cc2640.pdf. [Accessed: 05- Aug- 2015].

[52]E.  Inc, '690-004-621-013 EDAC Inc | 151-1080-ND | DigiKey', *Digikey.com*, 2015. [Online]. Available: http://www.digikey.com/product-detail/en/690-004-621-013/151-1080-ND/806179. [Accessed: 05- Aug- 2015].