



# Smart Home Management System

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# Table of Contents

<b>List of Figures .....</b>	<b>v</b>
<b>List of Tables.....</b>	<b>vii</b>
<b>1.0 Executive Summary.....</b>	<b>1</b>
1.1    Goals and Objectives.....	2
<b>2.0 Project Motivation.....</b>	<b>3</b>
2.1    Motivation.....	3
2.1.1  Renewable Energy.....	4
2.1.2  Environmental Impact.....	8
2.1.3  Existing Technology.....	9
2.1.4  Existing Products .....	14
2.2    Specifications & Requirements .....	20
2.2.1  Battery Specifications & Requirements .....	21
2.2.2  Solar Panel Specifications & Requirements .....	21
2.2.3  Data Storage Specifications & Requirements .....	22
2.2.4  Data Transmission Specifications & Requirements.....	23
2.2.5  User Interface Specifications & Requirements .....	23
2.2.6  Microcontroller Specifications & Requirements .....	23
2.2.7  DC/DC Converter Specifications & Requirements.....	24
2.2.8  Inverter Specifications & Requirements .....	24
2.2.9  Sensor Specifications & Requirements .....	24
2.3    Roles & Responsibilities .....	25
2.3.1  Division of labor.....	26
2.3.2  Code and Lead Design Breakdown.....	27
2.3.3  Budget and Cost .....	28

2.3.4 Timeline.....	30
2.3.5 Group Meeting Timeline .....	32
<b>3.0 Research Methods.....</b>	<b>33</b>
3.1 Websites & Relevant Works.....	33
3.2 URL .....	33
3.2.1 Domain .....	34
3.2.2 Directory.....	34
3.2.3 File Name.....	34
3.3 Web Hosting.....	34
3.4 Clients & Servers .....	36
3.5 Database.....	40
3.5.1 MySQL .....	40
3.5.2 Oracle Database .....	40
3.5.3 Microsoft SQL Server.....	41
3.6 Security Risks.....	41
3.7 Scripting Languages.....	42
3.8 Mobile Application Environments.....	43
3.8.1 Android.....	44
3.8.2 Apple iOS .....	44
3.8.3 Windows.....	45
3.8.4 Choosing the Environment.....	45
3.8.5 Android Application.....	45
3.9 User Interface.....	47
3.9.1 Website GUI .....	47
3.10 Bluetooth.....	48

3.11	Wi-Fi .....	49
3.12	Network.....	50
	3.12.1 Categories of Network .....	51
	3.12.2 Mesh Network.....	52
3.13	Transceiver .....	53
3.14	Microcontroller .....	56
3.15	Charge Controller .....	62
3.16	Power Inverter .....	63
3.17	Relay.....	64
3.18	Battery.....	65
<b>4.0</b>	<b>Project Design.....</b>	<b>84</b>
4.1	Design Architecture.....	84
	4.1.1 Event System .....	87
	4.1.2 Battery Backup System.....	89
	4.1.3 Transmitter.....	91
	4.1.4 Temperature Sensor.....	92
	4.1.5 Light Sensor .....	94
	4.1.6 Motion Sensor .....	98
	4.1.7 Hardware Design .....	99
	4.1.8 Outlet.....	103
	4.1.9 Electronic Door Lock.....	106
4.2	User Interface.....	110
4.3	Hardware/Software Integration.....	116
<b>5.0</b>	<b>Project Design Summary .....</b>	<b>123</b>
5.1	Hardware Design.....	124

5.2	Software Design .....	124
<b>6.0</b>	<b>Project Prototype &amp; Testing.....</b>	<b>127</b>
6.1	Unit Test .....	127
6.1.1	Temperature Sensor.....	127
6.1.2	Light Detector.....	127
6.1.3	Motion Sensor .....	127
6.1.4	Outlets, Fan, LEDs.....	128
6.1.5	RF Transmitter.....	128
6.2	Functional Test.....	129
6.3	System Test .....	130
6.4	Software Test .....	130
<b>7.0</b>	<b>Project Conclusion .....</b>	<b>131</b>
<b>8.0</b>	<b>Appendices .....</b>	<b>II</b>
8.1	Copyright Permissions.....	II
8.2	References.....	IV

## List of Figures

Figure 1 – Total Energy Consumption .....	5
Figure 2 – Power Generation by Type .....	6
Figure 3 – Energy Source Comparison in 2010 .....	7
Figure 4 – Energy Source Comparison in 2030 .....	7
Figure 5 – Gas Emissions by Energy Type .....	8
Figure 6 – GSM Block Diagram .....	10
Figure 7 – ZIGBEE Block Diagram .....	12
Figure 8 – Bluetooth-powered Remote Home.....	18
Figure 9 – ZIGBEE-based Smart Home.....	19
Figure 10 – Roles and Responsibilities.....	26
Figure 11 – Code and Management Divisions .....	28
Figure 12 – Milestone Timeline.....	32
Figure 13 – Group Meeting Timeline .....	33
Figure 14 – CC2500 Transceiver Schematic .....	55

Figure 15 – CC2500 Transceiver Block Diagram.....	55
Figure 16 – TI Stellaris Microprocessor Schematic .....	60
Figure 17 – Main Microcontroller Block Diagram .....	61
Figure 18 – Role of Renewable Energy in 2008.....	73
Figure 19 – Market Share of Different PV Technologies .....	75
Figure 20 – Solar Cell I-V Characteristics .....	80
Figure 21 – Annual Average Solar Radiation Map .....	82
Figure 22 – Average Household Site Energy Consumption in 2009.....	85
Figure 23 – Households with Selected Appliances and Electronics in 2009.....	86
Figure 24 – Monitoring Home Equipment from the Office .....	87
Figure 25 – AVR Battery Backup System .....	89
Figure 26 – RF Transmitter Schematic .....	92
Figure 27 – Temperature Sensor Schematic .....	93
Figure 28 – Design Route Schematic .....	94
Figure 29 – Ultra-low Power Sensor .....	95
Figure 30 – Home Wireless Network Monitoring.....	96
Figure 31 – Lighting Interface Schematic.....	97
Figure 32 – MSP430F2013 Motion Detection System .....	99
Figure 33 – Motion Detection Software Flowchart .....	101
Figure 34 – MSP430 PIR Sensor Block Diagram.....	102
Figure 35 – MSP430 PIR Sensor Schematic .....	103
Figure 36 – Outlet Control Schematic.....	104
Figure 37 – Current Sensor Integration with Outlet Schematic .....	105
Figure 38 – Outlet Control Flow Chart Diagram .....	106
Figure 39 – Electronic Door Lock Schematic .....	107
Figure 40 – Electronic Door Lock Flowchart .....	108
Figure 41 – Door Locking Signal Flow Diagram .....	109
Figure 42 – Illustration of ViewGroup Objects.....	110
Figure 43 – Light Control via Graphical User Interface .....	111
Figure 44 – Outlet Control via Graphical User Interface.....	112
Figure 45 – Database Information via Graphical User Interface.....	113
Figure 46 – Power Usage Monitor via Graphical User Interface .....	114
Figure 47 – Android GUI Block Diagram.....	115
Figure 48 – Website Device Toggle .....	117
Figure 49 – Android Device Toggle .....	118
Figure 50 – Temperature Status .....	119
Figure 51 – Website Log-in.....	120
Figure 52 – Website Log-in with Limited Attempts .....	121
Figure 53 – Website Log-in with Increasing Access Delay .....	123
Figure 54 - Hardware Block Diagram.....	124
Figure 55 - Software Block Diagram .....	125
Figure 56 - UML Class Diagram .....	126

## List of Tables

Table 1 – Objectives and Specifications .....	20
Table 2 – Proposed Budget .....	29
Table 3 – Running Budget.....	30
Table 4 – Atmel XMEGA D4 Operation.....	62
Table 5 – Li-Ion Battery Tradeoffs .....	68
Table 6 – Comparison of Different Battery Types .....	69

## **1.0 Executive Summary**

In this summary, we will cover the main points featured in this design document. First, we will quickly touch on history of electricity and the purpose behind our project, followed by a brief explanation of the goals and specifications we hope to achieve. Second, we will provide a well-detailed overview of our visions, research, and design process of the project. Lastly, we will conclude by explaining our testing procedure and provide some final thoughts on our system and how it turns out, from the initial design phrase to the final finish product.

Thomas Edison invented the light bulb and George Westinghouse along with Nikola Tesla made the Alternative Current (AC) popular since it can travel longer distance than its counterpart, the Direct Current (DC). AC voltage can be transformed using transformers, therefore, it was possible to send large amount of voltage with small current through transmission lines and step down the voltage once it arrives in a residential area. AC has become the main source of power to be delivering to billions of households throughout the world.

There are two main ways to generate electricity, nuclear powered or fossil fuels powered. Fossil fuels have been the main method for our electricity; for, it is much safer. For power plants to generate electricity, it has to consume large amount of natural resources. These resources are not unlimited and consuming too much of it will have a negative impact on our environment, as carbon dioxide ( $\text{CO}_2$ ) will be releasing into our atmosphere. As a solution, we have decided to design and build a house management system that will help to utilize our electronic devices more efficient, with some extra features. That is the main purpose of this project is to utilize our natural resources more effectively.

We will demonstrate several advanced capabilities with our management system. The first ability is the ability to control the system by any android powered portable devices. Second, it is to implement of Bluetooth (V2.0 or greater) connectivity that enables usage approximately 10 meters. Third, it is to implement Wi-Fi (IEEE 802.11g) connectivity that allows connection to a LAN via a wireless point. Fourth, the system shall feature a user website that is accessible from any place that is internet capable, given that its wireless access point is connected to the internet. Fifth, the system shall implement an alert system that notifies the homeowner of unauthorized access via text message and/or email, given that internet access is available. Lastly, the system will feature these functions like: monitor power usage for each power outlet and indoor/outdoor lights, allow the user to control power features from the GUI, and provide power usage history that displays usage per hour for a history range up to 3 months prior.

There are a few objectives that need to be kept in mind throughout the planning and designing of this project. One of the main objectives is to create a unique design that has flexible set of features that will enhance its functionality. It is also important to keep the project simple when it comes to user interfacing. Next, all aspects of our project were researched extremely well before any design or construction began in an effort to be as

efficient as possible with funding. We looked at several similar products out there in the market and paralleled their research and design process. From these studies, we found that it was best to assign each member in the group to certain sections of our table of content and developmental tasks: programming, battery/solar panel, Wi-Fi and web development, and microcontrollers. Over the course of several weeks, each member researched all aspects associated with their tasks, in-depth, and communicates with group members on their findings.

## 1.1 Goals and Objectives

The goals of this project are to reduce needless power usage in homes with a system that is effective at reducing power use and noninvasive to daily lifestyle in a relatively inexpensive and simple way, without using more power than would be saved. So, a main objective of the home energy system would be low power usage. If the system is going to consume more energy than it saves, then the system would be simply useless and ineffective. Thus, the entire system must operate at a power usage lower than the amount of power the regular Vampire Draw would waste.

We will create multiple modules for switching power on and off as well as monitoring current. Also a small control unit will be built connected to a touch screen display, which will be the user interface for the system. Also, a unit which the user can monitor the usage over the Internet will be designed. The central unit needs to be user friendly and safe to use. The main idea is that with this system, the user will be able to see significant power bill reductions in a simple, nearly completely passive manner.

A current flow and current measurement module will be in line with each outlet in a system. The current used will be recorded using a current sensor that we will build and will be sent to the main control device. This main control device might be a microcontroller that is able to turn off the flow of power to anything beyond one of the modules.

Another sensor will be used to sense the presence of a person in any area of the house. The sensor might be a motion sensor or a body temperature sensor. The main control device will be receiving data from both sensors and sharing data with the LCD display and the unit that the user can monitor over the internet. A serial Ethernet device server will be used to allow the user to communicate with the main control device through the internet. The user will be able to choose to turn the power off an appliance or many appliances at the same time. This feature can easily be accomplished with the use of the microcontroller. The microcontroller will send out command of either a 1 or 0 to the designated appliance chosen by the user.

With the project's expectations in mind, the wireless communication will require a device that can allow data to be transmitted between the units in distances of possibly 35 to 60 feet. As houses do not always come in convenient, tiny box shapes, the device used must reliably send the data from the measuring units to the display units which would be set in a central location within the domicile. If the measuring units created a peer to peer network to pass along the data to the main unit perhaps that could solve any issues in

larger facilities. As well, if a wired network is chosen, data reliability must be taken into consideration and preserved over the existing power line infrastructure of the house.

The software goals of the project are to ensure that the user will want to save energy in a simple, passive way. The GUI for the project should be clean enough to not be distracting, but still informative enough that the user will want to look at it often. Also, the GUI must be responsive enough that the user does not feel frustrated while waiting for a window to load. The user must feel like they are in control of their energy usage, by offering them many options to customize their experience.

The demands of the project require the use of a microcontroller in each measuring unit, and a larger processor in the display unit to control the touch screen display. In theory, the microcontroller in the sensor units should be able to convert the analog measurement from the metering components and send that information to the display unit after completing and compiling any necessary calculations. The microcontroller needs to be small enough that the size of the sensor units will not become an eyesore to homebuyers and will still remain applicable in an end user situation.

This project demands an environment where real time graphs of power usage can be displayed on a touch screen with near seamless transitions. This should be possible with a strong control unit and enough memory. To accomplish that, an FPGA would be difficult to design. Instead, a microprocessor will be used. Because a microprocessor is needed, a support system for that is necessary. This includes RAM, flash memory, and communications access. Research in the following sections will include these issues.

## **2.0 Project Motivation**

### **2.1 Motivation**

The ultimate motivation behind our project is we want to conserve our planet for generations to come. Our population is bigger than ever before and continues to growth. Plus, there are more people that are living in cities than in the past. We are concerned with the power consumption in today world. We will develop a home management system that will control and help run most of the household electronic devices more efficiently; most of these devices will be charge or power by solar panels. The design a smart home management system providing people with the luxury of using a smart phone, tablet or personal computer to turn lights on/off, cut off electricity going to an outlet in the case when a power outlet is not in use, and even allow them to open their front door, everything done remotely. We also plan on adding some security features enabling people to know what is going on at their homes when they are away at work or on vacation. If an intruder breaks into the house, the homeowner would get a text message/email notification of the event.

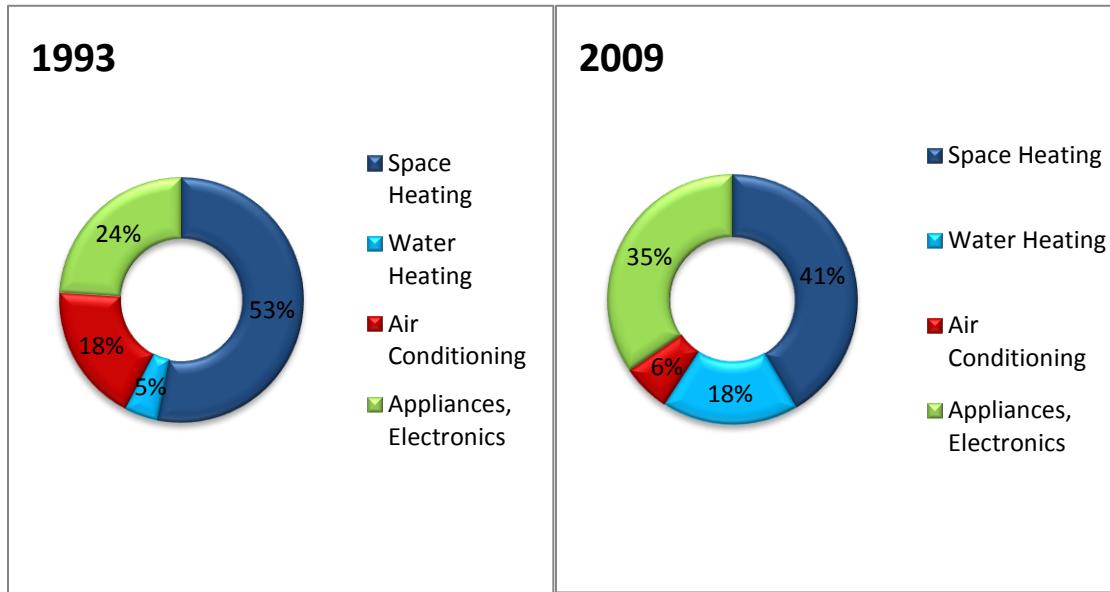
However, if the homeowner is out of the country, it may be difficult or even impossible to get messages via text. For this reason, emailing the homeowner comes in handy. We plan on implementing Bluetooth to enable the user's smartphone to communicate with

the power outlets, lights, and electronic door lock. In case people want to use their personal computers to monitor their homes while they are away, this task will be possible via a website where the user will be able to monitor their use of electricity and control their electronics. The website will provide access to a history of power usage throughout the day, for a period up to several months past. In addition, the user would be able to see the amount of money they're spending on their electric bill. This way, it could be easily seen how much power is being used and how much money is owed to the power company on a daily basis, encouraging the conservation of energy. On top of that, the monitor system will discourage consumers from wasting electricity on devices that are not in use since the consumers can see how much they are being bill, which we hope will a sense of urgent to the consumers to conserve energy and use it wisely. Next, we will discuss about the overview objective of the project and what we want it to achieve.

- Self- Sustaining, it should draw no additional power from the external sources, including but not limited to the power grid
- High Power, Must generate enough power to run large appliances or several small appliances continuously
- An easy way to monitor their home from any location that has internet access
- Give the consumers the ability to narrow down and complete breakdown of each device consumption
- Give the consumers the satisfaction of seeing the power they are saving from their electronic devices
- Expose the consumers to green technology and be energy independent

### **2.1.1 Renewable Energy**

Millions of households in America consume electricity every day. [1] In 2009, the U.S Energy Information Administration calculated that the average annual electricity consumption in a household was 11,280kilowatt-hours (kWh), an average of 940 kWh per month. For decades, heating and cooling (space conditioning) accounted for more than half of all residential energy consumption in the U.S. However, in the recent years we have seen a steady rise of energy consumption for appliances, electronics and lighting. In 1993, they were accounted for only about 24% of our total energy consumption but have risen as far as 35% in 2009. This is shown in Figure 1 below [1].

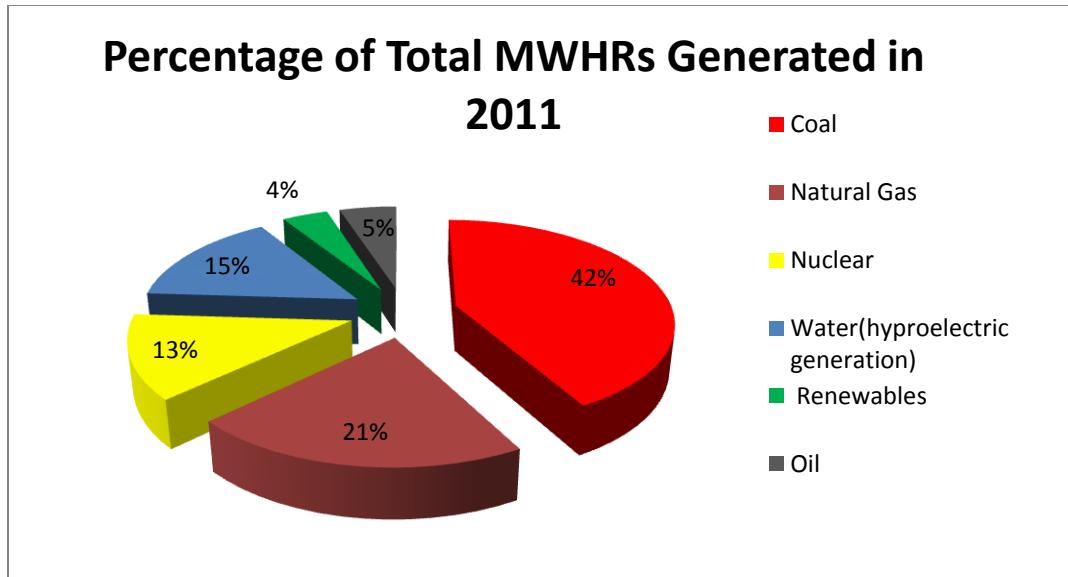


**Figure 1 – Total Energy Consumption**

(Figure created using data acquired from [1])

We are faced with the challenge of conserving energy and preserving our environment for future generations. As a group, we were discussing of ways to make our homes more efficient. It's been known that when electronics are left plugged in power outlets, vampire power is being consumed even when the devices are turned off. Our vision is to design a smart home management system that will be able to effectively control most of the electronics and lighting in a house, with the ability to proactively track and manage electricity usage in real time, along with security features that notify the homeowner in case of an emergency, such as home invasion. With our vision being energy conservation and efficiency come in second, we have envisioned that in the future the world will steer away from natural resources and lean on renewable sources for producing energy.

There are many ways to generate electricity using renewable methods, currently in use and in development, but the two most popular are wind onshore/offshore and solar panels. Wind onshore/offshore is one of the best ways to produce clean energy but for the scope of our project, it is out of the realm, complexity and funds wise. This led us to solar panels. Although Solar panels market share is very small compare to fossil fuels, the traditional method of generating electricity, Solar panels have come a long way since it was developed approximately in the 1940s. It is currently produce more power per square foot and relatively cheap compare to 10 years ago. Therefore, it is logical to make solar panels the main source to power our project, given our purpose is to conserve energy and to build a house management system that will be powered by clean source with no or minimal environmental impact. We will be using solar panels to power most of our hardware. Figure 2 shows the power generation percentage by type of energy source.



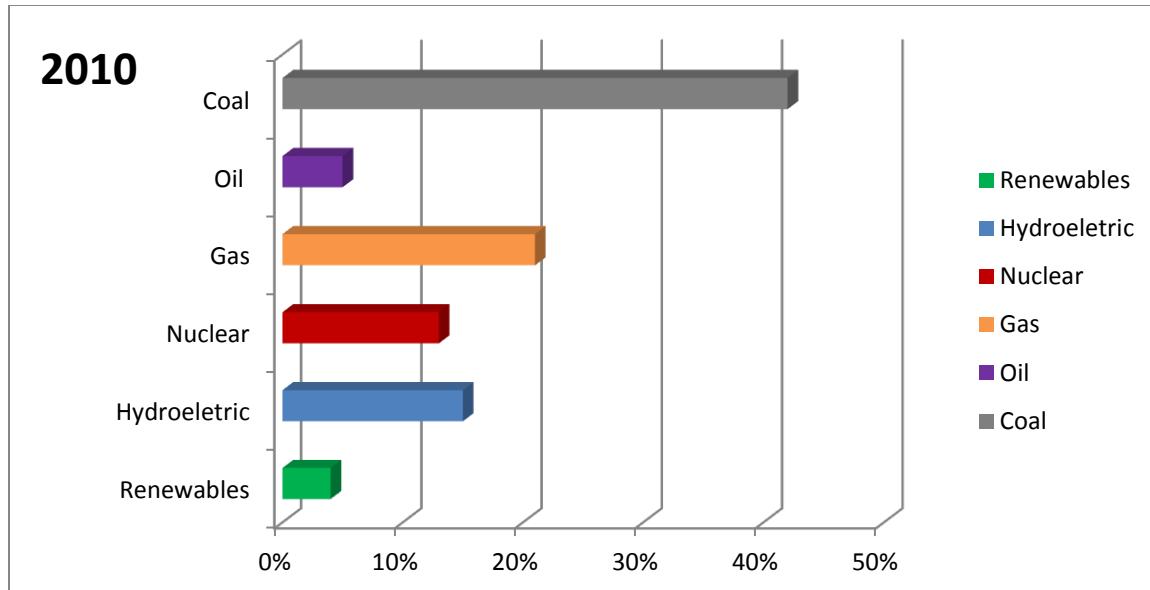
**Figure 2 – Power Generation by Type**

(Figure created using data acquired from [1])

During the recent survey data, it is shown that coal is still the world leading source for generating electricity, following by natural gas. Renewable methods only accounted for roughly 4% of the world source for electricity. In that 4% of the total renewables, solar panels responsible for 27%, solar PV and solar CSP. Like we have mention earlier, solar panels is still relatively small compare to others but we have no doubt that this technology will become widespread throughout the world in the near future. With that, we plan to implement this wonderful technology within our project like we briefly described above.

We plan on building a smart home. We are thinking of providing people with the luxury of using a smart phone, tablet or personal computer to turn lights on/off, cut off electricity going to an outlet in case that outlet is not in use and even allow them to open their front door via their smart phones. We also plan on adding some security features enabling people to know what is going on at their houses when they are away at work or on vacation. If an intruder breaks into the house, they should get a text message/email depending on what they have access to. Since we know that if one is out of the country it may be hard or even impossible to get messages via text, which is why being able to email the owner comes in handy.

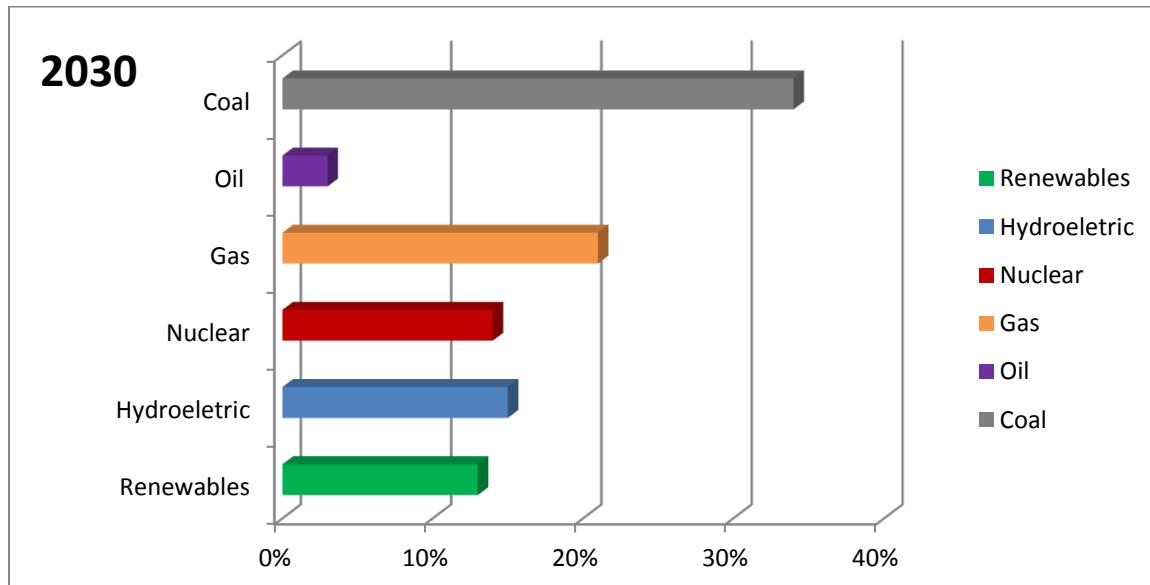
We plan on using Bluetooth that will enable their smartphone to communicate with the outlets, lights, and the door entry. Incase people want to use their personal computers to monitor their homes when they are away, this task will be possible via a Wi-Fi network, where people will also be able to monitor their use of electricity. They will have access to a history of power usage throughout the day. Plus, people should be able to see the amount of money their electricity bill is. If only people could see how much power is being used and how much money they owe the power company on a daily basis, they can make an effort not to waste energy. Figure 3 shows the comparison between the usages of different energy types in 2010.



**Figure 3 – Energy Source Comparison in 2010**

(Figure created using data acquired from [1])

According to U.S Energy Information Administration, Residential Energy Consumption data, the renewable sources will have the highest growth in the next 20 years compare to the traditional generation methods. This projection is shown in Figure 4 below.



**Figure 4 – Energy Source Comparison in 2030**

(Figure created using data acquired from [1])

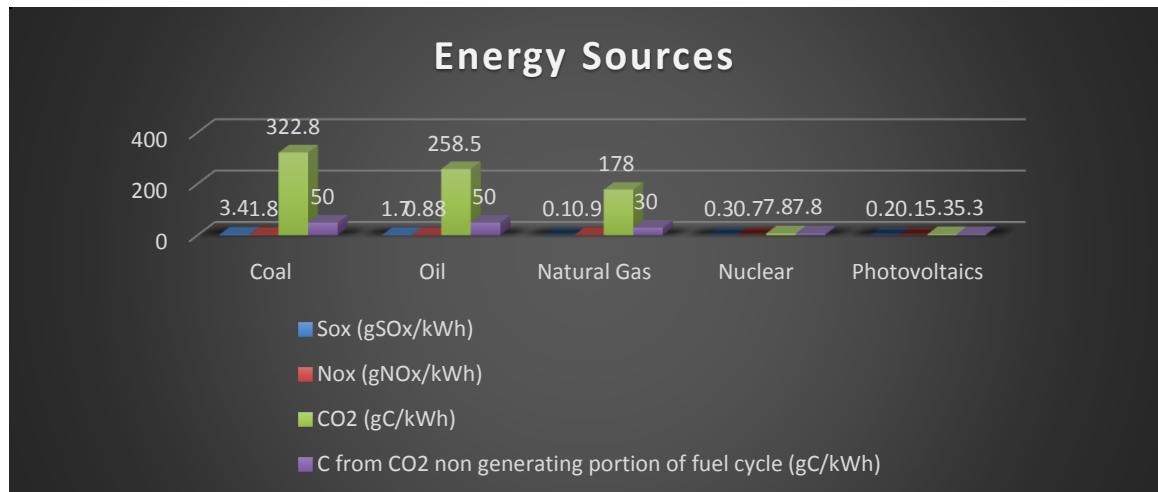
## 2.1.2 Environmental Impact

The idea behind this project is for the user to save energy using several different methods, such as having the ability to remotely turn off power to electrical outlets so as to eliminate vampire power, having access to a handy power usage monitor that records usage overtime, telling the user where power has been used most/least, and by having solar energy to power the more simpler components, such as indoor and outdoor lights. This project consists of both promoting energy-saving concepts and ultimate convenience for the user. Home security is an added feature that is proposed to exist in this project, where an electronic door lock will be implemented, along with SMS/email messages being sent to the user when unauthorized access occurs. The result of this project would effectively aid in saving our environment from further devastation.

There are environmental factors that can be considered compared to conventional power generation [2].

- Generated offsets per k-Watt generated
- Up to 16kg NOX Nitrous oxide
- Up to 9 kg SOC Sulfurous oxide
- 600-2300 kg CO<sub>2</sub> carbon dioxide

Figure 5 below depicts the generated amount of each of the labeled gases. This is from a variety of generating sources primarily used in the United States.



**Figure 5 – Gas Emissions by Energy Type**

(Figure created using data acquired from [2])

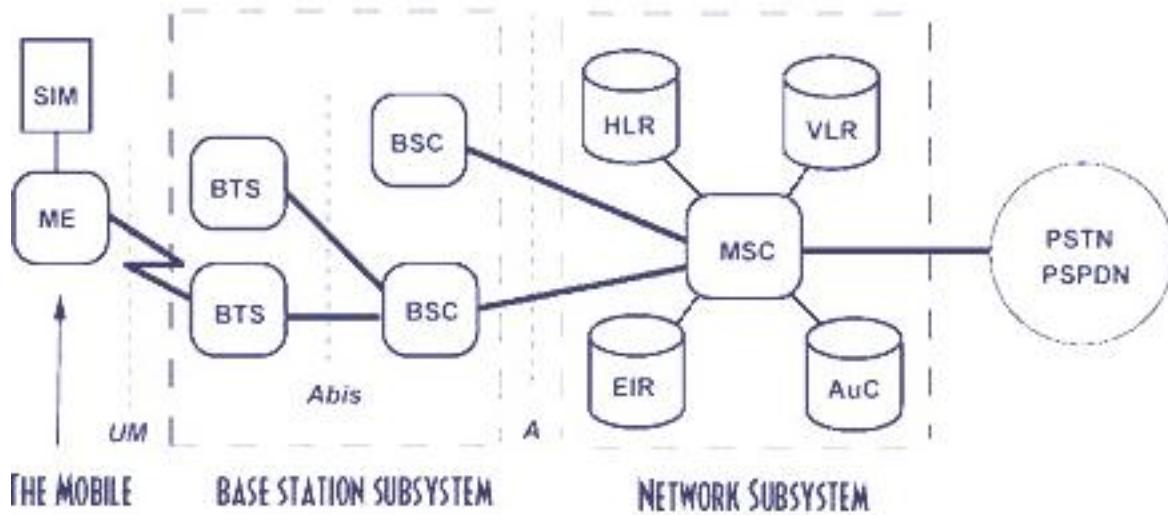
The average home will require a 2.5KW system to satisfy most needs of its power needs. The 2.5kW system will also take about 400 square feet, which some of the requirement for size are dependent on the size of the size of the best panel for price and efficiency. With interests in cost saving control and access, and environmental aspects, there has

recently been a lot of interest in legislation to help the industry along. After many of the rolling black outs in the late 90s the western United States has had a great push for helping the green technology industry take off.

### **2.1.3 Existing Technology**

Our group is not alone in the quest of creating an efficient household; there exist several systems out there that try to tackle different ways to make a home more efficient. They try to come up with different technologies that would not only push people to make energy conscious decision but also help in providing a more environmental friendly solution that could benefit everybody in the long run. There are several kind of technologies out there that people make use of to build Home Automation System. Among them are GSM, ZIGBEE, Li-Fi, Bluetooth, Wi-Fi direct, and Wi-Fi; we might also take a look at the new Microsoft's platform for experimental research called LOT.

One the latest technologies being used out there in home automation systems is the Global Systems for Mobile known to a lot of people as GSM [3]; because GSM uses stylish MODEM which can easily interface to entrenched microcontrollers. Some observers think that everything is going to be automatic because of the use of this technology; the Global Systems for Mobile enables us to access devices remotely. The way GSM works is that its controllers use mobile phone technologies to communicate. Imagine that you have a smart home that uses Global Systems for Mobile technologies. If anything were to happen at that house, let say someone uses force to break the front door to get inside the home, because of sensors at the home; there would be communication between the sensors and the GSM controller. The antenna output will give information to the system and let it know that there is an intruder(s) in the house, when that command is received, the controller would decode it then it would activate the required procedure which in this case would be sending a text message to the home owner or in some cases call 911. Figure 6 below is a block diagram of the GSM system.



**Figure 6 – GSM Block Diagram**

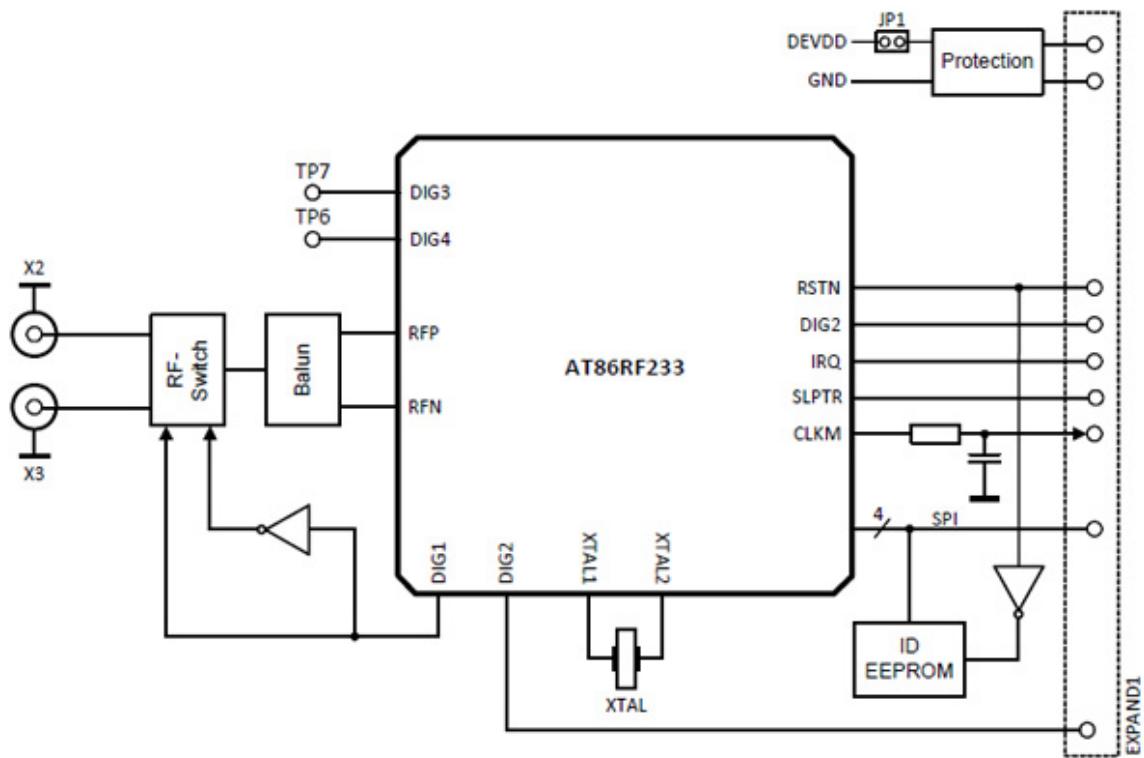
(Permission Pending)

Li-Fi, an alternative to Wi-Fi that transmits data using the spectrum of visible light, it has achieved a new breakthrough, with UK scientists reporting transmission speeds of 10Gbit/s more than 250 times faster than ‘superfast’ broadband [4]. Many experts claim that Li-Fi represents the future of mobile Internet thanks to its reduced costs and greater efficiency compared to traditional Wi-Fi. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible light. This is a distinct advantage in that the visible light is far more plentiful than the radio spectrum (10,000 times more in fact) and can achieve far greater data density, Li-Fi signals work by switching bulbs on and off incredibly quickly – too quickly to be noticed by the human eye. This most recent breakthrough builds upon this by using tiny micro-LED bulbs to stream several lines of data in parallel. Existing LED light bulbs could be converted to transmit Li-Fi signals with a single microchip, and the technology would also be of use in situations where radio frequencies cannot be used for fear of interfering with electronic circuitry. And although Li-Fi bulbs would have to be kept on to transmit data, the bulbs could be dimmed to the point that they were not visible to humans and yet still functional. One drawback is that the data receiver would have to be in sight of the transmitter-bulb, as visible light does not penetrate solid materials.

LOT, short for Lab of Things is a platform for experimental research from Microsoft that uses devices in the household [5]. It is created with the idea of making home monitoring, controlling, and automating easier. The idea behind it is to allow the use of computers and the Internet to access every device in the household. The other thing is that LOT empowers developers to build APPs that can make those devices work in new ways. Lab of Things (LOT) enables easy interconnection of devices and implementation of application scenarios; all of these are being possible by the use HomeOS that was another Microsoft research software package that was used in gesture control of home appliances, that same software was used to build an APP that configures home automation devices.

Due to the difficulties of installing products for the homes such as security cameras, thermostats, and motion sensors, and how hard it is to make them work independent from one another LOT provides the kind of environment that makes controlling and monitoring different smart home appliances easier. By installing the software to your computer, it enables the detection of every single device from that that smart home that are connected to that same network. Let us all assume that there is sensor that detects whether your doors are opened or closed, LOT can be arranged in such a way with a web interface that configures an alert and send you an email as soon as the sensor detects that your front door is opened. One can also use a log in to log to their Lab of Things account and be able to see via the web footage of security cameras from your home. LOT enables easy deployment and monitoring of field studies and analysis of data from experiments. Because of it we can share data, code, and its use further lowering the barrier to evaluating ideas in a diverse set of homes. According to Samuel Arjmand, providing a common platform will help ready technology for consumers who want to automate or augment their home, said Samuel, by making it easier for researchers to try out new ideas and create home automation applications.

Aside from GSM, ZIGBEE is another technology that is widely used in home automation systems [5]. Not only it is a low cost and low power device, it also supports mesh networking. It is a radio frequency communication that is based on the IEEE 802.15.4. According to its standard, the ZIGBEE technology provides 250 kbps data rate, that technology is attracting to people because its low installation and running cost offers new alternative, new ways on how to tackle the expensive and complex architecture problems of Home Automation Systems. If someone is trying to build a smart home where low power consumption is the primary goal; ZIGBEE is the way to go. A ZIGBEE node is at sleep most of the time, and it can go from sleep mode to active mode in approximately 30 ms. In order to build a home with ZIGBEE technologies a coordinator, routers and several end devices are needed. The way it works is that all the devices that you need to control are connected to the coordinator. The coordinator is responsible for creating and maintaining the network. The ZIGBEE coordinator manages all the devices in the home, such as Washing Machine, Television, Computer, and Stereo. If you want one device to communicate with another one, the connection has to be done via the coordinator. Figure 7 below shows a diagram of the ZIGBEE system.



**Figure 7 – ZIGBEE Block Diagram**

(Permission Pending)

Wi-Fi Direct is an emerging wireless standard that allows you to create a connection between any two devices without going through a wireless router. Want to create a Wi-Fi hotspot, connect your computer or smartphone to your printer or stream movies from your tablet to your television? There is a good chance that Wi-Fi Direct is doing the heavy lifting. What makes Wi-Fi Direct so compelling is the ability to create a virtual network with no central hub, all controlled through your smartphone. For instance, in your home, you could print straight from your smartphone by connecting it to your printer. Or, stream a YouTube video to your smart TV from your smartphone or control your thermostat. At the office, Wi-Fi Direct could enable two employees to share information peer-to-peer without using email or “bumping” phones (which uses a different wireless connection protocol called Near Field Communications) [6]. Smartphones have been able to support Wi-Fi Direct for a while now. The capabilities are starting to expand as operating systems like Android 4.3, iOS 7 and Windows Phone 8 begin to grow and realize that there is a whole world of devices out there that can be controlled through a smartphone or tablet. As the technology, security and compatibility of Wi-Fi Direct has matured, companies are starting to come up with more advanced uses of the standard. This is where it starts to get interesting. Motion sensors have a very vast variety of types and constructions all depending on what kind of motion is to be detected. The desire to detect the movement of people in a room pretty well narrows that list down to optic sensors. In the optics department there are two ranges of light that are most commonly used: visible and infrared. Regardless of which is

picked, both require additional processing to determine if motion is present. For the sensors working in the visible light range, a fairly high pixel count is needed as well as a processor to determine the differential between the images captured. All in all it is a bit of a pricey endeavor if purchasing a premade sensor and a headache if trying to code the processor from scratch. As with audio, not a lot of resolution is needed because no recording or playback is required. With this in mind, a much more plausible route is found in the infrared spectrum. A sensor can be combined with a processor to watch for the change in infrared intensity, and as both can be had fairly cheap, this is the ideal motion sensor for this project.

The temperature sensor is another input that needs the consideration of an analog to digital converter. A thermometer that outputs an analog voltage can be had very inexpensively; the analog signal could then be converted to digital and fed into a microprocessor for decision-making. As with all the other analog signals, this would require a lot of input pins. The easiest option would be to use an analog thermometer and a Schmitt Trigger set to go off at a preset temperature; the only drawback being that the user would have no way to change the threshold value once set. Another option is to buy a sensor that takes a reading, converts it to digital data, and outputs a signal over one pin that is to be read in by the processor. These sensors become much more expensive than the other, but are already designed to be very power efficient. Some of these sensors even have the ability to communicate over a bus, which would be extremely desirable if something like I<sup>2</sup>C is used to connect all the processors together.

Microprocessors also known as central processing unit (CPU); it is a small computer integrated on a single chip. Microprocessor is at the heart of pretty much everything that we use nowadays; it can be found in normal computers, servers, and even most appliances in the home these days contain microprocessors like the washer machine, microwave and so on. In order for one to understand the way a microprocessor works he has to learn the logic used in creating one. It executes a collection of machine instructions that tell the processor what to do. The microprocessor can basically do arithmetic operations like addition, multiplication, subtraction, and division. It can also move data from one memory location to another location; it can also make decisions and jump to a new set of instruction. We will be confronted with a large variety of microprocessors to choose from. Our decision will be based on energy consumption and whether or not the microprocessor supports Wi-Fi and Bluetooth technology.

The Atmel's XMEGA D4 is one of the best microcontrollers out there; it truly has low power capability and it is designed with what Atmel calls picoPower technology [7]. That technology makes it possible for both large Microcontrollers and small ones to have the same low power characteristics. The Xmega has a large memory range, low sleep current with real time counter; it also has a full Static Random Access Memory retention for fast wake up and reaction time. With that microcontroller, we can avoid moving to more expensive multi-chip power management solutions as the memory requirements grow in applications where low sleep current is vital for the battery life. With more memory, it enables us to support more functions and larger software stacks.

An alternative to the Atmel's XMEGA D4 is the Texas Instrument's Stellaris; it was discovered that Texas Instruments' Stellaris microcontrollers offering Ethernet

connectivity provides an excellent solution for intranet and internet control of embedded applications. In many circumstances, basic TCP/IP or HTTP protocols are adequate for control and status communication but in security-conscious applications, the additional protection offered by industry-standard Secure Sockets Layer (SSL) or its successor, Transport Layer Security (TLS) is desirable. In a commercial version of this project, since the nature of this project includes appliance control (which one would not want to fall in the wrong hands), maintaining a secure server would be extremely important. Since the Stellaris microcontrollers offer the ability to embed a web server, and also give the option to secure the web server, the Stellaris is an extremely viable candidate to act as the embedded web server.

Embedded web server; programming on the web comes in two types there is the client-side and the server-side. In the server-side programming, a program is placed on a server that hosts a website. That program placed on the server is then used to modify what are in the web page and its structure. In some cases users can request that specific information be displayed on a page. Web servers are computers that host webpages. Every web server has an IP address and a domain name. So when someone is trying to access a web page say we want to access [fifa.fr](http://www.fifa.fr/home.html); you enter the Uniform Resource Locator //<http://www.fifa.fr/home.html>, it lets the web server that has [fifa.fr](http://www.fifa.fr) as domain name that someone is requesting access. The server in return fetches the page with the name [home.html](http://www.fifa.fr/home.html) and sends it to your browser. There are multiple ways to implement a server. Any desktop computer can be turned into a server just by installing server software and get it connected to the Internet. There are also public domain software from NCSA and Apache, and there are also commercial package from companies like Microsoft and Netscape.

An embedded web server serves up a graphical user interface that allows a user to view and control multiple outlets, lights and appliances, and that microcontroller will be the main access point for our project. In the event we choose to go with the TI Stellaris, it will be connected to the local Internet. And people will be able to access everything with the help of a computer located anywhere that has Internet access; people will be able to just input the IP address of the microcontroller into a web browser and be able to control all the devices inside of the smart home. The geographic location will have no impact whatsoever on what they should be able; once someone is logged into the system, he should be able to manage lights, outlets, and be able to see a history of power consumption, that person should also be able to see power consumption in real time.

## 2.1.4 Existing Products

There is a large variety of technology and project dedicated for home automation and efficiency being researched and sold to the general public. Due to the advancement in communication and networking we are being empowered with the possibilities to use these new products to control your home solely by using your smartphone. We are being offered complete line of traditional security and surveillance systems to protect our houses and love ones from all sorts of dangers. Some innovations even have the latest

biometric fingerprint door locks, communicating smoke carbon monoxide detectors, and wireless sensors to ensure that everyone is protected from dangers inside and outside of the house. One of the home automation systems out there is the X10. The way that system works is that it enables you to use the technologies already at your disposal. The X10 protocol uses the electrical wiring in your house to send a digital control signal [8]. Due to the fact that the house is already wired it makes it a no brainer for people to jump to that technology. It is easy and inexpensive to implement that new system because you don't have to run any wires. It is worth noted that X10 is not new to the market, what it offered 10 years ago was not what people would look at and say wow! I want that for my home. It was not really anything sophisticated. 10 years ago, the way the X10 technology worked was that assuming you wanted to use X10 for your lamps. That lamp would have been plugged to into an addressable switch module, that module in return would have been connected to into a wall socket, and there would have been a controller that is plugged into a wall power receptacle somewhere in the house that could turn the lamp on/off. Was that any different than plugging that lamp in an outlet next to your bed or your book shelf and turn it on/off in time of need? They come up with a standalone mini-computer along with wireless motion detectors. What these new technologies enable you to do is that now it is a user-friendly point and click control that helps control your devices straight from your computer and smartphone. The way this is done is that their active home pro kit two-way interface computer enables you to X10 macros and with those macros a single X10 command can be used to trigger a sequence of X10 commands. On-screen representations of switches allow you control X10 devices directly from your computer by clicking on them.

Other products out there being used in Home Automation/ security is the Smart home SELECT SecureLinc 2 Wireless Home Security System with Internal GSM offered by SAMRTHOME [9] . The secure link system is complete wireless alarm systems with build in with Global Systems for Mobile (GSM) cellular communication. Due to its versatility and its connectivity it enables you as a homeowner to be able to see what is going on at your house, be able to control your home from anywhere via any web browser or mobile phone. The GSM technology implemented in the Smart home SELECT SecureLinc 2 empowers the system to work over a cellular network. It provides two-way voice communication that allows remote programing over telephone connections and enables it to respond to SMS commands from cell phone. The channels can easily be enabled or disabled in order to allow or prohibit the module from using it for the event reporting and it can be programmed as primary, back-up or dual reporting with either PSTN or Broadband. For the many homes that no longer maintain a landline, the GSM Modem for Web-Enabled Security Kits allows operation over a cellular network instead of a telephone network, providing communication to the central station or private numbers with or without POTS lines.

Another system that is available commercially out there is the HAL which is short for Home Automated Living. The Home Automated Living is a software system that uses a personal computer to control the home. It empowers the homeowner with the possibilities to use speech command interface. What make that kind of technology attractive to people is the fact that it can send signals/commands all over the house by simply using electrical wires that already exist inside the home. In that case people are willing to go with HAL

because they don't have to make any kind of innovation all that suggest that the Home Automated Living is easy and inexpensive to install. Saying all that the system does come with some headache, most of the HAL products that are being sold in the market are very expensive hence make people kind of reluctant to buy something that heavily priced. One last thing the system often requires significant home makeover.

There is also the Jarvis Project. Project Jarvis was created to be a "Digital Life Assistant," which entailed not only home appliance control but also allowing the user constant updates from social networking, Netflix, and other services the user subscribes to. The approach he uses for communication between the user and his apartment is twitter, instant messaging and voice commands. Using twitter or an already created media is an approach the group could take instead of creating a web service as the primary communication method. Also, Jarvis coordinates many of its home automation tasks through the use of the GPS system most smart phones now have. The complete synchronization of the user and the home is a very interesting aspect of Jarvis. The approach to this project was in terms of improving energy efficiency, with the side goals being improved home security and automated, synchronized electronics. Jarvis took the approach of complete automation, with different aspects of his design to do the thinking for the user. The GPS aspect of this allows the home to "prepare" for the user to come home, which is a nice feature. However, with the goals of the senior design project in mind, preparing the home for the user to arrive could potentially lead to more power usage through turning on lights and electronics pre-emptively. It is a possible side project to be explored beyond the design of the prototype, to see if the extra power consumed through this prepping is minute enough to be considered negligible in the scope of the senior design project's goal to minimize power consumption. Both of these technologies are very useful to this objective and may assist in finding the optimal and most efficient design.

Another similar product is the home automation offered by Leviton Security and Automation (LSA). The main idea behind their products is basically what we are trying to implement in our project. They cover a long range of features from Security, Surveillance, Lighting, Energy Management, Access Control, Entertainment, Interfaces Software, and Voice Intercom. We are trying to implement some of those features in our senior design project and some of them might come down the road depends on how everything unfolds during the building process. Contrary to other systems like the Control4 which we have discussed, the LSA home automation services are not sold to users to be installed by themselves; these services are installed by Leviton Security and Automation and cater to each individual's needs and monetary constraints. The group would like the system to be, even though it will be a prototype as opposed to a marketable product, a simple system where the average homeowners could install the system's tools and set up the home automation themselves. Home Automation, Inc. Offers phone applications, control via Internet, and touch screen control inside the abode. All of these features are also features the group would like to implement, with the Internet connectivity being a hard requirement and the phone application and touch screen control being a "nice to have." The mood control features, including playing music into various rooms, different lighting settings depending on the occasion, etc. are features that Home Automation, Inc. Has in their system, but are not key features to the

senior design system as the design is looking more into efficiency and security and are less focused on those features that are more geared toward a marketable product. For their interface, they have a multitude of ways they interface their features to their user. Home Automation, Inc. Uses a thumb drive that when plugged into a laptop will interface the user to the system. An application can be installed on most smart phones that provides the user a graphical control from anywhere with their phone. A home PC can be set up to control the system, with windows media player configured to control music choices being played in multiple rooms. Windows home server may be installed for advanced users, as well as various touch screen controls anywhere in the home. The portability and interfacing options given to the user makes this system very desirable for those who can afford it. However, as their products are not offer to be installed by the consumer himself or herself, using their system can be very costly. The portability is not a main goal of the project, and is not stressed in the design. The aforementioned features however could be implemented in future design.

Another system out there that people tend to use for home automation system is the Control4. It offers the consumers the luxury to control their home and appliances from wherever; it creates a system with low complexity but that has very high capability. The way it works is that the customer is able to buy the pieces that he/she want wants and install them. The system comes with a little disappointment. It lacks compatibility. It only can interact with home automation device of its own brand. The homeowner only hope is to find devices that use Z-ware or ZIGBEE communications technology. Due to the fact that the control4 technology uses the same kind of communication technology; you can find other devices with ZIGBEE or Z-ware technology to make a system expansion. But the drawback in all that is the Control4 leverages makes it difficult to integrate new devices. The Control4 system offers mobile apps, different interfaces, lighting controls, audio/video input and output climate control, and security features. With the system you can control devices in your house from a centralized location. It can be by using the Control4 touchpad, laptop/desktop computer, a tablet or any smartphone. As long as there is Internet access where you are in control. One cool thing about the system is that you can schedule events. You can basically use a complex trigger option to turn off your lights at a particular time. You can also lock your doors, turn down your thermostat in order to save energy. This is basically in the range of what we are trying to do with our project just being able to manage the use of electricity and make the home kind of more efficient. We are trying to create a system that adds comfort, savings of peace of mind to the homeowner.

There are also two projects that were posted on the website of the International journal for Engineering and Sciences (IIES) that are pretty interesting. One of them is the Bluetooth Remote Home Automation Systems Using Android Application and the other one is the Wireless Home Automation System using ZIGBEE. Those two projects are in the area of what we are trying to accomplish. Their system is constructed in a way so it can be easy to install and maintain. The only difference is that for their wireless project they use voice recognition.

Their Bluetooth system basically uses the electrical switches on the wall. The system enables Bluetooth wireless connection via a graphical user interface (GUI), that in turn

allows people to use their smartphone and laptop with the help of the system main control board to control their home appliances. The system provides three different types of physical control method. The first one is low voltage activating switch. The idea behind that is to eliminate the risk of electrical shock by wet hands. The second and third ones are the wireless remote control to the appliances. One of the controls is by clicking on the graphical user interface that is on the personal either with the use of a mouse or touchpad that enables people to control the home appliances without going to the main switch. The third one is done by android graphical user interface installed on a smartphone. Both the GUI on the computer and the one on the smartphone have the same function, which differ from our project. For our project we want the GUI on the computer to act slightly different from the one on the smartphone. We will be using the smartphone app to control appliances in the home. The graphical user interface on the computer will not only help control home appliances, but it will also provide a database of how electricity is being used in the house. We are hoping based on the data people will be able to see the peak hours when they spend more energy and they can make a consensus effort to reduce their expense. Figure 8 shown below is a functional block diagram of their system.

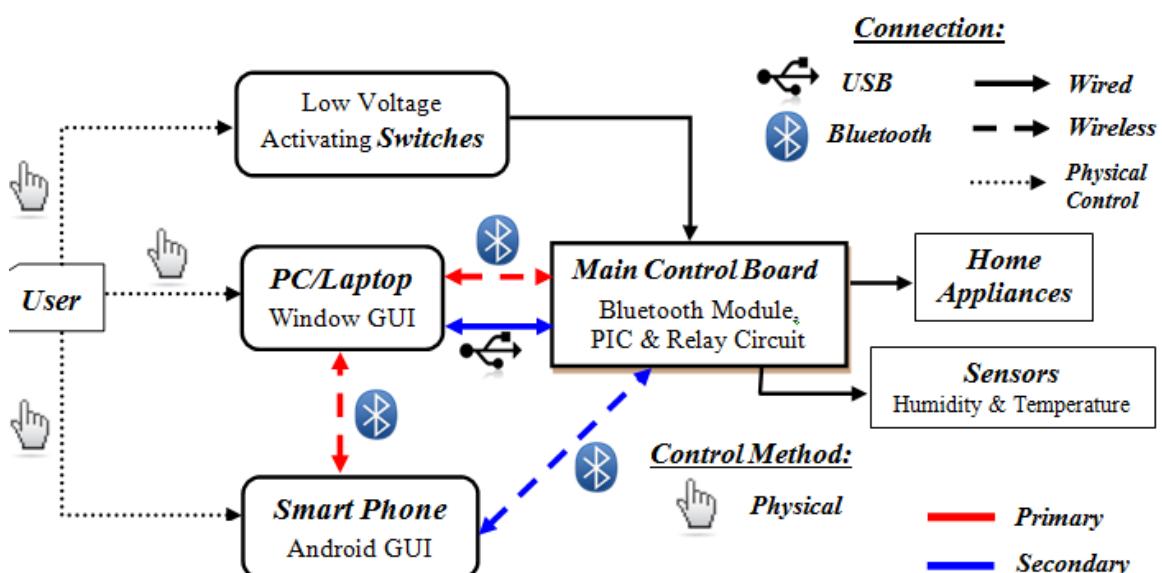
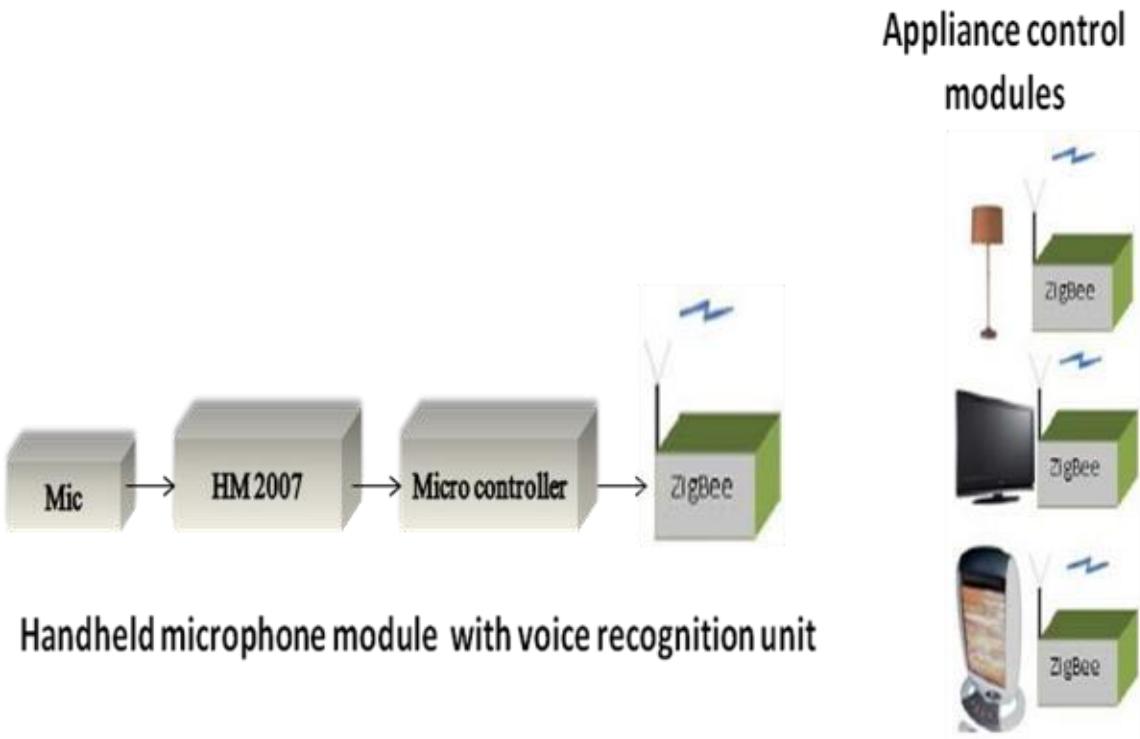


Figure 8 – Bluetooth-powered Remote Home

(Permission Pending)

The other system, which is the one that uses ZIGBEE technology is more voice oriented. It has two main modules. One is a Handheld Microphone Module that has a microphone with RF module and voice recognition unit. The other one is an Appliance Control Module with controlling circuits. Whenever people want to control some appliance, they just use their voice, that voice command is captured by the microphone that upon

receiving and recognizing the command sends control characters wirelessly to the specified appliance address. Depends on what is trying to accomplish, stuff can be turned ON or OFF, you even have the capability to increase or decrease volume. Figure 9 below illustrates the functional block diagram of the system.



**Figure 9 – ZIGBEE-based Smart Home**

(Permission Pending)

There is one more interesting project made possible by StickNFind called MeterPlug. The MeterPlug is a device that is connected between the outlet and the device; what it does is that it enables people with the help of a phone app to see their usage of power. When a device is plugged in the MeterPlug it measures the power consumption and relays that information over Bluetooth to the smartphone; it enables consumers to turn on or off any devices connected to it. When the smartphone gets the information from the MeterPlug it analyzes it and based on what it gets it has the capability to display how much money the appliance being connected to the MeterPlug is costing you; it also has the capability to display live information depending on where you are; it also keeps an history of power consumption cost of past hours, days, weeks and even month. The app has three features a vampire power shield, a proximity control, and an On/Off manual. Imagine that you own an appliance that like a phone charger that is consuming power even when your

phone is not connected to it, as long as the charger is connected power is being consumed; with the vampire power shield you can program the MeterPlug to turn off power going to that appliance when it detects that the appliance in question is consuming phantom load. With the proximity control one is able to program the MeterPlug to turn off a device when he is walking away and turns it back on when he walks back in; and finally the On/Off manual put the consumer in control; with that feature one can turn on or off any device connected to the MeterPlug within a 100 foot range. The MeterPlug empowers people to determine what appliance in their home is causing their power bills to go high and from the information they get they can come up with better ways to save.

## 2.2 Specifications & Requirements

With a project like this, we will have to set goals as well as specifications and requirements before we do anything. We have regular meetings and discussions about what each one of us want to see featured in the project. Table 1 below briefly describes what we want to achieve for this project. It includes some goals as well as some specifications and requirements. The term “Smart Home System” is denoted by SHS. Following that, we will cover each component, both hardware and software, and briefly cover the detailed background of each and why it is important in our project.

**Table 1 – Objectives and Specifications**

ID	Objective/Specification
1	The SHS shall implement solar energy to power indoor and outdoor LED light bulbs.
2	The SHS solar panel shall be rated at least at 100 W.
3	The SHS solar panel shall charge a 12 V lead-acid battery.
4	The SHS shall include a power inverter that converts 12 VDC to 110 VAC.
5	The SHS power inverter shall have a peak efficiency of at least 90%.
6	The SHS shall implement Bluetooth connectivity that allows pairing of Bluetooth enabled devices that are within approximately 10 meters of the Bluetooth module.
7	The SHS shall feature a mobile application compatible with devices running Android OS that allows the user to control SHS power features.
8	The SHS shall implement Wi-Fi (IEEE 802.11g/n) connectivity that allows connection to a LAN via a wireless access point
9	The SHS shall feature a user website that is accessible from any place that internet capable, given that its wireless access point is connected to the internet.

10	The SHS user website shall allow the user to control SHS power features from the graphical user interface (GUI).
11	The SHS shall monitor power usage for each SHS enabled power outlet and indoor/outdoor lights.
12	The SHS user website shall provide power usage history that displays usage per hour for a history range up to 3 months prior.
13	The SHS shall record power usage history on a database for simple data retrieval.
14	The SHS user website shall require login credentials to gain authorized access to the system.
15	The SHS shall implement an alert system that notifies the home owner of unauthorized access via text message and/or email, given that internet access is readily available.

### 2.2.1 Battery Specifications & Requirements

The battery is the next most important part of any solar system that is not grid-tie and is recommended for those that are. Other than cost, the most important criteria to choose a battery based on include voltage, charging algorithm complexity (which will add or reduce cost in the dc/dc converter), and reliability. This project will be operating under experimental conditions, thus, to limit variables due to battery inconsistencies, a battery that is simple to charge, is not affected by the memory effect, robust to rapidly changing conditions and reliable for extended periods of time will be chosen. To summarize, our batteries will

- The project is mainly focus on responsible energy management system; it is in the interest of the environment for as little waste as possible to be produced. A reusable battery should be considered.
- The battery should allow the user to store up to 5 hours of usage
- The battery's technology should allow for partial charges and partial discharges, as well as a tolerance for overcharging
- The battery's technology should allow for a variety of temperatures in a  $\pm 20^{\circ}\text{F}$  band from ambient of  $70^{\circ}\text{F}$  to accommodate for any enclosing structures
- Cost effectiveness of the system should be at a maximum, so affordability is a major concern

### 2.2.2 Solar Panel Specifications & Requirements

Solar panels to harness energy from the sun and convert it to useful electrical power, the solar panels used should be low cost and low maintenance, while being as efficient as possible. In general, the lower cost panels output a lower amount of power. For this reason, the cheapest panels cannot be automatically selected, and instead price must be balanced with the power requirements of the system as a whole. Since solar panels generally output a DC voltage, storage of the energy created by them in a battery will be a straightforward process. Since one of the overall goals of the system as a whole is to be portable, the size and weight of the panels must be limited. Thus, the panels chosen must maximize power generated for its size and weight when compared to other available panels. The solar panels will be mounted to a tripod stand. The tripod stand will be the base of the power generators for the entire system. The method for mounting the solar panels should be such that they can be quickly and easily removed when the entire device needs to be relocated. This also includes a quick and easy way to connect/disconnect any and all cabling that is related to the panels.

The solar device specifications were driven by the need to make the device portable, easy to install, but the primary motivation for the solar device was to make the device self-sufficient.

- Low cost components less than \$50 for prototyping
- Must be able to tolerate all environment conditions -10C to +70C
- Must be able to use power from Solar String DC volts from 6-600V
- Sense voltages from 6-600 volts Dc
- Must weight no more than 50 pounds
- Capable of at least powered 10 electronics at 10-30 watts each

### **2.2.3 Data Storage Specifications & Requirements**

In this project, the data from the sensors have to be stored in some location to allow a user to access it for future log updates. Without a log of information, there would be no way to distinguish the efficiency of the project itself. A data storage unit must be used for this function; the data gathered from the sensors must be transmitted to a data storage unit in order to be stored for a period of time. The data storage must also follow these criteria:

- Must have enough data storage space for 3 months' worth of current, voltage and temperature data
- Must be able to have connections available so the sensors can connect to them properly
- Must be able to correctly read and identify the data from the sensors so as to properly organize the information
- Must be able to have wireless capabilities
- Accuracy must be +/- 5%

## **2.2.4 Data Transmission Specifications & Requirements**

The data gathered from the sensors must be transmitted from the data storage unit to a user interface to allow a location from which to view the data. Either connecting the sensors to the data storage unit using a USB cable or a wireless transmission will be used, though a wireless transmission is preferable. Research must be conducted in order to determine what kind of wireless transmission will be used to accomplish the following specifications:

- Data will be sent via wireless transmission using a router to a user interface
- Wireless network range must have range of 50 ft. and be secured

## **2.2.5 User Interface Specifications & Requirements**

In today's day and age it is not enough to say that the designed power generator is making energy just by being outside people want to see proof. That is why as part of the design an LCD screen was included. Even if there is no breeze during a sunny day and the generator looks as though it is doing nothing looking at the LCD screen will show that there is some kind of activity coming from the generator. It is also very useful to be able to look at a screen and be able to find out how much power is left in a system if a user knows that they are going to need to use it at a later time. Plus, the user interface will be implemented in the project in order to allow access to the data that is stored in the data storage unit. The data storage unit will be connected to the user interface, allowing the interface to act as a navigational unit for the data acquired from the sensors, as well as conduct extra features that is represented as the following specifications:

- Real time tracking of voltage, current, power and array temperature must be accessible by user

## **2.2.6 Microcontroller Specifications & Requirements**

Selecting a microcontroller targeted for the right application is a necessity to achieve optimal results. Several aspects of the microcontroller required for this project must be considered before selecting one for the final design. The following list represents important necessities needed for the microcontroller chosen in this project:

- Low power microprocessor with wireless capabilities
- Microprocessor capable operating frequency of at least 16 MHz
- No more than 1  $\mu$ A current draw in stand-by mode
- Wake-up time from stand-by mode no greater than 1  $\mu$ s
- Capable of serial communications via SPI, I<sup>2</sup>C protocols
- Analog-to-Digital converter of at least 10-Bit resolution

## **2.2.7 DC/DC Converter Specifications & Requirements**

A dc/dc converter can greatly affect the overall efficiency of the array as a whole. Using it wisely can extract a greater portion of the panels overall power in the form of added charging current that would otherwise be lost. However, improper use of the dc/dc converter can and will damage either your array or your batteries. Therefore, a proper design should strive to prevent this while still transferring as much power as possible. The dc/dc converters in this project will be designed under the following criteria:

- Should prevent damage to battery bank due to overcharging/undercharging
- Should transmit 90%+ of the panel's effective power to bank to ensure there is enough energy to run test equipment in all battery modes

## **2.2.8 Inverter Specifications & Requirements**

Converting the power extracted from the solar array to AC power is essential for both grid-tie and non-grid tie systems. A majority of household appliances either use AC power or have built in AC/DC converters to extract what they need from the power grid. Thus, choosing an inverter is important if the extra power, and the design itself, are to be useful to a consumer. There are several things to consider when deciding on an inverter that is proper for any given design. The first of which, is the region it is being designed for, as that will have an effect on the frequency and expected input voltage of devices sold in that area. Failure to adhere to this restriction will render your array useless to the consumer or possibly even dangerous if a device they plug in becomes volatile under those conditions. The next thing to consider is the type of devices that will be plugged into your array. Devices that use timing based on the shape of the AC power being input may require a true sine wave in order to function. The last thing to consider is the power output expected from the device. The inverter must be rated for the power being drawn from the device from all equipment plugged into it at any given time. Given that the array in this project is intended for use in the United States and that it includes controllers and processors that may require a strict waveform, the inverter must have the following:

- An output of 60Hz and 100-127VAC
- At least a 300W continuous Power output
- A high enough max rating to meet the start-up power for all devices

## **2.2.9 Sensor Specifications & Requirements**

In order to decide if the project was successful in meeting the design objectives, a way to measure the output of the system must be implemented. In addition, the solar tracking controllers require sensors to determine which direction to rotate and the user requires a way to track the temperature of the system to ensure it is being properly cooled, as the

efficiency of the array degrades as the temperature goes up. The exact method in which this is accomplished will be determined in the research section but the following criteria must be met to ensure that the sensors do not skew the data significantly:

- All sensors must not draw considerable power from the array before it reaches the inverter and is ready for use, to avoid skewing the data to lower efficiency than is real
- Temperature, voltage and current sensors must take readings every minute and transfer them to the data storage unit via the data transmission subsystem

## 2.3 Roles & Responsibilities

It is such a big project so we must work together and affectively to get to our goals, which are to research, design, build, and test our final product. Before we began this project, we decided to divide the workload evenly. The work is distributed among each and every one, therefore; making it manageable since everyone knows his or her assignment and is responsible for it at all time. Like any successful group, whether it is business, engineering, or a senior design project, the proper division of labor is paramount and organizational skills must be well understood and documented. Our group composition consists of four members, three electrical engineers and one computer engineer; with this in mind, the chart below was created to show how the project was going to be divided. Each member was responsible for his individual tasks as well as to let the group know any important details that could affect other group member's tasks. Ultimately it is a project of collaboration; we are all working together to the same goal and we all share details of our individual tasks with one another on a weekly basis. This chart is merely the specialties each member is expected to achieve at the end of the 1st semester, so when the prototyping begins and a question comes up; the group will know who to turn to for the answer. After that, we will cover the roles and responsibilities of each person, ranging from labor, resources, budget, time, and a project block diagram that show the progress and steps that we have reached along with future milestones. Figure 10 shows the breakdown of each individual's responsibilities.



**Figure 10 – Roles and Responsibilities**

### 2.3.1 Division of labor

Danny's primary responsibility for the definition section of the paper is the specs and requirement. This is an extremely important part of the paper as it drives much of the research. He is also responsible for the software and how the user implementation takes place. Danny played a big role in the design and research of the micro controller that we use in this project.

Loc's primary responsibility for the definition section of the paper was the executive summary, motivation, goals, and objectives. These sections define in more detail what the project is supposed to do, what was the reason the project was conceived in the first place, and how the group is going to get to its objectives. The objectives portions is nearly as important as the specs because it shows the group members the guidelines to follow in their research and what exactly the sponsors need from the device. Loc was

responsible for the construction, research of similar project, and how to come up with the test procedures to find and test the readiness of the devices.

Oz was in charge of the software and little bit about the hardware, like the sensors, transmitter and receiver, and the server. He focused on more of the software which is the heart of our project. Oz play a very important role is that he did most of the research on the software and he will be responsible for most of the coding and setting up the server.

Levener was in charge of the project budget and goals. He maintains a spreadsheet that covers our expenses and projected expenses that will be provided for the document. Levener is responsible for the basic components of the project as well, like fans, electronic lock, and the server.

### **2.3.2 Code and Lead Design Breakdown**

The following figure is a continuation of the roles and responsibilities of figure above. It also goes into more depth of how the paper will managed and the breakdown of who will be responsible for coding. The group agreed upon this division of labor on the date for the Senior Design I.

The coding will primary takes part during the second semester and will be discussing in more detail in each research section. However, since there are especially three sections to the project: The Website, Microcontroller, and User Interface, it was deemed appropriate that we divvy up the coding for each device. This decision was mainly done because there may be different languages used for each device. All of the group members also showed a desire to become more proficient in coding by the end of the senior design class.

Danny and Oz were responsible for the coding of the microcontrollers, which will control the majority of our hardware. The specifics on this will be discussed in more detail in the research portion of the document. Danny was the lead designer of the microcontrollers and responsible for all interoperability issues. This basically represents the need to have someone take charge of making the devices communicate with each other. Designing each device independently of each other has the inherent danger of the devices not being able to easily communicate with each other. By signaling that each member is responsible for this from the beginning, we reduce this risk by designing with communication at the forefront of our minds. Figure 11 shows the management divisions amongst all individuals.

Danny	Oz	Loc	Levener
Micro controller coding for User Interface	Website Code and Design	Management and Oversees all Research	Management and Oversees our Permission Requests
Lead Designer of the User Interface	Lead Designer of Wireless Communication and Website	Management and Oversees all Meetings	Management and Oversees all Implementation/Testing
Lead Designer of the Android Application	Management and Oversees Bluetooth/Wi-Fi Set Up	Management and Oversees our Progress/Timeline	Management and Oversees our Budget

### Code and Management Divisions

Figure 11 – Code and Management Divisions

#### 2.3.3 Budget and Cost

At the beginning of our project, we do not have any sponsors or significant contributors. The group was planning to present the project before “Duke Energy” to see if they can be our sponsors since the project is related to energy conversation. If the group is unable to find sponsors to finance the project, the group will split the cost evenly among us. However, we made a proposal and turned it in to Dr. Richie for him to present to Duke Energy, and we have received the good news that Duke Energy will sponsor 100% of our cost. It is a huge boost financially and morally to our group, as we know we will not have to worry about the finance and focusing all our attention to design and build the best project we could possibly do.

According to the research we have done on the price values of the different resources, our “Smart Home System” will be cost \$1501.46 for the equipment, parts, tools, hardware and software. Below is outlines the potential devices and their estimated costs. This is for a potential installation estimated to be a useable size. For our prototype, we will likely only have one solar panel to test our concept. The budget is shown in Table 2 below.

**Table 2 – Proposed Budget**

Part	Cost per unit (USD)	Quantity	Total Cost
Solar Panel (100W)	199.99	2	399.98
Lead-acid Battery	119.99	2	239.98
Charge Controller	69.99	1	69.99
Power Inverter	39.99	1	39.99
LED Light Bulb	12.99	4	51.96
Fan	14.99	2	29.98
Temperature Sensor	2.49	1	2.49
Motion Sensor	10.99	4	43.96
RF Transmitter/Receiver	4.99	5	24.95
Bluetooth Module	29.99	1	29.99
Wi-Fi Module	49.99	1	49.99
Outlet	1.99	4	7.96
Relay	3.99	10	39.90
Capacitor	0.10	50	5.00
Resistor	0.05	50	2.50
LED	0.15	20	3.00
Operational Amplifier	0.50	10	5.00
Voltage Regulator	1.99	5	9.95
Microcontroller	0.99	5	4.95
Development Board	29.99	1	29.99
Printed Circuit Board	99.99	3	299.97
Hard Disk Drive	59.99	1	59.99
Wireless Router	49.99	1	49.99

TOTAL			\$1,501.46

As of the time of this writing, the current running budget is shown in Table 3. The running budget consists of parts that have already been selected and are soon ready to be ordered.

**Table 3 – Running Budget**

Part #	Cost per unit (USD)	Quantity	Total Cost
MSP430G2553IN20	2.43	4	9.72
ATXMEGA128D4	3.68	2	7.36
ACS758LCB-050B-PFF-T	7.18	6	43.08
SPR1CT52R103J	0.23	30	6.90
T350E106K025AT7301	1.70	20	34.00
CC2500RGP	4.03	4	16.12
S108T01F	4.12	8	32.96
ENW-89835A3KF	16.56	1	16.56
XB2B-WFPS-001	35.00	1	35.00
PIRSN-GM-357	13.95	3	41.85
TOTAL			\$215.65

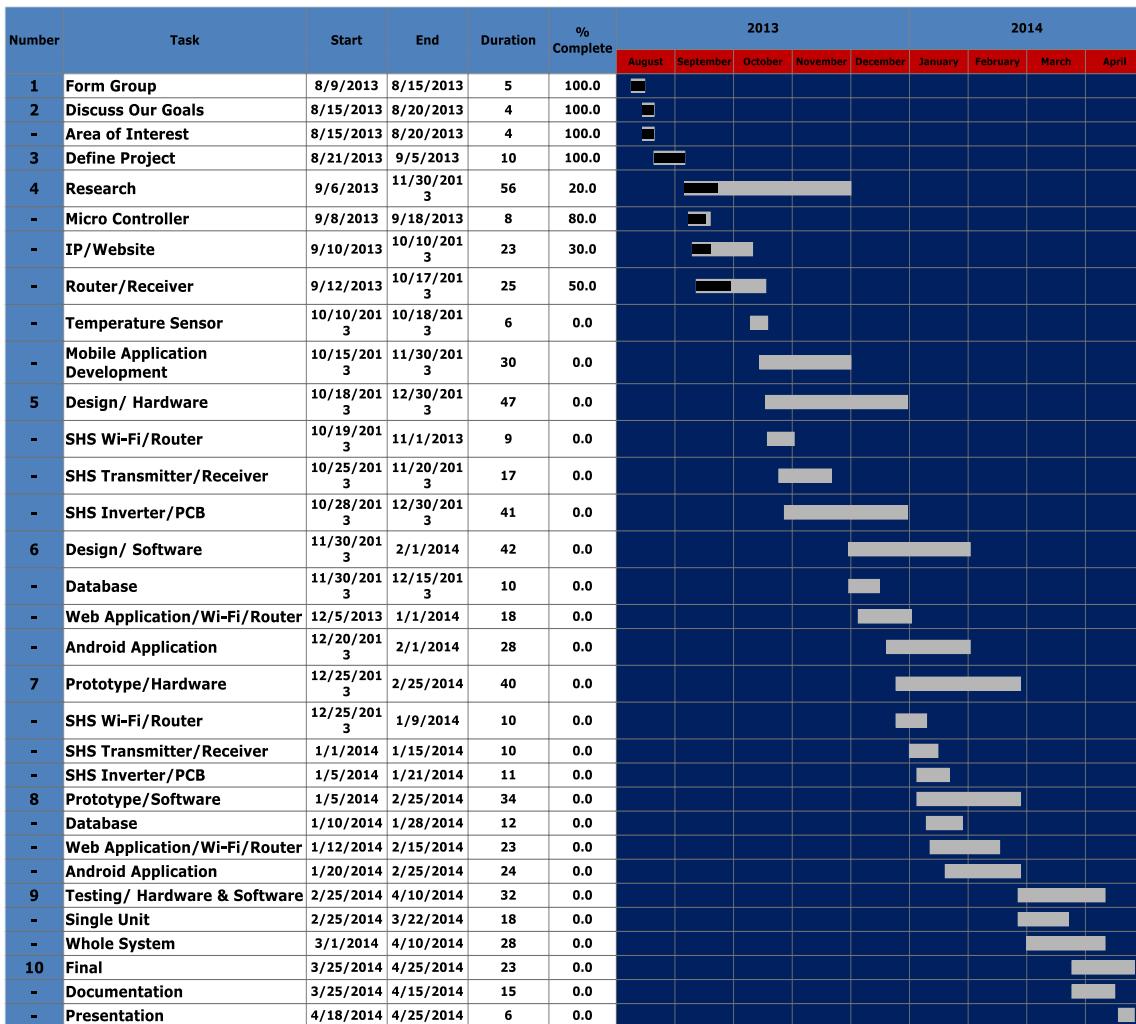
### 2.3.4 Timeline

In order to remain focused on our project throughout both semesters, we will complete the initial design review and create a list of milestones used to monitor our progress throughout. These milestones will be used to create reference points, and also to schedule the group two to three times per week for meeting, researching, and testing. The goals for our project are illustrated in the table below, which will effectively keep track of our

work. The group has agreed to meet each week outside of school to discuss any findings as well as to meet our milestone deadlines. All dates of import will be shown.

This is one of the primary tools use to access the timely completion of our goals and objectives. The group decided in the first kick off meeting to establish certain milestones for our group. These milestones would help us in several ways. Firstly, it would give us some concrete dates to have our work finished by. Thanks to Dr. Richie's advice about not writing your paper all in the last weekend we thought that also having a relative page count help us progress at a reasonable rate so we do not suffer a schedule creep like many other project do. The list below describes portions of Figure 12 that follows.

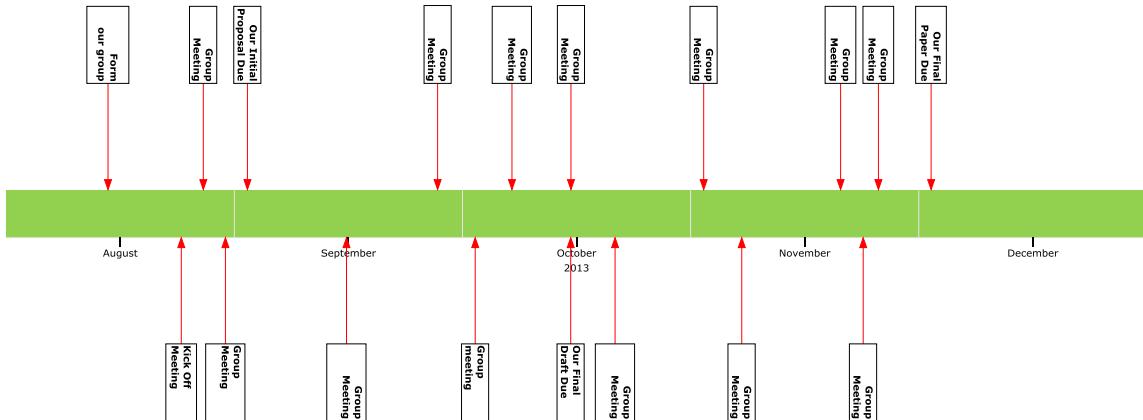
- 1-3: This is essentially our executive summary and contains all of the components that the executive summary is supposed to have. While revision of this document is necessary before tuning it in, it was written with the intent to be incorporated directly into the senior design paper.
- 4-6: This is a big milestone for the group. On average most senior design projects have about 70% of their paper done in the research portion. I think this is largely due to the need to find and disseminate the knowledge and it is also the easiest thing to write about since the prototype has not been built yet. This milestone should be largest page count to date.
- 7-9: We have begun design on all of the various parts of the project and need to convene with each member and work on interoperability among devices, and to simple get a pulse for the group and make sure the integrity of the project is on target.
- 10: The group decides who will responsible for the printing and binding of the project. We will all go to turn in the paper just to be safe, but one member is responsible for organizing this effort. The decision on what kind of bindings and all last minute changes are finished. The group will split the funds as necessary to print and bind.



**Figure 12 – Milestone Timeline**

### 2.3.5 Group Meeting Timeline

The chart shown the group meeting, it consists of all four members of the group meeting either after class or outside of school. These meetings form the backbone of how our group connects with one another; it is both a social event, progress report of the efforts going on at the time, and a forum in which to discuss concerns or problems members encounter during their research. The meetings range from an hour to an all-day event, while they illustrate the major meetings our group has, they by no means reflect the numerous emails, phone calls, and conversations help outside of the group meetings. We are a true group in the sense that we work as a team on every level of the project. Figure 13 shows a group meeting timeline.



**Figure 13 – Group Meeting Timeline**

## 3.0 Research Methods

The initial kick off meeting was a brain storming session on how we would try and meet our requirements. The team brainstormed numerous ideas for how to tackle the project. A strategy was concluded, and it involved posing cogent and relevant questions that we felt at the time needed to be answered for the group to have a good understanding of Solar Panels, Wireless devices, and coding with micro-controllers. Of course, as the research process got more involved, so did the list of questions we sought to answer.

### 3.1 Websites & Relevant Works

The primary research tool was the Internet. The initial process of “Googling” provided a few good resources. They were few and far between, but there were some. Among the truly useful resources was <http://www.solarhome.org>. This website served as the very basis for getting a clear understanding of how solar systems work. Utilizing this resource helped the team immensely in answering some of the core question posed during the brainstorm session about solar energy and how the systems were organized. The website essentially served to give us a very high-level overview of what solar energy was and how it was managed in practical applications.

### 3.2 URL

After going through all the trouble learning X/HTML and how it interacts with languages like such of JavaScript (JScript), PHP, and python you upload it on the web server and now you want to access it but you just don’t what to do. The thing designed to help you locate that website is called a Uniform Resource Locator (URL). One thing we have to understand is how a URL works. Most URLs have three parts domain, directories, and file name.

### **3.2.1 Domain**

The domain is the part of the web page that is being controlled by the hosting provider whoever that may be. It is formed by the rules and procedures of the Domain Name System (DNS). In reality the domain for your website is what DNA is to human beings. The fact that each and every one has his own set of DNA; the website works that way. No website can have the same domain. This is what helps people finding the website on the Internet. The domain name should be something that people can remember. The servers to determine ownership or control over a resource use domain name. People use domain name two ways. Some organizations are trying to create a unique identity, so they try to make it easier on people by adopting their names as their domain name such organizations are [fifa.fr](http://fifa.fr), [nab.com](http://nab.com). Some use what they call generic domain names to generate popularity; what they do is that they choose a name that defines the entire line of business that they are involved in. Such website is [cookies.com](http://cookies.com).

### **3.2.2 Directory**

The directory is more about how the website is being listed. Most websites are listed by category and subcategory. Directory is anything you placed in a website header to make it visible to a search engine. It usually includes some set of information regarding the website as a whole. Some web-hosting provider will even require a username, that something that has to be discussed with the provider to see what its specifications are on web directories. Depends on what kind of audience one is trying to attract. The directory usually large in scope and it covers a wide range of categories, languages, and regions. It is up to the designer to set the restrictions. A webpage only focus on restricted regions, single language.

### **3.2.3 File Name**

The file names are name like default.html, home.html. This is the actual name of the file that is uploaded from the hard drive. Like the directories, you determine this when you saved the file to your hard drive. One thing to keep in mind is that most of the web hosting providers out there use either UNIX or Linux that make them case sensitive. So one has to pay attention to what they write. Home.html is different from home.html.

Once all of those points above are taken care of, the website should be visible to any one that wants to access it. However, one thing left to do is to get a server.

## **3.3 Web Hosting**

As stated in the URL section, the user interface website will have to be hosted on a server on the Internet. There are two possible ways to accomplish this, we could either install server-based software on an existing computer, or connect that computer to the Internet or we can use a third party server hosting services. Both possibilities have their advantages and disadvantages.

Using server-based software would make the most sense economically since all you need

is a computer, access to Internet and one of the leading software out there. We may choose either apache or any other free software that there is. The drawback with this is that the computer would be running at all times and be connected to the Internet. In our case it is impossible for us to have server-based software on an existing computer due to the fact that we would not be able to have that computer connected to the internet at all time. The thing is we would be able have it at our house but we would have to disconnect it so we bring it to campus which would mess up the whole thing. The only thing that we have to consider now is the third party server hosting service.

There are so many things to consider before that we make a decision about which to go when it comes to the web hosting part. Not only do we have to consider the features that web hosting companies support but we also have to determine between free, dedicated, and shared hosting.

Free hosting is some kind of web hosting service where one is allocated some free web space on a web-hosting server in order for you to be able to create and host your own website. Like all thing in life, free web hosting has advantages and disadvantages. The advantage with free web hosting is of course the fact that you don't have to pay a monthly fee or annually fee. the thing with those web hosting websites offering free web hosting to consumer is that they have to cover their cost hence a disadvantage; it is true that you have access to a free web hosting, but your webpage is bombarded with forced ads; another thing is that the free web hosting server is limited in features; most the companies providing free web hosting in order for them to make up for their losses they place advertisement on the web site like banners, text links and popups which I don't think anybody would want on his website. Some those companies offering free web hosting do not do kind of stuff though; in order for them to make a profit they come up with different strategies, instead of placing those advertisements on your website, they display ad for the webmaster to click on their control panel, sending emails ads, they also have something called forum posting that's kind of a way to deceive you; the forum posting not only displays ads, but also cause to create free websites contents for the free web hosting companies. Some other one offers limited web page space, bandwidth limits, and most of the time we cannot use any scripting languages that would be any help to us. They do however offer the capability for you to have a subdomain of the name of their domain in an attempt to attract more customers; the thing with free web hosting is that it is not too reliable, it would be a bad idea for us to go in that direction although it would make sense economically; it would not be a good way to present our project.

Dedicated hosting is one of the best options available out there for people trying to build a web site and share its content over the World Wide Web. The thing with dedicated web hosting is that you have to share nothing with any other subscriber. All the services are available to you, bandwidth, disk space; you basically have access to everything in the server. Dedicated hosting is good if someone is trying to have full access to his website; it is mostly used by big companies due to the large amount of people that they have visiting their website every day; due to the large traffic to their website. Unless one has the means to manage a dedicated website, he should consider other options; everything pertaining to the maintenance of the website is your responsibility. Since one has total control over the web page, he has to account for the administration of website which

includes the hardware and software part. The main benefit of the dedicated option is that one can enjoy privileges like speed in the downloading and uploading process, privacy, and an improvement in traffic.

Shared hosting is kind of the more popular one out there; it is hugely used among small business and people interested in blog. How it works is that several website are using the server. They also use the same server IP address; they also share the cost of costing. Due to the fact that a lot of people are using the server, they also have to use the same bandwidth and disk space that would make it kind of limiting in the kind of service that can be offered. The more people who use that shared server the more the cost of traffic will be. Some benefits of shared web hosting are that most of them are scripting language friendly. They also allow the implementation of databases; for our project we need to be able to use databases. We will probably have to use the services of a shared hosting company for our project; it will not be flooded with ads and we think that is just what we need for our project; after all dedicated web hosting would be somewhat beyond of our economic capability.

In order for us to choose a shared web-hosting server for our project, we have to look at certain criteria. We have to find out what kinds of features are supported by that web hosting company. We have to make sure that whichever one we choose support MySQL for databases purposes.

### 3.4 Clients & Servers

In general, all of the machines on the Internet can be categorized as two types: servers and clients. Those machines that provide services (like Web servers or FTP servers) to other machines are servers. And the machines that are used to connect to those services are clients. When you connect to Yahoo! at [www.yahoo.com](http://www.yahoo.com) to read a page, Yahoo! is providing a machine (probably a cluster of very large machines), for use on the Internet, to service your request. Yahoo! is providing a server. Your machine, on the other hand, is probably providing no services to anyone else on the Internet [10]. Therefore, it is a user machine, also known as a client. It is possible and common for a machine to be both a server and a client, but for our purposes here you can think of most machines as one or the other. A server machine may provide one or more services on the Internet. For example, a server machine might have software running on it that allows it to act as a Web server, an e-mail server and an FTP server. Clients that come to a server machine do so with a specific intent, so clients direct their requests to a specific software server running on the overall server machine. For example, if you are running a Web browser on your machine, it will most likely want to talk to the Web server on the server machine. Your Telnet application will want to talk to the Telnet server, your e-mail application will talk to the e-mail server, and so on.

To keep all of these machines straight, each machine on the Internet is assigned a unique address called an IP address. IP stands for Internet protocol, and these addresses are 32-bit numbers, normally expressed as four "octets" in a "dotted decimal number." A typical IP address looks like this: 216.27.61.137 the four numbers in an IP address are called octets because they can have values between 0 and 255, which are  $2^8$  possibilities per

octet [10] . Every machine on the Internet has a unique IP address. A server has a static IP address that does not change very often. A home machine that is dialing up through a modem often has an IP address that is assigned by the ISP when the machine dials in. That IP address is unique for that session -- it may be different the next time the machine dials in. This way, an ISP only needs one IP address for each modem it supports, rather than for each customer. If you are working on a Windows machine, you can view a lot of the Internet information for your machine, including your current IP address and hostname, with the command WINIPCFG.EXE (IPCONFIG.EXE for Windows 2000/XP). On a UNIX machine, type nslookup at the command prompt, along with a machine name, like www.howstuffworks.com -- e.g. "nslookup www.howstuffworks.com" -- to display the IP address of the machine, and you can use the command hostname to learn the name of your machine. (For more information on IP addresses, see IANA.). As far as the Internet's machines are concerned, an IP address is all you need to talk to a server. For example, in your browser, you can type the URL <http://209.116.69.66> and arrive at the machine that contains the Web server for HowStuffWorks. [10] On some servers, the IP address alone is not sufficient, but on most large servers it is -- keep reading for details.

Because most people have trouble remembering the strings of numbers that make up IP addresses, and because IP addresses sometimes need to change, all servers on the Internet also have human-readable names, called domain names. For example, www.howstuffworks.com is a permanent, human-readable name. It is easier for most of us to remember www.howstuffworks.com than it is to remember 209.116.69.66. The name www.howstuffworks.com actually has three parts: [10] the host name ("www"), the domain name ("howstuffworks"), the top-level domain name ("com"). The Domain names within the ".com" domain are managed by the registrar called VeriSign. VeriSign also manages ".net" domain names. Other registrars (like RegistryPro, NeuLevel and Public Interest Registry) manage the other domains (like .pro, .biz and .org). VeriSign creates the top-level domain names and guarantees that all names within a top-level domain are unique. VeriSign also maintains contact information for each site and runs the "whois" database. The company hosting the domain creates the host name. "www" is a very common host name, but many places now either omit it or replace it with a different host name that indicates a specific area of the site. For example, in encarta.msn.com, the domain name for Microsoft's Encarta encyclopedia, "encarta" is designated as the host name instead of www.

A set of servers called domain name servers (DNS) maps the human-readable names to the IP addresses. These servers are simple databases that map names to IP addresses, and they are distributed all over the Internet. Most individual companies, ISPs and universities maintain small name servers to map host names to IP addresses. There are also central name servers that use data supplied by VeriSign to map domain names to IP addresses. If you type the URL "<http://www.howstuffworks.com/web-server.htm>" into your browser, your browser extracts the name "www.howstuffworks.com," passes it to a domain name server, and the domain name server returns the correct IP address for www.howstuffworks.com. A number of name servers may be involved to get the right IP address. For example, in the case of www.howstuffworks.com, the name server for the "com" top-level domain will know the IP address for the name server that knows host

names, and a separate query to that name server, operated by the HowStuffWorks ISP, and may deliver the actual IP address for the HowStuffWorks server machine [10]. On a UNIX machine, you can access the same service using the nslookup command. Simply type a name like "www.howstuffworks.com" into the command line, and the command will query the name servers and deliver the corresponding IP address to you. So here it is: The Internet is made up of millions of machines, each with a unique IP address. Many of these machines are server machines, meaning that they provide services to other machines on the Internet. You have heard of many of these servers: e-mail servers, Web servers, FTP servers, Gopher servers and Telnet servers, to name a few. Server machines provide all of these.

Ports any server machine makes its services available to the Internet using numbered ports, one for each service that is available on the server. For example, if a server machine is running a Web server and an FTP server, the Web server would typically be available on port 80, and the FTP server would be available on port 21. Clients connect to a service at a specific IP address and on a specific port. If the server machine accepts connections on a port from the outside world, and if a firewall is not protecting the port, you can connect to the port from anywhere on the Internet and use the service. Note that there is nothing that forces, for example, a Web server to be on port 80. [10] If you were to set up your own machine and load Web server software on it, you could put the Web server on port 918, or any other unused port, if you wanted to. Then, if your machine were known as xxx.yyy.com, someone on the Internet could connect to your server with the URL <http://xxx.yyy.com:918>. The ":918" explicitly specifies the port number, and would have to be included for someone to reach your server. When no port is specified, the browser simply assumes that the server is using the well-known port 80.

Once a client has connected to a service on a particular port, it accesses the service using a specific protocol. The protocol is the pre-defined way that someone who wants to use a service talks with that service. The "someone" could be a person, but more often it is a computer program like a Web browser. Protocols are often text, and simply describe how the client and server will have their conversation. Perhaps the simplest protocol is the daytime protocol. If you connect to port 13 on a machine that supports a daytime server, the server will send you its impression of the current date and time and then close the connection. The protocol is, "If you connect to me, I will send you the date and time and then disconnect." Most UNIX machines support this server. If you would like to try it out, you can connect to one with the Telnet application. In UNIX, the session would look like this: *%telnet web67.ntx.net 13Trying 216.27.61.137...Connected to web67.ntx.net.Escape character is '^J.Sun Oct 25 08:34:06 1998Connection closed by foreign host.* On a Windows machine, you can access this server by typing "telnet web67.ntx.net 13" at the MSDOS prompt. In this example, web67.ntx.net is the server's UNIX machine, and 13 is the port number for the daytime service. The Telnet application connects to port 13 (telnet naturally connects to port 23, but you can direct it to connect to any port), then the server sends the date and time and disconnects. Most versions of Telnet allow you to specify a port number, so you can try this using whatever version of Telnet you have available on your machine. Most protocols are more involved than daytime and are specified in Request for Comment (RFC) documents that are publicly available (see <http://sunsite.auc.dk/RFC/> for a nice archive of all RFCs). Every Web

server on the Internet conforms to the HTTP protocol, summarized nicely in The Original HTTP as defined in 1991. The most basic form of the protocol understood by an HTTP server involves just one command: GET. If you connect to a server that understands the HTTP protocol and tell it to "GET filename," the server will respond by sending you the contents of the named file and then disconnecting. [10] Here's a typical session:

```
%telnet www.howstuffworks.com      80Trying      216.27.61.137...Connected to howstuffworks.com.Escape character is '^J'.GET http://www.howstuffworks.com/...Connection closed by foreign host.
```

In the original HTTP protocol, all you would have sent was the actual filename, such as "/" or "/web-server.htm." The protocol was later modified to handle the sending of the complete URL. This has allowed companies that host virtual domains, where many domains live on a single machine, to use one IP address for all of the domains they host. It turns out that hundreds of domains are hosted on 209.116.69.66 -- the HowStuffWorks IP address.

Now you know a tremendous amount about the Internet. You know that when you type a URL into a browser, the following steps occur. The browser breaks the URL into three parts: The protocol ("http"), the server name ("www.howstuffworks.com"), the file name ("web-server.htm"). The browser communicates with a name server to translate the server name, "www.howstuffworks.com," into an IP address, which it uses to connect to that server machine [10]. The browser then forms a connection to the Web server at that IP address on port 80. Following the HTTP protocol, the browser sends a GET request to the server, asking for the file "http://www.howstuffworks.com/web-server.htm." (Note that cookies may be sent from browser to server with the GET request -- see how Internet Cookies Work for details.) The server sends the HTML text for the Web page to the browser. (Cookies may also be sent from server to browser in the header for the page.) The browser reads the HTML tags and formats the page onto your screen.

You can see from this description that a Web server can be a pretty simple piece of software. It takes the file name sent in with the GET command, retrieves that file and sends it down the wire to the browser. Even if you take into account all of the code to handle the ports and port connections, you could easily create a C program that implements a simple Web server in less than 500 lines of code. Obviously, a full-blown enterprise-level Web server is more involved, but the basics are very simple. Most servers add some level of security to the serving process [10]. For example, if you have ever gone to a Web page and had the browser pop up a dialog box asking for your name and password, you have encountered a password-protected page. The server lets the owner of the page maintain a list of names and passwords for those people who are allowed to access the page; the server lets only those people who know the proper password see the page. More advanced servers add further security to allow an encrypted connection between server and browser, so that sensitive information like credit card numbers can be sent on the Internet. That's really all there is to a Web server that delivers standard, static pages. Static pages are those that do not change unless the creator edits the page.

## **3.5 Database**

The need of a database is required in order to have the user interact with controlling of the smart home features. The database would store the state of the lights and power outlets, allowing the website GUI to display the whether an outlet/light is on or off. In addition to providing the power state, the database will be used to store the power usage history of the lights and power outlets over a specified amount of time. With this feature, the user would be able to fetch power usage data over a past period of up to 3 months (TBD). The database would accomplish this task by keeping a sum of the wattage dissipated from each individual power outlet and light source over the specified amount of time. This would allow the user stay informed about the amount of power being consumed daily/weekly/monthly basis. Another task the database should be able to do is store user credentials for authorized access to the system. This is a requirement to maintain security of the smart home system. If unauthorized access to the system were to occur, the intruder could maliciously gain control of the home's automated features. Although still not perfectly secure, the database would provide an additional line of defense by requiring the user to input the correct user identification and password information in order to gain access to the smart home system. In order to achieve these tasks, a properly configured relational database written in SQL is required. Structured Query Language, or SQL, is used to manipulate data existing on a database. With the use of SQL, the microcontroller updating the power usage data will be able to update the data existing on the database, whereas the user will be able to fetch the data from the use of the GUI. This makes the use of SQL an important part of this project in order for the user to interact with the features of the automation system. Without the use of a database, there would be no data for the user to manipulate/access. For this reason, a few different flavors of database software are considered.

### **3.5.1 MySQL**

The first database management system considered is MySQL. Being a widely used relational database management system (RDBMS), MySQL is an extremely popular choice of database for use in website applications. MySQL is cross-platform, having the ability to be set up on many different environments and operating systems, including commonly used Microsoft Windows, Mac OS X, and Linux. MySQL Workbench is a free IDE that enables the user to graphically administer MySQL databases by allowing visualization when designing database structures. MySQL also supports the use of many other third-party free graphical administration applications to make database management more manageable. MySQL is also very popular in cloud computing, where host providers often support MySQL database management as a service available to the user. MySQL offers the Community Edition, which is open-source and is free to download, as well as several other editions for commercial use, such as Standard Edition, Enterprise Edition, and Cluster Carrier Grade Edition. Since this project is not currently for commercial use, only the Community Edition will be considered.

### **3.5.2 Oracle Database**

Oracle Database is another relational database management system. In contrast to

MySQL, Oracle Database is closed-source. The benefit of closed-source however is that 24/7 technical support is usually available, at a cost however. Oracle Database is also compatible with many different operating systems including popular consumer operating systems such as Microsoft Windows, Mac OS X, and Linux. It also supports a few more programming languages than MySQL. Oracle does provide an Express edition of Database that is free to use with limitations. For the purpose of this project, only the Express Edition will be considered.

### **3.5.3 Microsoft SQL Server**

Microsoft SQL Server is a relational database management system that is closed-source. In contrast to MySQL and Oracle, Microsoft SQL Server is compatible only with Microsoft Windows. This is a downside for those who use Linux or Mac OS X. Also, the list of supported programming languages is less than both MySQL and Oracle. Microsoft SQL Server offers an Express edition like Oracle that is free to use with some limitations. For the purpose of this project, only the Express Edition will be considered. Overall, Microsoft SQL Server appears to be the least favorite when compared to both MySQL and Oracle Database.

## **3.6 Security Risks**

The implementation of a home automation system gives the homeowner an elevated level of ultimate convenience, with the ability to use a mobile phone or computer to control power related features of the home. However, with comfort also comes risk. Allowing the homeowner to have access to the home's power features electronically could introduce attacks from hackers that gain unauthorized access to the system. An attacker that gains access to the system could maliciously control the flow of power throughout the home. The attacker would also be able to view the use of power over a previous time frame. With this information, the attacker could know whether anyone has recently been living in the house. For example, if the homeowner is away on vacation, the attacker could see the lack of power activity in the home, making for an enticing opportunity to break in. However, this could be prevented if the homeowner chooses to randomly control the use of power from a distant location, giving the impression of people currently living in the home. The online system is intended to be password protected with user credentials being required for login. Yet, this may not be a sufficient method to secure the online access to the home's power features. Port forwarding will need to be set up in a way that protects the system as much as possible. Having a port exposed introduces the possibility of cyber-attacks. Along with security risks related to the website, there are many risks involved with access to the system via a mobile device running Android OS. Since the mobile version of this functionality will only work within a certain range of the home, no login credentials are expected to be implemented. This could potentially pose a threat if an unauthorized user gains access to the mobile device without permission, or if a sophisticated attacker intercepts the Bluetooth signal being sent between the homeowner's mobile device and the home itself. These are security features that must be considered if this home automation system was to be deployed in the market.

### 3.7 Scripting Languages

Finding the best scripting language to build our website seem to be tiresome; there are so many scripting languages and every single of them comes up with its advantages and disadvantages. We are still undecided about which one to use. We settle on 4 among the many that there are out there. In this part we'll try analyze Python, PHP, JavaScript, X/HTML. We will look at some characteristic like sustainability, extensibility, compatibility, and efficiency.

We start up with X/HTML. The Extensible Hypertext Markup Language is one the most used scripting language in the world. It is a set of rules on how to define data being put/shared on the web. One thing to keep in mind is that X/HTML is not a formatting language because it cannot define how the contents of a web page will look like. Using X/HTML is simple, all the developers have to do is to follow to rules because they do not have any control over what the user will use to in order for him to view the website. The user may decide to use a cell phone, a smart television, in case the user has some kind of handicap he can decide to use a device that renders the web page in braille or even oral speech. What it means is that with X/HTML web pages can be made simpler and they can be handled by small devices. That makes it a good thing for mobile devices and any other devices have microprocessors with embedded programming and smaller memories. The Extensible Hypertext Markup Language offers a lot of advantages [11] . One of the advantages that X/HTML offers is extensibility. By being extensible X/HTML allows consumer to implement X/HTML documents by using other forms of markup language such as the Math Markup Language, the Scalable Vector Graphics. People are even allowed to use their own Markup Language due in part to a feature named namespaces. The only problem with namespace is that not too many browsers support it. The extensibility allows people to implement things that they could not afford to do before. X/HTML also offers compatibility. Its compatibility enables people to build something that can be used in any kind of devices. And if the stuff we do is within the rules, you have the opportunity to convert an XHTML file to another file like Portable Documents Format (PDF), Rich Site Summary (RSS), or Rich Text Format (RTF). When using X/HTML one really has to follow the W3C recommends not only that it is also a must to find out what kind of X/HTML features the browser market support. Due to update being done every year or so older features are deprecated. So it is the job of the person using X/HTML to know what features are phased out. The reason is that some browsers are new and meet the latest W3C specifications on the order hand some older browsers still support the deprecated or phased out ones. Hence a dilemma, it is detrimental to be familiar with the phased out features. The fact that they are deprecated doesn't mean that you will not encounter them. It is hard to predict the future. One does not know how long it might take before deprecated features disappear from common usage. This fact make using X/HTML a little disadvantageous.

The second one that we are seeing is JavaScript. JavaScript is an interpreted language.it is not like Java meaning that it can be executed without compiling. The build it in a way so that it can meet the requirements that someone needs to build a programmable web page.

Like X/HTML using that language might present some sort of dilemma. Due to the fact that some browsers do not support some of its features it had to go through some revisions. Browsers like Internet Explorer do not support JavaScript hence a slightly different version is created solely for Internet Explorer Browser, which is called Jscript. The thing with the two versions is that some commands that are supported in JavaScript are not so much in Jscript. It is recommended that people test JavaScript programs on several different browsers because due to updates, some commands on the new versions of JavaScript and Jscript might not work on older browsers so it is imperative that everything is checked out.

The third one that will be talked about is PHP. PHP is another scripting language that one can use to build a web page. Unlike JavaScript, it is executed on the server-side rather than the client-side. It is very portable due to a lot of features that are designed solely for use on web pages [12] . In cases we are trying to build a secure web page where we would need username and password before that the content becomes available PHP is the way to go because it would enable us to build secure web pages. The other thing that makes it attractive is that the language interacts pretty well with databases. We can store information and display information pretty easily. Lastly it works well with X/HTML. Due to all those factors, it makes building a web page easy. Everything that is needed to build the perfect web site is included in PHP.

We cannot talk about scripting language without mentioning python. Python is a feature-rich scripting language that has gained broad acceptance in a wide range of applications. Unlike programming languages such as C, C++ or FORTRAN; python is what is known as an interpreted language. This means that it doesn't have to undergo an extensive compilation process before it can be used. Developing scripts in Python is fast and easy. All the examples given in this document are fairly short and deliberately avoid advanced language features. However, all Python language features are available from within Maestro including the use of nearly all of the hundreds of third party modules<sup>1</sup> available for Python. What makes Python so valuable for us is that it is both embeddable and extensible. We have embedded Python in Maestro so that it can provide scripting facilities to control the program. At the same time we have also extended Python by providing access to a whole range of Maestro functionality for dealing with chemical structures, Maestro files, and projects.

### **3.8 Mobile Application Environments**

Mobile devices have become a dominant form of technology in this modern era. The majority of people nowadays have at least one mobile device capable of performing sophisticated tasks such as web browsing and running all sorts of mobile applications. The integration of mobile devices in this project is a perfect way to use a commonly available resource to aid in the control of a home automation system. In today's mobile phone market, smartphones are of the most popular variety. Along with smartphones is the popularity of tablet computers. The small and portable size of tablet computers makes them attractive contenders in the mobile world. Among the many different types of smartphones and tablet computers available to the public, the most common types run one of three operating systems: Android, Apple iOS, or Windows. With these facts put

into consideration, the development of a mobile application for use on one of these platforms becomes justifiable. Despite the platform chosen, the graphical user interface would give the user the option of checking the states of the power outlets and indoor/outdoor lights, as well as controlling each individual one by appropriately turning them on or off. This is done with communication via Bluetooth between the mobile device and the home automation system. This also brings up an important point regarding Bluetooth-powered devices. In order to be able to use the mobile application to control the home automation system, the device to be used must have Bluetooth capability. However, this may seem like a rather moot point considering the vast majority of mobile devices today implement Bluetooth capability by default. Therefore, the question of whether a particular smartphone or tablet computer is Bluetooth-enabled is not a substantial concern.

### **3.8.1 Android**

Among the most common operating systems for mobile devices is Google's Android. Known for its vast popularity, Android is an open-source operating system that prevails with an overwhelming share of the mobile market. Google Play is the digital distribution platform used in Android devices to obtain applications and digital media. Android application development allows anyone to create standalone Android applications that can later be added to Google Play and made available for download. Android application development, typically done in Java, is possible for anyone using development tools offered by the Android developers themselves. Using Android SDK, anyone with some previous experience in Java programming can create a fully functioning Android application that can do anything imaginable. For the purposes of this project, creating an Android application would be a fantastic way to reach a large portion of the public that use Android as they're primary mobile operating system. Also, with the large array of resources available on the internet regarding Android development, the effort required to have a fully functioning program running in a short period of time becomes reasonable.

### **3.8.2 Apple iOS**

The other most commonly used mobile operating system is Apple's iOS, found running on Apple's iPhone and iPad. Apple iOS is a closed-source operating system that owns the other majority of the mobile market, alongside with Android. The Apple App Store is the digital distribution platform used for iOS devices to obtain application and digital media. Like for Android, there are many resources available for developers to create application for iOS devices. Apple features Xcode, an integrated development environment for creating applications for Mac, iPhone, and iPad. The Xcode IDE includes the Instruments analysis tool, iOS Simulator, and the latest SDKs for iOS and OS X. The Xcode IDE integrates code editing, user interface design, testing, and debugging. Unlike Android development, Apple iOS development is typically done in Objective-C. Therefore, without having previous knowledge of Objective-C, the learning curve to develop a fully functioning iOS application might be steeper. However as previously stated, many resources are available on the Internet to help with the learning curve and understand the procedures behind iOS development. Like Android, developing the application in iOS environment is attractive due to the large amount of popularity amongst users.

### **3.8.3 Windows**

Another common operating system among mobile devices is Windows Phone for mobile phones and Windows 8 for tablet computers. Although not as popular as Android or iOS, Windows platform makes a great contender for application development due to its increasing involvement in the mobile market. Microsoft Windows SDK is the software development kit used for Windows operating systems. Development in the Windows Phone environment is done using Windows Phone SDK. The developer has a choice of several languages to program in such as C++, C#, and Visual Basic. Windows development has many online resources available for creation of a fully functioning Windows application. A downside of choosing to develop in Windows is its lack of popularity as compared to Android and iOS. The objective is to target the largest audience possible while at the same time keeping the time to develop short and in perspective. For this reason, it is unlikely that development in the Windows environment will happen at this time.

### **3.8.4 Choosing the Environment**

As stated previously, selecting the appropriate environment for mobile development is dependent on several factors such as the size of target audience, the time to develop and test, and the straightforwardness of development in general. The size of target audience is the greatest amount of people that can be targeted with development in a single environment. The time to develop and test relies on factors such as familiarity with the programming language used and the clarity of using each environment's unique software development kit. Taking into consideration all of these factors, the development environments considered are Android and iOS. Being that Android and iOS combined make up almost the entire mobile market, the size of target audience would be greater with these two platforms. As far as clarity of using each environment's SDK is left to be known. However, more importance is given to targeting a larger audience rather than simplicity of development. Having stated that, development in the Windows environment will not be considered in this project. Thus, software development for mobile devices will occur in either the Android or iOS platform.

### **3.8.5 Android Application**

For our project we are primed to work with android and java to create the user interface, we cannot start using a tool without trying to understand firsthand how they work and how they might impact our project as a whole; we are trying to see how android application works and why we chose to work with it instead of mac iOS. Let's just talk a little bit about the fundamentals of android application; the application for android is written in java, it has an SDK tools that enables the code along with any type of data, resource files to be compiled into an android package. They are being compiled into an archive file with an .apk suffix. In android, everything containing in .apk file is considered an application, and the android powered device use that file to install application. In android each application is assigned a Linux user ID due to the fact that the android operating systems is a multi-user Linux system. Due to the way that the system works that ID provided to the application can only be used by the system only; the

application has no idea that the it is assigned a user ID nor does it know how the user ID works; the system make sure that only the user ID assigned to an application can access them. Because the operating system is a Linux system, every single application is able to run its own Linux process. That process is started by android itself when it feels that a component to an application needs to be executed; after the execution if the process is not being used or there is a need for memory recovery then android takes the initiative to shut the process down. If one is dealing with android application he has to understand the components of an android application. The components play a huge role in helping define the application that is being built. There are four types of application components: activities, services, content providers, and broadcast receivers. An activity in the android application is what the user interface with on the screen. An application might have several activities, but each one is independent from one another. It's like when you open an app like the Samsung WatchON on the galaxy's phones; there might be an activity that shows what is on TV at the present time, there may be another one showing what is available on Netflix, and another one allowing you to search what is going to on TV at a later time. Although all of them work together they do function independently. In Android an activity is a subclass to Activity [13]; then there are services; a service works differently from an activity, is service is what is going on in the background while we are using the activity; it performs work for remote processes. An example of services would be listening to iTunes while I am surfing the Internet or texting a friend. It has the capability to do his work without interfering with what an activity is doing. Like I can update an app while I am watching YouTube; the update is going on in the background therefore it causes no interruption to the YouTube app being used. Service is implemented as a subclass to Service; another component is the content provider, the content provider is there to manage some application data that can be shared. Assuming that some data is shared over the Internet as long as your application allows it, other applications can access and make some modification to it through the content provider. One can also use the content provider component to read and write data that is private. The content provider is a subclass of ContentProvider in order for other applications to interact with it the content provider must implement a standard set of APIs. And finally the broadcast receiver is a component that facilitates communications among other applications, it let them know when some data has been downloaded and if that data is available for use by them or not; that status bar that appear on your screen and let you know when a picture has been captured, when the battery is low. The broadcast receiver initiates service to perform some work based on the event; for example when Wi-Fi is available in some places; not only do you get a notification saying Bright House Network free Wi-Fi but also it initiates the log in process. The broadcast receiver is implemented as a subclass to BroadcastReceiver and each broadcast is delivered as an intent object. Another area of interest in working with an android application is the manifest file. The way android works is that before it starts something, it must know that what it's starting actually exists. With the help of AndroidManifest.XML; if we want our project to work let alone an app that can be used on android devices we have to make sure that everything used by our application is declared in the AndroidManifest.XML file; not only does the manifest file declares the components of the application, it also does the identification for any permissions that the user might need whether it is internet access or read access to the user's contact. It also takes care of any hardware or software features that the application

might need such as camera Bluetooth services or multi-touch screen. It is also empowered to declare the minimum level of the Application Program Interface and which Application Program Interface needs to be linked against other ones. There are two types of components in android; the activating component and the content provider. The activating component is made possible due to something called intent. What intent does is that it makes sure that every single component is binding to one another at runtime. Intent can be either explicit or implicit. Intent enables your application to request that something is done; it can be like showing an image or opening a web page; in the case of broadcast receivers, intent just defines the information that is being broadcasted. The content provider on the other hand works differently from the activating component. It does make use of intent but rather ContentResolver; all direct transaction with the content provider is controlled by the control resolver. Because of that all transactions being performed between a component and a provider does not need to call method on the ContentResolver object.

## 3.9 User Interface

This project is greatly centered on the impression of a homeowner being able to control aspects of their home that are not normally controllable in the average house. The ability to individually switch on/off each power outlet and light source in the home is not only an extraordinary convenience, but also a remarkable way to save electricity from being wasted. Many devices, more so inefficient ones, consume considerable electricity when not in use. Standby power is an issue that many people overlook, costing billions of dollars of wasted energy nationwide. Manually unplugging all devices connected to power outlets would remedy the situation, but for most, the constant action of plugging/unplugging devices is left to be desired. Therefore, one of the goals of this project is to eliminate the existence of standby power by giving the homeowner ultimate control of the electricity flowing through each power outlet, as well as to indoor and outdoor light fixtures. The solution to this would be to provide the homeowner with this ultimate control directly in the palm of their hand.

### 3.9.1 Website GUI

Similar to how a user can control home automation features with the touch of a screen using a mobile device, a user can also control the same features with the click of a mouse. The website is meant to give the homeowner not only the ability to turn on/off power outlets and lights, but with the added benefit of being able to do so from up to thousands of miles away. No matter the location, as long as there is an active connection to the Internet, the homeowner would be able to instantly check the status of the power features and toggle the states from a short or long distance away. The option to view and control the indoor temperature is also proposed to be available so that the homeowner could keep the temperature at an appropriate level, depending on their location at the time. An additional feature the website can provide that the mobile version cannot is the access to a power meter. The power meter is proposed to provide power-usage history for any given power outlet or light source. With this feature readily available, the homeowner could easily pinpoint where most of the electricity is being consumed and could therefore make appropriate adjustments, such as replacing inefficient electronics with Energy Star

rated ones. The homeowner would also be able to witness firsthand the amount of energy that is wasted due to standby power. With the ability to track energy usage over a period of several months, the homeowner could keep track of their energy consuming habits and appropriately adjust based on the data that is provided by the website's database.

### 3.10 Bluetooth

Bluetooth is one of the standard communications protocol for wireless personal area networks. The stuff that it can be used on varies from mobile phones, laptops, printers, digital cameras, and video game console. It is implemented in these products to allow them to connect to other products and easily exchange information among them. It is good to know that the communication that Bluetooth technology facilitates with other devices is secure and it is made through an unlicensed short-range radio frequency. It operates in the industrial, scientific, and medical band at 2.4 to 2.485 GHZ. It uses a spread spectrum, frequency hopping, full-duplex signal, that rate at which it does that is about 1600 hops/sec. The reason why it uses the 2.4 to 2.485 GHZ frequency is for the fact that this band is available in pretty much every country. There are three different classes of Bluetooth; based on the class that one is using the operating range can be determined. The different classes are class 1, class 2, and class 3. For class 1 the maximum power permitted is 100mV and it can expand up to 100 meters, class 2 allows 2.5mV and goes up to 10 meters, and finally class three permits a maximum power of 1mV and range approximately 1 meter. For our project we will be using the class 1 Bluetooth just to facilitate a better control of the house pretty much in any room. If we go with the other two, we would be constraint to use the system in certain area of the house whereas in other area it would be unreachable. Bluetooth is kind of different from other radio technologies such Mobile phones, FM radio, and television. It is true that Mobile Phones, FM radio, and television use radio waves to send information wirelessly; it is also true that Bluetooth technology uses radio waves too, but it does so over a shorter distance. The other technologies mentioned above Mobile phones, FM radio and television cover a lot of territories Bluetooth on the other hand sends information within your Personal Area Network. Noticed that due to advancement made in the Bluetooth technology, it can be used nowadays in smart home. It is used nowadays to help consumers control lights, temperature, household appliances, window and door locks; it can be used to even control security systems. With the help of Bluetooth technology one can monitor everything that he cares about. With the help of software of some kind, it is possible to simplify all the everyday tasks just by having alert sent to a personal computer or a smartphone. It is also useful in power consumption. Imagine one wants to use smart metering. Because the price for energy is skyrocketing, we are in the process of finding alternative ways to help people save. They come up with intelligent energy, which is a two-way communication enabled. It allows smart meters to send data of energy consumption to users. Bluetooth technology allows people to do that because of its low energy technology, it provides secure wireless communication that in return ensures accurate metering, control of electricity meters. In sum it gives people the opportunity to minimize energy consumption. It is possible to control costs and make sure too much energy is not being used when the appliances are not in use. There are two different type of Bluetooth technology out there that extends the Bluetooth brand, the Bluetooth Smart and the Bluetooth Smart Ready. The Bluetooth smart ready can be

connected to both classic Bluetooth and Bluetooth smart low energy products. On the other hand, the Bluetooth smart collects data and runs for month in some cases even years on a tiny battery. The Bluetooth Smart is considered like a sensor that works for a long period of time without changing battery whereas the Bluetooth Smart Ready is considered as a collector. It is more like a when one has a smartphone at his disposal. That smartphone can be used to receive information that same information can be displayed in an application. All of those are done through the smartphone that is how all Smart Ready Product works.

### 3.11 Wi-Fi

Wi-Fi just like Bluetooth is a technology that enables people to connect to the Internet wirelessly; it also helps exchanging data in between devices using a radio wave. A lot of devices out there support this technology. It is found in personal computers, video game consoles, digital cameras, tablet computers, and in digital and audio players. They all can connect to a network wirelessly. Wi-Fi network uses radio technology known as IEEE802.11 to provide a secure connectivity among devices. There are several generations of Wi-Fi available. Depending on the lower case later following the 802.11 one can tell the performance, frequency, and bandwidth. Another layer is that each generation includes features that can be implement if a manufacture feels the need to do so, most of them also furthers security enhancement. There are at least 5 generations of Wi-Fi the 802.11a, 802.11b, 802.11g, 802.11n, and 802.11ac. The 802.11a technology has a band frequency of 5GHz and a maximum data rate of 54Mbps, the 802.11b has a frequency band of 2.4GHz and a bandwidth of 11Mbps, the 802.11g has a frequency of 2.4GHz and a maximum data rate of 54 Mbps, the frequency of the 802.11n technology varies between 2.4 GHz and 5GHz and the maximum data rate is 450Mbps, and finally the frequency band of the 802.11ac is 5GHz and the maximum data rate is 1.3 Gbps. Those bands mentioned above are known as license-free bands in most countries. So if one wants to build a product that uses these bands, he does need authorization from any government entity. The only thing that one needs to be worried about is the set of instructions set forth by IEEE. It is called the standard of interoperability, which means that products from different companies should work together. If someone purchases something they don't want, that person to be constrained to a single band of Wi-Fi product. In reality manufactures have to make sure that their products don't go out hands. Because other products like remote control toys that are non-Wi-Fi products make use of the same bands; they have to make sure that signals from those devices do not interfere with each other. How does Wi-Fi work? The Wi-Fi technology can be used in two different modes. The one that we are most interested in is the infrastructure mode; it connects clients made of laptops or smartphone to another network such as the Internet. The communication for this mode is done through what they call an access point (AP), the client sends and receives packets via the access point which in turns makes the connection with other network. The access points are not wirelessly connected; their connection is done mostly through wire called a Distribution Center. The other mode is the ad hoc network; this is a bunch of computers connected together and they directly send frames to each other; there is no access point in that kind of mode

### **3.12 Network**

If one were to define a computer network, it would be a system that enables several computers to share data among themselves. Nowadays, computer network exist pretty much everywhere. Computer networking is at the forefront of communication; all of the innovations in communication have in fact been possible due to the advancement in computer networking. There are several types of networks; one way to characterize the different types of computer network out there is based on their scope or scales. It is good to know that industry categorized of all them as some type of area network. We will try to explain the most frequently mentioned ones, chose the one that will be used for our project, and try to explain to the best of our ability why we decide to go that route.

We have to note that every network contains at least two computers server or client workstation, a networking interface card (NIC), a connection medium that can be a wire or cable the connection can also be wireless, a network operating software such as Microsoft Windows NT or 200, Novell NetWare, Unix, and Linux.

The most commonly use network are the LAN (Local Area Network), WLAN (Wireless Local Area Network), WAN (Wide Area Network), MAN (Metropolitan Area Network), SAN (System Area Network), CAN (Campus Area Network), PAN (Personal Area Network), DAN (Desk Area Network).

The wide Area Network (WAN) is made of several Local Area Networks (LAN), which are separated, based on a larger area. Like if a company wants to connect one of his offices in New York with one in San Francisco the WAN would be the way to go. Noticed that WAN can be as simple as a modem and remote access server for employees or it can as complex as several offices around the world linked together using special routing protocols [14]. The Local Area Network (LAN) is mostly used in houses, offices. It is required for short distance. It is a collection of computers that communicate with one another over a network that they share. It may be as three computers at the least, but it could be several hundreds of computers that may be spanned to several buildings as long as those buildings are not too far from one another. For our project we have decided to use a LAN. There are two types of LAN a LAN network can be wired or wireless. Nowadays wireless network are very popular, it is being used in houses, older offices, and in places where they have trouble installing cables. In a wireless LAN, each computer is equipped with a radio modem and an antenna that enables the computers to communicate among themselves. In most cases, there is something called Access Point (AP), wireless router or a base station that relays something called packets among the computers and the Internet. Not always that the computers will make the use of the Access Point, if the two computers are close enough to each other they can communicate to each other in a peer-to-peer manner. The standards for wireless Local Area Network (WLAN) is the IEEE802.11 known to most people as WIFI. The wired LAN on the other hand is built by using a different technology; transmissions are possible due to copper wires and in some instances optical fiber. The wired Local Area Network tends to be way more reliable than the wireless one. It exceeds the WLAN in all dimensions of performance because it is way easier for signals to be propagated over a wire than it is through the air.one thing to note is that a wire LAN makes very few mistakes.

### **3.12.1 Categories of Network**

There are two kinds of network, peer-to-peer networks and server-based networks. In a peer-to-peer network, there is no computer designated as the server due to the fact that all computers are considered equals. All of them occupy the same functions they are all serving as Client/Server. None of them is assigned the role to be an administrator, which is responsible for the entire network. We mostly encounter that kind of network in small business because all of the users are in the same area; we also have to mention that this kind of network is popular in places where they are not too concerned with security issues and where they know that there won't be any need for growth anytime soon. On the other hand the client/server based network is considered the most efficient way to go if one wants to create a reliable network. The concept is that applications are being shared between a server and client. It is mostly used for databases and management of applications such as communications and management of documents, and for files storage.

Two references to get familiar with in a network are the Open System Interconnection (OSI) and the Transport Control Protocol/Internet Protocol (TCP/IP). It has become the international standard by which networks are built. It is if you will the constitution of networking. So every vendor that plans on designing a product must do so following the specific guidelines implemented by the Open System Interconnection (OSI) model. Because back in the days, it was a nightmare to build a computer network; due to the fact that every vendor used to create their products based on their own guidelines it made it difficult to buy accessories from a lot of different ones. In case you got your stuff from different vendors, you would have to build several different networks and find a way to connect them at the end thus costing time and money. But with the Open System Interconnection (OSI); we are being provided of a description of how the hardware components of the network and the software part should work together in a way to make communication possible among them. It also instructs how components should look like. Communication is made possible due to seven layers, which are the core of every network. There are the physical layer, the data link layer, the network layer, the transport layer, the session layer, the presentation layer, and finally the application layer. The physical layer is mostly the physical part of the network such as cables, wires etc. Its role is to transmit raw bits over communication channels. The data link layer is mostly used for error detection and correction. It makes sure that data are being sent and received; it transforms raw transmission facility into a line that appears free of any sort of errors that occur during transmission. The network layer provides the information that enables two dissimilar networks to be connected. It controls subnet operations. The transport layer breaks up data into smaller packages in order for them to be passed to other nodes. It takes the information and sends it to the network layer and making sure it got there correctly. The session layer carries out data from one node to another. It permits users to establish sessions among them. The presentation layer helps in coding and decoding data sent to a node. It is responsible for syntaxes of information being transmitted. And then the application layer enables the communication with operation system of a server. The most commonly used application protocol is the Hypertext Transfer Protocol (HTTP) that is used in the World Wide Web. Basically when one is trying to access a web page, the browser sends some of the web page to the server via HTTP, the server then returns the

page back. For the other reference model which is the TCP/IP. There are several kinds networks topology in our case we are interested in mesh network.

### 3.12.2 Mesh Network

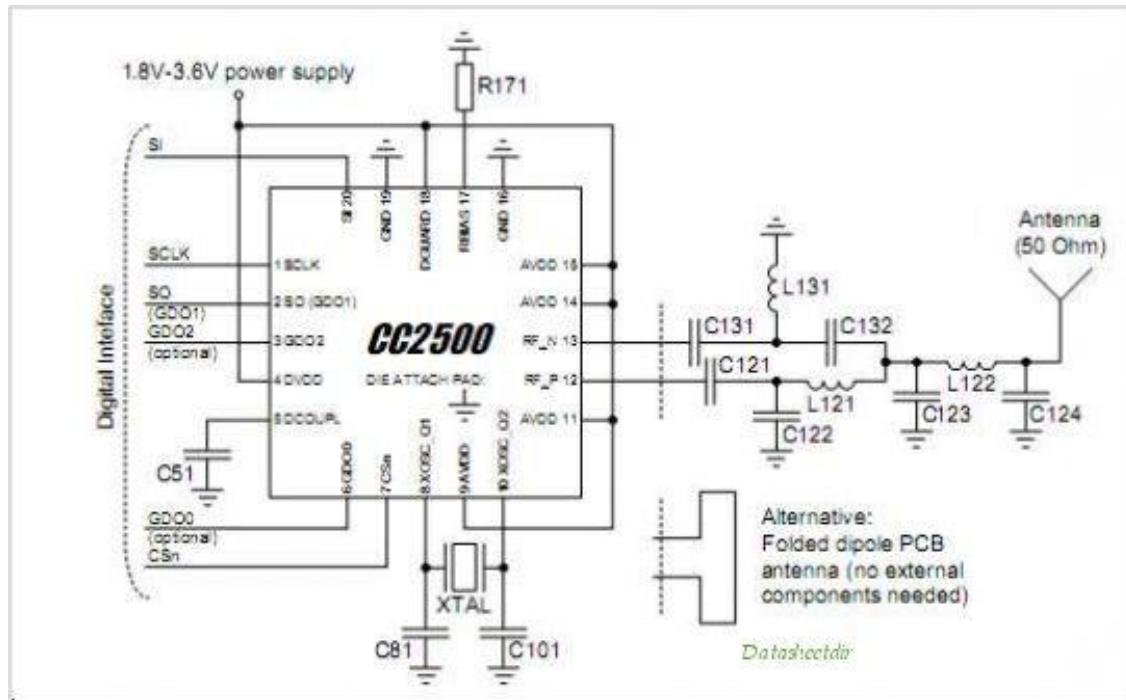
The way mesh network works is that every device has a dedicated PointToPoint to every other device. That way communication among all the devices is always available even if there is some disconnection somewhere no one will be affected. A mesh network can be either wired or wireless. The thing with setting up a wired mesh network is that it is very costly, not only that a wired mesh network may take a large amount of time to get set up. Wireless mesh network on the other hands makes it easier for people to pursue a mesh network technology. Because communication in between devices is enabled without the use of wires or cable, thus any addition or subtraction of any nodes is made easier; there is no need for any physical cable. A mesh network is usually implemented in two basic modes. The two modes are infrastructure meshing and client meshing. Both of those modes are to be used in a single network. The client-meshing mode allows the creation of wireless peer-to-peer networks in between client's devices. The thing with that kind of mode is that there is no need for any network infrastructure. Because the way a peer-to-peer network works is that there are no designated servers. If a device wants to communicate with another one, that data just has to bounce from device to device until it reaches the other device in the network. The infrastructure mode on the other hands generates wireless backhaul among wireless routers; the backhaul generated enable an increase in network coverage and reliability. For our project we are more interested in wireless mesh networking; the way a wireless mesh network works is that it that the connection is spread in between several wireless mesh nodes; since all those nodes establish some kind of connection among themselves, the network is expanded to cover a large area. A wireless mesh network works kind of like a wireless router. It is made of small radio transmitters. The nodes make use of 802.11a, b, and g standards to communicate wirelessly among themselves [14]. In order to set up a wireless mesh network, the nodes need to be programmed so they can know when to interact with each other. The data will hop wirelessly from a mesh to the next. The nodes usually choose the safest and quickest path; that process is known as dynamic routing. One thing to keep in mind when talking about mesh networking is that one of the nodes needs to be wired to a network connection. The most common connection may a DSL Internet modem. The single node that is wired to the Internet enables the other ones to access the Internet wirelessly. The way it works is that each node shares the connection wirelessly with the one closest to it; from one node to the other the Internet connection is spread throughout the network. Mesh network are mostly constituted of mesh routers; the mesh routers installed enables the communication with one or more adjacent nodes. Each of those Wi-Fi nodes automatically can automatically discover its peers; this is made possible due to the name that had previously been assigned to the mesh. It is up to the mesh routers to exchange data among themselves and determine the paths that are available and the best way to get to its destination. Before implementing a mesh network one has to make sure that some functionality are respected. Those functionalities are Ethernet, a robust security, and the quality of service. Speaking about Ethernet, for us to determine how reliable and how useful a wireless mesh network we have to see how well it works with existing network standard technology; that is where Ethernet comes in handy. Ethernet is

mostly supported by every network device in use nowadays; those devices included access point, switches, and routers; the thing is that for us to say that our wireless mesh network works it has to make sure that any traffic in between nodes are transparent to any Ethernet device being connected to the network. There are two kinds of Ethernet the classic Ethernet and the switched Ethernet. A wireless mesh network often creates a cloud that operates in either the 2.4 GHz or the 5 GHz spectrums. Another factor to consider when it comes to mesh network or in our case wireless mesh network is security risk. When building a mesh network, we should make sure that outside devices don't have access to the internal to the internal mesh traffic. In order for us to make sure that only authorized devices have access to the internal mesh traffic we can make use of digital signature. Digital signature works more like a hand written signature, the only difference is that the digital signature unlike hand written cannot be forged. Digital signature is considered as a process in which a recipient got a message but it told that a known sender sent the message and that there is no way that the sender can deny sending the message. It gets a guarantee that the received message was not altered during. Another thing that can be used to ensure the security of traffic in between those nodes is encryption; by using encryption we prevent the effect of wireless eavesdropping which is some kind of unauthorized interception of a communication of some sort. The wireless mesh network should also be able to support other standard security features that are available for wireless network and networks that support Ethernet technology. The other thing is quality of service; due to interferences that usually occur among devices that share close proximity to one another, IEEE is working on a standard that would enables all wireless devices that are working relatively close to one another to behave in a way that supports end-to-end quality of service. That new standard would be called IEEE 802.11e. Despite the fact that the fact that the comprehensive standard is still in process, vendors have taken the initiative to come up with new architecture that supports end-to-end quality of service. One of the efforts made is to enable devices to support the standard of Ethernet class of service what it does is that it prioritizes traffic; this kind of strategy allows what they call the per-hop latency of each mesh node.

### 3.13 Transceiver

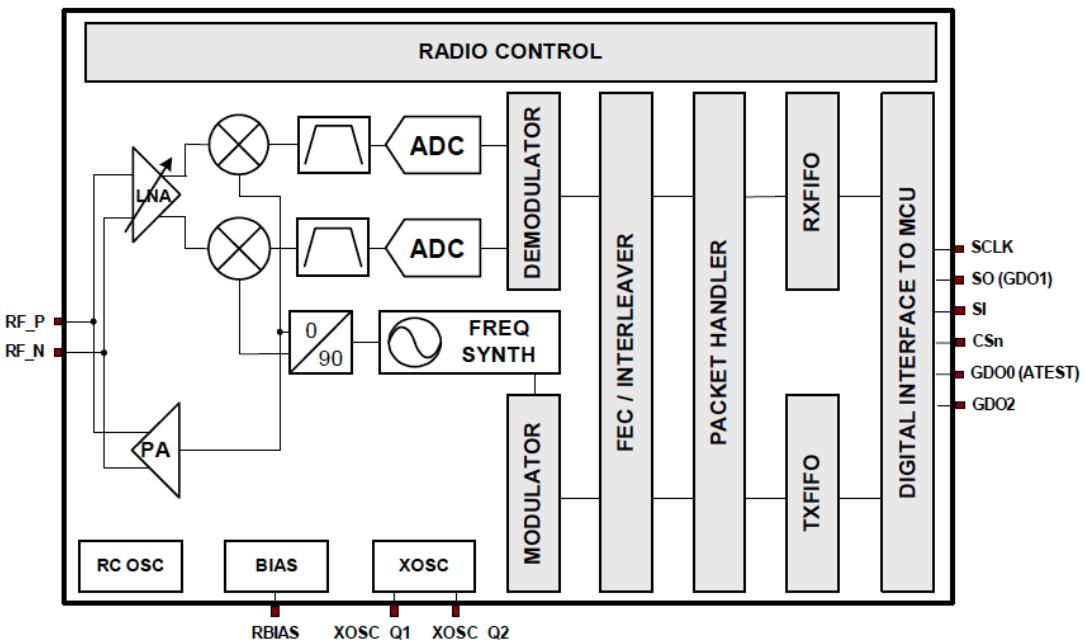
A transceiver also known to some people as a transceiver/receiver is some sort of device that is made of a transmitter and a receiver that are both combined together and they both have the capability to share common circuitry. They combine a significant amount of the transmitter and receiver handling circuitry. If one wants to be able to use wireless communication, he has to have access to a good transceiver for transceiver is one of main components for wireless communication. They can be found in Ethernet application, 1x Fiber Channel, high-speed storage devices, Local Area Network, Personal Area Network, network bridges, point-to-point channel. There is a large variety of transceiver available to users out there. If one is thinking about transceivers one of the first things that come to mind is a phone; through the phone lines you can send and receive data. We have access to two categories of transceivers full duplex and half duplex. In a full duplex transceiver, communication can be made possible by sending and receiving data at the same time, the phone at the home is an example of full duplex transceiver because as you are talking the people on the other hand of the line have the capability to also speak hence data is being transmitted and received at the same time. On the other hand a half-duplex transceiver

only allows one-way transmission. It is like the railroads two trains cannot use the same railroad at the same time. While one party is transmitting the other one is on standby mode. They have several different types of transceivers, the main ones are RF transceiver, wireless transceiver, and Bluetooth transceiver. In order for us to choose, we have to determine its capacity and range. We know that the more area a transceiver covers the more expensive it is to buy one. Satellite uses a very large range of frequency whereas the radio that law enforcement organizations use is limited to the city in which they operate. Transceiver can support analog or digital signals in some cases it can support both. We have a choice between transceivers from Texas Instrument and the ones from Atmel. But after going through a large variety of Atmel transceiver; they were all for Zigbee product, so we just decided to go with the Texas Instrument's ones. Texas Instrument has a variety of transceivers available in the market, but the ones we are more interested in are the TI CC1200 series and the CC2500; the CC 1200 series is a new family of transceivers launched by Texas Instrument; it has data speed of up to 1Mbps and it offers 1 GHz wireless connectivity for advanced metering; it is to be used in Home Area Network (HAN); it can be used in home and building automation systems, alarm, and security systems applications. It should be very effective especially in large sensor networks; the objective behind that design is that it can be used for high performance at very low power and low voltage operation in wireless systems that are cost effective. The CC2500 on the other hand is a low cost 2.4 GHz transceiver that is designed for low power wireless applications. It is short-range device built for the 2400 to 2483.5 MHz industrial, scientific, and medical range. It provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication, and wake-on-radio. It does support both Analog and digital features; the analog features make it suitable for frequency hopping and multi-channel systems due to a fast frequency synthesizer with 90 us settling time. The digital features enable support for packet oriented systems. We might have to go with the CC2500, it is not too expensive and it seems that it would better work with what we are trying to accomplish with this project. Figure 14 shown below is a schematic of the CC2500 transceiver from TI. Figure 15 illustrates the block diagram of the CC2500 transceiver.



**Figure 14 – CC2500 Transceiver Schematic**

(Reprinted with permission from Texas Instruments)



**Figure 15 – CC2500 Transceiver Block Diagram**

(Reprinted with permission from Texas Instruments)

### 3.14 Microcontroller

The goal of this project is basically about power consumption; therefore the system is about energy serving. Atmel has one of the best microcontrollers that can be used for this project. There are many different types' microcontrollers at there right now, the group has decided to with the most efficient one, which high performance, and with low power. Atmel has a family of low power, high performance, and peripheral rich 16-bit microcontrollers based on the AVR enhanced RISC architecture. Since the project's mean idea is power consumption, therefore, it is important to use the most efficiency processor as it can be. And again the main goal in building this system is to control the amount of power that coming into the house, in other word, is to make sure that the microprocessor that will be used can alter the magnitude and the phase of the power that coming in as little as possible.

Let's look up some other microcontrollers that can possibly be used as slave microprocessors in connection with the main processor. Atmel was the first choice, and Texas Instruments was the second option. Having looked and researched for the most low power microcontroller, the group went on starting to compare each of the two companies to see which one should be more efficient for the project. Since the group mostly interested in building a system that has all essential power-saving; that was the essential goal from the beginning. Therefore the team must focus on a microcontroller chip that designed for a low power. Atmel is a champion in that, the essence of an AVR picoPower device goes beyond merely the various picoPower feature included in an AVR device [15]. The group somehow is considering using this type of microcontroller as one of the processor slave that will connect with the master one. "For the design methodology, the process geometry, and even the kinds of transistors used are all essential power-saving part of an AVR picoPower device." [10] With respect to design all AVR picoPower devices are designed from the ground up for low power consumption utilizing Atmel's proprietary low leakage processes and libraries to provide industry leading low power consumption in all sleep modes. Some microcontrollers are 1.62V operation; an easy way to reduce power consumption in any design is to lower the operating voltage. But this would be mostly useless if analog performance was compromised. Central to the AVR picoPower technology are carefully designed analog functions that continue to operate all the way down to 1.62V.

For various microcontrollers there is one problem, the various features of a microcontroller become unstable or even unusable at different voltage levels. Inaccuracies in analog peripherals, limited operation or an inability to write to non-volatile memory prevents designs from running at lower voltages. This leads to shorter battery life, again in our case that would not be the a problem because the main microcontroller has its own battery backup, larger and more expensive batteries, or a lot time spent trying to find workarounds for something that should be addressed by the microcontroller to begin with. Atmel AVR microcontrollers offer true 1.62 V operation, including all analog modules, oscillators, and flash and EEPROM programming. So what does this mean in practice though? It basically means that different microcontroller features will not shut down one by one as the voltage drops. You can run the same application at different voltages without making comprises. All peripherals are available

regardless of supply voltage. That is the reason why the ADC, for example, can be used to measure the supply voltage as the cutoff voltage is approached, and when detected, it enables the application to store vital information and ensure a safe shutdown, enabling and even a glitch-free restart after changing batteries if needed. Power consumption is proportional to supply voltage, and so running at as low a supply voltage as possible saves power. For battery operated devices, the Atmel AVR microcontroller can make use of the remaining power available at lower battery voltage levels as the battery depletes.

**Sleepwalking:** As far for the sleep walking the group is very anxious of it, this is the best microcontroller that can be used for the project. As part of the AVR PicoPower technology, Atmel has added intelligence to the AVR peripherals. What this will do basically, this allows a peripheral to determine if incoming data requires use of the CPU or not. This is being call Sleepwalking because it allows the CPU to sleep peacefully until an important event occurs, which mean whenever the user enter the house or access to a home. It also has capability of eliminating millions of false CPU wakeups. In other way of explaining this, is that the internal timer wakes up the microcontroller periodically to check whether certain conditions that require its attention are present or not. Until an event happen it will continue to stay on sleep mode. But however, the CPU and RAM traditionally consume the majority of the power in active mode, and so waking up the CPU to check for these conditions will consume a lot of power in the long run. In some cases where the reaction time is too short, it might not even be possible for the CPU to go back into sleep mode at all, but this is not going to be the case in this project.

The Atmel AVR microcontroller solves this problem with its Sleepwalking peripherals. Sleepwalking allows the microcontroller to be put into deep sleep and wake up only upon a pre-qualified event. The CPU no longer needs to check whether or not a specific condition is present, such as an address match condition on the TWI ( $I^2C$ ) interface, or a sensor connected to an ADC that has exceeded a specific threshold. With Sleepwalking, this is done entirely by the peripherals themselves. The CPU and RAM will not wake up until the condition true. Sleepwalking is only one of the many innovative technologies found in all Atmel AVR microcontrollers that reduce total system power consumption in your application.

**Faster Wakeup:** Entering a sleep mode shuts down parts of the microcontroller to save power. Oscillators and clocks can consume a considerable amount of power when in use, and when waking up from sleep modes, these clocks need to be stable before they can be used. Waiting a long time for the clocks to be available and stable will result in wasted power. The Atmel AVR microcontroller can wake up from sleep mode in eight clock cycles when running from the internal RC oscillator. In addition, a digital frequency locked loop replaces the traditional phase locked loop to provide a programmable internal oscillator that is much faster and more accurate [15]. It can also eliminate external components, which reduces the total system power consumption even more. When in sleep mode with the synchronous clocks turned off, the microcontroller can still wake up from asynchronous events such as a pin change, data received or even an  $I^2C$  bus address match, enabling multiple wake-up sources from even the deepest sleep modes. The Atmel AVR microcontroller spends less time waking up so the total power consumed is put to the best possible use.

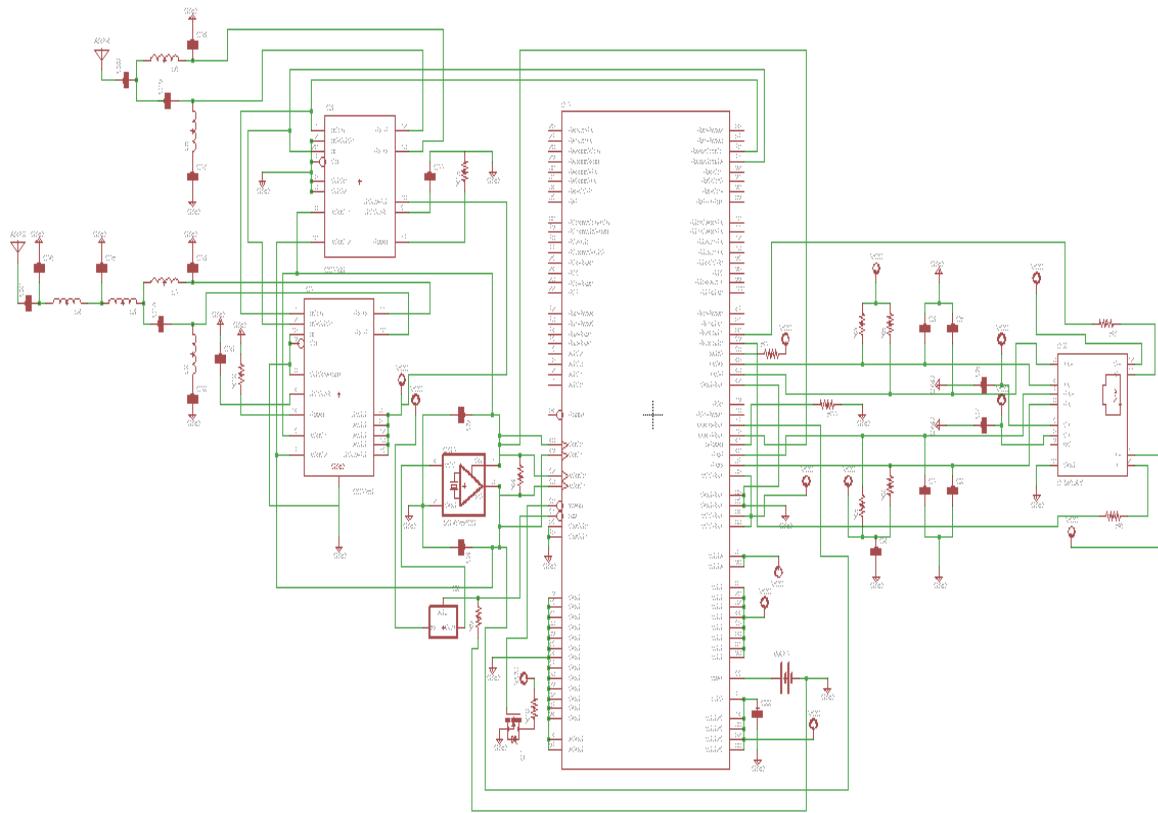
The group has analyzed the Texas Instrument made Stellaris LM3S8962 microcontroller for the system if it is connected to the main processor, which will monitor the whole systems. Just in comparison between the two, the Atmel product XMEGA D4 and Texas Instrument made Stellaris. Here is some of the details on the 32-bit microcontroller from TI, which will also work for the system, but, however, during the research, it seems like the Atmel XMEGA D4 which is the 16-bit processor will do the same work needed for the system, and will have the capability to handle all the other devices that will connect to it. So this is a 32-bit microcontroller with multiple ports from Texas Instrument. This Stellaris model is the world's most energy friendly microcontroller device particularly suited for use in low-power and energy sensitive applications. There are multiple types of microcontroller like this one out there that could do the same job as this one, but some of them are high power performance and the cost is little too high compare to the 16-bit microcontroller from Atmel which has capability to handle the system same as this one. For instance, in comparison with a small case study: 8-bit and 32-bit microcontroller for higher performance and it comes with more ports which will match perfectly with the system that the group designed which will be a great idea. However, there is a plan to use two of Texas Instrument microcontrollers MSP430 as a slave processor in connection to the main microprocessor.

This Stellaris microcontroller has a CPU speeds which is part of its capability. However, for the clock speeds of the 32-bit microcontroller systems offer significantly greater performance too, and then they basically can run at higher clock speeds and do more per cycle with a 32-bit instructions set and data. In addition, this microcontroller also come with an ARM Cortex-CM3 (LP1765) again this one has a great value with a maximum clock speeds of 100MHZ. it also can be set to run at a lower clock speed to save power. Moreover, the process is to build a system, which would, help save power by deactivate all components in the houses or businesses when they are not in used. Therefore, the group has chosen the most common one that most popular which is low power capability with the processor having the ability to run in sleep mode for up to three years continuously off the battery power of a watch battery. This is important one, this controller would have ability to put to sleep mode when not in use for power consumption and would an interrupt system to take it out of the sleep mode when the user needed to execute instruction as transmitter by the active sensor controller then process these and then transmit the instructions to the lighting and the main power controllers. The system had timer instructions per clock cycle, which designed specifically to handle any safety precaution when it is an active mode.

There is possibility of using this Stellaris 32-bit microcontroller in junction with the main microprocessor from Atmel XMEGA D4 which is the 16-bit in the figure 5 below, which has a special features, such as power-on reset and programmable brown-out detection, internal and external clock options with PLL and prescaler, it operates on a power supply of 1.6 volt to 3.6 volt, and operates on a frequency range of 0-12MHz from 1.6V and 0-32MHz from 2.7, and then it has 34 programmable I/O pins, 44-lead TQFP, 44 pad VQFN/QFN, and 49 ball VFBGA [15] . It built in with a programmable multilevel interrupt controller, the Atmel XMEGA D4 comes with five sleep modes in which will be very critical for the system, built with a watchdog, a power supervision, event system controller, one of the thing that the team looked at was in this microcontroller was an

event routing network that it comes with, a port that support a battery backup controller which also call battery supervision in relationship with the oscillator circuits/clock generation and the real time counter. All these features are needed and will apply to control each and individual element in the room, and mostly things that burn more power in the house will be the group main goal, such as fan, heating, cooling, lighting, laundry, computers and the routers, a program will need an interrupt control that will send the signal to the main microcontroller and put on to a sleep mode as quickly as possible every time the user stopped using these equipment. Figure 16 below shows the Stellaris model processor that has multiple components built with it such as an Ethernet Jack, RF transmitter, and wireless transmission.

Observe the configuration of the hibernation module of the Stellaris in Figure 16. The hibernate pin will be drn by a simple voltage regulator. When the voltage regulator is active, it will drive the hibernation pin to active low, causing a system wake-up. The wakeup pin will be configured to an open drain circuit, allowing a high signal to hibernate to wake up the system. The clock will be driven by a 32.768-kHz external crystal oscillator, with this same clock driving multiple components of the system. The crystal oscillator will also function as the clock for the RF transmitter and RF receiver, allowing them to be driven by the same clock cycle. For power savings, the design will configure the processor to run off a small lithium-ion battery when it is in hibernate. Because of its low current draw, this is ideal and the processor could run continuously in hibernate off of the battery for 3 years, so considering the processor won't be continuously in hibernation but as much as often, running off of battery will be ideal and not lead to a constant need to replace the battery.



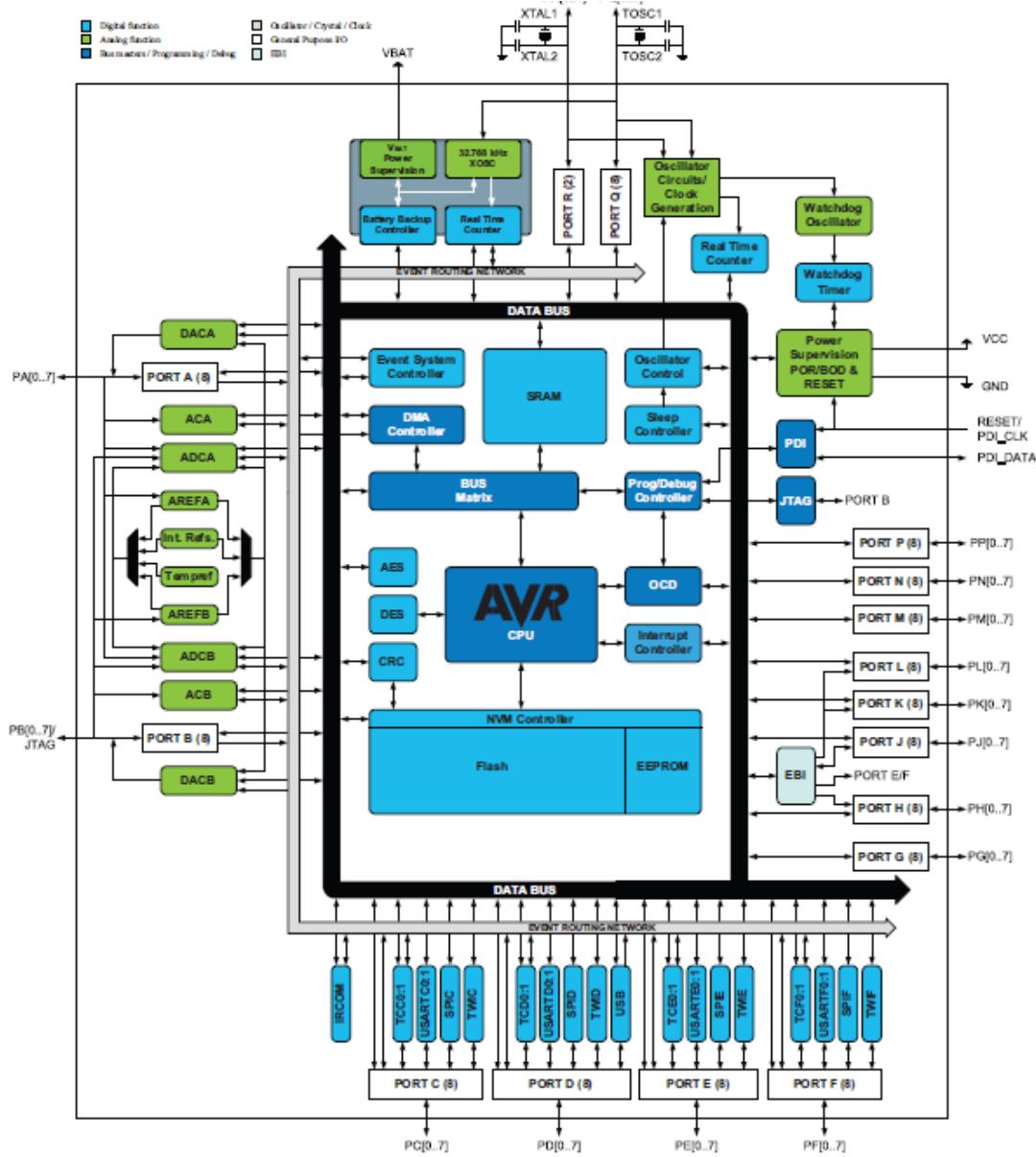
**Figure 16 – TI Stellaris Microprocessor Schematic**

(Reprinted with permission from Texas Instruments)

Atmel XMEGA D4 the 16-bit the be the group is the choice as right now to use this technology to make an environmental project which will trigger power waste could save the customer hundreds of dollars per year. Figure 17 illustrates the main processor for the project, which is capable for the system intended. It comes with multiple feature integration, which will have role to play in the system. Four-channel event system and programmable multilevel interrupt controller in which the group will use significantly for the great purpose for the system. It has two USARTs, two two-wire serial interfaces; those pins are very important pins that would allow the team to put a variety of connections as needed. It built up with two serial peripheral interfaces. The most important to look at is much current this thing will use, now let look at the current consumption for the active mode and the sleep mode. In full active mode maximum current it used is 12mA at 3 volt and at a frequency 32MHz.

For the Idle power consumption it used is 5.5mA at 3 volt and at a frequency 32MHz. Now when power-down the watchdog and sampled BOD will enabled and power consumption it used is 3.0  $\mu$ A at a low temperature of 25 °C which is 77 °F, at a high temperature it used 0.0  $\mu$ A of 85 °C which is 185 °F [15]. The watchdog timer will work on two operation modes, the normal mode and window mode and also has a configuration lock to prevent unwanted changes in the system. It is there to monitoring

correct program operation, and it will make it possible for the system to recover from error situation such as runaway or deadlock code. The WDT will constantly running when enable, if in case the WDT is not reset within the timeout period, what is going to happen it will issue microcontroller reset. It has to run in active mode and all sleep modes. See figure below for more details.



## **Figure 17 – Main Microcontroller Block Diagram**

(Reprinted with permission from Atmel)

As stated previously, there are multiple processors out there that the group could choose from, but decided to go along with this model because of the potential advantage that it has. There will be several other microcontrollers that will be used as slaves. This Atmel AVR XMEGA D4 is a family of low-power, high-performance, and peripheral-rich CMOS 8/16-bit microcontrollers has an outstanding feature, having the program and debug interface, a fast, two-pin interface for programming and debugging is available, and will able the group to make any of change in the system, have the system do anything from instruction [15] . The XMEGA D4 devices have five software selectable power saving modes. The idle mode stops the CPU while allowing the SRAM, event system, interrupt controller, and all peripherals to continue functioning on behalf of all the main processor. The power-down mode saves the SRAM and register contents, but stops the oscillators, disabling all other functions until the next instruction by user, which means whenever the user is doing work around the house in term cleaning or pin-change interrupt, or reset. In power-save mode, the asynchronous real-time counter continues to run, allowing the application to communicate with the entire system and to maintain a timer base while the rest of the device is sleeping.

In standby mode, the external crystal oscillator keeps running while the rest of the device is sleeping which what the project is about, so whenever a person access any of the door from a room or from the front or the door, the crystal oscillator will be in direct contact with all the sensors for a possible wakeup call. This allows very fast startup from the external crystal, combined with low power consumption. In extended standby mode, both the main oscillator and the asynchronous timer continue to run. This is where it's going to be a challenge, the main processor also come with a powerful peripheral clock, what it does is to further reduce power consumption, and the peripheral clock to each individual peripheral can optionally be stopped in active mode and idle sleep mode.

Table 4 shows in details the voltage and frequency it will be operating, it has an operating voltage and the operating frequency, which really critical since the system is to be low power consumption.

**Table 4 – Atmel XMEGA D4 Operation**

Operating Voltage	Operating Frequency
1.6 volt	0-12MHz from 1.6 V
3.6 volt	0-32MHz from 2.7 V

### 3.15 Charge Controller

The charge controller is a vital component in every solar energy system. The purpose of a charge controller is to maintain proper charging voltage on the batteries storing the solar energy. If the input voltage from the solar array rises, the charge controller effectively

regulates the charge going to the batteries to prevent overcharging. The use of a decent charge controller consequently extends the lifespan and improves performance of the batteries used in the solar energy system. Charge controllers also perform controlled discharges, where it prevents a battery from being completely drained, which could also reduce the lifespan of a battery. The best charge controllers use Maximum Power Point Tracking (MPPT). MPPT controllers match the output of the solar panels to the battery voltage to insure maximum charge. If the battery used is operating at a lower voltage than the solar panel is rated for, the MPPT controller compensates for the lower battery voltage by delivering a higher current to the battery, maintaining the full power potential of the solar panel's power rating. Also used are pulse-width modulation (PWM) controllers; however the MPPT charge controller is dominant when it comes to charge efficiency of the batteries used in the solar energy system. Selecting the proper charge controller involves the charge rating required to keep the batteries charged at optimum levels.

### 3.16 Power Inverter

Using energy acquired from the sun to power most everyday appliances would not be possible without a power inverter. Since batteries store the solar energy in the form of low DC voltage, a power inverter is used to convert it to a high AC voltage, typically 120 volts AC. This is the same voltage that is made available by utility companies in North America, as well as other parts of the world. Although an inverter's purpose is to convert a DC voltage to an AC voltage, not all inverters achieve the same outcome. The quality of the power inverter depends on its ability to create a clean AC signal. If voltage is measured with an oscilloscope at any traditional power outlet, the resulting signal would be a sine wave with a peak of 120 volts rms. However, not all power inverters have the capability of producing a pure sine wave when converting from DC to AC voltage. Modified sine wave power inverters are the most economical and popular type. The signal produced by a modified sine wave inverter is somewhere between a square wave and a pure sine wave. Although not a pure sine wave, many appliances will function with modified sine waves. An exception to that might be appliances that use motor speed controls or timers that may not operate properly with modified sine wave inverters. Even less desirable than modified sine wave inverters are square wave power inverters. Although the least expensive, square wave inverters produce a signal as a square wave that is inefficient and is hard on many types of equipment. This type of inverter is not desirable for home use and therefore will not be considered for this project. True sine wave power inverters produce the closest to a pure sine wave and are most ideal for all applications. Most appliances will run more efficiently and use less power with a true sine wave power inverter. The only disadvantage of the true sine wave inverter would be its expensive price tag. Another important aspect in choosing a suitable power inverter is noting its power rating. The continuous and peak power ratings of a power inverter will dictate the amount of total power that can be consumed by the appliances connected to it.

For the purposes of this project, a modified sine wave inverter or true sine wave inverter may be considered. If price margins are found to be considerable between both types of

inverters, then a modified sine wave power inverter may be more desirable. Its popularity and ability to function well enough with most electronics make the modified sine wave power inverter a sound choice.

### 3.17 Relay

The use of relays in this project is important to implement automatic switching of devices and lights. Relays are to be used by the microcontroller to electrical switch on/off a device or light appropriately when required. There is no question that this type of device is suitable and in fact necessary for this application. However, relays come in many different types, some being suitable for specific applications, while others suitable for multiple applications. The most common types of relays will be discussed here, such as electromechanical relays, reed relays, solid-state relays, and FET switches.

One of the most widely used relays is the electromechanical relay. Electromechanical relays are made of a coil, an armature mechanism, and electrical contacts. A magnetic field induced by current flowing through the coil moves the armature that opens or closes the contacts. This allows for switching with complete electrical isolation between the coil and the armature. Electromechanical relays support a wide range of signal characteristics, such as low voltage and high voltage applications, along with DC to AC in the GHz frequencies. For this reason, electromechanical relays are suitable for a wide range of applications. The contacts on electromechanical relays tend to be larger and more robust than other types of relays. Thus, a disadvantage is that larger contacts require larger package sizes. As a result, more space is required to mount multiple electromechanical relays in close proximity. Also, electromechanical relays are slower when performing switching. The slow speed of electromechanical relays makes them unsuitable for applications requiring high speed switching. For the purposes of this project, the speed of electromechanical relays would not cause significant concern since the switching operations need not be high speed. Along with slower speed, electromechanical relays typically have shorter mechanical lifespans than other types of relays, despite advances in technology that have increased their mechanical lifetime. However, an electromechanical relay's electrical lifetime may be comparable or in some cases better than other types of relays. Electromechanical relays are available in both latching and non-latching varieties. Latching relays use permanent magnets to hold the armature in its current position, even after the drive current is removed from the coil. Non-latching relays require continuous current flow through the coil to keep the relay actuated. For this project, non-latching relays will be considered to stop current flow through the device/light when the microcontroller drives the pin low [27].

Reed relays are similar to electromechanical relays in the sense that they both have physical contacts that are mechanically actuated to open/close a path. The difference comes in the size of the contacts and overall mass. Reed relays overall have much smaller contacts with smaller mass than those used in electromechanical relays. Reed relays are made of coils wrapped around switches. The reed switch is composed of two ferromagnetic blades, hermetically sealed within a glass capsule filled with an inert gas.

When the coil of the reed relay is energized, the two reeds are drawn together such that their contacts complete a path through the relay. Upon the coil being de-energized, the spring force in the reeds pulls the contacts apart. Since reed relays have less massive contacts and a different actuating mechanism than the electromechanical relay, reed relays can switch about an order of magnitude faster than an electromechanical relay with equal ratings. Along with faster switching is also a longer mechanical lifetime as compared to the electromechanical relay. However, reed relays are susceptible to contact damage due to arcing as a result of their smaller contacts. Despite this disadvantage, reed relays offer considerable switching speed that can be useful in many applications [27].

Solid-state relays are different from electromechanical and reed relays as they lack the use of coils. Alternatively, solid-state relays are constructed using a photosensitive MOSFET device and an LED to actuate the MOSFET and allow current to flow. Solid-state relays are faster than electromechanical relays when it comes to switching since their switching time is dependent on the time required to power the LED on and off. In addition, since solid-state relays have no mechanical parts, their life expectancy is significantly higher than an electromechanical or reed relay. When there is no gate drive on the MOSFET, the drain-source channel on the MOSFET has a very high resistance providing the disconnection between the contacts. Although solid-state relays are not as robust as electromechanical relays and are susceptible to damaging surge currents, solid-state relays are still very useful in both DC and AC applications, even in high voltage scenarios. Solid-state relays are also silent since they contain no moving parts when switching [27].

Similar to solid-state relays, FET switches have no moving parts and use a series of CMOS transistors to implement switching. FET switches differ from solid-state relays in that the control circuitry drives the transistors' gates directly rather than having an LED to actuate a photosensitive transistor. Since the control circuitry directly biases the transistor, switching speeds with FET switches are even faster than with solid-state relays. As with solid-state relays, FET switches have high life expectancies and can be condensed into small packages since they lack mechanical parts and LEDs. The major drawback to FET switches is that they can only be used in low voltage applications. Since this project involves switching 120 volts AC, FET switches are not suitable for this project and will not be considered [27].

For the purposes of this project, the relays to be considered are electromechanical, reed, and solid state. Due to the nature of the solid state relay in terms of space efficiency and silent operation, along with good performance with high voltage applications, solid state relays will be primarily considered, followed by reed relays and electromechanical relays.

### 3.18 Battery

The battery charger is a part of the solar device and its main function will be to power the solar device during hours of limited or no solar activity. The charger has given the group an interesting and challenging design problem. Foremost among them, How do you pull energy from a load that can reach levels of 600 volts into a small rechargeable battery

without destroying it, as well as destroying the battery charger circuit? This problem will be more thoroughly discussed in the design and prototype sections, I mention it only because it has driven the research of the battery and battery charger circuit a great deal. Other considerations do exist however. The battery charger must take into account its need to be rechargeable. That design spec is; that the charger unit should be as low maintenance as possible and have as long as a life-span as feasible given the limited amount of time to do trade-studies and our limited expertise in the area. Several rechargeable battery types were researched and will be discussed with further detail below.

Another consideration for research of the battery charger is its size and its volatility in extreme conditions. The solar device is going to need to be a small device that can attach to the strings that run off of solar panels; this limits the use of several larger battery types that could have possibly handled the 600 volt load, but is a very important requirement. It also means that using battery cells in a package would not be feasible since most come in relatively large packaging. Ultimately the size should be something akin to a highlighter or pen in length and no thicker than inch to an inch  $\frac{1}{2}$  in diameter.

Many batteries can decompose over extended periods of time, destroying the circuits and eventually our solar. In general, it is advisable if a battery is not exposed to 110 degrees Fahrenheit conditions, or 100% humidity, or freezing temperatures. The solar device does not have this luxury and so its battery does not have this luxury. No battery exists that will be able to fulfill all of these requirements perfectly, but the ‘best’ possible choice will be found with the research.

A review of the requirements driving the battery and battery charger circuit are:

- Remain small in size for portability.
- The battery needs to be affordable.
- Be rechargeable to fulfill our requirements for longevity of the device and to ensure low maintenance.
- Be able to keep the device active during hours of no solar activity and during hours of limited or partial solar activity.
- The battery needs to robust enough to survive extreme weather conditions.
- The battery needs to have a long life span, having the largest amount of recharge cycles possible.

### **Rechargeable vs. Traditional Batteries**

One of the communalities between the rechargeable batteries is their reduced voltage rating when compared to similar sized alkaline metal batteries. Rechargeable batteries have a voltage rating of approximately 1.2 volts and the alkaline metal batteries have a voltage rating at approximately 1.5 volts. This is not really a disadvantage for our solar device since all of the parts we will be using in the solar device will have very low draws and should not require even 1.2 Volts to function properly. Rechargeable batteries also have a problem with ‘self-discharging,’ meaning that they lose their charge much quicker if they are not being used or charged. They lose on average 10-25% of their charge over a

month if they are not used. Another common disadvantage to rechargeable batteries is their capacity. The capacity of alkaline batteries is roughly 2400 mAh, whereas the average rechargeable is in the range of 500 to 1300 mAh. This capacity difference may be a large factor after during the prototype stage to see if we need a battery that requires more charge capacity. A battery with 1300 mAh that can be recharged on a daily basis should, by our estimates, be enough to maintain and supply power to our devices during the hours of little or no solar activity. The size difference between the rechargeable and alkaline batteries is negligible, as the capacity goes up so does its size. Both batteries seem to come in the size that our project requires. Overall, the rechargeable seems to be the better choice simply because it will allow us to meet more requirements than alkaline batteries will. The follow is the breakdown of the research done on the various rechargeable batteries and there pros and cons as they pertain to the solar device.

The three most common types of rechargeable batteries are:

- Nickel Cadmium Battery
- Nickel-Metal Hydride Battery
- Lithium-Ion Battery
- Lead Acid Battery

Plus, some notable battery types that are not as common:

- Lithium Sulfur Battery
- LiPO4 Battery
- Rechargeable Alkaline batteries

## Lithium

Lithium-Ion batteries, also referred to as Li-ion batteries, are another type of rechargeable battery we considered for the solar device. They have a change/discharge efficiency of about 85%; they last for up to a year and a half and have a cycle durability of up to 1200 cycles. The voltage on these batteries is also slightly higher than the NiMH batters rated at 3.6 volts. Lithium-ion batteries can be formed into a wide variety of shapes and sizes so as to efficiently fill available space in the devices they power.

Lithium-ion batteries are lighter than other energy-equivalent secondary batteries—often much lighter. A key advantage of using lithium-ion chemistry is the high open circuit voltage that can be obtained in comparison to aqueous batteries (such as lead acid, nickel metal hydride and nickel-cadmium).

Lithium-ion batteries do not suffer from the memory effect. They also have a self-discharge rate of approximately 5-10% per month, compared with over 30% per month in common nickel metal hydride batteries, approx. 1.25% per month for Low Self-

Discharge NiMH batteries and 10% per month in nickel-cadmium batteries. According to one manufacturer, Li-ion cells (and, accordingly, "dumb" Li-ion batteries) do not have any self-discharge in the usual meaning of this word [16] . What looks like a self-

discharge in these batteries is a permanent loss of capacity (see below). On the other hand, "smart" Li-ion batteries do self-discharge, mainly due to the small constant drain of the built-in voltage monitoring circuit. Lithium-ion batteries have a very high energy density relative to other battery technologies. While they boast a specific energy of 90-110 Wh/kg, other common rechargeable batteries like nickel-cadmium and nickel metal hydride exhibit 30-60 Wh/kg and 50-90 Wh/kg respectively.

### Disadvantages of Traditional Li-ion Technology

#### Shelf life

A disadvantage of lithium-ion cells lies in their relatively poor cycle life: upon every (recharge, deposits form inside the electrolyte that inhibits lithium ion transport, resulting in the capacity of the cell to diminish. The increase in internal resistance affects the cell's ability to deliver current, thus the problem is more pronounced in high-current than low-current applications. The increasing capacity hit means that a full charge in an older battery will not last as long as one in a new battery (although the charging time required decreases proportionally, as well). Also, high charge levels and elevated temperatures (whether resulting from charging or being ambient) hasten permanent capacity loss for lithium-ion batteries. The heat generated during a charge cycle is caused by the traditional carbon anode, which has been replaced with good results by lithium-titanate. Lithium-titanate has been experimentally shown to drastically reduce the degenerative effects associated with charging, including expansion and other factors. See "Improvements of lithium-ion technology" below. At a 100% charge level, a typical Li-ion laptop battery that is full most of the time at 25 °C or 77 °F will irreversibly lose approximately 20% capacity per year [17]. However, a battery in a poorly ventilated laptop may be subject to a prolonged exposure to much higher temperatures, which will significantly shorten its life. Different storage temperatures produce different loss results: 6% loss at 0 °C (32 °F), 20% at 25 °C (77 °F), and 35% at 40 °C (104 °F). When stored at 40%-60% charge level, the capacity loss is reduced to 2%, 4%, and 15% at 0, 25 and 40 degrees Celsius respectively. Table 5 lists the tradeoffs of Li-Ion batteries.

**Table 5 – Li-Ion Battery Tradeoffs**

Advantages	Disadvantages
Lightweight	Intermittent volatility
Do not need complete discharge before recharging	A complete discharge will ruin the battery completely, this highlights the importance of the battery management system
Most batteries have 500-1000 charge-discharge cycles	Li-ion batteries are more expensive per watt-hour than other battery technologies
Does not lose as much charge over time as other battery types	Battery life is very sensitive to heat. It would be crucial to maintain good ventilation with a Li-ion battery

## Internal resistance

The internal resistance of lithium-ion batteries is high compared to other rechargeable chemistries such as nickel-metal hydride and nickel-cadmium. It increases with both cycling and chronological age. Rising internal resistance causes the voltage at the terminals to drop under load, reducing the maximum current that can be drawn from them. Eventually they reach a point at which the battery can no longer operate the equipment it is installed in for an adequate period. High drain applications such as power tools may require the battery to be able to supply a current that would drain the battery in 1/15 hour if sustained; e.g. 22.5 A for a battery with a capacity of 1.5 Ah). Lower-power devices such as MP3 players, on the other hand, may draw low enough current to run for 10 hours on a charge (e.g. 150 mA for a battery with a capacity of 1500 mAh). With similar battery technology, the MP3 player's battery will effectively last much longer, since it can tolerate a much higher internal resistance. To power larger devices, such as electric cars, it is much more efficient to connect many smaller batteries in a parallel circuit rather than using a single large battery.

## Safety requirements

Li-ion batteries are not as durable as nickel metal hydride or nickel cadmium designs and can be extremely dangerous if mistreated. They may explode if overheated or if charged to an excessively high voltage. Furthermore, they may be irreversibly damaged if discharged *below* a certain voltage. To reduce these risks, lithium-ion batteries generally contain a small circuit that shuts down the battery when it is discharged below about 3 V or charged above about 4.2 V. In normal use, the battery is therefore prevented from being deeply discharged. When stored for long periods, however, the small current drawn by the protection circuitry may drain the battery below the protection circuit's lower limit, in which case normal chargers are unable to recharge the battery. More sophisticated battery analyzers can recharge deeply discharged cells by slow-charging them.

- Other safety features are also required for commercial lithium-ion batteries:
- Shut-down separator (for over-temperature),
- Tear-away tab (for internal pressure),
- Vent (pressure relief), and
- Thermal interrupt (over-current/overcharging).

A detailed comparison of the different technologies is listed in Table 6. Lithium ion batteries achieve this by incorporating the highly reactive lithium ion into their chemistry, making it possible to hold more charge per atom than other battery chemistries. These ions are coupled with Carbon atoms to make the battery light weight. Most lithium ion batteries have built-in temperature sensors, a regulator circuit, a voltage bus (for the many cells in one battery), and a battery charge state monitor. These are all in place to protect the battery because of volatility issues.

**Table 6 – Comparison of Different Battery Types**

Battery system	NiCd	NiMH	Li-ion
----------------	------	------	--------

Average operating voltage (V)	1.2	2.3	3.6
Energy density (Wh/I)	90-150	160-310	200-280
Specific energy (Wh/Kg)	30-60	50-90	90-115
Self-discharge rate (%/month) at 20°C	10-20	20-30	1-10
Cycle life	300-700	300-600	500-1000
Temperature range (°C)	-20 – 50	-20 – 50	-20 – 50

Another battery technology that is regularly used in applications is the lithium-ion polymer battery. This battery has the same chemical composition as the traditional Li-ion. The major difference is that instead of the cells holding in the electrolyte as a solvent, the inner composition of the battery cell is a solid polymer. This makes these batteries cheaper to manufacture. However, these batteries rarely exceed capacity values of other comparable size packages (low energy density) and are extremely volatile. Each individual cell's charge must be monitored and each must be charged in balanced quantum increments. This technology's sensitivity and low energy density is the reason why the design team ruled it out as an option, although it is commonly used in hobby projects.

### Nickel Cadmium

Nickel Cadmium batteries are available in two types: sealed cells and vented cells. Vented cells require water for operation and they must be placed in a way so they can vent properly they are mostly used in commercial and military applications. Whereas vented cells don't require any water and can be placed in any position with no need to vent, these cells operate as a closed system that recycles the resultant gases, eliminating electrolyte loss. Most of these cells when commercially produced have a resalable vent mechanism as a safety feature but are still referred to as sealed cells [18]. The safety vent opens under excessive pressure and safely releases gas into the atmosphere then re-seals automatically. Next, Nickel Cadmium uses a nickel oxide hydroxide and metallic cadmium as its electrodes. This gives it several advantages in regards to the solar device and its requirements. First, it is very difficult to damage when compared to other batteries. This fact alone makes it a likely candidate since there are so few batteries than can handle the extreme stresses that the solar device will have to handle. Another advantage is that NiCd batteries typically have larger number of charge/discharge cycles than other rechargeable batteries. However this advantage is crippled by the fact that NiCd batteries don't last very long before needing a recharge. NiCd batteries also have toxic metals inside of them, so while they are more versatile as a whole, if they do in fact break then it could damage the solar panels themselves. These toxins also mean that they are not safe to throw away. This could have implications to our sponsors if they have to manage a large quantity of the devices in the field. It is also somewhat counterproductive in their field, since solar energy is in essence trying to save the environment, to use devices that essentially harm it. You also cannot over charge NiCd batteries, while we can certainly design a battery charger circuit to stop charging when the battery is at a reasonable level if we do happen to miss judge the threshold, or if we overcharge the battery by too much, it could destroy the battery entirely. Overall NiCd batteries are more than probably not a good choice for our solar device.

### **Advantages:**

- High energy density about 50% better than Nickel Cadmium.
- Low internal resistance but not as low as Nickel cadmium.
- Typical life is 200 – 300 cycles.
- Can be deep cycled.
- Flat discharge characteristic.
- Wide operating temperature range.
- Because of potential pressure build up due to gassing they usually
- Incorporate a re-sealable vent valve.
- Initial voltage 1.2 volts or 7.2 volts.

### **Disadvantages:**

- Very high self-discharge rate, nearly ten times worse than lead acid or
- Lithium batteries.
- Might suffer some memory effects but not as much as the Nickel
- Cadmium.
- Higher rate of self-discharge compared to Ni Cd.
- Slow charging is required, and less tolerant of overcharging.

NiMH's have replaced NiCads as the rechargeable battery of choice, because they have a higher capacity than NiCads and don't have the special disposal requirements that NiCads do. Unlike NiCads, NiMH's contain no toxic metals and have no special disposal requirements [19] , so when they won't hold a charge any more you can throw them away. Unlike alkaline batteries which lose their voltage steadily, NiMH batteries maintain most of their voltage over the whole charge and then suddenly plummet.

- Nickel-Metal Hydride Battery:
- NiMH's have much higher capacity than NiCad's.

For this reason many electronic devices that tell you how much battery life is left have a hard time reporting an accurate level for NiMH's. The voltage is very similar for both a fully-charged battery and a nearly-spent battery. Some devices (like my GPS wristwatch) let you specify in the setup menu whether you're using NiMH or alkaline, so they can try to be more accurate with the battery-remaining indicator.

### **Lead Acid Batteries**

There are two kinds of lead-acid batteries. The first kind is a cranking or starting battery and it is used primarily in motor vehicles for delivering high amperage levels for short periods of time at the vehicle's start. Physically, this battery contains a higher density of thin lead plates that assist it in performing this function. The second kind is a deep-cycle lead acid battery. The deep cycle variety has thicker plates, which allow it to withstand

the physical demands of a charge-discharge cycle. This type of battery is used in marine and electric vehicle applications.

Each kind of lead acid-battery has three categories. Wet cell lead acid batteries have lead plates impregnated with a sulfuric acid electrolyte solution. This solution is typically 65% water. As the battery discharges, the sulfuric acid in the solution bonds to the lead plates. As it recharges, the sulfuric acid bonds are split apart and the acid returns to the solution. This process decomposes the plates and causes a sediment buildup in the battery. Over time, this buildup will cause the various cells to short together, killing the battery. This type of lead acid battery has been around since 1859, and is still very popular. It is also the least expensive of the lead acid technologies.

The second kind of lead acid technology is the gel cell. The gel cell is a VRLA (valve regulated lead acid) and the solution found in wet cells is mixed with a silica content that makes the solution a gel, and thus immobile. This keeps the battery from spilling issues that are more common to the wet cells. This also allows the battery to be used in varying positions, although they should not be charged in any but the upright position. Because of the gel interior, this type of battery is more resistant to vibration-heavy applications. The tradeoff is that this battery is more sensitive to overcharge situations, and has a lower charging voltage than most lead acid batteries.

The third subcategory is the AGM (Absorbent Glass Mat). Depending on the orientation and geometry of the cells internal to the battery, it can be a traditional AGM or a “spiral wound.” The electrolyte in this type of battery is held by a mat of glass fibers because of these mats, the lead plates are relieved of the duty of holding up their own weight. This gives more flexibility in the design and application of this battery. The mats and plate proximities also reduce the internal resistance of the battery. Good for deep-cycle applications, these batteries can be discharged and recharged quickly and feature the highest energy density of the lead acid batteries. The AGMs are also the most expensive. Another consideration is whether the battery is a deep-cycle battery or a starter battery. Starter batteries are common and are used in vehicles. Deep cycle batteries are used in backup power systems and in RVs and boats as power sources. They are made of the same chemical profile, but their optimization at manufacture is different. A car battery, or starting battery, has a lot of plates to increase the surface area of the lead plates with the electrolyte and this way is able to provide large amounts of current for turning the motor when the car is started. After the motor runs, the alternator provides the vehicle’s power and the battery is recharged but otherwise untouched. A deep-cycle battery, on the other hand is optimized to provide a constant current for a long period of time. In the table below is a comparison of the technologies; all taking in mind a deep-cycle design.

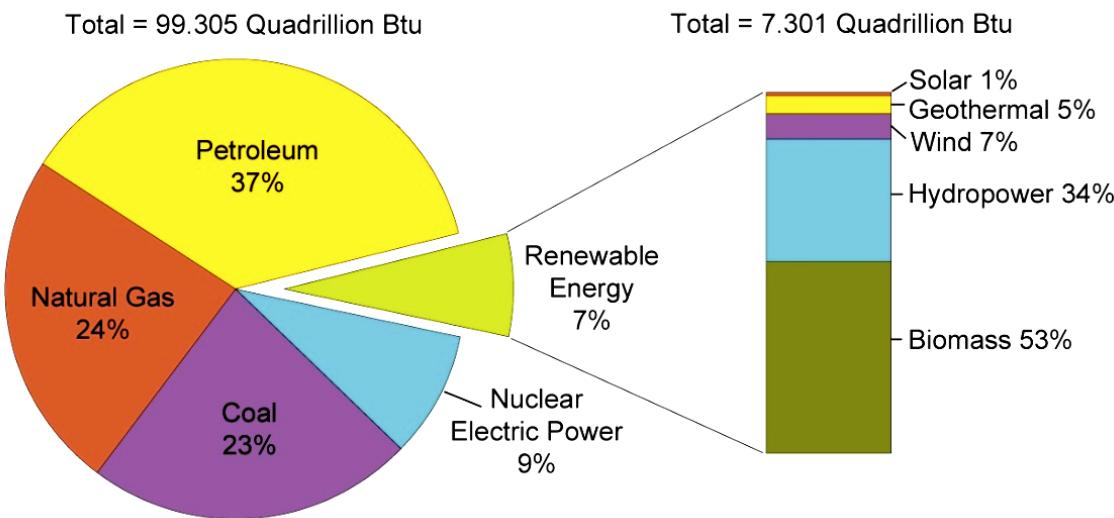
## Solar Energy

Traveling at the speed of light, it takes sunlight eight minutes and twenty seconds to reach Earth’s surface. Solar energy, in the form of irradiance or sunlight and thermal energy or heat, is one of the most abundant and cleanest energies used on planet Earth. [20] Solar energy is considered a renewable source. As shown in

Seen in Figure 18, renewable energy makes up 7% of consumption in United States’ energy supply for year 2008. Solar energy was accountable for less than 0.1 percent of

electricity consumption in the United States in that same year. [21] The solar energy market is projected to double by 2020, even though today this type of energy is not as commonly used to produce electricity as other renewable sources of energy available, like hydroelectric, geothermal, or wind. [22]

### The Role of Renewable Energy in the Nation's Energy Supply, 2008



**Figure 18 – Role of Renewable Energy in 2008**

(Permission Pending)

The fact that solar energy is renewable and also cleaner than any other energy produced from fossil fuels makes this resource of sustainable energy very important for the planet's future. Solar energy is virtually available everywhere in the world. In conclusion, the advantages of solar energy are its abundance and the "zero emission" factor. On the other hand, its main limitation is the fact that this kind of energy is not constant even during the daytime. Due to Earth's atmosphere and its atmospheric conditions, it is approximated that only half of the solar energy that is directed to the planet reaches its surface. Another disadvantage of solar energy is the limitation that the current available technologies place on the efficiency at which this energy is harvested and utilized. Even though there are numerous solar panel and solar cell technologies available, the highest efficiency at which these devices convert solar energy to electricity is lower than 30%. This last factor is another reason why harvesting solar energy is still not the most popular way of producing energy.

### Harvesting Solar Energy

Solar energy can be harvested in two different ways, directly using photovoltaic or indirectly using Concentrated Solar Power (CSP). The photovoltaic effect is used in the conversion of light or photons to electric current or electrons. [17]

Solar or photovoltaic cells are primarily made of crystalline silicon and are connected in series to attain a desired voltage or in parallel to attain a desired current. These

interconnected cells form a solar panel that traditionally produces a DC potential. The panels are built of aluminum for durability. The cells are usually placed behind tempered glass for safety, durability and protection of cells against weather conditions. A clear resin is used to insulate the back of the solar cells and also keep them in place against the top panel glass. The CSP process involves the use of mirrors and lenses to intensify sunlight and its thermal energy is used to heat up water and produce steam. Steam is then used to drive steam turbines, which produce electricity. This project is going to make use of solar panels, which were first used in space projects to power orbiting satellites. A brief discussion and research on different types of panels and their efficiency is required in order to select the best solar panels to use for this project. Panel placement and panel temperature are also important in increasing the efficiency at which solar panels capture solar energy.

### **Advantages:**

- Electricity produced from solar cells is clean. During production and use, end-wastes and emissions are manageable using existing pollution controls.
- Small-scale solar plants can be installed on unused space on rooftops of existing buildings.
- A PV system is scalable, meaning it can be constructed in any size based on energy requirements.
- After initial cost of installation, it can operate for many years with little maintenance. In other words, the operating costs are extremely low compared to existing power technologies.

### **Disadvantages:**

- Photovoltaic systems are costly to install.
- Solar power is a variable energy source, with energy production dependent on the sunlight. It cannot be produced at night and can be much reduced in cloudy conditions. Therefore, storage is required.

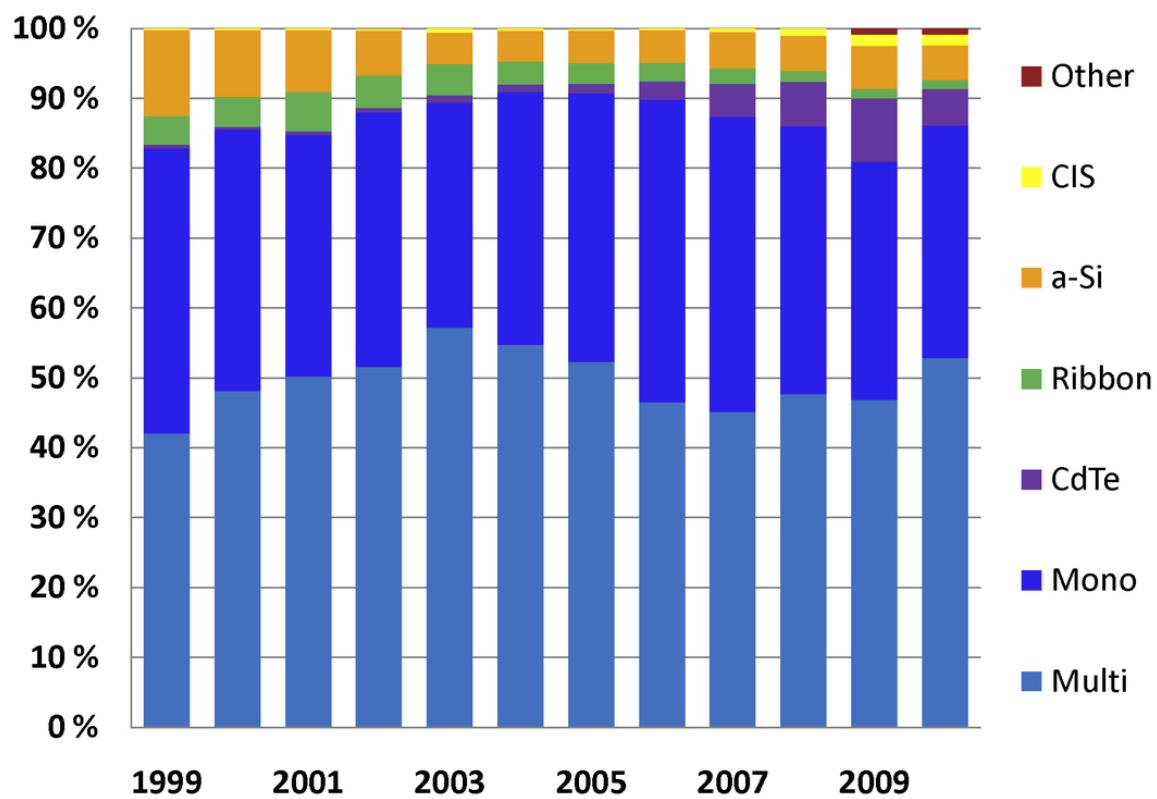
## **Solar Cells and Manufacturing Technology**

There are many different types of solar cells and various materials used to make them, but the two most popular technologies used in today's solar energy market are silicon, which is considered a first-generation technology and thin film which is considered a second-generation technology. Both technologies mentioned above divide into two separate groups: mono-crystalline and polycrystalline. Mono crystalline thin-film solar cells include Gallium Arsenide (GaAs). Polycrystalline thin-films include solar cells like: amorphous silicon (TF-Si), Copper Indium Gallium deSelenide (CIGS), and Cadmium Telluride (CdTe). Thin film solar panels are made by placing thin layers of semiconductor material onto various surfaces, usually on glass. The term thin film refers to the amount of semiconductor material used. It is applied in a thin film to a surface structure, such as a

sheet of glass. Contrary to popular belief, most thin film panels are not flexible. Overall, thin film solar panels offer the lowest manufacturing costs, and are becoming more prevalent in the industry. A third generation technology used today, which is also the latest in the thin film category, is the organic solar panel technology. In this fabrication process the solar panels are built by placing a conductive organic polymer, usually plastic, layer between two conductive plates.

These organic panels are not widely used and harder to purchase. They are very inefficient and therefore a lot of them are needed in order for this project to work.

Space is one of the major factors to consider in implementing this project, therefore organic solar panels are not going to be used. The annual market share of different solar panels according to different materials used in their manufacturing is shown in Figure 19. [23] For the main purpose of finding the most efficient and cost effective panel for the project, a quick review of the different types of panels is needed. Efficiency is more important than cost since in this MPPT charge controller project, the batteries need to be charged in the fastest manner possible. A solar panel that will do the best job at converting solar power into electricity (higher efficiency) is a major requirement, considering that sunlight is at its full potential for only half of the daytime hours.



**Figure 19 – Market Share of Different PV Technologies**

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## **Mono-crystalline Silicon Panel**

The first type of crystalline silicon used in solar panels is mono-crystalline. Even though not the most commonly used, this technology is one of the oldest and most proven in comparison to the rest. As the name implies this type of solar cells are made from the same silicon crystal, which is very pure and has less irregularities and imperfections than polycrystalline solar cells. This type of silicon is produced using the Czochralski process where seed crystal silicon is dipped into molten silicon and withdrawn very slowly. This process produces a two meter long cylindrical single-crystal ingot as the molten silicon crystallizes around the seed. [18] The silicone can be intrinsic or doped with impurities depending on its future use. The ingot is then sliced into thin wafers. These same wafers are also used for semiconductor device fabrication. Considering the square shape of a solar cell, a lot of silicone material is wasted in the process; hence the main drawback of this type of solar cell is its price point. This manufacturing process is also more complicated and more silicon is used to make mono-crystalline solar cells. These last facts contribute to a high price per panel compared to the rest of the solar panels in this review. However, due to the lack of imperfections and cell structure this type of solar panel is the most efficient, with percentages averaging around 11% - 16%. [24] Efficiency is the factor at which absorbed light is converted to electricity.

Because of the higher efficiency level these panels perform better and have been proven to last longer than the rest of the silicon technology panels. These panels are estimated to last at least 25 years. And some have been proven to last up to 50 years, so the higher price is justified by the returned energy cost that these panels produce during their long life. [19] Another positive factor about these panels is the fact that the user will get the most watts per square foot of panel used, since these panels are so efficient. As a result these panels are a good choice when limited space is an issue. Mono-crystalline solar panels are very fragile, and care must be given during the shipping and installation processes.

These panels will be used to implement this project. Most online solar panel retailers have recently dropped the prices for these panels to competitive levels with the prices of the polycrystalline panels, making this panel a sensible choice for this project.

## **Polycrystalline Silicon Panel**

Next in the silicon solar cell category is polycrystalline silicon. Polycrystalline solar panels are the most common type of solar panel in home installations today, due to their low cost and average power efficiency. In this fabrication process molten silicon is usually casted and then cooled in a rectangular shape for a more profitable outcome. The block is then sliced similarly to the monocrystalline ingot to create the thin solar cells. As the name implies the ingot is made of multiple crystals resembling pieces of shattered glass due to the manufacturing process. This process is a faster and a lot easier to implement. As a result, these types of silicon cells are cheaper and therefore cost less to produce in comparison to mono-crystalline cells. The lower grade semiconductor used in fabrication and the imperfections drop the solar cell performance. Efficiency is the main disadvantage of polycrystalline solar panels. They convert only 10%-14% of the solar

energy that hits their surface. [24] Efficiency for these solar panels drops in comparison to their mono-crystalline counterpart because of the energy loss at the separation or fusion points between two adjacent crystals. Polycrystalline panels like mono-crystalline panels perform poorly in shade or low light conditions. These panels account for most of the market shares in the solar panel manufacturing industry in the past decade.

### **Amorphous Silicon and Thin Film Panel**

Thin film technology is newer than the crystal silicon technology discussed previously. Amorphous silicon or other non-silicon semiconductors are used, instead of crystal silicon. The semiconductor is placed between flexible laminate, glass or steel plates. The flexible laminate is most commonly used to produce these panels. Thin film solar panels are cheaper and faster to produce since the entire panel is considered a solar cell, unlike traditional panels constructed of numerous solar cells. The manufacturing process makes these panels the most readily available solar panel on the market. The flexible laminate makes these panels bendable and therefore easier to mount on uneven surfaces and also more durable to extreme weather condition like a hailstorm. This factor is extremely important for thin film technology, considering that these panels are often laid on house roofs to replace traditional roofing materials. In case of damage the thin films panels with continue to work at a lesser rate, while crystalline silicon panels stop working altogether if a single cells is damaged. Another advantage of thin film panels is their weight. Thin film panels weigh less than crystalline silicon panels, making them easier to mount and work with for residential use. Another advantage that thin film panels have is their performance in hotter climates. Thin film semiconductors used today like Copper Indium Gallium Selenide does not lose as much efficiency as their temperature increases. Because of this ability to withstand hotter temperatures thin film systems have an added advantage over the crystalline rivals in hot climates like the southeast. This also makes it easier to design solar panel systems as the solar panels perform closer their manufactures rating without factoring high temperature as much. Thin film panels perform better than the competition in shade or low light conditions. So in conclusion the main advantages of thin film panels are: cost, weight, durability, flexibility, high heat and shade performance.

However, as with all the solar panels in this review, thin film panels have their disadvantages. The most significant disadvantage is their efficiency, which is also the main reason why this new technology has not replaced older silicon technology. Thin film technology efficiency ranges between 4% - 7%. [24] This means that in order to produce the same amount of electricity twice as many thin film panels are needed in comparison with polycrystalline panels and almost three times as many when compared to mono-crystalline. Last of all disadvantages of thin film technology is longevity. Because the technology is fairly new, it is unknown how these panels perform over time.

## **Copper Indium Gallium (de)Selenide CIGS Thin Film Panel**

Another type of panel to be reviewed is the CIGS panel in the thin film family. The semiconductor in this type of panel is composed of copper, indium, gallium and selenium. Like in other thin film panels the CIGS compound is layered on a glass back plate. This compound has a high optical absorption coefficient, therefore very little is needed to produce the panels. As a result CIGS panels are very light in comparison to crystalline silicon panels. Another advantage is their unmatched performance in higher temperatures. Unlike silicon, CIGS efficiency is not affected as much as the panel temperature increases, making CIGS panels appropriate for hotter climates like here in Central Florida. CIGS panel efficiency ranges from 10% - 15% with a record of 19.9% achieved by National Renewable Energy Laboratory with minor modifications. [10] Due to the moderate efficiency associated with these panels their production is projected to increase rapidly in the future. However these panels are usually very expensive and hard to find due to their vacuum based fabrication process, so they will not be considered for this project.

## **Cadmium Telluride CdTe Thin Film Panel**

CdTe was one of the first semiconductors that were used in thin film technology to improve the low efficiency experienced with amorphous silicon. CdTe panels are manufactured on glass substrate like CIGS. They are the most common type of thin film solar panel on the market and the most cost-effective to manufacture. CdTe panels perform significantly better in high temperatures and in low-light conditions similarly to CIGS panels. However CdTe thin film panels have maxed out at 16.5% efficiency and range between 7% - 12% on average. [25] The limited supply of Tellurium and toxicity of Cadmium make these panels expensive and dangerous for the environment.

## **Gallium Arsenide GaAs Thin Film Panel**

The last type of solar panels reviewed in the mono-crystalline thin film group is GaAs panel. The semiconductor compound used to make these panels is Gallium Arsenide, a mixture of Gallium and Arsenic. GaAs in a single crystal form is very expensive. It is important to note that Gallium is a rare material and Arsenic is very poisonous, making these panels expensive and dangerous if damaged to the point that the semiconductor is exposed. The main benefit of GaAs panels is their efficiency. GaAs efficiency can range between 20% - 25%, with a record near the 30% mark. [26] This high efficiency is mainly due to the nearly ideal GaAs band gap. The role of the semiconductor material band gap will be discussed in the next section. GaAs panels are very useful in space applications because of its resistance to radiation damage and insensitivity to heat. So CdTe and GaAs photovoltaic modules have similar advantages in heat tolerance and high temperature performance.

## **Photovoltaic Effect in Solar Cells**

In order to fully understand the photovoltaic effect and make a better decision on the most expensive part of this project, a brief review is needed to show how solar panels convert solar energy to usable electricity for the end user. The photovoltaic cell is usually constructed of some light absorbing material, which is usually silicon or some other type of semiconductor. All semiconductors are associated with a specific band gap. [16] The potential difference between the lowest energy level on the conduction band  $E_c$  and the highest energy level on the valence band  $E_v$  is called band gap energy or  $E_g$ . Electrons with enough input energy can jump this band gap from their usual steady state spot on the valence band to an excited state on the conduction band. These electrons are responsible for the direct current that the solar cells produce. Solar energy packets or photons that contain different amounts of energy correspond to different wavelengths of the solar spectrum. When the photon energy matches that of the semiconductor band gap, the semiconductor material absorbs these photons. Consequently photons with higher energy levels than  $E_g$  are also absorbed but their excess energy is reflected or dissipated in the form of heat (wasted energy) and photons with lower energy levels than  $E_g$  are not able to get absorbed at all.

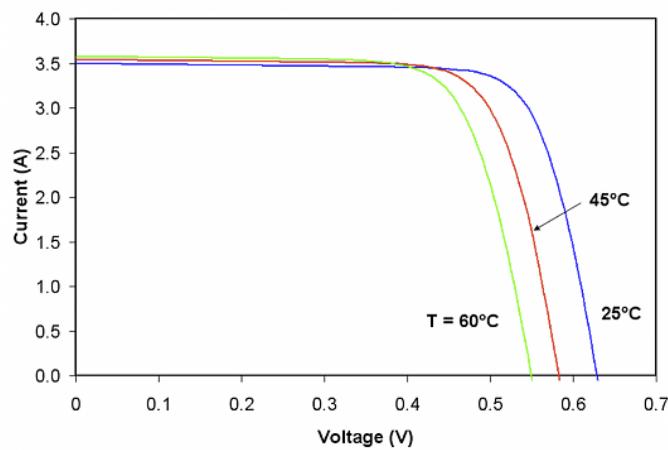
Ultimately the goal of a solar cell designer is to choose a semiconductor material with optimal band gap energy near the middle of the energy spectrum for solar radiation. No single semiconductor has a band gap that can respond to sunlight's full range, from the low-energy infrared through the visible light to the high-energy ultraviolet. Full-spectrum solar cells have already been invented, but not at a suitable consumer price. Scientists at the Solar Energy Materials Research Group in the Materials Sciences Division (MSD) at the U.S. Department of Energy's Lawrence Berkley National Laboratory have tested and produced a GaNAs solar cell that responds to almost the entire solar spectrum. The main objective in this new technology is to produce a solar cell that stacks three different semiconductors with different energy band gaps. These semiconductors are usually connected in series. [16] A solar cell can be compared to a diode because of the p-type and n-type semiconductor materials used to fabricate them. As in all diodes there are two metal contacts attached to each side of this p-n junction. When the electron-hole pair is formed across the p-n junction, a forward voltage or photo voltage is created between the two photovoltaic cell terminals. Traditional photovoltaic cells are usually protected from the outside elements with a protecting layer such as glass or clear plastic cover. A clear encapsulate is used to attach the rest of the cell to the glass. Then an antireflection coat covers the top or front contact (n-type terminal), which is connected to the n-type silicon.

## **Photovoltaic Panel Performance**

From the previous part of this review it is quite clear the solar panels in all the various makes and models are not very efficient at converting solar energy. So panel performance and means to increase it are very important to this project. All solar panels suffer from naturally inherited issues such as temperature effect, electron-hole recombination rate, and light absorption efficiency. Electron hole recombination is the main reason why mono-crystalline cells perform better than polycrystalline ones. The impurity

concentration and structure abnormality associated with multiple crystal silicon increases electron-hole recombination rate, which in turn, decreases panel efficiency. Temperature is another negative factor that affects solar panel performance. As mentioned earlier, crystalline silicon panels suffer the most when their cell temperature rises. The main reason why researchers use non-silicon semiconductor materials on thin film panels is to reduce panel sensitivity to temperature. Ironically, solar panels perform at their best on a cold and sunny day. Unfortunately those days are very few and far in between in hot and sunny Central Florida. Therefore this project will have to take great consideration of temperature effects on the selected solar panel. As the semiconductor temperature goes up so does its conductivity. Higher conductivity reduces the electric field at the silicon p-n junction, which in turn reduces the voltage across a solar cell. A smaller cell voltage translates to a smaller power output, which also means lower efficiency. Solar panels will usually have a temperature coefficient, which is usually the rate of power reduction for every degree the above normal operating temperature of 25 degrees Celsius.

Every solar panel has an I-V curve or I-V characteristics associated with it. The area under the I-V curve is approximately the maximum power that that a panel would produce if it would operate at maximum voltage or open-circuit voltage and maximum current or short-circuit current. Figure 20 shows how temperature affects the I-V characteristics of a solar cell. It is quite clear that the area under the I-V curve (total cell power) shrinks as the solar cell voltage drops due to the higher cell temperature.



**Figure 20 – Solar Cell I-V Characteristics**

(Permission Pending)

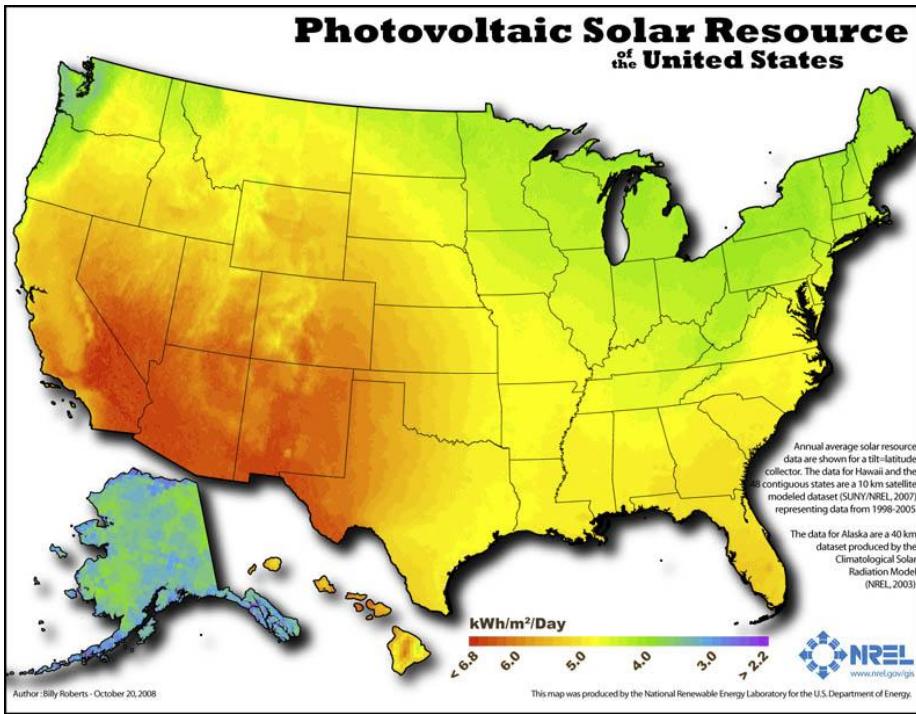
In order to increase or maintain an optimal efficiency the solar panel temperature needs to stay low and close to room temperature range. There is a lot of research being done in cooling methods used to lower panel temperature. There are active and passive-cooling methods suggested in maintaining a lower panel temperature. Pumping a coolant or some type of refrigerant through the backside of the panels is an active method. Attaching a heat sink or cooling fins is a passive way of dissipating heat from the panels. Usually these methods are not very cost effective in comparison to the gained efficiency or power from the panels.

The last inefficiency associated with solar panels is their ability to absorb light. It is a well-known fact that solar panels cannot make use of the entire light spectrum. Some light is lost due to reflection, which is why antireflection coating 20 is used on top of every solar cell. As mentioned earlier the semiconductor will absorb only the amount of light that has matching or higher wavelength energy to the semiconductor band gap. This makes more than half of the spectrum of light available useless to the solar panels. Band gap engineering is one of the methods used to increase the light absorption efficiencies. The design engineer can maximize power by maximizing photocurrent or photo voltage individually. To maximize photocurrent, it is desirable to capture as many photons from the spectrum of solar radiation as possible. A small band gap may then be selected so that even photons with lower radiation energies can excite electrons into the conduction band. However, the small band gap results in a lower photo voltage.

Additionally, the photons with higher energies will have much of their energy wasted as heat, instead of conversion into electrical energy. Alternatively, the designer can choose a higher band gap, but then will not capture any photon energy less than that band gap, resulting in a lower photocurrent and, in turn, reducing the output current of the device. In designing conventional single junction solar cells, these two competing issues are balanced by choosing optimal band gaps near the middle of the energy spectrum for solar radiation. Conveniently, high-quality wafers of silicon, with a band gap of 1.1 eV, and GaAs, with a band gap of about 1.4 eV, are readily available and have nearly the optimal band gap for solar energy conversion in a conventional single-junction solar cell. [16]

## Solar Radiation

The intensity of solar radiation or irradiance is the main reason which explains why solar panels perform better in the middle of the day versus in the morning or in the evening. Solar radiation is the electromagnetic (EM) radiation emitted from the sun. Insolation is expressed by the amount of energy received on a given surface in a given time. It is expressed by watts per square meter ( $\text{W/m}^2$ ) or kilowatt-hours per square meter per day ( $\text{kWh}/(\text{m}^2 \cdot \text{day})$ ). Considering Earth's distance from the Sun, the amount of insolation from the Sun on Earth's surface averages at  $1368 \text{ W/m}^2$ . Figure 21 shows the annual average solar radiation map of the United States. [11] According to this map Central Florida averages close to  $5 \text{ kWh}/(\text{m}^2 \cdot \text{day})$ . The southwestern United States would be the best area to design and test this project since the average solar radiation there is close to or above  $6 \text{ kWh}/(\text{m}^2 \cdot \text{day})$ .



**Figure 21 – Annual Average Solar Radiation Map**

(Permission Pending)

There are a few methods to increase solar panel performance to make up for lower levels of solar irradiance. They would include direct methods like solar tracking and light concentration or indirect method such as the one covered in this project, which considers the use of an MPPT charge controller. Solar tracking is used to minimize the angle of incidence between the sunlight and the panels. In other words, this method ensures that the solar panels face the sun at any given point of the day. This is achieved by mounting the solar panels on a single or double axis mounting mechanism that is controlled by the intensity of the sunlight. Light concentration is achieved with the use of mirrors or lenses above or around the solar panel in order to intensify the amount of sunlight that hits the panel. MPPT is an indirect method of maximizing the efficiency at which the solar panels deliver electricity to an on-grid or off-grid scenario like charging a bank of batteries. MPPT charge controllers optimize the output voltage of the panel to match the required-state voltage level of the batteries. This is achieved by maintaining the panel's power level and therefore changing the panel's output current accordingly. So for example, if the batteries require a lesser voltage from the panel the MPPT charge controller will reduce the PV output voltage and increase the PV output current in order to maintain the same level of power.

## Charge Controllers

Charge controllers are designed to maximize the output efficiency of a solar panel or solar array. Usually used in an off-grid scenario, charge controllers are used to monitor and regulate the solar array output voltage to the batteries, which store the energy

generated. Output voltage regulation is very important in battery charging because batteries require a specific charging method with various voltage and current levels for each specific stage. These charging methods are needed to prolong battery life and performance. This is where the charge controller does most of the work.

Depending on the type of controller, the input voltage will be regulated to match the battery required voltage at the output. This can be done by using standard or MPPT charge controllers. Standard charge controllers will typically be used in a situation where the input voltage from the solar panel is higher than the voltage from the battery. In this case the voltage will be reduced by the controller while the current that the panel is outputting will stay the same. This will result in power loss from the total power generated from the panels. MPPT charge controller use smart technologies, such as microcontrollers, to compute the highest possible power output at any given time. In this scenario the voltage will be monitored and regulated without power loss. Therefore in the same conditions as above, where the input voltage is higher than the output voltage, the MPPT charge controller will lower the voltage and simultaneously increase the current to the batteries.

This results in higher power transfer efficiencies, which means less solar power is lost during the storage process.

## DC-DC Regulators

The DC voltage from the panel will vary depending on light intensity based on the time of day and solar panel temperature. On the battery side of the system, the battery voltage will vary depending on the load connected to it. In order to maintain optimal battery charging, it is extremely important that the panel voltage and current matches the required battery charging stage at that particular moment.

A DC-to-DC regulator is needed to increase or decrease the input panel voltage to the required battery level. These regulators are also known as switching regulators where a power switch, an inductor, a capacitor and a diode are used to transfer power from input to output. These components can be arranged to form different types of DC-to-DC regulators. The switches are either passive or active. Passive switches usually consist of a diode, while the active switches are usually some type of a MOSFET transistor. MOSFET transistors are an efficient and fast way to allow a pulse width modulation (PWM) signal to control the frequency and duty cycle of the ON and OFF time of the “switch”. The higher the duty cycle the more power is transferred from input to output. One of the advantages of the PWM is that the signal remains digital from the source, in this case from the microcontroller to the MOSFET, reducing or even eliminating the need for any analog-to-digital signal conversion. Digital signals are not affected as much from outside noise, unless the noise is sufficient to change the signal from one to zero or vice versa.

There are many DC-to-DC converter topologies used today, such as Buck, Boost, Buck/Boost, CUK, and Sepic. These regulators do not produce power. In fact these regulators consume some of the input power according to their efficiency.

Therefore the adjusted voltage level affects the current level, ideally maintaining the same power level. Since current and voltage are both directly proportional to power, it is

intuitive that in buck mode the voltage is lowered as the current increases. While in boost mode the voltage is increased as the current decreases.

## 4.0 Project Design

### 4.1 Design Architecture

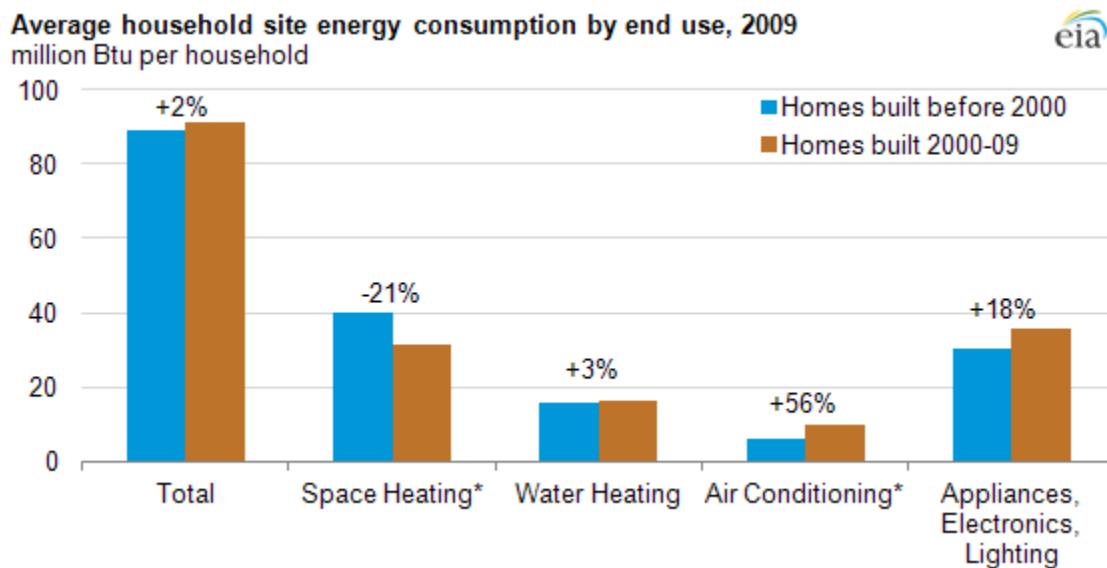
This figure below is the possible main microprocessor block diagram for the project, which contains multiple inputs and multiple pins that will be used to design the system. It offers lots of features, which would allow the team to make multiple updates on possible existence project, and also allow the team to upgrade the system to a more energy consumption. The processor would have multiple other microcontrollers in parallel with it which will serve as slave relies on the main microprocessor, and need to communicate with in different area. The design will have an RF transmitter and receiver that will have a major role to play in the system when configuration occurs. Would be able to receive data or instructions from the user, and then transmit it to the output. A possible GPS is to be input for satellite signal, which will be used if the person is out of the house go to the store or go to work wants to monitor the devices in the house, the user basically can either use an APP from a Smartphone to access the equipment, or link to a web site, there will be multiple sensors placing in the house to monitor when a person is walking to the room.

One or two sensors per room, light sensors will be placed on all light bulls that use lots of power. Each fan in the house or in the back porch will need a sensor; according to some progress energy technicians each fan in the house cost the customers at least \$5 a month, which is focus of this project to reduce the power usage so people can have more money left in the pocket. The motion sensor will be a non-stopped logic, the timer will be set up a time the person walked passing the living room go to a room, in the matter of 30 or 40 seconds the peripheral will send a signal to deactivate lights. And activate back when the person walks back to the living room. However, this scenario will use the same for running fans in the house. A video camera is possible and is important to have it, because if the user is out for the whole day or happen to be on vacation, it gives a better view of what going on in the house, if there are children left at home for instance, the video camera for that purpose will be used to track on their activities. And then it also can be used for any unfriendly person is happened to walk in or walk around the house without permission from the owner, that is also can be seen and monitored from far away. Possible Altimeter will be installed to control the altitude and temperature in the house. The vampire power in the house is the heating, cooling, lighting, laundry, and the computers routers. Those if unplugging all of this equipment when not in use the user will save up to 5% of the monthly bill.

The focus of the project has motivated the group for further research, looking different agencies for comment over high energy bills. According to Analysis from EIA's most recent Residential Energy Consumption Survey (RECS) shows that U.S. homes built in 2000 and later consume only 2% more energy on average than homes built prior to 2000,

despite being on average 30% larger. Homes built in the 2000s accounted for about 14% of all occupied housing units in 2009. These new homes consumed 21% less energy for space heating on average than older homes (see graph), which is mainly because of increased efficiency in the form of heating equipment and better building shells built to more demanding energy codes. Geography has played a role too. About 53% of newer homes are in the more temperate South, compared with only 35% of older homes.

The increase in energy for air conditioning also reflects this population migration as well as higher use of central air conditioning and increased square footage. Similar to space heating, these gains were likely moderated by increases in efficiency of cooling equipment and improved building shells, but air conditioning was not the only end use that was higher in newer homes. RECS data show that newer homes were more likely than older homes to have dishwashers, clothes washers, clothes dryers, and two or more refrigerators. Newer homes, with their larger square footage, have more computers, TVs, and TV peripherals such as digital video recorders (DVRs) and video game systems. In total, newer homes consumed about 18% more energy on average in 2009 for appliances, electronics, and lighting than older homes. [14]

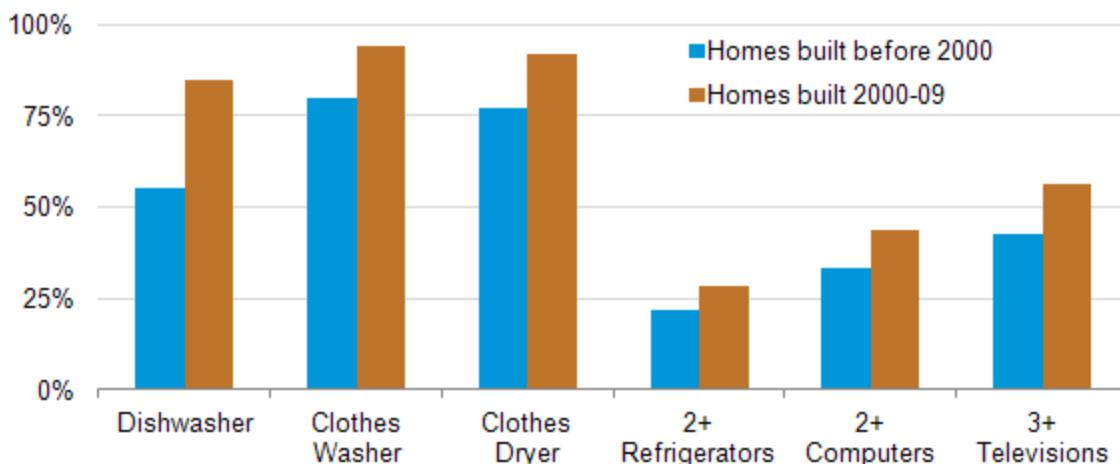


**Figure 22 – Average Household Site Energy Consumption in 2009**

(Reprinted with permission from U.S. Energy Information Administration)

**Households with selected appliances and electronics, 2009**  
percent of households

eia



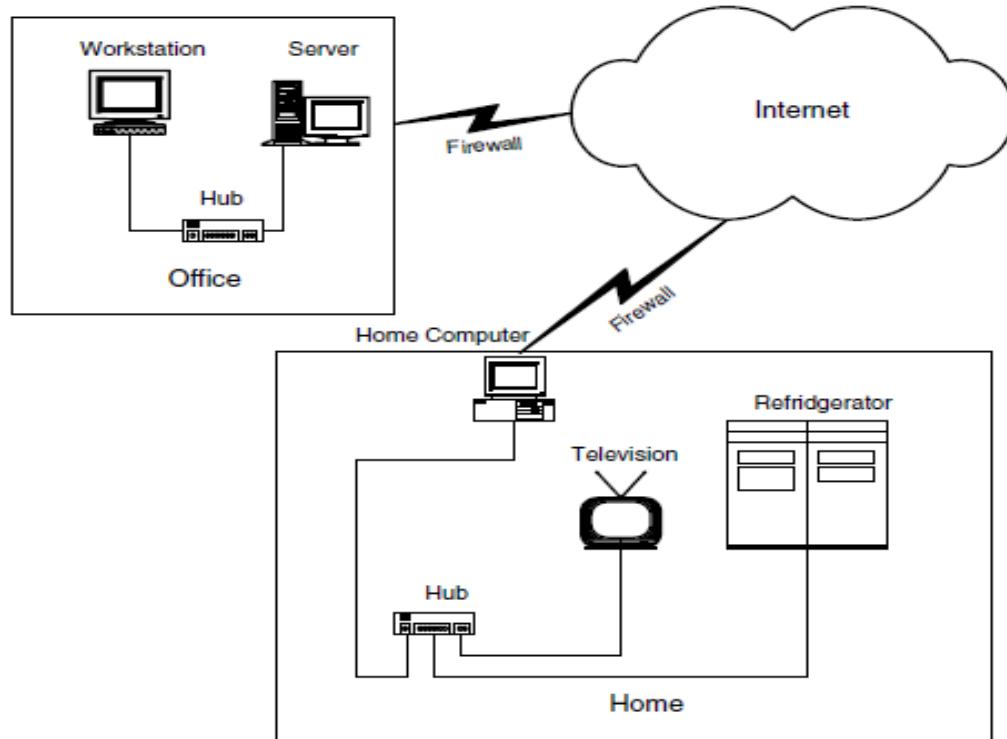
**Figure 23 – Households with Selected Appliances and Electronics in 2009**

(Reprinted with permission from U.S. Energy Information Administration)

These are matters which need a clean focus on. To design a system that will do this job will require time and money. The technology is there, but the question is how it will be used. The team is capable and ready to face the challenge.

Shown below in Figure 24 is an AVR460 embedded web server setup to show how the user can setup a network to monitoring the equipment and the devices around the house, it is an Atmel designed which is one of the most embedded wed reference designs is designed for integration in digital equipment at there. This will be able to monitor every device in the house or business. First, it will be connected to the internet and oblige a microcontroller to able it communicate with the other network devices in the house such as routers, computers, printers, refrigerator, television, lights, outlets and fans etc. The AVR460 embedded web server has a transmission control protocol built with it; this will allow the user programs it into the system. TCP will be use and sending segments and receives data from other users. It basically work on reservation, it a signal sent and there is an error it will whole the data sent and waiting for the other end to acknowledge the reception of the segment. Note that if an acknowledgement is not received in time, the segment will retransmit. It will use to maintain a checksum on its data header page. This is an end-to-end checksum whose purpose is to detect any modifications of the data in transit. This transmission control protocol will discard any fault or unnecessarily signals, and does not have to acknowledge that it receiving it. The Embedded Web Server is designed with an extensive feature which includes a “complete web server with TCP/IP support and Ethernet interface.” It also includes support for sending email, and software for automatic configuration of the web server in the network. All electronics in the house

can be controlled from a computer that is connected to the internet by the user. However, if every server is to be connected to a network in the house by embedded it in most units, the system on the other hand can be controlled anywhere in the world by unique IP address for the server.



**Figure 24 – Monitoring Home Equipment from the Office**

(Permission Pending)

#### 4.1.1 Event System

This processor has an Event System that enables the system for direct peripheral-to-peripheral communication and signaling. The peripheral's job basically is to directly send receive, and react to peripheral events. It has capability to work in active mode and idle sleep mode. This event system will allows a change in one peripheral's state to automatically trigger actions in other peripherals. Any changes the user will make in the house will not necessary affect the system, however, all changes need to be added or put into the system configuration, and so the system can trigger the element and put it to a sleep mode when it's unused. That is why this event is necessary, it allows for autonomous peripheral control and interaction without the use of interrupts. Having all that features on this processor becomes a big challenge to the group as well to program the event system features. However, the system will be very stable when complete, and will be usefully not only for residential homes but also for any businesses which interested to save power can used it. Another thing the event system can also do is directly connected together with an analog to digital converter if needed, and analog

comparator, with input and output ports pins available for those, which can be for the real-time counter, timer/counters, and also IR communication module. Events can also be generated from software and the peripheral clock. This will trigger the signals of each device before putting it into a sleep mode. The user will need this system to be as fast as possible for when the user walks into the house from work or from anywhere. Here SPI the serial peripheral interface will be capable of handling the communication between the main microprocessor and all slaves' processors which will also be in contact with the main processor. The serial peripheral interface is a high speed synchronous data transfer interface using three or four pins. It allows fast communication between the main processor and peripheral device; it also supports full-duplex communication. The way this will work is to have the device connected to the bus of the master or the slaves of the microprocessor. The master initiates and controls all data PORTC and PORTD each will have one Serial Peripheral Interface. What seems so exciting about this feature is that two-wire interface can be used in connection with the master; again the master initiates a data transaction by addressing a slave on the bus and telling whether it wants to transmit or receive data. One bus can have many slaves and one or several masters that can take control of the bus.

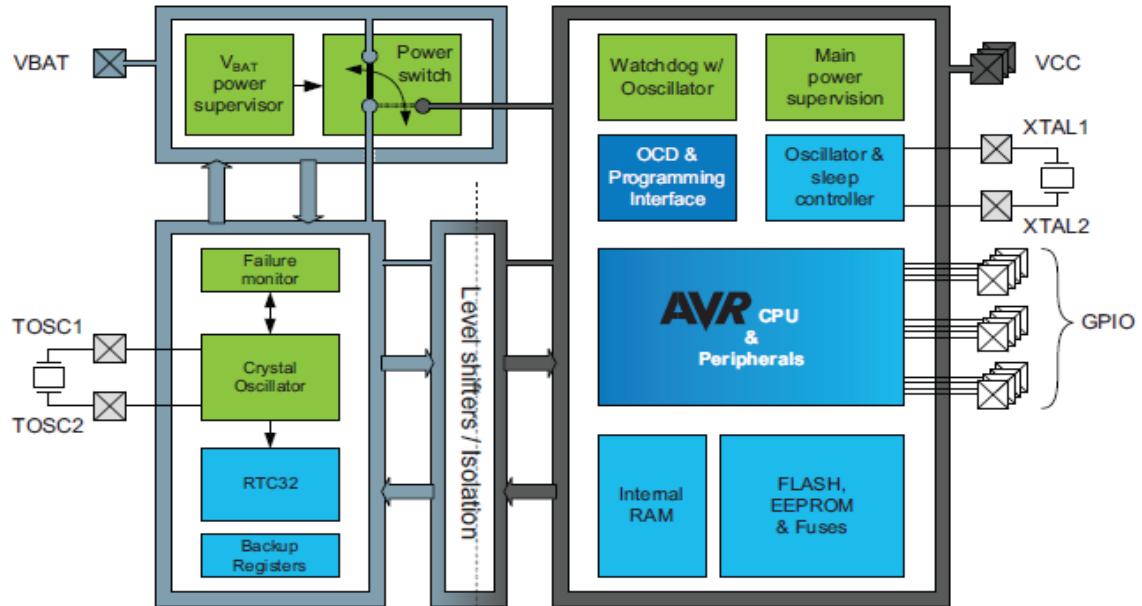
This system can monitor two homes wirelessly if the group wants to. An arbitration process handles priority if more than one master tries to transmit data at the same time. Mechanisms for resolving bus contention are inherent in the protocol. The TWI module supports master and slave functionality. The master and slave functionality are separated from each other, and can be enabled and configured separately. The master module supports multi-master bus operation and arbitration. It contains the baud rate generator. Both 100 kHz and 400 kHz bus frequency is supported, which will not be at that range just to show the capability of it. Quick command and smart mode can be enabled to auto-trigger operations and reduce software complexity. The slave module implements 7-bit address match and general address call recognition in hardware. 10-bit addressing is also supported. A dedicated address mask register can act as a second address match register or as a register for address range masking. In general, the slave continues to operate in all sleep modes, including power-down mode. This enables the slave to wake up the device from all sleep modes on TWI (two-wire interface) address match.

The user doesn't have anything to worry about. That is the reason why this bidirectional is put in place in the system. It is possible to disable the address matching to let this be handled in software instead. However, the TWI module will be able to detect START and STOP conditions, bus collisions, and bus errors. Arbitration lost, errors, collision, and clock hold on the bus are also detected and indicated in separate status flags available in both master and slave modes. All those errors are to be expected. But, however, the teams will make sure to minimize the risk of these errors to be small as possible. It is possible to disable the TWI drivers in the device, and enable a four-wire digital interface for connecting to an external TWI bus driver. This can be used for applications where the device operates from a different VCC voltage than used by the TWI bus. The event routing network routes the events between peripherals that would be very important for the system, because part of the project will contain and will have the doors going to be electronics magnets put into them. It consists of eight multiplexers, which can each be

configured to route any event source to any event users. The output from a multiplexer is going to be referred to as an event channel. For each peripheral, it is selectable if and how incoming events should trigger event actions not only someone strip on the sensor the signal can be sent, but also if the user access the door by insert a key to open the door, the sensor will detect the movement and select sending it to event, so it will be process to the processor. Eight multiplexers mean that it is possible to route up to eight events at the same time. It is also possible to route one event through several multiplexers. Not all XMEGA devices contain all peripherals. This only means that a peripheral is not available for generating or using events to do job. However, the network configuration itself is compatible between all devices.

#### 4.1.2 Battery Backup System

This is the important component built with the system which needs the attention is battery backup system, if any chance there is a lost power outage happened the system will still functioning on the battery backup system until the main power restored, then the battery backup system will automatically switch back to being powered from the main power again. The integrated battery backup system ensuring continuous, real-time clock during main power failure, has battery backup power supply from dedicated  $V_{BAT}$  pin to power, supported with one 32-bit real-time counter, one ultra-low power 32.768kHz crystal oscillator with failure detection monitor, and with an automatic power switching between main power which is power supply and battery backup power at main power loss and the switching from battery backup power to main power at main power return. It does require a time clock which already built in it that will keep running continuously, even in the event of a main power loss or failure. This is shown in Figure 25 below.



**Figure 25 – AVR Battery Backup System**

(Reprinted with permission from Atmel)

However, the battery back system does not provide power to other parts of the volatile memory in the device such as SRAM and I/O registers outside the system. Understanding, the battery backup is drained only when main power is not present, and this ensures maximum battery life. Figure 7 above is the Block diagram showing how this thing is going to look like.

Atmel XMEGA D4 has another great feature that the system will depend on is USART, the universal synchronous and asynchronous serial receiver and transmitter is a fast and flexible serial communication module. It supports full duplex communication and asynchronous and synchronous operation. The important thing is that it can be configured to operate in SPI master mode and used SPI communication. In addition, that communication is frame based, and the frame format can be customized to support a wide range of standards the USART is buffered in both directions, one is enabling continued data transmission without any delay between frames. It has a separate interrupts for receive and transmit complete enable fully interrupt driven communication. However, frame error and buffer overflow are detected in hardware area and indicated with separate status flags.

The transmitter consists of single write buffer data, a shift register, and a parity generator. The write buffer allows continuous data transmission without any delay between frames. For the receiver on the other hands also consists of a two level receive buffer data and a shift register. Data and clock recovery units ensure robust synchronization and noise filtering during asynchronous data reception, this one is including frame error, buffer overflow and parity error detection. So when the USART is set in master SPI mode, that will make all USART specific logic is disabled, however, it will leaving the transmit and receive buffers, shift registers, and baud rate generator enabled. Pin control and interrupt generation are identical in both modes. The registers are used in both modes, but their functionality differs for some control settings.

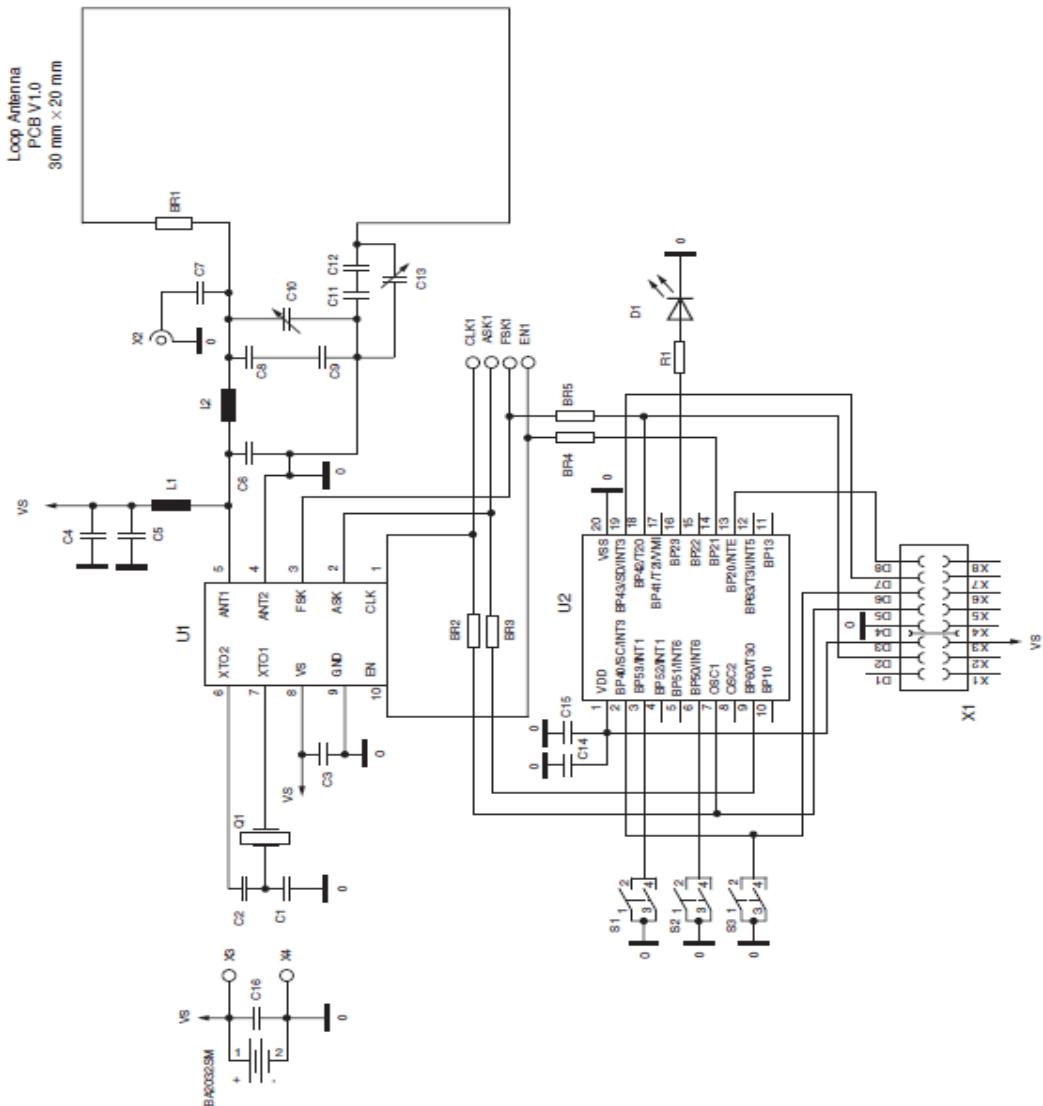
Note that in the system there will be more than one processor, the multiprocessor communication mode effectively reduces the number of incoming frames that have to be handled by the receiver in a system with multiple microcontrollers communicating via the same serial bus. In this mode, a dedicated bit in the frames is used to indicate whether the frame is an address or data frame type. If the receiver is set up to receive frames that contain five to eight data bits, the first stop bit is used to indicate the frame type. If the receiver is set up for frames with nine data bits, the ninth bit is used. When the frame type bit is one, the frame contains an address. When the frame type bit is zero, the frame is a data frame. If 5-bit to 8-bit character frames are used, the transmitter must be set to use two stop bits, since the first stop bit is used for indicating the frame type. If a particular slave MCU has been addressed, it will receive the following data frames as usual, while the other slave MCUs will ignore the frames until another address frame is received.

In context, what could happen with more than one which system will have couple, all slave MCUs are in multiprocessor communication mode. The master MCU sends an address frame, and all slaves receive and read this frame. Each slave MCU determines if it has been selected. The addressed MCU will disable MPCM and receive all data frames. The other slave MCUs will ignore the data frames. When the addressed MCU has

received the last data frame, it must enable MPCM again and wait for a new address frame from the master.

### 4.1.3 Transmitter

The RF transmitter will be the most critical element in the system; it will be built with the Atmel XMEGA D4 microcontroller. It is a PLL transmitter IC with a single-end output. It consumes a high output power at 8.1 mA at frequency of 315 MHz and 8.5 mA at frequency of 433MHz. That means this transmitter after being built; it will be able to send signals at a range from 315 MHz to 433 MHz, one the advantage it has is a power down Idle and power up modes to adjust corresponding current consumption through enable input pin. And its power supply voltage is 2.0 V to 3.6V in operation temperature range of -40°C to +125°C which convert to -104°F to 257°F. This type PLL transmitter IC was developed for the demands of RF low-cost transmission system. In addition, it can also be used in both frequency shift keying and amplitude shift keying systems. Figure 26 illustrates the RF transmitter schematic.



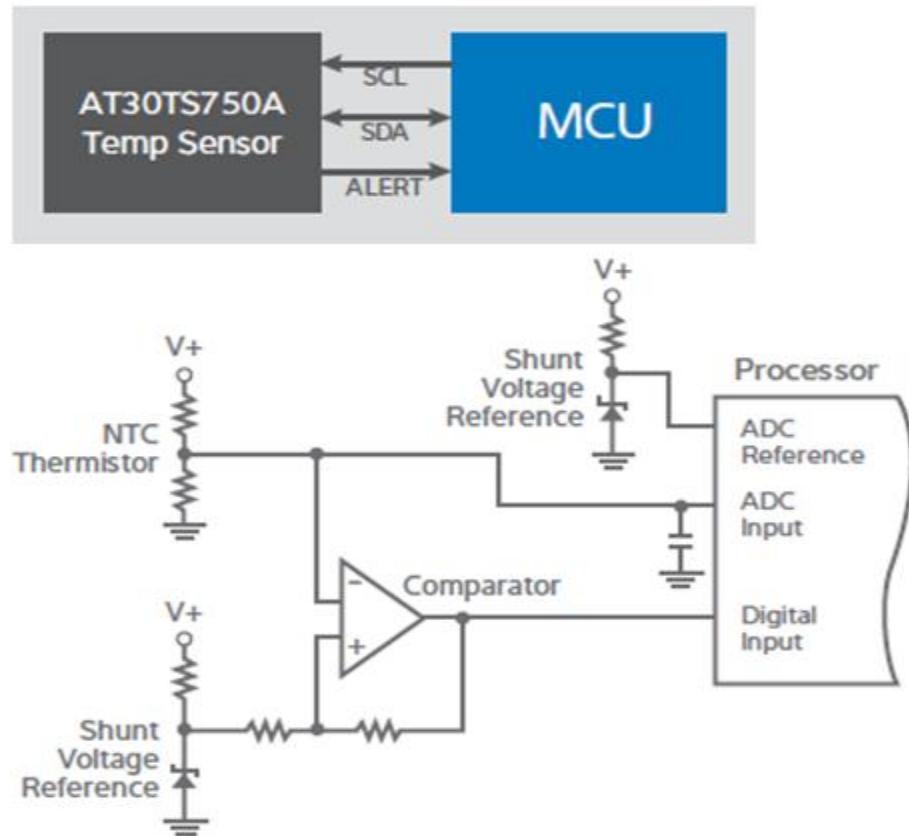
**Figure 26 – RF Transmitter Schematic**

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#### 4.1.4 Temperature Sensor

It becomes so important that in every application temperature sensors turn out to be essentially more necessary. Some may ask why do applications need a temperature sensor. Well the answer might be simple to understand. Atmel cooperation has explained it quite well, with the advance technology today and the demands are huge. As today's electronic systems run faster and as silicon content increases, these applications are generating more heat than ever now, that really making the need to monitor temperature increasingly important. A temperature sensor can effectively measure the system and processor temperatures and allows the processor and system bus frequencies to be

throttled back when the temperature exceeds a preset limit. This ensures product safety and reliability while minimizing the need for cooling fans and heat sinks which may not be practical in today's increasingly compact designs. For systems that do include a fan to maintain proper conditions, such as temperature sensors can be used to vary the fan speed as needed to reduce noise, reduce power consumption, and prolong the life of the fan. Figure 27 illustrates the schematic of the temperature sensor.



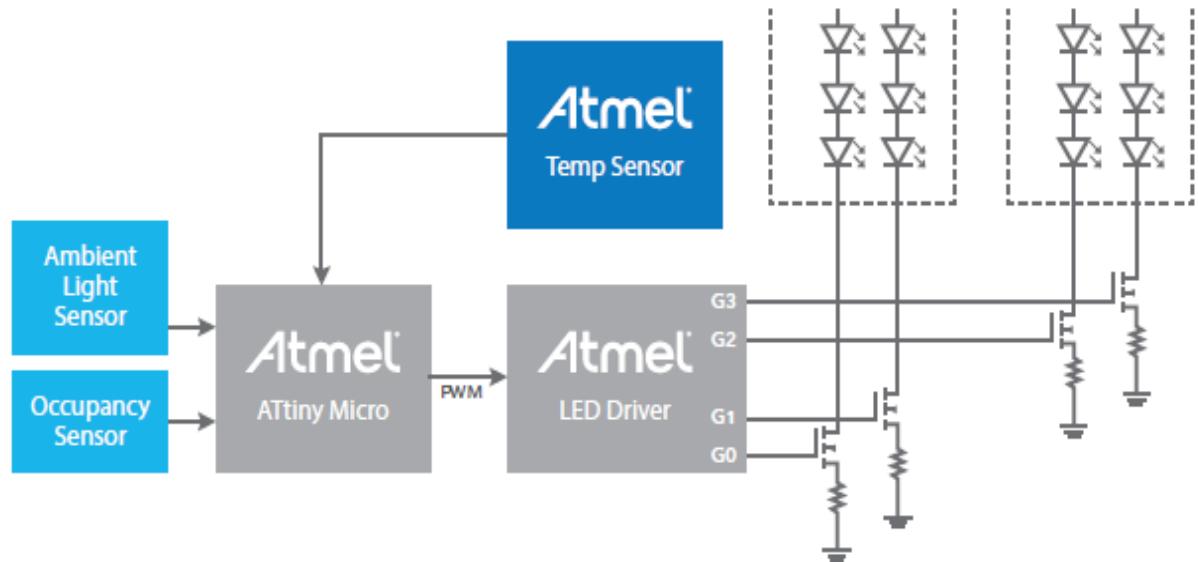
**Figure 27 – Temperature Sensor Schematic**

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The team put a plan in place to make sure that the system has reliable equipment to work with. In portable applications that utilize Li-ion or Li polymer batteries, temperatures in excess of 60°C can cause the batteries to overheat and swell, catch on fire, or even explode. A temperature sensor can actively monitor the battery temperature, allowing the system to warn the user to shut itself down, or to even shut down the battery charging in the event of an over temperature situation, thereby increasing the safety and reliability of the application, which the group's idea to have a temperature sensor to protect any damage in system. In figure 8 above is the design and schematic for the temperature sensor.

This type of temperature sensor is very easy to install to the system, the big advantages and benefits with this temperature sensor make the group more excited to use it. It's because there is no calibration and ADC required, it will increase the system reliability, it

has ability to control other circuits, has power saving and also it will lower overall system cost. This digital temperature sensor provides highly accurate measurement to better control temperature and prolong the life of the LEDs. However, it also provide enhanced features, such as integrated EEPROM and nonvolatile register is needed, improve flexibility and product reliability, and again enhance application safety. Also, in terms of performance, the Digital Temperature Sensors offer an excellent accuracy and a precise, fully calibrated, then the digital temperature reading in degrees Celsius. It eliminates the need for additional components, such as an A/D converter, within the application, that is not big deal because the main microprocessor has it built in it, it is capable enough to handle the job that the A/D converter would do, and there is no need to calibrate components or the system at specific reference temperatures as required when using thermostats. Atmel Digital Temperature Sensors take care of it all, enabling the critical system temperature monitoring function to be simplified. Figure 28 illustrates the design route schematic.



**Figure 28 – Design Route Schematic**

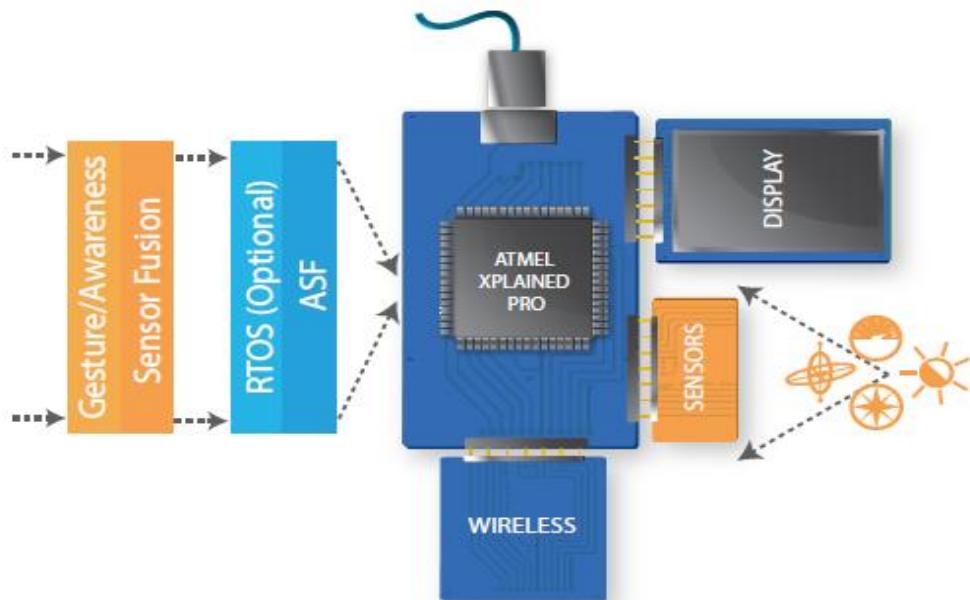
(Reprinted with permission from Atmel)

#### 4.1.5 Light Sensor

In world technology, today, sensors are all around us in every corner, and today, engineers are continuing to design them into an increasing number of everyday products. Of course there are some requirements, too, have changed, from simple monitoring to comprehensive interpretations of a device's status. Moving from one place to another, this can require simultaneous analysis and fusion of data from different sensors and sensor types, such as accelerometers, gyroscopes and magnetometers, as well as environment sensors like light level which is the system's main idea, color, temperature, pressure, humidity, etc. Again, there are many different applications for sensors regarding

detection of objects or areas. Detecting even pieces from human body to detecting a shape to detecting different terrains; sensors are in important part of all products and elements that surrounding us. In this application the sensors will be used to sustain the house equipment health against high power. The primary operation of the sensors on this system is to detect the elements of higher power such as water heater, microwave, computer and routers. Below in figure 10 is an ultra-low power sensor, reduces power by up 50% when compared to others competitive solutions. This sensor type architecture differentiating technologies such as capacitive touch and wireless enable your end product to stand out from the competition. Each room would have couple sensors to monitor the lights and any devices that may be plug in.

Sensors will play an essential role in this project, reason, because every devices or equipment in the house will have to be monitored, another to do so, sensor has to be install in each room, door way, light, fan, water heater, refrigerator, and computer and television etc. Here below a possible home wireless networking monitoring design how each device can remotely turn off wirelessly. The design has its own panel control center what would directly connect to an input to the microcontroller. This version of ZigBee is designed similar with Texas Instrument's model, but redesigned with extra features. ZigBee is a standards-based technology for remote monitoring, it's a control and sensor applications which will use to monitor the system. Figure 29 illustrates the ultra-low power sensor.

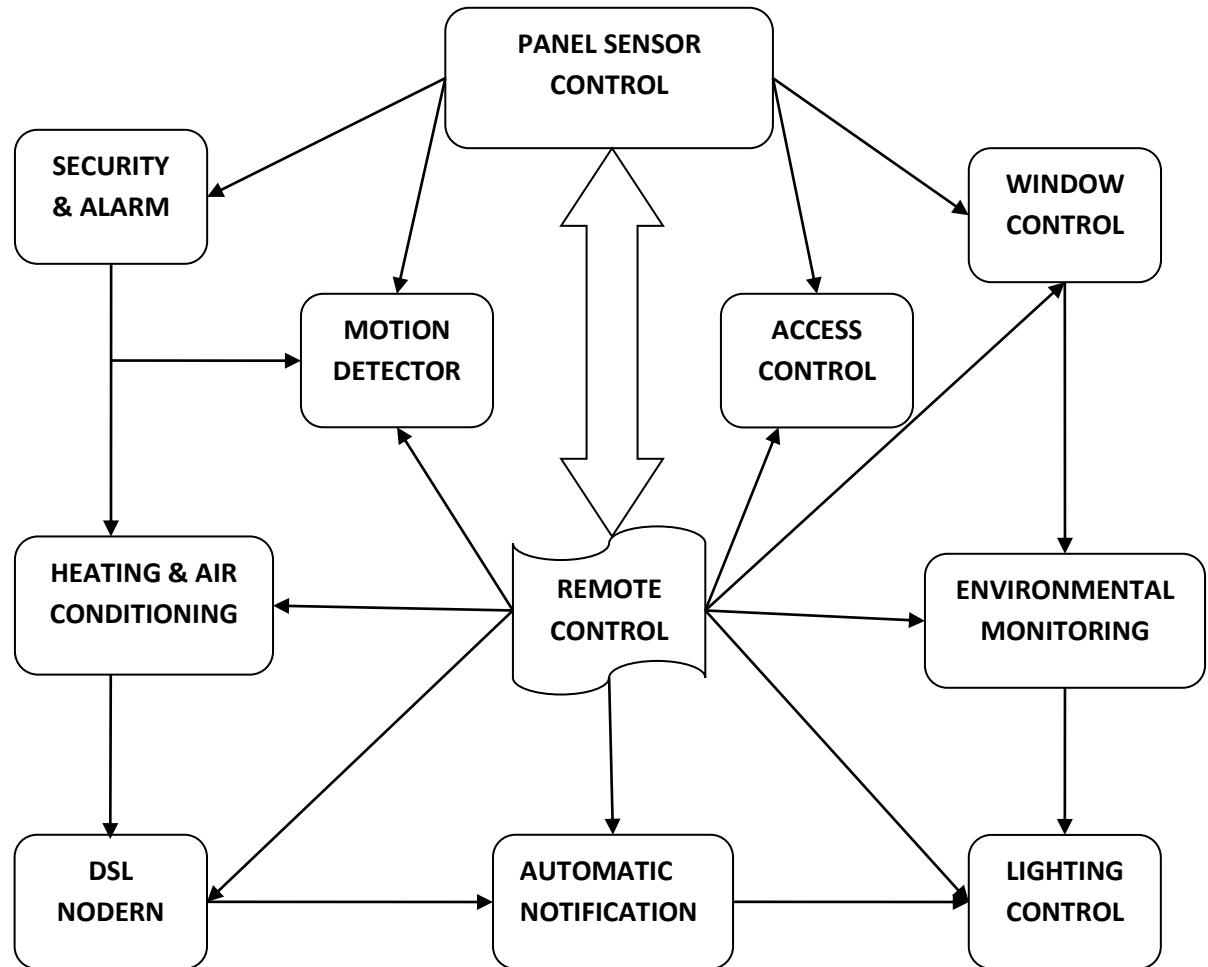


**Figure 29 – Ultra-low Power Sensor**

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It was designed specifically for a cost-effective that would support a low data rates, security, low-power consumption, and also reliability. It will allow nodes to access to any new routes throughout the network, what is more excited about this network is that, if route fails for instance, it will automatically making it way to a robust wireless solution

its access. To simplify the task, Atmel has partnered with leading sensor manufacturers and sensor fusion specialists to provide a complete, easy-to-implement Sensor Hub ecosystem. These data can be used to provide the desired contextual awareness with minimal power consumption and maximum battery life, and are often required in a broad range of products such as smartphones, tablets, ultra books, Internet of Things (IoT) enabled devices, gaming, healthcare, and wearable computing [10]. Figure 30 illustrates a wireless network monitoring flow chart.



**Figure 30 – Home Wireless Network Monitoring**

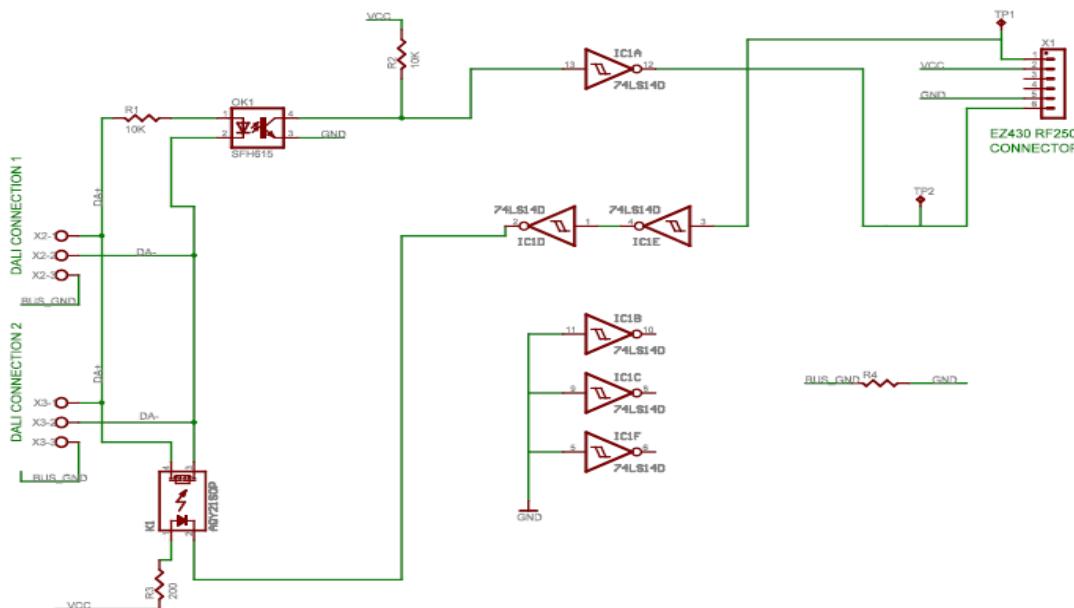
Each box would play different functionality in the system. For Access Control, it is key fob which can be used to lock doors, turn on alarm and turn off lights. However, Motion Detector will be an active mode most of the time and will go to sleep mode last when all devices are put on sleeping mode. It is used by alarm and lighting systems. The design has its own Security and Alarm, which are sensors can use lighting network for visual alarm in addition to sound. For the Heating and Air Conditioning, a wireless temperature

sensors to maintain ideal temperature while lowering energy cost. For DSL Modem, is used as gateway to internet for monitor and control of home network. For the Window Control, a light sensor and remote controls can be used to control the blinds and also the temperature of the window from outside heat. Then for Environmental Monitoring, a wireless sensors for temperature humidity and pressure minimize water usage and also energy cost. For the Lighting Control, light schemes will be used to dim or turn on/off large number of lights. For the Automatic Notification, that will use gateway to GSM or other standard to be notified of alterations directly to a handset. In addition, all these can be turned on/off by remote control by user by seating down in anywhere in the house.

The schematic shown in Figure 31 below is a digital addressable lighting interface that define a common communication protocol and also physical interface standard for use in light control application, for either, outside and inside lights, made by Texas Instruments, the sensor will enable any of this light either be on sleeping mode or happen to be regulate by sensor detector. This light interface has the ability of tracking the data instructions and use the RF transmitter to transmit the information to the output for final signal before put the device to a sleep mode. Texas Instruments has recently update it by included an LED device type control gear.

Features include:

- DALI protocol implementation using on-board MSP430 timers
- PHY design for DALI interface of the MSP430 provided
- For use with the TPS62260LED- 338 EVM
- MSP430 G2 launch pad support also provided
- This reference design is tested and includes software, hardware design files and document



**Figure 31 – Lighting Interface Schematic**

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Some of the implementation with the MSP430 ideally provides two timers, one is WDT and the other one is Timer\_A3. The Timer\_A3 updates the PWMs that basically driven the LEDs. And then the WDT+ is going to use to fade the LED intensity per the DALI standard and also manage the special communication requirements of configuration commands. Having said this, the Opto-isolators itself will translate signals between the DALI physical layer and the MSP430 as it shown in the figure 12 above. However, that will depend upon the application; the lighting can be controlled with either analog or digital module within the MSP430, and other word the lighting application is controlled with a PWM that generated from the Timer-A3 module within the MSP430, so that could be very challenging when to program this piece.

#### 4.1.6 Motion Sensor

To secure the system from false signals or unwanted signals is to structure a enhance sensor the increased functionality of an occupancy sensor is represented with features such as signature analysis, adaptive time out, adaptive occupancy sensing, and audible and visual alerts. One of the toughest challenges for a motion sensor is to be able to reject unwanted signals such as those caused by pets or wind-based motion of curtains, papers, or plants. In complex surveillance systems this is accomplished using a video camera and a high-performance digital signal processor. On the other hand, in an inexpensive occupancy sensor, movement in a room is captured and processed by an ADC and the resulting conversion is stored in SRAM. When the signature of the room is analyzed, the microcontroller compares this with values stored in a flash memory for conformation.

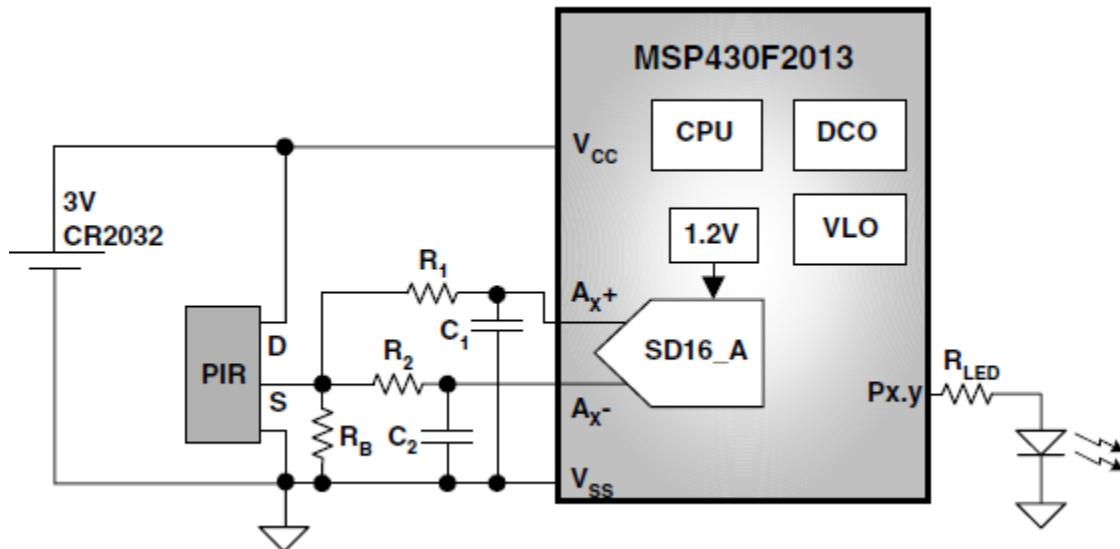
In addition, to using a motion sensor to determine room activity, an infrared sensor combined with an ADC channel scans the room and identifies small changes in the thermal environment. The PYRO technique is one algorithm used in conjunction with the infrared sensor. This technique divides the room into segments and continuously compares the samples of these segments. Another ADC channel measures the ambient light level. Based on information from the IR sensor, the amount of ambient light will be used to determine if the light switch should be triggered. An infrared sensor can be used with the PYRO technique to segment a room and compare the infrared value to a control database stored in flash memory. The occupancy sensor can also be fitted with an adaptive time out mechanism to determine when to shut off the switch. Using the microcontroller's on-chip real-time clock, the microcontroller can calculate the time out base on how the space is used. [10]

The system can begin to develop usage patterns and log data every 12 minutes over the previous week (also known as learning) to build a database and understand how the space is used. Another important feature is the ability to warn people prior to the switch turning off. The question is "How many times have you been motionlessly working in a conference room and the lights automatically turn off, leaving you in solid darkness?" You can take advantage of the microcontroller's PWM channel and its compare and capture feature, combined with an external piezo speaker element to generate different sounds for different user settings. Alternatively, the system can generate a warning by flashing the room's lights on and off. Additional user feedback can be communicated

with a flashing LED built into the sensor. This LED can be connected to the microcontroller's I/O ports that can sink or source 20mA without the need for external circuits or current limiting resistors. The high boundary mark of 20mA allows a direct connection of an LED to the AVR microcontroller without a resistor.

#### 4.1.7 Hardware Design

Intending to use this type of motion detection sensor using pyro electric infrared, or PIR sensor element is a common method used for such application. The system again is capable of detecting motion using a dual sensor element PIR sensor as seen in figure 13 below using the MSP430F2013 microcontroller. This motion sensor using the integrated 16-bit sigma-delta analog-to-digital converter and built-in front-end PGA, it will provide all the required elements for interfacing to the PIR sensor in a small footprint or any hand wave from a room to another room, processing a performance in a small package and a low cost. [1]



**Figure 32 – MSP430F2013 Motion Detection System**

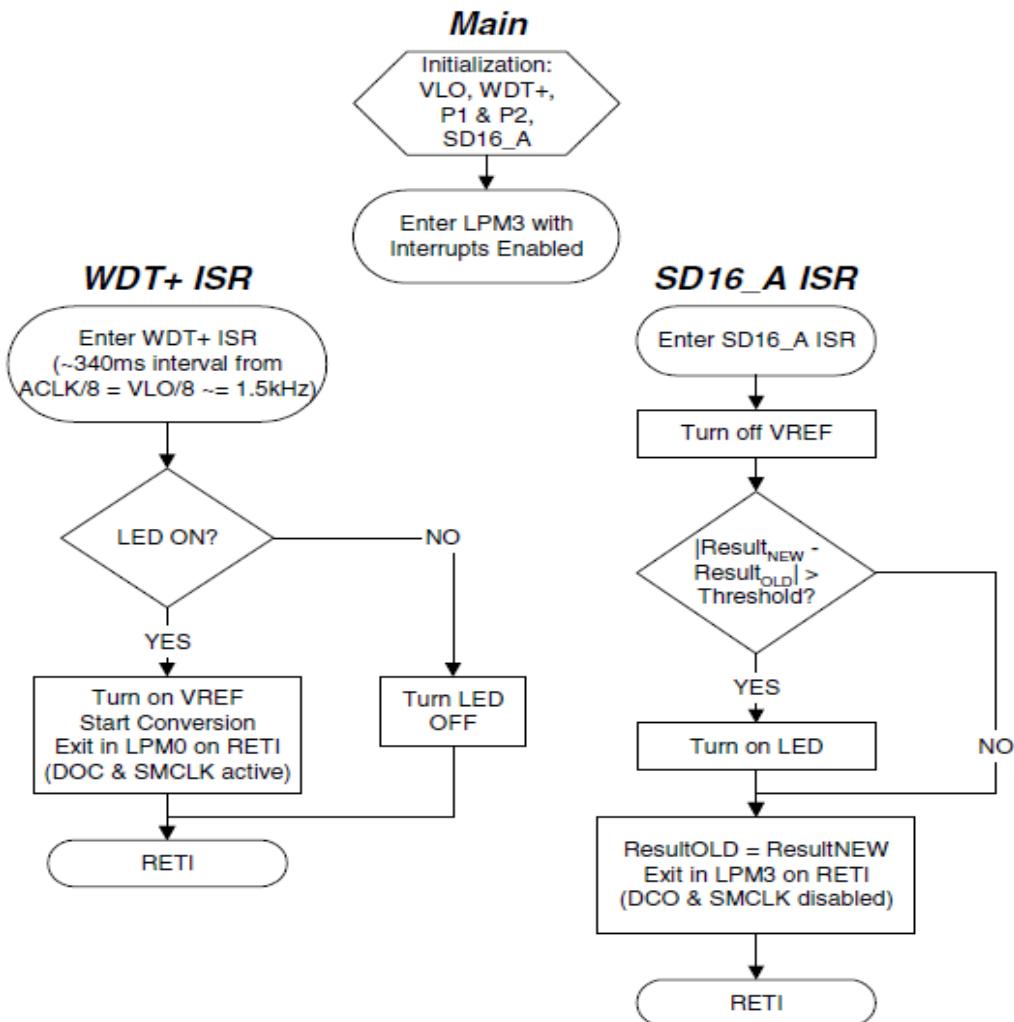
(Reprinted with permission from Texas Instruments)

To ensure of what kind of work this sensor will charge to do, here in each room or the specific area where is going to locate, however, Figure 32 shows a PIR sensor output display & signal condition when the user walking into a room out of room to the living room, every time the user either step on the wire sensor or push the door to open it, the sensor will automatically record and send the data and display a waveform signal from input to the output on the LCD screen that might be an option in project.

Figure 32 shows a simplified circuit that is used to process the PIR sensor output signal. The external components consist of the bias resistor, RB, required for the sensor and two RC filters formed by R1/C1 and R2/C2. The two filters serve two different purposes.

Since the input to the SD16\_A is differential, both a positive and negative input must be provided. R1/C1 serves as an anti-aliasing filter on the AX+input. The second RC filter made up of R2/C2 serves to create a DC bias for the AX- input of the SD16\_A. This is required due to the large offset of the PIR source output with respect to VSS with relation to the input range specification for the SD16\_A. Figure 13 shows the respective signals in the circuit during detection of a motion event. [2]

In addition to the PIR sensor and the analog signal conditioning, a port pin is used to drive an LED. The LED is illuminated to indicate to the user that motion has been detected. This signal could also be used to drive an analog switch or relay to turn on the lamps, the fans, and active all outlets for devices such as TV, Computers and Printers or telephone or otherwise indicate motion in a real-world system. As a final aspect of the hardware design, use of a Fresnel lens is critical to establishing good directionality of the sensor detection field. The internal architecture of the dual element sensor provides good noise immunity and false trigger rejection but also creates a limited directionality of the sensor's sensitivity. Use of the lens widens this field, making the final solution more robust. An analysis to all these is presented to this figure 12 below is a motion detection software flowchart. The software consists of three main elements, such as main routine, watchdog timer interrupt service routine and analog-to-digital converter interrupt service routine. The entire flow is interrupt driven using the internal very low frequency, very low power oscillator. The VLO is approximately 12 kHz and provided internally on the ACLK clock line. This signal is then divided by 8 and drives the WDT+ to give the CPU an interval wakeup. With an interval divider of 512, this equates to a wakeup time of 512 clocks / (12 kHz / 8) = 341 ms. After initialization of all peripherals. The CPU enters into LPM3 via the VLO waiting for a WDT+ interrupt trigger [4]. Figure 33 illustrates a motion detection software flowchart.

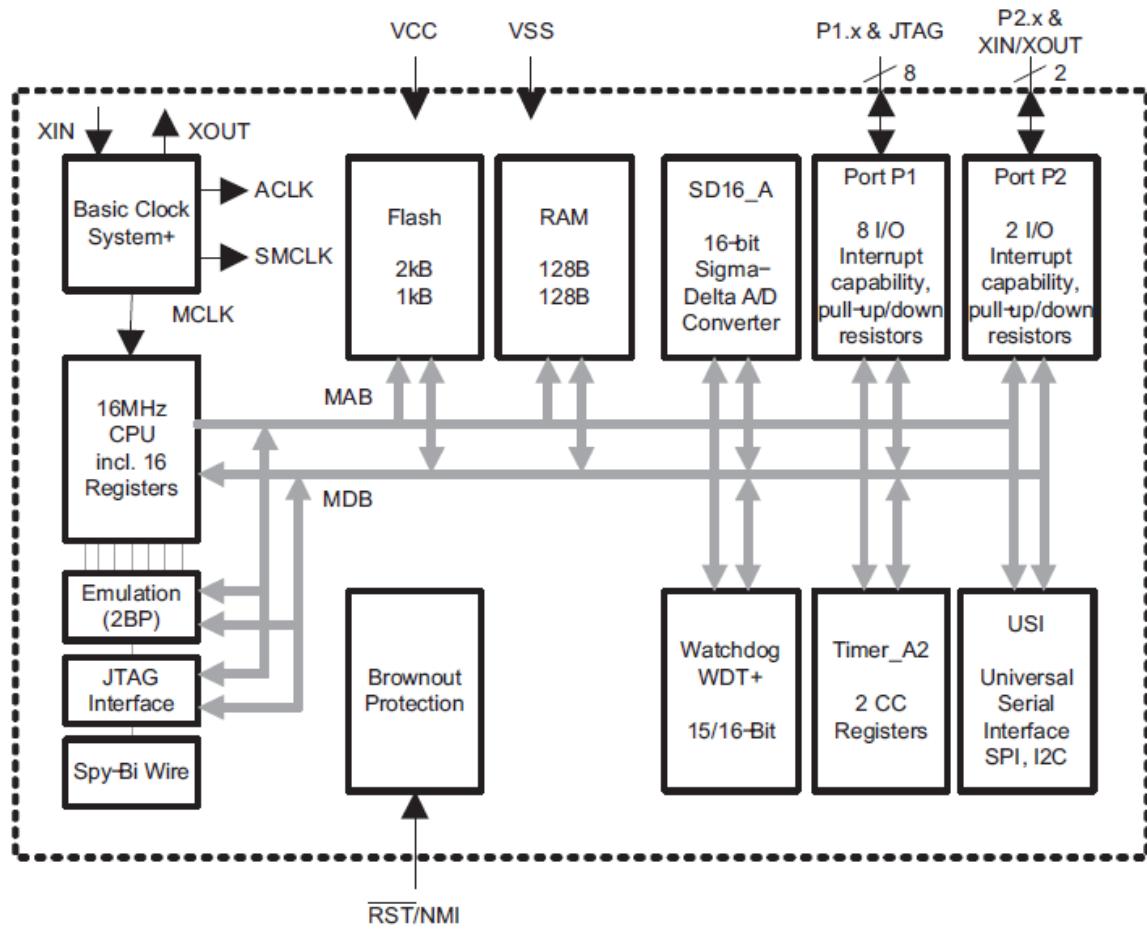


**Figure 33 – Motion Detection Software Flowchart**

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Figure 34 below is MSP430-PIR sensor from TI, which the group decided to use in conjunction with other sensors. The group is anticipated in using this PIR sensor with MSP430F2013 Microcontroller for the project for some of the great feature that it comes with. Here are some of the feature it comes with MSP430F2013-EP has low power PIR sensor, status LEDs, CR2032 battery holder, JTAG connector, supports both Olimex and TI SBW layout, consist of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes is optimized to achieve extended battery life in portable measurement applications, and has a dimension 42.27x25.89 mm, a low supply voltage range from 1.8V to 3.6V very compatible with the main microprocessor and it will also be compatible with the other slave processor which is connection with the master. Power consumption, it use very little current which is match with the system needs. It will operate on active mode from

220 $\mu$ A at 1MHz, and 2.2V. The standby mode is only 0.5 $\mu$ A, and for an off mode is 0.1 $\mu$ A and then has five power-saving modes.

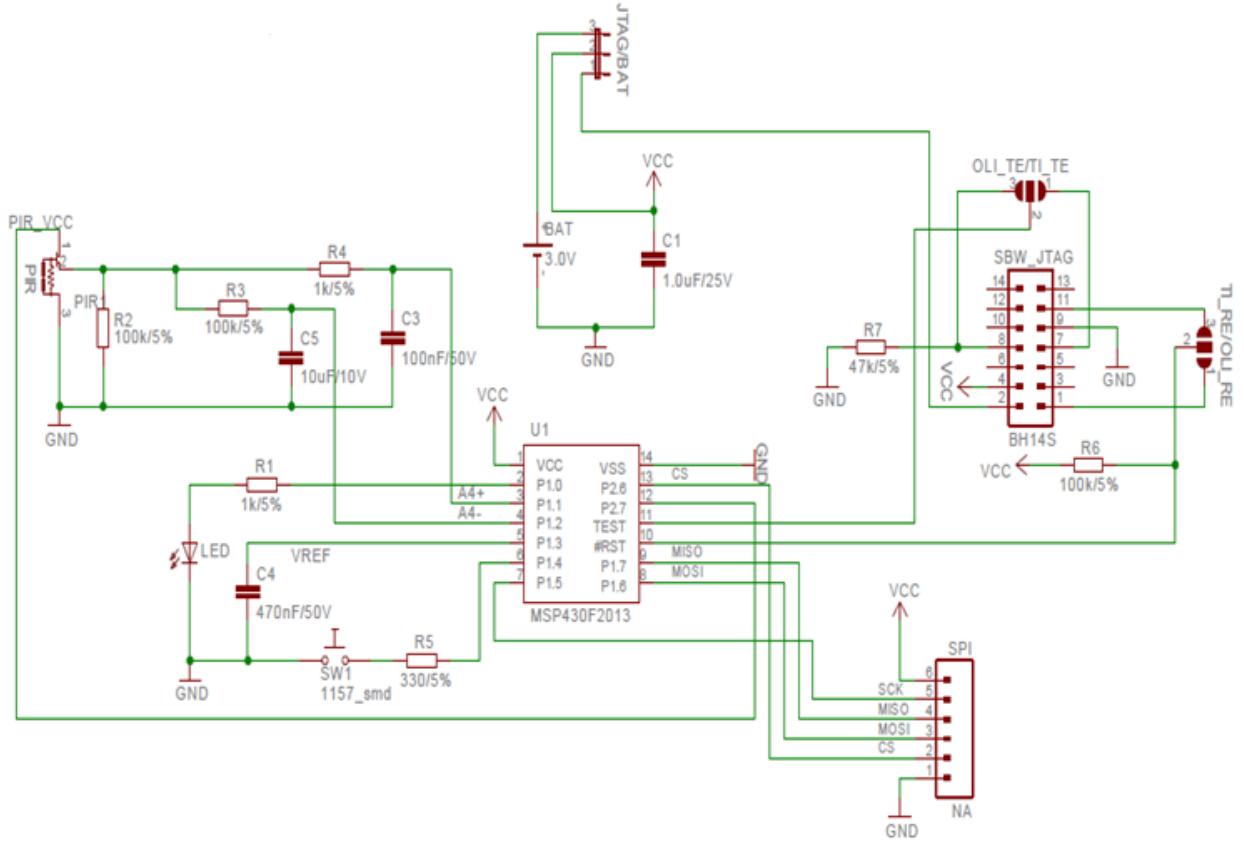


**Figure 34 – MSP430 PIR Sensor Block Diagram**

(Reprinted with permission from Texas Instruments)

The most important thing it has ultrafast wake-up from standby mode in less than 1 $\mu$ s, that is how quick it can detecting the user move around the house at any angle and transmit the signal to a slave processor then that will collect the data and forward it to the main processor and system will wake-up from a sleep mode. All of these will be supported by the main processor. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator allows wake-up from low-power modes to active mode in less than 1 $\mu$ s. The MSP430F2013 is an ultra-low-power mixed signal microcontroller with a built-in 16-bit timer and ten I/O pins. In addition, the MSP430F2013 has a built-in communication capability using synchronous protocols (SPI or I2C) and a 16-bit sigma-delta A/D converter. Typical applications include sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system. Stand-alone RF sensor front end is another area of application. Note that the crystal oscillator cannot be operated beyond 105°C and its

ADC performance characterized up to 105°C only. Figure 35 below is the schematic for MSP430 PIR sensor.



**Figure 35 – MSP430 PIR Sensor Schematic**

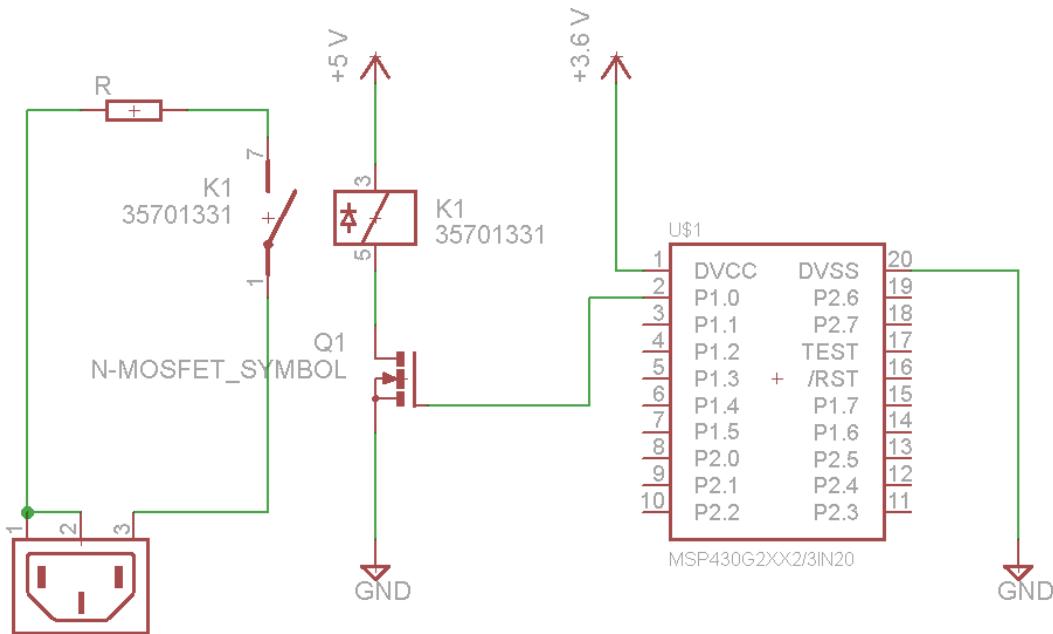
(Reprinted with permission from Texas Instruments)

#### 4.1.8 Outlet

System outlet electronics is to be installed in the system to control every outlet in the house. There will be processor in place directly for monitored all outlets. A signal will be sent back in forth to see if the outlets are in used or not, it will send the signal to the main microcontroller and the system will disable or put them on sleep mode. It was decided that an MSP430 is the right choice to implement in the system to provide outlet control. The reason why a MSP430 was chosen is for its power efficiency, another reason was for choosing it is for the safety that it is compatible with the main microcontroller. If noise in the circuit caused by one the slave processor to activate prematurely, a potentially hazardous situation can occur. Because the MSP430 will have two inputs, one to wake it from sleep mode and one to tell it what state to take, this whole confusion and problem are avoided. If noise in the circuit happens to wake the MSP430, the line telling it what mode to take will always be off unless the main processor is specifically sends the on signal. Furthermore, the likelihood of noise both waking up the MSP430 and sending a

false on signal is very slim as it will only be on for a few seconds before going back to sleep otherwise the user will use remote control to put to sleep instead, however, the system is capable enough to put it to a sleep more.

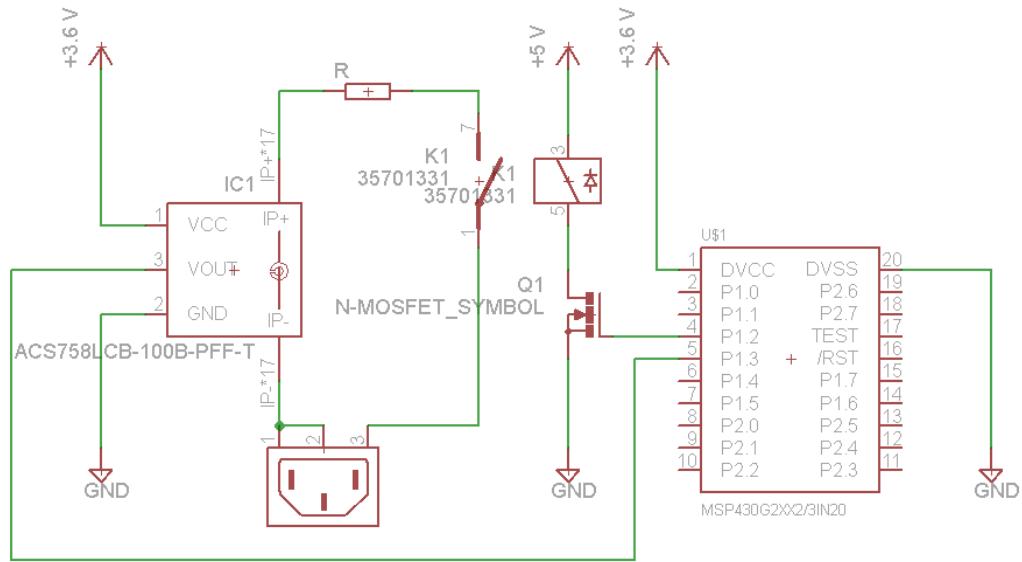
For any reason a complication arises, however with the MSP430 and that is its inability to provide a driving current for peripherals. Way to fix it is simple, taking a trip back to Electronics 1 class provides a solution; a MOSFET transistor does not need any current to become bias in the active mode. This provide the MSP430 with the means of turning the relay on and off without the use of another buffer. For a relay to function a voltage needs to be placed across it; however, as it is an inductor, once a current is established the voltage drops down to zero. This can be remedied by placing another component, like a resistor, across its two terminals forcing there to be a voltage drop at all times. In the interest of not burning more power, a diode connected the in reverse will be used in place of a resistor. The diode will provide the required voltage drop while preventing any farther losses. To insure the proper state has been assumed, the MSP430 will echo back the state of the relay. This way if the signal from the brain can be held until it knows that the appropriate action was taken. Figure 36 below provides a schematic of the outlet control circuit.



**Figure 36 – Outlet Control Schematic**

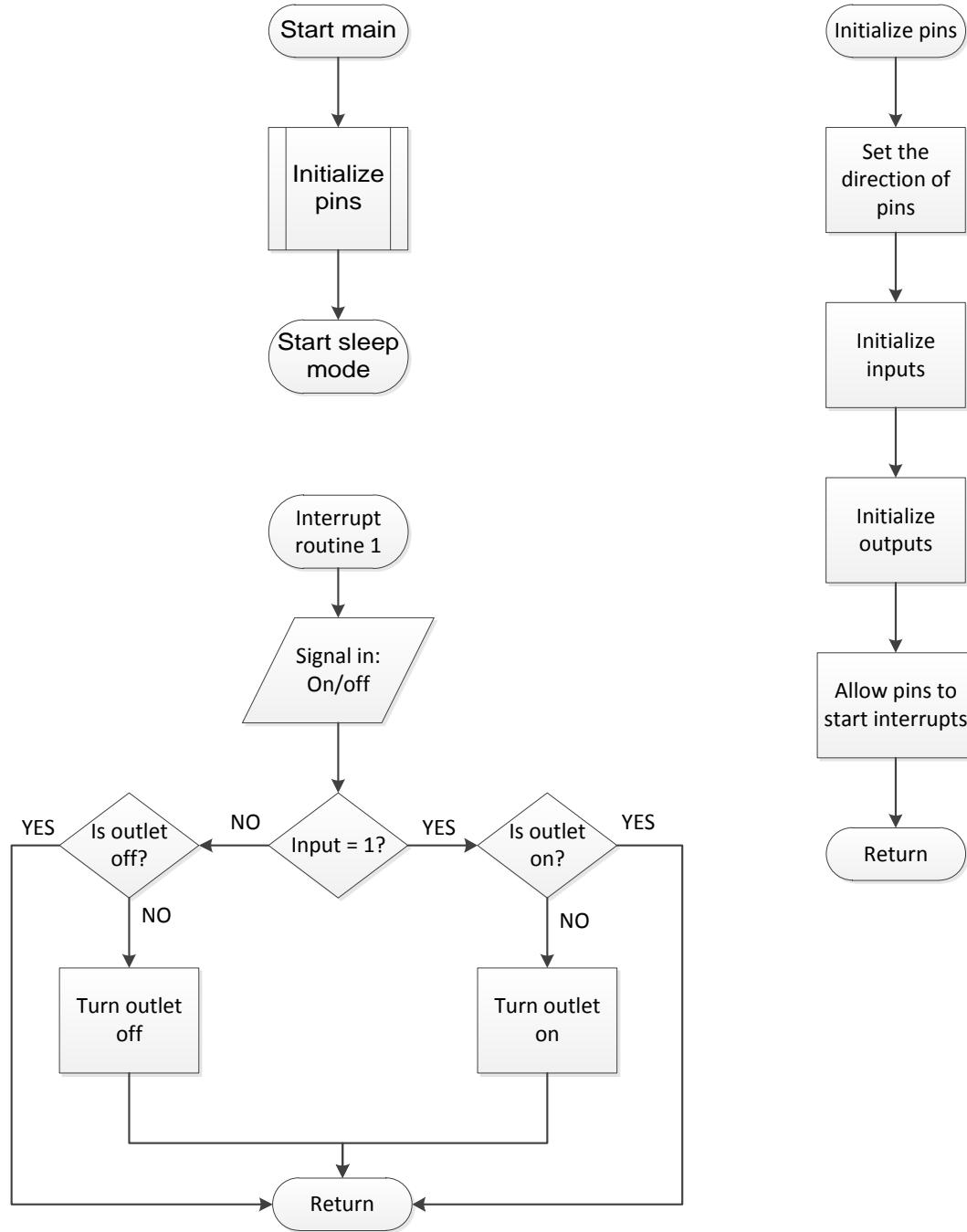
Since the Smart Home System will consist of a power meter that keeps track of power usage for each outlet, there must be a method to monitor the real-time power consumption at each outlet. The method proposed to do this is by determining the amount of current flowing through the load while it is powered on. By knowing the amount of current flowing through the load and the voltage coming from the power inverter, the results could be multiplied to obtain the real power being dissipated by the load. One way to obtain the amount of current flowing through the load is by using an ACS758 Hall

Hall Effect current sensor. The current sensor would sense the amount of current flowing through the load while the load is being powered. The current sensor linearly converts the sensed current to a respective voltage. Using this current sensor, along with an analog-to-digital converter to convert the voltage coming from the power inverter, would allow for calculation of total real power being consumed by any given load, with a marginal error. Figure 37 below illustrates the integration of the Hall Effect current sensor with the outlet schematic.



**Figure 37 – Current Sensor Integration with Outlet Schematic**

Overview of the code for this chip will be very basic due to the nature of the job it is taking on. Before going into sleep mode the only thing it has to do is call a function to initialize the pins. Once again the function of the MSP430 will be realized with the use of interrupts due to its power saving nature. When the main processor sends the wake up signal, the microprocessor will match its output with the input signal from the main microprocessor. Figure 38 below provides the code information data on how the signals are distributed by the microcontroller.

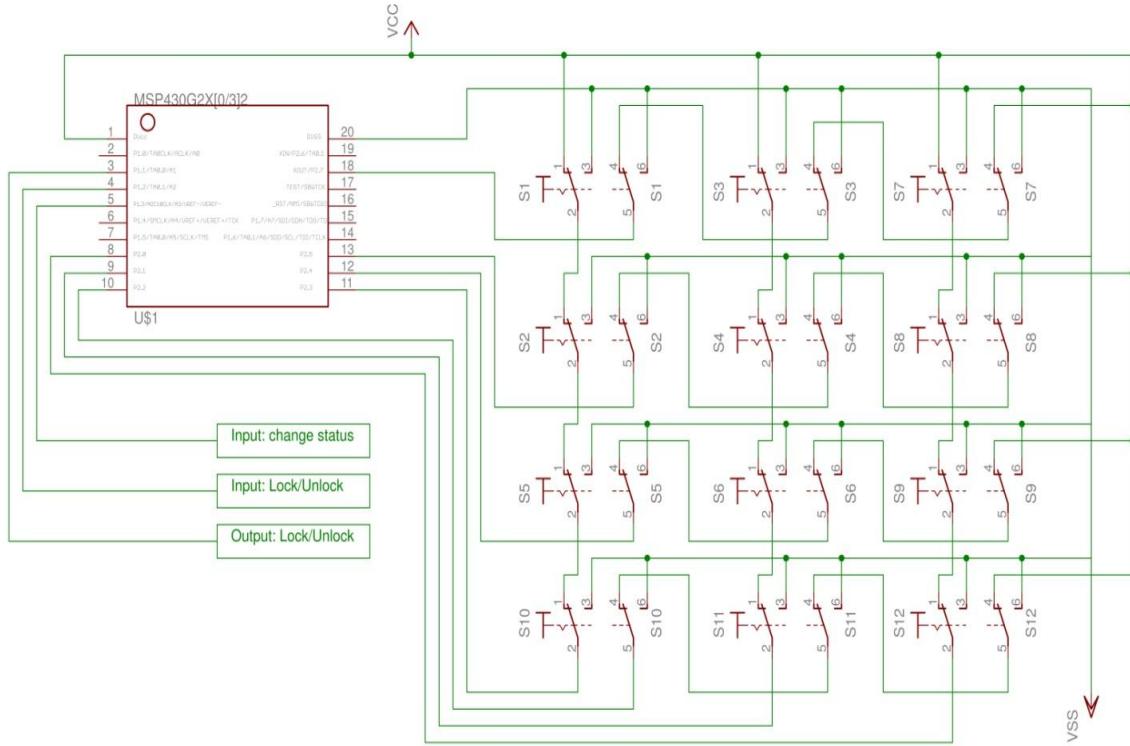


**Figure 38 – Outlet Control Flow Chart Diagram**

#### 4.1.9 Electronic Door Lock

As far as for the doors, the user can access in with a key for the house or remotely when enter toward the house in car, similarly the way the garage door is opened. The group has picked a microcontroller MSP430 that was chose specifically for the doors which has a power saving. This slave will be programming with code to access all doors, it will

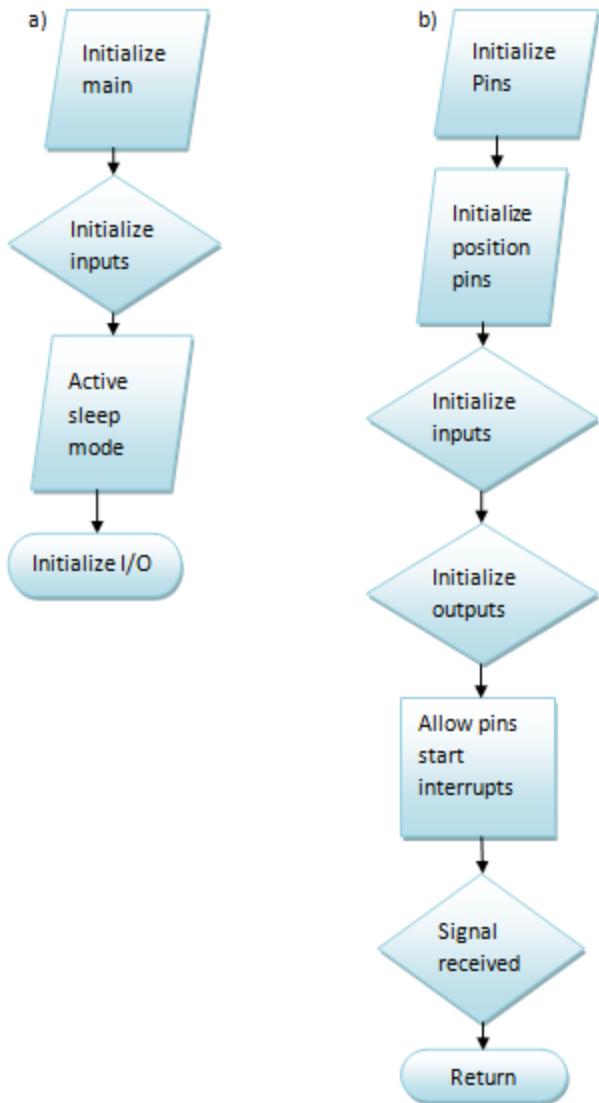
unlock the doors with an access remote or by a keypad. This microprocessor will send the signal to the main processor then the main microprocessor will send this signal to the RF receiver and then the magnet will either activate or deactivate the electronics doors which mean lock or unlock them. There will be multiple buttons from the keypad to press for access to the door. Each button will be connected to a pin. From this electronics schematic below, when pressed a button, two of the pins will be automatically grounded and immediately the MSP430 will distinguish which of the two pins were pushed. below is the schematic for an electronic door lock.



**Figure 39 – Electronic Door Lock Schematic**

(Permission Pending)

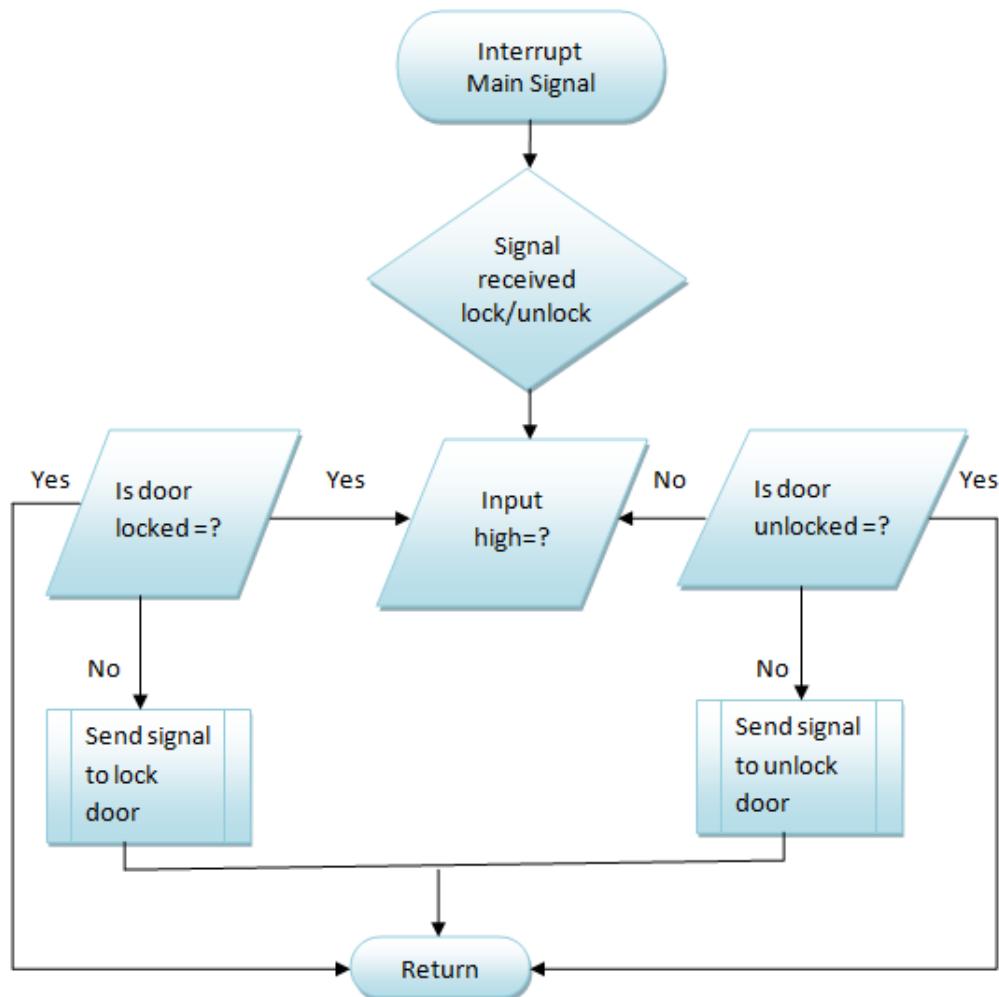
Note that the bulk of the program code will be processed in interrupt routines. After initializing of the MSP430 is completed the signal will be sent to the main. Figure 40 shown below illustrates the process of initializing I/O pins. Only one output will be needed, and however, 9 input pins are connected. Thus seven of the input pins will be used to read in the data from the keypad while the other two will be received the input signals from the main microprocessor. The most important one output needed is the motor that will able to lock and unlock the door. Once that happen, the user into the room then the door will immediately lock back in after 5 second accessed it. That is call return back routine. Figure 40 below shows in detail how the signal passes through the transmission line by the RF transmitter to direct the signal to the right pins for a final destination.



**Figure 40 – Electronic Door Lock Flowchart**

Having initializing the pins, one of the interrupt routines will be initiated to an active mode when the main processor sends a signal. This signal will be received in two parallel bits. The first will activate the routine, and then the second will hold the command for the MSP430. In lead waking up the first thing the microcontroller MSP430 will have obligation to check that second bit. For any high parity it will mean that the door needs to be locked, otherwise it needs to be unlocked. Here again the safety measures in the outlet pops up to be appreciated. However, the routine some time disturbing by noise in the transmission line, If there is a noise detected in the transmission line happens to activate the routine, the probability of noise simultaneously will send a second signal to unlock the door is very dubious for this to happen. Now, upon receiving the signal to lock the door, the microcontroller MSP430 must first check the condition of the door. If the condition of the routine is already locked the microcontroller MSP430 will simply go back to sleep mode; otherwise it will notify the main processor by sending out the correct

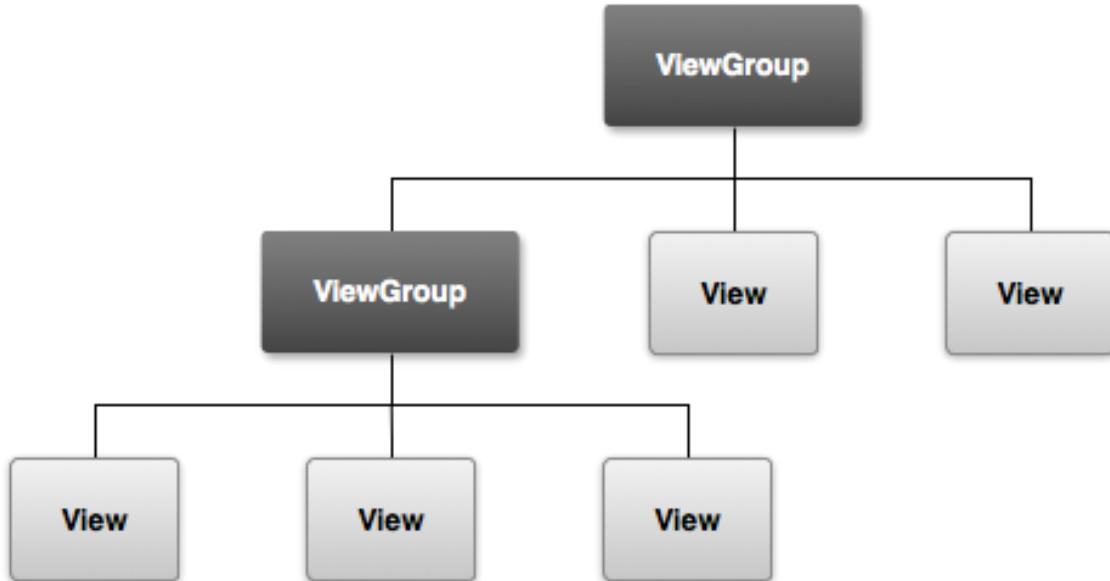
signal to the main and the main will initiate an authorization to the motor to lock the door. And again, if the signal from the main processor was to lock the door, the microcontroller MSP430 again will first check to see what the status is before sending signal, and if the door is unlocked the microcontroller MSP430 will again simply go back to sleep mode until another even happen, however, if it is locked the microcontroller MSP430 will again notify the main by sending out the correct signal to lock the door before going back to sleep mode again. The door locking flow chart diagram is shown below in Figure 41 to see how the signals are sent out to check status of doors are locked or unlocked, once the signals are received by the main, and then the main will decide if the condition is to lock or to unlock the door.



**Figure 41 – Door Locking Signal Flow Diagram**

## 4.2 User Interface

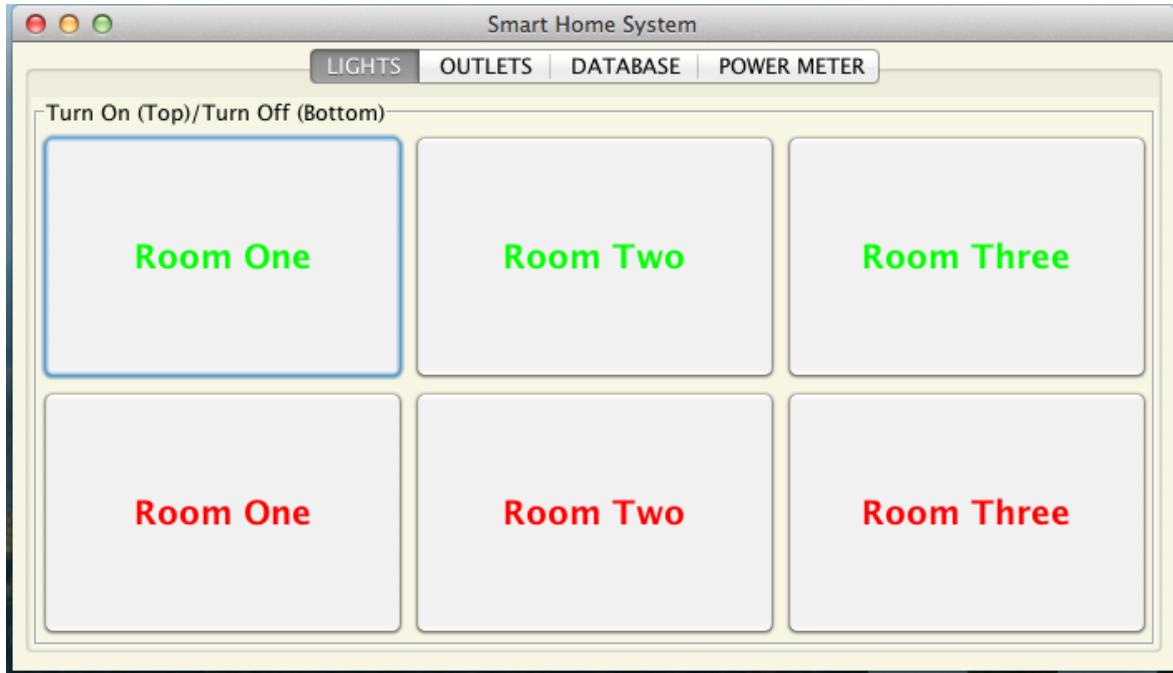
In order for us to allow people to manipulate our system. We plan on building an android app and a web page that will enable user to interact with our system. It is made up of hardware and software. The system should be easily controllable using an android smart phone and/or a personal computer. The android app will only be able to turn on/off light and will do the same for the outlets. The GUI on the other hand will have the capacity to do what the app can do and more. By accessing the GUI you should not only be able to turn/on/off the lights and outlets you should also be able to see how much power is being consumed; there will also be a database of enabling people to see how electricity is being used in the house. For the android enabled user interface; we are going to build an app. In order to build the android app, there are a few things to understand from building an app standpoint. The two things that we have to get used to are ViewGroup and view; we also have to understand how the android layout manager works. The user interface for an android app is built using the hierarchy of View and ViewGroup objects. The ViewGroup and View objects work in different ways; pretty much every item in the User Interface is a subclass of the android.view.View class, the View object is usually User Interface widgets like buttons, CheckBox, TextFields, ProgressBar and TextView. The View can also contain multiple other views that are known as composite view; the composite view is a subclass of the android.view.ViewGroup. The ViewGroup is an invisible container its role is to define how child views are laid out. The android ViewGroup is subclass of View. Figure 42 below is an illustration of Android app works; every app is collection of ViewGroup and View [13].



**Figure 42 – Illustration of ViewGroup Objects**

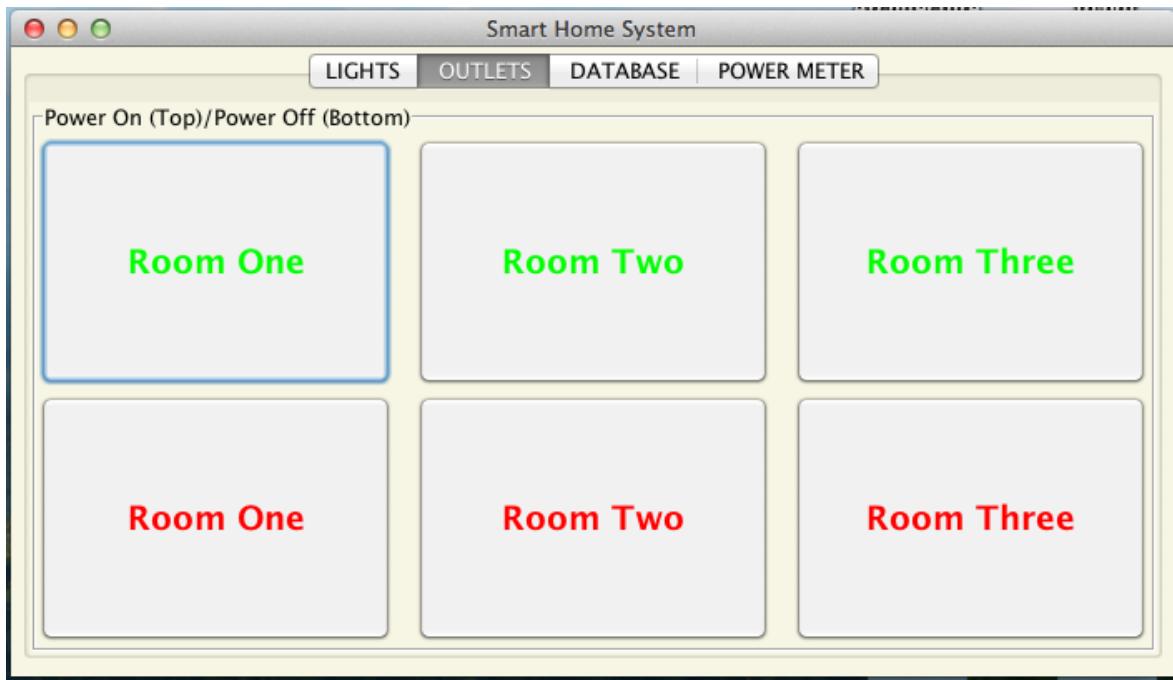
As we mentioned above we need to also understand how the layout manager works. The Layout is what defines the visual structure for User Interface; it can be for an activity or an app widget. There are two ways to declare a layout you can either declare the User Interface elements in the Extensible Markup Language (XML) or it can be instantiate at runtime. Either of those two or both can be used to declare and manage the User Interface application. It is somehow advantageous to use the XML for declaration of User Interface application this is help in separating the presentation of the application form the form the code that control its behavior. There are three different kinds of layouts; there are the Linear Layout, the Relative Layout and the Web View Layout. The linear Layout organizes all of its children into single Vertical or Horizontal view, in the event where the length of a window is way larger than the length of the screen a scrollbar is created. The relative layout makes it possible to specify the location of child relatives to another one or a child with its parents. It enables us to place stuff on top of each other; whichever way pleases us.

Like we mention before, we expect the java GUI to enable people to turn on/off lights, cut off electricity going to the outlets, give them access to a history of power consumption and people should also be able to see power consumption in real time. The GUI will have four frames; with the first one, which is titled LIGHTS, people will be given the options to turn on the lights from room 1, 2, 3 with top buttons; the bottom ones will enables them to turn them off as desired. An initial GUI design is shown in Figure 43.



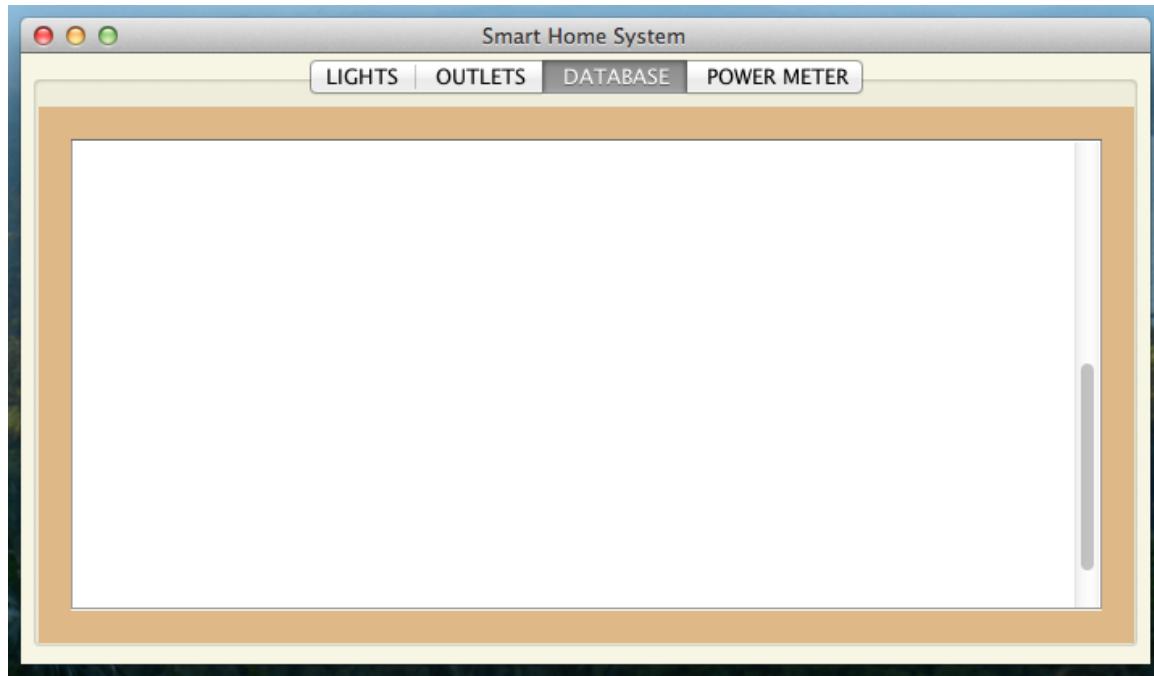
**Figure 43 – Light Control via Graphical User Interface**

The following GUI is the one that will be used to help with powering on and powering off the outlets. It contains 6 buttons like the Graphical User Interface for the lights; it helps in the case where if someone knows that he is not going to use an outlet he has the option to cut off the electricity going to it. The GUI is shown in Figure 44.



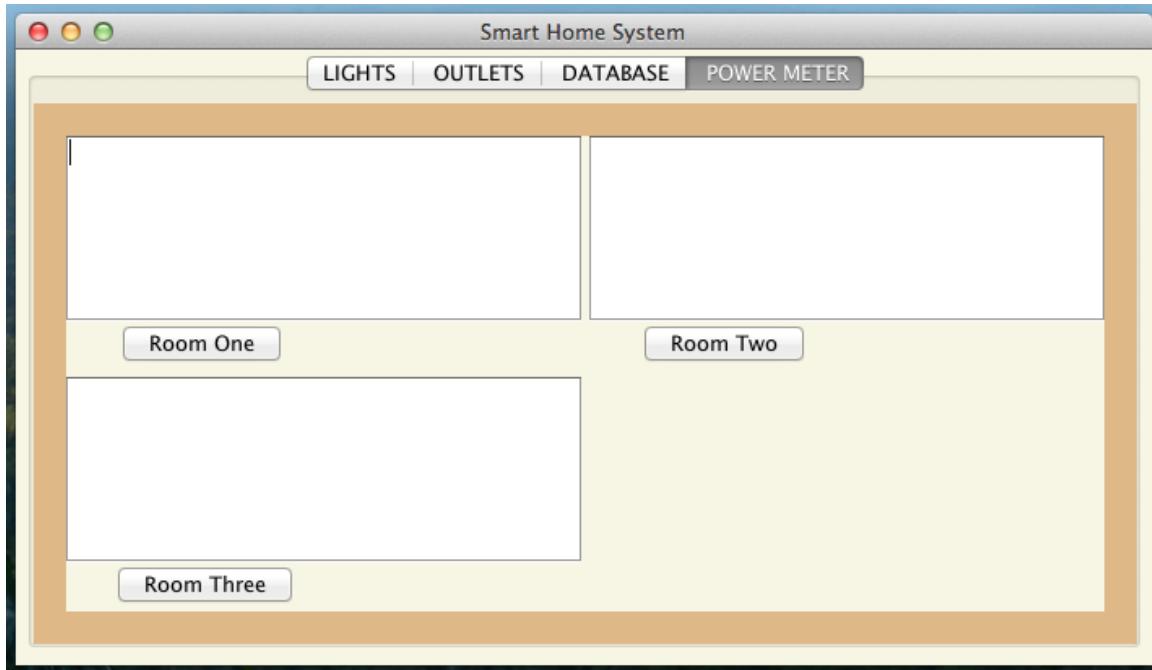
**Figure 44 – Outlet Control via Graphical User Interface**

The next one does provide the history of power consumption over a period of time stored on the database; so people can go back and see how much power they consumed three days or three weeks ago, for instance. The GUI is shown in Figure 45.



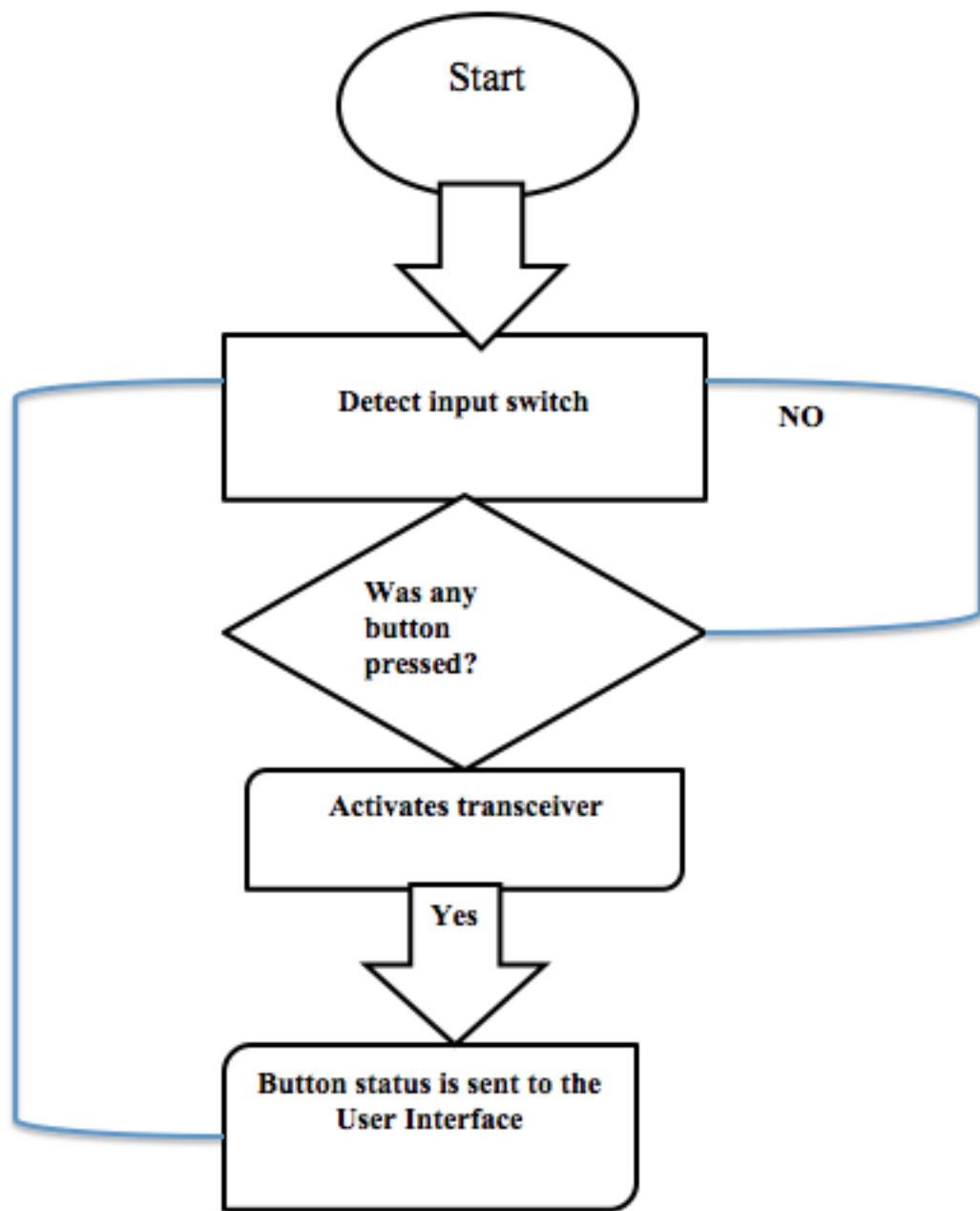
**Figure 45 – Database Information via Graphical User Interface**

Finally, the Power Meter Graphical User Interface is the one that people go to in order for them to see what is going on in real time; the three buttons Room One, Room Two, and Room Three will allow them to refresh the system in an attempt to get the exact watt that is being consumed; information will be displayed in each one of these boxes. The GUI is shown in Figure 46.



**Figure 46 – Power Usage Monitor via Graphical User Interface**

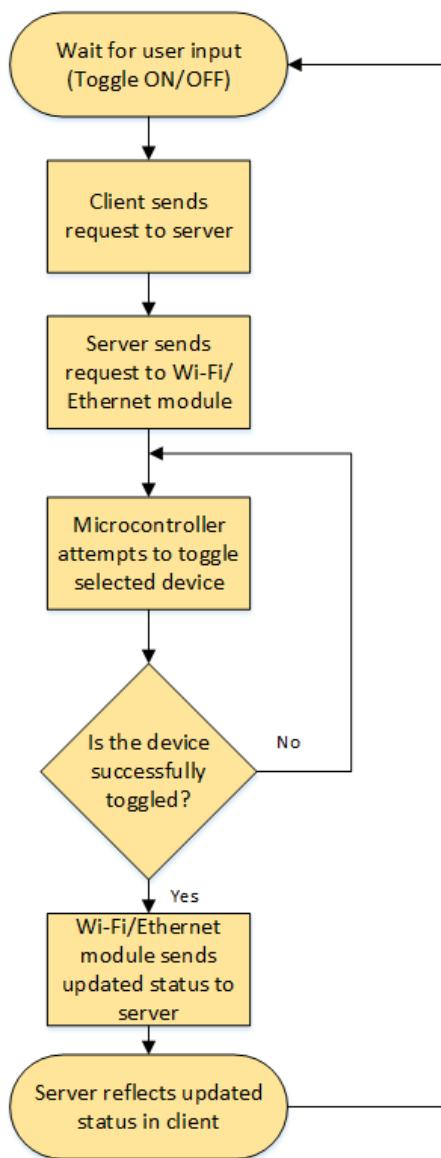
We will have to build a Graphical User Interface for people with Android devices; the Android GUI will be different from the Java GUI; with the android app one will only be able to manage lights and outlets only; history of power usage and real time power consumption are only reserved to the Java Graphical User Interface; the android app is to be used around the house; we discussed about having the android app to be like the java Graphical User Interface and we realized that it may not be in our advantage to do that; it may not be doable for us because it might take time to accomplish both task; in the event that we finish with everything and we are done with building and testing; we may try to integrate the features of the GUI to the Android User Interface. As much as Personal Computers are used; we do understand that nowadays pretty much every body has either an android phone or an iPhone; it would be in their advantage to be able to check what going on around the house without having to turn on a computer or having to move to the family room where the desktop computer is situated; it would be handy to everyone being able to just grab the smartphone and just check for power consumption in real time, making sure that whatever the lights in other rooms are turned off; it is easier for people to just grab the phone and make sure that no outlets is consuming power for no reason; we also think that people would be more willing to make the effort. Let's face it, if someone is already in bed and the that person realizes that the light in the room next door is on; laziness might keep him from getting up and go turn it off or even go the laptop or the desktop computer to take care of that whereas if that person would be than willing to just extend his hand, get the phone, and turn it off; we have a block diagram shown in Figure 47 of what the Android app is supposed to be doing [13].



**Figure 47 – Android GUI Block Diagram**  
(Pending Permission)

### **4.3 Hardware/Software Integration**

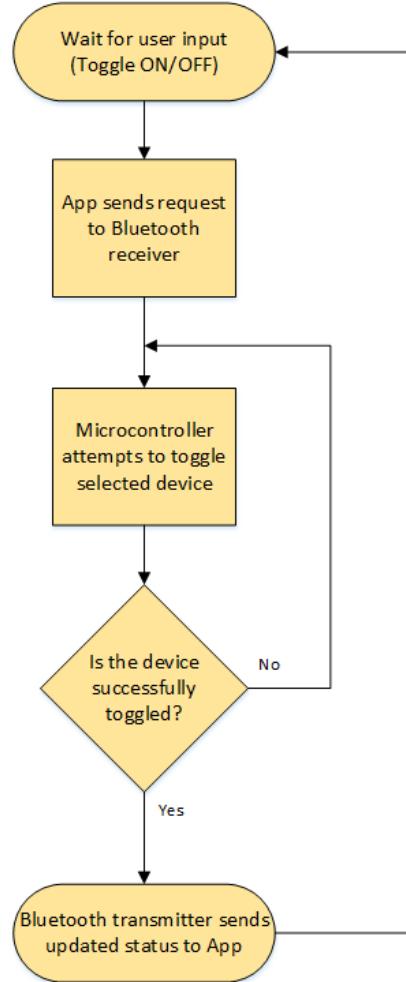
The integration of hardware and software is an important aspect of this project in order for the system to function as intended. To integrate hardware and software means to properly configure the communication between the hardware components and the software interface. Hardware and software integration for the website consists of how changes reflected in the GUI affect the states of the power outlets/lights and vice versa. In a proper setup, any change of states of a power outlet or light is sent as a signal from an auxiliary microcontroller to the primary microcontroller. Upon receiving the signal, the primary microcontroller sends the signal to the server via Ethernet or Wi-Fi, in which the server responds by updating the appropriate values. Upon having the server update the data, the client-side reflects the change on the GUI so the user can see the updated states. In a similar fashion, when the user clicks on a button in the website's GUI, the response is sent to the server. Upon having the server reflect the change, it proceeds to send the signal of the desired updated states to the primary microcontroller via Ethernet or Wi-Fi. The primary microcontroller sends the signal to the appropriate auxiliary microcontroller that is connected to the desired outlet/light that is to be toggled. The auxiliary microcontroller then proceeds to toggle the desired outlet/light. Figure 48 below depicts the cycle of toggling a device or light on/off from the website.



**Figure 48 – Website Device Toggle**

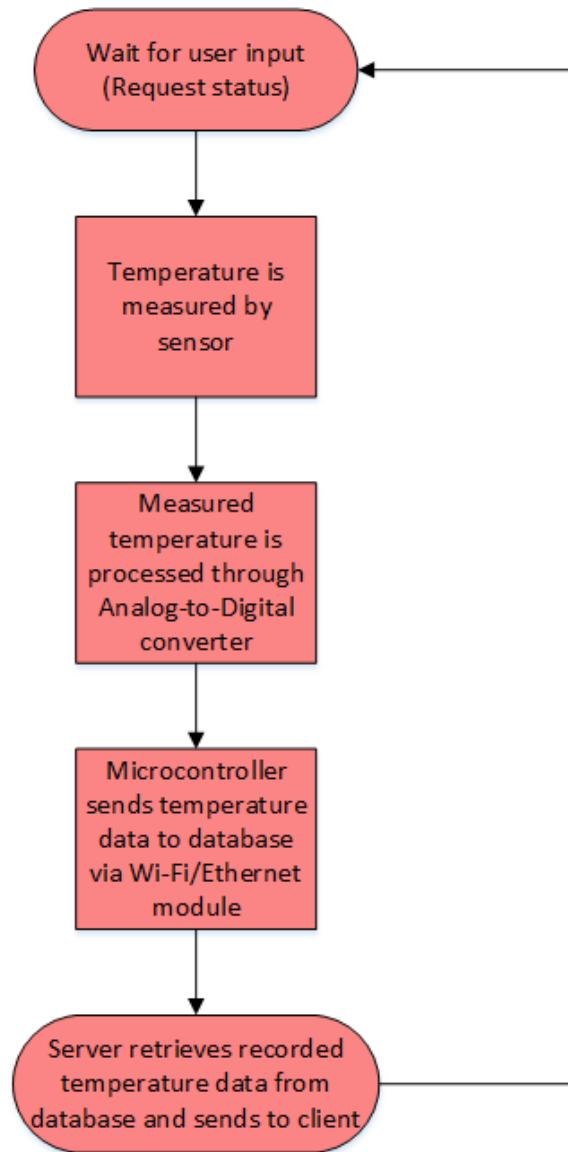
The same idea applies to integration between the hardware and mobile application. When a power outlet/light is toggled from the mobile device, the signal is sent to the Bluetooth module connected to the primary microcontroller. The primary microcontroller proceeds to send the signal to the appropriate auxiliary microcontroller that toggles the desired state. The updated state is then reflected in the mobile application in the same process in reverse. The integration between the hardware components and the mobile application is a simpler process than for the website since communication is strictly between the application and the primary microcontroller via Bluetooth. In the integration between the hardware components and the website platform, data from the hardware states are recorded in a database, updated in the server, and reflected in the GUI. With more layers to go through, there is more overhead when processing signals in the website platform. This is especially the case when recording power usage in the database. As long as a light

source is turned on or a load is drawing current from a power outlet, the database is being updated according to the amount of watts being consumed. This data then gets sent through the server and updated in the GUI so the user can easily see the amount of power being consumed. Thus, the data is being transferred to the database, then to the server, and finally to the client-side GUI. Therefore, the complexity of the website integration is expected to be higher than for the mobile application integration. Figure 49 below depicts the cycle of toggling a device or light on/off from the mobile application.



**Figure 49 – Android Device Toggle**

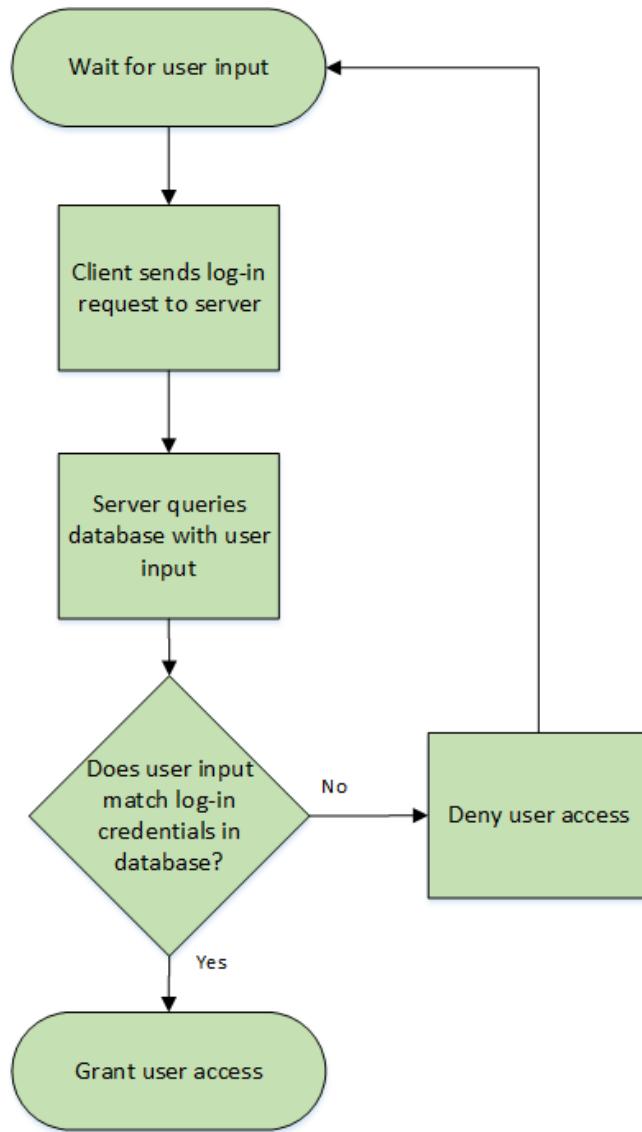
The website GUI will additionally have the ability to display the temperature of the home's interior. This is accomplished using a temperature sensor that performs the measurement with relatively good accuracy. Upon the temperature sensor measuring the temperature, the result is sent to an analog-to-digital converter that allows processing by the microcontroller. Once the microcontroller has processed the data, the data is transmitted and sent to the database for storage. Upon storing the data in the database, the server proceeds to retrieve the data and send it to the client for display on the GUI. Figure 50 below depicts the cycle of updating the temperature status from the website.



**Figure 50 – Temperature Status**

In order for the Smart Home System to be accessible from the website, it is a requirement for the user to log into the system with the proper credentials. With the use of log-in credentials, this gives a shallow sense of security in an attempt to prevent unauthorized access to the system. This is important to make sure that only the homeowner/user is authorized to control aspects of the Smart Home System. For first time use, the user must create a password that complies with the password requirement set forth. The password requirements consist of creating a password of at least 8 characters in length, with at least one number and one special character. Once the user has set the password, it is stored in the database where it will be accessed when comparing user input to verify the passwords match, allowing the user to gain full access to the Smart Home System. If the user enters a password that does not match with the password stored in the database, the website will deny the user access to the system and prompt the user to try entering the password again.

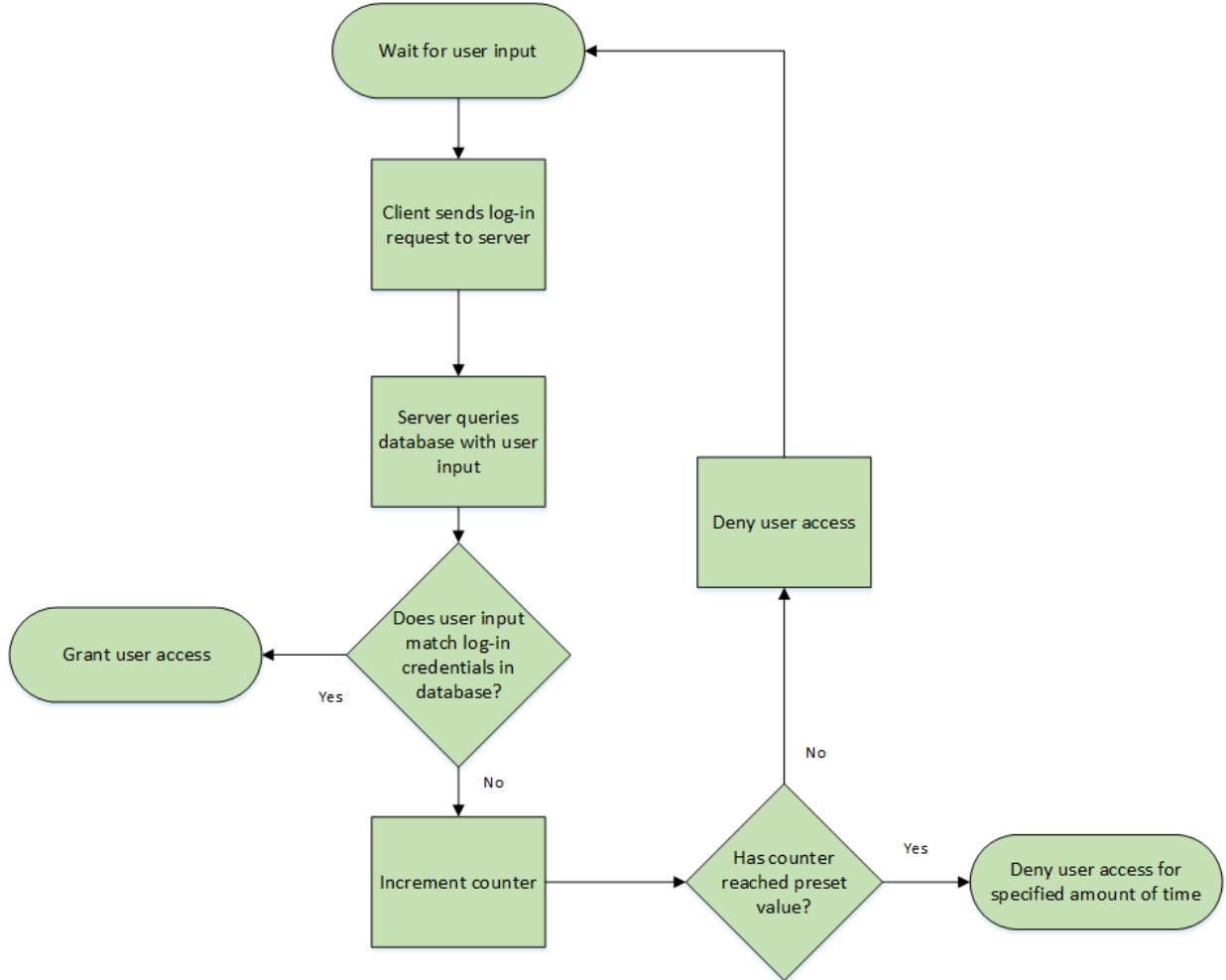
For as long as the user enters an incorrect password, the user will be able to keep trying to enter the correct password indefinitely. Figure 51 below shows the behavior of this log-in cycle to the website of the Smart Home System.



**Figure 51 – Website Log-in**

As seen in Figure 51 above, the system initially waits for user input. Once the user enters a password, the client sends the log-in request to the server. Upon receiving this request, the server proceeds to query the database to compare the user input with the password stored in the database. If a match is not found, the user is denied immediate access. If the passwords match, the user is granted system access. Although this method of security is better than none, it may still be an unsafe method of implementing system security. To better protect against unauthorized user access, the user should be limited when trying to input the password after a failed attempt. For instance, a counter could be set so that when a user enters an incorrect password 3 consecutive times, the system will lock the

user out, forcing the user to wait until enough time has expired before attempting to log-in again. This method deters someone from using a brute force approach to gain unauthorized access to the system. The figure below illustrates the alternative approach to logging into the system.



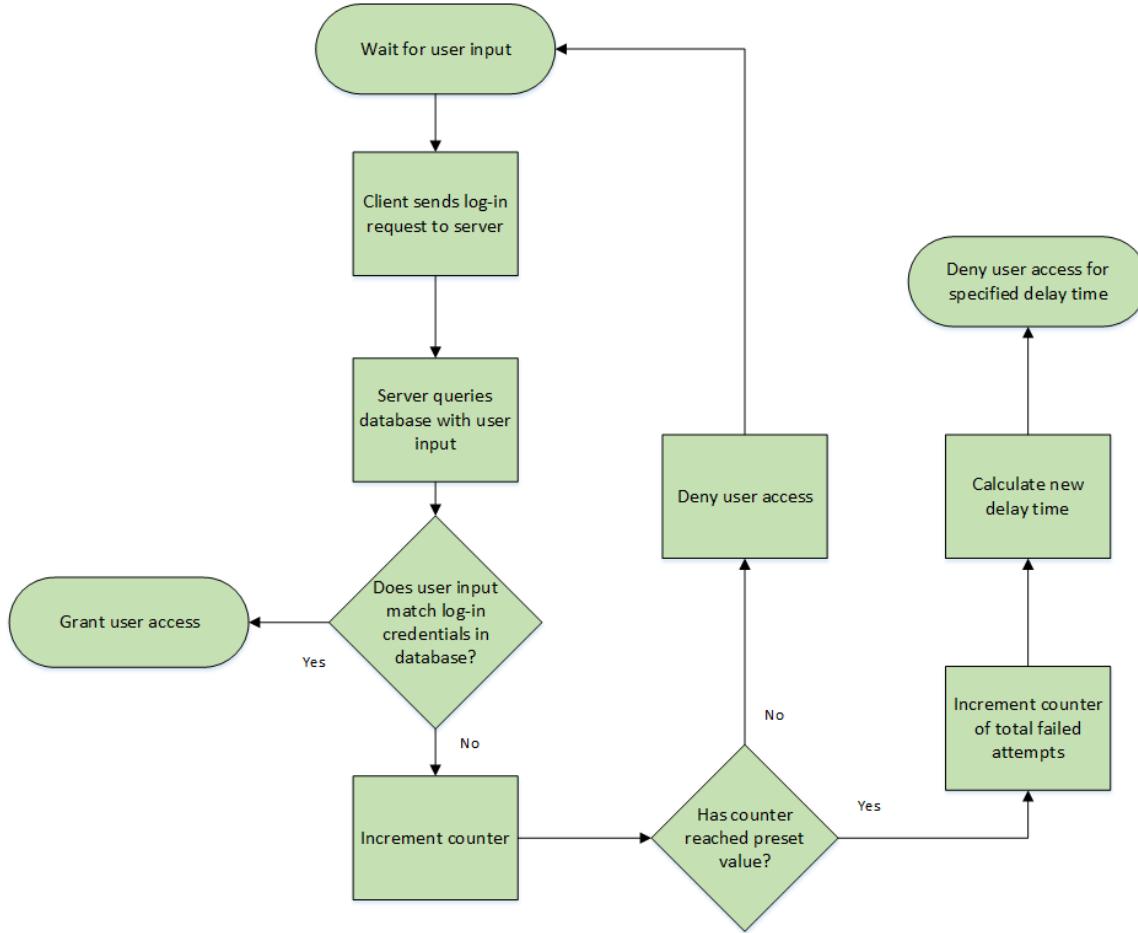
**Figure 52 – Website Log-in with Limited Attempts**

As seen in Figure 52 above, the system initially waits for user input. Upon receiving input from the user, the client sends the log-in request to the server, in which then the server proceeds to query the database with input received from the user. The database compares the data input by the user with the password stored in the database. If the passwords match, the user is granted access to the system. However, if the passwords don't match, a counter is incremented. This counter represents the number of consecutive failed log-in attempts made by the user. Once the counter has incremented, it checks whether the count has reached a predetermined value. This value can be set to any reasonable number such that the user can reenter the password upon mistakenly entering the wrong password the first time. For this implementation, a reasonable count limit can

be set to 3. Thus, if the count has not reached 3, the system will simply deny the user access and allow the user to reenter the password again upon the denial of access. This cycle will repeat for as long as the count has not reached 3. If the user continues to input the wrong password by the third attempt, the count will reach 3. Once the count reaches 3, the system will deny the user access for a specified amount of time. The specified amount of time refers to the delay between the time the user is denied access and the time the user is allowed to reenter a password. This delay serves as the protection mechanism against intruders that attempt to access the system by brute force approach or other method that takes advantage of vulnerable systems. This specified amount of time, or delay, must be set to a reasonable value such that the user can try to access the system in the short future. For instance, a delay time of 1 hour can be used to lock the system from being accessed such that the user has failed to input the correct password 3 times. This delay time should not be too long given the rare chance that the user being locked out is in fact a legitimate user that happened to insert the wrong password each time. This could possibly happen if the user has forgotten their password to the system. In this case, there would be a method to safely reset the password. At this time, although such a password reset system has not been designed, it will be considered for future use later. As the delay time shouldn't be too long, it should also not be too short in the case when the user trying to access the system is not a legitimate user, rather an intruder attempting to gain unauthorized access to the system. If the delay time were to be too short, it would give the intruder more opportunity to break into the system by brute force or similar method. Therefore, each time the count reaches 3 and the user is locked out, the system will enable a delay time of 1 hour before the user can reattempt to gain access to the system once again.

Although this method is an improvement from the previous method, there are still better alternatives to implementing security when logging into the system. For instance, instead of setting the delay time for 1 hour each time the count is incremented to reach 3, the system could use an algorithm to calculate the delay time that is dependent on the number of times the user has previously failed to input the correct password. This would involve another counter that keeps track of the total number of failed attempts, even after the system releases its lock status and allows the user to input a password again. The difference between the two counters is that this one keeps track of all failed log-in attempts until the user is finally granted access into the system. Once the user is granted access, the count is reset to 0. The other counter that was present in the previous design, which kept track of the number of consecutive times the user would enter an incorrect password before being locked out of the system, would also exist in this one. The algorithm implemented in this design would use the number of failed log-in attempts upon each successive failed attempt after being locked out of the system. For instance, the initial delay time could be set for a benign period of 5 minutes. This means after failing to input the password 3 consecutive times, the user would be locked out of the system for a period of 5 minutes. Once the 5 minute period has passed, if the user fails to enter the correct password 3 more consecutive times, the counter would invoke the system to lock the user out again. At this point, the other counter currently indicates that the system was previously locked once upon a failed attempt. Since the system was previously locked out once and the user has failed to input the password 3 consecutive times again, then the system calculates what the new delay time should be according to

what the previous one was. At this point, the delay time could be increased to 1 hour. Thus, the user would have to wait 1 hour to go through the process of attempting to log-in again. If the user happens to fail inputting the correct password for 3 more consecutive times, the delay time would increase to 3 hours, for example. The actually calculated delay times would be dependent on the algorithm designed to calculate the delay time upon each successive failed attempt to access the system. This process of logging in is seen in Figure 53 below.



**Figure 53 – Website Log-in with Increasing Access Delay**

## 5.0 Project Design Summary

Below is a high level representation of our entire project; it is on a component level and shows the two major portions of our project, the hardware and software. Each figure below shows how the parts will be interconnected with each other and who is responsible for them. Figure 54 illustrates the high-level hardware block diagram, whereas Figure 55 illustrates the high-level software block diagram.

## 5.1 Hardware Design

The overview of the hardware design, shown below in Figure 54, consists of all the major high-level components that as a whole form the core of the entire system. The microcontroller depicted in the block diagram represents the Atmel XMEGA D4. The auxiliary MSP430 microcontrollers intended to be used are not shown in this diagram.

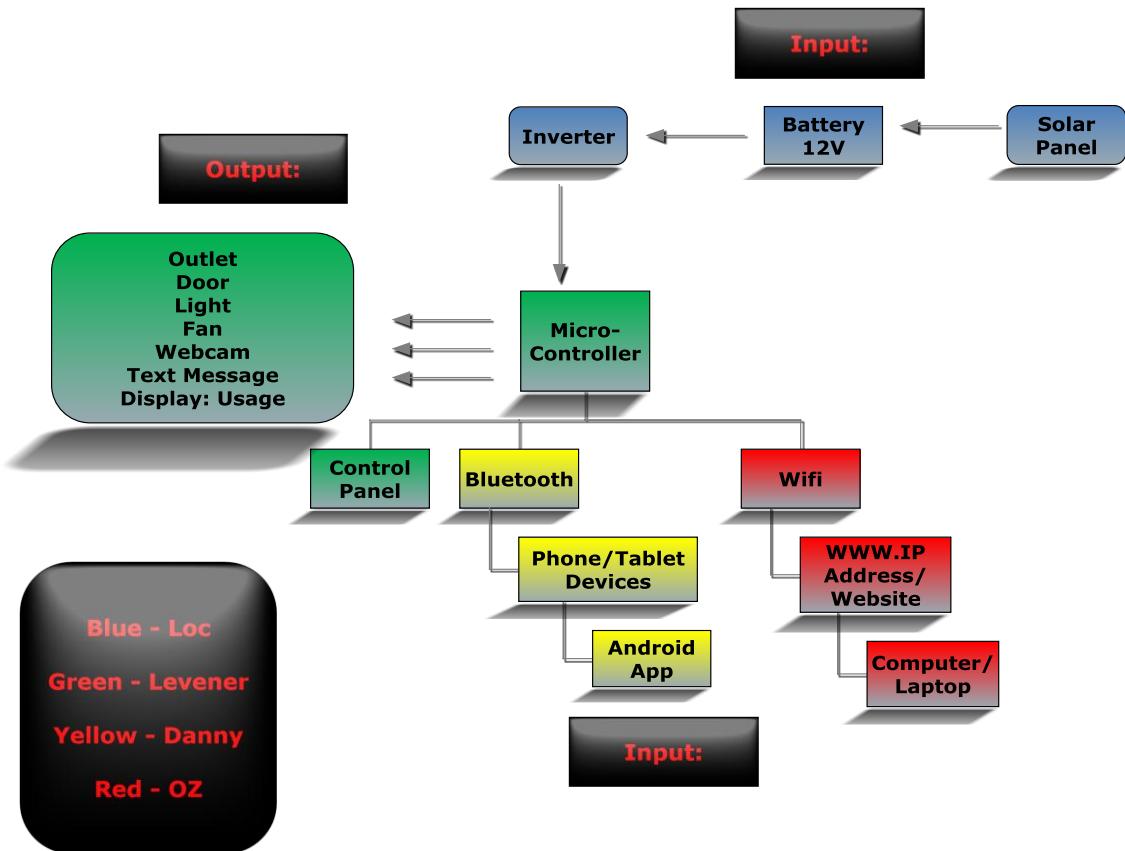
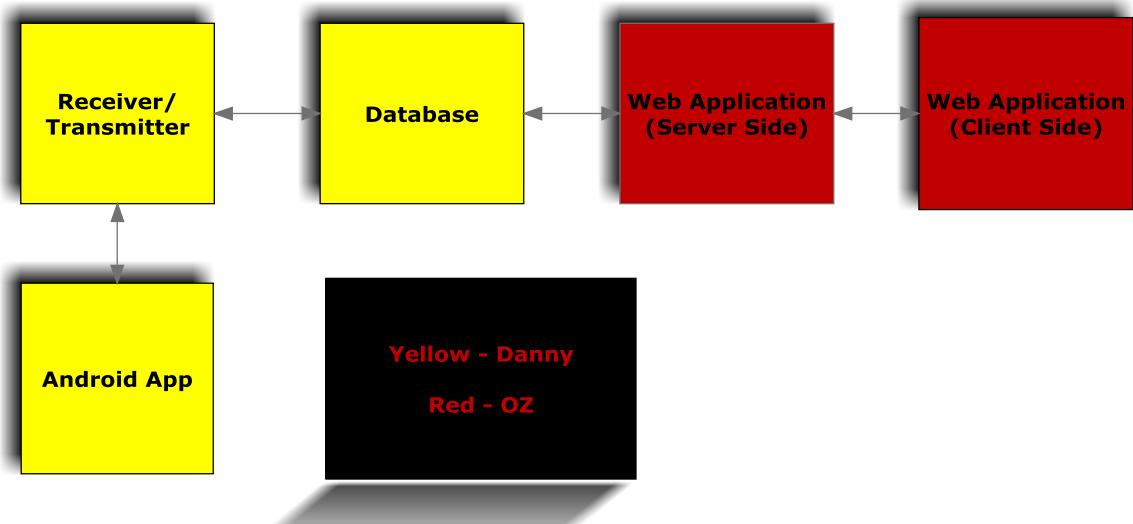


Figure 54 - Hardware Block Diagram

## 5.2 Software Design

The overview of the software design, shown below in Figure 55, consists of all the major high-level components that make up the core of the software system. These components include the web server, web client, database, and mobile application. The transceiver is included to signify its importance with communication between the software and the hardware devices.



**Figure 55 - Software Block Diagram**

For the software design, we are going to have several classes; we will have one class for the outlets, one for the lights, one for the power meter, one for user, one for log, one for door; the way it is going to work is that user class will enable people to log in or log out based on a username and password; when that user logs in the log class will keep track of how many times a user try to gain access to the website; in case a subject exceed the trial limit, he will be kicked out; no one should be able to access the website after three fails attempts; the way it will be setup is that for the first three fails attempts, one will be kept from accessing the website for five minutes, in the event someone did not get in after the first trials, he will be delayed for three hours; the delay time will keep on increasing until the website lock that person out. The lights class is basically for lights in the rooms; there will be an event listener that enables the system to determine which one the user wants to turn on or off same can be said for the outlets. There will be a class for the doors too; what that class does is just look out for the when the door opens or closes; in the event that someone breaks door the door, the owner should get a message letting him know that something is wrong; the block diagram below is representative of all the classes that will be in the coding. A basic UML diagram is shown in Figure 56.

## UML Diagram

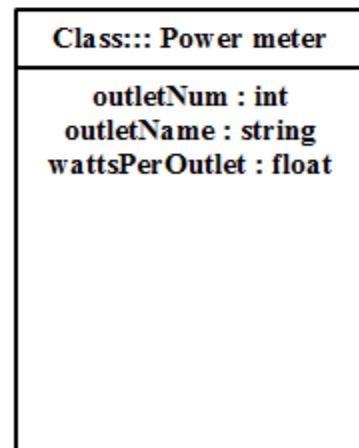
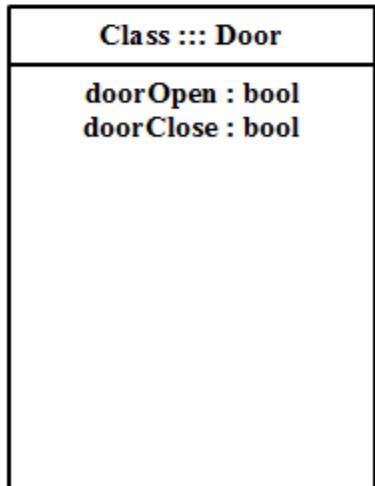
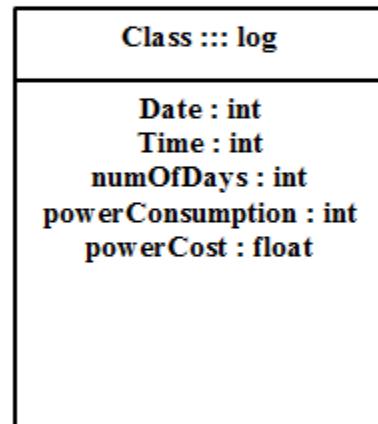
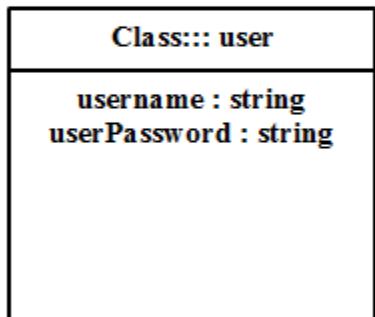
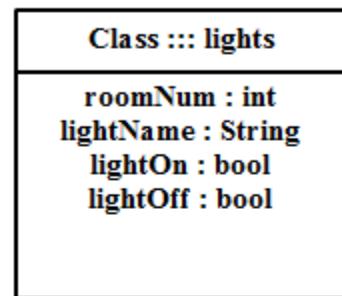
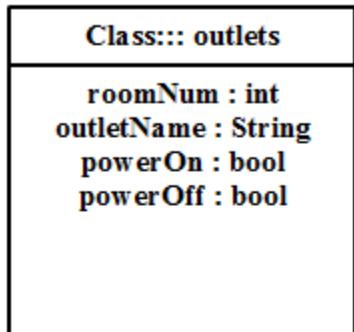


Figure 56 - UML Class Diagram

## **6.0 Project Prototype & Testing**

The procedure of testing this equipment will take place in the main senior design lab Engineering I building, at the University of Central Florida. The following test will be on how to test these devices. First there will be a measure of precaution and safety before starting the test. The team will build a small house of wood; it will contain three rooms and two bathrooms. There will couple outlets in each room, one light bulb, and possible a fan, with two doorways, one main coming into the house, one to access the back porch, each will have an access doorway, the main microcontroller will be positioned in center of the house taking signal from other slave processor and making concrete decision when the doors need to lock or unlock, when to turn the outlets off and on, and check status of the lights when to put them to sleep.

### **6.1 Unit Test**

#### **6.1.1 Temperature Sensor**

Two sensors will be installed in each doorway controlling by microcontroller MSP430 in connection with the hardware interface module and main microprocessor, and there will be another two motion sensors in connection to the same input modules of the MSP430 to monitor the move of the user in the house. One MSP430 will connect to the temperature sensor to display the room temperature, the user can make adjustment on the temperature if needs too depends if the house I too cold or too hot.

#### **6.1.2 Light Detector**

There will be sensor connect with hardwire to main and determine when the light must turn on or off. The will be a motion sensor that will monitor the movement of the user when to send signal to main. Now when the user is approaching the room the motion sensor will send signal MSP430 and the MSP430 microcontroller will transmit the signal to the main microcontroller via transmitter communication to notify it so it can turn the light on all that will happen in the matter of micro second.

#### **6.1.3 Motion Sensor**

In the case of motion sensor, each room will have one, there will be on at the doorway, it will be connected with hardwire to the microcontroller another to communicate with main processor, when someone move around the house or wave hand above the sealing it will detect that move then it will send signal to MSP430 then MSP430 will transmit via RF once the signal has transmitted through the receiver, then the receiver forward date to main for final decision.

### **6.1.4 Outlets, Fan, LEDs**

Each room will have an outlet, and each outlet in the room will be connected in series with each other, the reason for that is to prevent of using another MSP430, one MSP430 will be able to handle all outlets at the same times. The outlets connect with one MSP430 and wiring to the main XMEGA D4 microcontroller. The way to test them is, if outlets are not in use the main microcontroller will send a signal to the relay to turn the outlets on or off, and this data code will specifically coding for the outlets only, unless changes made by the user.

**LEDs:** On the circuit board there will be multiple LEDs, some LEDs light will display on green, red, and yellow. For instance if one the slave processor is on direct contact with the main microcontroller in exchange signal for confirmation status on any event, now there should be a way notification for the user to read when a green comes on what does it mean so on. An example on a room temperature, if the room temperature has changed from either high to low or low to high, now once temperature level drops or increase passed the threshold, the MSP430 microcontroller would decide either to turn the fan on if the temperature is high, it will send a signal to the main to initiate a signature to turn on the fan, so the green LEDs light should come on, once the temperature reach the proper room measure the LEDs light should automatically change to yellow which mean it's at normal temperature. That also means the fan is off is not on anymore. If the red light of the LEDs is on that mean the fan is completely deactivate and put on sleep mode. In addition, the LEDs will work just like for any other event take place in accordance with the system.

**Fan:** the system will be programming with a specific code to run to the fan when necessary, the system will be set up for 5 minutes above room temperature level and decreased slowly until it reach its threshold which below temperature level. The MSP430 which is one of the slave microcontrollers will then determine that the fan must be turned on, so it must send the signal to the main so the main will respond by send back the signal to the MSP430 authorize it to turn the fan on. From that point of this test, if the fan turn on correctly as planed therefore the system is working fine. The displayed will increase until its reach the threshold which means room temperature. And when that happens the fan will turn off, if it turns on time at the room temperature that proves everything is working perfectly fine. And the same test can be done for temperature drop.

### **6.1.5 RF Transmitter**

In this project RF transmitter will play a major role, the RF transmitter will be directly connected to a MSP430 microcontroller which will use as a slave processor in the system. It will have the sensors connect to it and link directly to the main microcontroller XMEGA D4. The transmitter will in contact with the sensor that connect to it, take signals from it transmit the signals to the MSP430 then forward it to the main, remember the main has to connect with the interface via the RF connection so all communication between them can be received without error. The way this test will conduct to see if the

transmitter is successfully sent the signal correctly and found out if the signal has also received, there will be an LEDs in some of the devices that light up to indicate that if signal has sent and received. On the testing bench the group will monitor each LEDs lights, there will be a green light indicate that the system is awake doing activities, or it could mean the signal is received. More testing will occur when the system is actually built. And there will be a yellow from the LEDs which will indicate that everything is normal system awake waiting for signal or instructions, and the last light will be a red light, red light will indicate that either the system is on sleep mode, or there is an error in the transmission line, which can explain that there is no movement in the house therefore the system remain in sleep mode to save power.

## 6.2 Functional Test

The Graphical User Interface testing is a process that we have to go through to make sure that the User Interface meets all the criteria; it is a way to make sure that all specifications are met. In order to make a test case we have to understand a few things when it comes to GUI; two strategies that we have to consider are mouse position capture and event capture. One of the popular methods used in Command Line Interface is capture/playback. The capture playback is a process that enables people to capture the system screen. It is captured as a bitmapped graphic during several steps of the system testing. The bitmapped graphic enables people to play back to the testing process so that the screens that you get from the output can be tested against the expected screens. Another method is the event capture; during that process what a tester does is collect GUI interaction data from the underlying windowing system. The capture of the window event is made into log; that capture enables the decoupling of the system's format from the appearance of the Graphical User Interface. We can also build a driver in the Graphical User Interface; that driver enables commands or events to be sent to the software from another program. Building the driver is mostly the way to go in order to test to see if a GUI is working the way that it is created to. This method of sending and receiving commands is very good; by that input and output testing can be fully automated and we have a chance to eliminate user error. In order to generate a set of test cases for the Graphical User Interface one has to make sure that the suite covers all the functionality of the system; one also has to make sure that the suite exercises the GUI itself. To create a test case one has to deal with domain size and sequences. The most difficult thing when one has to do testing for Graphical User Interface is regression testing; Regression testing is any type software testing that seeks to uncover new software bugs, or regression in existing functional areas of a system after changes such as enhancements, patches or configuration changes, have been made to them. The intent of regression testing is to ensure that a change such as those mentioned above has not introduced new faults. One of the main reasons for regression testing is to determine whether a change in one part of the software affects other parts of the software. Common methods of regression testing include rerunning previously completed tests and checking whether program behavior has changed and whether previously fixed faults have re-emerged. Regression testing can be performed to test a system efficiently by systematically selecting the appropriate minimum set of tests needed to adequately cover

a particular change. Regression testing is a problem due to the fact that the GUI sometimes goes through a lot changes across versions of the applications; what it does is that a test build to test a GUI might not work due to the fact that a button, menu item, dialog may have changed location or appearance. Because of all that it is kind of premature to say how the Graphical User interface will be tested; once everything is set up, we will have to figure out ways to test it so we can make sure that the GUI does everything that it is supposed to accomplish.

### **6.3 System Test**

System testing goes for both hardware and software; it is process that we have to go through to make sure that the project works, as it should. For that process we have to not only test the design we also have to test the behavior, and event. We have to test to see if the system meets all the expectations. The goal of system testing is to make sure that any inconsistencies between the software units that are integrated together. We also have to look into the hardware assemblage too. System testing is kind of limited; it just tries to detect defects within the system as a whole. The rules for system testing are that the system takes as input all integration software components that have passed any sort of integration system testing. System testing is usually referred as black box testing which is a kind of software testing that examines the functionality of an application. It is applied to every level of software testing.

### **6.4 Software Test**

Software testing is among a bunch of test that we are going to conduct on the Smart Home System. It is a way for us to see if the application meets the entire requirement for which it was designed. In order for to make sure that the software works, we have to complete the code; because we cannot build a good test case unless the requirement process has been defined. The main reason why we have to go through that is to find all the bugs in system and make sure that they are corrected. One to know is that by testing the software it is not going to tell us whether systems works fine under all conditions, but it is way for us to find out if it does work under certain specific conditions. The software testing will mostly be done in the environment in which we choose to write most of the codes whether it is code composer, eclipse, or any environment that might be of any help to us. We need to make sure that every single part works as it should be; we know that Graphical User Interface will contain four frames; the four fames will have one for the lights, one for the outlets, one for the database, and one for real time power consumption; each one will be tested separately, we basically have to ensure that every button works as it should. What happens sometimes is that due to some bugs in the software some stuff works different form is expected from it. It is like when the TV remote control is broken; everything goes out of whack; let's say one is trying to access MSNBC all of a sudden the TV is on Fox News; those are the kind of stuff that we will try to avoid. We want to make sure that that if we click on the button that is supposed to turn on the light in room 1 light in room two does not turn on instead. We will have to make sure that the software is acceptable to the target audience.

## **7.0 Project Conclusion**

Energy conservation and going green has become a top priority in today's society as the environment continues to be harmed by pollution caused by the use of fossil fuels. The motive behind this project is to promote energy conservation methods, as well as the use of renewable energy. The use of solar energy is amongst the most popular forms of renewable energy used today. This project promotes the use of solar energy to power everyday home essentials such as light and low-power electronics. While initial investment may seem relatively expensive, the tradeoffs outweigh the initial expenses by a large margin. These beneficial tradeoffs include having the solar system pay for itself over the course of several years, as well as taking a stand to help conserve the state of our environment. As the main objective of this project is to promote energy-conscious minds, the Smart Home System allows for users to keep track of energy usage at each outlet at any given time. This feature encourages the user to keep track of power consumption based on each device plugged into a power outlet, allowing one to determine whether a particular device is consuming too much power and should be replaced with a more efficient one, such as an energy star product. The feature of being able to remotely control power outlets and lights may also give the user an ultimate sense of convenience as well. To make the Smart Home System smarter, other included features are motion sensors to detect a live body entering a room. Additionally, the entrance to the home is proposed to implement an electronic door locking mechanism set up with a proper encryption algorithm. If there happens to be a security breech by means of unauthorized or forceful entry, the system is to be designed to send an automated message to the homeowner indicating the situation. With the motive of energy conservation, along with inclusion of these intelligent features, the Smart Home System is proposed to be the next state of the art technology with hopes of witnessing its implementation in every home in America and across the globe, for the sake of our planet.

## 8.0 Appendices

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