KNIGHT WATCH SECURITY (KWS)

Senior Design II Documentation

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1   EXECUTIVE SUMMARY

The following documentation contains the details and information describing the research, design, testing, and implementation of the home surveillance system: Knight Watch Security.

Knight Watch Security is a security camera and surveillance that can be mounted on a pole and can be placed anywhere outside the user's home. The camera has have a wide viewing angle and Wi-Fi connectivity with a specific range, so the location of the camera is up to the user's discretion. The system is powered using solar panels and is completely off the grid. Furthermore, the video being captured from the camera is transmitted via Wi-Fi to a specified computer. From the computer, which serves as the base station, video footage can be stored as well as viewed live. The camera will always be on and continuously recording video in intervals of three hours. This means that the camera will always be recording, but stops at three hours and then immediately start a new recording. Additionally, the system has remote monitoring capabilities. Video feed can be viewed live from any web browser at any time. Similarly, the video feed can be viewed from a smartphone using an application that can stream the video feed straight into the user's hand.

2   PROJECT DESCRIPTION

2.1 PROJECT MOTIVATION

A reliable, home security system has been desired by humankind since the dawn of time. While many homes throughout the world have implemented various designs for home security, very few homes use an energy efficient system. If homes were to use an energy efficient home security system, it will ease their daily struggles with safety, security, and finances. In addition, previous security systems have limited connectivity. With today's technology and society's "Go Green" outlook, many homes and families should have a desire to implement a home security system that is dependable, energy efficient, and easy to use. With a system like this, homeowners will be able to live their daily lives reassured that their personal assets are kept safe in a resourceful manner. They would also be satisfied knowing this system was simple to implement as well as user friendly.

In order to provide homes with a better sense of protection and a more versatile and dynamic structure, the idea of the Knight Watch Security (KWS) came about. KWS will satisfy all the surveillance needs of any homeowner, or similar, by being an autonomous, solar powered security system camera with network capabilities.

2.2 SIGNIFICANCE

KWS is designed to optimize the power output of its solar camera with maximum power point tracking and sealed lead acid battery. Taking the camera system off the grid allows for a more versatile and sustainable system. The system provides a crucial video link where grid power may not be available. This security camera is investing in a high output, low power consumption processor and WI-FI radio. The project is completely scalable and can be customized to fit many different applications.

Homes that desire a safe household or asset protection will want to use KWS. The amount of break-ins and robberies would decrease substantially. Users will be able to go on vacation and monitor their house from across the globe. They will even be able to have a good night's sleep knowing that KWS is like sleeping with one eye open. Similarly, users will take solace in the idea of being protected while also conserving energy. KWS is the future of energy-saving security systems.

2.3 GOALS AND OBJECTIVES

The primary goal of this project was to build a self-contained security camera that people will be comfortable and satisfied installing outside of their homes. Before that long-term goal was satisfied, several design objectives were to be fulfilled first. These include low-cost, efficiency, and user friendliness.

2.3.1   Low-Cost

Of course an important objective was to build this security camera using the least costly methods as possible. This means using the cheapest parts and software without comprising reliability, performance, and efficiency. The budget for this project was around $1,378 (see section 9.1). This is the goal for the design but the project was able stay under the budget due the discovery of more economical alternative sources. Other reasons to reach over budget were broken parts or the need for more unanticipated resources. However, the estimated budget was predetermined in preparation for the second possibility. Therefore, it was definitely possible for the project to remain under the budget.

2.3.2   Efficient

The most vital objective for this project was to build a camera that performs efficiently and build it in efficient way. One of the main purposes of KWS is to be "green" by taking the system off the grid to limit power consumption and conserve energy. Similarly, while building this project utilization of the most efficient methods is very important. The hardware was to be built in an efficient way in order to ensure product reliability as well as save development time. This

also applies to the software. The software must be designed and coded in an efficient way to decrease development time and eliminate software bugs or crashes.

2.3.3   User Friendly

As with any consumer product, the user interface and usability is very crucial. If this product is difficult to use or control then the desire to use it will be very low. The user will only be able to interact with the KWS camera through the desktop or smartphone interface. Therefore, the ease of use will be determined by the GUI and software. In general, the user interface will have to be simple and easy enough so that anyone who has a basic understanding of computers will be able to use it.

2.4 REQUIREMENTS AND SPECIFICATIONS

2.4.1   Solar Sufficiency

The KWS must consume no outside power. Power will only be supplied by the solar panel. The Power will be stored in an internal battery and utilized to power the security camera and all of its components.

Specifications:
- Supply: 50W Solar PV panel
- Storage: 12V Sealed Lead Acid Internal battery

2.4.2   Solar Power

Power will be supplied strictly by the solar panels. The solar panel must be able to use light energy from the sun to generate electricity that will power the KWS camera.

Specifications:
- PV panel 50W (24.4" x 25.3" x 1").
- Unit's housing will incorporate the panel design.

2.4.3   Internal Battery

The KWS camera will have an internal battery that will serve as the storage for the solar power. It will be used as the direct power source to the camera during periods of high sunlight and will also store energy for user during hours of little to no sunlight due to the time of day or weather conditions.

Specifications:
- Small application Sealed Lead Acid 12V.
- 22 Amp-hour Rating
- 16 lbs.
- 7.1" x 3" x 6.6"
- Power storage ability for 24 hours of self-sufficient function.
- At least one year of battery use before replacement.

2.4.4   Interface Capabilities

There are two methods in which the user can interact with the KWS camera. The user can interact with the camera through the user's desktop computer or laptop and through the user's smartphone.

2.4.4.1 Remote Desktop Access

The user will be able to view the live video feed from the KWS camera on their home computer. They will also be able to view previously recorded security footage. Additionally, the user should be able to view diagnostic information and record live video from the computer.

2.4.4.2 Remote Smartphone Access

The user will be able to view the live video feed from the KWS camera on their smartphone using a KWS Android application. The user should also be able to view diagnostic information and record a live snapshot from the smartphone.

2.4.5   Portability

The KWS camera should be a fully wireless operation. It will be mounted on a pole and placed outside of the home in a destination determined by the owner. The user will be able to view the live video feed through Wi-Fi data transmission that can be accessed by staying within a pre-determined range.

Specifications:
- Solar powered, with power storage ability.
- Wi-Fi data transmission capabilities (20m range).
- Self-contained (weather resistant housing).
- Lightweight (under 60lbs.).

2.4.6   Pan and Tilt

The KWS camera should have standard security features such as pan and tilt.

Specifications:
- Pan – Unit can be manually rotated horizontally through 180° of vision.
- Tilt – Vertical adjustment has 45° of freedom.

3   RESEARCH

3.1 PROCESSOR

3.1.1   Picking a Processor

KWS has investigated many different processors to work with the project. The processor is the lynch pin of the project. Power consumption, performance and features all must be taken into account. There are different schools of thought associated with embedded computing. The processor is responsible for three critical tasks:

1.   Receiving Input from the USB Camera

The camera will be streaming video to the processor at 30 frames per second. The processor needs to have the appropriate drivers onboard to decode the video feed. The processor will also be providing power to the camera via the USB interface.

2.   Recording a Portion of that Camera Stream

The camera uses the processor in combination with a microSD card to record a portion of the video stream. This allows the camera to operate autonomously and continue surveillance in the case of the base computer failing due to power failure or network failure.

3.   Host the video stream as a web server

The processor will also be an html host. It will be acting as a server allowing multiple users to access the video stream simultaneously. With these features in mind, the team set out to find a processor capable of facilitating the complex set of requirements without breaking the bank or burning all of the power form the solar set up.

3.1.1.1 FPGA

FPGA stands for field programmable gate array. FPGA's are flexible processing units which are ideal for in high speed, low power applications. FPGA's have replaced the need for discrete gate arrays and provide a flexible way to implement complicated logic. FPGA's through Xilinx offer two ways to program their chips.

The chip can be programmed in a schematic based graphical user interface (GUI) that allows for logic lines to be traced from start to finish. The second way to program a Xilinx chip is with a proprietary programming language known as Verilog. There is a test bench that allows for a complex array of tests to be performed. FPGA's have the capability to compute video images and apply algorithms but with the amount of embedded networking that is being attempted. FPGA's do not offer a viable solution.

3.1.1.2 Embedded

Embedded processors offer easy to implement solutions for simple projects. A thermostat or other small project is easily implemented on an embedded processor such as the MSP-430. The KWS project has advanced features that require a more advanced processing architecture. The MSP-430 is capable of a wide range of digital input and output (I/O) but Wi-Fi capabilities would be difficult to integrate.
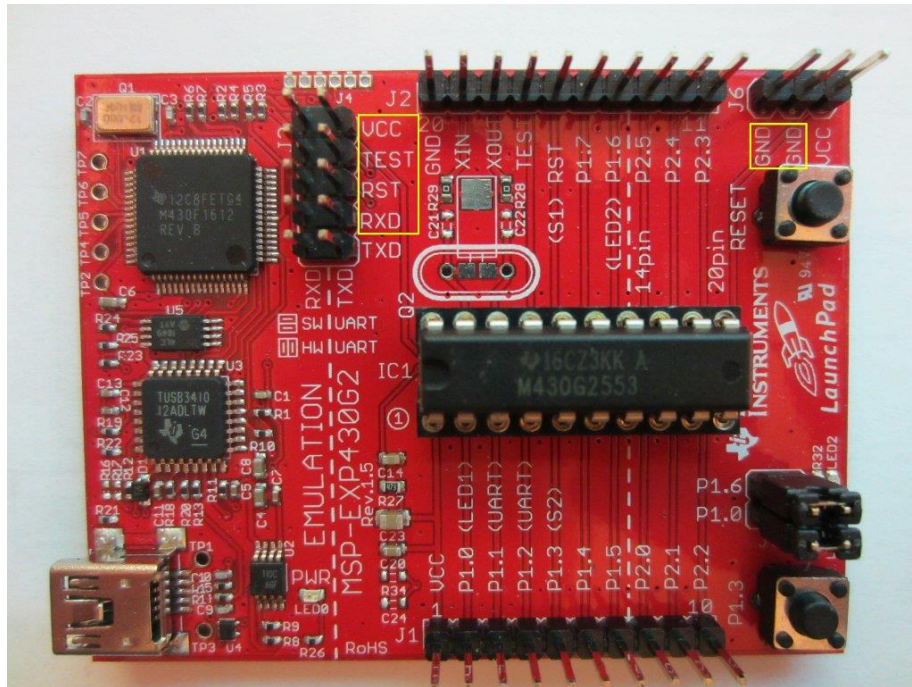
Figure 3.1.1-1 MSP-430

An embedded processor will be used on the KWS project on the independent maximum power point tracking system. The maximum power point tracking system will read in voltages and currents to an embedded microprocessor. After the data enters the processor, a hard coded algorithm will be applied.

With the results of this algorithm the processor will send a signal to the charge controller / DC to DC converter. The signal will set the input to the battery from the charge controller to a level that provides maximum charging power. Under

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consideration is the ability to monitor the battery status from the camera portal, but development plans for those features have not been drafted.

3.1.1.3 ARM/OMAP

ARM/OMAP processing has become the most efficient solution for the projects feature set. The AM3358 is a logical fit for the KWS project. TI offers a development board that has integrated Wi-Fi and is capable of running Linux. The AM3358 is a versatile yet low power solution. The board used for development even has USB and Ethernet capabilities.

Figure 3.1.1-2 AM3358 SK

The ARM architecture is basically a single card computer. TI offers packages with DDR3 ram. Different levels of L cache are available to support different computation levels. Most of the ARM processing series support many different operating systems. Android, Linux and a base level TI operating system are the most common. There verity of Linux distributions that can be used on the ARM processors. The Angstrom distribution is included with the AM335X development board.

Angstrom is based off of OpenEmbedded. Angstrom will run on any device that has a 2.6.0 kernel which OpenEmbedded supports. Angstrom is not the only option for embedded Linux. Ubuntu has started to support the arm processing architecture.

Ubuntu has been ported over to the ARM architecture with some help from Debian (a universal OS). Ubuntu has a large support community that can offer help with debugging and adding custom scripts to the base OS. There is also a vast package repository that is open and available for use. TI also offers support for developers.

TI has a Linux Boot Camp that provides training on a variety of different aspects of programming for the TI version of Linux. There are wiki pages devoted to the

ARM family of processors and TI hosts a forum type discussion board where people can get help from TI team members. The questions discussed on the board get posted directly to TI engineering staff. Running Linux on the ARM platform is going to provide the flexibility and scalability required for the embedded Wi-Fi camera being developed.

3.2 NETWORK COMMUNICATION

Network communication is a vast and diverse subject that has been discussed for over 100 years. The KWS project is going to rely heavily on the ability to transmit data wirelessly. The system needs to be autonomous and able to operate remotely with no wired connection to the grid or to the base station computer.

The ability to transmit wirelessly has taken many different forms in the past years. The following sections will provide information on different types of wireless communication and elaborate on their prospect for inclusion in the system

3.2.1 Bluetooth

Bluetooth is a widely used protocol operating on a public frequency band. Bluetooth uses the ISM band (2.400-2.4800 GHz). The ISM band is globally unlicensed. Bluetooth is designed to work over short ranges. Most Bluetooth connections are good to 30 feet depending on obstructions. Bluetooth creates a personal area network. The security of Bluetooth is weak compared to other forms of wireless transmission. Bluetooth relies on a 4 digit encryption. The maximum bit rate associated with Bluetooth is 3 Mbits/s using the latest 8DPSK modulation, but the base line is closer to 1 Mbit/s.

Bluetooth is probably not the best choice for the application giving the 30 foot range limited bandwidth and limited encryption. Similarly most Bluetooth connections have a master and slave relationship that would make advanced network functionality more difficult.

3.2.2 Zigbee

Zigbee was a promising new option on the market that was interesting. Zigbee was designed to facilitate high level communication using low power digital radios. The Zigbee technology is based off of the principle of swarming. Many radios in an area cross talking to transmit data from one end to the other. The Zigbee protocol forms an ad-hoc network. This centralized network can pass large amounts of data in total but the through put is limited. Zigbee was designed to run in an ultra-low power environment.
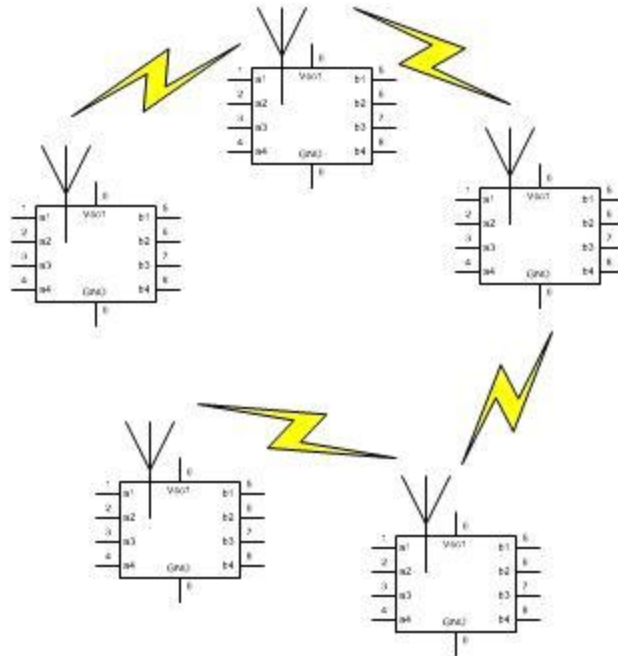
Figure 3.2.2-1 Zigbee Swarm

After more research the team ruled out a Zigbee solution. Zigbee would be more suited to delivering sensor data to a central processor. Carrying video images wirelessly over a long distance requires a different solution.

3.2.3   RF Link

RF Links have been implemented for over 50 years in long distances communications. The data rate and bandwidth are limited only by the amount of money you are willing to dish out. The frequency bands of RF communication are also virtually unlimited, again if you have the money to acquire the license for that frequency band. Some frequency bands are reserved for amateur operations and others are internationally unlicensed.

A plus for the RF link solution is that the data transmitted is not changed over the link. There is no stack protocol the data flows in one side of the link and appears on the other side of the link a short time later. This reduces the latency of the information transmission and also simplifies the onboard electronics on the camera its self. But in doing so more processes would be placed on the base station computer and if the link was disturbed data may be lost.

Figure 3.2.3-1 Commercial Grade RF Link

The prospect of unlimited data rates and bandwidth seemed appealing but the logistics of getting licensing would be a nightmare. The specifications were to have an operational range in the tens of meters. A RF link could provide a range in the kilometers which for the application is overkill. Another problem with RF Links is price. A link can cost anywhere from $800 to $32000. For the project application a different system could meet all of the requirements.

3.2.4   Wi-Fi

Wi-Fi is the most commonly used form of wireless communication. Nearly every household in the civilized world has a magic box with blinking lights more commonly known as a Wi-Fi router. That Wi-Fi router covers the household with a blanket of internet access and the ability to send information from any smart device to any other device on the network. Wi-Fi on the surface appears to be the perfect solution for getting data back from the camera wirelessly without breaking the bank.
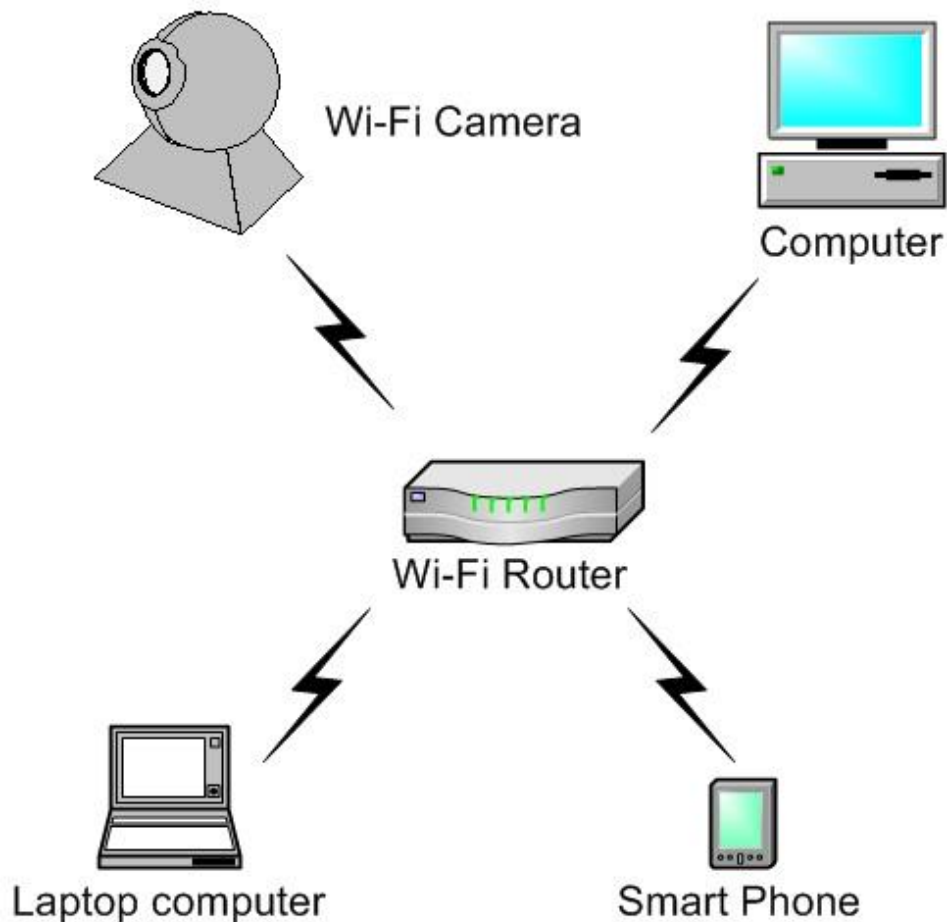
Figure 3.2.4-1 Wi-Fi Network

Wi-Fi is a WLAN or wireless local area network. Wi-Fi was introduced in 1999 for commercial use. Wi-Fi is based on IEEE 802.11b protocol for sending packets over a radio link. The packets are known as Ethernet frames. Ethernet frames have an error checking system. If a packet is destroyed before it reaches its final destination the packet is resent until the data is received at the target.

Wi-Fi certified devices work at any Wi-Fi access point anywhere in the world. This cross platform compatibility has led to the vast popularity of Wi-Fi. This compatibility will also allow our camera to be used with almost any Wi-Fi certified router.

Wi-Fi signals operate over five channels in the 2.4 GHz band which is a globally unlicensed band. The IEEE 802.11b has seen many revisions since 1999. The current revision is the IEEE 802.11n which is not yet fully supported by all Wi-Fi devices. IEEE 802.11n is currently the fastest Wi-Fi protocol with data rates up to 600 Mbits/s.

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The data rate required for the camera will be well below the maximum rate for a Wi-Fi link. The expected data rate will be around 256 kbps to stream around 15 frames a second over the Wi-Fi link. In summary a Wi-Fi link will be the most effective way of transmitting camera data back to the base computer.

Wi-Fi Protocol

Wi-Fi follows the legendary TCP/IP protocol that has defined how computer networks have transmitted data since the 1970's. TCP/IP provides a template for end to end connectivity, addressing schemes, data formats and routing. The entire TCP/IP Protocol is broken into 4 layers, each with their own set of rules.

1. Layer 1 is known as the link layer and contains all communications over the LAN or Ethernet network. This layer was designated to be hardware independent so the protocol can be used on anything from a laptop to a refrigerator. The link layer is used to transport packets form the internet layer to the host. The link layer can also be used to transport data between users on the same LAN network.

2. Layer 2 is known as the internet layer and is used to connect LAN networks together.

3. Layer 3 is known as the transport layer which defines host to host communication.

4. Layer 4 is the application layer and it defines how the web browser will interact with the web server.
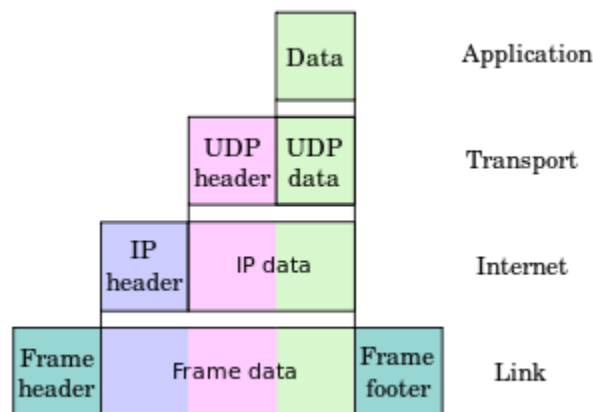
Figure 3.2.4-2 IP Stack Diagram

The camera will be an autonomous IP host. The camera will host the data as a web page that contains the video stream from the camera. The onboard processor will be running Linux which has web hosting capabilities. The ffmpeg library had utilities that facilitate streaming MJPEG format. The base computer

will be able to ask for the video stream and be able to record data using just the IP address of the hosted video stream.

IP addressing is another topic of discussion. An IP address is a computers soft address either designated by the user or assigned by the router. The IP address of the camera will be set so that the router cannot change it. This format is known as a static IP address and is used when a device on the network is going to be permanent.

Most computers and Smartphone's use a dynamic IP address scheme so that they can easily move from one network to another. In the dynamic scheme the user device asks the router what address it should take to insure a clear connection. The IP address itself is a 32-bit number defined under Internet Protocol Version 4. The address is usually stored in a form that a user can read such as 191.16.244.1 but the actual address is a binary string.
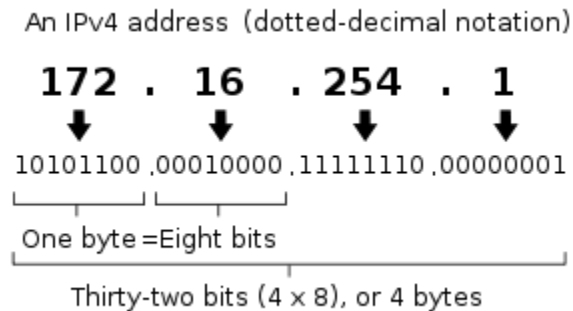
Figure 3.2.4-3 IPv4 Address Diagram

Wi-Fi Antenna

The dev board planned to be used for the project already has a built in Wi-Fi radio and miniature antenna. After the initial testing it may be necessary to have a higher output Wi-Fi radio with a possible external antenna. The product being investigated in that case is the WiFly GSX 802.11 b/g Wireless LAN Module.

The WiFly Module is compatible with the TCP/IP protocol that is being used for the video transmission. The Module offers up to 1Mbit/s sustained data rate which is more than what is required for the application. The WiFly has a UFL connection to an external antenna that would increase its overall range.

Figure 3.2.4-4 WiFly Module

The antenna of choice to pair with the WiFly Module would be the MikroTik. The MikroTik offers a gain of 3dBi in the 2.4 GHz frequency range. The antenna can rotate and mounts in a through hole fashion. The antenna can be easily integrated on the camera housing, extending range and overcoming any radio interference caused by the cameras housing.

Figure 3.2.4-5 3dBi Mikro Tik UFL Antenna

3.2.5 LAN

A LAN or local area network needs to be established to allow the Wi-Fi devices on the network to communicate. In most households a LAN is already established by the wireless router. The wireless router functions as a normal IP router, having 3-5 Ethernet ports, and as an IP radio delivering Wi-Fi signal throughout the house.

Picking an adequate wireless router is important for the project. The camera is going to be WEP compliant. The camera will not be streaming an extremely large amount of data so an older Wi-Fi router capable of 11 Mbps will suffice. The router that is specified for the project is a newer 802.11g capable of 54 Mbps, although the higher data rate is not required. Most inexpensive wireless routers today follow the 802.11g protocol. Range also plays a part in the selection of the router. Most cost effective routers have a range of around 40 meters indoors and 90 meters outdoors. If the camera is located close to the house, then no additional Wi-Fi routing devices will be needed. If the camera is mounted a distance away from the home a Wi-Fi repeater or a second Wi-Fi router may be required.

Figure 3.2.5-1 D-Link Xtreme N Gigabit Router

With adequate Wi-Fi signal established the LAN can be configured. Setting up the Wi-Fi router is usually covered in the instruction for the router. Generically the first step is to plug the router in. Next connect the supplied Ethernet cable into

the router through a router port and connect the other side into the computer. After an Ethernet connection is established between the two devices type the default IP address into an internet browser on the computer. You will reach a router login page. Input the router user name and password to access the router options. In the router options you can establish a new router IP address or set up a WEP encryption.

Having the LAN established allows all users signed into the router to access the video stream from the camera. The camera hosts its own html page that contains the stream. The team uses some freeware to record the video stream from the camera on the computer. The Android application being developed will navigate to the html page hosted by the camera.

3.2.6   WAN

WAN is basically another word for the internet. The WAN is an interconnected group of LANs. LANs are protected by the ports they allow information in and out through the firewall. In order to allow a phone application to access the camera video stream from outside the LAN the user must forward a new port to allow outside devices through the firewall. The video stream is directed to that port allowing the Phone to view the stream.
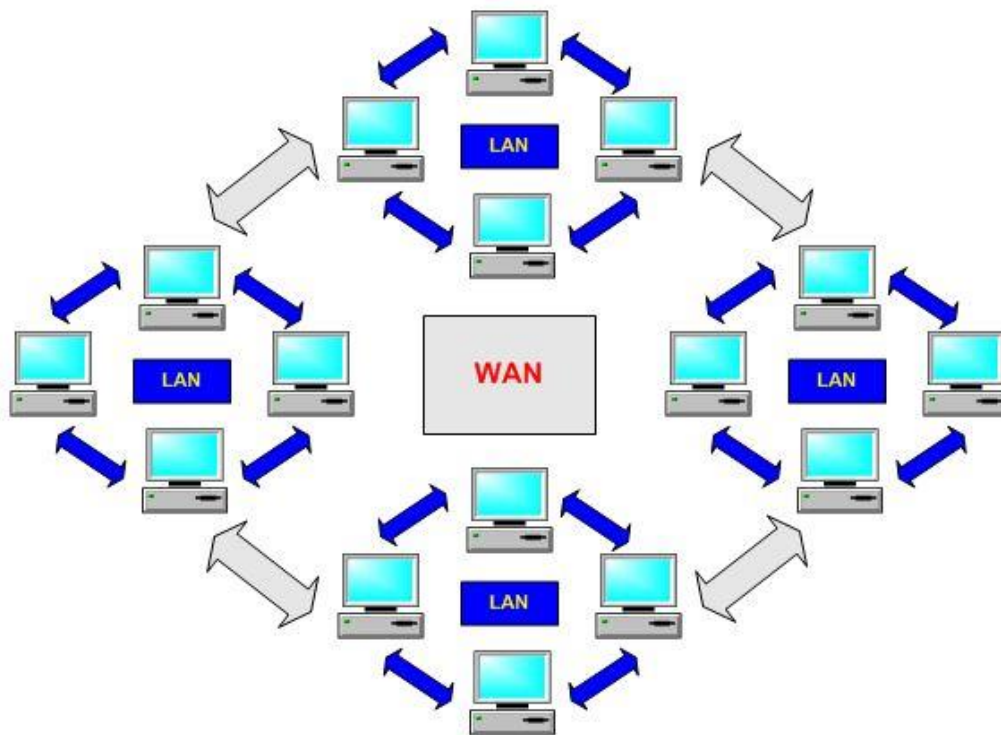
Figure 3.2.6-1 WAN to LAN Interconnect

The LAN is connected to the WAN through a modem. The modem is provided by the ISP and attaches to the wireless router. The port must be forwarded to the IP address of the camera stream. This is why having a static IP address established is so important. If the router changes the IP address then the forwarded port will be pointing at nothing and the video stream will not be able to be accessed. In some cases the router encounters an IP address conflict. During this conflict connection may be lost. IP conflicts happen when a static IP address is given to another device from the router. IP conflicts most commonly occur on networks with heavy traffic. Our camera is designed to be used on a private network thus IP conflicts are at a minimum.

3.2.7   Mobile Communication

The mobile network is very simple. Basically the phone acts as router and a wireless transmitter. The phone basically has unrestricted access to the internet when under cellular coverage. Once the phone accesses the WAN it can navigate to the users home LAN through the forwarded port on the router. The camera is streaming in MJPEG which is almost universally supported by almost browsers. The phone app will basically be a browser that only navigates to the camera stream.
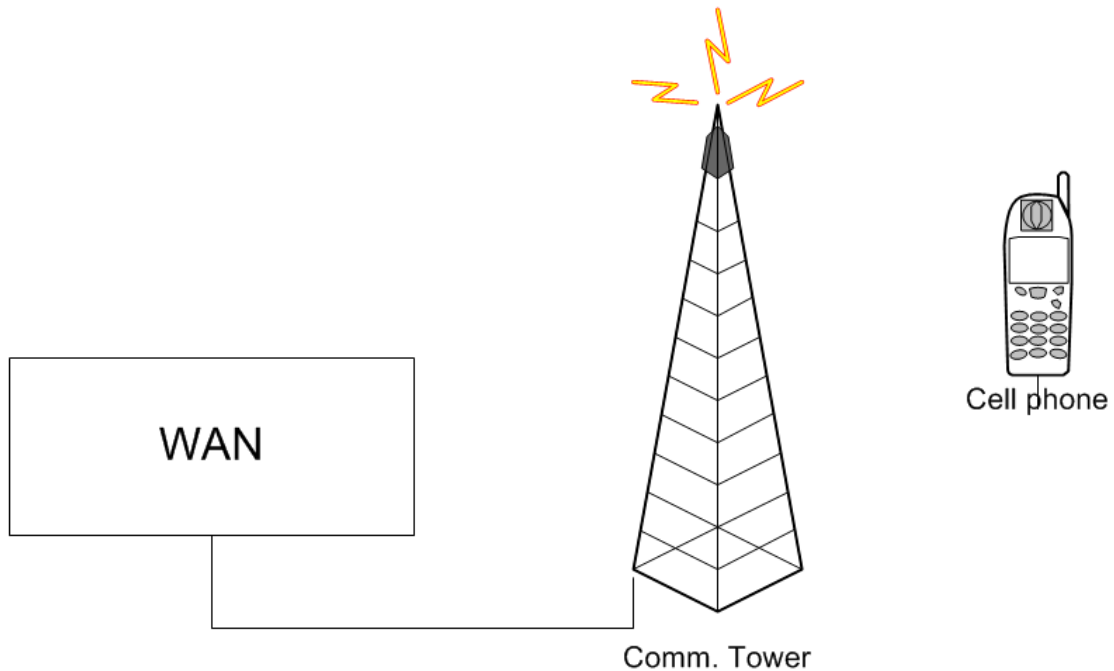
Figure 3.2.7-1 Mobile Communication

Network security is not a large focus. There will be open access to the camera stream with no required password. There are available hardware and software security products available to harden the camera stream if a customer found it

necessary to do so. A webpage with a username and password could be hosted on the camera to increase security.

3.3 HOUSING

The housing is an essential part of the overall project. The solar panel provides the roof of the housing. The solar panel included in the project will already be weather proof. The walls of the housing will need to mate to the base of the panel. The housing will need to accommodate the battery and all of the electronics keeping them safe dry and out of the weather. The following is an investigation of different materials for the housing.

3.3.1   Aluminum

Aluminum is an extremely low density metal that is highly abundant and relatively inexpensive. Aluminum is a very durable metal and when coated properly can withstand most environmental forces. Aluminum is a ductile metal and is relatively easy to work with. In most applications aluminum is riveted or welded into the shape required. Aluminum also performs well when casted or milled but that is beyond the scope of the project. Aluminum may also have a problem with corrosion. For the application aluminum would fulfill the design needs but there may be a better option available.

3.3.2   Acrylic

Acrylic glass, also known as the Plexiglas, would be an interesting option. Uncoated Plexiglas is transparent allowing the electronics to be monitored while they are installed in the housing. This could be beneficial for system testing as well as for demonstration purposes. There are many down falls to Plexiglas unfortunately. Sheets are expensive and in general hard to work with. Plexiglas is easily scratched and when left in the elements can become clouded. Thin Plexiglas cracks easily and must be carefully predrilled to keep it intact during assembly. Thicker more robust Plexiglas is very expensive and difficult to cut to size.

Plexiglas also has a green-house property allowing solar energy through and not allowing heat to escape. Extreme heat would put excess stress on all of the electrical equipment and the battery installed in the housing. There may be a better option available.

3.3.3   Wood

Wood is the down and dirty solution the group has decided to implement in the design. Plywood more specifically is widely available and a 4'x8' sheet is under $20. The seams of the enclosure will be sealed with marine grade silicone based

sealant. There are many different methods for keeping wood from distressing after being placed in the elements. Paint or deck sealant can be used to increase the longevity of the housing and protect the wood structure from rotting. Fiberglass could also be used to protect the wood from the environment. Fiberglass has been used for 60 years in the boat industry to keep wooden decks from rotting. Fiberglass is also good at sealing out moisture which is a concern for the project considering the amount of electronics onboard.

3.3.4   Camera Enclosure

The webcam will need to be protected from the weather just like the rest of the equipment. The camera intended for the project was not originally designed to be used in an outdoor environment. The camera must be placed in an enclosure that allows for pan and tilt adjustments to be made without the enclosure having to be modified.

A logical solution would be a weather proof pan and tilt exterior camera mount. The mount must have a weather resistant pass through for wires. The mount below is being suggested to fill this role.

Figure 3.3.4-1 Webcam Housing

This housing features the ability to pan and tilt. It has a grommet to pass wires and is mounted in the horizontal direction. The housing is hinged to allow access to the camera after installation. This webcam housing will be attached directly to the wood housing being designed to house all of the electronics. The webcam housing and arm will help to balance out the weight of the battery making the pole mount easier to execute.

3.4 POWER SUBSYSTEM

3.4.1   Solar Energy

Solar energy in the form of light or heat is one of the most abundant and cleanest energy sources in existence. Solar energy is often called "alternative energy" to fossil fuel energy sources such as oil and coal [1]. Solar energy provides an environmentally friendly alternative to fossil fuels and is vastly growing in product applications. Solar energy was utilized as the primary power source for the KWS design.

3.4.1.1 Solar Cell Characteristics

The solar cell or a photovoltaic cell is the electrical component that converts the energy of the sun's light into electricity. This is called the Photovoltaic effect. The photovoltaic effect is the property of absorbing photons of light and releasing electrons. When these free electrons are captured, an electric current results that can be used as electricity.
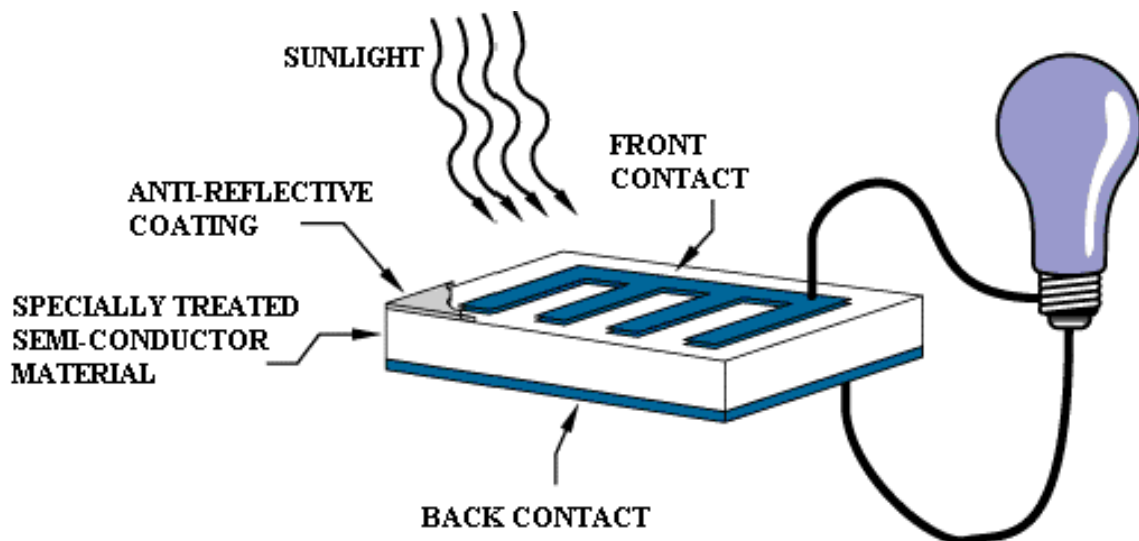
Figure 3.4.1-1 The operation of a basic photovoltaic cell.
Re-printed with permission from nasa.gov [2].

Solar cells are made of at least two layers of semiconductor materials. One layer contains a positive charge and one layer contains a negative charge.   The negatively charged layer contains electrons that are free to move. When the photovoltaic cell is exposed to sunlight, the negative layer absorbs photons causing free electrons to move to the positive layer.   This process creates a voltage difference, which allows an electrical current to be produced when a load is applied across the two layers [3]. This process is the means behind how the security camera will get its power to operate.

3.4.1.2 Solar Panel Characteristics

A group of solar cells connected electrically to each other and mounted in a supportive frame or structure is known as a photovoltaic module. Modules are designed to supply electricity at a certain voltage.   The current produced depends on the amount of sunlight received by the module. A group of modules wired together forms a solar array or panel. Photovoltaic panels produce direct current electricity and the panel surface area is directly proportional to the electricity it creates.

A solar panel was be employed in the power subsystem design to harvest the energy from the sun and convert it into electrical energy to be utilized by the security camera. All of the energy converted from the sun's light is sufficient enough to power every component in the design. A battery was used to store this energy and a charge controller with an implemented maximum power point tracking algorithm was applied between the photovoltaic panel and the battery to ensure maximum charging efficiency.
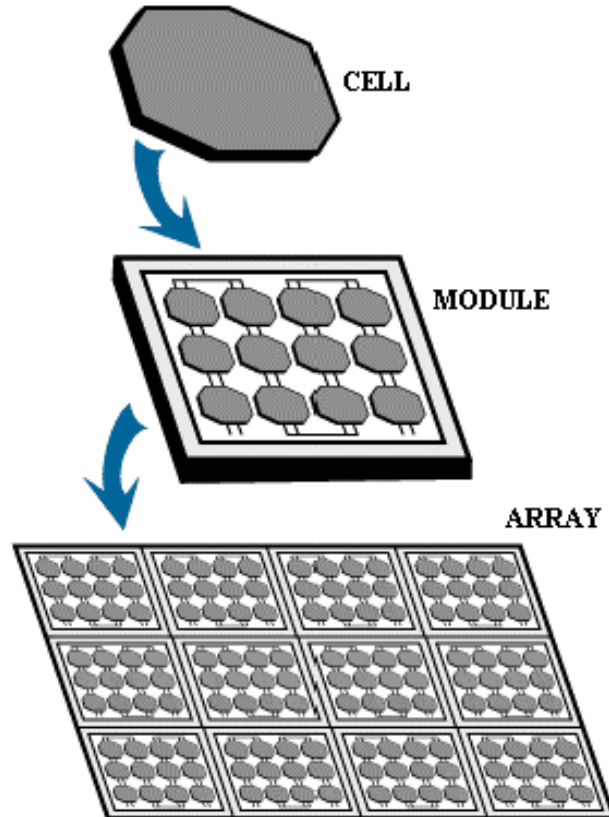
Figure 3.4.1-2 The construction of solar cells into modules and arrays.
Re-printed with permission from nasa.gov [2].

Monocrystalline Solar Panels

The oldest and first type of solar panel is the monocrystalline solar panel. This type of solar panel uses a single, very pure crystal of silicon in the production process. This pure technology results in a more perfect solar cell when compared with polycrystalline. The monocrystalline solar panels have many benefits over polycrystalline, which is why a monocrystalline panel was chosen in this design.

Monocrystalline solar panels are known as first generation solar technology, which proves their durability and longevity. Single crystalline solar panels last for very long periods of time and most performance warranties last for 25 years [4]. Monocrystallline solar panels are also capable of converting the highest amount of solar energy into electricity over any other type of panel.

The disadvantages of using a monocrystalline solar panel over a polycrystalline are minor. The only main concern with single crystalline solar panels is the initial cost of installation. The process to make a single crystalline solar cell can be costly and complex. This process can be very time consuming thus making production of monocrystalline panels a little more expensive than the competing

photovoltaic technologies. When considering overall lasting quality, this negligible factor can be ignored.

Polycrystalline Solar Panels

Polycrystalline solar panels are comprised of a number of small crystals. Polycrystalline solar panels are growing in popularity due to their low cost and average power efficiency. Their power efficiency is slightly lower than the single silicon technology due to energy loss at fusion points between multiple crystals. This is the reasoning behind why a single crystalline solar panel design was applied to the power subsystem design instead.

3.4.1.3 Irradiance

The amount of sunshine reaching the solar cells at any moment is referred to as irradiance. This is a very important concept when considering the maximum power point tracking algorithm. The amount of solar radiation affects the amount of electricity generated by a solar system. The intensity of irradiance or solar radiation is the reason why solar cells perform best during the middle of the day. Irradiance is measured in units of watts per square meter (W/m^2). Watts is a measure of how powerful the light from the sun is. The photovoltaic panel is working at full efficiency when the irradiance from the sun is the highest because solar radiation has a direct effect on the current produced in a solar cell. This was taken into consideration when positioning the security camera, so that maximum efficiency could be obtained.
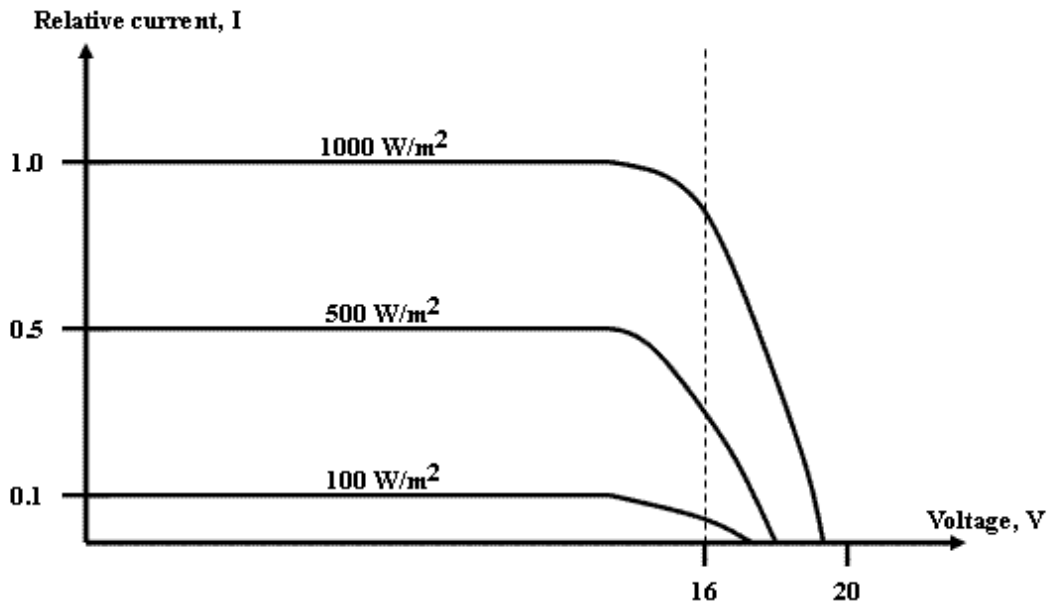
Figure 3.4.1-3 The effect irradiance has on the I-V curve.
Re-printed with permission from Solar Fast Track [5].

There are a few methods to improve solar panel performance to account for times of low-level irradiance. Direct methods of solar tracking and light concentration can be used or an indirect method known as Maximum Power Point Tracking (MPPT), which was utilized in this design, can be used to improve performance efficiency. A MPPT charge controller was designed to optimize the output voltage of the solar panel to match the required voltage level of the battery. This was created by maintaining the output current of the solar panel to maintain the same level of power between the solar panel and the battery. This prevented overcharging of the battery, which harms the life of the battery and decrease efficiency.

3.4.1.4 Photovoltaic Performance and Efficiency

Solar cell efficiency is a measurement of output per given area. The record solar cell efficiency at the moment is around 40%, but uses more expensive materials, which increases the cost of each cell. The majority of solar cells used in photovoltaic panels for electricity production are typically single junction type with efficiency around 15% [6]. This was the approximate efficiency of the solar cells used in the security camera design. This inefficiency is a main concern with using solar energy as a primary energy source, but with small-scale electronic applications such as our security camera, the issue becomes less of a weighing factor. The output efficiency of a solar cell is affected directly by temperature. For most crystalline cells the power output is reduced by .5% for each rising degree of Celsius [6].
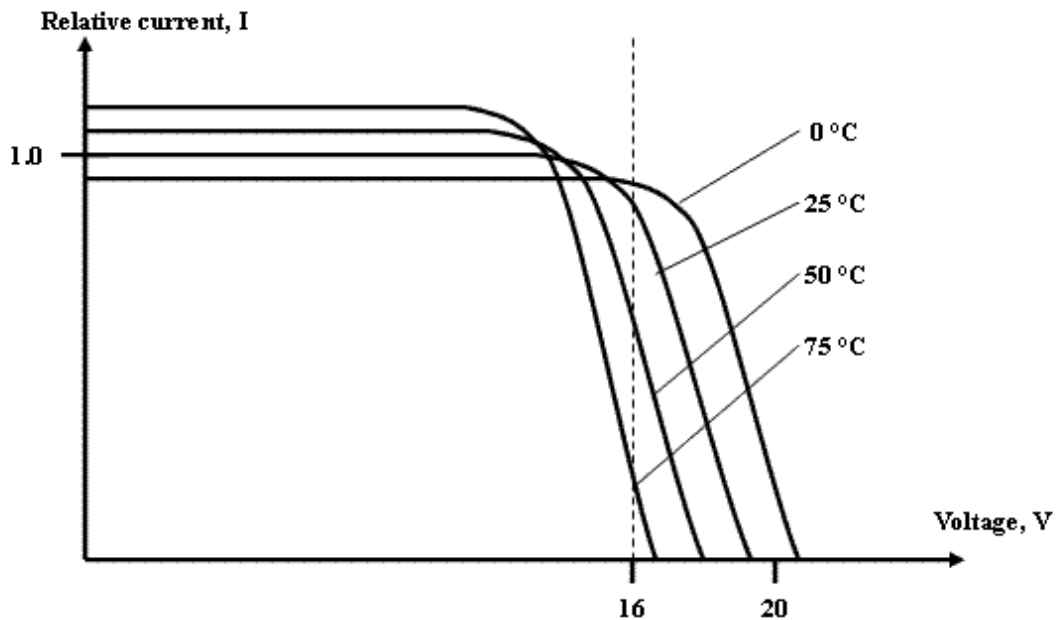
Figure 3.4.1-4 The effect of cell temperature on the I-V curve.
Re-printed with permission from Solar Fast Track [5].

This reduction is important to consider in hot climate regions especially in the summer months and was taken into account when designing the housing for the camera.

Another problematic effect on performance is shading. Solar panels produce less power output when not exposed to sunlight. Partial shading on a portion of the panel could have a huge impact on the output efficiency. The shade effect not only affects the cells that are being shaded, but also the current flow in the other solar cells that are connected in series with the shaded cells. This was also taken into consideration when designing the housing, wiring, and mounting of the photovoltaic panel.

A large majority of the efficiency loss in a basic solar system is the mismatch between the voltage produced by the solar panel and the voltage needed by the battery. As stated earlier, a maximum power point tracking charge controller was implemented to resolve this issue and improve overall charging performance. MPPT prevents damage to the batteries from over-charging by effectively cutting of the current to the PV panel when the battery voltage reaches a required level.

A MPPT system keeps the panel voltage at their maximum power point while supplying the varying voltage requirements of the battery. Manufacturers claim up to 40% power increase from the solar panels when implementing MPPT, which is one of the main reasons this project implemented this important feature [7].

3.4.1.5 Advantages and Limitations

Solar energy has many useful applications and with these applications comes advantages and limitations. There are many advantages of using solar energy. Most importantly, the power source of the sun is free. It is a continuous source of energy that does not deplete or run out. Advancements in the technology have made solar energy very cost effective as well. Most systems do not require routine maintenance, which means consumers will not need to put money into the system after the upfront cost of installation.

Solar technology is further developing and will continue to improve in cost effectiveness and efficiency. Using solar energy as a power source also takes a product off the grid, which means that the product has no reliance on the electricity connection grid. This means that if the power to your house were to go out, any device running on solar energy would not be affected. One of the most important advantages to solar energy is that it produces no pollution to the environment. This environmentally friendly principal is one of the main reasons solar energy is growing in power applications.

With advantages come limitations. Solar energy does not function well when little or no sunlight is present. This can prove to be an immense problem during nighttime or in regions of the world where very little sunlight is available. Another

criticism of solar energy is that it is relatively inefficient. A fairly vast amount of surface area is needed to produce a lot of electricity because of the vast divergence of the sun's light, which creates another disadvantage. Solar panels are very bulky for the amount of energy they create. Creating a small-scale product is extremely difficult when solar energy is being utilized as the primary energy source.

Another disadvantage to solar energy is the initial cost of installing the equipment. Solar panels can prove to be very expensive for the amount of energy they potentially create. Both the advantages and limitations need to be considered when attempting to create a product that utilizes the feature. For the application of this particular design, the advantages outweighed the limitations, which is why solar energy was executed in the final design of the security camera.

3.4.2   Batteries

A battery can be defined as any device that stores energy for later use. In electrical terms, batteries store electricity as chemicals inside the battery charge. A battery is an electrochemical device that converts chemical energy into electricity by a galvanic cell. A galvanic cell can be defined as a device composed of two electrodes of different metals, a cathode and an anode, and an electrolyte solution between them. A battery is composed of two or more of these galvanic cells connected in series [8]. A sealed lead acid or gel cell battery was selected for the camera design for a few reasons. Discussed below is how the group came to the conclusion of which battery type to use.

3.4.2.1 Lithium-Ion Batteries

Lithium-ion batteries are one of the most prominent and fastest growing battery types used in portable electronics. Lithium is the lightest metal and has the greatest electrochemical potential. Lithium provides the largest energy density per pound compared to other metals used in batteries. Due to safety conditions, a non-metallic battery was introduced using lithium ions. Lithium-ion batteries are a low maintenance battery and the self-discharge is less than half of a standard nickel-cadmium battery.

Lithium ion batteries also have many disadvantages. These types of batteries are not very resilient to abuse and require a protection circuit to maintain safe operation. A protection circuit within the battery limits the peak voltage of each cell during charge and the temperature in each cell is monitored to prevent heat damage to the cells.

Rapid deterioration and aging when not in use is another prominent concern when applying lithium-ion batteries. Lithium-ion batteries are not the best battery

to use when utilizing solar energy to charge the battery. Due to these limitations a lithium-ion battery was not chosen in this design [9].

3.4.2.2 Gel Cell Batteries

Gel Cell batteries are a type of sealed battery that contain acid that has been gelled by the addition of silica gel [10]. The advantage of using a gel cell battery is that the acid will not spill if the battery is broken, but there are many functional disadvantages to using this type of battery.
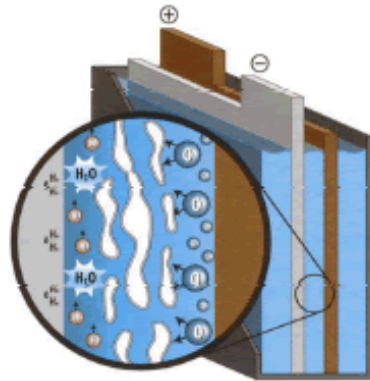
The voids that develop with the
gelled electrolyte battery design.

Figure 3.4.2-1 Gelled Cell Battery.

This figure illustrates the gelled cell battery and its ability to produce voids or pockets within the gel when the amperage is increased. This can impede acidic flow and decrease the capacity of the battery, which is another downside to using a gel cell battery in this design. Re-printed with permission from bd batteries [11].

The charge rate of a gel cell battery is much slower to prevent gas from damaging the galvanic cells. Current must be limited when using this type of battery in solar electric systems, which means they must be charged at a lower voltage than other battery types. The newer AGM batteries have all of the advantages of a gel cell battery without the disadvantages, but was too expensive for application in this design. Therefore a sealed lead acid battery was chosen for final implementation.

3.4.2.3 AGM Batteries

An AGM, or absorbed glass mat battery uses glass mats between conductive plates in the battery. The plates in the battery are very tightly packed and mounted and can withstand vibrations and shock better than any other battery type. This type of battery has all the advantages of a gel-celled battery, but is more resistant to abuse.
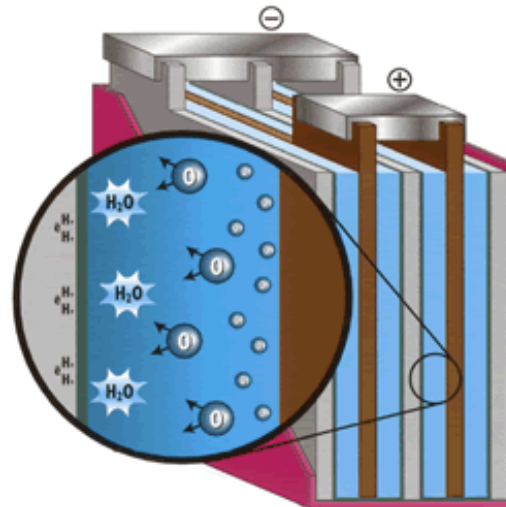
The recombination of the gases on charge with the absorbed glass mat (AGM) design.

Figure 3.4.2-2 Absorbed Glass Matt Battery
This figure illustrates the absorbed glass matt battery and its ability to eliminate deep pockets when charging. This is a major advantage to using an AGM battery over a gel-celled battery. Re-printed with permission requested from bd batteries [11].

Most types of AGM batteries will not leak acid even if they are broken. AGM batteries also require no maintenance and can survive most freezes. This was originally the type of battery that was decided to be implemented in this design due to its durable qualities. But AGM batteries turned out to be a little too expensive for the group.

3.4.3   Battery Charging

Battery charging takes place in three basic stages, bulk charge, absorption charge, and float charge. The first stage of battery charging is the bulk charge, where current is sent to batteries at the maximum safe rate they will accept until voltage rises to around 80 – 90% full charge level. A typical voltage level at this stage typically ranges from 10.5 to 15 volts.

The second stage of battery charging is called the absorption charge, where the voltage level remains constant and the current gradually decreases as the internal resistance in the battery increases. During the absorption charge, the charger is putting out maximum voltage. Voltages at the absorption stage are typically around 14.2 to 15.5 volts.

The third and final stage of battery charging is called the float charge stage. After the battery reaches full charge, the voltage level is reduced to typically around 12.8 to 13.2 volts to prevent overcharging and damage to the battery. This charge maintains the voltage to prevent the charged battery from discharging [12].
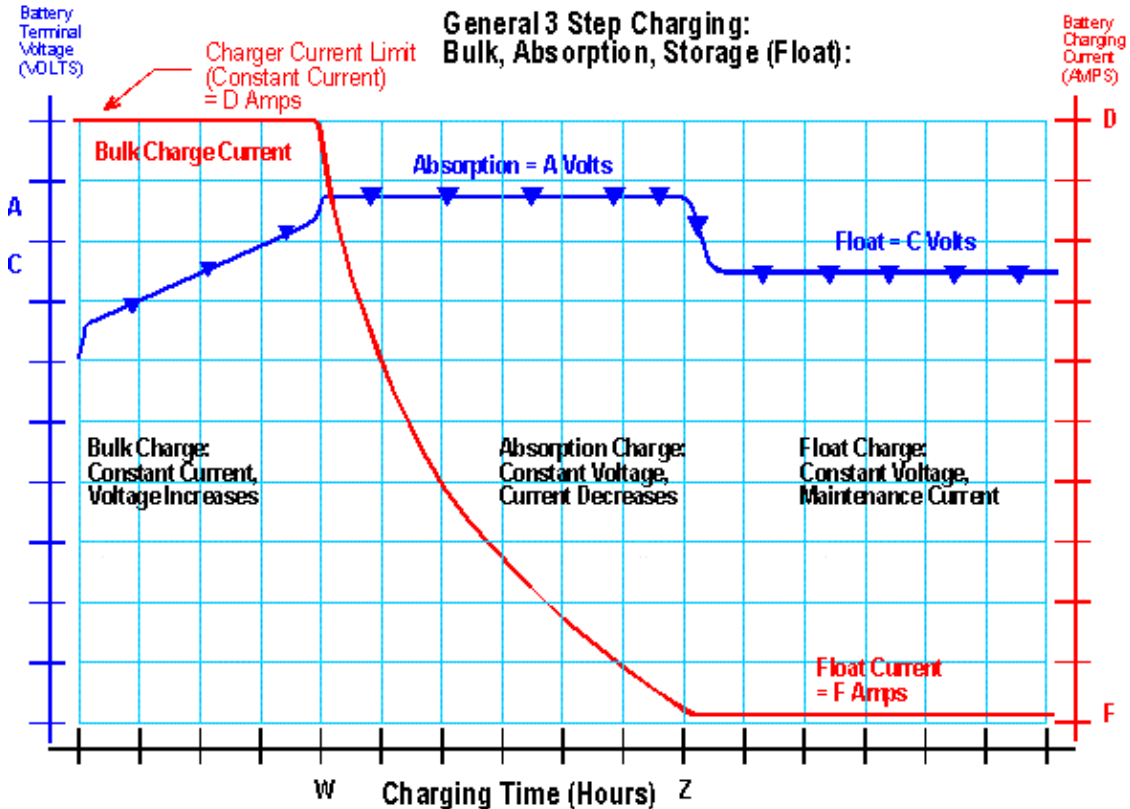
Figure 3.4.3-1 The General 3 Step Charging Algorithm
Re-printed with permission requested from batterytender [13].

Understanding the charging stages of the battery aided in the determination of the charge controller design. A charge controller with an implemented maximum power point tracking algorithm was used to regulate voltage levels to achieve maximum power efficiency and battery life.

3.4.4 MPPT Charge Controller

A charge controller regulates the voltage and current flow from the solar panel to the battery. The charge controller controls the voltage that is applied to the battery and the amount of charge current supplied to the battery. Regulators for solar systems are designed to keep the battery charge peaked without overcharging. Overcharging the battery destroys the galvanic cells, which damages the battery and eventually makes it useless and inefficient.

MPPT charge controllers use smart technologies, such as microcontrollers to compute the highest possible power output at any given time. The input voltage from the PV panel was monitored and regulated to prevent power loss. When the input voltage is higher than the required output voltage, the MPPT charge controller lowers the voltage while simultaneously increasing the current to the

battery. The result of using a MPPT charge controller to regulate the input voltage is higher power efficiency. Solar power lost during the charging process is drastically reduced with an implemented maximum power point charge controller.

To facilitate a better understanding of the functionality of a MPPT charge controller, consider the following situation. The goal of the solar system is to charge a 12-volt battery, but the input voltage from the solar panel is around 15 volts. Without the implemented charge controller, a direct connection between the battery and the Photovoltaic panel would decrease the operating panel voltage to 12 volts, which would clearly be a decrease in efficiency. The solar system would not be operating at its maximum power point and this over charging voltage between the solar panel and the battery would be detrimental to the functionality of the battery.

Instead of allowing this waste of energy, the MPPT charge controller allows the solar panel to operate at its maximum power point without harming the battery. DC-to-DC converters are used to compensate for the difference in voltage needed to remain functional. This implementation allows the system to optimize power efficiency and prevent significant losses.

3.4.5 MPPT Algorithms

The current and voltage at which a solar module generates the maximum power is known as the maximum power point. There are several common algorithms that are used to implement the maximum power point tracking feature. Each method varies in complexity based on the type of tracking they utilize.

The four methods used are Perturb and Observe, Incremental Conductance, Current Sweep Method, and Constant Voltage. The two most common methods and the reasoning behind which one was selected for application in the charge controller design is discussed below. Important factors to consider when choosing a technique to perform maximum power point tracking are sensors used, the ability of the algorithm to detect multiple local maxima, costs, and convergence speed [14].

The number and type of sensors used in the charge controller design depend on which MPPT technique applied. An increase in the quantity of your sensors makes the MPPT more accurate, but also more expensive and complex. For a small-scale application like the security camera, the amount of sensors used is not as complex as some of the other larger scale solar module applications.

The irradiance levels at different points on the solar panel can vary, leading to multiple local maxima points in one system. The maximum power point tracking algorithm applied determined the true maximum power point instead of locating multiple local maxima points. This was very important when designing the

charge controller because identifying a point that is not the maximum power point can drastically reduce efficiency.

The type of algorithm chosen for implementation also determines the amount of resources needed to run it. The type of hardware and the number of sensors used in the charge controller depend on the algorithm implied. Therefore, this had a direct effect on the cost of designing the controller.

As with all electronics, there is the importance of high speed. The time taken to converge to the maximum power point should be short in an effective and high performance system. The maximum power point system has to maintain the load at the maximum power point in a timely and efficient manner [14]. The two most commonly implemented MPPT algorithms are Perturb and Observe and Incremental Conductance. The implemented method chosen for this design was selected based on a few factors discussed in the following sections.

3.4.5.1 Perturb and Observe

The "Perturb and Observe" method is the most commonly applied algorithm due to its ease of implementation. This method modifies the operating voltage or current from the solar panel until the maximum power is obtained. The system increases the operating voltage supplied to each cell until the power output starts to decrease. The operating voltage is then decreased back to the maximum power point value of the system.

This process continues until the system is fully operating at the maximum power point value, meaning that the output power value oscillates around the maximum power point value until the system stabilizes. This method has its disadvantages due to the fact that the power value obtained still oscillates around the maximum power point when the system is in steady state. This method can also malfunction during rapidly varying levels of irradiance.
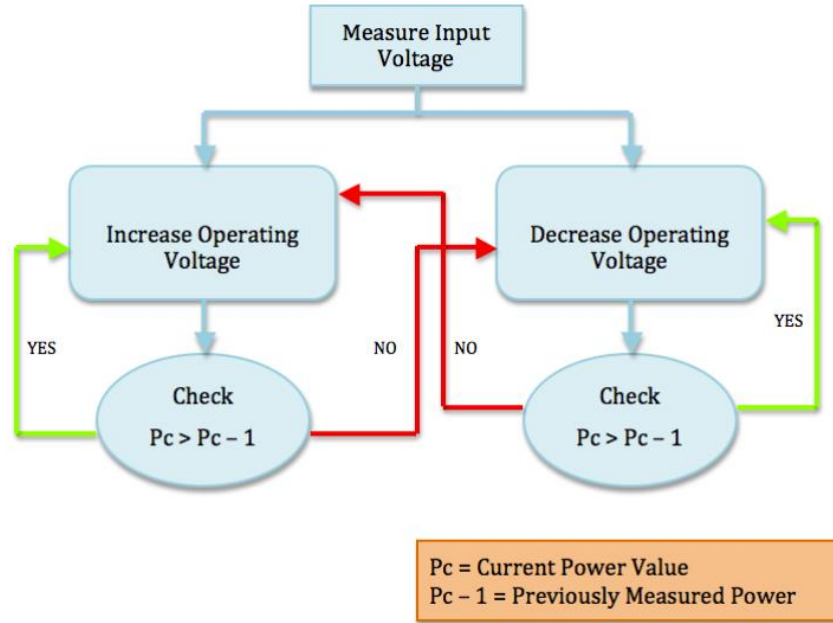
Figure 3.4.5-1 Flowchart for the Perturb and Observe MPPT Method

This algorithm was implemented in the design of the charge controller for the security camera due to its simplicity. The method is simple to implement which means it can be implemented quickly and effectively.

3.4.5.2 Incremental Conductance

A contrasting and more complex algorithm is the incremental conductance method. This method utilizes applied mathematics to determine when the slope of the power-voltage curve is zero. The maximum power point value occurs at this point. The slope of the power voltage curve is positive to the left of the maximum power point value and negative to the right of it.
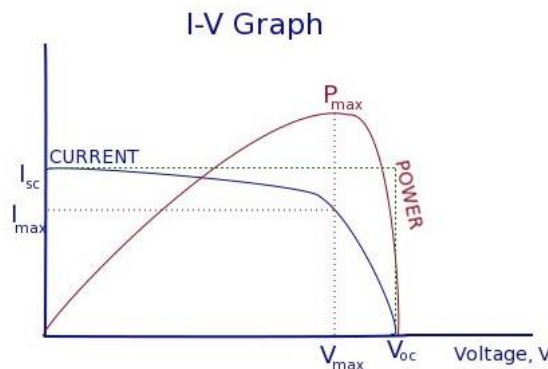
Figure 3.4.5-2 The I-V Graph for a PV panel

This figure illustrates the location of the maximum power point. Re-printed with permission requested from The Sheffield Solar Farm [15].

The solar module maintains this power point unless a change in the input current occurs. This can happen when changes in irradiance occur, and the algorithm modifies the operating voltage accordingly until the new maximum power point is reached.
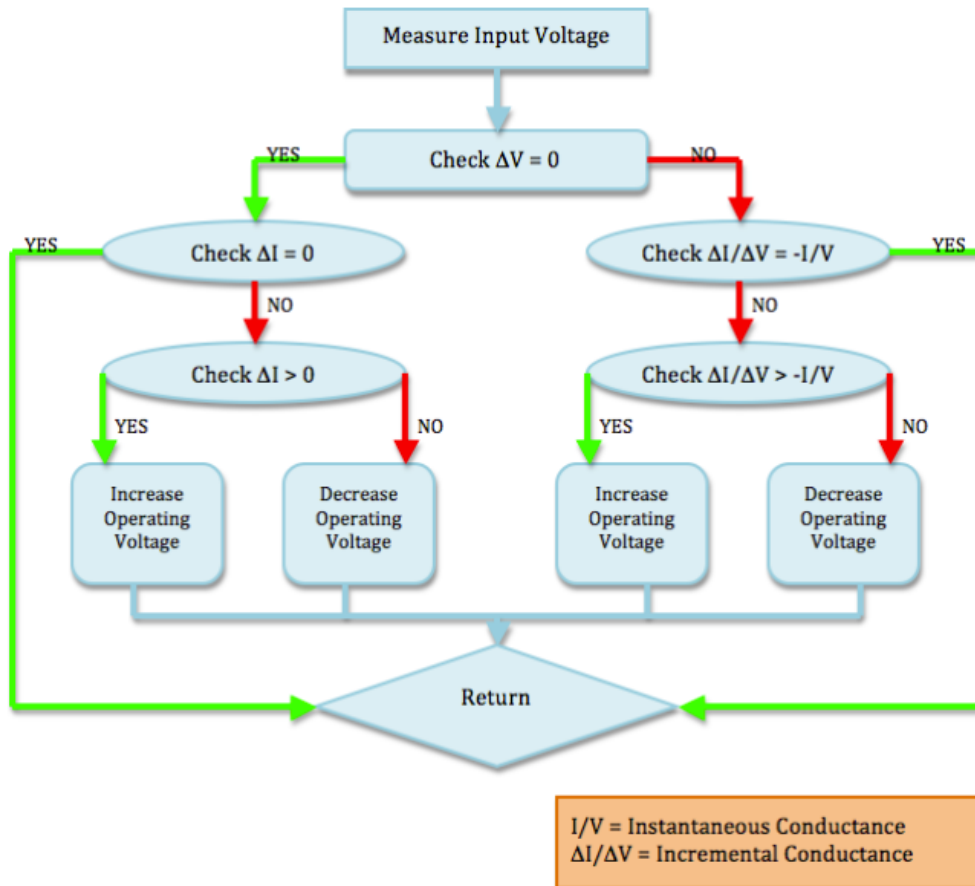
Figure 3.4.5-3 Flowchart for the Incremental Conductance MPPT Method.

As you can see from the flowchart above, the logic behind the Incremental conductance method is much more complex than that of the Perturb and Observe method. The incremental conductance has an advantage over the Perturb and Observe method because it can determine the maximum power point value without oscillations.

Because of this, the incremental conductance method can operate much more efficiently in varying levels of irradiance. Due to its complexity though, this method takes much longer to locate the maximum power point. This causes the speed of the sampling frequency rate of the operating voltage and current to decrease. This complexity factor alone led the group to the decision of selecting

the Perturb and Observe MPPT Method over the Incremental Conductance method.

3.4.6   Selected Microcontroller

The selected development board to prototype the MPPT algorithm was the Arduino Uno R3. The board operates using an ATmega328 microcontroller, which was programmed with the Perturb and Observe MPPT algorithm to determine the maximum power point. This board was chosen because the applied programming language is easy to navigate and it has a relatively fast clock speed. The prototyped design on the development board was later converted onto a printed circuit board using Cadsoft's Eagle software.

3.4.6.1 ATmega328 Microcontroller

The Atmel 8-bit AVR RISC-based microcontroller operates between 1.8 – 5.5 volts. A 5-volt voltage regulator was used to power the microcontroller. This high performance microcontroller combines the following components to execute powerful instructions in a single clock cycle: 32 KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose registers, three timers/counters with compare modes, internal and external interrupts, serial programmable USART, A byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, and five software selectable power saving modes [16].

The ATmega328 microcontroller has 14 digital I/O ports, 6 of which can be used as pulse width modulation outputs. The PWM pins allow the input voltage to be varied in order to locate and track the maximum power point. Two or four PWM outputs are required for the system depending on the design of the DC-to-DC buck converter circuitry. In this design, two of the PWM outputs were utilized. The specifications of this microcontroller met all the requirements of our solar system. It was chosen based on compatibility and ease of implementation.

Atmega168 Pin Mapping

Arduino function

Arduino function		Pin		Pin		Arduino function

reset — (PCINT14/RESET) PC6 □ 1

digital pin 0 (RX) — (PCINT16/RXD) PD0 □ 2

digital pin 1 (TX) — (PCINT17/TXD) PD1 □ 3

digital pin 2 — (PCINT18/INT0) PD2 □ 4

digital pin 3 (PWM) — (PCINT19/OC2B/INT1) PD3 □ 5

digital pin 4 — (PCINT20/XCK/T0) PD4 □ 6

VCC — VCC □ 7

GND — GND □ 8

crystal — (PCINT6/XTAL1/TOSC1) PB6 □ 9

crystal — (PCINT7/XTAL2/TOSC2) PB7 □ 10

digital pin 5 (PWM) — (PCINT21/OC0B/T1) PD5 □ 11

digital pin 6 (PWM) — (PCINT22/OC0A/AIN0) PD6 □ 12

digital pin 7 — (PCINT23/AIN1) PD7 □ 13

digital pin 8 — (PCINT0/CLKO/ICP1) PB0 □ 14

28 □ PC5 (ADC5/SCL/PCINT13) — analog input 5

27 □ PC4 (ADC4/SDA/PCINT12) — analog input 4

26 □ PC3 (ADC3/PCINT11) — analog input 3

25 □ PC2 (ADC2/PCINT10) — analog input 2

24 □ PC1 (ADC1/PCINT9) — analog input 1

23 □ PC0 (ADC0/PCINT8) — analog input 0

22 □ GND — GND

21 □ AREF — analog reference

20 □ AVCC — VCC

19 □ PB5 (SCK/PCINT5) — digital pin 13

18 □ PB4 (MISO/PCINT4) — digital pin 12

17 □ PB3 (MOSI/OC2A/PCINT3) — digital pin 11(PWM)

16 □ PB2 (SS/OC1B/PCINT2) — digital pin 10 (PWM)

15 □ PB1 (OC1A/PCINT1) — digital pin 9 (PWM)

Digital Pins 11,12 & 13 are used by the ICSP header for MISO, MOSI, SCK connections (Atmega168 pins 17,18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.

Figure 3.4.6-1 Pin Mapping of the ATmega168
This figure illustrates the pin mapping of the ATmega168, which is identical to the Atmega328 mapping. This pin mapping scheme was utilized when integrating the voltage and current sensing circuits, and the DC-DC buck converter into the microcontroller. Re-printed with permission requested from Arduino [17].

3.4.6.2 Arduino Uno R3

The Arduino Uno board is an open source hardware platform based on the ATmega328 microcontroller. The board has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ISCP header, and a reset button. The board is powered by a 5-volt voltage regulator circuit and contains everything needed to support the ATmega328 microcontroller [18].

3.4.7   DC-to-DC Regulators

The input voltage from the solar panel varies in magnitude based on the irradiance and temperature of the solar panel. A DC-to-DC regulator is required to regulate the input voltage of the panel to match the required operating charging voltage of the battery. The supplying battery voltage varies based on the load connected to it.

The power supplied to the load of the security camera is consistent because user operation does not need to be considered. The security camera runs on a single

35

invariant mode 24 hours of the day so the power required by the system remains constant. In order to maintain optimized battery charging efficiency, the input panel voltage and current should coincide with the required battery charging stage at all times.

A basic DC-to-DC regulator configuration is comprised of a capacitor, an inductor, a diode, and a power switch. These components arranged in different configurations form different types of DC-to-DC regulators. The two main types of DC-to-DC converters are the buck and boost converters. As seen in the previous I-V graph, current and voltage are directly proportional to each other. Therefore in buck mode, the voltage needs to be decreased as the current increases. In boost mode, the current needs to be decreased as the voltage rises.

3.4.7.1 Buck Converter

In this design a buck converter was utilized to regulate the voltage and current. As mentioned before the buck converter converts a high voltage and a low current into a lower voltage and higher current. The software controlled Arduino charge controller with the implemented MPPT algorithm controls the buck converter to step down the input voltage when the input voltage exceeds the voltage limit of the battery.

In a simple model of the buck converter a diode utilized as an uncontrolled switch is connected in parallel with a capacitor, the input voltage and a load, which dictates the output voltage of the circuit. A MOSFET used as a controlled switch is connected between the input voltage source and the diode, and an inductor is connected between the diode and the capacitor.

The uncontrolled switch of the diode and controlled switch of the MOSFET achieve unidirectional power from the input to the output. The capacitor and inductor serve to store and transfer energy from input to output. They also filter the input voltage and current to make the measurement more accurate.

The microcontroller creates a pulse width modulation that turns the MOSFET switch on and off, creating two different circuit configurations for the buck converter. The two operating states for the buck converter are one in which the switch is closed, and one when the switch is open. When the switch is on for a certain time duration, the switch conducts current through the inductor and the diode becomes reverse biased. When the switch is closed the inductor absorbs power as the current increases.

When the switch is turned off, the inductor current continues to flow due to the energy stored in the inductor. The current then flows into the diode for a certain time duration until the switch is turned on again. The resulting positive voltage across the inductor causes a linear increase in the inductor current.
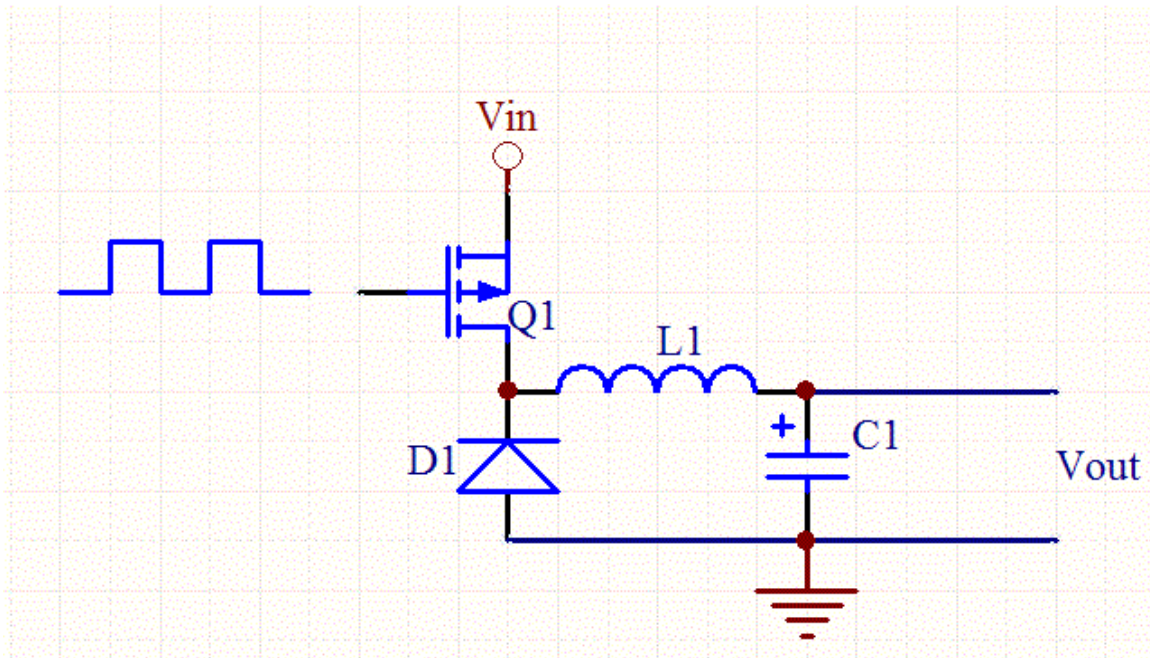
Figure 3.4.7-1 The Basic Circuit Schematic for a Buck Converter.
Re-printed with permission requested from Daycounter [19].

The buck converter was originally built on top of an Arduino shield protoboard controlled by the Arduino microcontroller. The design was initially prototyped on the Arduino protoshield to confirm functionality, and was then later transferred to a printed circuit board design. The DC-to-DC buck converter circuit sends the maximum power of the solar panel to charge the battery, which powers the security camera and its components.

3.4.8   Voltage and Current Sensing

The voltage and current sensing circuits measure the input voltage and current from the solar panel, which determine how the maximum power point tracking algorithm operates within the microcontroller. The sensing circuits allow the microcontroller to monitor the voltage at the input and output of the DC-to-DC regulator.

The voltage and current sensing circuits output an analog voltage, which is read in by the analog pins, A0 – A2 on the ATmega328 microcontroller. These voltages must be between 0 and 5 volts to prevent damage to the microcontroller. There are a total of three sensors; one for the solar panel voltage input, one for the solar panel current input, and one for the output voltage to the battery.

The microcontroller takes the analog readings from the sensing circuits and converts them into digital readings that the microcontroller can process through its programmed software algorithm. The microcontroller manipulates the

measurements from the sensing circuits to determine the maximum power efficiency.

3.4.8.1 Voltage Sensors

The voltage sensors are responsible for calculating the operating voltage from the solar panel. The voltage sensors monitor and calculate the voltage output from the solar panel by implementing a simple voltage divider circuit configuration. Two resistor values are connected in series with each other and in parallel with the solar panel. The resistor values were calculated based on the input power specifications of the solar panel and the microcontroller.

The voltage across the second resistor is the output voltage to be monitored to detect variance in the input voltage from the solar panel. The value of the first resistor was designed to be a large value to prevent damage to the microcontroller. The same design implementation was utilized when monitoring the voltage of the battery.

The monitored analog voltage is sent to the microcontroller. The value is sent to the microcontroller's analog to digital converter. The digital measurement value of the voltage is utilized by the MPPT software to determine the maximum power point. This value is then sent to the DC-to-DC converter to convert the value back to an analog voltage usable by the battery.

3.4.8.2 Current Sensors

A current sensor was applied to the overall schematic of the design to ensure maximum power output from the PV panel. The sensor monitors the input current from the PV panel at all times. The current value is sent to the microcontroller in the same way the voltage is read. The current and voltage are directly proportionally to each other and are both essential in determining the maximum power point. The current sensor IC picked for the design is the LTC6101HV.

The LTC6101HV integrated circuit is a current sense amplifier used to monitor the input current. This sense amplifier is a very precise, low-cost, and compact current-sensing solution. The high-side current monitoring IC is perfect for battery-powered systems because it does not interfere with the ground path of the battery charger [20].

3.5 CAMERA

This design features the Logitech C110 1.3 Megapixel Webcam as the surveillance camera. This camera was selected because both the features it offered and its durability. The goal was to pick a camera that would not limit any performance aspects throughout the entire project design and build. For example

the camera should not limit the device's video resolution, or the selection of an operating system. After categorizing all of the possible cameras based on their system requirements, quality and parts, the decision was simple.

Two major benefits of this camera is flexibility of both system requirements and video feed aspects. Meaning there are multiple built in recording modes which vary resolution, focus and color contrast to provide the best possible video quality. Since this camera is designed to function outdoors it must be resistant to weather. Thus a camera containing a CMOS image sensor and plastic lens was selected. This is explained in depth in the image sensor of section of this design report.

This camera offers flexibility in both software and hardware selection. It is a UVC compliant device. This means that it is compatible with the vast majority of operating systems. Linux kernel drivers were selected for this device, which is supported by this camera. Both types of USB ports (1.1 and 2.0) are supported, for this build only USB 1.1 is utilized to prevent excess strain and power consumption of video processing by the CPU. It also supports video streaming at 640 x 480 pixels. In addition to this it has a single frame capture feature. The most crucial aspect of this camera is its durability

Figure 3.4.8-1 Logitech C110 Webcam

3.5.1   Output/Video Class

To avoid unnecessary compatibility issues a Universal Video Class (UVC also called USB) video camera was selected for this project. This class of video feed devices provides cross-platform compatibility. This camera class may be run on literally any operating system including Microsoft Windows / Windows CE, Mac OS X, and every distribution of Linux. There are several reference designs that utilize a camera of this video class running on specifically Ubuntu, the most favored Linux distribution.

Additionally all cameras within this class are capable of still-frame photo capture, allowing this feature to be worked in at a later point. The still-frame photo capture feature is not included in the original design specifications because it is not currently supported by the Linux distributions UVC drivers[1]. However the Linux UVC driver does have a similar feature called single frame capture. This camera feature retrieves a single video frame from the video feed and saves the image as a jpg photo.

Regarding the majority of devices on the market, the still-frame feature offers a higher quality resolution than frame capture; however this sacrifice is warranted simply because of the community support behind the Linux distributions.

3.5.2   Camera Requirements (System)

As with many devices, this camera has two sets of system requirements. One set is for basic video quality and the subsequent set is to produce 1.3 Mega Pixel video quality. This product design will meet both sets of requirements. However these requirements are detailed for a standard operating system, not a system specifically designed for this camera. As shown below in order to function properly this camera requires 2 GB of RAM. This includes the necessary memory to run the operating system as well. This camera system runs on a basic version of Linux which will require less RAM than desktop operating systems. So this will increase flexibility within these parameters. All of the data displayed in the table below was gathered directly from Logitech's website[2].

System Requirements	Basic Requirement	1.3MP Requirement
CPU (Minimum)	1 GHz	2.4 GHz
CPU (Recommended)	1.6 GHz	2.4 GHz
RAM (Minimum)	512 MB	2 GB
RAM (Recommended)	2 GB	2 GB
Hard Drive Space	200 MB	200 MB
Connection Port	USB 1.1	USB 2.0
Upload Speed	N/A	1 Mbps

[1] http://www.ideasonboard.org/uvc/#status
[2] http://www.logitech.com/en-hk/webcam-communications/webcams/7794

3.5.3   Video Resolution/FPS4

Frames per second (FPS) is also a crucial aspect of any camera. The final design will offer a variable rate of fps, which can be increased or decreased depending on image processing capabilities, and other video transmission parameters. Also the autofocus feature of this camera automatically adjusts the rate based on video quality factors, such as low light and picture sharpness.

So this design needed a camera with a high enough frame rate, such that the design is not limited by the camera. This is to prevent slowing the fps of the video

relay system due to the cameras' high fps rate. At a resolution of 640x480 pixels, this camera can produce 30fps. However since this system utilizes wirelessly streams to mobile devices, this is more data than can be processed and displayed.

A defining feature of any camera is video resolution. In regards to video quality, HD (640 x 480 pixels) was desired since it will not inhibit video quality of the final system output (User PC or other device). Since this device runs Linux drivers, which does not support still-frame feature, this design uses the frame capture feature. The frame capture simply grabs a single frame from the video stream, the resolution of the video stream is directly limited by the resolution of the captured image. So with this camera it is possible to retrieve images from the video feed at 1.3 MP.

3.5.4   Lens

Camera lens are made of either plastic or glass. Typically CMOS cameras contain a plastic lens, while CCD cameras offer a glass lens. The Logitech C110 webcam has a plastic lens with an auto-focusing feature that will improve video quality. The focusing mechanism is a new fluid crystal design that auto-adjusts fps and color intensity. Since this camera will be utilized as a surveillance camera, this feature will be very beneficial. Ideally this focusing feature will help the camera to focus on any movement. Logitech has not disclosed any specific functions or mechanisms behind their fluid crystal zoom, undoubtedly for competitive reasons. As a result this topic is covered in a relatively vague fashion, in comparison with the other sections of this design report.

3.5.4.1 Plastic

A draw back to plastic lens is that it more prone to scratching. This camera is designed to function in an outdoor environment. So to overcome this, the camera will be mounted behind a protective window on the units housing. This window is made of transparent plastic sheet that is weather proof or at least resistant. This process is discussed further in the housing section of this research report, and an image of the housing is shown.

Below, in Figure 3.5.4-1, a generic CMOS camera from a webcam featuring a plastic lens is depicted. Like the Logitech C110 webcam, this camera also features a microphone. The camera used for this design will not utilize the microphone.

Figure 3.5.4-1 Plastic Lens CMOS Camera

3.5.4.2 *Glass*

Glass lenses offer superior scratch protection. A glass lens is desirable for this design. However nearly all glass lens cameras utilize a charged coupled device image sensor. CCD image sensors are not desirable for this design because the camera unit will be stationary. This image sensor aspect is intertwined with which lens type this project will utilize. The decision, of which lens type would be ideal, is based upon which type of image sensor is desired. This image sensor aspect is discussed further in the following subsection. The pros and cons of these image sensors are discussed in great detail within the following subsection appropriately named image sensor.

In addition camera's that feature a glass lens are almost always far more expensive. Typically CCD cameras price vary anywhere from three to ten times the price of a CMOS camera. These price comparisons are based on two cameras of equivalent pixel count. Purchasing a CCD camera would use unnecessary financial resources. These financial resources could be utilized in other sections of this project.

3.5.5   Image Sensor

There are two prominent types of image sensors on the Webcam market. This decision was between Charged Couple Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) cameras'. CMOS and CCD devices both output a

digital signal; however they differ on the location of their parts. The table below shows the comparison of the two. A diagram of how these devices produce a digital signal is displayed in figure 3.5.5-1 and 3.5.5-2 at the end of this section.

	CMOS	CCD
Price	Inexpensive	Expensive
Power	Low power consumption	Consumes up to 100x the power of CMOS
Noise	Susceptible to noise	Low noise
Maturity	Less mature	Long production span

3.5.5.1 CMOS

Typically CMOS image sensors have components related to timing and video processing on the semiconductor itself. This design has both benefits and drawbacks. For one CMOS sensors are more rugged than CCD cameras because their internal timing mechanisms are not dependent on the cameras circuit board. This advantage is very beneficial for this design because it will help the camera in two ways.

The first advantage is that the device will be more reliable and have a longer life span. The second advantage is that video quality will degrade much slower over time, than if a CCD was selected. On board components also make CMOS cameras more power efficient than CCD cameras.

Since this camera system is reliant on solar power alone, energy consumption has a huge effect on both the battery life and reliability of the device. Because these sensors have less data through put they are more vulnerable to noise from camera movement. On a positive note this vulnerability to noise will not affect the performance of the camera in any way, since it is stationary.
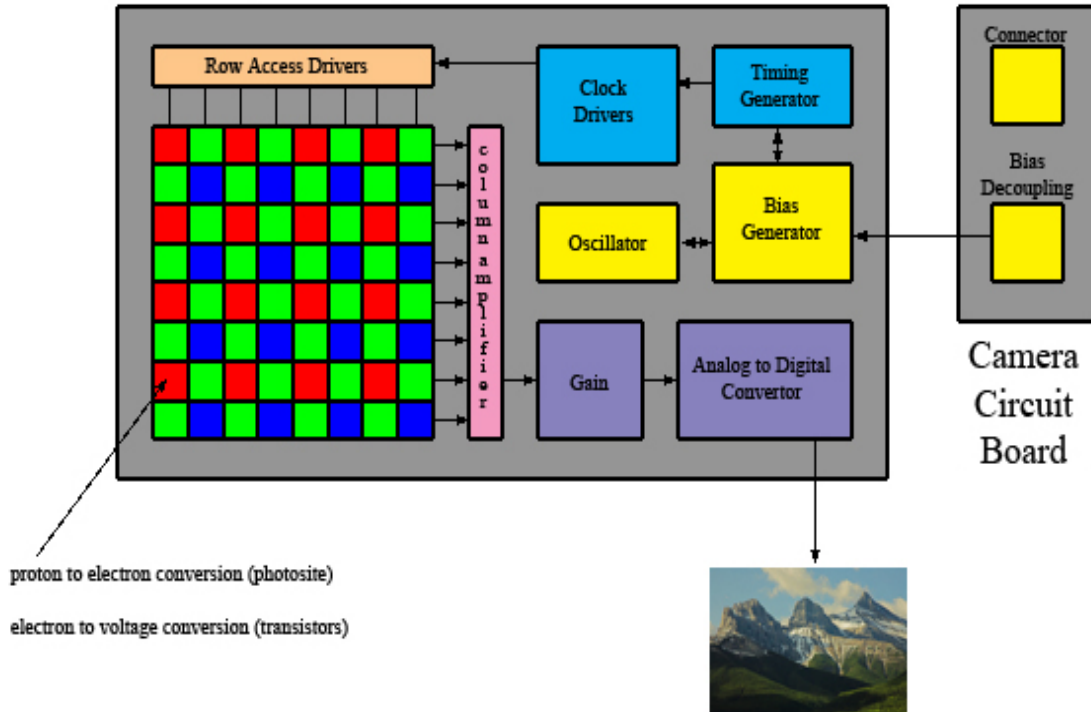
Figure 3.5.5-1 CMOS Image Sensor

3.5.5.2 CCD

The diagram below shows the locations of parts on a standard CCD image sensor. They rely heavily on the camera's circuit board for timing and video processing. This allows for more data through put; however the camera's circuit board is far less power efficient than the sensor.

Another drawback to this design is less reliability in rough environments. This was a factor in the decision, since the design is intended solely for outdoor use. CCD camera's biggest advantage is noise resistance due to movement of the camera. So this sensor would be ideal for an application that involves mounting the camera to person, vehicle or any other moving object. However, this offers the design little to no benefit, since the camera will be stationary.
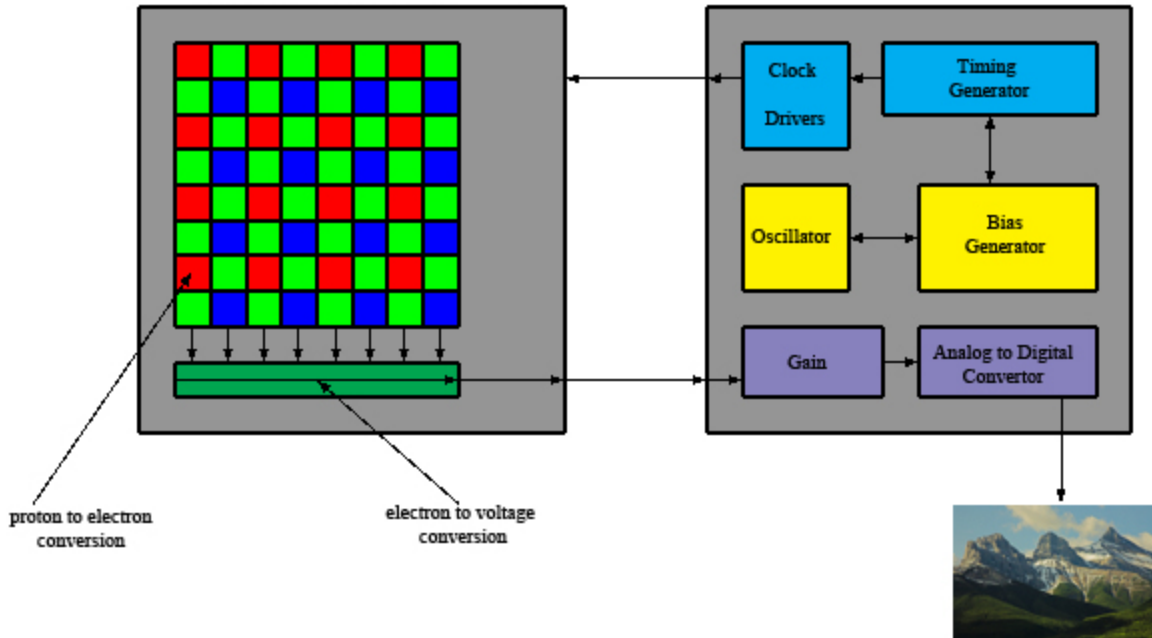
Figure 3.5.5-2 CMOS Image Sensor

3.5.6   Operating System

All possible operating system were placed into two categories whether it was intended for running a personal computer or a mobile device. An operating system designed for a mobile device is ideal. These systems offer a number of performance benefits. Primarily, allowing for a slower CPU, less RAM and a smaller hard disk. All of these factors decrease the power consumption of the device. After deciding to use a mobile device operating system there were three possible platform choices. The decision came down to Linux, Android or CE (Windows).

For this project using a customized kernel of Ubuntu (Angstrom) will free up the processor. Once the system is powered on, the current kernel will be completely removed. This will be replaced with a general kernel package containing Angstrom and many libraries that will not be utilized in this design. The touchscreen on the starter kit can be used to display all of the libraries contained within the kernel. This allows for quick deletion of libraries dedicated to unused input and output ports. As well as any wireless data transfer capabilities that are not utilized.

3.5.6.1 Linux v12.1 Distributions

The original version of Ubuntu was originally developed for use on smartphones and other mobile devices, same as Android. This application development is ideal for this design because power consumption in mobile devices has a very

high priority. Since the device is solar powered, this trait is highly beneficial. Embedded systems applications are ideal for Linux because it's not dependent on a GUI (graphical user interface). There were multiple Linux distributions available, including Ubuntu v12.1, Angstrom v12.1, Lubuntu v12.1, Kubuntu v12.1 and Xubuntu v12.1. The later four selected are altered versions of the original Ubuntu to be less cumbersome to the system. The decision came down to which of these had the largest support following, the most available packages and camera compatibility.

3.5.6.2 *Angtrom v12.1*

For this design Angstrom v12.1 was the best option, despite the fact that it requires more system performance. TI customized Ubuntu for their Arm 8 processor. The primary reason Ubuntu/Angtrom uses more system resources is the graphics involved with user interface. While these graphics are ideal for many applications, it is not desirable for a minimalistic power conscious system. Fortunately this distribution offers a quick fix. After the system has been installed, during startup a relatively simple set of commands can be executed to disable the high end graphical features. With the advanced graphics disabled it is still possible to interface with the system. This is done through text mode, which displays simple text with no visual effects. A sample interface of Ubuntu in text mode is displayed below in Figure 3.5.6-1.

```
Welcome to Ubuntu 12.10 (GNU/Linux 3.0.0-12-generic i686)

 * Documentation:   https://help.ubuntu.com/


To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

ubuntu@ubuntu:~$ _
```

Figure 3.5.6-1 Ubuntu v12.10 Command Screen

.

3.5.6.3 Other Canonical Linux Distributions

The remaining Linux distributions include Lubuntu, Xubuntu and Kubuntu. All of these distributions can be significantly more efficient on system resources than Ubuntu and Angtrom. They are simply modified kernel versions of the standard Ubuntu package. These systems are stripped down to conserve system resources. Their primary application includes designs that do not utilize graphical user interfaces or embedded systems.

The majority of these software modifications involve the decreasing the systems graphical interfacing capabilities, or disabling advanced graphics. These distributions were not utilized in this design because Ubuntu features an optional running mode called text mode. Text mode disables the advanced graphics and displays a simple text output screen. Using text mode makes this difference of efficiency insignificant. For example Lubuntu is a light version ideal for applications such as this. However while running in text mode Ubuntu and Lubuntu consume almost equal system resources. Additionally there is less technical information available for Lubuntu in comparison with Angstrom.

Canonical develops and releases security patches and software updates for these Linux distributions every six months. What is particular to the standard Ubuntu system is that every fourth distribution of the system will receive long term support (LTS). All LTS releases will receive system patches and updates for a minimum of five years after its original release.

Another big advantage to this particular system is that it's freeware and will allow more financial resources to be used in hardware purchasing. The Ubuntu kernel is compatible with all of the hardware and software selections. These systems were run on a similar system to this one, and are displayed in the table below. This table can be found from the Linux Wiki site.

Parameters	Ubuntu 12.10	Kubuntu 12.10	Xubuntu 12.10	Lubuntu 12.10
Size of ISO	790 MB	999.6 MB	727 MB	726 MB
Booting time (post installation)	9 sec	10 sec	8 sec	8 sec
Desktop	Unity with Gnome 3.6	KDE 4.9.2	XFCE 4.10	LXDE
Linux kernel	3.5.0-17	3.5.0-17	3.5.0-17	3.5.0-17
CPU usage (live boot)	20-30%	2-6%	1-5%	1-5%
RAM usage (live boot)	456 MB	270 MB	180 MB	134 MB
CPU Usage (post installation)	20-30%	2-10%	1-5%	0-5%
RAM usage (post installation)	412 MB	300 MB	160 MB	123 MB
Installation time (with 1 MBPS connection)	30 min.	30 min.	30 min.	30 min.
Wifi detection	Immediate	Immediate	Immediate	Immediate
Touchpad detection	Works by default	Works by default	Works by default	Works by default
Ease of use	A bit on the slower side	Works well on the system	Really smooth to use	Really smooth to use
Eye candy factor	Looks awesome!	Plasma interface looks good	Interface is brighter and looks better than ever	Interface looks more or less the same, a bit bland
Repository	Ubuntu Software Center 5.4.1.2	Muon Package Manager 1.4.1	Ubuntu Software Center 5.4.1.2	Lubuntu Software Center
File Manager	Nautilus 3.4.2	Dolphin 2.1	Thunar 1.4	PCManFM 1.0.1
Stability	Hanged while playing video in Gnome MPlayer	CPU utilization 100% while playing video in Dragon Player, but didn't hang	20% CPU utilization while playing video in VLC	14% CPU usage while playing video in Gnome MPlayer

Figure 3.5.6-2 Comparison of Linux Distributions

3.5.6.4 Building and Installing Linux Kernel

As mentioned previously in this report this design requires a custom Linux kernel to suite the specifications of this device. A cross complier is required to build this type of kernel. It is recommended that an AMSDK compiler be utilized. Also this compiler must be added to the complier path by the following code

```
export PATH="<sdk install dir>/linux-devkit/bin:$PATH"
```

Often times remnants of old kernel configurations remain in the compiler. It is recommended that prior to compiling any kernel clear the compiler of any remnants. The code below is used to accomplish this.

```
make ARCH=arm CROSS_COMPILE=arm-arago-linux-gnueabi- mrproper
```

The Kernel system is saved as image files after compiling. Before compiling the Kernel is it necessary to select which components will become part of the kernel and which components may be neglected, since they will not be utilized in the final design. It is recommended that using a default kernel configuration, and later modifying it to reduce these unnecessary components. The code below adjusts the kernel to a standard configuration to be modified later.

```
make ARCH=arm CROSS_COMPILE=arm-arago-linux-gnueabi- <config>
```

This code will search the directory for the configuration file, denoted by <config> at the end of the command. The AM335X and Beaglebone share both SDK and PSP coding configurations. The table below shows this, and several configuration files for multiple popular development boards.

Device	SDK config	PSP config
AM335x/Beaglebone	tisdk_am335x-evm_defconfig	am335x_evm_defconfig
AM37x	tisdk_am37x-evm_defconfig	omap3_evm_defconfig
AM3517	tisdk_am3517-evm_defconfig	am3517_evm_defconfig
Beagleboard	tisdk_beagleboard_defconfig	omap3_beagle_defconfig
AM180x	tisdk_am180x-evm_defconfig	da850_omapl138_defconfig

Figure 3.5.6-3 Dev. Board Configuration

Customizing the configuration is a fairly simple process. The command below displays the current kernel configuration of the system in the configuration window. Once this window is accessed all of the kernel components should be selected. The components that are not necessary may be deselected. Once the window is closed the component configuration is saved to be implemented upon the device memory of the system.

```
make ARCH=arm CROSS_COMPILE=arm-arago-linux-gnueabi- <config type>
```

Once the kernel is configured it may be compiled to generate a kernel image that may be booted from the SD memory card. The command below is used to create the image file in the arch/arm/boot directory.

```
make ARCH=arm CROSS_COMPILE=arm-arago-linux-gnueabi- uImage
```

Finally the kernel configuration may be installed on the memory space to be loaded once the system is initiated. This command causes the kernel

configuration to be saved as an image file so that it may be utilized as the operating system of the device being booted.

```
make ARCH=arm CROSS_COMPILE=arm-arago-linux-gnueabi- INSTALL_MOD_PATH=<path to root of file system> modules_install
```

3.5.6.5 Android

Android, along with Linux Angstrom, comes with this development board. Android was designed originally to run on smartphones, and later was adapted for use on tablets. It has gained momentum in many areas of application. This is primarily true for applications involving GUIs, Graphical User Interfaces.

This operating system has a disadvantage that it has limited software support pertaining to embedded system developments. As mentioned previously Android was not selected primarily because it is intended for applications involving graphical user interfaces, which will be disabled on this design. The software updates and security patches are not on a release schedule, like Ubuntu.

3.5.6.6 Windows CE 7

Windows Embedded Compact 7 (CE 7) is designed for use in industrial control system and simplistic user devices such as camera's and GPS systems. It is a good operating system with great capabilities. A major perk to this OS is that it may be burnt to a disc and run in a closed-mode. This means that it takes no user input and requires zero memory space. This feature cannot be utilized on the design since it does not have a cd drive. Additionally it entails a very steep learning curve. Since no member of this group has experience with this OS it was not selected.

3.5.6.7 Angstrom

Angstrom is an open source kernel Linux distribution that was developed for running embedded systems. This is actually one of the default software packages which come with the TI AM335X SK. This embedded system was created by the developers from OpenZaurus, OpenEmbedded, and OpenSIMpad.

Scaled down versions of Angstrom can be ran on systems with as little as 4Mb of flash memory. This would be ideal for many applications involving small amounts of power consumption and minimal computing power. The power consumption aspect of this system is desirable, however the processing board is far more powerful than this system requires. Since a large amount of processing capabilities will not be utilized in this design, the power saving will be greatly diminished.

Angstrom was selected for this design over Ubuntu for two primary reasons. Firstly Angstrom has a major advantage over Ubuntu the system because of its community support and following. In addition Ubuntu is a long term support release which means it will receive security patches and system updates every six months for a five year minimum.

3.5.7   Software Utilities/Video Format

3.5.7.1 Mjpg-Streamer

For this build Motion jpg format (Mjpg) was selected as the video format. This file format takes video feed directly from the camera as a series of JPEG images. These images are constantly refreshed to produce a video. Streaming video feed as Mjpg format is a lightweight process compared to using ffmpeg. This video capture process is not demanding on the CPU, which benefits both data overload and power consumption. Also this process has a large support among the video feed community.

Another advantage to streaming with Mjpg format is that this software package contains a small internal server. This allows forwarding of any video stream request from the user to the internal server using a script. Capturing video feed in this manner requires minimal CPU usage and flexibility in regards to the user's media player.

3.5.7.2 FFmpeg

Ffmpeg is far more robust than Mjpg, however it does have the capability to be saved as an FLV video file. This format is cross-platform compatible, which creates flexibility to user OS type. Ffmpeg can be used to stream video directly from the camera to the user's media player. However directly streaming ffmpeg video from the camera is far too CPU intensive in regards to both data overflow and power consumption.

To avoid this data bottleneck the system uses Mjpg feed through the Wi-Fi portion of data transmission. Only after the video is transmitted is it converted to ffmpeg. If ffmpeg had been used to stream and record video directly from the camera, it would create an overflow in the data stream, at the camera units' CPU. It would also waste power from the battery source on unnecessary processing.

3.6 REMOTE MONITORING

Remote monitoring refers to the two methods of interacting with the KWS camera. The user can control the various functions of the camera through either the user's home computer or through the user's smartphone. The home computer or laptop will be referred to as the base station. These two methods will

not have all of the same features, but the important feature that they share is the ability to view the live video feed.

3.6.1   Information Storage on Local Computer

Before discussing the methods of viewing the live video stream from the base station or from a smartphone, the possible implementations of storing and archiving recorded video must be explored.

3.6.1.1 Video Storage

Video surveillance systems can place great demands on storage. There are several methods of storing large amounts of data like video data. Choosing the method that best fits an application can be difficult. There is no one-size-fits-all storage implementation that meets the requirements of every video application. To determine which technique is best for KWS, the outcome of cost and performance must be analyzed.

Cost

Many video applications would not be financially feasible without inexpensive storage. While the cost of memory and storage devices has been decreasing year after year, it may still be costly to store as much data as a week of surveillance video. In KWS, two options are being explored. The first option is to strictly store video on the user's hard drive in combination with large external storage devices such as external hard drives. This can be costly due to the amount of available storage on the user's hard drive as well as the cost of an external hard drive which can range from $50 to $200. The second option is to store video on a website. However, website hosting can be costly as well. The first method is the most ideal because the reliability lies in the user's choice of hardware instead of the unreliable features of a website.

Performance

Video applications place different demands on storage than do other tasks. Traditional data storage applications consist of many random, small-block reads and writes. Video applications, however, usually consist of large-block, sequential streaming input and output (I/O). Performance will be greatly affected by the storage architecture. However, in the case of KWS, The storage architecture will strictly be the user's computer or laptop

3.6.1.2 Archiving

In parallel with video storage as discussed in section 3.6.1.1, archiving is another issue that can be solved in various ways. Archiving is the permanent storage of records. In the case of KWS, previously recorded surveillance video needs to be permanently stored. As mentioned, storing video data onto a person's computer is limited to the amount of available space on the hard drive. This means that repeatedly archiving surveillance footage in a user's hard drive can quickly eliminate any available space left for other data. This is definitely undesirable. A few options of archiving have been explored and are detailed in the following sections.

Cisco

Cisco Systems, Inc. has developed a system that operates and handles a video surveillance system. It is called the Cisco Video Surveillance Manager (VSM). This system allows users to manage and build customized video surveillance networks that meet their exact requirement. The software for the VSM implements many of the features that the KWS requires. It allows for highly scalable and flexible video systems that can be easily managed and monitored. The software can also allow the users to retrieve live or recorded video from anywhere on a web browser. The goal of the Cisco VSM is to optimize bandwidth and storage utilization. However, for the purposes of archiving, the Cisco VSM implements archiving through its encoding server, media server, and storage system.

The Cisco Video Surveillance Encoding Server is very useful because it is an all-in-one application. The Encoding Server was designed to encode, distribute, manage, and most importantly archive digital video feeds. It provides up to 9 terabytes of storage.

The Cisco Video Surveillance Media Server is the most essential element of the VSM. This component enables distribution, archiving and management of video feeds. Accordingly, the topic of interest is the Media Server's flexible archiving. It can archive video feeds at different frame rates, durations, and locations. In order to conserve bandwidth, the media server allows for redundant multi-site archiving. To avoid recording idle video feed, it also has record on motion and video clipping capabilities.

The most significant component for the purposes of archiving is the Cisco Video Surveillance Storage System. This provides flexible options for storing audio and video feeds using cost-effective, IT-caliber storage devices. It also has many benefits that include redundant archives and optional clustering for failover protection. The Storage System is configured to be combined with DAS, NAS, and SAN storage systems. Before discussing the Storage System, the three storage systems must be explained.

DAS

Direct-attached storage, or DAS, is the most basic level of storage. In this level, storage devices are part of the host computer, as with drive, or directly connected to a single server. Das is ideal for localized file sharing in environments with a single server or few servers.

NAS

Networked-attached storage, or NAS, is a device that is comprised of both hard disks and management software. It is dedicated to serving files over a network. NAS is an ideal choice for organizations looking for a simple and cost-effective way to achieve fast data access for multiple clients at the file level.

SAN

A storage area network, or SAN, is a storage network that transfers data between servers and storage devices and is separate from the local area network. SANs have the ability to move large blocks of data which is ideal for bandwidth intensive applications.

The combination of the three storage systems discussed above with the Cisco Video Surveillance Media Server's internal storage is the Cisco Video Surveillance Storage System. This combination allows for storage of video feeds in multiple locations where it can be accessed most efficiently. The Storage System gives up to 24 TB of internal storage on the Media server.

It is clear to see that the Cisco VSM is a viable option for archiving as well as for other video surveillance purposes. However, KWS is such a small-scale security system compared to the large-scale security system capabilities that the Cisco VSM can handle. Hence, this may not be the most practical implementation for archiving for KWS purposes. In addition, the Cisco VSM provides many additional features that are not relevant to KWS which result unused resources and wasted expenses.

Video Compression with HandBrake and Prism

One of the main difficulties with archiving video data is the high demand for storage space. A solution to this would be using video codecs. A video codec is usually software, or even a device, that can compress or decompress digital video. The term "codec" is derived from "compression-decompression." The difficulty with many data compression method, however, is the lossy compression. Lossy compression is a data encoding method that compresses data by discarding some of it. Therefore, producing the same data with some of it

lost. Even though some data is lost, this is still a practical method for minimizing the amount of data stored or transmitted for multimedia purposes.

As mentioned, a video codec also decompresses data. In general a codec can compress a data stream for transmission or storage and it can also decompress a data stream for playback or editing. However, when programs use a video codec the item of interest is usually only compression. As with the topic of archiving video for the KWS, decompression is not a necessity. Reviewing archived video for security purposes should not require much more than viewing, so a lossy video is not a detrimental feature.

Similar to video codecs, video transcoders is another method for handling video. In general, transcoding is the process of converting digital data of one encoding, or compression, to digital data of another encoding. This is typically seen with video data files and audio data files. This encoding results in a reduced file size, or a compression of a larger data file. A transcoder is capable of performing compressions that can turn a large video or movie file to about half the size.

The discussion of codecs, data compression and transcoding leads to the discussion of HandBrake. HandBrake is an open source, GPL-licensed, multiplatform, multithreaded video transcoder. Using Handbrake will result in a great decrease in the demand for storage when archiving old recorded surveillance video. Since it is an open-source transcoder, using Handbrake will save money, for the user as well as for the KWS project.

Similar to Handbrake is Prism Video Converter by NCH Software. This software is a comprehensive multi-format video converter. It can convert or compress video files and has batch video conversion capabilities. The use of Prism would be the same as Handbrake. However, the software is not open-source therefore it can be a costly resource.

Of course, with the amount of surveillance video being recorded, over time even compressed video storage is limited to the amount of space available on the user's choice of storage device. In the case of the KWS, this storage device will most likely be the user's hard drive. With large amounts of compressed surveillance videos taking up memory, other means of storage would be required.

External Storage

A basic method for archiving is using external storage devices or cloud storage services for backing up data. This method would strictly be under the user's discretion. The user will choose how to back up old surveillance video that are more than a month old, or any other pre-determined time frame. This will allow for less storage on the user's hard drive. Therefore, the only limitation to how much video a user can externally store would be the amount of space on the

external devices or services and how many devices or services the user decides to use.

Furthermore, there will be additional cost for external storage devices and cloud services. However, memory devices are becoming less and less expensive so this cost can be minimal. Similarly, many cloud storage services can be free and only charge in a charge-as-you-store manner in which the user will only be charged an extra fee if they wish to add more memory to the service. Therefore, a practical method of archiving surveillance video could be a combination of transcoding video files and using external storage or services.

3.6.2   Video Streaming and Broadcasting

The important decisions to make are choosing the most efficient and applicable methods and approaches with respect to the video feed. These questions that need to be answered in order to make these decisions include:

1. What format should the camera output the video feed?
2. How can the video feed be viewed?
3. How can the video feed be recorded?

The answers to these questions will be answered in detail in the following sections.

3.6.2.1 Video Formats

The range of video file types is very wide and includes many video formats that use different codecs to encode and compress video data. The video being streamed from the KWS camera will strictly be digital video. The most common digital video formats include Motion JPEG (MJPEG), MPEG-1/MPEG-2, MPEG-4, and H.264. The two codecs that will be considered will be discussed for the KWS are MJPEG and MPEG-4. However, before the two codecs can be compared, one must look into what makes up a video stream.

Video Streaming and Codecs

As mentioned in section 3.6.1.2, a codec is a device or software that can decode and encode a data stream. In the topic of IP networking, the term frame refers to a single unit of traffic across an Ethernet or other Layer-2 network. When discussing video streaming, the term frame will refer to one image within a video stream. Furthermore, a video frame can consist of multiple IP packets or Ethernet frames.

Essentially, a video is a sequence of still images, or photographs. The frame rate of a video stream is the amount of images per second being transmitted. A video stream with a lower frame rate will show motion that is choppy or broken. A

higher frame rate, up to 30 frames per second, will show motion that can be considered smoother and more pleasant to watch. However, typically a video stream with a frame rate of 15 frames per second is adequate enough for viewing and recording purposes. This information is important for the KWS project to understand and implement proper video streaming.

Motion JPEG (MJPEG)

Motion JPEG (MJPEG) is a format consisting of a sequence of compressed Joint Photographic Experts Group (JPEG) images. More specifically, MJPEG is a video codec where each frame is separately compressed into a JPEG image. The codec then transmits video as a sequence of JPEG encoded images. This is the most widespread picture compression format used today. It can be seen in everyday uses such as in a digital camera.

Similar to a digital camera, a network camera captures individual still images and compresses them into a JPEG format. To provide a stream with a frame rate of 30 frames per second, the camera firsts captures 30 individual images and compress them. It then makes them available as a continuous stream of images over a network to be viewed at the other end.

As mentioned earlier, a frame rate of about 15 frames per second and above is enough for viewing and recording. Each frame is guaranteed the same quality since each individual image is a complete JPEG compressed image. Hence, the quality is determined by the compression level as defined for the network camera or network video server.
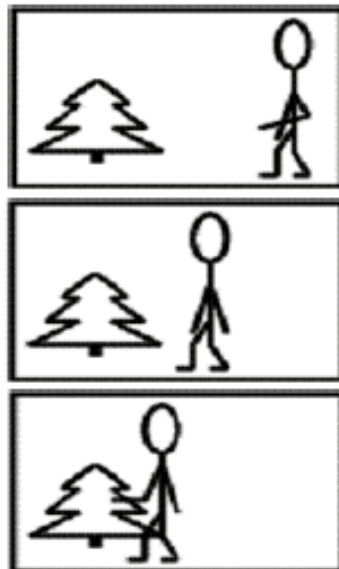
Figure 3.6.2-1 Sample of Consecutive Frames in MJPEG

MPEG-4

An MPEG-4 codec uses prediction algorithms to achieve higher levels of compression than MJPEG while preserving image quality. The codec uses key-frames and an object oriented differential compression format. As a result, frames may differ in size and bandwidth is directly affected by the amount of motion in the frame.

In general, the basic function of an MPEG codec is to compare compressed images to be transmitted over the network. It does this by using the first compressed image as a reference and only sends the parts of the image that differ from the reference image. Therefore, in order to achieve an MPEG-4 compression, the following types of video frames must be utilized:

- I-frames (intra-frames) – These frames are the reference frames and are also referred to as key frames. They contain all of the data that is required to display an image in a single frame.
- P-frames (predicted frames) – These frames contain only image data that has changed from the I-frame and previous frame.
- B-frames (bi-directional predictive frames) – These frames can utilize data from both preceding frames and future frames.

The network base station, or viewing station, is where the images are reconstructed based on the reference I-frame and the differing data in the B and P frames.

As a result, MPEG video compression transmits less data than that of an MJPEG. This is because an MJPEG will transmit the entire frame for each frame, whereas the MPEG transmits entire frames and partial frames.
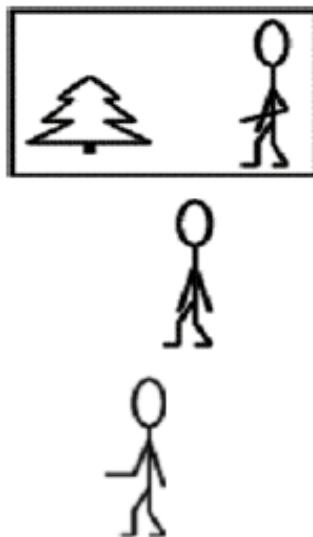
Figure 3.6.2-2 Sample of Consecutive Frames in MPEG-4

MPEG-4 versus MJPEG

Both MJPEG and MPEG-4 have their advantages and disadvantages. Discussing these will help determine which format is best for the KWS project.

One advantage of MPEG-4 is that it reduces the amount of storage needed. The amount of storage is less than that of MJPEG because not every frame is transmitted but many partial frames are transmitted. This is an important feature to archiving as discussed in section 3.6.1.2. Another advantage is the increase of the time duration per video that can be stored. This is because the amount of storage needed has decreased, therefore, leaving more storage available for more video. A final advantage is the reduction of the network bandwidth that is used by the surveillance system. Using P and B frames drastically reduces the consumption of bandwidth compared with sending full information for each frame.

A disadvantage of MPEG-4 is its ineffectiveness in analyzing frames, as in courtroom evidence for example. Its support for frame by frame playback is minimal because there are fewer frames to view. Any non-key frames only contain data that is the differential between the previous and subsequent frames.

In contrast, MJPEG would be perfect for courtroom evidence because each frame contains all of the information for that frame. Using MJPEG frame by frame playback is superior to MPEG-4 because MJPEG offers more frames to view. MJPEG is also much less computation-intensive than a predictive codec. Since the technology is simpler, it can be implemented with good performance on less expensive hardware. As a result, the price of the camera or video server can greatly decrease. A final advantage of MJPEG is that it has less delay issues when used with audio.

As mentioned, one disadvantage of MJPEG is its demand for storage space. MJPEG requires more storage because it transmits full frame data. However, this can be remedied by further video compression as discussed in 3.1.1.2.

In conclusion, it seems that MJPEG is the best fit for the KWS project. As a security system, frame by frame playback is a very important feature. This is especially true when a user wants to view video to identify who dropped off a package or who approached their house for example. Additionally, due to its less computation-intensive nature, less expensive hardware can be used and the overall cost of the camera can be reduced. The only issue the KWS project may face when using a MJPEG video format is the lack of storage space. However, this problem is that of archiving and this issue can be resolved with video compression and external storage devices.

3.6.2.2 Eyeline Video Surveillance Software

As discussed in section 3.2.4, the KWS camera will host the data as a web page that contains the video stream from the camera. The base computer will then be able to ask for the video stream and be able to record data using just the IP address of the hosted video stream. The question remains, how can the video feed be viewed via the base station?

The answer to that question is simply a program developed in either Eclipse or Microsoft Visual Studio. This program will allow the user to view the live video feed from the KWS camera on their home computer. They will also be able to view previously recorded security footage. Additionally, the user should be able to control the zoom, pan, and tilt capabilities from the computer.

The most important feature of the program is the ability to view the live video feed. The program will be able to access the video stream through the IP address. Furthermore, a desired feature for the KWS is motion detection. The developed program may implement its own motion detecting algorithms which can be a difficult task. An alternative would be to integrate Eyeline Video Surveillance by NCH Software.

This software is a video surveillance program that can allow users to create a multiple webcam security system. Eyeline has many extra features, but the item of interest is its ability to detect motion. With motion detection, storage space can be saved by only recording video when an event is happening. It can also help with security and safety purposes. When motion is detected, the program can alert the user by email, SMS text message, or by notification on the base station. This feature can greatly increase the practicality of the KWS.

3.6.2.3 Debut Video Capture Software

The method in which the user can view the live video feed has been determined, but how can that live video be recorded and stored for archiving? One method of recording the video stream would be to implement the Debut Video Capture, another program developed by NCH Software.

The basic feature of Debut is to capture video, which is one the most important requirements for the KWS remote monitoring program. This software has many other important features that can be utilized in the KWS base station viewing program as well. For instance, the software can capture video directly to the user's hard drive in a compressed format and it can record video alone or video and audio simultaneously. Another feature that may prove useful is the ability to schedule recordings. This allows the user to record surveillance videos during a pre-determined time without worry of forgetting to manually start recording.

The feature this software has that is most relevant to the KWS project is its ability to capture video from essentially any video recording system. This includes a webcam, computer screen, external video input devices, and most importantly network IP cameras. This feature will allow the base station to record streaming video directly from the IP address of the hosted video stream. Additionally, this software already compresses its video output, making it easier to store and archive video recordings.

3.6.3   Smartphone Application

An important feature that the KWS system must have is smartphone compatibility. The user should be able to view the live video feed from the KWS camera on their smartphone using a KWS Android application. This is the most important capability of the smartphone app and must be implemented. A desirable feature for this app is the ability to control the pan and tilt capabilities of the KWS camera from the smartphone.

It was discussed that the best smartphone app to develop would be an Android application instead of an iOS application. The main reason for this decision was that even though it is free to develop an iOS app, it costs $99 a year to publish an application into Apple's app store. Whereas developing an Android app is free and Google only charges a one-time $25 fee to get a developer account on the Android market which allows developers to publish Android apps.

Developers can develop Android apps using Windows, Linux, or a Mac, which is ideal for the KWS project. Another perk to developing an Android app is its free resources such as the Android Software Development Kit (SDK). The KWS app will be written, developed, and tested using the Android SDK.

3.6.3.1 Android SDK

The Android SDK provides developers with the API libraries and developer tools necessary to build, test, and debug apps for the Android environment. The SDK comes with several important components such as Android SDK tools, Android Platform tools, an Eclipse Integrated Development Environment (IDE), Android Development tools (ADT) plugin, and an Android Virtual Device (AVD).

Android SDK Tools and Platform Tools

The SDK tools package is a set of development and debugging tools for the Android SDK. These tools are used for debugging, testing, and other utilities required to develop an app. This component is key to developing the KWS app. Android releases revisions to the SDK tools periodically and developers can update to the latest version using the Android SDK Manager.

Using the SDK Manager, developers can download the updated SDK Tools or the updated Android platform tools. The platform tools contain platform-dependent tools for development and debugging. These tools support the latest Android platform, but are backward compatible to support older platforms. Similarly, developers can download the latest Android platform as well as previous platforms and can develop apps in the platform of their choice. The app can only compile if there is at least one Android platform installed.

Eclipse IDE and ADT Plugin

The most important component of the Android SDK is the Android Development Tools (ADT). The ADT is a plugin for the Eclipse IDE. It is designed to give developers an integrated environment in which to build Android Applications. It extends the capabilities of Eclipse and allows developers to build Android projects with an application user interface. Developers can also add packages based on the Android Framework API and debug the applications using the Android SDK tools. The KWS app will be developed in Eclipse using the ADT plugin.
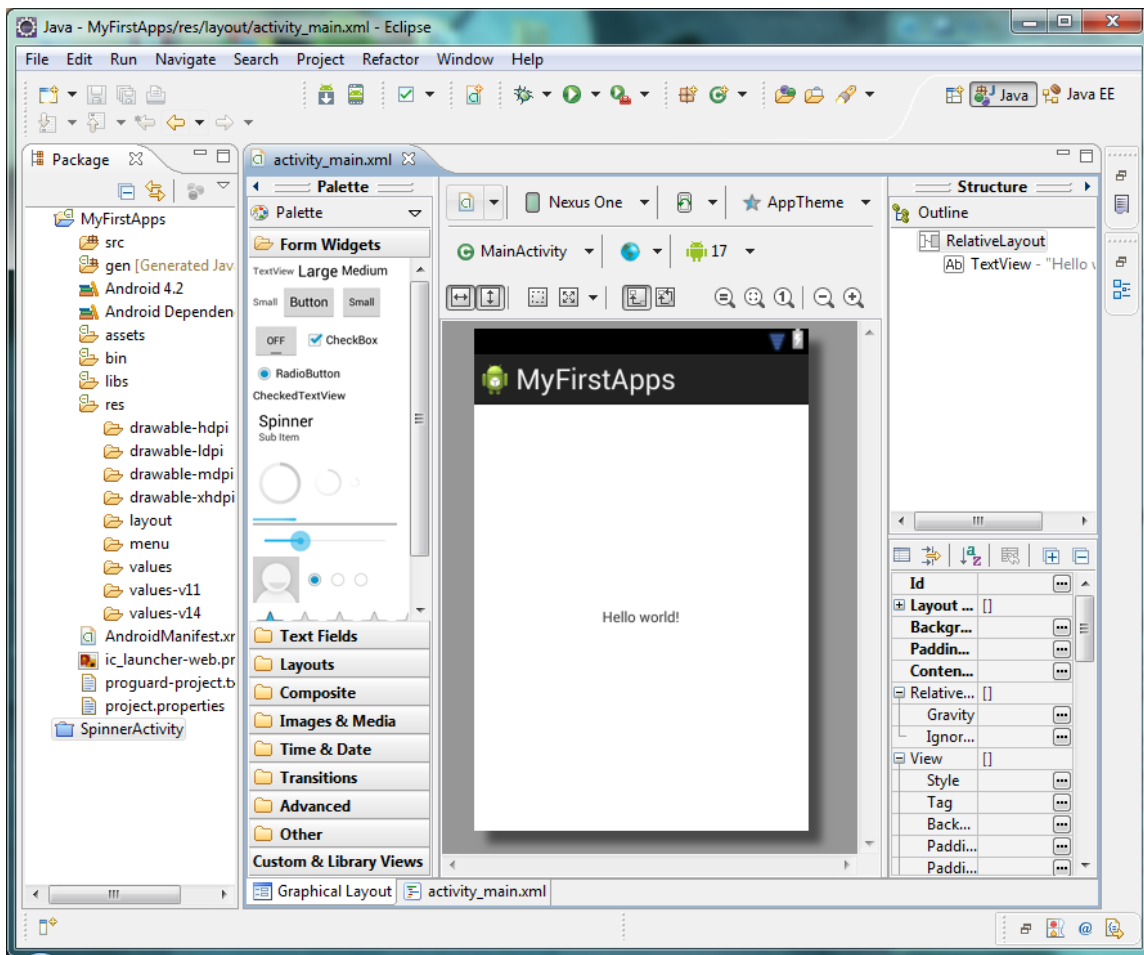
Figure 3.6.3-1 View of Eclipse IDE with Android SDK

Android Virtual Device

An Android Virtual Device (AVD) is an emulator configuration that allows developers to model an actual Android device. It defines the hardware and software options to be emulated by the Android Emulator. Developers can create an unlimited amount of AVDs and are encouraged to create one for every general device configuration to thoroughly test their app. An AVD can be created using the AVD Manager from the Android SDK.

When creating an AVD certain configurations are needed. A hardware profile is needed which defines the hardware features for the virtual device such as camera capabilities, keyboard capabilities, and memory. Another piece of information that is needed is which Android platform will run on the virtual device. This is important because users can test their app on older Android models as well as newer models. When creating an AVD, the appearance can also be configured to the developers liking.

All of these factors are important when developing the KWS app. The KWS project needs to develop an Android app that is user friendly and fully functional on every Android device. This is possible with the use of all the components in the Android SDK.
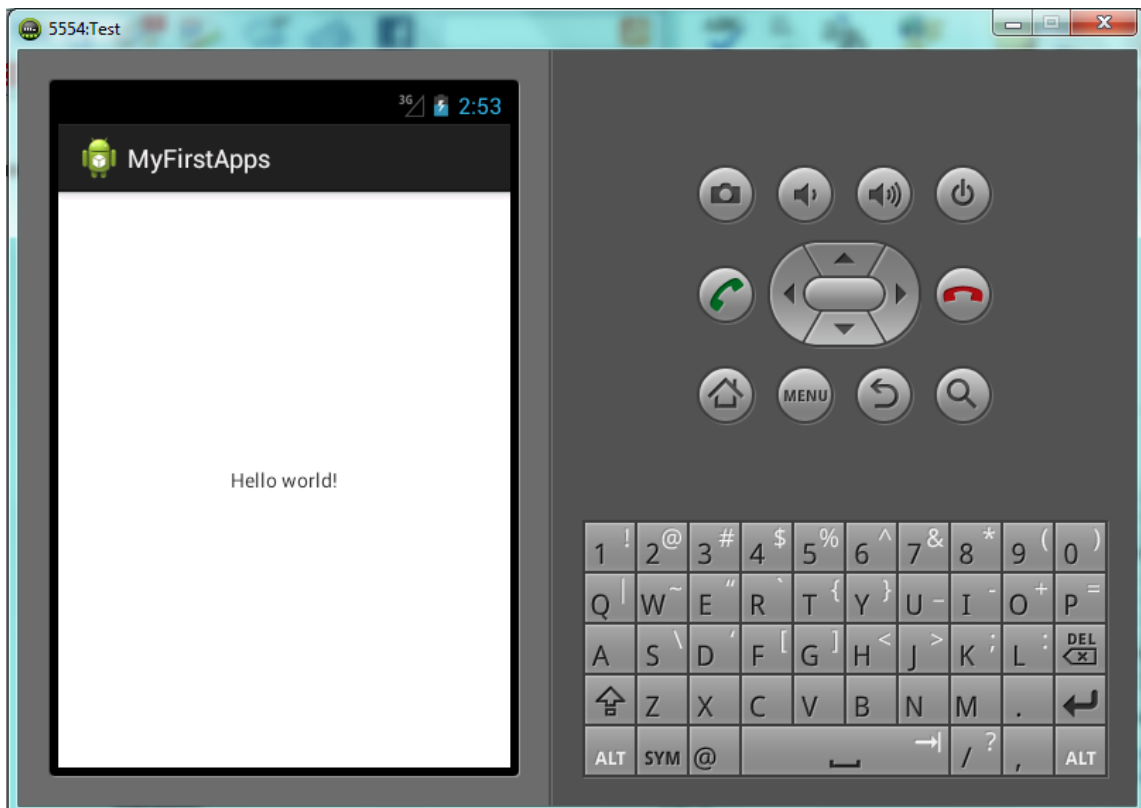
Figure 3.6.3-2 View of an Android AVD

3.6.3.2 Live Streaming

The way the KWS project streams the live video feed is a very crucial decision that affects the development of the smartphone app as well as the KWS base station program. It has already been discussed that the KWS camera will host the video data as a web page that contains the video stream from the camera. The base computer, or smartphone app, will then be able to ask for the video stream and be able to record data using just the IP address of the hosted video stream. The concept of having the video stream as a web page is the most practical method of getting the video stream to the end user. However, there were other options explored such as using BroadCam Video Streaming by NCH Software.

BroadCam Video Streaming Software

Another method of getting data from the KWS camera was discussed. This method was to have data transmitted wirelessly to the base station. From here, the base station program will stream the video over the internet. This can be done using the BroadCam software.

BroadCam is a program that can add live video or recorded video to website as well as compress videos to stream and broadcast for the internet. This software supports video streaming of MJPEG formats which, as discussed in section 3.6.2.1, is ideal. It can also connect and stream from a webcam or network IP camera so this software can prove to be very useful.

3.6.4   Port Forwarding

Depending on the implementation of the desktop program, remote monitoring from outside the home network may require port forwarding. Port forwarding is the redirecting of information packets that are sent through the internet so that they can reach their intended destination without being inhibited or blocked.

The Problem with Ports

Every device on the internet has at least one IP address and an IP address is divided into many ports. When one device sends data to another device, it is transmitting data from one port on its IP address to a port on the destination device's IP address. The problem is that a port can only be used by one program at a time.

With the case of IP cameras, when an outside device tries to access the camera through the IP address, the default port is usually a public port that is used too often which can cause problems. To solve this problem, port forwarding must be set up to forward the connection to a different, less used or unused, port which is

safe to use. Port forwarding must be set up through the user's router and the process can be different for different routers. The following two figures show an example of port forwarding.

Figure 3.6.4-1 Example of Port Forwarding – Setting the Port

Figure 3.6.4-2 Example of Port Forwarding - Enabling Forwarding

3.6.5   Existing Remote Monitoring Cameras

There are many wireless IP cameras already on the market. What set the KWS apart from these cameras are its energy efficiency, portability, and its use of solar panels. The KWS is also strictly for outdoor use whereas most of the existing wireless IP cameras are designed for indoor purposes. Despite the similarities and differences, the topic of interest here is their implementation of remote monitoring. The following sections discuss the existing wireless IP cameras produced by Foscam, Cisco, and Logitech,

3.6.5.1 Foscam

Foscam is one of the leading producers of IP cameras. Foscam provides several indoor and outdoor wireless IP cameras such as the Indoor FI8910W, the Indoor FI8918W, the Outdoor FI8904W, and the Outdoor FI8905W. All of these cameras are designed similar to KWS software requirements. For instance, they are all designed to deliver live video and audio to user's computers over the local network or Internet via a web browser or smartphone. With their self-contained

and compact designs, Foscam Wireless IP cameras allow users to remotely monitor their home and assets which is also an important goal of the KWS camera and aim to implement.

To further the discussion of Foscam IP cameras, the focus will now be directed to one of their most recent cameras; the FI8910W. This camera's smartphone capabilities are far beyond the goals of the KWS's smartphone app. The FI8910W is viewable over the internet using standard browser and is compatible with iPhone, Android, and Blackberry. The KWS will only focus on developing an Android app. However, the KWS can simulate iPhone and Blackberry compatibility by implementing the capability of viewing the video feed over the internet from a standard web browser.

The FI8910W has other features that are desirables for the KWS camera. It features pan/tilt capabilities, MJPEG image compression, remote internet viewing, motion detection, night-vision, embedded IR-Cut filter as well as a built in network video recording system. Some of these features such as pan/tilt, motion detection, and night-vision are features that the KWS project would like to implement. However, they are of low priority. These features will be implemented if the opportunity presents itself, but not having them will not be detrimental to the project.

3.6.5.2 Cisco

Similar to Foscam's various IP cameras is Cisco's Linksys WVC80N Wi-Fi Wireless-N Color Audio IP Camera. This camera has fewer capabilities compared to Foscam's. It does not have pan/tilt or night vision options but it does include motion detection similar to Foscam. It is designed to send live video to user's home computers or through the Internet to a web browser or smartphone. Additionally, there is an iPhone app for the camera that was developed by an authorized LDC provider for Linksys SMART Wi-Fi Routers. Again, the KWS will only be developing an Android app. Therefore, this camera will be used as a reference only for its other smartphone and web browser capabilities.

3.6.5.3 Logitech

Logitech offers a more intricate security system. They offer the Logitech Alert DIY Digital Video Security System. It is a DIY system because they allow customers to purchase as much as 6 cameras to their system and charge them accordingly. The Logitech Alert cameras have several features that the KWS project is interested in. These features include weather protection, night vision, motion detection, web and mobile viewing, and the Alert Commander software.

Of course, the item of interest is the camera's web and mobile viewing capability. From any laptop or desktop computer, users can log on to the Logitech website and can view cameras in multiple locations using a single login. Similarly,

Logitech has created an app for iPhone, Android, and BlackBerry. From these apps, users can watch live video from any of their cameras right on their smartphone.

The Logitech cameras motion detection capability is a particular item of interest. When the camera detects motion, the user is alerted via email or text message. The user can then view the alert and go directly to the live video feed either on their computer or phone.

The most compelling feature of the Logitech Alert camera is the Alert Commander software. This software allows users to set-up and configure their video security system, watch live video, review recorded video or backup stored video on their computer. It can allow the user to view multiple cameras from any computer at any time or they can view previously recorded video. Essentially this software allows users the ability to manage their entire video system from their computer.

Another feature that the Logitech Alert camera comes with is a micro SD card for built in video capturing so the computer does not have to be on to record. Recordings are automatically backed up to the PC when the user connects to the network. This feature is something that the KWS aims to implement as well.

It is clear to see that the Logitech Alert Digital Video Security System is an ideal candidate to use as a reference when developing not only KWS software and the smartphone app, but also when developing the KWS camera hardware.

4   HARDWARE AND SOFTWARE DESIGN

4.1 NETWORK COMMUNICATION

The network will not be designed; it will be configured to fit the needs of the project. Network architecture is already in place to support most of the functionality that the project needs to function. The network will be configured per the following sections.

4.1.1   Network Hardware Configuration

The network will consist of three major parts. There is the Wi-Fi radio on the processor board, the router in the home connected to the LAN and the base station PC either connected via Ethernet or Wi-Fi. The base station records the video stream so that it can be accessed in the future if necessary. Also if the camera system were to be stolen the data will be backed up securely on the base station allowing the video collected to still be used without the presence of the camera. This feature along with the cameras ability to log video creates a ring of coverage that protects the base station from power disturbances and protects the camera from theft.
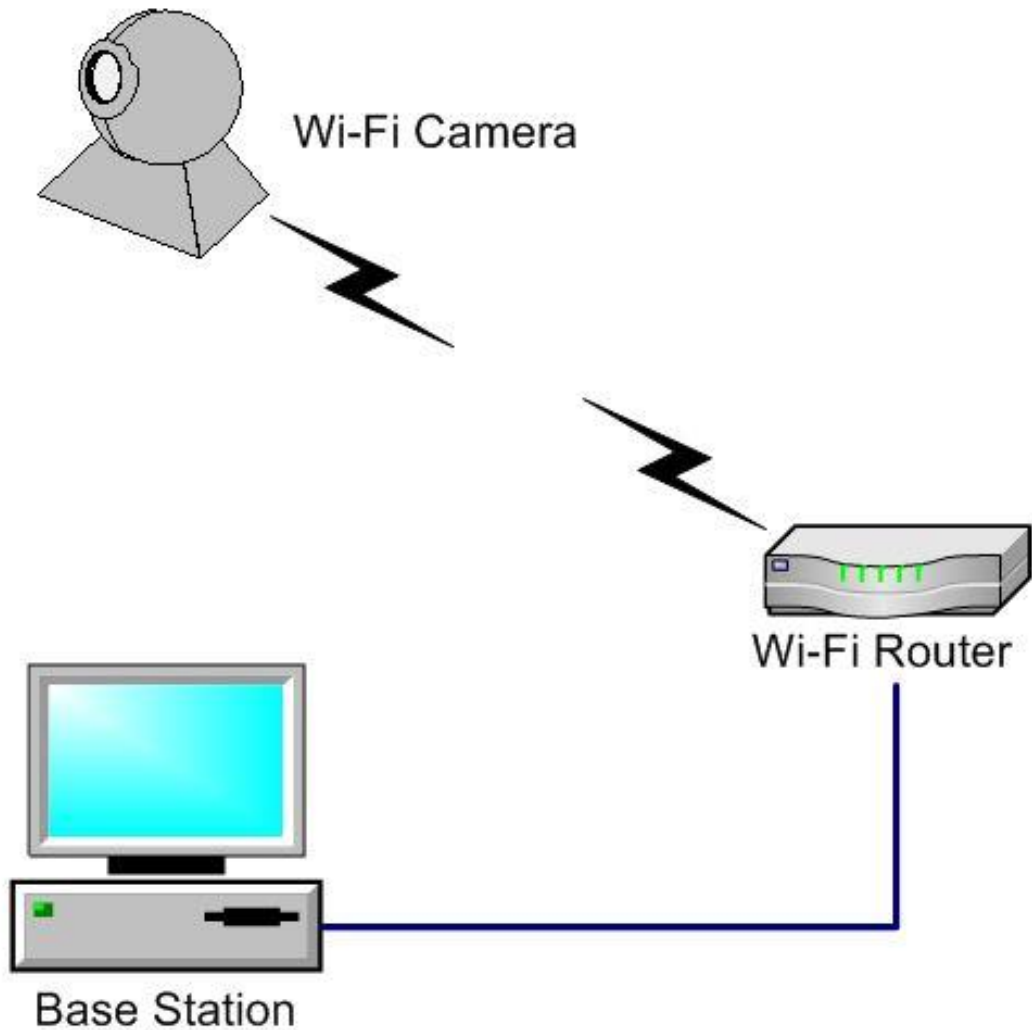
Figure 4.1.1-1 Basic Network Structure

4.1.1.1 Processor to Wi-Fi

The processor will be running Linux kernel version 3.2. This distribution is provided by TI. This version of Linux is packed with utilities that will be very useful for connection the processor to the wireless network. All of the drivers needed for the integrated Wi-Fi chip set are included on the TI version of Linux but if the WiFly chip is to be implemented further Linux drivers will need to be installed to make it compatible with the AM3558 processor. The SDIO bus from the AM3558 will need to be connected to the WiFly chip. TI also offers a Wi-Fi solution that could work well with the AM3558 but it lacks an antenna.

The AM335x SK development board has an external antenna jack that can be used to increase the Wi-Fi range of the development board. Some modifications are needed to allow the use of this jack. A resistor must be removed to

disconnect the onboard Wi-Fi antenna. After disconnecting the onboard antenna an external antenna such as the MikroTik UFL Antenna was added to the development boards UFL jack on the integrated Wi-Fi card.

4.1.1.2 Wi-Fi Link to Router

Once a viable Wi-Fi solution is integrated to the processor the data needs to be transferred to the router. In reality the data is not transmitted until the stream html is navigated to by a user. When setting up the router, an open internet connection will offer the quickest and least complicated connection to the router. Linux has built in support for WEP and WPA/2 but the configuration is cumbersome and not necessary for our project. The camera will need to be configured with a static IP address. Once the static IP address is established the camera stream should be accessible on the same IP address every time. From time to time an IP address conflict can occur in which case the IP address may need to be reset.
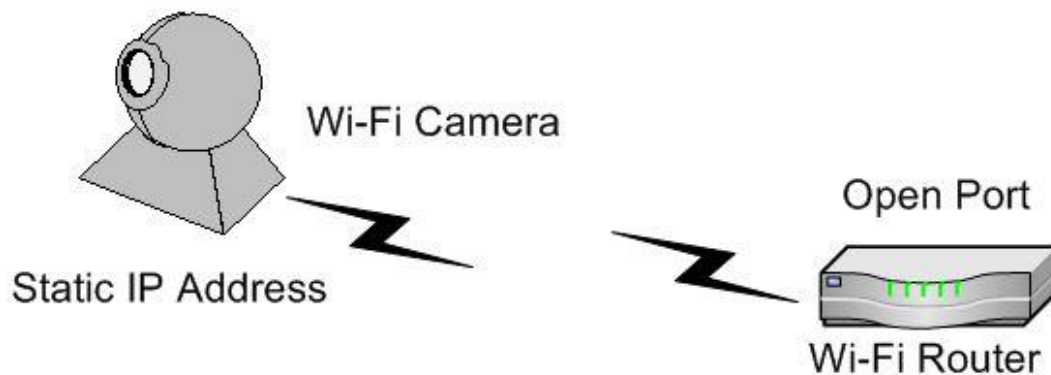
Figure 4.1.1-2 Wi-Fi Camera Configuration

If the IP addressing conflict occurs too often during testing some router settings may need to be changed. If no changes are needed the router will be used in the stock configuration with network security turned off. If major changes need to be made to the network configuration the router may be flashed with different firmware.

4.1.1.3 Router to Base Station

The base station is going to be a standard windows/Linux PC running either freeware or a custom script that will record the IP camera stream. The PC will connect to the open network through whatever network utility is installed on that machine. Once the stream reaches the PC different filters could be placed on the video.

Connected to the Wi-Fi router will also be modem of some kind. This modem will offer a connection to the WAN via an ISP. It may also be possible to play an archived stream that has been saved on the base station computer.

The base station may also be able to alert the user if connection to the camera has been lost. This could be beneficial but may also be annoying if too many false alarms are given.

4.1.1.4 Camera to WAN

With the correct ports forwarded on the router the camera stream could be reached from outside of the LAN. With the Android application in development a browser will be opened with the address of the stream and the device could connect over Wi-Fi or through a mobile 3G network to the camera stream if the correct router ports are forwarded.

The format of the stream is MJPEG. MJPEG is one of the most common video formats and is supported naturally by almost every browser including browsers integrated on Smartphones.

4.1.2 Network Software Configuration

The processor will take advantage of a Linux library that is already loaded into the SDK of the operation system. FFMPEG is a library of great utilities that can be used to manipulate multimedia data. When paired with the right webcam the FFMPEG library contains the required features to translate what the camera is seeing into a MJPEG stream and then host it on the device. A script must be developed that will run different parts of the multimedia management.

MJPEG-streamer is a plugin similar to FFMPEG with only one purpose. MJPEG-streamer streams a video feed in an MJPEG format and acts as a web host for the stream. MJPEG-streamer converts the video with very little strain on the processor keeping power consumption low. MJPEG-streamer is also able to save a series of jpeg images to the SDcard with very little additional processor uses. This utility is used to save images to the SD card. Given the importance of efficiency MJPEG-streamer is a logical solution for streaming video with the AM335x.

4.2 HOUSING

The housing will be constructed from 1/2" plywood. The camera is designed to be pole mounted so a receiver for a 2 inch pole will be attached to the bottom of the housing. The housing will feature a hinged lid to allow access to the battery and other electronic components including the charge controller and processor. The webcam will be mounted to the underside of the housing with a gimbal that will

allow the camera to be positioned as necessary. The webcam will be protected by a weatherproof housing that will be purchased from a third party.

An antenna needs to be added to the outside of the housing to allow extended Wi-Fi range. An internal frame of 1" by 2" wood struts will add support to the structure. The seams will be sealed with Marine 5200 formula sealant. The lid of the enclosure will be sealed with weather stripping to prevent wind driven rain from entering the enclosure. The latching system for the lid will insure a proper seal of the weather stripping. Ventilation may be needed to allow air to circulate in the enclosure. The following page shows a detailed design of the camera housing and webcam enclosure.
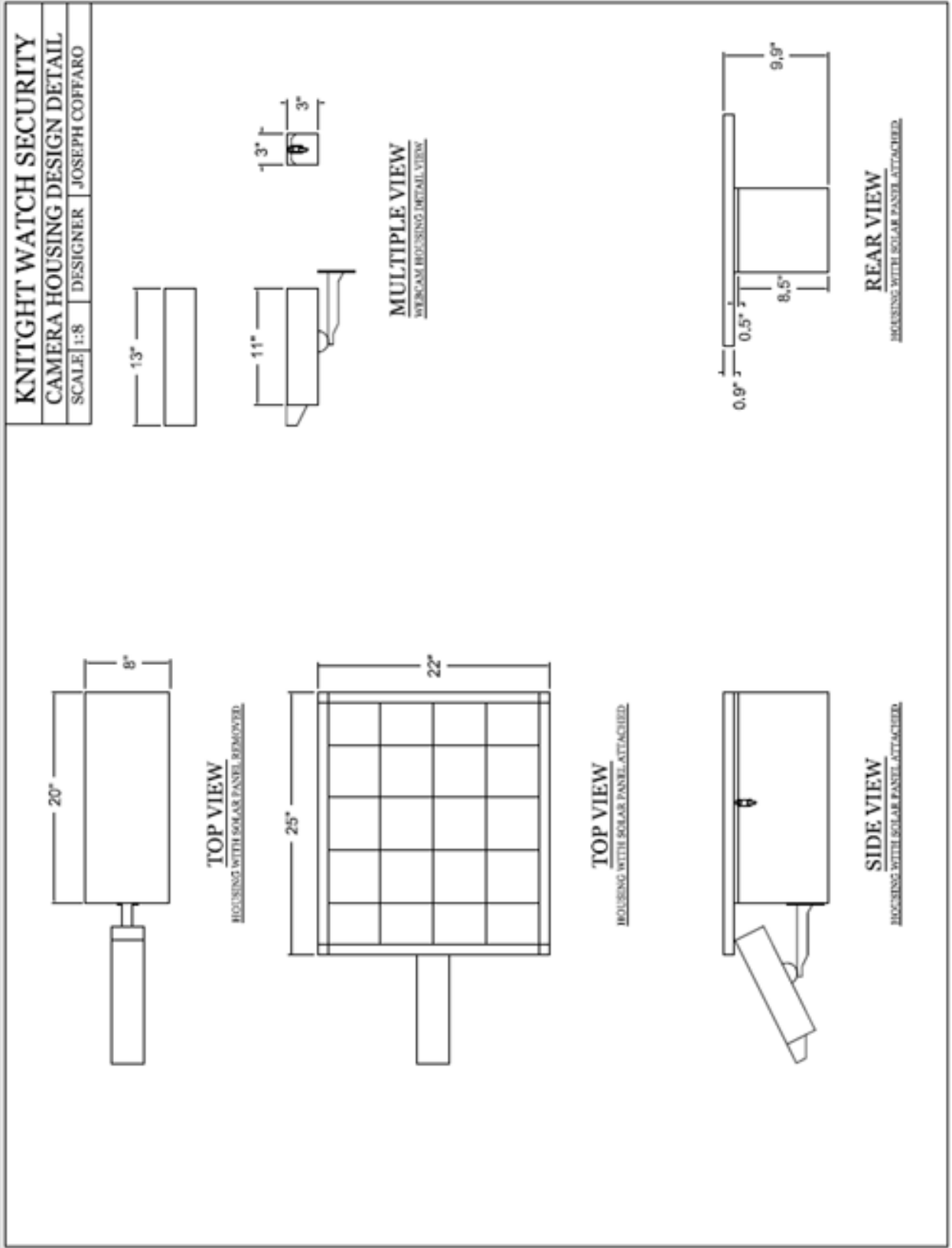
Figure 4.1.2-1 Detailed Camera Housing Design

4.3 POWER SUBSYSTEM

4.3.1   System Configuration

The main components comprising the power subsystem are the solar panel, the Maximum Power Point Tracking charge controller, the DC-to-DC Buck converter, the sealed lead acid battery and the security camera load. When sunlight hits the solar panel, the galvanic cells within the solar panel produce an electric current and an input voltage is supplied to the system.
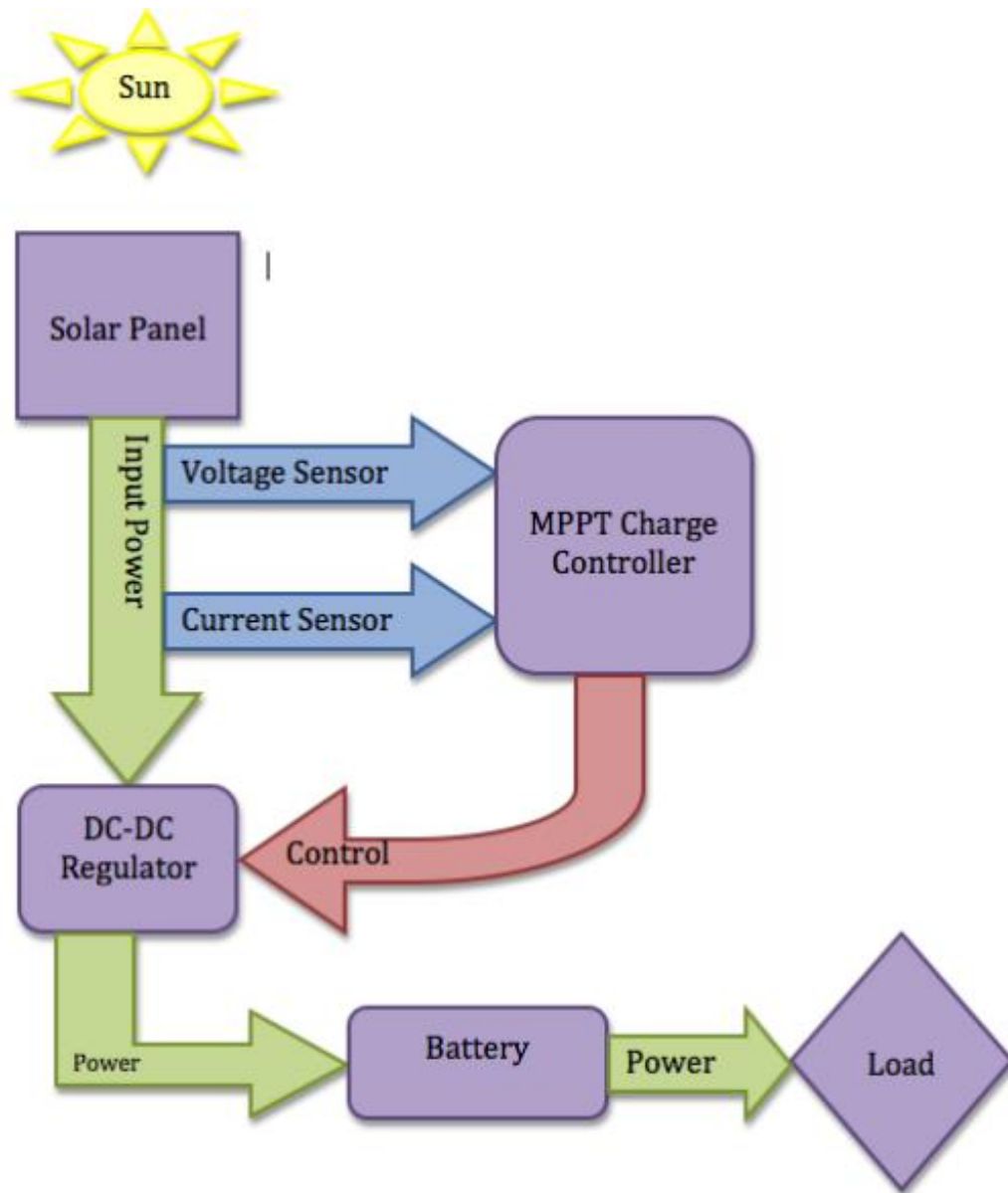
Figure 4.3.1-1 The Power Subsystem Configuration Flowchart.

The voltage and current sensing circuits then measure the input voltage and current values to determine how the microcontroller is going to control the DC-to-DC buck converter. The buck converter will step down the input voltage if it is higher than the 12-volt limit of the battery. The buck converter knows when to step down the voltage due to the programmed MPPT algorithm implemented within the charge controller's microprocessor. The logic of the algorithm determines the maximum operating power based on the input voltage and current values. This algorithm protects the battery from overcharging and increases power efficiency within the system.

The power from the converter then goes to the battery to charge and supply power to the security camera. The battery will serve as the storage source as well as the power supply to the security camera and all of its components. Part selection and how each component was designed and linked in configuration will be discussed in the next couple sections.

4.3.1.1 Solar Panel

A LiteFuze 50W mono-crystalline solar panel was used to power the security camera. The solar panel serves as the primary energy source for the system. The panel is made of tempered glass and has a durable heavy duty long lasting frame. The essential characteristics and specifications of the panel are shown in the table below.

Model	LF-SP50W
Open-Circuit Voltage (Voc)	21.6V
Optimum Operating Voltage (Vmp)	17.4V
Short-Circuit Current (Isc)	3.16A
Optimum Operating Current (Imp)	2.87A
Maximum Power (Pmax)	50W
Weight	9.5lbs
Size	24.42" X 25.26" X 1"

Figure 4.3.1-2 50-Watt Solar Panel Specifications

Mounting and Positioning

Mounting of the solar panel is a very important part of maximizing power efficiency. Factors such as weather and position were considered. Since solar panels are generally large flat objects, wind speed needs to be considered when fixing the solar panel. The solar panel should be securely fixed to a structure resilient to the force of the wind. Most solar panels are rain proof so that was not an issue for mounting and positioning.

The direction of the solar panel is very important during the mounting process. In most cases if you are in the northern hemisphere, the panel should face due south and if you are in the southern hemisphere the panel should face due north [21]. Obstructions such as trees and buildings should be taken into consideration when mounting the solar panel as well. The area of the most abundant sunshine should be the obvious placement for the solar panel.

4.3.1.2 Battery Selection

The battery selected for implementation is a 12-volt sealed lead acid battery. The Universal Power Group model number has a 22 amp-hour rating. The weight of the battery is 13 lbs and the dimensions are 7.1 x 3x 6.6 (L x W x H).

Figure 4.3.1-3 Sealed lead acid battery used

4.3.1.3 Charge Controller

A power supply containing a 5-volt regulator was used to power the ATmega328 microcontroller. The solar panel provides power to this regulator depending on the input voltage of the panel. When the solar panel's voltage increases higher than the batteries limit, the controller is powered by the solar panel. This occurs at times of abundant sunshine. Any time the panel voltage goes lower than the voltage limit of the battery, the board shuts off and the battery gets a direct charge from the solar panel and the battery alone powers the camera. This occurs at nighttime or during poor weather conditions.

The solar panel input voltage was connected to the Vin power pin on the board which goes to the voltage regulator that generates the 5-volts needed to run the ATmega328 microcontroller. The buck converter circuit will be first designed on the Arduino protoboard and that design will be later translated onto a printed circuit board along with the microcontroller and the sensing circuits.

The MPPT algorithm was programmed on the Arduino ATmega328 using the Arduino software. The software will take in parameters from the current and voltage sensing circuits in order to determine the maximum power point to control the DC-to-DC converter. The MPPT algorithm code was written such that these readings could be printed to the serial output monitor. The monitor includes the charger state, the PWM duty cycle, the solar amps, solar volts, solar watts, and battery volts reading.

4.3.1.4 Buck Converter

The chosen Arduino ATmega328 makes up the microprocessor for the project and an Arduino protoshield development kit was originally utilized to implement the charger portion. As stated earlier, the buck converter was designed using the Arduino protoshield to test functionality and then transferred to a PCB design. The Arduino protoshield circuitry will be connected directly to the Arduino development board and serves as the DC-to-DC converter for the system. The converter designed is in buck configuration and is controlled based on the software logic programmed to the microcontroller.

The software algorithm uses the Perturb and Observe method to determine the maximum power point based on the input current and voltage. The software controls the DC-to-DC converter to match the input voltage of the solar panel to the required voltage of the battery. The microcontroller controls the buck converter by generating a Pulse Width Modulated signal (PWM) that switches the MOSFET's in the circuit configuration on at a certain frequency. The transfer ratio of the input voltage vs. the output voltage is based on the duty cycle of the PWM signal.

4.3.1.5 PCB Design

After the prototype was tested for functionality, the design was transferred to a printed circuit board design. The board was designed using Cadsoft's Eagle printed circuit board design software. The board was be ordered at the beginning of the design process, after the prototype board was tested effectively. Below is the board schematic designed.
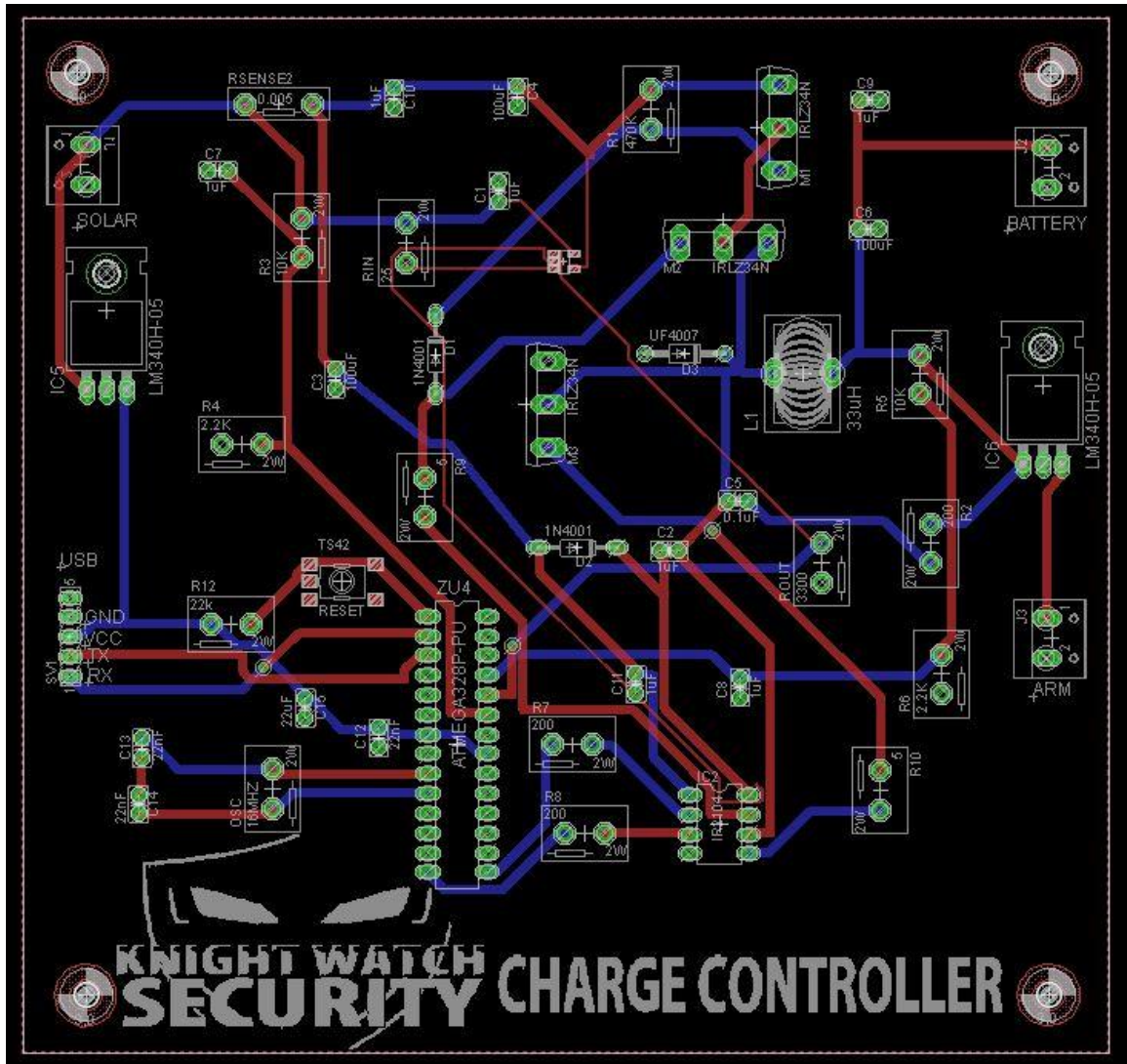
Figure 4.3.1-5 PCB board layout

The durability and appearance of the printed circuit board was a vital improvement when compared to the prototype board. The finalized product needed to be mobile and capable of withstanding certain conditions. The printed circuit board is able to withstand vibrations and other disturbances much better than the prototype board would be able to due to the professional mounting of

the implemented components. The excessive heat and vibrations created within the charge controller can knock a wiring connection loose much easier in a protoboard design because the connections are point-to-point, while a PCB design uses conductive pathways.

Printed circuit board design also allows for multi-level circuit schematics, which will be beneficial to the design of the power subsystem. There needed to be two 5-volt regulator circuits, one for the Arduino Uno charge controller board and one for the Arduino Arm processor that processes the video feed from the camera. The multi-level feature will be very helpful in minimizing space. The circuit components can be evenly split amongst the layers of the PCB and the traces can be made symmetrical.

A major downside to a printed circuit board design is the fact that after mounting, the components cannot be changed or removed. This is why the designs for all circuits used in the design were created on a protoboard first to ensure proper functionality.

4.3.1.6 PCB Software

The selected design software to layout the circuit schematic for the printed circuit board was Cadsoft's Eagle. This programming software was used to implement the charge controller circuits. In the program, the user can lay out all of the components used in the design based on their manufacturer part numbers. The values used for each component must be assigned and the nodes in the circuit should be named for simulation purposes.

The software allows for multi-layer design and the size and shape of the board can be designed within the program. After all of the parts are laid out on the board, the user can select the conductive traces between parts either manually or automatically using the auto-trace feature. After the design was finished, the gerber files were generated to send to a professional PCB manufacturer. The group chose 4pcb.com to manufacturer the board due to low cost.

4.3.1.7 Voltage Sensing Circuit

The solar panel input voltage is sent to a voltage divider R1 and R2, which is sent to the Analog_0 input of the Arduino board to be read by the microprocessor.

The following equations show how to calculate the value of R2 to ensure protection of the microcontroller when its allowed maximum input is 5 volts:

$$R_1 = 10k\Omega$$

$$V_2 = \frac{R_1}{R_1 + R_2} * V_{peak}$$

$$V_2 = 5V (Max\_Voltage\_Allowed)$$

$$V_{peak} = V_{oc} = 21.6V (Solar\_Panel\_Peak\_Voltage)$$

$$\frac{5V}{21.6V} = \frac{R_2}{10k\Omega + R_2}$$

$$R_2 = 3k\Omega$$

R1 was chosen to be a large value to prevent damage from high current levels. The value of R2 was calculated for the highest possible input from the solar panel, which is the open circuit voltage Voc. The equations illustrate that if the panel delivered a max voltage of 21.6 volts, the voltage across resistor R2 (V2) will never exceed the 5-volt allowable max of the microcontroller. This will ensure proper component protection. The actual value chosen for R2 was 2.2kohm which satisfies all circuit requirements.

This input voltage V2 is then sent to a voltage follower, which will isolate the voltage divider circuit from other components. This prevents alteration of the actual voltage reading. This final value is sent to the microcontroller for processing.

4.3.1.8 Current Sensing Circuit

The solar panel input current is read by the current sense resistor, which generates a small voltage signal when the current begins to flow. That voltage is then read by the LTC6101HV current sensing amplifier, which amplifies the signal. Therefore the voltage to be read by the processor is calculated by the following equation:

$V = R_{current\_sense} * I_{input}$

This input voltage V is then sent to a voltage follower, which will isolate the voltage reading from other components. This prevents alteration of the actual voltage reading. This final value is sent to the microcontroller for processing.

These sensing circuits allow the maximum power point tracking algorithm to find the maximum power efficiency. The algorithm operates based on the measurements taken from these circuits.

4.3.1.9 Equipment Protection

Equipment protection is always a very important concept when dealing with electrical components. Certain electrical components can be very sensitive to

high current flow and the proper precautions need to be taken to prevent wasted time and unnecessary expenditures. Fuses are a great way to protect electrical equipment from excessively high flows current. Fuses were implemented to the circuit design to prevent blowing up ordered parts and saved a lot of time and money in the design process.

The solar panel and battery are fairly expensive parts and should also be protected as best as possible. Proper housing was designed to protect the solar panel from inclement weather and other uncontrolled circumstances. The battery is protected from the implemented charge controller. A proper constructed charge controller configuration guarantees proper battery charging and will prolong the life of the battery to improve overall system efficiency.

4.3.2   Final Circuit Schematic

The following page shows the final eagle circuit schematic for the charge controller with all components integrated. The final schematic was drawn using Cadsoft's Eagle software.

4.4 CAMERA

4.4.1 Camera/Video Class

The Logitech C110 USB Webcam is a UVC compliant device. This means that it is compatible with nearly all operating systems and video formats. This class also allows the designer to pick either Mjpg or ffmpeg format for the video feed. To optimize power efficiency this design utilizes both formats, at different points in the data transmission. Mjpg is ideal for retrieving video feed from the camera and processing it for Wi-Fi transmission; however this format cannot be saved to the user's device. So after the video has been streamed to the server or user's device it is converted in to ffmpeg, so that it can be saved. This prevents overworking the onboard CPU of the camera system.

This camera features a CMOS image sensor. This has positive and negative aspects. They are inherently tougher than CCD cameras; yet do not perform as well in dim lighting. The auto focus feature on this camera will greatly reduce this, additionally the flood light will help as well. Since a CMOS image sensor is tougher than a CCD, the design will retain its video quality longer and improve the systems reliability. Additionally cameras that utilize CMOS image sensors consume less power than their CCD counterpart.

This camera contains a plastic lens, which means it is very cost effective. The down side to this lens type is that they are more prone to scratching, than glass lenses. To preserve the quality of the lens, the camera will be mounted behind a transparent protective shielding. This will protect the lens as well as the rest of the camera from weather and other environmental hazards.

Figure 4.4.1-1 shows a sample output of the Screen Capture feature on the left side. The video on the right side is live video feed of the Mjpg player.
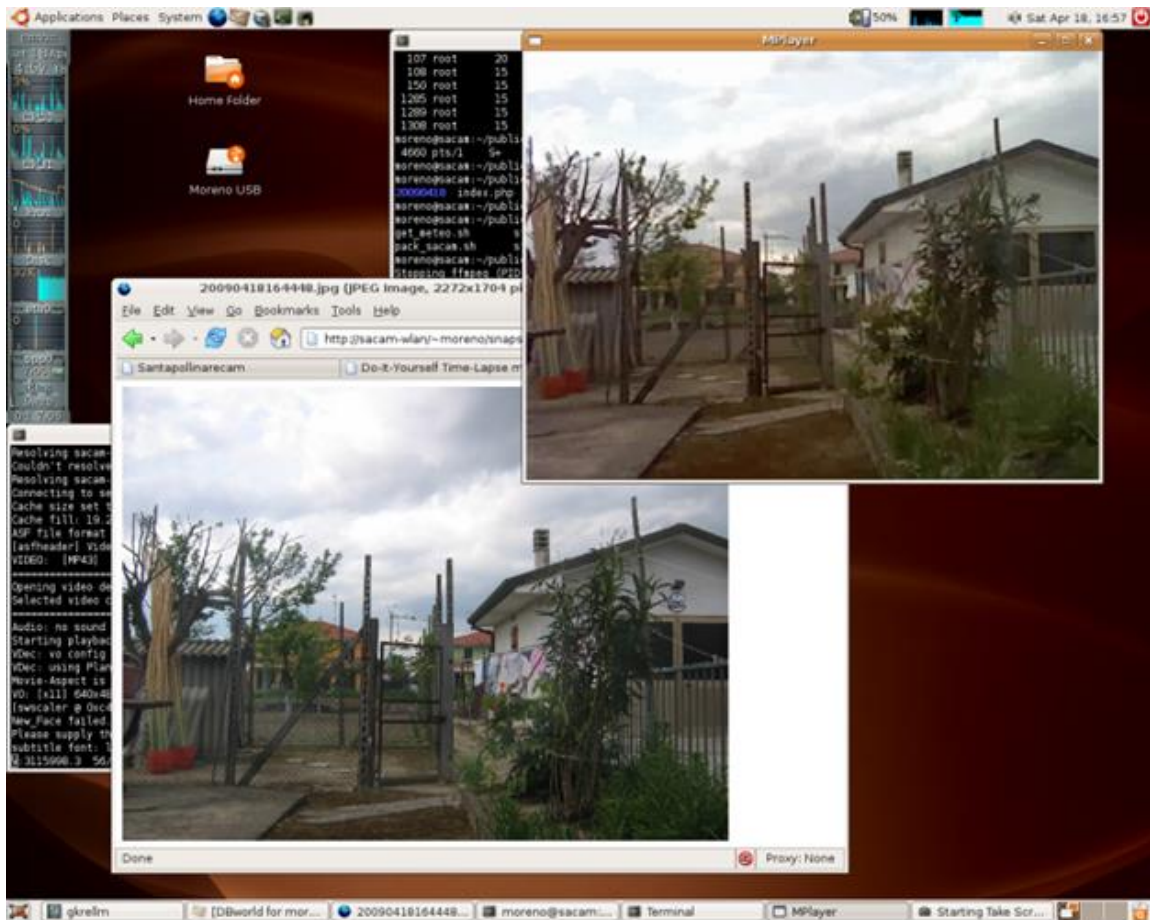
Figure 4.4.1-1 Mjpg and JPEG Output

4.4.2　Linux Ubuntu v12.1

Linux Ubuntu v12.1 is the latest distribution from Linux. It is configured to run on mobile devices such as smartphones and tablets. This operating system has great development support. The support for this operating system shadows that of both the Android and Windows CE platforms. Additionally this operating system is compatible with all UVC compliant devices, which includes the camera used in this project.

Since this design doesn't have a graphical user interface (GUI) it will run in text mode. Text mode reduces all graphics relating to user interface, and runs barebones text display with no variability. The user interface will only be used to program and configure the device. Once the system is working the interface will be completely unnecessary. This minimizes both the systems requirements and power consumption.

The various version of Linux developed for embedded systems are more efficient than Ubuntu; however text mode makes this difference insignificant. If a standard Ubuntu interface is desired it can easily be switched from text mode, back into

default display mode. Additionally Ubuntu has the most software packages because it is so versatile.

4.4.3   Video Format

This design captures raw video feed from the camera using Motion JPG or Mjpg format. This format simply retrieves a series or stream of JPEG images from the camera feed and refreshes them to create video. Fortunately using this format will not affect video clarity; however it may decrease the frame rate of the final video. This is a worthy sacrifice since it minimizes the power consumption of the system and prevent a bottleneck in the data stream from the camera to the server.

The primary drawback to Mjpg formatting is that it cannot be saved to the server or user's device. To overcome this after the video has been streamed from the unit to the server, it is then converted into ffmpeg format. The file is converted to ffmpeg format to enable video storage, which is in FLV video format. Instead of deciding to use Mjpg or ffmpeg the design calls for the use of both. Mjpg is the most efficient, so it is used on the device. Ffmpeg is desirable since it is capable of being saved as a FLV video.

It is possible to simply stream the camera's output using only ffmpeg format. However since this format type is more robust, it is very demanding on the onboard CPU. This creates two problems regarding both power consumption and data throughput. The first problem is that this the least efficient format to transfer, regarding power usage. Utilizing this file format would be an unnecessary drain on the battery overtime. The second problem is that it limits the processor selection because many of the ARM series processors do not have enough processing power.

4.5 PROCESSOR

4.5.1   Processor (TI AM335X SK)

The TI AM335X Starter Kit is the processing board selected for this design. The features of this development shell make it ideal for this build. This choice was made because it has advanced system features including video processing capabilities, wireless connectivity and abundant input and output ports. This allows for the highest quality video transmission and more team resources dedicated to user application development and the solar powered battery charging system.

This system is also very power efficient, primarily due to the microprocessor. The primary microprocessor, the TI ARM A8, only consumes around 1A during operation. Power consumption will be greatly reduced when the graphical user

interface is not being used. This board has a feature to disable the user touchscreen, and can function with the entire touch screen removed.

There are multiple reference designs involving this processing system with similar projects. This board can be programmed to the exact specification necessary and is cross-platform compatible. Most reference builds utilize Linux Ubuntu or a similar distribution of Linux for its simplicity. For demonstration purposes a Wi-Fi router will be used to optimize transmission distance.

This board is depicted below in figure 5.5.1, with the LCD touchscreen mounted. This screen may be removed once the device is functioning properly to increase efficiency. This board with the screen removed is displayed in figure 4.5.1-1.

Figure 4.5.1-1 TI AM335X SK

4.5.1.1 Microprocessor (AM3358)

This device is driven by a TI AM3358 processor, or ARM Cortex-8.It also features a NEON SIMD Coprocessor, for advanced graphics. This is one of the fastest microprocessor in the ARM series from TI. The AM3358 has a clock frequency of 720MHz with a 32-bit word size. The AM3358 has a part number of AM3358ZCZ.

This processor also has 64KB of L1 and 256KB of L2 onboard cache memory. This processor might be more robust than this design requires; however this will allow for ideal video quality. As mentioned above this unit consumes a small amount of power.

Depicted below is a functional block diagram of the AM335X series processing chips.
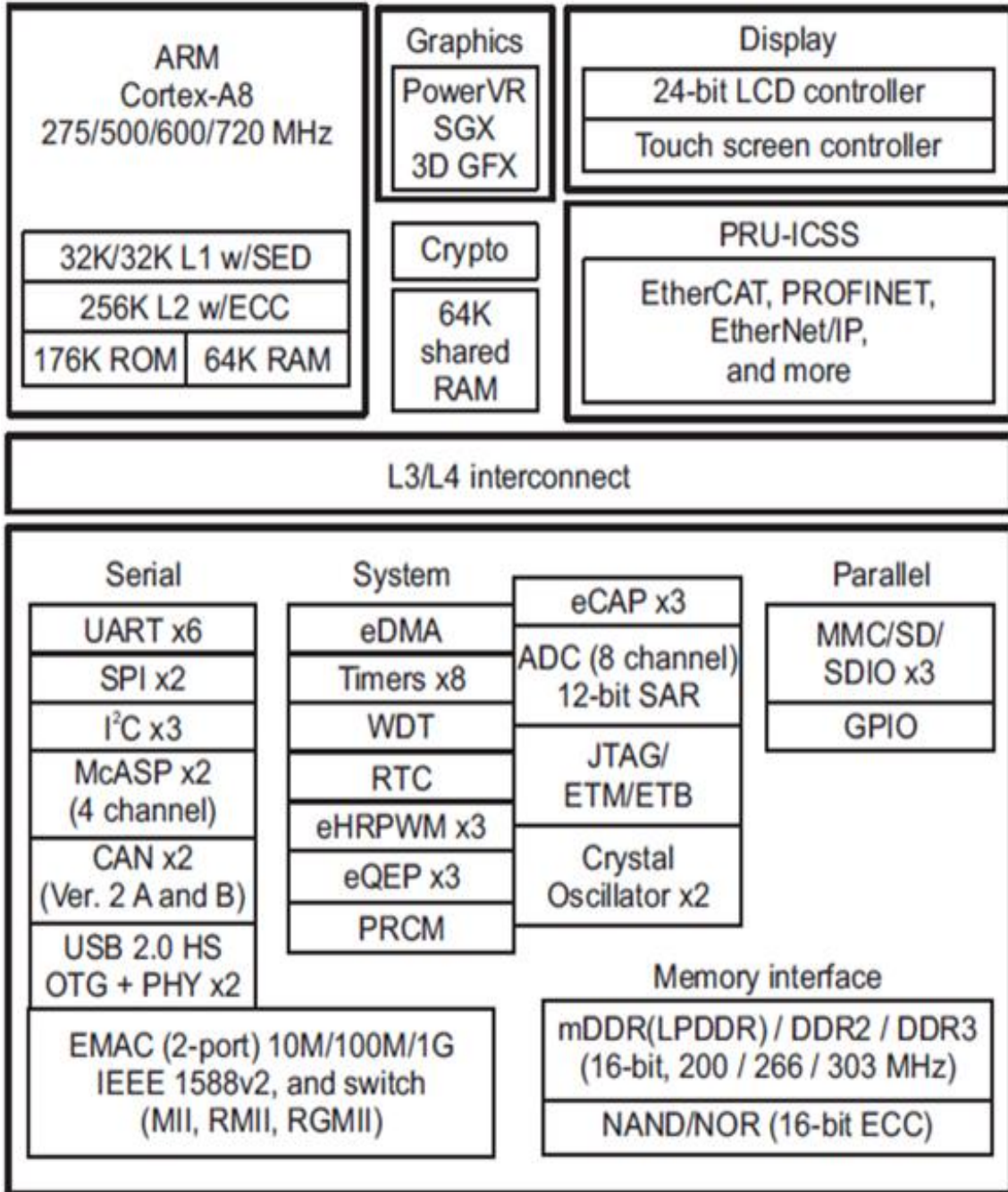
Figure 4.5.1-2 TI AM335X Functional Block Diagram

4.5.2 Input/Output Configuration

This features nearly every type of data port available. This device is capable of being powered by both AC and DC power supplies. It features two USB 2.0 ports, which are capable of 480 Mb/s data transfer rate. Having two USB ports is very beneficial since one port will be occupied at all times by the video camera input.

This board features two Ethernet switch ports that are capable of 1 Gigabyte per second data transfer.

This board has built in Wi-Fi Bluetooth connectivity capabilities. The Wi-Fi and Bluetooth card on this board can transfer a significant amount of data. These cards will be utilized, which is explained below. A 2.4GHz IEEE transceiver is integrated in this board.
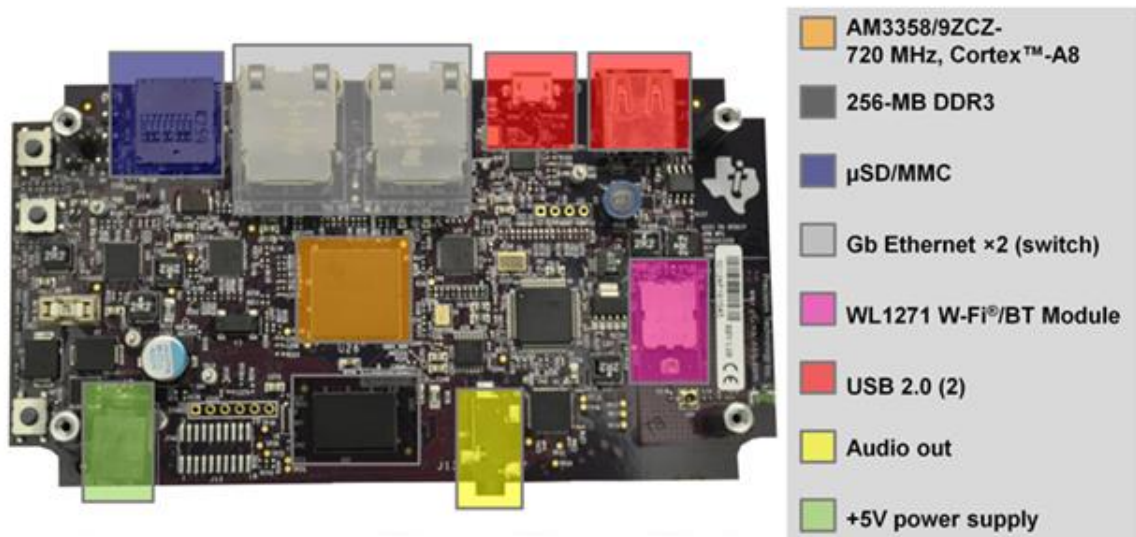
Figure 4.5.2-1 TM AM335X SK with Screen Removed
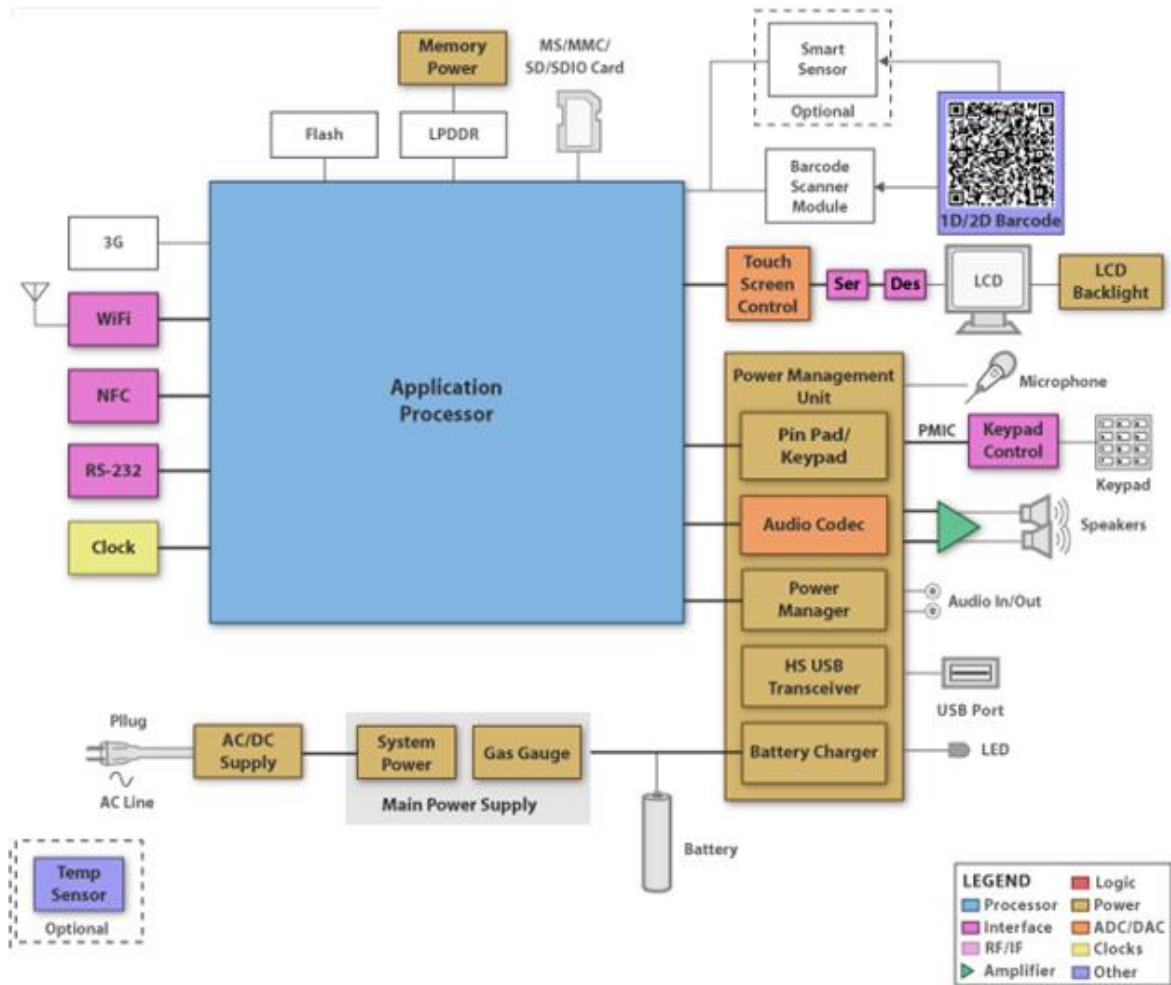
Figure 4.5.2-2 Input/Output Port Configuration

4.5.3 Graphical User Interface

The graphical user interface of this board utilizes a 4.3 inch Touchscreen LCD display. The graphic user interface of this shell allows on the spot programming capabilities to speed the prototyping phase of product development. This development board features a 720MHz ARM Cortex-A8 CPU and POWERVR SGX as a slave processor to enhance the capabilities of the graphics accelerator.

The graphics accelerator is completely unnecessary for this build considering the finished product has no graphical user interface on the device itself. To minimize power consumption once the device has booted up and is running, the graphical interface will automatically disengage.

The screen will be utilized to program the board until it is functioning properly, then can be disabled and removed from the device. This can be done by running simple disabling scripts which may be referenced from previous projects.

Removing the screen would automatically disable itself using the default Angstrom operating system; however these scripts must be utilized since Ubuntu will be the operating system running this device. The script must specify which input and output ports are being occupied by the touch screen.

4.5.4   System Specification

This board has 256MB DDR3 SDRAM on board that is capable of speeds up to 606MHz for 32-bit memory transfers. This amount of RAM is far more than this project requires. In fact many similar builds have run this kernel distribution with the graphics disable using less than 4 Mb of RAM.

Depicted below in figure 4.5.4-1 is a diagram of the processing system flow for this processor. This shows a generic view of where data is traveling from the input ports to the processor and then exits through the output ports.
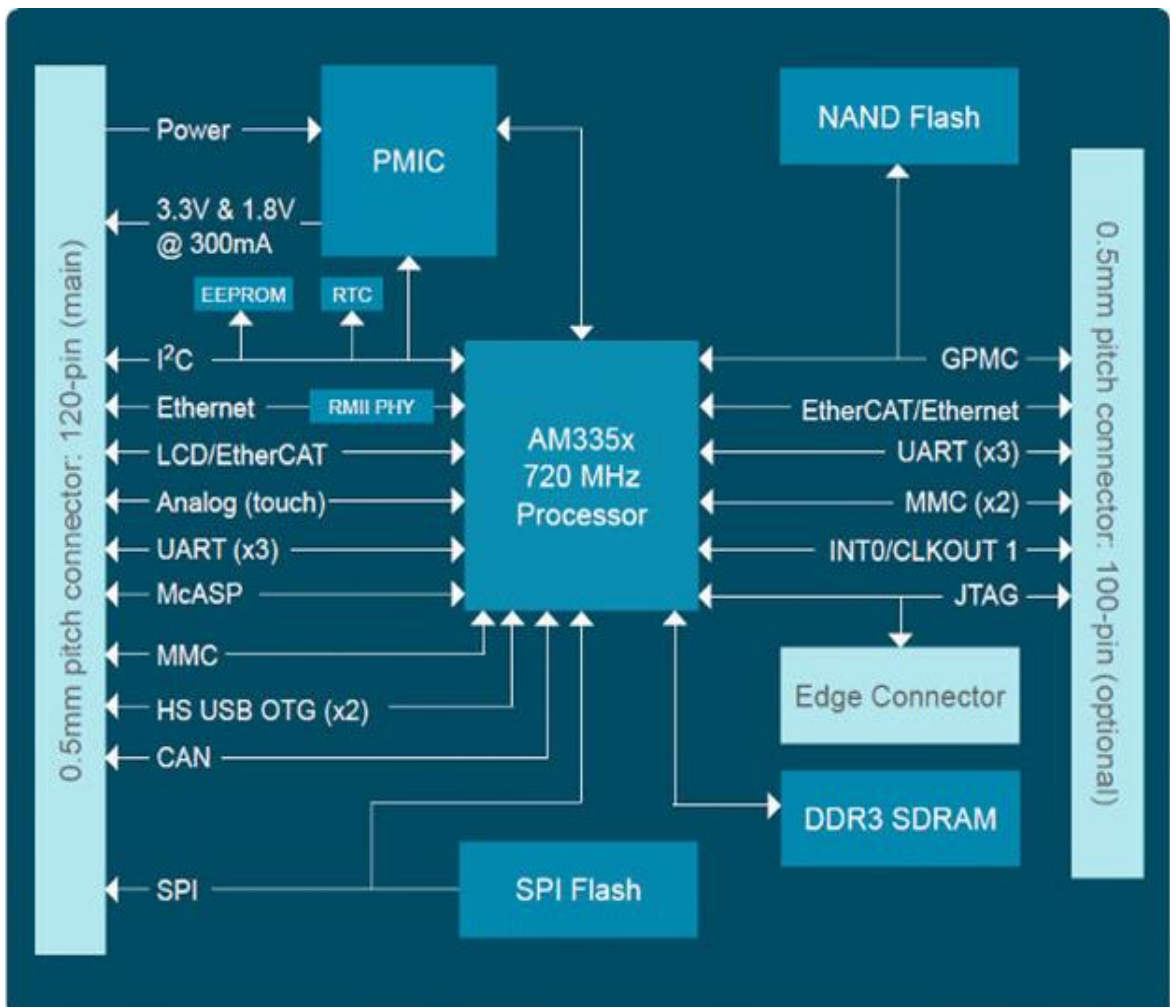
Figure 4.5.4-1 TI AM335X Data Flow Diagram

4.6 REMOTE MONITORING SOFTWARE

The remote monitoring system is divided into two parts: a desktop program and a smartphone app. The following sections detail the design of both aspects of the software. The details of the design assume the login feature with username and password has been implemented.

4.6.1   Remote Desktop Access

The desktop program that provides remote desktop access lays the foundation for the remote monitoring feature of the KWS project. It has several features that allow the user to communicate with the camera and access video feed. The user will be able to view live video feed, record live video, and view diagnostic information. The following section contains diagrams that illustrates the design of the desktop program.

4.6.1.1 Desktop Activity Diagram

The activity diagram for the desktop application for remote access is shown on page 97.

4.6.2   Remote Smartphone Access

The smartphone GUI environment is the primary method of remote monitoring outside of the user's home computer or laptop. It will have several features that allow the user to communicate with the camera and access video feed. The user will be able to view live video, view diagnostic information, and capture a snapshot of live video stream. The following section contains diagrams that illustrates the design of the desktop program

4.6.2.1 Smartphone App Activity Diagram

The activity diagram for the smartphone application for remote access is shown on page 97. The smartphone app has less features available than the desktop program but is still a useful tool for communicating with the KWS camera.
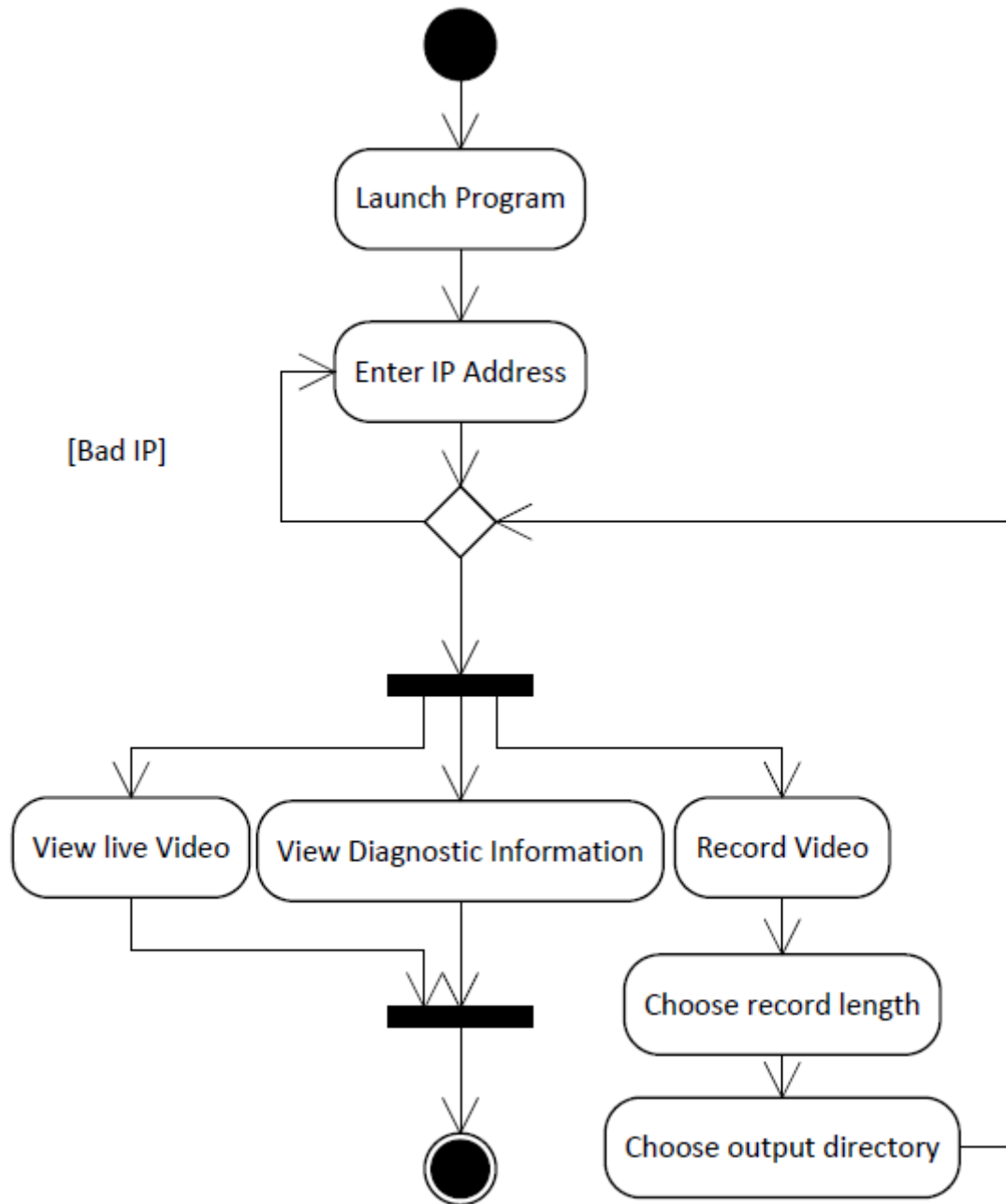
Figure 4.6.2-1 Remote Desktop Access Activity Diagram
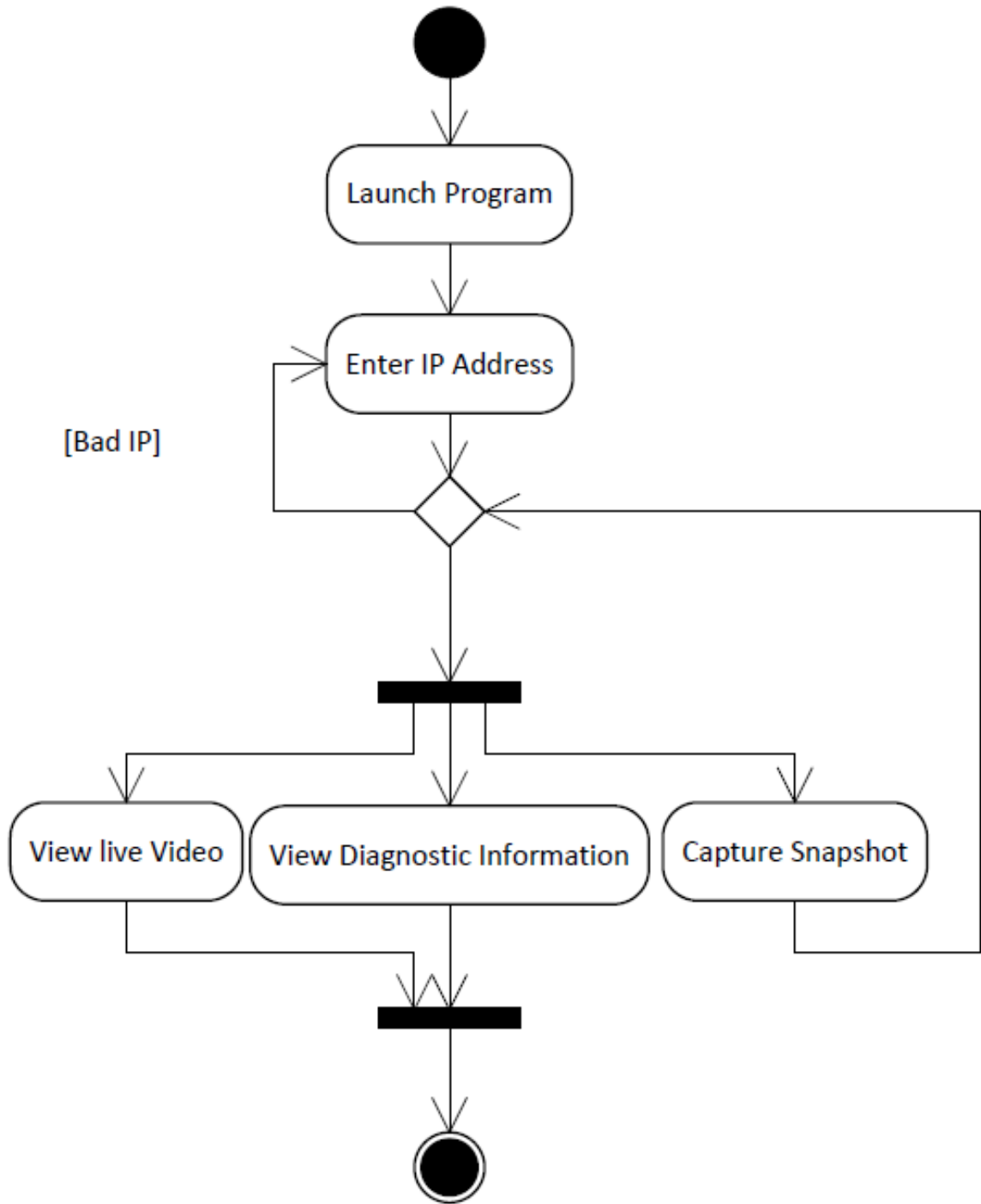
Figure 4.6.2-2 Remote Smartphone Access Activity Diagram

5   DESIGN SUMMARY

5.1 ARM PROCESSOR

The AM3358 processor provides the backbone to this integrated camera. The AM335x development board will be powered by the solar power system. The development board is vestal yet still low power enough for this application.

5.1.1   Powering the Development Board

The AM335x will be the heart of the camera operation. The AM335x will host the video stream and record a video stream to the onboard SD card. The development board is powered by the solar power system installed in the equipment enclosure.

The solar power system is driven by a twelve volt battery. The solar panel output voltage is also around twelve volts. These voltages, if applied directly to the development board would destroy the power management system. The maximum voltage that the development board can handle is near six volts. A voltage regulator is needed to reduce the twelve volt system to a respectable level of five volts.

The regulator will be attached to the custom maximum power point tracking printed circuit board. The regulator will feed directly from the twelve volt battery and down convert the voltage to a steady five volts. There are many different regulators and regulator circuits that could be used in this design.

The regulator that fits the specifications for the processors power demand was the LT323AT five volt three amp switching voltage regulator. This regulator can supply up to three amps to the processor. The maximum current draw of the processor is said to be around two amps at five volts.

A five amp quick blow protection fuse should be added to insure there is no damage done to the processor or the voltage regulator if there is ever a ground short. A short protection circuit could also be used to in conjunction with the fuse though it is not mandatory.

5.1.2   Powering Over USB

The webcam being used in this project is powered via its USB cable. The USB cable will connect to the development board and data will be transferred between the two devices. The development board has a powered USB input but it can only support a 500 milliamp load. The webcam will draw closer to 1.2 amps so there needs to be a circuit on the power management board that can handle the

USB power demands. Again another voltage reduction circuit needs to be added to the power management board.

The circuit will consist of a LT323AT five volt three amp switching voltage regulator that was used in the power supply for the development board. The LT323AT will lower the voltage coming into the power circuit to the webcams required twelve volts. There will also be an IRF640N Power Mosfet in the circuit to act as a switch. Without the IRF640N the webcam would be on constantly. The IRF640N will be the ground node of the webcam circuit. When the USB of the development board is powered on, the Mosfet will allow current to flow to the camera. More details can be seen in the figures below.

The USB 2.0 protocol that is supported by the AM335x development board has the following pin out.
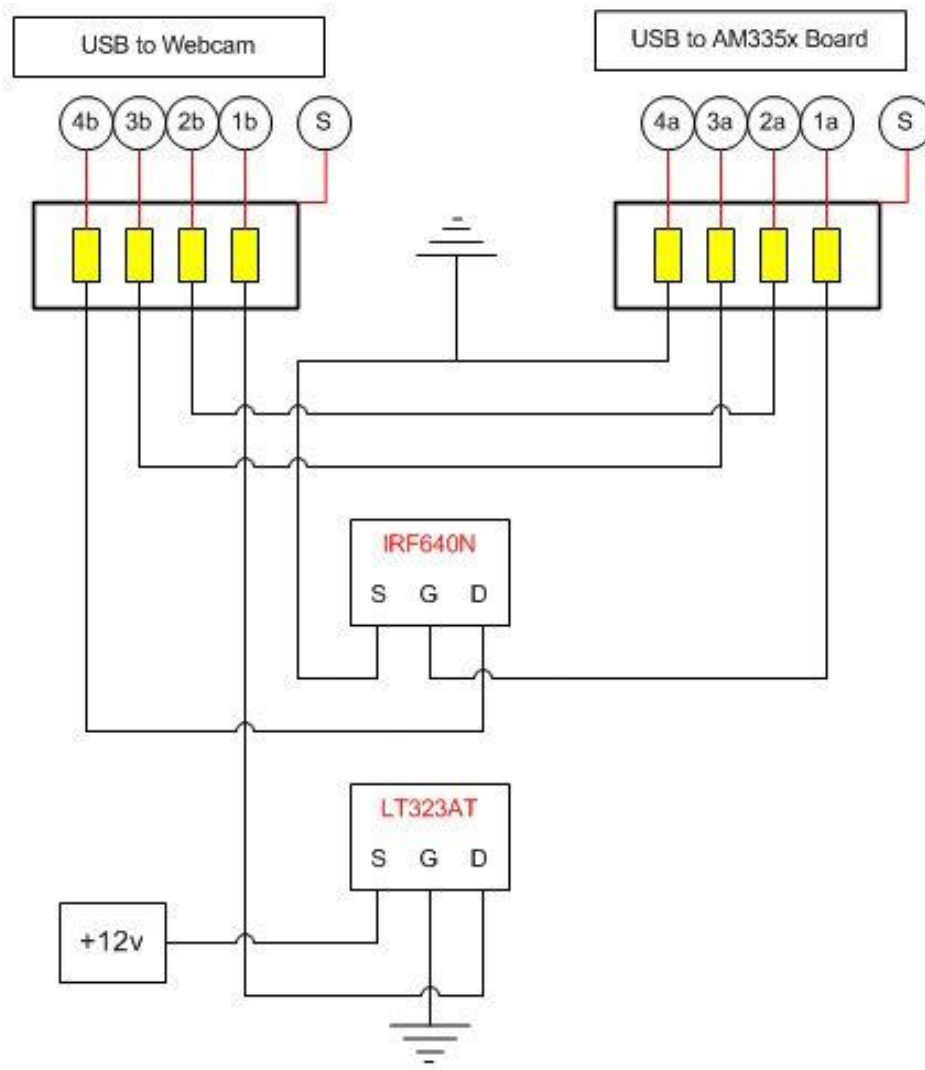
Figure 5.1.2-1 Power USB Diagram

The circuit on the power management board will consist of two USB receptacles. Pins two, three and the shielding will be connected strait through on the circuit board. Pin 1b will be connected to the five volt output of the LT323AT. Pin 4b will be connected to the drain of the Mosfet. The Mosfet gate will be connected to pin 1a and the Mosfet source will be connected to ground. The Mosfet will act as a switch to keep the camera from being powered on while the AM335x is not.

5.1.3   Interaction with Communication System

The AM3358 will communicate over the network through a Wi-Fi radio. The development board (AM335x Starter Kit) used to implement the camera has an onboard Wi-Fi interconnect. The onboard Wi-Fi of the AM335x Starter Kit has a LBEE5ZSTNC-523 Wi-Fi and Bluetooth RF chip. The 523 chip transmits at an RF power of 14.5 dBm at a data rate of 65 Mbps and a power of 20 dBm at a data rate of 11 Mbps. The RF sensitivity with the onboard antenna is -70 dBm at 65 Mbps and -88 at a data rate of 11 Mbps.

The circumstance under which the device will be used falls under the 11 Mbps range. The 523 chip also has an integrated UFL port to allow the addition of a 3 dBi hemispheric antenna to increase the range of the camera and compensate for any interference due to the housing. There is a procedure for using an external antenna instead of the integrated Wi-Fi antenna that is already on the board. The internal onboard antenna is attached through a resistor. Resistor R239 should be removed to avoid RF interference. Once R239 is removed the external antenna can be added through the UFL port on the LBEE5ZSTNC-523 Wi-Fi and Bluetooth RF chip.
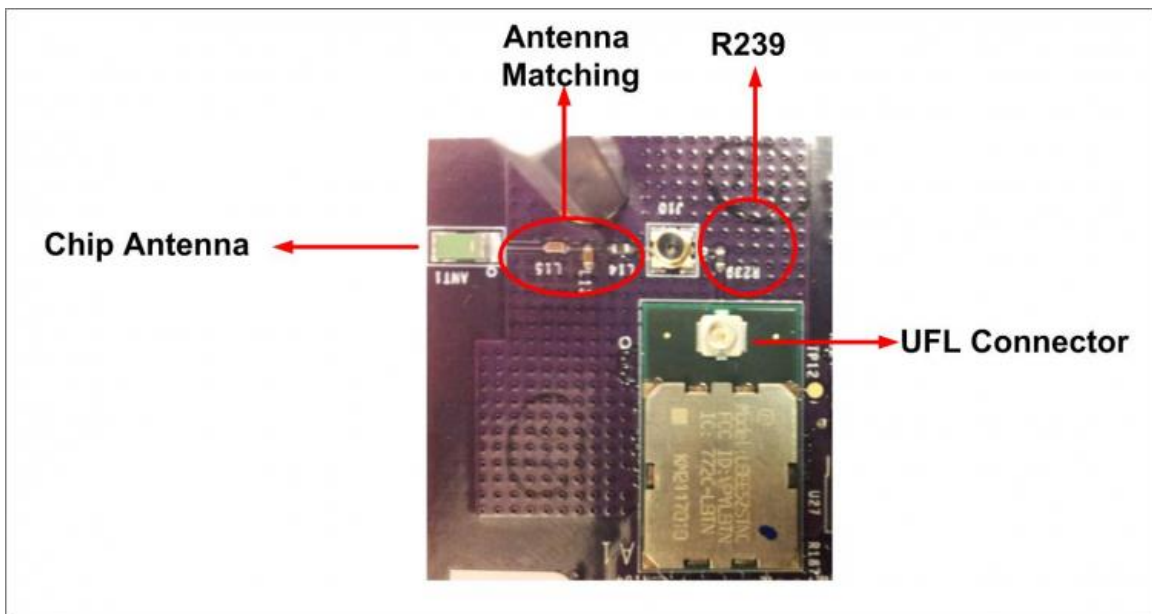
Figure 5.1.3-1 Close-up of LBEE5ZSTNC-523

If the Wi-Fi range is not sufficient during testing, a separate Wi-Fi radio can be added that has a greater transmit power.

5.2 NETWORK COMMUNICATION

5.2.1 Network Architecture Overview

The network depends on the router to operate. The router will direct IP traffic over RF to and from the camera as well as direct camera data to the base station through Wi-Fi or Ethernet. The router also allows access to the network through the WAN when it is connected to a modem.

5.2.2 Processor to Base Station Link

As discussed in the hardware and software section the processor will be running Linux with the FFMPEG utilities loaded. These utilities include tools for saving the MJPEG formatted video on the cameras memory. MJPEG-streamer will be used for streaming the raw video from the camera over the network. MJPEG-streamer has its own light web server that hosts frames of the raw video. The base station free ware will be pointed at the address of the MJPEG-streamer and that feed will be recorded on the base station.

5.2.3 Processor to WAN interface

Once the stream to the base station is configured the stream can be accessed from any network enabled device on the LAN. A browser enabled device can access the stream because MJPEG-streamer delivers a stream of jpegs that is supported by almost all browsers. With the proper port configurations on the router the MJPEG stream can be accessed from outside the LAN. MJPEG-streamer offers access to the stream through port 8080 which should be enabled on the router. Opening port 8080 only poses a slight security risk to the LAN network. A graphical user interface php page could be used in collaboration with a user login and password to prevent unwanted users from accessing the video stream.

Establishing a static IP address on the camera is vital in order for it to be accessed from the WAN. While on the LAN a user can see the other devices that are connected to the same router. For security reasons this is not possible from the WAN. With a static IP address established on the camera one address can be used to direct traffic to the camera from anywhere.
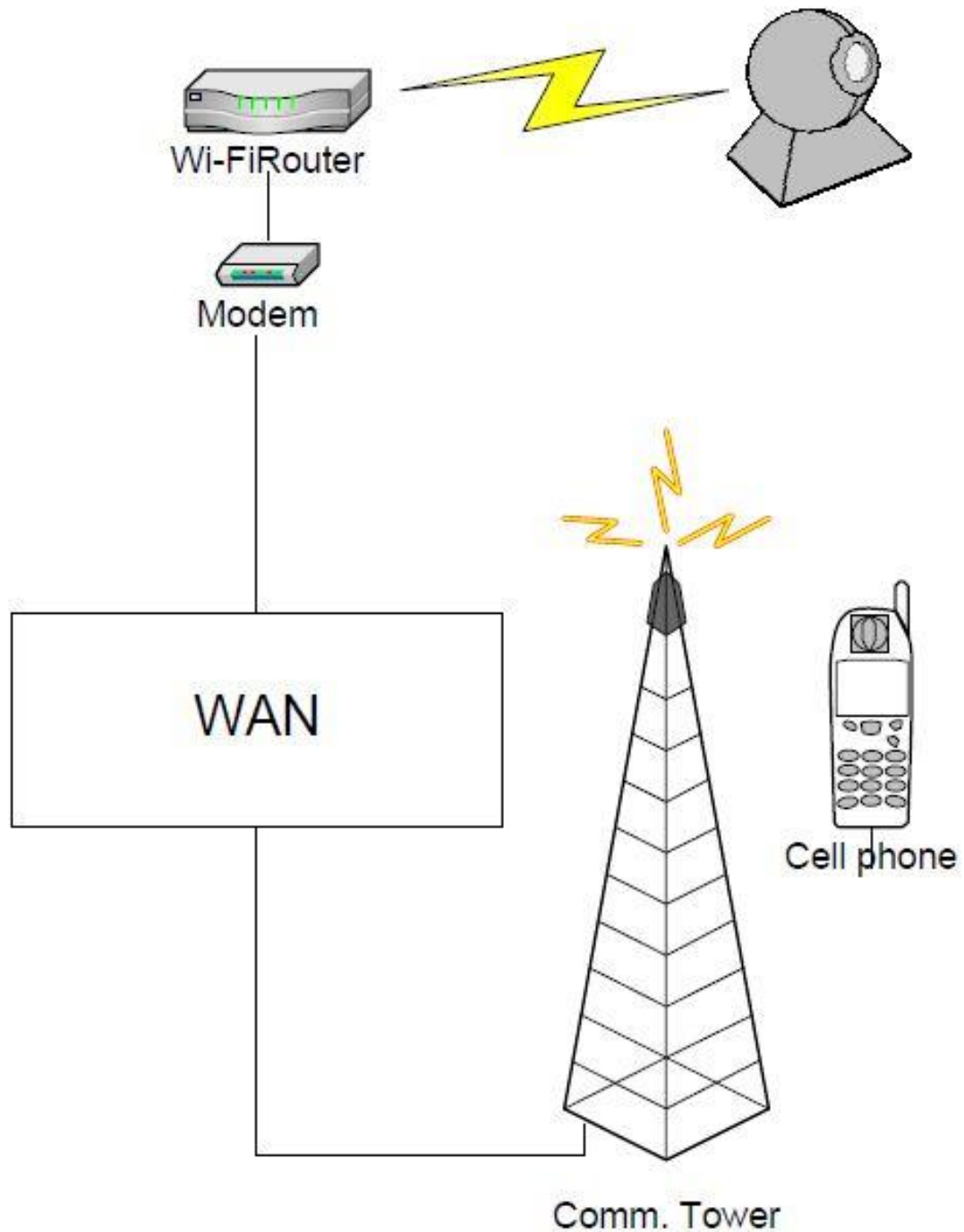
Figure 5.2.3-1 Camera to WAN Interconnect

To establish a static IP address some settings need to be changed in the wireless networking portion of the Linux operating system. When using embedded Linux the Wi-Fi configuration file must be edited to reflect the IP address desired. Because the AM335x SK also has two Ethernet ports additional

configuration is required to disable that connection. With the Ethernet ports disabled the Wi-Fi connection will become the default connection on boot up.

5.3 CAMERA

The Logitech C110 Webcam was the selected for this design for many reasons. The primary specification for this design's camera, was that it needed to be a Universal Video Class compliant device. Selecting a UVC camera was so important because it ensured compatibility with the libraries of the Linux kernel distribution, and the hardware selection regarding the processing system.

5.3.1   Camera Requirements

The Logitech C110 webcam is relatively low performance in the camera world. Though counter intuitive this will be useful because it will reduce power consumption in two ways. First the camera itself will require less power. Secondly the video processing system can be less powerful.

The specific system requirements for this camera are listed section 3.5.2. These requirements are greater than the camera will actually need. This is because these requirements are specific for running the camera on a standard operating system. This design will run the camera on a simple Linux kernel, which will be stripped of all non-vital system resources. This stripped kernel distribution will require far less system resources than a standard operating system. This leaves more processing capabilities for processing the cameras video feed.

5.3.2   Image Sensor

Another reason this webcam was selected is that it contains a CMOS image sensor. This has a few effects on the decision. Primarily cameras utilizing a CMOS image sensor are very power efficient, opposed to a CCD camera. This is vital to the design since it is powered entirely by a solar panel. CMOS cameras are also traditionally far less expensive than CCD camera's. The difference between these sensors is explained in more detail within the research section of this design report.

5.3.3   Lens

This camera features a plastic lens, which greatly reduces the cost. The bad side of this type of lens is that it's more prone to scratching and degrading the video quality. To prevent the cameras lens from acquiring scratches it will be mounted in a protective housing. Aluminum weatherproof surveillance camera housing can be purchased for relatively low cost. These housings contain a Plexiglas window that will prevent the camera from being worn out by the weather.

5.4 SOFTWARE UTILITIES/VIDEO FORMAT

5.4.1   Operating System

This design utilizes Angstrom v12.1, which is a Linux kernel distribution. The selection of an operating system was narrowed down to one of the Linux distribution because all of these distributions have such an extensive collection of community support packages. In addition to this all of the distributions are beginner friendly and are freeware, meaning they will not affect the budget.

There were many other possible operating systems. For instance Android or Windows CE have advanced features that cannot be replicated using a Linux based distribution. These two operating systems were not selected primarily because they require a steep learning curve to be implemented.

Once the processing system has been cleared of the previous kernel, it was loaded with the Ubuntu default library package. The Angstrom kernel is saved on an SD memory card, so that it may be modified or stripped down later. Using the systems touchscreen or an external Linux machine it is possible to display all of the default libraries contained within the kernel package. Finally all of the unnecessary libraries may be deleted to reduce boot time and save disk space on the SD memory card.

5.4.2   Mjpg-Streamer

For this build Motion jpg format (Mjpg) was selected as the video format. This file format takes video feed directly from the camera as a series of JPEG images. These images are constantly refreshed to produce a video.

Streaming video feed as Mjpg format has one major advantage. This advantage is that Mjpg is a lightweight process compared to using ffmpeg. Mjpg is lightweight pertaining to how CPU intensive the video processing is. Since this video capture process is not demanding on the CPU, this has two benefits for the entire system. Both data overload and power consumption are significantly reduced. Data overload occurs when there is a bottleneck of data waiting to be processed.

 Also this process has a large support among the video feed community; it has resources that are documented very well. Additionally several reference designs utilize this format for the reasons listed above. Multiple designs used similar microprocessors and were not capable of using ffmpeg video format alone. The primary problem these designers encountered was data overload. This occurs when the camera is feeding data to the processor at a rate faster than the processor can handle. This causes the video data to be saved in cache and RAM memory. These memory resources quickly fill and cause the system to dump all video data these memory locations contain. Thus most of the video feed is lost.

Choosing a more simplistic camera will decrease the rate at which data is being transmitted to the processor. This will help to prevent data overload at the processor.

Another advantage to streaming with Mjpg format is that this software package contains a small internal server. This allows us to forward any video stream request from the user to the internal server using a script. Capturing video feed in this manner requires minimal CPU usage and flexibility in regards to the user's media player.

5.4.3   Ffmpeg

Ffmpeg is a more robust video file type than Mjpg. It is possible to extract the data directly from the output of the camera as an ffmpeg file type. Since the file type is more robust it follows logic that it will require more processing power. This is not desirable since it will burden the process and create data overflow.

Since this design utilizes a power efficient microprocessor, the system cannot keep the video in ffmpeg format while being processed and transmitted. The video will retrieved from the camera as ffmpeg format and immediately converted to Mjpg format. This will prevent a bottleneck of data to be processed. After processing the data will be sent through the wireless transmitter, and displayed on the user screen as a constantly refreshing series of jpeg images.

Ffmpeg is utilized in this design specifically in the task of storing video to the external memory of the system. Mjpg format has a major drawback in that it cannot be stored as a video file. This is where ffmpeg is utilized. Mjpg video that is to be saved can simply be converted back into ffmpeg format and save as an flv video file.

5.5 PROCESSOR

5.5.1   Microprocessor (AM3358)

This development board has an AM3358 processor at its core. The AM3358 is capable of speeds up to 720 MHz at a 32 bit word size. This is one of the fastest processor offered in the TI ARM series of processors.

This processor is powerful enough to accomplish the task being implemented by this design. Running at maximum speed this processor only consumes around 7 mW. This is a highly power efficient processor.

5.5.2   Input / Output Configuration

To transfer the video feed from the camera to the processing system, a USB port on the development board will be utilized. This is the main reason why a universal video class camera was selected. All universal video class cameras utilize a USB port for data transfer.

The Logitech C110 webcam does not utilize a 2.0 USB port because it is only produces a 1.3 mega pixel video quality. The AM335X SK does feature two USB 2.0 ports. This design will not initially utilize these ports to their maximum potential because it is not required by this camera. If greater video definition is required at a later point, this camera can simply be swapped with a higher quality video camera. This replacement camera will only have one requirement, such that it is to be a universal video class compliant device.

This board features two 1 Gigabyte Ethernet switch ports. One of these ports will not be utilized.

5.5.3   Graphical User Interface

The graphical user interface of this board utilizes a 4.3 inch Touchscreen LCD display. The removable touchscreen can act as a tablet because it has a secondary processor that is primarily devoted to graphics.

Removing this board will limit the device's interfacing capabilities. This is not significant to this design since the processing system will be enclosed within the units housing. Additionally removing or disabling this screen will greatly reduce power consumption of the device. Not utilizing this screen will increase the battery capabilities of this device, meaning the functioning time on a single battery charge will be increased.

5.5.4   System Specifications

This board has 256MB DDR3 which in combination with the microprocessor throughput is not enough RAM to transmit the video feed entirely in ffmpeg format. As mentioned above the video feed will be converted to Mjpg format to alleviate stress on the processing system. If the video feed is to be stored, than it can simply be changed back into ffmpeg format and saved as an flv video file.

5.6 REMOTE MONITORING OVERVIEW

The remote monitoring feature of the KWS makes up the entire user interface system. There are only two methods in which the user can interact with the KWS camera. The user can remotely monitor and control the KWS video feed from

their desktop computer or laptop of their choice. The user can also remotely monitor the KWS video feed from their smartphone. The details in the following sections assume the login feature with username and password has been implemented.

5.6.1   Remote Desktop Access Design

A desktop application is required for the KWS camera. This is the main method of viewing and accessing the KWS video stream. This program was written in C++ while developed and tested in Microsoft Visual Studio 2010. It was also developed to run on a PC running Windows XP or newer. The program will be fully functional only if the base station is connected to the KWS network. When this is done correctly and successfully, the user will be able to use the KWS desktop program to properly connect to their KWS camera.

The program can be used to display the video stream, display the diagnostic information, and record the live video stream. When the user launches the program for the very first time, they will be prompted to enter the IP address of the KWS camera. The IP address will never have to be entered again unless the IP address changes or the user wants to connect to a different IP address. There will be an option to allow the user to change the IP address.

After the user has entered the IP address, their computer will serve as the base station and the user will be able to access the camera whenever they desire from the KWS program. The program will be displaying in real time two important items; the video stream and the diagnostic information as discussed earlier.

The other feature the KWS desktop program provides is the ability to record the live video feed. The user must specify the duration of the desired recording as well as the destination of the recordings. Those two details help make the features of the KWS camera user specific. In short, the user can implement their configurations.

To producing large files, the recorder forces a cutoff duration for the video files. The recorder can only record five minutes of video or less into a video file. This means that if a user wanted to record 21 minutes and 30 seconds of video, the recorder will output five video files: four 5-minute long videos and one that is 1-minute and 30 seconds long.

Additionally, there are two external requirements that are needed in order for the KWS desktop program to work properly. The first requirement is that the user must have the program VLC Media Player installed onto the base station. The second requirement is that the user must also have the internet browser Mozilla Firefox installed onto the base station.

5.6.2　Remote Smartphone Access Design

An important feature that the KWS system must have is smartphone compatibility. From a smartphone, the user will be able to launch the KWS app that allows them to interact with the KWS camera. At every launch, the user must enter the IP address of the camera. After a successful connection the user will be brought to a display showing the live video feed. The user will also be able to view the diagnostic information. There is also a button that will allow the user to capture a snapshot straight to the SD card of the Android device.

5.6.3　Remote Internet Access Design

As mentioned earlier, the KWS camera will be streaming in an MJPEG format over a network. In order to view this video stream, a web browser must be used that has support for MJPEG. Three popular web browsers were considered and it was determined that the KWS camera should use Mozilla Firefox if the user wanted to view the video stream from a web browser only.

6　PROTOTYPE DEVELOPMENT

6.1 REMOTE MONITORING SYSTEM

6.1.1　Acquisition and Uses of Software Tools

Before the remote monitoring software could be developed, the proper tools were needed. There were several software and development tools that were needed and each of these were used in different ways.

6.1.1.1 Microsoft Visual Studio

Microsoft Visual Studio (VS) was the dominant tool in developing the desktop application. The desktop application is primary user interface and must be the first piece of software to be developed. Microsoft VS is an excellent tool to use because it is free for students in the computer science or computer engineering field and can be downloaded from the www.msdn03.e-academy.com website using a student account. Another reason why it will prove to be useful is its easy-to-use GUI environment development tools. The desktop application was developed using Windows Forms (WinForms) in combination with the Microsoft Foundation Class (MFC) Library. With these tools, the KWS project was able to develop a user friendly desktop application that fits all the requirements of the design.

6.1.1.2 Android SDK and Eclipse

As discussed in section 3.6.3.1, the smartphone application was developed using Eclipse and the Android SDK. The Android SDK is an open source software stack for mobile devices. Since it is open source software, it can be downloaded from the www.developer.android.com/sdk/ website. This download includes a version of the Eclipse IDE with built-in ADT. Eclipse is an open source software that allows programmers to develop programs written in Java. Since it is open source software, it can easily be downloaded from www.eclipse.org/downloads website.

Using the Android SDK with Eclipse allowed the KWS project to develop a smartphone app with ease. The graphical UI builder that comes with the SDK allowed for easy interface development by providing drag and drop functionalities. Using this feature, it is easy to visualize how the application's UI will look like on various Android devices. This also provides support for working with custom UI components. Additionally, Android.com has many resources available to help new mobile application developers. With all these tools, the KWS project will be able to develop a fully functional app that meets all the requirements of a security camera application.

6.1.1.3 NCH Software Integration

Aside from Microsoft VS, Eclipse, and the Android SDK, there were other software that may be used to assist the development of the KWS desktop application and smartphone app. Such software will not be considered primary tools and will only be used as secondary tools. The majority of this secondary software will be from NCH Software.

NCH offers several software tools that handle various tasks that involve video. Such tasks include video conversion, video streaming, video surveillance, capturing streaming video, and several more. Much of this software has been discussed in earlier sections. The various NCH software tools that are under consideration of being used are Prism, Broadcam, Eyeline, and Debut as discussed in section 3.6.2. All of this software can be downloaded from the NCH Software website. They all can be purchased or downloaded for free with limited capabilities.

These software tools will mainly be used to help record video or assist with video streaming for the remote monitoring smartphone app. The way they will be integrated into the KWS system will be through scripting. This way the user will not have to use extra programs which would decrease the ease of use of the KWS user interface.

6.1.1.4 HandBrake Integration

Similar to the NCH Software that was used is HandBrake. Handbrake was discussed in section 3.6.1.2 and will be used to assist in archiving. The KWS camera aims to continuously record the video stream in a three hour interval. Of course, this causes a high demand for storage space. With the KWS system, the amount of storage space is limited to the user's hard drive. To lessen the strain on the hard drive, other means of storage are needed. Hence, the HandBrake software will be used as a tool for video storage. HandBrake is a multiplatform and multithreaded video transcoder. It will be used to further compress recorded video to a smaller file to decrease the KWS's demand for memory space.

HandBrake is Open Source and, therefore, it is free of cost and can be downloaded from the website handbrake.fr. Similarly, since it is open source it can essentially be used to cater to the needs of KWS with respect to video storage and archiving. The way it will be integrated into the KWS system is very similar to how the NCH software will be implemented. Using scripts, HandBrake can be used in the background without the user being aware of the process. Video compression can be a lengthy process, especially for many video files. Therefore, having HandBrake run without the user's knowledge will assist in the user friendliness of the KWS system.

However, the user does need to decide what to do with the compressed video files. The user can set a time frame in which the software compresses the video files outside of the time frame. This is one month by default. The user can then choose to continue storing video on their hard drive, or they can choose to store the video files by some external means.

7   PROTOTYPE TESTING

7.1 COMMUNICATIONS SYSTEM TESTING

Windows has many built in networking diagnostic tools that can detect error packets over the network. The ping tool is extremely useful.

In the windows command line the command ping will send a few packets to a network device. The user must define the IP address that the packets should be sent to such as 192.0.0.1 but in this test the user will enter the static IP address of the camera.

The ping command returns whether or not a packet is received and what the latency time is on the round trip. With the simple ping command a small report is printed with the number of packets sent versus the number of packets received and the percentage of lost packets. Along with the lost packet report a latency report is displayed with the minimum latency, the maximum latency and the average latency. There are expanded fields within ping tools that provide more

advanced IP testing conditions. The following is the format for advanced ping commands.

```
C:\Users\JTC>ping

Usage: ping [-t] [-a] [-n count] [-l size] [-f] [-i TTL] [-v TOS]
            [-r count] [-s count] [[-j host-list] | [-k host-list]]
            [-w timeout] [-R] [-S srcaddr] [-4] [-6] target_name

Options:
    -t              Ping the specified host until stopped.
                    To see statistics and continue - type Control-Break;
                    To stop - type Control-C.
    -a              Resolve addresses to hostnames.
    -n count        Number of echo requests to send.
    -l size         Send buffer size.
    -f              Set Don't Fragment flag in packet (IPv4-only).
    -i TTL          Time To Live.
    -v TOS          Type Of Service (IPv4-only. This setting has been deprecated
                    and has no effect on the type of service field in the IP Head
er).
    -r count        Record route for count hops (IPv4-only).
    -s count        Timestamp for count hops (IPv4-only).
    -j host-list    Loose source route along host-list (IPv4-only).
    -k host-list    Strict source route along host-list (IPv4-only).
    -w timeout      Timeout in milliseconds to wait for each reply.
    -R              Use routing header to test reverse route also (IPv6-only).
    -S srcaddr      Source address to use.
    -4              Force using IPv4.
    -6              Force using IPv6.


C:\Users\JTC>
```

Figure 6.1.1-1 Advanced Ping Functionality

For this range test the "-t" field should be used to continuously ping the target until the command line is forced closed with Ctrl-C or the "-n" field can be used with a discrete number of packets to send for example "-n 1000". The "-R" argument should be used in this test to analyze the round trip of the packet. The round trip packet test is important because it demonstrates that the RF module on the camera has enough power to send data back to the router. The RF module is the weak link in the communication network because it is designed for low power applications and it is also located inside of a metal and wood housing which partially block RF signals.

7.1.1   Range

Range is an important part of the cameras feature set. The goal for this project is to have a twenty meter outdoor range. The test procedure is as follows:

1.   Power on the camera and Wi-Fi router placing both outside and establish a connection between the camera and the Wi-Fi router.
2.   Connect a windows test machine (laptop or desktop) to the router. Connecting via Wi-Fi will increase the latency and may make troubleshooting more difficult.

3.   On the windows test machine start command prompt. On 7 or Vista search CMD in the program search. On XP type cmd is in the start menu run option.

4.   Use the ping command with the static IP address of the camera to insure everything is communicating correctly.

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\JTC>ping 10.36.60.88

Pinging 10.36.60.88 with 32 bytes of data:
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128

Ping statistics for 10.36.60.88:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\JTC>
```

Figure 7.1.1-1 Ping Results

5.   After confirmation that the packets were received in step 4 run a "ping -n 100 -R" followed by the static IP address of the camera.

6.   After that command is executed the user should see the following

```
C:\Users\JTC>ping -n 100 10.36.60.88

Pinging 10.36.60.88 with 32 bytes of data:
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128

Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128
Reply from 10.36.60.88: bytes=32 time<1ms TTL=128

Ping statistics for 10.36.60.88:
    Packets: Sent = 100, Received = 100, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\JTC>_
```

Figure 7.1.1-2 Ping Results of 100 Samples

7.   Now the camera can be mover a meter away from the router.

8.   Run steps 5-7 until the camera is 20 meters away from the base or until there is a packet failure

9. If the camera communicates properly at 20 meters a long term test should be performed at that range.
10. Run a "ping -n 10000 -R" followed by the static IP address of the camera. This command will take a large amount of time so the user and leave and return later.

```
C:\Users\JTC>ping -n 10000 192.168.1.8

Pinging 192.168.1.8 with 32 bytes of data:
Reply from 192.168.1.8: bytes=32 time=546ms TTL=128
Reply from 192.168.1.8: bytes=32 time=471ms TTL=128
Reply from 192.168.1.8: bytes=32 time=280ms TTL=128
Reply from 192.168.1.8: bytes=32 time=617ms TTL=128
Reply from 192.168.1.8: bytes=32 time=536ms TTL=128
Reply from 192.168.1.8: bytes=32 time=453ms TTL=128
Reply from 192.168.1.8: bytes=32 time=65ms TTL=128
Reply from 192.168.1.8: bytes=32 time=602ms TTL=128
Reply from 192.168.1.8: bytes=32 time=128ms TTL=128
Reply from 192.168.1.8: bytes=32 time=439ms TTL=128
Reply from 192.168.1.8: bytes=32 time=53ms TTL=128
Reply from 192.168.1.8: bytes=32 time=88ms TTL=128
Reply from 192.168.1.8: bytes=32 time=162ms TTL=128

Ping statistics for 192.168.1.8:
    Packets: Sent = 3756, Received = 3701, Lost = 55 (1% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 1657ms, Average = 265ms
Control-C
^C
C:\Users\JTC>
```

Figure 7.1.1-3 Ping Results of 1000 Samples

11. If more than 1% of the packets are not received then the camera does not meet the 20 meter requirement.

7.1.2   Latency

Network latency is the time it takes for the data to get to and from the transmitter to the receiver. The windows ping tool includes a measure of the data latency in milliseconds. If the latency in the following test exceeds 4ms for small packets the link may have trouble receiving and decoding the IP Traffic causing poor Wi-Fi coverage. The latency needs to be tested with range from the router in consideration. Once the above range tests have been performed the latency test should be tested at the maximum distance from the router. Under this condition the latency should be the highest.

1. Place the camera at the maximum range with no packet errors from the range testing (20 meters)
2. On the windows test machine start command prompt. On 7 or Vista search CMD in the program search. On XP type cmd in the start menu run option.

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3. Run a "ping -n 100 -R" followed by the static IP address of the camera.
4. Record the latency from the 100 pings and take note of the average.
5. If the average ping latency is over 4ms the range of the camera may need to be decreased to allow for better communication characteristics when handling larger data samples.

7.1.3   Bit Rate

Establishing a base line bit rate is important for understanding the amount of data that can be sent and received effectively over the Wi-Fi link. Under optimal conditions Wi-Fi routers are capable of 54 Mbps to 600 Mbps. Expecting this bit rate for real world applications is unreasonable. Under IP traffic with multiple users and with outside interference, a reasonable bit rate of 512 Kbps to 1 Mbps is to be expected. To test the bit rate the following equation will be used in combination with the ping tool.

$$Bit\ rate = packet\ size * Packet\ transmission\ time$$

The ping tool can send packets of any size using the "ping –l 100" where 100 is the number of bytes you want to send in each packet. The procedure for testing the bit rate is as follows:

1. Place the camera at the maximum range with no latency errors from the above testing (20 meters)
2. On the windows test machine start command prompt. On 7 or Vista search CMD in the program search. On XP type cmd in the start menu run option.
3. Run a "ping -n 100 –l 100" followed by the static IP address of the camera
4. The results of the 100 pings will be displayed, divide the 8000 (which is 100 bytes times 8 bits per byte) by the average latency.
5. The result should be no lower than 256 kbps to insure error free network communication.

7.2 WEATHER PROOFING

The camera housing needs to protect the electronics from the weather. Marine sealant will be used to seal the seams of the housing. The plan to have the roof/ solar panel hinge to allow access to the electronics for development and testing leaves a large area that needs to be sealed with weather stripping. To test the weather resistance of the housing, the interior of the housing will be lined with tissue paper. Once lined the camera housing will be closed and latched. With the weather stripping creating a seal, the housing will then be sprayed with a garden hose from a multitude of angles.

If any water intrudes into the camera housing the tissue paper will change color and consistency. With the leak identified measures can be taken to better seal the housing. If no water intrudes, the housing passes its weather proofing test.

7.2.1　Webcam Housing

The webcam housing is being purchased from a third party. The third party housing needs to be tested for weather proofing. The webcam housing will be lined with tissue paper and sprayed with water from multiple angles to insure that it is weather proof.

The webcam housing needs to be attached firmly to the main housing. The housing should be able to withstand windy conditions.

7.3 POWER SUBSYSTEM

7.3.1　PV Panel Testing

The solar panel was tested for functionality by exposing it to sunlight vs. shade conditions and connecting a multimeter to its terminals to test for proper voltage measurements. The panel was tested in direct sunlight and in cloudy conditions to confirm functionality. The voltage from the solar panel was much higher in direct sunlight vs. when the panel was in the shade. This confirmed a working solar panel ready for design.

7.3.2　Battery Testing

To test the battery status, a small load was applied to the battery and the output voltage was measured using a multimeter before and after applying a load to confirm the battery has the capacity to run properly. Voltage probes were connected to the multimeter and a range was selected within the battery's specifications.

The multimeter probes were then connected to the terminals of the battery. The multimeter was turned on and the DC measurement was distinguished. If the unloaded voltage measurement of the battery does not drop and is close to the voltage of measurement of the battery under load, then the battery is sufficient.

7.3.3　MPPT Charge Controller Testing

There are several components that make up the MPPT charge controller. Each component was tested individually to confirm proper functionality. Testing each component in the following order helped to remove the possibility of error and retracing of steps in the design process.

7.3.3.1 Arduino Uno R3 Testing

The Arduino Uno R3 and the printed circuit board were tested first before connecting other circuit components. The Arduino software was downloaded and used to program the Arduino Uno R3 with the Maximum Power Point Tracking algorithm.

Verifying that the Ardunio development board was working properly is important to do before soldering all of the electronic parts on to it. After installing the Arduino development software, the Arduino was connected to load the drivers. The Arduino was plugged into a laptop via the USB connector to install the Arduino software and begin coding implementation.

A sample code to blink the LED on the Arduino board was a proper test to ensure functionality. After opening the programming software a sample code to blink the board's LED was installed to make sure the board was working properly. When unloaded, the Arduino Uno R3 board should be drawing around 60mA when operating and the Arduino protoboard should draw about 30mA. After verifying that the Arduino could be programmed and powered, it was time to test the implemented power circuit.

7.3.3.2 Power Circuitry Testing

Before connecting any power through the circuit, a multimeter was used to test the resistance at the input. If components were connected properly, this resistance value should be fairly large to prevent damage to the circuit. A 12-volt power supply was used for testing after verifying sufficient resistance. The MOSFET driver (IR2104PBF) was tested for functionality in this test.

A driver test program was uploaded to the Arduino board and an oscilloscope was used to confirm the proper waveform of the PWM signal from the microcontroller. The output for this test is shown in the figure below and is as expected.

Figure 7.3.3-1 PWM waveform on oscilloscope

7.3.3.3 Load Circuitry Testing

After assembling the load circuitry, a new program was loaded to the Arduino to test that the PWM duty cycle is working properly. The operating frequency was used to test this feature, and a 2-channel oscilloscope was utilized to test the operation of the MOSFET's in the overall circuit schematic.

The input voltage on the solar panel input was set to 16.5 volts. The following duty cycles were tested and verified.
512/1024 = 50%   Battery voltage output = 8.25 volts
750/1024 = 73%   Battery voltage output = 11.5 volts
1024/1024 = 100%   Battery voltage output = 16.5 volts

7.3.3.4 Current Monitoring Circuitry Testing

The current monitoring circuitry was attached and tested. The circuitry allows the maximum power point algorithm to find peak power efficiency. At this point, the maximum power point algorithm was uploaded to the Arduino Uno to test the current sensor. If working properly the charge controller should regulate the input voltage. This was verified.

7.3.4   Buck Converter Testing

To test the functionality of the buck converter, a variable DC supply was connected to the PV terminal. The input voltage was increased from 11 volts to 19 volts in steps of 2 volts. The input and output voltages were measured. If the buck converter is working properly, charging current flows into the battery when

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the input voltage is less than the battery voltage. This was verified through the serial output monitor.

The efficiency of the buck converter was also tested. This was done by first connecting a DC supply and a DC load to the charge controller. The system was tested varying the input voltage between 12 and 20 volts by setting the input power at 5W intervals from 0 to 80W. The output voltage and current were measured and thus the input and output efficiency was calculated. The efficiency was calculated as a function of input wattage and the efficiency was around a minimum 98% efficiency.

7.4 REMOTE MONITORING SOFTWARE

The remote monitoring software for the desktop program and the smartphone application are strictly a means for the user to communicate with the KWS camera. To determine if the software is fully functional with respect to its user interface and capabilities, the GUI must be tested is if being run by the user.

While the remote monitoring feature is primarily for interface purposes, the reliability of the software must be tested as well. The following sections describe how the various aspects of the remote monitoring software will be tested. The details of the testing procedures assume the login feature with username and password has been implemented.

7.4.1   Desktop GUI Environment Testing

The desktop GUI environment lays the foundation for the remote monitoring feature of the KWS project. The procedure to test the GUI environment is detailed below. The procedure is described similar to that of a user guide.

1. Launch the KWS program.
2. Enter IP address
3. Verify live video streaming
4. Verify correct diagnostic information.
5. Enter a time duration in seconds in the record section.
6. Press the record button.
   a. Verify that video was saved in your desired directory.
7. If no errors have occurred, the program is fully functional.

7.4.2   Desktop Reliability Testing

The reliability of the desktop program must also be tested in conjunction with the GUI environment. Testing the reliability of the program will show that the functions executed by the program are done properly and fit the requirements of the KWS system. Several aspects need to be tested but not necessarily in order and are described below.

1. Video Streaming
   a. Verify that the network configurations for streaming are correct by seeing the live video feed in the program.
   b. Verify that the video feed is the correct video coming directly from the camera.
2. Video Playback
   a. Verify that the network configurations for video capturing are correct by seeing the video is recorded and displayed in the program.
   b. Verify that the video being recorded and stored is the correct video feed.
   c. Verify that playback is functional.
   d. Verify that video recorded outside of the time frame determined by the user is correctly compressed and put in the correct directory determined by the user.
3. Diagnostic Information
   a. Verify that the network configurations for diagnostic information is correct by seeing the information in the program.
   b. Verify that the video feed is the correct video coming directly from the camera.

If all of the above can be verified, the desktop program should be fully functional and ready for use.

7.4.3   Smartphone GUI Environment Testing

The smartphone GUI environment is the primary method of remote monitoring outside of the user's home computer or laptop. The procedure to test this GUI environment is detailed below. Some of the features available from the desktop program will not be available on the app. Therefore, the two procedures are not the same. The procedure is described similar to that of a user guide.

1. Launch the KWS program.
2. Enter IP address
3. Verify live video streaming
4. Verify correct diagnostic information.
5. Press the Capture Snapshot button.
6. Verify that the snapshot was saved on the SD card
7. If no errors have occurred, the program is fully functional.

7.4.4   Smartphone Reliability Testing

The reliability of the smartphone app must also be tested in conjunction with the GUI environment. Testing the reliability of the program will show that the functions executed by the program are done properly and fit the requirements of the KWS system. Several aspects need to be tested but not necessarily in order and are described below

1. Network Connection
   a. Verify that the network configurations are correct by seeing the app connected to the camera.
2. Live Video Feed
   a. Verify that the network configurations for video streaming are correct by seeing the live video feed is being displayed on the app.
3. Diagnostic Information
   a. Verify that the network configurations for diagnostic information is correct by seeing the information in the program.
   b. Verify that the video feed is the correct video coming directly from the camera.
4. Snapshot
   a. Verify that the network configurations for snapshot capturing are correct by seeing the snapshot is recorded on the SD card.
   b. Verify that the snapshot being recorded and stored is the correct snapshot.

If all of the above can be verified, the desktop program should be fully functional and ready for use.

8   CONCLUSION

The motivation for this project was to create a reliable home security system. The primary specification of this design was to run entirely off solar power. This move to run independent of the grid coincides with the popular cause of going green. Another advantage of being solar powered is that this security system will not rely on any external power. This means if the electricity to the user's home is interrupted the surveillance system will continue uninterrupted. Data recorded during this time is stored on a micro SD card that may be retrieved later.

This design will consist of two main parts. A portable device to record and transmit video in three hour increments, and a host server that will receive the video feed to be saved or distributed to remote monitoring devices. This will allow the user to keep an eye on their property from any location, given they have internet access and a device with a web browser. The defining feature of this camera system is that all of this will all be done using no external source of power.

8.1 PROCESSOR

This design features a TI AMM3358 that is capable of speeds up to 720 MHz. This system utilizes 256 Mb of DDR3 RAM and onboard cache memory. Diagrams that detail the processors layout, data flow and input / output port configuration of this board are depicted in the research section of this report.

This board features a 4.3 inch touchscreen graphical user interface. This touchscreen has a secondary processor for advanced graphics. This screen is not utilized in the final design for a few reasons. Primarily it is not utilized since the development board will be contained within the housing of the system. Since this board must be contained in the housing it cannot be accessible to the user once the device is built and functioning. Additionally not utilizing this screen greatly reduces the power consumption of the device. Finally disabling and removing the graphical user interface will enable the Linux kernel to run in text mode, which minimizes system resources and allows more processing capabilities to be devoted to video processing, converting and transmitting.

8.2 NETWORK COMMUNICATION

8.2.1   Wi-Fi

Wi-Fi is utilized to wirelessly stream the data from this device to the base computer. Wi-Fi was selected because it offers a good transmission range, low power consumption and it's cost effective. Additionally there is limitless supply of technical resources.

The final design of this project utilizes a D-Link wireless router to transmit the video feed. Using this router will improve the transmission range when coupled with the onboard wireless capabilities of this system. Also using an outside wireless transmitter is required in the project specifications for this design.

The two parts to this system are connected through a LAN system. This is done by setting up a static IP address as a host server on the portable part of the system. The base computer then links to this static IP address to retrieve the video feed. This system is not designed to require a password for connectivity. This was thought of as a hassle for users to setup. However the system can be password encoded at a later point if necessary

Transmitting the wireless video feed has three main steps. The video feed is fed from the camera through the microprocessor to be processed and converted. Once the video is in the correct format it will be broadcasted from the development board's wireless card. The wireless data is then received by the D-Link wireless router. Once the video feed is sent to the wireless router, it is possible to use any computer on the wireless network to access it. The base computing system receives video feed from this wireless router as well. This wireless router is also the source of video for the smartphone application.

8.2.2   Base System

This processor is also used to stream video as a web server to the base computer. To accomplish this, the processor is used as an html host. To efficiently stream the video with and avoid compatibility issues both the device and base computer will be running a Linux platform distribution or kernel.

If the base computing system is to fail this device is programmed to record the video onto a micro SD card which can be removed later and data may be retrieved from it. This allows the device to continue surveillance if the base system loses power or goes offline for any reason.

8.3 POWER SUBSYSTEM

The primary feature that differentiates this system from other security systems is the power subsystem. This power subsystem allows our device to function completely independent of external power sources. This was done in an effort to conform to the going green movement. This power subsystem consists of three essential components; the solar panel, the battery and the charge controller system.

8.3.1   Solar Panel

For cost reasons this design used a 50-watt mono-crystalline solar panel. This panel was the only power source for this device. Its optimum charging voltage is

17.4 volts at a current of 2.87A. It can produce a maximum voltage even higher than this, 21.6 volts. However both of these voltages are too high and might damage the battery. To prevent damaging the battery this unit implemented a MPPT charge controller. This charge controller is used to limit the voltage and current levels charging the device's battery.

8.3.2   Charge Controller

This system utilizes a photovoltaic solar panel. This panel converts energy from the sun to electrical power that is stored within the systems battery. A custom PCB board is implemented in this design as a charge controller. The PCB board was designed using Cadsoft's Eagle circuit design software. This charge controller implements a maximum power point tracking algorithm to charge the battery as efficiently as possible. The primary mechanism of this device is to match the voltage levels of the battery and solar cell.

The charge controller uses algorithms to select one of three separate charging modes. These modes are bulk charge, absorption charge and float charge. They have varied voltage and current levels that are specified for different battery conditions. This circuit improves the performance, charging time and reliability of the device. Both the battery and solar panel of this device will last longer. The battery and solar panel are two of the most expensive parts used in this build.

This charge controller also minimizes power fluctuations to the battery. Since the panel's electricity is dependent on the sun light, it can fluctuate rapidly. This will also improve the lifespan of the battery, since it will be charged with direct current power and no alternating current noise.

8.3.3   Battery

This design features a sealed lead acid battery that has an extensive lifespan. This is a deep-cycle battery, which means it is capable of being charged and discharged throughout its lifetime.

8.4 CAMERA

This project will utilize a Logitech C110 webcam. This camera is capable of 1.3 mega pixel video quality and features a CMOS image sensor. This is a universal video class (UVC) compliant device, which implements universal specs and drivers. This camera is compatible with essential every operating system and all hardware selections that feature a USB port.

8.4.1   Image Sensor

This camera is extremely power efficient in comparison with its high video definition. This is primarily due to CMOS image sensor it contains. CMOS image sensors are superior on power conservation because it houses the majority of its timing and video processing components on the semiconducting sensor chip. Additionally CMOS image sensor degrade very slowly overtime compared to cameras featuring CCD image sensors. CCD image sensors are notoriously unreliable in outdoor environments and are sensitive to bad weather.

8.5 HOUSING

The housing for this device will consist of two parts. The primary housing will enclose everything except the camera and solar panel. The solar panel will be mounted to the outside of this unit. This panel was required to be placed on the outside of the device simply because it must be exposed to the sunlight.

The camera will need to be protected from the environment. This design initially specified mounting the camera within the primary housing and protecting it with a Plexiglas window, so that its view will not be compromised. The flaw with this idea is that the camera view could not be adjusted. To rectify this problem the camera will be contained within a secondary housing that is attached to the primary housing.

This will be a generic housing for security camera, and will be purchased from a main stream vendor to minimize the cost. This secondary housing will also enable the user to set the video camera a long distance from the device. This distance between the camera and the primary device housing is only limited by the length of USB cable from the camera. This is only suggested for installing the camera to a permanent location.

8.6 SOFTWARE UTILITIES

The TI micro processing system will run on Linux Ubuntu v12.10 kernel distribution. The Linux kernel can be easily customized to the projects requirements. Once the package is downloaded it may be configured. The configuring process entails deselecting nonessential kernel components. This system is tasked with processing and converting the video feed from the camera, then wirelessly streaming it to a host system. All the kernel components not involved with either video processing or wireless communication will be removed.

This design will utilize the TI AM335X SK development board. This board was selected because it has low power consumption, high processing power, and is cross platform compatible. This board allowed the selection of any operating system or kernel distribution to run the device. This microprocessor can run up to

720 MHz at a word size of 32 bits. It is fastest enough to process, convert and wirelessly stream the Mjpg video feed from the device to the source system.

Video feed will be extracted from the camera as a series of JPEG constantly refreshing. This video format is call Motion JPEG or Mjpg for short. This video format prevents the system from creating a data bottleneck at the microprocessor. The primary drawback to this video format is that it lacks the capability of being saved. To rectify this, once the data has been wirelessly transmitted it will be converted to ffmpeg format so that it may be saved as an flv video file.

8.7 REMOTE MONITORING

The remote monitoring feature of this system enables the user to access the video from any device that contains a web browser and has connectivity to the internet. This connection can be done in three possible ways.

8.7.1   Base System

The first and most simplistic method is to view the camera feed is utilizing the base computing system. This system is a vital part of the surveillance system and by default has the video processing through it. This computer has the video feed streaming through it as a means of transportation to the internet. This computer accesses the video feed directly from the D-Link router. The video feed is streamed directly from the base computer to both the smartphone application and other desktop computers.

8.7.2   Desktop Access

The second method to access this video feed is through a remote desktop. Any computer with a web browser is capable of this. This is partially due to the flexibility of streaming video using an Mjpg format. Remote desktops can access this video feed without using a password. In other words the video feed produced from this camera will not be password encrypted.

8.7.3   Smartphone App

The third and final option for remotely accessing the surveillance footage from this camera is through the use of a smartphone. To accomplish this task an application must be programmed. The primary smartphone market consist of devices running on platforms of either Apple IOS or Android. To save time the application will be written in android code. The learning curve for writing software to be used on Apples software is quite steep.

Luckily once an application is written in Android it can be converted to run on Apples platform using a format converter. This will allow the development of two separate applications in the same time required to write a single application for a single platform. Formatting the application for both of these platforms encompass the majority of smartphones on the market.

Additionally software development tools specifically for the Android platform are free to the public. In addition to being free, there is a massive movement of support trending towards Android. This enables any amateur software developer to create state of the art applications. Another feature these applications will be capable of scheduling recording times for the surveillance system. So the user has the capability to save video feed specifically while they are at work or the property is unattended for whatever reason.

9 ADMINISTRATIVE CONTENT

9.1 BUDGET AND FINANCE DETAILS

KWS Project Budget				
Iteam	**Price**		**Money Allotted**	
Digi Key Order	$64.76			
Dev Board	$199.00		$1,378.00	
Solar FETS & Etc	$61.41			
Housing	$25.00		**Remaining**	
Camera	$18.51			
Ink	$30.51		$217.32	
Battery	$41.45			
Router	$79.99			
Solar Panel	$144.99			
Wifi Antenna	$7.95			
Led Strip	$11.98			
Atmega328 Kit	$10.90			
FT232RL USB to Serial	$14.95			
Atmega328 Kit_2	$10.90			
FT232RL USB to Serial_2	$14.95			
4PCB	$151.19			
Solar FETS & Etc (2)	$28.33			
Battery Housing	$109.17			
Battery Housing	$73.74			
Power Supply	$61.00			
Total Spent	$1,160.68			

9.2 PROJECT TIMELINE AND MILESTONES

Fall 2012

	Task Name	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Finalize project idea	■							
2	Get idea approved and find a sponsor	■							
3	Research video subsystem module	■	■	■					
4	Research networking subsystem module	■	■	■					
5	Research software development module	■	■	■					
6	Research power subsystem module	■	■	■					
7	Research how to integrate each subsystem into one		■	■					
8	Research parts (price, specs, etc.)		■	■					
9	Finalize expected design			■	■				
10	Finalize semester project report			■	■				

Spring 2013

	Task Name	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Review and Confirm Designs					■			
2	Order and Receive Parts					■			
3	Build and test video subsystem module					■	■	■	
4	Build and test networking subsystem module					■	■	■	
5	Build and test software development module					■	■	■	
6	Build and test power subsystem module					■	■	■	
7	Combine all modules						■	■	■
8	Verify and test combined system						■	■	■
9	Modify system to resolve issues						■	■	■
10	Finalize combined system							■	■
11	Prepare final presentation and present							■	■

APPENDICES

APPENDIX A – COPYRIGHT PERMISSIONS

Photovoltaics figures permission

mpanich
Friday, October 26, 2012 10:02 AM

To: gilbear@sciencerules.com

Hello Mr. Knier,

I am an electrical engineering senior at UCF and it is required by the university that students get documented permission for any references used in our senior project design. I wanted to request permission to use your figures on photovoltaics and solar energy in our written report. Thank you for your help.

-Michael Panich

irradiance figure permission

mpanich
Friday, October 26, 2012 10:54 AM

To: solarfas@yahoo.com

Good Morning,

I am an electrical engineering senior at the University of Central Florida and it is required by the university that students get documented permission for any references used in our senior project design. I wanted to request permission to reference your figure on solar irradiance in our written report. Thank you for your help.

-Michael Panich

Untitled Message

Send | Options... HTML

To... alastair.buckley@sheffield.ac.uk

Cc...

Subject: I-V Graph Reference Permission

monospace | 14 | B I U

Hello Dr. Buckley,
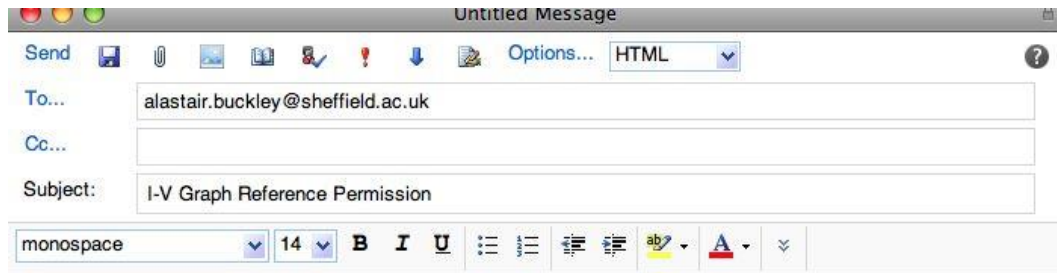
I am an electrical engineering senior at UCF and it is required by
the university that students get documented permission for any
references used in our senior project design. I wanted to request
permission to reference your I-V graph figure. Thank you for your
help.
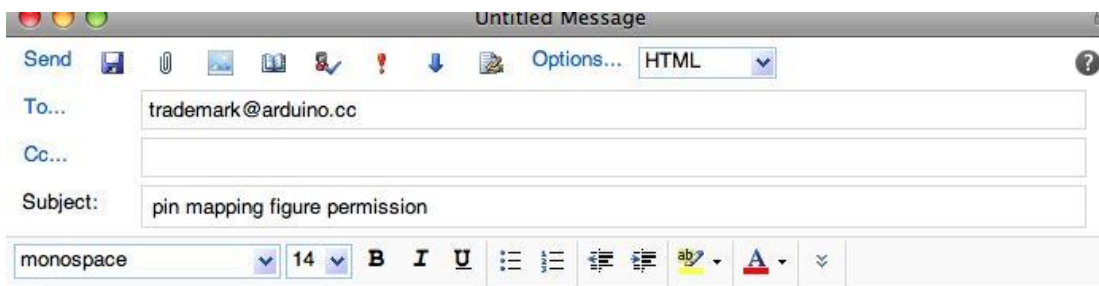
-Michael Panich

Untitled Message

Send | Options... HTML

To... trademark@arduino.cc

Cc...

Subject: pin mapping figure permission

monospace | 14 | B I U

I am an electrical engineering senior at UCF and it is required by
the university that students get documented permission for any
references used in our senior project design. I wanted to request
permission to reference your figure illustrating the pin mapping
schematic for the ATmega328p microcontroller. Thank you for your
help.

-Michael Panich

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Please contact us at:

Voice: 1.801.938.4264
Fax: 1.801.512-2957
Skype: vegetronix

You can contact us via email using the following form
We normally respond within a few hours.

First Name: *   Last Name: *
Michael   Panich

Email: *
mpanich@knights.ucf.edu

Company: *
University of Central Florida

Phone:*
407-730-1533   extension:

Enter your message: *

I am an electrical engineering senior at UCF and it is required by the
university that students get documented permission for any
references used in our senior project design. I wanted to request
permission to reference your Buck converter circuit schematic figure.
Thank you for your help.

Untitled Message

Send   💾 📎 ✉ 📖 ✍ ! ⬇ 📝   Options... HTML ▾   ❓

To...   sales@wholesalesolar.com

Cc...

Subject: AGM battery specifications permission

monospace   ▾ 14 ▾ B I U   ⋮≡ ≡ ⋯ ⋯ ✎ ▾ A ▾ ≫

I am an electrical engineering senior at UCF and it is required by
the university that students get documented permission for any
references used in our senior project design. I wanted to request
permission to reference your figure illustrating the specifications
of the AGM PVX-420T battery our group is planning on using in our
design. Thank you for your help.

-Michael Panich

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* First Name	Michael
* Last Name	Panich
pany/Organization	University of Central Florida
* Email Address	mpanich@knights.ucf.edu
Telephone	407-730-1533
City	Orlando
State	Flordida
Country	United States ▲▼
stions/Comments	I am an electrical engineering senior at UCF and it is required by the university that students get documented permission for any references used in our senior project design. I wanted to request permission to reference your circuit schematic for the LTC6101HV current sensing circuit. Thank you for your help.

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Email: *	lbsurfer90@knights.ucf.edu
Type of Service: *	Resources for Educators
Product Group:	Educational Resources
Product:	Professional Development
Purchase Time:	October · 2012
Customer Type:	Student
Enter Product Serial (Handheld) or Product License (Software):	(Serial# on back of Product - Example: XXXXXXXXXN-1199)
Select Computer Operating System (Software Questions):	Windows® 2007
Description: *	Good Afternoon,

I am a University Of Central Florida Student working on a Sr. Design Project. I would like to use some of your Wiki figures and some of your stock photos for our research report. This report is going to be used for educational purposes only. Can you release (grant promission for) these figures for our use.

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APPENDIX B – REFERENCES

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