EEL4915 GROUP 10

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 sought to propose a different solution to the problem of private home security. In order for this solution to be viable when compared to many of the alternative currently purchasable in the market place, it was required to be capable of performing many of the similar functions while being improved in other aspects. The security system being that was proposed by the team will be able to detect the presence of intruders, and in the case of when such an intrusion occurs, it shall inform the homeowner 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 proposed 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 informs the user via their cellular device or any email account the user wishes to use when the intrusion occurs. This gives the homeowner peace of mind and the capability 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. This 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 security company who provided the system steps in and agrees to monitor your home for intrusions for 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 homeowners who wish to save money, the system provides 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 combines security at economical costs the team has 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 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 has begun to increase.

This caused the team concern and led them 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 system.

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 or able to be afforded by the housing complex in which they reside.

Based upon this motivation the goal of the team was to by the completion of senior design have a working prototype that is capable of functioning as close as possible to a professional security system while still being available at a fraction of the cost of a professional system. The prototype is capable of detecting home intrusions via both doors and windows, as well as alerting the homeowner of the intrusion when it occurs. The team also included several other features that will help set this security system above many others that are detailed in the following sections of this documentation.

2.2. Objectives

In order to successfully attract possible 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. The following is the list of objectives that the team used to define the operation of the prototype that was created.

1. The ECO-SEC shall 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 ECO-SEC shall be able to track intrusions into the house by being able to determine if a window or door was opened while the security system is armed.
3. The security system shall be able to detect if an intruder has broken a window.

4. The ECO-SEC shall include an infrared sensor to watch for intruders by detecting the movement of the heat source generated by an intruder’s body heat.
5. The ECO-SEC shall be to send a text messages to the homeowner's mobile device in the case an intrusion has been detected. This will allow the homeowner to decide to call the police or not in the case that the intrusion was expected.
6. The ECO-SEC 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 mode the system currently operates in.
7. The ECO-SEC shall be easy to install using simple step by step directions.
8. The ECO-SEC shall be low cost in order to be more economically friendly.
9. The ECO-SEC shall 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.
10. The solar panel of the ECO-SEC shall 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.
11. The battery of the ECO-SEC shall 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.
12. The ECO-SEC shall 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.
13. The battery of the ECO-SEC shall be managed automatically. The user will not have to frequently change or discharge the battery.
14. The requirements for the solar panel used in the ECO-SEC shall 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 as the creation of the project that the final prototype of the ECO-SEC home security system must be able to 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 32 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 15 feet away from the sound.
6. The ECO-SEC system shall have a delay of no more than 1 millisecond 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 shall provide power to the alarm system for 24 hours without being recharged. The system will maintain a backup of 24 hours at all times when sufficient solar power is available.
10. The solar panel for the ECO-SEC shall provide 30 WH 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 shall 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 shall be able to be recharged in 4 hours from a totally discharged state while power is available to the system.
13. The ECO-SEC's shall 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 took when contributing to the final working prototype of the ECO-SEC. Although group members were primarily responsible for their own roles, the ECO-SEC is a project that required a lot of team effort and work to get all the individual parts of the various subsystems working together so team members were called upon to help each other with their various roles as the need arose in order to ensure all parts of the final prototype were completed on time and functioning correctly.

Brian Kelly as an electrical engineering student and being most familiar with the required concepts was primarily responsible for designing the power subsystem for the ECO-SEC. This included designing the schematics for 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. The power subsystem was also responsible for converting the solar power to the correct voltages in order to power the rest of the ECO-SEC

David Gardner was responsible for the subsystem dealing with the sensors. This sensory array system required creating a series of circuit boards for each sensor. These boards would then use a wireless connection to the microprocessor to inform the system when they detect that an intrusion has occurred in order to allow the microprocessor to cause the system to produce the appropriate response. The three sensors that were created include a door/window open sensor, a window glass break sensor, and a motion detection sensor.

Diana Escobar-Pazo was primarily responsible for the microprocessor used by the ECO-SEC and creating the various modes of security that the ECO-SEC security system is capable of providing. The microprocessor was one of the most important subsystems of the entire prototype and required some of the most work in order to enable it to correctly communicate with the rest of the subsystems of the prototype. The microprocessor is responsible for the primary logic that will determine how the system should respond when an alarm has been triggered. The various modes of the ECO-SEC system were 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 was responsible for the subsystem dealing with the embedded web server, the subsystem dealing with the LCD touch screen interface, and the subsystem dealing with the security camera. The embedded web server subsystem required both interfacing the server with the microprocessor so it can communicate with the microprocessor as well as designing the website that allows the user to change the settings for the security system remotely. The LCD touch screen interface required programming the interface that the screen uses to allow the user to change system settings as well as configuring the LCD touch screen to correctly communicate this information to the microprocessor. The camera subsystem required researching and purchasing a security camera that was capable of streaming a live video feed. This video feed is displayed on the system website that is hosted on the embedded web server subsystem.

3. Project Related Research

3.1. Similar Projects and Products

The products most similar to the ECO-SEC security system that was 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 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 the team used to compare our final prototype are as follows:

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

On these websites, the team found many alarm system components and entire systems sold. They sell known and not so known alarm systems, from ADEMCO© and GE©, to Visonic©, Ltd. and Elk©. This research was used to compare how well the design the team implemented 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 covers most of the more important features. 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 have been no larger than the dimensions of any of its competitor models but if possible the team attempted to make the overall dimensions smaller. By making the system smaller than most competitor models it became less obstructive for the homeowner to have the system installed and added more appeal to the final prototype if the situation where the ECO-SEC were ever to be made into a marketable product ever occurs. 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 was 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 was 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 having a secondary company to monitor the system that 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 also served as the ECO-SEC's answer to GSM support. Although the final design created by the team did not include GSM support, the embedded web server serves the same function by being used to contact the homeowner whenever a security breach occurs. Finally each system incorporates a siren that will sound when the security system detects an intrusion and a similar siren was incorporated into the ECO-SEC final prototype design.

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 was not similar to any other projects developed for the same Senior Design class, there have been 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 was 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 was 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 that was implemented by the team.

3.2.1. Solar Power

One of the objectives of the ECO-SEC was to design a home security system that operates independently and does not have a high maintenance cost. To achieve this goal, the system incorporated both solar power with a backup battery and a standard AC power source available in all modern homes. In ideal conditions, the system does 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 during times in which the amount of solar power available is insufficient to power the system alone.

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.

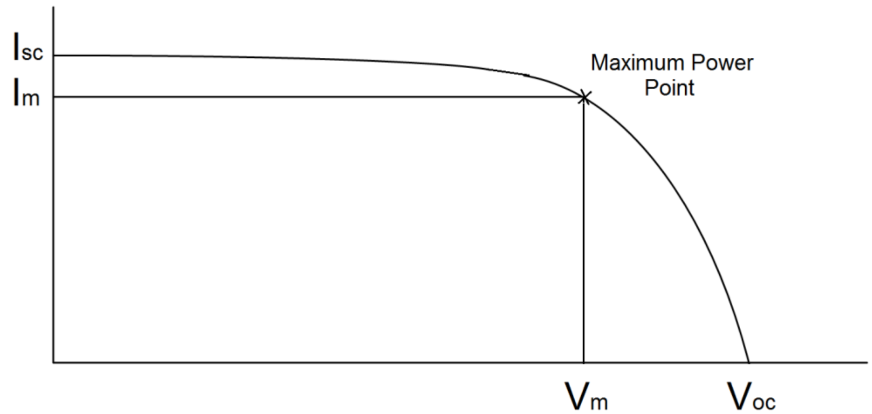

Figure 1: IV characteristics of a solar cell

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.

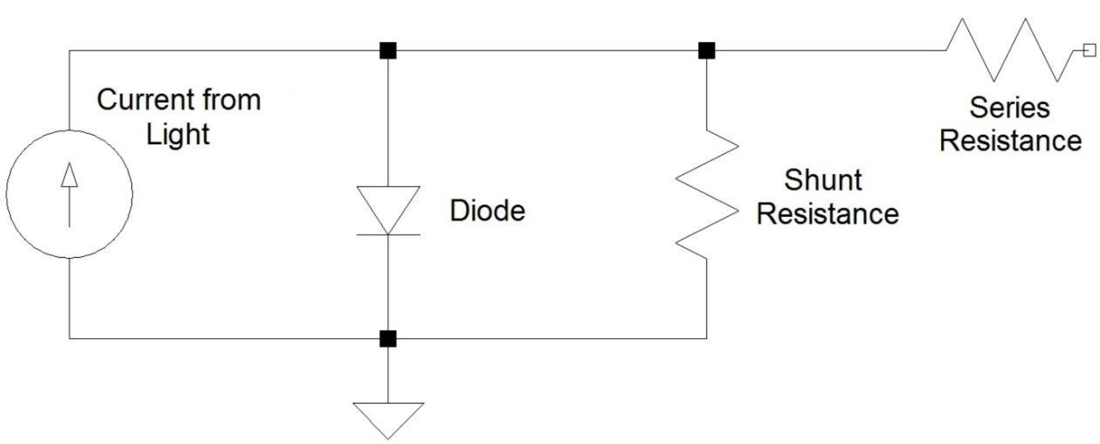

Figure 2: Equivalent circuit for a solar cell

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 monocrystalline 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 had to be able to store a large amount of power in the batteries; otherwise, solar power would not have been a practical solution. Fortunately, the ECO-SEC was a relatively low power device on average. The touch screen display used a great deal of power while fully illuminated, but if the brightness is reduced and the sound turned off the LCD will use only milliwatts of power. Since the display will only be active for short periods of time, the solar panels were 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 was 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 does 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 was 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.

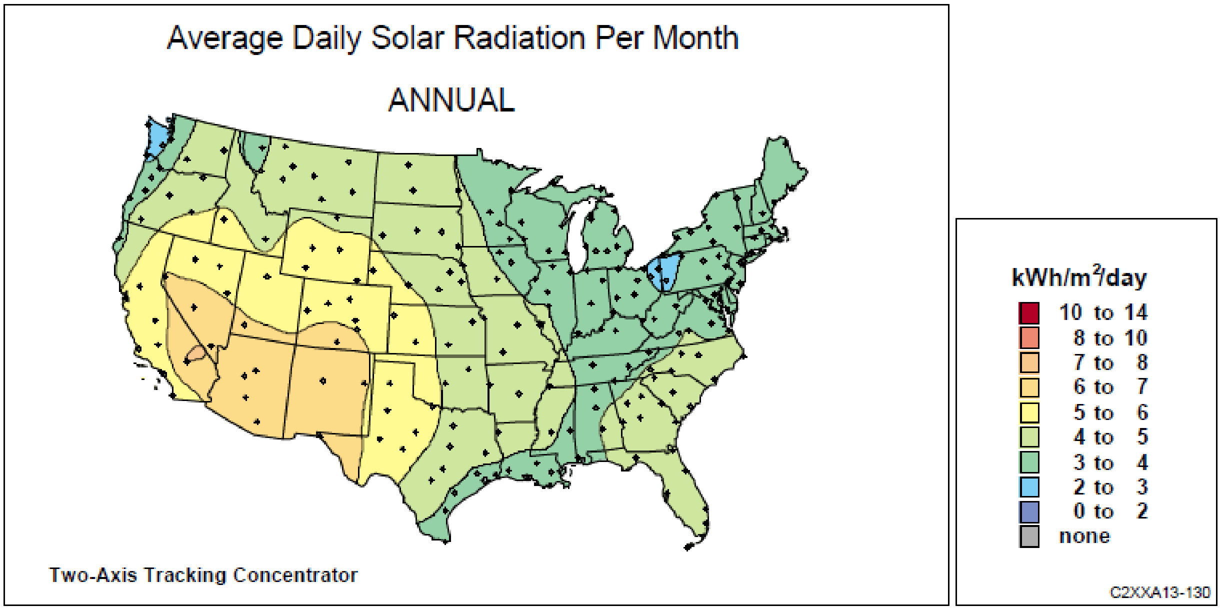

Figure 3: Average Solar Radiation, reprinted with permission from National Renewable Energy Laboratory, (http://www.nrel.gov/rrdec)

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, the team considered the possibility of creating a solar panel of acceptable quality for this project by purchasing the proper protective materials. This issue and the final decision the team made on it is 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 contradicted one of the key motivations of this project of developing a more economically friendly security system that was 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. This completely eliminated the need for a third person party to monitor the final prototype. The ability to contact the homeowner in the case of an intrusion was one of important features that needed 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 serves little to no point other then as a false deterrent.

The team examined two different approaches that could have been 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 detected 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's phone can be configured in the manner that it causes the phone to treat it as though it were a text message. This would allow any phone with the ability for internet connectivity or standard texting support to be able 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 have allowed 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. Additionally, in order to access a service providers GSM network, the user must often have a contract requiring monthly fees with the provider. The team decided that this was not something that should be included in the prototype because it opposed the main objective of being economically friendly.

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 ended up being a positive addition to the design of the final prototype for 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 would have raised 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 was having to pay a monthly service fee in order to get the security system to operate correctly. This also served 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 have brought 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 ended up providing 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 allows 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 added additional functionality that allowed this system to match many currently available on the market. This raised 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 ended up costing less than a hundred fifty dollars which was 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 an embedded web server brought more functionality at a reduced price when compared to a GSM module which made 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 would be used for the design of the ECO-SEC system the most important choice that had to be made was which technology of touch screen is best to use; resistive, capacitive, or acoustic wave. In order be able to make this decision on which technology to use, it was important to understand exactly what design requirements of the final prototype the LCD had to be able to fulfill. 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 display needed to be able 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 was not designed to be a large screen taking up a large portion of the homeowner's wall space. It was designed to only serve as an interface between the system and the user. As such, the system did not require an overly large display and realistically a smaller sized display ended up being 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 have served the needs of the prototype the best.

The LCD display module was 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 did not need to be able to display moving pictures or animations or display any video of any other kind. All the final design required the LCD touch screen to display was 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 was important that it was 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 to minimize the number of IO pins used. In the end this connection was made using a DB-9 Serial UART connection.

One of the requirements of the ECO-SEC system was 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 was important to attempt to minimize the power requirements of each individual subsystem of the design as much as is possible. So ideally the technology that required the lowest amount of power should be used as long as it was capable of meeting the other requirements the touch screen must fulfill.

As it’s 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 would have been unable to meet the requirement of being economical, so the technology chosen must have been able to be purchased at the low end of the cost spectrum for LCD touch screen displays.

Based upon the previous discussed requirements the ECO-SEC system expected from the LCD touch screen display the team decided the best technology to use for a touch screen was a resistive touch screen. Of the three 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 did not require a large powerful screen. This helped 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 individual touch screens can vary somewhat based upon the requirements of the controller board used for the display but over all this technology resulted 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 was the most ideal technology for the ECO-SEC system. One of the advantages was 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 helped make it a better interface for the security system. Also resistive touch screens are spill resistant unlike an acoustic touch screen so in the case of the screen being exposed to a minor amount of liquid it is still be able to function correctly. Resistive touch screens share 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 prototype would need the touch screen replaced constantly and on average homeowner can get many years of use out of it before it wears out. So even despite this disadvantage the team decided to 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. Security Systems

The system that was designed is a prototype for a “security system”. There are many commercially off the shelf products available 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 security systems are electronic alarms (devices) designed to alert the user to any danger. There are various types of security systems, but the one that the team implemented for this project was a system that protects against home intrusions and burglaries.

3.2.4.1. Security System Components

A successful security system must be able to trigger an alarm by correctly determining when a home intrusion occurs. Most security systems accomplish this through the use of a series of sensors. A similar approach was used by the team in the final prototype of the ECO-SEC. The sensors use by the ECO-SEC system are described in greater detail in a later section of this document but the main sensors and other components that most security systems use are as follows: (Although the follow covers a majority of such components many others exist on the market that are not covered here in this section of the documentation for the ECO-SEC.)

1. Siren – receive input from the system to alert anyone nearby (inside or outside of 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 Security Systems

If the team were to ever to decide at a later date to use the final prototype of the ECO-SEC to produce a marketable product, the system would need to be able to meet several certification standards for security systems. These standards are certified by several agencies and are used to determine if the system is capable of successfully being able to protect a home against intrusions and other events. 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 did not have the design officially certified. However, if this project were ever to be taken to the next stage and marketed as a purchasable product at a later date such certification would be required.

3.3. Product Comparison

The following sections detail a comparison of different products the team considered when selecting parts that would were used to build the final prototype of the ECO-SEC security system. Each subsection details a product comparison for a different part 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 were used within the final implementation of the prototype for this design.

3.3.1. Main Microprocessor

The main microprocessor in the final prototype was responsible for controlling the logic behind the ECO-SEC. This means that the prototype for the ECO-SEC is controlled mainly by this microprocessor. However this did not mean that the team had to spend hundreds of dollars in such a 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 was used needed to cost less than ten dollars ($10), and give 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 ARM M3 MCU, LM3S1968 microprocessor from Texas Instruments. The reasons for selecting this microprocessor will be given in later subsections of this documentation.

3.3.1.1. Microcontroller Selection

When searching for a microcontroller, the question that the team asked was "what was needed to get the system running?" without looking at the reality being that a microcontroller is capable of doing a lot more than what was needed for the final prototype of the ECO-SEC system and at such a low price that selecting the microprocessor that does the most was the best approach. Because of the above reason, there was no need to worry about cost, performance, or input and output pins, as most microprocessors have at least 100 pins. These 100 pins were more than what was 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). The following subsections describe the requirements that the microprocessor was required to meet in order to fulfill all the specifications of the final prototype detailed in this documentation.

3.3.1.2. I/O Required

The following were the I/O requirements of the microprocessor for the final prototype of the ECO-SEC security system. The microprocessor chosen by the team had to be capable of fulfilling these requirements.

1. 3 UART connections. One UART connection is used by the LCD touch screen interface. One is used by the embedded web server. The final UART is used by an XBee transmitter which the final prototype uses to allow the sensors to communicate with the microprocessor.
2. Power VCC pin requiring no more than 3.3 V that would be provided by the power subsystem.
3. Pins – at least 30 or more individual pins. Two pins were used to connect the siren/buzzer to the microprocessor to allow it to sound an audible alarm. The remaining pins the team decided to hold in reserve in order to leave room for the possible expansion of the design if the team wished to make it marketable at a later date. These extra pins however, were not used in the design of the current final prototype.

3.3.1.3. Programmability

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

3.3.1.4. Processing Power and Memory

Since the majority of the instructions that are performed by the microprocessor chosen for the prototype are relatively simple computationally, then not much processing power or memory was required. However, selecting a microprocessor that has more processing power and memory then was used by the design of the ECO-SEC. This was a preferred situation when purchasing a microprocessor as opposed to choosing one that did not have enough performance or memory. This situation was also useful in case when updates were required to be added to the software by guaranteeing that any future updates would not use more memory and processing power than was remaining after implementing the prototype.

3.3.2. Battery

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

There are many different types of batteries that the team considered; however several different types could be ruled out quickly. To start, the lead acid battery was 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 was a concern. In rare cases homes will not have AC or solar power for an extended period of time. Therefore, the ECO-SEC required the ability to have a long lasting battery allowing the system to function for a few days without a power source. For similar reasons, alkaline rechargeable batteries were 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 required a battery that could 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 satisfied this goal.

It was more difficult to make a choice between the remaining types of rechargeable batteries. There were three general types of batteries left to consider were: Nickel Cadmium (NiCd), Nickel-Metal Hydride (NiMH), and lithium batteries. Nickel Cadmium batteries were 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 due to the large size of the battery. This type of battery also has performance problems if not fully discharged periodically. If not properly maintained, NiCd rechargeable batteries 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 required a battery that can be continually charged and rarely, if 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 required strict charging limitations would have been 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 final design of the ECO-SEC was a relatively low-power device. Having a high output was unnecessary. The disadvantages to NiCD batteries far outweighed their advantages when considered for this project.

Nickel-Metal Hydride batteries were 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 design does not require the user to 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 would be required to use trickle charging to keep the battery working. This was 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 made 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 required a battery that could 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 would have added 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 if it were to be used in this design.

The final type of battery under consideration was the lithium battery which was 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 which made it an ideal choice for the ECO-SEC. This was because these batteries do not have the memory effect involved in the other types. Furthermore, lithium batteries have a high cell voltage which made 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. The final design of the ECO-SEC required designing a similar protection circuit to use lithium batteries. 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 was justified by the decreased size of the battery and making a much more practical charging circuitry design. The decreased size also made the power subsystem easier to manage and more user-friendly. Despite these faults, it was clear that lithium batteries were 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 that the team had to consider: Lithium Ion and Lithium Polymer. Lithium ion batteries provide the highest energy density when compared with the Lithium polymer. They also offered 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 was important for the ECO-SEC because the team did not want the user to have to frequently replace the battery or worry about the battery failing during a power outage. Another drawback to the lithium polymer was its high internal resistance. As a result, it was not able to deliver large and fast bursts of current to the 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 was 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 which would have made the design for the power subsystem simpler. 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 were more important to the ECO-SEC's design.

Batteries also differ based on the amount of power they deliver and the voltage at which they operate. Since most of the subsystems receive their power from the battery, the general idea was 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 was 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 desired 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 was that it provided very little additional support to pass information to the microprocessor. This server only supported standard HTML and would have required CGI scripts to provide this communication. This would have made designing and coding the embedded web server a very complex task. The high cost of this chip also 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 were 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 have required that every calculation be completed by the microprocessor and would have greatly increased the amount of code needed to successfully program the microprocessor. The DS80C400 also had 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. This alone would have made 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 have been 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 specifications that the team required of the website that the security system uses. The website built for the system was aimed more at simplicity and ease of use over appearance and the numbers of users logged in at once so it did not require a very power web server. Additionally the SP1 was 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 had successfully used this chip within their own senior design project as well as other sources recommended this chip for projects of similar levels of difficulty with similar requirements. As a result the team decided to use the SP1 - SitePlayer HTTP Web Server OEM Module to implement the website that can be used to configure the security system. Additionally another aspect which placed the SP1 ahead of other available embedded web servers on the market was the relative ease in which it could be incorporated into the prototype design. Programming the SP1 was simpler that most web servers because it used a coprocessor that handled a lot of the more complex instructions for the user. The user simply had to issue a command to the Site Player through a serial interface and the coprocessor for the web server handles the rest. So instead of needing to add extra complex logic to the design of the microprocessor like other models the SP1 allowed the team to 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 was 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 was naturally the interface used to connect the web server to the internet allowing outside access to the webpage. The SP1 contained all the necessary Ethernet stack protocols built in. This allowed for easier programming to use the SP1 and the designer was not required to include extra code for implementing these networking stack protocols. The next interface the SP1 had was pins to support a standard RS232 Serial Port. This allowed the site player to easily communicate with either a standard PC or a microcontroller. This is the interface that was 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 could 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 attach 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 could 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 included 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 it's 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 also left the team with more time to develop the printed circuit board that will be used to house the power subsystem and the microprocessor as well as to complete the other subsystems of the ECO-SEC prototype.

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 was used to interface the development board with the microprocessor in the final prototype design, and the RJ45 Ethernet connector was used to allow the web server to be accessed from a remote location via the Internet. Also included is a power regulator system so the power subsystem developed for the ECO-SEC only needed to provide the correct input voltage and amperage. The development board handled the rest of the regulation.

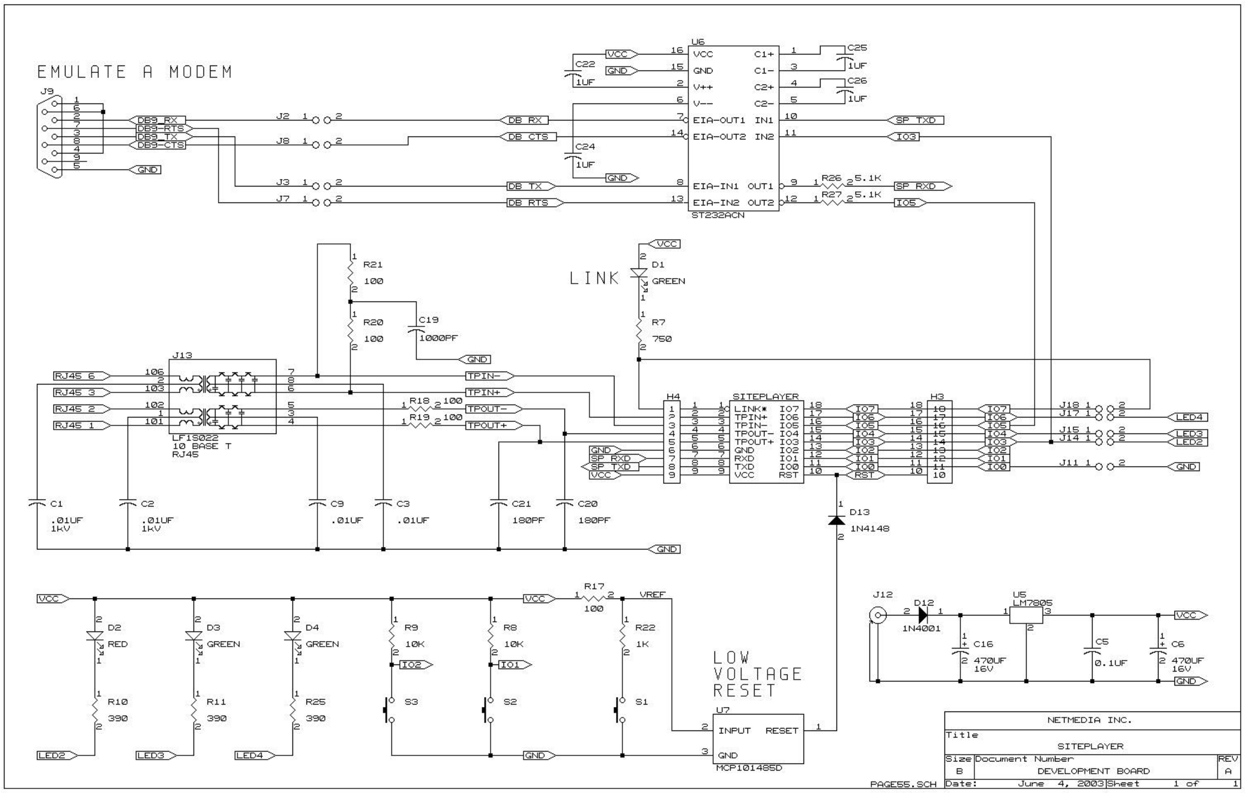

Figure 5: SP1K Development board Schematic, permission requested from Net Media Inc.

The SP1 chip costs $24.95 while the development board only costs $79.95. The team decided to purchase the SP1 development board for the final prototype. This was because it included all the parts necessary to implement it within the design of the prototype as well as saving the time and cost to produce a PCB that would be almost exactly the same as the SP1K development board. In the end the team decided that this subsystem should be more software focused than hardware by using a prebuilt and designed board.

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. 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 was extremely expensive. The screen alone for this display cost $81. This cost also did not include any controller boards for the display. Any LCD touch screen interface requires a controller board for the screen to function correctly. 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 was much larger than the project requires with a much higher resolution. The security system was designed to use the LCD display to display buttons and status indications for the system and as a result did not require a screen of that size or resolution. For these reasons the group decided to rule out this touch screen display as a possible choice for the final prototype.

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 could operate anywhere from -10 to 60 degrees Celsius and was 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 cost approximately $43.75. This cost was 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 did not include a controller board, so once again more expense would have been needed to buy a controller board, not to mention finding a board that would be usable with the display as well as be easy to implement in the final prototype 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 was available for purchase from Reach Technology Inc. This display was a standard resistive touch screen. It boasted a resolution of 480x272. Although this was much lower than the others previously examined it was more than enough to display what was required by the security system prototype. Additionally this screen possessed the largest temperature range of operation at -20 to 70 degrees Celsius. This range allowed the screen to be used by the security system in any home in any kind of environment within reason. What truly separated this screen form the others was Reach Technology sells it in the form of a development kit. This development included the screen as well as the SLCD43 controller board that was used by the display win it was implemented in the final prototype of the ECO-SEC security system. This development saved the team time and effort by not having to locate an individual controller board as well as making sure it was 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 cost $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. Additionally the higher cost could be justified due to the increase user friendly functionality allowing this LCD screen to have been easy to implement within the final prototype design.

Since the main benefit of the development kit from reach was the included SLCD43 controller board, a more detailed description of the technical specifications of this board was required. This controller board was designed to be the same size of the screen and is mounted behind the screen. This worked 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 if the ECO-SEC where ever decided to be marketed at a later date. Additionally this board interfaced extremely well with others devices capable of communication via a RS232 serial port. This worked well because the microprocessor chosen was 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 contained 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 was 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 would have added 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 if these other displays where used in the prototype. However, the SLCD43 Controller board used its own syntax to program that was easy and quick to learn which allowed 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 used a security camera to serve one primary function. This main function was to allow the homeowner to be able 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 had to be able to support this feature.

To achieve the primary function the security camera had to be capable of communicating what it "sees" with the embedded web server in real time. This was possible to accomplish by using HTML to create a composite HTML page that is in reality two separate pages but when viewed by the user via their browsers appears as one. So with regards to the ECO-SEC the first page created was the actually website while the second page was the live feed from the camera. The chosen embedded web server supported this feature of HTML but with one minor condition that had to be fulfilled. In order to have been able to create a page from the camera, the camera had to be able to be assigned its own unique IP address. This address was 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 limited the selection of security camera available for purchase on the market that meet this requirement. These cameras became limited to network cameras. 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 was a powerful and small camera based upon software that was fully and completely open source. The CMUCam3 was capable of communicating with an attached device via a standard serial connection. This would have allowed the camera to be easily interfaced with the ECO-SEC system's microprocessor if it final design had required any additional information from the camera. The main requirement however, as previously mentioned was the ability for the camera to have its own unique IP address in order to allow it to be able interface with the embedded web server to create a live camera feed for the website. The camera itself had no support for these feature and did 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 was 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 was the AXIS M1054 security camera. When compared to CMUCam3 as well as other models not included within this documentation, the M1054 was 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 was designed specifically for security system and would have worked well with the design of the ECO-SEC. The M1054 naturally had the ability to detect motion in several different which would require the sensory array subsystem to use one less sensor. This would have allowed the team to use the option that was the most accurate for the setting that the ECO-SEC is design to operate in. These modes could 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 included 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 M1054X was one of the best cameras with regards to support for motion detection. The M1054 was also designed as a network IP security camera. This design is what allowed the M1054 to fulfill the prime requirement as discussed previously. The built in API for the M1054 included 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 would have accessible 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 could have been configured via a long series of options in order to configure its appearance and quality. This would allow the team to be able to choose 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 was more 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. This camera was no exception. Upon examination of several companies which sold this model camera it was found to cost in the price range of $300 dollars. In the end the team decided that the price was too high and ruled out the use of the camera.

Since the team liked many of the features of the previously examined M1054 camera with the exception of its price range, another camera from AXIS was examined as a possibility for the security system prototype. This camera was the AXIS M1011. This camera was an older model camera from the same family as the AXIS M1054. It included the same built in support for IP addressing and streaming to a website as the M1054 previously discussed. However it did not contain any support for motion detection that the M1054 did. However, the team decided this feature was not needed as the sensory subsystem was already designed to fulfill these criteria. Additionally the M1011 also as a more dated camera featured a lower quality of resolution than the M1054. The M1011 due to this lack of features, however, was also a much cheaper choice than the M1011 running around $170 for a new camera. In the end since the team did not require many of the features of the M1054 and the M1011 contained all the features that were required by the final prototype design as well as being much cheaper to purchase, the team decided to use the M1011 in the final prototype of the ECO-SEC security system.

3.3.6. Sensor Array Subsystem Microprocessor

The goal of designing the sensor array was to create a series of modular sensors that were 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 was only connected to the main microprocessor at one point using a wireless communication module. This interface allowed 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 require its own microprocessor separate from the main microprocessor of the ECO-SEC. This secondary processor performs all the calculations necessary on the sensor readings before passing it to the main microprocessor. The team decided to use a MSP430 microprocessor because of their low cost and ease of use to implement the sensor arrays within the final design of the prototype. This saved the main microprocessor from having to do these calculations allowing the microprocessor to focus on the required calculations needed to implement the other subsystems in the prototype design. The programming experience that the team had with microprocessors had been mainly on Motorola based microprocessors so any more modern microprocessors such as MSP430, ATTiny or PIC16 would have had 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 had experience using, making it easier to understand how to program these newer microprocessor models. These microprocessor all possessed similar features and the price was roughly the same for the various different models. For the sensor array subsystem, the microprocessor used in its design did not require high speed or performance since it did 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 MSP430G2253 microprocessors that the team explored using for the sensor array design. These processors were compared on several different important features including cost, program memory, performance, and most importantly power consumption.

Feature	ATTiny 24	MSP430G2253
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. MSP430G2253 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 was 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 was 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 interfaced 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 four alarm modes that will be implemented into the design of this prototype are:

1. Off –This mode is activated when the system is disarmed. This mode turns off all sensors by causing the microprocessor to ignore any alarms triggered by any of the sensors.
2. 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. While in this mode all three sensors for the system are activated.
3. 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.
4. 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 accepted as a zone when the alarm is in Stay 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

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 silent alarm code. That is, a code that was 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 was 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. Instead when the user enters the silent alarm code the system simply will email the homeowner as normal.

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 most of the other subsystems in the ECO-SEC prototype. The power signal to each subsystem had to 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 were needed. As shown in the diagram, these output signals can travel to all of the necessary 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 reduced the complexity of the power subsystem, since charging the battery can involve a great deal of design. Overall, it was 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 an efficient way to manage power. If a low battery power level is detected, the system will switch to AC power until the batteries charge state has been restored. The power to perform these checks on the system will come from the incoming AC power, so it was 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 in figure 6.

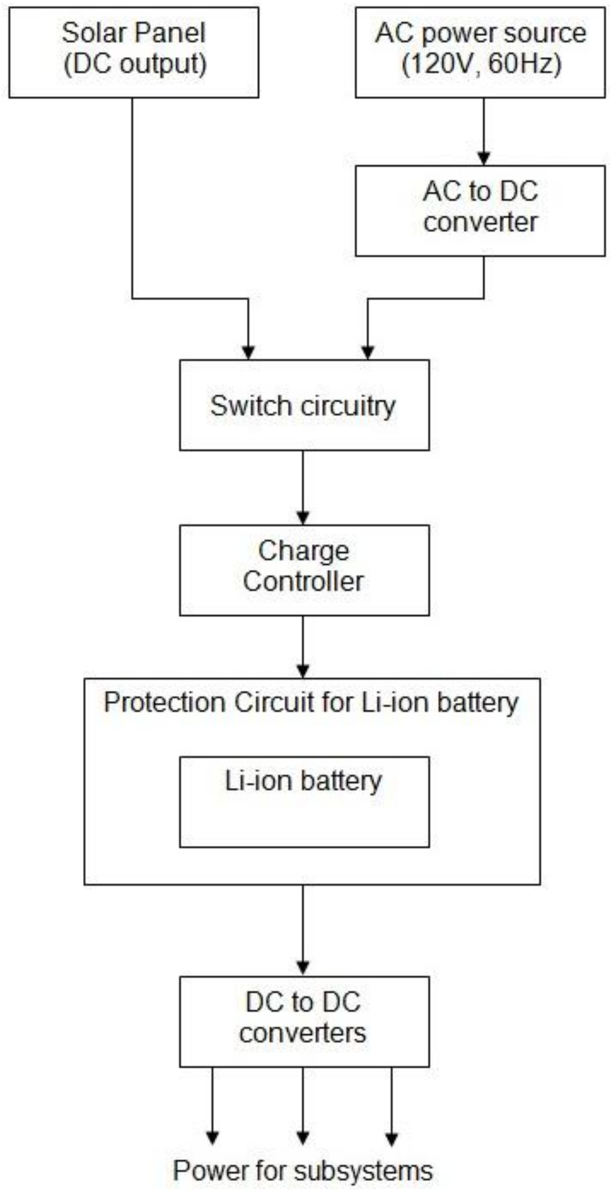

Figure 6: Power Subsystem Block Diagram

4.3.2. Power Considerations Design

In order to design the power subsystem, the power requirements for each individual component had to be considered. The power requirements for the touch screen, web server, and microprocessor were the main components considered since the power subsystem was responsible for providing power to these parts. Since the power requirements for the security camera was so high it was decided to power the camera directly from standard AC power instead of connecting it to the battery. This modification prolonged battery life significantly and reduce the size of the required battery. Furthermore, the camera was 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 involved having the touch screen to adjust its settings. The backlight is reduced to low which reduces power consumption as shown in the table below. This power consumption was further reduced by turning off the ability for the touch screen to audibly admit a beeping noise when a button is pressed. In terms of power, this makes the touch screen much more practical to implement. The last component that consumes a great deal of power was the web server; however, there is no way to optimize its power use. The web server was 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 do not connect to the main power board since this would defeat the entire purpose of a wireless component; therefore, a battery had to be used. The sensors were 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 was 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 only needed power continuously when the alarm is in a particular mode. However, the system was 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 was 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 had 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 was useful when determining the size and life of the battery needed to fit the ECO-SEC's specifications and requirements. The system had 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 was a power loss while charging the battery and when drawing power back out of the battery since the voltage had to be regulated.

4.3.3. Battery and Protection Circuit Design

As discussed in the research section, the battery used was a lithium ion battery. The first issue to discuss is the voltage of the battery. It was decided that an 11.1V battery was to be used to charge the system. In order to achieve this voltage, three lithium ion battery cells had 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 was the best choice for the ECO-SEC since it provided 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 80% efficiency. When considering the combined effects of price, power, and size, it was decided that a 50Wh battery would be a good choice. This implies that the battery stores 4.4 Ah of current which requires a 6 cell battery pack with three groups of three series connected cells connected in parallel. This battery costs roughly $70 including the protection circuit. After calculating for the power loss in the voltage regulators, the battery life is found to be a day. 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 9 to 12 cell battery pack would have to be purchased. Not only would a 12 cell battery be very large and heavy but it would also be expensive costing roughly $125. 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 2 A. This implies that the lowest maximum output is 18 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 is able to simultaneously charge and draw power from the battery. This implies that the battery is 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 did 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 allowed 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 was also important when considering the slight voltage variation across the solar panel that may occur.

The selected charge controller had to meet a certain set of criteria. First, it had to 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 was 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 22V at the input. This is the open circuit voltage of the solar panel and is consequently, the highest voltage expected at the charge controller’s input terminal. Also, the charger will have an efficiency associated with it. A high efficiency was 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 was the MAX745.

Table 7 shown below shows the specifications of the charge controller that was 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 was 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 had to be selected.

4.3.5. Solar Panel Design

The first design issue considered with the solar panel was 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 was 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 had to aligned in a particular way to prevent as much shading as possible.

Many solar panel power systems use maximum power point tracking to force the solar panel to run at the maximum power point. Without such a circuit, the voltage across the panel may not be ideal thus reducing power. It was decided that the ECO-SEC will not use such a system due to the added complexity and cost to the project. Therefore, a "brute force" implementation will be used. Consequently, a larger panel will be required.

The design goal for the ECO-SEC solar panel was 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. While the sunlight varies, the voltage across the panel will change. If the open circuit voltage drops below 15.5V the solar panel will be unable to charge the battery. Balancing price and power, it was decided that a solar panel with an open-circuit voltage of 21V was acceptable. The maximum power point of the panel is 18V. 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. Also, the lack of maximum power point tracking must be considered. Without such a circuit, the solar panel will almost always be wasting power even if its maximum power point produces just enough power to charge the battery. After weighing these issues, it was decided that a 30W panel was a good choice for the ECO-SEC. 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 was 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 was 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 showed 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 was to buy a solar panel within the design parameters described above. A 30 WH panel was 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. The idea behind the switch is to always use solar power unless the battery is low. This implementation is almost ideal as it neglects the case where there is enough solar power to charge the battery and the battery is low. However, this case is rare because if sufficient solar power is available the battery should not reach the low state.

An issue with the switch is that it is difficult to check the amount of power available from the solar panel. The solar panel’s voltage varies with sunlight, but its voltage is more dependent on whether the panel is loaded or not. When a solar panel is unloaded, it operates at its open circuit voltage which in this case is 21V. When the switch connects the solar panel to the circuit, its voltage will drop significantly. Since maximum power point tracking is not used, the solar panel’s output voltage when loaded has no relationship to the amount of power it is receiving from the sun. It depends more on the impedance of the load. To simplify, checking the solar panel’s voltage will not provide a good way to check its power.

An improvement to the switch was also considered where the microcontroller would be able to override the logic presented above based on the information from several flags. The first flag was the battery flag which indicates the state of the battery. The battery flag is also used in the more basic circuit that does not involve the microcontroller. Therefore, additional circuitry is minimal for this flag. Using this information the microcontroller can determine what the circuit will do if it does not send its override signal. The second flag checks the charge rate of the battery using the IBAT pin of the charge controller. This pin outputs a current proportional to the charge current; therefore by placing a resistor between IBAT and ground and checking this voltage the battery charge status flag can be created. This flag is used for determining if sufficient power is available from the solar panel when the microcontroller uses its override pin to force the switch to select the solar panel. Due to the added complexity of this circuit and the minimal benefit to the user, the simpler approach which did not involve a microcontroller connection was selected.

In both approaches, a method for determining if power is available from a particular source was considered. 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).

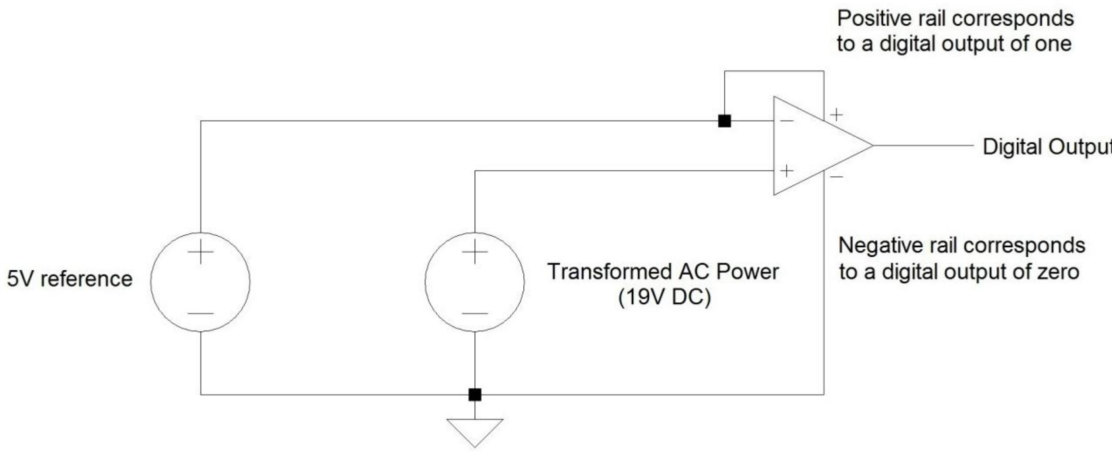

Figure 7: AC Power Flag

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 20V or non-existent.

A better and simpler approach for checking the AC power is to power the five volt reference from the converted AC power then use that signal to feed the rail of the comparator circuit for checking battery voltage (discussed below). In this manner, if AC power is not available, the battery flag will be a logical low. By making the high battery state (use the solar panel) a logical low as well, an AC power flag is not needed. Due to simplicity, the ECO-SEC does not use the additional comparator circuit to check the AC power source.

Checking the standard AC power is simple since the power is either on or off and intermediate voltages will not be present. However, the battery is more complex because the circuit must determine which voltages correspond to high and low output signals. The best way to detect the battery 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 1V and 12V, since the battery voltage varies between 9 and 12.8V. When the voltage drops below 10V, the battery flag will become high indicating that AC power should be used. When the voltage returns to at least 12V, the solar panel will be used instead. In this manner, the flag will not bounce between the different states, and a battery backup is retained. Because the battery 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 8 for the inverting trigger. 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).

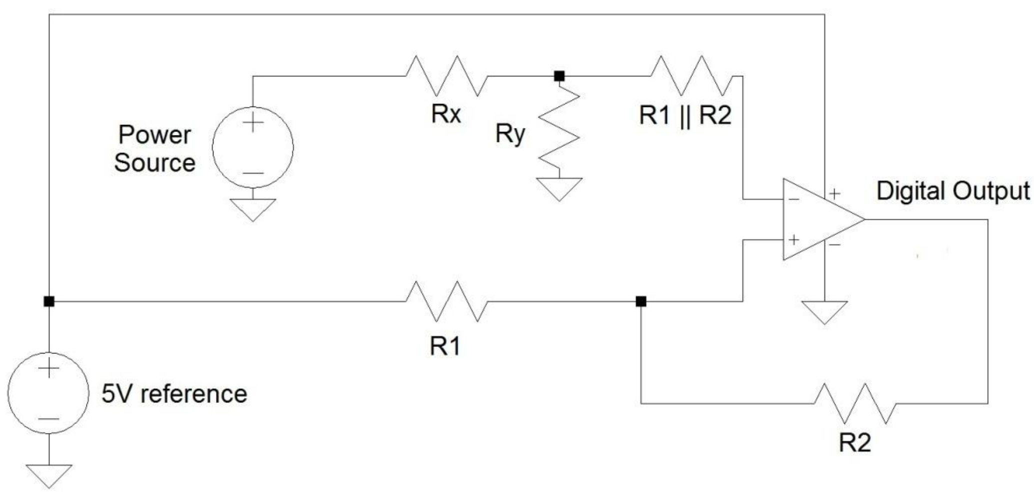

Figure 8: Solar Power and Battery Status Flag

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. However, if the current is made too low it may interfere with the comparator's operation. Secondly, the output current of the op-amp is limited; therefore it should not be used to power another IC.

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 22V. 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.

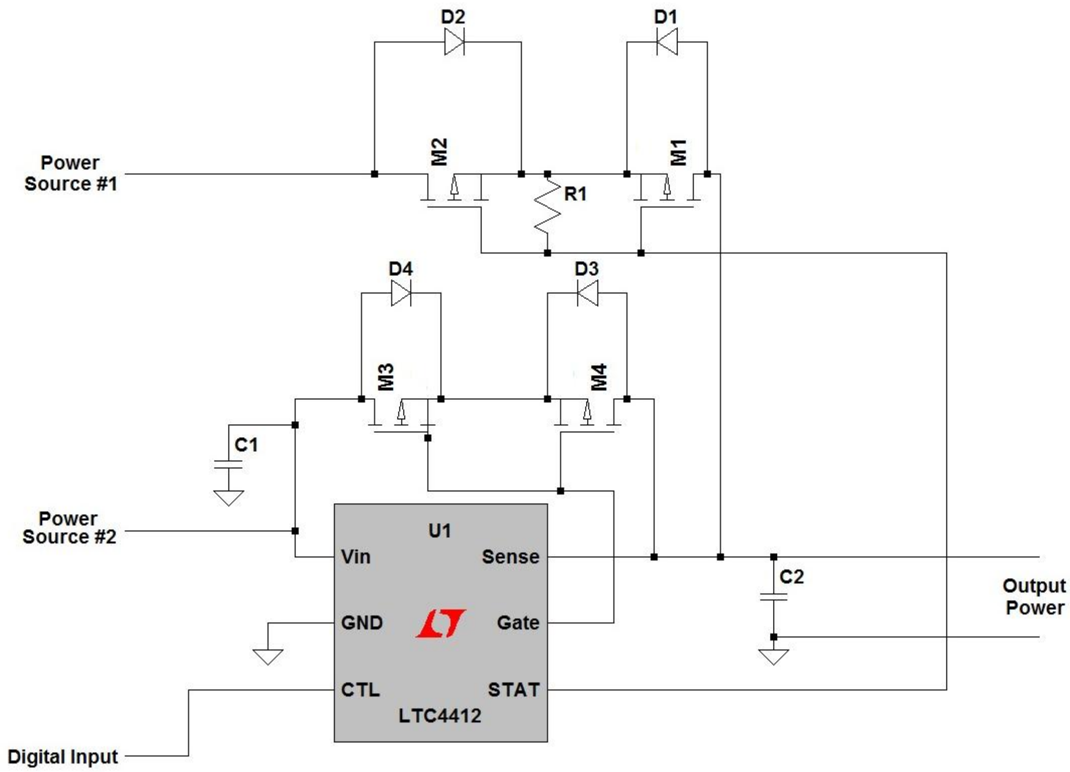

Figure 9: Power Source Selection

A similar but simpler circuit is required at the Power Source #1 connection point. The circuit above is unable to select one power source or the other. Therefore by including another LTC4412 circuit designed to block or allow an input signal, full control over which signal charges the battery is achieved. The battery voltage flag can connect to the CTL line of both LTC4412 ICs. However, the circuit shown above will require an inverter prior to the CTL pin because the battery flag is low when solar power is in use. Powering this inverter proved to be more difficult than originally believed. If power is pulled from the 5V reference, there is not sufficient power for the battery flag circuit. Connecting the output of the 5V regulator to the inverter is a solution. However, when the battery is dead, the inverter will always be low. Notice that this does not create a problem because the battery flag will be high when the battery is low; therefore, the low output of the inverter is the inverted signal. Below a table is shown which illustrates the logic of the CTL pins.

AC Power Status	Battery Power Status	CTL pin #1 (solar power)	CTL pin #2 (AC power)	Result
Available	High	0	1	Use solar panel
Available	Low	1	0	Use AC power
Available	No power	1	0	Use AC power
Unavailable	High	0	1	Use solar panel
Unavailable	Low	0	1	Use solar panel
Unavailable	No power	0	0	Use solar panel (highest voltage signal)

Table 9: Switch Logic

4.3.7. AC/DC and DC/DC Converter Design

The design 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 more manageable signal (21VAC). 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 20V 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.

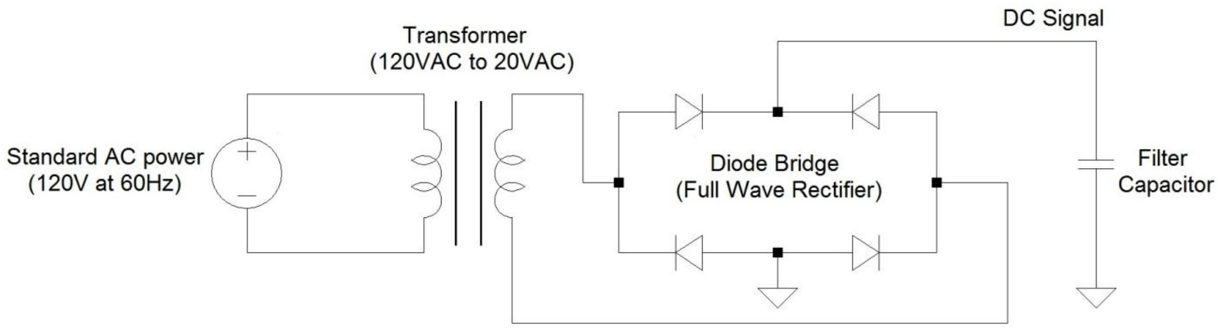

Figure 10: AC to DC Conversion

The diagram above discusses the construction of a linear AC to DC converter. These converters are inefficient and typically require a large transformer especially when working with signals above 15V. Consequently, it was decided to buy a switching AC to DC converter that can connect directly to a wall outlet. This not only simplifies the project, but it increases the efficiency of the converter. Switching AC to DC converters tend to be smaller than linear ones because the high frequency signals require a smaller transformer.

The second type of converter needed is a DC to DC converter that runs from the battery to all other subsystems. These converters were designed to deliver enough power to each subsystem at the correct voltage. This was 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 was 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 allowed 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 10: Regulator Specifications

The voltage regulator for the touch screen and microcontroller was LM2675-ADJ. This regulator has an adjustable output and is therefore an acceptable device for both components. This regulator required 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 was 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 required 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 have simplified the design, but would have caused 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 11 shows the parameters that the Stellaris LM31968 microprocessor possesses and is capable of operating at. The specifications that the team was most concerned about were 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	64 KB	**CAN**	0
StellarisWare	No	**Memory Protection Unit**	Yes
Max Speed	50 MHz	**ADC Channels**	8
Timers	5	**Internal Temp Sensor**	Yes
Capture Pins	4	**Operating Temperature Range**	-40 to 105 °C
USB	0	**Package Area**	100 x 196 mm
UART (SCI)	3	**Approximate Price**	$4.60

Table 11: Stellaris LM3S1968 Parametrics

4.4.2. Electric Characteristics of the Stellaris Microprocessor

Table 12 below shows the electric characteristics of the microprocessor the team chose 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 would unable to function correctly. This table gives the correct input voltage for 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 12: 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 an 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.

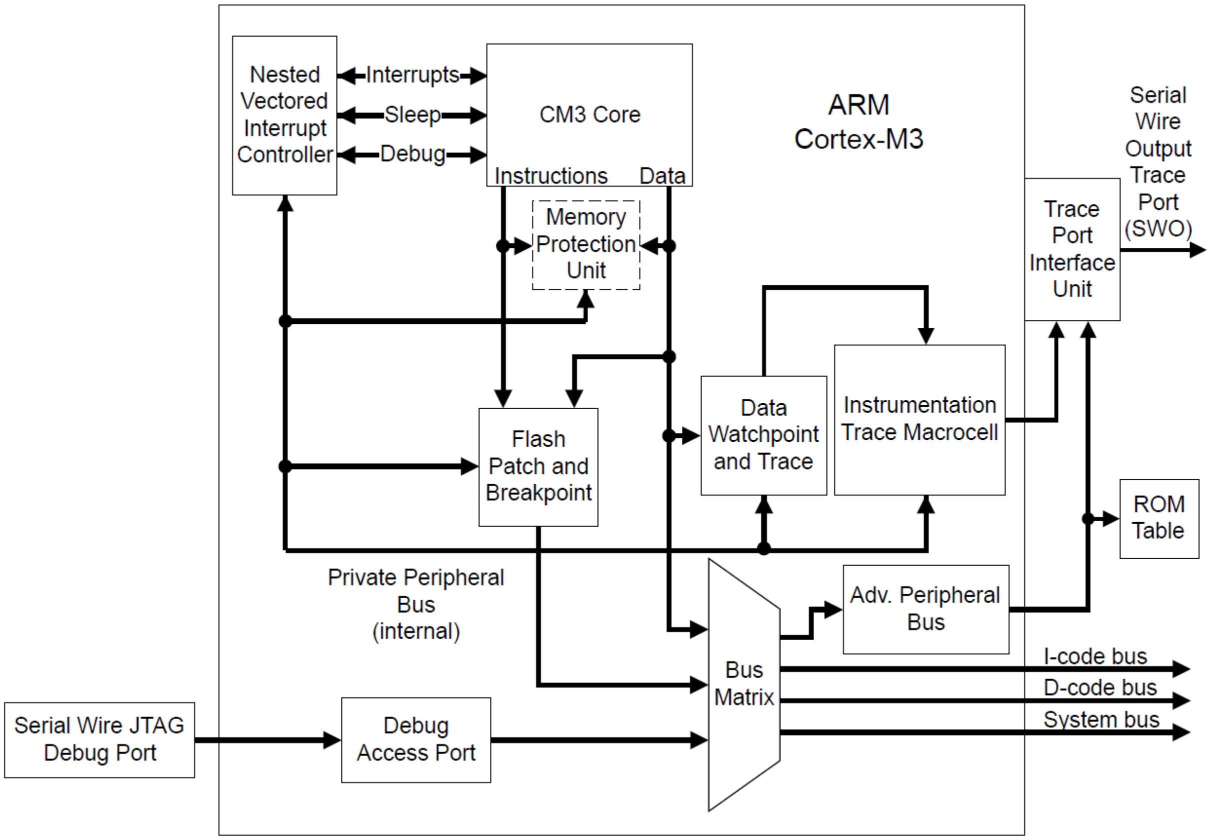

Figure 11: Stellaris® M3 MCU – LM3S1968, reprinted with permission from Texas Instruments

4.4.4. Programming the Stellaris Microprocessor

The microprocessor chosen by the team was capable of being programmed in the C programming language. This was 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 required assembly language programming as well. Although this was not the preferred language of choice by the team, they did have experience developing code using such languages and were able to successfully program the microprocessor with regards to how it was 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 ended up being one of the simplest in terms of design but it still fulfilled an important functionality with regards to the final design of the ECO-SEC prototype. The security camera provided the live video feed stream for the web site.

4.5.1. M1011 Electrical Characteristics

The AXIS M1011 can be powered via two different sources with different power requirements. Table 13 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 13: M1011 Electrical Characteristics

4.5.2. Camera Video Feed

One of the most important features of the M1011 security camera was 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 accessing the camera video feed via the web site was accomplished using a simple Java Script embedded within the HTML code used to create the ECO-SEC website. This was able to be accomplished 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 M1011. So all the website needed to do was dedicate a portion of the site that will display the website using the chosen URL provided by the camera.

4.5.3. Setting up the Camera

Setting up the camera involved two main steps. The first was setting up the hardware used by the camera and the second was setting up the software that governed the behavior of the camera. Setting up the hardware for the camera was a relatively simple process. All this entailed was 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 were used by the security camera. These connections entail connecting the power port of the camera to the correct power source and connecting the Ethernet port the same router that the embedded web server is connected to. This allowed the camera to be able to be located on the network by the embedded web server in order to display the video stream on the website as previously mentioned.

The next set in setting up the camera was to setup the software that governs the behavior of the camera within the design of the ECO-SEC prototype. The first step was to setup the IP address that is used to identify the camera on the network for the ECO-

SEC system. This IP address was used to login to the camera to changes the options on how it operates. After this the camera was set up with a password. This prevented anyone from logging in and turning off the camera remotely or changing how it operates. This security was important to have in the design of a security system. Setting up these two features was accomplished through a simple installation program that is included when purchasing the camera. This software was also available online in case the camera was purchased second hand as a used item. The team however ended up purchasing a new camera instead of using a used model.

After the IP address and password for the camera has been set up the next step was to change the options that govern how the various features of the camera operate such as the quality of the video stream and if a password is required to view the video stream. This was accomplished by logging onto the camera using the IP addressed assigned to it. This took the team to a webpage which contained a live view of the camera as well as menu choices for the user. The most important of these was 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 needed to be setup were the video stream and assorted security parameters.

Setting up the live video feed from the camera consisted of setting up several different options. The most important option of the feed was the frame rate. The camera could 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 was set too high, the camera began to use all the bandwidth of the network it was on preventing any other network activity. In the case of the ECO-SEC this prevented the homeowner from being to access the website or to use any of its features. In order to prevent this, the frame rate was limited to 30 frames per second. The next step hat needed to be set up was what type of video encoding the camera will use for the live stream. These were 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 was important because if an incorrect encoding was used that was not support by most browsers, the homeowner will be unable to see the stream correctly when using the web site. The M1011 supported a few different encodings including MPEG and Motion JPEG which was designed specifically for video streaming. However, since it was a slightly older out of date model, the M1011 does not support the newest video encoding format of MPEG-4. In the final prototype, the team ended up using the Motion JPEG format to stream the video to the ECO-SEC website. These were the two most important settings for the video feed. The user was also able to adjust camera settings such as brightness and contrast as well which will affected the images the video camera recorded for the stream.

4.6. Sensor Array Subsystem

This section of the documentation will describe the various sensors that were included within the design of the sensor array subsystem for the ECO-SEC security system. This subsystem included three main sensors; a glass break sensor, a door/window TIR sensor, and an infrared motion detector. Each subsection below will provide greater details on how the technology behind these different sensors work and how they functioned and what purpose they served in the 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 was 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 was 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 required a different type of microcontroller because it required the ability to sample sound at a rate of around 32 kHz. This sensor was designed based up schematics provided by Texas Instruments as an inspiration. Modifications were made from the Texas Instrument designed in order to better fit the needs that the prototype had for this sensor. This design used a serial interface to the wireless transmission module which was powered by an MSP430 microprocessor and XBee to communicate to the base station located on the main microprocessor printed circuit board. The microcontroller of the sound detector was a MSP430F2274IDA. This microcontroller is capable of cycling on at 8 MHz; it is in an off state for 2us and then listens for 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, is 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 is not fully perfect nor was expected to 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 attempted to account for this variation as much as possible in order for it to function correctly as possible in the final design of the ECO-SEC prototype.

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 was that the distance that was 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 would have had to be installed about ¾ of an inch apart in order for them to work reliably. The solution that the team used in the design of the ECO-SEC prototype was 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 indicated that the fiber module could be installed an inch or more away from the LED and photodiode. This was tested later during the design phase of the prototype. Ideally the frequency was as low as possible to conserve battery but fast enough so that it cannot be open and closed without detection. The team estimated that this frequency was around 1-2 Hertz or if security was needed it could also have been a random frequency.

The pulsing of the light was 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 MSP430G2253 microprocessor 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 resume 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. Along with all of these features a 7 segment display was used to aid in troubleshooting by sending error codes if needed.

4.6.3. Infrared Motion Detector Sensor

The motion detector used was a digital quad type element that senses movement via its Fresnel lens. This sensor was designed implement 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 came with a built in amplifier circuit, stabilized power supply and comparator ready to connect to a microcontroller giving it a 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 10 M types. For the design of this system the team chose the 10M model but there was not a 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. The design needed 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 the team picked this motion sensor was 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 was when movement is detected it was 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 12 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 was used in the final prototype for the ECO-SEC.

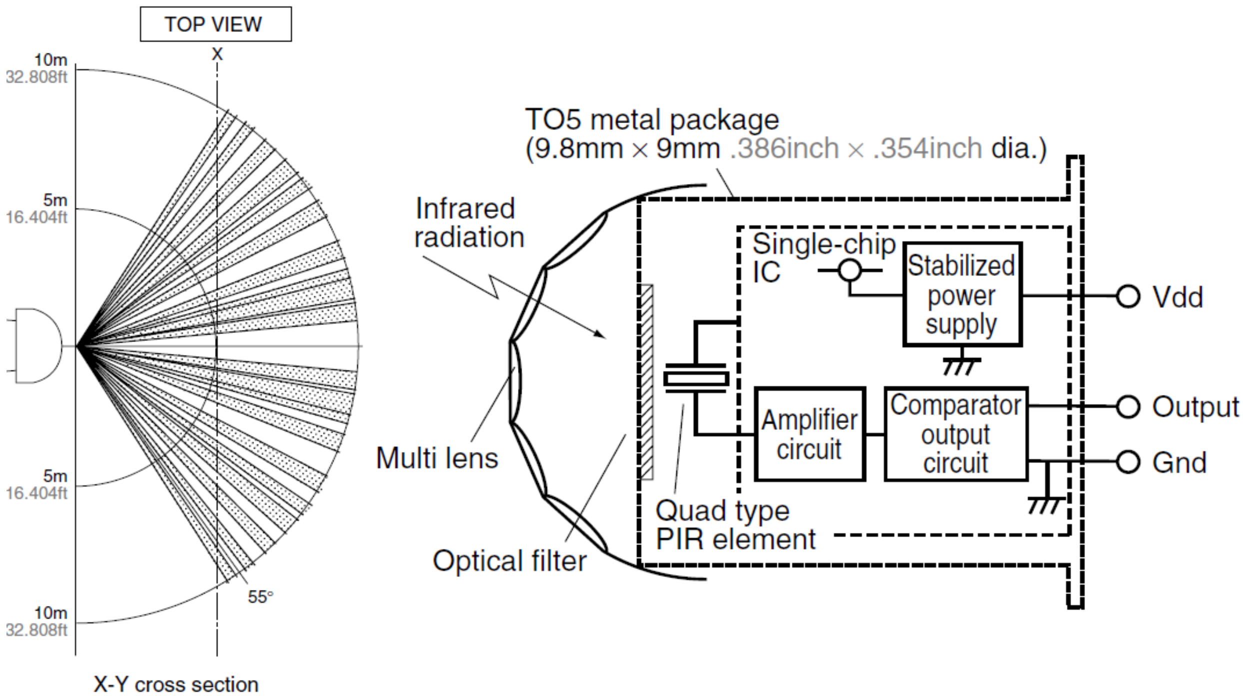

Figure 12: Infrared Motion Detection Sensor, permission pending from Panasonic

The connector itself was only 23mm in length including the leads, this made the motion detector very good for hiding inside toys or other inconspicuous devices not just your plain white rectangular motion detector found in most home security systems if the team had decided to. The planned method to connect the motion detector to the MSP430 and the battery was 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 MSP430G2253 are both rated at 3.6 volts so they did no need to have their voltage adjusted. They only needed capacitors that were 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 to allow the user to easily change which mode security system is operating in. This was 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 was 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 change the systems mode. Instead the user can simply press a few buttons on screen as they walk out of their door. The web server was 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 was 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 was 51-007. Although some of the specifications of the display were discussed previously when doing a product comparison of various LCD displays, it was important enough to give a full specifications of the display in order to understand fully how it fulfilled the requirements of the project.

The LCD display was connected to the SLCD43 Controller by the interface connector. The controller was the more important part of the display subsystem and was responsible for determining the layout of the touch screen and how it responded 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 related to the overall design of the final prototype for the ECO-SEC security system.

4.7.2. Interfaces

The LG Phillips display module contained only one main interface. This interface was used to connect the display to the controller board. The microprocessor that was attached to handle passing data to and from the display was connected to the controller board. The microprocessor was never directly connected to the display module itself. The interface used by the LG Phillips display was 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 had to receive power within the correct voltage and amperage range. Inability to correctly provide power would have caused the display module to fail to function and could have very likely resulted in damage to the physical components of the module. Power to the module was supplied through select pins provided by the LCM connector on the display module. Main power for the display was sent through the controller board. The controller board explained later in this documentation contained 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 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 was the processing power behind the LCD Display. It was responsible for providing the interface the user sees on the display when they use the interface as well as determining how the interface should have responded to the user pressing the screen. It served to bridge the gap between the touch screen display and the microprocessor of the security system. The SLCD43 board was designed to fit perfectly with the size of the 4.3 LG Touch Screen Display.

Figure 13 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 was used to connect the SLCD43 Controller Board to the LCD display module. The J2 COM Connector was used to connect the SLCD43 Controller Board to the PowerCom4 Board to provide power to the controller board.

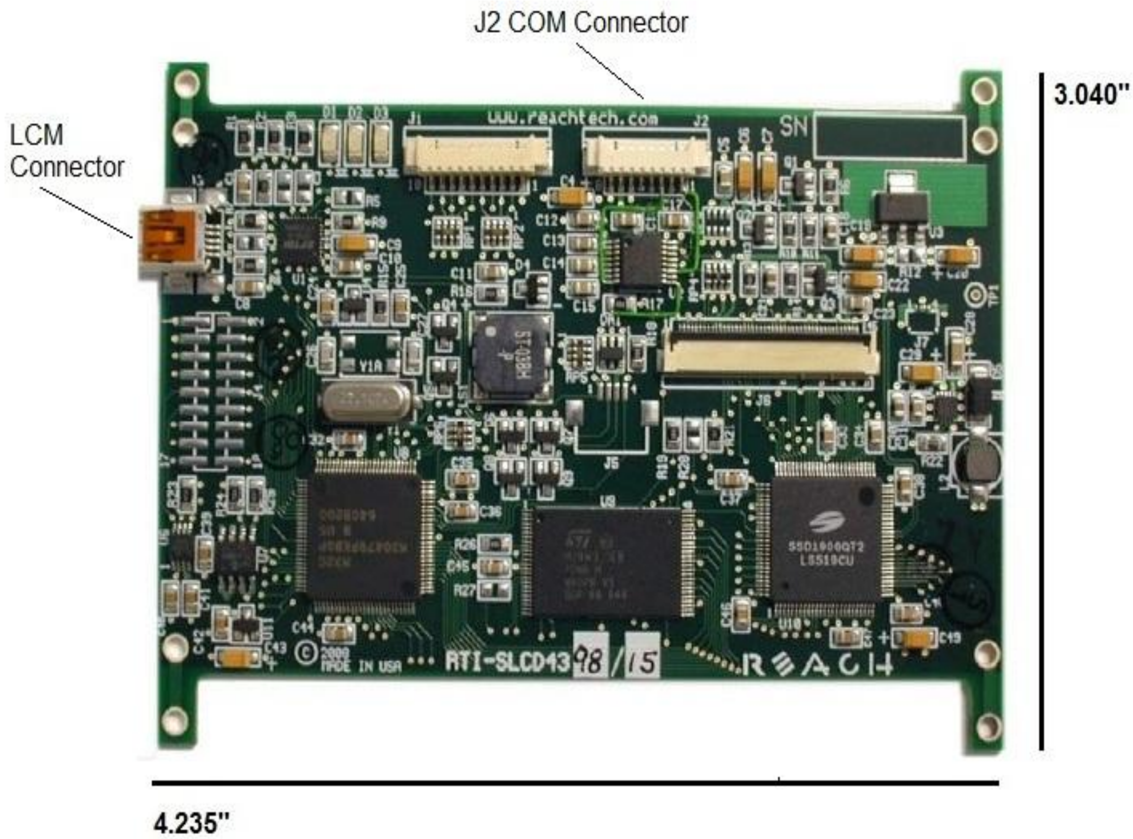

Figure 13: SLCD43 Controller Board, reprinted with permission from Reach Technology Inc.

The SLCD43 included flash memory as well as a small CISC processor. These components of the controller board are what allowed it to load the images that were displayed on the screen and change the images as the screen was used, such as changing the appearance of a button when it is pressed down versus not pressed. The CISC processor was also used by the controller board to handle processing macros created that are executed when a button, switch, etc. was 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 was required from the PowerCom4 board to power the controller board. The SLCD43 always requires 5 V of DC current in. What differs was the amount of amperage this voltage must provide. The amperage varies based on two settings for the LCD touch screen display, whether the beeper was 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 was on full or if it was on low. In order to limit the amount of power this subsystem required to ease the burden it placed on the power subsystem particular with regards to solar power and the backup battery the team decided that the LCD touch screen display would 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 was responsible for providing the necessary firmware to drive the Phillips touch screen LCD and was more important relative to the overall design of the ECO-SEC system. The PowerCom4 board purpose was to support the controller board and it does so several ways. The first was 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 contained the DB9 RS232 communication port that the controller board uses to communicate with the attached microprocessor. The controller board filters the 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 contained several useful features 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 was functioning correctly and recognizes the users touch. This feature was useful in allowing the team when developing the prototype to check to make sure every button programmed onto the LCD touch screen was recognized by the controller board and that the interface took the appropriate action when the user the pressed a button on the screen.

Figure 14 shown below shows the PowerCom4 board that supported the SLCD43 as part of the development kit that was used to implement the LCD touch screen subsystem within 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 was used to reset the LCD screen in case an error had occurred during prototyping or use. SW2 is the select switch which was used in the case an LCD screen was not attached to the connected controller board. This could have been used to prototype without having the actual screen attached but was not used by the team during development phase of the ECO-SEC. J2 and J3 are the connectors used to connect the controller board to the PowerCom4 board. Which of these two connectors was used determined which of the two serial connectors needed to be attached to microprocessor. The LCD display module used was design to support two connected devices but with regards to the design of the ECO-SEC system only one was needed. The J4 connector was not currently used by the main design and was reserved in the case that the team decided in the future that they would like to expand upon the features of the ECO-SEC at a later date, but with respect to the final prototype of the ECO-SEC system this feature was not used.

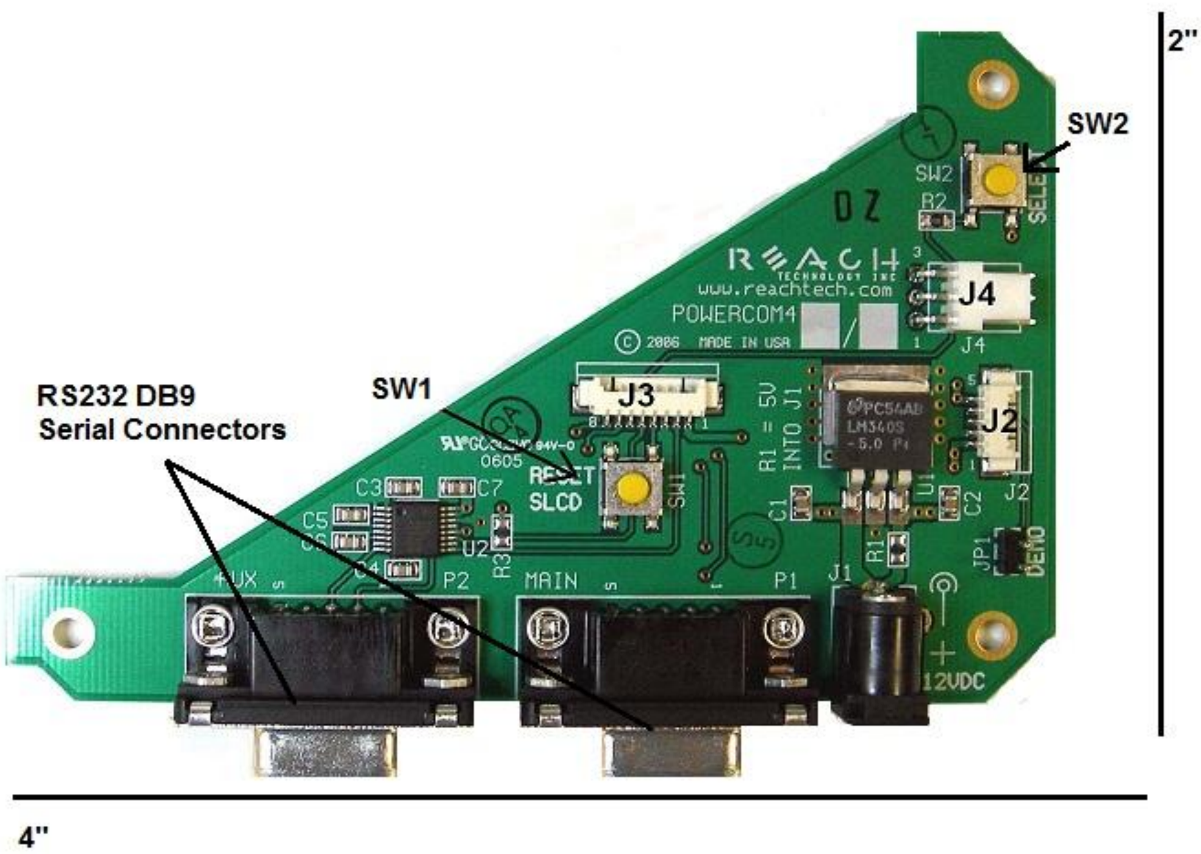

Figure 14: The PowerCom4 Board, reprinted with permission from Reach Technology Inc.

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

Bitmap files are loaded onto the SLCD43 using the program BMPLoad. This program was included as part of the purchased development kit. Figure 15 shows the BMPLoad program when it was first run. The following sections will detail how the program worked and it was 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 was the software that was used by the team to load what images were to be displayed on the touch screen display during prototype development.

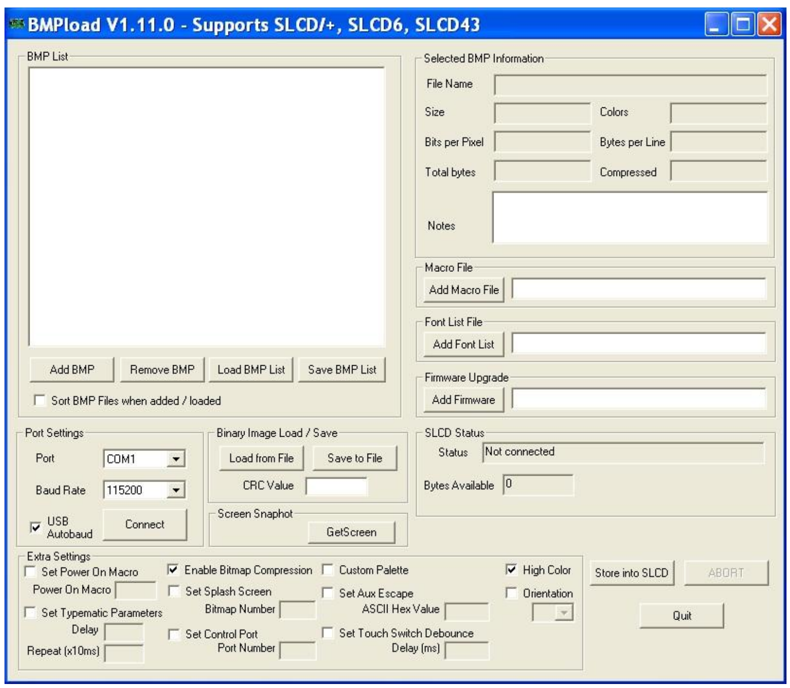

Figure 15: BMPLoad Program, reprinted with permission from Reach Technology Inc.

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

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

The next step was to connect to the controller board using the serial port connection between the board and the PC in order to issue the commands that were used informs the controller board where to load what images and what should these images do if they are touched by the user. (This is important in the case of buttons, switches, and etc. that use .bmp files for their appearance and then produce a result when pressed.) These commands were issued from the PC to the SLCD43 using a terminal program that recognizes the connection between the PC and the controller board to test that the design created was what was desired. Later when the design was finalized all these commands used to create the interface were stored in a macro file. More details on macros as they pertain to their use in the design of the LCD touch screen interface are given later in this documentation. Lists of recommended terminal programs are included within the development kit.

Table 15 below shows some of the more important program commands that were 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 made sole 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 were the most relevant with relation to designing the final working prototype for the ECO-SEC security system. Note that additional commands were used when creating the interface but the table below shows how these are commands are structured and what syntax they use.

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 an 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 supported the use of macros that could be loaded into the memory of the board similar to Bitmaps images. These macros were loaded into the controller board's flash memory in a similar method as .bmp files by using the Add Macro file button. Macros allowed for a series of commands to be executed by issuing a single command. This saved a lot of communication overhead by not requiring multiple commands to be sent from the attached microprocessor to the SLCD43 board over the serial port when a changed needed to be made to the interface because the macro file and commands are saved on the board in flash memory. This made it so the microprocessor had to only send the one command to call the macro. Macros used by the controller board were limited in the number of macros, the number of arguments, the call depth of macros, etc. These limitations were defined by the firmware for the SLCD43 board. Specific details on these limitations can be found in documentation for this controller board. Macros were used to implement the changing the status of the system being displayed when the system enters a new mode of operation. When the microprocessor needed to handle the logic for switching the security system to a new mode of operation it simply issued a command to the SLCD43 controller board to do so. The microprocessor simply had to call the correct macro that contained 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. Macros were also used to create each of the three individual screens that formed the LCD interface. Exact details on these macros can be found in the section of this documentation dealing with the prototype design for the LCD touch screen interface for the ECO-SEC security system's final prototype.

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. to incorporate the web site user interface developed for the ECO-SEC security system prototype. 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 ended up being needed by the team during product development and eventually used in the final prototype design. Some of these include the serial connector, the Ethernet connector, and the power connector. Since the board was 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 required 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 was 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 16 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 was a led indicator that lit up when a connection was successfully made with the SitePlayer SP1 module on the development board. This feature was useful when prototyping the web server because it allowed the design team to easily determine if a connection was successfully 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 was not overly large and did not contain a lot of parts that were wasted within the design for the final prototype. The only features the final prototype did not use in the final implementation was the two input switches but the reset switch was used to reset the system in case of a system crash occurring during design or use of the embedded web server. 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 were a series of jumpers which could be used to configure the serial interface of the development board. This allowed the board to be easily connected to any other device with a serial connection whether it was a PC used during development, or the microprocessor subsystem for the final product prototype.

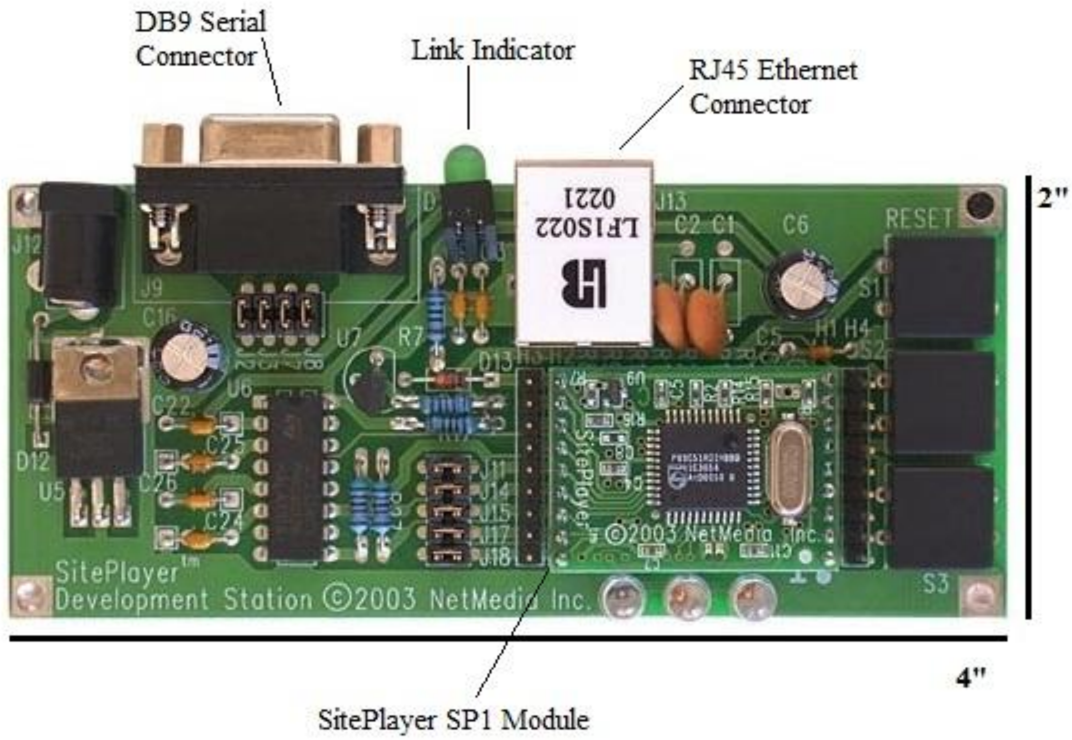

Figure 16: SitePlayer SP1K Development Board, reprinted with permission from Net Media Inc.

4.8.1. Interfaces

Although briefly mentioned previously this section provides 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 was the serial connector. This was a standard DB9 RS232 connector. However the SP1K used 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 inverter to enable or disable it by adjusting the jumpers on the board. For the purposes of the ECO-SEC prototype the inverter was enabling in the final design in order to allow the SP1 to communicate correctly with the microprocessor subsystem. The serial connection was 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 was 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 was readable by the microprocessor was another reason why the development kit was 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 17 below shows a table that illustrates how these connections could be manipulated to change the operation of the developments boards' inverter. The inverter used by the board was the ST232CAN inverter. Although some microprocessors do use the inverted signals most do not so including the microprocessor used for the final design of the ECO-SEC. The inverter was set active in order to switch the commands reached from the SP1 into the correct format that was 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 17: SP1K Development Inverter Configuration Header Connectors permission requested from NetMedia Inc.

The second important connector contained on the SP1K was the connector used to connect the web server to the internet that allowed remote users to login in and access the website contained on the server. The SP1K used a LF1S022 Ethernet connector to accomplish this. The LF1S022 connector shared the same form with a more standard RJ45 Ethernet connector but included 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 as 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 was included as part of the design for the ECO-SEC. This connection allowed 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 was 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 was important to provide a detailed review of the power requirements for a Site Player SP1K Development board as it was used as the main hardware for the embedded web server subsystem. The SP1K board uses a standard cylindrical plug as its power connection and required a steady 12V DC power source with 100 mA (minimum) center conductor positive current. This was 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 required a lot of power which will brought a strain to the power subsystem and was difficult to be able to incorporate it to be run off of solar power with a backup battery as provided by the power subsystem. Finding a way to successfully implement was one of the more challenging concerns the team faced 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 was important to understand how the embedded web server needed to be programmed in order to correctly display the desired website. This process was not overly difficult but contained more difficulty then designing an average website simply because the web site designed on the web server had to be able to communicate with the microprocessor. This is what allowed the microprocessor to adjust its behavior as the user adjusts settings via the web site on the embedded server. The Site Player SP1 was 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 a standard form of HTML as well as creating the Site Player Interface File (.SPI), and assembling and downloading onto the SP1 web server the Site Player Binary file (.SPB) using the SiteLinker program.

The first step in programming was designing the definition file. This file was structured in a manner than was very familiar to a more standard assembly language file. The .SPD file was divided into three main sections, the definition section, object section and export section. The definition section was used to specify the initial start up parameters of the Site Player SP1. This included such things as site player update passwords, enabling or disabling DHCP, defining the static IP address of the SP1 server, etc. The second section defined any objects used by the Site Player website. Objects are variables with a defined name, size, and default value. These objects are how the Site Player and the website it hosts were able to communicate with the attached microprocessor that was used to in the design of the security system. Naturally in order to facilitate this communication between the website and the microprocessor, the objects defined in the .SPD file were required to have the same variable name as their counter parts contained within the HTML files that are used by the Site Player to generate the website used by the security system. The final and third section in the definition file was the export section. This part defined how and where the Site Player exported files during the linking process. This could have been 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, the security system did not require any such action, and as a result this section was not needed by the project. This did 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 was ever expanded beyond the specifications developed during this course. With regards to the design of the ECO-SEC, Site Player objects were 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 entered one of these changes on the website, using a SitePlayer object allowed the site to simply change the value associated with this object and then the SP1 simply had to pass these new values to the microprocessor in order to inform it how it needed to change its mode of operation to reflect system changes made by the user via the web site.

The definition file was divided into several subsections. The definitions section was 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 was the object definition section. Each object was defined by a name followed by the type of data it represented followed by an initial default value that this object takes when the web server is reset. These data types were limited to those that can be expected to be supported by most assembly languages. These objects could then be used later by the designed website to pass their values to the attached microprocessor. The last section was the export section. The export section as previously mentioned was not used in the design of the ECO-SEC prototype embedded web server subsystem because it was not needed to meet the goals of the subsystem. The sections with the most relevance to the design of the ECO-SEC were the definition section and the object definition section. The definition section needed to be used to correctly set up the correct IP address and other features for the SitePlayer so that users could successfully access the website. Incorrectly implementing this aspect would have prevented the SitePlayer from being able to be located by users. The object definition section was 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 most important object defined in this section was an object that held a string indicating what mode the system was operating in so the web server was capable of displaying the correct status information. Other objects were created in order to implement the use of the serial port to allow the web server to pass data to the microprocessor.

The second step in programming the Site Player module was to design the website that is hosted on the embedded web server chip. The website was designed using standard HTML code. More details on these HTML pages as they pertain to the design of the website for the security system is included later on in this document under the section detailing the design of the prototype with regards to the embedded web server subsystem. The HTML code for the website was important because although the team did not plan to design an overly complicate website it did need to be aesthetically pleasing to the homeowner who uses it while still being simple to use as well as functional. If the website was too complicate to use and did 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 eased 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 replaced the standard static graphic and text HTML objects with the objects designated within the definition file as Site Player objects. These objects were placed within the HTML file by the use of an up arrow (“^”) followed by the name of the Site Player object. This caused the HTML page every time it is loaded to use the most current value for this object that the Site Player has. This was where the true power of the Site Player came through and was 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 a very complicated process but the use of Site Player objects made this process very easy and it could be done in a few lines of HTML code. This allowed the team to greatly enhance the appearance and functionality of the ECO-SEC website while still keeping its design very simplistic and easy to use.

Additionally the Site Player objects contained within the HTML pages could be modified before they were displayed. This gave the programmers 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 feature could have been useful in designing the website by changing the value of the site play objects in order to get them to behave in the manner the team needed them to so they correctly interface with the rest of the system. However, such functionality was not needed because the amount of information that the website needed to store was simply the status text.

Table 16 below shows the different modifications that could 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. These further increases the use of Site Player objects and also allows for them do accomplish a wide variety of functions.

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, reprinted with permission from NetMedia Inc.

As previous stated, Site Player objects could 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 could 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 feature was not used in the version of the website used for the final prototype. However the use of these objects could have allowed the team to greatly expand upon the website design if more time was allotted to create the final prototype to include more features. Normally however, this prevents the website from needing multiple copies of the same page with different status text and instead would have allowed 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 is 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 as well as to actually reload the page in the user's browser.

One important concern that had is addressed when designing the website and accompanying HTML pages and images was 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 did not seem like a large amount, the security system being designed did 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 held for the site. Luckily the website did not require many images and only required what was necessary to display the status of the system and a few images for the logo of the ECO-SEC system. 48K of memory was more than adequately hold these images as well as the code for the actual site itself. However originally the team did run into difficulty with the first few designs of the website simply because they used too many graphics which ended up using more memory than was available on the web server. So these difficulties ended up forcing the team to use a more simplistic in appearance web site.

The second part of step two for programming the Site Player SP1 module chip involved creating the Site Player Interface (.SPI) file. This file was 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 modified the value of Site Player objects. The interface file functioned 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 could 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 were needed. The name used to refer to any forms or link within the HTML page had to be changed to match the name of a Site Player object previously declared within the declaration file. These forms determined the method used by the website to collect information from the user about the security system. In particular the homeowner is able to select the mode they wish for the security system to function in and the website sends this choice to the embedded web server which in turn passes it onto the microprocessor subsystem via a serial connection. From this adjusted value of the mode object, the microprocessor was able to determine how the system should now behave as well as to inform LCD touch screen to update the status of the system that it displays.

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

Figure 18 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 were used to create and transfer the binary file for the website onto the Site Player development board. The SiteLinker program was designed specifically to work with the unique structure of the SitePlayer web server and such was the software that was 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 is simply an example of what the program was capable of doing and does not reflect the status of the Site Player as it related to the current design that was implemented by the team.

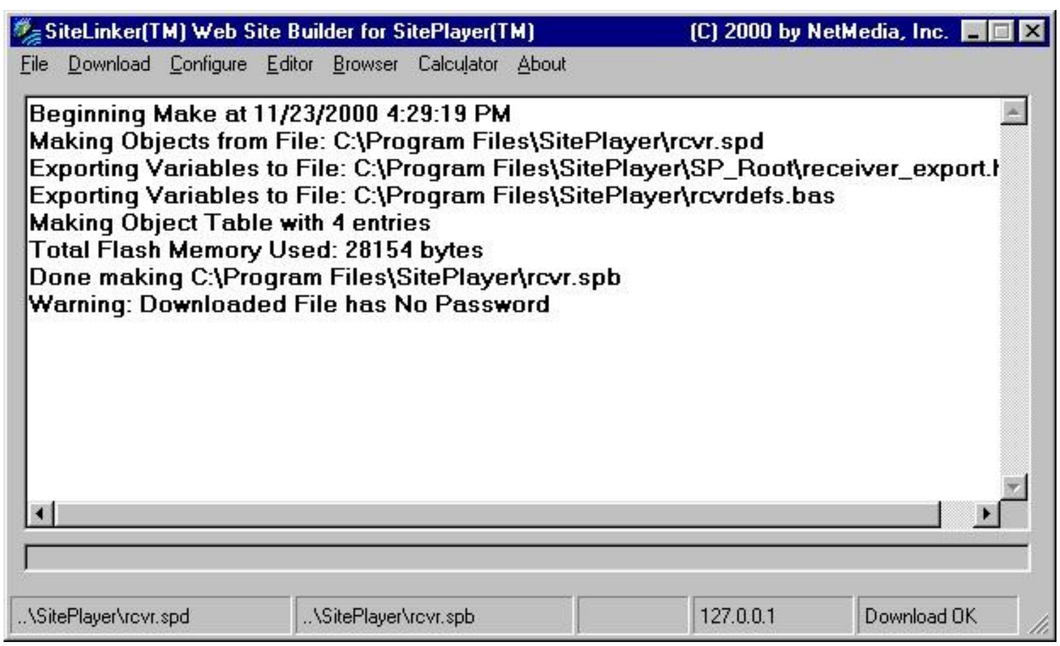

Figure 18: SiteLinker Program reprinted with permission from Net Media Inc.

The File menu in the program was used to control which specific files definition files, interface files, HTML files, etc. that were used to create the binary file that was eventually downloaded to the Site Player SP1 module. Opening and locating these files was done using the standard operating system interface for locating and opening files. The download menu was used to control the creation and downloading of Site Player binary files. Many of the options under the download menu were not available until a proper definition file was 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 was accomplished by using the Make Download File option in this menu. The second option in this menu was the Download Site Player option. This became only available when the user had selected a complied binary file using the file menu. A third option called Make and Download file combine these two procedures into one and allowed the user to create a binary file and download it onto the Site Player SP1 all in one step. The third menu was the Configure menu and was one of the more important ones within the SiteLinker program. Here was where the user configured which IP address the SiteLinker program used 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 was useful for checking to make sure that the website was correctly downloaded to the Site Player chip. The Calculator menu was the last menu of any important and it simply opened a calculator for use by the user if it was needed. From this it is possible to see how the SiteLinker program was 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 was the Assembly Progress Window. This aspect of the program took up the largest amount of space and provided details to the user about the current state of what was being executed within the SiteLinker program. This became especially important when making and downloading binary files for the SP1 module. This displayed status and progress text during these processes as well as indicating any error messages if an error occurs during such a process. During early development of the website the team encountered several errors and this information was useful in debugging and fixing these issues.

Once the binary file was successfully downloaded onto the Site Player module the programming process was complete. The user could now feel free to browse the website developed and hosted on the embedded web server by using the IP address assigned to the web server. Another interesting aspect of the programming section was the SitePlayerPC program that was used to emulate a Site Player SP1 chip. This was 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 was used will be covered in later sections detailing the process that was used to test the web site in order to verify that it functioned 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 that was used for creating the final prototype of the ECO-SEC security system. Figure 19 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 the LCD touch screen, embedded web server, and the microprocessor subsystems. The camera was powered using an AC source simply because the power requirements were far too high for a moderately priced solar panel to support. The individual sensors in the sensory array subsystem required so little powered they were simply powered by small batteries. The all the subsystems but the security camera were interfaced with the microprocessor. The microprocessor was responsible for receiving communications from the other subsystems and instructing the rest of the ECO-SEC system on what actions they should take in response to a particular event. The camera subsystem interfaced with the web server in order to transmit the live security feed to the ECO-SEC website. More details on the design of each individual subsystem will be given in the following subsections of this documentation detailing the prototype design.

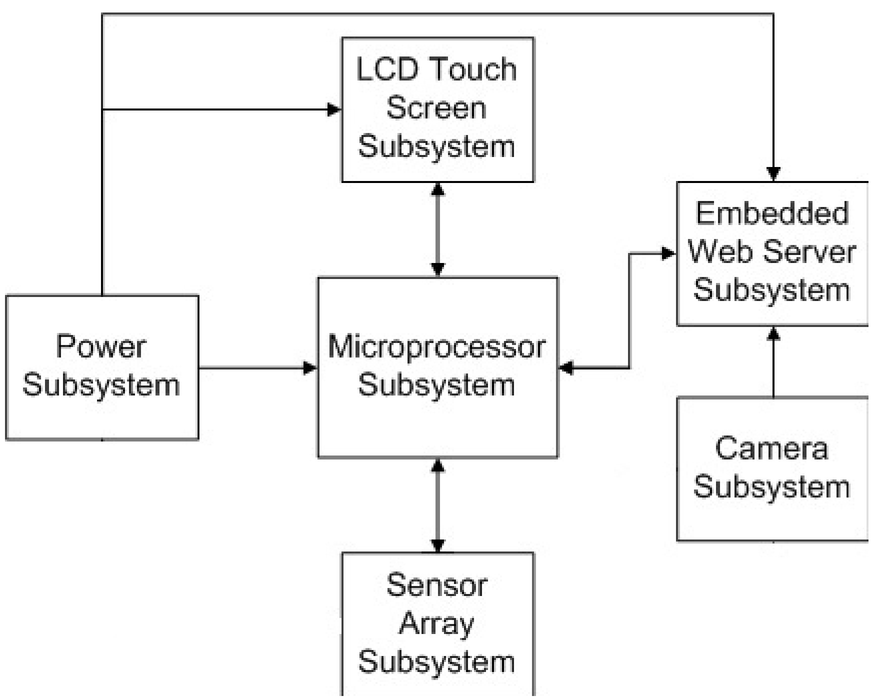

Figure 19: Overall System Design Architecture

As previously stated the microprocessor contained functions that controlled the logic for the prototype and was responsible for handling any communication between the various subsystems of the prototype as necessary. This made the overall system's design for the ECO-SEC a wait and respond style structure. The microprocessor was designed to simply wait until it received 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. Once the microprocessor received a signal from one of the various subsystems it responds correctly by calling functions designed to handle this input. These functions then change the behavior of the system via the microprocessor data variables as well as having the microprocessor send commands to other subsystems of the ECO-SEC as needed. These commands inform the various subsystems of any actions they need to complete in response to the action the original subsystem took. The power subsystem was 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 with the exception of the microprocessor. The power subsystem communicates information on the current state of the power supply but this information is not passed on or used by any other subsystem of the final ECO-SEC design. More details on this are in the subsections dedicated to describing the power subsystem. In short, however, the power subsystem sole responsibility was to provide power to the other various subsystems of the ECO-SEC whether it came from the solar power source or the backup battery as was 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 required the least amount of power and provided the lowest manufacturing costs. The sensors share a common architecture to communicate to with the main microprocessor subsystem and to allow for them to be as modular as possible. A low power XBee ZD wireless module was used to communicate to the ECO-SEC main system microprocessor along with a MSP430G2253 where the battery that houses the sensors is attached. The MSP430G2253 microprocessors were used to handle and calculate the results obtained from the various sensors and determine if the sensor needed to inform the rest of the security system that an alarm had occurred. When this occurs the sensor sends a serial instruction to the microprocessor subsystem via the XBee Wireless communication node. The microprocessor subsystem then parses this command and determines what action the rest of the prototype must take.

6.1.1. Wireless Communication

The design of the wireless sensor system was to allow the sensors to be able to communicate with the microprocessor subsystem from a distance. The wireless communication used by the sensor subsystem required four separate XBee wireless modules. Three of these modules were used as transmitters for the three different sensors included as part of this subsystem. The fourth sensor was included as part of the design for the microprocessor subsystem and acts as a receiver allowing the three sensors to send data to the main microprocessor wirelessly.

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	MSP430G2253	Digikey	$2.17	$10.85
4	MHB14K-ND (Jag)	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 for the Sensor Subsystem Wireless Communication

6.1.2. Glass Break Sensor Design

Table 18 show below is the various parts and their cost and quantities that were needed to build the glass break sensor for the prototype. Although this sensor required several different parts many of them were fairly cheap to purchase and the entire sensor was implemented for approximately $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*	1N4148WTPMS CT-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

Qty	Value	Device	Parts	Digi-Key #	P.P. Item	Total
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
1	JTAG	ML14	*X1*	A31135-ND	$2.35	$2.35
1	MBR0530	MBR052X	*D2*	MBR0530TPMSCT-ND	$0.42	$0.42
1	MSP430F2274IDA	MSP430F2274IRDA38PINTSSOP	*U1*	TI Sample	$0.00	$0.00
1	RED	LEDCHIPLED_0805	*D1*	160-1176-1-ND	$0.40	$0.40
1	TPS61040DBVR	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 20 shown below shows the schematic that was used to create the printed circuit board for the glass break sensor. This schematic was based upon a design by Texas Instruments but small changes were 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. Additionally it should be noted that instead of using a MSP430G2253 microprocessor as the other two sensors did, this sensor used a MSP430F2274 microprocessor for the additional functionality needed to processor the audible information that the sensor listens for to detect the sound of glass breaking.

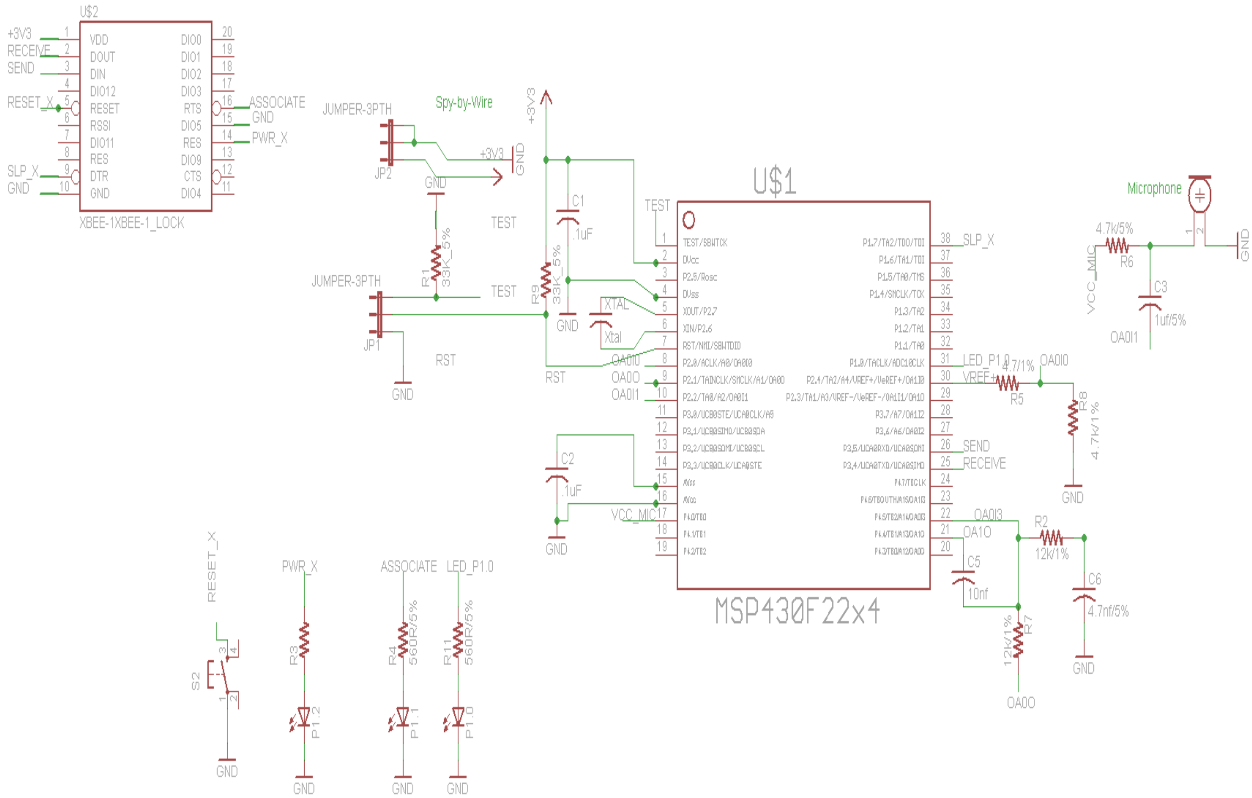

Figure 20: Glass Break Sensor Schematic

6.1.3. Infrared Motion Detector Sensor Design

As state in previous sections the infrared motion detector sensor was designed to allow the ECO-SEC system to detect the presence of intruder already in the user's home by detecting their movement. This sensor looks for movement in the home using an infrared sensor and when it detects such movement it send data to the main microprocessor informing prototype of that an intrusion had occured.

Figure 21 shown below illustrates the schematic used to create the motion detector sensor. This sensor was designed to function vary similar to the TIR door/window sensor. Like the TIR sensor it uses a MSP430G2253 microprocessor to process the information received from the motion sensor as well as an XBee wireless communication transmitter to send this information to the main microprocessor.

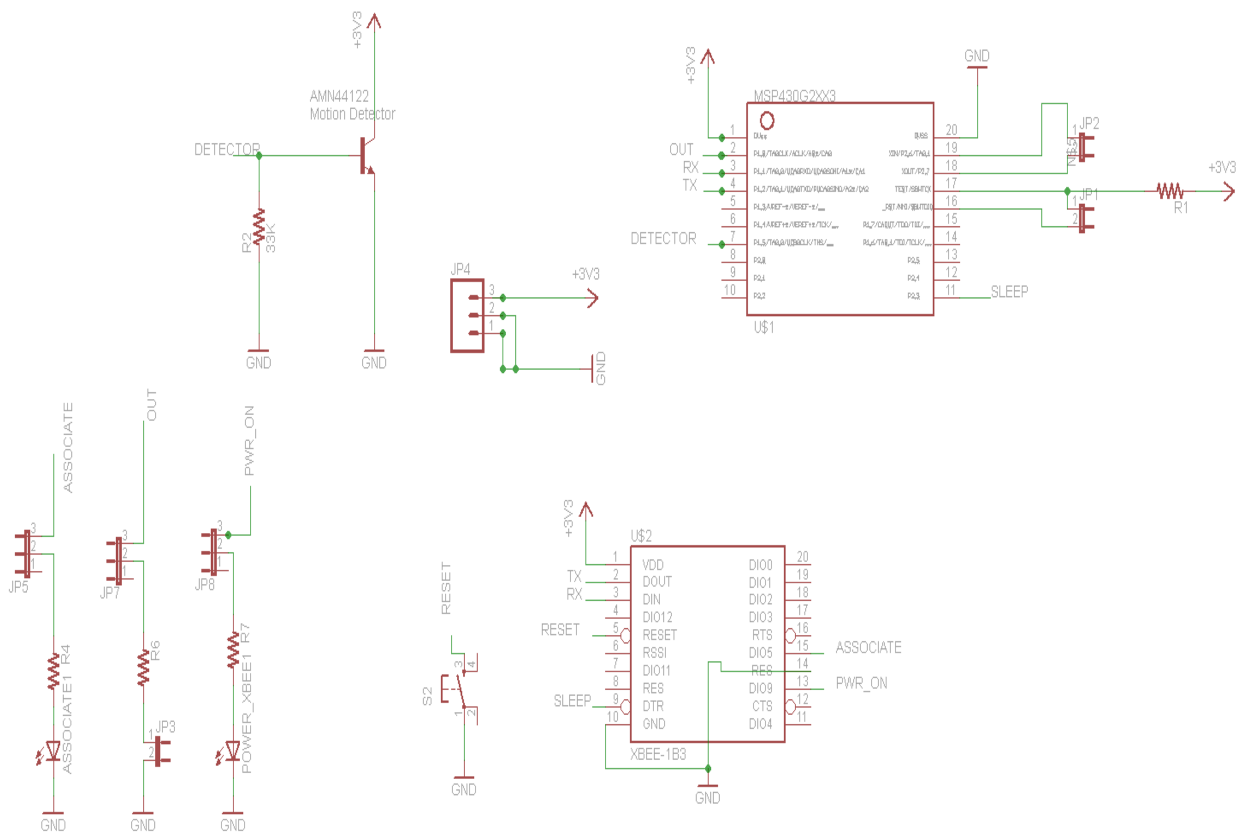

Figure 21: Infrared Motion Detector Sensor Schematic

6.1.4. Door/Window Open TIR Sensor Design

The door/window open detector sensor was built to function as described in previous sections. To recap briefly this sensor was 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 were required to build this sensor. As with the other sensors because of the parts chosen this sensor was cheap to manufacture and required low power to operate. The expensive part in the table was the seven-segment LCD and was not used in the final implementation of this sensor but was 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

Figure 22 shown below illustrates the schematic that was used to create the door/window sensor. Similar to the other two, this sensor uses a MSP430G2253 microprocessor to parse the input from the infrared detector and correctly pass the necessary information to the XBee sensor in order to allow this information to be communicated to the main microprocessor subsystem.

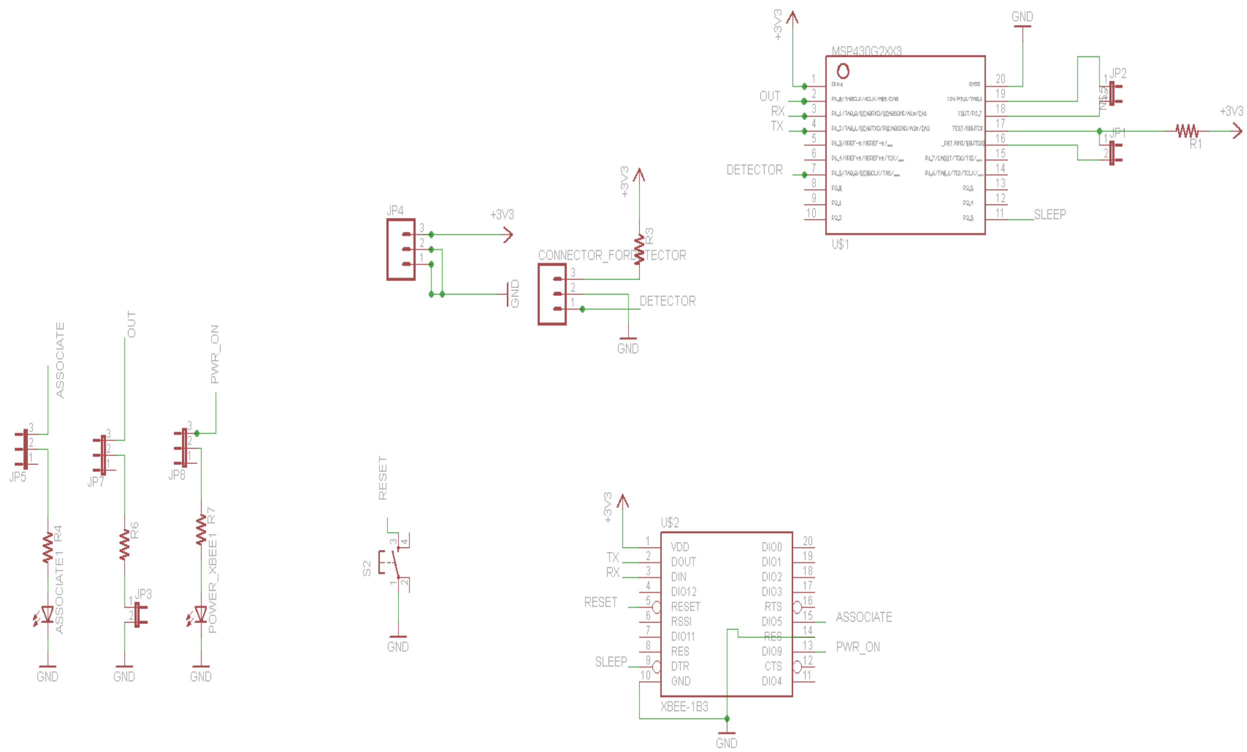

Figure 22: Door/Window TIR Sensor Schematic

6.2. Embedded Web Server and Website Development and Coding

The embedded web server subsystem was very easy hardware wise to develop. The server only required 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 were pretty straight forward and will attach to the appropriate places to the printed circuit board developed for the microprocessor and power subsystems respectively.

The Ethernet connection was still relatively simple but required more hardware. One of the goals of the web site hosted on the embedded web server was the ability to provide a live stream of the feed from the security camera that was included in the design of the security system. In order to accomplish this, the feed from the camera had to be merged with the design of the HTML pages for the website. In order to provide this merge correctly, both the camera and the embedded web server had to be connected together on the same local network. This was accomplished by connecting the two to a small hub which with regards for the prototype design the team opted to use a Netgear Wireless

Router since one member of the team was able to donate it for the project. Any other brand of router would have functioned just as well and would have worked in the design.

This router was then connected to the outside internet, which allowed the home owner to access the device from outside of their home network. In order to access the website from outside the local network the user needed to use the IP address of the router they are using followed by a colon followed by the port number that the router uses for the embedded web server. The port number chosen for the router for the prototype was 1000. This was set up by entering the configuration menu for the router and choosing to forward port 1000 using the IP address of the embedded web server. The embedded web server was defaulted to use the IP address of 192.168.1.104 for the prototype. The IP address of the web server was set up during the software design phase of the subsystem. If attempting to access the website from within the same local network, i.e. connected to the same router as the web server, the user simply needed to use the IP address of the web server. This made it very easy for the user to access the web server both remotely and locally.

The software design for the embedded web server was where this subsystem became more complicated in terms of design. This was mostly due to how the Site Player SP1 is programmed. It required more than simply designing a series of HTML pages to be used as a web site. It also required 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 had to be designed as well. All these files used to create the website for the prototype including the HTML pages and any accompanying graphics or other media all had to fit in fewer than 48K of memory in order to not overflow the flash memory of the Site Player SP1K embedded web server. Although these steps were not terribly complicated on their own, a single mistake in one part of any of these files could have caused 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. However a brief description of what parameters used and what objects were created using these files is necessary. The most important thing when designing the definition file was including the correct use of Site Player objects. These objects were 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 update the values of these objects by a simple serial command. This serial command tells the Site Player to update the value of the Site Player object at a set memory location to a sent value. The main SitePlayer object used by the prototype design was the status object. This object was used to store a string that contained what mode the ECO-SEC system was currently set to operate in. The value of this object was then used to display the status of the system on the website. This made it so in order for the system to update the status on the webpage when a change to the system was made; this value had to be simply updated by issuing the correct serial command.

The other important part of the definition file was what parameters were used by the web server. The first was used was to turn DHCP off for the web server. This was done in order to force the web server to use a static IP address in order to prevent it from conflicted with other devices on the network by using a high IP address that was unlikely to ever be used. The next parameter set up was naturally what static IP address was used. For the reason previously listed the IP address was chosen to be 192.168.1.104 because it would be extremely rare for enough devices to be connected to the router in order for the DHCP to actually assign a device that IP address so a conflict would be very unlikely. The last important parameter set up was the download password. This forces the web server to require a password to be used in order to download new files to the server. This helps prevent a malicious individual from remotely attempting to make changes to the website.

The website itself was keep relatively simple in terms of design in order to fit into the memory limitations of the SP1K. It consisted of two main HTML pages. Each page was created using standard HTML code. Exact details of the code will not be given here, instead this subsection will describe what the design for each page included and how it was created for the page. The first web page contained nothing more than a logo informing the user they are on the ECO-SEC website and a simple input box allowing the user to enter a user password to login to the website. The user simply needs to enter the correct password into the field and click the submit button next to password field. If the password is correct the user will be granted access to the main webpage. This was designed to prevent outside users who have no connection to the homeowner from being able to disarm the security system remotely. The password was stored as part of a java script on the HTML code for the login page. The password was also encrypted using an encryption algorithm in order to prevent anyone with knowledge of HTML from simply being able to view the password. Although this does provide a measure of security to the website it is capable of being bypassed by individuals who truly wish to. However, for the purposes of this prototype the level of security provided by the java script is more than adequate for the purposes of the team. The script is able to prevent the average internet user from being able to crack the encryption to the password in order to login to the website, 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 website, but this was outside of the scale and the timeframe the project had.

The second page of the website was the page that will be of most interest to the homeowner. This page was once again laid out fairly simply. The top of the page displays the ECO-SEC system logo created as well as banner indicating to the user that they are on the ECO-SEC website. The page will then display the video feed from the security camera subsystem. The feed was created using another java script embedded into the HTML code for the web page. The scripts using the static IP address of the camera and the native API of the camera to pull the video stream from the camera to display in the website. The script then sets up the display parameters to cause the video stream to be displayed in a 640x480 square area on the page. The area just below the video streams displays the status text for the security system. This text was used to inform the user what mode the ECO-SEC system was currently operating in. This section used the status Site Player object as previously described to hold a value that indicates the current status of the system in terms of operating mode. The website then displayed this value whenever the page was accessed by the homeowner or whenever the homeowner changes the mode of the system.

Although this sounds simple it required a series of communication between the microprocessor and the embedded web server, which was 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 section following the status text was a more active part of this web page. This area consisted of a series of three links that allow the user to select between the different modes of the system. This reference links were labeled "OFF", "AWAY" and "STAY" to match the corresponding operating mode for the prototype. When one of these links is pressed the embedded web server passes this the information about which link was used to the microprocessor which then carries out the appropriate steps to adjust the behavior of the security system accordingly. After this the webpage automatically updates and refreshes in the users browser to reflect the new status chosen. Additionally if a change to the status of the system is made via the LCD touch screen interface the attached microprocessor sends a serial command to the Site Player to change the values of the status Site Player object. By changing the value of this object the text displayed on the website is automatically changed to reflect the new status of the ECO-SEC system so that it will match the status of the system the next time the user logins into the website.

In addition to being able to host the website the embedded web server subsystem was designed to help fulfill one other key specification laid out by the team for the security system. This objective of the security system was the ability to be able to send out a text message alert to the homeowner's cell phone in the case that the security system detects an intrusion and activates its alarm. The web server only supports the use of email but 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. The exact address for each provider can be easily located using an internet search and is not provided here. The prototype was tested using an ATNT cell phone but any provider's cell phone that can receive text messages would work by only requiring a small change in the recipient email address used by the web server. This sounds simple but because of a few limitations of the embedded web server chosen this was one of the harder objectives of the security system to implement. The main reason for this was that the Site Player SP1 chosen as the embedded web server provides no support for DHCP protocols or TCP/IP protocol stacks and instead only provides support for UDP datagrams using static IP addressing. Most standard email servers today use a dynamically allocated IP address and only support the use of TCP/IP protocol and not UDP packets. This meant in order for the Site Player web server to be able to send emails a work around was required. This solution was to use a PC that was included on the same local network as the embedded web server was. 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. This was accomplished by running a visual basic program called UDP2EMAIL that was free to download from Net Media, the company which produces the SP1K web server. This program binds a port on the PC to listen to UDP packets. When the PC receives a UDP packet the program records the time and sends out an email indicting an alarm has occurred at this time to an email address that the program is configured to use. This is accomplished by using the PC's built in TCP/IP protocols to send the mail instead of using the web servers UDP protocols. Exact details on how to use and set up this program are given in the sections detailing the operation of the ECO-SEC security system. So in order for the web server to send email the microprocessor simply issues a serial command to the server that tells the web server to send out an UDP packed to the IP address of the PC on the local network using the port that the UDP2EMAIL program is listening on. This would force the PC to send out an email as appropriate when an alarm has occurred. This serial command therefore would only be issued by the microprocessor when it determines that an alarm has occurred.

6.3. LCD Touch Screen Development and Coding

The LCD Touch Screen Display subsystem required very little hardware design because of the nature of the hardware that this subsystem employed. Because the LCD display chosen came with a completed controller board as well as screen the extent of the hardware design involves correctly interfacing the display with the microprocessor subsystem and the power subsystem. A serial connection between the microprocessor and the controller board interfaced the LCD touch screen subsystem with the microprocessor subsystem. The controller board came with the connection built in, but this connection needed to be wired to the microprocessor as part of the printer circuit board. A successful serial connection was important because this interface was how the LCD will pass information to and from the microprocessor. This information included the LCD informing the processor what mode the user has set the system as well as the microprocessor informing the LCD when it needed to update the status of the system that is displayed on the screen. The second interface was the power interface. This required 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 for the power subsystem was not be able to use a simple trace to bring power to the controller board, instead the power had to be supplied through a wire than terminated 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 was 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 is that is uses a native build in API that took care of much of this difficulty. Instead the programming of the LCD involved using the preconfigured syntax designed for the controller board used by the team. This syntax was simple to use and was composed of simple one line 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. These commands were then placed within a series of macros that were used to create each individual screen. Details on how these macros were created for the interface can be found in the section detailing the LCD display subsystem itself.

The display created by the team was envisioned to be fairly simple in terms of appearance; it was designed more for ease of use as opposed to an 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 chosen prevented the display from becoming overly complicated and detailed. The display designed included three main screens. The first is used to secure the terminal, the second is to allow the user to enter a code to unlock the terminal, and the third is the main screen of the interface that allows the user to change with mode of operation the ECO-SEC was currently functioning in. These three screens were created using a unique individual macro for each one as well them sharing a few special generic macros.

Several different generic macros were used. The most important general macro that the team created was the power on macro. This macro was set to be automatically called when the LCD screen is first powered on. It automatically sets many of the important power parameters for the LCD screen such as screen brightness, the level of sound made when user presses the screen, as well as actually turning the display on in order to allow it to show the interface screens that were created. Other generic macros were used to create the header and footer sections that are displayed on each of the three main screens. The header simply displays the ECO-SEC logo and text informing the user that this interface is part of the ECO-SEC system. The footer simply displays the semester that the ECO-SEC was created and the group number of the team that created it. This way the when each screen is created it simply has to call these two generic macros for the header and footer instead of creating them uniquely each time.

The first screen that the LCD interface was designed to display when it is first powered on is the interface locked screen. This screen was designed not to display any information about the ECO-SEC system and serves instead as a mean to secure the interface when it is not in use so unwanted user's cannot access the system to change its operating mode. This screen was designed to only display the ECO-SEC header and footer and a single button. This button was labeled "UNLOCK" and when it is pressed by the user it calls the macro that creates the second passcode screen of the touch screen interface.

The passcode screen was created in order to allow the user to enter a passcode to unlock the LCD touch screen interface. When the user enters the correct code the screen will unlock the main interface screen which grants the user access to the system. This screen like all the others displays the ECO-SEC header and footer. It also displays on the left side of the screen a series of twelve buttons. Ten of these buttons are labeled with the digits "1" to "0". Pressing these buttons allow the user to enter one digit at a time the passcode used to unlock the screen. The digits of the passcode the user has entered automatically appear as text on the right side of the display. For security these digits are displayed as simply "*". This way the user can see how many digits of the code they entered but if someone else was looking they could not as easily see what exact digits were entered. The passcode was chosen to be limited to only four digits, but the team felt that this still gave enough different combinations of codes to make it very unlikely that someone could guess the interface passcode easily. The two other buttons are label "CANCEL" and "ENTER". When the user hits the cancel button the interface calls the macro to recreate the locked screen. This allows the user to change their mind about unlocking the interface and return it to being locked and secured. When the user presses the enter button the interface calls a different macro. This macro takes the passcode the user entered and passes it onto the microprocessor through the serial port using a special command. The microprocessor is then capable of determining if this was a correct passcode, incorrect passcode, or the silent alarm code and informing the LCD touch screen to respond correctly by invoking the appropriate macro by issuing a serial command to the LCD touch screen. If the passcode was correct the microprocessor needs to call the macro to create the main screen. If the passcode is incorrect the microprocessor instead calls the macro to create the locked screen once again securing the screen because the user entered the wrong code. If the passcode matches the silent alarm code, the microprocessor will call the code to create the main screen similar to if the correct passcode was called. The microprocessor will also however, sound the silent alarm as necessary. Details on what this entails can be found in the section describing the microprocessor subsystem prototype design.

The main screen was designed to be of the most interest to the user. The screen naturally like all the others, always displays the ECO-SEC header and footer. The rest of the screen can be divided into two parts, the right side and the left. The right side is used to display the status information for the system. This is displayed as two lines of text that inform the user what mode the ECO-SEC is currently operating in. The status of the system is stored in a single string type variable on the LCD memory. This allows it so that when the LCD needs to changes the status of the system it simply updates the value of this variable. These prevented the team from having to create three unique different main screen macros for the interface for each mode; instead the team could use the same main screen macro for all modes. The left side of the screen is a series of four buttons. One of the buttons is labeled "LOCK" and when pressed invokes the macro to create the locked screen for the interface. This was designed to allow the user to secure the terminal when they are done making changes to the system. The other three buttons are labeled "OFF", "AWAY", and "STAY". When these buttons are pressed they call a macro that changes the mode of the system to the appropriate mode. These macros do three things. First they change the value of the variable used to store the status of the system on the LCD to the new mode. They then pass this new mode through the serial communication port to the microprocessor. This allows the microprocessor to adjust the behavior of the rest of the ECO-SEC system as appropriate. Finally these macros call the macro that makes the main screen in order to reload the main screen so that it will display the need mode that the user switched the system to.

Additional macros were also required to handle the event in which a change is made to the system using the website instead of the LCD. The LCD touch screen interface needs to be able to adjust what information it displays on the main screen to match what change was made using the website. This is done by using three additional macros. These macros simply change the value of the variable used to store the status of the system on the LCD. Thus when a change is made by the web server and the microprocessor reads and makes these changes, the microprocessor simply has to invoke the correct one of these additional macros in order to make the LCD display to correctly reflect the changes made.

Once the software was correctly written for the LCD touch screen display all that remained was to interface the LCD with the rest of the system. This was accomplished by simply connecting it to the power subsystem and the microprocessor subsystem using the appropriate interfaces as previously described several times in this documentation.

6.4. Microprocessor Development and Coding

6.4.1. Microprocessor Interfacing

Figure 22 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 was placed as part of the Printed Circuit Board (PCB), as this was where the main layout of the system was built from. The touch screen is the controller/interaction for the user. The LCD is connected using one of the two DB-9 connectors on the PCB. The sensors send data to the microprocessor by the Zigbee based protocol XBee from Digikey. The web server serves as another user interface for the user to check the status of the system from a computer. Like the LCD touch screen the web server uses one of the DB-9 connectors to communicate with the microprocessor. The siren is an audible sound that alerts residents close by about an intrusion. Finally, the microcontroller is the logic behind the prototype that puts everything together in the ECO-SEC design. 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. It was required to use a device to match the voltage difference between UART’s TTI and RS-232. In the final prototype this was accomplished using a MAX-3232 chip in order for the LCD touch screen and the embedded web server to communicate with the microprocessor.

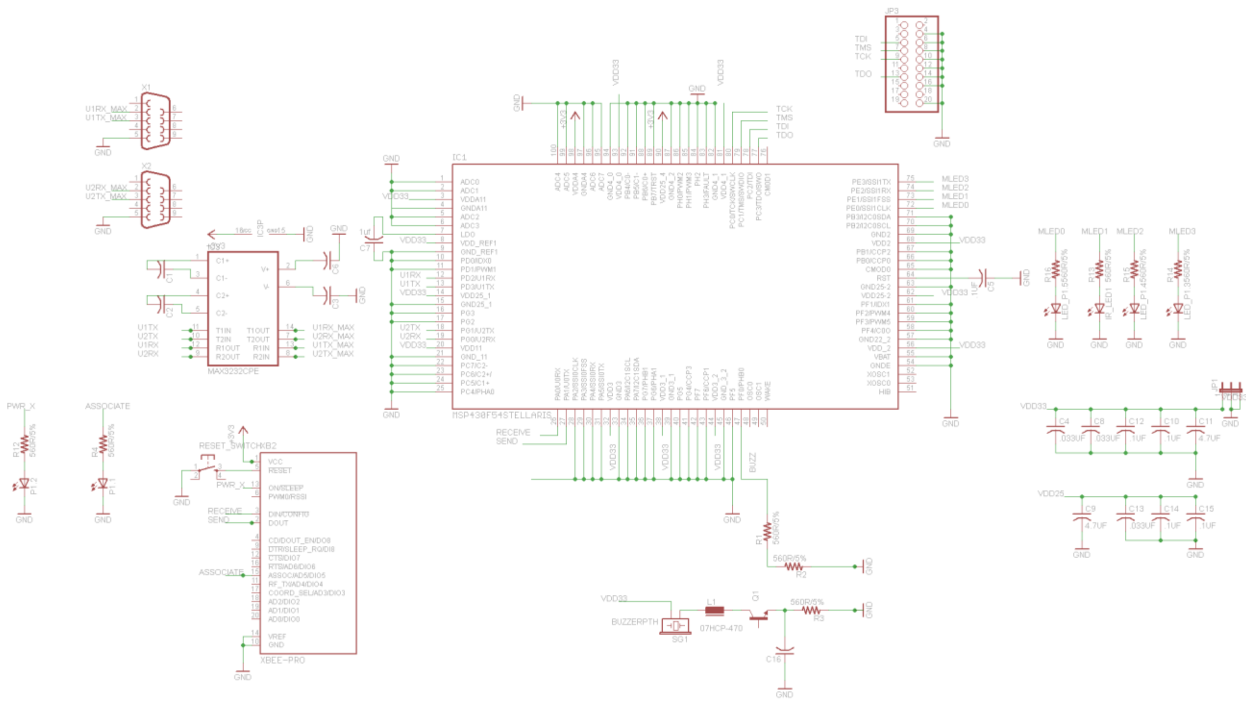

Figure 22: PCB Schematic

6.4.2. Software Module Overview

Three main software modules comprised the software that was incorporated into the ECO-SEC design:

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

These software modules made up the design of the microprocessor coding for the ECO-SEC and determined 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 was based from and executed by the microprocessor’s power-on timer hardware, and does not directly interface with the processor.

The primary function of the POT Module was 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 supersedes 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 was 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 was 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.

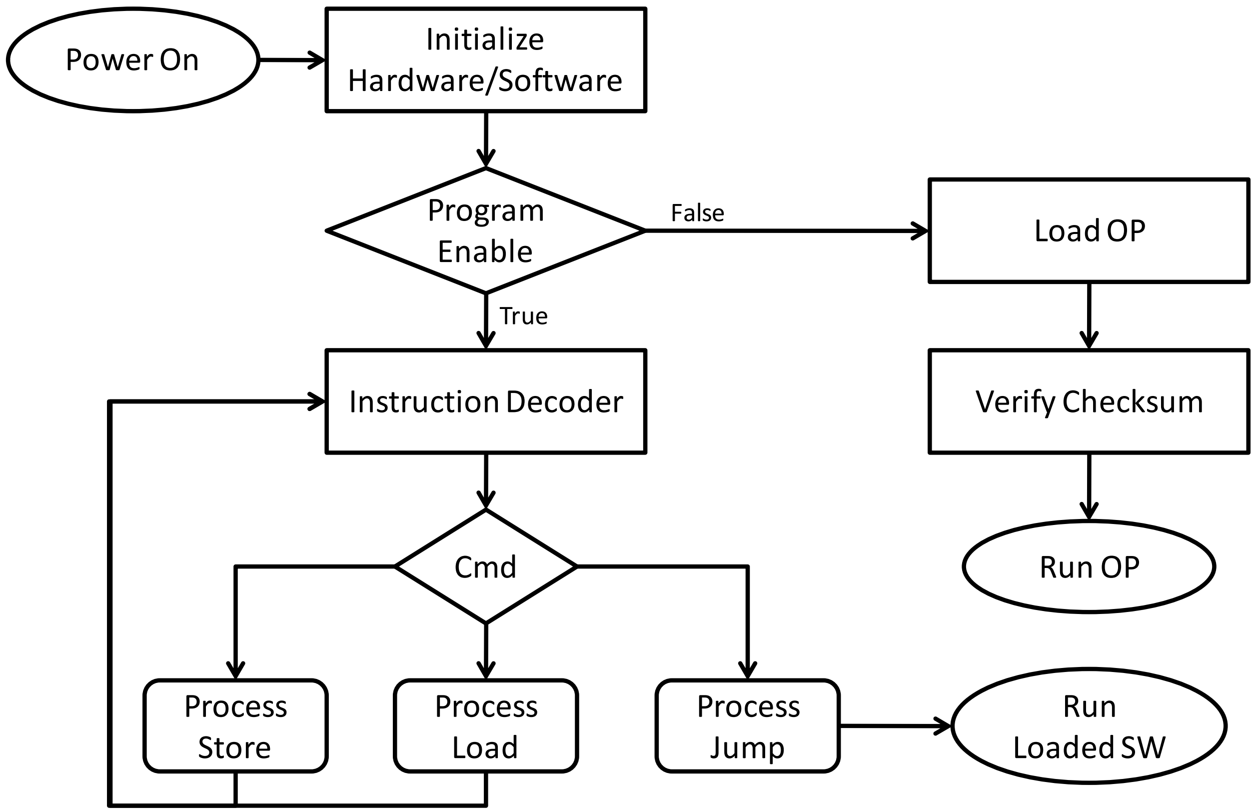

Figure 23: BOOT CSCI Operational Flow Diagram

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 processor.

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 24 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. This module then takes over operation of the system until the ECO-SEC loses power or is disconnected.

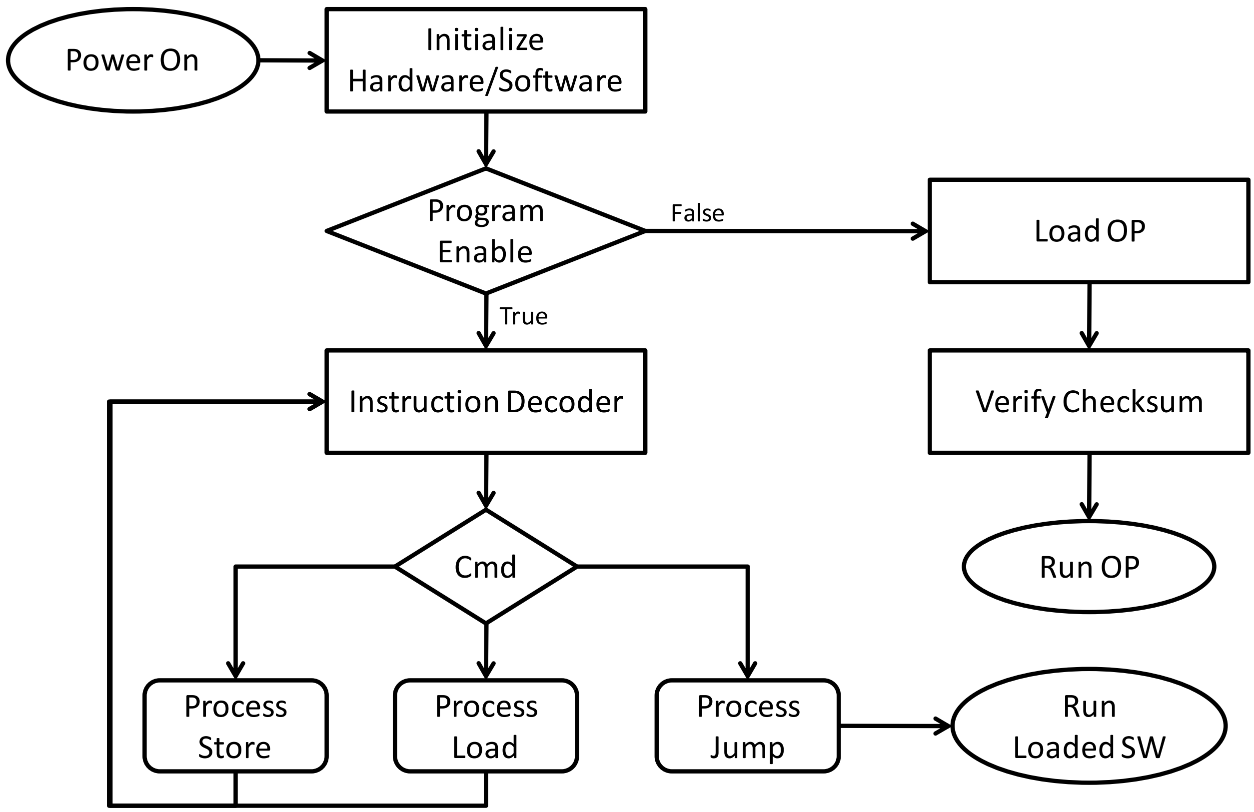

Figure 24: Software Modules' Operational Flow Diagram

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 control the logic 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.

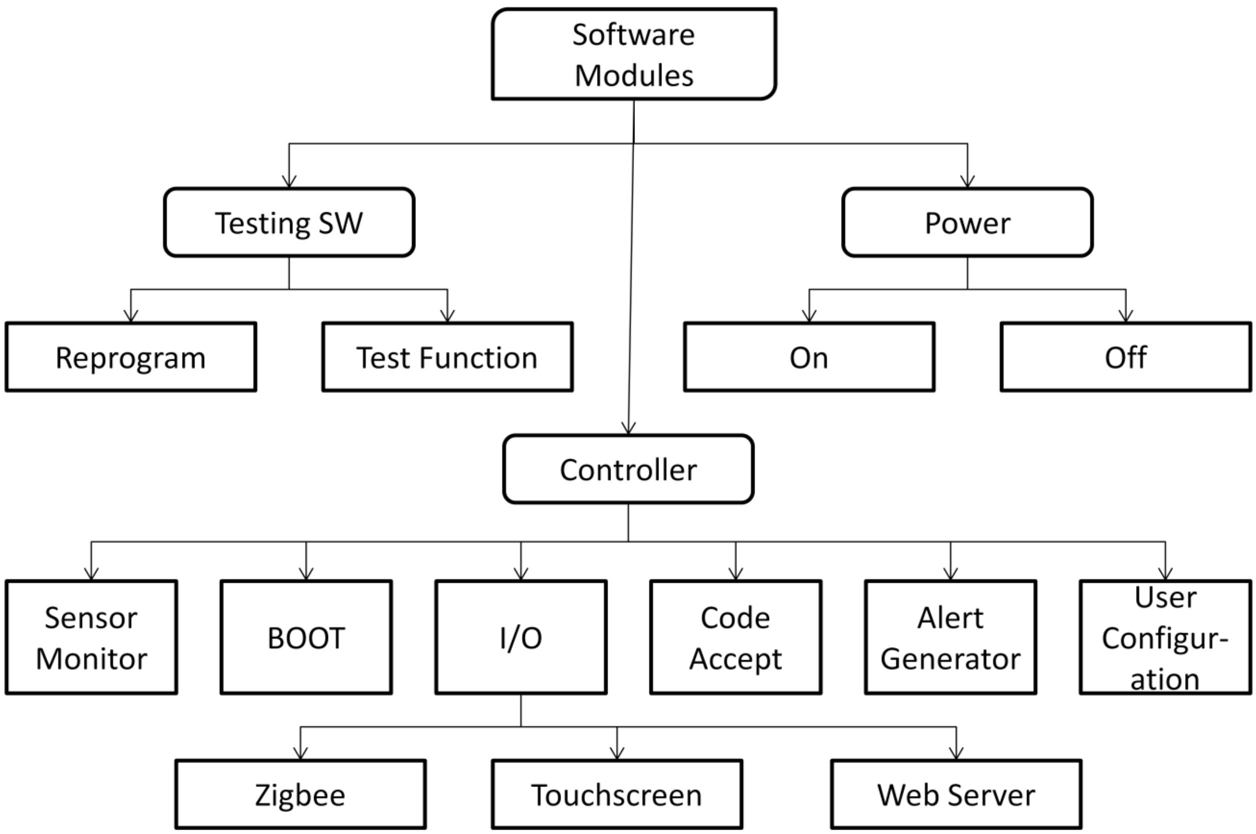

Figure 25: Software Modules' Breakdown

The Testing Software was 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 26 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.

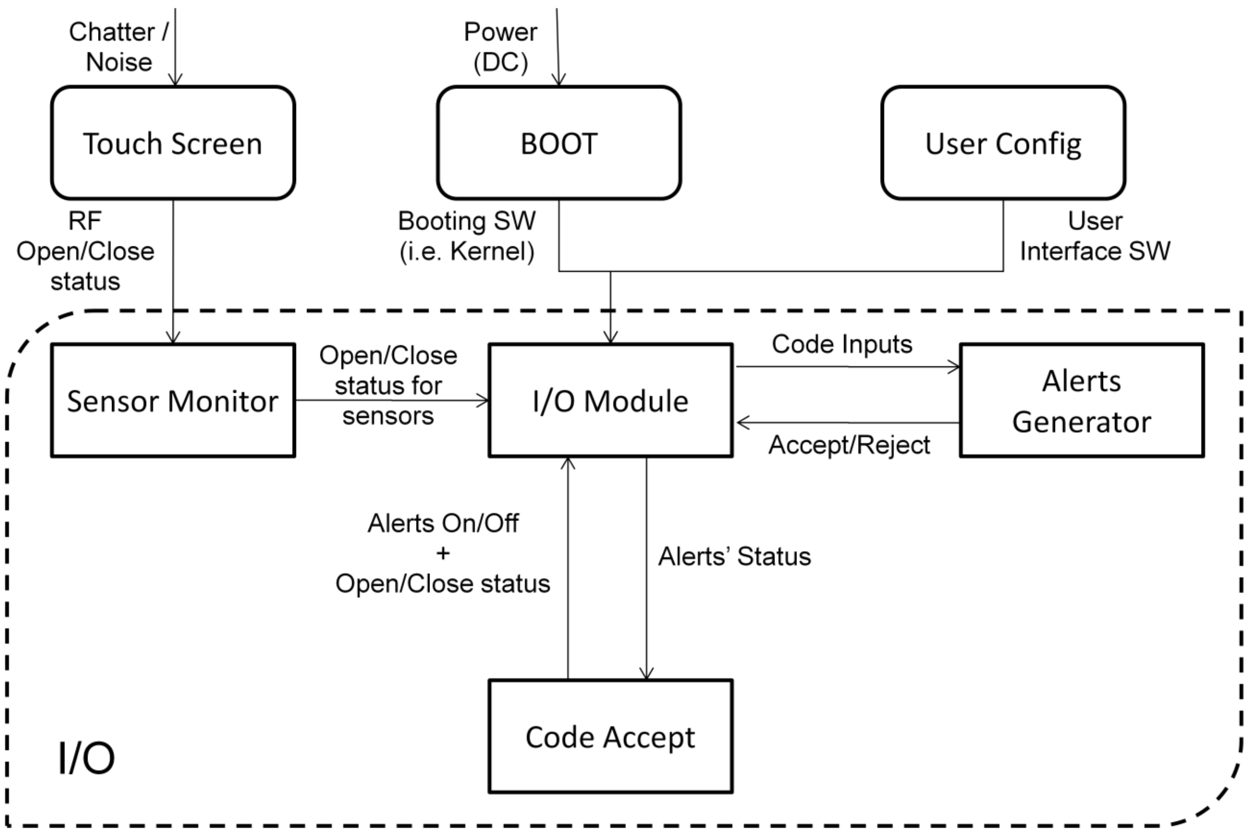

Figure 26: I/O Block Diagram

The wireless sensor monitoring device from DigiKey, called XBee is based upon the Zigbee protocol from Texas Instruments and is 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 XBee and generates alerts accordingly. For example, if the alerts are on and a sensor gets an 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.

The OP Module has four basic modes of operation:

1. Off
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 "Off" mode is the initial Alarm Mode, where the system awaits for an arming sequence –like "Away" or "Stay". The mode is changed using either the embedded web server web site or the LCD touch screen interface. Figure 27 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.

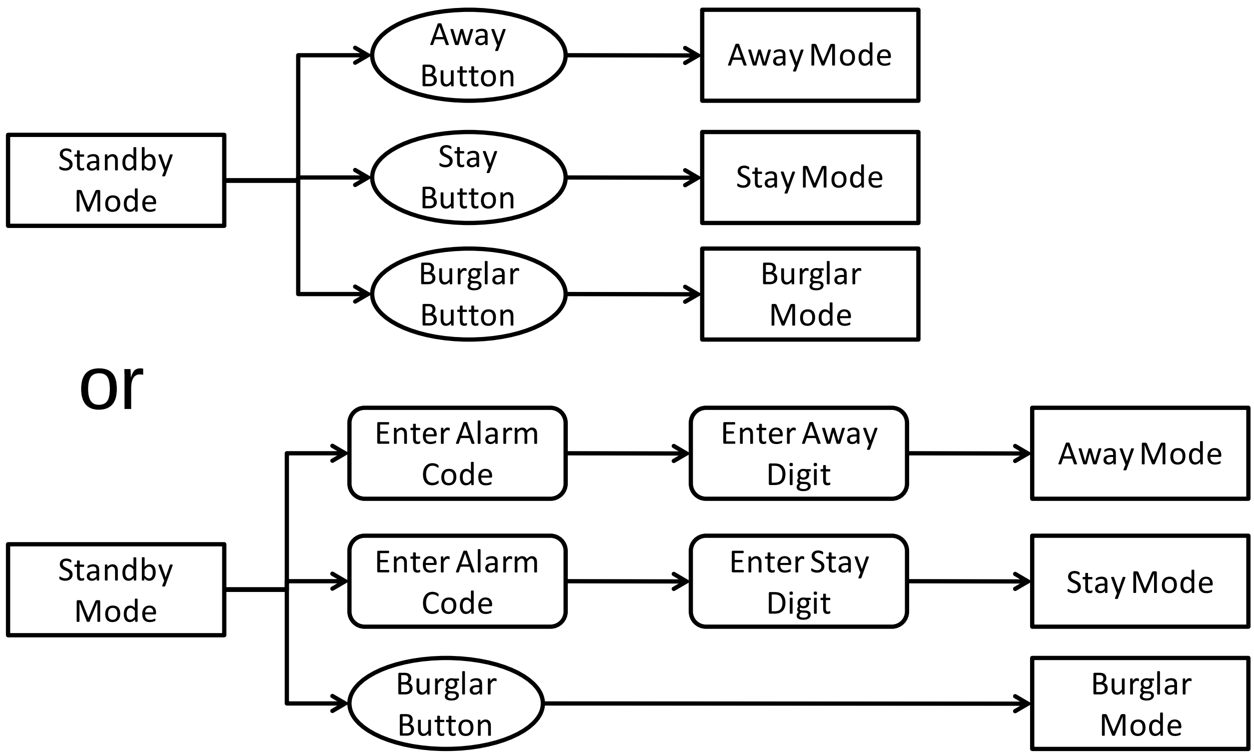

Figure 27: Sequence Diagram for Standby Mode

The “Away” mode indicates that all Alarm Components are 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 on the LCD or web site. 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 or silent alarm code to enter burglar mode or enter the alarm code to enter standby or stay mode based upon which the user selected.

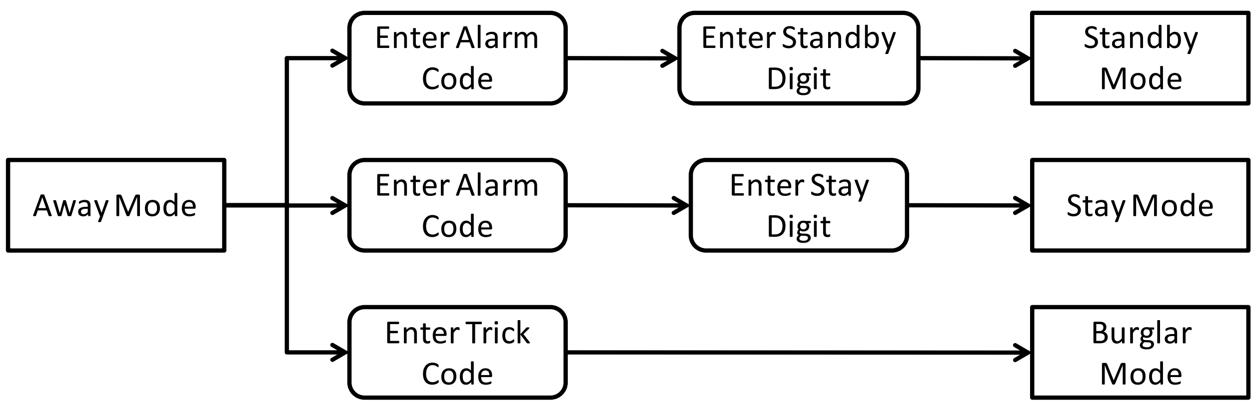

Figure 28: Sequence Diagram for Away Mode

The “Stay” mode indicates that some Alarm Components (door/window sensor and glass break sensor) are 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 has 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.

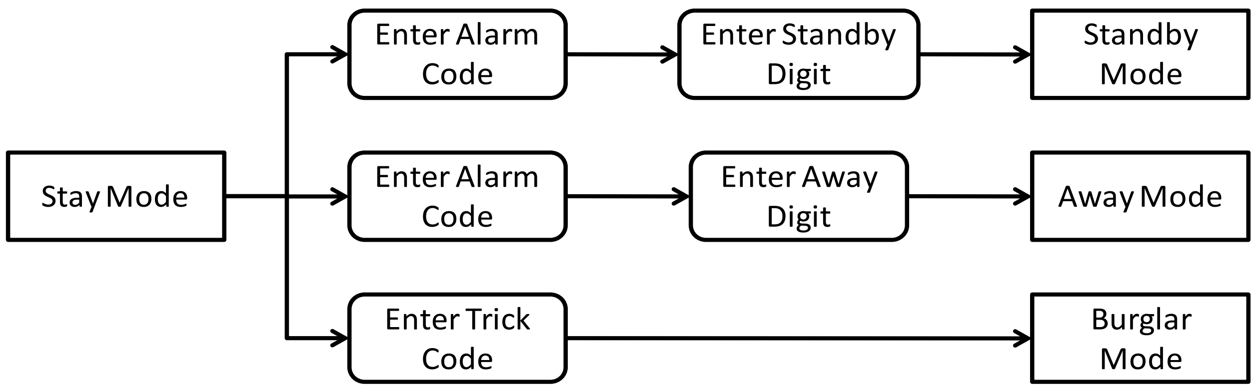

Figure 29: Sequence Diagram for Stay Mode

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 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.

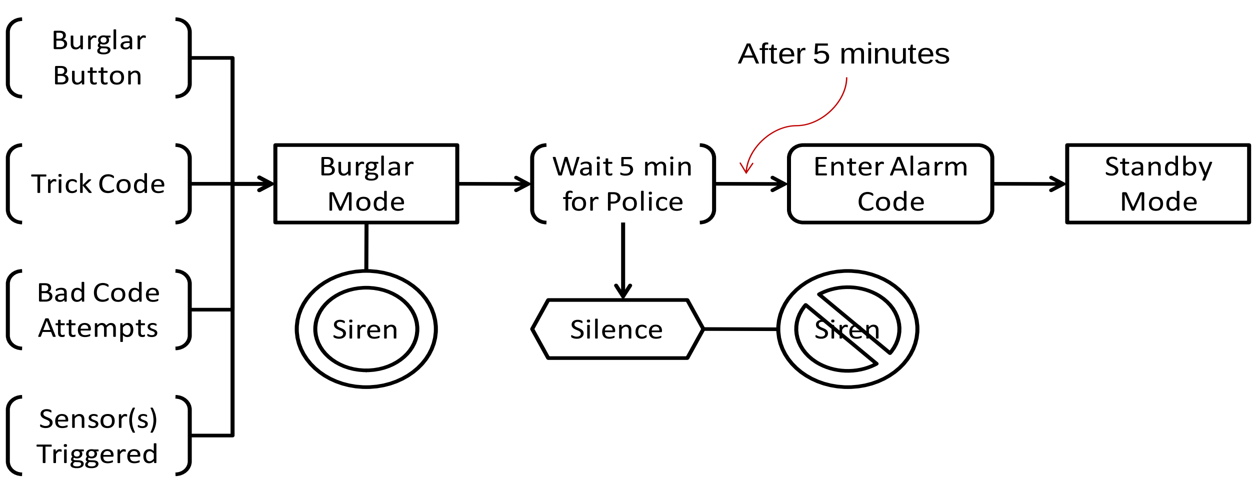

Figure 30: Sequence Diagram for Stay Mode

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 “Off” 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.

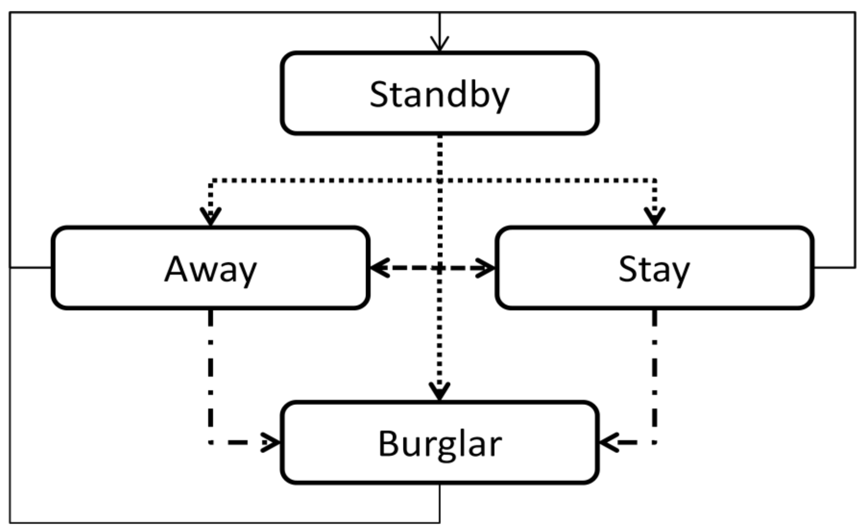

Figure 31: OP Module Simple Mode Transition Diagram

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 were based upon how it interfaced with the embedded server. The exact details of this interface and its connection have 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 from the security camera to the embedded web server was a simple Ethernet connection using a standard RJ45 connector. The camera however did not directly connect to the web server and needed a small hub or router in between the two. The use of this router allowed the embedded web server to locate and pull the video stream from the security camera in order to display it on the web site. The second interface was the power connection which needs to supply the correct DC voltage and wattage to the security camera. This power was not supplied by the power subsystem but instead was supplied using a standard AC outlet. This was because the power requirements for the camera were too high for a solar power based power system to power using a smaller scale solar panel.

Once the security camera was properly interfaced with the embedded web server and supplied power by an AC outlet, all that remained to develop the security camera subsystem for the final prototype of the ECO-SEC was to set the various options that controlled how the M1011 functioned within the scope of the design namely characteristics such as the IP address of the camera and what quality video feed it should use. Each of these settings although briefly explained in earlier sections describing the M1011 security camera will be covered more completely here.

The first series of settings that were needed to be set up was the settings governing the video feed from the camera that was streamed to the web site for the security system. The most important choice that needed to be made was what encoding to use for this video stream. The best choice of the forms of encoding supported by the M1011 was 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, Safari, and Internet Explorer allowing most user's browsers to support loading the video stream. Although Internet Explorer does provide inherent support for it the camera did require the user to install add-ons to their browser the first time they access the website to view the camera stream. This process was only required once the first time the user logs onto the website. Once they have installed the correct software they do not need to install it every time. So this encoding was used since it is a form that works well with the HTTP protocol and was supported by almost any type of browser that the user is likely to use. The one downside to the MJPEG format is it required high bandwidth but was mitigated by limiting the frame rate of the video feed to around 30 fps. So although some lost of clarity will occur resulting in a slightly grainy picture, the image was still clear enough for the user to see the state of their home remotely. Addition settings that were needed for the video feed were the color level, the brightness, the sharpness, and the contrast of the video images. Experimentation was required as part of the testing to determine which of these settings produced the best video stream while still maintaining good performance without using an excess amount of bandwidth for the system.

The second setting that was required to be set before the camera subsystem could be implemented within the design of the ECO-SEC security system was configuring the default IP address that the security camera would use on the local network it was connected to. This step was important because this IP address would be used by the website on the embedded web server to locate the camera. The embedded web server could find the camera simply because they were on the same local network which is why a router or hub was required as a bridge to connect the subsystems together. In the end in order to attempt to avoid conflicts with other devices the camera was assigned a high default IP address of 192.168.1.105. This setting can also be changed by logging into the camera's API and changing it manual. This change would also be required to be made to the website design as well so that site can still locate the camera using the new IP address.

These two settings were all that was required for the security camera subsystem. This system itself was not difficult to develop and required little work on its own. Most of the difficulty associated with this subsystem was included as part of the embedded web server design in the form of editing the HTML code used to create the web site hosted on the server in order to allow the website to be able to locate the camera and display the stream from the camera on the website. The exact details on how this was done can be found in the section of the documentation detailing the embedded web server prototype construction.

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 was important to break the project down into smaller steps. Doing so improved the team's ability to understand how the power system should work and assisted in finding potential problems with the design. It was 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 created several different test points where a component's performance can be evaluated. Furthermore, since each component was able to stand alone, the team could ensure that a particular part of the project was working before connecting another. This allowed problems to be isolated and corrected with greater ease. There was also an order of importance to the subsystems listed above. If there is not enough time to complete all features of the project, it would have been still important to produce a working prototype. Since the power subsystem was very modular in its design, all parts of the system did not have to be implemented in order to have a functional security system. Another construction goal was to minimize the time and money lost from re-design steps that may be necessary if there were problems with the design concepts. Finally, each component of the power subsystem had to 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 are mounted on a single PCB. These components included the switch, charge controller, and DC to DC converters. The battery connects to the board, but was not mounted on it due to its large size. Similarly, the leads on the solar panel were connected 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 was 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 in figure 32. The output of the AC to DC converter, discussed in the appropriate design section above, was connected as shown. Furthermore, the leads of the solar panel connect directly to the switch. On the left side of the diagram, there is a

Schmitt trigger used to detect the voltage of the battery. Also, the battery voltage detector triggers high at 10V indicating that the battery is in a low charge state. At this point the system required that the battery return to 12V 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 two LTC4412s 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 was 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 did 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 in figure 33.

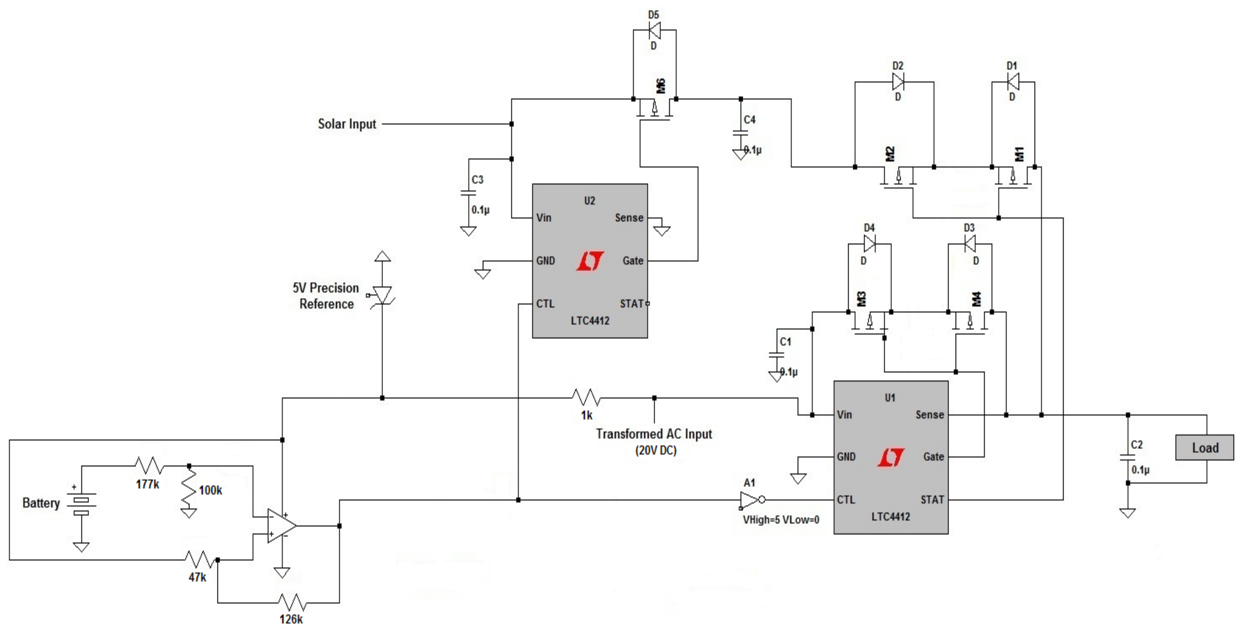

Figure 32: Switch Schematic

Attached at the load of the switch is the charge controller circuitry. This circuitry is centered on 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 33 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 had to be set by external circuitry. These limits were 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 was unnecessary for this project, the SETI pin was 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).

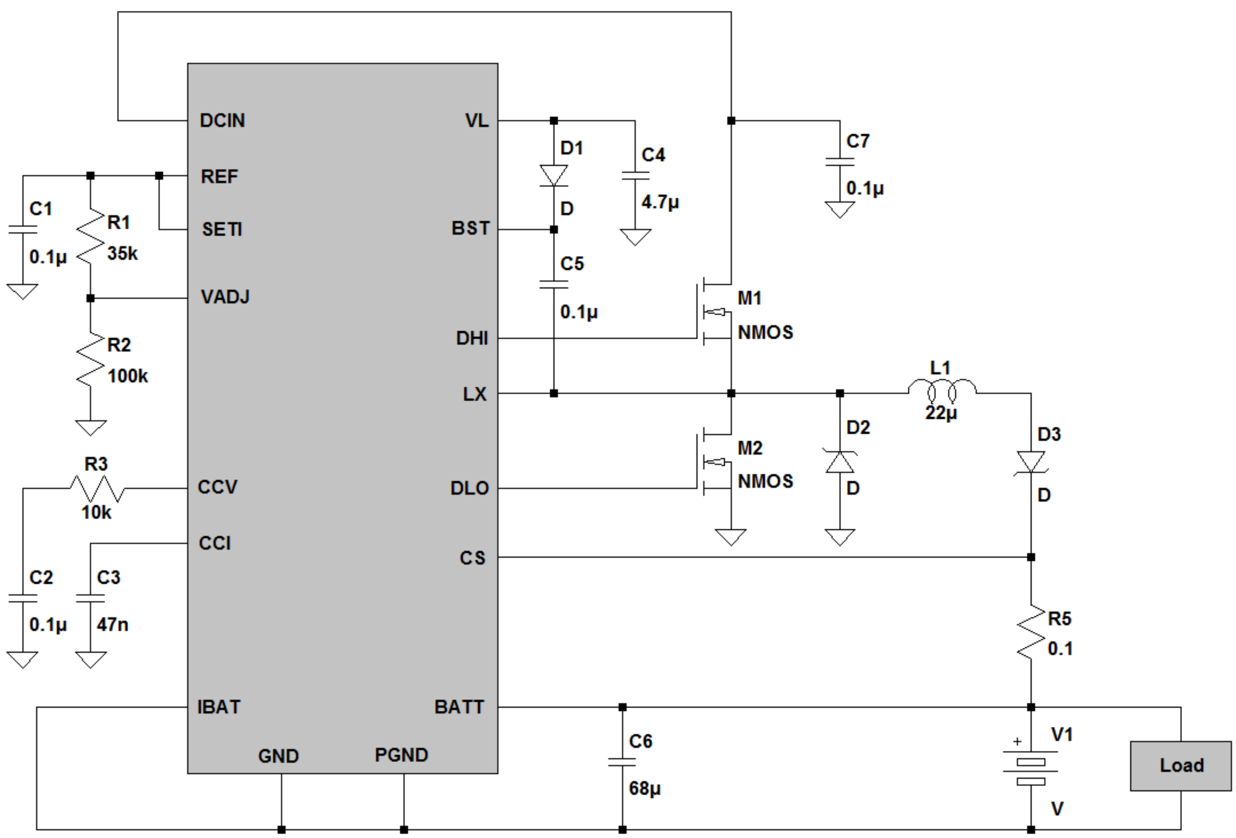

Figure 33: Charge Controller Schematic

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 was 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 are 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 required 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 recommended that the Cb capacitor be ceramic. Furthermore, the diode connected from FB to ground was a schottky diode and should be rated to support at least 200mA of current. This type of diode was advantageous because it has a low voltage drop. Since this is a switching regulator, it was 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 34).

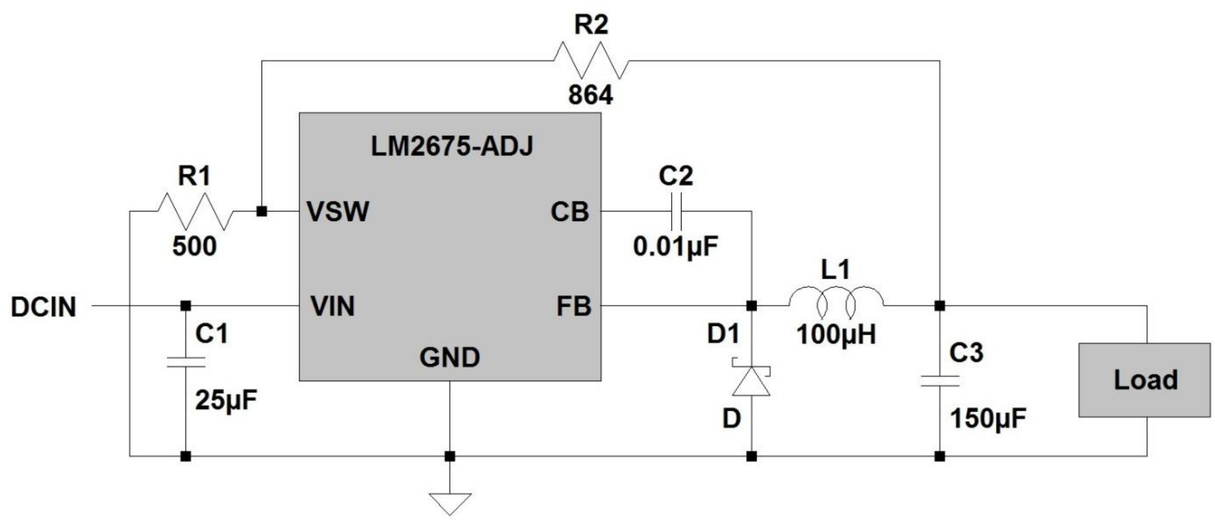

Figure 34: 3.3V Regulator Schematic

A schematic for the 5V regulator is shown below in figure 35. The load of this schematic was 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 was different because of different input and output parameters of the circuit. Also, the inductors and capacitors required a higher voltage and current rating because this circuit had 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 had to be able to support 600 mA of current. The final parameter deals with the schottky diode which had to be rated at 320 mA of current. The schematic follows (figure 35).

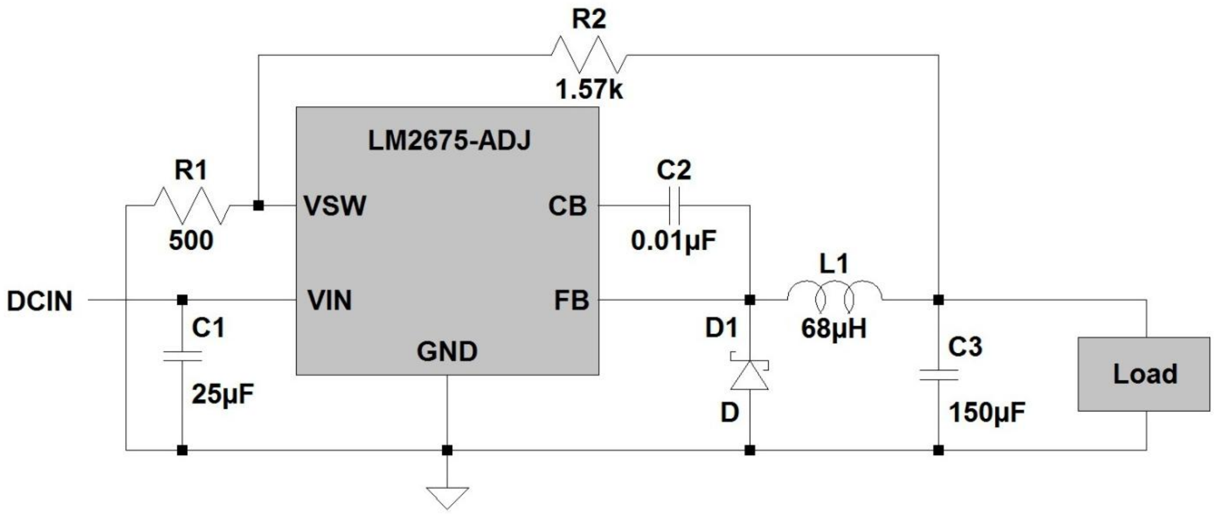

Figure 35: 5V Regulator Schematic

The final regulator was the buck/boost converter for the web server. Below the schematic is shown in figure 37. The additional complexity was 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 was reduced and a capacitor with a higher ESR was selected. The schematic below in figure 36 is based upon using one output capacitor with a high ESR to correct the output waveform.

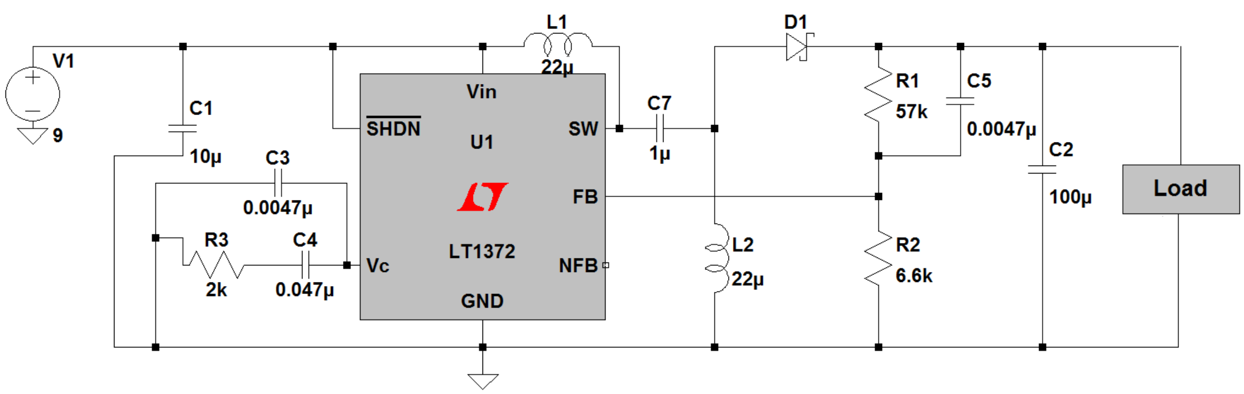

Figure 36: 12V Converter Schematic

The last design issue to cover with the power subsystem was 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 provided 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 were 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 were currently in-stock. The other components could 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

It is important to discuss the specifications of a few components. First, the solar panel selected has an open circuit voltage of 21V which is ideal for the ECO-SEC since this voltage will remain higher than the required 15.5V from the charge controller under optimal sunlight. Also, the solar power flag has been designed to work with this voltage. Also, this panel has a maximum power output of 30W 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 was purchased online from www.onlybatteries.com since they provided 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 underwent 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 was a relatively simple process. This was because the M1011 camera naturally has great support for this. All that is required to test the hardware for the security camera was to ensure that all the interfaces of the camera were properly connected so that the camera could communicate between the web server in order to produce the live stream to display n the website. Once the Ethernet connection and the power connection are correctly made an LED on the camera illuminates to inform the user that a correct correction has been made. By checking for this light the team was able to determine that the camera was properly interfaced. The second part of testing the camera to was to verify that the video was working and to check to make sure that the quality of the video was adequate. This was tested by simply logging onto the camera using the camera's IP address. This displays the native API for the camera where the user can changes its settings as well as the video stream being produced by the camera. By examining the feed the team was able to determine that the video stream of the camera was functioning correctly and at a quality that was adequate to meet the needs of the ECO-SEC prototype that was developed.

7.1.3. Power Subsystem

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

The first circuit that was constructed on a breadboard was the voltage regulators. The regulators output a constant voltage as long as long as the input voltage stays within the battery voltage range. When testing, it was important to load the regulators as this can reduce the output voltage under certain circumstances. Each circuit was able to output enough current to power the other subsystems. Furthermore, the efficiency was calculated to be between 70 and 80% on all switching regulators. Lower efficiencies occur on the regulators that output less power such as the microcontroller. When testing, voltage spikes were seen on the output even when using low ESR capacitors. These spikes were especially noticeable on the 12V regulator. Using simulations and testing, it was found that the spikes were caused by voltage variations in ground. These voltage variations occur because the high frequency signals in the regulators see a great deal of impedance through the long ground traces that are common on breadboards. On the final PCB, this issue was corrected by using a ground plane on both layers of the double sided board. This ground plane reduces the distance to all ground points and maximizes the trace width thus reducing impedance.

The second circuit that was constructed was the charge controller. Since the charge controller is also a high frequency circuit, it had a similar problem to the regulators with the ground point. Instead of causing a voltage ripple, it interfered with the charge controller's ability to appropriately regulate current. Consequently, the output current was much lower than expected. The ground plane on the final PCB resolves this issue. The charge controller also properly sets a voltage limit of 12.8V on the battery. Once at this voltage, the charge current is reduced until trickle charge is needed.

The next circuit to test was the switch. The switch was divided into two parts: the power path controllers and the battery voltage flag. The power path controllers worked very well the first time they were tested. If only one signal is used, the system can take several minutes to detect that a source is connected and switch to it. If two power sources are present, this issue does not occur. Also, if the power source is removed, the device is able to switch to another power source in sufficient time to prevent the regulator's output from being interrupted. The battery voltage flag proved to be more difficult. If high resistances are used in the Schmitt trigger, the system uses less power, but becomes more unstable. Therefore, lower resistance values were used to ensure proper operation. Also, the inverter had to be powered from the 5V regulator because it was difficult to pull additional power off of the 5V reference line while still providing power to the rail of the comparator. All of the different conditions were tested on the logic circuit to make sure it functioned properly. A DC generator was used instead of the battery so a varying input signal could be studied.

The final circuit to test was the final PCB. The circuit was tested for shorts because if not soldered correctly a trace could be shorted to ground due to the ground plane. When testing the board, care was taken to ensure the positive and negative input terminals were connected correctly and not reversed. If a mistake was made, it could damage either the power board or the subsystem to which it was connected.

7.1.4. Microprocessor

Testing the hardware of the microprocessor is not a complicated process. This mostly requires checking that the microprocessor successfully connects to and is able to communicate with any other subsystems it is attached to. These interfaces included 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 was one of the few that were 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 embedded web server is properly connected to the router as well as to the power subsystem. This process luckily was made relatively simple due to the nature of the SP1K development used for the web server. This development board included an LED that will light up when the web server correctly recognizes an attached device. So in order to verity that the connections were correct and functioning the team needed to simply connect the server to the power subsystem and the router then verify that the link indicator LED does in fact light up signaling the successful connection. The other aspect that the team was required to test was to make sure that the embedded web server was able to communicate with the microprocessor subsystem. This was done by having the web server and the microprocessor communicate commands between the two. Since both subsystems were able to send and receive commands the team deduced that the interface was functioning properly. This communication was tested largely as a part of the software testing for the embedded web server as detailed later in the software testing subsection of the documentation.

7.1.6. LCD Touch Screen

The LCD touch screen display was another subsystem that did not require a lot of hardware testing as the majority of its design within the ECO-SEC system was 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 as well as between the LCD touch screen and the power subsystem the team did need to perform tests on this aspect of the subsystem in order to guarantee that it functioned correctly. The first thing the team needed to test was the connection to the power subsystem. If the power subsystem was supplying the correct power to the LCD touch screen the screen should automatically start up and call the initial default screen. When this did occur the team was able to determine that the power connection was functioning correctly.

The team then tested the serial connection that the LCD would use to communicate with the microprocessor. This was done by connecting the LCD to a PC running a terminal program that simulates a serial connection to the LCD. The team then pressed buttons on the LCD that caused it to produce some output to the serial communication port.

When the team received data on the terminal they concluded that the serial connection most likely worked. Once the coding was complete on the microprocessor the team also performed the same tests but instead connecting the LCD to the microprocessor and has the two send data between each other. This was done in conjunction with the software testing for the microprocessor and LCD touch screen and is covered in more detail in later sections of this documentation.

7.2. Software Testing

This subsection details the process that the team underwent to provide an in-depth testing of any software code that was required for the final implementation of the security system being designed. There are three main portions of software that required 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 was primarily being focused on testing the website in order to verify that it functioned 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 was 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 allowed the team to test the site contained anytime a change was made without uploading the newest version of the website to the server each time. This program also provided 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 the team could guarantee that the web site could still communicate and respond correctly with the attached microprocessor. This eliminated that possibly that any errors that occur during testing were hardware related and not software related. This also made 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. Once the team was confident that the web site was functioning correctly using the SitePlayerPC program, it was uploaded onto the web server and then tested again to verify that it still worked after being uploaded. In addition to using the SitePlayerPC program the team also used a terminal program to simulate a serial connection when the web server was attached to the PC. This was done in order to view what exact information was being sent from the web server to ensure that it was correct before attaching the server to the microprocessor. The terminal program was also used to send serial commands to the web server to make sure that it responded correctly to these commands similar to how it would when the microprocessor sent them to the web server. The rest of this subsection will explore in greater detail how exactly the team tested the ECO-SEC website to verify that it functioned correctly.

The first page that the user encounters, when attempting to visit the website, is the login page. Therefore the team decided that this was the page to start the testing on. First by visiting the page itself on the web server allowed the team to verify that the page loaded correctly as well as allowed the team to check its appearance to make sure that it matched what the team wanted for its design. Once the page correctly loaded in a browser the team needed to make sure that the login feature of the page worked. The team entered several incorrect passwords to verify that the page would not load the next page on the site and instead informed the user that the password was incorrect. The team then entered the correct password which causes the website to load the main page for the ECO-SEC. By testing both of these scenarios the team was able to determine that the login page to the website functioned perfectly as the team originally envisioned it to.

The team then thoroughly tested the main page of the website. Because this page was more complicated and more important to the overall design of the website the team devoted most of the software testing time for the web server to testing the main page of the website. Once again the first thing the team examined was the page itself. The team did this in order to verify that the page loaded correctly and had the appearance that the team desired. The team then examined the video. This allowed the team to make sure the video stream loaded correctly when the user visits the webpage as well as to check to make sure that the quality was at the level the team determined. Once the team verified that the stream was functioning correctly they moved on to test the more complicated aspect of the webpage which was responsible for displaying the status of the system as well as to allow the user to change the status from the web page.

The first examined the status text to make sure that it correctly displayed the current status of the system which for the case of testing was defaulted to "OFF". The team then used each of the three links on the webpage that allows the user to change the status of the team. This allowed the team to test and make sure then when using one of these links the web server updated the status of the system and reloaded the webpage as well as send out the appropriate serial information. The serial information was tested by first using a terminal program to display the information then attaching the microprocessor to make sure it received the correct data from the web server. These tests were repeated for all three links in order to guarantee that they all functioned correctly. The team then examined updating the status on the website as if the microprocessor instructed it to via serial commands to simulate the situation where the user updated the system using the LCD and the website had to update to reflect that change. This was done by using first a terminal program and then the microprocessor to send the serial commands to change the status of the system variable on the web server. After this change was made the page was then reloaded to make sure that it correctly took place.

Once the status information and changing was determined to function correctly the last thing that the team tested for the web server was the email feature. This was done by setting up all the necessary programs on the PC as described elsewhere in this documentation and then sending the serial command to the Site Player instructing it to issue a UDP packet. When an email alert was then correctly send out as appropriate the team determined that the email feature of the web server was functioning correctly.

7.2.2. LCD Touch Screen Display

Of the three main sources of software coding the LCD touch screen display subsystem was the least complicated of the three. Despite this however there was still a level of complexity to this subsystem with regards to how it interacted with the microprocessor. As a result of this, it became important to guarantee that the LCD touch screen display correctly functioned both independently of the other subsystem as well as together with it. This was accomplished by the team performing a through test of all aspects of the software design for the LCD touch screen display subsystem.

The team tested the LCD touch screen in a manner similar to the embedded web server. First the LCD touch screen was attached to a PC running a terminal program to show inputs from the LCD as well as allowing commands to be sent to the LCD. Once all the testing using this set up was successfully completed the team repeated the same testing procedures but instead of having the LCD touch screen attached to the PC the team attached the LCD to the microprocessor as it is in the final prototype design. This allowed the team to successfully determine if first the software worked correctly for the LCD touch screen subsystem and secondly that it still worked with the attached microprocessor.

The first thing the team tested was powering up the LCD. This resulted in the LCD setting up the correct settings and displaying the initial locked screen. This allowed the team to determine that the power on macro was correctly called and it successfully set up the LCD display as the team wanted. By doing this the team determined that this aspect of the LCD software was correct. Once the power on macro was determined to function correctly the team began to test each of the three individual screens of the LCD subsystem to test for their correctness in functionality.

The first screen tested by the team was the locked screen. The team first examined the appearance of the screen to make sure that the header and the footer as well as the unlock button were all in the correct places as the team wanted in its design. The team then pressed the unlock button. When pressing this button automatically transitioned to the passcode screen the team was able to determine that the macros involved in creating the locked screen as well as responding to the press of the unlock button were correctly designed showing that the software for this screen was successfully completed.

The team then proceeded to examine the passcode screen. As with the first screen the team first checked the appearance of the screen to make sure that the software correctly placed all the images and buttons where the team wished it to in its design. The team then checked each button individually to determine if the macros associated with each button worked correctly. The first button the team tested was the cancel button by pressing it and making sure that it correctly returned the LCD to the locked screen. The team then pressed each of the passcode digit buttons to make sure that the LCD stored what button was pressed as part of the passcode. This was check by making sure the passcode status of the right side of this screen updated each time that another digit was entered. Once four digits were entered the team tested the enter button. The team used the terminal first and later the microprocessor to make sure that the entered passcode was correctly transmitted via the serial connection. The team proceeded to repeat this test several times with all different combinations of passcodes to thoroughly ensure that the passcode screen functioned entirely correctly.

Once the team was sure that the passcode screen functioned correctly the team examined and tested the main screen of the LCD. Once again the test first examined the appearance of the screen to make sure it matched what the team wanted in its design. The team examined the status text of the LCD. The team wanted to make sure that it correctly displayed the current status of the ECO-SEC system when the screen is first loaded. Similar to the embedded web server, the system was defaulted to the OFF mode for testing purposes. The team then tested each of the individual buttons located on the main screen of the LCD. First the team tested the lock button to make sure then when pressed it correctly returned the interface to the first locked screen to secure it. The team then tested each of the mode buttons that the user would use to change the mode of the ECO-SEC using the LCD touch screen display. When pressing each of these buttons the team made sure that first the LCD main screen was reloaded with the status text reflecting the new mode the system was set two. Secondly the team made sure that when pressing each button the appropriate serial data was sent out from the LCD touch screen by using first the terminal program again and then the microprocessor subsystem itself. By doing this process with each of the three mode buttons the team determined that the software for the main screen of the LCD functioned correctly.

The last thing the team needed to test for the LCD touch screen software was the ability for the microprocessor to update the status displayed on the LCD screen using serial commands to simulate when a change is made using the website as well as to check to make sure that the microprocessor can tell the LCD which screen to load, the locked or main screen when it checks to determine if the passcode entered to unlock the interface was correct or not. First the team used a terminal to send the correct serial commands to update the status variable on the LCD. The main screen was then loaded to show that the change did take place correctly. This was done first again using the terminal followed by the microprocessor. Finally the commands to load the locked screen and the main screen were tested by sending serial commands to the LCD to simulate the microprocessor telling the LCD to unlock or stay locked depending on the passcode the user entered when using the interface. Once all these features were successfully test the team deduced that the LCD touch screen subsystem software was functioning correctly in all aspects.

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 required 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 were in turn triggered and the system as a whole was 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 was 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 required testing are 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.

8. System Operation

This section describes the use and operation of the ECO-SEC prototype that was developed as described within this documentation. This section is divided into two subsections. The first details the steps necessary to set up and install the hardware, and software necessary to use the ECO-SEC Security System. The second subsection describes how to operate the ECO-SEC system once it has been correctly installed. Upon successfully understanding these subsections the user should be capable of operating the system successfully.

8.1. Setting up the ECO-SEC System

Successfully setting up the ECO-SEC security system is a twofold process. The first involves setting up the physical hardware that is required for the prototype to be successfully implemented. The second requires the setting up and installation of the software components of the ECO-SEC that are used to correctly control the hardware of the prototype.

Setting up the hardware to use the ECO-SEC system is a relatively simple process. The first part will be setting up the hardware for the embedded web server. First the user needs to connect the embedded web server's Ethernet port to an empty connection on a wireless router using a standard Ethernet cable. This can be the same router already in use by the homeowner if they already have installed in their home. The embedded web server DB-9 serial port then needs to be attached to the PCB containing the microprocessor using the correct serial cable. Next the user can set up the security camera used by the ECO-SEC prototype. The user simply needs to plug the Ethernet port of the camera into the same wireless router as the embedded web server using again an empty connection on the router with a standard Ethernet cable. Then simply connection the power port on the camera to a standard wall outlet using the correct power cord. This will successfully install the security camera for the ECO-SEC system. Finally the user needs to have a computer connected to the network provided by the router using either a wired or wireless connection. After these steps the user will have successfully setup the hardware required for the web site interface of the ECO-SEC prototype.

Next the user can setup the LCD touch screen display. The user simply needs to connect the power port on the LCD touch screen module to the correct plug provided by the PCB containing the power subsystem. Next the user needs to connection the DB-9 serial port of the LCD to the microprocessor PCB using the correct serial cable. Note that the LCD contains two serial ports to allow other devices to use the screen at future dates. However this is not needed for the prototype and to correct set up the prototype the user will need to use the port that is physically closest to the power port on the LCD to allow it to correctly function within the prototype. This completes setting up the LCD touch screen interface hardware for the ECO-SEC prototype.

Setting up the microprocessor is a relatively simple process. The user simply needs to connect all the correct cables to interface the subsystem with the rest of the ECO-SEC system. The user will need to connect the correct serial cables from the microprocessor to LCD touch screen and the embedded web server as previously described. The microprocessor will then need to connect to the to the power subsystem using the correct power cable. Once all three of these cables are successfully connected the microprocessor subsystem will be successfully set up.

Setting up the sensor array subsystem is one of the easiest steps to installing the ECO-SEC prototype. Since this system interfaces with the other subsystems using a wireless connection no physical connections are required. Additionally the sensor subsystem is power off of batteries and not the power subsystem directly and as such requires no direct connection to it. Instead all the user simply needs to do is make certain the batteries powering the sensor subsystem are still good and that the sensors themselves are not damaged in anyway.

The power system is almost entirely self contained on a printer circuit board causing it to require little hardware set up. The only thing the user will need to do to set up this system is to connect the corresponding power cables to the microprocessor, embedded web server, and LCD touch screen subsystems. The user will also need to attach the battery used as a backup to the power subsystem. These steps will complete the hardware set up for the power subsystem.

Once the user has successfully set up all the hardware necessary to implement the ECO-SEC prototype the next step is to set up the hardware for the system. This involves setting up the correct software on the PC that is connected to the router. This mostly to facilitate the sending of email alerts by the system. Note that although for the purposes of this prototype, it is done on a personal computer it could very easily be implemented on a server designed to do nothing but send email alerts out for the system. First the user needs to install the UDP2EMAIL program on their PC. As stated previously in this documentation, the UDP2EMAIL program listens for UDP packets set from the web server, and when it receives one will send out an email to a selected address or a series of addresses. The UDP2EMAIL program can be obtained from the Net Media Inc. website at http://netmedia.com/siteplayer/webserver/downloads.html under the section for applications. This program does require the PC to be capable of running visual basic programs. Next the user needs to set up the email account on their PC that will be used to send out the email alerts. Details on how to do this on the operating system used by the user's PC can be found online and will not be covered here. For the testing and demonstration of this prototype, the Windows OS was used. Next the user needs to install and select a default email client for their PC. This program will be used by the UDP2EMAIL program to send out emails. The development team used Microsoft Outlook 2007 to test and demonstrate the email alert for the final prototype.

Additionally in order to allow computers outside the network to be able to reach the website hosted on the embedded web server the router must be assigned port forwarding for the IP address of the server. In order to do this the user must first login into their router to configure its setup. Details on how to do this can be found from the manufacturer of the router being used. Typically this can be done by having a computer on the routers network access the address 192.168.1.1. Once logged into to the router the user needs to forward a port using the default IP address of the embedded web server. For the purposes of the ECO-SEC this would be 192.168.1.104. So for example if the user wishes to use port 1000 to access the web site remotely they would forward the port 1000 using the address 192.168.1.104. Details on how this information will be used to access the web site is given in the sub section detailing how to operate the ECO-SEC prototype.

Once all of the previous steps have been completed the user will need to run the UDP2EMAIL program and set up a few variables that will correctly allow the web server to use the PC to send out email alerts. When the UDP2EMAIL program is first started it will display a window for the program. In this window will be several fields of information the user will need to fill out to use the program correctly. The first field the user needs to fill in is the PC IP. The user would then enter the IP address that the PC uses on the local network. This can be determined in a variety of different ways which will not be covered in this documentation. The next field is the PC Port. This is the port number the web server sends the UDP packets to and the program will listen for them on. This field should be set to 2552 which is the port the web server is selected to default to. Under the from field the user should enter the name of the email account that they previously set up on the software as described in previous steps. This will be the email account that the ECO-SEC prototype will send the email alerts from. Under the to field the user will fill out the email address they wish to send the alerts to, separated by a semicolon for multiple addresses. Note that in order to send a text message alert the user will need to enter email address for their phone which is determined by the service provider of their phone. For example to send a text message email alert to a phone with service provided by AT&T would be ##########@txt.att.net assuming that # represents a digit in the phones ten digit number. The final field that needs to be filled out is the subject field. This will be the subject of the email that is sent. Note that the text field is left intentionally blank. The UDP2EMAIL program will automatically place the date and time that an alert occurred in this field before sending out an email message. This field will then become the body of the email message sent. Once everything has been set up the user simply needs to start the UDP2EMAIL program. This is done by simply check the AutoSend box will forces the program to immediately send a message anytime an alert occurs, and then clicking the Bind Port button to make the program begin to listen on the port for packets from the web server signaling the need to send out an email message. Note that although this appears to be a lot to fill out ideally this information should change very little so once the program is set up once it should not be required to be changed often.

Once all the above steps have been successfully completed, the ECO-SEC prototype is fully set up and configured for the homeowner to begin to use. The following subsection of this documentation will explain in detail how the homeowner operates the ECO-SEC once it has been set up.

8.2. Operation of the ECO-SEC System

The ECO-SEC prototype was designed to be simple to operate and final resulting product is relatively easy for the user to understand how to use and how to operate. This subsection will describe in detail the steps the user would take to operate the system. Primarily this will be focused on explaining how the user interacts with the system via the LCD touch screen interface and the website hosted on the embedded web serve included within the ECO-SEC prototype.

Operating the LCD touch screen interface is relatively simple. The first screen the user is presented when the interface is first powered on is the locked screen. This is used to secure the terminal when it is not in use and does not provide the user with any information on the status of the system. This screen primarily consists of a single "UNLOCK" button. When the user presses this button the interface will transition to the next screen.

On this screen the user is given the option to enter a four digit numeric code. This code is entered using a series of buttons representing the digits "0" to "9". The interface will automatically prevent the user from entering more than four digits and will only record the first four entered. Once the user as typed in their passcode, user has two remaining options on the screen in the form of buttons, the "ENTER" button or the "CANCEL" button. If the user presses the "CANCEL" button the interface will drop the entered passcode and return to the first locked screen. If the user instead presses the "ENTER" key the system will send the passcode to the attached microprocessor. The microprocessor will then check the code and determine if it is correct, incorrect, or the code for the silent alarm feature. If the passcode the user entered was correct the microprocessor will inform the LCD interface to unlock and present the user with the main screen. If the passcode was incorrect the microprocessor will instruct the interface to instead return to the first locked screen. If the code entered matched the code for the silent alarm the microprocessor will instruct the LCD interface to unlock as if the code were correct, while proceeding to generate an alarm as appropriate using the rest of the ECO-SEC system. The correct passcode is defaulted to "1111" and the silent alarm code is defaulted to "2222". These defaults can be changed by simply changing the appropriate values in the microprocessor code. Although not ideal, the system is only a prototype and was not designed to be completely user friendly. Instead the focus was on developing a prototype that acted as a security system to the best of its ability.

Assuming that the user entered the correct passcode on the appropriate screen of the interface will proceed the main screen. This is the part of this interface that will be of the most interest to the user. This screen can be divided into two main parts. The first is a set of status text that informs the user what mode the ECO-SEC prototype is currently operating in. This can be either off, stay, or away. Note that the interface will never display when an alarm is actively going off, only what mode the system was in when the alarm was triggered. More details on the various modes will be given later in this section of the documentation. The second part of the main screen of the interface is a set of four buttons. Three of the buttons contain the labels of "OFF", "STAY", and "AWAY". When the user selects one of these buttons the system will change the operating mode of the ECO-SEC to the appropriate type and reload the main screen to allow the user to see that the update correctly occurred. The fourth button is labeled “LOCK" and allows the user to return the interface to the first locked screen to secure the terminal when they are done making changes to the operation of the system. This concludes the operation of the LCD touch screen interface for the ECO-SEC prototype.

The secondary method for the user to interact with the system is through using the website for the ECO-SEC system that is hosted on the embedded web server. In order to access the website the user needs to enter the correct address into an Internet browser of their choice. If accessing the website from the same local network that the embedded website is hosted on the user can simply access the website using the default IP address of 192.168.1.104. This default address can be changed by adjusting the code for the embedded web server if this causes a conflict. If attempting to access the website from a computer that is not a part of the same local network as the embedded web server the user will need to use the IP address of the router the embedded web server is attached to, followed by the port number previously assigned to the web server. This is entered into the browser in the form of http: //xxx.xxx.xxx.xxx:yyyyy/ where xxx.xxx.xxx.xxx represents the IP address of the router and yyyyy represents the port number assigned to the server. For the purposes of demoing and testing the ECO-SEC the router used as assigned the IP address of 205.204.16.9 with the port number of 1000 so for the user to access the site using this set up they would need to enter the address http://205.204.16.9:1000/ into their browser to access the site.

Once the user has successfully access the website either remotely or locally they will be presented with a login screen. This screen will display the ECO-SEC logo and prompt the user for a login password. The user needs to enter the correct password into the given text box and then click the Submit button. If the password is correct the user will gain access to the main page of the website. If the password is incorrect a pop up will occur informing the user that the given information was incorrect and the embedded server will block the user from accessing the main website. For the purposes of the ECO-SEC the password was defaulted to "1234abcd" This was a simple password used for testing the website. This password can be changed easily by making a few adjustments to the website design. Information on where these changes would be needed can be found in the sections of this documentation detailing the website construction.

Once the user has entered the correct password the web server will display the main page of the website. When first logging into the site, it may prompt the user to install ActiveX content. The user will need to accept to install this content in order to be able to view the live stream from the security camera. This content simply installs the necessary software in order to display the information from the camera in the browser. The main screen contains several sections of information. It informs the user they are logged into the ECO-SEC and then will display the image that the security camera is currently viewing of the user's home. The next line informs the user of the status that the system is currently operating in. Similar to the LCD interface these modes can either be OFF, AWAY, or STAY. The line below this contains three links labeled "OFF", "STAY", and "AWAY". By clinking of these links the user will adjust the operating mode of the ECO-SEC to the appropriate setting. The embedded web server will then reload the page to show the user that this change has occurred and then will pass this information to the attached microprocessor which handles all other necessary steps to accommodate the user's changes. When the user is done making changes to the simply they can log out of the ECO-SEC website by using the logout link in the upper left corner of the page under the ECO-SEC logo. Upon logging out of the site the user will be redirected to the login page. This concludes how to operate the ECO-SEC system remotely using the website hosted on the embedded web server.

9. Administrative Content

9.1. Project Milestones

The following table was the schedule for the milestones related to this senior design project as they were completed by the team. The team 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 began purchasing all the necessary parts so upon the beginning of Senior Design II the team could begin to immediately construct the prototype. The prototype was completed by the middle of June. This left enough remaining time to allow the team to adequately be able to fully test the prototype to ensure that it functioned as intended. This stage was also 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
	Research	Jan to Feb 2011
	Initial Project Identification Document	Jan 31st 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	July 2011
	Final Test Results	July 2011
	Source, Executable, Build Instructions	July 2011
	Final Prototype Document	July 2011
	Demo ECO-SEC	July 2011

Table 22: Project Milestones

9.2. 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	Cost
4.3" LCD Touch Screen	$349.00
Site Player SP1K Board	$79.95
30W Solar Panel	$100.00
49 WH Battery with Charger	$115.00
Power Subsystem Components	$165.00
AXIS M1011 Camera	$169.00
Stellaris LM3S1698 Microprocessor	$0.00
Wireless Module	$125.85
Glass Break Sensor	$23.45
Door/Window Sensor	$29.44
Motion Sensor	$25.00
Final Cost	$1181.69

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 was that the prices for each of these parts were based upon buying the parts individually. The manufactures of the various parts used often offered 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. Additionally some of these parts were required only for testing the prototype and would not be needed to produce every copy of the prototype which helps further reduce the overall cost of the prototype. So although the prototype ended up being more expensive than originally envisioned by the team it is still comparable to most other security models on the market without counting the fact that it has no additional monthly fees which can make it a cheaper solution for a long term investment in a security system. 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 increased the cost of these associated subsystems.

10. Conclusion and Summary

The goal of this documentation was to provide a detailed explanation of the ECO-SEC security system as it was 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 was 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 was 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 decide which parts were the best fit for the design and were to eventually purchase 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 subsystems 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 the embedded web server. The embedded web server uses the camera to provide a live security feed of the homeowners. The security feed was incorporated into the website design using a java active script. So although this subsystem did not require much hardware or software construction on its own, additional design was required in the website development to allow the camera to properly work with it.

The power subsystem was designed to provide power to the rest of the components of the security system. This included the microprocessor, the LCD touch screen, and the embedded web server. 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 was implemented on a printed circuit board of the teams own design.

The last remaining hardware subsystem required by the ECO-SEC was 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, the glass of a window being shattered, and motion detection provided by the use of infrared technology. This subsystem is connected to the microprocessor by a receiver on the microprocessor subsystem. When every one of the sensor in the array is activated it sends a signal to the microprocessor indicating this. The microprocessor then responds and signals an alarm.

The microprocessor subsystem was a combination of both hardware and software but the main focus of the subsystem was to manage the logic behind the ECO-SEC system. The hardware for the microprocessor subsystem was 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 was concerned the microprocessor controls the logic behind 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 was 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 was 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 was primarily composed of software and has two main purposes. The first was 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 was 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 was 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 was accomplished by sending the user a text based email message.

The ECO-SEC was designed around seven separate but equally important subsystems. When the final prototype was successfully implemented the development team completed a fully functioning security system that was comparable to professional systems available on the market for a similar cost. Although the final prototype was intended to be fully functional, the prototype still requires some additional improvements to able to be successfully marketable. This created 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 follows the design guidelines previously stated in the course of this documentation.

Appendix A: References

1. http://en.wikipedia.org/wiki/GSM (info)
2. http://en.wikipedia.org/wiki/Subscriber_Identity_Module (info)
3. http://computer.howstuffworks.com/question716.htm (info)
4. http://www.touchscreenguide.com/touchscreen/res.html (info)
5. http://www.touchscreenguide.com/touchscreen/cap.html (info)
6. http://www.touchscreenguide.com/touchscreen/acoustic.html (info)
7. http://www.picoweb.net/prodpw1.html (info)
8. http://www.maxim-ic.com/datasheet/index.mvp/id/3609 (info)
9. http://netmedia.com/siteplayer/webserver/sp1.html (info, manufacturer)
10. http://www.neutronusa.com/prod.cfm/727291/glb (info)
11. http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=BER275-ND (info)
12. http://www.reachtech.com/products/development_kits/ (info, manufacturer)
13. http://www.planartouch.com/101/select/ (info)
14. http://en.wikipedia.org/wiki/Burglar_alarm (info)
15. http://www.pvresources.com (info)
16. http://www.planetarypower.com.au (info)
17. http://www.solarpower2day.net/solar-cells/efficiency/ (info)
18. http://www.solarserver.com/knowledge/basic-knowledge/photovoltaics.html (info)
19. http://www.soton.ac.uk/~solar/intro/start.htm (info)
20. http://www.isofoton.com/energy-solutions/developments/concentration-systems/# (manufacturer)
21. http://www.alpstechnologyinc.com/ (manufacturer)
22. http://www.suniva.com/ (manufacturer)
23. http://pvcdrom.pveducation.org/ (info)
24. http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/ (info / map)
25. http://www.virtualsecrets.com/build-a-solar-panel.html (build)

26. http://www.sunelec.com (distributor)
27. http://batteryuniversity.com (info)
28. http://www.powerstream.com/li.htm (info)
29. http://www.onlybatteries.com (distributor)
30. http://batteryspace.com (distributor)
31. http://www.maxim-ic.com (info, manufacturer)
32. http://datasheets.maxim-ic.com/en/ds/MAX745.pdf (datasheet)
33. www.digikey.com (info, parts)
34. www.element14.com (info, parts)
35. www.linear.com (info, part)
36. www.national.com (info, parts)
37. http://www.maxim-ic.com (info, manufacturer)
38. http://www.cmucam.org/ (info)
39. http://www.axis.com/products/cam_m1054/index.htm (info, manufacturer)
40. http://grieg.gotdns.com/blog/?p=215 (info, table)
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. - Granted

To whom it may concern,

Hello Nathan,
Permission is granted to use the copyrighted SitePlayer material for your educational purposes as requested.

David Holcomb
davidh@netmedia.com

Nathan Schroeder wrote:
> 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

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