University of Central Florida

Department of Electrical & Computer Engineering

EEL 4915
Senior Design

QwikCam
Final Document

Design Project

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1-Executive Summary

In the United states alone there are over 25,000 high school and junior programs. Extracurricular activities such as school sponsored sports and athletics make up a significant experience for millions of students and their families every year. Whether it be through direct contact and participation of an individual or the commitment of the family to come and support those that are participating. Being able to record, stream, and access footage of these athletics are crucial to many different clients and personnel in the junior athletic world. This can range from family members out of state wanting to tune in for a Friday night football game of their family member to a coach wanting to record the play on a soccer pitch to show his players later on in practice sessions what can be approved upon.

As there is a need for a system to record and stream these events, products have become available. However, most of these products are at a price point that is not obtainable for the schools or companies to allow for these events to be captured. This is mostly because the systems need to be able to capture many different sports that may require different needs in terms of camera and the ability to pan to different areas. If a company does decide to purchase and use one of these systems most of them use proprietary components and standards that make it more expensive to repair and requires parts to be purchased from the manufacturer which may take time to receive.

2-Project Narrative

2.1-Project Background

QwikCut is a video and analytics company based in the central florida area that is contracted to go to high school athletics such as football games, soccer matches, lacrosse matches, etc and their objective is to record, stream, and relay these games in real time from their current camera and tripod setup. This recording and live streaming can be used for some of the examples listed in the above sections and gives the customer a great service in filming these events. QwikCut's current setup coincides with a 25' tall tripod that is mounted with a Bescor motorized head with a Sony handycam and three cables used for streaming.

However, over the years that QwikCut has been operating they have found their tripod and camera setup to be less than adequate to handle the needs of the company and have been running into some issues that need to be addressed. The current setup as listed above has problems with its three cables system in which these cables are always needing to be replaced which is a great expense, the motorized head that is used at the top of tripod does not pan fast enough for sports and uses four AA batteries as a power unit, and the HDMI that is currently used does not carry audio while streaming the video. Along with these design issues another big issue comes from the fact that Florida's weather does not always give the company perfect conditions to film in, especially when the current equipment is not waterproof. In order to solve these downfalls QwikCut has called upon us to improve upon their current setup and design a new filming tripod that they call the QwikCam.

QwikCam will improve upon all aspects of the previous design in that it will feature more adequate and updated technology that can be used to better serve QwikCut themselves but also their customers. The system will consist of a Pan-Tilt-Zoom (PTZ) camera that will be housed in a waterproof container that will run via either a singular USB 3 or CAT 5 cable that will run to a computer to be recorded and streamed in real time. This PTZ camera will be able to stream in at least 1920x1080 clarity and will be able to be controlled by a wired game controller connected to the computer.

The goal for our customer is to create a portable, lightweight, and overall simple system that can be taken to a wide variety of schools, athletic events, and locations around the central Florida area and be used by the QwikCut team in order to make their recording and streaming of games as efficient and easy as possible.

2.2-Motivation

There are many things we can look at while watching game film that can be very useful for both the student and the coach. These films are meant to be a very important part of moving from the highschool level to the collegiate level in many cases. In the quest of trying to reach that level, it's well known that using game film lets you become your own coach in a way and see things that may be too hard to explain. It provides players a means of reflection with an opportunity to notice the other teams or their own strengths and weaknesses. When players can see first hand and recognize a role they can improve on, they become much harder to overcome.

In our group, we have either seen, shot, or edited a game film at some point in time and we see there are things that can be improved on as well as problems that need to be fixed. We feel like the issues QwikCut has expressed to us, when fixed, can make the world of a difference in the eyes of a student trying to up their game, a coach or even a prospect trying to get more information which can then turn this into a make or break moment.

As a group it was exciting to think of the improvements we can make along with how this idea can be brought to the next level of convenience, with streaming being a large portion of media consumed today, we are streaming more than ever. This is due to the newer forms of entertainment being brought about and with an even bigger obstacle we face every day now with COVID-19. Living with the virus today has made most of us uncertain with how big groups will gather in the future and streaming has been a big part of that.

With all these factors in mind, we felt like this was a project that was perfect for our group to tackle. We feel that we can take the needs and requirements from QwikCut and deliver on something all parties can be proud of at the end of the day. Below we can also see the setup that QwikCut is working with so we can get an idea of devices and requirements we must use to make this project a reality.

2.3-Existing Design

The existing design is relatively similar to what this project wishes to achieve. The main difference is the camera system and user interface. The speed of the existing camera head is the biggest limitation in this design along with the more sensitive wire connections. The components that will be carried over is the tipod, the box that will contain the batteries, besides that the system will be completely different.

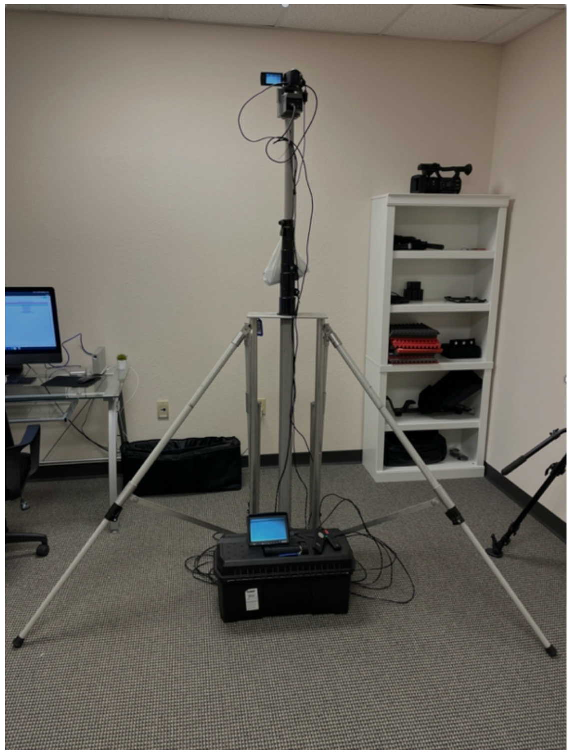


Figure i: Existing Full System

Figure ii: Existing Camera Setup

Figure iii: Existing Motorized Head

Figure iv: Existing Game Controller

2.4-Requirements Specifications

Going off the previous build and tripod for QwikCut the new and improved QwikCam will need to be able to meet the specifications of our sponsor. This project will fulfill the following requirements:

- Use a Pan-Tilt-Zoom (PTZ) camera that is PoE (Power over Ethernet) capable
- Would need to be easily mounted to the current 25’ tripods that QwikCut uses
- Use only 1 cable to run down to a laptop, possibly USB 3 or CAT 5
- PTZ camera would need to be able to be run by a game controller connected to the computer
- Video needs to be stored on either an SD card in the camera or internal hard drive of the computer or both
- This system/build will need to be waterproof as well

Possible extra requirements or alterations we could add:

- Wireless communications system from the computer to the camera, no wired connection
- Motorized system to build onto tripod to lift the system into the air up to the 25’ requirement
- Possibly multiple cameras around to be switched to remotely.

		Panning Speed	**Quality of Video**	**Battery Life**	**Weight**	**Target**
		+	+	+	-	
Panning Speed	+		↓	↓	↓	Full Field In 10 seconds
Quality of Video	+	↓		↓↓	↓↓	1080P
Battery Life	+	↓	↓↓		↓↓	10-12 Hours
Weight	-	↓	↓↓	↓↓		=< Existing

Table 1: House of Quality

3-Related Standards and Realistic Design Constraints

3.1-Design Constraints

Below is a list of constraints that are outlined in the project description given by QwikCut.

Part Required	**Specification and Type**
Tripod	• At least 20' Tall
Camera	• Capable of 1920x1080 quality or higher • 180 pan angle • 90 degree tilt angle • Zoom capability of at least 120 yards • PoE powered • Waterproof - Preferably IP66 waterproofing • Programmable
Camera Mount	• Balanced • Easy to connect • East to store for transportation
FPGA/Microcontroller	• Wireless communication
Computer	• QwikCut sponsor use of a new laptop. • Needs to have at least a 4 hour battery life • Needs Ethernet Jack
Controller	• Wired, 360 degree motion control
Microphone	• PoE powered, range of at least 50 yards
QwikBox	• Waterproof container for limited storage
SD Card	• At least 64 GB
Network	• Verizon wireless network @ 15GB

Table 2: Project constraints

3.2 Block Diagram

This section will divide portions of our project into respective sections that will be researched and looked into by our group members. Every section has been completed.

As shown in Figure 1 the project has been divided evenly by the initial estimate of complexity. It was also divided by the field that each member would like to pursue. Although it may seem like the amount of work is not evenly divided based on the diagram, that is because some aspects of this project could be broken down into subtasks more easily than others. As a general outline Mark and Kevin worked on the electrical systems while Steven and Santiago worked on the computer and software.

3.3 Budget and Financing

The table below lists all needed parts and aspects of this project with a minor description of the part along with a price. Quantity and suppliers are also listed.

All parts and pieces will be provided by our sponsor at QwikCut and most if not all parts and supplies needed for this project are to be funded by our sponsor. QwikCut was not required to cover the cost of failed parts or extra unused materials. Much of our projected budget and cost for this overall project was left open ended. Please refer to table 3 below for more information.

Our goal for the budgeting for this project was to not exceed the total cost of their existing system. This includes the cost of the existing QuikBox and camera setup. The cost of the existing QwikBox is around 1500 USD and the camera is 600 USD.

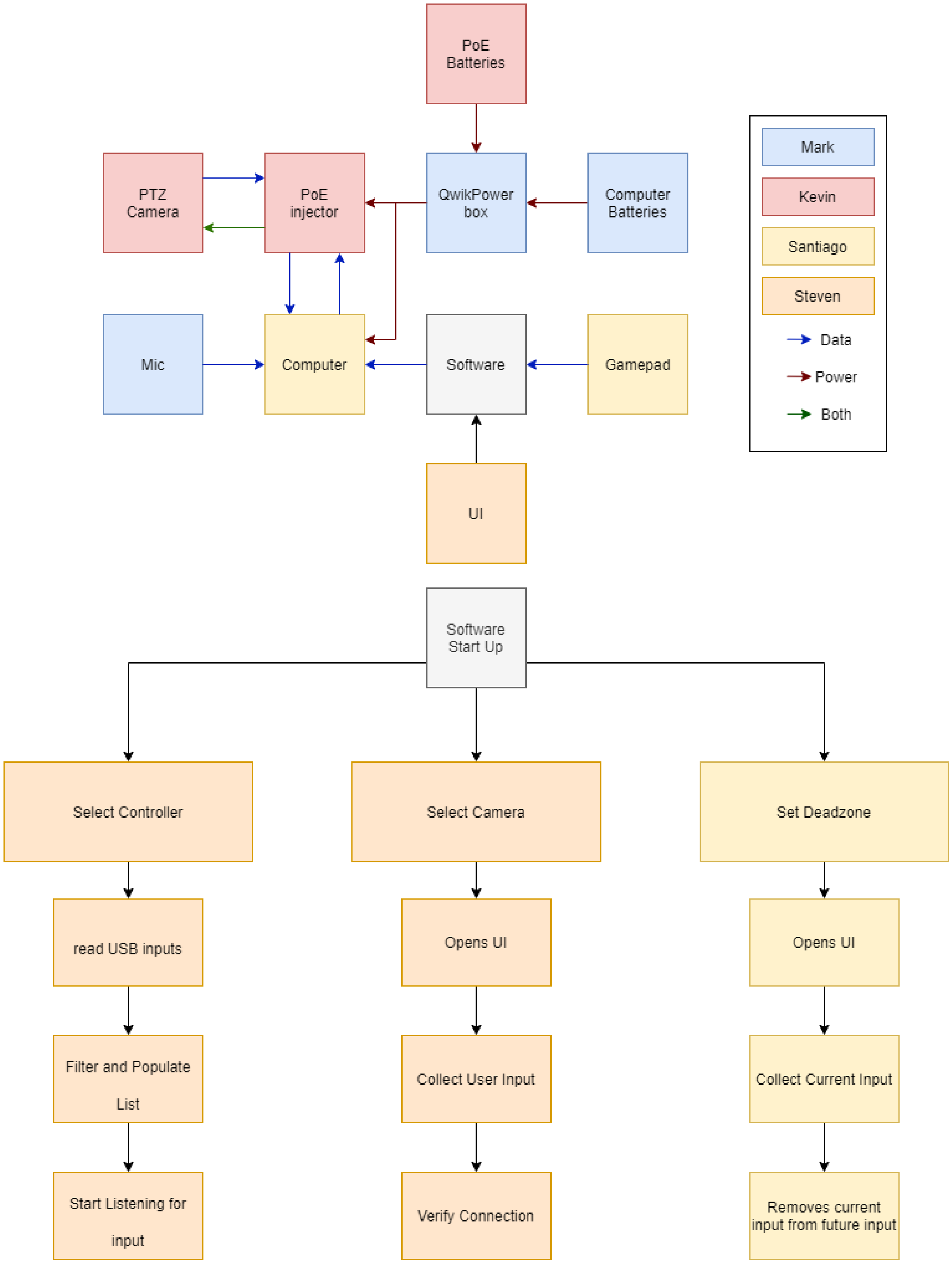


Figure 1: Block Diagram

Part	**Part Description**	**Quantity**	**Price ($USD)**	**Supplier**
Housing unit	Waterproof containment apparatus	1	45	TBD
PTZ Camera	Camera to be used in the filming	1	330	TBD
Tripod	Tripod the system needs to be mounted upon	1	0	QwikCut
Game controller	Controller to control the movement of the PTZ camera	1	0	QwikCut
Cable	CAT 5e cable to be connected to the computer and the camera	10m	25	TBD
Batteries - POE	External batteries to power PCB board or PTZ camera	1-4	236.44	TBD
Batteries - Computer	Batteries to operate the laptop - Minimum 4 hour life	1-3	0	TBD
Computer	Laptop to operate and control the camera from	1	524.99	QwikCut
Poe Injector	Injects power into a ethernet cable	1	60	TBD
Camera Mount	Custom mount for PTZ to tripod	1	50	TBD
		Total Price:	$1,271.43	

Table 3: Budgeting and finance

3.4 Project Milestone

This section details and lays out the basic groundwork for how our group researched, prototyped, and built our final project.

Objective	**Semester**	**Start date**	**End Date**	**Status**

Senior design idea generation	Spring 21	1/11/21	1/18/21	Completed
Confirmation of project	Spring 21	1/19/21	1/22/21	Completed
D&C V1	Spring 21	1/23/21	1/27/21	Completed
Meeting with professor Richie	Spring 21	2/2/21	2/2/21	Completed
D&C V2	Spring 21	2/3/12	2/12/21	Completed
Respective research for all 4 members	Spring 21	2/13/21	3/19/21	Completed
60 Page Draft	Spring 21	3/19/21	4/2/21	Completed
100 Page Draft	Spring 21	4/3/21	4/16/21	Completed
120 Page- Final Documentation	Spring 21	4/17/21	4/27/21	Completed
Final meeting with sponsor to confirm ideas before building	Summer 21	4/29/21	4/29/21	Completed
Order components	Summer 21	TBD	TBD	Completed
Initial building and testing	Summer 21	TBD	TBD	Completed
Build Prototype	Summer 21	TBD	TBD	Completed
Test and Debug	Summer 21	TBD	TBD	Completed
Redesign if needed	Summer 21	TBD	TBD	Not Applicable
Final Documentation senior design 2	Summer 21	TBD	TBD	Completed
Finalize project	Summer 21	TBD	TBD	Completed

Table 4: Milestones

4-Research related to Project Definition

4.1-Relevant Technologies

4.1.1-POE Systems

We are using a PoE system as our main way of powering the devices for our QwikCam design. PoE is a medium for carrying electric power over traditional data cables (CAT cables). With the PoE specified devices, we are passing a current through the ethernet cable along with the data that is also carried by the ethernet cable. These power over ethernet devices supply power according to the IEEE 802.3 device generation. The generation is indicated by the suffix “af”, “at”, and “bt”. These can also be more basically seen as PoE, PoE+ and UPoE. These PoE standards offer a larger power budget per device on the network, delivering from approximately 15.4 watts, 30.8 watts, and 60 watts respectively.

Network cables, or our ethernet cables, like our Cat 5e and Cat6, are made of eight wires grouped as four twisted pairs. Two of these pairs are used for sending information, which are known as the data pairs. Leaving the other two pairs unused and they are referred to as the spare pairs. We know that electrical current flows in a loop, so we need at least two conductors to carry our electric current. This is obtained by the PoE treating each pair as a single conductor, so it will utilize either the two spare pairs or even the two data pairs to carry that current. When power over ethernet is injected onto the cable at a voltage between 44 and 57 volts DC, the standard practice and what is typically used is 48 volts. This voltage may seem high but it allows for more efficient means of transferring power from endpoint to endpoint. This voltage is also still at a low enough level to be considered safe. Under normal circumstances with dry skin the 48 voltage may give a shock and wake you but is rarely enough to be lethal. Before our PSE or our power sourcing equipment can enable power to our desired PD or powered device, in this case will be our pan tilt zoom camera, it must perform a signature detection process. When this process takes place, our PSE uses a lower voltage to detect the characteristics signature of IEEE compatible powered devices mentioned previously. When this signature has been detected, the PSE knows that higher voltages can be safely applied by detecting the resistances as seen on table 5. We can see a more in depth depiction of the powering stages for PoE devices.

Stage	**Action**	**Volts (IEEE standard)**	
		802.3af	802.3at
Detection	PSE detects if the PD has correct signature resistance of 19-26.5kohm	2.7-10.1	
Classification	PSE detects resistor indicating power range	14.5-20.5	
Mark 1	Signals PSE is 802.3at capable. PD presents a 0.25-4mA load.	-	7-10
Class 2	PSE outputs classification voltage gain to indicate 802.3at capability	-	14.5-20.5
Mark 2	Signals PSE is 802.3at capable. PD presents a 0.25-4mA load.	-	7-10

Startup	Startup Voltage	>42	>42
Normal operation	Supply power to device	37-57	42.5-57

Table 5: PoE startup

Any device that can utilize a PoE connection through an ethernet cable, only needs one cable connection for power and data. This can allow our design to be much more clean and simple, which is a main goal of the QwikCut sponsor. Having a power over ethernet connection also holds the benefit of being less expensive and easier to maintain. Rather than using a power and a data connection separate like the existing setup, the power over ethernet design offers more reliability and safety. Having multiple power cords often in its existing form makes the system cluttered and oftentimes more prone to breaking. Having a lower number of devices allows us to use a device called a PoE injector. These are smaller devices that receive an external power source which will reside between the computing device or the device providing power via PoE and the endpoint device to be powered. Using injectors for a larger system can be very cumbersome and complicated, almost eliminating the reason for the PoE system in the first place.

While there are some limitations of some power over ethernet systems, they have been taken into account and they include transmission distance, device compatibility, and power delivery rates. Our design is meant to be smaller than a typical PoE camera system and will only need a transmission distance of less than 50 feet. This is well under the maximum transmission distances of around 100 meters and we are making sure the camera is power over ethernet compatible so it may be a more user friendly system for our sponsor and it also meets the sponsors needs of using a Pan-Tilt-Zoom camera.

4.1.2-IP camera Systems

This project is based around the recording and streaming of sporting events. To achieve this and keep to the other requirements outlined above we have elected to utilize IP cameras over more traditional cameras. This choice was also driven by the fact that IP cameras exist with PTZ technology built in. Luckily, security cameras have increased in quality in recent years while having the price points drop. In this section we will discuss the methods that cameras use to send the video feed over the network, how to communicate and power the cameras, and lastly the general hardware that seems like a good fit for this project given the price point the sponsor has outlined.

4.1.2.1-Video Streaming

Security cameras that are IP based will stream the video feed to the network. This allows for anyone on the network to capture and rebroadcast the video feed. This allows for QwikCam to both have a local recording and web-based stream while keeping the system relatively simple. Most cameras on the market allow for a few ways to encode and broadcast the images that are captured. The most common way is H264 or H265, these methods are more compute heavy on the camera end but can have specialized processing chips to make it fast enough that it produces a smooth video feed. The other common way is FFMPEG which is an open source and lighter weight package that instead of producing a video stream it produces a stream of still images that are individually sent. This method can aid in reducing overall latency from camera to recording device but requires that the capturing software can accept this type of input.

These video encoding methods then use other protocols to then send the information over the network. The two most common methods for this network transmission are Real-Time Streaming Protocol (RTSP) or Hypertext Transfer Protocol (HTTP). Most modern IP cameras do not use HTTP over RTSP for the video streaming since RTSP is dedicated to video streaming while HTTP is used almost primarily for the transmission of files. RTSP uses both TCP and UDP over port 554 to allow for both the control of the video source and data transmission. For this project, the control of the video source is not important since it will be the raw input that is then used to produce the video that QwikCut needs. One of the more interesting aspects of technology advancing is the Adobe Flash has very recently been phased out. This has a side effect that we must make sure all aspects of the system no longer require Adobe Flash since it is now unsupported and deprecated. An example of how this could affect this project and the potential sale of the system by QwikCut is that all the cameras need to be verified that the firmware is updated to remove Flash. Adobe Flash was a widely used interface for HTTP to implement embedded video among other features which would now no longer work.

QwikCut has outlined that it has used Open Broadcasting Software (OBS) in their other camera applications. Knowing this the configuration of the camera must be set so that its main video feed is output in a format the OBS can open to allow for the local recording and output the web-based stream. OBS does both natively support opening and processing of both H264/H265 and FFMPEG. This removes most of the limitations from the camera side since both major standards are compatible and the relaying over the network of either format is done via similar methods such as RTSP. OBS can open RTSP streams readily so all that is needed is the stream URL. Although this stream URL should remain consistent throughout the life of the system, in our software that will be described later will derive the URL when the connection is established since the RTSP URL should remain very similar. Beyond this the ONVIF standard that is also discussed later may be utilized to implement a discovery service for the camera.

4.1.2.2-Power and Communication methods

The two key parts of an IP camera system are power and communication. Both aspects are discussed in more detail in other parts of this documentation; however, there will be a quick discussion on why these topics are necessary regarding the QwikCam system. The power aspect for IP cameras takes one of two forms, these are POE or direct power. POE is what QwikCam will utilize as it allows for a simpler method to meet the requirements that QwikCut has outlined. The direct power method allows for a typical wall AC/DC adapter to directly power the camera. However, since that would require a secondary wire to be run for power this will be avoided in favor of POE.

To transmit the video and potential audio there are many solutions. However, to keep with the requirement of limiting wires the system will be Ethernet based which allows for

POE. The next best method is direct video out with something like HDMI or S/PDIF with the required motion control going over a serial connection which may implement different connection standards. However, the simplest method is just to use Ethernet for a bi-directional connection to the camera that can also provide power. More discussion will come later that covers how we are communicating with the camera for motion controls.

4.1.3-ONVIF

4.1.3.1-What is ONVIF

ONVIF or Open Network Video Interface Forum is a global and open industry forum that has the goal of developing a global open standard for the interfacing of IP-based security products. This standard the ONVIF has developed and maintained has become a very widely adapted standard. ONVIF announced that as of February 2020 more than 14,000 conformant products were on the market. That number may not include the large number of products that are not developed by its members but are still ONVIF compliant or partially ONVIF compliant. Most of what ONVIF aims for is the standardization of the network layer of video products, this allows for devices to use a common interface to achieve both complex and simple tasks without the need to proprietary software or hardware.

4.1.3.2-What does ONVIF do

ONVIF is broken into six core profiles that each address different abilities. These abilities are IP configuration, device discovery, device management, media configuration, real time viewing, event handling, PTZ camera controls, video analytics, and security. These were the goals that ONVIF specification version 1.0 covered, since 1.0 ONVIF has expanded to add two more profiles and external standards for some additional abilities. ONVIF profiles are always broken down into two use cases, the device, or the client. Each profile must have both a device and a client to be useful in the application. A quick example is that the recording device must have a client that controls the recording device or changes its configuration. The table below outlines which profiles are responsible for what, to read this table M means that for the profile that ability is mandatory, C means it is conditional, and O means it is optional.

Features		Profiles											
		G		Q		S		T		C		A	
		Device	Client	Device	Client	Device	Client	Device	Client	Device	Client	Device	Client
General													
System Settings		M	C	M	C	M	C	M	C	M	C	M	C
User Authentication	WS-Username Token					M	M						
	Digest Authentication	M	M	M	M	O	M	M	M	M	M	M	M
User Handling		M	C	M	M	M	C	M	C	M	C	M	M
Query Services and Capabilities		M	M	M	M	M	M	M	M	M	M	M	M
Device Discovery		M	C	M	M	M	C	M	M	M	C	M	M
Default Access Policy				M									
Network Configuration		M	C	M	C	M	C	M	M	M	M	M	C
Zero configuration				C	C	C	C						
Firmware Upgrade				C	C								
Backup and Restore				C	C								
TLS Configuration				C	C								
IP Address Filtering						C	C					C	C
NTP						C	C	C	C			M	C
Automatic IP Assignment				C	C								
Media Profile Configuration						M	C	M	C				
Media Transport	RTP/UDP	M	M			M	M[1]	M	M[1]				
	RTP/RTSP/HTTP/TCP	M	M			M		M					
	RTP/RTSP/HTTPS/TCP	C	C					C	C				
	RTP/RTSP/TCP/WebSocket							C	O				
	RTP/UDP Multicast					C	C	M	C				
Video													
Video Streaming	MJPEG	O	M			M	M						
	MPEG4	O	M			C	C						
	H.264	O	M			C	C	M[2]	M				
	H.265								M				
Video Encoder Configuration						M	M	M	M				
Video Source Configuration						M	C	M	C				

Table 6: ONVIF profiles

4.1.3.2.1-Profile A

Profile A is used for access control configuration including granting and revoking credentials, creating schedules, and assigning access rules. Profile A is very similar to Profile C, which will be discussed below, however, Profile A is geared towards Physical Access Control Systems or PACS. ONVIF describes Profile A compliant devices as a device that “shall provide functionality to retrieve information, status and events and to configure the PACS related entities such as access rules, credentials and schedules. As Table 6 shows Profile A only covers things that are PACS related, these stem from making sure the device is secure and that it performs the tasks at hand.

4.1.3.2.2-Profile C

As mentioned prior, Profile A and C are closely linked. However, Profile C is geared toward door control and event management including site information and configuration, event and alarm management, and door access control. The main difference from Profile A is that Profile C does not deal with network-based security.

4.1.3.2.3-Profile G

Profile G is the first of the remaining profiles that are currently published and released that focus on security camera systems. Profile G is focused on edge storage and retrieval specifically focused on configuring, requesting and controlling recording along with receiving audio and metadata streams. Profile G is focused on a device that can record video data over an IP network or on the device itself. This is one of the first profiles that will be discussed that have a very clearly defined client and device role in the operation of this profile. In profile G the client can configure, request, and control the recording of video data by the profile G device. The client does not actually record the data but tells the device to do so, the client is however responsible for the streaming of videos from the device.

4.1.3.2.4-Profile Q

Profile Q is one of the very useful profiles as it pertains to the ability for the device or client to have a quick installation. This includes easy setup, discovery, configuration, and control of conformant devices. This profile is also focused on the security of the IP-based video systems including Transport Layer Security (TLS) and device defaults that are known and can be used for malicious actions. TLS allows ONVIF devices to communicate to clients on the network that protects against tampering and eavesdropping. Referencing Table 6 it can be seen that Profile Q is the only profile that handles default access policies and as such should be treated with care.

4.1.3.2.5-Profile S

Profile S is the most vital profile for IP cameras. This profile handles the communication between devices such as NVRs and clients like software that controls the cameras and recordings. While these features are important and useful, they do not apply to this project. However, this profile also handles PTZ control, audio input, multicasting and relaying outputs for both devices and clients that support the features. For this project we are going to need this profile to tell the camera which way to move, when to move and how fast to move.

4.1.3.2.6-Profile T

Profile T is very similar to profile S however, it is not meant to be a replacement but more of an extension to allow for more features without the need to modify existing devices to be able to handle the expansion. This project will also use this profile to aid in the movement that profile S provides. The useful part of this profile is that we can configure PTZ aspects like movement speed and range limits. The other features this profile allows is HTTPS streaming, motion region configuration, digital inputs, relay output, and bidirectional audio. These additional features are not currently needed for this project however they can be used if the project is expanded since it allows for inputs and outputs to allow for more features.

4.1.3.3-Why Use ONVIF

The advantage of utilizing ONVIF is that it allows for different cameras to be used so long as they support ONVIF. This is useful since if the camera that the project will utilize does not meet the needs of the client once it is deployed it can easily be changed. Alongside that fact if new cameras are released to have features that the software does not need to be modified extensively. Alongside this fact is that as ONVIF becomes more widespread it is advantageous to use it before the point that any other solution becomes obsolete.

The other solutions are all proprietary and nonstandard. When using one of these systems the modifications to achieve what this project needs to meet the requirements may not be possible without having to create our own hardware. Although creating our own solution would be interesting, the issue is that most requirements push us closer to just creating our own version of preexisting technology. Along with this fact the requirement that parts be easily and readily available does not lend itself to nonstandard or proprietary solutions.

4.1.3.4-How is ONVIF used

The three key features that this project will utilize from ONVIF is PTZ control, PTZ configuration, and device discovery. The features are the basics of this project. This is the ability to use the PTZ in a smooth and controllable motion while allowing for a one click discovery of cameras to display the URL that is used for streaming the output. This discussion of how we interface to ONVIF will be discussed in the software section. The general outline of interfacing with ONVIF is as follows; the device has a service running on it that broadcasts over the network to a port, usually 8000, which presents an XML file that can be parsed and modified to control different aspects of the camera. For the end user of this product there will be very little need for knowing anything about ONVIF, the most important aspect for the user to know is that any camera they wish to use needs to be compliant. Unfortunately as the software progressed it was discovered that the device discovery aspect could not be implemented.

4.1.4-Controlling Software

4.1.4.1-Why is it needed

The software is one of the main components that is required to get this project to function as intended. The software is responsible for identifying, controlling, and presenting all required information for the user to be able to stream the video feed and control the PTZ functions. Having a hardware piece control the function would work however, and a computer is needed for the streaming of the video feed as such the utilization of a hardware solution would make the overall project more complex and harder for the end user to use efficiently.

4.1.4.2-Pre-existing Products

There are pre existing pieces of software on the market however, to the best of our knowledge none of these allow for a gamepad to control the camera. These solutions either have custom pieces of hardware to implement a joystick and buttons or only use the mouse and keyboard for the camera inputs. These solutions would not meet the requirements outlined since they are either using proprietary not readily available hardware or will not be able to give the fine input control that is needed. Since we are using ONVIF, if the end user decides to try one of these existing products it will just require the knowledge of connecting to the camera via that software.

4.1.4.3-How will it work

The general outline for this custom software is as follows. The main GUI will allow for the user to connect to the camera, select the controller they wish to use, set controller dead zones, adjust input maps, and adjust camera speed limits. This program will not be responsible for the capturing or recording of the video stream, this will be handled by another piece of existing software that QwikCut has used before, this is OBS. Overall our software is broken down into three main problems: the GUI, the camera controls, the controller input. Each of these problems will be discussed in more detail below. The next general requirement is that this software should be able to run on almost any modern computer and be extremely lightweight. To achieve this, we will use Java as it has all the abilities and functions that are required and can be developed such that it is lightweight and user friendly.

4.1.4.3.1-The GUI

The graphical user interface or GUI is the main point of interaction our project has with the end user. A general wireframe outline of how we intend this software to look is outlined in figure 2. The GUI will present all compatible input devices to the user in the dropdown box labeled “Controller Selection" these options are populated on program startup. Unfortunately, the controllers cannot be dynamically checked and selected, this is an artifact of the input library that is being utilized. The controller input will be discussed more later. All the buttons will open other GUIs that perform the respective tasks. The last function the GUI is responsible for is to present error messages that may be generated when other parts of the software error, these errors must be intuitive to allow for the user to be able to fix the issue with minimal downtime of the camera. This GUI will be developed with Java Swing, this is a package that handles all aspects of GUIs. The GUIs will run on a separate thread from the other features to make sure the program remains responsive regardless of what the other functions are trying to do.

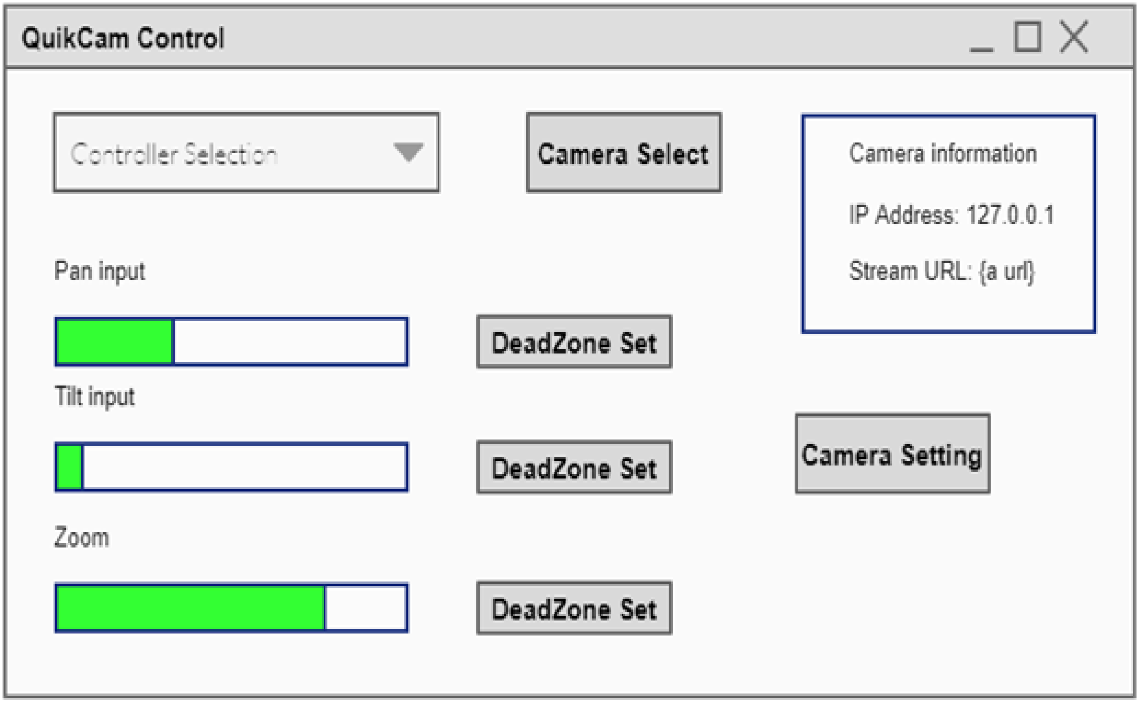


Figure 2: Wireframe

4.1.4.3.2-Controller inputs

This is the first of the more complex aspects of the program. This is all handled via the Jinput library. This library requires three dll files which must be on the computer and in a location that the software already knows about. To make sure this works regardless of user setup, the program will always check for these files in the temp folder of the operating system. If it finds the files it will proceed to its normal operations, if it is not present it will extract the dll files from the package that makes up the program and then will register and proceed with the normal operations. This verifies that no errors should occur from missing dll files.

Once it starts the Jinput library will scan the Universal Serial Bus, USB, hubs to find all attached devices. It will then filter these devices by type and will allow for the user to select one of these devices. The user must select a device for the rest of the program to function. Once selected Jinput will poll the device and read the inputs that the user maps to functions to check for input. These inputs value from -1 to 1 and will be processed by the program to update the display and send the ONVIF thread the values to move. The main thing the Jinput thread must be able to do is detect and connect to the USB device, poll, and send the values, and stop the program if something happens to the USB connection. The GUI reads these values and updates the input level displays based upon the values. This information is transferred between threads with an interface to block potential thread exceptions.

4.1.4.3.3-Camera Interface

This is the most complex part of this software as it handles processing the inputs and relaying that to the camera and reporting back the status of values. For this we will use the previously mentioned ONVIF standard. In terms of Java there are no official packages for ONVIF support. To achieve the support we have two main approaches, make a custom solution or find a package that is open source. In our investigation we found that making a custom solution would not be preferred since we would have to learn how to process the XML into Java objects, this process is done via Simple Object Access Protocol or SOAP. We found ONVIF-Java-Lib is an academic project that has been refined to be able to perform all aspects of ONVIF communication via Java.

However, there is a problem with ONVIF-Java-Lib, that is the fact it has not been maintained. When trying to compile and utilize this library in an update environment there were around eight supporting packages that were obsolete and replaced with newer versions. However, in Java when changing packages all the imports need to be refactored to allow for Java to know to use the new versions. Along with this it was found that the library did not support the newer ONVIF methods of authentication, this may limit the use of some cameras since the camera will not accept the authentication that is generated.

Once the package is implemented in your project it becomes very easy to access the ONVIF standard in Java. For this project all the ONVIF interactions will be handled on a separate thread and will interface with the other classes via a custom interface to prevent thread access exceptions. From this point on it is as simple as telling the ONVIF interface to perform actions given the inputs. When reading values from the ONVIF device they will be reported back to the main thread to allow for the utilization of these values.

4.1.4.3.4-Multithreading

The easiest to implement but most complex part of this project is handling the threads and the data following between them. The concept of multithreading allows for a program to run more then one task simultaneously. However since a computer cannot actually multitask the values and tasks must be handled as individual programs. When doing this it is very easy to have issues with the threads accessing data which is in the same overall program but is not in its runtime.

To work around this Java has Interfaces which can be utilized to allow for a controlled access of the data while verifying that no threads access or modify the data at the same time. There are two ways to actually handle the accessing of the data. You can either rely on Java to handle it for you or you can implement the access control yourself. For this project we relied on Java as it makes the overall complexity of the code far easier to understand.

For this project the current plan is to have four threads and interfaces. Each thread will have an interface that it will use with the main thread to distribute the data. The first thread is the one that is launched by default and handles all the initial runtime setup, which includes the startup of the other thread. This main thread is also the crossing point for the data between threads as it will allow each thread to see the other interfaces to get any new values. The next thread is for the GUI itself and will have an interface that allows it to receive input from the other threads and send information collected, such as the camera details, to the camera thread for use. The next thread is the controller handler, it will poll the USB device and present the information to the other threads via its interface. The interface for the controller will also allow the setting of deadzone values and initial device selection. The last thread that is run is for ONVIF, this thread is used to send and receive the inputs and outputs for the camera itself.

4.1.5-Controlling Computer

To properly be able to manage all the software required to stream, and deal with the information that is sent along the ethernet cable the computer we must select must meet a list of minimum requirements. As mentioned, the computer we have selected for this project best fits in the form of a laptop. This is due to it being more lightweight and easy to use. The drawbacks to using a laptop instead of a normal tower PC is a lack of customization. Laptops typically when sold have most of their components custom fitted to the body or use proprietary versions of hardware. This means normally only the ram sticks and occasionally the harddrive can be changed, this is not always the case. For example the line of surface books, no hardware whatsoever can be changed after purchase. With the possibility of being unable to change the hardware internally, the laptop chosen must meet all the requirements from time of purchase. To fully understand what requirements are needed for the laptop, the type of work it must perform must be fully understood. At the moment the biggest requirements to fulfil are physical ports, and sufficient calculation power to perform streaming at a consistent quality and bitrate.

4.1.5.1-Physical Interface

To maintain consistency with our current plan, the laptop must support an hardware ethernet connection. Ethernet has many standards with different limitations based upon the network card, motherboard and the cable itself. The most typical of the standards of the cable include Cat 3, Cat 5, at 5e, Cat 6, Cat 6a, and Cat 7. The chart below demonstrates the different qualities of each type.

Category	Shielding	Maximum Transmission Speec (at 100m)	Maximum Bandwidth
Cat 3 cable	unshielded	10 Mbps	16 MHz
Cat 5 cable	unshielded>	10/100 Mbps	100 MHz
Cat 5e cable	unshielded	1000 Mbps / 1 Gbps	100 MHz
Cat 6 cable	shielded or unshielded	1000 Mbps / 1 Gbps	250 MHz
Cat 6a cable	shielded	10000 Mbps/ 10 Gbps	500 MHz
Cat 7 cable	shielded	10000 Mbps / 10 Gbps	600 MHz

Table 7: Ethernet Cable Standards

For this project the most appropriate cable type would Cat 5E or Cat 6. It has a good balance of affordability, speed, and being wildly available in many lengths. The speed requirement is due to the typical transmission of a stream of ethernet cable at the quality needed. Shielded cables minimize the electromagnetic interference that is caused by nearby power lines or appliances. For higher speeds it is also necessary to reduce the interference caused by the twisted pairs of wires within the cables as well. The maximum bandwidth at 5E and Cat 6 are more than sufficient for the throughput of a single camera stream.

Furthermore the Network Interface Card(NIC) on the laptop must be sufficient to transmit at the speeds we need. NICs take in the data from the ethernet cable and connect to the motherboard normally with either a PCIE or PCI slot. Without being able to change it afterwards we must find a laptop that is recent enough to support a standard speed that is needed for streaming. Standard NIC speeds are typically at 10Mbps, 100 Mbps, 1000Mbps, and with more expensive cards even 10Gbps is possible. For our purposes a card with the range between 100Mpbs and 1000Mgbs will be sufficient. The NIC interfaces with the motherboard directly and if we were not buying a laptop, there would be a concern on whether the motherboard included with the laptop would be able to interface properly. With a prebuilt laptop we will just need to look at the stated speed.

The current plan is to use a plugged in gamepad and ethernet cable. The laptop picked would have space for both of these, USB ports are not difficult to find when buying laptops, however we are potentially also going to have to read SD cards from the camera.

A laptop with a built SD could be a bonus, but there is little to no speed loss with instead using an adapter for the USB port to SD card.

4.1.5.2-Hardware

Outside of the physical interface, the other concerns for the requirements of the laptop include CPU, GPU, Battery Life, Resolution, RAM, Hard drive type/size, weight, and price point. The major limitation for all qualities is the price. With an unlimited budget buying a laptop that held no compromises on any of the qualities could be possible, but our current limitation is $600. Currently QwikCut uses a premade intel NUC, and as such the laptop should roughly match or exceed the specs of that machine so as to minimize any conversion costs.

The CPU the current setup uses is an intel I5-7260U Processor with a 4M cache, up to 3.4 GHz. To understand the requirements for the laptop, the current CPU must be understood.

- Microarchitecture: Intel has several CPU types, they are typically known as i3,i5,i7 and recently i9. The difference between these chips are small microarchitectural changes between each. In basic terms an i9 will outperform an i7, a i7 will outperform a i5, and an i5 will outperform an i3. This does not always hold for example if the i5 was a 3xxx series CPU versus a 10xxx series i3.
- Generation: The generation also holds importance, overtime in accordance to moore's law, transistors have become smaller. Smaller transistor leads to more of them within the same chip size. There is a drawback of dealing with power efficiency to not become thermal throttled. Generation is the 4 - 5 numeric value, in the current setup it is 7th generation.
- Letters: Each generation of chip outside of its microarchitecture, also can have differences in terms of it being a K series, G series or U series. The K series are unlocked chips which allow consumers to overclock the CPU. The G series indicates that there is a built in graphics processor. The U series shows that the chip is the Ultra-Low powered version, used in laptops or mobile devices. No letters would indicate it is the base model.
- Clock speed: The clock speed is indicative of the number of cycles your CPU can execute per second. A higher number means more instructions per second however, it can be misleading. As before, in later generation CPUs have also become more efficient with their code. What before needed 3 instructions could now take 1. So 3.5Ghz processors of a different generation will have different capabilities in performance.
- Cache: A cache allows the CPU to store data that is frequently accessed closer to the processor. This increases the speed of the access without having to get the information from the hard drive. The larger the cache, the more information may be stored. In the current CPU it appears there is only a L1 4M cache, but Cache can have different levels. The CPU may include a L1,L2 and L3 cache. Each increasing in size. The more frequent information is used the lower the level, and if it is outside of the L3 cache it is accessed via the hard drive.

All the factors must be taken into consideration when seeing which CPU best fits our needs. Typically programs will have a list of requirements such as OBS needing at 2GHZ clock speed to run smoothly. But as can be seen just looking at any one quality on its own can lead to incorrect conclusions on performance. The current selection of laptop instead of an intel CPU, uses an AMD CPU. There are differences within the architecture but a majority of the same information applies.

The GPU in the current setup is an Intel Iris Plus Graphics 640. The graphics card is of importance when it comes to video streaming. Most software will use hardware acceleration to offload some of the computation time and power. The laptop for the project must have a dedicated graphics card unit within the laptop as we cannot change it for a different one when bought, and having a dedicated unit would allow us to maintain the highest quality for the stream itself. The GPU outside of maintaining video streaming quality for us would also generally work as a speed up for the laptop itself. There are many tasks that can be helped especially by using GPU versus a CPU, this is due to the difference between the two technologies. The two can be differentiated by thinking along the lines of the CPU being amazing at doing complex tasks quickly in succession, the GPU is great at doing a huge amount of small calculations in parallel. Streaming when broken down into its requirements is many problems of calculating the difference in pixels across a certain period of time. This can be more rapidly achieved with a GPU. That is why in this project it is necessary to take that into account when purchasing a GPU. The quality of a GPU can be broken down into a few understandable parts.

- Architecture: As GPUs have developed the manner in which they are implemented has also changed. For example NVIDIA’s 2000 and 3000 series cards are capable of implementing ray tracing for complex light simulation, while the 1000 series and below are not. Within the architecture itself there are many variations with VRAM and CUDA cores changing.

- CUDA Cores: A CUDA core is the method used to do the mass parallel computation that GPUs are well known for. A higher count can be indicative of higher performance.

- Clock Speed: A faster clock speed allows for more calculations per second. Typically not the largest factor for purchase.

- VRAM: Virtual Random Access Memory. Additional VRAM will allow more image data to be stored when the GPU is calculating and showing the image. For streaming this is less needed as the project will not be computing to create an image but computing to do encoding for the project.

- Power Consumption: As the project will be relying on battery power, power consumption is a major constraint. This is the factor that balances all other qualities of a GPU, we need an efficient GPU with minimal power consumption to properly meet the specifications of the product.

When taking all qualities into consideration the laptop we have chosen is the Vega 3 integrated graphics, as the computation power needed did not require a heavy power consumption card.

The next factor to consider when selecting the controller computer was the battery life. To best suit the needs of the sponsor, a battery life of around 8-10 hours is considered optimal. However with the usage of UPS, the battery life of the laptop can be supplemented. This addition allowed us to take the constraint of the maximum battery life of a laptop and nearly remove it. The laptop chosen is rated for above 5 hours of usage, with a more typical usage of around 7.5 hours. A more expensive laptop could have been found to have a higher battery life but, we have to take into account budget constraints. Practically with a battery system already included within the overall project, a backup battery for the laptop made more sense. To achieve a higher battery life, more than likely a laptop would have more expensive components. To stream at the appropriate resolution and bitrate, that would be unneeded.

Resolution of the screen is a normal factor to consider when purchasing a laptop however for this particular use case, the need for an ultra high definition screen was unneeded. The intel NUC setup used had an extremely small monitor attached to see what the camera was capturing. The quality of the resolution of the laptop was chosen such that the full screen resolution captured by the camera and streamed was able to be seen without any need for shrinking or stretching the image. This is to minimize any distortion that may not have been evident on a smaller monitor. The laptop will be a 15.6'' inch screen with a FHD display. This means that the screen will be 1920 by 1080 pixels. It was possible to have chosen a screen with a higher resolution or more pixels per inch but for our purposes 1080p was more than sufficient as that is the quality we are aiming to stream at.

RAM(Random Access Memory) is used to keep track of all the currently open software running on the system. It is a way for the computer to be able to rapidly access any information that is needed. Our program for streaming OBS, and the demands of a modern OS, and running potentially several things at once dictate that we need a minimum amount of RAM. A good benchmark these days is 8 GB of ram, unless more is needed with RAM intensive software. For our purposes 8 GB of ram is more than sufficient, and as such it was selected for our laptop. The speed of the ram stick also matters if you are doing a lot of rapid access to the memory. The Intel NUC used, was likely using in the range of 4 -8 GB of RAM, specifically DDR4-2133 SO-DIMM which means it uses 4th generation ram sticks with a speed of 2133 Mhz. With the laptop we have selected we will be using 8GB DDR4-2400 Mhz of SO-DIMM RAM. At that speed and capacity we will be able to stream and do anything else needed at a basic level. The reason it was selected was that RAM is expensive, and upgrading past that would be an unneeded cost. 8GB and DDR4 are the most common being sold for modern day computation machines.

The hard drive is an important aspect to consider, it dictates part of the quality of the experience the user will undergo while using the project. With an especially slow hard drive, every action will take longer to register and as such will feel clunky. To avoid this user experience typically SSD type hard drives are used instead. With electronic storage instead of a spinning hard disk, it is much faster and a complete experience. The biggest worry when purchasing a laptop in our use case will be having sufficient space for programs they may have and having a speedy system. The amount of storage in this use case is not as big of a concern as the normal usage will be using SD cards on the camera itself to maintain any footage shot. The laptop chosen has space for about 128GB of information, which is more than sufficient for the OS, and the recording/streaming software. The speed of the SSD will be based on its underlying chips and how the manufacturer decided to create it. The difference in SSDs are according to whether it is Single - Level Celled, Multi - Level Celled, Triple - Layered Cell and so on. At the moment Triple layered cells are the most common type of SSD. With each additional cell layer the capacity increases, but the reliability and the speed decreases. Optimally we would be using an SLC however they also have higher costs. For example a typical 1 TB TLC, may cost a similar amount to a 128GB SLC. The laptop we are purchasing does not specify what type of cell structure the SSD is, but due it budget limitation and practicality, it is more than likely a TLC type SSD.

	SLC	MLC	TLC
Bits per cell	1	2	3
P/E Cycles	100,000	3,000	1,000
Read Time	25 µs	50 µs	~75 µs
Program Time	200-300 µs	600-900 µs	~900-1350 µs
Erase Time	1.5-2 ms	3 ms	4.5 ms

Table 8: SSD Types.

Weight effectively was a small factor to consider when purchasing the laptop. The use case for our project is mostly stationary, without any need to constantly move and shift around. The laptop chosen does lean towards the lighter side but that is a bonus and not a constraint. The physical dimension of the laptop had to be considered however, with the method of waterproofing that is being considered. A laptop too large would not fit well within the built protection system, but with the chosen laptop, there will be no issue.

The last major constraint on the purchase of the laptop will be it's price point. With a budget maximum of $600, all the factors previously mentioned will have to be taken in consideration with how important they are to the goals being achieved. Some of the compromises that were made were battery life, resolution, hard drive space. Those factors were not needed as much as decent computation in the CPU and GPU. The laptop we have chosen is the Acer Aspire 5 Notebook. This fits within the budget, has the physical port needed and enough computational power that the stream should remain high quality.

4.1.6-Gamepads

Since the input device for the camera was specified by QwikCut to be a gamepad it is necessary to determine what types of gamepads are on the market and which have the inputs needed for this project. In general since we need fine control of the inputs they must be analog, the number of these inputs must be at least two if both have an X and Y component. More generally the gamepad must have three uniquely readable analogy axes. In terms of connectivity the gamepad must be easily connectable to a computer, this can be achieved either wired or wireless so long as the device registers on the computer. The controller must also be readily available on the market to allow for it to be quickly and easily replaced if needed.

4.1.6.1-Types of available controllers

For the most part there are two main types of controllers on the market, XBox style and PlayStation style since these are the two most common consoles on the market that use handheld controllers with analog sticks. The newest versions of these controllers can be expensive and need adapting to USB however, there are many 3rd party versions of these controllers that would work and these tend to be cheaper and some come as wired versions standard.

In terms of using one of these controllers the software described above must be able to handle the controller inputs. These will be done by a customizable input map that will be discussed in detail later in the document. However, if the input was not able to correctly or easily handle the controller plugged in there are pieces of software available that can emulate a supported device based on the inputs from the actual controller. If the end user determines that they do not want to use a standard gamepad for input the software will support any emulation so long as the emulation presents itself as a USB device.

4.1.6.2-Native wireless controllers

Wireless controllers are becoming more readily available than their wired counterparts. Since most end users will be on a windows based system we can utilize some more modern features built into the latest versions of windows. Since XBox and Windows share a parent company they have become very interlinked over the past few years. One of these features is that the new XBox controllers utilize BlueTooth to connect. Most modern laptops have a BlueTooth adapter built in, this allows for the XBox controller to connect wirelessly via BlueTooth. Since QwikCut wishes for a reduction in wires this may be their choice in controllers. If one of these controllers is used the laptop in theory will only need two wires, power input and data output.

4.2-Batteries

For many electrical and electronic devices today using battery power, the biggest benefit is having the aspect or portability. Some of the biggest categories where batteries apply to everyday life are laptops, remote controls etc.

Batteries consist of one or more electrochemical cells that store chemical energy for later conversion to electrical energy. A variety of electrochemical cells exist and batteries generally consist of at least one voltaic cell. These voltaic cells are sometimes referred to as galvanic cells. The chemical reactions and the generation of electricity is spontaneous within a voltaic cell. As we know electricity is energy that is produced by the movement of electrons. For the battery, the electrons flow from the anode which is the negative side toward the cathode which is the positive side. With these movements of the electrons in mind, it generates the energy.

4.2.1-Types of Batteries

There are primary and secondary types of batteries which are both represented in the examples above. Primary batteries are non-rechargeable and disposable. The electrochemical reactions in the primary batteries are non reversible in this case. The materials in the electrodes are completely utilized and cannot regenerate electricity. These have more applications in cases where long periods of storage are required as they have a much lower discharge rate than the secondary batteries. Some more examples of these can be smoke detectors, flashlights etc. Secondary batteries are rechargeable. When these batteries undergo electrochemical reactions that can be readily reversed. These are reversible because the components that react in the battery are not completely used up. These batteries need an external source to recharge them after the energy is expended. Mobile phones and car batteries are popular uses of secondary batteries. We will be looking more into the different types of secondary batteries for our application.

4.2.2-Lithium-ion

In Lithium ion batteries, the positive side is made of lithium where the negative is carbon. These batteries are a very common source of power in everyday products. As this tech evolves which has a big focus on speed, mobility and large data, which are the important parts of reliable portable power is on the rise. These types of batteries can give us many advantages which may include the following characteristics:

1. **Maintenance:** Unlike flooded lead-acid batteries with the levels of water that must always be monitored, the lithium-ion batteries do not need to be watered. This reduces the maintenance obviously that is needed to keep the batteries up and running. This also reduces some costs that may come into play when training new team members or customers to monitor these machines and ensure everything is running at an acceptable level.

2. **Longevity:** The lithium-ion battery has an average lifespan (for a larger capacity battery pack) of as long as eight or more years. The longer service life of these batteries will give a larger return on investment as far as lifetime.

3. **Charging:** This subject will be a more in depth section to further explain the intricacies of charging but there are some benefits that can quickly be explained. The lithium-ion batteries typically have a faster charge time while in its charging phase. This is a way to reduce downtime of the machine or device you are using the battery for. The design of these batteries also allows opportunity charge. This is a way of saying that it does not need to be fully charged for use, meaning the system does not need to be designed around a tight time frame or multiple batteries for swapping.

4. **Safer Facilities:** For this design it is beneficial to have lithium-ion batteries because of the container we are planning on using. Lithium-ion batteries have an improved indoor air quality compared to the other types. This reduces risks of accidents by eliminating exposure to battery acid and flammable fuels. The lithium-ion batteries also are more desirable with lower noise dBa levels while operating.
5. **Environmental:** With lithium-ion batteries and the steady increase of electric vehicles, the lithium-ion batteries provide an immediate impact on the reduction of carbon emissions. This is a much smaller scale operation in comparison to a car but any improvement is still an improvement.

Some of the larger factors to consider when comparing lithium-ion batteries to other types are things like how the storage of our units will be and how important it will be to the design. While they may not be as robust as other types of batteries. These batteries require very tight voltage and current control. We will need to provide a protection circuitry which saves the battery from being overcharged or overheated. Lithium-ion will be helpful in the aspect that it will be enclosed along with the fact that the lightness of the battery will be a big help when carrying it around. A downside may be that the lithium-ion batteries have a much higher price point than a lot of other options. For example, these batteries cost about 40% more than the NiCad batteries, but the life-time value may outweigh the cost.

It's important to note that while we are mostly looking at the lithium ion battery for the application of our project, there is another type of battery that is similar and starting to become very popular. These batteries are slowly replacing the lithium-ion in the smartphone industry due to them being much more superior when it comes to safety, form factor, and weight attributes in high-end devices. The lithium-polymer battery falls under the same category and the largest difference is the chemical electrolyte between the positive and negative electrodes. It's a newer technology than the lithium-ion and made its way into smartphones most recently. While the advantages of the lithium-ion battery are expressed above with the high power density, lack of memory and the much lower cost than the lithium-polymer. The lithium-polymer batteries are very robust and flexible, especially when it comes to the size and shape of the build. They are lightweight and have an extremely low profile with a low chance of suffering from leaking electrolyte. These batteries are not perfect and are significantly more expensive to manufacture and do not have the same energy density or lifespan as the lithium ion meaning they won't last nearly as long as the lithium-ion batteries we plan on using.

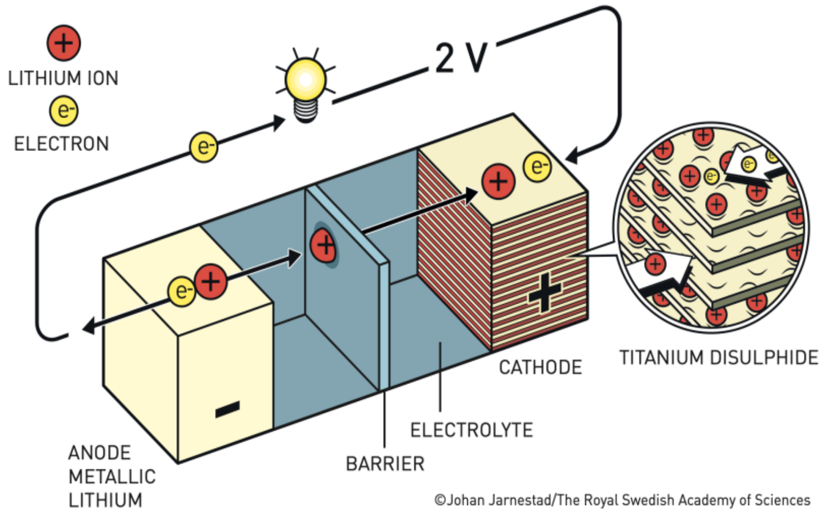


Figure 3: Lithium-ion Battery Composition

4.2.3-Nickel Cadmium

Nickel Cadmium batteries are secondary also known and denoted as NiCd batteries are a popular type of batteries. These batteries are not as widely used as they once were back in the day. One of the reasons the NiCad batteries are not as widely used today is that in the cadmium battery there is a toxic substance, making the disposal of these batteries a hazard. The typical voltage of the nickel cadmium battery cell is 1.2v which is less than many other batteries. The positive end of the battery is made of Nickel-oxide-hydroxide and the negative side is made of cadmium. The electrolyte inside is potassium hydroxide. Looking at the characteristics of the NiCd battery:

1. **Charging:** The NiCd battery prefers a fast charge to a slow charge and does not prefer a DC charge. Most other chemistries prefer a shallow discharge with moderate load currents. It is known as the strong and silent worker and has no problem dealing with larger load currents. A periodic full discharge is very important and if this does not happen, large crystals will form on the cell plates and the NiCd battery will lose out on its performance.

2. **Longevity:** The NiCd battery provides a good performance and a long shelf life in any state of charge. It remains a popular choice when taking this into account and is mainly popular when under the category of radios, emergency medical equipment, and even power tools. Although batteries with higher densities and less toxic materials are causing a diversion from NiCd to newer technologies.

3. **Environmental:** NiCd batteries are unfortunately very environmentally unfriendly, listed before these batteries contain toxic metals. Some countries are even limiting the use of the NiCd battery because of these limitations.

4. **Limitations:** For the NiCd batteries, they have one of the largest limitations being stated above as the toxicity. As for other limitations we can see that the NiCd has a limitation in the fact that they must be periodically exercised to prevent memory

and they have a relatively low energy density compared to the newer battery options.

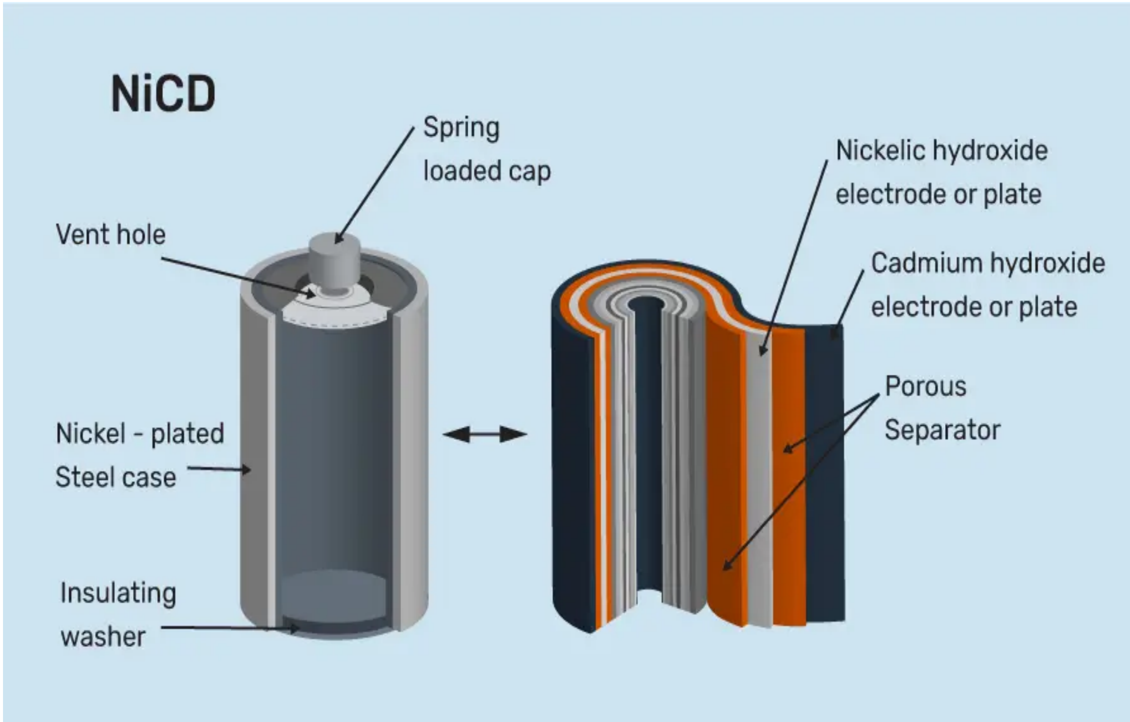


Figure 4: NiCd Battery Composition

4.2.4-Nickel Metal Hydride

Nickel Metal Hydride batteries (NiMH) are also secondary along with the previously listed. The positive end of the battery is made of Nickel-Oxide-Hydride and the negative end of the battery is made from hydrogen absorbing alloy. This battery has positives over the NiCd battery in terms of energy density and capacity. These batteries have improved over the years but there are many limitations that remain. Most of these limitations come from the shortcomings of nickel-based technology and they are shared with the NiCd battery. It is widely agreed upon that NiMH batteries are the intermediate step to Lithium-ion. There are also more characteristics of this type of battery are:

1. **Longevity:** The NiMH battery is less durable than other secondary batteries including the NiCd. These batteries can not operate under higher temperatures, so cycling and storage of these will be difficult and most likely reduces the service life. NiMH also suffers from high self-discharge.

2. **Environmental:** NiMH batteries are actually more environmentally friendly compared to the NiCd because they contain only a mild amount of toxins. That can also make these batteries more profitable for recycling in the future. The NiMH has been replacing the NiCd batteries in markets where wireless communication is used and mobile computing. This is widely due to environmental concerns about the disposal of a battery that is no longer usable.

3. **Charging:** The charging capacity of the NiMH batteries are 30 to 40 percent higher capacity when compared to the standard NiCd. The NiMH batteries have a potential for higher energy densities. The discharge rate of NiMH batteries are also around 50% higher than that of NiCd batteries.

4. **Safer Facilities:** For the NiMH batteries, they have a positive when it comes to the transportation because they are not as subject to regulatory control.

5. **Limitations:** There are many limitations when we take a look at the NiMH batteries. They have a smaller life because if they are repeatedly cycled at higher loads then they will deteriorate after around 200 to 300 cycles. They also have a limited discharge current, even though they are capable of higher discharge currents. As stated before the higher loads decreases the battery cycle life. The NiMH batteries require better operating conditions which make it harder for them to be used in a larger range of applications, where they need to be stored in a cool place and at about a 40% state of charge. With all these limitations in consideration, they are also about 20% more expensive than the NiCd counterpart because of the higher current draw.

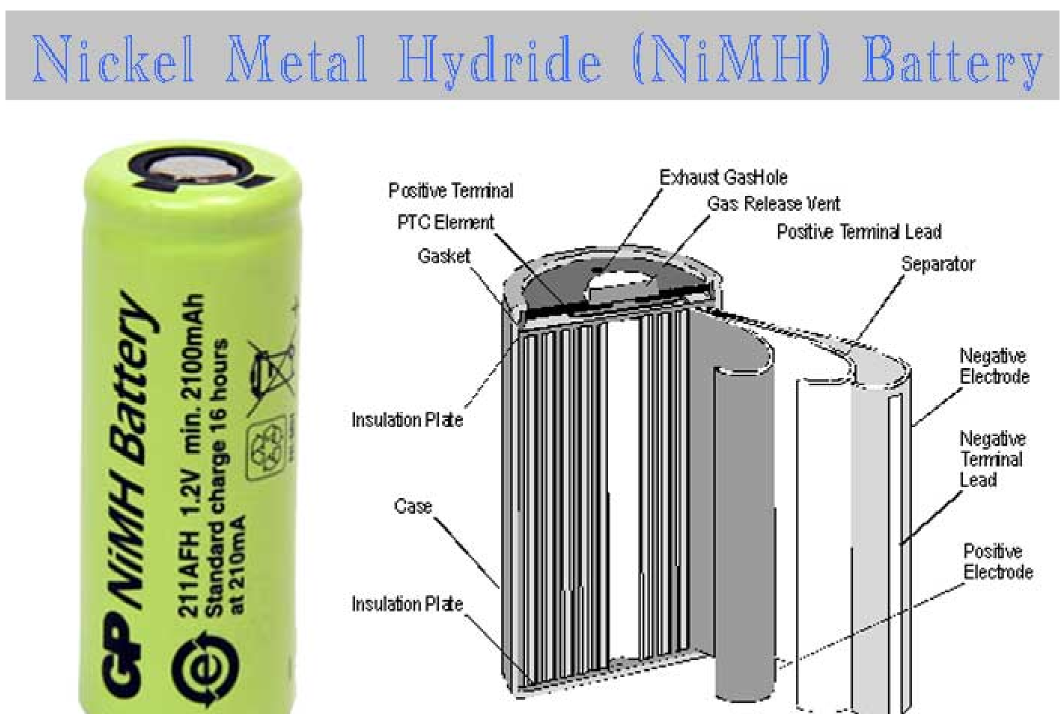


Figure 5: NiMH Battery Composition

<u>4.2.5-Lead Acid</u>

The lead acid battery was the first rechargeable (secondary) battery for commercial use. Today the lead acid battery is used more in automobiles, forklifts, and large uninterruptible power supply systems (UPS). In the late 1900's researchers actually developed a maintenance free lead acid battery that could operate in any position. The liquid electrolyte that takes place inside these batteries was transformed into moistened separators and the enclosure was then sealed. Of course safety valves were added because there is still a need for venting of the gas during charge and discharge phases. Two battery designs came from this battery, the small sealed lead acid battery and the large valve regulated lead acid. They are the same in the design and parts because it is not possible to have a truly sealed lead acid battery. For our emphasis on portability we will be focusing on the sealed lead acid battery. Some characteristics of these types of batteries include:

1. **Charging:** The SLA is designed with a low over voltage potential to prohibit the battery from reaching its gas generating potential during charge. Excess can cause gassing and water depletion. Another interesting point is these batteries can never be charged to their full potential. A positive is that they are not subject to memory, so they can sit on a float charge for a long period of time and not cause damage. Its retention and being able to keep the charge is also the best when compared to all other rechargeable batteries.

2. **Environmental:** For the lead acid batteries, unfortunately, the electrolyte and the lead content can cause environmental damage. There are also transportation restrictions that come along with the lead acid batteries. These concerns include the possibility of spilling in case of an accident.

3. **Limitations:** Leaving a SLA battery in a discharged condition causes sulfation, which is a condition that makes the battery difficult and seemingly impossible to recharge. With the SLA batteries you are also on;y allowed a limited number of full discharge cycles. These batteries also have a low energy density, which limits use to stationary and wheeled applications.

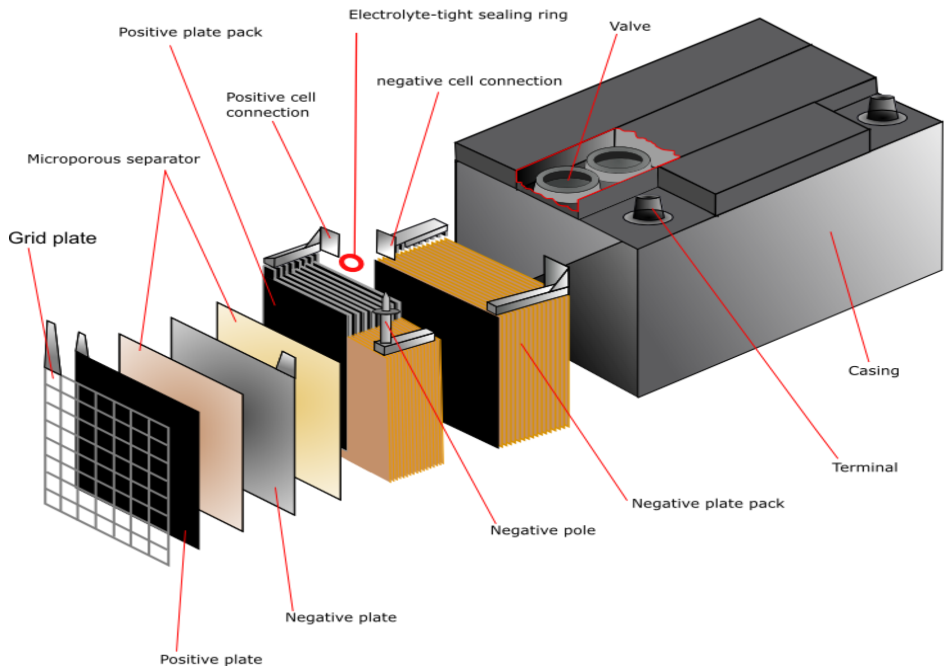


Figure 6: Lead Acid Battery Composition

4.3-Charging

An important aspect that must be researched when talking about batteries and the different ways they can be charged and how it's done. We will need to charge every time these batteries get low and if we don't use the right type of charging, it can badly impact the batteries and possibly decrease the life of our batteries or POE injector. This can mean costs will be more expensive and the system will be less efficient. There are three types of common charging methods, the constant voltage, constant current and a combination of constant voltage and constant current which is with or without a smart charging circuit. Here we will only be looking at the constant voltage, the constant current charging and the smart charging with a smart charging circuit.

4.3.1-Constant Voltage Charging

The constant voltage charging allows the full current of the charger to flow into the battery until the power supply reaches its preset voltage. The current then tapers down to a minimum value when the voltage reaches the appropriate voltage level. The battery can be left connected which is nice, because you don't need to have a time on when to disconnect the battery. During that time when the charger is left connected it will remain at that “float voltage” or a float charging mode to keep the battery fully charged. A constant voltage charger may return as much as 70% of the previous discharge in the first 30 mins. This type of charging has an advantage when it comes to simple circuit structure and easy control circuit design.

An example that would be somewhat popular is a low cost battery charger for home use or basic battery backup for power systems. For these applications, the constant voltage charging enables faster charging rates and is suitable for lead acid types but is not as good for the Nickel Metal Hydride (Ni-MH) or the Lithium-ion (Li-ion) types.

The constant voltage charging also has many downsides that can affect the battery. In the initial stage of charging mentioned before, the starting charging current is too large due to the low voltage at the battery end, so the electrode plate of the battery is easily damaged and the temperature of the battery itself is increased causing the life of the battery to possibly be shortened. In order to improve a disadvantage like this, a multi-stage voltage charging method can be used so that the charging is performed with a lower charging voltage at the beginning of the charge and the charging voltage can be raised after the voltage at the battery terminals is raised.

4.3.2-Constant Current Charging

The constant current charging is a simple form of charging batteries with the current level typically set at 10% of the maximum battery rating which will be the fixed current. This method is still very similar to the constant voltage method. When the battery is fully charged, the charger must be converted into a trickle like charge. The charge times are relatively long which is a downside along with the damaging and overheating we will look at next.

Compared to the constant voltage method, this method can fully charge the battery in a short time, but we must pay attention to the charging degree of the battery because the charger will always provide a constant current charge to the battery of whatever current was set at the charger. If we do not stop the charging immediately or switch over to the trickle mode charge. The overcharge will cause the battery to overcharge, damaging the battery plates, reducing the battery life. This again means that we must disconnect or use a timer function once the batteries are charged.. This method of charging is mostly suitable for Ni-MH type batteries.

Below is a simple diagram that can make it easier to visualize these two types of charging methods before we move on to the next one.

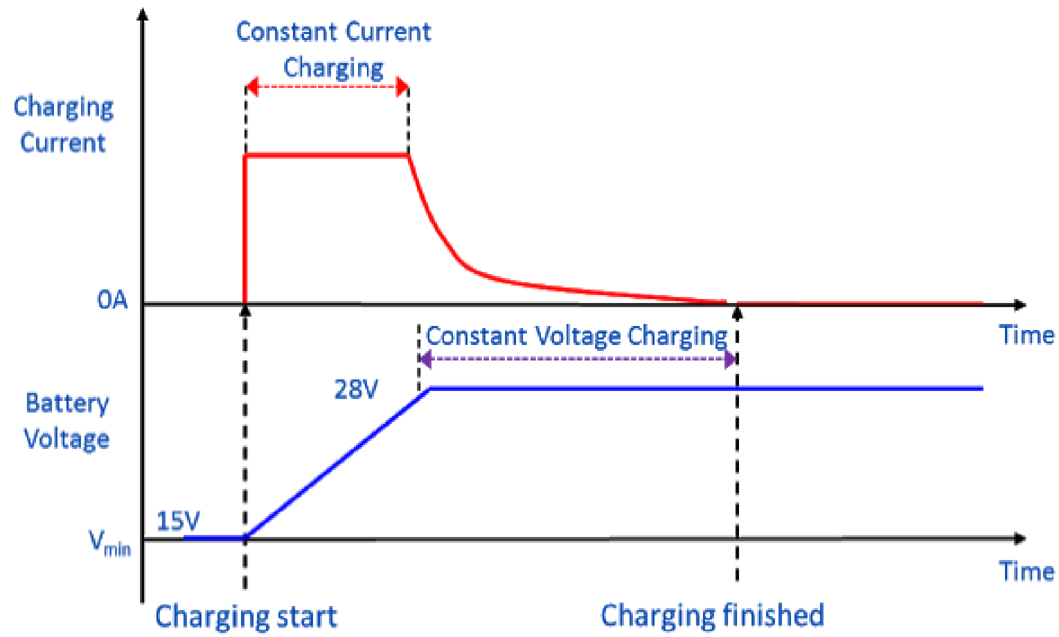


Figure 7: Constant Voltage Vs. Constant Current charging

4.3.3-Smart Charging

Smart charging is the next type of charging we will be looking at. It involves the use of a micro-controller to compensate for temperature rise, adjust the charge current and charge with time according to the battery specifications. Using a system like this drastically extends the battery life and is most commonly used with the Lithium ion battery types. That is a main reason why we are planning to use a battery management systems (BMS) type microcontroller for our system. A microcontroller like this can be fitted externally to the charger or the batteries themselves. There are a number of power semiconductor manufacturers that offer control circuits that can perform this function for ease of the customer building multiple systems.

Smart charging uses a combination of the above two methods. The charger limits the amount of current to a preset level until the battery reaches a preset voltage level. This is often determined by the microcontroller used. The current is then reduced as the battery becomes fully charged. The controller allows fast charging without the risk we run with other types of charging like over-charging because of the disconnection. The smart charging is most suitable with the lithium ion batteries we are planning to use.

Our smart charging consists of having a battery management system which is an electronic controller that manages the rechargeable cells. In simpler terms it keeps the battery bank from operating outside its safe operating area. The BMS may monitor the states of a battery represented as various items, such as voltage. Whether it be the total voltage or voltage of individual cells. It may monitor the current going in or out of the battery and also the temperature.

4.3.4-Adaptors

Connected to our planned BMS controller will be a female DC connection that can be plugged into an AC-DC adaptor for easy charging to the customer. AC adaptors convert a higher voltage alternating current to a lower voltage direct current for use of devices that only need a relatively constant voltage. Direct current is required to charge our batteries making these AC adaptors a must have for electronic devices like laptops and our battery bank.

A simple AC adaptor interior consists of a transformer, a rectifier, and an electronic filter. The transformer will do the conversion of a relatively high voltage alternating current (AC) that is supplied by an electrical receptacle to a lower voltage which is suitable for the device being powered. The rectifier then converts alternating current into the desired direct current. There are two types of rectifiers that were further discussed in electronics 1 class but to understand the rectifiers and what is really going on inside the adapter, we will briefly look at the half and full-wave rectifiers.

The half wave rectifier blocks the current flow in one direction with the use of a diode. With half of the current being blocked, this creates a pulsating direct current. Much of the supplied energy is lost and the mean voltage of the half wave rectified power is lower than that of the full wave rectifier. *Figure 8* shows the input voltage on the left and the output voltage on the right for the half-wave rectifier.

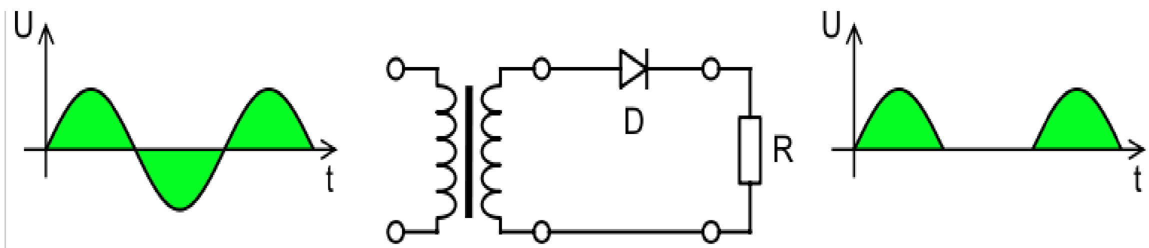


Figure 8: Half-wave Rectifier

The full wave rectifier has several types, but rather than blocking the electric current in one direction, the rectifiers flip its direction so rather than a lower pulsating current, there is a constant pulsing direction as the current output. The full wave bridge rectifier in *figure 9* shows the input voltage on the left and output voltage on the right also.

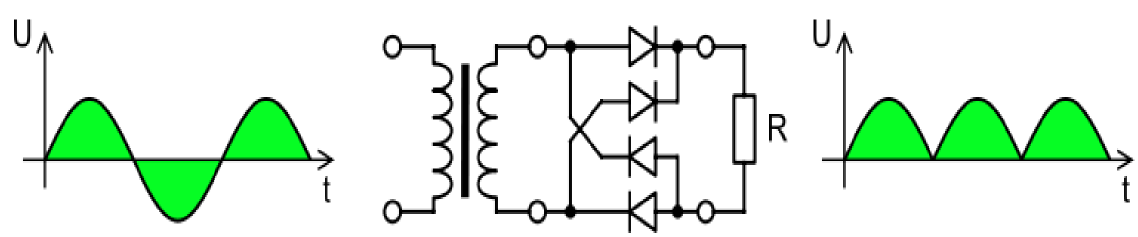


Figure 9: Full-wave Rectifier

As far as modern AC adaptors go, most utilize the switched mode power supply or (SMPS) which are considerably more complex than just linear power supplies and have clear advantages. The main advantage for these systems is that it gives DC supplies that can deliver more power for a given size, cost and weight of the adapter. The SMPS is used in the same applications as expressed above along with other consumer electronics.

4.3.5-UPS systems

A UPS stands for an uninterruptible power system. It's important when under the umbrella of charging because this can be very useful when it comes to our system and how we may implement it with the laptop, which can't be stopped after the charge of the built in battery is expended. A UPS is an autonomous source of alternate power that is used to supply electronic loads such as computer centers, telephone exchanges and monitoring systems. The systems that utilize these UPS systems require power that is always available and of good quality. A UPS provides a voltage and satisfies a power capability that is:

- Free of all disturbances present in utility power and is in compliance with the tolerances required by the loads.
- Available in the event of a utility outage, within the specifications.
- Providing an autonomous alternate source, through use of a battery.
- Stepping in to replace utility power with no transfer time, in other words without any interruption in the supply of power to the load, through use of a static switch.

These are the characteristics that make a UPS the ideal supply for sensitive electronics, whatever the state of utility power may be.

The Basic parts that make up a UPS that are important to understanding how they work are:

- The charger, which produces a DC power to charge a battery and supply an inverter
- The inverter, which produced the electric power free of all utility-power disturbances, most notable in micro-outages. A typical inverter for the UPS is connected in parallel with the AC input but in our case the main source of power is the battery of the laptop.
- The battery, which provides sufficient backup time to ensure the safety of life and property by replacing the utility as required afterwards
- A static switch, which acts as a semiconductor based device that transfers the load from the inverter to the utility and back, without any interruption in the supply of power.

The UPS can also be in one of three states. The Passive standby or (off-line), the Line interactive, or the double conversion of (on-line). An easy way to see how the UPS is set up is to look at how it acts in line-interactive mode seen below:

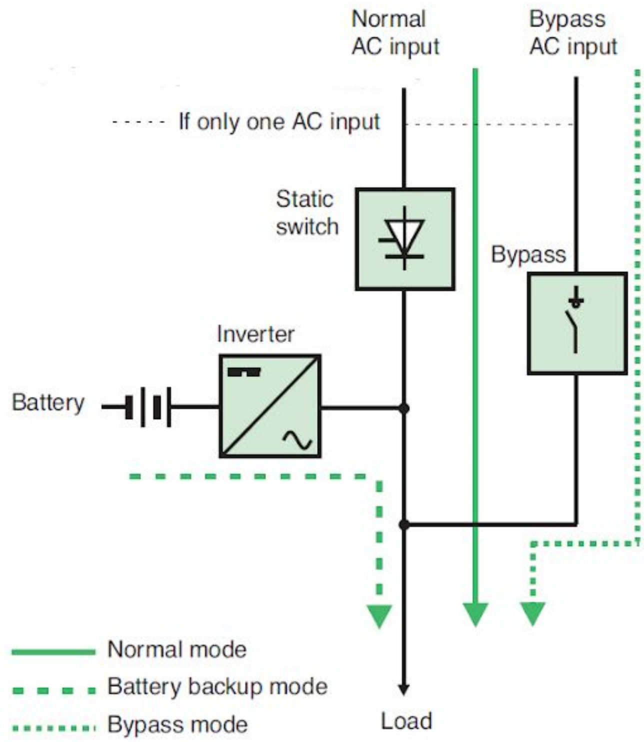


Figure 10: UPS Operating in Line-Interactive Mode

4.4-POE Transmission

As we worked towards our final project design we have looked at what POE (Power Over Ethernet) is, what type of batteries will work best for our system, and how we can recharge these batteries to increase the lifespan of our custom battery pack. We have researched and decided what type of POE transmission type we would like to use that would work the best for our sponsor QwikCut and will provide the proper specifications for powering our camera. This system was hand built on a PCB in order to accommodate the specifications and overall tasks that we have been ordered to adhere to. So this section will look into all the different types of POE power and connections and what is best for our project.

Whether you are a busy tech company that needs to monitor and power hundreds of devices or just a residential user/client that needs to power security cameras around their house. There are many different options and methods to achieve the desired outcome of limiting as many cables and wires as possible to simplify the powering and data extraction process. POE transmission can be broken down into a few different categories based on a few different characteristics and needs that a user will have in achieving power and data to a source. These categories and methods can be seen in the following sections while being compared to one another. We will also display the pros and cons for each and decide which option will work best for our project and sponsor to use.

4.4.1 PSE and PD

Before we get into the different methods of transmission and descriptions for transferring data and power through POE we need to discuss a general network diagram of the process as well as general terms that will be used to describe different portions of the system.

- **PSE:** We first need to start with PSE (Power Sourcing Equipment) and what role it plays in the system. As the name suggests PSE is the equipment that is used to supply the power to the ethernet cable that will go to the devices or devices that need to be connected. When looking at the PSE side of the POE network there are only a few methods and options available to power our PD devices. These options include POE switches, injectors, NVRs, splitters and media converters. PSE devices can be broken down into two separate categories for powering our devices. They are known as midspan devices and endspan devices. These will be explained more in the following section on the different types of POE systems for transmission. In either example the PSE is responsible for initiating the process of the handshake for our POE devices and will determine if we are able to power said device.
  - **PSE Responsibilities and Requirements**:
    - Detect a valid PD
    - Classify the power capabilities of the PD
    - Provide 4 W to 90 W of power at 44 to 57 volts to the PD
    - Perform power optimization and allocation
    - Perform fault monitoring and disconnection when necessary
    - Shutdown the power to the appropriate port if an undercurrent condition is detected
    - Provide overvoltage protection
    - Provide isolation from switch circuitry
- **PD:** PDs (Powered Devices) are the devices that are to be powered and function in a POE network system. These are devices that can be powered from an ethernet cable and are able to transmit data along the same ethernet cable as well. Unlike PSEs there are many different products and technologies that are able to be powered and connected to ethernet cales.As seen in many parts of the world today many different PD devices today include IP phones, IP cameras,wireless access points (WAPs), etc. For our purposes our PD will be an IP camera or IP security camera that will be repurposed for our project. PD's play a crucial part in the handshake process by determining to the PSE how much voltage is needed to power the device at a consistent voltage level and current range. If the PD does not have built in voltage detection and is POE/POE+ compliant the PSE will not

power the system due to safety of supplying too high of a voltage and possibly destroying the powered device.

- **PD Responsibilities and Requirements:**
  - Provide polarity protection
  - Provide signatures for detection and correct classification
  - Perform power optimization
  - Provide isolation
  - Provide for an optional bias for DC/DC startup
  - Convert 57 V down to the required regulated supply voltage used by the application

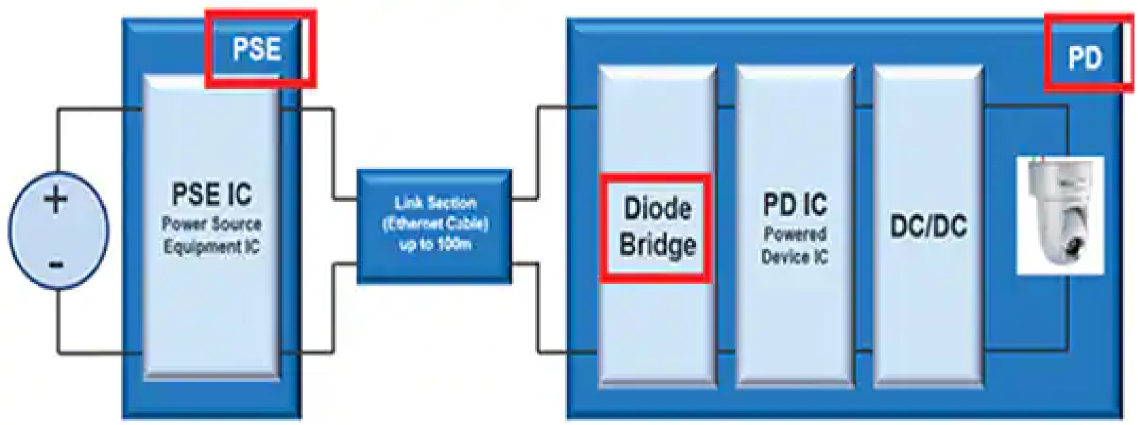


Figure 11: Basic PSE and PD device connection

Now that we have defined and described the two important portions of a POE process we need to move onto the different ways we can power our PD's and think about which of these PSE systems we can use to power our PTZ camera from our battery pack. The PSE portion of the system will be our main focus in supplying power and a steady voltage to our IP cameras since POE compliant PD devices will have the built in protections and converters on the camera side.

4.4.2 POE Switches

The first Power Source Equipment we will look at are POE switches. POE switches are a common method of powering POE devices in the modern world due to their IEEE compliance, multiple port accessibility to many devices at once, and the other features they provide when powering and operating PD's. Power injection is built into most POE switches and provides power over the ethernet without the need of an additional power source. However, there are switches that are not POE capable and require an additional power source. There are currently all kinds of switches on the market with a variety of port numbers. Port numbers can range from 4, 8, 12, 24, and 48 port systems. Switches with multiple ports allow the user to connect to multiple POE devices at once and create a large network depending on the needs of the user or business that is implementing the switch.

Going back to the earlier section where we discussed the descriptions and differences between PSE's and PD's we talked about endspan and midspan classifications. POE switches are defined as endspan due to their location in the POE system. The switch is located at one end of the system and provides the power to the PD directly thus coining the name.

Figure 12: POE Switch diagram and Flow

Now that we have looked at the general form of the POE switch we need to take a look at the pros and cons and how they relate to our sponsored project and if a POE switch will be the correct choice in designing our system. The pros and cons can be seen below:

- **POE Switch Pro's:**
  - Great flexibility- Can power a lot of different devices with a small amount of connections. (One cable per device)
  - Simplicity
  - Cost efficiency
  - Accessibility
- **POE Switch Cons:**
  - Distance limitations - The system can transmit the POE requirements to a max distance of about 100m. Can be a problem for larger businesses and corporations with large land use.
  - Power constraints - When powering multiple devices the voltage and power draw per device may strain the connections and may strain the system.

  - Too many connections for what our sponsor requires and needs
  - May not be able to get powered by a 12V battery pack

Overall, the POE switch is an effective method for powering our IP camera and devices but it may be overkill and too much for what we need in our overall design. One big consideration may be deciding if we can supply enough power to the system. This is an option and will be considered before our final design and building of a PCB.

4.4.3 POE NVRs

Similar to a POE Switch, a POE NVR (Network Video Recorder) has the built in POE injection and can power IP cameras and many other POE devices without the need for an additional power supply. NVR's are commonly used with IP cameras and video surveillance systems and have the responsibility of encoding and processing the video data that comes in. As well as recording it and storing it for viewing at a later time. A POE NVR is also considered an endspan device as it connects to the singular end of the system.

Since the NVR is similar to a Switch it has some of the same pros and cons as well as some additional features as seen here:

- **NVR Pros:**
  - Simplicity
  - Only needs one ethernet connection for both power and data transmission
  - Cost efficient - Similar to the Switch the NVR is cost effective because it decreases the amount of wires needed
  - Accessible
  - Can record and store data without the need for a separate recording system
- **NVR Cons:**
  - Distance limitations - Like switches after 100m the power connection may lose the ability to power the PD
  - Power constraints - Similar to switch if multiple devices are powered and connected at once it can cause some power shortages to one or more devices due to the power draw needed by each individual source
  - Possible storage limitations if powering multiple IP sources

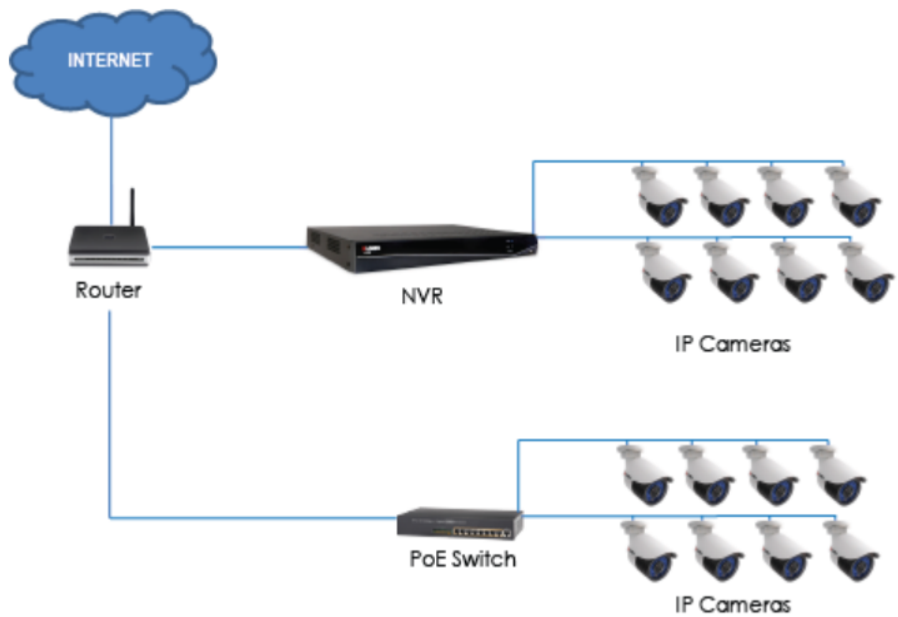


Figure 13: POE NVR Diagram with Switch comparison

So overall, a POE NVR is a viable option for our sponsored project and provides a little more in the data recording and viewing aspect. It is a great option for the sponsor and one to be considered.

4.4.4 POE Splitters

Now that we have looked at options that provide POE capabilities to POE devices, how could we possibly power a capable camera for our project without power over ethernet. This method uses a process of combining a POE switch or NVR that can power an ethernet cable that will connect from a PSE to a PD with an adapter known as a POE splitter. As the name suggests the POE splitter will take the singular ethernet cable and divide the DC power and data transmission back into two separate entities.

The main purpose and use of a POE splitter comes into play when a non-poe powered device is being used but has no reasonable or efficient way to power the device. It will also have the added POE benefit of using a sole ethernet cable to provide this. So this POE adaptation can use a singular port to do so. These splitters are commonly used with a system that only needs a singular or fewer devices than a POE switch alone. Generally most POE Splitters on the market today are IEEE compliant with 802.3 at/af standards and will comply with the POE standards as long as they output less than 15.4 W and 30 W respectively.

The figure shown below will show a common connection when using a POE Splitter and how when we connect our ethernet cable to a POE switch and connect a splitter on the other end to a non-POE device we are able to achieve the necessary requirements for powering and operating.

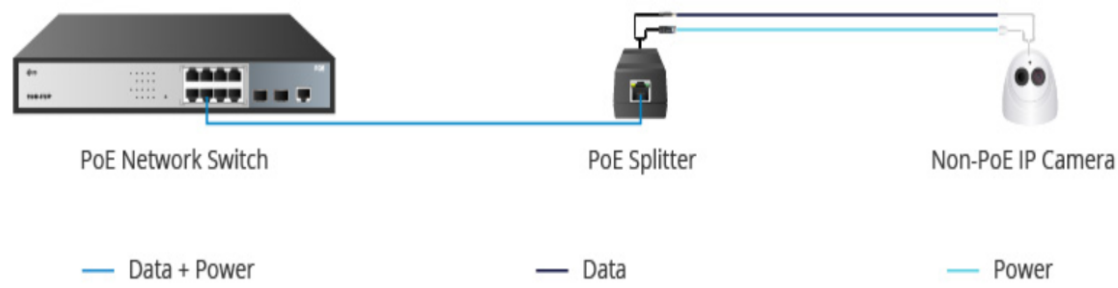


Figure 14: POE Splitter diagram

Now that we have learned about the POE Splitter we need to look at the pros and cons to be considered before building:

- **POE Splitter Pros**
  - Has the benefit of powering non-poe capable devices
  - Can achieve the same effective connections that POE Switches provide
  - Easier connection for the general user
- **POE Splitter Cons**
  - Although it has a singular ethernet cable, an additional adapter is needed. This creates an additional part that would be needed and possibly be replaced over time. This does not meet the sponsors requirement but could be discussed
  - Creates the need to make sure that the splitter is IEEE compliant
  - Limits that use to only non-poe devices. Would be a waste if a device is POE capable

Figure 15: General POE Splitter on the market today

4.4.5 POE Injectors

Now that we have looked at POE switches, NVRs and Splitters we will now shift our focus to one of the most common methods for powering singular POE PDs using a lone port. A POE injector is used when the source or main connection for data does not have the capabilities of providing power over the ethernet cable initially. Say we use a non-poe switch, we must find a way to provide the power to our system while also only using a sole ethernet cable. The solution is putting the POE Injector between the Data connection source and the PD, this puts the PSE in the middle point. This limits us back to the second main type of PSE connection that we discussed earlier, Midspan connections.

Injectors on the market today are capable of meeting both IEEE 802.3 at/af standards by using products that can regulate their power to work with both POE, POE+ and beyond. This is done by connecting the injector to an AC outlet to power the device which will convert from AC to 48 V DC and transfer that power over the ethernet to the PD.

The system diagram below shows ral connection for the POE system and how an POE injector can operate a system in a simple a genemanner:

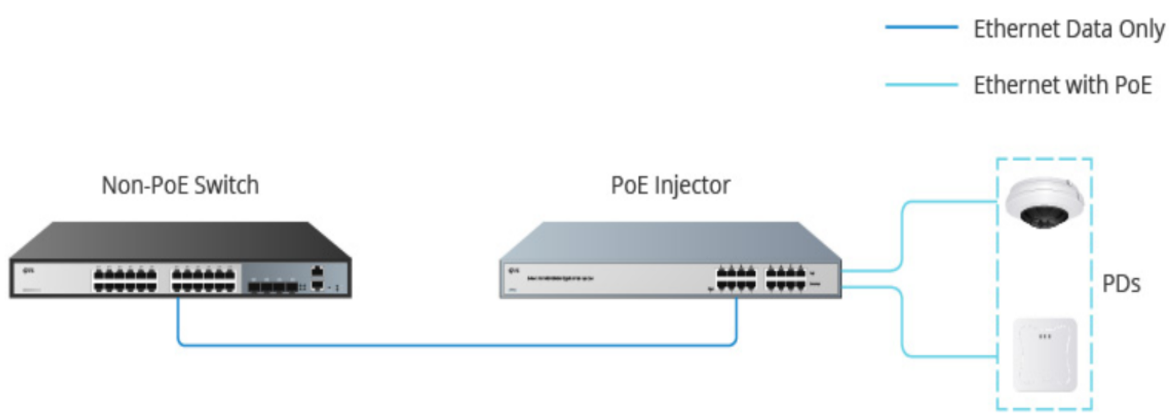


Figure 16: General Injector Diagram

POE Injectors can be divided mainly into 12V, 24V and 48V respectively according to the output voltage they provide. When purchasing or building a POE injector it is important to consider each design and voltage requirements for the POE PD we are trying to power. If we have an injector that doesn't give the correct voltage the device will not power up or connect properly. If we provide too much voltage we could permanently damage the device as well. So choosing an adequate POE injector is a must. Another consideration is how many devices you may need to power using the injector. Like I stated earlier, most injectors are used for single port and PD designs. There are injectors on the market and tools to make multiple port injectors to power multiple devices at once.

Now that we have delved into the key aspects and descriptions for a POE injector we need to look at the pros and cons in comparison to our design needs:

- **POE Injector Pros**
    - Simplicity of connection - As shown in the diagram above, we simply need to connect the injector to both the PD and the data source to complete the connection
    - Flexible to network expansion - Since the injector is connected between the data source and the PD we can run a longer cable before the need to connect to the power source injector. This means we can run a longer ethernet cable, connect to the injector, and connect a smaller ethernet cable to the output to avoid voltage loss and other factors that could hurt transmission
    - Can be purchased or built with IEEE 802.3 standards
    - Can be powered by a DC Battery pack
    - Can be used in smaller areas or spaces to power a remote device
- **POE Injector Cons**
    - Is unnecessary if the device we are using or switch has built in POE capabilities
    - Needs to be powered in order to inject the ethernet cable with POE capabilities
    - Is another connection that needs to be used in our device

Overall, the POE injector is a great tool that can be used in our fina design. With some minor adjustments and PCB building we can create a simple injector to power our device remotely without the need to run a microcontroller and system controlling it as it will be self contained. At the moment the POE injector is the frontrunner for our design with a single PD source and can be changed to another transmission type easily if our sponsor ever needed to.

4.4.6 Passive POE and Active POE

Now that we have looked into the basic design and functionality of a poe injector we now need to look at two different methods that are on the market using the PSE's listed above. These methods for powering our PD are broken down to Passive POE and Active POE. Each has their own benefits and downsides that can be explored and tested to see what the best option for our design would be

The first method we will be looking at is Passive POE. Generally a POE Injector, Passive POE is used for powering POE devices but does NOT conform to the IEEE 802.3at ,af, and bt standards respectively that have been laid out. Passive POE devices generally run on 18V to 48V DC to directly supply power to the ethernet cable and run the POE capability. However, this method of POE design does not complete the handshake process laid out in the beginning of our paper and can cause some serious problems and damage if the improper voltage, current and overall design are not used.

- **Passive POE Pros:**
    - Supplies power over ethernet through a simple design that can be easily implemented
    - Can power poe devices if it is used with a proper voltage compliant device
    - More cost efficient than active poe
- **Passive POE Cons:**
    - Can be very harmful and severely damage PDs if the incorrect voltage and parameters are used
    - Not IEEE compliant, can cause problems trying to implement

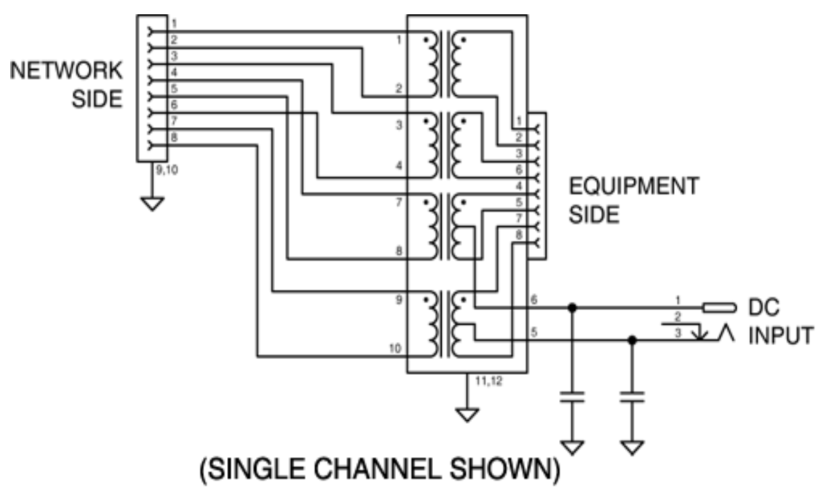


Figure 17: Passive POE example circuit

The second method we will be discussing is Active POE. This method of transmission can be any of the previous PSE types displayed above and unlike passive POE does follow the IEEE 802.3 at, af, and bt standards respectively. The active POE devices will attempt the handshake of compliance between the PSE and the PD. For example, if we are using a POE injector, the PSE will not even power up if the proper acknowledgement and standards have not been met so that the PD can power up. This means that the 802.3af/at/bt injector will check the power coming in and if the power doesn't meet the device requirements it won't get powered up, ensuring the safety of the PoE device. Normally, voltage levels in this range for active POE will be between 44-57V.

- **Active POE Pros**
    - Is IEEE 802.3 compliant for all standards

    - Easily implemented into most IP devices and cameras we may use
    - Can be replicated and design to fit our system
    - Completes the handshake aspect of poe to make sure the device can handle the voltage provided
- **Active POE Cons**
    - In comparison to the passive poe it is more costly
    - Requires more components and configurations to be considered
    - More complex than a passive poe build and will need more time and wiring

Overall, between these two different methods, Active POE seems to be the best choice for our system and the best to build a PCB to help power our IP camera.

4.4.7 Tools for POE

Now that we have explored all of the options that we can use to implement power over ethernet to our PTZ or IP camera. There are some devices out there that can be used to help eliminate and help improve some of the options in the previous sections. If we can possibly eliminate or decrease some of the cons that arise with the different options that may be able to help us in the long run. While other devices can help us determine different parts of the PSE and PD system. Knowing what standard, connection type and mode we are working in can be rather helpful in our building so we do not damage any equipment when testing.

The first piece of equipment we see that can be used is a **POE Extender**. This will help us address one of the major cons that both poe switches and NVR's face when being used in a POE system and design. That issue is the limitation and distance constraint that occurs when we try to supply power to a PD whose distance is greater than 100m from the initial point where it is connected. Once we pass 100m the voltage drop and current drop due to the resistance in the cables and overall efficiency drop our PSE will not be able to supply adequate voltage to the PD and the system will not work. Extenders unite networks that use twisted pairs to transfer the power through the ethernet cable to span the large distances that are used in places such as hotels, businesses, academic campuses and sporting venues.

The extender works by re-sending / re-implementing the original signal to send it for another 100m. The general rule of thumb for how many extenders you need is about 1 per every 100m past the initial 100m. So for example if we have a PD device 300m away from the PSE we will need two extenders to make sure the PD can be operated and powered efficiently.

The basic diagram for the POE extender can be seen below:

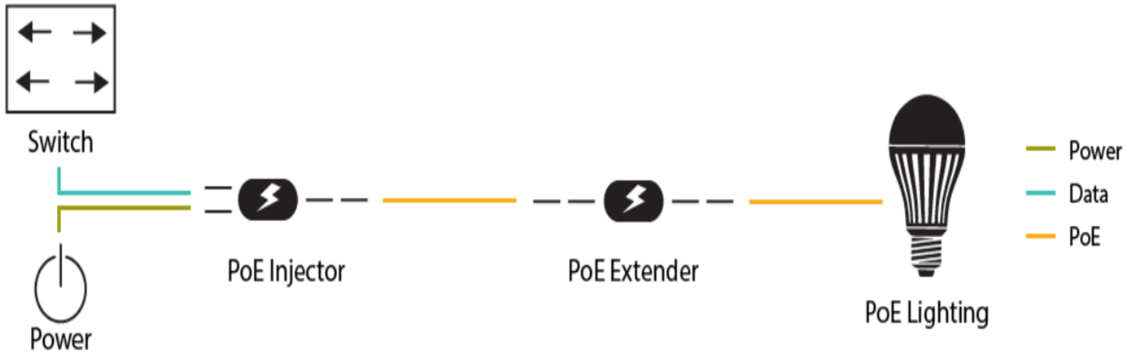


Figure 18: POE Extender Diagram

The second piece of tools we will look at are POE detectors and connectors. These connectors and detection type devices are crucial to making sure we are using IEEE standard devices and that we are running proper POE power. The main purpose would be to connect the detection piece to either the output or a switch, NVR, or injector to determine what power output the device is providing. The main pieces of connection we are looking for are:

- If the switch, injector, NVR, or other PSE are compliant with the POE/POE+ specification for the needed PD
- If the connection is POE Passive or POE Active, thus saving the equipment if it is needed
- If the system is running power through type A or type B

An example of a POE detector can be seen here in this diagram below and can be purchased online or from a variety of retailers. The cost of this device is invaluable in the long run of our project in order to save equipment and show that our built PCB device is properly functioning.

Figure 19: POE Detector Example

4.5-Ethernet Cables and Connections

Now that we have looked at the different ways to inject power over an ethernet cable, we need to explore the actual ethernet cables themselves and the different connections, types, and modes that are used on the market today. This section will help us understand how we can use these cables in our project and how they can work with the different POE transmission types and tools seen in the above section of this report.

4.5.1 Ethernet cables

As the name Power Over Ethernet suggests the power is supplied over the ethernet cable to power the IP camera we are going to implement in our design. When POE was first developed in the early 2000s the ethernet cables that were used were the cat 3 and the cat 5 cables respectively. These cables were able to transmit about a maximum of 100 Mbps. These cables still faced the limitations that we have today of 100m in distance for use but got the job done. Today's modern forms of ethernet transmission include Cat 5e, Cat 6, and Cat 6a. These cables are easily able to implement and send 10/100/1000 mbps of data as well as the up to 90 W of power necessary. These standard ethernet cables can be broken down into 8 different pins/ports for data transmission and have two main standards when it comes to connection design.

As stated in the previous paragraph these connections are divided into T-568A and T-568B respectively. While very similar in design these two ethernet designs move some of the transmission pairs and data pairs around for ease of use and use different transmission ports. The following table will show the color coordination for each ethernet type with pin designation:

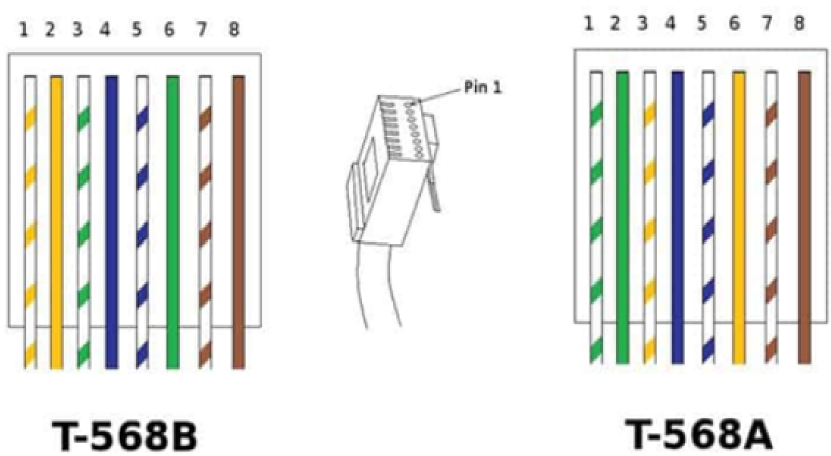


Figure 20: Ethernet Connection Types

Although these two settings are almost identical we can see minor differences in the color coordination layout where the orange and green pairs of the wiring are switched depending on the type you are using. In general for lower data transmission known as 10BASE-T and 100BASE-TX, for 10 mbps and 100mbps respectively, only two of the four pairs of pins are used for data transmission. The 1-2 pair and the 3-6 pin pairs in each respective type are used for the data transfer whole leaving two open pairs that are not used. However, when we want fast data transmission such as 1000BASE-T (gigabit ethernet), all eight pairs are used for transmission leaving no open pairs to use. When looking at the two types T-568B is a more recently introduced scheme and generally regarded as the go-to schematic in the world today and offers a lone pair of reverse compatibility. Although T-568B is the most widely used, the T-568A wiring scheme is seen as the better wiring scheme for RJ45 modular plugs because it provides reverse compatibility to not only one, but also two-pair USOC wiring setups. Overall, T-568B is more available in the world today.

For our design we will be looking at what connections will be compatible with a PCB built system and what will provide the max consistency and efficiency. Now that we know the different types of ethernet cables, what they are capable of handling and their overall orientation we now must decide which method for putting power into these cables we would like to use.

4.5.2 POE Transmission Mode

Now that we know what ethernet cables and standards are available in the market today we must learn the tw0 different methods for implementing and injecting power through the ethernet cables. These two modes are classified by the names A and B respectively. We will look into how each mode works, how to connect the power to the ethernet cable to provide power, and the pros and cons of how these different modes operate.

We will first start off with Mode A. Mode A refers to adding power on the two pairs of pins that we are already using for data transmission and adding power to these pins as well. This is used for 10BASE-T and 100BASE-TX exclusively as we will see an exception later on when trying to power the 1000BASE-T ethernet cable. This will work due to the data transmission and DC voltage running on different frequencies in the wire and will not distort either portion of the wavelengths. Mode A transmission of power will work on either T-568A or T-568B cable, and can be implemented rather easily. As stated earlier these cables use pins 1-2, and 3- respectively for data transmission. All we have to do is hook up our DC polarities in a similar manner. We connect the positive DC pole to pins 1-2, while connecting the negative poles to pins 3-6. When we do this connection this is referred to as phantom power due to the fact that all the data and voltage is transmitted on the same pairs. Thus it seems that the power is coming out of nowhere.

Mode B will do the opposite of mode A and put the power on the unused pairs that are available in the ethernet. So instead of putting the positive and negative DC voltage on the 1-2, and 3-6 pairs respectively we will instead put the 4-5 and 7-8 pairs of pins. The positive poles will connect to the 4-5 pairs and the negative will connect to the 7-8 pairs. This is the difference between the two modes and is seen in many different aspects in our society.

Now that we have looked at the power modes for the 10BASE-T and 100BASE-TX transmission we need to look at the 1000BASE-T transmission and see how it works as an exception. In order to run 1000mbps transmission the ethernet cable will use all four pairs to transmit data from one end to the other. So no matter what mode we use we will always be transmitting power over data transmission pins. However, the Modes A and B still come into play and still determine what pins will be used for injecting the DC voltage. So for mode A we will still use pairs 1-2 and 3-6 for powering the ethernet cable and for mode B it will use pairs 4-5 and 7-8. So no matter the pairs it is still running on the same cable as the data transmitted info.

Devices that are powered with 24 volt PoE always use Mode B. Devices that are powered with 48 or 56 volt PoE will almost always power up in Mode A or Mode B, but for the sake of simplicity we can think of Mode A as the default choice in most settings. Most times when looking at a device that uses 48V POE it doesn't matter which mode of power injection we use but we must make sure that when we purchase our PTZ camera that we are using one that is compatible with either power connection. The following diagram will show the complete view of how we should connect the ethernet cable to our power injector and pin generation:

Pins at switch	T568A color	T568B color	10/100 mode B, DC on spares		10/100 mode A, mixed DC & data		1000 (1 gigabit) mode B, DC & bi-data		1000 (1 gigabit) mode A, DC & bi-data	
Pin 1	White/green stripe	White/orange stripe	Rx +		Rx +	DC +	TxRx A +		TxRx A +	DC +
Pin 2	Green solid	Orange solid	Rx −		Rx −	DC +	TxRx A −		TxRx A −	DC +
Pin 3	White/orange stripe	White/green stripe	Tx +		Tx +	DC −	TxRx B +		TxRx B +	DC −
Pin 4	Blue solid	Blue solid		DC +	Unused		TxRx C +	DC +	TxRx C +	
Pin 5	White/blue stripe	White/blue stripe		DC +	Unused		TxRx C −	DC +	TxRx C −	
Pin 6	Orange solid	Green solid	Tx −		Tx −	DC −	TxRx B −		TxRx B −	DC −
Pin 7	White/brown stripe	White/brown stripe		DC −	Unused		TxRx D +	DC −	TxRx D +	
Pin 8	Brown solid	Brown solid		DC −	Unused		TxRx D −	DC −	TxRx D −	

Figure 21: Ethernet Connection mode A vs B

Overall, each cable, connection method, and mode of power injection have their own pros and cons and will need to be considered when we build our PCB and injector.

4.6-POE Camera Options

After looking at all of the different POE methods of power injection and powering our ethernet cable we will now need to find a suitable camera that we can use to attach to the top of our tripod and broadcast over the ethernet connection we have already established. Unlike the POE connections and transmissions there are multiple different products on the market that are readily available for purchase and use that can be included into our design. For this project we feel that the most effective and efficient way of achieving our goal to our sponsor is to purchase a pre constructed and built camera system with POE capabilities involved so that we can just plug into our project and use it. This will make sure that we appropriately address the sponsor needs while also building the best possible system we can while adhering to IEEE standards along the way. If we can find an existing video camera or possibly redesign and repurpose a camera of a different variety to our purposes this will give QwikCut the ability to easily produce multiple of our system and achieve what we have been asked to do.

The sections below will look at some existing camera types and categories on the market and what specifications are vital to our sponsor. We have researched and learned the ins and outs of these devices before we made a final decision on which camera meets all of our needed requirements and we can then use it to build our prototypes.

4.6.1 IP Cameras

The first section and type of video camera on the market today is known as an IP camera. Internet Protocol Cameras (IP Cameras) are digital video cameras that are similar to a webcam in which they receive and transmit data over a network or internet connection. However, unlike a standard webcam, IP cameras are a standalone unit that has its own IP address and requires nothing more than a network connection to transfer images. This network connection can be done similarly to any other product on the market today such as laptops and tablets either by a hardwired connection or a wifi connection. Another possible method of connection would be to just connect the camera to a laptop directly and obtain the images through an ethernet connection. The only thing that would be required would be a way to power the camera as we have discussed above.

A majority of IP cameras on the market today can be set up and connected relatively easily and can provide some key functions to users such as live viewing, video recording, operating at scheduled times and can be triggered by certain events. The live viewing and video recording aspects of these cameras will be crucial to our project design and how we can accomplish our sponsored goals. Another important aspect of these cameras besides the video and audio capturing portions of these devices is the fact that many of these cameras can be controlled remotely. As well as the versatility in design they offer we can also use them either indoors or outdoors as well, as long as they meet the requirements.

4.6.2 Fixed IP cameras

The first category of IP cameras we will look into are fixed IP cameras. Fixed IP cameras are as the name suggests and are fixed to a singular point and generally only look at a singular view or area of focus. They adhere to all of the benefits of the IP system and can be connected remotely or wirelessly to a network to be used. They can come in many different arrangements, camera styles and overall configurations that we can use to build our design. The specifications and standards for these cameras will be discussed in a section below.

However, the downside to these cameras is the fact that they are stationary in design and have no way to move besides the zoom function that is implemented into most design styles. This can be solved with a motorized unit that can connect to the base of our camera that will serve as the pan and tilt function. This would allow the camera to cover multiple areas of focus and give us the ability to possibly use it in our design. The process of designing a motor to work with our design may be an issue though when it comes to wiring and connection as it may not meet our one cable connection constraint that our sponsor has asked us to build. This will need to be considered when selecting our camera. A standard Fixed IP camera can be seen in the figure below:

Figure 22: Fixed IP Cameras

4.6.3 PTZ Cameras

Now that we have looked at fixed IP cameras we need to look at another viable option on the market and one that I believe will provide the most benefits and accessibility for ourselves and for our sponsor. This option is referred to as a Pan-Tilt-Zoom Camera, PTZ Camera for short. As the name suggests these IP cameras have the pre-built ability to Pan up to a 360 degree radius around a focal point in the x-axis, Tilt upwards and downwards in a y-axis manner, and Zoom in and out on an object or area in the z-plane. PTZ cameras can come in many shapes and forms on the market today and can be used for a variety of uses such as home security. Like the fixed cameras mentioned above the PTZ counterparts have all the abilities of the IP system and can connect to a network or device through one cable. If we can possibly repurpose an existing security camera and use it for our purposes of videoing games and sporting events these cameras can be a crucial aspect of our design and project. As long as they meet the proper camera specifications that we will now look at.

Figure 23: Standard PTZ Camera

4.6.4 Crucial Camera Specifications

Now that we have narrowed down two design options that we may use for our project and design we will not need to look at a few specifications and requirements that these cameras will need to meet for our implementation. Power and data connection will not be discussed here since we have already established that IP cameras have POE capabilities and can work with an ethernet cable.

Zoom: The first requirement that our cameras will need to have are proper Zoom and proper optics for viewing areas that are a great distance away. For our project we will need a camera that can cover the entire distance of a football field which is about 120 yards, which equates to 360 feet in total. This means that if we have a camera that has a zoom whose capabilities are less than 320 feet this will not be adequate enough for our design. So we need to calculate what focal length and magnification will be necessary for our design. This will need to be done through testing and calculations on what kind of picture our sponsor would like. A wide view vs a tight view of a subject will help determine this. However, for our purposes we believe that a minimum magnification of around 15x will be needed to cover the length of a football field.

Pan: The second area and requirement we will need to look at is the panning of the camera in the x-plane and see if our camera has enough pan, in degrees to cover the needed area of surveillance and viewing. Some camera options have 360 degree viewing ability built in and some have much less, we need to look at the maximum field of coverage we will need to view in this range. Our sponsor covers football, basketball and many other sports that run a long distance from side to side. Thus needed an adequate pan range to look at. Using the same football field analogy as above we need to cover a range of 320 feet from one side to the next and possibly more depending on the position of the camera. So a safe estimate on the pan range will need to be at least 180 degrees in order to make sure we are obtaining the proper coverage. Another important aspect would need to be the speed in which we can pan, professional athletes can cover 40 yards of space in less than 5 seconds. So having a camera that will keep up is crucial. We will need a pan speed of at least 0-20 degrees a second. That i'll give us the proper speed needed to keep up with the athletes.

Tilt: The third main specification we need to look at is the tilt of our camera, the range of movement in the y-axis. This is the movement looking upward and downard. This will be needed when the action is closer to the camera and needs to look downward to capture the full picture. This is similar to pan as well in which we will need a certain speed to maintain the picture that we are looking to adhere to. A safe estimate would be a range from 0-(-90) degrees in the y-axis. This would give the camera the ability to look straight down. A proper speed would be similar to the Pan in which if we could move 0-20 degrees a second that would be adequate.

Quality/Definition: The fourth main focus of our camera and possibly the most important portion itself is the overall quality of picture and definition that will be captured by the video. Even if we find a camera that meets the P-T-Z requirements above it would be worthless to purchase and test if the video quality does not meet that standards and requirements presented to us. As stated in the requirements section at the beginning of the report we need to have a camera capable of capturing 1080p HD at a minimum with the possibility of a higher definition if it falls within a reasonable price point and achieves at a much greater quality. This will be crucial when streaming live games and recording for schools, coaches, and individual clients that will rely on these videos. Along with the definition that we can record these games in, it will also be crucial to have a camera that is capable of higher frames per second on display. Frames per second (FPS) refers to the number of consecutive full-screen images that are displayed each second in videos and camera screens and is a common video measurement. According to many sources, the human eye can process about 12 images or photos per second, this means that a rate of 12 FPS can display motion and be detected. However, this motion will appear choppy and very jagged in movement throughout the video and subject you are capturing. Once the frame rate passes 12 fps the frames start to blur together and form a clearer picture. 24 fps is commonly used to shoot movies and film as it creates a smooth look and appearance. Some cameras and video recorders are able to record in 30 FPS or even 60 FPS creating an even better and smoother picture to the viewer. So for a minimum specification we need to have at least 25 FPS, a little better than what they use to shoot movies, or better to meet an adequate goal.

Overall, all of these specifications and aspects of a camera will be required in our selection and should easily be achievable with the supplies on the market today. This will help us adhere to the needed requirements and give QwikCut the needed video quality they are looking for.

4.7-Microphones

Microphones are an important part of capturing game film, playback, and streaming. It's important we use the correct type of microphone to ensure the best quality sound and also make sure we don't pick up on too much else besides what we are recording. Different types of microphones work best for different jobs and looking at the differences will help with our selection. There are three types of microphones we will be mainly looking at so we can make the best selection. These include condenser, dynamic and ribbon microphones below. While the shapes and location of the microphone will make a big difference in whether it is a directional microphone, or an omnidirectional microphone, we will be looking at the basic pros and cons of each to get an idea of the main characteristics that make them up.

1. **Condenser Mics:** These microphones feature a diaphragm suspended inside a capsule that moves as sound hits it. As the diaphragm moves, the changing distance between the diaphragm and the other side of the capsule is converted into an electrical current. The current is usually provided either by battery or sent down the microphone cable. Most of these microphones can operate with phantom power voltages which range from 11 to 52 volts. These types of microphones capture sound with more fidelity which is basically more detail and high frequency energy than the other microphones. The recordings that come from these have a lot of detail and texture, so typically they are the best when it comes to vocals. Condenser mics are more expensive than dynamic mics and they are less suitable for loud sounds up close.

    - **Condenser Mic Pros**

    - Picks up the largest range of frequencies so the sound is more realistic and true to what it really is.
    - These microphones have affordable options.
    - These are offered in a directional format so they are not picking up too much audio from behind or what is not necessarily intended.
    - Can be small in design.

    - **Condenser Mic Cons**

    - These mics can not handle very loud sounds. This makes them not very ideal for situations when recording up close like a band or loud music.
    - There is a limit to the maximum signal level the electronics can handle.
    - They tend to be more complex than dynamic microphones and are more fragile when affected by extremes like temperature and humidity.

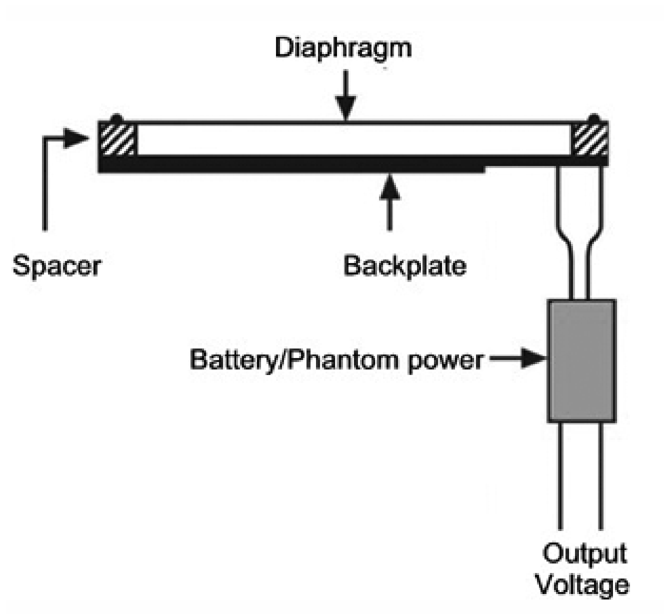


Figure 24: Diagram Showing Diaphragm and Backplate of Condenser Mic

2. **Dynamic Mics:** When the sound enters the dynamic microphone, the diaphragm vibrates and bounces a coil fixed in a magnetic field. This is how the electrical current is created that varies according to the sound that is hitting the mic. These microphones are not as sensitive to the load sounds, low and high frequencies as the previously looked at condenser mics are. Although the sound that is picked up is described as more "colored" this is a way to describe how it sounds a little different than the way the sound naturally occurs. The lack of sensitivity to loud sounds make them a good choice for a broad range of applications.

   - **Dynamic Mic Pros**

   - These mics can pick up loud sounds without disorienting.
   - They are very durable and hard to break. These mics are built to last and can survive being in very high impact situations. These mics will last much longer and wont fall apart or break easily.
   - They're more affordable than the previously looked at condenser mics.
   - These mics are also available for different applications which allows us to select more of a directional application.

   - **Dynamic Mic Cons**

   - These mics don't pick up low frequencies as well so they wont pick up all the nuances and background noise as much that is most likely not wanted in the recording.

- These may not pick up all the characteristics of sound that condensers do. Overall not very good for recording instruments up close where you may need all the nuances.

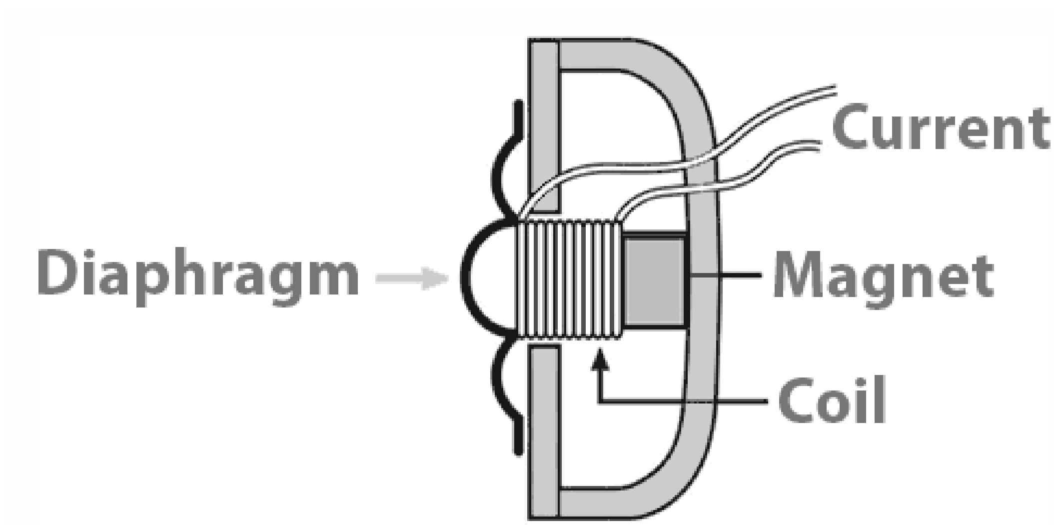
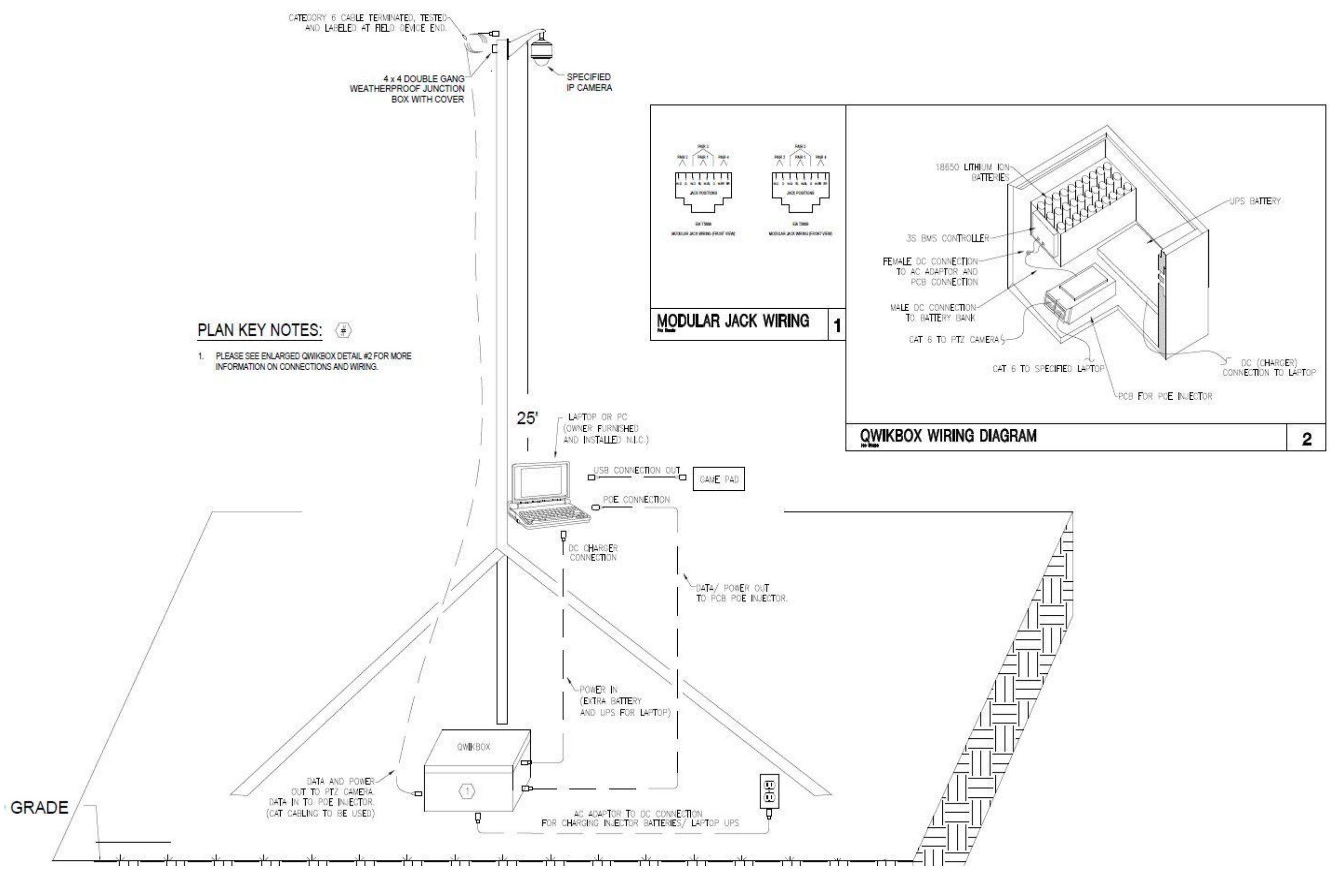


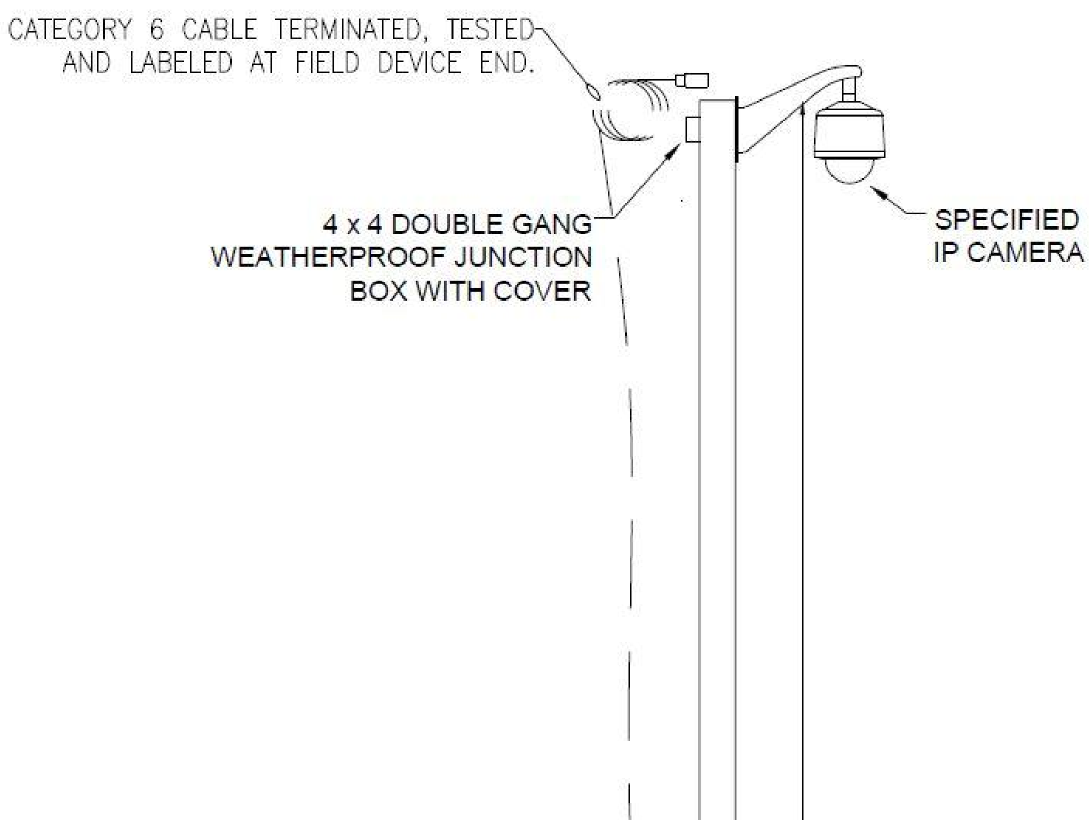
Figure 25: Inner Workings of a Dynamic Mic

3. **Ribbon Mics:** This microphone is most likely not to be used but it's interesting because it uses a thin metal sheet called a ribbon. When the sound waves hit the ribbon, it vibrates producing the electrical current. This type of mic has been around for close to 100 years. Almost all of them have a figure 8 polar pattern. This means it picks up from both the front and the back of the mic. The ribbon mics require an audio interface with quality preamps since the output of these microphones are usually very quiet and often need to be significantly boosted. These microphones are also very fragile, expensive and can even be broken if blown on them too hard for the older models.

5-Design Related to Project

In this section we will be getting more into the design and specifics of the project and our plans for the next semester where we will be creating the new system and testing all the components together to complete the design for QwikCut. First, included is a wiring diagram, schematic and basic setup of how the QwikCut setup will contain. This is a rough schematic created in AutoCAD that contains plan key notes and details to further show how the physical aspect of the design will go. This is a way to make all group members get a visual for how we are planning to use the components we are buying and designing all in one working diagram. Please see below for the overall schematic which will be broken up more for a closer look.


CATEGORY 6 CABLE TERMINATED, TESTED AND LABELED AT FIELD DEVICE END.
4 x 4 DOUBLE GANG WEATHERPROOF JUNCTION BOX WITH COVER
SPECIFIED IP CAMERA
PLAN KEY NOTES:
1. PLEASE SEE ENLARGED QWIKBOX DETAIL #2 FOR MORE INFORMATION ON CONNECTIONS AND WIRING.
25'
LAPTOP OR PC (OWNER FURNISHED AND INSTALLED N.I.C.)
USB CONNECTION OUT
GAME PAD
POE CONNECTION
DC CHARGER CONNECTION
DATA/ POWER OUT TO PCB POE INJECTOR.
POWER IN (EXTRA BATTERY AND UPS FOR LAPTOP)
QWIKBOX
DATA AND POWER OUT TO PTZ CAMERA DATA IN TO POE INJECTOR. (CAT CABLING TO BE USED)
AC ADAPTOR TO DC CONNECTION FOR CHARGING INJECTOR BATTERIES/ LAPTOP UPS
GRADE
MODULAR JACK WIRING
1
18650 LITHIUM ION BATTERIES
UPS BATTERY
3S BMS CONTROLLER
FEMALE DC CONNECTION TO AC ADAPTOR AND PCB CONNECTION
MALE DC CONNECTION TO BATTERY BANK
CAT 6 TO PTZ CAMERAS
CAT 6 TO SPECIFIED LAPTOP
PCB FOR POE INJECTOR
DC (CHARGER) CONNECTION TO LAPTOP
QWIKBOX WIRING DIAGRAM
2


CATEGORY 6 CABLE TERMINATED, TESTED AND LABELED AT FIELD DEVICE END.
4 x 4 DOUBLE GANG WEATHERPROOF JUNCTION BOX WITH COVER
SPECIFIED IP CAMERA

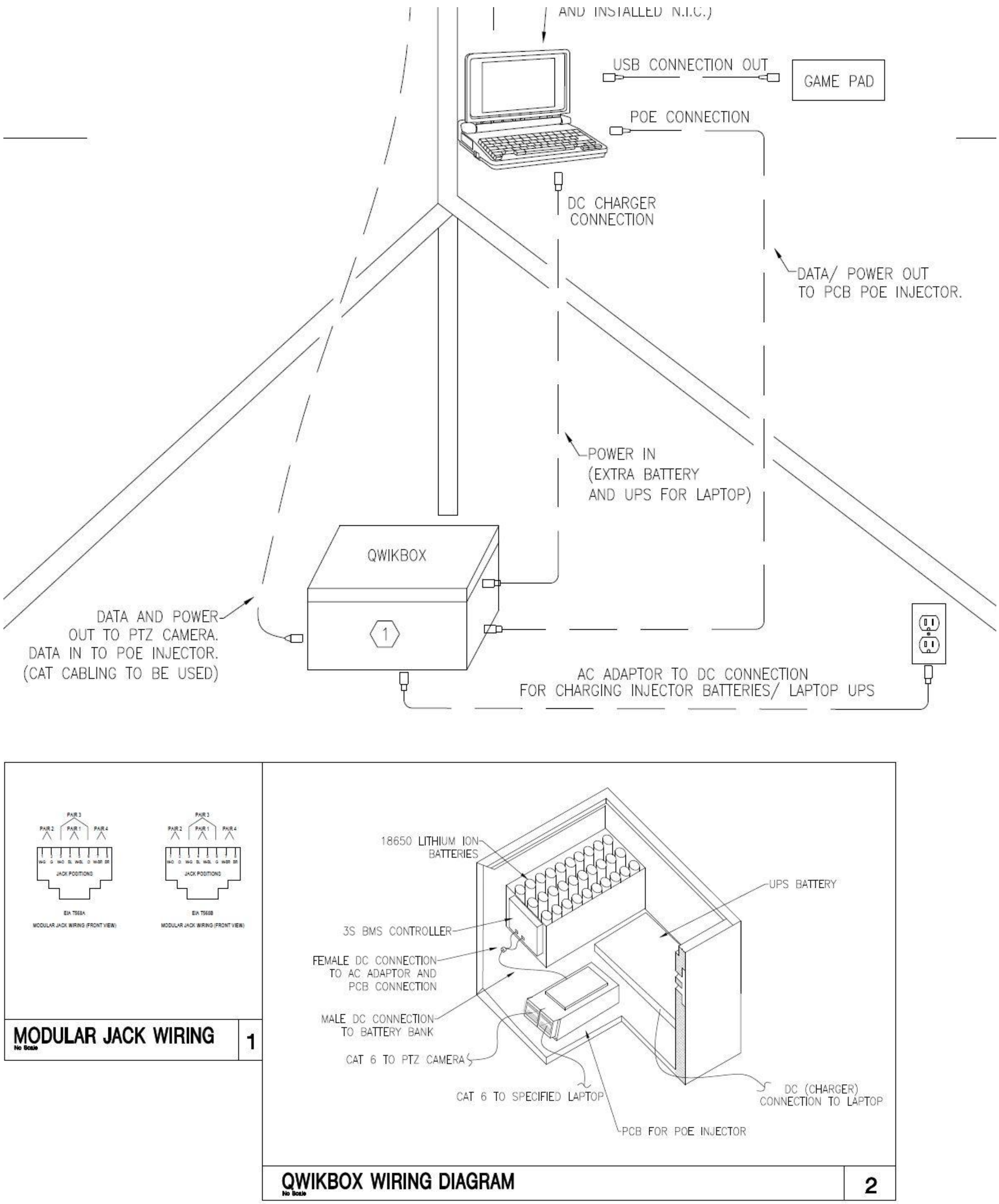


Figure 26: Design Schematic Diagram and Details

5.1 Injector Battery

Using the information from above for the batteries, using the lithium ion battery will be the best benefit to the customer mainly for maintenance, size, and ventilation for more waterproof applications. It has the most promising chemistry of all the batteries and many applications of using lithium ion batteries are based on the 18650 batteries. It is one of the most mature lithium ion formats available and is produced in high volume with a low cost per watt hour. The 18650 battery size (18mm diameter and 65mm length) is the same shape but a bit larger than a AA battery. We are planning on making a battery bank using 18650 lithium ion batteries. The specifications of these battery cells include 3.7V and 3400mAh. The POE+ camera includes a draw of 600mA at 48V which would give us 2400mA at 12V which is our desired voltage. This is a conversion at 100% efficiency which is 28.8W to 28.8W. Our system is thought of to be around 80% efficient after transmission which would give us a draw of 600mA at 48V still at the camera but coming from the battery would give us 2880mA at 12V desired. This is an 80% conversion which increases our battery power from 28.8W to 34.56W. We know we need a 12V battery bank, so looking at the specs of our 18650 batteries, we need them to be in a series of 3 which would increase our total voltage to 11.1V. The following calculations give us the relation between the size of battery in terms of amp hour we will need and how many hours it should provide for us depending on how many of the 18650 batteries we will be using in parallel.

Efficiency	**Number of 18650 batteries in parallel**	**Resulting Amp Hour Battery Bank**	**Amp Hour battery Bank / draw from POE+**	**Hours Provided**
100%	5 x 3400mAh	17Ah	17000mAh/ 2400mA	7.08 Hours
	6 x 3400mAh	20.4Ah	20400mAh/ 2400mA	8.5 Hours
	7 x 3400mAh	23.8Ah	23800mAh/ 2400mA	9.916 Hours
	8 x 3400mAh	27.2Ah	27200mAh/ 2400mA	11.33 Hours
80%	5 x 3400mAh	17Ah	17000mAh/ 2880mA	5.902 Hours
	6 x 3400mAh	20.4Ah	20400mAh/ 2880mA	7.08 Hours
	7 x 3400mAh	23.8Ah	23800mAh/ 2880mA	8.26 Hours
	8 x 3400mAh	27.2Ah	27200mAh/ 2880mA	9.44 Hours
	9 x 3400mAh	30.6Ah	30600mAh/ 2880mA	10.625 Hours
	10 x 3400mAh	34Ah	34000mAh/ 2880mA	11.81 Hours

Table 9: POE Injector Battery Calculations

Some items we will be needing to build the battery bank will include some of the following:

- 30 x 18650 batteries
- A 3S 25A or 30A BMS Board that manages the lithium ion battery pack. This offers an overvoltage range of 4.25-4.35V and over discharge voltage range of 2.3-3V maximum operating current of 0-25A or 30A depending on the selected board.
- Ni Strips for connection of the batteries in series and parallel. Two types of nickel strips are common where we will use pure nickel, which may be slightly more costly but offer a much lower resistance which means less heat generation during charging and discharging for a longer battery life. We must also use soldering for the connection to the batteries.
- Battery Level Indicator and Rocker switch to see the battery level whenever required.
- Female port DC jack (connected to the BMS for charging and supply to the injector)
- Holder for the 18650 batteries . These can be connected with simple hot glue and are used to allow fresh air to pass and easily cool the batteries. It can be oriented in any way and makes the bank solid and reliable. The last thing these provide is an anti-vibration to our battery bank.

For connection, our BMS will have four soldering pads, a B-, B1, B2, and B+. We first want to connect the first parallel group. We will connect the negative terminal bus to the B- and the positive terminal bus to the B1. We will also be connecting the third parallel group negative terminal bus to the B2 and positive terminal bus to the B+. Soldering the nickel strips to the PCB will provide a sturdy connection. An enclosure can be provided or 3D printed easily for the battery bank to reduce the risk of accidental shorting.

5.2 Laptop Power

The laptop we are using for our design is the Acer Aspire 5 Notebook. For power specifications, the laptop contains a 4-cell lithium ion battery along with a 45 watt AC adaptor for charging when not in use. These are the specifications given for the laptop we plan, along with another laptop we are planning to use that will be similar. With this, we are expecting to have a baseline battery life of around 5 hours. We are wanting to keep a battery life of around 10-12 hours. This is when we will look at using a UPS along with the chosen laptop. This UPS can also be swapped out in the form of a portable charger that can stay attached to the phone and will essentially extend the life of the battery on the laptop we are currently using.

This might be the better option because these will be much easier when thinking about our client and how they can get parts for the system that are more compact, cheaper and easier to use. Since the UPS systems are most commonly plugged into an AC connection because they are not typically used for battery powered devices, having a battery powered UPS isn't as useful because we will be waiting for the battery to shut off, then activating the UPS when we can just have a portable battery that will act like an extension of the laptop so it will be a much longer time before the battery on the laptop gets low. This will also be much easier on the client for charging purposes.

Laptops can use a wide range of amps depending on what is being conducted. This can range from somewhere along the lines of 0.41 to even 3 amps per hour under heavier and more demanding applications. Streaming and recording can be very demanding so we can use that 3 amp per hour max draw from the laptop to be safe on how to see what size the portable power bank can be. The existing G3 Tiger K2 battery that is being used in the QwikBox has a large capacity of 50,000mAh. Using a 3 amp per hour draw from the laptop at most, we would be looking at just over a 16 hour battery life for the laptop just using the existing G3 Tiger alone. This is a sufficient amount of time for our goal of 10-12 hours of uptime for the system. Not only will this be cheaper for QwikCut because these units are already in the box meaning they will not have to re-purchase a battery for the system, but this is a battery everyone is already familiar with. There is a USB portable charger option that boasts a 30,000mAh battery that is fast charging and can keep our laptop charged for still a significant amount of time at around 10 hours using the same draw. This battery can be purchased for around 60 if it is not desired to use the existing battery and can still be a good option.

5.3 PCB Injector

After careful consideration by our team and considering multiple design choices that we have come up with over the last few weeks we feel that choosing a POE Injector will be the best approach in obtaining our design. This is due to the fact that with the laptop that we will be using to connect the PTZ camera will not have the ability to power our camera as this laptop does not adhere to the IEEE 802.3 standards for powering a POE device. So an injector will be required in order for us to power the camera and transmit the data back to our laptop. However, we will need to make some modifications to the standard POE injectors on the market due to the nature of our project and the location that this camera will need to reach.

Our PTZ camera will be attached and mounted to the top of a 25 ft tripod and hoisted into the air when recording and streaming. We will need to power this camera using our injector without the use of an AC power source due to the fact that we will mostly be in situations that will require battery operated tools due to the nature of most high school and athletic facilities around the playing area. This creates the need to make our PCB injector battery operated using the custom battery pack designed in the earlier section of the report. This battery pack will provide the necessary amp hours necessary for what our sponsor needs and give us all day battery life to connect to the PTZ. It will also provide an adequate voltage to the system that we can possibly boost in order to meet the POE threshold.

Now that we have determined how we will power the PCB injector, we will need to design a PCB capable of handling all of the responsibilities and outputs required for a POE device. The PCB will need the following aspects to perform and operate as a POE Injectorfrom battery powering up to data and power transmission in the following order :

Female DC input jack with adapter: For the first portion of our PCB we will need to make sure that we can power and operate our injector at the proper voltage and current needed for POE products. This will require the use of batteries to power our board and a connection to transfer the power from the batteries to the board. As seen in the above section on our battery pack the batteries will run in parallel and in series in a 10 x 3 matrix in order to create a 12V power pack. It will be connected to a female DC power input jack connected back to the batteries. This will let us run a 12V ac to dc power source to the batteries and recharge them. So since we need to connect this battery pack to our PCB the logical option to this was to attach a male DC input jack to the board so we can just connect to the battery pack directly. However, after researching parts on ultra librarian and other parts catalogs online I came across the issue that most options for a male DC input would not be able to be attached to the PCB directly through soldering. Most if not all male DC input require a wired connection via screws and connector that would not be mounted to our board. After looking into this I found that most PCB boards don’t have the capabilities to do this due to the nature of wiring and the possibility of the connection being easily damaged or torn off entirely. Thus leaving a PCB unoperational with no functionality.

The solution to this was a simple one, use a female DC input jack with a dual male adapter in between the connector and the battery pack. This will allow us to solder a female jack directly to the board with a voltage and ground connection and attach a dual male input to output connector on the input portion so it would be compatible with the battery pack. In order to make sure we are using adequate supplies to make this connection work we need to make sure we are using a proper diameter plug and input port.

The DC input port can come in a number of sizes such as 2.1mm x 5.5mm, 2.5mm x 5.5mm, and even 3.5mm x 5.5 mm. The most commonly used and widely available ports are the 2.1mm x 5.5mm connectors and thus will be used for our design. This will make sure that we can easily obtain the parts necessary and easily have access to power ports on the market at a cheaper price and materials cost.

Figure 27: Standard DC input jack example and male to male input jack

Looking through the eagle software and the ultra librarian it was crucial to make sure that we are using a 2.1mm x 5.5mm capable device and adapter. We have found compatible jacks in our research and the part specification, overall design and PCB orientation will be seen below.

Another option that we will consider as a backup to this in case of availability and functionality we will also consider using a wired DC input that can connect to our PCB as well. On the market today are a variety of 2.1mm by 5.5mm wires that are already split and colored positive and negative that we can use to connect to our board as well. These wires can be cut and used as needed and either directly soldered to the board or connected to a terminal block. These terminal blocks are very cheap at around less than 50 cents per piece and can be soldered to the board for easy wired connection between the battery pack and PCB. This option will be considered if the main connection we plan to use has any downsides or issues that arise during the building process.

12V to 48V DC to DC converter:

Now that we have come up with a solution to powering and connecting our PCB to our battery pack we need to come up with a way to make our 12V batteries go up to a nominal 48V DC. This can be done by designing and testing a DC to DC converter into our design before it is connected. This design process can be done easily and efficiently by using online based services such as the Texas Instruments Webench design program. This allows us to create our DC to DC converter circuit without the need for trial and error and can be easily downloaded to put into Eagle. The main requirements for this converter will have to be high in efficiency since we are trying to make this power last as long as possible. Footprint and overall cost are not as important due to the fact that we have a large enough space to store a decently sized PCB and the overall cost of this PCB will be under $60. So we started going to the webench design and stating the necessary requirements for our PCB. We know from the battery sections above that our chosen batteries have a maximum storage of 4.2V and a depleted level of at most 2.5V. So multiplying by the three series of batteries in connection we have a lower level of 7.5V up to 12.6V. This is the range that will be built and put into the webench design. For the output we will need a nominal voltage between 48V and 55V depending on the autonomous PSE controller that we will choose to build. This voltage level will need to be accompanied by a maximum current of 0.35 Amps for POE and 0.6 Amps for POE+. With the 48V nominal voltage this will give us a power output of about 28.8 Watts at maximum current which would be less than the maximum IEEE rating for POE+. For the 56V power needed we may have to alter and change this to make sure we come under the maximum power that the PD can allow and handle.

So the most logical choice will be for us to design a DC to DC converter for the purposes of our project that will be able to power both POE types and methods to cover all bases and then let the PSE choose which voltage and power level will work the best for our device. This will give our sponsor QwikCut the option to use different cameras and electronics if they so desire and can easily power a variety of devices and systems in the long run. Making this design very beneficial.

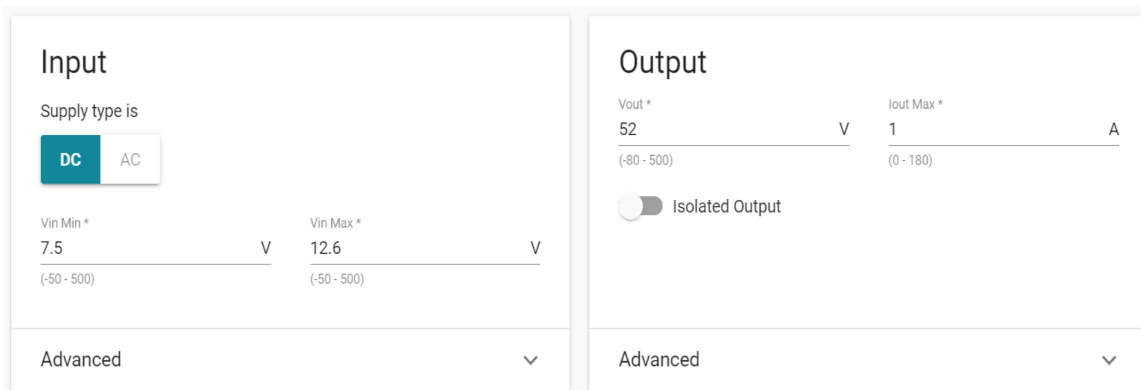


Figure 28: Webench DC to DC input for PCB design

As seen in the image above for our first POE PCB injector we are using the minimum and maximum inputs from the range of 7.5-12.6V with a maximum voltage output of 52V and a max current of 1 Amps. We are doing a little over 48 volts due to the small amount of voltage drop that will happen when we transfer the power over the ethernet cable and into our PTZ camera. This will allow us to stay under the maximum power necessary for IEEE 802.3 af (POE) standards. This will also allow us to power IEEE802.3 at (POE+) devices as well and cover all of our bases for PTZ cameras and systems. If necessary a redesign can be done and implemented into this system and can give the system different voltages and maximum currents depending on the PSE controller and device we will choose. The PSE and its datasheet will dictate what voltage and current maximums that it can handle and how the system can function and give us greater understanding of how our design will need to come together.

Overall, this section of the design was very simple and allowed us to focus a majority of the problem on the power classifications and creating the ample POE system for our client.

Autonomous PSE Controller:

Now that we have looked into and made our DC to DC converter the main focus comes to the Autonomous PSE controller that we will implement in our design. This is maybe the most important piece in our design and will be the most crucial component for the PCB in general. This PSE will have the responsibility of implementing the handshake and determining if the device that gets plugged into our PCB design will be capable of being powered over the ethernet connection. This piece will help shape the PCB design and give us a clearer picture of how we can build our injector to fit our needs.

In order to find a proper PSE controller we need to find a controller that can accommodate the 48V or 56V Dc to DC converter we have built while also determining the current and voltage that the PD can handle and determining what POE level (POE or POE+) of voltage will power the camera. We can look for different manufacturers and specifications throughout the internet and use ultra librarians to acquire parts and models to be used in the EagleCAD software. Looking through ultra librarians database and many different reference models and examples through many manufacturers online databases we needed to find a POE compliant and single port controller with the internal switch and compliant with the IEEE 802.3af designs. After doing some searching for a controller that could be paired with our 48V (+-4V) nominal DC to DC we found the 'TPS23861PW - 2-pair, type-2, 4-channel Power-over-Ethernet (PoE) PSE with autonomous mode' by Texas Instruments. This design and PSE system was used in a Texas Instruments reference in designing a POE device and is open to free use as long as it is being paired with proper Texas Instruments pieces and following the design that it has been associated with. This product is a proven working device and will be the perfect candidate for us to include in our design. Looking through the data sheet of this controller we see that the PSE can handle the 48V (=-4V) input and can accommodate the 1Amps max of current that will be produced from the converter.

After looking through the ultra librarian website for some other possible designs we found a good assortment of controllers and designs that we can keep for backup purposes or alternatives to our current design in order to make sure that we are providing enough open ended options to use just in case our main design needs altering. Texas instruments is a very notable and experienced brand when it comes to PCB design and implementation. So following their footsteps in the design process and build will be ideal for us in creating our own board and system. The main connections that will need to be made are from the PSE controller to the actual ethernet ports themselves.

Along with the base TPS23861PW, there is an additional TPS7A4001 voltage regulator that will take the 48 volts input voltage and regulate it down to a 3.3V system so it can power the 2 pair TPS23861PW. This will make sure the proper voltage is being used and that a proper system is being designed that will not damage any components on the PCB along with any high price equipment that our client may use. This will adhere to the higher voltage IEEE 802.3 at standards. Now that we have found a controller that can be made to fit our needs it will be most beneficial to us to use and have both designs ready for building so we can possibly implement both of them if needed. The TPS23861PW PSE controller schematic can be seen in the figure below. This is the main component in this section and a diagram and schematic of the voltage regulator will be seen in a later section when we finish building our PCB design.

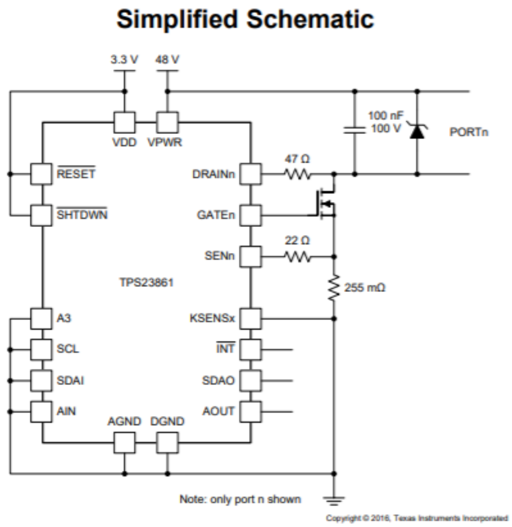


Figure 29: TPS23861PW PSE Controller

Overall, many designs and different pieces will be considered and tested before the final product is built and tested for final clarification. Multiple pieces and connectors will be ordered to make sure that we have adequate backup as well.

Rj45 ethernet ports and transformers:

Now that we have chosen a PSE controller that will handle the handshake portion of the design for both POE and POE+ standards it is time for the final connection for the powered device to be connected to. These would be the RJ45 ethernet ports that are standard in today's world. These connectors will need to be able to sustain and handle a larger voltage passing through them while also allowing data to pass through as well with no noise or frequency difference. Along with the voltage requirements that are needed for the ethernet ports we must have the ability to use 1000BASE-T data transmission providing us with the fastest possible designs and overall transmission data. This will be crucial for the camera's data transmission and overall flow of information from the camera to the QwikCut laptop.The only ethernet cables that we must focus on and compare for use in our system are Cat5e and Cat6. So we must make sure that we are choosing adequate RJ45 ports that will be able to run the 1000BASE-T connections with the voltage running through them. The biggest issue is making sure that the voltage is only going to the singular ethernet port that we desire in our design, this will require the use of an ethernet transformer as well. These transformers will be paired with the RJ45 ethernet ports and will be the midspan device between the two and let us know how we are able to connect them properly. This will help in the transmission of the voltage over POE and the smooth data transmission from one ethernet port to the next as well. Texas Instruments and many other manufacturers produce high end technical documents and products that can be implemented in our design to use and overall add to the system.

The RJE45-188-1401 ethernet ports will be our selection for these connections as they are Cat6 rated, thus being Cat5e backwards compatible and will adhere to the 1000BASE-T requirement for our system. Along with this selection in RJ45 port we will be using the H6096NL Transformer to be in between the connections of the ethernet ports. These pieces were chosen due to the reliability that they pose in the system and the fact that they have proven use in already existing systems. These components have been used in Texas instruments designs and many other high impact places in the field as well.

Overall, the key portions that are to come out of this section is the data capabilities are met and that we can control the voltage of the sole ethernet port that we are desiring to power. This will allow us to accurately finish our design and begin giving us a clearer idea on how we are going to build in the next section.

Rough Sketch Schematic:

Now that we have talked about the components that we will need to implement into our design it is time to generate rough sketches and follow existing designs on the market today to develop and build our PCB POE injector. The sections below will go into the overall schematic designs for each part we talked about earlier on in the report and then combine them all together to form the final rough design for our PCB. For this design we will be using the EagleCAD system that was introduced to us by ucf.

Input jack: Starting with the input jack there is no schematic design necessary other than the overall specification that a 2.1mm x 5.5mm female jack is used. We will then need to purchase the male to male adapter to use for powering. The design used in eagle produces the positive voltage at the 1 pin and the ground connection or negative voltage is connected to the 2 pin at the leftmost side of the schematic. This section was rather simple and many different options are available in the market today for us to use. This will be seen connected to the 48V (+- 4V) DC to DC converter to simplify the design process as well. As we stated above this input jack can easily be an input jack or a terminal block that we can connect a spare wire to in order to complete the power connection to our board.

DC to DC: Now that we have designed the input jack and overall connections we needed to design the 48V (+- 4v) DC to DC converter. Using the specifications above on the webench online tool we were able to create the following sketch that uses TI controllers to create the Boost schematic. The figure below shows the DC input jack connected to the DC to DC 48V boost converter that will be used in our PCB design. The LM5022 from texas instruments will help convert the DC current to the level that we require and help accomplish The Vin will be replaced by the Female input jack connection or the male wired terminal connection and the current out will be deleted and connected to the voltage regulator at the positive position and will be connected to the ground at the bottom portion of the design. After taking the base design we saw that the recommended components used very small components, sucha 0402 resistors, this design seems way too small and inconsiderate to our sponsor just in the case it needs to be replaced at one point.

We have customized this design below to use 1206 code resistors to help increase the size of the components so that they can easily be assigned and soldered to the PCB. We can do this due to size and storage not being an issue in the QwikBox design and will let our client have easier access. We have also chosen surface mount components in order to make sure that they can be applied to the board and that they are readily available in the market today. In today's day in age more surface mount components are used over the through hole designs of the past.

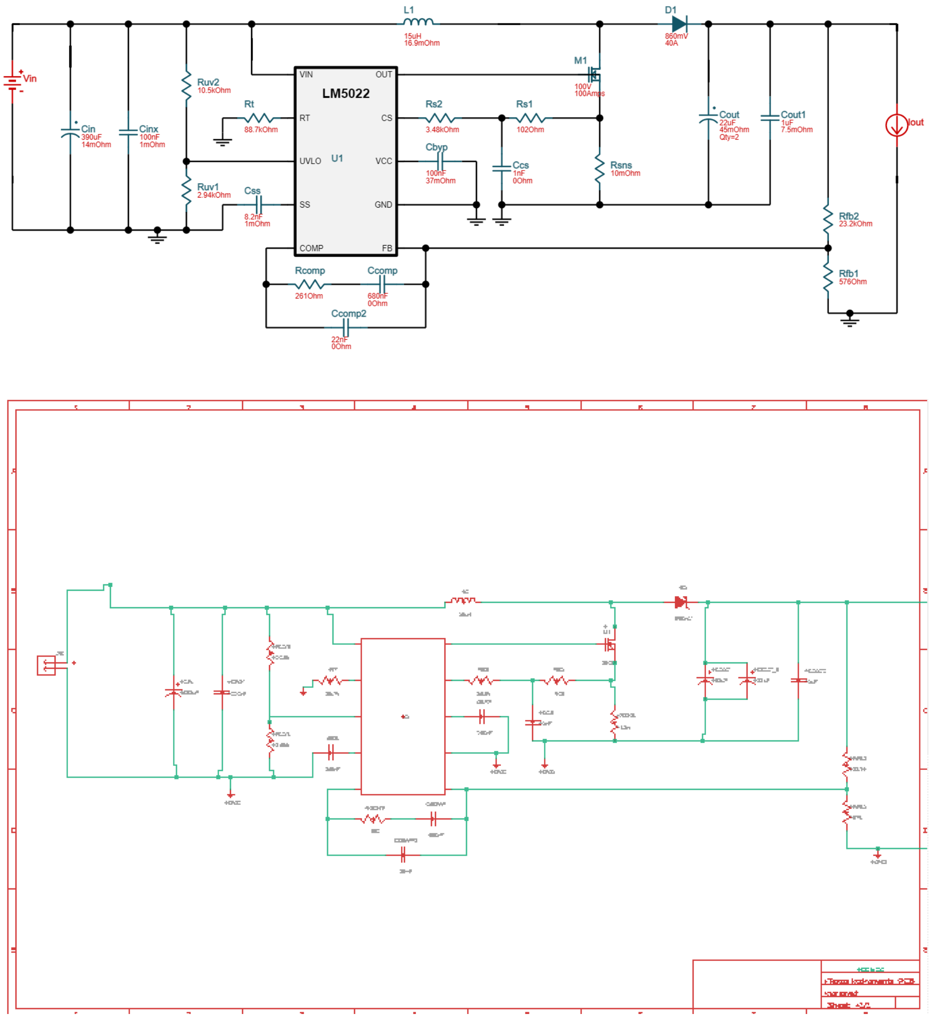


Figure 30: 52V DC to DC Converter 1 Amp

PSE Controller: As we stated in the previous section we will be using the TPS23861 Autonomous PSE Controller and the TPS7A4001 voltage regulator in our design and this will be the main component responsible for the handshake process between the PSE and the PTZ camera. In order to connect our design we needed to read through the data sheet and specifications presented by the manufacturers in order to know how we would connect our design. The 28 pin controller and 8 pin voltage regulator with a ground pad underneath design has pins for voltage control, current control, classification types, power management, and a midspan detection among many other features. The key to these connections were making sure we were applying proper connection types and making sure we were putting our controller in the midspan position since our design will be the middleman between the two. Following the designs and standards laid out by the TI website and the respective datasheets we apply the proper voltages and current to our system and respective PD. The Eagle schematic is shown below with the connection from the input to the DC to DC converter and the voltage regulator that will produce the 3.3 volts that will be required to power the PSE controller. Once we move onto the PSE controller we assign resistors and capacitors in series to test and include the proper settings for our midspan device. Once we leave the PSE we will run into LEDs and fuse to help protect the expensive cameras and products that may be connected through the ethernet ports. This design can be seen in the following figure.

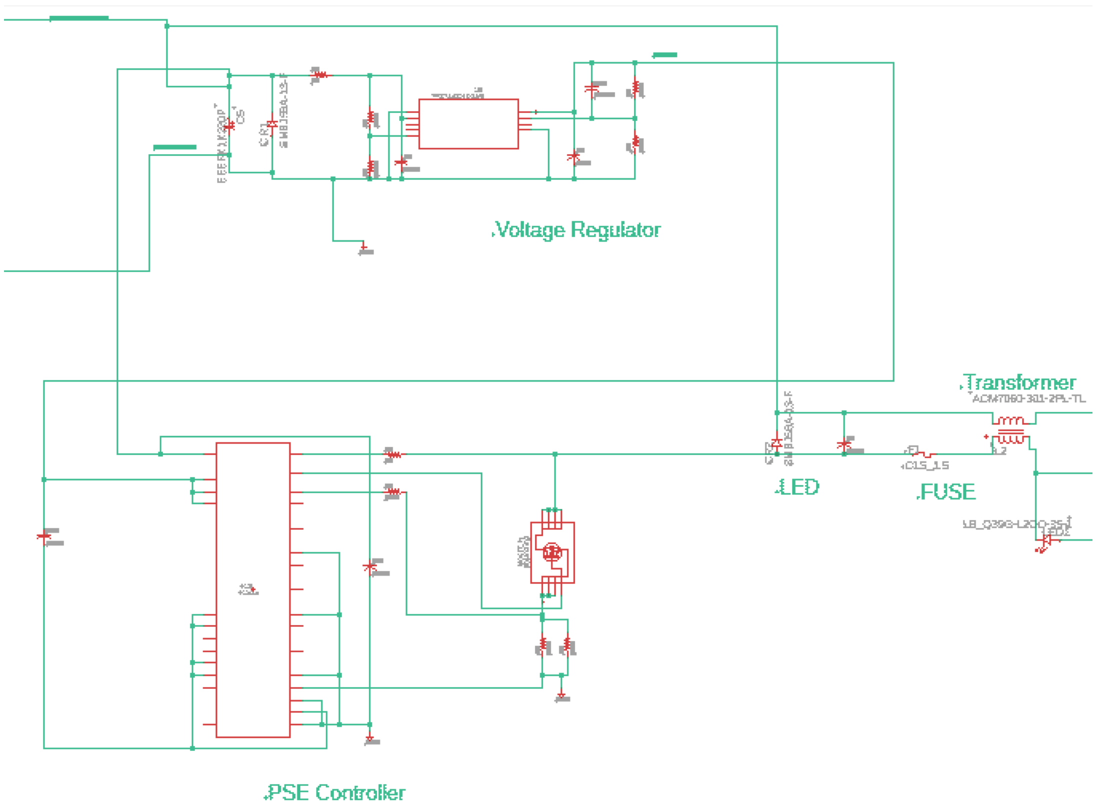


Figure 31: Midspan Connection Schematic - Voltage Regulator and PSE

The main LTC controller can be seen in the middle bottom with resistors and capacitors connected between pins to help regulate the voltage that will be needed to power the LTC and power management settings. The voltage regulator is located in the upper middle and the connection to the transformer and the LED and FUSE can be seen as well connecting to the PSE.

Ethernet Jacks and Transformers: Now that we have completed our schematic and determined the connections that we will need to make for our system it was time to design the ethernet connections and transformers using the parts discussed in the previous sections. The connection between the transformer and the PSE controller is in a reverse polarity orientation due to the nature of the controller and how the transformer transmits the voltage through itself and into the PD. Each polarity is connected to the base of the transformer that corresponds to pins 1,2 and pins 3,6. Each pair controls the negative and positive portions respectively. These connections to the base of the transformer are also connected to a set of capacitors and resistors for each pair. This side of the connection is mirrored on the following side except there is no power connection to the ethernet port. The RJ45 ethernet connections and transformer can be seen in the following figure below showing the connection types.

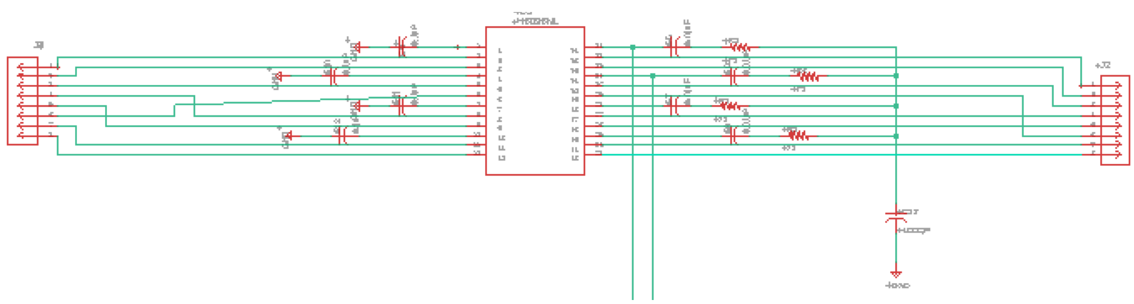


Figure 32: RJ45 Ethernet Ports and Transformer

These connections will be seen clearer in the over PCB layout and final design for ordering that will be seen in the upcoming section. A final schematic can be seen here for the overall board from a zoomed out position.

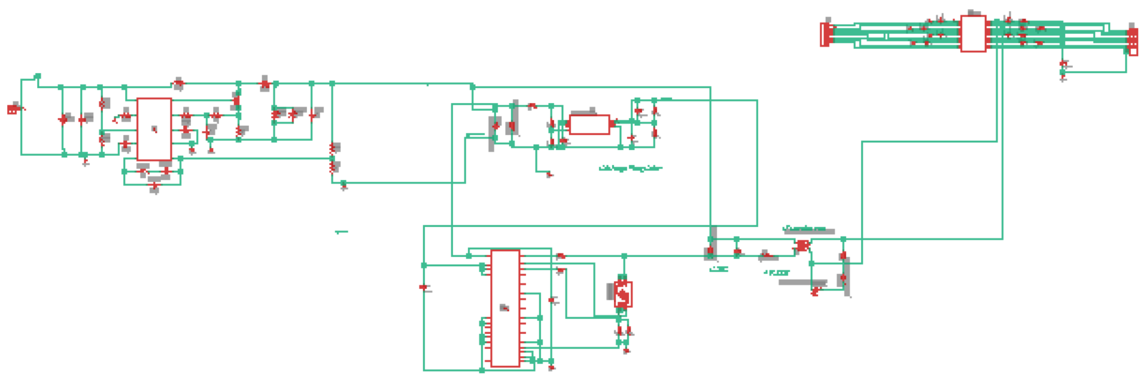


Figure 33: Complete schematic for our PCB Injector

This schematic shows the male DC input jack and the far left followed by the DC to DC converter, then connecting to the PSE design on the right hand side just below the ethernet connections and transformer. Overall, this is a very simplistic design that has 4 main sections for completion.

Eagle PCB Design:

Now that we have combined all of the schematics and overall designs together to form our final design it is time to connect the airwires and components together in eagle and complete our prototype breadboard for testing and purchasing. This will be useful for us to order as soon as possible for testing and redesigning if needed. In order to maintain a clear circuit board we attempted to implement the parts on the PCB board with what section they correspond to. Meaning all of the DC to DC converter components will be connected together in close proximity while the PSE is in another position on the board and so on and so forth. This led to a simplistic board design and leaves us plenty of room for board building and implementation. The complete Eagle PCB Design can be seen in the figure below:

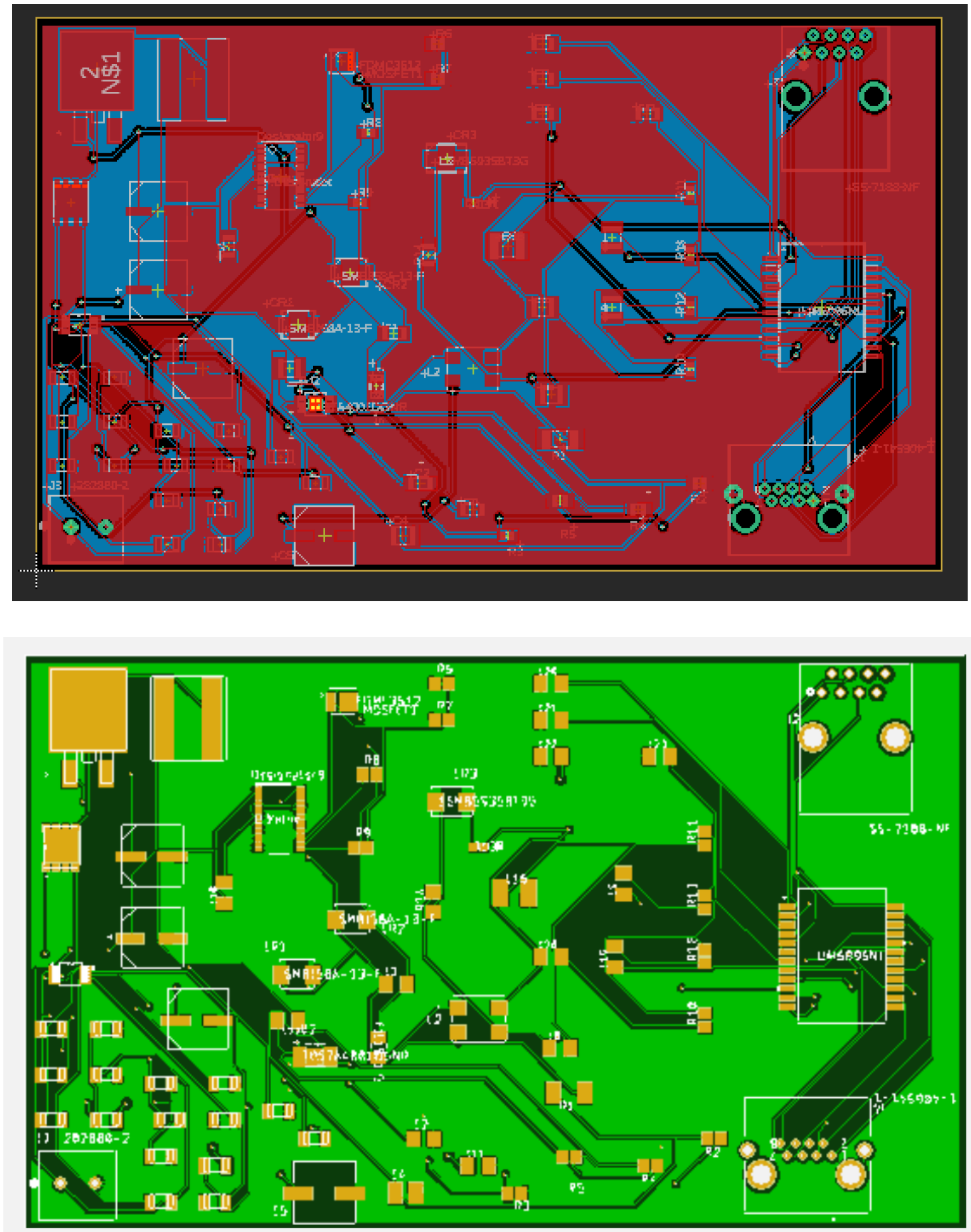


Figure 34: Completed PCB Injector with connections

For our design we can see the wire connection in the bottom left corner, the Power and Data RJ45 in the bottom right corner and the data only transmission out to the laptop on the top left corner.

PCB Components list/sellers:

Now that we have designed our complete PCB design we will need to order the board and all of the components for testing and design. This will go through a few different vendors and PCB designers to complete the build and overall completion of our design. The tables and graphs below will show the overall pricing, specs, dimensions, and additional details we will need for building and design. We will order multiples of each component to give us adequate equipment in case of a redesign or if a mistake happens in the shipping process of the building process respectively. However, the BOM below will just list the necessary pieces and quantity to complete a singular PCB Injector.

Board Section	Component	Value	Vendor	Quantity	Price $ (Total)
DC Input	Terminal Block	NA	Digi-key	1	1.65
DC to DC	LM5022MM/NOPB	IC REG CTRLR BOOST/SEPIC	Digi-Key	1	2.72
	Resistor	RES 0.01 OHM 1% 1/2W 1206	Digi-Key	1	0.56
	Resistor	RES SMD 88.7K OHM 1% 1/4W 1206	Digi-Key	1	0.10
	Capacitor	RES SMD 88.7K OHM 1% 1/4W 1206	Digi-Key	1	0.26
	MOSFET	100V 5.3mOhm Pwr	Mouser	1	1.82
	Schottky Diodes	REC D2PAK 40A 250V SHOTTKY	Mouser	1	2.33
	Resistor	SMD 1206 102ohms 1%	Mouser	1	0.10
	Resistor	SMD 1206 10.5Kohms 1%	Mouser	1	0.10
	Capacitor	SMD/SMT 50V 0.1uF X7R 1206 10%	Mouser	`1	0.21
	Resistor	SMD 1206 3.48Kohms 1%	Mouser	1	0.10
	Resistor	SMD 1206 23.2Kohms 1%	Mouser	1	0.10
	Resistor	SMD 1206 576ohms 1%	Mouser	1	0.10

	Capacitor	22UF 80V ESR=45	Mouser	2	5.14
	Capacitor	SMD/SMT Ceramic, 100V, 1uF	Mouser	1	0.48
	Capacitor	SMD/SMT 50V 0.1uF X7R 1206 5%	Mouser	1	0.34
	Capacitor	SMD/SMT 1206 0.022uF 50volts C0G 5%	Mouser	1	1.09
	Capacitor	.68uF 16VDC 20% 1206	Mouser	1	0.79
	Resistor	SMD 1206 2.94Kohms 1%	Mouser	1	0.10
	Capacitor	SMD/SMT 50V 1000pF C0G 1206 5%	Mouser	1	0.24
	Resistor	SMD 1206 261ohms 1%	Mouser	1	0.11
	Inductor	5uH Shld 20% 13.8A 18.6mOhms	Mouser	1	5.25
	Capacitor	20volts 390uF ESR 14mohm	Mouser	1	1.82
PSE Controller	MOSFET	100V 3.3A/16A 8MLP	Digi-Key	1	0.94
	LED	LED BLUE DIFFUSED 0603 SMD	Digi-Key	1	0.35
	Diode	22V 550MW SMB	Digi-Key	1	0.50
	Capacitor	SMD 22uF 80V	Mouser	1	0.70
	Diodes/Suppressors	600W 58.0V	Mouser	2	0.86
	Resistor	SMD 3/4watt 0ohms	Mouser	1	0.30
	Capacitor	SMD/SMT 1210 100VDC 2.2uF 10% X7R MID HIGH VOL	Mouser	1	0.81

	Capacitor	SMD1206 10VDC 10uF 10% X5R	Mouser	1	0.30
	Capacitor	SMD/SMT 100V 0.01uF X7R 1210 10%	Mouser	5	2.10
	Resistor	SMD Thick Film Resistors - SMD 182K 1%	Mouser	1	0.10
	Resistor	SMD 825K 1%	Mouser	1	0.10
	Resistor	SMD 0.1W .1% 10PPM 100K	Mouser	1	0.93
	Capacitor	SMD/SMT 100V 0.1uF X7R 1206 10%	Mouser	7	3.36
	Resistor	SMD 1/10watt 22.1ohms 1%	Mouser	1	0.10
	Resistor	SMD 1/10watt 32.4Kohms 1%	Mouser	1	0.10
	Resistor	SMD 1/10watt 47ohms 5%	Mouser	1	0.10
	Resistor	SMD 0.25W 1% 0.51 Ohm	Mouser	2	0.45
	Fuse	1.75A, 63Vdc, 1206 Time Lag SMD Fuse	Mouser	1	0.10
	Inductor	COMMON MODE FILTER/CHOKE	Mouser	1	2.02
	Resistor	SMD 1/4watt 7.5Kohms 1%	Moser	1	0.10
	Capacitor	SMD/SMT 2kV 1000pF X7R 1812 10%	Mouser	1	1.08
	Resistor	SMD 1/10Watt 75ohms 1%	Mouser	4	0.12
RJ45 Ports	RJ45 Port	CONN MOD JACK 8P8C VERT UNSHLD	Digi-Key	1	1.37
	RJ45 Port, POWER+Data	1X1 8/8 R/A INV SHLD	Mouser	1	3.04

Actual Board Build	PCB Board	NA	JLCPCB	5	8.00
TOTAL Price					**$53.44**

Table 10: PCB Bill of Materials

Fortunately when ordering all of our components we were able to find all the recommended or alternative parts necessary to build our design while also increasing the size of the components for convenience. Now with this bill of materials we are able to order our components for the PCB and vendor to build the actual board we can focus on the storage of all the electronic components and cables that will need to be used in our design.

5.4 Water Resistant Storage

For storage of power devices, the best action was decided to go with a larger tool/ work box. We don't need exactly full submersion waterproof because the basis of this product is to be used during an outside or inside sports event. If there was full or even partial submersion, the game is no longer playable anyways. Used in the existing QwikCut system currently is a plastic type Kobalt with metal latches. The tongue-and-groove construction keeps water out and adds to the strength of keeping out anything that may be harmful.

The new QwikCut system design is intended to be durable and survive the weather that is playable in weather where sports can continue. Rain can be a danger to the system and

With this in mind, it would be of benefit to us and a benefit to the customer to keep this Kobalt box known now as the QwikBox. This will save money in the budget, as long as it saves the time of replacing all the QwikBoxes that are already owned and in place. Size will not be an issue with this existing box. There is an internal shelf where items are held where now that may not be necessary and there are many more contents of the existing box than the contents of the new system.

The QwikBox currently has no known issues of leakage, overheating, or not being able to protect the batteries and devices. This proves the idea that saving these boxes to be used will be the best option to move forward with our design.

5.5 PTZ Camera

For the final portion of the hardware design it was time to decide on a Pan-Tilt-Zoom camera that would be adequate for our design and that our sponsor Todd would approve of. After a lot of deliberation and searching online we decided to present three different PTZ cameras at three different price levels. We have done this due to the fact that in previous meetings and email with him he has stated that while he may only want a singular system at the moment. If we can design a functional and replicable system that many users and other companies can buy or purchase and use for their own purposes he may sell or make more of these for commercial use. So the key when determining our camera options overall came down to price, availability, functionality, and general design.

After looking at all the paragraphs and information included in this report we have come up with a standard design that will be suitable for all the different camera options on the market today with just a change in mount or adapter to the tripod. This leaves us with three levels or requirements we need to choose. Now that we have narrowed it down to these characteristics we decided that providing different options and designs to our sponsor would be best so he can choose and interchange them at any time if he would like or give us a little better quality that one of the other cameras may not possess. All this while being done at reasonable price points and overall

Now we will look into our three camera choices that we recommend for use in our design:

5.5.1 $500 + Price range category

We will first start by looking at a PTZ camera option that falls into the $500+ category and meets the necessary requirements that we are looking for. This camera is the Annke CZ500 Ultra. The Annke CZ500 Ultra is a state of the art PTZ camera that is POE capable and is regularly available on the Annke website. The Annke camera comes in at a standard price of $579 with an included 24 month free warranty that can be upgraded to a value up to 72 months worry free. This IP camera is a Dome type construction and would require a special bracket be made to accommodate the PTZ device to our tripod. This can easily be done with a 3D printer or with one of the available accessory brackets that are available on the Annke website.

We will break down some of the important specifications of this camera and what capabilities it can handle. This will allow us to make the best choice for the price point that possible clients may have when buying the design from our sponsor.

Category/Specification Description	**Value**	**Information**
Price	$579	Higher than standard market price
Video Quality	4MP - 2560 X 1440 pixels	Great quality, above the 1080p necessary for the project
Optical Zoom	25x zoom	Better than standard
FPS capability	50 Hz: **25 fps** (2560 X 1440, 2048 X 1536, 1920 X 1080,	Excellent- 60FPS is much greater than the standard

	1280 X 960, 1280 X 720) 50 fps (1920 X 1080, 1280 X 960, 1280 X 720) 60 Hz: **30 fps** (2560 X 1440, 2048 X 1536, 1920 X 1080, 1280 X 960, 1280 X 720) **60 fps** (1920 X 1080, 1280 X 960, 1280 X 720)	fps rate that many other PTZ cameras on the market offer.
Bitrate capability	Compatible up to 1000BASE-T	Excellent-Gives a great data stream with fast information relay
Waterproof Protection	IP66 Waterproof	Standard/ Very Good
Video Compression	H.265+/H.265/H.264+/H.264	Standard
Audio	Built in	Standard for some PTZ cameras

Table 11: Annke CZ500 Specs

Annke Pros:

- The Annke CZ500 offers great 4MP quality
- Excellent waterproof design and standard video compression
- Excellent frame rate and video transmission bit rate

Annke Cons:

- High price for some clients and designs
- Unsure about if the system is ONVIF compatible
- Not a well known brand to many users and clients

Overall, this is an excellent camera option and provides the POE capabilities that are necessary in our design. This can easily be introduced and plugged into our design.

5.5.2 $500-$300 Price range category

Now that we have looked at the higher price categories we are looking a little above what our sponsor has spent on his previous camera he used for this purpose. The 4K Outdoor PTZ IP POE 8MP Security Camera by Alptop is a great midrange PTZ camera. The Alptop PTZ camera is available on the Amazon website giving it some of the easiest availability as a product on this list through a respectable vendor and shipper. The Alptop 4K camera comes in at a price of $330 on the amazon marketplace and includes all of the return and replacement packages that come through the amazon website and company.

This gives the product great reliability and overall customer support if needed for any reason over the product's lifetime. This camera comes in a speed dome package with an included bracket for ease of design if we connect this design to our tripod. This will ease the cost of design as well even just by a little bit. In comparison to the camera options above this price range and below this price range, there are very little improvements in quality and specifications the higher in price you go.

Similarly to the Annke, we will look at the 4K PTZ camera and look into the specifications and overall details that this camera system possesses. The following table can be seen below:

Category/Specification Description	**Value**	**Information**
Price	$330	Great Price for the specs
Video Quality	8MP - 4K- 2560 X 1440 pixels	Great quality, above the 1080p necessary for the project
Optical Zoom	30x zoom	Excellent
FPS capability	Mainstream: 3840*2160@**20fps**, 3072*2048/2592*1944/2560*1440/2304*1296/2048*1536/1080P/960P/720P/D1@**30fps** Substream: 720*480D1/VGA/640*360/CIF@**30fps**	Great- 30FPS is a great option since it will give clear picture with different options available for many different quality settings
Bitrate capability	CAT5 cable/CAT5 Above	Excellent-Gives a great data stream with fast information relay
Waterproof Protection	IP66 Waterproof	Standard/ Very Good
Video Compression	H.265/H.264	Standard
Audio	Built in	Standard for some PTZ

		cameras
ONVIF Compliant?	Yes	Crucial

Table 12: Alptop 4K PTZ Camera

Alptop 4K Pros:

- The Alptop 4K offers great 8MP - 4K quality, better than almost all cameras on the market at this price range
- Excellent waterproof design and standard video compression
- Excellent frame rate and video transmission bit rate
- ONVIF compatible
- Excellent pricing for the functions and specifications you are getting for the camera
- Good customer support

Alptop 4K Cons:

- Not a well known brand to many users and clients
- Slightly higher in price than what the original camera system would cost

Overall, this is an excellent PTZ camera on the market today and can adhere to the requirements for our project design.

5.5.3 Under $300 Price range category

Now lastly we will look at our final price point and cheapest category, which is the sub $300 range category. This category is very hit or miss in the open market and can sometimes be challenging to find a proper camera that can meet the POE standards and definitions while also being a reliable hardware choice. For this section we have chosen the Hikvision Compatible Outdoor 8MP PTZ PoE IP Camera. This camera is similar to the Alptop PTZ camera in that they are both available on the amazon marketplace and have great availability on the world stage. This would make it easy to replace or get multiple of these cameras and systems

Category/Specification Description	Value	Information
Price	$249.99	Great price
Video Quality	8MP - 4K- 2560 X 1440 pixels	Great quality, above the 1080p necessary for the project

Optical Zoom	18x zoom, 30x Digital	Very good
FPS capability	(3840 × 2160)@20fps	Good - 20fps. Not the smoothest video but is a good option
Bitrate capability	CAT5 cable/CAT5 Above	Excellent-Gives a great data stream with fast information relay
Waterproof Protection	IP66 Waterproof	Standard/ Very Good
Video Compression	H.265/H.264	Standard
Audio	Built in	Standard for some PTZ cameras
ONVIF Compliant?	Yes	Crucial

Table 13: Hikvision Compatible Outdoor 8MP

Hikvision 8MP Pros:

- The Hikvision 4Koffers great 8MP - 4K quality, better than almost all cameras on the market at this price range
- Excellent waterproof design and standard video compression
- Excellent frame rate and video transmission bit rate
- ONVIF compatible
- Excellent pricing for the functions and specifications you are getting for the camera
- Good price, similar to what our sponsor paid with the initial design

Hikvision 8MP Cons:

- Not a well known brand to many users and clients
- 18x Zoom is a risk for capturing video from a long distance away

The Hikvision 8MP is a great option for a lower price, it does have some downsides in that the zoom may be a risk depending on the grounds and facilities it is used in as well as the overall frame rate for streaming high speed games but can be addressed.

Overall, looking at all three of the designs that have been recommended based on the price point that our sponsor would like to look at. We would recommend the one that falls under the $500-$300 category. The alptop is a great PTZ camera that would just need to have an audio microphone attached to the camera to obtain a great audio sound.

6-Design Related to Software

As mentioned in Section 4.1 the software is broken into three main components. In this section we will discuss the design goals and aspects for the software we are creating. This discussion includes providing understanding for how we are relating the different input and outputs including their value maps and configuration. This program will have a very configurable mapping of controls that will be outlined in an upcoming section. The other aspect related to this is having a way to save the configuration as to remove the need for reconfiguration on program startup.

6.1 Saving of values:

As mentioned prior a goal of this software is to have it reload any customized fields that were set on the last execution. Since this program is running across multiple threads with values that need to be saved from each thread the method of saving must be thread safe. This will be achieved with an interface that all threads share. When the program is closed it will call a method that will read the values via the interface and write the values to a file. This file will be located in the folder the program creates on first execution where it extracts the DLLs mentioned in 4.1. At this point the file will be a yaml or flat file that can be easily read or edited by the user if absolutely necessary. If as we develop the software we determine that the file should not be editable by the end user we will change it to an encoded file that represents the data.

The formatted flat file approach will be what is used during development as it allows us to quickly and easily determine if everything is being saved and read properly. We will include a large number of aspects that may not be accessible outside of this file that the program uses internally to allow for easy testing of different values without the need for a recompilation. For example, if we allow for a non-linear input map for an analog input the exponents or other attributes of the equation used may be saved and read from this file as to allow for manipulation of the values without just hard coding them.

The option of saving the file as an encoded class or data structure is also a possibility. Most of these encoded file saving methods result in a non-human readable file. The main advantage of changing over to an encoded file is that it is easier and more efficient for Java to reinterpret the data back into variables that can be directly used. On this subject having an encoded file also allows for a more streamlined process for saving and reading the values since it typically just takes the whole class or data structure and writes it to a file in a way that Java knows what everything is and where to place the values. This option may be implemented and tested near the end of the development cycle since a flat file has more advantages when developing and the modification will be easy since the means of collecting the data will already be in place for the flat file.

6.2 Running the program:

Java programs are not typically user friendly to run unless they are repackaged. This software once compiled is a runnable jar, however, you cannot simply left click and run this application. For the sake of making this as user friendly as possible we will wrap our output to an executable file or exe. Once this is done the end user can simply left click to run this file. To achieve this we will use a tool called Launch4j, this tool allows for this wrapping and allows for customizable error messages, customizable icon, and prepackaged files if necessary. Since exe files are windows only this application will not be supported outside of windows when wrapped. However, we will support non-windows computers via a shell script that will run the application via the command line. Another consideration for non-windows computers is that we must be able to detect the operating system on launch to allow for any operating specific support files to be correctly exported and registered. This will be achieved via analyzing system properties attributes that Java collects on run time.

For the scope of this project we will not be focusing on making the modifications that allow for other operating systems to run the application. As most of the code is generic, modifying this aspect after the fact will be relatively straight forward. As this project will have a windows laptop as part of the sponsors requirements this drives the decision to not worry about other operating systems at this time.

Another important thing regarding the running of this software is that there should only be one instance of the program running at any given time on the computer. Since we will be wrapping this program into an exe, Launch4j allows for the specification that only one instance can run and allows for naming the instance with a given Mutex name as it will allow for the management of this fact. Since we are not worrying about other operating systems at this time there will be no logic implemented into the Java code to solve this problem.

The icon for the executable will be a modified version of QwikCut's logo. This use and modification is done with permission from the sponsor and as they are sponsoring this project the original image that is used for the icon will be given to them once the project is concluded. This image is shown below in figure 35

Figure 35: Image for Icon

6.3 Input Mapping:

The input to a system is an important part maintaining usability and providing a good experience to the user. Due to the use of a controller, setting the potential inputs to the controller to something familiar would expedite the speed of adoption of the system. The most important quality to any control style is how intuitive the flow of the controls is. The user can do what they want without a lot of intermediate steps all the while it is making sense relative to common sensibilities.

The first step to making this a good system is finding the most intuitive setup. The default in most gaming setups with zoom features is to use the right and left trigger to modify the zoom. Pan as it is left and right movement would be set to the left joystick horizontal axis, and tilt as it is vertical movement would be set to the right joystick vertical axis. To best suit the user, this would ideally be remappable to any buttons they desire. Potentially other buttons on the controller could be a "return to home" for the camera for a more centered shot. Pressing the right joystick could toggle between set levels of zoom. At the moment no other controls are planned for the controller but with feedback from the user this may be changed.

The specifics on zoom controls may be changed depending on what QwikCut requires. We have examined previous footage of football matches they have recorded and noticed that a majority of the time the amount of zooming is minimal, and if there is much zooming it is micro adjustments. This leads into the idea of using quadratic curves for the zoom levels. This would allow for more control of small adjustments on zoom. The trigger ranges from -1 to 0 on the left, and 0 to 1 on the right. The float values are then converted into an integer in the range of -1000 to 1000. The goal is to create a formula that would allow for more control of micro adjustments but still be able to rapidly change if needed. To achieve this a quadratic curve is needed.

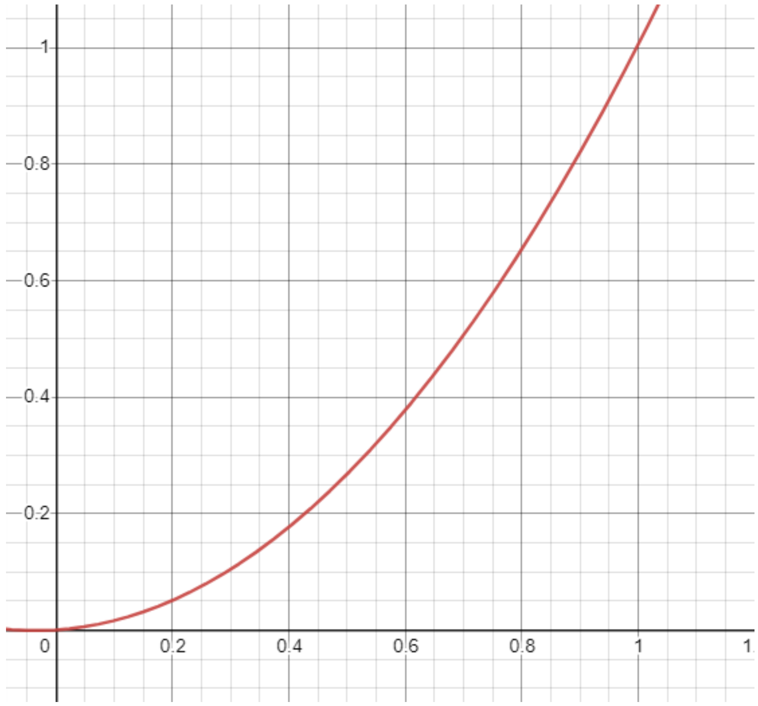


*Figure 36: Zoom Curve Y=0.065*X+0.94*X^2*

At the moment the current zoom levels are as seen in the previous figures. At approximately halfway pressed the camera is zooming at 25% of max. at 75%, it is about 60%. The curve was fitted to the values {(0,0),(.5,.25),(.75,.6),(1,1)}. This curve is subject to change according to the feedback from the user and with additional testing. A major component of zoom is also the autofocus feature of the camera. The camera on intense zooms will need a second to auto focus, and limiting this could be set as a priority. With quadratic zoom the user will need to put more effort to zoom quickly but this will prevent out of focus shots.

The next aspect to be considered for the controls is the pan features. The camera needs the ability to be able to turn left and right across the field as needed. With horizontal movement typically the changes are linear, micro adjustments are not too normal. And as such the math behind the pan is linear across the spectrum of possible values. As seen in the graph below.

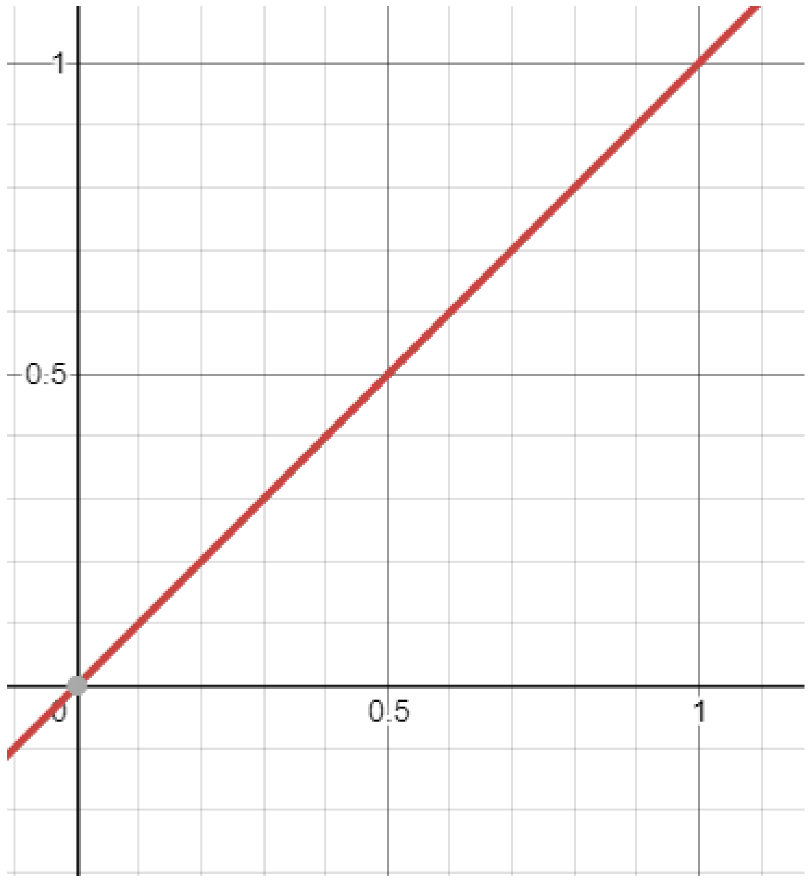


Figure 37: Linear pan controls

Tilt on the right joystick vertical access to control the orientation of the camera vertically. This should also be subject to similar movement as pan, and as such will be also linear. It will be using the same controls as the linear pan controls.

Dead zone is an important feature on a controller. Over time controllers' joysticks or triggers can start reading as if they were moving in a direction they would actually be interacted with. This can cause false movements or larger readings than intentionally done. For example if the controller was reading +1000 vertical axis while sitting at (0,0) the movement would move as if they were moving it full throttle upwards, and if they tried to shift the axis to -1000, it would stay still without any possibility to tilt back down. To deal with the issue we have implemented a set dead zone button. There is a dead zone button for each type of movement: zoom, pan, and tilt. When pressed it will take in its current movement and offset future readings by the same amount. Using the same example as before, if the controller was reading +1000 and the dead zone button was pressed, it would start subtracting 1000 from all future inputs of that type of movement. This is until the user hits the dead zone again. This will allow the software to compensate for any potential issues that come with the controller.

Additional Features of the controller as spoken about before can include features like mapping one of the face buttons to a return to home feature. The camera includes a return to home already built into it and all that would be required is to map the face button to trigger this function. Furthermore, preset zoom, pan, and tilt numeric values could be saved to different face buttons. This can be further modified with the bumper buttons to work like on a CTRL or SHIFT key on the computer. This feature is still being considered whether it will be implemented or not. To implement this the software would take the current location of the camera and the zoom feature and store it, then recall it. This would depend on how the camera tracks the location, if there is not a clear way of getting the coordinates of the camera, a possibility is to build an XYZ axis into the program itself. This would result in many complications when dealing with boundaries and other potential issues. This issue could be as simple as an error in the axis itself saving it incorrectly, interfering with the built-in tracking from the camera, this feature introduces many more avenues to issues. With the saved locations features another thing to consider is how quickly the user wishes to arrive at that location. With filming it is possible to want to go to the other side of the field immediately to catch an action shot, or to want a built-in pan at a set rate. This type of changing in view is typical in animation and implementing it is similar to that of the zoom graph but being able to modify it on the fly could prove an issue.

All these features of the camera are subject to change upon field testing and feedback of the camera. As such the code will have to be easily changeable to match the needs of the user. How to test the camera and receive this feedback will be touched up on during the testing section, however, the current idea is to have a typical user use the software and see if it matches their desires. These default values have been set using reasoning and watching the videos previously used but lack the practical experience to be sure it will not be changed in the future.

The type of controller to be used will also become part of the system. The easiest solution is to have one type of controller be the standard for all uses of the system, but this can be impractical. With the widespread usage of QwikCut it might be necessary to be compatible with as many controllers as possible. To take this into account a few solutions exist. Create a list of the most common controllers, and test to see if the button mapping lines up with the usage. For example, testing both an Xbox Controller and PlayStation controller. With the images QwikCut sent us, it was shown that the controller they were using was a Logitech based one. To minimize the cost of adaptability, this should also be tested. Another solution to these issues can be used instead of or in addition to the previous solution. This other solution is the ability to remap the controller to the user's liking. Solutions like this already exist and as such inspiration can be taken from. The next figure demonstrates the ability to remap all the functions of a PlayStation controller.

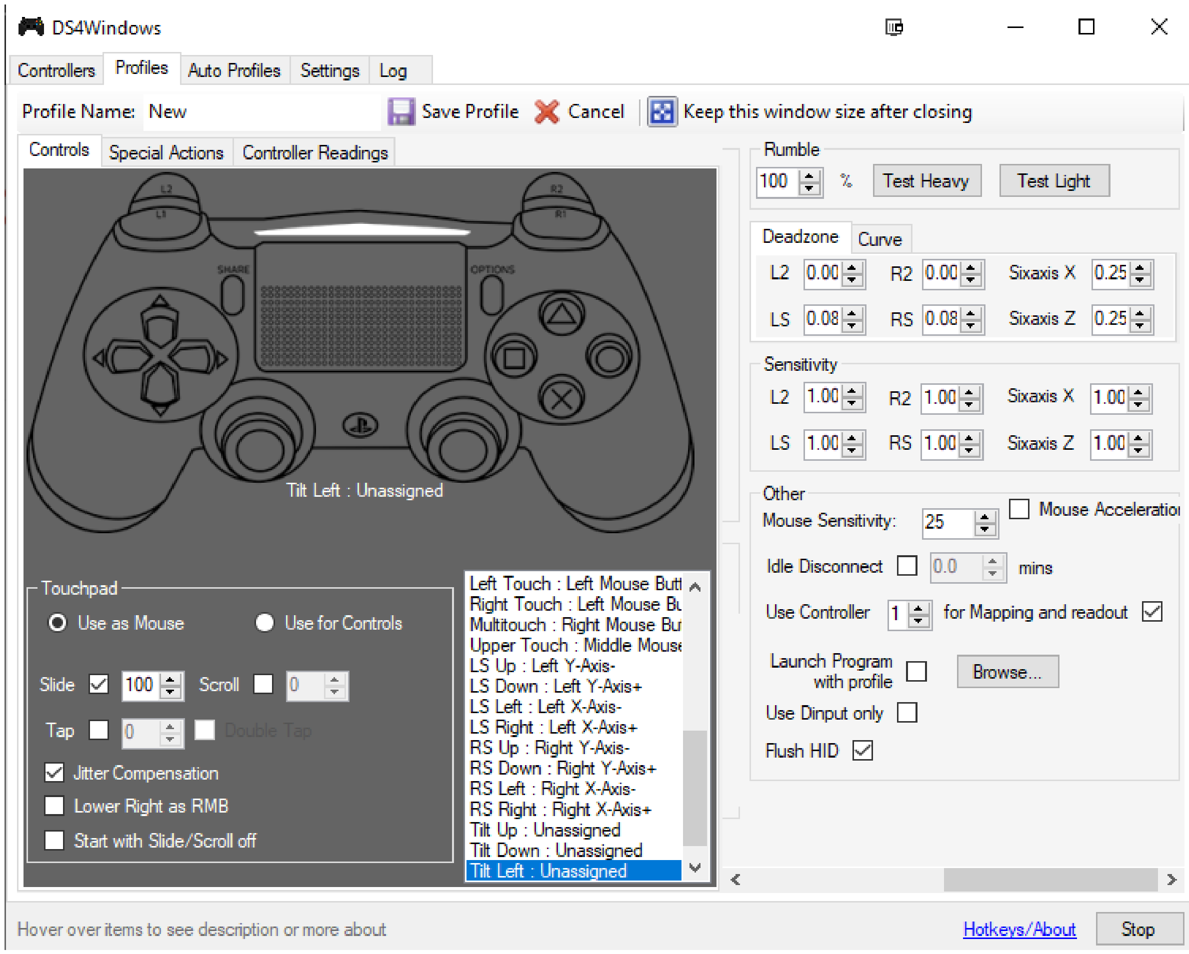


Figure 38: Example of a remapping solution by DS4Windows

To implement this type of solution, the user would select the type of feature they would want to edit, then press the button on the controller they would wish to use. For example, if they wish to use the horizontal axis on the right control stick instead of the left control stick

7-Design Relating Mounting Camera

The next key design component is the mounting of the camera on top of the existing tripods. The mounting system must be easily changed back to one that suits a standard camera to allow for the same tripod to be used for different applications. The mount for the PTZ camera must also be strong enough to support the camera and any needed accessories regardless of the environment that it must operate in. QwikCut has specified that this mount needs to be balanced, easy to connect especially for short people, and easy to store for transportation. This mount may be an expansion of a standard camera mount or a completely custom solution, this decision will be driven based on the strength and ease of use for the mount.

The first key component is that the mount be balanced. What is meant by this is that the weight of the mount must be as close to the centerline of the tripod as possible to make sure that the tripod will not become unbalanced. This is critical because when the mount is twenty feet above the ground its weight can make the tripod easier to become unstable.

Secondly the mount must be easy to connect. To achieve this our goal is to have the camera attached to the mount in such a way that the mount will connect to the tripod without having to deal with mounting the camera itself. The camera system will have only one cable and as such will be very easy to connect. Depending on the route taken to achieve the final solution this mount will have one point of securement as to make it easy for the operator to use.

Lastly the mount must be easy to secure for transportation. To achieve this our design must be a form factor that can easily be stored in existing products. Since the mount will be as balanced as possible to help with stability, it will be relatively uniform in size and shape and will most likely end up rectangular in nature.

7.1 Design Ideas and prototypes:

The idea of making a custom attachment solution is currently the most likely solution simply because it will be a quicker design process and does not involve manufacturing an adapter to fit a standard camera mount. However, since we have not been hands on with the tripod that QwikCut will use, the designs are based only on the images provided. The primary idea for a custom attachment solution is to attach our mount directly to the metal tube that extends vertically from the tripod. Depending on the current mounting system this may be adapted to attach to that instead. From our communication with the QwikCut about the current mounting system it is possible that the top of the tripod has a ¼” threaded piece that mounts attach to. If that is the case we will make a tapped hole into our customized design to allow for this.

7.1.1 Custom design:

A general first sketch for a custom mount is shown in figure 30. Since we are using a PTZ camera that is mounted from a wall we need a vertical structure to secure the camera to. The easiest solution is to make a plate that attaches to the top of the tripod that then supports a vertical plate that has the camera mounted to it. This idea also has the advantage that if the camera needs more viewing angle that may be obstructed by the triangulation it can be simply remounted to the back side of the same vertical plate. This will attach to the tripod via a circular coupling on the bottom that will slide over the vertical tube of the tripod and will be most likely secured via a set screw. This design with the camera mounted on the inside of the L shape should be very close to perfectly balanced since the weight of the camera will be very close to the centerline of the tripod. I will also be easy to attach with a single set screw and the ethernet cable extending out of the center whole of the mounting surface.

Based on the calculated area of each plate we can estimate the overall weight of the custom mount. This mount has approximately 0.4 square feet of plate area, this was found via the dimensions used to make the model, 3/16” steel has a lb/ft^2 value of 7.65 nominally. Therefore this mount will weigh approximately 3.04 pounds without the camera or other accessories. Once the camera is added the weight will be approximately

6.75 pounds. This weight should be manageable for the operators to handle when mounting to the tripod. The calculations for the weight of the mount is shown in the table below.

A possible expansion on this design may be adjusting the method that the mount attaches to the tripod. If during the initial prototyping phase it is noticed that the single set screw is unable to keep the mount still relative to the poll it may be necessary to add another set screw or even slightly modify the tripod itself to allow for the set screw to get a better grip on the poll. This modification should not interfere with any existing mounts the QwikCut uses. The modification may be as simple as grinding a few flat spots on the round pole to give the screw a place to apply more pressure uniformly. If we deem this to be too damaging to the tripod or still ineffective we may explore using a pin that goes through the pole and mount and uses a retaining clip to prevent it from falling out. This solution would be similar to how truck ball hitches are inserted and prevented from moving.

Item and count	Dimensions	Area (sqin) each	Area (sqft) each	Weight by sqft	Overall weight
Base Plate x1	4”x4”	16	0.1111	7.65	0.85
Support x2	4.066”x2.875”x2.875”	4.1328	0.0287	7.65	0.4391
Upright	4”x8.25”	33	0.2292	7.65	1.7534
					3.0425

Table 14: Mount Revision 1 weight calculation

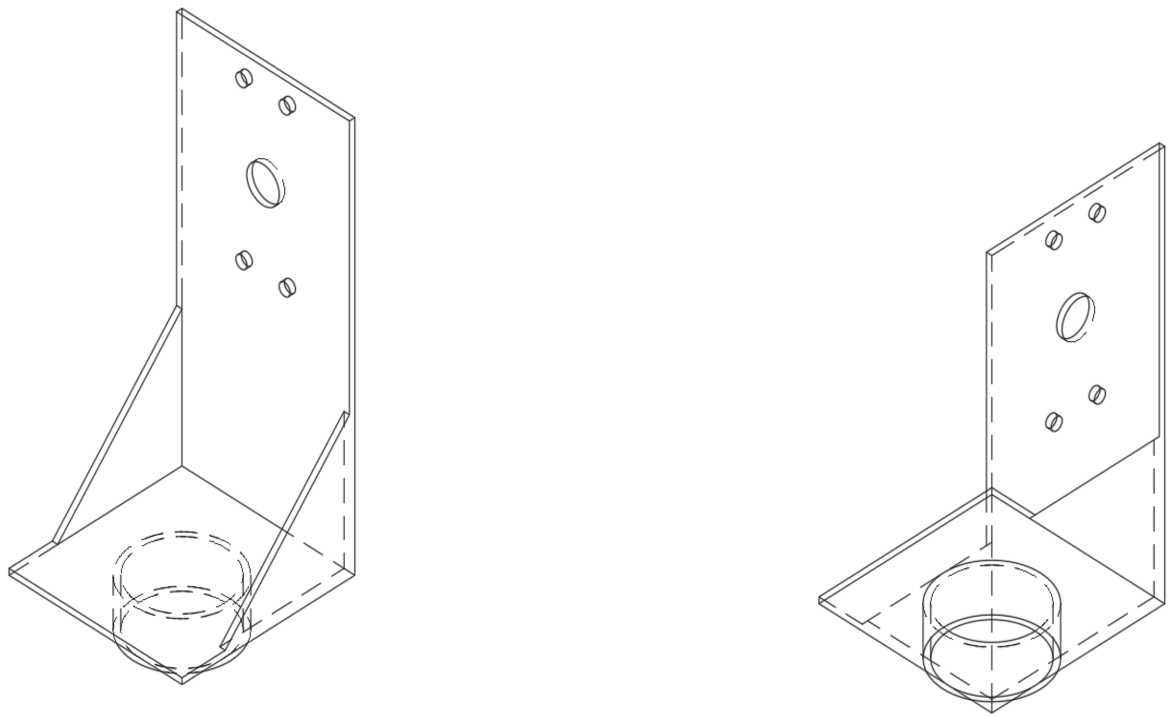


Figure 39: Custom mount first revision

7.1.2 Using existing mounts design:

Tripod mounts for PTZ cameras are not typical and are hard to find if any exist. In terms of commercially available mounts for PTZ cameras they are usually for mounting dome style PTZ cameras from an interior ceiling or wall. The other common style of mount is for the relocation of cameras used for conferences. Most of these mounts will not work directly for our application and some modification would be needed.

The other common mount for PTZ cameras that could work are pole mount adapters. These are typically used when fitting a new camera and mount to an existing pole mount that drops down from the ceiling. However, this style of mount would also need extensive modification as they are typically used as a stop gap measure and are not designed well for long term use. Due to these reasons we will most likely not use an existing mount design for this project however, we may have to purchase a mount to be able to use parts of it to achieve a system of connecting to the existing tripod.

7.1.3 Construction materials:

The finalized design will be made of sheet metal, most likely steel, and will be welded together. We will utilize stainless steel hardware to prevent corrosion that may cause the removal of screws to become troublesome over time. The wire pass through hole will have a rubber grommet to prevent water intrusion and any possibility of the ethernet cable rubbing against the metal. This mount will probably end up being powder coated if time and budget allows, if this is not viable we will simply paint the mount.

During the rapid prototyping stage the build material will either be wood or metal depending on how much is planned to be changed during the revisions. The benefit of using wood for this is that it is easier to manipulate and reattach than a welded metal joint. The use of a 3D printer is ruled out simply due to the size of the part. To print this part to scale would take far too long and would make the prototyping process very slow. Any wood construction will be done with plywood as it has the closest dimensions to the potential metal used in final assembly.

8-Related Standards to Design

Standards are documents that explain procedures and specifications used to design different materials and products that companies and even the general public use every day. These standards are what provide the guidelines for manufacturers and developers to utilize when creating and implementing a specific product. There are many protocols that need to be followed when designing a product or application to avoid scrutiny or liabilities that could come about if these standards are not followed. For our application, we will have power hardware and software standards and documents that must be followed. For some standards related to the project, IEEE and other organizations request money in exchange for the documents. The related standards in this section may be free or low cost. Students and professionals have the option and ability to join a tech engineering organization called the Institute of Electrical and Electronics Engineers, which has a vast amount of info on new technologies and standards for applications dealing with power, information, technology, electronics and other electrical industries. These include over 1,000 published standards and acts as a leading force in the world for international standards.

8.1 Battery Standard

IEEE standard 1679-2010, IEEE recommended practice for the characterization and evaluation of emerging energy storage technologies in stationary applications is to be used in conjunction with the IEEE standards. Secondary electro-chemistries with lithium ions as the active species exchanged between the electrodes during charging and discharging are included in the category of lithium-based batteries. Lithium-ion, lithium-ion polymer, lithium-metal polymer, and lithium-sulfur batteries are all examples of batteries that fall under this IEEE standard.

In an assessment taken out of the fire protection research foundation for lithium-ion batteries they historically have been largely impacted by codes and standards developed by several organizations: The hazardous materials transport regulations developed by the UN, the consumer electronics safety standards developed by UL and, more recently by the Institute of Electrical and Electronics Engineers (IEEE), and the IEC. These standards continue to define the safety for the lithium-ion cells. Recycling and product stewardship regulations targeted at used batteries are becoming more and more common in the United States. In some states all battery types must be recycled, and may not be disposed of as solid waste.

Lithium-ion cells are classified as hazardous materials and dangerous goods. So, in the United States, transport of lithium-ion cells that are “in commerce” is governed by title 49 of the Code of Federal Regulations (49 CFR), Parts 100-185. These codes are enforced by US federal agents. 49 CRF provides rules to determine the hazard class of given material, once that class has been determined, there may be requirements for testing, packaging, and labeling material as well as specific transport requirements.

Two UL standards are particularly important for lithium-ion cells and batteries: the UL 1642, “Standard for Lithium Batteries”, and UL 2054, “Standard for Household and Commercial Batteries” with both of these standards written for the purpose of ensuring consumer safety. They are designed to “reduce risk of fire or explosion when batteries are used in a product” and to “reduce the risk of injury to persons due to fire or explosion when batteries are removed from a product to be transported, stored, or discarded”. User-replaceable batteries, as opposed to tech replaceable batteries, are subject to additional test requirements, including flaming particle and projectile tests.

In response to reported incidents of lithium-ion battery failures, two IEEE standards underwent revisions in the last decade according to the same fire protection research foundation. IEEE 1725 and IEEE 1625 shortly after. Fundamentally, both of these standards emphasize that battery pack safety is a function of a number of interrelated components including the cells, the battery pack, the host device, the power supply accessories, the user, and the environment. The IEEE standards establish that the “...responsibility for total system reliability is shared between the designers/ manufacturers/ suppliers of the subsystems, and the end user.” Both standards require cells and battery packs to comply with UN and UL 1642 requirements, and recommended testing to UL 2054 and IEC 62133 requirements. These two standards include some additional testing that goes beyond the standard tests already described. Both of these tests require that the cells can withstand exposure to 266 degrees F conditions for one hour. This is in addition to many tests taken by the IEEE Standards.

1725 5.6.5 1625 5.6.6 and 5.6.7.2	Cell thermal test	Cell or battery placed into an oven initially at 20°C (68°F); oven temperature is raised at a rate of 5°C/minute (9°F/min) to a temperature of 130°C (266°F); the oven is held at 130°C for **1 hour**, then the cell is returned to room temperature; testing of fresh cells for 1725, fresh and cycled cells for 1625
1725 5.6.6	Evaluation of excess lithium plating	Production lot of cells cycled 25 times at maximum charge/discharge rate specified by the manufacturer at 25°C (77°F). Minimum five cells then to be subjected to UL external short circuit test at 55°C (131°F). Minimum five cells dissected and examined for evidence of lithium plating
1725 5.6.7	External short circuit	Short circuit the cell through a maximum resistance of 0.05 ohm; testing at 55°C (131°F); testing of fresh cells
1725 6.14.5.1	Validation of maximum voltage protection	Cell is subjected to the maximum voltage allowed by protection electronics; cell is insulated to create adiabatic conditions for 24 hours
1725.6.14.6	Pack drop test	Fully charged packs dropped from a height of 1.5 m onto smooth concrete for up to six repetitions on six sides (36 times); open circuit voltage monitored for evidence of internal shorts

Table 15: Unique IEEE 1625 and 1725 Safety Tests

The battery is the basis of the power for this design. If we did not have both batteries in the system, or less even one of them. This system will not be able to function properly. While the majority of the safety precautions take place in the handling of the battery during the connection and soldering portion, it is still important to look at these standards to understand that the lithium-ion batteries have a risk of being hazardous and or dangerous if not handled correctly.

The fact that batteries can fail on rare occasions in an uncontrolled manner has brought an increased awareness for battery safety, with some big recalls on mobile, portable, computer batteries being recalled. Thermal runaway may propagate to adjacent cells. If one cell in our 18650 pack undergoes a thermal runaway reaction, it is likely to cause thermal runaway in adjacent cells by way of various heat transfer mechanisms which may include direct case to case contact, impingement of hot vent gasses or impingement of flaming vent gases. Recent FAA tests provide a demonstration of thermal runaway propagation through bulk-packaged 18650 cells. Since we are in fact using a multi-cell pack design we can affect the likelihood of thermal runaway propagation by adjusting the cells using spacers and an orientation to minimize heat transfer and explained in our design.

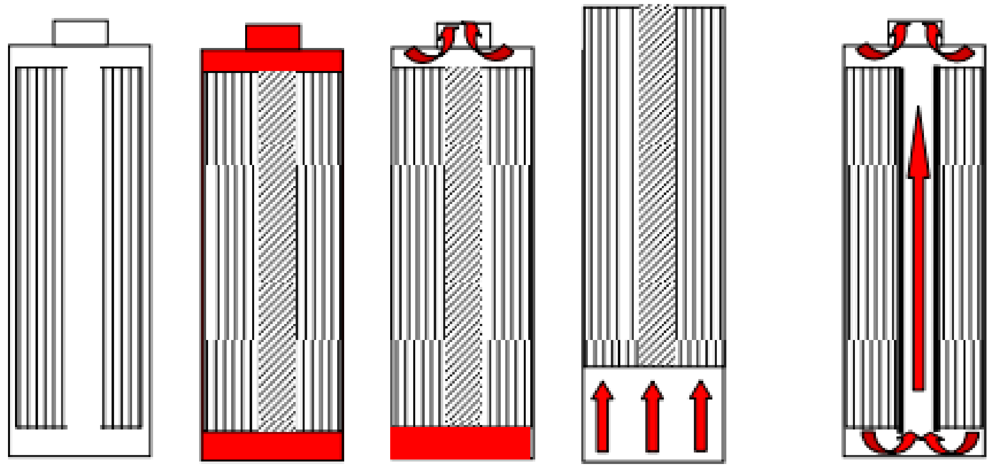


Figure 40: 18650 Ejection and Windings

The windings can eject from a cylindrical cell when subject to the thermal runaway reaction. During the reaction the windings expand and collapse into the central core. The cell venting then allows for a relief of pressure at the cell cap but not at the cell base and then the base acts as a piston, ejecting the cell windings. In contrast, a stiff center tube will maintain an open cell core and allow pressure equalization, to help prevent the ejection of windings.

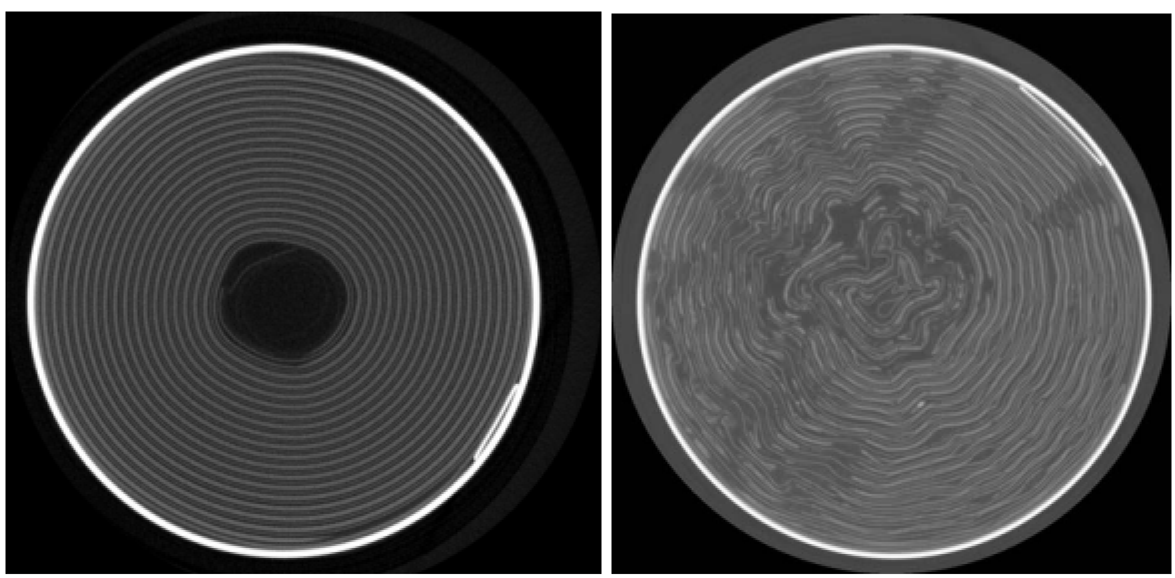


Figure 41: 18650 Thermal Runaway Scan Before and After

8.2 Soldering Standard and safety

The National Aeronautics and Space Administration (NASA) has a soldering standard, with a PDF called "NASA Technical Standard: Soldered Electrical Connections". In this document there are many key points to making proper soldering connections. Many diagrams are included that show solder connections a few on single point connections which would fit our design more as far as connecting our connecting component to the batteries and connecting our wiring to the BMS.There also important parts to pay attention too while soldering which include Facilities, Equipment, Materials and Parts according to NASA-STD-8739.3.

For the Facility Cleanliness section, the NASA standard explains how the shall be clean and in orderly condition. SMoking, eating, and drinking in soldering areas or at the workstation where the soldering will be taking place is not permitted. Nonessential tools and materials are also not permitted within the station to be soldered because this can cause issues with the connections if there are interferences.

For the Environmental Conditions, the soldering area should also be in a controlled environment where the temperature and humidity are monitored and maintained within the limits defined as the comfort zone. This comfort zone is the sweet sport or the best possible range of temperature and humidities to solder and make a connection. This zone has connections that are best made in an environment of 30-70% humidity and 70-83 deg Farenheit.

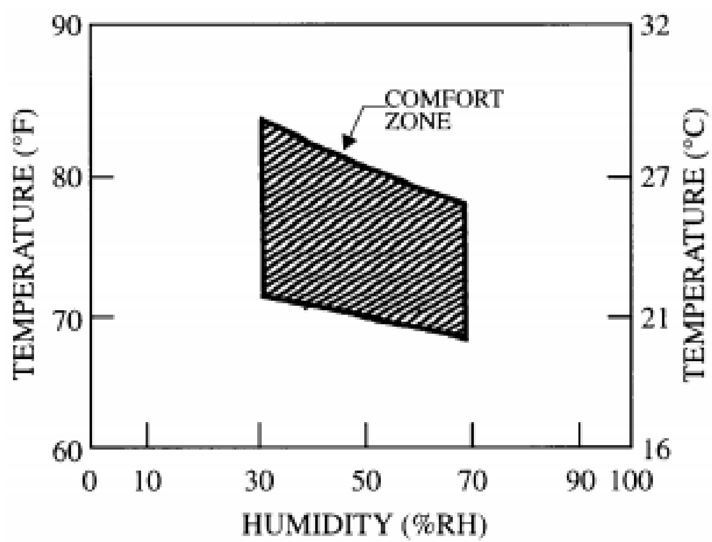


Figure 42: Soldering Comfort Zone

In field operations where the required control environment conditions cannot be effectively achieved, which would be in our case. Special precautions shall be taken to maximize the quality of the solder connections and minimize the effects of the uncontrolled environment on the operation being performed on the hardware. These precautions shall also be identified in appropriate documents.

Regarding tools and equipment control, there are many specifications that are requirements for the supplier. Some important specifications regarding the supplier of the equipment are:

- The supplier shall have a documented calibration system in accordance with ANSI/NCSL Z540-1.
- Document or reference in the suppliers soldering program, detailed operating procedures and maintenance schedules for the tools and must be traceable to the NIST.
- Maintain records of tool calibration and verifications.
- Power tools used during the soldering process shall comply with the tool requirements herein and have a three-wire grounded power cord. The area making contact with the workpiece shall be grounded. When measured from the workpiece contact point to ground, the resistance shall not exceed 2 ohms and the potential difference shall not exceed 2 millivolts RMS using methods indicated in suppliwers engineering documents.

For soldering tools and equipment, if using a Resistance-type soldering, the electrodes of tweezer or clamp design with surfaces that contact the items to be soldered, shall be maintained parallel with each other and free of pits, corrosion and contamination. For the conductive-type irons, they shall be of the temperature controlled type, controllable within plus or minus 10 degrees F of the preselected idling temperature.

The last important portion of the NASA soldering standard that pertains to our project is that all solder used for tinning and solder connections shall conform to ANSI/J-STD-006. Flux-cored solder shall be either composition SN60 or SN6 containing types R or RMA, or equivalent. For all soldering applications where adequate subsequent cleaning is not practical, only solder containing flux type R is to be used. For high temperature soldering, or for operations where connections are to be subsequently reheated, the use of high temperature solder alloy is permitted.

For soldering safety, there is a document by Carnegie Mellon University about safety precautions when working with lead. One of the primary concerns is the solder fumes that are produced when melting the solder. When hand soldering parts, the fumes can become an issue. The document from CMU specifies that working in a well ventilated area or under a local exhaust ventilation while making every effort to avoid inhaling fumes should be exercised at all times with lead based solder. It's also important to wear proper clothing while soldering at any time, which typically includes lab attire such as closed toed shoes and more importantly eye protection. The UCF TI lab is a good example of a proper soldering station, the location is relatively open with good ventilation.

It's obviously still important to not touch the tip of the soldering iron while it is being used, as most are around 650 degrees and higher up to 750 degrees for lead free based solder. Before leaving the area where you are using the soldering iron it is obviously important to make sure the station is turned off and unplugged. Leaving it on and heated while unattended is a major fire concern, the tip of the soldering iron could easily fall off the cradle and onto a flammable surface, heating very quickly and causing a fire.

Eye protection is an easy preventative step to take when looking at lead exposure. This eye protection is recommended for soldering appl;ications as the solder has a tendency to split, which means the metal will disperse smaller pellets of molten solder in the air. This is one of the most important points of looking at why we need eye protection. Having the solder on our skin is also a health concern so we need to make sure we wash hands in order to rid any deposits left from working with the solder. Typical skin on lead contact is not a primary health concern but it is when it stays on your hands and accidentally ingested while eating.

When soldering, it's very important to make sure the circuit we are working on is not live. Reasons for this are, ranging from the safety of the parts on the board to the protection of the user not getting electrocuted. If using a live circuit, it is entirely possible to get a solder bridge, accidentally connecting two pads that are not intended to connect. WHile this does happen rarely when using a stencil and solder paste, but when using soldering methods by hand, this is much more likely to happen. Of primary concern, as previously mentioned is the safety of the user. When working with high voltage applications, the user can technically become part of the circuit if not grounded properly and the result can be an electric shock. Some soldering irons have a ground pin that can be affixed to the circuit or to earth ground in order to prevent these problems from occurring, but this is not a one solution fix all. The easiest way to prevent all these issues is to make sure the power has been removed from the device we are working on.

8.3 Ingress Protection Standard

The ingress protection standards that are common through modern consumer electronics are developed by the International Electrotechnical Commission or IEC. This standard developed by the IEC is a rating system for ingress protection or IP. In general the higher the number associated with the rating the more protection that device has towards the ingress of foreign objects and water. The standard is broken down into two different scales that make up the numeric value of the rating. The first number is related to solid objects while the second is for water. The chart that outlines this rating is shown in figure 34.

Most modern consumer electronics that have a rating are portable and this rating is heavily advertised since it makes the device more durable. For example, the iPhone XS has a rating of IP68. The 6 represents that dust should not be able to enter the device and the 8 represents that the device can be continuously immersed in water between 0.15m and 1m in depth.

For the scope of this project the device should be able to withstand natural rain showers and outdoor elements. For all sensitive electronics to meet this standard it should be atleast IP55 or higher. This ratings definition is that it is not completely dust tight but minimal dust shall enter and that the device is protected against direct water jets. For evaluating the dust resistance that the amount of dust entering shall leave no deposits or interfere with operations or safety requirements of the device. The dust used to test shall be no larger than 75 micrometers in size, the testing procedure calls for this dust to be suspended and circulating. The second number represents that the device can withstand 12.5 l/min of water from a 6.3mm nozzle at 2.5 to 3 meters in distance for at least 3 minutes. If this device can withstand these tests it should be able to withstand weather that sports could still be played during.

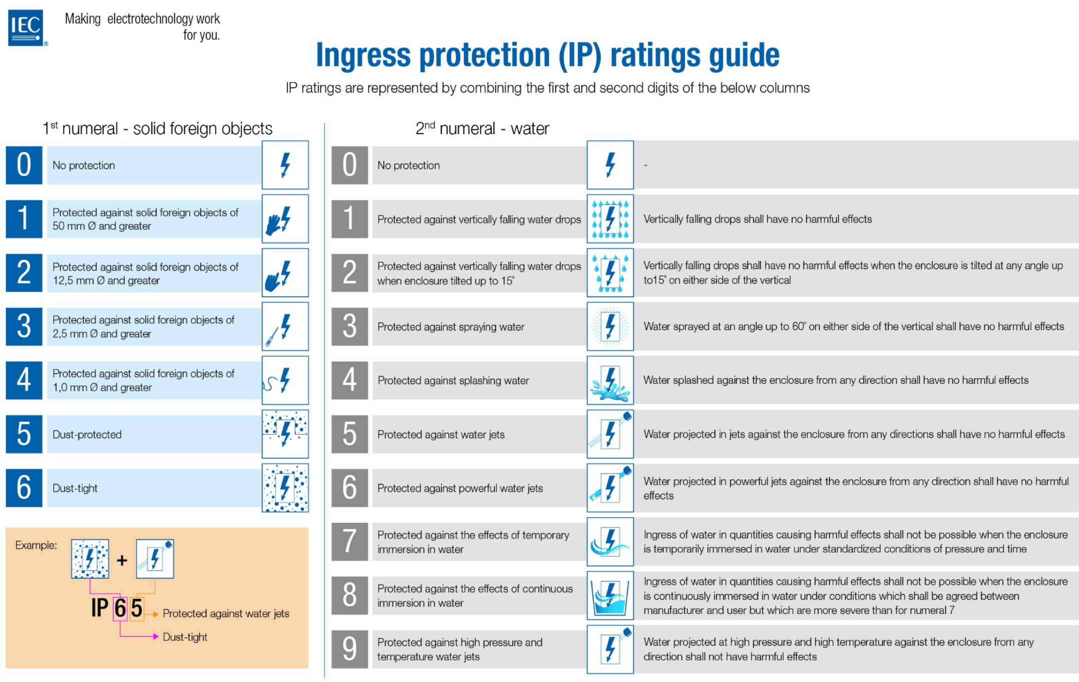


Figure 43: IP Rating Chart

The camera type that will be utilized for this project is typically designed based on the idea that it should be more durable then actually needed. Most security cameras are IP66 or higher and as such we should not need to worry about any ingress protection from the body. The weakest point in the ingress protection on security cameras is where the camera connects to the network and potentially power. In typical applications this is done in an area that is relatively protected, as our connection may be exposed we must consider this when finalizing any designs.

There are other less widely used ingress protection standards such as American Nation Standard Institutes version of the IEC IP standard which is NEMA. NEMA maps the IEC values to their own system and expands it as they see fit. However, this project will only evaluate based on the IEC IP standard as it is more concise and direct towards the protection that is needed for this project.

9-Project Integration and Testing

In this section we will be discussing the testing of our design. We will be explaining our testing procedures, the equipment used for the testing, and some restraints that may come about during or the planning of our testing.

9.1 Injector Battery Testing

For testing of the injector battery, the first step will be making sure we get reliable batteries. The 18650 batteries that are from reputable companies like Panasonic, Samsung and LG are documented to have much better performance characteristics and great quality control. These batteries may be slightly more expensive but last longer.

When we are testing the individual batteries, we will be checking the individual voltages WHen connecting the individual cells in parallel, the voltages of the cells will need to be near each other or there will be a high amount of current flowing from the cell with the higher voltage to the cell with the lower voltage. This can cause damage to the cells, so it's important that we will need to test and make sure the voltages are close. We will be buying the 18650 batteries so we shouldn't have a problem with the capacity or voltage. If we were buying them used or depleted then we would need a charger to charge the 18650 cells before joining them. Using new cells, the batteries should be near the 3.5V to 3.7V range, in which case it is good for them to be joined together. If the batteries are not at the voltage where they can be joined, this may be a constraint.

We will need to join the batteries together after we are done with the testing.Joining the batteries can be a part of the testing process because it is an essential part of the way the batteries will act in the system. This will be a constraint for the batteries also because we will be using a soldering iron to join the batteries together. The soldering iron is much cheaper and more accessible to be used. We will be making sure we minimize the contact time of our iron and cell because we will not want to apply a lot of heat to the cell which may damage or lose capacity in the cells. A high quality iron (80W) iron with good thermal capacity will be sought out and used for best results.

Testing if the soldering is successful or not is a simple process. If the nickel strip doesn't come off with hand pressure or it requires a lot of strength to remove, then it is good. If it can easily be peeled off, then we will need to increase our time or area of soldering. Same goes with soldering the nickel strips from the connections to the BMS board. For soldering the BMS we will first be applying the solder to the pads. After that, apply a little more solder to the strip to solder them together.

We will need to test the wiring components of the battery bank also. To test the DC jack, the battery level indicator and the switch that will be soldered to the BMS, we can use a multimeter. With our plan being to have the switch connected to the battery level indicator, with the ground end of the battery level indicator connected to the DC jack then connecting to the negative terminal of the BMS. Having the positive ends of the DC jack connected to the BMS on the P+ pad and the switch indicator combo connected individually to the P+ pad and negatively connected to the P-. The multimeter can be used to test the switch indicator combo to see if the soldered connections are holding up and there are no short circuits. The same can be done for the female DC jack that will be connected to the BMS. To keep these connections protected for testing, we will be using electrical tape around connections we are sure are made correctly.

9.1.1 Constraints

If the batteries are not at the correct nominal voltage to be joined, this may pose an issue where we will need to purchase new batteries, or we will need to purchase a li-ion battery charger to charge all the cells before joining.

The Soldering iron will be used because it is most accessible, where we could be using a spot welder to join our batteries. The spot welder can securely join the cells together without adding much heat to the cells. This is more of a budget constraint because even cheap the spot welders can go for around 200-300 dollars.

9.1.2 Equipment

We will be using a soldering iron for the joining of batteries in series and parallel. This will also be used to solder the nickel to the BMS board.

While creating and testing the battery bank for the injector, we will need to keep them close enough but separated to allow fresh air to pass using a 18650 battery holder which is made of plastic holders/ spacers. This will also make sure the battery pack is solid and reliable while also acting as an anti-vibration pad for the cells.

During the testing we will want to avoid accidental shorting by designing an enclosure around the battery bank. This can be 3D printed and created in Autodesk. This piece of equipment is owned by a group member and can be used for this application. Using an STL file of a similar 18650 battery holder and making adjustments will be simple. We can adjust these files to make the enclosure longer and fit the 30 18650 batteries we have designed for. The openings on the ends are for the battery level indicator and the switch. The lip on the bottom shown is there as an idea to keep the battery pack centered and to keep them from involuntarily sliding around inside the enclosure. There is also a lid that can be screwed into the base of the enclosure from the top to keep it all together and aesthetically looking nice.

Figure 44: Battery Enclosure

The wire stripper/ cutter is another piece of equipment that will be used when testing the equipment because the components will need to be stripped back to make the connections or cut back to reduce slack. A quick summary list of equipment used for testing includes:

- Soldering iron
- Wire stripper and cutter
- Multimeter
- 18650 holders/spacers with possible charger
- Heat shrink or electrical tape

9.2 Microphone Testing

For testing the microphone, There will be a few trials we will need to run while the whole system is in place to see if the built in microphone on the PTZ camera will suffice. We will need to test the built in microphone while it is on the tripod when it is high up in the air. A factor that may affect the microphone when it is that high up may be wind and if the microphone is picking up sounds and contents that are not intended to be on the recording, meaning behind the camera there could be bands, and crowds that can drown out the sound on the field. Trial and error for different situations, inside and outside will be the best form of testing for this microphone if it works out.

The next step of testing for the microphone will happen if the trial and error for the first microphone doesn't work as intended. We are prepared to use a simple USB microphone that can be placed along the tripod. This can also be tested by a simple trial and error. This microphone can be used to overwrite the audio from the PTZ camera and we can place it up high or in a lower location on the tripod so we can still get the picture from up high while getting a possibly more clear version of the audio and what should be heard on the field or court. Trial and error will be the best form of testing how the audio will come out for multiple situations.

9.3 PCB Testing

Testing the PCB Injector that we will implement and have designed is crucial in the overall success and functionality of our project. There are many components and connections that need to be built as designed or our injector may not work as intended and not provide power over the ethernet connection. This would be a disastrous situation for our sponsor and thus requires us to test it thoroughly to make sure it is working as intended. Our testing can be done in a variety of ways and testing methods but we feel that the best manner would be to test each section of our board individually.

DC input and DC converter Testing: When looking to test our DC to DC converter we can make a smaller subcircuit on the side and connect a multimeter to test the current and voltage coming from the end of our converter. We can connect the multimeter directly to our circuit board and connect it to the end of our resistor to see how much voltage is coming from the system and then test it in series to determine the current that is running through. Another testing option due to the cheap nature of the components for this section is to create a separate circuit board with just the DC input and our DC to DC converter. We could then connect another terminal block to the other end and connect wires to it for testing. This would allow us to test the circuit before actually building our final product and let us re-adjust the values and specs if needed depending on what our readings would be. These are the simplest methods for testing our design and overall DC to DC. This section of the board is easily created and tested with very little trial and error due to the webecnh resources and equipment we can use.

PSE Controller Testing: Now that we have tested our DC to DC converter we need to look at our PSE controller and see if the settings and connections that we created in eagle are coming to fruition on our prototype design and test. However, there is a slight problem. We can test the voltage that goes through the positive interval of the controller but it will not regulate and control the output unless it has been detected connecting to a PD or our PTZ camera in this instance. This can only be done with a completed board and injector design and connecting to a camera with POE capabilities. So in order to test this PSE controller we must fully build the system and connect our board to a POE camera. In order to be the most effective in our testing we have purchased POE testers and poe determinate device that we can connect to the end of the power+data port and see overall how much voltage is going through, how much power is being transferred into the system, what mode and connection types are being used and much more.

This section of the PCB will require the most trial and error for our completion and it is crucial to order backup parts and materials to use just in case we need to alter our current POE design or possibly fix some mistakes that could have come from the factory building.

RJ45 Ethernet ports / Transformer: Almost in the same manner as the PSE controller, the ethernet ports will be easy to test once building has been completed and our full system is in place. This will allow us to connect a multimeter to the ethernet pins inside and see how much voltage is coming from the 1,2 and 3,6 pin pairs respectively. This will let us know that power is being completely transported through our board at a constant level and with no current drop. Similarly we will be able to use PoE detectors and meters when an ethernet cable is connected to test what numerical values we were getting. However, we are still able to share and transfer data between two sources with the ethernet cable without the power but we will not be able to power our device with POE capabilities. This will allow us to make sure our data connections are at least viable and able to transmit up to 1000BASE-T data before a voltage is applied to the system.

Overall, this PCB injector will be broken down into smaller subsections for testing and will be looked at from all angles to make sure things are working as according to plan. If any need for alteration we will look back to our initial design and see what improvements or design choices we may need to reconsider. With the nature of this project and the Power over ethernet designs in the world today a majority of this section will need to use trial and error with some redesigns almost guaranteed to happen and become necessary in order to give Todd and QwikCut the best possible outcome. Now that we have looked at the overall PCB test we will need to look into software testing and how we will implement our design on the laptop portion.

9.4 Software Testing

Testing software is a demanding job and may require outsourcing testing to as many people as possible that have the needed equipment to fully utilize the software. For this reason we have divided the testing procedures into three main groups. Each group has its own methodology for testing and their own criteria for if the implementation is successful. Once each aspect is tested individually we will test the software as it is meant to be used. This entails being a version out to the field with the rest of the system to allow for QwikCut employee to attempt to operate the camera as they see fit without putting any limitations on them. At this point we will know if there are other features that are needed in the software. Below are the descriptions for how the main components are to be tested.

9.4.1 GUI Testing

Testing the GUI is done via having someone use the GUI, so long as the tester knows what the GUI should be able to do but has no explanation of how it works they will be able to find bugs that would be hard for the software developer to find. For example, if there is a close simple on a popup and it closes not only the popup but the main application itself. For the developer they may know that you should hit the close button but not the exit and thus never press it even though it is available.

Since there will be many layers of windows and some of them may only be accessible from other windows, testing the application in its entirety may take a good bit of time. For the most part resolving any issues that are found requires the developers to be able to recreate the issue to allow for them to find what causes this. For this reason during testing we may run screen recording software that tracks the mouse and any inputs, this will allow us to follow their inputs.

To keep track of issues that are found we may utilize a task tracking tool such as Trello or github's own issue tracker. Depending on the scale of testing and utilization of the software we may elect to use github's solution as it can scale very well to the potential large number of user reports. These tools are currently not implemented at this stage of the project as we are yet to develop the software beyond a simple verification of features and GUI designer.

9.4.2 ONVIF Testing

Testing the ONVIF implementation of this project is one of the more straightforward parts of testing. To test and verify that ONVIF features are working as intended and our implementations are performing as expected we will do some basic unit testing. This testing will not be automated like a lot of unit testing is. The reason for not automating this testing is that the feature set is from an imported library that we have modified. Therefore, we can make a separate testing program to verify the features of the library work. Once the features are known to be working we only need to test the operations of our program.

Since this project is only using ONVIF to interface with a IP camera that has PTZ features the libraries features that need to be verified are limited. This library utilizes a large number of support packages and we cannot directly interface with the supporting files so they must work in order for the features we can interface with to work. The first test will be to verify we can discover and connect to the ONVIF device that is on the network. Once we confirm that we can connect the next step is to simply interface with the camera, to do this we will request the current date and time the camera has. This will test not only the main ONVIF profile for IP camera but all the supporting SOAP packages that handle the reading of the XML and interpreting of the data into the java classes. Now that a basic IP camera ONVIF profile is working we test the PTZ profile by telling the camera to move in all possible directions and speeds. At this point the testing for ONVIF is done since we have tested all features that this project needs.

For this aspect of the project if any part fails or does not perform as intended the solution is to start debugging the code. Since the library that was modified for this project was 5 years out of date this may be a real possibility.

9.4.3 Input Testing

To test the input, we have currently taken controllers that we currently own and have tested the software against them. This has then given important feedback from all members of the team. Some of the changes we have currently made was switching a decrease of zoom on the right trigger, to the left trigger. This testing allowed us to understand the need for the ability to remap the set actions of the controller to one of the user's choosing. This is why we are attempting to implement a solution that would allow the user to set whichever button on their controller to that of an action in the software.

Further testing will most likely be receiving feedback from the known users of QwikCut previous solutions. The most ideal way would be being able to join QwikCut at one of their programs and being able to survey and ask questions of the camera operator. Ideally, we would be able to take notes of how they handle their solution, what they want out of their own solution, and then be able to translate those notes into software.

We would ask about the speed of panning, tilting, and zooming in. How different sports have to be recorded, in terms of features like the zoom curve and the return to home functions. The new solutions would then be demonstrated to QwikCut and asking them how intuitive the system is and what changes they would need to be the most suitable. With regards to the different sports that may be recorded, if the games are very different it may be suitable to create a sort of profile for each type of sport. For example, football might be micro adjustments on zoom but a game of soccer might require larger changes to zoom. This would cause the need for a different quadratic curve. This could either be setup on the spot or if using the profile system, the program could ask which type of sport is being used or even being able to select different curves regardless of the sport.

Depending on the final setup the changes could be implemented on the spot in regard to the changing curves of the zoom, or it might have to be more extensively worked on in another iteration.

To test the input of various controllers we are currently going through the controllers that the members already own and seeing what the default setup for each type should be. Currently we are able to detect the different types of controller through the usage of drivers on windows. To get more data to ensure that the program will work despite the controller we would use, it might be necessary to emulate other types of controllers with software. Asking QwikCut for the type controllers they would be using is also imperative as to ensure they are able to use the controllers that are already owned without the need to purchase many more controllers.

9.5 Camera Testing

Now that we have chosen an existing PTZ camera for implementation in our project we will need to make sure that we are testing all of the components that come along with the camera itself and that will be needed for crucial implementation in our design. This testing will mainly need to look at the pan speed, tilt speed, and zoom speed/range compared to what was stated on the camera's specifications and what constraints we were under. If one of the following specifications does not meet the standards that we need we will need to look into other options for a camera to use and secondary cameras will need to be on standby to be ready for the same testing.

Pan: The first crucial condition for testing will be connecting our camera to a power source and using the built in controller or our created obs designed software to move the camera on the x-axis and test quickly we can control the speed of rotation from 0 degrees to 180 degrees. This testing will need to capture a person/subject moving at full speed in a smooth and non-jerky manner. The smoother the pan capabilities and ability to follow a subject the better our sponsor will be able to provide for their audience in terms of quality and overall experience. If the camera we have selected is not fast enough we will have to look into some options for either increasing/decreasing the speed of movement depending on the outcomes of our testing or looking into other camera options on the market.

Tilt: Similarly to the pan testing we will need to do some speed and range testing compared to the stated manufacturers specifications and how accurate they are in our implementation. We will need a camera whose function can look from 0 degrees straight down to 180 degrees straight up in the y-axis. We will compare the numbers and make sure that we are achieving the desired outcome and overall level of movement we will need from the following movement settings. If need be we may be able to alter the motion settings of the camera or find a camera that is capable of the movement speed we are desiring.

Zoom: Maybe the most important aspect of the camera we will need to test due to the nature of where the camera and tripod setup will be placed on the football field and on a basketball court. We will need to test the zoom capabilities and focus level of our camera by connecting our camera and zooming in all the way we can both with the optical zoom that will be built into our cameras and digital zoom that can be used using the ONVIF standards and capabilities that are included into our system. This test will include sending a member of our team or other subject go 120 yards away and see the quality that we are obtaining and the overall zoom that we are achieving. Although, we do not need to have a very finely tuned zoom into a small area we will still need to have the capability to clearly see a person from a good distance away. If we are unable to achieve the zoom that we are desiring we will need to look into if there are more digital zoom options or touch up capabilities that OBS will be able to give us. If not, similar to all the other options, we may have to look at other cameras on the market and maybe try and repurpose another PTZ camera or other video camera.

Quality/Definition: When it comes to the quality and definition of the camera we will need to look at this as the lifeblood of the camera and the main focus other than the overall movement from the PTZ camera. The constraint that we needed to abide by was having a camera that could capture in 1080p HD and provide our sponsor with a clear image. This camera has higher capabilities and quality than that 1080p but it will need to be checked to clarify and make sure. This will be done using the general functions of the camera and recording a small video looking at the quality of the stream when moving the camera with its normal functions and overall system. We can do this using OBS and the software system that we are going to use for the software control and recording and watch the video stream. This will give us the ability to check the definition and the frames per second which is another major component to our camera.

Overall, this camera system must pass the four major tests as stated above. All the tests just look at the fact that they are capable of actually achieving what the manufacturer said they are capable of. If the specs that are claimed are not accurate we will need to order an additional or replacement camera that is capable of achieving our desired purpose. This is to be seen after purchasing and running the tests during our building processes.

9.5.1 Hardware Testing

This hardware test was described in the sections above and looks at the overall quality and movement of the system. However, two main functions that need to be tested are if our camera can be powered by a POE capable injector, as well as if the camera is IP66 rated waterproof and dust tight.

The POE capabilities can be tested by just applying a capable POE injector that we have obtained online and plugging the system in, if it is unable to power up it will be useless in our overall design and we will need to get back to the drawing board with what cameras we can use. We will need to use the proper cat5e/cat6 ethernet cables to test this since these are what we will be using with our 1000BASE-T system and PCB.

Along with the basic POE capability testing we will need to make sure our camera adheres to the IP waterproof and weatherproof standards as well. This can be done using some minor features around the house and testing some lesser cameras as well with the same rating to determine if they would be able to maintain their functionality and overall performance in the florida weather that can change rather quickly depending on the day. A heat test and water test will need to be applied with a crucial covering possibly being necessary depending on the results. If the camera is not 100% water efficient we may have to redesign our mounting system to include a cover around our camera and make a hole for the video to be recorded and transmitted through this. This would help maintain te POE capabilities while also not jeopardizing the connection with a bad weather surge that could permanently damage the system

9.5.2 Video Stream Testing

Video streaming and testing will be an important characteristic of our design as it will be used and needed from our sponsor on a daily basis and will need to be achieved in as high of a quality as possible. Different protocols and options can be used to test the overall functionality and needs of the system. A standard video relay and system can easily be assembled. Can also mention the potential different protocols and how to test for which one is best.

9.5.3 Movement Testing

Movement testing of the camera will be driven by software. For the initial verification that the camera can move and verify that all aspects work we will use third party tools that can both utilize the ONVIF features and control the motion of the camera. One of the key aspects of this testing is that we can verify that the camera can both move at slow consistent speeds and faster movements while being able to maintain decent image quality.

For testing the basic functionality of the camera we will most likely use an application called iSpyConnect. This is a rather light weight tool that can both discover ONVIF devices and generate the streaming urls that the camera has to allow you to open the stream in applications like VLC or OBS. VLC or Video Lan Converter is a very powerful tool that specializes in opening media files and video streams of many different types. OBS or Open Broadcasting Software is already used by QwikCut for recording and streaming of events, this software is also capable of opening and displaying the streams that most IP cameras broadcast. Once connected via iSpyConnect and having a stream open in either VLC or OBS we can then tell the camera to move. Since iSpyConnect is utilizing ONVIF to tell the camera to move we will then know if the camera will work with our software. If it fails to move at this point we will access the web interface for the camera to see if it will move via the built in controls.

9.6 Mounting System Testing

The mounting system tests are focused around its ability to perform its task while not interfering with the view or operation of the camera. The mounting system will be considered suitable if it is easy to use and adjust, durable against the elements and any potential mishaps that may stem from the weight, and that it does not interfere with the view of the field that the camera is to record. If the mount is not capable of meeting these requirements and pass the test plans described below it must be redesigned.

9.6.1 Easy of Use

The requirements of the mounting system outlines that it must be easy to install and transport. To test these properties we will ask employees of QwikCut to install the mount and camera on the intended tripod and to store the assembly and their view of the transportation method that is to be designed. If any person that can reach the top of the tripod while not handling the mount cannot easily install and secure the assembly the test will be considered failed. At this point we will analyze what caused the failure and what can be done to modify the mount to make it easier to install. In terms of transportation of the mount if an employee deems the weight or size of the transportation solution to be too much we will attempt to redesign the solution to make it lighter or more compact depending on which aspect failed. These tests are all subjective in nature and all testing participants' views on the system will be taken into account to evaluate if the design is suitable.

9.6.2 Durability

The mount assembly must be durable enough to withstand the elements and be able to take the possibility of the tripod tipping if the winds are high enough to cause that. Weather testing relies on mounting the camera to the mount and verifying that it is still capable of passing a basic water ingress test. This ingress test will focus on making sure the camera can operate while in a rainstorm. The evaluation of results are very simple; it either remained operational or failed during the test or immediate time period after the test. For testing if the mount assembly is capable of surviving the hopefully rare event of a tripod tipping we will attach the camera to a pole of at least 15’ in length. Once attached the pole will be raised to a vertical position and allowed to fall. If the mount bends, cracks, or fails in any structural way it needs to be redesigned. Another failure case is if the camera becomes damaged from the resulting fall. Although we cannot guarantee that the camera assembly and mount will not take damage from a fall we wish to try and minimize any damage and allow for the system to be used after any corrective measures are taken after an incident.

9.6.3 Camera View

Since the initial design of the mount is in the shape of a L it will need to have some triangulation to achieve the rigidness needed to minimize movement once in use. However, these supports may interfere with the viewing angle of the camera if the camera is mounted inside the L. Depending on how much impact the supports have the mount may need to be redesigned. The testing for this is purely subjective and is for the sponsor to decide. If the sponsor deems the initial design suitable we will only redesign it based on the other criteria, however if it is not suitable this aspect will drive the design until it reaches an acceptable state.

10-Administrative

In this section of the paper, we will be exploring and talking about administrative conversations that have happened outside the design and plan of the actual project itself that aids in the completion and presentation of the project.

10.1 Permissions

Permissions are very important when working with a sponsored project. We have been advised to not use a company logo unless it has been approved in writing by the owner or the sponsor even though it is a sponsored project.

Issues that have taken place in the past include the BOEING trademark and logo. While Boeing was sponsoring the project and organization, Boeing could not find any information or evidence that there was permission to use the Boeing mark to market the design. The students were then immediately asked to stop the unauthorized use of the logo on the pages or website.

ME Mark Escott
Sat 4/17/2021 1:00 PM
To: Todd Denoyer <todd@qwikcut.com>
Cc: Steven Little; santi131313@gmail.com; kjbrown883

Todd,

Sounds great. Do we have your permission to use the Qwikcut logo on the research paper we are developing as well as in any presentation that may be conducted for the project? This is necessary before use as there have been issues with UCF in the past when it comes to the use of company logos even if it's a sponsored project.

Thanks,

...

T todd@qwikcut.com
Sat 4/17/2021 1:15 PM
To: Mark Escott

Yes
That's fine by me.

Sent from my iPhone

> On Apr 17, 2021, at 1:00 PM, Mark Escott <mescott0519@knights.ucf.edu> wrote:
>

Great, thanks! | Thank you! | Works for me too.

Our Sponsored project has gotten the go ahead with the use of company logos within the research paper and with any presentation that may use the QwikCut logo.

10.2 Financing

For the financing of the project, we are informed by our sponsor that while we are to stay within a budget range. We are to inform the sponsor of items purchased to be refunded, or we can inform him on any larger purchases that are to be made for specific items in our design.

Our design is intended to stay in the range of what QwikCut is currently using. The contents of the QwikBox is very expensive and the total cost of the whole system is around 2,000$, with the price of the larger batteries going up this has increased over time.

With the items and devices we are purchasing, we have in writing the way we are to go about either being paid back by QwikCut or the way to have them pay for some of the larger items.

Todd,

My name is Mark Escott from UCF taking on the Qwikcam Senior design sponsored project. We have a few questions while we put together our second version of Divide and Conquer that we will be sending to you.

- What is the desired laptop for the new system? Is this something that Qwikcut has that they want to use? Or would you guys like us to decide on a new one.
- The Existing setup is said to be around 490$ and I assume we would like to keep prices around that cost if possible. Is this desired or Is there a slightly larger budget for the New Setup.
- How would you like us to report back on funds used? We can provide updates as we go along with our report submissions for our items bought, or we can come to you before any big purchases.

Thank you,

TD

Todd Denoyer <todd@qwikcut.com>
Mon 2/8/2021 9:02 AM
To: Mark Escott
Cc: Steven Little; santi131313@gmail.com; kjbrown883

Group 16,

I am excited to get rolling on this. Let me answer your questions and then make some comments.

1. I don't have a desired computer picked out. I would like to keep it as inexpensive as possible. I was using Intel's NUC and a monitor. That was kind of expensive (NUC - $750, Monitor $150 with batteries). The NUC and monitor was much easier to make waterproof. I purchased tool boxes from Lowes and kept everything in the tool box. The monitor - I used a 1 gallon ziploc baggie. The NUC currently runs OBS for our streaming service. Whatever is decided (Perhaps we build our own) it needs to be waterproof and it needs to be able to stay cool during the hot weather here in Florida..

2. Here is what I am currently paying for a set up: $600
Sony HDR CRX 405 - $185
Cell phone charger - $20
SD card $12
Bescor Motorized head with 20' cable - $125
Monitor with batteries and charger - $150
25' HDMI and Remote control cable for camera - $60
Remote control for camera - $50

Qwikbox cost: $1,460
Intel NUC - $750
Battery to run the NUC - $125
Converter: HDMI to USB3 - $400
Monitor (When used with small tripod) - $150
Tool Box - $20
2 - 6' HDMI cables - $12

The Qwikbox is used to stream games. We are doing more and more of that. So there needs to have the ability to Stream the games and just store them on either the laptop and an SD card for a back up. I would like to keep the cost down as low as possible. Let that be your guide. The big picture is this - If Group 16 comes up with a simple solution that is economical, we will begin to manufacture this set up and bring it to market for every football team in the US. I would anticipate hiring 1-2 team members

3. If Mark is the one heading up the troops, contact me and I will purchase what you need. I don't want you paying for anything. I can cash app you money or order it for you?

...

10.3 Consulting

In this section for administrative duties. We are going to show the conversations we've had as far as consulting about the project itself. Majority of consulting has happened through Todd Denoyer also which is also who we spoke to as far as financing the project. There have been ideas that have been going in the way of Todd for ideas which have aided in the research as far as selecting parts for the design and specifications. Camera, Laptop, and specifications for these are some main points of conversation.

Todd Denoyer <todd@qwikcut.com>
Wed 3/3/2021 3:18 PM
To: Mark Escott; Steven Little; santi131313@gmail.com; kjbrown883

Mark,

I have read through everything and I have a couple of questions.
The camera will be used in the end zone for high school football and will need to zoom 120 yards to the opposite goal line.
Will a 4X zoom be enough?
The camera has a 5 MP camera, that seems kind of low for possible getting a sharp crisp picture?

Do you know what distance a 4X zoom can cover? And is the 5MP big enough?

Thanks

Mark Escott
Wed 3/3/2021 4:14 PM
To: Todd Denoyer <todd@qwikcut.com>
Cc: Steven Little; santi131313@gmail.com; kjbrown883

Todd,

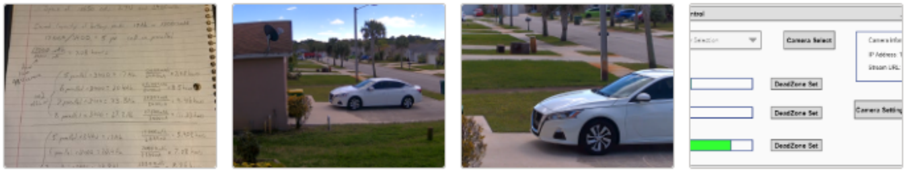
Looking at this is, its the best mix we can find of quality and cost. This can be increased if budget allows and we were using this as a base for power and specs, but the 5mp should help with the zoom quality. The camera is 2560x1440, given this we can use digital zoom to effectively have 8x overall since 1080 is 1/2 the pixels of 1440. At this zoom level we can expect to have the whole end zone in view but no closer without a drop in image quality.
Would it be sufficient to have the end zone in full frame? Or do we need to be closer and be on top of individual player and only have them in frame?

Regards,

Todd Denoyer <todd@qwikcut.com>
Wed 3/3/2021 4:19 PM
To: Mark Escott
Cc: Steven Little; santi131313@gmail.com; kjbrown883

Team,
I thought I read 4X on the camera specs? The end zone angle will need to cross the field length wise which is the end zone and 100 yards. The end zone angle gets a tight shot from tackle to tackle. It would never zoom on 1 person. Perhaps this work fine. I know in the digital camera world, you don't get much more from a camera if you jump for $200 - $600. Perhaps that is the same in the security world as well?

Mark Escott
Wed 3/17/2021 3:05 PM
To: Todd Denoyer <todd@qwikcut.com>
Cc: Steven Little; santi131313@gmail.com; kjbrown883



4 attachments (13 MB) Download all Save all to OneDrive - Knights - University of Central Florida

Todd,

Just to provide you with another update.
-Weve got battery (18650 Li-ion) calculations for the POE injector we will need on the PTZ camera
-We have a basic wireframe of the app for the camera and
-One of us needed a security camera for at home purposes so we've been able to test out the camera and check on some of the important aspects of the PTZ camera we spoke on.
Ive attached some images for more details. We are still working on research and developing more components of the system for our 60 page paper due in the next couple weeks. I will provide you with the paper we are going to submit at that time so you will have all information.

If there is anything else you may need please let me know.

Regards,

We've adjusted portions of our planned design to better fit the needs of QwikCut and what Todd is wanting. We tested a camera that fits the budget and have made adjustments because of possible zoom and quality issues. With these conversations there have been adjustments to our specifications and design plan. Our original camera changed the most where we increased our zoom from 4x to a zoom that can completely scale the football field from endzone to endzone in the case where it is needed.

With this as an example, it's important to see how important it was to have consulting type emails and messages with Todd for this sponsored project so we can deliver a product that is concurrent with the vision of QwikCut.

11-Basic Operation Manual

In this section we wish to outline a basic operation manual for QwikCam. As the device is not constructed or tested at this point this manual will be generic and modified as we build and test QwikCam. The goal for this manual is to outline everything that is needed to make the system operational and to explain how to connect everything together correctly for either charging or using the system.

11.1 Equipment Description

This section will outline all the required components to set up and use QwikCam. If any of the mandatory components are missing it must be sourced for QwikCam to operate as intended. If the minimum attribute field is not filled out for a specific area then the component is not required to achieve the functionality for that environment.

11.1.1 Component List

Component Name	Quantity	Minimum Attributes	
		Field	Office
Tripod	1	Must be compatible with the mounting system	
Camera	1	Attached to tripod mount or hardware present to attach	
Ethernet Cable	2	Length of at least 25 foot, no longer than 300 foot	Length of at least 10 foot, no longer than 300 foor
Computer	1	Must have OBS and QwikCam Control Software installed. Charger is present.	
Camera Mount	1	Set screw(s) present for attaching to tripod	
GamePad	1	Must be compatible with the QwikCam Control Software and able to be connected to the computer	
QwikBox	1	Batteries for injector and Laptop fully charged. Injector PCB present for connection in and out to camera. AC adaptors for charging when not in use.	

Table 16: Component List

11.1.2 Overview

The table LABEL outlines all the required components needed for the system to function. Each of these components also has minimum attributes that specify what is the minimums for each feature, these include cable length and components needed. If these minimum attributes are not met then the operation of the system cannot be outlined or guaranteed by this manual.

11.2 Setup (How to connect)

In this section we will describe how to setup QwikCam in the field and office settings and what needed to achieve different functions. These steps outline what to connect to where and when to perform specific actions.

11.2.1 Field Use

1. Verify that all components are present and that all minimums are met that are defined for field use, these can be verified by looking at table 16.
2. If the camera is not attached to the tripod mount, securely attach the camera to the mount with the hardware designated for attachment. Make sure all wires pass through the wire hole in the mount and are not pinched.
3. Attach one end of the Ethernet cable labeled "QwikBox to Camera" to the corresponding connection on the camera.
4. Attach the camera mount to the top of the tripod. Verify all set screws are tight.
5. Extend the tripod verifying that the Ethernet cable remains attached while extending.
6. Connect the Ethernet wire labeled "QwikBox to Computer" to the corresponding connection on the computer.
7. Connect the remaining ends of each Ethernet wire to their corresponding ports on the QwikBox.
8. Connect the gamepad to the computer along with any other accessories that extend QwikCam's feature set.

11.2.2 Office Use

1. Verify that all components are present and that all minimums are met that are defined for office use, these can be verified by looking at table LABEL.
2. If the camera is needed and QwikBox does not need to charge, please follow field use, the tripod does not need to be extended for this.
3. If QwikBox needs to be charged, The Adaptors are present inside the box. The laptop battery may be charged using the DC adaptor to a wall outlet and the injector battery will be charged in the same manner using a different DC adaptor. Battery level indicators are present to show when the batteries are fully charged.

11.3 Operation (How to use)

In this section we will describe how to operate QwikCam in the field and office settings. These steps outline how to use the QwikCam Control software and QwikBox to perform different actions.

11.3.1 Field Operation

In this section we will describe how QwikCam is intended to be used in the field. We will outline how to use the software to establish communication with the camera and how to use the QwikBox to supply power to everything.

11.3.1.1 Hardware

1. Turn on the QwikBox which includes turning on the laptop battery and making sure the injector battery is turned on and connected to PCB injector.
2. Turn on the computer.
3. Verify that the camera performs its startup procedure, this is typically it moving around. There should also be an LED indicator letting you know that the device is receiving power as well.

11.3.1.2 Software

1. Start QwikCam Control
2. In QwikCam Control click Camera Select. Enter the camera information that is stored in the QwikBox. Click Check Connection, if this fails please check wiring, otherwise press Confirm and close.
3. Start OBS
4. In OBS verify your input media source matches the camera connection details on QwikCam Controls main interface.
5. In QwikCam Control select your input device from the drop down.
6. Adjust the camera speed limits to the recommendations stored with the camera information by clicking Camera Settings.
7. Adjust the controller input map and deadzone by clicking Controller UI.
8. Press Confirm Controller
9. Verify QwikCam Control is working properly by commanding the camera to move.
10. Everything is established and OBS is ready to record.

11.3.2 Office Operations

In this section we will describe how QwikCam can be modified in the office along with the charging and verification of battery status before and after being used.

11.3.2.1 Hardware

Pre-Event

1. Verify the batteries are fully charged with DC connections for battery-PCB connection present.
2. Verify all components are present via referencing the table 16 above.
3. Verify all needed software is on the laptop and that it is fully charged.

4. Securely store and transport all components.

Post-Event

1. Verify all components are present and undamaged via referencing the table 16 above.
2. Connect the QwikBox batteries to the chargers. Follow the procedure outlined in section 11.2.2 step 3.
3. Store all components properly.

11.3.2.2 Software

Pre-Event

1. Verify all needed software is installed and can be opened.
2. Verify both the computer and camera SD card has enough storage to record the event.
3. Verify the gamepad is functional and the mappings are set properly via QwikCam Control's input mapping.

Post-Event

1. Transfer all recordings off the computer and SD card.
2. Restore all input mapping modifications to default in QwikCam Control via the input mapping menu.

11.4 Troubleshooting (What to check)

In this section we will outline some basic checks that can be performed if a component or feature is not performing how it is expected. This section is broken down into hardware and software components that may reference each other.

11.4.1 Hardware

1. Computer battery pack not working
    a. Make sure the connections for the input and output of the system are located and positioned correctly.
    b. If the problem still persists, Make sure this battery has been fully charged and check the voltage level.
    c. If the problem still persists, Check the battery for possible defects, corrosion, or other signs of fault. This may require a battery replacement.

2. PCB Battery not working

    a. First check to see that the battery pack has been charged fully and has an ample power supply.

    b. If the problem persists, unscrew the top of the battery pack compartment and look inside to make sure the connections haven't been disconnected or compromised

    c. If damage or wire connection is interrupted make sure to reconnect the wires properly to the labeled locations and re-check the system. If problems keep pertaining after this, a new battery pack will be required.

3. PCB Not supplying power to the camera

    a. Check that the PCB Injector is receiving ample power from the PCB battery pack (Go to option 2 in the hardware troubleshooting). A multimeter or power gauge may be necessary.

    b. Scan the PCB for all labeled components and make sure that they are all in the proper locations and nothing is damaged or missing.

    c. Check the PCB for any defects, damage, or possible failures that may be seen on the board (Faulty connections and wire routing can be common issues).

    d. Finally, check the ethernet connections on the PCB to the camera and to the computer. Make sure that the data and power side of the ethernet connection are running to the PTZ camera and not the computer (This may damage the board or just supply no power at all). If this process has not fixed the problem a review of the PCB board and replacement may be necessary for proper operation to resume.

4. Camera not operating or functioning

    a. Check that the PTZ camera is receiving ample power from the PCB Injector and battery pack. A PCB checker will easily tell you the voltage and mode that the camera is attempting to use in the system. (To be provided with the PCB Injector, also easily available online)

    b. Check that the PCB board is running power + ethernet to the camera for ample power transfer. Necessary for powering.

5. Camera not being picked up by the computer

    a. Make sure the power and POE connections to the PTZ camera are provided with sufficient power.

b. Check the datasheet and instructions with the camera to determine the proper IP address and setup requirements for basic use. This datasheet will provide all the information necessary for connection to OBS and the QwikCam software.

c. If the proper instructions have been followed and the device is still not resposnisve reset the device and power system. The reinitiate the process of connecting the device (making sure we are using the proper frame rate and quality are crucial to its functioning)

11.4.2 Software

1. Software not starting or crashing
    a. Open a command prompt and run "Java -jar QwikCam.jar"
    b. Look for error messages and attempt to solve the source of the problem
2. Software not finding your gamepad
    a. Verify the gamepad is properly connected
    b. If the QwikCam Control is open close it and reconnect the controller
    c. If this did not solve the issue, restart the computer.
    d. If restarting did not change anything, replace the controller.
3. Camera not being discovered by QwikCam Control
    a. Verify the camera is properly connected.
    b. Verify the computer is configured correctly
        i. Open settings
        ii. Open Network and Internet
        iii. Click Ethernet then Change adapter options
        iv. Right click Ethernet, then click Internet Protocol Version 4, click properties
        v. Verify that Use the following IP address is filled in
            1. IP address should be almost identical to the camera besides the last number
            2. Subnet mask should be 255.255.255.255
            3. Default gateway does not need to be changed or set

4. Save and close the windows

c. Verify the computer can see the camera.

i. Open command prompt

ii. Ping the IP address of the camera

1. If replies retry the connection

2. If timeout check wiring

4. QwikCam Control not moving the camera

a. Close QwikCam Control

b. Relaunch QwikCam Control and establish a connection and attempt to move.

c. If the problem is still present follow section 11.4.2

12-Senior Design II Additions

In this section of the report we will document the final semesters of work and information that was added for senior design II and any additional information that happened and was put into our project. This includes general information about possible design changes or just general input and work that happened throughout our time working on the project.

12.1 Hardware Parts and Implementation

Once our final design was chosen and approved for building after our initial semester of brainstorming and research on our project it was time to build and finalize a design for our sponsors at Qwikcut. The sections below will discuss our times building and testing our actual implementations for our project.

12.1.1 Batteries/Battery Pack

When we received all components for the battery, The first thought was to test and see what the maximum charge of a single one of the 18650 batteries. We found out that they in fact were received in the 3.55V range and at full charge are 4.2V. This should give us a fully charged pack of around 12.6V. When the battery pack is first built with uncharged 18650 batteries the pack will be around 10.68V. Using a multimeter, we check all the voltages of the uncharged batteries to make sure the voltages are around the same and insert them into the battery holders in an orientation that suits the 3 series wiring diagram. During that time, we designed and made a 3D printed case to the size of what the finished battery should be.

While making the connections of the battery we decided to use spot welding and go against the idea of soldering the batteries. Its safer and can provide a better connection because soldering can be potentially dangerous to the batteries. After welding the battery together and making sure the BMS board is welded on correctly, we made sure the voltages were reading correctly off the board. At that time the voltage was reading to be 10.7V which is right where we should be. The battery level indicator was installed and worked well, so next step was wiring the DC port for input and output and after that was installed, a test was given to see if 10.7V is still reading at the DC port. This test also passed giving the correct readings.

One problem faced after assembling the battery was charging. After trying to charge the first time the battery pack was not holding a charge at all. I noticed the installation of the DC port was backwards so that needed to be fixed, and also the Adaptor that was purchased to charge the pack was not giving us the correct output voltage to charge. So a new 12.6V 2A charger was ordered and after a night of charging, we were getting a reading of 12.5V coming from the pack. Using it with an injector plugged into the camera, it works as planned.

Figure 45:Completed Battery Pack

The battery was tested in conjunction with the Camera and injector. The battery pack was checked in the beginning to be 12.54V and after under just a couple hours, only dropped to around a tenth of a voltage ending at 12.44V and the battery level indicator was still showing a full charge. There was also an overnight test given to test the duration of power that can be delivered to the camera and at 11.5 hours, our voltage dropped from 12.54V to 11.1V which still gave a little charge to give as it has run at 10.7V at the lowest charge. This test shows that we are meeting the specifications of qwikcut and have a camera that will last the time they need.

12.1.2 PCB Injector

Upon receiving our PCB from our supplies at JLCPCB we began to build and test our design to see if any changes or alternate parts needed to be purchased for completion of our project. The standard PCB can be seen below in figure 45. Most of the components were soldered by hand using a soldering station and using a hot air gun with some solder paste. However, for the smaller components such as our autonomous voltage regulator and autonomous PSE controller we used a helpful connection from our advisors at UCF and used the services of QMS (Quality Manufacturing Services) located in the southern Sanford area. This let us know that our design was built correctly and that the components would work in a proper fashion. The final PCB completed and built can be seen in Figure 46 below.

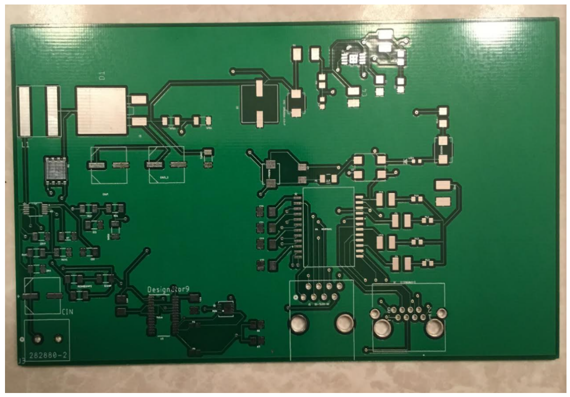


Figure 46: PCB obtained from JLCPCB

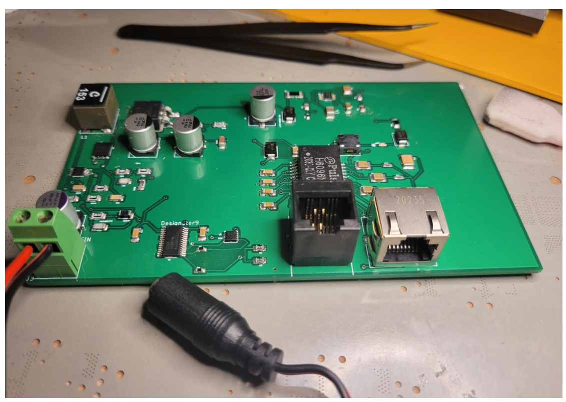


Figure 47: Completed PCB of our POE Injector

Upon completion we began testing and making sure our device was IEEE 802.3af/at compatible and checking all the standards necessary for our device. However, upon showing this design to our sponsor we had to move into another direction based on a request they had for the overall design for the new Qwikbox.

After showing this design to our sponsor they had concerns based on the unique nature of the PCB and how accessible and easily replaceable this design was. Being a singular unit and our sponsor wanting to possibly streamline our end product to that of a fully built design we needed to alter the PCB portion of the design to accommodate an existing injector. So they asked us to look into an already existing design on the market today and to have a small redesign for the final implementation.

So going off of this we found suitable POE Injectors on the market today and just needed a PCB to autonomously control and regulate the voltage from our hand built battery pack. We were able to take part of the existing design. We repurposed the autonomous voltage controller and regulator into a singular board that could directly connect to the battery pack and then output a steady 55V stream to the POE Injector. This would supply efficient voltage to the camera and overall create a simple design that our sponsor could easily recreate if needed using any retail PCB manufacturer using basic parts and equipment. This was done simply by changing some of the resistor and capacitor values while maintaining the same design and overall functionality. The changes and standard autonomous controller and voltage regulator board can be seen below in Figure 47.

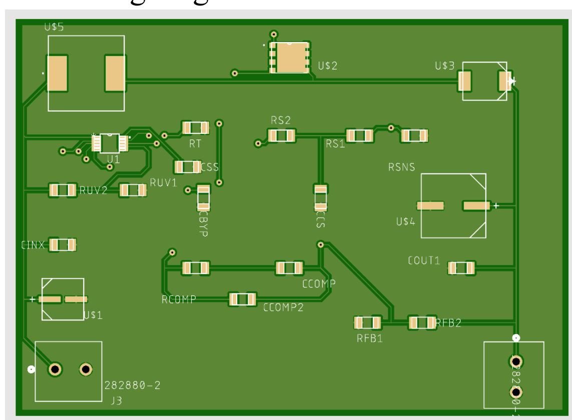


Figure 48: Voltage Regulator and Controller board

This small change easily allowed us to connect to the battery pack and the existing injector seamlessly and without the need for further building to make this design very simple. The final design below can be seen outputting the proper 55V needed for the system to function properly and output IEEE 802.3at/af standards needed.

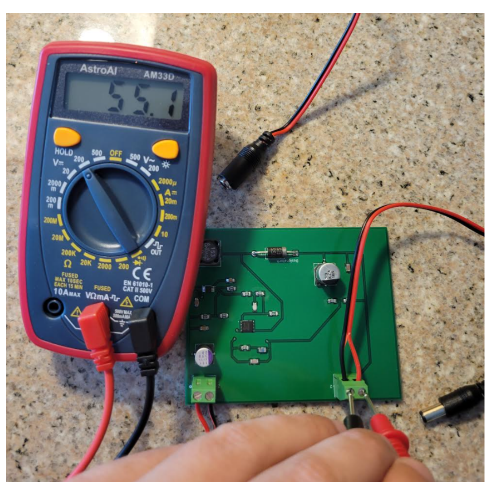


Figure 49: Controller board outputting proper voltage

Overall, this section of our design was a success but needed some redesign and work based on some of the sponsor feedback and the overall specifications that our sponsors wanted to meet. Now it is time for us to discuss how our PTZ camera function and how we were able to incorporate it into our final design.

12.1.3 PTZ Camera Operation

Upon receiving our PTZ camera from our online retailer we began doing testing and work on making sure that we could functionally control and meet the needs of our project with this camera. Upon connecting the camera to our laptop and try to connect to our software we initially ran into issues with connectivity and just getting the camera to comply and communicate via the ONVIF standards that the camera stated it included. This initially led us to believe that the Alptop camera may need to be replaced and be scrapped for an alternative design as well.

However, after doing some research and looking at the settings that come default via the manufacturer for our camera we found that the settings for the ONVIF connectivity were different between the two and a simple setting needed to be altered to fix this. This was done and upon retesting we were able to receive a clear signal from the laptop and stream the necessary video accordingly. We connected the camera to the laptop through the POE Injector as well letting us know that our injector was supplying enough operation power and current to easily power the device. This was another plus of the testing as well in having almost the complete setup be part of the testing and trials for the camera.

Upon connecting our laptop and camera we were able to easily control and move our camera via the game controller that was provided. We were able to easily control the speed and movement settings that our PTZ camera possessed and was able to achieve. We test the Pan, Tilt, and Zoom functions as follows in an open field at a distance of 120 yards plus in order to make sure all of our specifications were met and maintained to the level we are requiring for our sponsor.

Figure 50: Zoom and Quality Field Test

As seen in Figure 50 above we tested the movement of the camera by having members of the team walk out to an extended distance and test the Quality from a great distance. As seen we can easily see the detail of the group members and still meet the 1080p HD requirement that our sponsor needed. This let us look at the full extent of the zoom capabilities as well and was more than needed for our sponsors recording and streaming needs. We then had the members move at a steady pace in a linear and non-linear pattern and were able to adequately meet the movement needs that would be needed by the sponsor in a normal manner.

The only downside of this camera that we found in the end design was that this camera will only take a singular movement input at once. This means that we can only pan or tilt. We cannot move in a diagonal line in a smooth motion. However, you can input two separate inputs into the system and achieve the required result from the camera. Another noticeable mention is that the camera can however pan and zoom or tilt and zoom as needed.

Overall, our camera meet every specification and requirement needed for our sponsor and has the ability to be easily replicated and needed. This part of the project as a whole was a great success.

12.1.4 Tripod and Camera Mount

As for our camera mount and tripod setup we were able to take an existing tripod that was provided to us from our sponsor and create a camera mount for our ptz camera using some spare metal. The mount was easily able to be attached due to the tripod having existing standard camera threads and a mount attached at the top which let us easily create a design to match that system. The camera mount follows the previous design we implement in the previous sections of our report. The camera mount and PTZ can be seen in Figure 51 below:

Figure 51: Camera Mount and Tripod Setup

Overall, no changes in design were needed based on the camera mount and tripod configuration and we successfully met the goals provided. Any necessary changes needed by our sponsor can easily be changed as well.

12.2 Software Section

There were no changes necessary for the software section of senior design II as the code was produced and made during the senior design semester and worked as intended for or sponsored. Minor tweaks such as camera speed and overall ease of use changes were all that were needed in the completion of the hardware section.

12.3 Final Design and Project Showcase

This section of the report will showcase our final product and design that will be presented to our sponsors at Qwikcut. We will show each hardware and component that makes our project whole.

12.3.1 Camera Connectivity

To briefly discuss our final design we obtained our laptop that can easily stream and record the games as needed for our sponsor and can be connected directly to our PTZ camera and game controller for the movement of the camera. Once the camera is plugged into the camera via a singular ethernet cable we can easily open the software control board and connect the controller to the camera. The laptop will have a pop-up acknowledging the connection of the devices. We can then begin to start the connection process. This can be seen in the dropdown menus and buttons on the software layout seen in the left hand side of the figure. You press the corresponding buttons needed depending on if you need to connect to the camera or controller respectively.

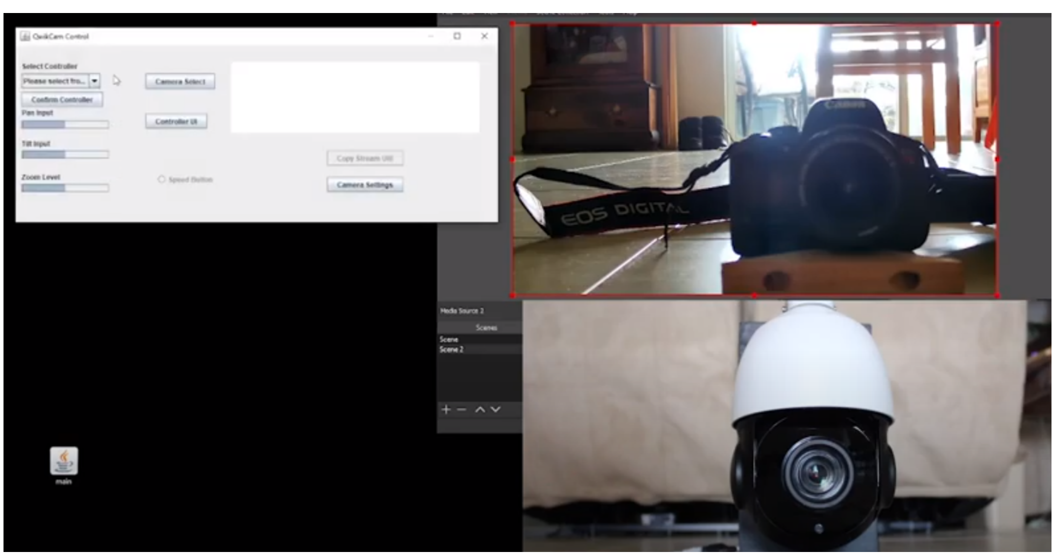


Figure 52: Camera and controller connectivity

Once this connection and communication is met we can then begin to stream and record the software via the OBS streaming software that can easily be downloaded.

12.3.2 Qwikbox setup

Moving onto the Qwikbox setup, this is what will power and run the POE capabilities to our camera while streaming the ethernet connection back to the laptop. The finalized setup and components inside of our Qwikbox are the handbuilt 12V battery pack with a recharging cable and connectivity to our POE injector, a handbuilt POE autonomous voltage controller and regulator to power our injector, and the IEEE 802.3 at/af poe injector to power the camera. Each of these components are velcro to the inside of the box as to not damage any of the components inside during transmission and moving if needed. This can be seen in figure 53 below.

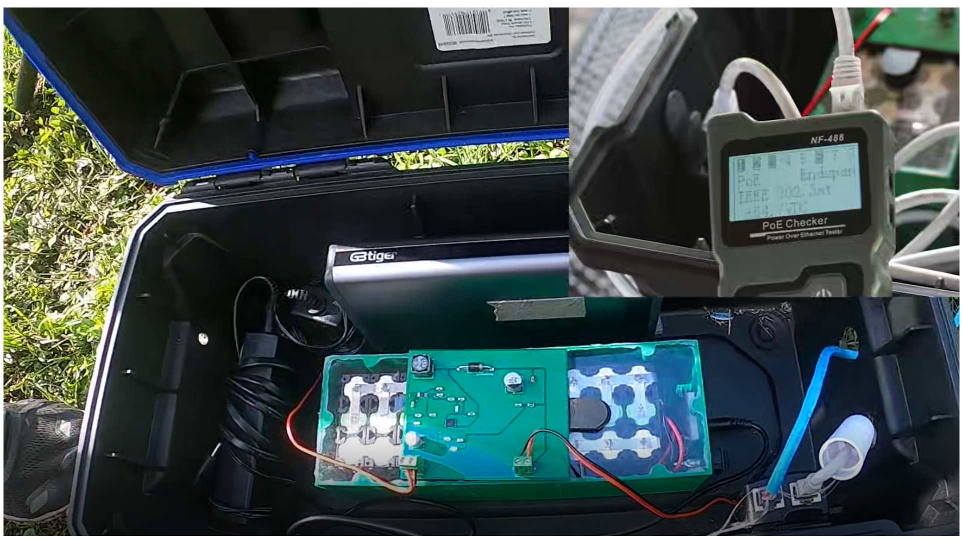


Figure 53: Qwikbox Setup

We can see all of the components in figure 53 in action and outputting IEEE 802.3 at/af standards. This is successfully running a singular ethernet cable to the camera for power and communication meeting the requirements and requests of our sponsor.

We can see the camera and tripod that was previously discussed in an earlier section completed and being power by our qwikbox in Figure 51. This completes our system as a whole and completes the QwikCam project while meeting every specification and requirements possessed by our sponsor.

Overall, we wouldn't change this design for any of the previous ones we considered and we hope that our sponsors feel the same way about this design.

On behalf of group 16 we would like to thank all of the support and backing we have received from our sponsors at Qwikcut and from the professors at the University of Central Florida and our Advisor Professor Richie. Without their commitment and belief in our group none of this would have been possible.

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