ECO-SEC

An Economical Solution to Home Security

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1. Executive Summary

Applications of computer and electrical engineering working together have been more common than ever before in recent decades and today it is possible to see these two disciplines working in almost any aspect of everyday life. One important area that requires incorporation of these two fields together is the arena of home security. In recent years due to a variety of social and economic factors concern over private home security has continued to grow each year.

The team proposes here the develop their own solution to the problem of private home security. This solution in order to be able to be viable when compared to many of the alternative currently purchasable in the market place must be able to perform many of the similar functions while being improved in other aspects. The security system being proposed here by the team will be able to detect the presence of intruders, and in the case of when such a detection occurs the system shall be capable of informing the home owner that a security breach has occurred.

The ability to detect intrusions and report them is not a ground breaking new feature but the manner in which the team proposes to introduce it will help set it apart from some of the currently market available security systems. The system proposed when it detects the intrusion instead of keeping a simple log of the intrusion will inform the user via their cellular device when the intrusion occurs. This will give the homeowner peace of mind that they are capable of knowing the status of their home no matter where they are located.

A secondary concern with many home security systems is the cost of purchasing them. Most home security systems are complicated to install and require an outside technician to come to your home to install the system. Naturally that usually then requires the security company charging what they consider a "service" charge to install the system. Once the homeowner has paid this service fee to get the system installed they wish to be able to use it. Once again the security company who provided the system steps in and agrees to monitor your for intrusions from a monthly fee that can often be quite expensive.

In order to make the proposed security system much more appealing to the more middle class homeowner who wishes to save money , the system shall be able to provide the same features as these home systems at a reduced cost without requiring additional fees to install the system or monthly maintenance fees to keep the system operating. Since the proposed system shall combine security with economical costs the team as dubbed this project as the ECO-SEC for economical security.

2. Project Description

2.1. Motivation

Although a relatively safe area, crime is not an unknown phenomenon in local housing areas near the University of Central Florida. Every student at the university most likely has memories of periodically receiving emails from the university advising and warning against recent increases in home break-ins and invasions. During the freshmen years and sophomore years of the members of this team these warnings were far and few in between. In the last few years particularly senior year more and more of these warning emails have begun to go out as the number of home invasions among college age housing complexes as begun to increases.

This has causes the team concern and causes us to begin to brainstorm a way that we could prevent such intrusions from happening or at least providing a way to mitigate the effect such an intrusion would have when it does incur such as providing a way to catch the intruder. This brainstorming lead to the development of the idea that would eventually become the ECO-SEC home security.

Naturally when presented with this dilemma the obvious choice reached by the team was the installation of a home security system within the group members private domicile. However there is one situation that is very common among college students that proposed to be a factor that prevented this from becoming an ideal solution. This situation was a relatively simple one, most college students are broke, working low paying jobs while trying to pay tuition and rent. So this gave the team the main motivation behind the ECO-SEC, trying to provide home security via a security system that would be similar to a professional market purchased system while at a price range affordable to most college students.

Based upon this motivation the goal of the team is by the completion of senior design have a working prototype that is capable of function as close as possible to a professional security system while still being available at the fraction of the cost of a professional system. This prototype will be capable of detecting home intrusions via both doors or windows, as well as alerting the homeowner of the intrusion. The team also plan to include several other features that will help set this security system above many others.

2.2. Objectives

In order to successfully entice possibly users to employ this security system it must incorporate several features in order to make it comparable if not superior to most systems available on the market.

1. The security system will include a camera to provide surveillance of the rooms being monitored by the system. The security camera used by the system should be adequate enough to provide coverage of an average size room using only one security camera.
2. The system will include a method to backup the video recorded by each camera for later viewing. This backup should allow the captured video to be played on any standard computer.

3. The security system will be able to track intrusions into the house by being able to determine if a window, door, or garage door was opened while the security system was active.
4. The security system will be able to detect if an intruder has broken a window.
5. The security system shall include an infrared sensor with each camera to watch for intruders by detecting the movement of the heat source generated by an intruder's body heat.
6. The security system shall be to send a text message to the home owner in the case an intrusion has been detected. This will allow the home owner to decide to call the police or not incase the intrusion was expected.
7. The system shall use a touch panel display to system status and settings as well as allow the home owner to enter the code required to turn the system on or off. The touch screen setting options should allow the user to switch which phone number the system contacts, as well as other features important to the operation of the system.
8. The security system shall be easy to install using simple step by step directions.
9. The security system will be low cost in order to be more economically friendly.
10. The ECO-SEC will be able to collect power from both a solar panel and standard AC power. With these two power sources connected all the time, it will use one power source to charge the battery while blocking the other.
11. The solar panel of the ECO-SEC will be able to recharge the battery over the course of one day under a moderate amount of solar radiation. This is achieved by using a battery to store excess power collected by the solar cells.
12. The battery of the ECO-SEC will be able to provide a sufficient battery backup for the touch screen, web server, and microcontroller. Additionally, the battery will store enough power so that the system can wait for solar power to become available before attempting to recharge the battery thereby making the ECO-SEC more energy efficient.
13. The ECO-SEC will only draw power from solar power unless the battery charge status becomes too low. In this case, it will recharge the battery using any power source available with a priority on solar panel. This logic is handled independently of the microcontroller and will therefore function optimally even if the alarm system is powered down.
14. The battery of the ECO-SEC will be managed automatically. The user will not have to frequently change or discharge the battery.
15. The requirements for the solar panel will be easy to accommodate allowing the user to select and install a new panel if needed.

2.3. Requirements and Specifications

The following is a list of the requirements and specifications determined by the team that the final prototype of the ECO-SEC home security system must meet. These requirements and specifications also fulfill all objectives for the security system as previously described in prior sections of this documentation.

1. The ECO-SEC system shall use infra-red sensors that cover a range of at least 40 ft. to detect intruders.
2. The ECO-SEC system shall use infra-red sensors with a field of vision that covers an angle of 90 to 120 degrees.
3. The ECO-SEC system shall trigger an alarm when a temperature change to around 98.6°F is detected by the infra-red sensor indicating the presence of an intruder.
4. The ECO-SEC system shall withstand 300 pounds (180 kg) of pressure against entry doors.
5. The ECO-SEC system shall contain sensors capable of detecting the breaking of windows 30 to 40 feet away from the sound.
6. The ECO-SEC system shall have a delay of 30 seconds before sounding an alarm when the alarm is set to "Intrusion", allowing the resident to leave the property.
7. The ECO-SEC system shall have a delay of 45 seconds before the alarm is set off when the resident enters the property to allow the resident time to disarm the system.
8. The ECO-SEC system shall have a delay of no more than 1ms before the alarm is set to "Intrusion", when any of the following conditions are met:
    a. Sound sensor is "Activated"
    b. Infrared sensor is "Activated"
    c. Glass break sensor is "Activated"
9. The Eco-Sec's battery can provide power to the alarm system for 40 hours without being recharged. The system will maintain a backup of 24 hours at all times in power is available.
10. The solar panel of the Eco-Sec will provide 40Wh of power under 1kW/hr of solar radiation. The efficiency of the solar panel will remain above 13% while producing enough power to charge the battery.
11. The Eco-Sec will on average consume 1.42W from the battery. The system may however for a brief period of time draw up to 3.4W of power.
12. The Eco-Sec's battery can be recharged in 4 hours from a totally discharged state while power is available to the system.
13. The Eco-Sec will be able to distribute power from the battery to other components in the system while maintaining an efficiency of 80%.

2.4. Roles and Responsibilities

This subsection will detail the different roles and responsibilities each group member has when contributing to the final working prototype of the ECO-SEC. Although group members will be primarily responsible for their own roles, the ECO-SEC is a project that will require a lot of team effort and work to get all the individual parts of the various subsystems working together so team members may be called upon to help another team member with their role in order to ensure all parts of the final prototype are completed on time and functioning correctly.

Brian Kelly as an electrical engineering student and being most familiar with the required concepts, will be primarily responsible for designing the power subsystem for the ECO-SEC. This will include designing the schematics for both the solar power source as well as the backup battery in order to get them working together and providing the necessary and correct amount of power to the various other subsystems that require it.

David Gardner is responsible for the subsystems deal with the sensor arrays and the subsystem dealing with the video camera. The sensory array system requires creating a circuit board that is capable of detecting when one of the various sensors has been triggered and sending a signal to the microprocessor when one of the sensors has been tripped in order to signal for the microprocessor to tell the security system to send out an alarm. The camera subsystem will require researching and purchasing a security camera that is capable of streaming a live camera feed and one that also supports motion detection. This motion detection will be used as one of the sensors that can be triggered to set off an alarm.

Diana Escobar-Pazo will be primarily responsible for the microprocessor used by the ECO-SEC and creating the various modes of security that the ECO-SEC security system will be capable of providing. The microprocessor is one of the most important subsystems of the entire prototype and will require some of the most work in order to enable it to correctly communicate with the rest of the subsystems of the prototype. The microprocessor will be responsible for the primary logic that will determine when an alarm has been triggered and what the system should do in such an situation. The various modes of the alarm system will be largely determined by the microprocessor based upon how it directs the system to behave when it is operating in the different security modes.

Nathan Schroeder is responsible for the subsystem dealing with the embedded web server and the subsystem dealing with the LCD touch screen interface. The embedded web server subsystem requires both interfacing the server with the microprocessor so it can communicate with the microprocessor as well as designing the website that will allow the user to change the settings for the security system remotely. The LCD touch screen interface will require programming the interface that the screen will use to allow the user to change system settings as well as to configure the LCD touch screen to correctly communicate this information to the microprocessor.

3. Project Related Research

3.1. Similar Projects and Products

The products naturally most similar to ECO-SEC security system being designed by the team are its direct competitors; the professional security systems currently available on the market today. There are many alarm systems in the market today and can be bought as COTS (Commercially Off The Shelf). These vary from standard remote signaling alarm or Audible Only and Hybrid Alarms, to wireless (using cellular connection as a backup or main form of communication without the need of a landline).

Some good references that were found to compare our prototype to are as follows:

1. www.AlarmSystemStore.com
2. www.HomeSecurityStore.com

On these websites, we found many alarm system components and whole system sold. They sell known and not so known alarm systems, from ADEMCO© and GE©, to Visonic©, Ltd. and Elk©. These researches were used to compare how well the design the team created for the ECO-SEC system compares to these professional models.

Table 1 shown below gives the result of this comparison. Although this table is not a full comparison of every feature of each of these alarm systems it does cover some of the more important ones. Each of these models share a similar dimensional size which will serve as a good indicator of what the size of the final prototype of the ECO-SEC should be. Ideally the ECO-SEC should be no larger than the dimensions of any of its competitor models but if possible the team will try to make the overall dimensions smaller. By making the system smaller than most competitor models it becomes less obtrusive for the homeowner to have the system installed and would add more appeal to the final prototype if it were to be ever made into a marketable product. Another important aspect to compare is the range that the wireless sensors can be away from the main system. Most have a range of 200 to 300 feet with the exception of the DSC models. The team decided this is a good range to aim for the wireless sensors to operate in order to allow the ECO-SEC to function on a similar level. Another important feature is that all these models support remote monitoring by a security company. This is the one feature which the team decided to differ with the design of the ECO-SEC system. Instead of have in secondary company to monitor the system the user would have to pay fees to the user is able to monitor the system themselves using the embedded web server included as part of the design for the ECO-SEC. The use of the embedded server will also serve as the ECO-SEC answer to GSM support. Although the design created by the team does not include GSM support the embedded web server will serve the same function by being used to contact the homeowner when a security breach occurs. Finally each system incorporates a siren that will sound when the security system detects an intrusion and this although not a top concern for the overall ECO-SEC design would be simple to incorporate. At this time however the team has not decided to add this alarm and has chosen to be satisfied with the system simply alerting the homeowner during an intrusion.

Model Name	**Wireless Range**	**Monitoring Support**	**H/W Siren**	**GSM Support**	**Dimensions**
2GIG Technologies	350 ft.	Yes	Yes	Yes	9.25" x 7.25" x 1.9"
DSC Power Series 9047	1148 ft.	Yes	Yes	Yes	5.4" x 8.07"x 1.5"
DSC Alexor	1200 ft.	Yes	Yes	Yes	10.5" x 8.5" x 2.3"
GE Simon 3	200 ft.	Yes	Yes	Yes	7.5"x 6.75" x 1.5"
GE Simon XY	200 ft.	Yes	Yes	Yes	5.7" x 7.05" x 2.1"
Ademco LYNXR2	200 ft.	Yes	Yes	Yes	10.4" x 7.2" x 1.75"
Visonic PowerMax	200 ft.	Yes	Yes	Yes	10.82" x 8" x 2.5"
Visonic PowerMax Pro	200 ft.	Yes	Yes	Yes	10.2" x 8"x 2.1"

Table 1: Product Comparison of Professionally available security systems

Although the ECO-SEC project is not similar to any other projects currently in development for Senior Design there have been a few past projects that are very similar in nature and same some of the same aspects as the current design of envisioned by members of the team. For example, one year a team developed a prototype designed to control an HVAC system for the home. Although this project is dissimilar from a security system that project did make use of an LCD touch screen as an interface for their system. This gave the team the idea to use the same type of interface to allow the user to communicate with the prototype for the ECO-SEC. Another team in the past developed a system to remotely open doors and windows of a home. Although this once again differs from a security system that project required the ability to detect whether windows and doors were opened or closed, which is very similar to the need of the sensory array in this design to detect when an intruder opens a door or window to break into the home.

3.2. Relevant Technologies

This section of the document contains information on the background research that was done by the team. Each subsection explores a different technology that was researched and explored as a possible solution to one of the requirements or specifications set forth as part of the design for the security system being implemented by the team.

3.2.1. Solar Power

One of the objectives of the ECO-SEC is to design a home security system that operates independently and does not have a high maintenance cost. To achieve this goal, the system will incorporate both solar power and the standard AC power available in modern homes. In ideal conditions, the system will not have to use AC power at all in order to maintain the battery's charge; however, due to the variability of solar power, it may become necessary to charge the battery from an AC power source.

Solar power is a virtually limitless source of power making it an ideal choice for the ECO-SEC. Solar power is collected through an array of solar cells which contain a p-n junction. The solar energy excites the electrons and holes thus creating current. A solar cell therefore has similar IV characteristics as a diode except the curve is shifted along the axis representing current due to the collected light energy. Ideally, the maximum amount of current that can be drawn from a solar cell is referred to as the short circuit current and the maximum amount of voltage across the solar cell is called the open circuit voltage. Since the power at the open circuit voltage and short circuit current is zero, acquiring the maximum power from the cell forces the voltage and current to lower values. This point is called the maximum power point. One parameter of a solar cell is its fill factor which is the maximum power from a solar cell divided by the product of the short circuit current and open circuit voltage. Figure 1 shown below illustrates these concepts.

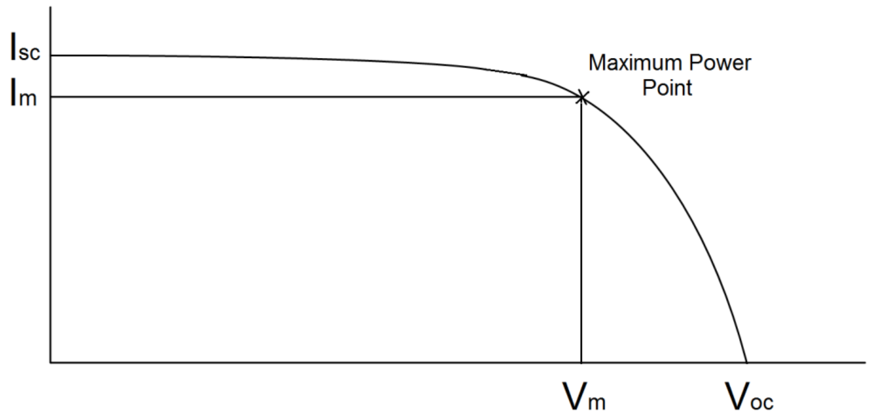

Figure 1: IV characteristics of a solar cell

Solar cells have two resistances associated with them: series resistance and shunt resistance. The source of series resistance is obvious as it refers to the resistance of the solar cell itself and the cells contacts. The second type of resistance is shunt resistance which is a parallel resistance associated with current finding an alternate path in the solar cell. Ideally, series resistance should be zero and shunt resistance should be infinite, but in practice, this is not the case. It is also important to consider the relationship between shunt and series resistances since it is the relationship that determines the output current. When the light intensity on a solar cell is low the series resistance increases. Because the series and shunt resistances are closer together the output current can decrease by up to half of the ideal value. In figure 2 below, the equivalent circuit diagram for a solar cell is shown including both the shunt and series resistances.

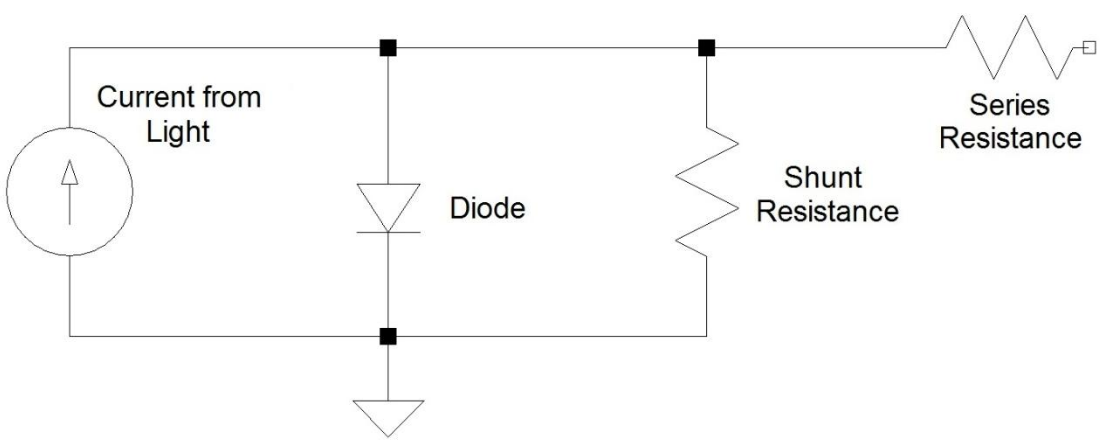

Figure 2: Equivalent circuit for a solar cell

Due to the properties of silicon, each solar cell has an open circuit voltage of roughly 0.6 V. However, solar panels based upon amorphous silicon have an open circuit voltage around 0.8 V for each cell. Once connected into the system, the maximum voltage from each cell drops to roughly 0.4 to 0.5 V for the crystalline solar cells. The amount of current depends on the amount of power that can be collected from the sun and the efficiency of the cell. Many cells have currents around 3 to 5 A. The power produced from solar cells is DC. Each solar cell has a busbar which is the line where the generated current can travel. To increase the voltage across the solar panel, several solar cells can be connected in series; however, this reduces the current available since the solar cell collecting the least amount of power will define the current through the cells. Furthermore, the series connection increases resistance which will further decrease the current through the line. Connecting the cells in parallel will increase the amount of current available but leave the voltage at 0.5V. However, each parallel cell must have the same voltage; therefore, each cell will have a voltage equal to the lowest voltage of each of the individual cells. Because cell voltages are all ready very low, it is common to connect the cells in series when designing a solar panel. Since the current and voltage vary during operation of the solar cells, a voltage regulator and current limiter will be needed to charge the battery.

As stated before, shaded cells can reduce the power output of a solar module connected in series. Furthermore, a shaded cell can also become very hot as the additional power generated from the working cells ends up being dissipated in the shaded cell. If only a few cells are shaded, this heat can damage the cells. To correct this problem a bypass diode can be used. The diode is connected in parallel with a group of cells and the diode is connected with opposite polarity to the solar panel. Since the resistance in a shaded cell is high, current can flow through the diode instead of the solar cells and prevent increased heating of the shaded cell. In solar modules, it is also common to include a blocking diode following the output of the system. A blocking diode prevents current from traveling from the battery back into the solar panel. This is common when there is a low amount of power being generated by the solar cells. Essentially, a blocking diode prevents the solar panel from draining the battery.

Despite its potential, solar power has a few drawbacks including its efficiency and its availability. Efficiency is largely dependent on the quality of the solar cell material. Amorphous silicon has a very low efficiency around 6%. This type of material is practical for low power applications such as calculators, but will not produce the desired output and size parameters for the ECO-SEC. Although more expensive, it is more practical to use either polycrystalline or moncrystalline silicon which have efficiencies around 15% and 17% respectively. In laboratories, efficiencies much greater than 20% have been achieved, but in real world applications the efficiency is closer to the statistics above. In addition to the material, temperature also affects the efficiency of the solar cells. Higher temperature balances out the electrons and holes in the p-n junction thus causing less current when solar energy strikes the cell. The efficiency decreases by roughly half a percent for every degree Celsius above room temperature. Therefore, it will be important to place the cells in a location that is ventilated. Temperature issues can be further reduced by connecting a heat sink to the cells or by using a cooling system. Also noteworthy, the amount of solar power from day to day can change greatly. To overcome this, the ECO-SEC will have to be able to store a large amount of power in the batteries; otherwise, solar power will not be a practical solution. Fortunately, the ECO-SEC is a relatively low power device on average. The touch screen display will use a great deal of power while fully illuminated, but while in a standby mode it will use only milliwatts of power. Since the display will only be active for short periods of time, the solar panels will be able to supply the battery with enough power for the system. Below typical specifications for solar panels from various manufacturers are shown.

Company	Product	V_{osc}	Power	Efficiency	Size
Alps Technology	ATI-125E/S1 (Polycrystalline cell)	0.612 V	2.5 W	16 %	5” x 5”
Alps Technology	ATI-156E-L5 (Polycrystalline cell)	0.606 V	3.5 W	14.6%	6” by 6”
Alps Technology	ATI-125S/U4 (Monocrystalline cell)	0.62 V	2.62 W	17.6%	5” by 5”
Isofoton	C3ISF200SB4125 SP (Monocrystalline cell)	0.622 V	4.1 W	17.3%	6.14” x 6.14”
Artisun	Artisun 156-18.2 (Monocrystalline cell)	0.623 V	4.34 W	18.15%	6.14” x 6.14”

Table 2: Solar Panels from Various Manufacturers

As stated before, notice that the high efficiency monocrystalline solar cells only produce an additionally 0.6 watts at most for each cell. Due to the ECO-SEC power requirements, the amount of space the solar cells occupy is of little concern. The amount of space available will far exceed the space requirements needed here. However, monocrystalline cells will decrease the required space but make the solar modules more expensive. Therefore, polycrystalline cells seem to be the best choice for the ECO-SEC.

It is also important to consider that the sun’s angle on the solar panel influences the power available. Some solar power systems attempt focus more light onto the panel while others adjust the angle of the panels as the day progresses. However, the ECO-SEC will not require a great deal of power so these solutions add unnecessary expense and complexity to the project. Below in figure 3, the annual solar radiation over the continental United States is shown. This information is important when determining how much power solar cells will produce. As the map points out, solar power solutions are more practical in certain parts of the United States.

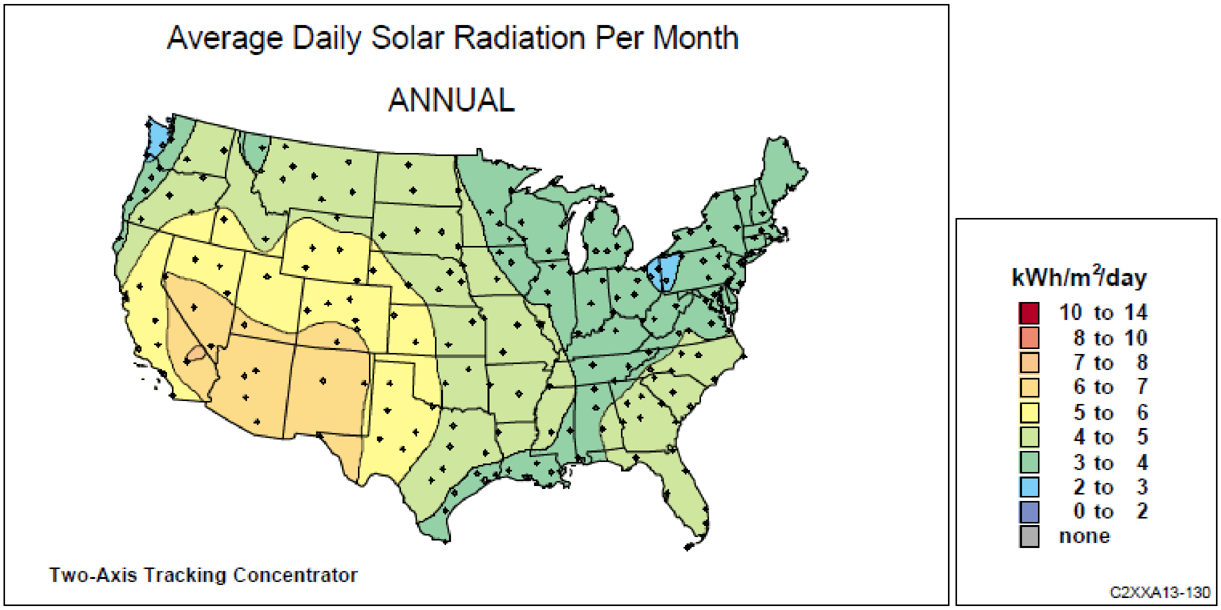

Figure 3: Average Solar Radiation, reprinted with permission from National Renewable Energy Laboratory, (http://www.nrel.gov/rrdec)

Another issue deals with purchasing a solar panel directly or building one from individual solar cells. The main concerns here are cost and complexity. Pre-made solar panels can be significantly more expensive then purchasing the individual solar cells. However, creating a solar cell module involves not only soldering the connections between the cells, but it includes protecting and cleaning the cells. To create a solar module as done in a factory would involve equipment that is too expensive for this project. However, it may be possible to create a solar panel of acceptable quality for this project buy purchasing the proper protective materials. This issue will be further discussed in the design section later in the report.

3.2.2. GSM vs. Embedded Web Server

One of the largest costs of most modern security systems available on the market is monthly payments to a third party company that monitors the status of your security system and will call emergency services for you should any alarm be triggered by the system. Naturally this contradicts one of the key motivations of this project of developing a more economically friendly security system that is comparable to those on the market today. In order to cut out the third party firms used in most security systems it was decided that in the event an alarm was triggered the system would contact the homeowners' cellular phone informing the user that an alarm has been set off. This would allow the homeowner to decide on their own if they wish to call emergency services or not. The ability to contact the homeowner in the case of an intrusion is one of important features that needs to be implemented for a security system to be able to successfully compete with other models on the market. After all if a security system fails to notify anybody when a break-in occurs it server little to no point other then as a false deterrent.

The team examined to different approaches that could be used to meet this goal. The first used a GSM phone module and a GSM transmitter in order to send out a text message to the homeowner's phone when the system detects an intrusion. The second approach considered was using an embedded web server built into the circuit board of the security system. The web server would then be used to send out an email to the user's mobile phone when an alert occurs similar to the GSM module. The email sent from to the user phones can be configured in the manner that it causes the phone to treat it as though it were an text message. This would allow any phone with the ability for internet connectivity to reach these messages. Although not everyone has this feature on their phone, more do today than ever before and this fact is no truer then when considering an area with a high population of college age users such as around the University of Central Florida.

Global System for Mobile Communications or GSM for short is currently the most popular technology for cellular communications. As a result, GSM technology encompasses most of the world allowing for cellular communication at almost any location. This would allow the security system to be able to communicate with the homeowner no matter where they are located. The only exception to this is the select few locations where GSM is unavailable which is mostly in third world countries. The GSM infrastructure also provides moderate security encryption. Although not perfect, this security encryption would prevent most intruders from being able to use the GSM connection to bypass the security system. In order for any device to be enabled to connect to and send data over a GSM network several things are needed. The first is a GSM module chip that contains the GSM protocols used by the networks. The second is a GSM transmitter to actually transmit the devices signal over the GSM network. The last component required is a Subscriber Identity Module, or SIM card. SIM cards store the personal identification information for a user for a GSM network and are issued by most GSM providers. SIM cards are required by any device that wishes to utilize a company's GSM network.

Traditionally, web servers required a fully functioning computer system to successfully host a website. Within the last decade, the hardware requirements of web servers have shrunk drastically. It is now possible to find servers design specifically for embedded microprocessor based designs where the entire server fits on a single chip less than an inch in size. These web servers are capable of hosting a website as well as communicating with an attached microprocessor. These embedded web servers provide great utility at a low cost to the user. Since the core of the security system is designed around a microprocessor to control the logic for the system, the ability to include a web server especially designed to work with embedded microprocessor would be a positive addition to the design of the ECO-SEC.

Both approaches were examined but in end the team decided used an embedded web server instead of a GSM module. This decision was made based upon several different reasons. One important aspect was the cost. On average a GSM module costs anywhere from fifty to over a hundred dollars. This cost includes only the module alone. Additionally the GSM transmitter needed to send the information to a mobile phone can cost upwards of an additional hundred dollars. Also to be able to even send GSM data out, the module must be registered with a GSM service provider by purchasing an SIM card and plan, in order to use their networks. In all this easily raises the cost to over a couple hundreds of dollars plus any additional monthly fees required for SIM card plan. This would lead the project design back towards one of the situations that the project had the goal of avoiding which is having to pay a monthly service fee in order to get the security system to operate correctly. This serves to counteract one of the main concepts behind that project of providing an effective home security system at an economical cost the user. A secondary reason behind not using a GSM module is the limited amount of features it could bring to the system. A GSM module would only be capable to sending or receiving GSM data which would not provide much functionality. Based upon the requirements and design idea development by the team the system would have no need to receive GSM information so this would limit functionality provided by the GSM to only sending data. The added functionality of sending GSM data would not justify the high cost that would be required to pay for this functionality.

An embedded web server however would provide much more functionality. The server would not only be able to send data to a mobile phone but also have the capability of hosting a website for the security system. This website would allow the user to monitor the status of the security system as well as change system options or turn the system on or off from any device capable of internet access. This adds additional functionality that allows this system to match many currently available on the market. This raises the question of at what costs does all the functionality of an embedded web server come at. Embedded web servers can be bought for less than thirty dollars. Development boards for the web servers can cost less than a hundred dollars. So even buying a development board to be used for prototyping as well as the single embedded server chip to be used in the final project prototype would cost less than a hundred fifty dollars which is much less than the estimated hundreds it would costs to buy a GSM module system for the final prototype alone not mentioning any development tools bought to be used for other prototyping purposes. So overall a embedded web server would bring more functionality at a reduced price when compared to a GSM module which clearly makes it the obvious choice as the solution that would work best for the needs of this design.

3.2.3. LCD Touch Screens

In order to decide which touch screen display will be used for the design of the ECO-SEC system that most important choice that must be made is which technology of touch screen is best to use; resistive, capacitive, or acoustic wave. In order be able to make this decision choice on technologies, it is important to understand exactly what design requirements that must be fulfilled by the display module that will be used for the ECO-SEC system. The most important factors that were used to decide which technology would work best for the needs of this design were: the size of the display screen, what the is the display expected to show, the ease of incorporating the display with the rest of the design, the power requirements of the display, and most importantly the cost of the display.

The display system is not supposed to be a large screen taking up a large portion of the homeowner's wall space. It is designed to only server as a interface between the system and the user. As such, the system does not require an overly large display and realistically a smaller sized display would be more ideal. The team decided that based upon the requirements of the ECO-SEC design as well as what functionality the LCD touch screen display subsystem must include, a screen size in the range of 3.5" to 6" would serve best.

The LCD display module is designed to be able to display information on the ECO-SEC system as well as to allow the user to provide input to the system via an interface using the touch screen itself. The display does not need to be able to display moving pictures or animations or display any video source of any kind. All the final design will need the LCD touch screen to display is a series of buttons for the user input and some simple text and static images to display status information for the ECO-SEC system.

In order for the LCD display module to be able to provide any functionality to the ECO-SEC system it is important that is able to correctly interface with the rest of the design most importantly with the microprocessor that powers the majority of the logic for the ECO-SEC. Some of the more complicated displays require multiple connections which would use a large amount of the available IO pins of the microprocessor. For the size and scale of this design this is not desired and as such the display should only require one connection to communicate with the microprocessor in order minimize the number of IO pins used.

One of the requirements of the ECO-SEC system is the ability to power the system using solar power in conjunction with a back up battery. In order to realistically be able to achieve this requirement within the design of the ECO-SEC it is important to attempt to minimize the power requirements of each individual subsystem of the design as much as is possible. So ideally the lowest available technology should be used as long as it is capable of meeting the other requirements the touch screen must fulfill.

As its the name implies, the main motivation underlying the design of the ECO-SEC system is providing a low budget approach to home security. The price of touch screens can vary based upon the technology behind them from anywhere in the low hundreds of dollars to several thousand dollars. Naturally a security system that requires components costing several thousand dollars for one subsystem alone is unable to meet the requirement of being economical, so the technology chosen must be able to be purchased at the low end of the cost spectrum for LCD touch screen displays.

Based upon the previous discussed requirements of the system expects from the LCD touch screen display the team decided the best technology to use for a touch screen would be a resistive touch screen. Of the tree main technologies available resistive touch screens have the disadvantage of having the lowest resolution and screen size supported by this technology. Based upon the fact the screen size required does not need to be overly large, as well as that the screen will mostly be responsible for displaying text and a few simple images it does not require a large powerful screen. This helps to limit would normally is the main disadvantage of resistive touch screens over the other technologies. Resistive touch screens also usually require the least amount of power of the three technologies to function. This results because of the nature of the technology and how it works from pressing conductive coatings together to generate a signal. The exact power requirements of the touch screen will vary somewhat based upon the requirements of the controller board used for the display but over all this technologies results in the lowest power requirements.

Resistive touch screens also provide a few other benefits not discussed as main requirements for the touch screen that also help to enforce why it is the most ideal technology for the ECO-SEC system. One of the advantages is the ability to use the touch screen by pressing it with almost anything from a finger to a stylus. This would allow the screen to be easier to use however the home owner feels most comfortable with which helps make it a better interface for the security system. Also resistive touch screens are spill resisted unlike acoustic touch screen so in the case of the screen being exposed to a minor amount of liquid it will still be able to function correctly. Resistive touch screens share the a very similar level of accuracy when it comes to the screen being able to determine the where the user presses on the screen. This becomes important because the system needs to be able to provide the correct response when the user provides input using one of the touch buttons. The system cannot correctly do this if the screen does not correctly recognize where the user presses the screen and activates the wrong button instead.

Although a resistive touch screen appears to be the most ideal technology to use it does have on additional disadvantage that is not easily mitigated. Resistive touch screens often have the lowest amount of screen endurance and often wear out faster than screens produced using the other technologies. However this is not as bad as it initially appears because even with this lower screen endurance a resistive touch screen can often function for at least 35 million touches. This still gives the screen a very good amount of reuse so the system will not be needing the touch screen replaced constantly and an average homeowner could get many years of use out of it before it wears out. So even despite this disadvantage the team decided to still use a resistive touch screen as the technology of choice when designing the LCD touch screen display subsystem of the ECO-SEC security system.

3.2.4. Alarms

The system that is being designed is a prototype for an “alarm system”. There are many commercially available off the shelf products in the market today and all have different ideas for implementing security; but, the sole purpose behind all of them is to keep an individual and family members’ perimeter secure. By definition, a Burglar (or intrusion), fire, and safety alarms are electronic alarms (devices) designed to alert the user to a specific danger. There are various types of alarms, but the one that the team will be implementing for this project is a home alarm system.

A home alarm system is basically used for indoors through the use of detectors and other mechanisms that aid the decision making of the system on whether an intrusion has occur or change alarm modes according to user commands.

3.2.4.1. Alarm Components

An alarm system doesn't just make a sound when an intrusion occurs as it needs various types of sensors that determine an event, making it possible for the alarm to logically determine whether an intrusion or false alarm has occur. Even though false alarms are very difficult (close to impossible) to define, the simultaneous use of sensors help reduce false alarms. These sensors are described in greater detail in a later section of this document but the main sensors that an alarm system can have are as follows:

1. Siren – receive input from the alarm control panel to alert anyone nearby (inside or outside the residence) that the property has been broken in when the sensors are logically triggered.
2. Motion Sensors – determine if there is movement inside the perimeter.
3. Passive Infrared Detectors
4. Ultrasonic Detectors
5. Door Magnetic Sensors – determine if a door has been opened or closed.
6. Glass Break Sensors – determine if a window has been broken.
7. Glass Break Vibration Detectors
8. Emergency Standard Sensors – alert the resident of an emergency to possibly prevent a tragedy. These are always active, and that is why they are called 24-hour zones.
9. Carbon Monoxide Detectors
10. Heat Detectors
11. Fire Detectors
12. Smoke Detectors
13. Other Convenient Options
14. Camera – to track zones real time or can also be used as an intrusion sensor with the use of image processing software to determine if a zone has movement, even though the perimeter is supposed to be clear of people (i.e. if the motion sensors detect movement, the camera gets activated to take pictures of a zone over a certain period of time; if these don't match, then there is someone in the property).
15. Door Magnetic Strip – allows the door to remain closed using a magnetic force (i.e. doesn't allow the door to be opened from outside when the alarm is set to Stay as no one should be coming into the property).
16. Web Server – to transmit data into a website that is accessible to the resident from anywhere outside the property.
17. GSM Capability – to send text messages, pictures, and even make automated calls, with status, to the resident while not being in the property.
18. And many more…

3.2.4.2. Industry Standards for Alarm Systems

The team will, in a way, make sure that the security system complies with the standards defined for this industry. These standards certify that the system meets all standards.

Even though this is only a prototype, it is possible to market a great product out of this senior design prototype. Some certifying agencies include:

1. Local Fire Department
2. Local Building Department
3. Underwriters Laboratories (UL)
4. National Fire Protection Association (NFPA)
5. National Electrical Code (NEC)
6. National Fire & Burglar Alarm Association (NFBAA)
7. Central Station Alarm Association(CSAA)

For the purpose of this prototype the team does not plan to have the design officially certified. However, if this project where ever to be taken to the next stage and marketed as a purchasable product such certification would be required.

3.3. Product Comparison

These sections detail a comparison of different products the team considered when selecting parts that would be used to build the prototype of the security system. Each subsection details a product comparison for different parts of the security section with each subsection providing an examination of several market available products and why or why not certain products were chosen by the team as the product that would be used within the final implementation of the prototype for this design.

3.3.1. Main Microprocessor

The main microprocessor is going to be the “brain” of the system so that means that the prototype for the ECO-SEC is going to be controlled by it. However this does not mean that the team will have to spend hundreds of dollars in such processor since nowadays, a microprocessor isn’t only cheap, but can do many millions of instructions per second (MIPS). For this reason, the microprocessor that the team will use needs to cost less than ten dollars ($10), and gives enough memory, performance, and capabilities to have the ECO-SEC system running as described in this document. In the end the team decided to use the Stellaris M3 MCU, LM3S5B91 microprocessor from Texas Instruments. The reasons for selecting this microprocessor will be given in the following subsections of this documentation.

3.3.1.1. Microcontroller Selection

When searching for a microcontroller, the question that the team asked was “what is needed to get the system running?” without looking at the reality being that a microcontroller does a lot more than what is needed for this system and at such a low price that selecting the microprocessor that does the most is the best approach. Because of the above reason, there is no need to worry about cost, performance, or input and output pins, as most microprocessors have at least 100 pins. These 100 pins will be far more than is required to implement all the necessary interfaces to connect the rest of the ECO-SEC system to the microprocessor.

Because Texas Instruments is a reliable company and provider, it was decided that using parts from such company was the best. For this reason, the only microprocessors that were looked at were those that met what was required for the design of the security system and readily accessible (on stock with low acquisition time).

3.3.1.2. I/O Required

The following are the most common points that are looked at while looking at a system's I/O selection:

1. Data transfer and communications – through RS232 and other pin driven interfaces.
2. Power – 12V provided by the power subsystem.
3. Pins – at least 30 or more preferably to ensure enough pins to meet any unseen future requirements that are not known at this stage of development
4. Operating Temperature – Room Temperature for a family home approximated to -50°C to 50°C
5. Other – should be able to hold, at least components, like a LCD touch screen, wireless sensor monitoring through Texas Instruments' (TI) Zigbee®, the security camera, and an embedded web server

3.3.1.3. Programmability

One concern with selecting a microprocessor to be used in designing the ECO-SEC security system is the ease in which the processor can be programmed. Luckily many processors today can be programmed in more advanced languages such as C or C++ as opposed to programming in an assembly language. The team preferred when selecting a microprocessor to use one that could be programmed a majority of its functionality in C since it is an easy to use language that the team is familiar with.

3.3.1.4. Processing Power and Memory

Since the majority of the instructions that are going to be performed by this microprocessor are relatively simple computationally, then not much processing power or memory is required. However, selecting a microprocessor that has more processing power and memory then is used by the design of the ECO-SEC is a preferred situation that purchasing a microprocessor that does not have enough performance or memory. This situation is also useful in case updates are added to the software, then there is no need to worry about having to add new memory or requiring a new microprocessor.

3.3.2. Battery

Also important, the ECO-SEC will contain a battery which will allow the system to store solar power and reduce the device's dependence on AC power sources. This battery must be rechargeable so that it can act as a buffer between the solar panel assembly and the rest of the unit. Without this buffer, solar power is not practical since the amount of power collected from the sun can vary greatly. Furthermore, a rechargeable battery maximizes the length of time the system can operate without power. Overall, a rechargeable battery is important to the ECO-SEC.

There are many different types of batteries to consider; however several different types can be ruled out quickly. To start the lead acid battery is not practical. Its energy density is very low, and it is one of the heavier batteries making it practical for heavy, low power systems. The ECO-SEC's battery must be small so that it can fit inside a moderately sized alarm unit. Also, power density is a concern. In rare cases homes will not have AC or solar power for an extended period of time. Therefore, the ECO-SEC must have a long lasting battery allowing the system to function for a few days without a power source. For similar reasons, alkaline rechargeable batteries are also not a good choice for the ECO-SEC. These batteries have a low energy density and can only be recharged roughly 50 times. To further complicate issues, these batteries are environmentally unfriendly. On the other hand, the ECO-SEC requires a battery that can be recharged a number of times allowing the battery to remain in the device for an extended duration. Secondly, it should be unnecessary for the user to keep a backup battery for the device in the event the alarm system fails. Due to its long life, a battery that can be recharged many times satisfies this goal.

It is more difficult to make a choice between the remaining types of rechargeable batteries. There were three general types of batteries to consider: Nickel Cadmium (NiCd), Nickel-Metal Hydride (NiMH), and lithium batteries. Nickel Cadmium batteries are not practical for this application because they contain hazardous materials and have a poor energy to size ratio when compared with other batteries. While the energy density is much higher than lead acid or alkaline batteries, the power system's size would be unnecessarily large. This type of battery also has performance problems if not fully discharged periodically. If not properly maintained, NiCd rechargeables can have crystals form on the plates of the batteries which will reduce the batteries ability to store power. This problem is referred to as memory. The ECO-SEC requires a battery that can be continually charged and rarely, ideally never, fully discharged. Also noteworthy, it is impossible to predict when solar power will or will not be available during the day. When solar power is available, the battery must charge in order to make solar power a practical option. As a result, a battery that requires strict charging limitations would be difficult to implement. On the other hand, NiCd does have the longest life meaning that it can be recharged numerous times. It also can output a large amount of current; however, the ECO-SEC is relatively a low-power device. Having a high output is unnecessary. The disadvantages to NiCD batteries far outweigh their advantages when considered for this project.

Nickel-Metal Hydride batteries are a good alternative to NiCd batteries because of their higher energy storage capacity and non-toxic metals. NiMh has a significantly shorter life than all other battery types under consideration which is a problem for the ECO-SEC since the user should not have to change the battery frequently. NiMh also has a very complex charge circuit. The battery has a tendency to lose its charge quickly, and as a result, the charger must use trickle charging to keep the battery working. This is also undesirable since the ECO-SEC will regularly run for half a day while applying no power to the battery. The variability in solar power even during daylight makes the concept of trickle charge even less practical. While the total battery self discharge is roughly 30%

every month, over 10% of this discharge occurs within the first day if no trickle charge is applied. Therefore, the ECO-SEC would require a battery that can store at least an extra 10% of the power that is required to ensure that the system can function when there is no power available. Also noteworthy, the battery generates a large amount of heat while charging which adds to the complexity of the charging circuitry. The final issue with the NiMh battery is that it must be regularly discharged to maintain performance similar to the NiCd batteries. As with the NiCd battery, this is due to memory issues. The high power density makes the NiMh batteries a better choice than NiCd, but there would be many problems to overcome with this design.

The final type of battery under consideration is the lithium battery which is the best choice for the ECO-SEC. Lithium batteries have higher energy density and a much lower self discharge rate than all other batteries considered. The battery also has a longer life than NiMh even though the NiCd has the longest life of all three types. Furthermore, lithium based batteries do not need to be periodically discharged making it ideal for the ECO-SEC. This is because these batteries do not have the memory effect involved in the other types. Furthermore, lithium batteries have a high cell voltage making it much easier to build battery packs that output at a higher voltage. Despite all of the positive characteristics, lithium batteries have several problems. First, they require a protection circuit to prevent overcharge and high output currents. Without this protection circuit, lithium batteries are very unstable and can explode if not maintained properly. These protection circuits are usually sold with the battery. Also, lithium batteries are more expensive than NiMh and NiCd. Lithium batteries cost roughly twice what a similar, in terms of power, NiCd battery would cost. For the ECO-SEC, this cost can be justified by the decreased size of the battery and the much more practical charging circuitry. The decreased size will make the power subsystem easier to manage and more user friendly. Despite these faults, it is clear that lithium batteries are a good choice for the ECO-SEC. The below table summarizes the advantages and disadvantages of these battery types.

	Nickel Cadmium (NiCd)	Nickel – Metal Hydride (NiMH)	Lithium batteries
Energy Density	45 – 80 Wh / kg	60 – 120 Wh / kg	100 – 160 Wh / kg
Nominal Voltage pr. Cell	1.25 V	1.25 V	3.6 V
Life	1500 recharges	500 recharges	500 – 1000 recharges (depends on type of battery)
Charge Conditions	Fast, pulse charge is better	DC charge then use trickle charge to maintain. Generates heat.	Constant current then constant voltage. No trickle charge.
Self Discharge	20% pr. month	30% pr. month	10% pr. month
Discharge Conditions	Full discharge to prevent memory	Full discharge to prevent memory	No memory
Safety / Environmental Concerns	Environmentally hazardous	None	Requires protection circuit

Table 3: Advantages and Disadvantages of Different Battery Types

There are two subtypes of lithium batteries to consider: Lithium Ion and Lithium Polymer. Lithium ion batteries provide the highest energy density when compared with the Lithium polymer. They also offer a much higher life cycle than Lithium polymer. Li-ion can be recharged up to 1000 times while the Li-polymer can only be recharged at best half the number of times. A high battery life is important for the ECO-SEC because the user should not have to frequently replace the battery or worry about the battery failing during a power outage. Another drawback to the lithium polymer is its high internal resistance. As a result, it is not able to deliver large and fast bursts of current to a system. On the other hand, Lithium polymer batteries offer a great deal of flexibility with their size and shape. It is possible to manufacture batteries as thin as a credit card. The size of the battery is also important for the ECO-SEC, but its shape is not. Consequently, Li-ion batteries still offer a better solution because of their higher energy density. Finally, Lithium polymer batteries are more expensive than lithium ion; however, the protection circuit is simpler and less expensive for Li-polymer. Consequently, the prices of these batteries with the protection circuit are roughly the same. Overall, the Li-polymer offers some desirable features, but the Li-ion battery has features that are more important to the ECO-SEC.

Batteries also differ based on the amount of power they deliver and the voltage at which they operate. Since most of the subsystems will receive their power from the battery, the general idea will be to use a DC to DC converter to modify the voltage to the desired level for all of the subcomponents. Lithium ion battery packs are usually sold in 3.7 V increments. This is because each lithium ion cell has 3.7 V across it. The battery pack is rated in Ah which represents the amount of current that the battery can supply for one hour. The current ratings usually are sold in 2.2 Ah increments due to the characteristics of each individual cell. However, lithium ion cells vary with the amount of current delivered so it is possible to find batteries that vary from the above increment. A battery pack's cost depends on the watts that it can store, typically given in Wh. Batteries around 50 Wh cost roughly $70 and consist of roughly 6 cells. There are also battery packs that can store 70 to 80 Wh; however, these batteries cost at least $100. These battery prices include the battery pack and the PCB protection, but no charger.

3.3.3. Embedded Web Server

Since the team decided that the embedded web server was the better option over a GSM module for reasons states prior, the next step that the team needed to reach was which embedded server best fulfilled the needs of the project. Several varieties of embedded web server chips currently exist on the market today. Choosing the correct model for the security system became an important decision that required examining several of the top choices available. Important factors that the team took into consideration when choosing which web server was the best fit was the performance of the web server, the cost of the web server especially when compared to the level of performance it brings, and finally the ease of programming the web server and how well it is capable of interfacing with a microprocessor.

On possibility initially examined was the PicoWeb Server. Upon examination of the chip, it was found to lack several features that were desired when decided upon which embedded web server chip to use. The chip in addition to an Ethernet connection to allow internet access also used a DB-25 connection. DB-25 in recent years is becoming a declining technology making it much harder to interface with other devices that would be used within the security system, as well as connecting to a PC during programming of the web server for the final prototype. Additionally the co-processor chip that the web server uses vastly surpasses what would be required by the system in terms of performance. Finally because of the high performance co-processor the PicoWeb is much more expansive than other models on the market running $149 for the development kit and another $99 for the chip and power supply. Another concern with the PicoWeb chip is how well would it interface with the rest of the ECO-SEC system and would it have the functionality to be able to provide the website interface the team wishes the web server to provide. The team desires the website to be able to allow the user to enter information changing the operating mode of the system. The web server should then be able to communicate this information to the microprocessor that it is attached to. The problem with the PicoWeb server is that it provides very little additional support to pass information to the microprocessor. This server only supports standard HTML and would require CGI scripts to provide this communication. This make designing and coding the embedded web server a very complex task. The high cost of this chip made it undesirable since most performance provided by the chip would not be needed by the system and would not be used. Also took into consideration was the difficulty in programming this web server compared to some of the others that are currently available on the market. As a result the PicoWeb was ruled out as a possible choice of web server chip.

The next embedded web server chip considered by the team was the DS80C400 network microcontroller chip. This chip was much more reasonably priced at only $27.99 per chip compared to the much more expensive PicoWeb chip previously examined. The DS80C400 is a powerful chip with larger amounts of ROM to store web pages as well as supporting up to 3 serial ports, multiple Ethernet ports that allow up to 32 users to connect to the website at once. For other applications this chip would be a very viable option but for the scale of the security system this chip provided much more performance than required. Because each security system would contain its own web server chip it is extremely unlikely that more than one maybe two, users would ever log onto it simultaneously. This leads the chip to become very wasteful as most of its features are not needed and as a result this chip was ruled out as a possible choice. Additionally to this the DS80C400 also has no coprocessor included with the network controller chip. This would require that every calculation be completed by the microprocessor and would greatly increase the amount of code needed to successfully program the microprocessor. The DS80C400 also has almost no inherent support for successfully hosting a web page or allowing it to interface with an attached device. All this would have to be manually handled by the development team. The makes the DS80C400 an absolute nightmare to program and the amount of time required to do so as well as the level of difficulty that could be expected from attempting to do so would not be feasibly possible in the time allotted to complete the final prototype. The team decided that it would be better to use a less powerful web server that could be successfully integrated with the rest of the system than a more powerful and cheaper web server that was unable to be integrated with the ECO-SEC system.

The SP1 - SitePlayer HTTP Web Server OEM Module was the next server chip to be examined. The SP1 Web Server is a lower performance model compared to many others available on the market; however it is easier to implement within a smaller scale project. This level of performance matches the speciation required of the website that the security system needs. The website built for the system is aimed more at simplicity and ease of use over appearance and the numbers of users logged in at once. Additionally the SP1 is one of the cheaper units available on the market at only $24.95 while the development board for the SP1 costs $79.95. Other teams in the past have successfully used this chip within their own senior design project as well as other sources recommending this chip for projects of similar levels of difficulty with similar requirements. As a result the team has decided to use the SP1 - SitePlayer HTTP Web Server OEM Module to implement the website that will be used to configure the security system. Additionally another aspect which but the SP1 over other available embedded web servers on the market is the relative ease in which it can be incorporated into the prototype design. Programming the SP1 is simpler that most web servers because it uses a coprocessor that handles a lot of the more complex instructions for the user. The user simply has to issue a command to the Site Player through a serial interface and the coprocessor for the web server will handle the rest. So instead of needing to add extra complex logic to the design of the microprocessor like other models the SP1 can use simple pre-included commands to accomplish the same thing.

In order to fully make an informed decision regarding which server chip to use a more detailed examination of the SP1's technological specifications was required. The Site Player SP1 chip is less than the size of an inch. This is the measurement for the chip alone and does not include the extra connections needed to be able to implement the SP1 within an embedded system. The SP1 contains 48 K Bytes of Flash memory used to store and host the web pages used for the site. These pages are authored in standard html code. The real strength of the SP1 is its simplicity in implementation with other devices within an embedded system. The SP1 contains pins that are used to provide a standard RJ45 connection interface. This is naturally the interface used to connect the web server to the internet allowing outside access to the webpage. The SP1 contains all the necessary Ethernet stack protocols built in. This allows for easier programming to use the SP1 and the designer is not required to include extra design for implementing these networking stack protocols. The next interface the SP1 has pins to support is a standard RS232 Serial Port. This allows the site player to easily communicate with either a standard PC or a microcontroller. This is the interface that is naturally used by the microprocessor of the security system to communicate with the web server. Microprocessors can send data to and receive data from the SP1 through simple commands that can be implemented within JAVA, C, C++, or Visual Basic code, which are easily supported by most modern microprocessors further enforcing the ease of implementation.

Figure 4 shows all 18 pins possessed by the SP1 and a brief description of their purpose. Important pins to note are pins 2 to 5. These pins are used to interface the RJ45 connection to the SP1 module. The hardware I/O pints will be used to attached the DB9 serial port interface to the module. More details on the important of these interfaces will be covered later in the documentation.

Pin Name	Description
1 Link LED	Pin low when link has been established, typically resistor to LED to VCC
2 RX+	10BaseT receive + typically connects to filter/transformer
3 RX-	10BaseT receive - typically connects to filter/transformer
4 TX-	10BaseT transmit - typically connects to filter/transformer
5 TX+	10BaseT transmit + typically connects to filter/transformer
6 VSS	Ground
7 RXD	Receive Data to UART Can direct connect to device UART TXD
8 TXD	Transmit Data to UART Can direct connect to device UART RXD
9 VCC	+5 Volts, typically 75mA
10 Reset	High - Reset, Ground or No Connect - Run
11 through 18	Hardware I/O port

Figure 4: Site Player SP1 Module Pin Name and Description, permission requested from Net Media Inc.

The Site Player SP1 module can be purchased as either a separated standalone chip or a full development board. The development board includes a built in RS232 and RJ45 connectors attached to the correct pins and well as a power connection. The development board also includes user LEDs and push buttons as well as a reset button making it ideal for practicing and beginning development. The development board is important relative to the design of the final prototype for the ECO-SEC because the final prototype will incorporate the SitePlayer SP1K board in its entirely because it includes many features that are needed and its size is relatively small. It is simply better designed and size that what the team could develop in the time frame to perform the same function. This leave the team with more time to develop the printed circuit board that will be used to house the power subsystem and the microprocessor.

Figure 5 below shows the schematic for the SP1 development board. Several things on the schematic should be noticed due to their importance to the design of the final prototype. The first is the SitePlayer SP1 module itself. This is the main chip that used by to host the website for the security system. Also of equal important are the two interface connectors provided by the SP1K, the RJ45 connector and a DB9 serial connector. The serial connector will be used to interface the development board with the microprocessor during later design stages, and the RJ45 Ethernet connector is used to allow the web server to be accessed from a remote location via the Internet. Also included are a power regulated system so the power subsystem developed for the ECO-SEC only needs to provide the correct input voltage and amperage. The development board handles the rest of the regulation.

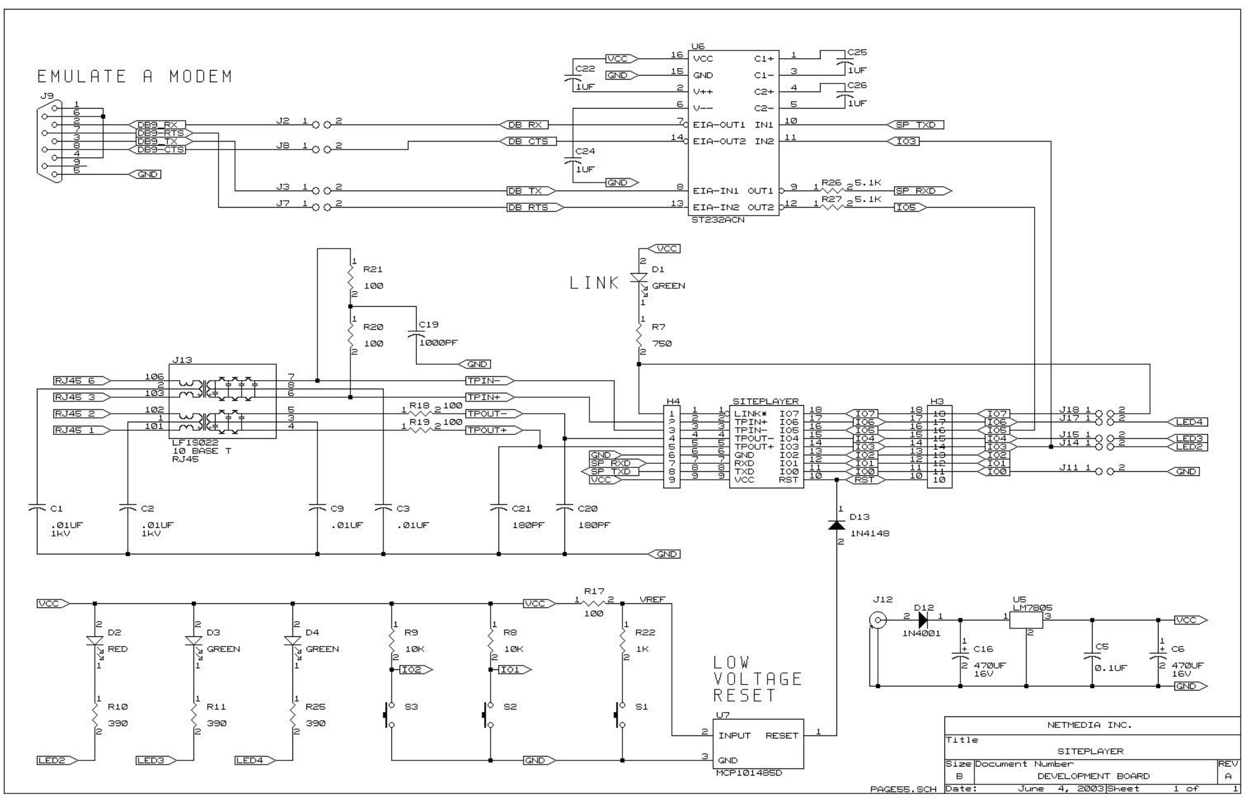

Figure 5: SP1K Development board Schematic, permission requested from Net Media Inc.

The SP1 chip costs $24.95 while the development board costs $79.95. The team decided to purchase the SP1 development board for prototyping and development, but the final implementation will use the stand alone SP1 module chip for the PCB developed by the team for the security system.

3.3.4. LCD Touch Screen Display

As discussed previous of the three main classifications of touch screen technologies the team decided to use a resistive touch screen display because this technology best fit the needs of the security system that was being developed. After selecting the correct technology the next choice was to select the individual display that would be used. Important criteria that were examined for each display were cost, graphical performance, size of display, and most importantly ease of implementation and use within the security system.

The first display examined was the IEI Technology 6.5” Resistive Touch Screen. [10] It boasted a great resolution at 2048 x 2048 dpi. It also had a decent life expectancy where a single display should last more than 10 million presses on the screen before beginning to malfunction. This display was also capable of operating anywhere in the 0 to 50 degrees Celsius range which would cover most home environments. However this level of performance is extremely expensive. The screen alone for this display costs $81. This cost also does not include any controller boards for the display. Touch screen displays require a controller board in order to correctly determine what to display on the screen and what to do when the screen is pressed in a certain location. A decent controller board alone can cost several hundred dollars without including any extra interfacing that may be required to use the board. Additionally the size of the screen is much larger than the project requires with a much higher resolution. The security system is designed to use the LCD display to display buttons and status indications for the system and as a result does not require a screen of that size or resolution. For these reasons the group decided to rule out this touch screen display.

The next display examined was the Bergquist 5.72” Touch Screen Display. As with the display from IEI examined previously, this display used resistive touch screen technology. This touch screen display contained similar qualities to that of the previous display as a result of the technology used. The Bergquist display can operate anywhere from -10 to 60 degrees Celsius and is capable of lasting 10 million single point activations or touches on the screen. Ideally the team would prefer a slightly longer life span for the touch screen as most resistive touch screens are capable of lasting 35 million single point activations. The cost of this screen at a whole sale distributer such as DigiKey costs approximately $43.75. This cost is drastically lower than the previously IEI Technology screen. It however still presents many of the same problems. The screen size of this display is much larger than would be needed by the project and much of the screen would very likely be wasted. Additionally, as with the other screen this display does not include a controller board, so once again more expense would be needed to buy a controller board not to mention finding a board that will be usable with the display as well as be easy to implement and able to correctly interface with the microprocessor used by the security system.

The next display examined by the team was the LG Philips 4.3" TFT Touch Screen display. This display is available for purchase from Reach Technology Inc. This display is a standard resistive touch screen. It boasts a resolution of 480x272. Although this is much lower than the other previously examined it is more than enough to display what is required by the security system. Additionally this screen possesses the largest temperature range of operation at -20 to 70 degrees Celsius. This range would allow this screen to be used by the security system any home in any kind of environment within reason. What truly separates this screen form the others is Reach Technology sells it in the form of a development kit. This development includes the screen as well as the SLCD43 controller board that would be needed to use the display within the security system. This development would save the team time and effort by not having to locate an individual controller board as well as making sure it is guaranteed to work with the LCD display chosen. For these reasons this development kit from Reach Technology was chosen to be used to implement the LCD touch screen display used by the security system. This development kit costs $349. At first, this amount appears to be staggering compared to the previously examined displays, which counteracts the goal of a economically friendly system, but those displays did not included the cost of an controller board. If the cost of the board were to be added to the system the price would be very similar. This also would not include any of the software, extra cables, extra interfacing electronics that come included with the development kit that would have to be purchased separately for any of the other touch screen displays.

Since the main benefit of the development kit from reach is the included SLCD43 controller board, a more detailed description of the technical specifications of this board is required. This controller board is designed to be the same size of the screen and is mounted behind the screen. This works well for space constraints as no additional circuit board sticks out larger than the display and makes it easier eventually develop a case and mounting for the display it this system where ever decided to be marketed. Additionally this board interfaces extremely well with others devices capable of communication via either a RS232 serial port or a standard USB port. This works well because the microprocessor chosen is designed to support serial ports for both the touch screen display as well as the embedded web server discussed previously. The SLCD43 controller board also contains a small 16/32 bit CISC processor that is used to help implement the touch screen. This will be covered in later detailed upon closer examination of the actually implementation of the LCD touch screen that is included later in this documentation. Another important benefit is the ease of programming this controller board. Many other controller boards examined required installation of special operating systems as well as learning new programming languages designed specifically for these operation systems. This adds a large amount of complexity to the security system that the team was unsure would be able to be successfully completed in the time allocated for this project. However, the SLCD43 Controller board uses its own syntax to program that is easy and quick to learn allowing for successful integration of the LCD screen into the project in the time frame allotted. More specific details on the programming methodology of the controller will be discussed later in this documentation.

Table 4 below shows the full list of technological specifications associated with the 4.3" LG Phillips Touch Screen. Some of these specifications are not directly located on the display itself but are included when the SLCD43 board is connected to the display.

Part Number	52-0007	**Storage Temp**	-30°C to 70°C
Board Model	SLCD43	**Supply Voltage**	5 V DC ± 10%
Manufacturer	LG Phillips	**Power Requirement**	450 mA max
Size and Type	4.3" TFT	**Interface Connector**	Molex 53261
Viewing Area (mm)	53.9 (H) x 95.0 (W)	**Serial Interface**	RS232 / 3.3V CMOS
Horizontal Viewing Angle (degrees)	130	**Backlight Display**	LED
Vertical Viewing Angle (degrees)	60 (Top) 50 (Bottom)	**Number of Serial Ports**	3
Screen Resolution	480x272	**USB Port**	Yes
Screen Type	WQVGA	**SD Card Slot**	No
Brightness (cd/m2)	350, with touch	**Microprocessor**	16/32 bit CISC
Touch Panel Type	Resistive	**Flash Memory**	4MB
Operating Tempt	-20°C to 70°C	**ROHS**	Yes

Table 4: Technical Specifications of the 4.3" LG Phillips Touch Screen Display

3.3.5. Security Camera

The design of the ECO-SEC uses an security camera to serve two primary functions. The first is as an additional means to detect the presence of intruders and the second is to be able to allow the homeowner to remotely view the state of their home via the website developed for the ECO-SEC by providing a live stream to the site. So in this regards the camera must be able to support this feature.

In order to fulfill the primary function of the subsystem, the camera should have the ability to detect intruders via the use of motion detection. Since developing an accurate form of motion detection for the camera is both complicated as well as time consuming, this is unable to be realistically achieved due to the cost and time constraints of the development phase of the prototype. As such, the security camera chosen by the team must include in its native API the ability to detect motion and report such detections to an attached device, which in regards to the design of the ECO-SEC would ideally be the microprocessor used by the design prototype.

To achieve the second function the security camera must also be capable of communicating what it "sees" with the embedded web server in real time. This can be accomplished by using HTML to create a composite HTML page that is in reality two separate pages but when view by the user via their browsers appears as one. So with regards to the ECO-SEC the first page create is the actually website while the second page would be the live feed from the camera. Luckily the chosen embedded web server supports this feature of HTML but with one condition. In order to be able to create a page from the camera, the camera must be able to be assigned its own unique IP address. This address is what is used by the HTML code to locate the camera feed and combine it with the website into a single page. So the ability to assign the camera a unique IP address as well as the ability for it to support built in motion detection limited the selection of security camera available for purchase on the market that meet these requirements. The team proceeded to compare a couple of these cameras in order to select the one that best fulfilled the requirements of this subsystem.

The first camera the team considered was the CMUCam3 developed by the computer vision center in Carnegie Mellon University. This camera is a powerful and small camera based upon software that is fully and completely open source. So although this camera itself does not include native support for motion detection, because the software is so open, several programs have already been developed by other users to allow the camera to detect the motions of humans within its view frame. Many of these programs could easily be used to detect the motion of an intruder. Additionally the CMUCam3 is capable of communicating with an attached device via a standard serial connection. This would allow the camera to be easily interfaced with the ECO-SEC system's microprocessor to allow the microprocessor to signal an alarm when the camera detects motion. From these the CMUCam3 is more than capable of fulfilling the first requirement of having the ability to detect motion more or less already built into the camera. The other requirement however, as previously mentioned was the ability for the camera to have its own unique IP address in order to allow it to interface with the embedded web server to create a live camera feed for the website. The camera itself has no support for these feature and does not provide any Ethernet connectivity of any kind. Although some research has been done on the camera by outside sources on using additional hardware connected to the camera to allow for this feature, the hardware needed to do so as well as the added complicity of getting such a setup to be fully function would not be feasible to be able to be successfully completed by the team in the time allotted. So for the fact that the camera cannot easily interface with the web server the team decided to rule out the use of the CMUCam3 as part of the final prototype for the ECO-SEC system.

The second camera the team explored using is the AXIS M1054 security camera. When compared to CMUCam3 as well as other models not included within this documentation, the M1054 is capable of fulfilling all the same functionality plus several more features most available models are unable to support. This is due to the fact that the M1054 is designed specifically for security system and as such works well with the design of the ECO-SEC. The M1054 naturally has the ability to detect motion but that can be accomplished not just in a single manner like most camera but instead in several different methods with different options. This would allow the team to use the option that is the most accurate for the setting that the ECO-SEC is design to operate in. These modes can range from detecting when an intruder crosses a single point line in the cameras view or to a full body recognition mode. The M1054 also includes an alarm input and output port that will allow it to be capable of communicating with an attached device such as the microprocessor. With these features the M1054 is one of the best camera with regards to support for motion detection. The M1054 is also designed as a network IP security camera. This secondary design is what allows the M1054 to fulfill the second requirement as discussed previously. The built in API for the M1054 includes software and options to allow it to generate a live feed stream that can be viewed via the internet using any standard browser. This stream is accessed using as a single webpage using the IP address of the camera, it can easily in corporate within the design of the website for the ECO-SEC to allow it to provide a live stream of the camera to the site. Additionally this stream can be configured via a long series of options in order to configure its appearance and quality. This would allow the team to be able to chose the settings for the stream that would allow it to work best with regards to the design of the ECO-SEC website. As a result of these features the M1054 is capable of fulfilling both requirements of the security camera subsystem. Once the team determined it fulfilled all the necessary requirements the next concern was the price since AXIS cameras are notoriously expensive. Luckily however, this is a much older and obsolete model, although it still more than meets the teams needs, which allows it to be able to be purchased at a vastly reduced price. This camera can be purchased brand new for anywhere from 200-400 dollars but also since it is such an older model, it can often be found slightly used for a much cheaper price. This would allow the team to be able to purchase the camera while still trying to fit in the model of designing an economical security system. Due to all the previously mentioned reasons the team decided that the M1054 was the best choice available on the market and decided to use it as the security camera for the subsystem for the development of the prototype for the ECO-SEC security system.

3.3.6. Sensor Array Subsystem Microprocessor

The goal of designing the sensor array is to create a modular entity that is capable of operating independently from the rest of the subsystems of the ECO-SEC security system. The sensor subsystem would then carry out all its own calculations as necessary separate from the rest of the system and is only connected to the main microprocessor at one point. This interface is to allow the sensor array to communicate with the main microprocessor to pass the on the status information of the sensors in the array, i.e. if they have been triggered by an intruder or not. In order to accomplish this the team decided that the design of the sensor array would requires its own microprocessor separate from the main microprocessor of the ECO-SEC. This secondary processor would perform all the calculations necessary on the sensor readings before passing it to the main microprocessor. This will save the main microprocessor from having to do this calculations in addition to the rest of the calculations needed for the other subsystems. At this point the team decided to examine possible choices for the secondary microprocessor for the sensor array subsystem. The programming experience that the team has with microprocessor has been mainly on Motorola based microprocessors so any more modern microprocessors such as MSP430, ATTiny or PIC16 would all be about the same in learning curve from the documentation found online. All of the major families of microprocessor utilize C as their programming language which the team has experience using making it easier to understand how to program these newer microprocessor models. They very similar features and the price is roughly the same for the various different models. For the sensor array subsystem, the microprocessor use in its design does not have to be high speed or performance since it will not require very fast sampling rates in motion detection or for the window/door sensors or for controlling the XBee wireless interfaces.

The following table compares the ATTiny 24 and the MSP430G2231 microprocessors that the team explored using for the sensor array design. These processors are compared on several different important features including cost, program memory, performance, and most importantly power consumption.

Feature	ATTiny 24	MSP430G2231
Price (Digikey)	2.52	2.14
Program Memory	2KB	2KB
RAM	128KB	128KB
EEPROM	128KB	256KB**
Max. Clock Rate	20Mhz(10Mhz*)	16Mhz
Max. I/O Available	12Pins (inc. reset)	10 pins
Voltage Range	2.7-5.5V (1.8-5.5V)	1.8-3.6V
ADC	10-bit, 8ch	10-bit,8ch
ADC sampling Rate	15ksps	200ksps
Timers	1x8-Bit, 1x16-Bit	1x 16-bit
Serial Interfaces	I2C,SPI	I2c,SPI
Architecture	8-bit	16-bit
Active Power @ 1Mhz	546uW*	484uW
Lowest Power Draw	.18uW*	.22uW

Table 5: ATTiny 24 vs. MSP430G2231 Microprocessor
* Data for the slower, low power ATTiny 24.
**This chip does not have EEPROM but instead uses flash "Information Memory" for permanent storage, 64B of which is for calibration data by default

Choosing a microprocessor for the sensor array subsystem was pretty challenging since the system is designed to use wireless sensors. The team decided to go with the MSP430 family of processors for its low power consumption and low start up costs at $4.50 for the programming board. AVR’s are in the $49 range for most of their startup kits. In terms of support there is also a very large online community that has a fast growing base. The team also had explored the possibility of choosing the ATMel family of Arduino based processors, the ATMega168 and the ATMega368, but they are not low consumption microprocessors and did not meet the requirements needed by the sensor array subsystem.

4. Project Hardware and Software Design Details

4.1. Hardware and Software Design Description

The design of the ECO-SEC security can be broken into six different subsystem and the overall prototype consists of building these six subsystem and correctly interfacing them to work together to create the final working product. These six subsystems are the power subsystem, the sensor array subsystem, the security system subsystem, the microprocessor subsystem, the embedded web server subsystem, and the LCD touch screen subsystem. Following sections in this document will provide a more detailed explanation of each of these subsystems and what is required for their design for the final prototype of the ECO-SEC security system.

In additional to understanding how each individual subsystem works in order for the team to complete the prototype it is necessary to have an understanding of how each subsystem interfaces and works together with each other. Most of these subsystems are interfaces together at a single point using one connector. A full detailed view of how the various subsystems are interfaced together is included in the section of this documentation dealing with designing the final prototype for the ECO-SEC system.

In addition to defining the details on these six previously described subsystems, this section of the documentation also provides details on the different modes of operation for the ECO-SEC security system prototype being developed by the team. These modes will determine how the system reacts to the presence of an intruder.

4.2. Alarm Modes

A home alarm system is basically used for indoors through the use of detectors and other mechanisms that aid the decision making of the system on whether an intrusion has occurred or change alarm modes according to user commands. There are many modes that can be implemented but can be defined for future improvements of this prototype as we will only implement seven.

The six alarm modes that will be implemented into the design of this prototype are:

The seven alarm modes that will be implemented into the design of this prototype are:

1. Off –This mode is triggered when power is removed from the system. Oppositely, when power is applied to the system, the alarm is placed on Standby mode.
2. Standby – This mode is activated when the system has booted after application of power. Also, it is triggered whenever the user disarms the alarm and places it on Standby because the resident might be going in and out without knowing when exactly is a good time to switch the alarm mode to a secure mode like Away or Stay.
3. Away – This mode is triggered when the user enters the appropriate password/code required to place the system on this mode. When this mode is activated, the system will give the user some time to exit the property or change the mode of the alarm. After such allotted delay time of no more than a minute, if the alarm mode stays Away mode, the system assumes that there is no one inside the property and activates all sensors. When the property’s entrance door is opened while the system is in Away mode, the user has 30 seconds to deactivate the alarm from “Away” to “Standby” or “Stay”. Otherwise, it will assume that an intrusion has occurred.
4. Stay – This mode is triggered when the user enters the appropriate password/code required to place the system on this mode. It activates all door and window sensors inside the perimeter immediately, according to the areas that the user wants to be activated while selecting this mode. These are often called zones, where someone who has a pool might want the sensors from that

area to not be active since the pool is going to be in use; but, since the main entrance and windows are going to be vulnerable, then those should be active. It assumes that there is someone inside the property, letting the internal motion sensors not be active but the other sensors should be working as normal. When the entrance door is opened, it will immediately assume that an intrusion has occurred. So the alarm has to be deactivated before walking outside.

5. Emergency/Burglar – This mode is triggered by many events. One of them being that a door or window is opened when the system is in Away mode. The same with when the system is in Stay mode, except it will be against the doors and windows that are not excepted as a zone when the alarm is in Stay mode. Another being when a person inserts between one and three invalid tries to disarm the alarm from Away or Stay mode. Finally, when the system is manually placed in Emergency/Intrusion mode. When this mode is triggered, it immediately sounds the alarm and alerts owner, cell-call, text, cops, sirens, lights, etc. according to the features that are active on the resident's system. NOTE: Many of the mentioned alerts are not part of the initial prototype for this system. A possible added feature for this mode will be to contact Emergency Response Units and the owner through a GSM module that will play a pre-recorded message according to the situation/emergency. This feature although possible to add for a future date will not be added for the design of the final prototype for the ECO-SEC
6. Test/Reprogram/Configuration – This event is triggered when the support team for the system accesses the system through a series of commands that are for testing, reprogramming, and configuration purposes only, not accessible to the user. This access is to be combined with physically wiring a port on the microprocessor to access the software and be able to perform the above mentioned events. This mode might give access to the user through another master code to give the ability to install updates to the system's software without the need for a support person having to travel or the user needing to get a new system in the event that it is not possible to update the one being used. This mode is not yet set in stone and will need more research on how to implement; otherwise, it is considered a future improvement.

When someone enters an invalid code (even if the system is in Standby), the person not only has two more tries to enter the correct code, but these have to be entered within 30 seconds of the first failed attempt; otherwise, the alarm will assume that an intrusion has occurred. It is not yet determined if the code to place the alarm in Away mode or Standby mode or Stay mode is going to be the same.

Sometimes, an intruder force enters the property, as the resident is opening the door, and asks the resident to disarm the alarm. Well, this system might incorporate, what will be called, a trick code. That is, a code that is programmed into the system by the user that when entered, it alerts authorities and contacts stored in the system to inform that an intrusion has occurred. When this code is entered, the audible alarm does not sound. This is done so that the intruder thinks that he or she are safely in the property, without knowing that the police are actually on their way. However since the current design of the ECO-SEC is not capable of calling the police this feature will not be implemented in the final prototype. If this design were ever expanded to become a fully marketable product this feature would most likely be implemented in that market design.

4.3. Power Subsystem

4.3.1. Block Diagram of the Power Subsystem

It is important to consider the general layout of the power subsystem as shown in the diagram below (figure 6). This subsystem provides, stores, and collects the power for all of the other subsystems in the ECO-SEC. The power signal to each subsystem must be voltage adjusted to meet the requirements for that particular subsystem. All of these DC to DC converters have been draw in one block, but it should be clear that many DC to DC converters for each voltage level required will be needed. As shown in the diagram, these output signals can travel to all of the subcomponents of the system.

Also notice the method of charging the battery. It was decided to use an AC to DC converter to properly modify the signal so that it can be charged with the same circuit as the solar panels. The other option was two have two charging circuits and use the switch to select which charging circuit would be connected to the battery. However, there is voltage regulation in both the AC and DC chargers in the previous method. Consequently, two separate circuits would have similar components to each other. The first method suggested however, is smaller and less expensive due to the reduced redundancy in the circuit. Also, the first method only involves designing or purchasing one charge controller which significantly reduces the complexity of the power subsystem, since charging the battery can involve a great deal of design. Overall, it seemed to be a better idea to convert the AC signal so that it can be used by the solar power charge controller.

Because the alarm system uses both AC and solar power, the system must have a way to logically switch between the two methods. The decision for which power source to use will be handled by the switch circuitry. When designing the switch it was considered to use the microcontroller to handle a good deal of this logic; however, it was determined that it was simpler to design a circuit to directly process this information. The specifics regarding the switch's design will be covered in the design section later in this report. The switch will detect the status of the battery, AC power, and solar power then proceed to select the most energy efficient way to manage power. Therefore, the system will always use solar power if the panels are collecting a sufficient amount of power. If a low power level is detected, the battery's charge status will be checked and used to determine if the AC power should charge the battery. The power to perform these checks on the system will come from the incoming solar and AC power, so it is important to ensure that the switch functions as expected if both power sources are not available for a period of time. The full block diagram for the power subsystem follows (figure 6).

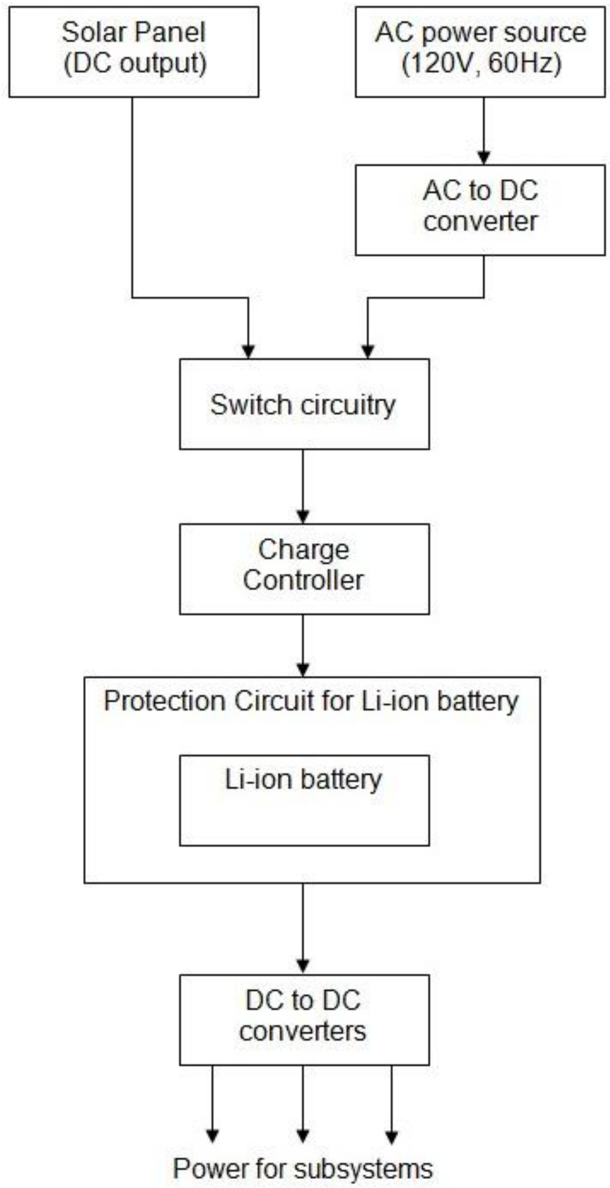

Figure 6: Power Subsystem Block Diagram

4.3.2. Power Considerations Design

In order to design the power subsystem, the power requirements for each individual component must be considered. The power requirements for the touch screen, web server, and camera are the highest; therefore, it is important to consider methods to reduce their impact on the power subsystem. As a result, it was decided to power the camera directly from standard AC power instead of connecting it to the battery. This modification will prolong battery life significantly and reduce the size of the required battery. Furthermore, the camera is not a fundamental component to the security of the home. During a power outage, when conserving battery charge is important, it would not be a good idea to waste power on a nonessential component such as the camera; therefore, this modification does not notably reduce the system's value to the homeowner. The second method to reduce power involves allowing the touch screen to enter a standby mode. When the screen is not in use, the backlight will be reduced to low which reduces power consumption as shown in the table below. This power consumption can be further reduced by simply allowing a switch to turn the touch screen on or off. In terms of power, this makes the touch screen much more practical to implement. The last component that consumes a great deal of power is the web server; however, there is no way to optimize its power use. The web server is important to the alarm system because it allows the user to check the status of their home at any time from a multitude of locations. Consequently, disabling the subsystem is not possible or practical; it must run at full power all the time. The below table summarizes the power requirements for the individual components.

Subsystem	**System's State**	**Voltage Required**	**Typical Current Draw**	**Power Consumed**
Touch Screen	Full backlight with beeper	5V DC	330mA	1650mW
Touch Screen	Full backlight without beeper	5V DC	280mA	1400mW
Touch Screen	Low backlight without beeper	5V DC	140mA	700mW
Web Server	Always on	12V DC	100mA	1200mW
Microcontroller	Always on	3.3V DC	56mA	184.8mW

Table 6: Power Requirements

To improve the portability of the system, some of the low power components can operate wirelessly. These components will not connect to the main power board since this would defeat the entire purpose of a wireless component; therefore, a battery must be used. The sensors will be powered in this manner, and therefore are not included in the power requirement's table above. The design of these components is discussed in the appropriate design section.

The next step is to consider the average amount of power that the system will consume from the battery. The average power of the system should be calculated by adding the typical power requirements for all subsystems with one exception: the LCD screen. Some of the subsystems such as the microcontroller and web server must receive power continuously. Other components such as the alarm, sensors, and camera will only need power continuously when the alarm is in a particular mode. However, the system should be designed considering the most power demanding mode since a homeowner may want to leave the house for an extended period of time while operating all components of the alarm system. Also important, the table given above and the average power calculation use the typical power as opposed to the maximum power consumed by the device. This is because the device's power use is being considered over a wide range of time so the typical values will be closer to the desired value.

The exception to the average power calculation is the LCD screen which takes a large amount of power when fully illuminated. Since the touch screen will not run at full power all of the time as discussed previously, adding its full backlight power requirement into the average power calculation would be an overestimation. Instead, the power to have the screen fully illuminated for 30 minutes over the course of the day will be added to the average power. The average power for this component will be calculated by taking the power at full backlight in Wh and dividing by 48. This is an overestimation since it does not account for the low backlight stage of the LCD screen; however the high power requirement has been reduced from 1.65 Wh to 0.034 Wh. Therefore, the touch screen will have a small overall impact on battery life.

Now the average power can be found by summing the average power estimations from the microcontroller, touch screen, and web server. The result is 1.42Wh. This calculation will be useful when determining the size and life of the battery needed to fit the ECO-SEC's specifications and requirements. The system will have to be designed to produce and store a greater amount of power than this because the efficiency of the power circuitry is not 100%. Consequently, there will be a power loss while charging the battery and when drawing power back out of the battery since the voltage will have to be regulated.

4.3.3. Battery and Protection Circuit Design

As discussed in the research section, the battery will be a lithium ion battery. The first issue to discuss is the voltage of the battery. It was decided that an 11.1V battery will be used to charge the system. In order to achieve this voltage, three lithium ion battery cells have to be connected in series. An 11.1 V battery runs at a higher voltage than all other subsystem's in the security system except for the web server which requires 12V. A 14.4 V battery would normally output above the web server's voltage requirement; however, when the battery reaches a low charge state, its voltage will drop below the requirement. An even higher voltage battery is possible, but this requires groups of five lithium ion cells in series which would lead to a large 10 cell battery to meet the power requirements of the ECO-SEC. Furthermore, lithium ion batteries charge at a higher voltage than their operating voltage, so higher voltage batteries impose a limitation on the solar panel required. Either a less common step up charge controller would have to be used to charge the battery from a lower voltage or a very high voltage solar panel would be required. While high voltage solar panels are not difficult to find, they will output much more power than can be used to charge the ECO-SEC's battery resulting in a large amount of wasted solar power and added expense. Furthermore, higher voltage AC to DC conversion requires a larger transformer which is also undesirable. A battery that operates at less than 11.1 V takes more time to charge since a higher Ah rating is required. Overall, the 11.1 V battery appears to be the best choice for the ECO-SEC since it provides good compatibility with the other components of the power subsystem.

Now the wattage of the battery can be determined. It was determined that it was practical and cost effective to create a battery that can store between 24 and 48 hours of power for the system. The size and cost of the battery is important as well. A battery that stores less than this would not be practical due to the irregularity in solar power and the need to have a power source when no AC power is available. To determine the minimum wattage needed, the power for each of the subcomponents must be summed and multiplied by 24. The multiplication by 24 converts the wattage to Wh since the battery needs to run for at least one day. However, this amount of power is not sufficient because power will be lost in DC to DC conversion. A rough approximation is 85% efficiency. When considering the combined effects of price, power, and size, it was decided that a 70Wh battery would be a good choice. This implies that the battery will store 6.4 Ah of current which will require a 9 cell battery pack with three groups of three series connected cells connected in parallel. This battery will cost between $90 and $110 including the protection circuit. After calculating for the power loss in the voltage regulators, the battery life is found to be 40 hours. Therefore the battery will be able to effectively act as both a buffer for the solar system and as a backup in the event of a power outage.

A larger battery design was also considered since it could be desirable to have a battery backup of more than two days or to possibly power the camera from the main power board. However, there are some difficulties with such a design. The obvious issue being that a 12 to 15 cell battery pack would have to be purchased. Not only would a 15 cell battery be very large and heavy but it would also be expensive costing roughly $150. This price is out of the budget for the ECO-SEC battery system and is difficult to justify since a larger battery would not add a great deal of worth to the security system. Another alternative option would be to use two battery packs. The advantage here is that more power consuming devices could run from one battery which would simply act as a buffer between the solar panel and the other subsystems. Less power intensive systems could run from the second battery and have a long battery backup time. In this manner systems such as the camera could be connected to the battery while still maintaining a long battery life for essential components. However, this approach would increase the complexity of the charging circuitry since two charge controllers would be needed and the amount of power drawn for each battery would have to be controlled. Overall, the best solutions were to either purchase a larger and more expensive 11.1V battery pack or to use the smaller 9 cell battery pack. Due to cost, the smaller battery was chosen.

The next design issue is to consider the output of the battery. The battery's output is limited by the protection circuit to 6.6 A. This implies that the lowest maximum output is 47.52 W. That value was determined by multiplying the minimum voltage of the battery by the maximum discharge current. Obviously, this is more power than the ECO-SEC will ever draw; therefore, there is no compatibility problem here. It is also important to note that the system will be able to simultaneously charge and draw power from the battery. This implies that the battery will be loaded by the rest of the system which will reduce the amount of charge current due to the parallel connection. However, it should be noted that the instantaneous power requirements for the ECO-SEC are less than the amount of power available from either the standard AC power or solar panel components. Consequently, if the switch is sending power to the charge controller, the battery will be gaining charge.

4.3.4. Charge Controller Design

The purpose of the charge controller circuit is to optimally charge the lithium ion battery. The battery charging occurs in three general stages. First, the battery is charged with a constant amount of current. One the battery reaches 70% of its capacity the charge controller will begin charging the battery at a constant voltage which, in this case, is 12.8V. The final stage is designed to top off the battery after self discharge. Since Li-ion have a low self discharge rate, this cycle does not occur very frequently. The charge controller also serves as a voltage regulator. Therefore, the input terminal can accept a varying voltage and convert it to the optimum voltage for the battery. Consequently, AC to DC conversion does not have to be perfect since the voltage regulator will correct any distortion on the signal. Therefore, the size of the filter capacitor can be reduced. Furthermore, voltage regulation also allows the converted AC power and the solar panel to output at different voltage levels. Since only one of these signals will be sent to the charge controller, the charge controller serves to correctly modify the signal to charge the battery. This is also important when considering the slight voltage variation across the solar panel that may occur.

The selected charge controller should meet a certain set of criteria. First, it should be able to charge a battery with at least three series lithium ion cells. This means that the charge controller must be able to output a voltage of 12.8V or greater. The second parameter is the input voltage. Most charge controllers use step down voltage regulation and the ECO-SEC has been designed to output at a higher voltage than the battery. However, the charge controller should be able to accept at least 19V at the input. This is the voltage expected from the AC to DC converter and is consequently, the highest voltage expected at the charge controller's input terminal. It is probably a good idea to get a charge controller rated significantly above this voltage to prevent potential problems. Also, the charger will have an efficiency associated with it. A high efficiency is desirable since the ECO-SEC is supposed to be energy efficient. Another issue is the method of charge termination. For the ECO-SEC, charge should be terminated through setting a current limit and maximum voltage as discussed above. Finally, the amount of charge current must be considered since this defines how quickly the battery can be charged. This value should be at least 2 A. A charge controller that meets these parameters is the MAX745.

Table 7 shown below shows the specifications of the charge controller that will be used within the final prototype of the ECO-SEC security system as part of the power subsystem. This table shows the parameters of the Max745 compared with the requirements of the ECO-SEC design.

	Max745 Parameter	ECO-SEC Design Parameter
Maximum Input Voltage	24 V	Larger than 19V
Maximum Number of Series Li-ion Cells	4 cells	3 cells or more
Maximum Charge Current	4 A	At least 2 A
Charge Termination Method	Current Limit and Maximum Voltage	Current Limit and Maximum Voltage
Efficiency	90%	As high as possible

Table 7: Charge Controller Specifications

The charge controller cannot step down any voltage that is higher than 12.8V. It is expected that at least 15.5V will be required at the input terminal of the device to appropriately charge the battery. The only concern here is the solar panel, since this forms the minimum limit for the panel's voltage. Therefore, a solar panel that will output at or above this voltage while producing a significant amount of power must be selected.

4.3.5. Solar Panel Design

The first design issue to consider with the solar panel is the methods to focus sunlight onto the module. As mentioned in the research section, solar panel efficiency can be increased by focusing solar energy onto the cells or by rotating the solar panel to point toward the sun throughout the day. Both of these designs add a great deal of complexity to the solar panel subsystem. The focusing of solar energy would be difficult unless the orientation of the sun with respect to the panel was known. Consequently, utilizing this method would add a large amount of complexity to the system and would require purchasing additional materials. The second option was to rotate the panels to keep them in-line with the sun. However, moving the module would require construction of a motor to move the panel with the sun and a sensor to keep track of the sun's location. This information would have to be sent to the microcontroller to process and communicate with the motor. Again this adds a great deal of complexity and cost to the project. Fortunately, such high efficiency solar power is not required for the ECO-SEC since only an alarm system will be powered from the solar panels. Since the ECO-SEC is supposed to be a low cost home security solution, these designs are difficult to justify. Therefore, the solar panel must be aligned in a particular way to prevent as much shading as possible.

It is also important to define where the ECO-SEC solar panels will be designed to operate since different geographic locations receive a different amount of power from the sun on a given day. The map in the research section gives the average annual solar radiation. The ECO-SEC will be designed to operate in areas that receive at least 4 kWh/m^2 on the average each day. This minimum corresponds to the light green area on the map. If a region drops below this level for a large portion of the year, such as many of the states in the north east United States, it may not be practical to use the

ECO-SEC solar panel system for power. Most solar panels are rated based upon 1 kWh/m^2 of solar energy reaching the cell continuously. This implies that 12 kWh/m^2 each day would have to reach the panel in order for it to produce its rated power for half of the day. Consequently, it is unrealistic to expect that the solar panel will function at the wattage listed in the specifications.

The design goal for the ECO-SEC solar panel is to create a system that can maintain the lithium ion battery under ideal conditions and reduce the user dependence on AC power. As discussed in the battery design section, the solar panels must be able to charge an 11.1 V battery. Lithium ion batteries charge at a higher voltage than they output. In this case, 12.8 V is needed to charge the system, but the charge controller requires an input voltage of 15.5V to charge the battery at this voltage level. Therefore, to maximize power efficiency, it is reasonable to use a module that outputs slightly above 15.5 V. A smaller panel would require a boost DC to DC converter to step up the voltage to the desired level. This adds additional cost to the power subsystem and greatly limits the number of charge controllers available. Although the sunlight varies, the voltage across the panel should not vary by more than 10% while the solar panel is producing a significant amount of power. Consequently, the module should output at 17.3V or greater in order to work without the step down converter and accepting a voltage decrease of 10%. Since the panel would be producing a minimal amount of power at this level, a 17V solar system would also be acceptable. This module requires roughly 30 cells connected in series.

Additionally, the amount of power produced by the solar system needs to be determined. The battery can be charged by at most 2 A of current in 4 hours. Most solar cell modules output at 4 A of current; however, this output can only be expected under ideal situations. The amount of current produced by the solar module is directly related to the solar power available to the system. Furthermore, it is possible to buy cheaper solar modules that contain cells that output a much lower current which may be a good idea for the ECO-SEC since it will reduce cost. Since the output power of the solar panel can be expected to vary by as much as 66% on an average day, there is a tradeoff between having a solar panel that will not waste any power and a panel that will permanently sustain the system. A 30 Wh panel would not waste any power and is therefore considered the minimum for the ECO-SEC. However, such a solar module would be unable to permanently sustain the system, because some days may produce less than average solar power. Now that the power issues have been discussed, the size of the panel must be considered. In many cases, the size of solar cells varies with the amount of power they produce. After comparing many products, it is reasonable to conclude that 125mm by 125mm or 4.9in by 4.9in provides 2W of power for polycrystalline cells. This implies that a 30 W panel would have dimensions equal to 0.234 m^2 or 2.5 ft^2. This is an acceptable size for the ECO-SEC; however, it is a minimum. The 60 W solar panel would have an area of 0.469 m^2 or 5.04 ft^2.

It is also important to discuss a solar panel that would be able to minimize the chance of the system drawing on standard AC power. In order to build such a module, one must consider the worst case for the amount of sun available on a given day. This worst case scenario is roughly 2 kWh / m^2 of solar radiation in Florida. Under this level of radiation, the voltage and efficiency would drop below by 10% of their ideal values during the course of the day. As a result, a 75W panel would be required to charge the battery over the course of a day with a poor amount of solar radiation. Larger panels would be impractical because much of the power would be lost since the battery can only accept a certain amount of power at a time. A 75 W solar panel would have an area of 0.586 m^2 or 6.307 ft^2. Such a module is larger than desired for the ECO-SEC and increase the expense of the solar system.

After determining the specifications for the solar cell, it is important to consider the module construction. As stated before, the cells will be wired in series to maximize the panel voltage. The positive end of each cell should be connected to the negative end of the next cell. It is not practical to expect equal lighting on all cells in the solar panel since no rotation or light focusing system is being used. Usually, a bypass diode is used to prevent hot spots in the solar panel; however, in a small solar panel it is common neglect this issue because of the low power in the panel. Since there is a voltage drop across each bypass diode used, such a setup reduces the power of the system. In larger panels, the voltage drop of the diodes is more acceptable since the power output is all ready high. Furthermore, larger panels produce more power causing the hot spots to become even warmer to the point where the solar panel may break. In a 30W panel, this issue does not exist. Bypass diodes are practical in 50W or greater solar modules. A second type of diode called a blocking diode should be used. The purpose of blocking diodes is discussed in the research section. One of these diodes should be placed in series with the panel to prevent current from flowing back into the solar module.

Also, the solar cells must be protected. The solar panel should be able to survive poor weather conditions and heat. The backing for the panels must be able to absorb heat so as to prevent the panels from decreasing in their efficiency. The panels must also be protected on the front side by a clear material to allow light to pass through and prevent the cells from being scratched or broken. The material must also be resistant to severe weather conditions including rain and hail.

It is also possible to purchase a pre-constructed solar module. Such a module would have the proper backing and protective characteristics discussed above. The closest match to the desired voltage characteristics that is commercially sold is an 18V panel. It is also common to find panels that output at a voltage around 17V. Consequently, the 11.1 V battery, which requires 15.5V on the charge controller, was chosen to allow compatibility with solar panels of this class. The problem with this option is price as pre-designed solar panels can be expensive. 30W panels are commonly found online to cost around $150 while the 75W are approximately $300. However, it is possible to find more reasonable prices. The table shown below shows solar panels that are compatible with this project at a more reasonable price.

Product	Maximum Power Point Voltage	Maximum Wattage	Dimensions	Price
SUN-SP-30W-18.3V	18.3 V	30 W	27.13 in x 15.15 in	$90.00
UPG-30	16.7 V	30 W	23.13 in x 11.38 in	$84.00
UPG-40	17.2 V	40 W	25.59 in x 21.06in	$128.00
SUN-SP-60W-16.9V	17.4 V	60 W	29 in x 21 in	$165.00

Table 8: Solar Panel Specifications and Prices (Solar Panels above are sold by Sun Electronics. Information was retrieved from their website, www.sunelec.com)

Overall, the best solution seems to be to buy a solar panel within the design parameters described above. A 40 Wh panel would be an optimal choice since such a panel would be able to sustain the system under favorable conditions while not wasting a great deal of power under optimal sunlight. The decision to buy a solar panel over building one can be justified when considering the reduced complexity and the advantages to having a professionally designed solar panel. The cost of the solar panels in the table above is similar to the cost for building a solar panel from individual cells.

4.3.6. Switch Circuitry Design

The purpose of the switch is to select the appropriate power source to use for charging the battery. There were two designs considered. The first was to design a variety of flags that would output digital information to the microcontroller on the status of the battery, solar panel, and AC power. The microcontroller would then be able to choose which power system to use to power the battery. The second approach involved processing the flags without using off-board components such as the microcontroller. In this approach, a variety of flags are still created that output digital information, but these flags are then processed using logic components installed on the power board.

In both approaches, a method for determining if power is available from a particular source is required. For detecting AC power a simple comparator circuit can be used. The comparator will take the input power signal and compare it to a voltage reference of several volts. If the signal is below the reference, the output will indicate that no power is available from that source since the voltage level is very low. If the microcontroller is used to process the information, it will check these flags periodically to determine if power settings need to be changed. If the power is greater than the voltage reference, a one will be outputted back to the microcontroller. Otherwise, the output will remain zero. The comparators voltage reference will be powered by the AC power source with a high resistance on the line to reduce current drain. Consequently, the flags will read as zero if no power is applied to the system. This is not a problem because if the battery has no power the microcontroller will be off and the system will be charging from AC power. This idea is shown in the schematic below (figure 7).

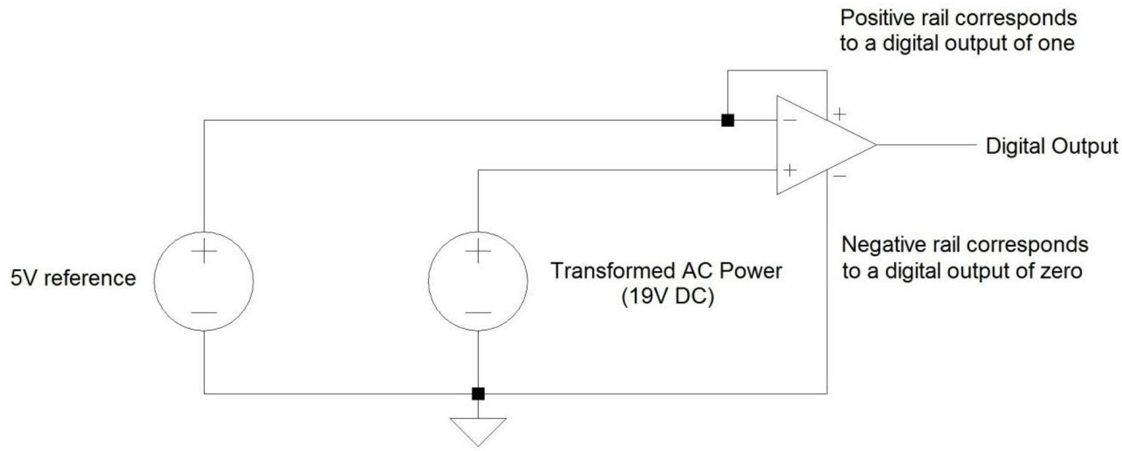

Figure 7: AC Power Flag

The 5V reference can be created by either pulling a signal off of the 5V regulator which will all ready be needed for the touch screen. A better solution would be to use the battery and a 5V precision reference component. Furthermore, it is important to note that this circuit assumes the AC power to either be on or off, because it compares it with a 5V reference. With the AC power source this is the case, so the AC signal will always be 19V or non-existent.

Checking the standard AC power is simple since the power is either on or off and intermediate voltages will not be present. Detecting the charge from the solar panel is more difficult since it is the current that determines if the solar cells are receiving power. However, when solar cells are under of low level of radiation their voltage drops even though the current drops by a much greater amount. Comparators can detect very small voltage drops, so it is possible to use a comparator to detect when the solar voltage drops to roughly 0.9 of its original value which corresponds to a one volt difference. Another issue with using a similar circuit to the one shown above is that when the solar panel approaches the trigger voltage the output will jump between a logical one and zero. In the microcontroller approach, this is not a major problem since the system will be able to check the flag multiple times over a short period of time to determine if the solar panel is close to the trigger approach. However, without a microcontroller the problem becomes significantly more complex.

The best way to detect the solar panel power status is a Schmitt trigger. An applied reference voltage will be required because the trigger points should not be centered about 0V. Good triggering points for the solar panel are 16V and 16.5V, since 90% of an 18V panel would be 16.2V. Because the solar panel voltage is high and a reference of only 5V is available, the input voltage must be scaled down by a voltage dividing network. A schematic is shown below in figure ? for the inverting trigger. Consequently, this flag will output a digital one when the solar panel is low. The Rx and Ry resistors represent the voltage divider while the R1 and R2 resistors define the triggering points for the circuit. The effect of the voltage divider is easy to calculate because very little current travels into the op-amp. Consequently, Rx and Ry are not loaded by the resistance of the rest of the circuit. The diagram follows (figure 8).

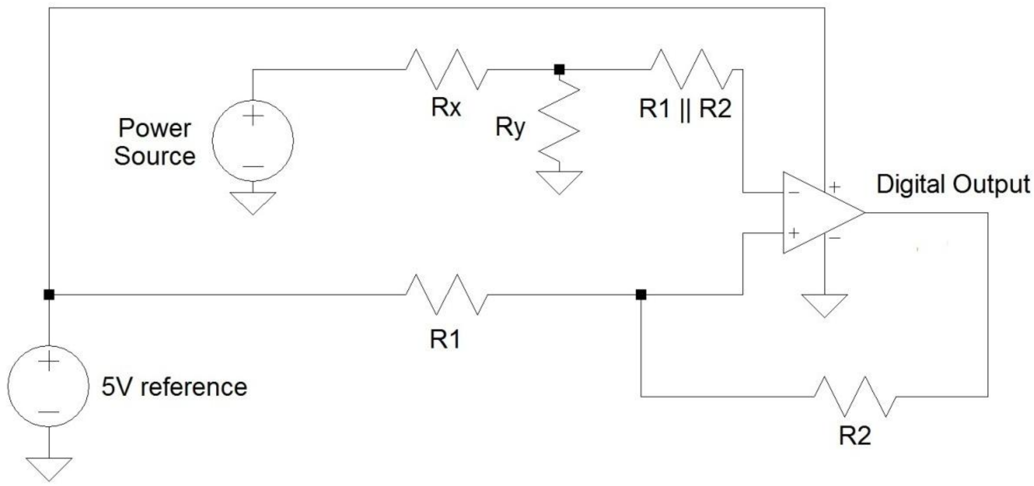

Figure 8: Solar Power and Battery Status Flag

There are a few things to note about this circuit in figure 8. First, the power consumption is greater than the first comparator circuit due to the added voltage division network. If these resistances are chosen to be large the current from the solar panel and 5V reference are reduced and as a result, power consumption decreases. Secondly, the tolerances of resistors play an important role here. The system needs to detect a voltage that varies by 10%, so 1% resistors or better must be used. Consequently, the termination condition will not be exact, but should be sufficient to act as a flag to the microcontroller or logic circuitry.

The last circuit needed to communicate with the microcontroller is the battery charge status circuitry. This can be done by reading the voltage of the battery. A similar circuit to the one shown above in figure 8 can be used as a simple low battery flag by choosing a voltage that represents a low battery. A low battery flag can be outputted at a voltage of 9.8V. In order to maintain a proper battery backup, the upper limit for the Schmitt trigger will be set to 10.8V so that the battery is required to almost recharge completely before the flag indicates that the battery is high. While reading the battery voltage is not a perfect reading of the batteries charge, it will provide the microcontroller or logic circuitry with sufficient information on whether to charge the battery from standard AC power or continue to wait for solar power availability.

In order to switch between the power sources an ideal diode can be used. Linear Technologies offers the LTC4412 ideal diode which will function very well in this project. It accepts up to a 28V input signal which satisfies the ECO-SEC's requirements since the highest voltage through this circuit is 19V. The device can be used with four p-channel MOSFETs accept two input signals and send one to a load while blocking the other. Normally, the power source with the highest voltage is selected; however, through a CTL pin the device can be forced to block the power source connected to the device's V_{IN} pin. A schematic for this circuit is shown below (figure 9). In this case, power source one would be used if the CTL line was high.

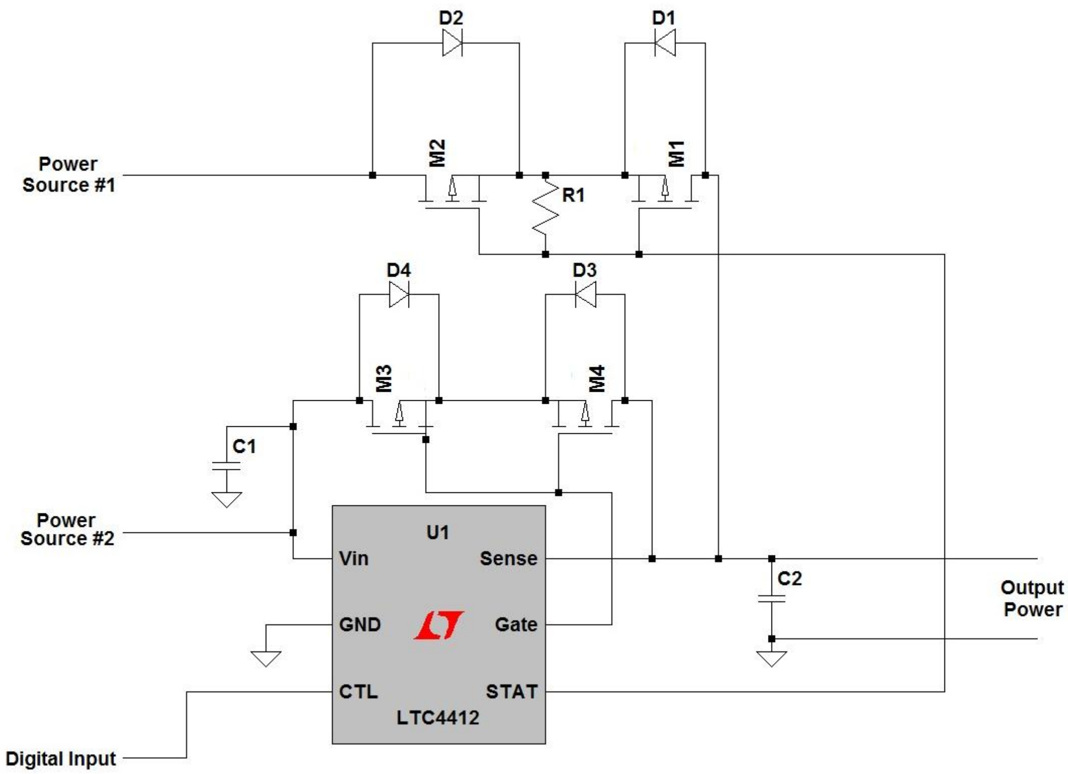

Figure 9: Power Source Selection

At this point it becomes clear that it is better to use logic components on the power board instead of the microcontroller for determining which power source to use. In order to use the microcontroller to select a particular source, two LTC4412 would be required. One would be used in the application shown above and the other would be used to block or allow power source one. This is the only way to have full control over which source is used. This design however, does not take advantage of the fact that the LTC4412 can be used to determine which voltage is higher. If power source one is made the solar power signal and power source two is made the AC power signal then the AC signal will always be used unless it is not available. This is because the AC signal outputs at 19V which is higher than the solar panel at 18V. Therefore, the CTL line must be high if the solar panel is high or the battery is high. This is the condition to charge the solar panel. Because inverting Schmitt triggers were used for the digital flags, the CTL line must be high when the solar panel flag is low or the battery is low. As a result, only one NAND gate is needed. This logic is shown in the table below.

Solar Panel Status	Battery Power Status	Solar Panel Flag	Battery Charge Flag	CTL Pin
High	High	0	0	1
High	Low	0	1	1
Low	High	1	0	1
Low	Low	1	1	0

Table 8: Schmitt Trigger Logic

Due to the simplicity of this design, the switch will not connect to the microcontroller. One advantage to this method is that the switch will continue to select the optimum power source even if the alarm system loses power and the microcontroller is powered down. The switch can power its NAND gate and voltage references from AC power all of the time. Therefore, if AC power is not available both the battery flag and the solar power flag will output a logical zero. Since the AC signal is low the LTC4412 will always output the solar panel regardless of the output of the NAND gate. Finally, notice that the AC power flag was not used in this approach. The flag would be necessary to connect with the microcontroller since it would need the status of the AC power.

4.3.7. AC/DC and DC/DC Converter Design

The deign goal for the AC to DC converter is to take the standard 120V 60Hz input signal and convert it to a DC signal at a voltage level compatible with the charge controller. The charge controller requires 15.5V, so the output voltage of the AC/DC converter must be at least at this level. The converter does not have to convert exactly to this setting because the charge controller will contain a voltage regulation circuit. An AC to DC converter can be constructed from a transformer, full wave rectifier, and capacitors. The transformer will step down the 120V 60Hz signal to a 20V AC signal. This signal then must be rectified by using a diode bridge that is rated to handle the transformed AC signal. Unlike a single diode, this diode bridge will rectify the entire signal and thus reduce the power loss during conversion. The full wave rectifier will reduce the output voltage level by 1V; therefore, the output voltage is 19V DC. The rectified signal can then be converted to a DC signal by connecting a large capacitor in parallel with the load. It is important to use a large capacitor and not rely on the charge controller’s voltage regulator to convert to the DC signal. This is because the LTC4412 used in the switch circuitry works with DC signals only. If the input signal is not DC, it will not properly determine which of the input voltages is larger. The charge controller circuitry will regulate the voltage of the output of this circuit to the desired level for the battery. As a result, the AC to DC converter does not have to output exactly at the battery charge voltage. A simple diagram of the AC to DC conversion is shown below in figure 10.

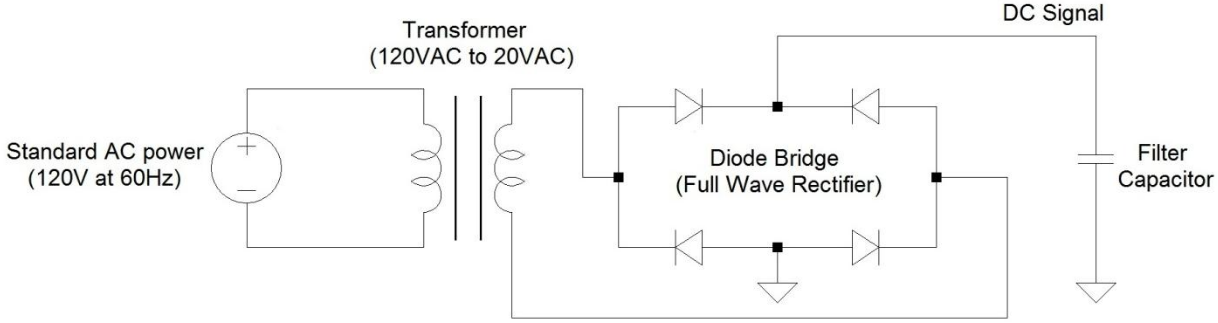

Figure 10: AC to DC Conversion

The second type of converter needed is a DC to DC converter that runs from the battery to all other subsystems. These converters will be designed to deliver enough power to each subsystem at the correct voltage. This is necessary because the battery voltage can vary greatly during normal operation. When selecting DC to DC converters, it is important to remember that battery voltage can change when the battery expends a good deal of its charge. Consequently, the DC to DC converters should be able to accept an input that can vary be at most 4V. In order to improve efficiency of the circuit, a switching power supply will be used for the DC to DC conversion. Switching power supplies are more efficient than linear circuits, but also have an increase in the amount of noise. Therefore, it is important to make sure the noise on the output can be tolerated by the particular subsystem it powers. The below table summarizes the needed DC to DC converters. It also list the maximum amount of power needed for that subsystem since the voltage regulator must be able to provide the correct output. The camera was not included in the DC to DC regulation since it will be powered by its own power supply. This allows the camera to be separate from the power board so that the camera can be placed at any location in the home.

Regulator	Voltage Specifications	Regulator Type	Maximum Output Specifications
Touch Screen	7-12.8V to 5V	Buck Regulator	400mA, 2000mW
Web Server	7-12.8V to 12V	Buck / Boost Regulator	100mA, 1200mW
Microprocessor	7-12.8V to 3.3V	Buck Regulator	56mA, 185mW

Table 9: Regulator Specifications

The voltage regulator for the touch screen and microcontroller can be the LM2675-ADJ. This regulator has an adjustable output and is therefore an acceptable device for both components. This regulator requires a 6.5V signal to step down to a 3.3V signal which is perfect for the ECO-SEC since the cutoff voltage of the battery is 7V. Another desirable feature of this regulator is its efficiency. When the device is outputting power at the voltage levels required for the ECO-SEC, the efficiency is above 85%.

The web server's voltage regulator is more complex since the maximum voltage from the battery is 12.8V. The LTC1372 buck/boost converter can be used to satisfy the design requirements here. This device can be appropriately configured to output a 12V signal with a 7V to 12.8V input signal. This configuration requires the use of two inductors and is slightly more complicated than the buck regulator design used above. This design issue was expected since an 11.1V battery was selected for compatibility with an 18V solar panel and a step down charge controller. A high voltage battery would simplify the design, but cause other compatibility issues.

4.4. Microprocessor Subsystem

This section of the documentation covers the specifications of the microprocessor chosen for the ECO-SEC system and how to successfully be able to implement it in the design of the ECO-SEC security system. Details on the exact nature of the role the microprocessor plays in the design of the prototype will be given in a later section in this documentation.

4.4.1. Specifications of the Stellaris Microprocessor

Table 10 shows the parametrics that the Stellaris LM3S5B91 microprocessor possesses and is capable of operating at. The specifications that the team was most concerned about was the flash memory and ram available. The team felt that the amount provided by this processor was more than the design would likely require. Also the team chose a higher power microprocessor in terms of performance capable of operating at 80 MHz. This decision was made because the design team felt it was better to have access performance than to have a slow microprocessor which could create visible delays in the operation of the final prototype. The interfaces that the team was most concerned about the UART interfaces. These will be needed to create the RS232 connections that are required by several of the other subsystems in the final prototype design.

Flash	256 KB	**I2C**	2
RAM	96 KB	**CAN**	2
StellarisWare	Yes	**Memory Protection Unit**	Yes
Max Speed	80 MHz	**ADC Channels**	16
Timers	5	**Internal Temp Sensor**	Yes
Capture Pins	8	**Operating Temperature Range**	-40 to 85 °C
USB	1	**Package Area**	100 x 196 mm
UART (SCI)	3	**Approximate Price**	$6.45

Table 10: Stellaris LM3S5B91Parametrics

4.4.2. Electric Characteristics of the Stellaris Microprocessor

Table 11 below shows the electric characteristics of the microprocessor the team has chosen to use. These characteristics are important with regards to interfacing the microprocessor successfully with the power subsystem of the ECO-SEC. If the power subsystem is unable to provide the correct power to the microprocessor it will be unable to function correctly. This table gives the correct input voltage for both the processor and the pins, as well as the current needed for the pins. The last important characteristic is the maximum voltage that can be supplied to a pin when it is supposed to be off. If this value is exceeded by the power subsystem the microprocessor will be incorrectly tricked into assuming that the pin is supposed to be active.

Parameter	Parameter Name	Minimum Value	Maximum Value
V_{DD}	I/O supply voltage	0 V	4 V
V_{DDA}	Analog supply voltage	0 V	4 V
V_{IN}	Input Voltage	-0.3 V	5.5
I	Maximum current per output pin		25 mA
V_{NON}	Maximum input voltage on a non-power pin		300 mV

Table 11: Electrical Characteristics of the Stellaris Microprocessor

4.4.3. Microprocessor Block Diagram

Figure 11 shown below shows the internal block diagram of the Stellaris microprocessor the team chose to use in the implementation of the ECO-SEC security system. As can be seen from the figure the Stellaris processor is powered by a ARM Cortex - M3 CPU. This figure also shows how the various buses associated with the processor are connected. However for the purposes of the development of the ECO-SEC security system the internal design of the microprocessor will not be changed. The team will use the pins of the microprocessor to connect to the other subsystems of the design and will be more concerned with the interfaces provided by the processor.

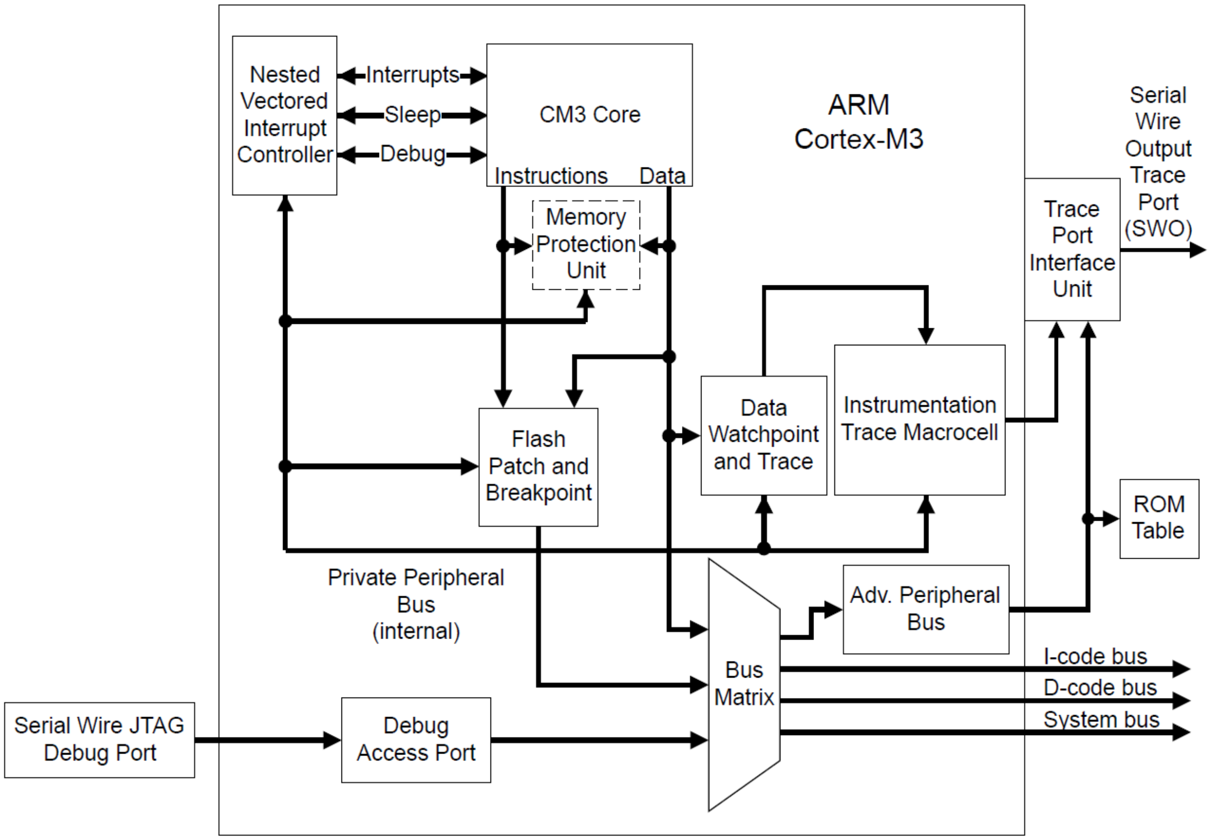

Figure 11: Stellaris® M3 MCU – LM3S5B91, reprinted with permission from Texas Instruments

4.4.4. Programming the Stellaris Microprocessor

The microprocessor chosen by the team is capable of being programmed the majority in the C programming language. This is mostly for programming the various functions that will be implemented for the different modes that the ECO-SEC system is capable of operating in. However some aspects of the microprocessor will require assembly language programming as well. Although this was not the preferred language of choice by the team, they do have experience developing code using such languages and should be able to successfully program the microprocessor with regards to how it is required to operate in the final prototype of the ECO-SEC security system. Full details on the syntax of the C and assembly programming code for the Stellaris microprocessor can be found in the associated datasheet for the processor.

4.5. Camera Subsystem

The security camera subsystem although one of the simplest in terms of design fulfills a large amount of various functionality with regards to the final design of the ECO-SEC prototype. The security camera provides motion detection as an alarm detection source to the ECO-SEC as well as it also provides the live video feed stream for the web site. An additional feature of the M1054 that is also examined in this section is the ability to send email alerts. Although originally planned to be accomplished using the embedded web server the option of accomplishing this feature using the security camera is also explored within a later section of this documentation. Also this document will detail other minor features that can be implemented within the prototype of the ECO-SEC by using the various functionality of the M1054 security camera.

4.5.1. M1054 Electrical Characteristics

The AXIS M1054 can be powered via two different sources with different power requirements. Table 12 shown below illustrates these two possibilities. As can be seen below the two main sources that the camera can be powered by is from either a standard DC power source or powered using the attached Ethernet connection. This connection however requires using the IEEE 802.3af standard to accomplish which is not inherently supported by the rest of the design of the ECO-SEC particularly with regards to the embedded web server chosen so the team has decided that the better approach to the camera is to power it with a standard DC power source.

Power Source	Voltage	Watts
DC Power Source	4.9 - 5.1 V DC	Max 6.5 W
Power over Ethernet	NA	Max 6.49 W

Table 12: M1054 Electrical Characteristics

4.5.2. Motion Detection

The M1054 Can detect motion in two different main ways; by detecting when movement within the frame of the view of the camera, or by using the passive infrared sensor that is built in as part of the camera. Motion detection by using movement as an activation trigger can be configured to control its behavior in several different manners. The camera can be configured to only detect movement within certain areas of the camera view in order to compensate for areas where movement is guaranteed to occur yet, the user does not want that movement to trigger an alarm. Also the size of objects that the camera is capable of detecting when moving can also be configured. In the case of the ECO-SEC system this can be changed to allow the size to detect humanoid size so that that the alarm is set off the presence of a burglar only. Several other lesser important options for this configuration exists and full details on what these features entail can be found within the User Guide for the AXIS M1054 security camera. However using this feature does have a few negatives associated with it. Using motion detection that is supplied by the video from the camera can lower the performance of the video produced by the camera. This in turn will be capable of affecting both the quality of the stream sent to the embedded web server website as well as increasing the delay between the what is currently occurring in the view of the camera and what is being send to the web site. Also this method can throw false alarms since it detects by movement, so false triggers by movement of shadow and light from different sources, etc can result in incorrect behavior from the camera as it throws false alarms.

The second option that the camera is capable of using for motion detection is to use the build in passive infrared sensor of the camera. This sensor uses the body heat of an intruder to detect when motion occurs and to send an alarm in the case of such an event. The only setting for the this sensor that can be adjusted is its sensitivity. Increasing the sensitivity of the sensor increases the range of the sensor, and is capable of allowing the sensor to detect movement from up to 6 feet away in the dark. This will allow the camera to be able to detect motion in a dark room during the night, which is something that the other method of motion detection has issues accomplishing. Additionally because it uses infrared this method is much less likely to throw false alarm alerts causes by the movement of shadow and light unlike the other method. Additionally the sensor is a separate component from the actual lens of the camera and as a result using this method will not hinder the performance of the security camera's live feed. Due to the numerous advantages the team will use the passive infrared sensor as the means to detect movement.

When motion is detected the camera can use this event to trigger an alarm. This is one of the largest advantages of the security camera. What events exactly trigger an alarm can be configured as well as how the camera responds in the case of an alarm. This response can vary from sending an email message to sounding an alarm and blinking an LED light. More details on events and how they can be created and trigger will be covered in the section of the documentation detailing event alerts.

4.5.3. Camera Video Feed

One of the most important features of the M1054 security camera is the ability to produce a live video stream. This stream is constantly generated as long as the security camera is properly set up and is powered on. Assuming the camera is properly connected to the embedded web server and is set up correctly as detailed in previous sections, accessing the camera video feed via the web site will be simple to accomplish. This is because the camera video feed can be accessed using a unique URL that located the camera on the network and pulls the video feed from it. This URL varies based upon the protocol used to stream the video. The exact details on these options and which protocols they support can be found in the user's guide for the M1054. So all the website needs to do is dedicate a portion of the site that will display the website using the chosen URL provided by the camera. This is nothing more than embedded an HTML page inside another HTML page and can be accomplished with only a few additional lines of code added to the HTML page for the ECO-SEC web site.l

4.5.4. Event Alerts

The largest advantage of the M1054 camera is the ability to create event alerts. Event alerts consist of a pair of two items, an event and a response. A event is a trigger designated by the user that the security camera listens for. When the event trigger is activated by the event occurring the camera immediately implements the response that is associated with the triggering event. The use of these system will allow the camera to know how to react to the various situations that can be expected to be encountered by the ECO-SEC design. In order to fully understand how this system can be used within the design of the ECO-SEC it is important to first know what events can be used to trigger the system, as well as what responses is the camera capable of activating.

The following list describes the various events that the M1054 supports as triggering events for the previously described system:

1. The passive infrared sensor is activated by movement
2. Detected movement within the camera video view
3. Sound at a certain decibel level
4. Tampering with the camera
5. Signal sent to the camera via the input port.

As can be seen from the previous list the camera is capable of responding to several of event some of these more important than others are will be incorporated by the design of the prototype for the ECO-SEC. The primary event that the camera will need to respond to is when the infrared sensor is activated. This will be the form of motion detecting that is employed by the security system and will signal the presence of an intruder. The camera subsystem will also be designed with an event to respond to sound at a certain decibel. This will be used as a mean to detect when glass is broken such as a burglar breaking a window. Setting the decibel level to the level produced by glass breaking will allow the camera to handle this situation which will lighten the requirements of the sensory array subsystem. This is important because this feature is normally semi complicated to implement within the sensor array but can easily be done instead using features built into the security camera. Another important event will be tampering with the camera. This event is triggered when the camera is moved or shaken, or when someone attempts to cover or block the lens of the camera or sensor in some manner. This will prevent intruders from being able to disable the camera without triggering an alarm. The final setting used is when the camera detects a message being sent to it from the input port. This input port will be connected to the microprocessor. Using this the microprocessor can signal the camera when a sensor in the sensor array subsystem is triggered so the camera will know how to correctly respond by using the programmed response. The important of these event is further defined by how the camera is capable of responding to the event triggering.

There are two main important ways in which the camera can respond to these triggering events. The first is an audio alarm along with a blinking light. The M1054 has a built in speaker than play any audio clip as a response to an event. In the case of the design of the ECO-SEC this will be used to play a loud alarm sound when an intruder has been detected. The blinking light results from a LED that is included as part of the camera along with the speaker. The other typically way for the camera to respond is to send an email message when the event occurs. Although the team plans to implement this feature using the embedded web server, the web server does not include support for dynamically assigned IP addresses which makes it harder to send out emails using a web server. If the team cannot figure successfully create a system for the embedded web server to send out emails the security camera can be used to accomplish this task. The security camera does support dynamic name resolution so all that is required is either the host name or IP address and port numbers of the SMTP server for the email service you wish to use. The camera is then capable of using this feature to send out an email when the triggering event occurs. More details on how these event and response systems will be used in the design of the ECO-SEC will be explored in the section detailing the camera subsystem of the final prototype.

4.5.5. Setting up the Camera

Setting up the camera involves two main steps. Setting up the hardware used by the camera and setting up the software that governs the behavior of the camera. Setting up the hardware for the camera is a relatively simple process. All these entails is mounting the camera to the stand designed to hold it in place for the ECO-SEC system and to make all the necessary connections that are used by the security camera. These connections entail connecting the power port of the camera to the correct power source and connecting the I/O port to the microprocessor to allow the camera and microprocessor subsystems to be able to successfully communicate with each other. The other hardware connection that is required is the connecting the Ethernet connection of the camera to a hub. This hub will serve to connect the embedded web server and the camera to be on the same local network. This hub will then connect to the outside Internet. The step is necessary to allow the embedded web server to be able to communicate with the camera which is necessary in order to allow the camera to be able to send the live stream of its video feed to the web site hosted on the embedded web server.

The next set in setting up the camera is to setup the software that will govern the behavior of the camera within the design of the ECO-SEC prototype. The first step is to setup the IP address that will be used to identify the camera on the network for the ECO-SEC system. This IP address will be used to login to the camera to changes the options on how it operates. After this the camera must be set up with a password. This will prevent anyone from logging in and turning off the camera remotely or changing how it operates. This security is important to have in the design of a security system. Setting up these two features are accomplished through a simple installation program that is included when purchasing the camera. This software is also available online in case the camera is purchased second hand as a used item.

After the IP address and password for the camera has been set up the next step is to change the options that govern how the various features of the camera operate as well as setting up any event triggers and responses used by the camera as described in other sections of this documentation. This is accomplished by logging onto the camera using the IP addressed assigned to it. This will take you a webpage which contains a live view of the camera as well as menu choices for the user. The most important of these is the setting menu which will allow the user to set up the all the various parts of the camera. With regards to the design of the ECO-SEC the parts of the camera that need to be setup are the motion detection, the video stream, the events and responses system, and finally what audio clip the camera will play in the event of an trigger activating and the response requiring the camera to play the clip. All though this menu can be used to set up many other features these are the ones that are most relevant to the design of the ECO-SEC prototype.

Setting up the motion detection is a relatively easier since the team chose to use the passive infrared sensor as opposed to the video capture to detect motion. The video capture for motion detections requires setting up many options along with designating which portions of the camera view the camera should detect for motion. Instead all the is needed to be set up for the infrared sensor is the level of sensitivity for the sensor. This can range anywhere from 0 to 100% but defaults at 75%. The level of sensitivity will determine how far the camera will be able to detect motion from. At the maximum setting the camera is capable of using the infrared sensor to detect movement from up to 6 feet away.

Setting up the live video feed from the camera consists of setting up several different options. The most important option of the feed is the frame rate. The camera can be set up to allow the stream unlimited frame rate or a set limited frame rate from 10 to 30 fps. If the frame rate of the stream is to high, the camera will begin to use all the bandwidth of the network it is on preventing any other network activity. In the case of the ECO-SEC this will prevent the homeowner from being to access the website or to use any of its feature. In order to prevent this the frame rate will most likely need to be limited. The next that needs to be set up is what type of video encoding the camera will use for the live stream. These are presented as a series of choices in a drop down box for the user to select from when creating the profile for the video stream. Choosing the correct video encoding is important because if an incorrect encoding is used that is not support by most browsers, the homeowner will be unable to see the stream correctly when using the web site. The M1054 supports a few different encodings including MPEG and Motion JPEG which is designed specifically for video streaming. However, since it is a slightly older out of date model, the M1054 does not support the newest video encoding format of MPEG-4. These are the two most important settings for the video feed. The user is also able to adjust camera settings such as brightness and contrast as well which will affect the images the video camera records for the stream.

Although setting up the series of event triggers and responses used by the camera sounds like a complicated processes luckily the API for the M1054 makes it a relatively simple process. Setting up the event requires only three things; a name for the event, what actions trigger the event, and which responses should be taken in case of the event being triggered. The kind of events that can be triggered are limited what has been previously described. The responses that will be used by the team in designing the ECO-SEC system is an email alert, playing the audio clip loading into the camera, and sending an output signal from the camera to the microprocessor which will indicate that an alarm was set off that the camera detected and that the microprocessor needs to respond to it.

Setting up the audio clip used by the security camera is a simple process. On the correct screen in the browser when allow to chose to Upload an file. This will allow the user to use an audio file located on the hard drive of the computer they are using to set up the camera as the audio file for the camera. The audio clips that the camera supports uploading for must be in the .au format with encoding at either 8 or 16 kHz sample rate.

4.6. Sensor Array Subsystem

This section of the documentation will describe the various sensors that will be included within the design of the sensor array subsystem for the ECO-SEC security system. This subsystem will include three main kinds of sensors; a glass break sensor, a door/window sensor, and a infrared motion detector. Each subsection below will provide greater details on how the technology behind these different sensors work and how they will function and what purpose they will serve in the eventual final design of the ECO-SEC prototype.

4.6.1. Glass Break / Sonic Detector Sensor

A glass break detector is an important piece in any security system design. The purpose of this sensor is to be able to listen to the frequency at which glass breaks and upon hearing this frequency trigger an alarm. This aim of this sensor in the design of the ECO-SEC is to be able to detect when an intruder breaks a window instead of opening it in order to break into the homeowner's domicile. This detector requires a different type of microcontroller because it requires the ability to sample sound at a rate of around 32 kHz. The team will design this sensor using schematics provided by Texas Instruments as an inspiration. This design will use serial interfaces to the wireless transmission board which will powered by an MSP430G2231 and XBee to communicate to the base station. The microcontroller of the sound detector will be a MSP430F2274IDA this microcontroller will cycle on at 8Mhz, it will be in an off state for 2us and listening to an event for 37.5us. If a sound is detected in the 37.5us that the device is turned on then it will increase its speed to 12MHz and record the sound for 60us. After it is recorded it will be passed to an analog to digital converter and broken up into 2336 samples and trough a pre-written algorithm it is time averaged, then the peaks are detected and only the zero crossings are kept. After it is passed through a high pass filter the lattice wave digital filter (LWDF) of the processor is set to the following parameter specifications:

1. Filter response type = High pass
2. Sampling frequency = 38.960 kHz
3. 3-dB cutoff frequency = 9.74 kHz
4. Stop-band attenuation = 44 dB
5. Filter type = Elliptical
6. Filter structure = Bireciprocal
7. Filter order = 7
8. Filter coefficients = –0.109375, –0.375, and –0.75

These settings will allow the sensor to be able to filter out other noise and listen for the sound of glass breaking. However this system will not be fully perfect because there are many variables in sound signal processing that make the task of sound detection a difficult one. If one were to listen carefully to the sound of glass breaking, it changes from each type of glass used, for example, older window glass will be different from tempered glass. Furthermore, if glass it hit with a hammer instead of a rock the sound can be slightly different. The design for the sensor will attempt to account for this variation as much as possible in order for the it to function correctly in the final design.

4.6.2. Door / Window Open Detector Sensor

Commercially available door/window open detectors work with two magnets on opposite sides of the window or door frame and work by sending current via a magnet and detecting current flowing through it. A problem with these type of detectors is that the distance that it is needed for them to function on low currents has to be very minimal because the magnetic field diminishes greatly as they move apart. Most of the available magnet style devices have to be installed about ¾ of an inch apart in order for them to work reliably. The proposed solution that the team plans to use in the design of the ECO-SEC prototype is to use a low power but concentrated pulsed Infrared light that will be transported via a fiber optic tube and return the light to a photodiode that will detect the infrared light emanating fiber and the pulsed frequency. Initial estimations indicate that the fiber module can be installed an inch or more away from the LED and photodiode. This will be tested later during the design phase of the prototype. Ideally the frequency will be as low as possible to conserve battery but fast enough so that it cannot be open and closed without detection. We estimate that this frequency will be around 1-2 Hertz or if security is needed it can also be an random frequency. The type of fiber tested will initially be a multimode telecom fiber in order to provide as broad of a launch and exit angles as possible.

Figure 12 below shows a mock up of a rough prototype for this sensor. The black wire represents the fiber, the casing is the green clay, white and red LED represents the photo detector and the infrared LED. Since the casing in this design has to be a snug to the between the fiber and medium and also be able to withstand heat and cold the team would like to encase it in Styrofoam because of its cost and thermal properties. Initially the team will most likely use clay or plaster to be able to properly align the light sources and receivers. To block some of the light traveling through the fiber and to protect it the design will use a strip of unexposed developed film as a crude but effective IR filter.

Figure 12: Example Mock Up of the Prototype of Door/Window Sensor

The pulsing of the light will be done by a 14 pin LED driver from Texas instruments model TCA6407. This device can handle Up to 7 LED's and will be listening for programming instructions from an MSP430G2231/Xbee ZD modules that will then communicate to the base station of the sensor array subsystem if the window or door is opened or closed. If the window is open then it will slow down the frequency of pulses to conserver battery but once the window is closed it will resume to its normal pulsing frequency. When the sensor detects that the frequency of pulses has slowed down it will trigger an alarm signaling an intruder entering the home. A button will be installed on the side of the case to test if the system is running low on batteries or if the user wants to test it. Along with all of these features a 7 segment display will aid in troubleshooting by sending error codes if needed.

4.6.3. Infrared Motion Detector Sensor

The motion detector used will be an digital quad type element that senses movement via it's Fresnel lens. Although the security camera use also provides a similar function it has a relatively limited range and this sensor is designed to complement this sensor to extend the range of the motion detection ability of the ECO-SEC prototype. As discussed in prior sections of this documentation, of the many sensors the team found this was the most compact and integrated of them all. This sensor comes with a built in amplifier circuit, stabilized power supply and comparator ready to connect to a microcontroller giving it a really big advantage over others sensors. Other sensors have to use amplifiers and are affected by noise. Just like the Zilog sensor, it can be purchased with several fresnel lenses to choose from; standard, motion, spot and 10M type. For the design of this system the team has chosen the 10M model but there is not wrong choice because they all have their strengths depending on the application. The type of lens chosen was based on the fact that it provides the widest coverage of a room in the x direction as shown on the figure. Ideally the design will need the beams to be disturbed from the x y plane and not the z plane which in this case would be walking in directly towards the sensor. One of the biggest reasons we picked this motion sensor is for its ability to use very little power when it is turned on and detecting it uses 46uA-60uA plus 100uA if it has detected movement. Since the biggest consumption time of power is when movement is detected it is recommended to use a trigger to minimize the time that the microcontroller will listen for a signal to conserve power. Movement will happen at a fairly slow rate compared to the speed at which a processor is able to sample a signal.

Figure 13 shown below demonstrates some of these mentioned characteristics and behavior of the infrared motion sensor described previously. The left part of the figure shows a top down view of the range of detection that will be granted by the sensor. The right part of the figure shows an internal view of the parts that will be required to design the infrared motion sensor as it will be used in the final prototype for the ECO-SEC.

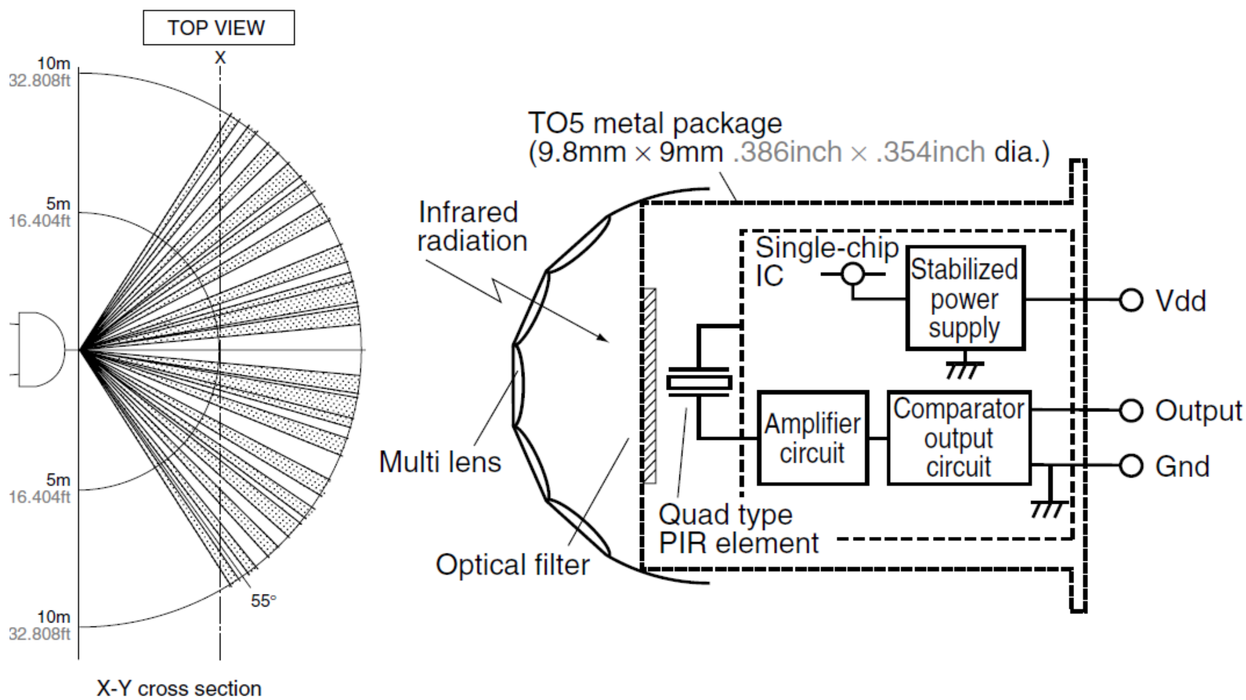

Figure 13: Infrared Motion Detection Sensor, permission pending from Panasonic

The connector itself is only about 23mm in length including the leads, this makes the motion detector very good for hiding it inside toys or other inconspicuous devices not just your plain white rectangular motion detector found in most home security systems. The planned method to connect the motion detector to the MSP430 and the battery will be to use a high efficiency buck down voltage converter from Linear technologies

LTC4063 to adjust the voltage from 3.6 to 3 volts for this device. The Xbee ZD and the MSP430G2231 are both rated at 3.6 volts so they will not need to have their voltage adjusted. They will only need capacitors that will be determined at the time of actual testing to minimize any noise that could be on the line.

4.7. LCD Touch Screen Display Subsystem

The purpose of the touch screen display in the security system designed is to allow the user to easily arm or disarm the system as well as to changed the different options and configurations associated with the security system. This is one of the two interfaces the homeowner can use to interact with the ECO-SEC security system. Although this appears redundant to the user by serving a very similar purpose as the web server for the security system, this part is designed to bring more ease of use to the homeowner, by not requiring them to log onto the internet with a device every time they leave their house and wish to turn the system on or changes its settings. The web server is intended to be used when the user is away from their home and they wish to change the system settings such as disarming the system to allow a friend entry into their house. The LCD touch screen is meant to be used by the user when they are at their home to turn the system on or change its settings before they leave.

4.7.1. 4.3" LG Phillips Display Module

As discussed previously, the LCD display module chosen was the 4.3” LG Phillips Touch Screen display packaged as part of the Reach Technology development kit along with the SLCD43 controller board. The exact part number for this display is 51-007. Although some of the specifications of the display were discussed previously when doing a product comparison of various LCD displays, it is important to give a full specifications of the display.

The LCD display is connected to the SLCD43 Controller by the interface connector. The controller is the more important part of the display subsystem and is responsible for the layout of the touch screen and how to respond to touches on the screen. The following subsections provide a greater detailed examination of the 4.3" LG Phillips Display module and its accompanying SLCD43 controller board with respect to how it will relate to the overall design of the final prototype for the ECO-SEC security system.

4.7.2. Interfaces

The LG Phillips display module contains only one main interface. This interface is used to connect the display to the controller board. The microprocessor that handles data to and from the display is connected to the controller board. The microprocessor is never directly connected to the display module itself. The interface used by the LG Phillips display is a 45 pin, 0.5mm pitch LCM connector. The exact purpose of the various pins in this connector can be found in the datasheet for the LG Philips display module bit are not included here.

4.7.3. Electrical Characteristics

In order to operate correctly, the display module must receive power within the correct voltage and amperage range. Inability to correctly provide this power can cause the display module to fail to function and could very likely result in damage to the physical component of the module. Power to the module is supply through select pins provided by the LCM connector on the display module. Main power for the display is sent through the controller board. The controller board usually will contain the circuitry in order to manipulate the incoming power to the correct range required by the display module before sending to the module via the LCM connection.

Table 13 below shows the optimal electrical requirements for a correctly operating display module. Logical Input and Output Voltage is shown in terms of high and low voltage. Digital Input Voltage is shown based on where the power select option on the module is set to either zero or one. Exact determination of this setting comes from the controller board circuitry. As stated previously the exact values of these voltages will not have to be directly supplied by the power subsystem of the ECO-SEC. Instead the controller board will regulate the correct voltage and amperage to the touch screen display and the power subsystem is only required to supply the correct voltage and amperage to the controller board. The exact details on the electrical characteristics of the SLCD43 controller board will be given later in this documentation. Note that a dash inside the following table means the associated field is irrelevant with regards to the particular parameter it references to.

Parameter	Symbol	Minimum	Typical	Maximum
Digital Input Voltage	VDD	2.3/2.8 V	2.5/3.3 V	2.8/3.5V
Frame Frequency	f_{FRAME}	-	60 Hz	-
Dot Clock	f_{CLK}	-	9.0 MHz	155 MHz
Logic Input Voltage	V_{IH} / V_{IL}	0.7VDD / 0 V	-	VDD / 0.3VDD V
Logic Output Voltage	V_{OH} / V_{OH}	VDD-0.4 / 0 V	-	VDD / 0.4 V
Power Consumption	W	-	720 mW	-

Table 13: Electrical Characteristics of the 4.3" LG Phillips Display Module

4.7.4. SLCD43 Controller Board

The SLCD43 is the processing power behind the LCD Display. It is responsible for providing the interface the user sees on the display as well as determining how to respond to the user pressing the screen. It serves to bridge the gap between the touch screen display and the microprocessor of the security system. The SLCD43 board is designed to fit perfectly with the size of the 4.3 LG Touch Screen Display.

Figure 14 below shows the actual SLCD43 Controller Board from Reach Technology Inc. The actually size of the board, length and width are included. Other important features that this figure shows are the LCM Connector and the J2 COM Connector. The LCM connector is used to connect the SLCD43 Controller Board. The J2 COM Connector is used to connect the SLCD43 Controller Board to the PowerCom4 Board to provide power to the controller board.

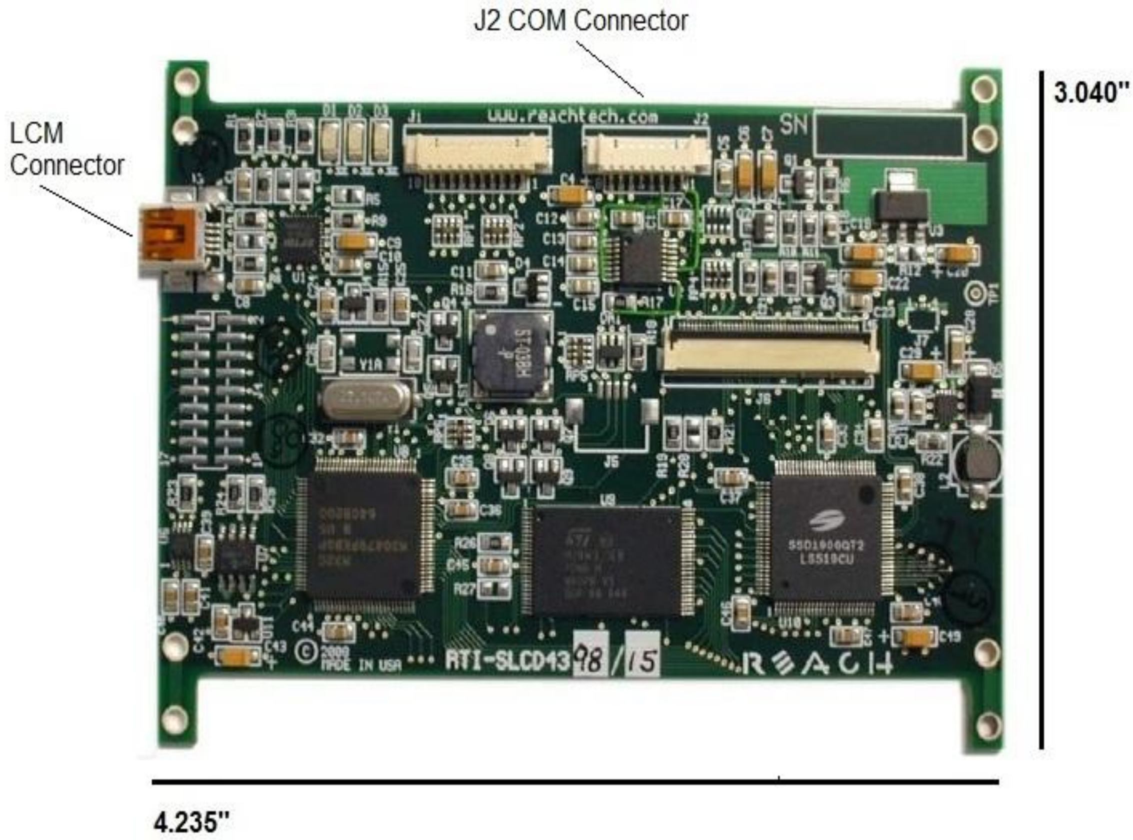

Figure 14: SLCD43 Controller Board, reprinted with permission from Reach Technology Inc.

The SLCD43 includes flash memory as well as a small CISC processor. These components of the controller board are what allow it to load the images that are displayed on the screen and change the images as the screen is used, such as changing the appearance of a button when it is pressed down versus not pressed. The CISC processor is also used by the controller board to handle processing macros created that are executed when a button, switch, etc. is activated on the LCD display.

4.7.4.1. SLCD43 Electrical Characteristics

Table 14 shown below indicates the power requirements of the SLCD43 controller board. These power requirements determine the amount of power that is required from the PowerCom4 board to power the controller board. The SLCD43 always requires 5 V of DC current in. What differs is the amount of amperage this voltage must provide. The amperage varies based on two settings for the LCD touch screen display, whether the beeper is on causing the screen to emit a noise when the user presses it or if it is off and whether the LED backlighting the touch screen display is on full or if it is on low. In order to limit the amount of power this subsystem requires to ease the burden it places on the power subsystem particular with regards to solar power and the backup battery the team decided that the LCD touch screen display will be used with the beeper off and the back light on low.

Configuration	Typical Amperage at 5V	Max Amperage at 5V
SLCD43 with LED backlight on full, beeper on max	0.330 A	0.400 A
SLCD43 with LED backlight on full, beeper off	0.280 A	0.330 A
SLCD43 with LED backlight on low, beeper off	0.140 A	0.160 A

Table 14: Electrical Characteristics of the SLCD43 Controller Board

4.7.5. PowerCom4 Board

Although SLCD43 controller board is responsible for providing the necessary firmware to drive the Phillips touch screen LCD and is more important relative to the overall design of the ECO-SEC system. The PowerCom4 board purpose is to support the controller board and it does so several ways. The first is that the PowerCom4 board contains the circuitry to convert power from a standard US 12 V wall outlet to the correct voltage required by the SLCD43 controller board. The PowerCom4 board also contains the DB9 RS232 communication port that the controller board will use to communicate with the attached microprocessor. The controller board filters it communication through the PowerCom4 board which converts the signal into the correct format to be read through a standard RS232 serial port. The PowerCom4 also contains several useful feature for debugging and prototyping the programming for the LCD touch screen subsystem. These include several LED that can be used to indicate successful connections to an attached device or programmed to display when the user presses a button they created on the screen to test that the button is functioning correctly and recognizes the users touch. This feature will be useful in allowing the team when developing the prototype to check to make sure every button programmed onto the LCD touch screen is recognized by the controller board and takes appropriate action when the user the presses it on the screen.

Figure 16 shown below shows the PowerCom4 board that supports the SLCD43 as part of the development kit that is used to implement the LCD touch screen subsystem with the design for the ECO-SEC system. From the figure the dimensions of the PowerCom4 board can be seen. A few important features to note are SW1 and SW2. SW1 is the reset switch which is used to reset the LCD screen in case an error occurs during prototyping or use. SW2 is the select switch which is used in the case an LCD screen is not attached to the connected controller board. This is used to prototype without having the actual screen attached but will most likely not be used by the team during development much. J2 and J3 are the connectors used to connect the controller board to the PowerCom4 board. Which of these two connectors is used determines which of the two serial connectors needs to be attached to microprocessor. The LCD display modules used is design to support to connected devices but with regards to the design of the ECO-SEC system only one is needed. The J4 connector is not currently used by the main design and is reserved for any extensions that maybe needed to the current display module. Again currently the team does not believe this subsystem will require any extensions but the option exists if the need does arise during later stages of prototyping.

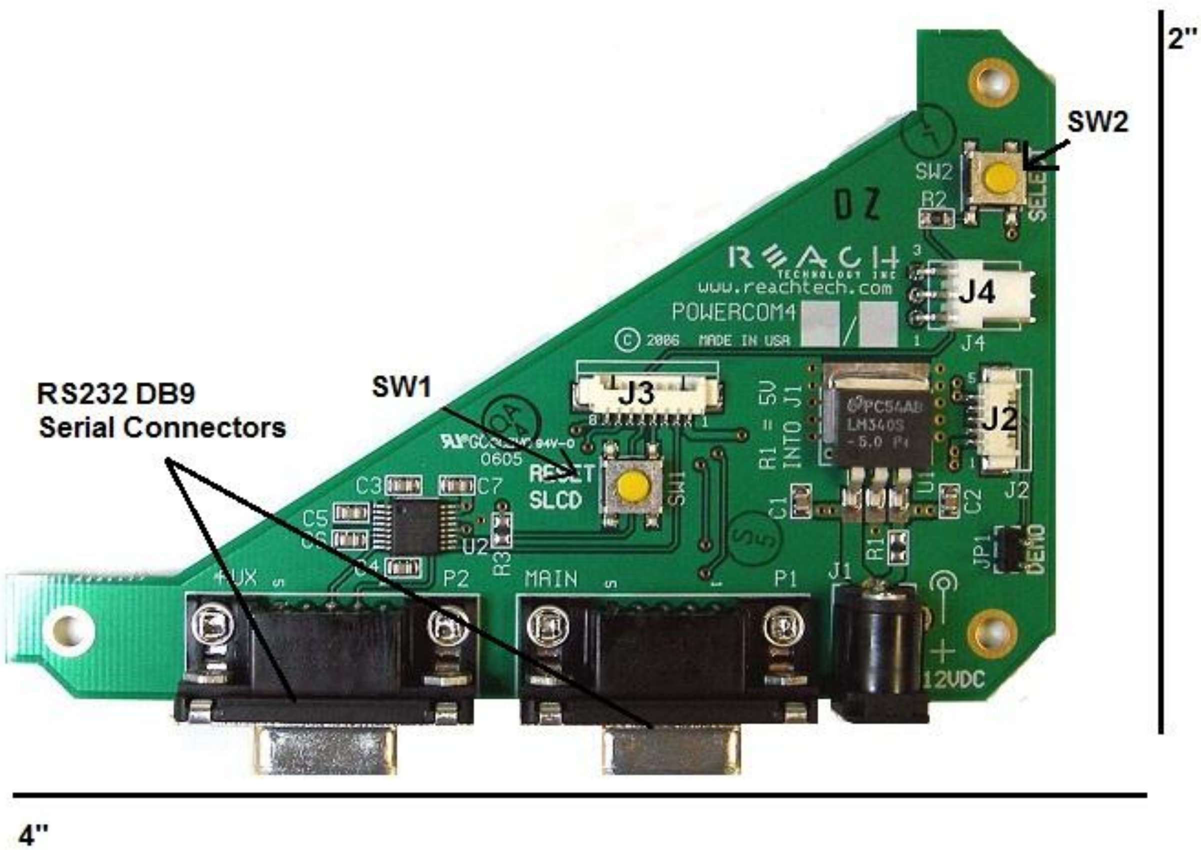

Figure 16: The PowerCom4 Board, reprinted with permission from Reach Technology Inc.

4.7.6. Programming the SLCD43 Touch Screen Controller

One of the main difficulties in selecting an LCD touch screen display was the level of difficulty in programming the display to work as needed in order to fulfill all of the requirements of the security system being designed. SLCD43 controller board appealed to the team because of its ease of programming that did not require learning a full language like many others on the market did.

Programming the SLCD43 is relatively easy. Everything on the LCD display, whether it responds to a user's touch or not, is simply a Bitmap (.bmp) file. These files are stored on the controller board in its 4 megabytes of flash memory, which is more than an adequate amount to store all the necessary Bitmap files that would be used to design the touch screen interface for this security system.

Bitmap files are loaded onto the SLCD43 using the program BMPLoad. This program is included as part of the purchased development kit. Figure 17 shows the BMPLoad program when it is first run. The following sections will detail how the program works and it used to program the display. Note that some of the details contained in the figure are simply for configuring the program and are not detailed as they are largely irrelevant to programming the LCD display. The BMPLoad program is the interface that will be used by the team to load what images will be displayed on the touch screen display during prototype development.

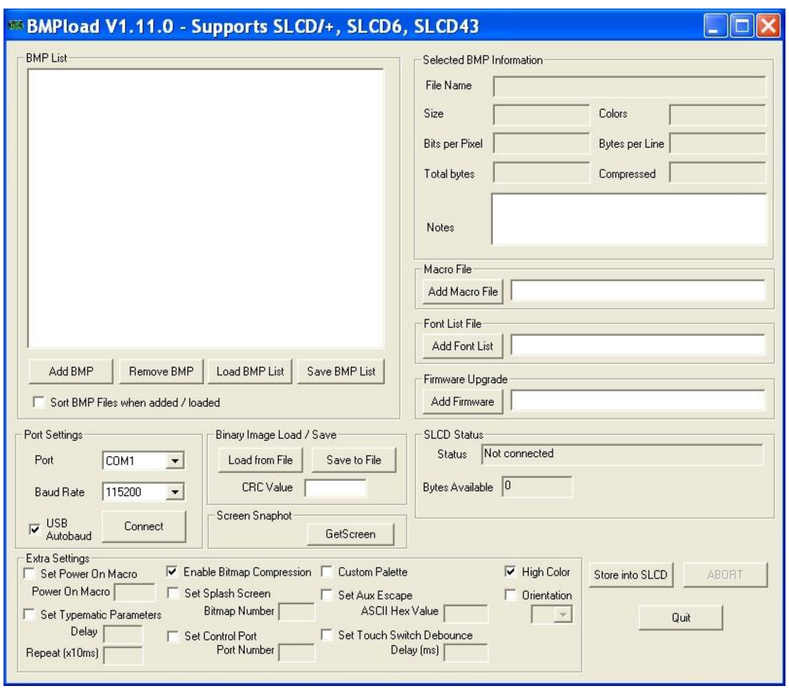

Figure 17: BMPLoad Program, reprinted with permission from Reach Technology Inc.

BMPLoad allows the user to add .bmp files to the memory of the SLCD43 by two different methods. The first is to manually add the files one at a time by using the Add BMP button. The second method is to add the .bmp files using a listing file. This file is a simple text file with the .lst file extension that contains the name of the .bmp files one per line. Once the Bitmap files are loaded into the program they are display in alphanumeric ordering within the text box of the program. Bitmap files can be removed from the program naturally using the remove bitmap number. Additionally an important notation is that each .bmp file is indexed using a unique number. These numbers become important later when actually programming the LCD Display because the syntax used by the display to load images references the files on the controller board using these index numbers.

Once the developers have added all the .bmp files they wish to add to the controller board into BMPLoad they used the Store into SLCDx button. This will begin the download process of the .bmp files into the flash memory of the controller board. This downloading process uses a serial connection between the PC hosting the BMPLoad program and the SCLD43 controller board. Which serial port is being used is designated under the options for the program. When the download processes is successfully completed the next step is to move on to using these Bitmap images to create the various buttons, switches, logos, etc that will be displayed on the touch screen.

The next step is to connect to the controller board using the serial port connection between the board and the PC in order to issue the commands that will inform the controller where to load what images and what should these images do if they are pressed if anything. (This is important in the case of buttons, switches, and etc. that use .bmp files for their appearance and then produce a result in pressed.) These commands are issued from the PC to the SLCD43 using a terminal program that recognize the connection between the PC and the controller board. A listed of recommended terminal programs are included within the development kit.

Table 15 below shows some of the more important program commands that will be used in order to create the LCD touch screen display module used by the security system being design by the team. One important note about the table is the difference between a visible and an invisible hotspot. A hotspot of either type is an area on the screen designated to respond to a users touch. Pressing a non-hotspot point on the screen will produce no response from the display. An invisible hotspot gives not visual indicator to the user when the screen is pressed at this location. A visible hotspot when pressed inverses the color scale on the location pressed to briefly inform the user that a hotspot has been pressed. All though the visible hotspot is more informative, it requires drawing portions of the screen and is more expensive in terms of performance then using invisible hotspots. A secondary important note is the difference between a momentary button and a latched button. A momentary button that when pressed goes down and when unpressed goes back up. This behavior is typical of a normal button found anywhere. A latched button stays pressed down when released and will only return to the unpressed state when pressed again. Both serve to fulfill different needs when programming the LCD display. The LCD touch screen will most likely solely make use of buttons to provide user input, text to display information, and images to indicate the status of the ECO-SEC system. The table below shows only a fraction of the commands available when programming the LCD display. A full description of all the available commands can be found in the software reference manual for the SLCD43 controller board. The table below only includes the commands that will be the most relevant with relation to designing the final working prototype for the ECO-SEC security system.

Command	Description
xi <index> x y	Displays the Bitmap image indexed by <index> at coordinates (x,y) with the top left corner of the image at these coordinates.
t "text string" x y	Displays the text string at coordinates (x,y).
bd <n> x y type "text" dx dy bmp0 bmp1	Creates a button at location (x,y). Displays the text within the button image at location dx,dy. Bmp0 and bmp1 are the images representing the unpressed and pressed states of the button. N defines the index number of the button.
bd <n> x y type "text0" "text1" dx0 dy0 dx1 dy1 bmp0 bmp1	Creates a latching button at location (x,y). Type defines what type of latching button it is. Text0 and text1 are the text display on the buttons in the unpressed and pressed states. Dx0, dy0, dx1, dy1 are the text locations on the buttons and bmp0 and bmp1 are the images representing the unpressed and pressed states of the button. N defines the index number of the button.
x <n> x0 y0 x1 y1	Creates a visible touch spot with a rectangular shape defined by corner locations (x0,y0) and (x1,y1), N defines the index of the hotspot. This number is returned trough the serial connection to the microprocessor when this hotspot is pressed.
xs <n> x0 y0 x1 y1	Creates a invisible touch spot with a rectangular shape defined by corner locations (x0,y0) and (x1,y1), N defines the index of the hotspot. This number is returned trough the serial connection to the microprocessor when this hotspot is pressed.

Table 15: Example Set of SLCD43 Programming Commands

The SLCD43 controller board also supports the use of macros that can be loaded into the memory of the board similar to Bitmaps images. These images are loaded into the controller board's flash memory in a similar method as .bmp files by using the Add Macro file button. Macros will allow for a series of commands to be executed by issuing a single command. This saves a lot of communication overhead by not requiring multiple commands to be send from the processor to the SLCD43 board over the serial port because the macro file and commands are saved on the board in flash memory. This makes it so the processor only has to send the one command to call the macro. Macros used by the controller board are limited in the number of macros, the number of arguments, the call depth of macros, etc. These limitations are defined by the firmware for the SLCD43 board. Specific details on these limitations can be found in documentation for this controller board. Macros will be used to implement the changing the status of the system being displayed when the system enters a new mode of operation. When the microprocessor handles the logic for switching the security system to a new mode of operation it will issue a command to the SLCD43 controller board. The microprocessor will simply have to call the correct macro that will contain the commands informing the controller board to switch the images and text on the touch screen display to match the new correct mode that the ECO-SEC system is currently operating in.

4.8. Embedded Web Server Subsystem

As previously discussed in the product comparison section on embedded web servers, the team decided to use the Site Player SP1 embedded web server chip from Net Media Inc. in order to incorporate the web site user interface for the security system developed. To simplify the physical hardware development of this subsystem the team decided to purchase and use not the single SP1 chip but the Site Player SP1K development board for this project.

This decision was made based upon the fact that the majority of extra features contained on the development board was in fact needed by the team during product development and eventually use. Some of these include the serial connector, the Ethernet connector, and the power connector. Since the board is designed to correctly work with the web server the team decided using it would be the better approach over attempting to try to recreate it as part of the design for the final prototype especially when it would accomplish exactly the same thing. Despite using the development board this subsystem still will require a substantial amount of work in order to not only get the website for the ECO-SEC designed but also get it up and running and installed on the web server as well as configuring the web server to be able to successfully communicate with the microprocessor. This communication is important in order to allow the microprocessor to register any changes that the homeowner made to the operation of the security system through the web site.

Figure 18 below shows the SP1K Development Board. This figure shows the two main interfaces of the SP1K; a standard RS232 DB9 serial connector, and a RJ45 Ethernet connector. Another useful aspect of the development board is a led indicator that will light up when a connection is successfully made with the SitePlayer SP1 module on the development board. This feature is useful when prototyping the web server because it allows the design team to easily determine if a connection are made to the device. This figure also shows the size of the SP1 module relative to the size of the SP1K development board. As can be seen from the figure below the SP1K development is not overly large and does not contain a lot of parts that will be wasted within the design for the final prototype. The only features the final prototype will most likely not implement is the two input switches but the reset switch will be used to reset the system in case of a system crash. The reset button reboots the SP1 chip in case of an error occurring and restores the website contained on the server chip back to the initial conditions it held. Also useful are a series of jumpers which can be used to configure the serial interface of the development board. This will allow the board to be easily connected to any other device with a serial connection whether it is a PC used during development, or the microprocessor running the security system during final product prototyping.

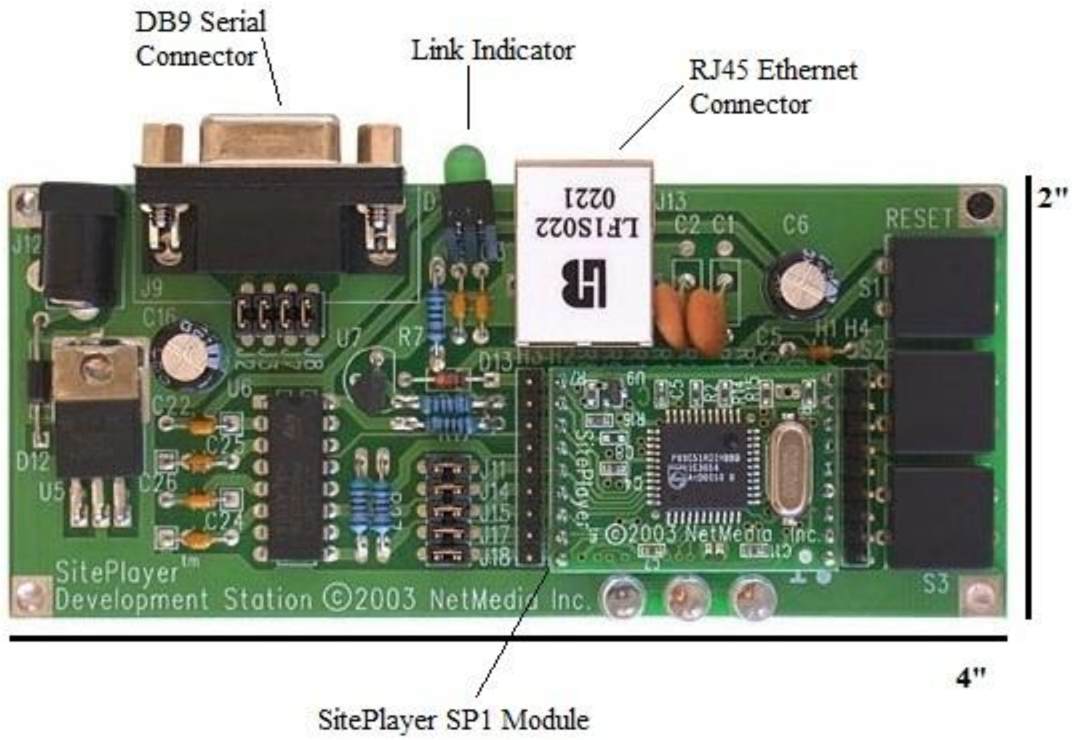

Figure 18: SitePlayer SP1K Development Board, permission requested from Net Media Inc.

4.8.1. Interfaces

Although briefly mentioned previously this section will provide a much more detailed look into the interfaces used by the SP1K development board in order to connect with the rest of the security system as well as outside devices via the internet.

The first important interface used by the SP1K is the serial connector. This is a standard DB9 RS232 connector. However the SP1K uses inverted RX and TX signals. In order to allow the SP1K to correctly interface with PCs and most microprocessors which do not use inverted RX and TX signals, the inverted signals generated by the SP1 chip are routed through an inverter on the board to convert these signals into the PC friendly standard format. Additionally the user can configure this on board inverter to enable or disable it. These are accomplished through a series of header connectors. This connection is used both to connect to the PC when uploading the web site to the SP1 module chip on the development board as well as to connect to the microprocessor that is used in the prototype developed for this security system. The inclusion of this inverter to correctly fix the commands sent from the SP1 chip module into the correct format that is readable my the microprocessor is another reason why the development kit will is both time saving and efficient to use in the final design for the ECO-SEC. If the SP1 module was used alone this inverter would have to be recreated in order to perform this inversion for the module to work correctly with the microprocessor.

Figure 19 below shows a table that illustrates how these connections can be manipulated to change the operation of the developments boards' inverter. The inverted used by the board is the ST232CAN inverter. Although some microprocessors do use the inverted signals most do not so for the final design of the ECO-SEC the inverter will be set active in order to switch the commands reached from the SP1 into the correct format that is readable by the RS232 port on the attached microprocessor.

Header	Pin1	Pin2
J2	DB-9 Pin2 (PC RX)	ST232CAN EIA-OUT1 (SP TXD)
J3	DB-9 Pin3 (PC TX)	ST232CAN EIA-OUT2 (SP I/O 3)
J7	DB-9 Pin7 (PC RTS)	ST232CAN EIA-IN1 (SP RXD)
J8	DB-9 Pin8 (PC CTS)	ST232CAN EIA-IN1 (SP I/0 5)

Figure 19: SP1K Development Inverter Configuration Header Connectors permission requested from NetMedia Inc.

The second important connector contained on the SP1K is the connector used to connect the web server to the internet to allow remote users to login in and access the website contained on the server. The SP1K uses a LF1S022 Ethernet connector to accomplish this. The LF1S022 connector shares the same form with a more standard RJ45 Ethernet connector but includes additional circuitry to add filtering and isolation to the connection to provide better performance for outside users attempting to connect to the web server remotely. In relevance to the final design of the prototype this connector is also used to link the SitePlayer server to not only the outside Internet but also to allow it to connect to the security camera that is included as part of the design for the ECO-SEC. This connection will allow the website hosted on the SP1 to stream a live video feed from the camera to the website in order to allow the homeowner to be able to view their home from any remote location with Internet access.

4.8.2. Electrical Characteristics

One important key part of the design of this security system is the power subsystem. In order to successfully design a power subsystem it is important to understand the power requirements of any other subsystems that draw power from it. As such, it is important to provide a detailed explanation of the power requirements for a Site Player SP1K Development board that will be used as the embedded web server subsystem. The SP1K board uses a standard cylindrical plug as its power connection and requires a steady 12V DC power source with 100 mA (minimum) center conductor positive current. This is one of the biggest draw backs of using an embedded web server. Due to its small size relative to the level of performance it brings the SP1K requires a lot of power which will bring a strain to the power subsystem and will be difficult to be able to incorporate it to be run off of solar power with a backup battery. Finding a way to successfully implement this will be one of the more challenging concerns the team will face when designing the final working prototype for the ECO-SEC system.

4.8.3. Programming the Site Player SP1 Module

In order to successfully incorporate the embedded web server into the security system being developed it is important to understand how the embedded web server is programmed in order to correctly display the desired website. This process is not overly difficult but contains more difficulty then designing an average website simply because the web site designed on the web server must be able to communicate with the microprocessor. This will allow the microprocessor to adjust its behavior as the user adjusts settings via the web site on the embedded server. The Site Player SP1 is programmed through three main steps: Defining and creating objects for the website using a Site Player Definition file (.SPD), creating the actual web pages using any standard form of HTML as well as creating the Site Player Interface File (.SPI), and assembling and downloading onto the SP1 the Site Player Binary file (.SPB) using the SiteLinker program.

The first step in programming is designing the definition file. This file is structured in a manner than is very familiar to a more standard assembly language file. The .SPD file is divided into three main sections, the definition section, object section and export section. The definition sections used to specify the initial start up parameters of the Site Player SP1. This includes such thing as site player update passwords, enabling or disabling DHCP, defining the static IP address of the SP1 server, etc. The second section defines any objects used by the Site Player website. Objects are variable with a defined name, size, and default value. These objects are how the Site Player and the website it hosts will communicate with the attached microprocessor that is used to run the security system. Naturally in order to facilitate this communication between the website and the microprocessor, the objects defined in the .SPD file must have the same variable name as their counter parts contained within the HTML files that will be used by the Site Player to generate the website used by the security system. The final and third section in the definition file is the export section. This part defines how and where the Site Player will export files during the linking process. This can be useful because it allows the Site Player to generate data files that can be passed to other assemblers, compilers, etc. However, as concerned with the requirements and specifications of the system being design by this team, it is very unlikely that the security system will require any such action, and as a result this section will most likely not be needed by the project. This does not prevent it from being a useful feature that could be a great benefit to other projects or even to this security system if it were ever expanded beyond the specifications developed during this course. With regards to the design of the ECO-SEC, Site Player objects will be used to replace the input forms used by the website to allow the homeowner to change the operation mode of the security system. When the user enters one of these changes on the website, using a SitePlayer object will allow the site to simply change the value associated with this object and then the microprocessor can poll these objects and use their values to determine what the correct mode of behavior the system should enter.

The definition file is divided into several subsections. The definitions section is simply a series of definitions and accompanying arguments that will set the start up operation of the SP1 chip. A full list of these definitions and their arguments is not included here but can be found within the Software Reference documentation for the Site Player SP1. The second section is the object definition section. Each object is defined by a name followed by the type of data it will be followed by an initial default value that this object will take. These data types are limited to those that can be expected to be supported by most assembly languages. These objects can then be used later by the designed website to pass their values to the attached microprocessor. The last section is the export section. This section is set up very similar to that of the definition section in that is just a series of formatting and destination locations for files that will be exported during the linking processes. For this exportation to occur the final command within this section needs to be the export command as can be seen in this example. Once again a full list of export commands can be found in the Software Reference documentation. The sections with the most relevance to the design of the ECO-SEC are the definition section and the object definition section. The definition section will need to be used to correctly set up the correct IP address and other features for the SitePlayer so that users can successfully access the website. Incorrectly implementing this aspect prevents the SitePlayer from being able to be located by users. The object definition section will be used to define all the site player objects that will be used within the creation of the website for the ECO-SEC to allow the user to input data to the microprocessor (indirectly) correctly.

The second step in programming the Site Player module is to design the website that will be hosted on the embedded web server chip. The website is designed used standard HTML and can be accomplished in whatever development system that the user is most comfortable with. More details on these HTML pages as they pertain to the design of the website for the security system will be included later on in this document under the section detailing the design of the prototype. The HTML code for the website will be important because although the team does not plan to design an overly complicate website it does need to be aesthetically pleasing to the homeowner who uses it while still being simply to use as well as functional. If the website is too complicate to use and does not provide the functionality it is supposed to the web server subsystem would serve no purpose and would fail to work correctly within the design of the ECO-SEC.

The Site Player eases the process required to make the designed web pages look active by not requiring any sort of JAVA or Visual Basic scripting to perform updates of the webpage objects, unlike designing a website to be hosted on a more standard web server platform. Instead the Site Player replaces the standard static graphic and text HTML objects with the objects designated within the definition file as Site Player objects. These objects are placed within the HTML file by the use of an up arrow ("^") followed by the name of the Site Player object. This will cause the HTML page every time it is loaded to use the most current value for this object that the Site Player has. This is where the true power of the Site Player comes through and is the main reason the Site Player was chosen as the embedded web server to be used within the final prototype design. Designing a website with graphics that automatically update themselves based on what the user does can be very complicated but the use of Site Player objects makes this process very easy and can be done in a few lines of HTML code. This allows the team to greatly enhance the appearance and functionality of the ECO-SEC website.

Additionally the Site Player objects contained within the HTML pages can be modified before they are displayed. This will give the programmer more freedom in designing the appearance and functionality of the website. For example consider an object that could be used to hold a value, which is currently set as 544. These modifications could allow object to display a single select digit of the objects value, to add or subtract from the objects value before displaying it, and several other options. This will be useful in changing the value of the site play objects in order to get them to behave in the manner the team needs them to so they correctly interface with the rest of the system.

Table 16 below shows the different modifications that can be used on a site player object. As can be seen from the table Site Player objects can be manipulated in a wide variety of ways. This further increases the use of Site Player objects and also allows for them do accomplish a wide variety of functions which a few examples of that will be used by the team in the final design will be detailed later in the documentation.

Object Usage	Description of Action
^object	Displays the object
^object:n	Displays the digit number n of the numeric object counting from the right towards the left or the character n if a string object counting from left to right
^object+n	Adds n to the numeric object and then displays the result
^object-n	Subtracts n from the numeric object and then displays the result
^object*n	Multiplies the numeric object by n and then displays the result
^object/n	Divides the numeric object by n and then displays the result
^object&n	Logically ANDs the numeric object with n and displays the result
^object|n	Logically ORs the numeric object with n and displays the result
^object~n	Logically XORs the numeric object with n and displays the result
^object#n	Logically ANDS the numeric object with n and displays CHECKED if the result is non-zero and nothing if zero
^object$n	If object = n then displays CHECKED otherwise nothing
^object'n	Obtain the nth bit of the object counting from right 0 = the first bit

Table 16: Site Player Object Modifications, permission requested from NetMedia Inc.

As previous stated, Site Player objects can be also used as more than a means to display a value on the website generated by the HTML pages. The value of a Site Player Object can also be used as the part of a path to a static picture or other object. For example consider that the user wished to display a three digit number as a series of LED images on the website. This can be accomplished by using the object value and selecting a single digit at a time. This single digit than can be used as part of the file path to the LED image. This would allow the LED images displayed to be able to change as the three digit number changes if the user has LED images for all digits 0 to

9. This example helps to illustrate just how powerful the use of Site Player objects and their modifications can be in terms of designing an active and changing website. In particular with regards to the design of the website for the ECO-SEC this will allow the website to use the value of Site Player objects to automatically display the correct images that relates to the status of operation that the security system is currently in. This prevents the website from needing multiple copies of the same page with different status text and instead will allow the website to instantly change the status text as soon as the user changes modes via either the web site or the LCD touch screen interface. Note that although ideally this change should be instantaneous there will be a small delay simply due to the time required to transmit the necessary information between all the subsystems of the ECO-SEC that are involved in such a transaction.

One important concern that must be addressed when designing the website and accompanying HTML pages and images is the size of the memory contained on the Site Player SP1K board. The SP1K supports a limit of 48K memory size to be used to design the website and store any images used by the site. Although this does not seem like a large amount, the security system being designed will not require an immensely complicated and fancy website to accomplish its purpose and as such, 48K of memory should be more than enough space to accomplish the goals the team holds for the site. Luckily the website will not require many images and will only require what is necessary to display the status of the system and a few images for the logo of the system if desired by the development. 48K of memory will more than adequately hold these images as well as the code for the actual site itself.

The second part of step two for programming the Site Player SP1 module chip involves creating the Site Player Interface (.SPI) file. This file is used to interpret how to send data the user has entered into the website from the browser to the Site Player itself, especially that data which modifies the value of Site Player objects. The interface file functions very similar to a CGI file for those more familiar with standard HTML development. The interface file allows the browser to send data to the Site Player chip using either links or forms. Forms can be any of the standard form types included in HTML and can use either the GET or POST method. In order for this interface file to correctly extra modifications to the standard HTML pages created for the website are needed. The name used to refer to any forms or link within the HTML page must instead be changed to match the name of a Site Player object previously declared within the declaration file. These forms will be the method used by the website to collect information from the user about the security system. In particular the homeowner will be able to select the options they wish for the security system to function with and then hit to submit them to the system. The website will then use these forms to retrieve the data and adjust the values of the Site Player objects as necessary. From these adjusts values of the objects, the microprocessor will be able to determine how the system should now behave as well as to inform both the website and the LCD touch screen to update the status of the system that they both display.

Upon successful implementation of the declaration file, the interface file and the HTML pages used to design the website it becomes necessary to move onto the third and final main step of programming the Site Player module. In this step the development team will compile all these various files into a single binary file that is then export onto the Site Player chip via an Ethernet connection to the SP1K development board. This is accomplished through the use of the SiteLinker program which is included as part of the SP1K development kit when purchased from Net Media Inc.

Figure 20 below shows the interface of the SiteLinker program that is given to the user. The sections following this figure will detail the different functionality of this program and how they are used to create and transfer the binary file for the website onto the Site Player development board. The SiteLinker program is designed specifically to work with the unique structure of the SitePlayer web server and such will be software that is required to be used by the team during the design of the prototype. Note that the purpose of this figure is to show the interface of the program due to its relevance in the role it plays in designing this subsystem. The text displayed within the status frame are simply an example of what the program is capable of doing and does not reflect the status of the Site Player as it relates to the current design being implemented by the team.

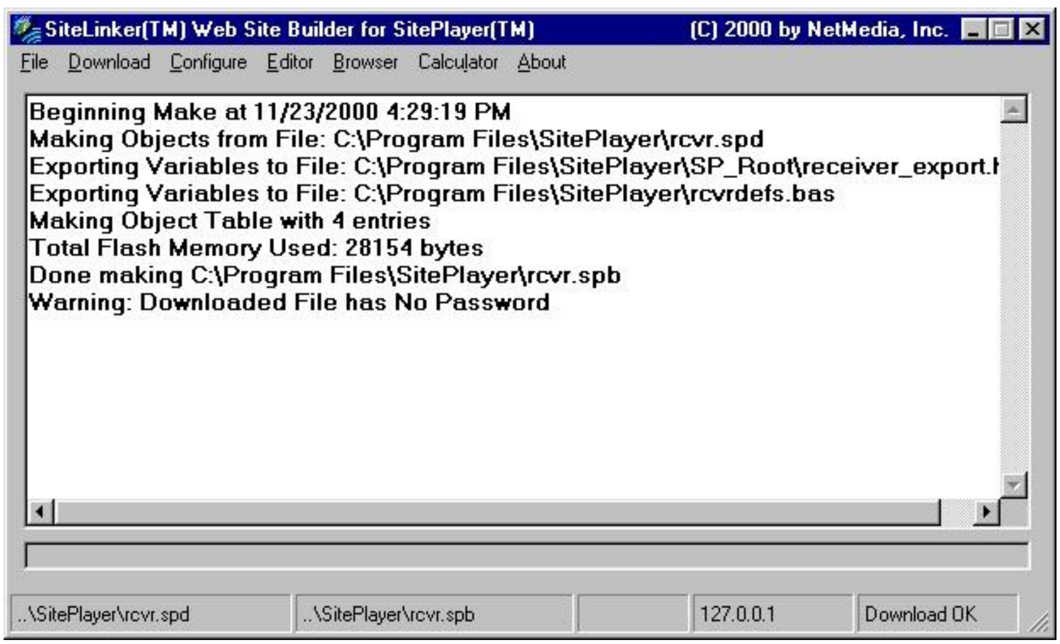

Figure 20: SiteLinker Program, permission requested from Net Media Inc.

The File menu in the program are used to control which specific files definition files, interface files, HTML files, etc. that will be used to created the binary file that will be eventually downloaded to the Site Player SP1 module. Opening and locating these files are done using the standard operating system interface for locating and opening files. The download menu is used to control the creation and downloading of Site Player binary files. Many of the options under the download menu will not be available until a proper definition file is loaded into the program via the file menu. Once SiteLinker detects the presence of a definition file the user then proceed to compile and create the binary file. This is accomplished by using the Make Download File option in this menu. The second option in this menu is the Download Site Player option. This becomes only available when the user has selected a complied binary file using the file menu. A third option called Make and Download file combine these two procedures into one and allows the user to create a binary file and download it onto the Site Player SP1 all in one step. The third menu is the Configure menu and is one of the more important ones within the SiteLinker program. Here is where the user configures which IP address the SiteLinker program will use to download completed binary files to. This must match the IP address assigned to the Site Player. Here the user can also select which download password to use. Once again to successfully download onto the SP1 this password must match the download password specified within the definition file for the SP1.The Editor menu simply displays which definition file is currently opened by the SiteLinker program. The Browser menu will automatically open a browser using the IP address indicated in the Configure menu. This is useful for checking to make sure that the website was correctly downloaded to the Site Player chip. The Calculator menu is the last menu of any important and it simply opens a calculator for use by the user if it is needed. From this it is possible to see how the SiteLinker program will be used by the team to implement the website and the web server as part of this subsystem for the final design of the ECO-SEC security system.

The final and most important part of the SiteLinker program is the Assembly Progress Window. This aspect of the program takes up the largest amount of space and provides details to the user about the current state of what is being executed within the SiteLinker program. This becomes especially important when making and downloading binary files for the SP1 module. This will display status and progress text during these processes as well as indicate any error messages if an error occurs during such a process. This window will allow the team to debug any errors that occur during the linking process when designing this subsystem. As errors are likely to occur during the design phases of the prototype the ability to visually see the errors will help in correcting them.

Once the binary file has been successfully downloaded onto the Site Player module the programming process is now complete. The user can now feel free to browse the website developed onto the embedded web server by using the IP address assigned to the web server. Another interesting aspect of the programming section is the SitePlayerPC program that is used to emulate a Site Player SP1 chip. This is useful for debugging and checking the functionality of the website before actually deploying it on the SitePlayer SP1 chip. A more detailed examination of this program and how it is used will be covered in later sections detailing the process that will be used to test the web site in order to verify that it functions correctly. This section can be found under the section of the document detailing the software aspects of the security system prototype.

5. Design Summary

This section details the overall system design architecture for the ECO-SEC security system. Figure 21 shown below shows a visual representation of this architecture design with regards to the individual subsystems and how they are interfaced with each other. Full details on each of these subsystems and what is required to interface them correctly is given elsewhere in this documentation. As can be seen from this figure the power subsystem supplies power to all the other main subsystems of the prototype design. The other subsystems interface with the microprocessor. The microprocessor is responsible for receiving communications from the other subsystems and instructing the rest of the ECO-SEC system on what action to take. One interesting note is that the camera subsystem also interfaces with the web server. This is done to simply allow the web site on the web server to include the live stream of the security camera feed.

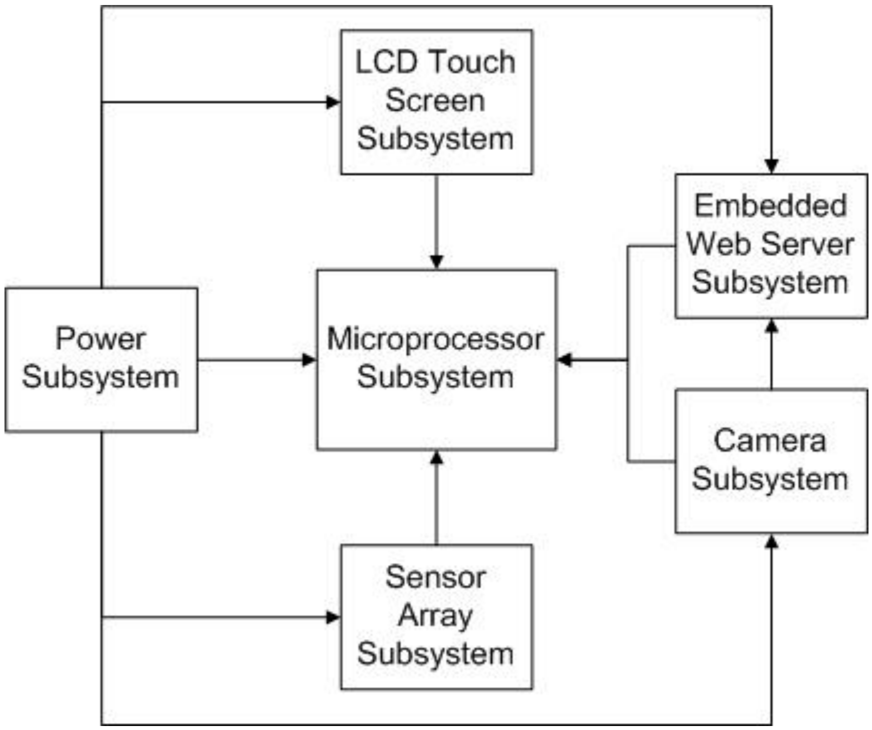

Figure 21: Overall System Design Architecture

As previously stated the microprocessor contains functions as the brain of the prototype and is responsible for handling any actions the system might take. The makes the overall system's design for the ECO-SEC a wait and respond style structure. The microprocessor will be designed to simply wait until it receives input from one of the other subsystems. For example when an intruder sets of one of the sensors the sensor array will signal the microprocessor that this has occurred. The microprocessor is in a wait mode but once it receives this signal it will respond correctly by calling functions designed to handle this input. These functions will then change the behavior of the system via the microprocessor data variable as well as have the microprocessor send commands to other subsystems of the ECO-SEC as needed. These commands will inform the various subsystems of any actions they need to complete in response to the action the original subsystem took. As in the example of a sensor setting off the microprocessor might have to inform the website to log that the sensor was set off.

The power subsystem is the one exception to the behavior of the overall design of the ECO-SEC prototype. The power subsystem does not directly interact with any of the subsystems with any form of communication between them. The behavior of the power subsystem is determined entirely in the subsystem itself. More details on this is the sections dedicated to describing the power subsystem. In short, however, the power subsystem sole responsibility is to provide power to the other various subsystems of the ECO-SEC whether it comes from the solar power source or the backup battery is determined by the power subsystem.

6. Project Prototype

6.1. Sensory Array Construction

The rationale behind the sensor array design was to use as few parts as possible so that they will utilize the least power and to provide the lowest manufacturing costs. The sensors will share a common architecture to communicate to each other and be as modular as possible. We will use a low power Xbee ZD wireless card to communicate to the ECO-SEC main system microprocessor along with a MSP430G2231 where the battery that will house the sensors will be attached. The MSP430G2231 microprocessor will be used to handle and calculate the results obtained from the various sensor and determine if the subsystem needs to inform the rest of the security system that an alarm has occurred.

6.1.1. Wireless transmitter / receiver module

The design of the wireless system will be to integrate all the sensors into a single, replaceable board with the components necessary to program the microcontroller, the battery and the wireless adapter. While this creates a larger footprint, it also makes for easier troubleshooting and replacement of parts, if needed, in the future life of the sensor array subsystem. This module will be used for the base station and all sensors.

Table 17 shown below shows the various parts needed to build this module. Included in this table is cost of each component and the number of them required. Using this data the total cost of implementing this module within the design of the ECO-SEC prototype can be determined.

Quantity	Component	Reseller	Item Price	Total
4	Xbee ZB	Direct from DIGI	$17.00	$68.00
5	MSP430G2231	Digikey	$2.17	$10.85
4	MHB14K-ND (Jtag)	Digikey	$1.98	$7.92
4	BHAA-3-ND	Digikey	$0.90	$3.60
4	TL-5903/S (battery)	Digikey	$7.24	$28.96
4	ESE-20C421 (on/off)	Digikey	$1.36	$5.44
4	754-1489-ND (led)	Digikey	$0.27	$1.08
			Total	$125.85

Table 17: Parts required to build Wireless Transmitter / Receiver

6.1.2. Glass Break Sensor Design

Table 18 show below is the various parts and their cost and quantities that will be needed to build the glass break sensor for the prototype. Although this sensor requires several different parts many of them are very cheap to purchase and the entire sensor can be implemented for around $23.45

Qty	Value	Device	Parts	Digi-Key #	P.P. Item	Total
3	JP1E		*JP2, JP3, X3*	A26529-01-ND	$0.59	$1.77
2	MA03-1		*JP1, X2, X4*	WM6503-ND	$0.38	$0.76
1	WM-61A		*M1*	P9925-ND	$2.16	$2.16
2	0.1u	CAP-NP0805	*C1, C3*	399-1170-1-ND	$0.01	$0.02
1	1N4148W-TP	1N4148SOD123	*D3*	1N4148WTPMSCT-ND	$0.03	$0.03
1	1u	CAP-NP0805	*C2*	495-1934-1-ND	$0.18	$0.18
1	1u	CAP-NP1206	*C9*	587-1328-1-ND	$0.39	$0.39
1	2.2M	RES0805	*R11*	RHM2.20MCCT-ND	$0.28	$0.28
1	2.2K	RES0805	*R1*	P2.2KACT-ND	$0.28	$0.28
1	2.4n	CAP-NP0805	*C5*	490-1629-1-ND	$0.25	$0.25
1	2.8K	RES0805	*R7*	RHM2.80KCCT-ND	$0.02	$0.02
1	2xAAA	KS2468NO_HOLES	*B1*	2468K-ND	$1.41	$1.41
1	10K	RES0805	*R12*	RHM10.0KCCT-ND	$0.03	$0.03
1	10u	CAP-NP0805	*C8*	587-1304-1-ND	$0.30	$0.03
1	10uH	IND1210	*L1*	490-4059-1-ND	$0.30	$0.30
1	18.2K	RES0805	*R6*	RHM18.2KCCT-ND	$0.02	$0.02
4	47K	RES0805	*R2, R3, R5, R14*	RHM47.0KCCT-ND	$0.03	$0.12
1	160K	RES0805	*R13*	RHM160KCCT-ND	$0.03	$0.03
1	180K	RES0805	*R8, R9*	P180KACT-ND	$0.04	$0.04
1	560R	RES0805	*R4*	RHM560CCT-ND	$0.03	$0.03
1	560p	CAP-NP0805	*C4*	311-1120-1-ND	$0.10	$0.10
1	680R	RES0207/10	*R10*	680QBK-ND	$0.07	$0.07
1	BC857C	BC857CSMD	*Q1*	BC857CINCT-ND	$0.04	$0.04
2	DNP	CAP-NP0805	*C6, C7*	eBay	$1.00	$2.00
1	DNP	QUARZ3	*XTAL1*	eBay	$1.00	$1.00
1	EFBRL37C20		*P1*	458-1060-ND	$2.61	$2.61

Qty	Value	Device	Parts	Digi-Key #	P.P. Item	Total
1	JTAG	ML14	*X1*	A31135-ND	$2.35	$2.35
1	MBR0530	MBR052X	*D2*	MBR0530TPMS CT-ND	$0.42	$0.42
1	MSP430F227 4IDA	MSP430F2274IRDA38 PINTSSOP	*U1*	TI Sample	$0.00	$0.00
1	RED	LEDCHIPLED_0805	*D1*	160-1176-1-ND	$0.40	$0.40
1	TPS61040DB VR	TPS6104X	*IC1*	296-12685-1-ND	$2.07	$2.07
1	ZTX451		*Q2*	ZTX451-ND	$0.64	$0.64
					Total	$23.45

Table 18: Parts required to build Glass Break sensor

Figure 22 show below shows the schematic that will be used as an inspiration for developing the glass break sensor. This schematic was developed by Texas Instruments but small changes will be made to fit the individual needs of the design of the ECO-SEC prototype. The part designation label matches the values given in the previous table which describes the parts needed to build this sensor.

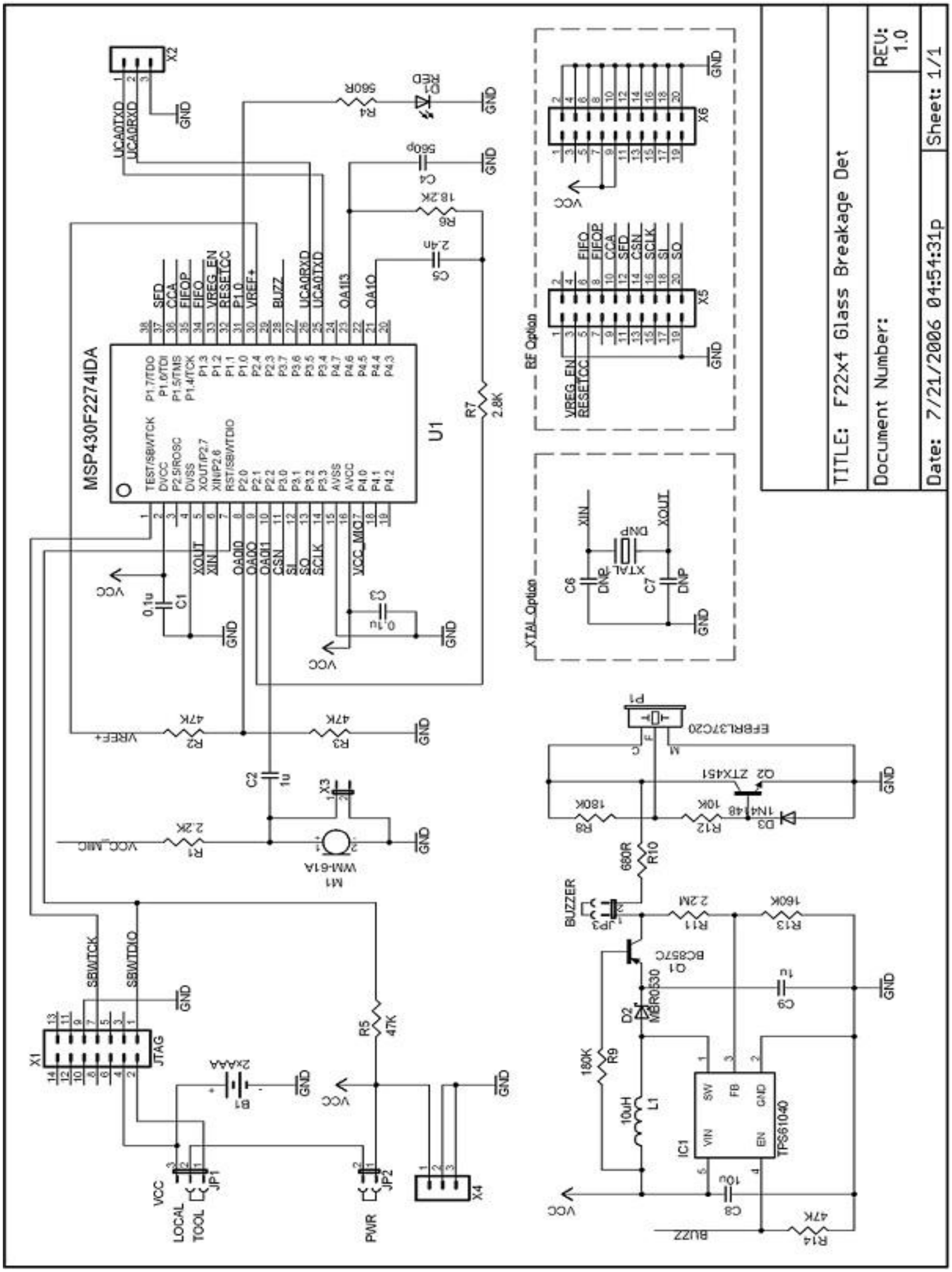

Figure 22: Glass Break Sensor Schematic, reprinted with permission from Texas Instruments

6.1.3. Door/Window Open Detector Design

The door/window open detector sensor will be built to function as described in previous sections. To recap briefly this sensor is designed to trigger an alarm when it detects a window or door being opened by an intruder while the security system is active. Table 19 below shows the parts that will be required to build this sensor. As with the other sensors because of the parts chosen this sensor will be cheap to manufacture and require low power to operate. The expensive part in the table is the seven segment LCD and is not required for the part to function but will be used for testing and troubleshooting purposes.

Quantity	Component	Reseller	Price per item	Total
1	Brick of clay	Jo-Ann Fabrics	$3.99	$3.99
1	M. M. Telecom fiber	Donation	$0.00	$0.00
1	160-1032-ND (P.D)	Digikey	$0.70	$0.70
1	73-1249-ND	Digikey	$23.39	$23.39
1	160-1571-5-ND	Digikey	$1.36	$1.36
			Total:	$29.44

Table 19: Parts required for Door/Window Open Detector Sensor

6.2. Embedded Web Server and Website Development and Coding

The embedded web server subsystem is very easy hardware wise to develop. The server only requires a simple serial connection to the microprocessor it wished to communicate with, an Ethernet connection to the Internet, and a power connection. The serial and power connections are pretty straight forward and will attach to the appropriate places to the printer circuit board developed for the security system. The Ethernet connection is still relatively simple but requires more hardware. One of the goals of the web site hosted on the embedded web server is the ability to provide a live stream of the feed from the security camera that is included in the design of the security system. In order to accomplish this the feed from the camera has to be merged with the design of the HTML pages for the website. In order to provide this merge, both the camera and the embedded web server will have to be connected together on a local network. This will be accomplished by connecting the two to a small hub. This hub will then connect to the outside internet, which will allow the home owner to access the device from outside of their home network. Additional software coding to incorporate the live stream will be needed in the design of the HTML page but more details on what this encompasses with be covered later in this section of the documentation.

The software design for the embedded web server is where this subsystem becomes more complicated in terms of design. This is mostly due to how the Site Player SP1 is programmed. It requires more than simply designing a series of HTML pages to be used as a web site. It also requires designing the definition file for all the Site Player objects that will be used. Also to allow the Site Player to be able to gather data the home owner has entered into the website an interface file must also be designed. Although these steps are not terribly complicated on their own, a single mistake in one part of any of these files can cause the entire subsystem to fail to function correctly. Full detail on what is required for each of these files can be found in the section detailing how to program the SP1 as part of the embedded web server subsystem. The most important thing when designing the definition files is including the correct use of Site Player objects. These objects will be the method used to convey communication from the web site to the attached microprocessor via the serial port. This is accomplished by having the microprocessor poll the values of these objects by a simple serial command. This serial command tells the Site Player to return the value of the Site Player object at a set memory location defined by the original serial command sent. This value is returned via the same serial connection. The coding for the microprocessor will tell it how to adjust the behavior for the system based on these values. More details on this will be covered in the section detailing the prototype design for the microprocessor subsystem.

The website itself will be keep relatively simple. It will consist of two main HTML pages. The first web page will contain nothing more than two simple input boxes allowing the user to enter a user name and password to login. If either of these is incorrect the website will not load the main webpage for the security system. This is designed to prevent outside users who have no connection to the homeowner from being able to disarm the security system remotely. Although HTML supports a security protocols to prevent unauthorized users from being able to crack the security of such a login page this system is not perfected and is capable of being bypasses by individuals who truly wish to. However, for the purposes of this prototype the level of security provided by the HTML protocol is more than adequate for the purposes of the team. If this product where ever to be made into a marketable product it would require a more advance security encryption to prevent unauthorized users from being able to access

The second page of the website is the page that will be of most interest to the homeowner. This page will be laid out fairly simply. One half the page will include two sections. The first being a area of the page dedicated to the live feed from the security camera. More details on how this will be implemented in terms of design for the embedded web server subsystem will be covered in following paragraphs in this document. The second area will display status text for the security system. This section will use Site Player objects to hold values that will indicate the current status of the system in terms of operating mode and whether the system is armed or disarmed. The website would then display these values whenever the pages are accessed by the homeowner or whenever the homeowner changes the status of the system. Although this sounds simple it will require a series of communication between the microprocessor and the embedded web server, which can be accomplished through a series of serial commands that are used to write and read values from Site Player objects. Full details on the syntax of these commands can be found in the software reference manual for the Site Player SP1. The second section is the more active part of this web page. This area will consist of a series of radial buttons that will allow the user to select between the different modes of the system and a second group of two radial buttons that will allow the homeowner to select whether the security system is armed or disarmed. Each series will be designed in order to prevent the home owner from selecting more than one option at a time from the series. Finally at the bottom of the section there will be a button that will allow the homeowner to send the selections they made to the security system. When this button is pressed the embedded web server will pass this information to the microprocessor which will adjust the behavior of the security system accordingly. After this the webpage will also automatically update to reflect the new status chosen. This automatic update will be triggered by the microprocessor. The attached microprocessor will send a serial command to the Site Player to change the values of select Site Player objects. These objects will be used to determine which image to display for the status information for the system. By changing the value of these objects the image displayed will automatically changed to update to reflect the new status of the ECO-SEC system. Although this is the design currently envisioned by the team for the website it is not yet fully finalized and is likely to undergo changes as the prototype approaches its final design.

One of the more complicated part of the website design is integrating a live stream from the security camera inside the website from its main webpage. This would allow the homeowner to be able to visually check on the condition of their home remotely from any device capable of internet access. Although the prototype for this security system is designed to function with only one camera, it could easily be expended to multiple cameras to for more marketability. This would allow the homeowner to view multiple homes in their house. This feature does not require very much in terms of additional software code added to the website but much more hardware added to the overall subsystem architecture. In order to integrate the stream to the website a small amount of additional code is needed to be added to the HTML page for the website. This HTML code can be found within the reference manual for the camera used by the team. This code will combine the HTML page for the website and the stream for the camera together when the user tries to access the website from a browser. In order for this combination to work the camera and the embedded web server must be set up using specific hardware. For example the camera used must be able to a network camera that is capable of being assigned its own IP address. This IP address is how the code added to the HTML page is able to know where the camera is on the network in order to bring its live stream to the website. Naturally for them to be on the same logical local network the web server and the camera must be on the same physical local network. This is accomplished by connecting the two of them together using a small hub. This hub is then connected to the outside Internet using another port. This will allow the web server to be able to see the camera will still being able to be accessed from outside the local network.

Another feature that the team explored implementing in the website design is a log that will keep track of the last time the alarm system was set off. Although not extremely important within the scheme of home security, this could be a feature that would be of interest to homeowner who wish to monitor when and how often something sets of their alarm to determine if it is accidental or more deliberate. The hardest part about implementing this feature is the ability to correctly generate the current time and date. This is mostly likely able to be accomplished by storing the data and time as a group of Site Player objects. From there the microprocessor of the security system would then be responsible of generating the date and time whenever the alarm is triggered. This time and date would then be send to the SP1 through the serial connection with the microprocessor using the serial command to update the value of the Site Player objects used to hold the date and time. This will require the microprocessor to be capable of storing the current date and time correctly. Although this feature is something the team would like to implement it is not a necessary feature that must be included and will be added as an extra part of the design upon the successful implementation of all the other features which the team has deemed to be required by the security system.

In addition to being able to host the website the embedded web server is designed to help fulfill other specifications laid out by the team for the security system. One of the objectives of the security system is to be able to send out an text message alert to the homeowner's cell phone in the case that the security system detects an intrusion and activates it's alarm. The security system has no inherent support for GSM which is normally used to send data to cellular devices, but instead does provide support for email. Email can be used to simulate the results of a text message by sending an email message using the receiver address as the devices phone number at a web address that is based upon the provider of the cell phone. This sounds simple but because of a few limitations of the embedded web server chosen this will be one of the hardest objectives of the security system to implement. One main reason for this is that the Site Player SP1 chosen as the embedded web server provides no support for DHCP protocols and as such can only contact email server that have a static IP address. Most standard email web servers' today use a dynamically allocated IP address. A second problem is that the Site Player SP1 provides no inherent support for the TCP/IP protocol stack. It does however provide support for UDP protocols and sending and receiving UDP data stream. A couple of different solutions for these has been considered for use in the design of the embedded web server subsystem. The first is to use a method supported by the web server to ping the current IP address of the email web server used to send out the alert message. The microprocessor would then take this result and parse the IP address from it. From there the SP1 could use this as a static IP address and send out an email message using some built in commands included with the web server. A second possible solution is to use a PC that is included on the same local network as the embedded web server is. The embedded web server would then hitch-hike its UDP datagrams through the PC in order to be able to provide necessary protocols for both TCP/IP and DHCP. At this stage of development both are being considered as a possible solution for this problem when implementing the embedded web server subsystem, no final decision has yet been reached by the development team. This decision will be decided by the team during the second part of this course by experimenting with both methods to see which method works better and more efficiently and is easier to implement.

6.3. LCD Touch Screen Development and Coding

The LCD Touch Screen Display subsystem will require very little hardware design because of the nature of this subsystem. Because the LCD display chosen comes with a completed controller board as well as screen the extent of the hardware design involves correctly interfacing the display with the rest of the system. The LCD display will be interfaced with the system at two key points. The first is the serial connection between the microprocessor and the controller board. The controller board comes with the connection built in, but this connection will need to be wired to the microprocessor as part of the printer circuit board. A successful serial connection is important because this interface is how the LCD will pass information to and from the microprocessor. This information will include the LCD informing the processor what settings the user has changed as well as notifying it if the system was turned on or off from the LCD screen. The second interface is the power interface. This requires a bit more hardware than the serial interface mostly due to the fact that the controller board uses a set style of power connector. The printer circuit board will not be able to use a simple trace to bring power to the controller board, instead the power will have to be supply through a wire than terminates in the correct connector. This exact termination of the power connector is covered in more details in the sections regarding the power subsystem and the development of it.

The more complicated part of designing the LCD display subsystem for the prototype of the security system is the software design and coding. At first this process seems complicated by attempting to figure out how to program the LCD screen to recognize a user's touch, but one of the main advantages of the display development kit chosen by the team takes care of much of this difficulty. Instead the programming of the LCD involves using the preconfigured syntax designed for the controller board used by the team. This syntax is simple to use and is composed of simple one like commands with a series of arguments which determine how the command will operate. More details on the nature of this syntax and how it is used can be found in the section detailing LCD display subsystem.

The display envisioned by the team will be very simple, designed more for ease of use as opposed to a actively changing and flashy display. This decision was made in order to guarantee that that LCD subsystem could be correctly completed during the time allotted as well as the size and type of the screen prevents the display from becoming overly complicated and detailed. The display will include two main parts, the first being the buttons that will allow the user to change the settings of the system as well as turn the security system on and off. The second part of the display will involve reserving a part of the LCD screen to display the status of the system.

The aspect of the LCD screen that will most be used by the user is the section of the screen that will allow the user to arm or disarm the system as well as to change which mode the system will operate in. These options will be presented to the user as a series of touch buttons. When the user presses a button the controller board will send a command byte of information to the microprocessor via the serial connection informing it which button was pressed. From there the microprocessor will decode the information sent and adjusts its behavior accordingly. More information on this will be given in the section detailing the development and coding of the microprocessor. Creating each button will involve two steps. The first will to create a hotspot on the screen where the button will be placed. This will allow the LCD controller board to recognize this area of the screen as an area where the user will be pressing the screen and expecting a response from the system. All hotspots used in the development of the LCD screen will be invisible hotspots. There is no need to highlight the area of the screen pressed with a visible hotspot because if the software is designed correctly the status section of the screen should change in reaction to the user pressing one of the buttons options. So by using invisible hotspots as opposed to visible hotspots the team can save some overhead in performance by not requiring the screen to redraw its images constantly each time a hotspot is pressed. The second step is creating the buttons themselves. This is accomplished using a simple one line command outline by the software syntax for the command board. Each button will use the same static button image that will include text in the middle of the button informing the user of what option it changes.

The second part of the system is more complicated and requires more software design then implementing the series of buttons for the first part of the LCD development. The status of the system will involve displaying two main parts of information. The first will inform the user of the power status of the system whether it is on and armed or off and disarmed. The second part of the system will inform the user what mode the system is currently operating in. The modes and the exact details of the differences between each mode can be found in the section of this document detailing the requirements of the security system. The status display section of the LCD is much more complicated to program than the buttons to change the settings of the system. This is due to the fact that the LCD display section will need to be updated any time one of the settings of the system has been changed. The easiest way to accomplish this is the use of a series of macros. This series will include a macro to change the display to each possible combination of status the system is capable of having. These macros will then in turn be called by the microprocessor when it detects a status change in the system. The security system will be designed that any time the status is changed the first system informed is the microprocessor. The microprocessor will then react accordingly in the case of the LCD display; it will call the correct macro to change the status on the screen to the correct status of the system. These macros will be called by the microprocessor sending a command to the LCD controller board via the serial connection.

Invoking the macros themselves are relatively simple, and only require the microprocessor issuing the correct call to the LCD controller board. The more complicated part is the commands included within the macros themselves. One thing that has to be worked around when designing these macros is the limitations placed upon them by the controller board. These limitations are discussed in more detail in the section detailing how to program the LCD display which is included as part of the section detailing the LCD display subsystem. Each macro will be limited to four separate commands. The first two commands will clear the current text used to indicate the power status of the security system and the text used for the mode of the system. The second two commands will set the text of the power status and the mode of the system in the correct place on the screen.

One additional feature that the team explored implementing is the ability to require a passphrase combination of numbers to be able to unlock the LCD touch screen display . This is done in order to prevent an intruder from entering the homeowners domicile and simply turning off the system to prevent it from sending an alarm. This feature is something that would be required to be implemented if the ECO-SEC were to be ever taken to the level to become a marketable product. Relating to the prototype for the

ECO-SEC this feature is not necessary and will only be implemented by the team if time remains. Mostly this is due to because the syntax for programming the LCD does not support this feature very well, and additionally the screen chosen for the LCD is not overly large and the team does not want to have to dedicate a large portion of the screen to being able to unlock it. It is preferred that the majority of the screen be saved for the main operation of the interface. It is being explored if the LCD touch screen could hold two different screen layouts where one would contain the necessary structure for entering the passphrase and the second would contain the main regular interface previously described. When the homeowner enters the correct passphrase ideally the system should change the display to the second screen. Currently it is unknown if this can be done by the display chosen and additional research is currently being committed to attempt to incorporate this idea.

Once the LCD display has been correctly programmed all that remains to complete this subsystem is to attach it to the rest of the security system which only involves connecting the serial connection of the LCD controller board to the serial connection provided for it to connect it to the microprocessor, and attaching the power supply from the printer circuit board to the controller board.

6.4. Microprocessor Development and Coding

6.4.1. Microprocessor Interfacing

Figure 23 shown below shows the physical location of the microprocessor within the final design of the prototype and how it interacts with the other subsystems of the ECO-SEC. The microprocessor will be placed as part of the Printed Wiring Board (PWB), also known as a printed circuit board (PCB) as this is going to be the place where the main layout of the system is built from. The touch screen is the controller/interaction for the user. The alarm sensors are going to be monitored by the Zigbee based protocol XBee from Digikey which constantly sends status of these. The web server serves as another user interface for the user to check the status of the system from a computer. The siren is an audible sound that alerts residents close by about an intrusion. The siren will be a part of the security camera that will be used in the creation of this security system. Finally, the microcontroller will be the “brain” that puts everything together to get ECO-SEC. From this figure it can be seen how the various interfaces pass data to the microprocessor which in turn will process it and respond with the results to all the other subsystems of the design that require this knowledge.

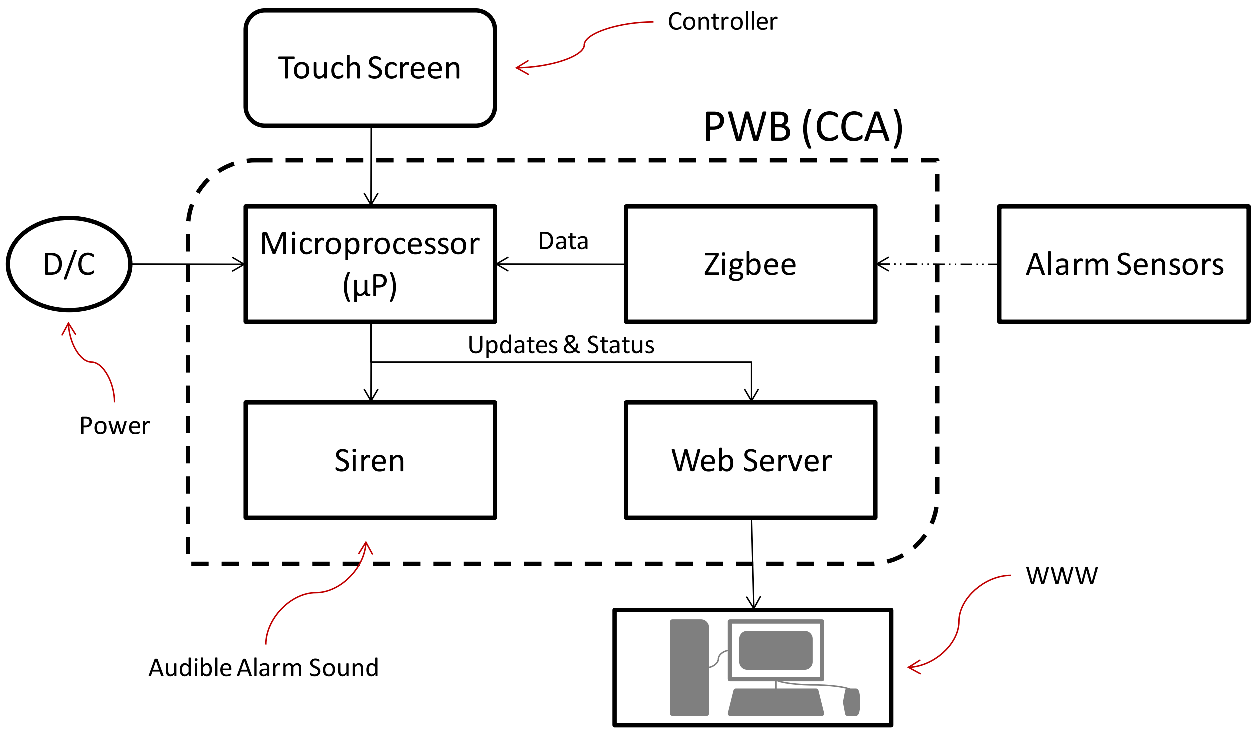

Figure 23: PWB Block Diagram

6.4.2. Software Module Overview

Three main software modules comprise the embedded software that is going to be incorporated into our design:

1. Power On Timer (POT) Module
2. Boot Loader (BOOT) Module
3. Operational Program (OP) Module

These software modules will make up the design of the microprocessor coding for the ECO-SEC and will determine how the microprocessor will respond to event occurring when operating in the different modes that the final prototype is capable of. More detail on what each of these modules accomplishes and is responsible for will be given in the following subsections of this documentation.

6.4.2.1. POT Module

The POT Module is based from and executed by the microcontroller's power-on timer hardware, and does not directly interface with the FPGA.

The primary function of the POT Module is to determine, store, and report cumulative operating times for Solar Power and Primary Power (from AC). The POT Module responds to commands that are received through serial interface communication.

Operating power is applied to the POT microcontroller when Solar and or Primary Power are applied. The microcontroller operating power is held for a brief period after all external power is removed, to allow storage of operating times before shutting down. External sources indicate which power source is available through derivation of logical signals. Primary Power will generate the power required to power the entire system. As soon as the system is powered, Solar Power will supersede as long as it has enough energy to continue power into all the components except for the LCD screen as we will not generate enough solar energy in this prototype to power this component.

The following is a list of the functions that are provided by the POT module. These functions are what the microprocessor will execute every time it begins to receive power after going a period of time without power:

1. The POT Module determines cumulative operating time on Solar Power, starting with stored Solar Power-On Time from a previous operation of the system, when Solar Power is present.
2. The POT Module determines cumulative operating time on Primary Power, starting with stored Primary Power-On Time from a previous operation of the system, when Primary Power is present.
3. The POT Module sets current values of Solar Power-On Time and Primary Power-On Time to zero.
4. The POT Module sets current values of Solar Power-On Time to its respective command value.
5. The POT Module sets current values of Primary Power-On Time to its respective command value.
6. The POT Module sends a response message that contains current values of Solar Power-On Time and Primary Power-On Time.
7. The POT Module stores current values of Solar Power-On Time and Primary Power-On Time into Random Access Memory (RAM), when external power sources are removed, such that none of the POT external sources are present as this indicates that the system is shutting down. NOTE: These times are only recorded when power is removed to avoid exceeding RAM limit.
8. The POT Module might record and report values of Solar Power-On Time and Primary Power-On Time with a range from zero to at least 8,760 hours (365 days), depending on what the storage capacity is for the web server.
9. The POT Module might record and report values of Solar Power-On Time and Primary Power-On Time within ±5% over the operational life cycle.

6.4.2.2. BOOT Module

The BOOT Module is based from and executed by the microprocessor's booting hardware, and does not directly interface with the FPGA.

The primary function of the BOOT Module is to support the loading of the OP software into RAM for storage and execution, and to transfer control to the OP when copying is complete. The BOOT Module gets initiated by the application of power on the processor (excluding Solar Power).The BOOT Module also supports the execution and loading of temporary testing software.

The figure shown below describes how the BOOT Mode transitions. Program Enable is the part of software that determines whether you are in user or admin/edit mode. A user can only use the system as an alarm for the purposes described in this system on what the alarm does. When the system is in admin/edit mode, it allows the system's software to be changed through serial communication on the microcontroller.

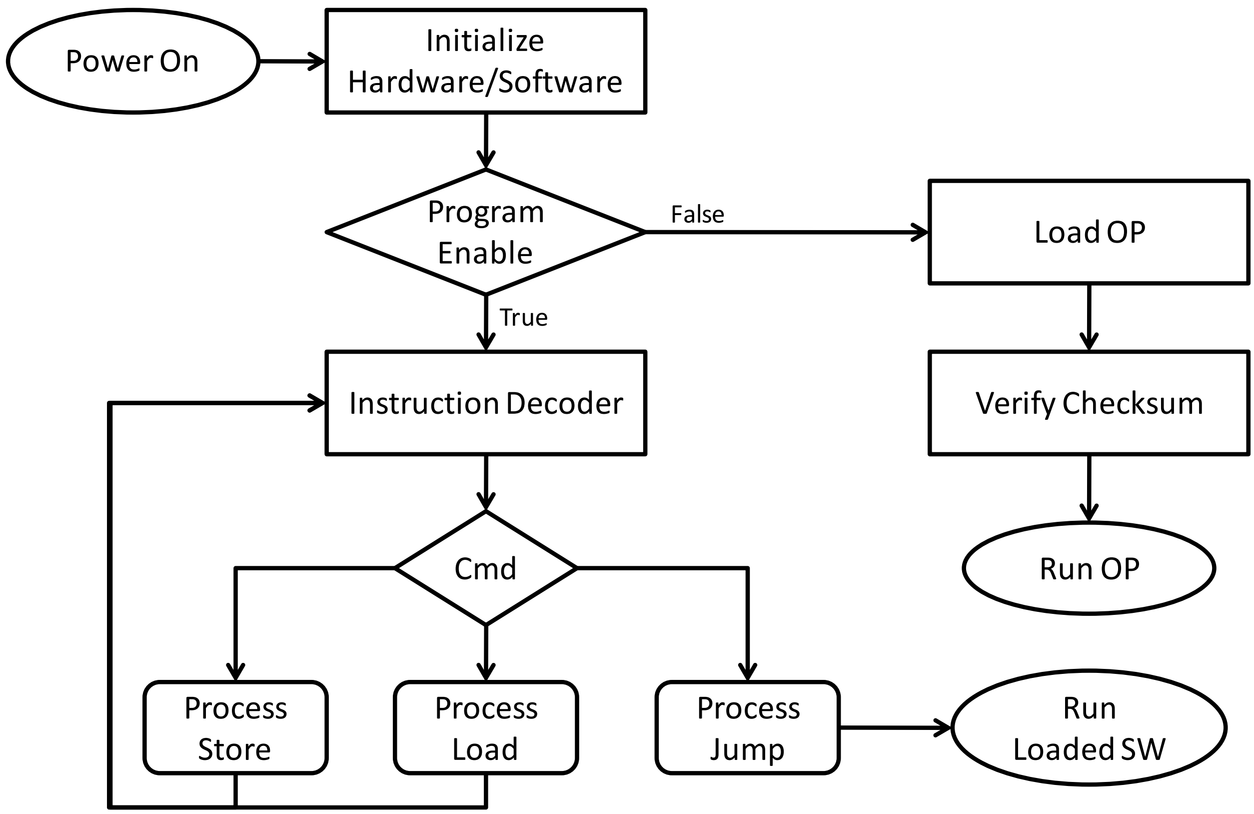

Figure 24. BOOT CSCI Operational Flow Diagram

The BOOT Module is the one that loads the software that will start the system and get it to the appropriate mode of operation.

1. "Off" – says that there is no power applied to the system.
2. "On" – says that power has been applied to the system and the BOOT Module can be loaded. When power is removed from the system, store any necessary data and switch to "Off" state.

The BOOT Module loads and or transitions control to the code that is provided by test equipment. For instance, when the Program Enable discrete input is high (1), the BOOT Module begins to wait for and process command inputs received via serial data. When these commands are invalid, the BOOT Module replies to the microprocessor with the same command it received.

6.4.2.3. OP Module

The OP Module is based from and executed by the microprocessor's booting hardware, and does not directly interface with the FPGA.

The OP Module controls the operation of the system from the time the BOOT Module activates it, until power is removed by shutting down the system. It also supports testing and simulation of events. The OP Module resides in the microcontroller's RAM and is executed by the microprocessor. Figure 25 shown below shows how the OP Module controls the operation of the system after it takes over. Once the BOOT module is finished is loads the OP modules and checks to verify that it is correct. If it is it runs the module. This module then takes over operation of the system until the ECO-SEC loses power or is disconnected.

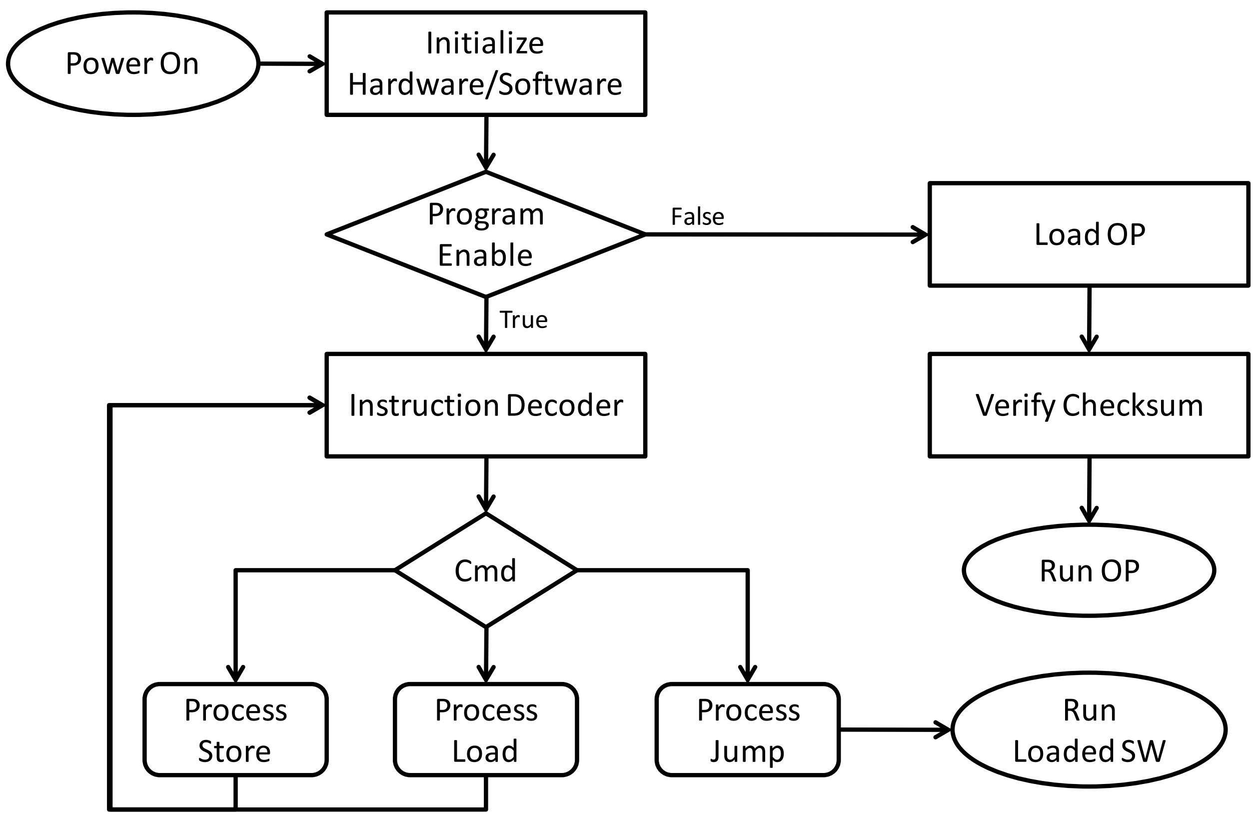

Figure 25: Software Modules' Operational Flow Diagram

Many of the functions performed by the OP Module are as follows:

1. Process code
2. Identify and track valid communication between the system's components
3. Control the Alarm

Some functions that would be useful for this system, in the future, are as follows:

1. Test hardware and software functionality and provide resulting status

2. Provide functionality used during testing, debugging, and integration
3. Provide detailed data and status that supports testing, debugging, and integration
4. Provide data for compensation of critical manufacturing variations

The OP has a set of Software Modules that are the “brain” to the alarm system. The figure below shows the set of software modules that the OP module will contain. The following pages in this documentation will define what each of these sub-modules will accomplish within the scope of the overall design of the final working prototype for the ECO-SEC security system.

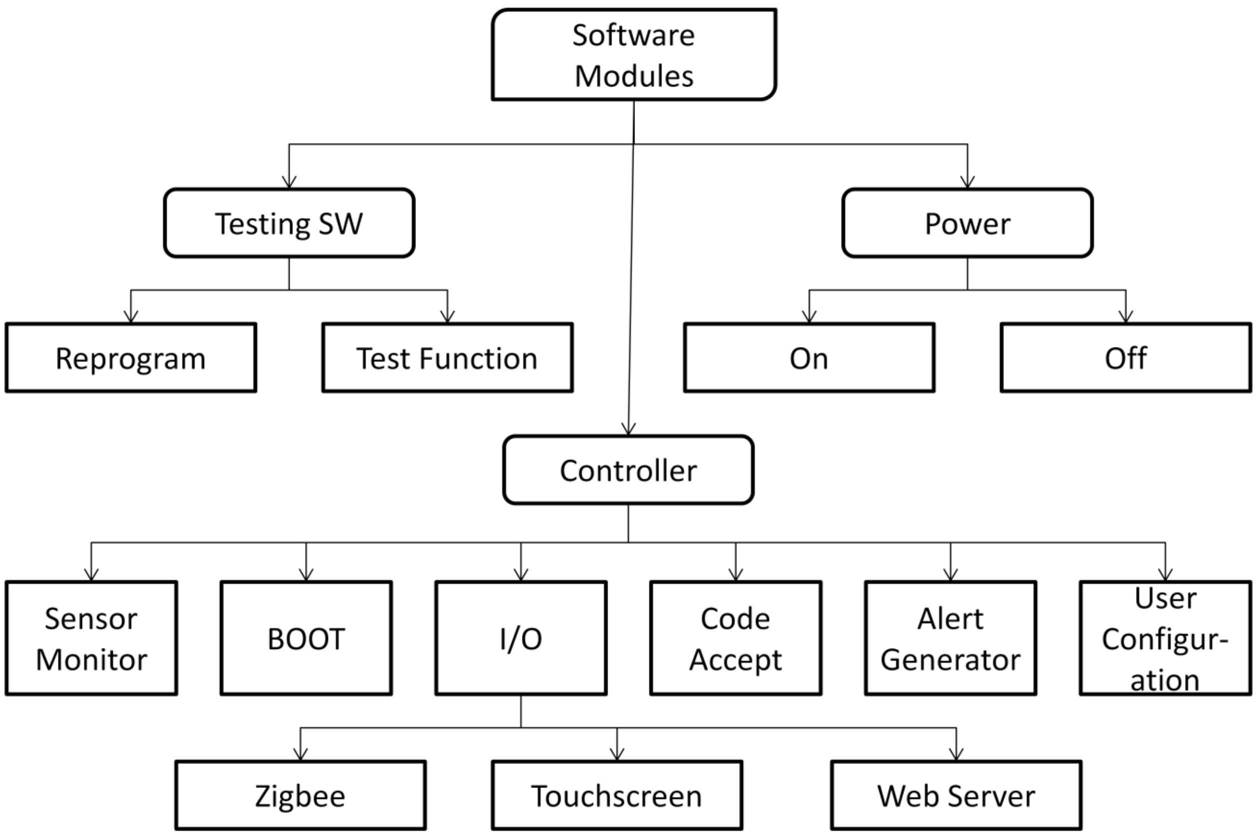

Figure 26: Software Modules’ Breakdown

The Testing Software is a feature of the software that is only accessible through the communication port (TBD) and the use of specific codes. This part of the software allows the updating, reprogramming, and testing of the alarm’s software.

The Sensor Monitor is a feature of the software that provides updates to the I/O about the status of the sensors that are on the system. The BOOT is the software that is loaded as soon as power is applied to the system and works like a “Kernel”. The most important task of this program is to load all necessary scripts required to get the alarm system up and running.

The I/O is the interface between hardware and software in the system. Its purpose is to make sure that these talk to each other and is controlled by the microprocessor.

Figure 27 below shows a breakdown of the I/O interface for the microprocessor OP module. This figure more clearly illustrates how the various subsystems of the ECO-SEC communicate with the microprocessor and what information is being passed along.

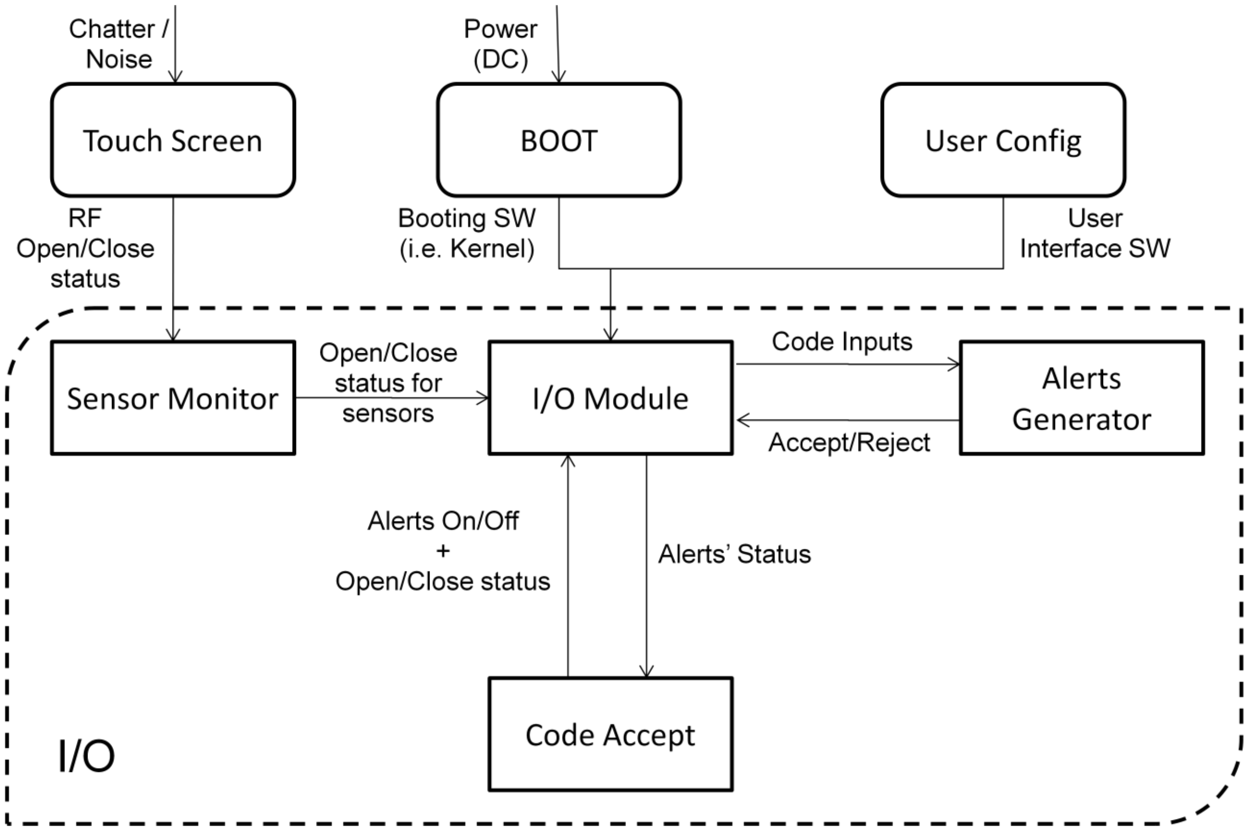

Figure 27: I/O Block Diagram

The wireless sensor monitoring device from DigiKey, called XBee is similar to the Zigbee protocol from Texas Instruments and are used interchangeably within this documentation, is used to receive status from the sensors that are on the system.

The touch screen serves as the interaction device between the user and the software. It is a hardware and software subsystem and is discussed in another section of this document in greater detail.

The Code Accept is the software that received input from the I/O Module and decides whether the information is useful and what to do with it upon receiving it. As an example, whenever someone input a code to deactivate the alarm, the Code Accept Module matches it to the one that is in memory and decides whether the one that was entered is correct or not, and reply accordingly to the user and Alerts Generator module.

The Alert Generator is the software module that receives discrete values from Zigbee/Xbee and generates alerts accordingly. For example, if the alerts are on and a sensor gets a Open/On status for at least 0.5 seconds, then set that sensor's discrete to open; otherwise, the sensor stays off.

The User Configuration is the software module that allows the user to change passwords to change alarm modes and some features according to the user's needs. These have not yet been established. For instance, the user wants to change the code required to place the alarm in Stay mode to be different to the one that is required to place the alarm in Away mode.

The BOOT Module copies the Operational Program into RAM when the Program Enable is low (0) at the end of BOOT initialization. A checksum gets performed to copy the file. If this verification fails, then the Operational Program will not launch; otherwise, the BOOT Module jumps to the location of the OP. OP Module Specifications

The OP Module has four basic modes of operation, known as Alarm Mode:

1. Standby
2. Away
3. Stay
4. Burglar

All modes require a sequence that is entered through the touch screen and processed by the microprocessor, to change from one mode to another.

The "Standby" mode is the initial Alarm Mode, where the system awaits for an arming sequence –like "Away" or "Stay" or "Burglar" Mode. Depending on how it is implemented, then just touching the "Away" or "Stay" or "Burglar" button is necessary to change to such modes. Otherwise, the user will have access to those modes after keying the correct code and then selecting the appropriate mode or adding the respecting number to the mode. Figure 28 below shows this concept in a visual representation. The top shows the how this mode will operate without needing to enter a security code while the bottom of the figure shows how it will operate while requiring the user to enter a security code to change operating modes of the security system.

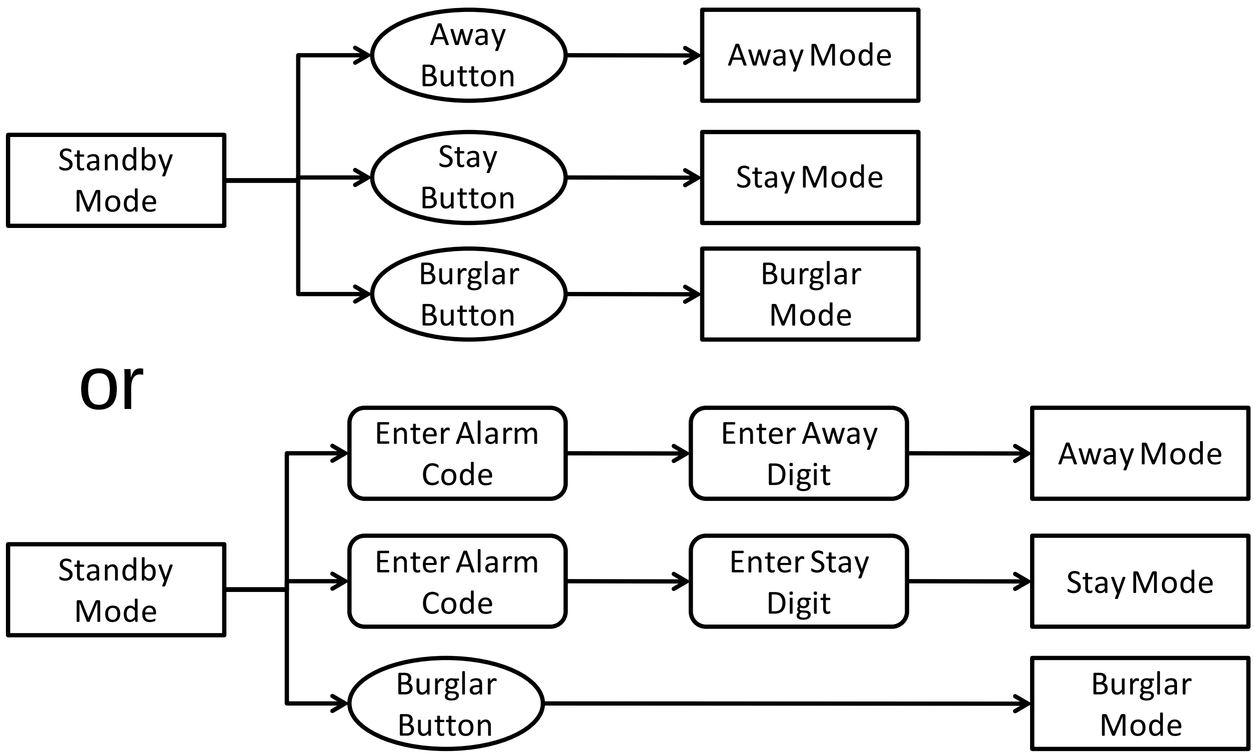

Figure 28: Sequence Diagram for Standby Mode

The “Away” mode indicates that all Alarm Components should be activated and prepares them for if a burglary occurs. To change out of “Away” mode, then the user needs to touch the appropriate code to be able to place the alarm out of “Away”. To change to such modes, the user will have to key in the correct code and then select the appropriate mode. The following figure shows the sequence that the system will follow when the user attempts to change out of "Away Mode". The user will either enter the trick code to enter burglar mode or enter the alarm code to enter standby or stay mode based upon which the user selected.

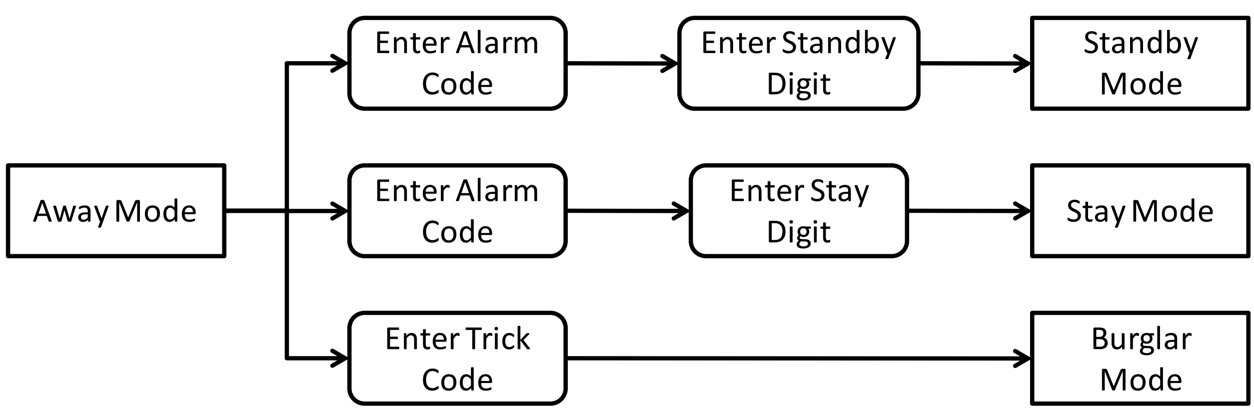

Figure 29: Sequence Diagram for Away Mode

The “Stay” mode indicates that some Alarm Components should be activated and prepares them for if a burglary occurs. To change out of “Stay” mode, then the user needs to touch the appropriate code to be able to place the alarm out of “Stay”. To change to such modes, the user will have to key in the correct code and then select the appropriate mode. The figure below shows this flow of mode operation in the form of a sequence diagram. Similar with the other alarm modes, in order for the user to change the system out of stay mode, it requires either the alarm code or the trick code in addition to the user specifying which mode then would like to change the operation of the security system to.

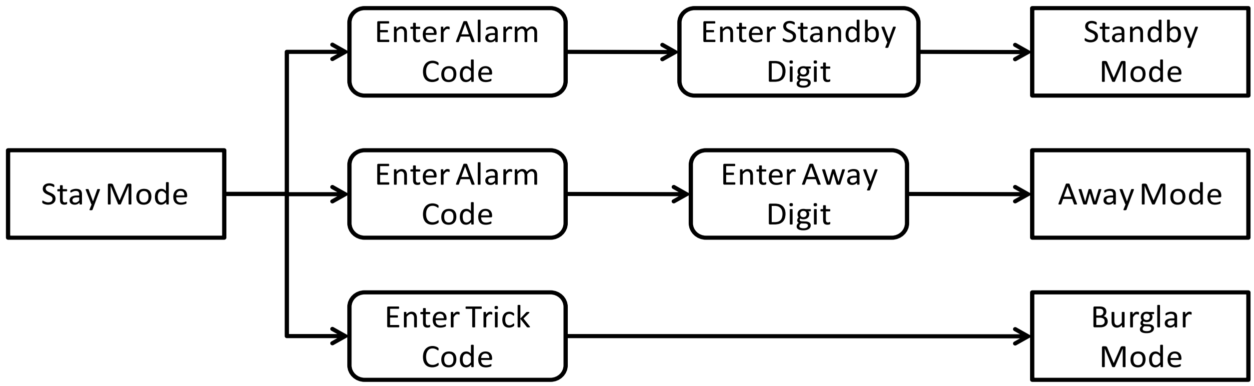

Figure 30: Sequence Diagram for Stay Mode

The “Burglar” mode indicates that one or many Alarm Components are communicating that a burglary or intrusion has occurred. In the case of having the tools to contact emergency agencies, this mode will set that discrete to contact them immediately. This mode can be applied by the user at any time to serve as an Emergency (i.e. panic) button. The figure below shows the operation of the burglar mode. Due to the limitations of this design however, where a marketed complete product would normally call the police when entering this mode, the prototype for the ECO-SEC system will instead contact the homeowner via email to their cellular device that an intrusion as occurred. If this prototype were ever made marketable the ability for the system to contact police services would need to be added to be able to compete with most other models available on the marketplace.

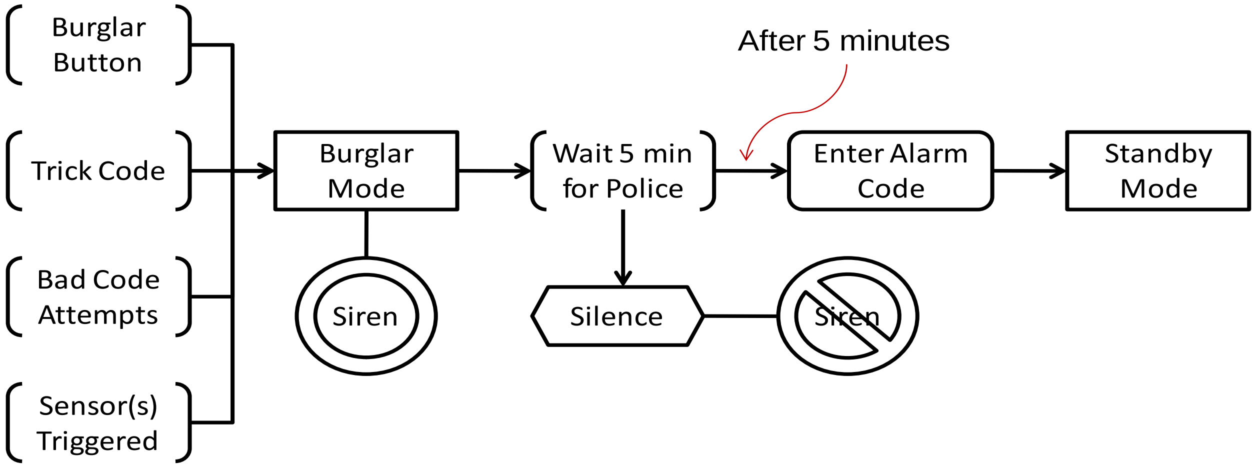

Figure 31: Sequence Diagram for Stay Mode

The OP Module will have a “Testing” or “Reprogramming” mode that is only accessible through a back door or specific command not available to a user. This mode will allow the team to deploy software updates as necessary. Although this feature will not be used by the prototype it is a possibility that will be left in the design for the ECO-SEC. By doing so the team creates the possible for the ECO-SEC to be improved upon in the future in the form of adding additional software to the microprocessor for the system.

The OP Module operates the “Standby” mode as soon as power is applied to the system. As soon as the OP Module detects a burglary or the user manually selects this mode, it should immediately transition to the “Burglary” mode. The OP Module transitions from “Standby” to “Away” or “Stay” when the user selects either. The OP Module transitions to “Standby” from any mode as seen in the following figure: The figure below shows this transition between modes that can occur. As can be seen from the documentation any alarm mode is capable of entering burglar mode when an intrusion has been detected per the how the sensor are functioning for each mode of operation that the prototype supports.

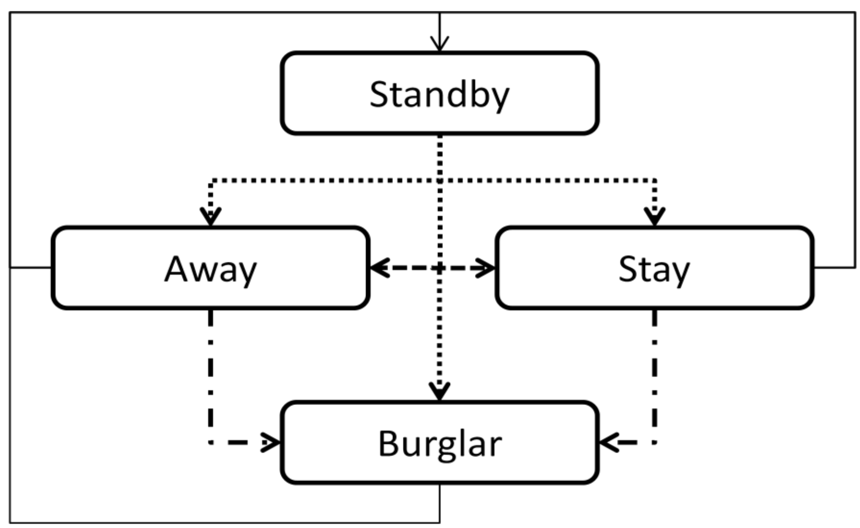

Figure 32: OP Module Simple Mode Transition Diagram

6.5. Security Camera Development and Setup

Most of the security camera subsystem design and its place within the overall architecture design for the ECO-SEC system is based upon how it interfaces with other parts of the security system namely the embedded server and the microprocessor. The exact details of these interfaces and their connections has been explored in other sections of this documentation. For the sake of granting a clear understanding of this, a brief if slightly redundant examination of these interfaces will be conducted again.

The connection to the microprocessor is simple. The M1054 camera has a 4 pin I/O port that contains 1 pin for an input signal, 1 for an output signal, and 1 for ground and 1 for power to the connector. This connector will then in turn be connected to the microprocessor using a similar terminating connector. This will allow the microprocessor to sent 1 bit signals to the security camera and to receive a 1 bit signal from the camera.

This is how the microprocessor will communicate with the camera to pass information during the event an intrusion occurs and the microprocessor takes charge and handles the event. The second interface is the connection to the embedded web server. This connection is a simple Ethernet connection using a standard RJ45 connector. The camera however does not directly connect to the web server and need a small hub or router in between the two. The last interface is the power connection which needs to supply the correct DC voltage and wattage to the security camera.

Once the security camera has been properly interfaced with all that remains to develop the security camera subsystem for the final prototype of the ECO-SEC is to set the various options that will control how the M1054 will function within the scope of the design. Each of these settings although briefly explained in earlier sections describing the M1054 security camera will be covered more completely here.

One of the settings that needs to be enable is the use of the passive infrared (PIR) sensor for motion detection. The sensitivity of the PIR sensor will be set to 100% for the use of motion detection in the ECO-SEC design. This is done to allow the camera to be capable of detecting motion from as far away as possible. The team currently plans to use this as the only means of motion detection. However, if during the course of testing the team decides that this range is not enough for all possible situations that the system could encounter the team will consider in addition to the PIR sensor using the motion capture video method to support this as a means of detecting motion at longer distances despite this method having some problems as previously discussed in earlier a section.

The second setting that needs to be set up is the settings governing the video feed from the camera that will be streamed to the web site for the security system. The most important choice that needs to be made is what encoding to use for this video stream. The best choice of the forms of encoding supported by the M1054 is MJPEG or motion JPEG. This encoding stores the stream as a series of JPEG snapshots and interleaves them to create the illusion of a real time videos stream. This encoding is supported most popular browsers today including Chrome, Firefox, Opera, and Safari. Although Internet Explorer does not provide inherent support for it, several free add-ons do exist for it to support this encoding. So this encoding will be used since it is a form that works well with the HTTP protocol and is supported by almost any type of browser that the user is likely to use. The one downside to the MJPEG format is it requires high bandwidth but this will be mitigate by limiting the frame rate of the video feed to around 30 fps. So although some lost of clarity will occur, the image should still be clear enough for the user to see the state of their home remotely. Addition settings that will be needed for the video feed are the color level, the brightness, the sharpness, and the contrast of the video images. At this stage of development the exact settings for these features is unknown. It will require experimentation as part of the testing to determine which settings produce a good video stream while still maintaining good performance without using an excess amount of bandwidth for the system.

The rest of the setting require configuring the event triggers and responses for them that will be used by the security camera in the prototype. The security camera will need to respond to the PIR sensor detecting movement, the sound sensor detecting the sound of glass breaking by hearing a noise of the correct decibel range, upon receiving an input signal from the microprocessor which the security camera is attached to, and in the situation of an intruder attempting to disable the security camera or tamper with its functionality in anyway.

The camera will need to respond to these events appropriately. First the camera will signal an audio alarm playing the audio clip of an alarm siren going off. This will be a auditory alert that the alarm has been triggered. Next if the camera is used as the means to send an email alert to the owner instead of using the embedded web server to do so the camera should handle this as well. And finally the in all situations except upon receiving input from the microprocessor, the camera should send an output signal through the I/O to the microprocessor informing it that another type of alarm has been triggered and detected by the camera.

6.6. Power Subsystem Development

It is important to discuss the construction details for the power subsystem. Considering these issues can greatly assist in determining the project's feasibility and in making the building process more efficient. To simplify this process, it is important to break the project down into smaller steps. Doing so will improve the team's ability to understand how the power system should work and may assist in finding potential problems with the design. It is logical to divide the power system into 5 different parts: battery charging, AC/DC conversion, DC/DC conversion, solar panel power, and the switch. Building the project in this manner will create several different test points where a component's performance can be evaluated. Furthermore, since each component will be able to stand alone, the team can ensure that a particular part of the project is working before connecting another. This allows problems to be isolated and corrected with greater ease. There is also an order of importance to the subsystems listed above. If there is not enough time to complete all features of the project, it is still important to produce a working prototype. Since the power subsystem is very modular in its design, all parts of the system do not have to be implemented in order to have a functional security system. Another construction goal is to minimize the time and money lost from re-design steps that may be necessary if there are problems with the design concepts. Finally, each component of the power subsystem must be compatible with the rest of the circuitry. Now that the objectives have been presented, it is time to discuss the actual construction of the power subsystem.

Most of the components in the power subsystem will be mounted on a single PCB. These components include the switch, AC to DC converter, charge controller, and DC to DC converters. The battery will connect to the board, but will not be mounted on it due to its large size. Similarly, the leads on the solar panel will connect to the switch circuitry as shown in the schematic below. The microcontroller, touch screen and web server have their own power connector; therefore, the power PCB will be built with the appropriate connector so that power can be supplied to these subsystems.

The first section of the power PCB to discuss is the switch circuitry shown in the schematic below (figure ?). The output of the AC to DC converter, discussed in the appropriate design section above, will be connected as shown. Furthermore, the leads of the solar panel connect directly to the switch. On the left side of the diagram, there are two Schmitt triggers used to detect the voltage of the solar panel and battery. The resistors for the solar panel flag set the trigger to go high when a voltage of 16V is detected. The trigger will return to its low state when the voltage returns to 16.5V. Also, the battery voltage detector triggers high at 9.8V indicating that the battery is in a low charge state. At this point the system requires that the battery return to 10.8V before the low battery flag turns off or goes low. In this manner, the system maintains its battery backup efficiently. The system is very sensitive to changes in resistor values since small voltage changes are being detected. Consequently, resistors with a tolerance of 1% must be used. The right side of the circuit uses the LTC4412 to choose which power source to use by adjusting the current to the gate of the p-channel transistors. These transistors will have a great deal of current flowing through them; therefore, it is important to select transistors will a low resistance from drain to source. A good value is around 20mΩ. Such transistors cost around $3.00 apiece as sold on Digi-Key, but are needed to allow the switch to provide the appropriate power to the load. Transistors with a smaller drain to source resistance are available, but they are expensive and do not improve the power efficiency by a great deal. The voltage drop from input to output at 30W is roughly 0.1V using the appropriate transistors. The design of the switch is below (figure 33).

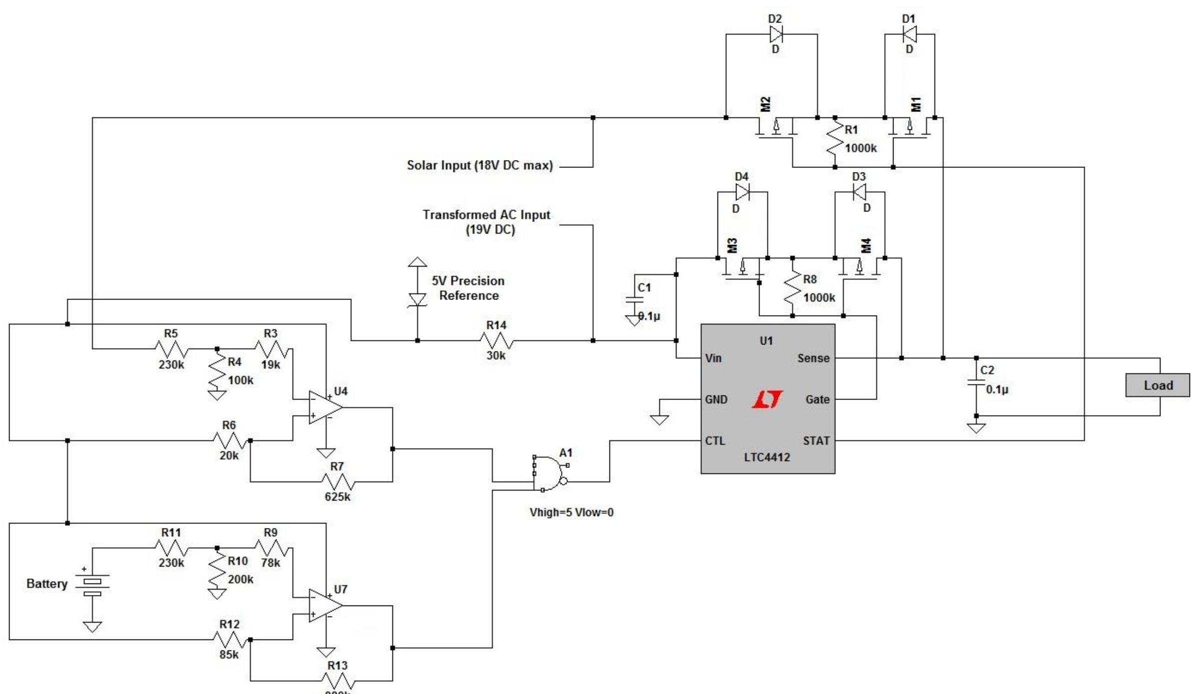

Figure 33: Switch Schematic

Attached at the load of the switch is the charge controller circuitry. This circuitry is centered around the MAX745 charge controller which is designed to charge lithium ion batteries given a voltage and current limit. Similar to the switch, the resistors in the circuit set terminals at very specific voltages so resistors with a tolerance of 1% are needed. Furthermore, similar transistors to the ones in the switch must be used to prevent a large loss in efficiency when charging the battery. The schematic below in figure ? shows how the battery is connected to the charge controller circuitry and how the load is connected to the battery. However, it is important to note that the battery will not be mounted on the power PCB due to its size. Therefore several leads will come from the power board to connect with the battery and the load of the battery will be connected in parallel with these leads.

When designing the charge controller, a current and voltage limit will have to be set by external circuitry. These limits should be 2A and 12.8V respectively. To create this voltage limit, the terminal labeled V_{adj} must be set to 3.79V as defined in the datasheet. The device has a port labeled V_{ref} which outputs a reference voltage of 4.2V. As a result, a voltage divider can be used to set V_{adj} to the appropriate value. On the other hand, the current limit is set by a resistor connected to the battery and the SETI pin. The purpose of the SETI pin is to modify the current limit without changing the resistor connected to the battery. Since this feature is unnecessary for this project, the SETI pin will be connected directly to V_{ref} which sets the current limit to the value defined by the resistor. A schematic of the entire charge controller is shown below (figure 34).

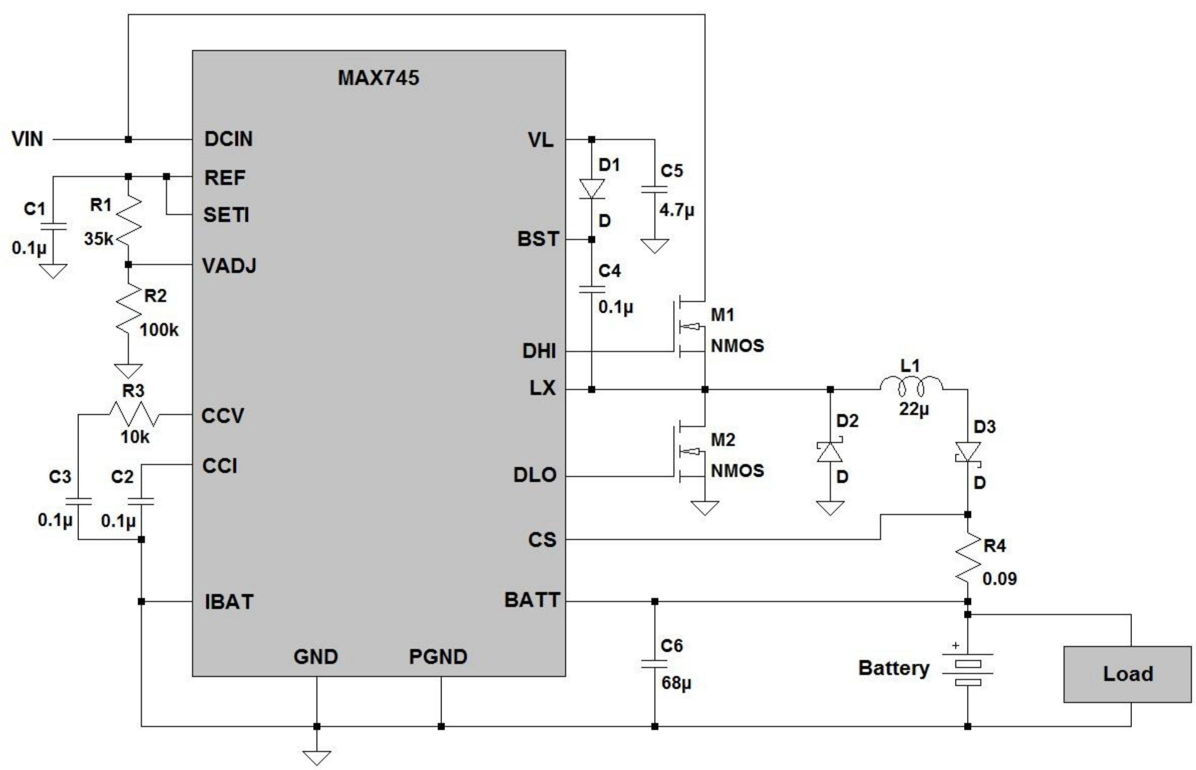

Figure 34: Charge Controller Schematic

The load of the charge controller and battery is three voltage regulators connected in parallel with each other. The first regulator is designed to output 3.3V power to the microcontroller. The LM2675-ADJ step down converter will be used to perform this task. One reason this regulator was chosen is because its voltage is adjustable and is therefore useable as the 5V regulator discussed later. The resistors labeled R1 and R2 set the voltage output of the device as described in the datasheet. The capacitors and inductors specifications can then be determined by considering the input and output voltages along with the output current. The inductor should be rated to allow at least 0.5A of current. Also, the input capacitor should be rated at 16V and the output capacitor at 16V or greater. The capacitor that requires the highest voltage rating is connected to the Cb pin and must except at least 50V. Electrolytic capacitors can be used in the design, but the data sheet recommends that the Cb capacitor be ceramic. Furthermore, the diode connected from FB to ground is a schottky diode and should be rated to support at least 200mA of current. This type of diode is advantageous because it has a low voltage drop. Since this is a switching regulator, it is expected that the output voltage will vary slightly. The capacitor connected in parallel with the load is designed to filter out a great deal of this noise to make the signal acceptable for the microcontroller. Below the schematic for the 3.3V regulator is shown (figure 35).

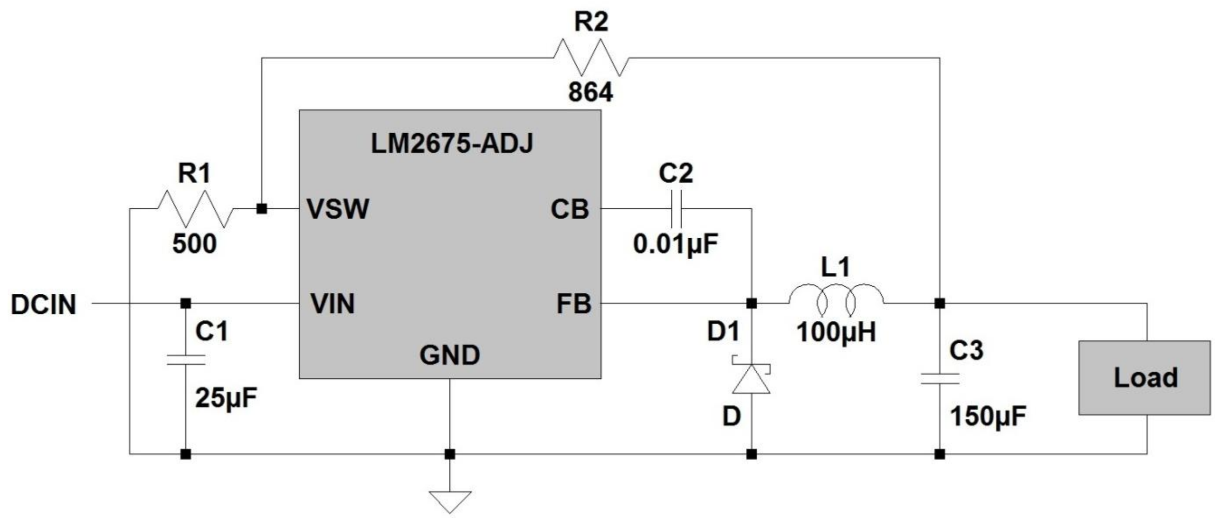

Figure 35: 3.3V Regulator Schematic

A schematic for the 5V regulator is shown below in figure ?. The load of this schematic will be the touch screen. The only difference between this schematic and the previous one is the resistors R1 and R2 which set the new output voltage. The required inductor is different because of different input and output parameters of the circuit. Also, the inductors and capacitors must have a higher voltage and current rating because this circuit will have a higher output power. In this case, the output capacitor must be rated at 35V and the input capacitor at 16V or greater. The capacitor at Cb has the same parameters as in the 3.3V circuit. Also, the inductor must be able to support 600 mA of current. The final parameter deals with the schottky diode which must be rated at 320 mA of current. The schematic follows (figure 36).

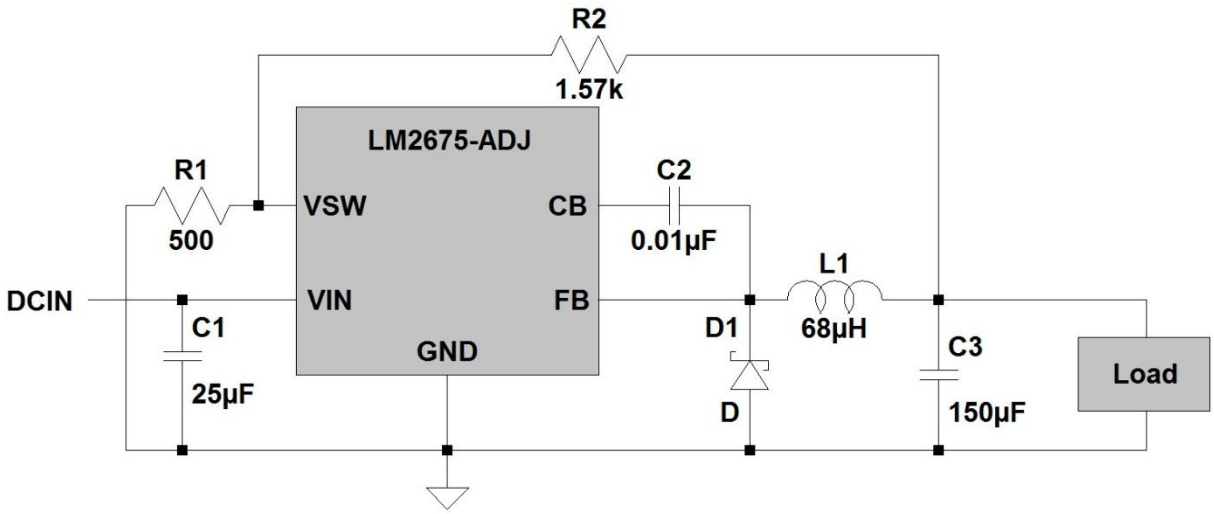

Figure 36: 5V Regulator Schematic

The final regulator is the buck/boost converter for the web server. Below the schematic is shown in figure 37. The additional complexity is due to the fact that this converter can perform both a step down and a step up operation to accommodate both a 7V signal and a 12.8V signal. The resistors R1 and R2 set the output voltage to 12.8V. Due to the use of two inductors, the efficiency of this circuit is roughly 80%. Also, since this is a switching regulator, the output voltage varies by approximately 0.1V. The output capacitor reduces the output voltage variation, but it is more effective if a capacitor with a low effective series resistance is chosen. By connecting output capacitors in parallel, the waveform's variation will be reduced and a capacitor with a higher ESR can be selected. The schematic below in figure 37 is based upon using one output capacitor with a high ESR to correct the output waveform.

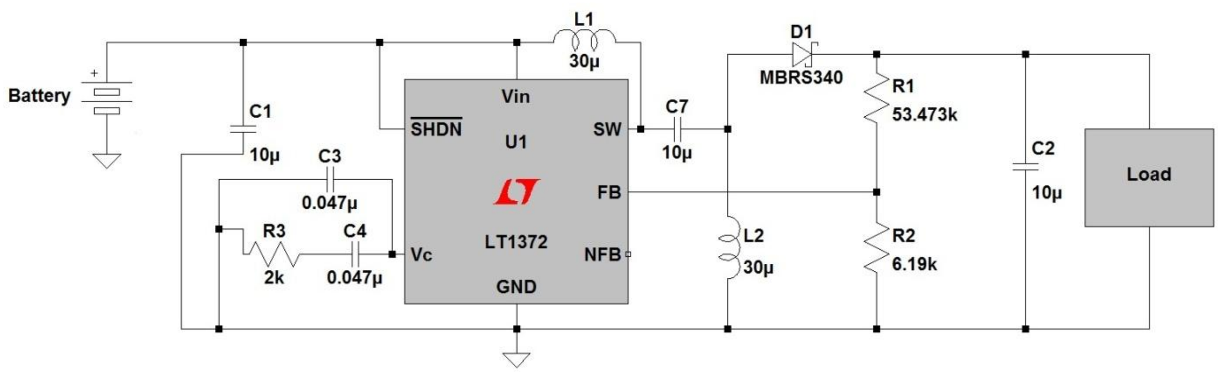

Figure 37: 12V Converter Schematic

The last design issue to cover with the power subsystem is the parts that will be used. Below a table of the specific parts that will be used is shown. For simplicity, most of the parts are through hole as opposed to surface mount. While this technology leads to a larger circuit board, it provides easier testing since the components work with a breadboard. Through hole parts are also less expensive than surface mount parts.

However, two components, the ideal diode and the charge controller, in the power board will be surface mounted. The only lithium ion charge controllers available from both Linear Technology and Maxim-IC are surface mount; therefore, the option of using through hole technology is not there. The same is true for the ideal diode. The vast majority of these parts can be purchased from Digi-Key and are currently in-stock. The other components can be purchased online by the distributor listed. These items are currently in-stock and have no lead time for acquiring the part. Table 20 show below shows these various parts and information about them include number, distributer, and the style of mounting they employ on circuit boards.

Generic Part	Part Number	Distributor	Mounting
Transformer	14A-30-20	Digi-Key	THT
Diode bridge	GBU4D-BP	Digi-Key	THT
Comparators	LM393N	Digi-Key	THT
Charge controller	MAX745	Maxim-IC	SMT
Ideal Diode	LTC4412	Linear Technology	SMT
Solar Panel	UPG-40	Sun Electronics	NA
P-channel MOSFET	SPP80P06PIN-ND	Digi-Key	THT
NAND gate	SN74HCT00N	Digi-Key	THT
Buck Regulator	LM2675N-ADJ/NOPB	Digi-Key	THT
Boost Regulator	LT1372CN8#PBF	Digi-Key	THT
5V precision reference	LM4040	Digi-Key	THT

Table 20: Power Subsystem Parts

The final design for the AC to DC converter is not discussed here because the parts for the system are given in the table above and a generic circuit diagram was given in the AC/DC design section above. The components simply have to be connected as shown in the diagram in that section.

It is important to discuss the specifications of a few components. First, the solar panel selected has a maximum power point voltage of 18V which is ideal for the ECO-SEC since this voltage will remain higher than the required 15.5V from the charge controller during normal operation. Also, the solar power flag has been designed to work with this voltage. Ten percent of the maximum power point operating voltage is the center point of the triggering in the solar panel flag. Also, this panel has a maximum power output of 40W which was the ideal value as discussed in the solar panel design section. Also noteworthy, the battery was not listed in the part list, but will be discussed here. The battery will be purchased online from www.onlybatteries.com since they provide an option that meets the ideal specifications for the ECO-SEC as discussed in the battery design section.

7. Project Testing

7.1. Hardware Testing

This subsection details the processes that the development team of the ECO-SEC security system will undergo to thoroughly test all the hardware components of the final completed prototype for the designed security system. The security system designed incorporates hardware and software but most subsystems of the design are primarily hardware based over software bases and as such hardware testing will take the team longer than software in order to do an extensive job.

7.1.1. Sensory Array

While the sensors are a part of an integrated security system, it was determined early in the design phase that the team should have the ability to test and troubleshoot the sensors separate from the other parts of the system. Again, this approach was taken to keep the system as modular as possible. Since different individuals will be responsible for the base station and other components of the security system, the team can predict that different parts of the system will be ready at different stages of the build process.

The first item to be built will be a custom interfacing program built from an Arduino microcontroller and XBee shield and one of our XBee modules. This will allow testing communication between the wireless transmitters/receiver modules independent of other parts of the system. At first, it will be operated directly attached to a computer, if time permits, convert it to a battery operated wireless remote control. This way, the sensors can be tested in different environments and under different conditions, all while independent of a computer. The interface of the remote control will be a 20x4 line LCD panel with two buttons designed to scroll up and down the menus and one to send a self-test command to the sensors. The remote control will be powered by one the 3.6 batteries or by a 9 volt battery. The wireless modules will have 3 LED's to indicate if there is trouble with controller. Table 21 shown below shows the individual parts and quantities of them that would be needed to design this testing module. Included in this table is also the cost of each of these parts as well as the total cost this testing module will add to the overall cost of developing the ECO-SEC prototype.

Quantity	Item	Cost
1	Arduino Duemilanove	Loan - $0
1	XBee Shield	$24.00
1	XBee ZD adapter	Previously Purchased - $0
1	73-1249-ND (LCD)	$25.78
1	P647-ND (9 volt battery)	$2.37
1	BH9V-W-ND (battery holder)	$1.37
	Total	$53.52

Table 21: Hardware required to build wireless testing module

The testing of the motion sensor will be pretty straight forward. To test if the sensor is working the team will power on the sensor using a regulated power supply providing 3 volts with and a max of 50mA and attaching an oscilloscope to the out connector, the out connector should go high with approximately 100ua of power when someone walks in front of it. The team will test it at around 5 feet way from the sensor walking so as to cross the x axis.

The glass break sensor will be fine tuned first with audio clips played trough a speaker and then we will purchase a large thin glass sheets that can be cut until small squares to test if it the sound detector will be set off. The team will then break these squares of glass by various means to test to see if the sensor successfully detects the glass being broken.

The optical windows/door sensor will be tested under various conditions. First the team will test the photodiode to make sure that there is current flowing trough it when a light strikes its surface, then alternate on-off cycles with a manual flashlight. After aligning the optical components we will test the transmission of infrared light trough the fiber to the photodiode. In well lit and cold room, the sensor should perform well since the temperature will most likely at ideal temperatures of 65-75 degrees Fahrenheit. The sensor will then be allowed to heat up outdoors for an hour or so under the bright sun and then be tested again for performance under extreme conditions. The results will be recorded and the sensors adjusted as needed. Once the various parts are shown to function correctly, the sensor will be attached to a door and a window which will then be opening. The sensor will be tested to determine if it correctly recognized that the window and door were opened.

7.1.2. Security Camera

Testing the hardware of security camera subsystem is a relatively simple processes. This is because the M1054 camera naturally has great support for this. All that is required to test the hardware for the security camera is to ensure that all the interfaces of the camera is reachable by the other subsystems so that communicate between the various systems can take place. Testing the power connection is simple because without a correct power system the camera is unable to function at all and cannot be powered on. So if this situation occurs it is mostly due to a problem with a power connection. The Ethernet connection for the camera can be checked by attempting to use a browser to access the setting page for the camera. If the camera is unable to be reached by an Ethernet connection to a part of the camera that is developed by the manufacturer and is assume to work, the team can determine that the camera Ethernet port is malfunctioning in some regard. The final interface of the security camera that needs to be tested is the input and output interfaces of the camera. These are much harder to test. The best way to test them is to use the microprocessor to send and receive commands from the camera to simulate communication between the two subsystems. If this communication is successful the team can assume that these connections work correctly. In all because the entirely of the camera is produced by a professional manufacturer the team can assume that most likely the camera will function correctly. This hardware testing only becomes more of a concern if the team ends up buying a used M1054 camera in order to reduce the cost of the prototype for the ECO-SEC system.

7.1.3. Power Subsystem

As the prototype is constructed, the performance of each component will be evaluated. Additionally, the entire device at different stages of the prototype will be tested to ensure that the system is functioning as expected. Due to the modular design of the power subsystem, a great deal of testing is needed. This will ensure that each component works before adding another, thus simplifying the debugging and redesigning that may be necessary.

The first stage of the power system to check is the battery and charge controller. The amount of charge in the battery can be approximated by simply measuring the voltage across the battery. A voltage around 11.1 V indicates a close to maximum charge when the battery is disconnected from the circuit while a voltage between 7 and 8 V indicates a very low charge. While charging the battery should initially be receiving a constant current and its voltage should steadily rise to 12.6 V. At the 12.6 V level, the battery should remain at a constant voltage level until charging stops. At this point, the batteries voltage should move down to 11.1 V over a short period of time. The battery's output current can be observed by connecting a resistor, preferably one with a very high resistance so as not to consume a great deal of power, to the battery and observing the output current with a multimeter. This method can be used to ensure that the battery can output the required power for the ECO-SEC. Furthermore, the charge controller must be tested. The circuit contains a voltage regulator so it should be able to accept a noisy DC input, such as the one it will receive after the AC to DC conversion, and convert it to a constant voltage. Also, the output current of the charger can be determined using a multimeter. The efficiency of the circuit should also be calculated by computing the input and output power from the charge controller. Running these tests can provide useful data that will assist in optimizing the charging circuitry to charge the battery efficiently, but in the least amount of time. Finally, the circuit should be tested while charging the battery with a load across the battery. A simple resistor can be used for the load. Now the total power efficiency can be determined which due to the nature of the battery, will be significantly lower than the efficiency of just the charge controller. Also noteworthy, it may be useful to purchase a fuel gauge for the battery to get an accurate readout of the battery's charge status, since measuring the voltage directly from the battery can be somewhat inaccurate. Throughout this testing process, it is important to observe the batteries temperature and make sure the input parameters are within specifications. While the protection circuit should prevent the battery from overcharge and overdrain, it is necessary to make sure the components are not defective and can perform under the worst case scenario for the ECO-SEC.

The second group of components to test is the AC to DC conversion. The AC to DC converter can be tested by measuring the voltage and current after every major component in the device. After the transformer, a particular AC voltage, determined by the specifications for the transformer, is expected. The amount of current will depend on the impedance at that point. IT may be necessary to connect a load resistor to the circuit to modify this impedance to ensure that the transformer can output the desired current and power. Next the diode bridge can be tested by measuring the voltage output and current. The current should be the same as before and the peak to peak voltage should be lower by several volts due to the voltage drop across the diodes. The signal should also undergo full wave rectification. After that, a filter capacitor can be connected to create the DC signal. This signal should be within the noise specifications of the charge controller as observed previously. After the individual components in the AC to DC converter are tested, the circuit should be connected to the charge controller and the battery's charge should be re-tested to ensure that there are no compatibility issues.

Next, the voltage regulators can be studied. The input and output voltages and current should be measured on each regulator. This measurement allows one to calculate the power efficiency of the regulator to make sure it is within the specifications of the ECO-SEC. To do this a load resistor must be connected to the end of the converter. The resistance should be chosen to simulate the correct current draw of the subsystem to which it connects. Another reason to check the output current is to make sure the output power is enough to power the particular subcomponents connected to the regulator. Furthermore, the waveform for the output voltage must be checked to ensure that the signal has a noise level that is within specifications. One way to visually check this is to compare it to the output of the power supply used on the subsystem powered by that regulator. The next item to check is the input voltage range. Most of the regulators will only step down voltages, but it is still important to test their operation under all voltages that the battery can output. This voltage range is 7.2V to 12.6V. The power efficiencies and output power level should remain stable at these variable voltages. As with the AC to DC converter, the entire circuit at this point should be tested. It is important to charge the battery from an AC power source during the process to observe the effect of loading the battery. This effect cannot be properly observed without connecting the correct load resistors to the DC to DC converters to simulate each of the subcomponents. At this stage, it is also important to check the currents through the AC to DC converter and the battery to make sure everything is operating as intended and that there are no compatibility issues.

Testing the solar panel is somewhat more time consuming than the other components due to the need to simulate variable lighting conditions. The open circuit voltage can be tested by placing the panel under decent lighting conditions and using a multimeter to check the voltage at the leads. Similarly, the short circuit current can be measured by measuring the current from one lead to another without any resistor in the connection. The panels operation should also be tested when it is connected to the system and under variable lighting conditions. This information can help in determining what the optimum triggering voltage should be on the switch. Also, the information will be important in determining the average amount of power produced by the system over the course of the day. This information is useful for determining how often the system will have to rely on AC power to charge the battery.

The last component to test is the switch circuitry. The triggers in the switch circuitry should be tested to make sure the digital output is correct so that the circuit will function efficiently when selecting which power source to use. A sine wave input can be applied to the triggers to see the triggering voltages. Furthermore, the ideal diode must be analyzed. It is important to make sure that the system selects the highest power source when the CTL input is at a logic zero. According to LTspice simulations, modifying the resistors in between the set of two transistors plays an important role in making sure this function is correct. Changing these values may correct any problems if they occur. The CTL lines functionality should also be tested when the input is a logical high. One of the most important parameters of this circuit is its efficiency when outputting the desired amount of power for the ECO-SEC. This can be determined by attaching a load resistor of roughly 9 Ω to the end of the circuit. This resistor will allow an 18V signal to output at 2A which is approximately the maximum amount of power that this circuit will be able to deliver to the charge controller. The efficiency of the circuit can now be found by dividing the output power over the input power. The efficiency should be very high, close to 97%, if the circuit is functioning properly because the expected voltage drop from input to output is very low. If the voltage drop is very large, it is likely that one of the transistors is adding a great deal of impedance to the circuit.

7.1.4. Microprocessor

Testing the hardware of the microprocessor is not a complicated processes. This mostly requires checking that the microprocessor successfully connects to and is able to communicate with any other subsystems in which it is attached to. These interfaces include such things as the microprocessor being able to recognize when the sensor array subsystem sends an alert to it in order to process the alert correctly and the embedded web server being able to send the changes the user makes via the website to the microprocessor so it can update the mode it is currently operating in. One other important thing to test however is the power the microprocessor is receiving from the power subsystem. The team needs to ensure that this value is correct so the processor is guaranteed to function without burning out from to high voltage or not turn on from having to low voltage supplied. The mass majority of the testing for the main microprocessor will be software based.

7.1.5. Embedded Web Server

This subsystem is one of the few that is primarily software based. Details on the software testing will be covered later in this documentation. This subsystem does however require a little bit of hardware testing which mostly consists of making sure that the microprocessor and the embedded web server are capable of seeing each other and to communicate with each other via the DB9 serial cable used to attach the two components together. This process luckily is made relatively simple due to the nature of the SP1K development used for the web server. This development board includes an LED that will light up when the web server correctly recognizes an attached device. So in order to verity that the connection is correct and functioning the microprocessor simply needs to be attached to the microprocessor and the team needs to then verify that the link indicator LED does in fact light up signaling the successful connection.

7.1.6. LCD Touch Screen

The LCD touch screen display is another subsystem that does not require a lot of hardware testing as the majority of its design within the ECO-SEC system is software based. However because it does have some hardware that is required to be capable of communicating between the microprocessor and the LCD touch screen subsystem the team does needs to perform tests on this aspect of the subsystem in order to guarantee that it functions correctly. This is important because even if the software aspect of the subsystem functions perfectly correctly if there is a problem with the hardware connection to the microprocessor the subsystem will fail to function correctly. The easiest way to test that all the components of the touch screen functions correctly is to write functions for the microprocessor that are designed simply to pass information to and from the LCD touch screen display. Although these functions would serve no purpose with regards to the final design of the system, if they work correctly it shows that the components are interfaced correctly and work. By making these functions relatively simple such as having the LCD touch screen pass the digit 1 to the microprocessor whenever the screen is pressed will make sure to eliminate any potential errors that could result from the function being incorrect. In this way the team could be certain that any errors that occur when trying to use these functions must be a result of a problem with the LCD touch screen hardware that needs to be corrected for the final design of the prototype for the ECO-SEC LCD touch screen display subsystem.

7.2. Software Testing

This subsection details the process that the team will undergo to provide an in-depth testing of any software code that is required for the final implementation of the security system being designed. There are three main portions of software that require testing, the embedded web server and its website, the LCD touch screen and its controller board, and finally the software that controls the microprocessor.

7.2.1. Embedded Web Server and Website

Testing the web server software code will primarily be focused on testing the website in order to verify that it functions correctly as intended. Fortunately the Site Player SP1K development kit comes with a tool designed specifically to make this task easier, the SitePlayerPC program.

The SitePlayerPC program is designed to emulate a SitePlayer SP1 chip on your PC without needing to physically set up the chip and upload the website to the embedded server. This program will allow you to visit the site contained on the SP1 as well as to simulate a attached device by changing the values of Site Player objects that are used within the HTML pages for the design of the web site. This program also provides support of attaching the microprocessor to the PC via a serial communications port similar to how the microprocessor and the embedded web server would be attached together in the real final prototype. This way you can guarantee that the web site will communicate and respond correctly with the attached microprocessor. This will eliminate that possibly that any errors that occur during testing are hardware related and not software related. This will make the entire process of testing the software for the embedded web server much easier for the development team. Full details on the SitePlayerPC program and how to operate it can be found within the software reference manual for the SitePlayer SP1 embedded web server.

Using the SitePlayerPC program to test the website, in order to verify that it does indeed correctly function in every aspect each part of the website needs to be tested individually. The first thing that needs to tested is the first thing the homeowner encounters when trying to access the website for the security system, the login page. This is designed such that the main webpage of the web site is only able to be accessed with the correct login information. This is easy to test by entering both correct and incorrect information to verify that the login page functions correctly in both scenarios. If the password entered for the website is correct it should automatically redirect to the HTML page which contains the main portion of the website where the homeowner can enter information into the ECO-SEC system. If the login is incorrect the system should redirect the user to a page saying the information is incorrect or notify them in a different manner that the information they entered is incorrect or not valid.

The second part of testing the website is testing the main page that the user encounters after entering correct login information. Each individual portion of this page should be tested very in depth as it is the most important part of the embedded web server subsystem. Testing the embedded live stream is a very simple process. When the site is loaded on member of the team will move into the view of the camera and move around in its view. Another member will view the web site at the same time. If the stream to the web site is truly live, the second team member should be able to see the first moving in the view of the camera. Although ideal the feed should be fully real time, a small delay is likely to be encounter simply due to technological limitations in transferring the stream from the camera to the website through the Site Player server. The second portion of the this page of the website is the status text and the inputs that allow the user to change the mode and status of the security system. These can be tested simultaneously to ensure that both of these parts function correctly together. To test this a team member will changes the options for the security system using the webpage trying out all the various possible combinations. If the embedded web server functions correctly these changes should all successfully be passed to the attached microprocessor. The microprocessor should then in turn inform the Site Player SP1 to update the status text on the webpage as each change occurs. If the status of the system on the site correctly updates as the team member enters information into the site this shows that individually these two portions of the web site function correctly, as well as correctly interfacing and communicating with the attached microprocessor used to power the logic behind the security system. The second test that is required for this part of the website is to have a member of the development team change a setting for the ECO-SEC system using the touch screen display. This change should then be passed to the microprocessor which will inform the website to update its status information. If the status information does correctly update it will show that this portion of the website functions correctly regardless of how the user entered information into the system, from either the web site or the LCD touch screen interface. If the status updates when the user enters input from the website but not when entered from the LCD touch screen or vice versus it will be a helpful indicator informing the development team which subsystem has an error someplace. If the update never occurs the error most likely will reside with either the design for the Site Player or the microprocessor incorrectly informing the website to update.

One additional feature of the embedded web server subsystem needs to be tested beyond the web site contained by the SP1 server. This feature is the ability for the web server to send an email to the homeowner's cellular device when an alarm is sounded when the rest of the system detects an intrusion. This test is simple to trigger. A team member will simply set of one of the alarms of the security system. If this feature functions correctly the web server should send an email to the homeowner’s device. In order to verify that this feature functions correctly for every alarm this feature will be tested by having a team member systematically trigger each alarm individually and guaranteeing that a message is send to the homeowner. By testing each alarm the team will be certain that no matter how an intruder set of the alarm the user will still be successfully notified when the alarm go off.

7.2.2. LCD Touch Screen Display

Of the three main sources of software coding the LCD touch screen display subsystem is the least complicated of the three. Despite this however there is still a level of complexity to this subsystem with regards to how it interacts with the rest of the software driven subsystems of the security system: the microprocessor and the embedded web server. As a result of this, it becomes important to guarantee that the LCD touch screen display correctly functions both independently of the other subsystems as well as together with them.

The LCD touch screen display as mentioned previously in the section detailing the development of this subsystem for the prototype, the LCD touch screen display consists of two main parts; a series of buttons that allow the homeowner to configure the operating mode of the security system as well as to turn the system on and off. The second part of the system is a part of the touch screen that is dedicated to showing the current mode the security system is operating in as well as the power status of the security system indicating if the system is either armed or disarmed. In order to test either of these parts of the LCD touch screen display the display needs to be connected to the rest of the prototype particularly the embedded web server and the microprocessor.

The first part of testing the software for the LCD touch screen involves testing that the buttons correctly allow the user to input their choices of options into the security system. To test this, the team will input all possible combinations of choices into the system. The team will then check to see if this change of status is reflected in the status text displayed on both the embedded server web site as well as on the LCD touch screen itself. If both sections update to match the correct options it shows that this aspect of the LCD touch screen display functions as the team intended. A successful test of this will show several different things. The first being that when the homeowner presses on the screen the screen recognizes the touch and activates the button the user presses. Then the test verifies that pressing this button sends the correct information to the microprocessor and that the microprocessor receives it correctly. Assuming the microprocessor software design is correct it should respond as intended and inform the LCD screen that it received the information and that the touch screen should update its status information. This verifies that communication between the touch screen and the microprocessor is working correctly at the software level.

Testing the status section of the LCD touch screen display is very simple. This section is designed to use macros to change the text indicating the status any time the microprocessor detects a change in system status whether this change comes from either the web site and the embedded web server, or the LCD touch screen display. To check the team will simply change the status of the system using the web site. Then the team will perform the same test by changing the status using the touch screen itself. Assuming that all the communications take place correctly between the various subsystems of the ECO-SEC system, if the macros uses to change the status are correct the status information should change to match the settings the system is currently in. If the status information does change but to incorrect status information it means either the macro for that change is incorrect and displays the wrong information or that the microprocessor is invoking the wrong macro to change the status. This can be corrected by the development team by simply checking both the macro and the code within the microprocessor design to make sure they use the correct commands with the correct parameters.

If the tests for both the input buttons and the status text are successful it will show that this aspect of the touch screen subsystem functions correctly. Furthermore it will show that the LCD touch screen and its associated controller board are capable of successfully communicating with the both microprocessor and the web server via the microprocessor. With a full series of test being successful the development team can rule that the LCD touch screen subsystem is correctly function and any errors that might be remaining within the design of the ECO-SEC security system must be the result of another subsystem.

7.2.3. Microprocessor

Testing of the software for the microprocessor will be one of the more complicated aspects of testing the final prototype. In order to full be able to guarantee that the software for the microprocessor is correct the rest of the security system must first be tested and ensured to be functioning correctly. This way when the team encounters any errors testing the microprocessor the team can be ensured that they resulted from an error within the code from the software for the microprocessor that the team implemented and not from another subsystem that the microprocessor is connected to and communicating with.

Testing the software of the microprocessor will require testing each of the various functions of the microprocessor which are designed to handle the various modes that the ECO-SEC security system is capable of operating in. Each of these modes will be in turn triggered and the system as a whole will be considered when viewing the response it takes from triggering these modes. If the entire system functions correctly it can be assumed that the software for that mode for the microprocessor is correct. If the system fails to function in the triggered mode correctly the team can assume that there is a problem with the software coding for the microprocessor. The team will be able to make this assumption because as stated earlier by testing all the other subsystems of the microprocessor first for errors, the team can rule out that the result of the error was from one of the other subsystems and that the error most likely resides within the design for the function responsible for handling that mode of operation for the microprocessor.

Some of the various features of the different modes that will require testing is as follows:

1. The POT Module must turn the alarm system on when primary or solar power is applied.
2. The POT Module must determine cumulative operating time when power is applied.
3. The BOOT Module must load upon application of power to the system. Then, it has to load the software that is required for the Alarm System to function accordingly.
4. The OP Module must be able to keep the software running while power is applied to the system, whether it is with Program Enable active or inactive,
5. The microprocessor should be able to process alerts through the Code Accept Line.
6. The microprocessor should let the user configure alarm features like passwords
7. The OP Module will output the results of each BIT's testing.
8. The OP Module will store a chronological record to document all BIT tests conducted.
9. The microprocessor must forward any status from alerts to the Code Accept, to determine whether these need further action by the I/O module.
10. The system must transition between modes as described above in the respective sections of this documentation.
11. The system must turn on the siren when the appropriate logic to turn it on is met (i.e. Burglar mode is activated).

Successful testing of these various features of the modes of the security system will go a long way toward guaranteeing that the software for the microprocessor is functioning correctly. However as the team develops the prototype additional testing above and beyond what is listed in this documentation will take place for the microprocessor to further determine that it operates correctly and as intended.

7.2.4. Security Camera

Testing the software of the security camera consists primarily of testing the video stream produced from the camera. The best way to test this will be to test it simultaneously while testing the website. The team will test all the functionality of the website including the live stream of the camera feed. If this feed works correctly on the website if can be assumed that the feed from the camera naturally is functioning correctly. However if the website stream fails to work the team can also attempt to view the stream using the built in interface provided by the security camera. If the stream does work using this the team can determine that the problem is not with the stream but with the design of the website and the embedded web server. However, if the stream still continues to fail this test as well it will indicate that a problem exists with the security camera and will most likely point to a defective unit.

8. Administrative Content

8.1. Project Milestones

The following table is a very tentative schedule for the milestones related to this senior design project. Note that these time estimates are a conservative guess at this point and are likely to change as the project develops. The team has planned to have the design for the prototype finalized and completed along with the documentation by the end of the first semester of Senior Design. At this stage the team also wishes to begin purchasing all the necessary parts so upon the beginning of Senior Design II the team can begin immediate construction of the prototype. Ideally the prototype should be completed by the middle of June. This would leave enough remaining time to allow the team to adequately be able to fully test the prototype to ensure that it functions as intended. This stage will also be used to complete any necessary additional documentation and other required work of a similar nature.

Phase	Artifact	Due Date
General	Meeting Minutes	Within 48 hours after meeting
	Individual Logs	Updated accordingly
	Research	Jan to Feb 2011
	Initial Project Identification Document	1/31/2011
Designing	High-Level Design	Feb 28th 2011
	Detailed Design	Mar 18th 2011
	Pre-Initial Documentation	Apr 6th 2011
	Initial Prototype Document	Apr 25th 2011
Integration and Testing	Purchase Parts	April 2011
	Test Plan	May 2011
	Integration	May 2011
	Implementation	May 2011
	Verification	May 2011
Re-Designing	Re-Designing (if required)	May 2011
	Re-Integration (if required)	June 2011
	Re-Implementation(if required)	June 2011
	Re-Verification (if required)	June 2011
Final	User's Manual	June 2011
	Final Test Results	June 2011
	Source, Executable, Build Instructions	July 2011
	Final Prototype Document	July 2011
	Demo ECO-SEC	July 2011

Table 22: Project Milestones

8.2. Project Budget and Financing

This section covers the budget and financing that was required to develop the ECO-SEC security system final prototype. Table 23 below shows each part used in developing the system as well as an estimated final cost to the development team base upon parts determined to be required as of this stage of development.

Part	Number Needed	Cost
4.3" LCD Touch Screen	1	$349.00
Site Player SP1K Board	1	$79.95
40W Solar Panel	1	$125.00
70 Wh Battery	1	$100.00
Charge Controller	1	$15.00
Ideal Diode	1	$2.00
Buck Regulator	2	$9.00
Buck/Boost Regulator	1	$7.00
Transformer	1	$20.00
Power Transistors	6	$20.00
Other Power Costs	Various	$50.00
AXIS M1054 Camera	1	$300.00
Stellaris Microprocessor	1	$6.45
Wireless Module	1	$125.85
Glass Break Sensor	1	$23.45
Door/Window Sensor	1	$29.44
Final Cost	NA	$1262.14

Table 23: Financial Costs of the ECO-SEC Security System

One of the original goals of the project design was for the system created to be economically friendly and be available fully complete for a fraction of the cost of other systems on the market. However, as can been seen from the previous table the estimates the team originally made for the ECO-SEC system vastly differed from the actual cost of purchasing the parts required to build the final working prototype. So unfortunately the cost was higher than anticipated or that the team wanted but, one thing the team has considered is that the prices for each of these parts was based upon buying the parts individually. The manufactures of the various parts used often offer a discounted price for buying their part in bulk. This is the method used often by marketed products to keep costs low, so if this was taken into consideration in the situation that the ECO-SEC system was made marketable, the actual cost could be brought in line to be closer to the cost originally estimated by the development team. Additional some of these parts are required only for testing the prototype and would not be needed to produce every copy of the prototype which helps future reduce the its cost. So although the prototype ended up being more expensive than originally envisioned by the team it is still comparable to most other security models by the time you count the fact that it has no additional monthly fee. Also the LCD interface and the security camera used by the system are of a much higher quality than you would see in most commercial security systems which increases the cost of those associated subsystems.

9. Conclusion and Summary

The goal of this documentation was to provide a detailed explanation of the ECO-SEC security system as it is envisioned and designed by the members of group 10. The ECO-SEC was originally proposed as a cheaper solution to home security that is priced in a range that is affordable to more people than most models available on the market. The growing concern has resulted from the increasing rate of home burglaries within the University of Central Florida area.

What is functionally required of a security system itself is relatively simple. A good security system must be able detect the presences of intruders in the home when the system is active. If such an intrusion is detected the system needs to be able to inform either the authorities directly or indirectly in order to respond to the intrusion. As easy as it is to define the functional requirements of a good security system it is equally difficult to design a system that effectively meets those requirements while still be able to be constructed and built at a budget.

The first step in being able to construct the system being defined within this documentation was to gain an understanding of the fundamental concepts that would be needed in construction of this design. In this regard extensive research on a wide range of topics was completed by the individual group members. Using this research the team was able to decided how each individual functional requirement would be fulfilled and what type of equipment, either hardware or software, would be required for this implementation.

Once the kind of equipment that was needed was finalized and decided the team committed to an in-depth analysis of several different kinds of each that were currently available on the market. This analysis was used to decided which parts were the best fit for the design and were to eventually purchased to be used in implementing the prototype for the ECO-SEC security system. The end result of the extensive research done by the team was a security system composed of several subsystem driven by both hardware and software components. The main hardware subsystems of the ECO-SEC security system were the camera subsystem, the power subsystem, and the sensor array subsystem. The main software subsystems of the ECO-SEC were the microprocessor, the LCD touch screen interface, and the embedded web server.

The camera subsystem ended up being the easiest subsystem to design. This system was designed to interface with both the microprocessor and the embedded web server. The embedded web server uses the camera to provide a live security feed of the homeowners domicile while the microprocessor uses the camera as another sensor to detect the home intrusions. This is accomplished by using the camera API's built in motion detecting firmware, and when the camera detects motion when there should be none, it alerts the microprocessor to the presence of an intruder. So although this subsystem does not require much hardware or software construction on its own, other subsystems made adjustments to their design in order to allow the camera to correct interface with them.

The power subsystem is designed to provide power to the rest of the components of the security system. It was decided the main bulk of the power for the system was to be derived from a series of solar panels. These solar panels are backed by an emergency backup battery to allow operation of the security system during periods of time without an adequate amount of sunlight to power the solar panels. Designing this subsystem required being able to not only devise a control method to allow the system to turn to the backup battery when necessary but also to regulate the amount of voltage and amperage provided by the power system to each individual component which requires power in order to guarantee the amount each component receives is within the correct range of operation for the component. Additionally this power subsystem is implemented on a printed circuit board of the teams own design. This PCB also included the microprocessor and the necessary interfaces required by that subsystem in order to reduce costs from having to produce a separate board for those components.

The last remaining hardware subsystem required by the ECO-SEC is the sensor array subsystem. This subsystem contains a series of sensors that are linked together to detect an intruder attempting to enter the user's home. These sensors include sensors to detect a door being opened, a window being opened, and the glass of a window being shattered. Also related but not directly connected to the sensor array is the motion detection by the security camera mentioned previously. This subsystem is connected to the microprocessor by a receiver on the microprocessor subsystem. When every one of the sensor in the array is shut off it sends a signal to the microprocessor indicating this. The microprocessor then responds and signals an alarm.

The microprocessor subsystem is a combination of both hardware and software but the main focus of the subsystem is the software. The hardware for the microprocessor is limited to providing the necessary interfaces to allow this subsystem to connect to the other subsystems of the ECO-SEC as required. As far as software is concerned the microprocessor servers as the brains of the security system. Any time another subsystem takes action for one reason or another it informs the microprocessor which then analyzes this action and informs the other subsystems of the ECO-SEC how to respond.

The LCD touch screen subsystem is designed to provide an easy to access interface for the homeowner to be able to change the settings and mode that the ECO-SEC operates on. This subsystem is designed to interface with the microprocessor subsystem. When the user changes a setting using the interface the LCD touch screen informs the microprocessor of the change, and then from there the microprocessor takes control and directs the rest of the system in how to operate.

The last subsystem of the ECO-SEC security system is the embedded web server. This subsystem is primarily composed of software and has two main purposes. The first is to provide a secondary interface for the user of the system to change settings, Although slightly redundant with the LCD interface in purpose, this subsystem is mostly intended to be used by the user when they are not at home and are in a remote location and yet would still like to be able to access some of the features of the security system. The second and most important feature of this subsystem is the ability for it to be able to provide a way for the ECO-SEC to alert the homeowner in the case of an intrusion occurring which is accomplished by sending the user a text based email message.

In all the ECO-SEC was designed around seven separate but equally important subsystem. When the final prototype is successfully implemented the development team hopes to have a fully functioning security system that is comparable to professional systems available on the market but for a fraction of the cost. Although the final prototype is intended to fully function the prototype would still need some improvements to able to be fully successfully marketable. This creates the possibly and room for growth in the future on the design presented here by this paper. But for the purposes of the final prototype as designed by the team it will follow the design guidelines previously stated in the course of this documentation.

Appendix A: References

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2. http://en.wikipedia.org/wiki/Subscriber_Identity_Module (info)
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30. http://batteryspace.com (distributor)

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41. http://www.ci.woodinville.wa.us/Documents/Live/Crime%20Prevention%20Facts %20About%20Alarm%20Systems.pdf (info)

Appendix B: Data Sheets and Manuals

1. SitePlayer Development Manual (available at http://netmedia.com/siteplayer/webserver/documents.html)
2. SitePlayer SP1K Manual (available at http://netmedia.com/siteplayer/webserver/documents.html)
3. SitePlayer Software Manual (available at http://netmedia.com/siteplayer/webserver/documents.html)
4. Reach 43 Display Module Data Sheet (available at http://www.reachtech.com/support/downloads/?fromlogin=true)
5. Reach SLCD43 Manual (available at http://www.reachtech.com/support/downloads/?fromlogin=true)
6. SLCDx Software Reference Manual (available at http://www.reachtech.com/support/downloads/?fromlogin=true)
7. AXIS M10 Network Camera Series Datasheet (available at http://www.axis.com/products/cam_m1054/index.htm)
8. AXIS M10 Series User's Guide (available at http://www.axis.com/products/cam_m1054/index.htm)
9. AXIS M10 Series Installation Guide (available at http://www.axis.com/products/cam_m1054/index.htm)
10. Stellaris LM3S5B91 Microcontroller Data Sheet (available at http://focus.ti.com/lit/ds/symlink/lm3s5b91.pdf)

Appendix C: Use of Copyrighted Material Requests and Permissions

1. Reach Technology - Granted

Hi Nathan,

Yes, we would like to grant you permission as you requested below. Please keep us informed of your project progress. We would love to hear how it goes.

The best of luck to you!
Janis Marshall
Reach Technology, Inc.
janis@reachtech.com
InsideSales/Customer Service Office: 510-770-1417 x112
Fax: 510-657-5055
4575 Cushing Parkway
Fremont, CA 94538

-----Original Message-----
From: nschroeder@knights.ucf.edu [mailto:nschroeder@knights.ucf.edu]
Sent: Thursday, March 31, 2011 7:56 AM
To: sales@reachtech.comSubject: [www.reachtech.com]
Re: Request of use of copyrighted material
date stamp: 2011-03-31 9:55 am
Full Name: Nathan Schroeder
Email: nschroeder@knights.ucf.edu
Subject: Re: Request of use of copyrighted material
Comments:

To whom it may concern,

I am an undergraduate student enrolled in at the University of Central Florida. My team for my senior design class has decided to use the 4.3"Development Kit (WQVGA), SLCD43 within our design for our class project. On behalf of my team I would like to formally request permission to reprint and reuse copyrighted material, figures, tables, etc. relating to this development kit in my team's technical documentation for our project. Naturally, all such use of copyrighted material will be correctly referenced with respect to Reach Technology as the holder of the copyright.

Thank you for your time,
Nathan Schroeder
nschroeder@knights.ucf.edu
University of Central Florida

2. Net Media Inc. - Requested

To whom it may concern,

I am an undergraduate student enrolled in at the University of Central Florida. My team for my senior design class has decided to use a SitePlayer SP1K development board within our design for our class project. On behalf of my team I would like to formally request permission to reprint and reuse copyrighted material, figures, tables, etc. relating to this development kit in my team's technical documentation for our project. Naturally, all such use of copyrighted material will be correctly referenced with respect to NetMedia Inc. as the holder of the copyright.

Thank you for your time,

Nathan Schroeder
nschroeder@knights.ucf.edu
University of Central Florida

3. National Renewable Energy Laboratory - Granted

Dear Mr. Kelly,
Yes, the Atlas for the Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors is considered public domain so you are free to use it in your report. We only ask that you credit NREL for the map (and data, if appropriate); and, if appropriate, provide a link to the NREL homepage (www.nrel.gov.)

My best wishes for you on your project and report.

Sincerely,
Mary Anderberg
National Renewable Energy Laboratory
1617 Cole Boulevard, MS/1612
Golden, Colorado, USA 80401
http://www.nrel.gov/rredc

-----Original Message-----
From: MM1152@aol.com [mailto:MM1152@aol.com]
Sent: Wednesday, April 20, 2011 7:17 PM
To: NREL E-Mail Contact
Subject: NREL.gov Web site inquiry

Name: Brian Kelly
Message: To whom it may concern,

I am an electrical engineering student at the University of Central Florida, and I am working on my Senior Design report. My team is building an alarm system that uses solar power as its primary energy source. I am wondering if my team can use the annual two axis tracking concentrator map from your website in our report. Thank you for your time.
The map can be found at
http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/serve.cgi

Brian Kelly

4. Texas Instruments (TI) - Granted

Texas Instruments is pleased to provide the information on these pages of the World Wide Web. We encourage you to read and use this information in developing new products.
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