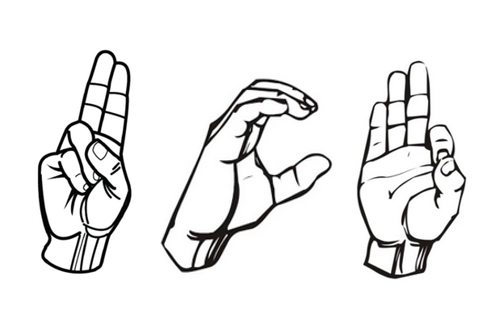
**ASL Motion to Text Projection**

**The University of Central Florida**

***College of Optics & Photonics***

***College of Engineering & Computer Sciences***



**Initial Project Documentation**

**Senior Design I**

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# Executive Summary

Today there are an estimated 6,500 languages spoken across our world. Some of these languages are very popular and considered world languages, like English, Spanish, French, and Chinese for example. There are also smaller languages which are spoken within a small group of people. However, together all these languages are part of what makes the world we live in a diverse and beautiful place. Every language is surrounded by its own rich and personal culture. One language which is very interesting is Sign Language. Sign Language is almost like its own category of Languages.

Growing up in the United States one can be naïve to how diverse and complex sign language is. One of the first things to understand about sign language is that not every region of the world shares the same sign language, in other words, just like there are many orally spoken languages, there is also many different sign languages. In America we are exposed to ASL (American Sign Language), but there are nearly 300 spoken sign languages across the world.

Learning a different language has been a very important aspect of American Education. Most people growing up in the states were either exposed to a language course as early as elementary school, others taking courses in high school, and most taking some type of foreign language course in college for graduation requirement. Learning Sign Language can be just as rewarding if not more than learning any other language. The Deaf Community has a very rich and beautiful culture. This culture and way of life has been passed down generationally in the Deaf community. Sign language involves gestures, body language, the lowering and raising of eyebrow, the opening of one’s eyes or mouth, it is a very complex way of speaking. Most languages speaking is done by words coming out of the mouth, but Sign Language uses almost every part of a person to speak.

The main goal for this project is to create a device which can be used mainly as a teaching device. The project will try to create a device which can be one of the first steps to teaching, at a large scale, people how to speak in sign language. The prototype for this project should be able to analyze a hand gesture (using a glove with various sensors) in real time and then convert it to text, then through wireless communication display the text on a power efficient projector. For testing, only the alphabet will be used in this project. Prospects of this project are that it will work with more complex sign language gestures in order to teach the language more in depth.

This type of project can also be combined with face recognition feature in the future to capture the full embodiment of sign language. ASL will be the primary sign language which will be focused on this project. There are several ethical and technological constraints with this project, but the goal of the group is to handle them with respect and understanding. We hope that this project is one that can be marketed towards Colleges and Universities to enrich their Sign Language curriculum. Learning is always easier when the student is interacting and seeing their action produce results immediately. Hopefully, this project can create an interactive and educational device which can be used in many settings.

# ProjectNarrative Description

Here we discuss a general overview of our project description, purpose, and goals. We discuss what was the motivation we had for choosing this project design and what we hope to accomplish at the end of this project design. The expectations for our project design are laid out and we discuss our expected function for the device. In this section we include our project engineering specification, our house of quality, project block diagram, and our though and design process. This is the first step in our design process, coming up with the project and laying down specifications and expectations.

## Project Description and Goals:

The purpose of this project is to create a connection between deaf people speaking sign language and others who do not. There exists several translation devices and service for most known languages, our goal is to create a device which can be used for translating sign languages. We plan on creating a wearable glove which will be used to sign the alphabet using a combination of flex sensors, force sensors, an accelerometer, and software (most likely using AI) to create a device which will translate the American Sign Language alphabet to visual letters. The implementation of photonics would be incorporated into our design by building a projector from the ground up. For the projector, different light sources are being investigated to create the image needed to be displayed and are mostly interested in using a blue laser as the light source.

The goal for this project is to create a mechanism which translates sign language swiftly and correctly. The margin of error required for the project needs to be minimal with a eighty-five percent level of accuracy. The reason for such percentage is because the device could be further implemented to accommodate the translation of different types of sign languages, although this would not be accomplished during the completion of the project due to various factors like costs and time. Our main goal is to create the beginning of what could be a larger project. Our design will only translate ASL and will only do alphabetical gestures/letters.

Another goal for this project is to ensure the device is energy efficient and cost effective. Energy efficiency is very important, as the glove is designed to be powered by a battery source, the source needs to last for a few hours to allow for the translation of the language. A device of this type would not be useful if it would only be operational for a few minutes at a time. If this is not possible, then the glove loses its efficiency and value. As for efficiency in terms of the projector, it must be very efficient because the projector needs to connect automatically to the gloves to gather the information needed to display to the viewer or user.

To do so, the consumption of energy needs to be taken into consideration, as users do not want to utilize equipment that consumes a lot of energy and is not cost effective. There is a personal reason for the device to be cost effective because we are funding this project on our own without sponsorship. There is also a practical reason which goes back to us wanting to create a marketable device, and production price is always a strong factor. Our final goal is to create a glove that is comfortable to wear and when used, allows for a clear and seamless translation from the glove to the projector.

## Project Motivation:

The motivation for this project began with the discussion of various project ideas. The ideas revolved around the idea of helping people in one form or another. After various considerations and thoughts, the discussion of the deaf community came to mind. One of the team members came up with the idea of learning of rare and important skill which is sign language. It did not take long before the realization we have all come across a situation where we tried to communicate with someone of a different language and how difficult it was to get information across. Then did the thought of how hard it must be for someone speaking sign language to be in those type of uncomfortable situations.

We originally wanted to build a project which would translate speech to sign language and display that to an LED board. But this seemed too simple and unchallenging. This idea was not also a good enough project for the photonics member in our team, as it did not incorporate the requirement needed from her department. After further discussion we came across projects that created a glove which could be used to translate live sign language to text. We researched this and concluded on making our own version of this project. Our team also wanted to make this a big display, for anyone to be able to read, this way the person speaking (in sign language) could talk to an individual or a large group. We hope to create a device that represents the deaf community, to give them a platform for their voice to be heard.

We also believe that providing education towards the deaf community is important. We all agreed if we are able to create a device which can be used to better the education of both sign language and the culture of the deaf community it would be a great goal to achieve. With this in mind we would like our project to have an educational aspect to it, giving others the opportunity to learn from a design like ours. We imagine this being used in large classroom settings to teach sign-language, or even in private small groups for a more intimate understanding of the culture surrounding sign-language.

## Project Function:

The function of our project will be live physical sign language being translated to text and then displayed for all to see through a team-built projector. The glove should be made of strong and durable material to hold the electrical components without tearing or falling apart. The glove also needs to be comfortable and flexible in order to allow an easy maneuver of the user’s hands when they are making the hand gestures. The plan for our project is to use a mixture of sensors combined with AI software to accurately capture the sign language letters.

Flex sensors will be used to determine which fingers are being bent and to what degree. These sensors will have varying resistance depending on how they are bent, and this input will be used to help determine which letter is being signed. We hope to also implement the use of an Accelerometer, gyroscope, or both. This implementation will even more accurately help determine which letter is being signed as it will record any movement that the hand makes while wearing the glove. The accelerometer will be more used for large gesture or if the whole hand is twisted or moved to another position. Since the flex sensors will learn finger

movements, we do not plan on using the accelerometer to determine fingers movement.

We are also looking into force sensors to help distinguish more letters, some letters in sign language are very similar and have small differences. Force sensors send input when the sensor is pressed, and if we accurately place these in touch hotspots then our results can be more accurate. All of these components will be connected to a PCB which we plan on having installed directly on the glove. The PCB will carry most of the electrical components which will receive the inputs.

Our project device should take the movements and finger placements as our input, this input will then be translated by software in our MCU into text. The text will then be displayed through our projector device. Both the glove and the projector will communicate via Bluetooth to have a wireless connection. The concept is someone who owns the glove can connect to one of our compatible projectors to display the sign they made. If time permits, we would also like to update our projection device to have a speech to sign language functionality, this way the deaf party can use the glove to speak and then translate, and the other party can translate a spoken language and then have the sign language equivalent projected.

Overall, the project design will consist of three separate parts (or sections). The first being the glove which will be used by a wearer and gestures will be made by the wearer, creating input through the sensors. The second part is the machine learning trained model which will take the inputs and using a prediction model make a prediction of what letter was made by the wearer. The third part is the projector which will take this prediction and display it. The three parts need to work as one smooth machine, even though there are different stages being done at different parts, to the viewer, everything runs concurrently together. This is the function we are expecting for our sign language glove.

## Requirements Specifications**:**

This project requires having a glove as the input to be connected wirelessly to a microcontroller which connects to a projector that would display the desired output. The glove is required to have an accelerometer and seven flex sensors. The accelerator is needed to accurately measure the hand’s movement. Five flex sensors would be on each finger to detect motion and the two other sensors would be for tilting and rotating. These sensors would detect precise signals from the hand’s movement while avoiding any distortion. The detected signal would then be processed by a microcontroller on the glove. The glove’s microcontroller would transmit the processed data via a Bluetooth or Wi-fi module to the projector’s microcontroller which is going to process the data received through a built-in software (Python). When the data is processed by the microcontroller, it would be able to send the information via HDMI to the projector to display the correct output.

Our team chose to build an LCD projector that would consist of three colors red, green, and blue (RGB). The RGB LCD would be combined by a light source through a prism and a filter to get a colorful image that can be viewed on the clear projected screen. This display setup will utilize back projection, which means that the images produced would be inverted. The projector lens requires to have a short focal length to project a clear image on a screen that will be within 5 feet from the lens, for that reason a short throw lens will be incorporated. The light source within the projector is a blue laser that should produce an image that is luminous enough to view under the circumstance of standard ambient room lighting.

## Requirements SpecificationsTable**:**

For our project design we are required to list specification of how we expect our glove to function. It is important that we set these specifications for us to know how we want to build our devices and if they are meeting the requirements for us to consider it a successful and working project. There are two types of specifications we are setting for our project, the first are general specifications which will help is in the overall design of the project. The second is the engineering specification which will help us set an expected function of our project. Since our project consist of two devices, the glove and the projector, we must consider both of these in our specifications. Below are the two tables which will be used as a reference for testing our project and to determine if it is meeting our expectations.

|  |  |
| --- | --- |
| General Specifications | |
| Glove Flexibility | Glove needs to be flexible to gesture all 26 letters |
| Electrical Components | The electrical components must all fit on the glove, and stay on without falling off |
| Sensors | There needs to be a flex sensor for every finger, at least one or two force sensors, and an accelerometer on glove |
| Input Data | Glove with sensors must be able to create input data |
| Software | Software must be able to receive data and translate |
| 26 Letters | Project must be able to predict all 26 alphabetical letters |
| Projector | Projector must display the correct (or predicted) letter |

Table 1: General Specifications

|  |  |
| --- | --- |
| Engineering Specifications | |
| Glove Power source | Battery:Lithium ion |
| Duration | 2 to 3 hours duration |
| Glove Consumption | Low ≈ 70 mWatts |
| Force Sensor | Touch should significantly change output |
| Bluetooth Connectivity | Show connection successful and data is being received on other device |
| Projector size | ≈ 10 x 10 x 7 inches |
| Projection distance | ≈1-2 feet between the projector and the screen |
| Flex Sensor | Bend Resistance Range: 45K to 125K Ohms, represented by change in output voltage |
| Projector consumption | 173 W |
| Projector Display Resolution | 1280 × 800 pixels |

Table 2: Engineering Specifications

We have listed expected specifications which can be visually demonstrated during our demo of our project. As of now these are our engineering goals for our project, and we hope to hit them all. We will demonstrate at least three, most likely the ones which demonstrate the best engineering features of the device as a whole. We understand that with any project actual outcome can be different than expected; therefore, we will try to reach these specifications, but are open to changing them to meet the actual output of our device.

## House of Quality

Below in *Figure 1* is an engineering development tool named the House of Quality (HOQ). This tool incorporated both engineering and consumer tradeoffs which is useful in market considerations throughout the products system life cycle. This tool can be used in different phases of development; this HOQ was focused on requirement specifications for the initial phase of development. The axis of this tool incorporates the engineering requirements (Horizontal) and the consumer requirements (vertical). The plus and minus signs show each categories’ correlation to the product that would contribute a positive output in the perspective of each axis. The up and down arrows also show the correlations of each of the intersected categories

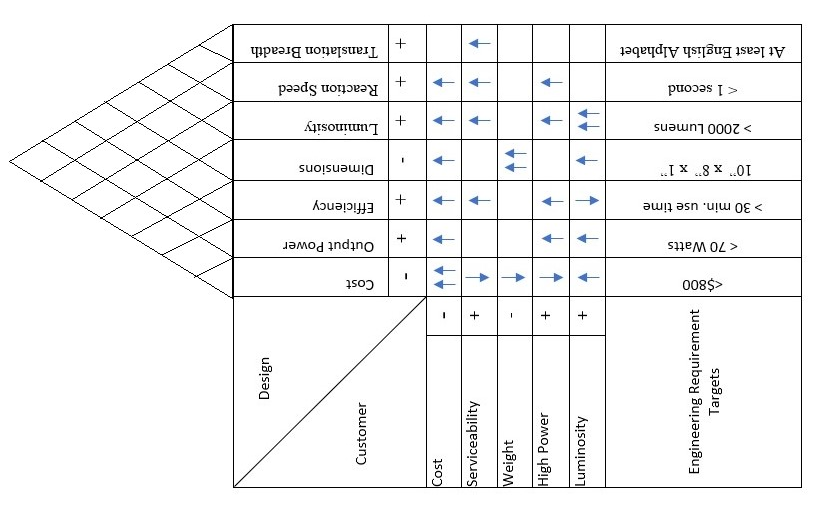


Figure 1: HOQ

## Project Considerations:

Fully Identifying and understanding what a project entails is paramount to deciding what project needs to be chosen. Gathering requirements by evaluating and prioritizing factors can be done via a decision matrix. This is needed as the decision to do this project must be based on several criteria. With cost and time being the most important factors. For this matrix, a rating scale for each criterion is established.

For our project decision we each brought an idea to the table. We didn’t know where to start so we believed it was best to brainstorm for our first meeting. When we started discussing which ideas could work, we considered first if it was practical and possible. We are very limited on when it comes to resources and experiences, because of this we didn’t want to bite more than we could chew. Second, we considered which projects had a considerable amount of design to them. Our main goal was to have a design heavy project which could be created in two semesters time. Other factors taken into consideration are Sponsorship, Experience/Familiarity with the project, Social Value, Motivation and Educational Role. Once we had these factors all laid out, we needed to decide which project would be best, this is where the decision matrix came in.

The logistics of the decision matrix is a numbered rating system. A rating between 1 to 9 was chosen, with 1 being the worst, 5 being moderate and 9 the best. We all discussed how we would rate each aspect of the projects considered and would come to an agreed upon number for each aspect, for it to always be a team decision. After careful considerations, the Sign Language Display was chosen as the lead project for the group.

A computer screen capture

Description automatically generated with medium confidence

Figure 2: Decision Matrix

## Project Block Diagram:

Here we have broken down the roles and responsibilities of each team member in our Project Block Diagram. Our diagram was designed to have a smooth and clear flow of not only who was responsible for which aspect of the project, but how these different parts and components will interact and flow with one another. The power supply can be seen as the starting point of our diagram, for without power our project will not work no matter how well it is designed. There are two direction the power supply goes, one towards the glove and the other towards the projector. The endpoint of our diagram is the display which will be where the projectors output is seen. To make it simpler for anyone to understand we color coordinated the responsibilities/roles and used a legend so anyone can know which team member oversaw what part. Since our project consists of electrical, computer, and photonics engineers, the work was divided accordingly to each team member’s area of study first and their preferences second.

Diagram

Description automatically generated

Figure 3: Block Diagram

# Project Research

The second part of our design process, and possibly the most important, is the research of our actual project. Research is a very important aspect of engineering because we are usually designing something which will be used by a customer or user and will need to make sure we are making an ethically appropriate device, and also using the best possible tools and resources to do so. Without proper research we risk making a flawed design, choosing components which may not meet our desired specifications, and even do something illegal. Below we breakdown our project research step by step.

## Project Research Breakdown:

The research for our project has many levels. First the research begins with finding similar projects that have been done by other students or companies (usually students). We needed to really understand how these projects have been approached in the past to learn how to improve and avoid possible mistakes encountered by others. We also found it very important to research the community our project could be targeting or/and impacting. We are designing a project around a language which also embodies a culture, therefore we needed to understand a. the language and b. the people who speak this language (whom we need to ensure we are respecting and considering).

Secondly, once we have researched the logistics of our project, we need to research how we will be designing the actual project. Our design will be broken down into three main portions, The Glove, The Software, and The Projector. Both the Glove and the Projector will have hardware components; therefore, we need to research which components are needed, and possible choices for these components. We break each of these down in this section with all the possible components we found from varying companies and why we would be interested in them. For the software research we don’t necessarily need any physical component, we will be looking into possible programming languages, how we plan on building our software, and what environments we will be using the code our software.

## Existing Similar Projects and Products:

Through researching our project idea, we found that there are various implementations of our project. There have been a few similar projects done in UCF as well as other universities. In the research for this project, it was very important for use to look into very similar past projects. Our design is going to require many different components, looking into what other teams considered would be a very big help towards the right direction. We also expect there to be several steps of failure along the road of building this design, which is why researching failures and mistakes of past projects is also essential.

Our project will consist of a two-part design. We will be designing a sign language translating glove which will wirelessly communicate with a laser powered projector, which we will also be building. Keeping this in mind, it was very important for use to look into past design for both types of projects. Another goal for doing this research is to possibly find areas to improve on past projects. Since this design is a learning process for all of us involved, we also wanted this research to help us develop this project smoothly and on time.

### Sign Language Glove, Monica Lin and Roberto Villalba, Cornell University

This was a project done by a group of students at Cornell University in which their goal was to create a glove which could be used to translate sign language to text. Their concepts and planning were very similar to ours. Their overall goal was the use a glove equipped with flex sensors, contact sensors, and an accelerometer to output their sign language in text.

The hardware they used was spectra symbol flex sensors, MPU-6050 three axis accelerometer and gyroscope, ATmega1248 MCU, and copper tape for contact sensing. Their project also used I2C, UART, and ADC. For software, their project used Python to implement Machine Learning.

There were many decisions the group had to make on both hardware and software. Being aware of these decisions and why they went the direction they did is very important for us to make the best version of our project. They had to decide on whether the machine learning computation would be done in the MCU or the PC, ultimately, they decided to do the computation on the PC, since machine learning computation can be very demanding. Another important decision was whether the glove would use a button or a switch to start receiving input or if they would leave it idle. Idle was the direction they went by implementing “nothing” and “relaxed: predictions. The MCU they used for their glove did not have its own I2C library, the group solved this by using Peter Fleury’s public I2C library.

This group broke down their expenses for the glove, their total cost was less than $100.00. They did not list the price for some components, we are assuming they had these components already or had them donated. This is helpful for us to have a grasp of what our cost might be at a minimum level. Our design looks to have more components and functionality; therefore, we are expecting a higher cost.

The project did face some constraints, which we can look at to prepare ourselves for any similar issues or work to solve them. One constraint the group faced was not being able to implement wireless communication in time. The glove they created still worked but did not perform any wireless communication, we plan on working on this early because wireless communication is an essential part of our project. The group also had issues with signs that had very little differences, like “u” and “v”. They used contact sensing with copper tape. We plan on using a similar approach, but also would like to use a different type of hardware to accomplish accuracy in this issue.

### Sign-a-Loud

Sign-a-loud was a project we came across while researching our project online. This is a project designed by two University of Washington students, Thomas Pryor and Navid Azodi, in which they also designed a glove which would record movements and hand positions and transmit these to a processor which would translate the data. We found this very interesting because the design is very similar to what we are looking to do for our project. They use sensors to record data, and Bluetooth to wirelessly transmit it to a microprocessor. The students actually won an award for their design and were also motivated by an interested in creating a connection with the deaf community. Unfortunately, besides an overall discussion of the project, not many details were given on their exact design process, images are shown which are helpful to reference. We will look more to the images to have a visual expectation of what we would like our glove to look like, and also to know what design has worked in the past.

### High 6, UCF Group 6 Senior Design Project, Spring 2014

We also though it was important for us to find a similar project designed in our university. High 6 is a sign language glove project designed by group 6 students, they began their project Fall 2013 and completed it Spring 2014. For their overall design they also created a glove with various sensors and electrical devices which would communicate via Bluetooth to a mobile app. The app would be in charge of doing the translation and displaying the computed results. The group designed their project to be power efficient. They implemented this in the power supply of the glove, being considerate of the power consumption on the mobile device and using Bluetooth smart for a low power Bluetooth device.

As far as components go, this project included SEN-10264 flex sensors from sparkfun.com, tekscan standard flexiforce sensors for force sensors, MPU-6050 3-axis accelerometer and gyroscope, and ATmega32u4 for the microcontroller. This design also used I2C and ADC implementations. As mentioned above the group opted for wireless communication using Bluetooth v4.0 low energy technology.

The group also decided that a mobile device via an app would be the main source of communication and output. They used Java for programming the app, since they chose to use an Android device and Java is the native Android development language. For gesture recognition this project uses machine learning and implemented the Hidden Markov Method. Since we plan on using machine learning for our project this is a methodology which we will look into as well to see if it is something we can also use or if we would want to go in a different direction.

This group did not mention their budget or expenses, but they do discuss their project limitations and present a lot of data on why they chose their hardware and software. This project is shows to be an excellent reference point for us to finalize our design specifications.

### Project Differences

One of the goals of our project is to make our design different than any one similar design out there. As engineers we want to be able to either improve on an existing idea or take one in a completely different direction. For our project we would like to see our glove as a translation device which can be used for someone trying to speak to a non-deaf person, or as a possible teaching device. This is the reason we are building an energy efficient laser projector along with our glove. We envision our device being used in large settings where the glove can be used to make sign languages gestures, and the results are immediately projected for everyone to see, in any type of setting. We strongly look forward to implementing a wireless communicating device but are going to steer away from a mobile app, because we see our device being used in settings with small to large groups.

## Sign Language

In this section of our research, we did some research on what it is to be part of the deaf community, what sign language is, and how our project can be seen by the deaf community, and its possibly impact on them. We needed to understand how our project would be interpreted and present itself to the main people it would be affecting. This was very important so we could design our glove with correct and ethical goals in mind.

### Understanding Sign Language

Our project is being designed with the purpose translating live sign language into text for the purpose of communication or education. Therefore, we found it essential to understand sign language, and determine which sign language we will use. Like audible languages there are a large variety of sign languages, the difference being that English is considered the universal [Audible] language, while there is not a single universal sign language. This needs to be considered while we are creating our project. Because of time constraints we would not be able to design a device which can be used in various sign languages and would need to use one which can be identified in our region of the world. We need it to be very clear that our device will only work for ASL, but we look at our device as one that can be changed to work in the necessary sign language, and in the future might be compatible with a large number of different languages.

### American Sign Language (ASL)

We chose ASL for several reasons, it is the sign language that our group is aware of at the time of project conception, in our region it is easier to find someone who speaks ASL over someone who speaks British Sign Language or Chinese Sign Language, also because we want it to be a device to initially teach ASL. ASL is also important to use because we can use it to translate our alphabet, which is important because of fingerspelling. Fingerspelling is a very important part of learning and using ASL.

It is when the English alphabet and words are written out with their fingers, these letters are then associated with hand signs or gestures. Even though ASL is not English, they use the same alphabet, which makes it more practical for our group since we all speak English. BSL was considered, since it is also a popular sign language, but the alphabet uses two hands, this would make a project a lot more complex, therefore we chose to stick with our original choice of ASL. Below *Figure 4* shows ASL alphabet (which our glove will be learning) and *Figure 5* shows BSL alphabet to show the distinct differences.

American Sign Language is also thought in most high-schools and universities across the country, making this a perfect implementation if our main goal is for possible educational purposes. It could be a tool provided to teachers to help their student learn more interactively. Our project is very constrained by this limit, it would be too difficult to design a glove which can translate more than one language. There would need to either be a very strong machine learning algorithm involved, or a possible switch to switch between translation languages. As a future goal for our project, it would be interesting to find a way to make it be able to translate more than one sign language. A glove with that type of capabilities would be a lot more useful worldwide.



Figure 4: ASL Fingerspelling Alphabet

**Obtained from** [**www.nidcd.nih.gov**](http://www.nidcd.nih.gov)

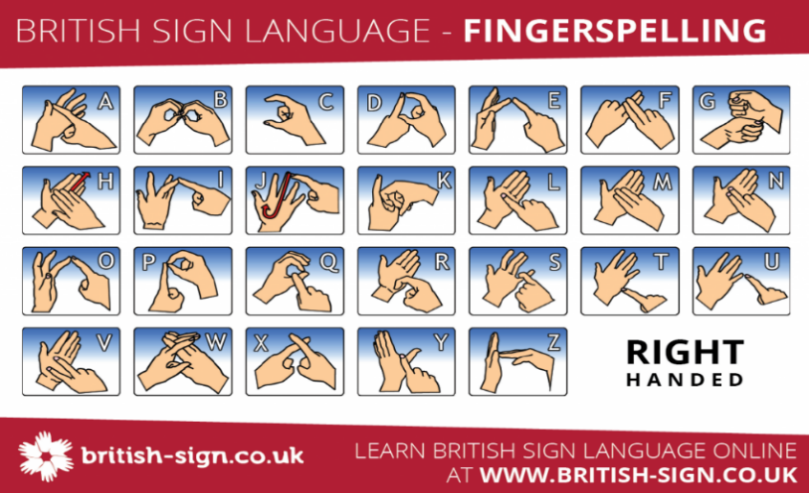


Figure 5: British Fingerspelling Alphabet

**Obtained from** [**www.british-sign.co.uk**](http://www.british-sign.co.uk)

## Considering the Deaf Community

With this project there were some ethical issues we had to consider as engineers and scientist. First, we want to represent the Deaf Community correctly and accurately. Our project strives to create a device which can help in certain social situations, or to be alternatively used as a teaching device. However, we do not want to make this device in a way to take away from the cultural richness the Deaf community has with the connection they build across their use of sign language. We also find it necessary to be aware of the difference between a deaf person and a person considered hard of hearing, due to illness or accident. Our project is not a solution for all who are hard of hearing, especially someone who is able to orally speak coherently and read lips, this device would be of no use to someone like that.

However, if said person was trying to learn sign language to better communicate with the Deaf community then this device could be a great teaching device. We also learned that whenever dealing with the Deaf community there are terms that are no longer accepted to describe a person in said community. Political correctness is very important when dealing with a project such as this which either targets a specific community or strives to learn from it. Terms like hearing-impaired, deaf-mute, and deaf-and-dumb should not be used to describe someone of the Deaf community. These are old terms that were used in past times to describe someone of this nature, but besides this section we will refrain from using such terms.

There is also a large culture around the Deaf community and how to live with sign language. I believe we have to be very careful to not cross any cultural lines. In no way are we looking to change or “improve” a deaf person’s life. These people have grown up learning and living like this, generation through generation. Our project hopes to learn from said community and understand their culture better in doing so, and help others come to an understand of it as well.

### Controversy Involving Sign Language Glove

Unfortunately, the idea of creating a device which can help communicate with the Deaf community is not a new one. This ideology has been around for a long time, and the idea of using a glove to assist a deaf person communicate with a non-deaf person has been tried many times. In an article published in 2017 by Michael Erard title “*Why Sign-Language Glove Don’t Help Deaf People”* [1] it discusses how this idea has been implemented several times, but has not once truly represented the Deaf community, and there hasn’t been one that is designed to help a deaf person over helping a non-deaf person. With the limitations of our technical experience, and without the necessary funding our project might fall into many of the negatives this article talks about. This article goes into detail about how a device as the one we plan on building lacks the ability to fully capture what ASL or any sign language means. The article also states that it is important to realize, as the project designer, that we are not the users, that research into how society has limited the Deaf community, and how they have struggled in being shown even the simplest human rights. The article was very eye opening, because it states very heavily that in the past, present, and most likely future, devices as these have never benefited the Deaf community as much as it has the non-deaf community.

## Project Design and Component Research

Here we begin our research into the components which will build both our glove and our projector, and we also research how we plan on implementing the software portion of our design. We start with the glove hardware research, followed by the software research, and finish off with our projector hardware research. We decided to structure it in this manner because our project will flow in that direction, Glove -> Software (translation) -> Projector. For many of our components when doing our research we looked into two to three options for the desired component. We needed to do this to ensure we were getting a component that could meet our design requirements, our budget, and was available to order easily and quickly. This comparison also helped us in understanding how to components operated and what we should expect from them.

### Glove Hardware Research

For this project we are building a two-part device. There will be a glove with its own electrical components which will communicate with a projector with its own components as well. Each device requires that we research the different parts and find ones which will work best for our desired output. This portion of our research details the various specs of different parts we have considered using in our project.

### Glove Components Research

For our glove portion of the project, we are going to need 5 main components. First, we need to find a physical glove which will be made from a strong yet flexible material. We also need the material to be able to have components either sewn onto or compatible with a strong adhesive. The glove will also need to have flex sensors attached to it, these flex sensors need to be either long enough for each finger, or affordable enough to have at least two per finger. The flex sensors also need to be able to send distinguishable input to be able to determine how much each finger is being bent.

Force sensors are also being considered for this design since we have found that in ASL there are a few letters which have very small differences, so small that flex sensors alone might not be able to differentiate them. An accelerometer and gyroscope will help with letter like C and O, where the palm will not be facing forward, and letter like J and Z, where there is an actual motion involved. Power Source is necessary for any electrical device, and our project should ideally be portable. Wireless communication will also be a key component in this project. Finally, all of our electrical components will communicate with a microcontroller all connected to a PCB.

#### Glove material/build

For our project we need a glove which we will be building on for our sign language glove. For the selection of our glove, we are looking for a durable material that is both comfortable and flexible. It is very important for our glove to be made of a strong material because it will be the home of a lot of electrical components and needs to do so without falling apart. The glove also needs to be durable since this prototype of will be enduring lots of testing to ensure that our device works correctly. Since our glove will be worn device, it needs to not only be comfortable for the user, but also flexible enough to make distinguishable sign language gestures, also needs to be light weight to not be too heavy on the user with all the electrical components. We looked into a few different gloves made of different materials in order to find one that would work best for this project.

#### OZERO Leather Work Gloves

The Ozero Leather Work Gloves are designed to be used for heavy duty work. The gloves are made genuine cowhide leather, making the glove wear, cut, and puncture resistant. The gloves are designed using Gunn Cut and Keystone Thumb designs, which allow flexibility. The gloves also have elastic wrist which is helpful to make sure the glove stays on. These gloves weight 5 oz according to the product specifications. The specifications also mention these gloves are a good fit for men and women. The Ozero’s are mainly designed for construction, line, or garden work; therefore, some of the features of these glove won’t be as important for the project. These gloves can be order directly from Amazon for about eleven dollars and be delivered fairy quickly.

#### Goatskin Leather Drivers Glove

The Goatskin Leather Drivers Glove can be found at Grainger for about ten dollars and can be delivered fairly quickly. Goatskin leather is durable while staying flexible. This type of leather is known for resisting abrasions, tears, and water damage. Being that these gloves are drivers gloves they are usually more formfitting than workers gloves. Having a flexible build is also an important feature for drivers’ gloves. These gloves should be able to work well with our project, especially for making distinguishable gestures.

#### Dex Fit Nitrile Work Gloves

The Dex Fit Nitrile Work Gloves are made of nylon, spandex, and nitrile rubber. The glove specification mention that this glove has a snug fit and feels like a second skin. These gloves would be the most comfortable and lightweight gloves. The gestures will be most distinguishable using gloves of this material. They are designed for everyday use; therefore, they can work well for our project. Since this glove is made with a knit design it has comfort and dexterity; however, there is more of a chance the glove will wear out faster with continuous use.

#### Nike Dura Feel VIII Golf Gloves

The Nike Dura Feel gloves are professional sport golf gloves which are available on Amazon. They are made from premium leather on palm and thumb and synthetic leather on back of hand. Nike products are known for their durability, and being a sports glove means it should be able to endure some form of use/abuse while staying intact. This glove is available in several sizes, ranging from small – X-large, and this is because the designers want the glove to be form fitting and snug. The gloves are also reviewed to be extremely comfortable, very flexible, and remain cool (no sweaty hands) even in the humid Florida heat.

### Sensors

From its Latin origin, the word sensor means “to perceive.” A sensor can be defined as a device that collects data from its surroundings and situation. Sensors are useful in our daily lives. They are objects that can detect elements in the environment without being detectable itself. That is, individuals interact daily with objects that contain sensors without their awareness unless they are reminded or educated about the subject. Among gazillions of other simple utilities such as detecting motion at the front door of a supermarket to automatically open a door when it senses a human approaching, sensors are also very important tools that help ensure safety, prevent health and environmental hazards, and unnecessary accidents such as car crushes.

Just as the human body has senses of smell, taste, hearing, touch, and sight, sensors can detect physical inputs which stimulate it to a response according to its function to give a specific output. There are several types of sensors, for instance, motion sensors, as its name implies, which detects movement; temperature sensors measure the changes in temperature, proximity sensors notice the presence of an element that is close to it, light sensor or photo sensor, alcohol sensor, infrared sensor (IR Sensor), touch sensor, color sensor, humidity sensor, tilt sensor, smoke and gas sensors, ultrasonic sensor, etc. However, in this project we will be focusing on giving more detail on four types of sensors only: flex sensors, force and touch sensors, and accelerometer or gyroscope.

#### Flex Sensors

For this project flex sensors will be an integral part of the design and function of the glove. The sensors will play to major role in sending input signals to determine which gesture or letter the user us trying to communicate when using the glove. The flex sensor we chose to use for our final design will need to have distinguishable value from when fingers are flat, partially bent, and completely bent. Since fingers only bend in one direction the flex sensor does not need to necessarily read from multiple bend directions, but such feature can still be considered. There are different types of flex sensors. The most popular being conductive ink printed flex sensor, there is also optical flex sensors and capacitive flex sensors.

Optical flex sensors use an LED light at one end of either a clear plastic strip or tube, and LDR (light dependent resistor) at the other end. This type of sensor works in the same fashion as the others, except that the resistance value is determined by how much light is received by the LDR. Unfortunately, it is extremely difficult to find these types of sensors on the market, and any available can be extremely expensive.

Conductive ink printed flex sensors work like all other flex sensors, the one we considered for this project was the Spectra Symbol Flex Sensor. As the name suggest, this technology consist of a resistive strip printed with conductive ink, which is then placed on a flexible plastic substrate. These sensors are the most available in the market and have been used in past technologies. Conductive ink printed flex sensors work as typical flex sensors, holding a steady flat resistance with variance depending on brand. As the sensor is bent its resistance value will increase, the larger the bend the larger the resistant output. Since these types of flex sensors are readily available in the market, they can be found in different lengths, which can be very useful for this project.

Capacitive flex sensors are the third type of sensor that was considered for this project. The design for this type of sensor consists of two elements, each having comb patterns of conductive material. These elements are placed on dielectric materials which are then combined so that the combs of the two elements are interlocked. These sensors work very similar to the others by changing the output value depending on the bend. The largest difference between these sensors and the other two is that the capacitance is what is being measured as the changing output. These sensors are usually advertised to have zero drift, meaning that they would have more accurate output. These sensors are available to purchase but are very expensive compared to the Conductive Ink Printed.

##### Spectra Symbol Flex Sensor

Spectra Symbol Flex Sensors are a patented technology. It is claimed that these were used in the Nintendo Glove. Even though the Nintendo Glove is considered a failed technology, it is reassuring to know these works well in glove technology. Spectra Symbol specifies that these sensors have a wide range of uses from robotics and gaming to medical technology. Spectra Symbol offers two different lengths for their flex sensors, either 2.2 inches or 4.5 inches. This is very useful because it allows for a more realistic hand design. The index, middle, and pointer fingers are usually much longer than the pinky and thumb, having two size options can be very useful in the glove design.

According to the datasheet the sensors use angle displacement technology, which gives varying resistant values depending on the angular bend. The sensors lifecycle is greater than one million uses (according to the datasheet), allowing for plenty of testing, and long lifespan in real world application. The temperature range is from -35ºC to 80ºC.

The datasheet mentions that the flat resistance (not bent) is 10K ohm, with a resistance tolerance of ±30%. Bending resistance ranges from 60K ohm – 110k ohms, allowing for plenty of distinction between different bent ranges.

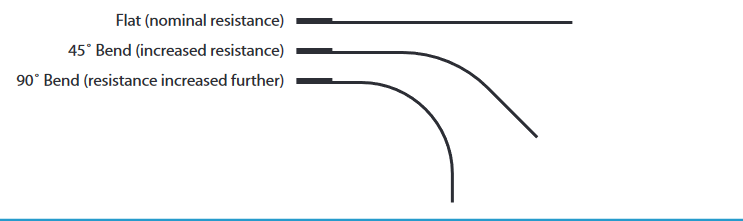


Figure 6: Flex Sensor Bend Resistance

The power rating for this flex sensor is 0.5 Watts continuous and 1-Watt peak. This sensor can be purchased from various vendors at varying prices, making its availability ideal. In *Figure 6* is an image from the Spectra Symbol datasheet illustrating how to bend angle affects the output resistance for the sensor.

##### BendLabs One Axis Flex Sensor

Bendlabs is a technology company which specializes in motion and flexible technological solutions. Their website offers two different flex sensors, 1-axis and 2-axis. For the purpose of this project the 1-axis is sufficient. The Bendlabs 1-axis flex sensor measures angular displacement with repeatability of 18º. This sensor is stated to maintain reliability and stability over time due to its zero-drift technology. As for material it is designed with elastomer silicon, which is a soft flexible material, allowing for unrestricted flexing and bending. The silicon design also makes the sensor water and weather resistant; this is the only sensor that is designed to withstand water/weather exposure.

The angular outputs of these sensors are repeatable and precise, without regard for the path, bend radius, and possible strain. The life cycles for these sensors are greater than one million, allowing much room for testing and real-world application. The datasheet also mentions that this sensor has ultra-low power consumption, with an active run current down to 78uA. The datasheet for this sensor specifies that the output uses I2C. The largest benefit of using these sensors over others is the ultra-low power consumption, and they will most likely produce the most accurate and precise results. The price is probably the largest negative for these sensors, they can only be purchased directly from Bendlabs for $49.00 per unit.

##### Home Designing an Optical Flex Sensor

The third option that was considered for our flex sensors was to create our own optical flex sensors. Since optical flex sensors are not readily available to purchase, the idea of building our own was looked into. There is plenty of resources available to find designs for an optical flex sensor, and the components are abundantly available. Since the sensors consist of an LED source, clear plastic medium (strip or flexible tube), and LDR, these sensors would be our most economical choice.

However, for the project we need steady values, which can be repeatable with small variance. Another issue with sensors as these is their output value is dependent on how much light is received by the LDR. Therefore, in testing we would have to make sure ambient light is consistent and repeatable (possibly similar to the lighting where to project will be demonstrated).

#### Force Sensors

Force sensors are commonly used in different types of technologies according to their usage. Force sensor is known as a device that can collect various applied mechanical forces such load, strain, tensile, pressure, and compressive forces to then change it to output signals. Usually controllers, computers or indicators process the electrical signals to measure the scale of the force to give informative values that operators can understand based on the collected input.

When force sensors collect data, the data are required to be as accurately as possible to reduce the percentage error. calibration is an important aspect that is performed on force sensors to give more accuracy on the data. There are diverse types of force sensors that exist depending on the technologies that they are being used on. The three force sensors that are commonly used are the Load Cells, Strain Gages, and Force Sensing Resistors (FSRs). [2]

##### Load Cells

Load cells are sort of force transducers that are used to collect and then convert different forces like tension, compression, pressure, or torque into electrical output signals. It is generally used to collect and measure weight pressure of an object that is translated into electrical digital signals that can be read and recorded to give a desired output. They are usually built-in electronic devices as weight scales.

Several types of load cells can be found in the market with different purposes depending on the usage. These are obtainable types of load cells that exist: Pneumatic load cells, Hydraulic load cells, and Piezoelectric crystal load cells, Inductive load cells, Capacitive load cells, Magneto strictive load cells, and Strain gage load cells. This paper however will not explain in depth the types of load cells mentioned above since it is not the focus for our project. [3]

##### Strain Gages

Strain Gauges (gages) is a type of sensor used to measure deformation or stress of an object. The electrical resistance from the strain gauge varies because of the application of external or internal forces. The electrical resistance is measured after force, weight, tension, or pressure is decoded into an electrical pulse. [4]The strain gauges are made of thin foils where the top part will agonize with tension and the bottom part will agonize with compression. The strain gauge gives resistance’s values between the two foils which can be converted to voltage’s values via an ADC to read and to measure the deformation or stress. It is principally used in numerous industries to measure force and stress of gear found in power plants, refineries, automobiles, and ships to give an electrical output.

##### Force Sensing Resistors (FSRs)

Force sensing resistors are piezoresistive sensing tech made of semi-conductive materials which are implanted between two layers that are parted by a space that detect physical pressure when squeezed. The resistance of the two terminals of the Force sensing resistor changes when physical pressure is applied on it. The harder force or pressure is applied to the sensing surface, the more the resistance decreases which allows more current to flow in the device. The Force sensing resistors are known for not having a steady accuracy and precision when used multiple times or repeatedly. The measurements may vary from 10% or more as stated on Adafruit's website. they do not require a lot of power to operate since they have a low power consumption. These devices are easy to use, and they are available at low costs. These sensors are usually very thin, measuring in the millimeters, therefore can be almost unnoticeable to the glove user. [5]

### Accelerometer/Gyroscope

An accelerometer is a device which can measure acceleration, changes in motion. This device will allow you to quickly incorporate movement sensing or detection. The way an accelerometer works is when there is a force applied, either by a change in motion or vibration (these can be considered the acceleration), this force then causes a “mass” to squeeze the piezoelectric material. When this “squeezing” occurs an electrical charge is created which is proportional to the force applied. The mass is constant in this device; therefore the change has occurred in the acceleration, making the charge proportional to the acceleration [6]. *Figure 7* below shows a visual example of how an accelerometer works to create a charge.

A picture containing shape

Description automatically generated

Figure 7: Accelerometer Visual

Obtained with permission from: [**explainthatstuff.com**](https://knightsucfedu39751-my.sharepoint.com/personal/jidekay_knights_ucf_edu/Documents/explainthatstuff.com)

Accelerometers are used in large scale projects like rocket launches and found in devices used every day like our very own cellphones. They have been used in navigation systems to help create accurate instruction when driving, as well as with vehicle airbag technology to detect if there is sudden crash for quick responses. With the current growing technology, many accelerometer devices now have separate or additional features of bits of precision or additional scaling options or capabilities. For our project an accelerometer can be very useful because there are a few letters in the ASL alphabet that require movement, J and Z specifically. An accelerometer being implemented will help with the model training and will be useful to produce better output results overall.

According to the Britannica dictionary, a gyroscope is a device containing a rapidly [spinning wheel](https://www.britannica.com/technology/spinning-wheel) or circulating beam of [light](https://www.britannica.com/science/light) that is used to detect the deviation of an object from its desired orientation. Gyroscopes can be used in simple or small-scale systems such as used in our project, and in more complex systems or large scale like an Inertial Measurement Unit (IMU), a gyrocompass, Attitude Heading Reference System (AHRS), and Inertial Navigation System (INS) which have different performance based on their scale. They are even found in our very own smart phones today, which is how some of the games and apps work. Gyroscopes are devices mounted on a frame and able to sense an angular velocity if the frame is rotating. Gyroscope devices exist in many classes or types depending on the involved technology or based on an operating physical principle. Generally, gyroscope device falls within one of three categories of types of gyroscopes [7].

There exist Ring-Laser Gyros, Fiber-Optic Gyros, and Vibrational Gyros. Ring-Laser is used in large scale device like rockets and aircrafts, Fiber-optic falls in the middle, and Vibrational are for smaller usually handheld devices. We will be looking into Vibrational for it will be enough to meet to specifications for our project. Figure 8 illustrated how vibrational gyroscopes work. It starts at a static state of no movement, but when there is a change in rotation there is then a vertical vibration created. This vibration causes the vertical drive arm to bend, which produces a sensing motion in the sensing arms. Finally, a potential difference which will be outputted as an electrical signal. For our project implementing a gyroscope will be useful in the cases where the hand orientation is not up-right. Some letters in ASL require a different orientation of the hand and this can be useful for gesture prediction accuracy [8].

Diagram

Description automatically generated

Figure 8: How Gyroscopes works

Obtained with permission from: [**epsondevices.com**](https://knightsucfedu39751-my.sharepoint.com/personal/jidekay_knights_ucf_edu/Documents/epsondevices.com)

#### LSM6DSOX 6 DoF Accelerometer and Gyroscope - STEMMA QT / Qwiic

This accelerometer plus gyroscope 6-DOF IMU sensor is specifically placed on a compact breakout board which has voltage regulation and level-shifted inputs useful for both power and logic devices. This IMU sensor has 6 degrees of freedom - 3 degrees each of linear acceleration and angular velocity at varying rates within a respectable range. For the accelerometer, it is specifically designed with ±2/±4/±8/±16 g at 1.6 Hz to 6.7KHz update rate specifications.

For the gyroscope: It has ±125/±250/±500/±1000/±2000 dps at 12.5 Hz to 6.7 KHz. There are also some nice extras, such as built-in tap detection, activity detection, pedometer/step counter and a programmable finite state machine / machine learning core that can perform some basic gesture recognition. For interfacing, you can use either SPI or I2C - there are two configurable interrupt pins. With the I2C interface, you can easily connect it up with two wires including the power and ground wires.  It has [SparkFun qwiic](https://www.sparkfun.com/qwiic) compatible [STEMMA QT](https://learn.adafruit.com/introducing-adafruit-stemma-qt) connectors for the I2C bus. For advanced usage, you can attach additional devices to an external I2C/SPI port - used for optical image stabilization.

#### ADXL337 Accelerometer

The ADXL337 accelerometer device is a low power, small, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The board measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

It gives the user the capability to selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins, as well as, selecting the Bandwidths to suit the application, with a range of 0.5 Hz to 1600 Hz for X and Y axes and a range of 0.5 Hz to 550 Hz for the Z axis. Its analog to digital (ADC) reading can vary depending on whether it is using a 3.3V or 5V power source which may affect the values that the microcontroller reads [9]

### MCU

One of the components that is vital to our project is a microcontroller. According to the Merriam-Webster dictionary, a microcontroller is an integrated circuit that contains a microprocessor along with memory and associated circuits and that controls some or all the functions of an electronic device or system. It is a compressed microcomputer built to control the functions of embedded systems in products such as robots, appliances, vehicles, or any product that reads, stores, measures, calculates or displays information (EIT).

A microcontroller is comprised of a processor (also known as CPU), a non-volatile memory (also known as ROM) for the program, a volatile memory (also known as RAM) for processing data, a clock and an input/output control unit and other peripherals that will see in detail shortly (pcmag). The screenshot below gives the perfect example of what is included in a typical microcontroller.

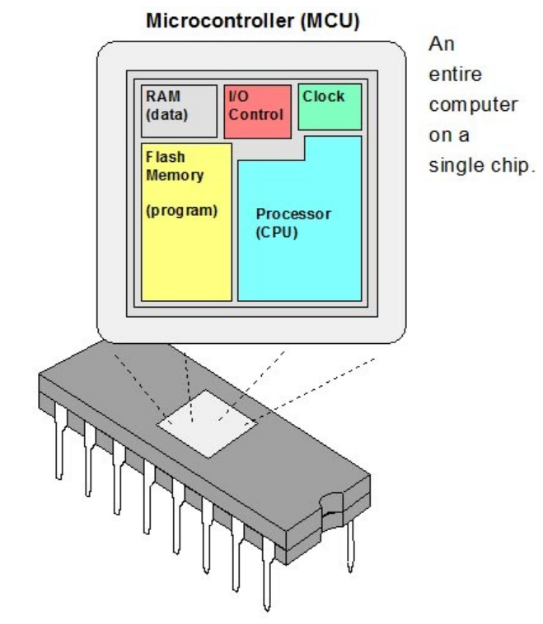


Figure 9: Image of an MCU taken from <https://www.pcmag.com/>

According to EIT, the basic structure of a microcontroller is comprised of the following items:

1. **CPU**: known as the brain of the microcontroller, a CPU is the device used to fetch data, decode it, and execute the assigned task.
2. **Memory**: a microcontroller uses volatile and non-volatile memory
3. Non-Volatile memory: also known as ROM or Flash memory is used to store program source codes.
4. Volatile memory: also known as RAM is used to process data
5. **Input/output ports**: I/O ports are used to interface or drive different appliances such as printers or monitors.
6. **Timers**: are used to control timing or counting operations within the microcontroller. The main operation of the timers is pulse generation, clock functions, frequency measuring, modulations, making oscillations, etc.
7. **Serial Ports**: give serial interfaces amid microcontrollers and various other peripherals such as parallel ports.
8. **ADC (Analog to digital converter**): is used to convert analog signals to digital ones. The digital signal production can be utilized for various digital applications including in gadgets used for measurement.
9. **DAC (digital to analog converter**): this converter does the opposite of what an ADC converter does. In other words, it converts digital signals to analog ones. This converter is used to supervise analog appliance such as DC motors
10. **Interpret Control** is a controller used to give delayed control for a working program. The interpret can be internal or external.
11. **Special   Functioning   Block:** used for microcontrollers that are built for special products such as space systems, or robots. This block provides additional ports for special operations.

Microcontrollers are divided into different categories according to their memory, architecture, bits, and instruction sets. Different microcontrollers would be compared against each other, to determine the ideal one to be used for the project. We would also be considering an MCU that can be used in conjunction with the LCD and other components included in the projector.

#### MCU 1: Texas Instruments MSP430FR6989 Mixed-Signal Microcontrollers

Texas Instruments MSP430 architecture is a 16-bit ultra-low-power consumption microcontroller built for low cost and explicitly for embedded applications. It is designed with a RISC architecture that provides multiple registers that can be loaded with input data for concentrated application to give a high performance in calculation. These registers facilitated the calculations’ operations that are stored afterward into RAM as results. The MSP430 brings forth full real-time capability at tremendously ultra-low power consumption. The CPU and Some other functions turned down the average power consumption to the lowest when functioning. it retains specific low-power peripheral functions active the rest of the time to well-maintained power.

In Addition, the MSP430 has an active mode of operation where the CPU is used with its capabilities to accomplish calculation, decision-making, I/O functions, and other actions that need to be executed. MSP430 has various generations which can be distinguished by device types, series, and feature sets. It has embedded microcontroller that has a 16-bit RISC architecture up to 16-MHz clock, 51 instructions, 7 addressing modes, and constant generation with an extensive supply voltage range from 1.8V up to 3.6V with SVS levels that limit the minimum supply voltage, and single cycle registration operation. It also has bit, byte, word processing, and a 1MB unified memory map.

These are just a few features this specific microcontroller has: an ultra-low power mode optimization, and intelligent digital peripherals, etc... This part focuses on the MSP430FR6989 launchpad which has an embedded LCD microcontroller. This controller does not have any type of wireless capabilities like Bluetooth or Wi-fi built-in. However, it can have more design options counting USB, RF, LCD interface, and encryption with the 40-pins BoosterPack plug-in module headers connector that can help by adding external boards to extend the launchpad’s functionality. It features the EZ-FET emulator for programming and debugging, and EnergyTrace++ technology support for real time current measurement. Even if it lacks wireless connection, it can still be used when chosen for any type of project with its extended addressing modes which can improve code density and have faster executions.

#### MCU 2: Texas Instruments CC3200 SimpleLink™

The Texas Instruments CC3200 is the first programmable Wi-Fi development board with high-performance microcontroller to develop a variety of Wi-Fi enabled products. With only a single integrated circuit (IC) on board, the MCU has the capability to let users revolutionize a whole application because of its high performance. The cc3200 strong Wi-Fi SoC allows users to effortlessly connect to the internet to read and translate data without any companion’s board. It has a 40-pin Booster Pack plug-in module headers connector that can easily connect to numerous technologies and peripherals. It has simple programming and debugging with a direct micro-USB connection from launchpad to PC by FTDI based JTAG emulation with serial port for flash and programing. It has 8 bits or 1MB serial external flash and has on-board an accelerometer and temperature sensor.

The board includes a chip antenna and can add an external antenna by U. FL connector. The power-management subsystem has an integrated DC-DC that holds up a wide range supply voltage from 2.1 to 3.6 V and has an advanced low-power mode that can hold a 2xAA battery for over a year. It has a clock source up to 40.0-MHz crystal with internal oscillator and 32.768kHz crystal or external RTC clock. The cc3200 has many features which would make it a preferable candidate for any project that would require wireless connections like Wi-Fi.

#### MCU 3: Texas Instruments CC2652RB SimpleLink™

According to Mouser electronics, the Texas Instruments CC2652RB SimpleLink™ Wireless Microcontroller is a crystal-less BAW multiple protocol with 2.4 GHz wireless connection with built-in Bluetooth. It is designed to support Thread, Zigbee®, BLUETOOTH® 5.1 Low Energy, IEEE 802.15.4, IPv6-enabled decent objects (6LoWPAN) since it has an integrated TI Bulk Acoustic Wave (BAW) resonator technology. The CC2652RB frequency stability operates at full voltage 1.8 V to 3.8 V at temperature -40°C to 85°C because of the RF high performance. It has 10 years senectitude performance and greater enduring clock steadiness which makes it a reliable product to use for a project at a low cost. According to TI website, it has a 12% on an adjusted Bill of Material (BOM) and saves a significant space when implemented on a PCB. The CC2652RB has low power consumption with an external regulator mode of 1.7 to 1.95 V and its normal consumption as mentioned above which basically it is like most of TI’s MCUs function. It has 256KB of ROM for protocols and library purposes. This MCU is a great choice for any type of project that requires usage of wireless connections to accomplish a desired goal. [10]

#### MCU 4: Texas Instruments CC2652RSIP SimpleLink™

According to Texas Instrument’s the CC2652RSIP which is part of SimpleLink™ Wireless Microcontroller platform is an integrated DCDC components, balun, and crystal oscillators which contains a small 7-mm x 7-mm certified system-in-package module 2.4GHz. The device comprises a single core software development kit which is easy-to-use development environment because of the mutual MCUs that it is housing. It contains Wi-Fi, Bluetooth Low Energy, Thread, Zigbee, Sub-1 GHz MCUs. The device permits users to reprocess 100 codes whenever designing the requirement modification because of the one-time incorporation of the SimpleLink™ platform that empowers users to augment multiple amalgamations of the device into a required design.

The device has extended battery life radio receiver applications with low reserve current of 1 µA with full RAM preservation as mentioned on the Texas Instrument’s website. It operates at frequency stability of complete voltage from 1.8 V to 3.8V at temperature from -40°C to 105°C due to the industrial temperature arranged with minimum exigence current of 11 µA. It is going to be favorable for any design that requires any type of wireless connection because of its exceptional radio responsiveness and durability with its Bluetooth’s performance at low energy.

#### MCU Comparison Table

Below in *Table 2* we break down the differences between the four microprocessors we researched for our project. We wanted a visual representation of what each offered for easier decision making when it came time to decide which microprocessor to order. The main factors we considered are price, processor speed, data-bus bandwidth, protocols, volatile and non-volatile memory, SPI, IO pins, and operating temperature and voltage. Our ultimate decision would be based on which met the specifications we wanted and was readily available to order. There were other differences and similarities amongst the microprocessors we researched, but these were the most valuable specifications for our project needs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Microcontrollers | MSP430FR6989 | CC3200 | CC2652RB | CC2652RSIP |
| Price | $3.817 | $4.312 | $1.990 | $8.274 |
| Processor Speed | 16-MHz | 80-MHz | 48-MHz | 48-MHz |
| Data Bus Bandwidth | 16-bit | 32-bit | 32-bit | 32-bit |
| Protocols | None | Wi-Fi 2.4 GHz | Bluetooth Low Energy 5.2 | Bluetooth Low Energy 5.2, Thread, Zigbee 3.0 |
| RAM | 2-KB | 256-KB | 88-KB | 88-KB |
| Non-volatile memory | 128-KB | 16-MB | 352-KB | 352-KB |
| SPI | 4 | 1 | 2 | 2 |
| I/O Pins | 83 | 64 | 31 | 32 |
| Operating Temperature | –40°C to 85°C | –40°C to 85°C | –40°C to 85°C | –40°C to 105°C |
| Operating Voltage | 1.8 to 3.6V | 2.1 to 3.6V | 1.8 to 3.6V | 1.8 to 3.6V |

Table 3: Comparison between MSP430FR6989, CC3200, CC2652RB, and CC2652RSIP

### Bluetooth Module

Whether or not a Bluetooth module would be used is still very much into consideration and depends mostly on the MCU to be used for this project. Also, further investigation into the advantages and disadvantages of different Bluetooth modules that can be used in conjunction with the MCU would be made. There are two modes to a Bluetooth module, single or dual mode, but we would be focusing on the dual mode Bluetooth technology. The single mode utilizes the Bluetooth low energy module, and the dual mode uses both Bluetooth low energy and Bluetooth classic energy.

|  |  |  |
| --- | --- | --- |
|  | HC-05 Module | CC2564MODA |
| Operating Voltage | 4V to 6V | 2.2V to 4.8V |
| Peripherals | USART | UART, PCM |
| Default baud rate | 9600bits | 115.2kbps |
| Operating Current | 30mA | 169µA (master) & 199µA (slave) |

Table 4: Bluetooth Module Comparison

#### HC-05 Bluetooth Module

There are two modes of operation a Bluetooth module can operate in Command and Data mode. The command mode allows for communication with the Bluetooth module to configure and change parameters like Baud rate, module name and various other default device settings. The data mode allows for the transfer and receiving of data from other Bluetooth enable devices. The HC-05 module operates at a voltage range of 4V to 6V and has a range of not greater than 100m. It also works with a Universal Synchronous/Asynchronous Receiver/Transmitter (USART), and operates in either master or slave mode or both.

#### CC2564MODA

The CC2564MODA is a dual-mode Bluetooth and serves as a module and transceiver. It is made by Texas Instruments, and it is based on TI’s CC2564B dual-Mode Bluetooth. The CC2564MODA has two variants equipped with integrated and external antenna. It supports up to 10 simultaneous connections and it is its best in class for RF performance, transmission power, receiving sensitivity and blocking. This Low energy Bluetooth mode is at the top of its game and is a very well-designed module. It is Bluetooth 4.1-compliant, and is compatible with most MCUs, and provides twice the range of any other Bluetooth-low-energy module.

### Analog to Digital Convertors

One very important aspect of our project is the data being created by the sensors and received by the microprocessor. This data is the cornerstone of our project, because without this data we cannot do translation and therefore our project will not work. With this in mind, all of our sensors will be creating analog data. For example, the flex sensors will change its resistance due to a change in the bend angle, and will then have a different output voltage. This output voltage will be our sensor data. In order to use this we would need to convert the analog signal into a digital one. The microprocessor can only receive and understand digital data, therefore conversion is extremely important. If an ADC is needed in our design it is important that we know we have enough pins in our MCU to be able to include this. We plan on using a flash ADC for our project because it is the most commonly used and is known for its speed. We will make sure the include an ADC in our PCB design if it will be the overall best option for our project outcome.

### Power Source

A power source is the root of incoming electricity source like an outlet, battery, or generator. Without a power source our glove and projector will not be able to function, even with a flawless design in every other aspect. For this project, we need two different sources of power as we are required to supply electricity to the components that will make up the glove for sign language and the projector. In this section, we are going to look at different ways to power up these two devices and we will compare some researched power sources. For the glove part, we are looking to use batteries that can be rechargeable as the glove would not need a huge amount of electricity to operate. The glove will also want to be portable in the sense that we don’t want it to have to be near an outlet to work. Factors like the life of the power source in sense of one time use and overall use are important, and the weight needs to be on the lighter side. For the projector, we will either need a powerful rechargeable power source or need to have it directly powered through an outlet connection.

#### Lead-Acid

Lead acid is a battery source that has been around for over one hundred years. It is one of the first commercially used rechargeable batteries, and even though it has some age on it, it is still used today and will be continue to be used for the foreseeable future. Its main appeal is that it is dependable and cost effective, considered to be cheap. However, they do not have a long life-cycle. On average, these batteries will see a life cycle of two hundred to three hundred cycles between charges and discharges. Another negative about lead acid is they can take long periods to charge, some taking up to more than fifteen hours to achieve a full charge. With this being in mind, lead acid will most likely not be a battery source we use for our project, even though it will be the most cost effective we might use it full life cycle in testing, and charging could be a headache.

#### Alkaline Batteries

Alkaline Batteries are usually used to power up small devices that don’t need a lot of power to function. They are the types of batteries used in calculators or remote controls as they have a reputation of lasting longer. An Alkaline Battery is an electrochemical cell that is an instantaneous process that converts chemical energy to electrical energy. Rechargeable alkaline batteries are utilized in devices that are intermittently used with low drainage. These batteries can be entirely rechargeable according to the way manufactures designed them. However, Alkaline Batteries no matter their size from AAA to D, they will naturally give 1.5V which is not favorable for our project as we need at least voltages range from1.8 to 3.6V for the glove.

#### Ni-Cad (Nickel Cadmium)

Nickel Cadmium batteries were probably the first rechargeable battery which would be used in place of single use AA or AAA batteries. They are considered older technology when it comes to rechargeable batteries and can be found for fairly cheap prices in today’s market. Like stated earlier they do come in standard sizes of AA or AAA and usually each battery cell provides 1.2V, so if we used three, we would have 3.6V. Nickel Cadmium batteries are known for have a long life cycles, most over 500 cycles, others even reaching 1000 cycles. They are considered easy to recharge and for that reason are still used in some technology like cordless phones and RC cars. The largest negative with these rechargeable batteries is that they are known to suffer from memory issues. If the battery is put the charge before completely depleting its previous charge it will affect the memory of the charge; therefore, the battery will hold less of a charge. Charging memory issues could hinder our testing and presentation, so if we use these, we will need to have several back up batteries just in case. Since Ni-Cad are older technology, we will most likely go in another direction, but if they are readily available compared to the other options they could be used for our project.

#### Ni-MH (Nickle Metal Hydride)

Nickel Metal Hydride are the newer rechargeable batteries which come in standard sizes, like AA or AAA, and are far more favored than Ni-Cad. They are considered to be more expensive than Ni-Cad, and actually cost double the price (Ni-Cad can go for $1 for an AA, while Ni-MH will go for $2) meaning it will affect our budget slightly more. These batteries provide 1.25V per cell, which finds itself right between Ni-Cad and Alkaline (1.2V and 1.5V respectfully). This means we will still need to use three of them, possibly four to get our desired voltage. Nickel Metal Hydride usually have a decent life cycle, most up to 500+ cycles. Ni-MH are easy to recharge as well, but do suffer from self-discharge, which means they will lose charge even if not being used. Ni-MH does not often suffer from memory charge issues like Ni-Cad, meaning we don’t have to be as conscious of when we put them to charge. Compared to Ni-Cad we would prefer to use these rechargeable batteries; they have all the pros with less cons. The self-discharge should not affect our project presentation, as long as we make sure to always charge the batteries before the day, we plan on using them.

#### Lithium-Ion

Lithium-ions are fall in the classes of rechargeable batteries generally used to power up devices that need substantial electrical current usage. According to ION Energy, these batteries were established in the 1970s and were first commercialized in Japan in 1991 and now they are used to power smartphones, laptops, and electrical vehicles, etc. In addition, as the utilization of these batteries are now in high demand, the safety of them have increased and basically encompass less contaminated metallic elements than other batteries. The basic fact of how these batteries can be favorable is that 1 kilogram of lithium-ion battery can store 150 watt-hours of electricity compared to NiMH Battery pack that has merely 100 watt-hours per kg or Lead Acid battery that has only 25 watt-hours per kg as motioned by ION Energy. We can see that a lithium-ion can be in handy as they can be small, and still store a significant amount of energy. A typical lithium-ion battery has a voltage range from 3.0 to 4.2V when it is fully charged, and it has a lifespan of about two to three years, or 300 to 500 control cycles as mentioned on Home depot’s website.

#### Projector Power Source

For the projector, we will not need a battery as a source of power since several projectors are known to consume a lot of energy. A typical projector can consume up to 173 W for a normal power consumption mode and 118 W extended or quiet power consumption mode when it is plugged in an outlet which has basically voltage range 100 to 240 VAC ±10% supply power. Therefore, there is not a lot to research on for the projector as we could only use an outlet as our power supply that can provide us with enough energy to power up the projector that we are going to build depending on our specifications. In addition, some of the projectors operate at a frequency rate of 50/60 Hz.

#### Rechargeable Battery Comparison Table

Below is a comparison table we made for the rechargeable batteries we researched. We know we wanted to go in a rechargeable battery route and that is why alkaline batteries aren’t included. We noted the key features that differed amongst the batteries and would be important for our project design. We looked into common uses, voltage, the average life-cycles through both charging and recharging, power density, charging capacity, price, and which batteries are affected by charging memory loss and self-discharge. We made our decision for which rechargeable battery we would use based off these features and specifications.

|  |  |  |  |
| --- | --- | --- | --- |
| Battery Type | Ni-Cad  Nickel Cadmium | Ni-MH  Nickel Metal Hydride | Li-Ion  Lithium Ion |
| Uses | Older technology  Wireless Telephone | Small Device: flashlights,  Battery operated games | Larger Device  Laptops, smart-phones |
| Voltage | 1.2V | 1.25V | 3.0V – 4.2V |
| Life Cycles  Charge/recharge | 500+ avg cycles | 300+ avg cycles | 300+ avg cycles |
| Memory Charge Effect | Highly affected | Slightly affected | No affect |
| Self-Discharge effect | Slightly affect about 20% of time | Highly affected about 30% of time | Insignificant affect about 3% or less |
| Power Density | 60 Wh/Kg | 100 Wh/Kg | 126 Wh/Kg |
| Charge Capacity | 1000mAh | 25000mAh | Varies  ~750mAh for cellpone battery |
| Price | Avg. $1.00/battery | Avg. $2.00/battery | $10.00 and up |

Table 5: Comparison between Ni-Cad, Ni-MH, and Li-Ion

### Wireless Communication

Wireless communication is one major medium or mode of communication that involves the transfer of information without any electrical conductor and is used for both long and short distances. Wireless communication is implemented in many forms of communication such as radio communication, broadcasting and mobile radio systems that use radio frequencies, Infrared, laser light, and other forms of wireless transmission of data or signal. The two most popular wireless communications are currently the wi-fi and Bluetooth wireless communication.

Bluetooth uses radio waves to transmit data in both short and long distance because of its low maintenance, no additional wiring costs, and easy mobility of devices. Wi-Fi consists of a wireless local area network and connects portable computing devices way easily to the internet. These types of wireless communication are ecofriendly, and their connection speed is always getting improved alongside improvement in its communication security of data transfer. This section is going to be focusing on giving few details on Wi-fi, Bluetooth, and infrared communication.

#### Wi-Fi

Wi-Fi works as most other wireless device, by sending signals using radio frequencies. Wi-Fi frequency is measures in Gigahertz, while most other wireless devices (car radio for example) use Kilohertz or Megahertz. Wi-Fi compatible devices either work in 2.4GHz or 5GHz, hence todays 5G speeds. This high frequency allows Wi-Fi to send a lot of data between devices, allowing high speed actions like streaming, gaming, web-browsing, etc. Usually in a person’s home Wi-Fi is connected via a router, the router is like the central hub where devices connect to get internet connection.

Wi-Fi’s main purpose is to connect devices to the internet, and one Wi-Fi connection can connect multiple devices/users. Wi-Fi has a wider range when it comes to connecting devices. In a home alone a Wi-Fi signal can connect to devices far from the router, and additional devices like Wi-Fi range extenders can make the connection go even further. There is also the viewpoint that since Wi-Fi connects devices to the internet it has the longest range of connectivity, i.e. a device in Florida can communicate with a device in Hong Kong with both connected to the internet via Wi-Fi. Wi-Fi is considered to have high security measures by adding additional layers of security protocols, such as WEP, WPA, WPA2, and WPA3.

#### Bluetooth

Bluetooth has been around since the 1990s and is used to connect devices together wirelessly. Bluetooth also uses radio wave to send signals between devices to establish a connection. Bluetooth is designed to be used in proximity devices, on average between 10ft to 30ft in distance. Bluetooth operates in Gigahertz as well, and usually stays in the range of 2.45GHz. Bluetooth is also great when it comes to power consumption, since the range is not far it uses very little power. When using Bluetooth, the radio waves are divided into 79 channels. The various channel allows for multiple devices to be connected via Bluetooth without interfering with each other’s connection.

Usually, the number of devices which can share a Bluetooth connection is not large, on average there can be no more than eight. When it comes to security Bluetooth uses encryption to secure the data being sent over the connection. Bluetooth also has device level protection – which only allows trusted devices to connected via Bluetooth. There is also service-level security – which restricts what certain things can do with other devices over the Bluetooth connection. Bluetooth connection form a piconet topology and will have one master and multiple slave devices. The master will control the devices, and the slaves will do as the master requests. For the purposes of this project our group decided Bluetooth would work best for our goals. We do not need a long-range connection, and the data that is being sent over will not be sensitive such that it would require higher security measures.

#### Infrared Communication

Infrared Communication is found widely in most homes. Devices like TV, Fans, or other devices which have a remote most likely use infrared communication. Infrared works via the transportation of invisible lights, which send signals which cause an action to occur. For infrared to work the sender and receiver must be able to receive the light. This type of technology is too simple for our project, we worry it will not be able to send all the data over the communication line. We also worry that there is a lot of room for communication interruption, if the light signal is blocked then the signals will not be received, therefore our devices will not be able to communicate amongst themselves. Distance wise this technology does meet our project standards, but that would be about it.

### Wireless Technology Comparison Table

In *Table 5* we have provided a table with key differences we learned about between infrared, Bluetooth, and Wi-Fi technology. The table shows the comparison in specifications amongst all three technologies. This is a table we could reference when making the final decision for the integration of components for our project design. What mattered most to use was the uses of the wireless technology, its operation frequency, power consumption, and connection type, we also included a few other features to get a clearer picture of the differences between the devices.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Infrared | Bluetooth | Wi-Fi |
| Uses | Television, electric fans | Cellphones, speakers, most wireless devices | Smart-technology, computers |
| Operation Frequency | 300-mHz – 400 gHz | 2.4gHz | 2.4-5.0gHz |
| Complexity | Low | High | High |
| Power Consumption | Low | High | High |
| Range | 1m | 10m | >100m |
| Security | No security | Light encryption  Low security | High Security |
| Connection Type | One connection, light connection | Piconet, up to 8 devices | Point Host, many devices |

Table 6: Wireless communication comparison table

We broke everything down to better understand which device would work best for the purpose of our project. We were leaning more towards Bluetooth or Wi-Fi but still wanted to consider a third option. Everything included in the table are the features which either matter more for our project purpose or differed amongst all three options. It was important for us to make a side-by-side comparison of our wireless communication option to make the most reasonable decision for our design.

### PCB

Printed Circuit Boards (PCB) are the building blocks for all modern technology and electronics. Today a PCB can be as simple as a single layer board, which can be found in most household electronics. Advance technologies with many features, like smart devices have multilayer PCBs, most smartwatches having 6 layers for example. Super computers and servers are extremely complex and can do very large computation have had up to 60 layered PCBs. Essentially a PCB will act as the foundation for any electronic device and gadget which will be where most if not all other electrical components will be attached to.

Even though there are other ways to begin testing a project, like prototype boards or breadboards, a PCB is essential for a project which expects to be seen as serious, organized, and functional. From a broad point of view there are two main types of PCBs, being rigid and flexible. However, on average, 90% of PCB manufactured and ordered are rigid, while flexible will only account for 10% at most. Flexible PCBs are interesting because they are allowing for bending and flexing, if the technology would require it. There also exist a hybrid of both types of boards, referred to as rigid flexible PCBs. There type of boards has portions which remain rigid, but also has a portion which allows for flexion.

When looking at a PCB one can expect to find various electrical components, all connected via printed copper wiring. The copper is a very important component because it is essentially how other components communicate with one another, and it is how power is transported across the board. The exact components will be determined by the expected function of the board. Some boards will be very simple with few components to perform a possible few task (sometimes even just one task), other boards can be much more complex to allow for many possible operations/tasks. PCBs are highly desirable in electronic design for a several reasons. One of the strongest benefits of using these boards is that they are small and lightweight. In today’s technological advance portability is always a highly desirable quality and using traditional wiring would not allow a lot of devices to obtain high levels of portability. PCBs are used across large industry when designing electronic devices, this includes medical, aerospace, military, industrial and commercial markets.

Another feature which makes PCBs great for project designers is that most PCBs are custom-made. Using PCB design software one can design a PCB that is specific to their project needs. There are a large variety of PCB design software, some being free for small basic designs, other for large industrial designs. Some of these are Eagle (Autodesk), Protel (Altium Designer), PADS (PowerPCB), ORCAD, among others.

Being that using a PCB design in our project is a requirement, we found it very important to find a PCB software and manufacture which would meet the needs for our project. When it comes our PCB, we want a reliable company which can deliver a set amount of PCBs with fast shipping at an affordable price. We also needed to make sure the software we used for our PCB was user friendly and could help us design a PCB which would work with the components we need for our project.

#### PCB Design Software

As mentioned above, we will be using a PCB for our Sign Language Glove and Projector Project. We will be needing at least one PCB, which will be for the glove, and potentially another for the project, even though we are considering using a raspberry pi for our projector. Even though the PCB is part of the hardware design of our final project, to get our PCB, we need to use design software to do so. Choosing the right software is very important.

##### Altium Design

Altium Design comes from the company Protel, which was established in 1985. Therefore, Protel has been creating PCB design software for over 35 years. Over the years, Protel has created and upgraded many versions of its PCB design software, currently their software is called Altium Design, and it is considered one of the best PCB design software available in the market. Altium Design advertises that it has an intuitive and powerful interface, which allows the user to connect to every aspect of the electronic design. A feature of this software is Native 3D, which can create the PCB in a realistic 3D environment. Altium Design also feature interactive routing, which allows for very fine-tuned routing, as fast as possible. Altium Design comes with every feature needed for PCB design, and possibly more features than we will need for our project alone. The company prides themselves in their customer support and providing the customers with any software updates as soon as released.

Pricewise, Altium Design possibly has the highest price tag. The entire Altium Design system can be purchased either through a term license, which will cost $325.00/month, or a perpetual license (permanent) can be purchased for $10,790. Altium does offer a version of their software with less feature, Altium Design SE, for a lower price. For this software package the price runs at $115.00/month, which is significantly lower than the other price. The SE version is a fully featured schematic editor and has a rich set (as mentioned on the website) of schematic capture features. Altium offers everything we would need to design a great PCB, but the price is more than our budget would permit. However, through further research we came across Altium Education, which allows students to use their software for free, if proof of enrollment in a STEM program or University Engineering Degree. Having this software available can be very good for the outcome of our project.

##### OrCAD Capture

OrCAD Capture is another PCB design software, and according to its website it is considered one of the most widely for creation and documentation of electrical circuitry. OrCAD was created by the company OrCAD Systems Corporation, which was establish in 1985. Therefore, this company also has over 35 years of PCB software solutions. OrCAD Capture has the option of OrCAD CIS (Component information management), which streamline component management. Their website states that with OrCAD CIS the design process can be accelerated and allows for low project cost. This software also has integrated design flows, to makes sure your connections are setup to run as smooth as possible.

OrCAD is sold by EMA Design Automation and can be purchased (perpetual license) as a standard package for $1300.00/year or the professional package for $2300.00/year. Again, these prices are above our project budget; however, EMA offers a student full access to all of all of OrCAD professional resource for free (with the validation of university student credentials).

##### Eagle

Our group leaned more towards using Eagle for our PCB design from the beginning because three out of four of us had previous experience using Eagle, Through our Junior Design Course. Eagle Features schematic capture printed circuit board layout, auto-router, and computer-aided manufacturing features. Eagle has the ability to import libraries in order to use footprints from a wide range of components needed to complete a project. The newest software is Fusion 360, which is a cloud-based platform for 3D modeling, CAD, CAM, CAE, and PCB design. Eagle runs on many operating systems, i.e. Windows, Linux, and Mac OS.

Eagle/Fusion 360 is priced at $347.00/year, which is very much more affordable than other PCB design software. Eagle does offer a free download version; however, this version is very limited, and has the potential to not meet some design requirements. We will possibly start working with Eagle, but if any constraints are encountered, we have decided to look into moving to another software.

##### Allegro

Allegro is provided by Cadence, and it is advertised as a constraint driven environment. Constrain driven means it will provide real-time visual feedback to ensure the PCB will not only be developed at fast pace, but also that it will maintain its functionality and manufacturability. Allegro also has a team design feature which allows for multiple designers to work in parallel on the same design. This feature really stands out for us, because since we are working in a team project it can allow more than one of us to work on the PCB design, even if we are in different locations. Routing is also very important to PCB design and Allegro has routing algorithms which improves the designing of both simple and complex routing. Overall, it seems as if the main goal of Allegro is to provide a functional PCB design, with feature that reduce design time. For our project time is a strong limiting factor. Working with a PCB design software that intends to reduce design time is a must. Allegro features a full development suite, even though we couldn’t find an actual price, it does require a license to use, therefore we can assume its price is similar to other PCB design software. They offer a limited version for students who register and prove they are student, but it is very limited.

##### DipTrace

DipTrace is a PCB design software which first stands out because of its trial options. DipTrace offers a 30-day free trial, with full features and libraries (many trials of only offer a limited number of features). 30 days is a good length, as many other companies only offer 7-14 days, with 30 days our group will have plenty of time to dedicate to our PCB design without having to pay for a full software suite. DipTrace also offers a free version with limitation, but not time limit on use. This was the largest attraction for us to research DipTrace, to get full functionality at the lowest cost.

DipTrace also offers great features including Schematic Capture, PCB Layout, Libraries, and 3D modeling. All these features will be extremely useful for us. Schematic capture allows for us to create a PCB directly from a schematic and vice-versa, which can help us design a very efficient PCB or schematic diagram of our device. PCB layout is our focus, and DipTrace offers manual routing and auto-routing. Having a libraries feature is essential for the PCB design software we use. There is a large probability that we need specific electrical components and being able to import a library to get the footprint is essential. 3D modeling is a great additional feature, even though it is not necessary for our final design, it is extremely useful to visualize our PCB before we order. There are several possible PCB design software, and we will be testing most of them to see which one we are most comfortable with.

## Software Research

Software is going to be a large portion of our project. We are going to have a glove with several sensors which will all be connected to an MCU. The MCU will be programmed to receive data from each sensor to essentially construct a dataset for the gesture being performed. This dataset will essentially be sent over to a PC which will be acting as the main brain for our project. The PC will have a program which will receive the data and translate it from the dataset into an Alphabetical letter. The goal is for speed and accuracy when it comes to the translation. For the MCU the programming language depends on the MCU itself, most MCU will work with a certain IDE, therefore the language used will most likely be set as well. As for the translation, we need to decide how we will implement the translation, are we hardcoding values? Or are we using some form of AI? And if we do use AI, how are we implementing it?

### Artificial intelligence

Artificial Intelligence (AI for short) has been sweeping the technological world for the last few decades. The question of what AI is exactly has always been asked. In its simplest definition AI is the objective of creating an extremely smart computer or program. The goal is for the computer/program to be able to think on its own and work almost as a human mind works. Making decision and predictions is a large part of Artificial Intelligence. AI has been around and discussed since as early as 1950 when Alan Turing created the turing test, where he attempted to ask the question of whether machine can think. AI is implemented in many field of our everyday life. AI is in our phones and smart-device, AI is in the stock-market, and AI even is how many of us see advertisements based on our likes and wonder how they appear.

Most projects and programs these days used one form or another of Artificial Intelligence. This is one of the reasons we wanted to design a project which would need some form of AI to work as best as expected. This allows us to take on a challenge which we can use for our future careers as engineers. AI is the overall circle which encompasses all aspects of itself. After that there is machine learning which is a subset of AI. In machine learning it contains its own subset which is deep learning; therefore, deep learning is also a subset of AI. Below we have created a figure of this very idea. For our project goals we will be using machine learning, but do not believe we will need to go into deep learning. We however, understand that there might be some deep learning involved an will look into it if necessary for a better overall output.

Artificial Intelligence

Machine Learning

Deep Learing

*Figure 10: AI and Subsets*

### Machine Learning Research

One of the main goals of our project is to be able to translate a sign language gesture into an alphabetical letter. To accomplish this, we could either hardcode some expected values or use some form of machine learning to learn what certain gestures will look like. Hardcoding is an option, but there are a lot of factors which can produce incorrect results, it would be difficult to always produce the same values from the sensors, and we would leave a lot of room for error. Machine Learning will be the best option for our project to produce to best output results. Machine Learning uses data and algorithms in an attempt imitate human learning, with increased accuracy over time. Machine learning uses statistical methods to train algorithms to make predictions. Machine Learning can be broken down into three important parts: a decision process, an error function, a model optimization process. Machine learning methods can be supervised, unsupervised, or semi-supervised. Machine learning has been used in real world application like automated customer service, speech-to-text systems, and computer vision for example.

Supervised machine learning is defined by using labeled datasets which are used to classify data or accurately predict outcomes from the data. Supervised learning uses a cross validation process to avoid overfitting or underfitting. It does this by adjusting weights to fit model properly as input data is fed into the model. A few machine learning methods which use supervised learning include neural networks, naïve bayes, linear regression, logistic regression, random forest, and SVM (support vector machine).

Unsupervised machine learning differs from supervised by using certain algorithms to analyze and cluster unlabeled datasets and tries to do so without human intervention. Because of the nature of unsupervised learning most of the applications using this type of machine learning involve ones such as image and pattern recognition, and exploratory data analysis. Unsupervised learning also has a few methods that are commonly used, which include neural networks, k-means clustering, and probabilistic clustering methods. Another feature of unsupervised machine learning is the process of dimensionality reduction, which is when the number of features in a model are reduces. Two common approaches to accomplish this is PCA (Principal component analysis) and SVD (Singular value decomposition).

Our project will consist mostly of supervised machine learning, and use certain methods associated with this type of machine learning. Further understanding these methods and algorithms will help produce the best outcome for our project. Our experience as a group using machine learning, or any type of AI, is very limited. We decided it was best to investigate different machine learning algorithms which could be helpful in our project.

#### Neural Networks (Supervised Learning)

Neural networks in machine learning is designed to work or “think” the way our mind thinks. The architecture for neural networks is inspired by our neurons, the neural network simulates neurons by collecting data, learning about it, and predicting outcomes. A neural network can consist of at least three neurons, which are the input layer, hidden layer, and the outcome layer.

The input and outcome layers are as they seem, but the hidden layer will consist of many neural layers. Neural networks use fine tuning, which is the weights of the connections are improved in order to produce more accurate predictions. This process occurs the more the networks learn the data. When there are many layers to the network it is considered a deep neural network (can have up to 1000 layers), and will use a subset of machine learning, called deep learning. The more layers a neural network has, the more computation power it needs, this is why deep neural networks usually require GPU’s to train. *Figure 10* illustrates a general ML neural network.

Western Governors University states that neural networks usually learn in three processes. First there is the training process, which is when the network is given a set of random numbers or weights. Here they begin their learning either through supervised or unsupervised learning. Another process is transfer learning, here a neural network is fed a similar problem which it can then reference to accelerate training and improve overall model. The third process is called Feature extraction, this is when all the data which will be fed is taken and bundling it into more manageable data sets, any data which can be seen as redundant is removed. This process can be very useful for cutting down on computation time. When implementing neural networks, it will be very helpful to keep this process in mind [11].

A picture containing shape

Description automatically generated

Figure 11: Simple Neural Network

**Obtained with permission from:** [computerhistory.org](https://knightsucfedu39751-my.sharepoint.com/personal/jidekay_knights_ucf_edu/Documents/computerhistory.org)

#### Naïve Bayes Algorithm

Naïve Bayes algorithm is a classification technique based off of Bayes Theorem. Bayes Theorem is used to describe the probability of an event using past knowledge of which conditions can be related to the event. This theorem has historically used in statistics to solve for posterior probability but has also found strong use in machine learning. Essentially the way the naïve bayes algorithm works is by identifying particular features in an event that are particular to that event and won’t be found as a feature in a different event. Naïve Bayes is useful when working with large datasets, it is known for its simplicity, and for being about to outperform other classification algorithms. As stated, before naïve bayes is based on Bayes Theorem, which calculates posterior probability, which gets P(c|x) from P(c), P(x), and P(x|c). below is an image which describes the equation used. Naïve Bayes is a great algorithm for real time prediction because it is usually a fast learner. Using this algorithm can be helpful for our project, since there will be some ASL letters which will have distinct features not found in others.

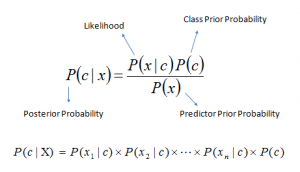


Figure 13: Equation (Bayes Theorem)

**Image used with permission from:** [analyticvidhya.com](https://knightsucfedu39751-my.sharepoint.com/personal/jidekay_knights_ucf_edu/Documents/analyticvidhya.com)

This is the breakdown of the equation above for posterior probability.

* P(c|x) is the posterior probability of class (c, target) given predictor (x, attributes).
* P(c) is the prior probability of class.
* P(x|c) is the likelihood which is the probability of predictor given class.
* P(x) is the prior probability of predictor.

#### Support Vector Machine (SVM)

Support Vector Machine, or SVM for short, is another powerful machine learning algorithm which can be used both as a regression technique and a classification technique. SVM is usually used for classification over regression, and it is very popular amongst machine learning programmers because of its ability to produce accurate results with usually lower computation power. The objective of SVM algorithm can be defined as attempting to find a hyperplane in an N-dimensional space which distinctly classify the data, where N equals the number of features in the event. A hyperplane can be defined as a decision boundary which are used to classify the data points. Then these data points will be attributed to different classes, depending on what side of the plane they reside. A hyperplanes dimensions will be determined by the number of features. SVM can be used with two or three features. For two features the hyperplane will be shown as a straight line, and for three features it will be shown as 2D plane.

Hyperplanes become difficult to physically picture/describe. The orientation and position of the hyperplane is influenced by support vectors. Support vectors are the datapoints which would be closest to the hyperplane. The support vector’s goal is to maximize the margins of the classifiers. The maximum margin is the maximum distance between data points of the classes. SVM might be useful when using machine learning to translate our gestures for our project. We will look for resources on how to implement this and determine if it could help achieve accurate results.

#### Random Forest

Random Forest is one the most used machine learning algorithms because it is considered simple and diverse, being able to be used for both regression and classification (much like SVM). Random Forest can create precise results in most cases without the need for hyper-parameter tuning. Random forest is a type of supervise machine learning, and it consists of decision trees, which is where the forest comes in. These tree’s in the forest are trained using the bagging method, which combines all the decision trees (bags) and then produces a more accurate and stable prediction. Random forest is known for adding randomness to the model in the way that it grows the tree.

Usually in the splitting of a node an algorithm might search for the most important feature, random forest instead searches for the best feature amongst a random subset of features. The results from doing this is generally better. Random forest has the ability to easily measure the relative importance of each feature on the prediction. Sklearn has a tool which automatically scores each feature after training in order to distinguish importance. This allows for the dropping of a feature if it is not contributing enough or at all. This helps reduce the chance of overfitting or underfitting. Random forest has very useful hyperparameters which can be used to increase predictive power or to help make the model faster. These hyperparameters include:

* Increase Predictive Power
  + n\_estimators
  + max\_features
  + min\_sample\_leaf
* Increasing Model Speed
  + N\_jobs
  + Random State
  + Oob-score

Random Forest is a great algorithm to determine whether an event will occur or not. For example, some banks will have random forest computation to determine whether a customer will pay back their debt or not, or even how likely a person is to use their banking features. It is used in online ads by determining which ads a person is more likely to pay attention to base on their web history and other ads they might have clicked on. Random forest has even been used in the medical field to help identify correct components in medicine. There might be ways that we can implement random forest into our project to help get better results, it is also an algorithm we will be testing with our design. For reference we have added an image below *(Figure 13)* which shows how a random forest would look conceptually as it is making a prediction, this model would predict either 1 or 0.

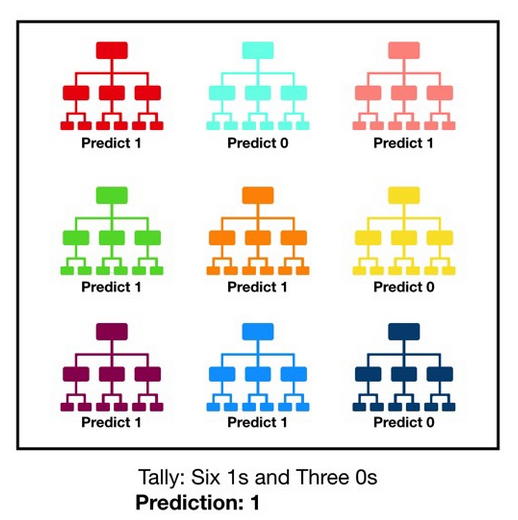


Figure 13: Visualization of Random Forest making a prediction.

#### Difference Between Random Forest and Decision Trees

In our project we might use both random forest and decision trees, so it is important to note that even though random forest uses decision trees, there are some differences. Firstly, the most upfront difference is that random forest is a collection of decision trees, like trees in a forest. The second difference is that decision trees will form a set of rules when being trained on a dataset with certain features and labels. These rules are therefore based on the features and labels from the data. Random forest does something similar, but it selects features and observations at random, which it uses to build decision trees, and then it takes an average of the results. Another key difference is when using decision trees alone one might encounter deep decision trees, and these are more likely to encounter overfitting. As mentioned earlier random forest has technique to avoid this. The technique is useful but has the potential to slow down computation speed and is not guaranteed to work every time.

#### Machine Learning Algorithms rated (1-4)

Here in *Table 6* we found a rating of some features of machine learning algorithms that we researched. We inserted these ratings into a table to help us decide which algorithms to use for our project. In this table, a 1 represents a low rating (not necessarily bad, just not where the algorithm strives) and a 4 represents a high rating (again, just shows where the certain algorithms strive).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Naïve Bayes | SVM | Random Forest/Decision Trees | Neural Networks |
| General Accuracy | 1 | 4 | 2 | 3 |
| Speed of Learning | 1 | 1 | 3 | 1 |
| Speed of Classification | 4 | 4 | 4 | 4 |
| Tolerance of irrelevant attributes | 1 | 4 | 3 | 1 |
| Tolerance of noise | 2 | 1 | 2 | 2 |
| Tolerance of missing values | 1 | 2 | 3 | 1 |
| Dealing with Overfitting | 1 | 2 | 2 | 1 |
| Model Parameter Handling | 1 | 1 | 3 | 1 |

Table 7: ML Algorithm ratings table

### Programming Languages Research

When it comes to programming, there is not a lack in possible languages to be used. The language should be chosen depending on what the specifications of the project are, the programmers understanding of (or ability to learn) the language, and the resources the language provides. For our project we found out we might need to use at least two languages, one to program the MCU and the other to create a program which will do actual translation for our project. We wanted to make sure the language we chose to focus on for this project would be able to have necessary resources and libraries to handle the expectations for our project. We considered looking into C, Java, C++, and Python as possible languages we would use for our project. So, the breakdown of which languages we will use comes down to which one is best for the MCU and which one will be best for the translation program, which will use some form of machine learning.

#### Programming the MCU

The MCU we will first be programming will find its home on the glove. This MCU will have all the sensors, the accelerometer/gyroscope, and a Bluetooth module connected to it. The MCU main function will be to obtain values given by all the attached components and send them to a PC. This will be the first step for our translation. We plan on getting our MCU from Texas Instruments (TI), and most of their MCU’s are compatible to be programmed using the Code Composer Studio (CCS) IDE. CCS uses C/C++ depending on how you wish to program your MCU. C and C++ are similar, and C++ is essentially a superset of C.

C is a procedural language, providing instruction in a top-down approach. C programs usually run faster because there is less procedures involved which can be found in more advance languages. C is known for being used in embedded systems and microcontrollers, which is why we are strongly considering it. C++ can do everything C does since it is a superset of it. C++ is also very similar to C when it comes to syntax and keywords (even though C++ has more keywords). C++ is considered an object-oriented language and emphasizes on inheritance and object creation. While C++ offers everything C does, we believe that a lot of its features will not be necessary for what we need our MCU to do. Our group has also had more coursework experience in C therefore feel more comfortable starting with this language. C’s high speed is also very appealing for this project because we would like the sensor data to be received and sent over at a high speed.

#### Translation Programming

For our project we will also need to create a program which will take the input received from the glove, this will be our data, and output an alphabetical text. This program should use machine learning technique to train the machine to determine what letter the gesture represents. After the translation is done, this becomes the new data, which needs to be sent to our energy efficient projector and displayed on our choice of medium. It is very important that we choose a programming language which can be used to create a program that uses machine learning. We need to program to be efficient, user friendly, and potentially easy to learn (or at least learnable over the timeframe we have to complete the project). We are considering two main languages, being Python and Java, but will also look into C# because it is starting to catch up in machine learning implementations.

##### Python

When usually dealing with any form of AI, and machine learning specifically, one tends to lean towards Python as the primary language to use. Python offers the flexibility, stability, and the large resource of tools and libraries needed to build a successful AI project. Firstly, python is now for its simplistic and readable coding style, most languages syntax are complicated and not necessarily what would be considered “readable”. Python is known for being one of the most user-friendly programming languages. This is the first important step when working with machine learning because it allows the programmer to spend more time and though on the actual machine learning implementation rather than the language itself.

Python is also considered one of the easier programming languages to learn. Because of its readability and easiness to understand, picking it up is not a too difficult of a task. Python features various libraries, extensions, and a simplistic framework which helps the programmer in learning how to work with python. Python is very useful when working on projects involving collaborative work. For our project the programming will be divided among at least two of us (if not more), and we will most likely be working on the program on separate devices, programming in a language which is known for collaborative work is a must for our project.

When it comes to the actual AI work, python has the benefit of various pre-built libraries and frameworks that can be used (and often used) to implement a form of AI. This includes libraries as:

* Keras, TensorFlow, and Scikit-learn for machine learning (very useful for our project)
* NumPy for high-performance scientific computing and data analysis
* SciPy for advanced computing
* Pandas for general-purpose data analysis
* Seaborn for data visualization

This helps reduce development time, and allow for quick prototyping, and more time to test the program and develop a strong training model. Another useful feature with python is its platform independence, meaning the same code can be used across different platforms, without having to be altered. In a group project like the one we are designing there is always the chance of different members using different platforms, making this extremely useful.

##### Java

Java is one of the oldest and possibly most used programming languages. Developed by Oracle, Java is an object-oriented language and is what most devices we encounter in a daily basis are programmed with and is a preferred language in enterprise computing. Lately, Java has found to be useful in machine learning programming as well. One of the first reasons for Java being used in machine language is its age. Usually old means outdated and irrelevant, but in Javas case it makes it more useful. Java is most likely being used by any said company in one shape or another, therefore adding it to a new feature would work smoothly. This means companies who might start to work with machine learning might already work with software, applications, and infrastructure which uses Java, meaning a possibly smoother transition.

Java also has the Java Virtual Machine (JVM for short) which many developers consider an extremely useful platform, especially because it allows for identical code across many different platforms or devices. Java is also known for making scalability an easy process, making it an excellent choice when dealing with complex machine learning that might be being built from scratch. Most machine learning projects are going to use a lot of data and can be a lot of work. Even with this being true, most people using a device that uses either machine learning or AI expect fast results, some languages do not work very fast; However, Java is known for being a fast processing language, which would be great when implementing machine learning. For our project quick results is very important, we do not want the output to take more than a few seconds to display. Java would also be useful for our project because if its many available libraries. For example, there is a java-based workbench called Weka 3, this workbench is popularly used for algorithms in machine learning, as well as some big data projects. [12]

#### C#

C# was developed and launch by Microsoft in 2000, and it is considered one of the most versatile programming languages in the world. Recently C# has found its way into machine learning projects, even making Github’s to 10 list for most used programming languages for machine learning. C# can implement machine learning using the .NET Core machine learning platform known as ML.NET. Firstly, .NET is an excellent platform which is open-source, cross platform, and free. It can be used to build many different types of applications, and can do so using multiple languages, editors, and libraries. Now, ML.NET is very useful for machine learning, because it used the same framework as .NET. What makes it very interesting is it allows developers to build and develop their own models and infuse custom machine learning into their application [21]. .NET also API’s specific for training machine learning models, model prediction, and other machine learning algorithms. C# would be an excellent option for our project as well, being that it is very modern and is open-sourced. Unfortunately, none of us have worked with .NET, therefore there would be a lot to learn. We will keep C# as an option in order to create the best outcome for our final project.

### Programming and Development Environment

As important as it is to choose the right programming language for our design project, it is just as important to choose the right development environment. When doing any project involving programming one usually works with an Integrated Development Environment (IDE for short). The main purpose of an IDE is to consolidate different aspects of the program in order to increase productivity. Most IDE’s accomplish this by combining several task to one environment, tasks like: editing source code, debugging, and creating executables. The benefits of IDE making writing code smoother and quicker, by means of auto-coding, which is when the IDE recognizes the programming languages and can finish some of what the programmer is writing. Built in compilers make it easier to run code because the IDE can compile and run at once. IDE usually are built to be used with a few specific languages, and some offer more features than others. Some IDE are more project specific as well; therefore, research various IDE’s is very important for our project design. We have considered using Python, Java, and C# for our project, hence we looked into IDE that are popularly used with these languages. Since machine learning will be implemented in our project it is also very important that the IDE works well with machine learning projects. The IDE’s we will be considering for our project include:

* Eclipse PyDev
* Microsoft Visual Studio Code
* IDLE
* PyCharm

#### Eclipse PyDev

First it is important to understand what the Eclipse IDE is. Eclipse is an open source community which is commonly used to develop Java based projects but is not limited to it. Eclipse has been used by several of us in our group for both university course assignments and personal projects. Eclipse is very user friendly, has a great user interface, and has plenty of online resources on how to use it. PyDev is a plugin for Eclipse, which through its Eclipse can be used as a python specific IDE. PyDev has some feature for python programming which are very useful, including: Powerful and useful debugger, auto import and code completion for fast coding, and Git integration for code control. PyDev is also free since it is a plugin for eclipse (which is also free), and for new users it is considered extremely easy to use.

#### Microsoft Visual Studio Code

Microsoft Visual Studio Code is another useful IDE, which has built in support for many programming languages including C#. Visual Studio Code also has the option to add plugins where other languages like python can be used to create projects. One of Visual Studio Codes most lucrative feature is how well it work with its built in Git. This allows for great team collaboration when it comes to projects. Using this feature allows for commits directly from the editor, allowing for pushing and pulling from any host SCM. Visual Studio Code has a feature called Intellisense, which is the IDE’s way of auto completing code, but it does it in a sophisticated and efficient manner. Intellisense performs it autocomplete using what they call smart completion. As a programmer possibility writing a lot of code, a smart autocomplete can be very useful and helpful. Visual Studio has plenty of plugins and extensions available for many different project needs, a powerful feature with these extensions is that they will run on separate processes in order to not slow the IDE.

#### IDLE

Since our project will use machine learning and python looks to be the best choice for the programming language to use, we thought it was very important to look into IDE’s which are designed to work very well for python projects. IDLE is and IDE that came up on our search that is commonly used for python projects. The reason IDLE is such a popular IDE with python is because when python is downloaded for anyone IDLE automatically comes bundled with it. IDLE stands for Integrated Development and Learning Environment, it is considered the starting point for programming with python in a development environment. IDLE can be used as both an interactive interpreter (shell) or an editor. The shell can run snippets of python code, usually for testing, and display the output right away. For larger codes IDLE’s editor can be used to write them and then can easily be executed. IDLE features autocompletion for fast coding, auto indentation for organized coding, and code context to be able to distinguish what part of project is being worked on for very large projects.

#### PyCharm

PyCharm is another IDE which will work great for projects using python. PyCharm is developed by JetBrains, and it is considered a hybrid-development environment. PyCharm is the python IDE used by developers for large and well-known organizations like Pinterest, Facebook, Twitter and Amazon for example. PyCharm in comparison to IDLE is considered to be used by programmers with more python experience and for larger projects, where IDLE is more a beginner’s python IDE. PyCharm can be ran on Windows, Linux, or Mac devices, and along with a large fleet of features can be customized to meet needs of the developer. Some of the most useful features of PyCharm includes:

* Intelligent Code Editor – helps easily identify error and quickly, uses auto complete, while providing a well laid out color scheme to help develop quality code.
* Refactoring – quick and efficient changes to local and global variables, helps improve the project’s internal structure while not affecting external structure.
* Web Technology Assistance – create resource for developing web applications, working with HTML, CSS, and JAVASCRIPT.
* Python Scientific Library Assistance – supports libraries such as Anaconda, Numpy, and Matplotlib, great for building projects in data science and machine learning.

The largest negative with PyCharm when compared to the other IDE’s is that it is not a free software. Most developer using PyCharm need to obtain a license to use it for their projects. The other IDE’s we investigated were all free and saving on our budget is very important for us. JetBrains does offer a free license for university students but requires registration and approval. We will most likely try to obtain a student license, and if we are able to, we will very likely try to use PyCharm for our project. It being more targeted towards experienced python developers is another factor we must consider. When looking over all these choices our group will most likely develop the code for our project in either PyCharm or IDLE, and both will most likely be tested.

#### Version Control

When it comes to working on our code as a team version control is possible just as important as the language and IDE being used. Version control is how changes to a program code is tracked and managed. It is how large development teams can work on a single project with everyone adding their own parts. Version control helps keep track of what changes are made by which contributors. Since different changes can be made by different contributors, there might be instances where there is incompatible work, and this can be detrimental to a code, version control keeps track of all versions of the project after every edit and can be used as a time-machine to go back in time and restore and older version that worked.

From early on when version control was discussed our group decided the best version control system, we could use would be to use GitHub. GitHub is a repository hosting service which is used heavily in programming projects and works very well for collaboration. It is a free and open-source system and is integrated with many IDE’s for direct updating. GitHub is an easy way to organize the programming aspects of our project, and since it is open source there is a lot of help available for many types of projects. We plan on using GitHub as our primary way to push edits on our program as a team.

### User Interface

Our project will have data which will be created by the sensors on our glove and received by the microprocessor on the PCB. The microprocessor will then send the data (in now a dataset) to our computing device, through Bluetooth, and this dataset will be translated through our trained model to create a prediction, which will then be displayed through our projector. The part of all this when the computation is being done is a topic in which we as a group need to decide how it will be seen by the user. There are in general two options, one we let all this computation occur in the background of our project and it will never be seen by the user or anyone, even though work is being done; or, two we create a user interface which will display everything that is going on so the user has a visualization of the computation occurring. We do not expect either of these routes to change any aspect of our project, because even with the user interface it will not be the main display of our output, the projector will. The reason we wanted to still research our options on this was because we wanted to have it available if it made understanding the process of what is going on easier to grasp.

If we decide to create a user interface we have two general options. The first is to create a mobile app that works either on an android device or an apple device. The second option is to create a application which can be ran from a PC and this will act as the user interface. We like the idea of a mobile app because it means our device’s computation can be done virtually anywhere one of these are available, but we worry that a phone might not have the necessary computation power we need for our machine learning model. The PC application calls our attention because we know a PC should be able to handle the computation, and it will be a large display to easily see how to computations are occurring.

When it comes to the expectations of the user interface we expect simple. The purpose of a user interface, if we chose to implement one, will be to give the user a clearer picture of how the computation of our input data is being translated. Therefore it will not have any actual function or buttons, it will be more of a reference display that will be additional to our projector display.

### Android Application

If we were to make a mobile application, there is a strong chance we would use the android development platform. This platform is owned by google and is heavily used to develop android applications. What is great about this platform is mainly that it has its own IDE, Android Studio, has many free open source projects which is helpful for developing applications, and it is free to publish on the google play store. A neat feature with android studio is that it allows one to use their own android device to test programs, but one can also use a virtual android device to test their programs as well.

Android app development has many positive aspects, but for our team most of us use apple iphones. This isn’t a dealbreaker for us, but it will be a bit of a learning curve when it comes to the OS, and also have devices readily available to test on. Even with the virtual device it runs slow at times, which can become frustrating. Only one of our team members has actually used Android studio so we would also have to learn about the IDE.

### Apple Application (IOS)

Developing an IOS application is very similar to android in a lot of aspects. Apple has its own developmental platform called XCODE which is the IDE used for creating IOS applications. XCODE is similar to Android studio in the sense that it provides all the necessary resources to create great applications, and it use a simulator (not emulator) which gives a visual representation of how the application would work on an Apple device.

The largest difference we found between creating an IOS application and an Android application is that it is not free to publish an app on the apple store. One must be a member of the Apple Development program which has tiers of membership, with the lowest starting around one hundred dollars. Even with this membership there are more guidelines to adhere by in order to be able to publish their application, so there is a more strictness around this type of development. Another thing we noticed is even though all of us have an iphone device as our personal smart-phones, none of us have ever created a IOS application, so this would be completely new for all of us.

### PC Application

Our third option is the create a computer desktop application which will work as the user interface for the computation of our data. We really like this possibility because we will be working on our computers to test the components and could just continue to use our computers a the central hub for everything without having to bring another device in to play like a phone or tablet. We would also save some potential expense since we would not have to buy a developments android phone (since we all own iphones) or pay for a membership to publish on the apple store.

When it comes to the actual development of a desktop application we have some coursework experience in doing so. We will create a front end application most likely using Java swing. We have used Java swing in some of our previous course in UCF and it would therefore be the best option. Java will always provide some much online resources and documentation that it is in our best interest to use this. We can create a clear and concise GUI which will display our computation. Since we have planned on using a PC to do our computation this will most likely be our best option. Since we all have Microsoft devices we will most likely make an application that works on Microsoft, we cannot guarantee it would work on MAC or Linux devices.

## Projector Research

Another important part of our project is the projector we will be designing to display our translated results on a display medium. We found it essential to research similar projects which have used projection to display results. We wanted to research projects that used different light sources and technologies to decide which would be best for our design. Next, we needed to research the actual components which would be used to make an actual projector, this included lenses, light source, beam splitters, mirrors, and display. One member in our group is a CREOL student therefore they took most of the research portion for the projector design, but we made sure to have her explain her findings to us so we could also learn how this part of our project works.

### Existing Technologies

There are many existing projector technologies that are used to suit different environments. These visual displays have been used for many different purposes, like home theaters, classroom use, and even as a GPS. The idea of our projector was for it be as cost effective and portable as possible, while being able to project three identical displays at different angles that can be seen in common ambient room lighting. There are several different technologies that were taken into consideration in brainstorming the design of our product.

#### Blue Laser Projector

The first projection technology that was researched was the common projector using a blue laser. This type of projector can operate in full color while only using a blue laser as the light source. Many other projectors use multiple LEDs or multiple-colored lasers to create a fully colored display. The idea of only having one light source in the perspective of this project being self-funded caught our attention. Some drawbacks of this projector is that since it utilizes only blue laser, it would need a phosphor and color wheel to create the colors that it needs for a full spectrum display. Both the phosphor and color wheel would be constantly moving while the projector is running, which means that we would also need to incorporate motors.

This projector also utilizes LCDs, which means that in order to create the fully colored image, 3 LCDs are used that combines its images using a prism. [13] We aimed to have our projector to be as compact as we can make it for it to be portable and user friendly, which was a heavy deciding factor of making the projector monochromatic. Although we have thoughts of displaying animation on our display, just utilizing one color for our text display would greatly simplify our optical design. The idea of having a display system that has great resolution and brightness while being able to project a larger image was favorable in this projector.

#### Head-Up Displays

The technology that really caught our eye was the head up display. This technology was originally created for the use of fighter pilots for pilots to view information about the aircraft without looking away from their field of view. A small projection system is located on the dashboard and is used to be able to back project on to either the windshield or a small piece of glass propped in front of the windshield. This technology has more recently found use in the civilian world, being incorporated with cars. Some newer models of cars now come with head up displays that would be able to display information like speed, tire pressure, or even their GPS [14] [15].

This technology showed the use of projecting onto a clear screen at a very close distance which was closer to the ideal projector that we wanted to design. Some of the projectors that are used in head up displays are called Pico projectors. These projectors are usually small enough to fit in the palm of your hand, are less than 1 pound, and are very useful for creating smaller displays. The extremely compact design of the Pico projector was something that we were aiming for, but we were aiming to be able to create a larger display if needed. Such small projectors would not be very visible in a well-lit room to stretch out and create a larger image for viewing.

#### Ricoh’s Ultra Short-Range Projector

The last technology that was researched was another Pico projector, specifically by the company Ricoh. This product was specifically creating to make the projector itself as small as possible, while creating an image bright enough for numerous people in a well-lit room to view it. While looking up different projectors, we realized that we needed a short throw lens, or at least an optical system that mimicked a short throw system. The term “throw” is used to define the distance between a lens and its screen, in this case we were in search for something short distance.

Many short throw lenses themselves are very expensive, but while researching this product we have seen that creating an optical system that is able to function like a short throw lens does not have to be as pricy. This projector stands upright to take up at least space as possible and utilizes a free form mirror along with a concave lens to create a large image with high resolution and minimal distortion. [16] This system can project at an ultra-short range while projecting an image as big at 80 inches. Our team was aiming to create an image that was larger than the Pico projectors that are used in cars and aircraft, but an image as large as 80 inches is also not completely necessary for our aimed usage. The creativity of using a concave mirror along with a freeform mirror showed the extent of how much we can manipulate the optical system we want to design.

### Optical Design Components

The optical design in our projector will consist of lenses, beam splitters, and mirrors. The different aspects of each of these components were heavily researched and designed using resources given online and past optics classes. Below is a breakdown of each component and how the different characteristics of them will positively and negatively impact the main goal of our final design.

#### Beam Splitters

One of the main components that will be used in our product to be able to create the identical images are beam splitters. Beam splitters are glass optical elements that utilize a reflective coating to either split two beams or combine them together. Each splitter has a specified ratio of how much light is transmitted and reflected. Beam splitters are very common optical components that are used in most interferometers and in this case, projection systems. The two main categories of beam splitters are the cube and plate structures, which are shown in *Figure 13*.

##### Cube Beam Splitters

The cube beam splitter is made up of two triangular prisms that are cemented together. The outer surfaces of the cube have 100% antireflection while the surface of one of the cubes have a reflective coating. An advantage of using the cube splitter is the shape itself. Its cubic structure allows it to support itself and sit in place when using it in an optical system. The structure of the cube also holds the advantage of not causing any beam shift. This would make the alignment of the optical system quite simple. The disadvantages of the cube structure are that it is on the heavier side and are more expensive than other beam splitters. The disadvantages of the cube structure may be enough to look for other options, but they will still be kept in consideration.

##### Plate Beam Splitters

The other main structure that beams splitters come in are plate beam splitters. Instead of having two optical components fused together, this item is structured as a singular plate. For that reason, it is a lot easier to manufacture, making it cheaper to purchase. The plate beam splitter is just a flat piece of glass in which one side has a reflective coating, almost giving the appearance of a small flat lens. Some disadvantages of the plates surround the structure of them. Since they are used at a specific angle, how we set up and angle the splitter would have to be heavily considered. The cube is able to support itself on one of its sides while still executing a 45-degree splitting angle, while the plate would need precise support. The shape of the plate also causes a slight beam shift because of the parallel nature of it. The shift would need to be calculated to get precise angles and measurements that we would apply to our optical system. There are a few drawbacks to the plate beam splitter, but it will be more heavily considered in reference to the cube just for the sake of budgeting.

Chart, radar chart

Description automatically generated

Figure 14: Cube and Plate Beam splitter diagram [17]

### Optical Lens

Optical lenses have been used in traditional projectors for a very long time. Lenses themselves can both spread and condense varying amounts of light depending on several characteristics including the size, shape, and focal length. Convex lenses are more commonly used in projectors since they can create a real image when an object is placed between the focal point and twice its distance. The basic structure of just using lenses themselves for projection gives a downside of the optical system being too large, especially with our design idea of having multiple images being formed.

The use of lenses will be incorporated into our optical design but there would be a need for a reflective component that would allow us to decrease wasted space in our projection system. The only issue is making sure that the system can magnify the images at our goal projection scaling while still being bright enough to view and being cost effective. Lenses can be quite expensive to manufacture compared to mirrors, which is why incorporating both seem like the best route. Short throw lenses that are made for cameras and projectors can be from $200- $3000 considering the amount of highly crafted lenses that are used. We should be able to find some inexpensive lenses to use considering we are only attempting to display an image not much larger than the average inexpensive Pico projector.

### Mirrors

Mirrors are a very simple reflective optical component that would be able to help condense our optical system. Mirrors have been used in projectors to mimic short range rear projection with a short throw lens while making the system cost efficient. We plan on utilizing fully reflective mirrors and optical components with mirror coatings in order to make our design as efficient as possible.

### Screen

Since this design is meant to be used in short distance between the user and the screen, a clear display is incorporated. A trifold system will be used to increase the viewing angles of the information that will be displayed. The main substrates that were considered was acrylic. It is easily accessible both online and instore. Acrylic is favored over other materials since it is generally cheaper, lighter, and more durable than other clear materials.

The screen will also consist of a rear projection film that will be adhered to the acrylic. This allows the projection to be visible on the clear screen. The main factors of choosing a film is the costs, sizes available, and the transparency.

### Display

This project is aimed to be as compact and efficient as we can make it with our given resources. We were looking for a micro display that is easy to use in our optical system and inexpensive.

#### LCD

Liquid crystal displays (LCD) are low power flat panel display devices consisting of liquid crystal particles to function. They are commonly used and found in electronic devices like TVs, smartphones, laptops, and calculators, etc. LCDs devices do not produce light as the light emitting diode, LED. It usually absorbs and blocks light to produce a movable image or text. As they do not emit light, these devices do not consume a lot of energy compared to LEDs. They create an image because of the backlight that delivers light source to specific pixels arranged in a four-sided lattice as stated on Orient Display’s website.

They have a large resolution and improved picture quality because of the support that the thin display offers as the application of electric field is put on the miniscule pattern of the device. They are several types of design that make up LCDs such as twisted Nematic (TN) which is suitable for diurnal function, In-Plane Switching (IPS) which has decent pictures quality and pulsating color correctness, and vertical Alignment Panel (VA Panels) which has advanced quality as well as finest viewpoints topographies. This section is going to focus on giving few details on different LCDs.

##### LCX017DLT LCD displays

The LCX017DLT displays made by Sony are transparent or see-through 4.6cm (1.8 Type) Black-and-White LCD Panels used in projectors to create an image from an incoming light source. These LCDs do not have a backlight as they combine color to generate a pleasant color image or text that can be regarded on a projected screen. According to the LCX017DLT datasheet, they are made of polycrystalline silicon super thin film transistors with a built-in peripheral driving circuit of a diagonal active matrix TFT-LCD panel.

They are efficient of presenting acceptable text and vertical lines because of the striped prearrangement that is appropriate for data projectors. They can accomplish a high brightness level screen due to the structure of the DMS (Dual Metal Shield) adaptation, and This gives them the technology to provide viewers with an advance picture fame. By shifting the active surface at the mercy of the type of input signals, the LCD tolerate a S-XGA 5:4 and PC-98 8:5 data signals. They agree on taking the computer demand of XGA, SVGA, VGA, NTSC, and PAL and have high optical transmittance of 23% (typ.) [18]

##### 1602A-1 LCD Display Module

The 1602A-1 LCD Display Module is a type of display module made by Shenzhen Electronics Co., LTD in China. It is a certified product under the ISO9001 standard which specifies requirements for a quality management system. It allows for a 2 Line -16-character display format, with 4 bits or 8 bits input data interface. The display font is 5 x 8 and dotted, with a blue blacklight and 6’ o’clock viewing direction.  These modules are effectively used in Laser printers, fax, and copiers and would be adequate for the project in terms of size, and display quality.  The display presents the ability to be mounted on a PCB which allows for space conservation.

The module has 16 pins with different functions ranging from Data Input to Power Supply. It also has the option of enabling the backlight or switching it off depending on what is needed during the project. A datasheet is provided for reference purposes when the LCD module is to be utilized. The module is available for ordering and costs $3 per piece but can only be ordered in units of a thousand (1000). More research is being made to find these modules in well-known online websites like Amazon to get them at a cheaper price.

# Design Standards and Constraints

Engineering projects are driven by how effective the design can be, such effectiveness could be cost, time, sustainability, safety and so on. This project is not exempt, and various factors would be taken into consideration, as they limit the functionality, quality, and standards of the project. The factors taken into considerations are discussed below.

## Design Constraints

There are various constraints that can limit the project, these constraints can impact the outcome of a design. For our project we, would ensure not to violate the requirements specified by these constraints. It is important that we are aware of any constraints from the early stages of project design, this ensures that we can plan around these constraints and not violate any ethical boundaries or laws. We needed to look at constraints in a economic sense, ethics, political, environmental, and possible manufacturing constraints. Below are some of the constraints taken into consideration.

### Economic and Time Constraints

The main goal of this project was to create an effective design with a low budget. Our team has set up a budget between $100 -$1000. Since we decided to fund this project ourselves, we cannot afford to spend too much on our project. We are either full-time students with full-time/part-time jobs, or just full-time students. Therefore, we must be very careful about how we choose our parts. Our design is also limited to fit within our budget, compared to have a large budget which would remove such a limiting constraint. Besides price, parts chosen to complete were chosen on how effective they could be in terms of performance, durability, and accuracy. We decided to purchase more than one unit of each component needed to accommodate for any unforeseen circumstances that might happen like damages or the component just not working. This saves time as the constraint of ordering another part and waiting for it to get shipped would be eliminated.

Another constraint is our individual schedule and time, as each of us are juggling work, family, and other classes while trying to get the design completed, we chose a design that could be completed in a timely manner. For the time we have to complete this project we are very limited. We have two College semesters to decide on a project, research parts and design, order necessary parts, and design and build. We began on Summer 2021 semester, already reducing our overall time by several weeks, compared to starting in Fall. We will finish our project Fall 2021. With all this in mind the quality of the design would be limited, as there is not enough time to execute a full design plan and prototype. In completing this project, we would have to factor in time allowance for damages to the design from testing, modification, and replacement.

### Environmental, Social and Educational Constraints

The social impact for this product is lucid, we attain to create a product that appeals to a community that is not much talked about. We tend to create a product that if completed can be purchased at a very low cost. This would give customers the opportunity to learn a new language while also passing the “cool- vibe check.”

Educationally, as we would be building this project from scratch, we would be learning how different components work, reading up on documentations, user guides, and datasheets. We would also be using this as an opportunity to learn the American Sign Language too. What more would the project be if the makers have no knowledge on the language.

Environmentally, we are aware that we are building a project with electrical components which use natural resource to be constructed. We do not wish to build a device which 1. Will consume an unnecessary and unethical number of natural resources, 2. Create any environmental hazard, i.e. dangerous gas emissions, and 3. Cause any type of waste/pollution build-up. We do not see any possible hazardous danger with the construction of our project at the time. We know there is a potential of waste, but we will be very reserved with the use of our components to not waste, either by using components we already own or being responsible with how we treat our components. We will also be very cautious of how dispose of any electrical components which were either burnt-out, depleted in testing, or faulty, by researching proper and safe disposal. We also plan on recycling any electrical components via recycle centers like local BestBuy’s, Staple’s, or other business/offices which accept electronic recycling.

### Ethical Health and Safety Constraints

Safety is an important factor in any project. As engineers, we are required to follow appropriate guidelines and regulations when designing and creating projects. We designed this project to be as safe as possible by choosing parts that comply and are not prohibited in the USA. An example is the accelerometer and the PCB in general, both of which consist of components that are RoHS compliant by being lead free and prevent the human body system from being affected. As lead could cause anemia, weakness in fingers and memory. We are going to ensure the design meets the Occupational Safety and Health Administration standards, as well as ensure that all electrical connections are properly grounded and wired.

We also encountered the health constraint of starting the design of this project towards the end of a pandemic. We began our semester towards what is being considered the end of the COVID-19 pandemic. There have been many resources that have been taken away from us due to this health crisis, like doing Senior Design lectures over zoom. We also needed to decide as a group whether we would continue to follow the CDC social distancing guidelines or take the risk and meet in person. We ultimately decided to meet in person as we believed we would be more productive, but we did so assuming the risk of possibly exposing one another to the virus. UCF has stated that they plan on resuming normal operations beginning the Fall 2021 semester, so there will be some changes on how this health constraint affects our project as we enter Senior Design 2. Ethically, our goal is to complete a project that is safe even though we are confining the project to a low budget. The life and safety of humans and customers are paramount and valuable than anything in the world.

### AI Ethics

There is currently talk about the ethical misuse of Artificial intelligence. Some AI can be seen as being bias and discriminatory because of the nature of its design. For example a lot of banking companies will use AI to determine whether someone will qualify for a loan, and factors as zip code or city will have an affect independent of whether the person can actually afford to take out a loan. Another example is how some employers use AI algorithms to choose which applications meet “criteria” and will flush out any that don’t. Our project plans on using AI through machine learning, we are hoping that our design will not act in anyway like this. Even though our project isn’t making choices like someone getting a loan or getting a job, we still want to ensure it works correctly and not exclude any results.

### Manufacturability and Sustainability Constraints

Sustainability in engineering design is significant as it is a type of “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” [19]. The main factors that determine how a design can be sustainable are Economic, Social, and environmental. These factors can be viewed on how they affect the economy in terms of profit, the environment in terms of the earth and the social concerns on how it affects the people.

This project has been designed around the essence of these factors. For the glove, we designed it to be comfortable to the consumer wearing it. We ensured we chose a glove that was lightweight, and compatible to house the components to be attached to it easily. We would be taking into consideration the placement of the sensors and the PCB on the gloves, to ensure the comfortability to the user. Although the project is a low budgeted one, we plan to get a good glove. We understand that our prototype is not going to meet the needs of all possible users. Not everyone has the same glove size, gloves range from extra-small to extra-extra-large, so we understand our glove will not be a one size fits all. We also understand that there are people who are right-hand dominant, while others are right hand dominant. For our prototype we plan on using one size and building the glove only to be used on either the left or right hand but not both. If the glove was ever to be manufactured it would probably need to be custom made for each user, or enough research would need to be taken to create accurate sizes ranging from small to large.

As for the projector, a manufacturing constraint we would probably be facing would be the designing of the Lens to meet the engineering requirements for the College and Optics and Photonics. After the design is made, it would be sent out to a company for production. Asides from that, to limit the constraint and make the projector sustainable, other parts needed to build the projector would be purchased from common stores and website.

### Political Constraints

There are currently no political constraints limiting the design of the project, the developers, or the intended users. It is important for us as engineers to keep updated with any engineering standards that might change while we work on our project. If anything in government or state changes that can affect how our project can be designed, we must be ready to adapt if necessary.

### Legal Constraints

There are currently no federal laws that prohibit the invention of sign language interpreters, but instead there is indeed a federal law enacted by the United States Department of Justice, Title III of the Americans with Disabilities Act of 1990, as amended (“ADA”), 42 U.S.C. 12181 et seq. This law basically provides measures to prevent circumstances of where people with disability are discriminated upon. The ADA requires that the need for proper communication with the hard of hearing be provided.

This even more provides us with more incentive to create a product that could be purchased by individuals and companies to aid them in communicating with the hard of hearing, to prevent cases where these companies are violating the regulations and sued for it.

## Related Standards

Every engineering project has regulated guidelines and standard that must be followed, and this project is not excluded. The required guidelines needed to be followed would be further listed below.

### Bluetooth

Bluetooth is an industry specification for a short-range radio frequency (RF)- based connectivity for portable personal devices. The IEEE 802.15.1 Task Group created an adaptation for the Bluetooth specification, and we would be ensuring to adhere to the clauses on service access points (SPA) as well as the Medium Access Control (MAC).

### USB

Universal Serial Bus is an industry standard that establishes specifications between computers and electronic devices for connections, communication and power supply via cables and connectors. Examples of such peripherals that are connected with the use of USB are keyboards, monitors, printers, and other portable devices. In our case, some of the components used would require a USB connection, examples are the MCUs, power supply in the PCB. The USB could be used to provide power to the Gloves when the power supply on the PCB mounted on the glove is connected to a port on a computer. This eliminates the need for additional power supply cables.

The use of the USB interface is self-configuring and requires no need for a user to adjust a device setting or install a software to enable the use of it. It has a global receptable that is available on any computer.

The USB provides a wide range of transfer speeds and ranges differently between devices.

Although there are limitations with the use of USB, it still is generally required. Examples of such limitations are the USB cable length, limitation in the amount of broadcast signal to all peripherals, the host can only broadcast to one peripheral, and requires one USB per peripherals.

The development of USB began in 1994 by a group of seven companies, IBM, Intel, Microsoft, Compaq, DEC, NEC, and Nortel. They used integrated circuits to support USB.

There have only been four generations of USB specifications: USB 1.x, USB 2.0, USB 3.x, and USB4 *(Table 7).*

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Release Date | Transfer Rate | Notes |
| USB 1.0 | January 1996 | 12 Mbit/s | Full Speed |
| USB 2.0 | April 2000 | 480 Mbit/s | High Speed |
| USB 3.0 | November 2008 | 5 Gbit/s | Gen 1x2 and 2 x2 multi-link modes |
| USB4 | August 2019 | 40Gbit/s – 2 lane | Thunderbolt 3 protocol |

Table 8: USB Standards

**USB 1.x:**

USB 1.0 was originally released in January 1996 and a low-speed rate of 1.5Mbit/s and full speed of 12Mbit/s. It had a timing and power limitation; it prevented the allowance for the extensions of cables or pass-through monitors. A revision was made, and USB 1.1 was pushed to the market in August of 1998. The design was specified for any connector smaller than the standard type A or B connectors.

**USB 2.0:**

In April 2000, the USB 2.0 was released with a high-speed rate of 480bit/s. It had more features unlike USB 1.x. It allowed for battery charging on ports for devices with a current of 1.5A up to a maximum current of 5A. It introduced different sized connectors; Mini-A, Mini-B and Micro-USB, and made it possible for two USB devices to communicate together without the need for a separate USB host.

**USB 3.x:**

The USB 3.0 was released in November 2008 and allowed for s SuperSpeed transfer mode with a backward compatible plug, receptacle, and cable. The plug and receptable have a distinct logo and blue inserts that can be easily identified. Various versions were released with different variants. They provided faster speed and a transfer mode at a rate of 5Gbit/s. The USB versions are efficient and are currently being used today.

**USB4:**

The USB4 was released in August 2019 and is based on the specification of the Thunderbolt 3 protocol. The specifications for the USB4 are supported by previous generations and supports 40 Gbit/s signaling speed, it is also backward compatible with the USB 2.0 and USB 3.2

### PCB Standards

There are specific standards needed to be adhered to when manufacturing a PCB, and a body has been put in place to administer these standards. The Institute for interconnecting and Packaging Electronic Circuits (IPC) was accredited the American National Standards Institute (ANSI) as standard developing organization. The major job of the IPC is to help PCB manufacturers, and electronic industry suppliers build better long serving electronics. Some of the standards associated with PCB design, production and assembly are listed below:

* Materials Declaration
* Advanced Packaging
* Solderability
* Design and Assembly
* Surface Finishes
* Storage Handling
* Acceptability of Printed Boards
* Qualification for Printed Boards

For production phases, IPC has some standards to follow, a few would be explained below.

**IPC 2581:**

This is a generic standard for the design of Printed Board Circuit design. It is a standard used when information is sent between PCB designers and manufacturing companies. It lays out a standardized format for design data exchange to help ensure production result is consistent. We would be adhering to this standard, as we would be in communication with a PCB manufacturing company once our PCB design is made and ready to be sent out for production.

**IPC- 2221:**

This generic standard addresses design layouts, part lists and materials, electrical properties and so on. This is a standard we would be incorporating when designing the schematic and describing the logic behind the schematic and project in general.

**IPC-A-610:**

This is the most widely used standard published by the IPC, it is the Acceptability of Electronic Assemblies, and provides a criterion for the acceptance of end products.

All these standards and much more not listed are required to be followed, and we would do our utmost best to follow them in order to provide a good quality product.

### RoHs Compliance

The Restriction of Hazardous Substances (RoHS) is a directive implemented by the European Union (EU) to restrict the use of selective substances. These substances are hazardous materials that are restricted in the manufacturing of different sorts of electrical and electronic equipment. The restricted materials are lead (Pb), mercury (Hg), hexavalent chromium (CrVI), polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), and four different phthalates (DEHP, BBP, BBP, DIBP) [20]. These materials pollute the environment and landfills and pose a dangerous threat than good if humans are exposed to them, Hence, reducing the tendency of them being recycled. As the Consumer Product Safety Act and the Consumer Product Safety Improvement Act were enacted in North America, followed by the Electronic Waste recycling Act (EWRA) passed by the state of California to prohibit the sale of electronics devices that have been prohibited by the EU, and as other states in the US are currently debating on whether to adopt similar laws, our team will ensure all electrical components to be ordered and used are RoHS compliant. As safety is always paramount, we want to be first in safety and provide a product is safe to our development team as well as our customers, protecting them from the exposure of potentially harmful substances.

### Lithium-Ion Battery

To support the process of recycling we chose lithium-ion batteries as our source of power and storage. Li- ion batteries comprise of less toxic metals than other various batteries. They do not contain lead or cadmium and are mostly classified as non-hazardous wastes. These batteries can be easily recycled without posing threat to safety of consumers and the environment.

There are standards developed for the design, testing and installation of Li-ion batteries, these standards created by the International Electrotechnical Commission (IEC), Underwriters Laboratories (UL) and the Japanese Standards Association (JSA) have been selected to regulate and manage the use of batteries.

The standards listed below would be observed and used to ensure proper battery management and use in conjunction with our project. The standards are developed in three categories.

**Performance:**

IEC 61960-3 2017 – Enlists sets of criteria to evaluate the performance of secondary lithium cells and batteries purchased and used. It specifies performance tests, designations, dimensions and other requirements for secondary lithium single cells and batteries for portable applications. [21].

**Safety:**

UL 2054 2nd Edition – Specifies requirements for portable primary and secondary batteries for commercial and household use. These requirements are developed to diminish the risks of fire and explosion via the use of batteries in a product.

IEC 62281:2019 – Specifies methods and requirements needed during the transport of secondary (rechargeable) lithium-ion batteries to ensure their safety. IEC 62133-2:2017 – Indicates requirements needed for the safe operation of portable sealed secondary lithium cells and batteries including batteries made from them for the use in portable applications – Part 2: Lithium systems.

**Testing:**

IEC 61959:2004 – Secondary cells and batteries containing alkaline or non-acid electrolytes – Mechanical tests for sealed portable secondary cells and batteries.

### Coding Standards

Coding standards are rules and guidelines set out for programmers to follow to ensure safety and reliability of a product and prevent a negative effect on the developers and user of the product. There are various benefits to following proper code standards:

* It allows for software security.
* Generates a good code quality.
* Improves readability and reduces complexity.
* Complies with the industry standards.
* Reduces development cost.
* Accelerates the time to market.

Since we would be using embedded systems to generate our project, we would need to follow the required standards put in place for compliance. These standards include IEC 61508, IEC 62061.

**IEC 61508:**

This is a Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems published by the International Electrotechnical Commission. The standard comprises of methods on how to apply, design, deploy and maintain automatic protection systems. [22].

The standard is based on best practices to eliminate omissions and design errors, as well as a probabilistic failure strategy to account for the safety impact of device failure.

There is a certification which is a third-party attestation to a product, stating that a particular product meets all requirements. The requirements are listed in a document called the certification scheme.

**IEC 62061:**

This is a machinery specific implementation of IEC 61508, and deals with the safety of the machinery. It presents the applicable requirements needed for the design of all system levels of the types of safety related electrical control systems. examples of the types of requirements are duty cycles, frequency of operations etc.

In the developmental aspect of our code there are other standards we have to follow:

**Global Declarations:**

Global declarations are variables declared outside of a function and can be accessed by any function throughout the program. It is advised to declare variables needed locally in the function that needs it, except where necessary.

As the number of functions or components accessing the global variables increases, the higher the complexity of the interactions. When dealing with complex codes, modifying the global variable could lead to inconsistent data, as every function and declaration linked to it has to be recompiled.

Another issue might be name clash, as a local variable declared as the same name as a global variable could hide the global variable. Global variables are declared differently in different coding languages.

***C and C++:***

C language does not have a keyword, but variables are declared outside of a function.

***Python:***

Global variables in Python are declared with the keyword “global.”

***PHP:***

PHP also uses the global keyword and have different ways of using the global variables.

***Java:***

Global variables in Java do not exist, all variables that are not declared locally are fields of

a class.

**Naming Conventions:**

There are different types of naming conventions, and different languages allow for the use of different types of characters when naming variables. Our team has opted to use meaningful and understandable variable names to aid with easy understanding and reasoning behind the variable name chosen.

Following proper standards prompts us to avoid the of digits in variable names, to use camel case lettering when naming the variables. It is suggested to start local variables names with a small case letter (e.g. smallCase) and a global variable name with a capital letter as the first letter of the word (CapitalCase). When naming functions in our code, we would be writing the names in camel case starting the first letter with a lower-case alphabet.

**Indentation:**

Indentation is not a specific requirement of most programming languages, but it helps provide a well-defined structure to readers and programmers of a code. An exemption to this statement is Python, which uses indentation to determine the structure of a code and is

We would be ensuring we adopt proper indentation styles in order to help increase our code readability. Indentation varies in styles for each component of a code ranging from braces, tabs, spaces, size of indentations and even comments.

**Exception Handling Conventions:**

The standard is to ensure that all functions are to return either a 0 or 1 for easy debugging of code.

**Line Lengths and Breaks:**

The length of line of code in our program should be between 75 to 100 characters, to ensure easy readability. We would be adopting the style of breaking our lines before or after a operator.

#### Coding Documentation

Code documentation is written text that accompanies the code and explains how to use the code or how it operates. It is a critical part in the documentation process of a product and includes algorithms and ed user manuals for users and administrator of a product.

We would be creating a Project Level Documentation via a README file to help curate a general overview of the project. To aid with the documentation process of this project, the team decided to employ the services of GitHub to help host all information used.

GitHub is a platform that provides internet hosting for the development of software. It allows for the distribution of version control and source code management. GitHub provides so many features and when fully utilized allows for the easy development of a project. GitHub provides an online storage of the code written and the code can be easily accessed and cloned (downloaded to a local directory) by anyone who needs to work on that repository.

In the code itself we will also be sure to use clear and purposeful comments. As engineers we need our work to be understandable by any party that is looking into it. The commenting of our code is very important because we will be working on the code as a team and it is essential that every team member understands what each portion of our code is trying to accomplish. It will also be very helpful for any debugging to have clear and purposeful explanations of what is happening. Coding without comments is considered novice and we should do our work as professionally as possible.

### Housing Standard

How electronic devices and components are enclosed are determined by the International Electrotechnical Commission (IEC). The IEC standard: IEC 60529 defines a code known as Ingress Protection (IP) code which measures and rates the degree of protection provided by casings whether mechanical or electrical against factors like dust, water, accidental contact, intrusions and other solid or liquid hazards.

The ingress protection rating entails two letters from “IP” followed by either 2 digits or one digit and one letter. Each digit represents a measurement of protection, the first digit after IP represents protection against solid particles, the second indicates the protection against liquids. There could be a supplementary third character which could be optional and pertains to mechanical impact resistance or other types of protections.

In the United States, the National Electrical Manufacturers Association (NEMA) are responsible for defining the enclosure types with respect to the IEC 60529 IP code. They are like the IEC IP Codes, offer the same protections but cannot be mapped directly. They are rated in types and range from one to thirteen (1 - 13).

We plan to allow our device to be at least IP3X rated. This means it is protected from solid items greater than the human fingers and above, although not protected against a deliberate contact of a body part. The average male and female finger size are about 193.04mm and 172.72mm respectively and is therefore greater than the standard 2.5mm rating given. As we would not be doing any form of testing in or under water, we would not be rating the equipment for ingress of water, hence the “X.” Once the idea of mass production comes to play and all the constraints and goals have been met, we could factor in a liquid ingress

protection rating.

The table below shows the IP rating chart we used to determine the degree of protection for our product. It is very important that we are aware of keeping our project protected from all these variables, we only plan on designing one final prototype to present; therefore, we cannot afford any mishap or negligent mistake.,

|  |  |  |
| --- | --- | --- |
| IP rating | Ingress protection against solids | Ingress protection against liquids |
| 0 | - | None |
| 1 | >50mm | Dripping water |
| 2 | >12.5mm | Dripping water at a 15˚ tilt |
| 3 | >2.5mm | Spraying water |
| 4 | >1mm | Splashing of water |
| 5 | Dust protected | Water jets |
| 6 | Dust-tight | Powerful water jets |
| 7 | X | Immersion up to 1 meter deep |
| 8 | X | Immersion 1 meter or more deep |
| 9 | - | Powerful high temperature water jets |

Table 9: IP Rating Chart

### Optics and Photonics Standard

The International Organization for Standardization (ISO) is an independent worldwide organization composed of about 165 national standard bodies. The ISO currently consists of 165 members and 796 technical committees from different countries. There is only one member per country, and the committees are charged with the development of industrial, technical, and commercial standards.

The standards cover terms and definitions, methods for testing and evaluation, estimation, and prediction of behaviors of various types of optic and photonic areas and applications. These areas are not limited to lasers, optical fibers, mirrors, optical devices. A standard is reviewed every five years in order to ensure the ultimate requirements for the materials are up to par.

There are over 500 standards for optics and photonics, but we would be focusing on the fundamental standards, standards for optical materials and components and Laser and electro-optical systems. These can be referenced via technical committees, sub committees and working group types. There are 305 published ISO standards related to this committees under the direct responsibility of ISO/TC 172 secretariat. 52 of which are under the direct responsibility of ISO/TC 172/ SC 1, 28 under ISO/TC 172/ SC 3 and 47 under ISO/TC 172/ SC 9. Each of the TC and SCs have a structure set in place for easy references to the standards.

For ISO /TC 172/ SC 1 Fundamental Standards, we would be referencing the general optic methods and Preparation of drawings for optical elements and systems with a working group type WG 1 and WG 2 respectively.

For ISO/TC 172/ SC 3, standards for optical materials and components, we would be referencing the characterization of IR materials and Raw optical glass with working group types WG 3 and WG 1 respectively.

For ISO/TC 172/ SC 9, standards Laser and electro-optical systems, we would be referencing the lifetime of Lasers and other laser-related equipment (ISO 17526:2003), as well as safety (WG 3).

Access to these standards do not come free but are also cheap to get in the form of electronic portable document format (pdf) for an approximate price of $1.08 per standard. We tried going over the standards provided by the IEEE, but we felt the standards provided were not adequate enough as the ones provide by the ISO.

As more research is made and the prototype is being built or even after completion, we would be making sure to refer to the ISO website to view and reference more standards required. Producing a product that meets all the required standards is paramount to us and we would strive to ensure we uphold and meet them in order to have a good quality product that can be used for years without safety or any other form of issue.

# Project Design

The initial step we took, as a team, was to familiarize ourselves with the American Sign Language to understand what each finger movement corresponds to. From there, we came up with a design that will allow us to mimic the hand gestures via sensors which will be applied on each finger. The motions will be converted to the ASL alphabet as well as into numerical output. We identified each finger according to the French word for finger “doigt” by using the first letter of the word plus digits from 1-5 to it. This will facilitate us to differentiate and identify each finger movement. Therefore, we will have D1, D2, D3, D4, and D5 (thumb, index finger, middle finger, ring finger, and little finger.)

Our overall design consists of three parts. The first being the glove which will house most of our electrical components which will be used to obtain data for our gesture to letter translation. The second part of our design will be the software implementation. Our software is going to need to take the data from the glove as input, and through a trained machine learning program convert the data to alphabetical letters. The third and final part of our design will be the projector, the projector will be built mainly by our CREOL team member. The projector needs to be designed to be energy efficient and quickly display the results.

Afterwards, we decided which components we would be ordering for the testing of our project. It was important to choose components we were going to be satisfied with because we wanted our project to work smoothly. We made sure we chose components based on function, overall cost, availability, and available resource (i.e. datasheets).

## Glove Hardware Design

This section gives the design documentations and functionalities that outline the overall project. It describes the functionality of each component we have chosen to make up this design. The hardware design presents the essential procedure of the project. Most of the component chosen for this design will be explained in detail in the flowing sections. We begin with the hardware that has been chosen for the glove design portion of our project. The glove design is very important because it will be the first part of our project that anyone sees. The glove will also be the start of our project where data will be created essentially and sent over to our software and finally displayed through the projector. We spent a lot of time discussing the design for the glove which would work best for what we expect our project to accomplish.

### Glove Selection and Integration

One of the first parts we chose was the glove. The glove will act as the home for all our electrical components and will be what the user wears to translate their sign language letters. The glove we chose is the Nike Dura Feel VIII Golf Glove, because of its price and availability, its durability and comfort, and the brand. This glove could be found on Amazon for a decent price and with Amazon’s Prime shipping will arrive very quickly. This glove is a sports glove, so it is very comfortable when being used, and it is durable through use and abuse. Nike is a well-known and trusted brand; therefore, we know we can expect great quality from the glove. This is the best glove for our project needs.

### Flex Sensor Selection and Integration

For the flex sensors we decided on the Spectra Symbol force sensors. We firstly decided to use these because they come in two size, 4.5 inch and 2.4 inch. We found it very useful to have two sizes available to use because not all fingers are the same size, usually the thumb and pinky finger are a lot shorter than the others. This could allow us to test both sizes and see how they respond, and potentially build a more comfortable glove. Another reason we chose the Spectra Symbol flex sensor was its general availability and cost. These flex sensors always showed to be in stock on sparkfun.com, digikey.com, and could even be found in amazon. Sparkfun and Digikey even offered discounted prices for purchasing larger quantities. The price of these sensors were also very reasonable compared to the other sensors we researched from BendLabs.

Another reason we chose the Spectra Symbol Flex Sensor is because it has a datasheet available which will be very helpful when trying to figure out exactly how to implement them into our design. The datasheet even includes circuitry schematics for how to test the flex sensor in different ways. We are all students so besides labs we have done for electronical circuit classes this will be a first-time experience for most of us, so having these resources is very useful. Spectra Symbol flex sensors meet all the requirements we need for the flex sensors in our project and have also been used in large scale projects like the Nintendo Glove (which has similarities to our project) and other glove signal projects, therefore we see it as the best choice.

The Sensors will be attached to each finger on the glove, starting around the fingernail area and running down past the knuckles. These sensors will then be attached to our MCU which will be found at the center of hand. As the fingers of the user bends the sensors will bend with them. This will be how the majority of the data will be obtained for our project. Depending on the angle of the bend the resistance for the sensor will change, and thus changing the voltage that it will output. There are several ways to build the sensors into the circuitry, the datasheet provides these circuit schematics. Below we have provided the various ways the circuit can be designed, and each one can be used for specific desired outcomes. Before testing we do not know how the output values will differ at different bend angles, so it is extremely important for us to test various ways to implement the flex sensor circuit to find the most distinguishable output results.

First is the basic flex sensor circuit, which will basically use the flex sensor as a voltage divider and is useful because it reduces error. We will start with this implementation of the flex sensor circuit. Below is the circuit schematic, which we will use as a reference for when we are prototyping the flex sensors and figuring out how to get the best output for our project design.

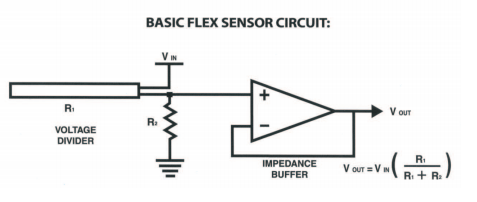


Figure 15: Basic Flex Sensor (Voltage Divider) Circuit

The datasheet also provides the circuit schematic for what they call an “Adjustable Buffer”, which adds a potentiometer which will allows us to adjust the sensitivity range for our sensor. This circuit is important because we might need to find a resistor value for our flex sensor circuits which will give us a specific sensitivity. We need our bend values to be distinguishable for different gestures, if the values are too similar it will make the training of our model that much more difficult. Below is the circuit schematic provided by the datasheet.

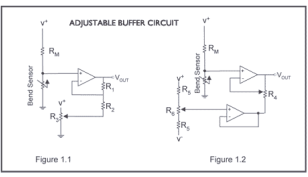


Figure 16: Adjustable Buffer

The other two circuit options allow the sensors to be used as a switch, and to be configured to output for small degrees of bending. Even though we might test these circuit we do not plan on using them for our design. We would only use them in possible testing to see the full potential of the flex sensors we are using for our design. Even though creating a switch could be useful for “turning on” the glove, but this is secondary to our main design. Therefore, only the voltage divider circuit and the adjustable buffer might be useful (and used).

### Force Sensor Selection and Integration

The forces sensor we chose for our project is the Interlink Electronics Force Sensitive Resistor. We chose this force sensor because it meets all the specifications needed for our design, it is available at the time we needed it, and its overall cost compared to other components is better for our project budget. This sensor is available from multiple retailers including Digikey, Sparkfun, and even Amazon. The price is similar throughout all vendors, so we had the option of going with whichever vendor had the quickest shipping. There is plenty of documentation available for this force sensor, making it highly desirable for us to use in our design. The sensor is ultra-thin, which will be great for our design, as we don’t want it to make the glove uncomfortable, we need this component to be almost negligible by the user. The force reading for this sensor is also said to be highly repeatable, which is necessary so that it can distinguish the gestured we need it to.

In the actual design we plan on placing the force sensitive resistor (FSR for short) in between the fingers. When we planned our design, we notice some previous projects implemented the force sensors differently. Some projects put a force sensor in between each finger, some used force sensors in between fingers and even on fingertips, and others used only one or two force sensors. For our design we are initially going with the use a very few force sensors. Our plan is to only use one or two force sensors on the glove. The main goal will be to help distinguish some letters that have very similar gestures, most specifically U and V. We do state this being our initial approach because with testing we are leaving ourselves open to possibly adding more force sensors if it shows to be necessary.

The datasheet for this FSR is readily available, which will be very useful for when we are testing and building or prototype. Circuit schematics are shown on the datasheet to help integrate the sensor into our project. The circuit will be built like a voltage divider, and a change in force will change the resistance, which will change the output voltage. Below is an image of the circuit provided by the datasheet.

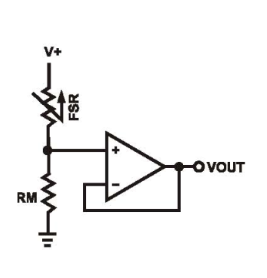


Figure 17: FSR voltage divider circuit

This can be implemented with a range of resistors which allows for fine tuning the output results sensitivity. Below is a graph provided by the datasheet which shows how the output voltage is affected by the force encountered, and how this is seen across different resistor values. From observing this graph we might be using the 10k or 30k resistor. However, our final decision will be based on the results observed during testing.

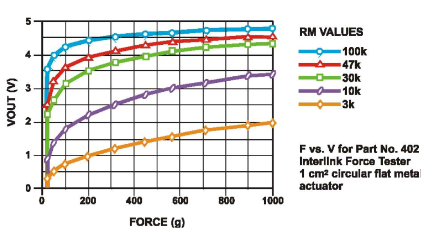


Figure 18: Force vs Voltage for FSR

### Force Sensor Senior Design 2 Update

For our demo we were having issues with the force sensors. Unfortunately, there was an issue we could not resolve which involved the force sensor causing our software in the MCU to crash whenever it was pressed. This caused the data values to be very unreliable and we could only get a few data values before the program crashed. The program would not send anymore data until the glove was reset. In order to avoid this, and be able to still do a demo, we removed the force sensor from the dataset. Essentially the sensor is still on the glove, but the MCU is not programmed to receive data from it. We worried that this would make our prediction accuracy very low. However, with the flex sensors and the accelerometer/gyroscope we still were able to maintain high accuracy, ranging between 96-100% most of the time.

### Accelerometer/Gyroscope Selection and Integration

For our design we will be needing both an accelerometer and a gyroscope to be able to build a trained model which can better predict which letter is being gestures. Some letters require movement or a rotation of the hand’s orientation. The accelerometer will act as sensors to capture these types of changes. We decided to use the Adafruit LSM6DSOX 6 DoF Accelerometer and Gyroscope - STEMMA QT / Qwiic. This was one of the first accelerometer/gyroscope that we found and researched.

We were very interested in it because it has both the accelerometer and gyroscope in one component, this means we can save both in over size of design and cost. This Acc/Gyro was also found to be inexpensive and fit within our budget. We did come across a small issue of it being unavailable in the states when we wanted to order it but were able to find it in Canada for relatively the same price. This component also has extra features which aren’t necessary for the project design, but are still impressive, including: pedometer, tap detection, and programmable finite state machine. The one feature which we found very interesting and is one of the main reasons we chose this acc/gyro is that this component has a machine learning core, which is specifically used for gesture recognition. This is going to be an essential component to our design and is going to help build a machine learning training model. This component can use either I2C or SPI for interfacing, which allows us to test which will be easier to implement with our design.

For integration we plan on having the accelerometer/gyroscope component to be attached to the PCB. We will either have a PCB designed with all the wiring set up and then solder this component (as well as others) to the PCB, or we will have a complete PCB built for us from a PCB vendor. Since we plan on having the PCB placed at the center of the back of the hand this is where the accelerometer/gyroscope would go also. This component will produce its own set of data which will be sent to the MCU. Its values will change depending on the movement of the glove and rotation of the glove. The data received from this component will be used to better predict which gesture is being made. This component is relatively small and can be hard to pinpoint for an observer of the glove in action. Below we are providing an image, so any reader knows how this component looks. Next to this image will be an example of how two different data values are sent from the component.

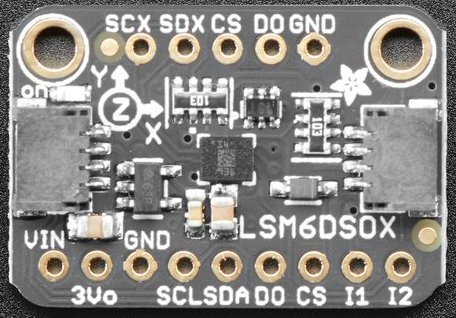
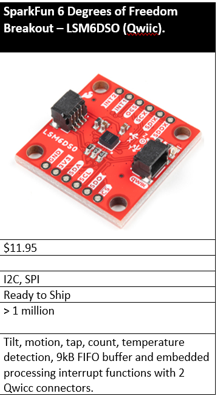
 

Figure 19: Accelerometer/Gyroscope (left) and output display (right)

### Accelerometer/Gyroscope Selection and Integration Senior Design 2 Update

When designing the prototype and final glove for our presentation we encountered issues programming the Adafruit LSM6DSOX 6 accelerometer/Gyroscope. Issues involved the embedded software and we were could not get it to output data. After several attempts we decided we needed to find an alternative solution. The ADXL377 was also having connectivity issues, we believed it had to do with the soldering and tried to implement it in different ways, all attempts also failed. One of our members had order a different Accelerometer/Gyroscope which we only intended to use as a last resort. The reason for us not initially trying to use it was because when we ordered it, it was backordered and didn’t know when it would arrive.

When we encountered these issues we had the third accelerometer. This one was the Sparkfun LSM6DSO. This accelerometer/gyroscope had all the necessary features we needed for our project as the others did. We found the necessary libraries, and were able to program it very easily. In several testing environments the accelerometer was able to produce X,Y, and Z values for both change in motion and change in orientation. This was perfect for our project, therefore we decided to use the LSM6DSO instead of the original one we planned on using. Below is a image of the device we chose to use and some of the key specifications of it.



### MCU Selection and Integration

As stated earlier, the MCU is one of the component that is vital to our project. We decided to go with the CC2652RSIP SimpleLink™ for the glove which meets most of our design requirement and it is favorable for our project. We chose this microcontroller as most the microcontrollers we did research on were out of stock or would be shipped from other countries causing a high shipping cost, and we decided to implement the CC2652RSIP SimpleLink™ in our design, which turns out to be an extremely affordable microcontroller which meets all our design requirements. The controller can be directly purchased from the Texas instrument’s website at a price of $8.274 which is affordable for our group. With such a affordable price we are able to buy multiple microprocessors to allow us room for any possible damaging, breaking, or chip burning. This MCU would enable us to have easy connection with all the components (sensors) we have chosen for the project as the MCU has 32 GPIO pins and Bluetooth capability that can connect wirelessly to other devices to read digital data. This section is going to present details on the integration of the MCU on the glove. Below is an image of the MCU’s pin layout which we will be referencing when designing our project.

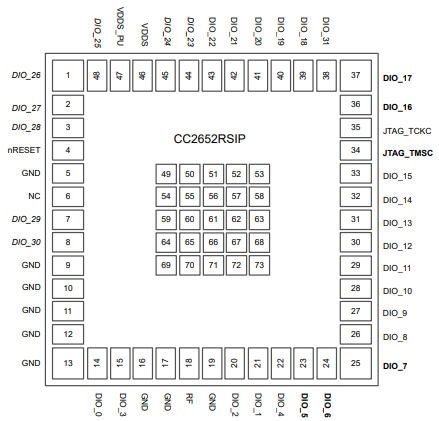


Figure 20: Displays pin diagram MOT (7-mm × 7-mm) Pinout, 0.5-mm Pitch of the CC2652RSIP module taken from TI’s data sheet for the CC2652RSIP

The CC2652RSIP SimpleLink™ MCU is RoHS-compliant package which is going to be integrated on a PCB as it is a 7-mm x 7-mm MOT with 32 GPIOs that will allow different components (sensors) to be connected directly to it. It has multiple capabilities for such a small MCU, and with its 48-MHz Arm Cortex-M4F processor, it is powerful enough to accomplish several functionalities that will enable us to receive data from all the sensors. With the MCU ultra-low power sensor controller with 4KB of SRAM, it is going to read and process as quickly as possible most of the data that the sensor will be sending in a form of electrical pulse. The microcontroller can sample, store, and process sensor data and can self-govern from the system CPU with a fast wake-up for low-power operation. We chose this device because it is going to operate by giving us digital signal that it is going to be easy to read. The majority of the data of different sensors on the glove consists of 8× 16-bit general-purpose timers, 12-bit ADC, 200 ksamplaes/s, and 8 channels as peripherals. Below we can see the microcontroller block diagram that gives us a brief understanding of its function.

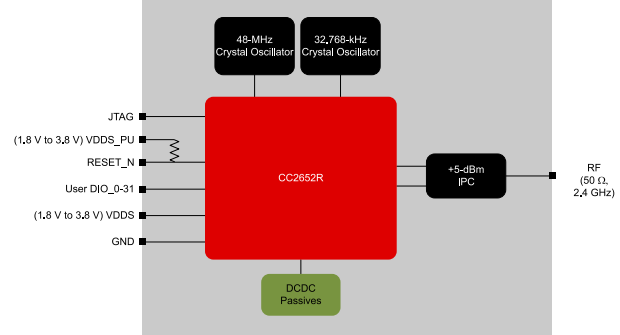


Figure 21: Displays the functional block diagram of the CC2652RSIP module taken from TI’s data sheet for the CC2652RSIP

In addition, when integrated, the MCU has multiple capabilities that we will need to use a range of resistors while connecting the different sensors to it to limit the flow of current in the circuit or to create a type of voltage drop for the MUC to receive sufficient energy to operate properly. We need to integrate the MCU so that it functions correctly with all the sensors connect to it as we don’t want the MCU to get overflow with different data from the sensor. We must create a channel or path for each component that it is going to be connected to it as it is going to permits us to analyze from which components or sensors the data are coming from. For the integration to be successful, we need to be familiar with the CC2652RSIP’s data sheet and user guide manual to know where all the pins should connect to. Below is the MCU’s hardware architecture that can give readers an understanding of what we are presenting. This is a figure we will also be referencing for the design of our project in order for us to all have a strong understanding of how our project is working as a whole.

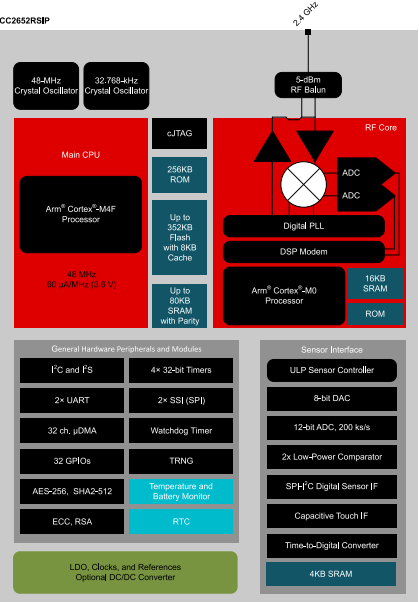


Figure 22: Displays a summary of the CC2652RSIP hardware taken from TI’s data sheet for the CC2652RSIP

### MCU Update Senior Design 2

Once we got the MCU in from the vendors we wanted to immediately use it to start testing within itself and the sensors. Unfortunately, we encountered a few issues with this MCU. The main issue involved a lack of datasheets and pinouts for the MCU. Originally we though we found some, but once we started to look into referencing it, the datasheet did not provide sufficient information to use the MCU. The most specific data we needed was the PINOUT and this was nowhere to be found. To solve this issue we decided to use a different MCU. We went with the MSP430FR6989, which is the MCU in the development boards we used for several other courses in UCF. Having the development boards allowed us to make up some time for testing while we waited on the shipment.

### Wireless Communication and Integration

Wireless communication was decided to be an essential part of our design since the conception of our project. Today everything is wireless, less and less devices are being developed wired, instead they are being moved to being wireless. We wanted our design to be relevant to the technology expectations of today. We researched Wi-Fi, Bluetooth, and Infrared wireless technologies. For our design we decided on Bluetooth for our wireless communication. Bluetooth had all the necessary features we needed for our project design specifically. Bluetooth technology has been being used for decades now meaning there are many resources for understanding how it works and even troubleshooting any potential issues.

The reasons we chose Bluetooth were because if it is simple to integrate into most projects, Bluetooth components are relatively inexpensive, and our device will always be near every design part (glove, pc with software, and projector). Wi-Fi was essentially too powerful and would not be necessary for this project design, and infrared could lose a lot of the data which could throw off our models’ predictions. The data we will be transmitting via Bluetooth is not sensitive; therefore, the encryption security provided by Bluetooth is sufficient for our project.

Initially we planned on ordering a separate Bluetooth module which would be either soldered onto our PCB or connected via wires to the PCB. The Bluetooth module we had been considering was a little large so it might be too big for the PCB. However, we came across a small issue when trying to order the MCU we initially decided to use. The vendor had run out of stock (it was in stock when we research it) when it came time to order parts. This caused us to find an alternative MCU with almost exactly similar specification. We ended up finding an MCU with almost identical specs, but it also has Bluetooth integrated in the MCU. This will allow us to still use Bluetooth, but we are now ordering one less part. We found this to be a positive, there is a cut in cost and build materials, there is also one less connection to establish (MCU to Bluetooth module). We did decide to order a Bluetooth module as a backup plan, just in case the MCU’s Bluetooth integration is faulty, or if we are able to order the original MCU.

For our project design we plan on implementing Bluetooth to mainly communicate between the microcontroller on our glove and the PC. The microcontroller will gather data from the glove’s sensors and create what we are calling the dataset. The dataset will then be transmitted via our Bluetooth connection to the PC, which will use this dataset to predict which gesture was made. We also would like to implement Bluetooth communication between the PC and the projector. This however is an implementation which we will decide on during final design. We would love to have a completely wireless system, but our main Bluetooth integration will be the glove speaking with the PC. Below we have included two diagrams of possible wireless communication setups, the differences will be the projector connection. We also use to Bluetooth master-slave framework, where the PC will be the master and the glove (possibly the projector as well) will be the slave. *Figure 23* illustrates our connection in a one-way scenario where only the glove and PC communicate via Bluetooth. *Figure 24* illustrated option 2 which will have a 2-way wireless communication and will be a considered a completely wireless design.

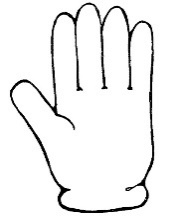
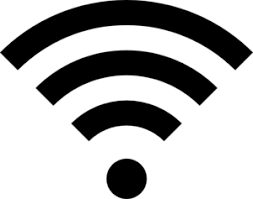
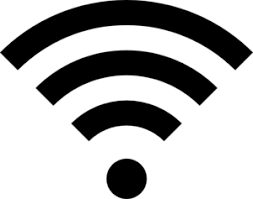
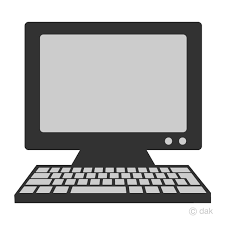
 slave → Bluetooth Connection ← master → wired connection → projector

Figure 23: Bluetooth Communication 1 way (option 1)

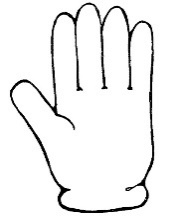
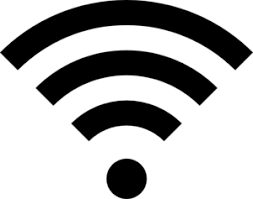
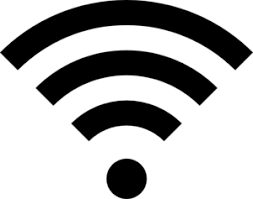
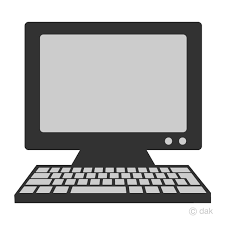
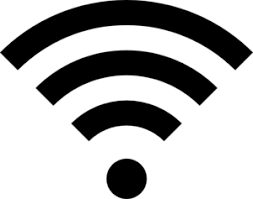
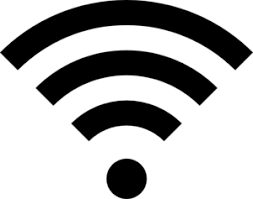
 slave → Bluetooth Connection ← master → Bluetooth connection → slave

Figure 24: Bluetooth Communication 2 way (option 2)

### Wireless Communication Changes Senior Design 2

Because we had to change the MCU we also had to change our implementation of Bluetooth. Originally the initial MCU would have integrated low energy Bluetooth. Due to us changing this we had to find a Bluetooth module which we could use. We found the HC-06 Bluetooth module, it was readily available and had plenty of resources to help with the setup.

### PCB Design and Implementation

When it comes to the design and implementation of the PCB it’s a little more complicated than picking one and ordering it. The PCB needs to be designed in PCB design software, once designed the PCB schematics can be sent over to a PCB developing company, which will be who actually makes the PCB. This is actually very useful, even though it takes thoughtfulness and patience, because the PCB will be designed and built to meet the needs that are project specific. This will eliminate having any unnecessary components or parts and can help in reduce project size.

We needed to decide which PCB design software we would use to actually design our board. There are so many options for PCB design software, ranging from completely free to extremely expensive. One of our main goals for this decision was to not impact our budget (free would be better) while still being able to use a well features design suite. Many of the options we looked into offered free student versions but did require registration of proof of enrollment. In the end we decided to use Eagle software. Eagle software became the obvious choice for three reasons. First, three of our group members had PCB design experience using Eagle. The three of us used Eagle in our Junior Design course at UCF. We learned how to design a schematic, a board layout, how to import schematics, and how to use many of the necessary features. Because we took this course at UCF, we still have access to the files which helped us use a lot of the features, so we could continue to reference them if needed. Second, Eagle has all the features we need for our design, our PCB is going to have some components, but will not be large, we are expecting a small PCB. The community version of Eagle has enough features for our design purposes.

There are generally two ways to go about ordering the PCB. The first way is to create a full design which includes the printed wiring and all necessary build components. This design will be sent over to a printing company which will develop the PCB and they will either obtain the components for it. This method created a professionally complete PCB, every component is integrated on the PCB and then delivered to the customers doorstep. The second method is similar, expect only the wiring and spacing for the components is printed on the board. What will be delivered is a PCB ready to have all the electrical components mounted. The mounting can then be soldered on by the customer, either surface mounted or through-hole. As of right now we plan on using the second method since we have order several of the components for our design already. Some members of our group also have soldering experience which will be useful for this part of the project design. Our third reason for choosing Eagle is that one of our team members has Fusion 360 by Eagle from the company they work for. Fusion 360 will give us the full suite of features if ever needed. Their experience using Eagle/Fusion 360 will make the PCB design portion of our project run smoothly.

As far as the PCB’s integration it will be physically attached to the glove, at the back of the palm. The PCB will be the central hub of all the electrical components and sensors. The PCB itself with have the MCU, Accelerometer/Gyroscope. The sensors will connect to the PCB, but they will not be housed on it. We will try to have the PCB covered to make the glove look more natural, but this will only be cosmetic and will not affect the function of the PCB or its design.

### Senior Design 2 PCB Issues

There were various issues we faced when trying to finalize the design of the PCB, due to parts being unavailable, we had to change up the schematic to accommodate what was available to us. Starting with the voltage regulator, the power source, the pins. We realized after our first design that the pins assigned to the LEDs were not in the TI code composer studio (CCS) and Energia library. One of our team members Olamijide, created and edited a new library with the pins P6.0 to P6.5 defined in the header file but to no avail. We came to a conclusion, after numerous research and inquiries that the pins were restricted for use, and decided to create a second revision for the PCB, with the LED pins reassigned. Other issues we faced were finding tactile switches that were available. After facing these problems, the team learnt that it saves a colossal amount of time in researching and buying the parts before exporting the schematic and creating the PCB design. As this would have prevented us from having to redesign the schematic and board most especially every time we had to change a part due to its unavailability.

Another issue we faced was the serial communication between the MCU and the Computer. As there had to be a form of easy debugging and communication, we decided to use the easiest and cost effective eay, which was using a pre-existing ez-FET from one of our MSP-EXP430FR6989 Lunchpad we already had. This saved us time, money as well as space on our PCB as we already had the battery holder taking more space than we originally planned. *Figure 32* in our Figure of tables can be referenced for easy understanding of the PCB.

### Power source/ supply selection and Integration

For this design, we decided to use batteries as our source of power to power up all the components on the glove. As a team, we chose to utilize the Li-ion batteries as they are not heavy, and they can fit perfectly with the glove design. It is favorable for us to use these batteries as they can hold a high-power density even when they are small. When we were doing research on different power sources, we wanted to have a battery that would not make the glove heavy and complex to use. We wanted all the components to fit perfectly on the glove so that it is going to be comfortable for anybody who wears the glove when trying to be utilized it. As stated early, they have voltage ranging from 3.0 to 4.2V when it is fully charged. Li-ion batteries are now used to power many electrical devices and we wanted to use them to be on the technology trend. These batteries are built to be safe for human to use in numerous sorts of environment as they are environment friendly. We need to use Webench which is a power design that create a made-to-order power supply. We are required to create a power supply that can provides us with an output of 3.3 V for the MCU and the accelerometer/gyroscope. In addition, the 3.3 V power supply, we need another output of 5 V for the Bluetooth module, the force sensing resistor, and the five flex sensors according the li-ion battery range.

In addition, When the li-ion are misused, they tend to explode as a result they have to be use according to their manual user guide when purchasing them. We are deciding to use a 2xAA battery mount where we can put li-ion batteries for space efficiency. The battery holder can be found on different vendors ’website like amazon, SparkFun and many other websites for a minimum cost of $1.50. We were also putting to consideration using the li-ion polymer which are now used in various smart phones as they are flat and last longer. When integrating the power source (batteries) on the glove, we need to put into consideration on how to regulate the flow of current in the circuit board so that all the components get enough power distributer accordingly to their specification. We will be required to have a range of resistors and other electrical components to control the current’s flow in the circuit as we do not want the components on the glove to burn. We need to create a type of voltage regulator in the circuit to disperse the power in the glove properly. Furthermore, the batteries will have to be implemented in a way that the components do not drain the batteries’ life quickly and drive them to explode. we need to familiarize ourselves with the batteries specification and user manual to avoid any type of electrical misuse of the device.

### Full Glove with All Components Design

In any design project it is very important to have an initial visual idea of how the project will look after everything is connected. This is a starting reference point which will help us in the physical design of our electrical glove. It is useful for comparing initial design to the final product. Below is an image of how we visualized our glove to look with all the components attached. This may be how our final prototype will look, but there is a potential for various changes along the way. As one can see from the image there will be five flex-sensors for each finger and thumb of the glove. There will be one force sensor between digit 1 and digit 2 (index and middle finger respectfully), this might be a part of our final design that changes, we will begin testing with one force sensor, but are open to add more if the design calls for it.

These sensors will then have wires that will run across the glove and connect to the PCB which is located centrally to everything. The PCB itself will house the microcontroller, the accelerometer/gyroscope, and other electrical components (capacitors, resistors, ac-dc convertors, power source, possible a switch to turn on and off). We have not decided how we will physically integrate the components onto the glove. Previous projects have either sewn the components or glued them on. We are leaning more towards using an adhesive to glue to components on to our glove. We would need to make sure the adhesive is noncorrosive and will not interfere with the component and their signals. We are not dismissing sewing and will possibly try both and see which is more practical, there might even be a combination of both.

For the initial prototyping we will stick mainly to this design because it is what we expect to work. If for any reason we find any issues with this design of the sign language glove we will change it to better fit our needs, whether it is due to comfort, function, or accuracy of results. We care more about the function and accuracy; however, we will consider changing design for comfort (if extremely uncomfortable for any reason) but only if it does not compromise function and accuracy. We will reference this initial design in our project presentation in order to show how close we got our final design to our initial design. The image is found below, and we created it ourselves.

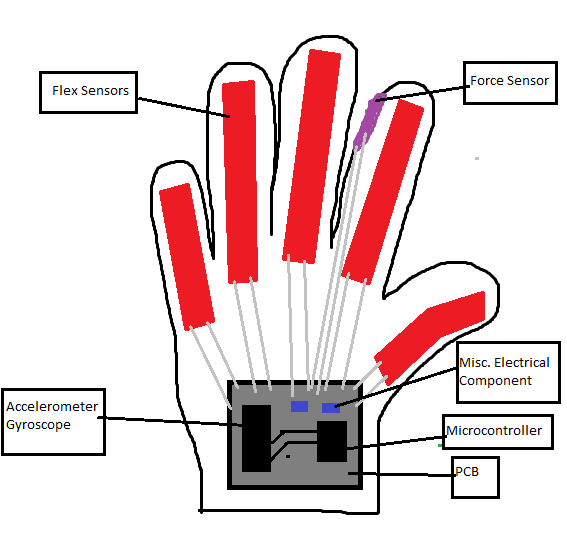


Figure 25: Initial Visual Glove Design

### Glove Design Changes

There was some changes to the glove design. Mainly it had to do with the size of the PCB and the batteries being used as the power-supply. These two components took more space than we anticipated. Making the glove a little more on the bulky side. We also had to move around some components including the accelerometer/gyroscope and the Bluetooth module.

## Software Design

Deciding how to implement the software portion of our project was the next step once we knew how the glove would be designed. It was important for us to choose a programming language which we could all use and learn, that way everyone could understand how our software would be working. Since machine learning will be used for our project it is important that our language of choice can use efficient machine learning algorithms. We also needed to choose an IDE which we all felt comfortable with and would be able to know how to use, or easy to learn how to use. Once those key factor were decided we needed to come up with a structure for our software design to create a good workflow, especially for the time of testing our software. Below is how we are imagining our software should flow from data received from the glove to projector output.

PC Python program receives data via Bluetooth

Machine Learning using Classification Algorithms Translates input data to output data

Projector MCU receives output data

Figure 26: Representation of how data is transferred from the glove and displayed via the projector

### Programming Language Selection

For the programming language it is not as simple to say we chose one language and will design our whole software around that language. We will be using more than one language for different parts of the software design. The main language we will be using will be Python for the machine learning implementation of our translation software design. Python is the king of machine learning, and has some main libraries and frameworks like Numpy, Pandas, Keras, SciKit-Learn, TensorFlow, and so many more, it was the obvious choice for the machine learning portion. The reason we say it will be our main language is because on the software aspect it will be the language that does the heaviest lifting. We will also be using C/C++ to program some of the electrical components like the MCU, the accelerometer, and possibly the projector. This portion of the programming will be more to get those specific parts of our project to work the way we need them to. We do not expect that software portion of the project to take too much time, so it will be considered secondary to Python.

Another reason we chose Python for the machine learning/translation and C/C++ for our electrical components is because we have all used these languages in past course at UCF, and some even worked on some independent projects with these languages. Python is considered one of the easiest languages to learn which allows for all of us to partake in the software design portion without having to learn a complicated language. Python was also the language used by most of the other similar projects we researched, therefore we will not try to reinvent the wheel, but use a formula that has been proven to work. The number of online resources for all these languages is also a reason we chose to use these, we know that if we cannot figure a particular issue out we can possibly find a resource online which can help us solve any issues.

### Machine Learning Implementation

We have known from the beginning that we will have to use machine learning to get a smooth-running project with a real-world application design. Hard coding was an option, but it won’t test our knowledge as much as implementing some form of AI which would require our software to predict which gesture is being made. We plan on using classification algorithms in our project like neural networks, random forest, support vector machine, and naïve bayes algorithm. None of us have truly used any of these algorithms before; therefore, we will start building machine learning training models as soon as possible to learn how to properly train a model. As of right now we are open to using any of these algorithms or a mix of them. As we train our model and start testing results, we will determine which implementation will be best for our final design. We also need to see which algorithms will give us the quickest results; one specification of our project is to give results quickly because we don’t want the observers waiting too long for a displayed result. Machine learning take a lot of computation, so we also need to decide how we are going to run the training for our model. Usually when training a machine learning model, a GPU is used, and sometimes even a virtual GPU is used. These are reason we need to start training early to know how to get the best result for our software design.

Our machine learning process will be broken down into two main parts. First there is the training of the model, then the testing of the trained model. We will use the output from our sensors during different ASL gestures, when all this output data is put together this will be our datasets. Our datasets will be fed into a training model which we have developed, and this is where the machine learning classification algorithms are used to create a model. Once we have a trained model the next step is to test our model. We will feed our model the dataset again, except this time we won’t be training but testing. Now we will see our results and start determining how accurate our model’s predictions are.

We know from our research of machine learning that training is going to take the majority of our process. We needed to have an idea of how we will distribute the development time for training and testing. It is important that we get well trained model for our translation software. Have a model which is improperly trained will lead to inaccurate results. We understand that there is no true possibility for one hundred percent accurate results, AI is great and powerful, but it is not perfect. Us being students with very little to no real-world development experience hinders us even more from obtaining “perfect” results. However, our goal is to develop a model which can be as accurate as possible with our tools, experience, and resources.

We plan on spending most of our development time on training, we are thinking around seventy to eighty percent of the time, and then we would use the remaining development time testing our model. We will of course mix training and testing (opposed to training for X-weeks, and then testing for Y-weeks), this way we can observe how our model improves or even worsens (overfitting/underfitting). We have made a diagram breaking down the training and testing plan for our software design. This makes it easier for the reader to understand how our software is using the data from the sensors and is also a figure we will reference to have a smooth implementation of our project idea.

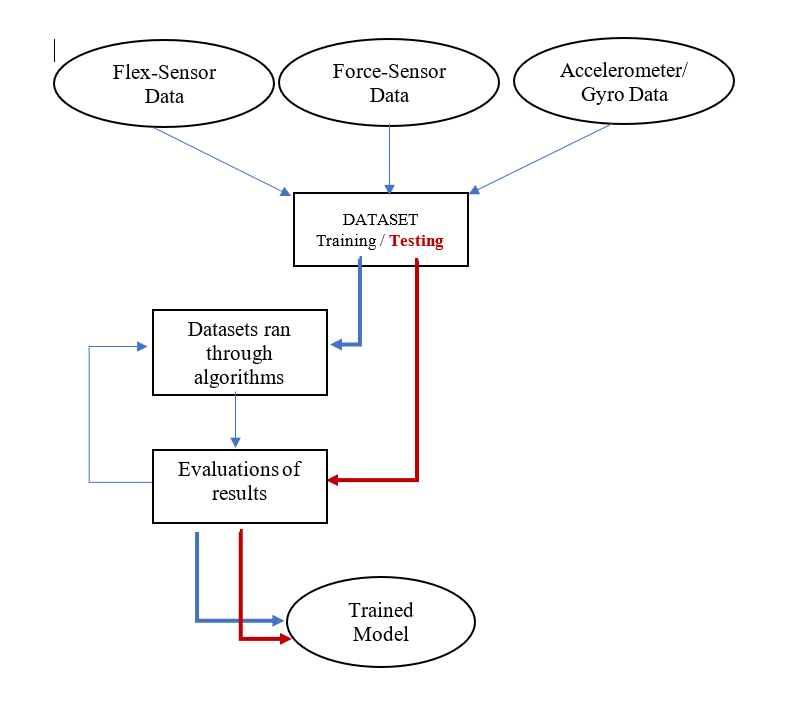


Figure 27: Basic representation of how our machine learning will be implemented

### Development Environment (IDE) Selection

For our development environment we wanted to use an IDE which could create python projects, but also had to option of creating projects in C/C++. We were very interested in Eclipse PyDev, but ultimately, we decided to use Visual Studio Code as our primary development, we did go ahead and have PyDev downloaded and ready just in case we came across any issues when using Visual Studio Code. Visual Studio became our best option because it work great for projects in C/C++ for any software development needed for our electrical component, but also has various plugins for other type of projects. The specific plugin we will be using is the Microsoft Python Extension, this will allow us to develop the python software for our project while reaping all the benefits of using Visual Studios. Most of us already had Visual Studios installed on our PC from previous UCF courses, making it a quick place to start our project software design.

Another great feature about Visual Studio Code which we found very useful for our project is the Git integration, this allows for smooth collaboration, with easy committing to a GitHub project. Since we will be using GitHub to work on our project simultaneously while in remote location this is an extremely useful feature. Git also has version control which is a safety net we will always have in case the code is ever broken, allowing us to return to past versions. Visual studio is also an open-source IDE, has great debugging tools (which we will most likely encounter various debugging issues), and has several libraries available to help use develop the best possible version of our software.

We are very hopeful that this development environment will create a positive software development experience. We plan on using all available resources for any possible roadblocks we encounter. We plan on reaching out to previous professors who use Visual Studio in their course if we have any questions about any aspect of the IDE. We also plan on looking into any threads available discussing possible issues other developers have encountered. Microsoft develops Visual Studios; therefore, we also plan to reach out to their technical support with any questions or concerns we might encounter during the development process. Our biggest goal is to work as a team as we would in a real-world development project.

### Development Environment Senior Design 2 Update

For the majority of the software development process we used two platforms. For developing the software the work with electrical components like the flex sensors and forces sensors we used energia to program them. Energia provided the necessary resources and was very user friendly for our testing, prototyping, and finalization of the project.

For the machine learning software we downloaded the anaconda development environment to use Jupyter notebooks. Jupyter notebooks allowed us to create the software and easily access all the necessary libraries and visual our data. Once software was developed we used sublime text editor to run the software through our PC command prompt.

Python flask was also implement to be able to create a web application which could use the data being sent via our glove to the PC. Python flask was developed using python and HTML/CSS. Our web applications goal is to display real data which is being received and used to make the translation. This was also developed on sublime text editor and tested on chrome browser using local host.

### Version Control Integration

From our research we found there to be various version control options available, but we knew from early on that we would use GitHub. GitHub is a version control environment that most of us have used in either personal projects or coursework projects. It is open source and widely used by the development community. GitHub is free, which is great for our project budget, and there are so many online resources to learn how to properly use it. Since we decided to use Visual Studio Code for our program development environment it was also best to use GitHub for our version control, since it is integrated in Visual Studio Code.

The use of version control will be primarily to be able to always have a safe and stable version of our program to go back to. There will be several of us working on the software for this project, and we will most likely be working at different times and from our own homes. In any programming project there is always the chance of breaking the code, sometimes these issues are easy to fix, but sometimes they are very difficult to find. Version control will allow us to go back to a working version which will save a lot of time and headaches. Using GitHub will also allow us to push and pull to the software programming easily from our PC to the repository. This will allow us to have a constant updated version of the codes we are working on, even if different members are working on different parts. GitHub has great documentation features and helps in organizing our programming portion of our project. Documentation and organization are essential in a programming development project to avoid clutter and confusion. We plan on organizing everything so anyone looking over our codes can understand the purpose of everything, and we will also include a README to document every aspect of our software design.

## Projector Hardware Design

For the project hardware design, we chose components that were both found at an affordable price for our project budget and available to be delivered before the end of our Senior Design I semester. Below in *Figure 27* is a schematic of the final design for our projector and screen. The image is not to scale but displays how the optics of the projector will function.

Diagram, schematic

Description automatically generated

Figure 28:Projector Schematic

We made sure that each component met the specifications for our project. Datasheets and documentation were also important for our selection that way we would know how to implement these components in our design. We broke down our selection and integration of each projector component below.

#### Beam Splitter Design

For the sake of weight and cost, we looked more towards using 2 plate beam splitters. More specifically the reflectance to transmission ratio we were searching for was 30:70 for both. The reasoning for this ratio was the fact that we are creating 3 identical images with the aim for them to all be close to equal image quality and brightness. Below are the two options that we considered for purchasing the beam splitters (*Table 8*).

|  |  |  |  |
| --- | --- | --- | --- |
| Manufacturer | Part Number | Dimensions | Price+ shipping |
| Edmund Optics | #46-688 | 18x33 mm (rectangular) | $89.93 |
| Thorlabs | # EBP1 | 25.4 mm (circular) | $85.54 |

Table 10: 30:70 R/T Plate Beam Splitters/ cost for x2

The restrains that we had for these components were cost and more importantly shipping time for testing. Unfortunately, there were other wholesaler websites found that sell beam splitters, but they all either take too long to ship or do not offer the reflectance to transmission ratio that we were looking for. Both options we were looking at had similar shipping time, so we decided based off price and the dimensions of the beam splitters. The cost of purchasing them from Thorlabs was cheaper, and the fact that it was circular seemed beneficial considering that we will be making our own lens holders since buying them will be expensive. The design of the lens holders will be V-shaped and will comfortably hold all the optical components if they are all circular.

#### Lens Design

The two main properties of the lens design that we were looking for is the diameter and focal length. Being able to collimate the light in front of the source gives some leverage as to how big or small we want the body of the projector to be. When a light source is collimated, it means that the resultant image created will stay the same size no matter how far the screen is. This happens when you position the object to have the image focused on infinity, instead of a specified point. Collimating lenses are usually either biconvex or Plano convex lenses, where the object is placed at the focal point of the lens.

The LCD that we are testing with is approximately 4 inches wide. To ensure that there are no issues with parts of the letters of the LCD screen cutting off, we ensured to design a lens that was close to 4 inches. The diameter of the lens is not the defining factor of how it would collimate light, but just how much light it is able to convert in a specific position. The LCD we are using is backlit with diverging light, which is why there is a need for a collimator. This is needed since this projector will be splitting a single image with beam splitters which are each 1 inch in diameter. Since the image will be split twice, it is important that the image that is created is collimated to be less than 1 inch so each of the images are equal size.

Diagram

Description automatically generated

Figure 29: Biconvex Lens Radius/Focal Length Relation

Hecht, E, C 2017, Optics, Pearson Education, Inc, USA [20]

The focal length of the lens is also related to the radius of curvature of the lens. The higher the radius, the shorter the focal length of the lens as shown in *Figure 28.* This is relevant considering that even though we want a short focal length, the higher the radius, the thicker and heavier the lens will be considering that the diameter of the lens is set to be 3-4 inches. Considering that we wanted the projector to be both small and light weight, we aimed to use a lens that had a focal length around 15 cm.

Below is a table showing three options for 3-inch double convex lenses (*Table 10*). Both double convex and plano-convex lenses can be used as collimating lenses, but double convex lenses seemed to be more accessible on multiple platforms. Since the PSE demonstration was approaching, it was important that the lens was able to ship quickly to ensure time for testing. It was decided that the Amazon lens would be purchased since it had 1-day delivery compared to the Edmund Optics lenses who has a processing time of 3-5 business days plus $8.99 shipping.

|  |  |  |  |
| --- | --- | --- | --- |
| Manufacturer | Part Number | Focal Length | Price+ shipping |
| Edmund Optics | #53-107 | 75 mm | $17.49 |
| Edmund Optics | #53-115 | 100 mm | $14.19 |
| Amazon (EISCO store) | #PH0534NCV | 100 mm | $9.89 |
|  |  |  |  |

Table 11: 3-inch Diameter Lenses

Considering the size of the LCD that our group already owns in respect to the beam splitters that will be used, in senior design 2 we will need to add to our optical system to minimize the image before it goes through the beam splitters and then apply a positive magnification to it for people to properly view it. To design our lens system, we will be using Gaussian and Newtonian lens formulas that can be easily found online, in past geometric optics lectures, and our Optics textbook by Eugene Hecht.

#### Mirror Design

Since mirrors are easily accessible, we considered the buying options for it last in respect to all other optical components. The collimated image formed in the optical system will be at most 1 inch to accommodate to the dimensions of the Thorlabs beam splitters that were purchased. Because of that we looked for cheap mirrors that we could use that were 1-2 inches wide in diameter and circular in shape to use easily with the lens holders that were designed. We were able to purchase a pack of 50, 2-inch, circular craft mirrors for $12 on Amazon that was able to ship within 2 days (Model number #46-688, Super Z Outlet ®). We are using far less than 50 mirrors, but we figured that we would not have to worry about damaging possible cheaply made mirrors when testing out the demo and final presentation of the projector.

#### Screen Design

With the idea of making this projector design more useful for the deaf community, we decided to go with a clear projector screen that would be situated close to the user. The reason for this is the importance of nonverbal communication. Having a screen that is able to project translations while also not blocking the users body language is one of the main goals of our display. The screen will be a trifold system for easy transportation and the ability to be visible multiple viewing angles. For it to be big enough to project clear images to increase viewing distance but for it to also be light enough for user convenience, it was decided that the panels of the screen would be no larger than 24” by 24”. We will be mainly looking for acrylic based material since they are more durable, lighter, and cheaper than glass. This projector system is short range and shouldn’t go above eye level when resting on a table, which means the base does need to be too high.

The projection screen will utilize rear projection film for the images to be visible on the glass. There are many options available online with a very wide range of costs. To be able to cut costs, we may look towards alternative markets found on platforms like eBay or Alibaba.

# Project Prototype Construction & Testing

Before assembling and construction of the product, it was adamant for us test the components and parts individually and collectively for confirmation of specifications, and to ensure they worked properly. After testing is completed, we would be constructing the parts in sections to allow for easy examination of the devices in case we run into any electrical or mechanical issues.

There are multiple ideas taken into consideration to allow for a smooth and successful testing procedure. First, is the location, for the testing of optics and photonics materials and data, we chose to do the tests in the CREOL lab. For the testing of the electrical components, we had more leeway in locations, as most of the team members all had the equipment needed to conduct the tests. With the reopening of the Senior Design Lab in the Engineering building at UCF, we decided to utilize the Lab to conduct some tests that we could not conduct in the convenience of our homes.

Also, for the testing of the gloves and projectors, since our rating standard did not include dust protection and water prevention respectively, we planned to limit the possibilities of transporting these items from one point to another. We decided to have the parts and materials stored as well as testing conducted in a closed, dust free room or office to avoid any chance of rain or water pouring on the items.

## Hardware Testing

As the design of the project requires electrical and optical components, individually testing the parts would be ideal. The components required for testing includes the Flex sensors, MCU, power supply, laser diode, accelerometer and gyroscope, and the PCB.

For our project it is vital that we begin the testing for these hardware components as soon as possible to ensure that we have working components and learn how to use them. We will do our testing in phases where we start will a simple test of the component to ensure that it works in general. Once we know the component works we will start to test it in the ways we plan on implementing it, and might even have a basic prototype we might use. The final part of testing will be testing it with other components it might need to communicate with. If our components cannot communicate we will have a difficult time with our project implementation.

We would be referencing the user guides and datasheets provided by the manufacturers in order to achieve the specification standards for each component. Rigorous testing would be done at different intervals, before putting all components on the gloves, and the case housing the electrical components of the projector. Most of our testing will use breadboards, and any basic electrical components (resistors, capacitors, transistors, etc) will be used from development kits we currently have in our possession.

### Power Supply Testing

The initial testing of the power supply for both the glove and projector would be performed on a breadboard. The voltage across each component would be tested and measured to ensure the required value needed are being received for the components to operate efficiently and to also avoid any electrical breakdown. We would be testing to see if the lithium-ion battery we are using is being charged accurately in a timely manner. We would also be testing how long the battery will last on a single charge. It is important that we ensure the battery doesn’t die quickly in order for it to be considered efficient. If the battery only last a short time when powering the glove, then we will need to test another Lithium Ion battery, or potentially think of using another power source.

For the projector we will test if the power source by making sure that the projector works when connected to a power outlet. We need to ensure that the projector does not get burnt out by the power being supplied by the outlets therefore we will make sure it can handle the power. The main goal for our testing here will be first that it can receive the power and second that it can handle it too.

Once we know both our power sources are working we can rest assured that our project will be able to be powered and work, this is a very important part of testing because without the proper power source we will either have a project that does not function due to lack of power, or can causes damage to the electrical components and have a dangerous design on our hands (literally).

### Flex Sensors Testing

A large portion of our data for our dataset will actually come from the flex sensors we will be using on our glove. The expectation is that the flex sensors will send different values depending on the angle it is bent. The way this will work is that a different angled bend would change the resistance across the flex sensor, therefore changing the output voltage for the device. This output voltage is extremely important because it will be our input data for our datasets. We will be using five flex sensors on the glove to represent five fingers.

The initial testing for the flex sensors will involve us designing the sensors with a voltage divider. We will physically test the flex sensors by bending them to certain angles and see the output it gives. We will change our angles to see how the output changes. We will also do repeat testing with similar angles to see if we can obtain repeatable results, this is important to know what values we should expect at certain bends. We will also design the flex sensors with a potentiometer to find the best resistance the have in the circuit to get the most distinguishable output results. We will need to test each flex sensor to make sure they are all working as expected, we are ordering a few extra sensors just in case there are any faulty sensors in order to not delay design time.

The secondary testing of the glove will be using multiple sensors on a prototype glove to see how they each send their own signal. This is the most important testing phase for our flex sensors because we are seeing them responding and sending data as a whole and it is how the glove is expected to work. We will do several of these test in order to record expected results for each letter to build a strong training model.

The third testing phase for the flex sensors will involve the values being sent to the MCU. This will be tested until proven that the MCU is receiving the correct data values or expected data values and not garbage values. The MCU records the voltage change and interprets it and links it to a certain letter. Each letter would be unique to the degree of bending of the flex sensors. Testing and adjustments would be numerous occasions to recognize the letter needed to be projected.

Overall, the testing phase for the flex sensors will involved circuits built on a breadboard for easy adjustments if needed. The breadboard will allow us to make changes in circuitry without much effort. When we start using them on a glove it might be a prototype glove which won’t be used in the final product. This is necessary because once we attache the flex sensors to our final glove we don’t expect to remove them. Our plan is to do as much testing as necessary with these sensors because they will create a majority of the dataset and we cannot afford to create erroneous data.

### Accelerometer and Gyroscope Testing

The accelerometer would be tested differently from the gyroscope as they are two different sensors. The accelerometer would be tested to ensure it senses the tilt and orientation of the hands. There are some ASL letters which look exactly alike except for the difference in hand orientation. A good example of this is the letters D and G, both of these letters are a closed palm with the index finger pointing out. The difference is in G the hand has a horizontal orientation. The accelerometer needs to be able to distinguish a change in orientation to distinguish the letters. There are several letters that have these types of similarities with a small different; therefore, the accelerometer is paramount in identifying and differentiating each letter. The major test would be the downward orientation of the hands, once a letter is identified when the hand is in a downward position, the accelerometer can be said to be functioning adequately.

The gyroscope will be tested in a similar manner, but the gyroscope will be detecting some type of movement. When a motion is detected, and most likely a swift motion, it should create an output which will help distinguish letters. Most of the letters in ASL have no movement involved, so the gyroscope will be useful in predicting the ones that do. Both the gyroscope and the accelerometer should work together for better prediction, and without them our results accuracy would be very low.

We plan on first testing this component (it is one component with both devices integrated) by programming the device and using UART and I2C to display the changes in values when the component is move, shifted, shaken, and other motions as well. Once we understand how the component works on it own, we will begin the integration into our glove testing.

### PCB Testing

Before the PCB is sent out for production, the components that make up the PCB need to be tested individually to ensure they are working efficiently. To achieve this, a prototype would be made by connecting all the required components and mounting them on a breadboard.

To design the schematic and layout of the PCB, the Eagle PCB design software from the Autodesk family would be used to create the schematic. We would be importing the CAD libraries, footprints and symbols of every component been used, this would be used to create the overall schematic of the PCB. Additionally, the schematic would be exported, and tested for any DRC or ERC errors. Th ERC command is used to perform a consistency check to ensure there are inconsistency between the implicit power and supply pins in the schematic and the actual signal connections in the board. The DRC is also used to perform consistency check on the board to ensure the design rules are being followed. Such rules could be the wire styling which cover the base areas of air wires and wires overlapping.

### PCB Manufacturing

After the components have been tested and configured on a breadboard, as well as designed on Eagle, and all errors and performance evaluated, the design and layout would be sent out to a company that specializes in the fabrication of PCBs. We would ensure to choose a company with a reputation of creating quality PCBs and a faster turnaround time. We will possibly order more than one PCB if they can be found at a reasonable price. We want to do this to ensure we have enough boards in case of any mishap or board failure. Time is very limited for our project; therefore, we cannot waste time waiting for a secondary or backup component to arrive. As we would require the PCB to be in our hands for the design to take place, and for further testing once the design is completed.

## Optical Testing

There are various components that make up the projector, after design, these parts would need to be tested to ensure the specifications and optimal standards are met to allow for peak performance. Some theoretical tests and evaluations would also need to be made before the design is sent out to be manufactured, if needed. Such tests include getting the right focal length, refractive index, position of Lens and mirrors, etc. As the device would be used in different locations or environment, it is ideal for the projector to be tested under different conditions.

It was important for us to note that while testing our initial optical components, we used the flashlight from a phone. The average phone light is usually no more than 100 lumens, which is low for what we were aiming for. After the demo we would start testing the brightness of the LCD with a built-in backlight that was already owned by one of the group members to see if we would need to use a separate back light to get the projection brightness that we were aiming for.

### Lens Testing

For testing the lenses, various properties of the lenses were examined, the major variable being the focal length. The focal spot of the lens will be detected by the process of directing a collimated light source directed towards the lens. Then the distance from the lens to the minimum width of the beam projected would be measured. This distance is the focal length and should correspond to the value provided by the manufacturer of the lens. The focal length could also be calculated by summing up the measured distance of the lens to the projected image in focus and the distance of the object to the lens.

The collimated lens that was purchased from Amazon was initially tested by placing a phone flashlight at the stated focal point of the lens. We then used one of the mirrors that were also purchased form Amazon to reflect that light on to the wall that was about 5 feet away from our position and it created a focused image of the light aperture. We were able to confirm that the lens’ stated focal length was accurate by moving the mirror to different distances away from the collimating lens, while also confirming the quality of the mirrors. We observed that the image that was projected on to the wall maintained its image quality, brightness, and most importantly for this application, size. The collimating lens was also used in conjunction with the beam splitters that were also easily tested. Using a white trifold as the screen, we manually held up the beam splitters to align with the direction of the phone flashlight. To our surprise, the reflected images (30% reflectance) was not extraordinarily dimmer than the transmitted image (40% overall transmittance).

## Software Testing

Testing our software is going to be very important for making sure our project can be presented as a complete project. Hardware is going to be the physical aspect of our project, which will be used obtain data values. The software on the other in is going to be the hidden aspect of the project which will take the data created by the hardware and predict what letter the gesture is trying to make and finally send it over to our projector to display. If the software isn’t developed correctly, we can have high levels of incorrect results or a project which doesn’t deliver.

It is important to start testing software as soon as possible. We will test software designed around the sensors, software which will create a dataset, software to build a machine learning model, and software to give the projector the output to display. We expect to run into bugs throughout the development of our software and will need to be ready to start debugging as soon as possible. Our goal is to create software which works quickly and efficiently, creates accurate as possible results, and can produce repeatable results without crashing. We expect to make mistakes along the way, but we will learn from them and work as a team to get our software behind our project working smoothly and professionally.

### Electrical Components Software Testing

Our sensors are all hardware components, which will give an analog output, i.e. change in resistance or change in output voltage. In order to obtain these outputs and use them as data for our datasets we need to build software which will take these outputs as data and store them. We will be designing programs which through ADC will be able to create actual values for the analog output of each sensor. It is important we test this software as soon as possible. It is important that we research similar programs and have expected values, this way we have something to compare our results to. Our software needs to create repeatable (won’t be 100% exact) results to show that it is obtaining real results and not garbage data. This is the first step in our software testing because it will be the first step in our project design execution as a whole. We will need to design software for the electrical components which can get data from each sensor at the same time, can distinguish which specific sensor is creating that data (i.e. Digit-3 has a value of X), and can be stored to our memory. With this we are able to build a software which creates our data for our prediction model and also can test our hardware at the same time.

### Machine Learning Software Testing

As far as software testing goes, the majority of our testing will be dedicated to determining how our machine learning model is working. We will need to create datasets to train our machine learning model, training is going to take a larger portion of the time when we are working on our machine learning software. In training we will actually be building the program and learning ourselves how to best train it. Along the way of training we will implement testing, it is important to test as we go in order to see how the machine learning model is either improving or worsening to changes, we make in our training model.

The way we will physically test our machine learning software is in two steps: first we feed the datasets to the training model and allow the program to run, second we use the physical glove to send a dataset and let the model make a prediction. The training will take the larger chunk of testing time because we will be writing the code and making sure it works, and then letting the model train, which just takes time on its own. The smaller part of the testing, but possibly more important, is to actual do a test of the trained model to see if it is predicting the correct letters to gestures. The way we are going to do this is by having the glove fully developed, with all sensors and electrical components where they need to be and make a gesture. Once the gesture is made, we will know the expected outcome, but we have to see how the model uses the data and what it predicts. Believe it or not the first big stride in our testing in this manner will be the model making any type of prediction at all, right or wrong, it will show us that the model is indeed at least doing its intended purpose.

Once our software testing has reached the stage that it at least predicts letters for the gestures being made we need to start testing for accuracy. Since we are working with alphabetical characters we will start with A and move our way down to Z. Our testing will work with A and see if the machine learning model can predict that the gesture is equivalent to the letter A. If the model cannot predict it we can move to B and see if it predict this letter. We will continue this method until we get a correct prediction. If we get a correct prediction, we will repeat that letter several times to determine if the result is repeatable. This repeatability is important to distinguish a true positive result from a false positive result. We will do this repeatability method for a few iterations or until we got an incorrect result, once we finish the repeatability method we will move on to the next letter/gesture. If we don’t get a single correct prediction our testing has proven that our model has not been trained correctly or enough and we must really look into the training data. We will continue this testing method until our model begins to improve and produce more correct results than incorrect results.

Our goal is to tweak our model and training along the way, and our testing results will be how we base what we tweak. This will be a first for all of us in developing with machine learning so we will really be experimenting on where we make changes to our training model to improve results. Version control is going to be very important in this part of testing because we might edit our code to improve training but run the risk of completely wrecking our training model, so being able to go to a past version is essential. There a several ways we can change the training model to change our model’s prediction results. The first we will always try to investigate and change if needed is that datasets the model is training with. The datasets could be increased or decreased, and we can then observe the prediction results this creates. Another option is to change the classification algorithm being used by the training model. One of the reasons we researched various machine learning algorithms is to potentially test all of them to see which one’s will produce the best possible prediction results. As we change the training model it is important that we keep documentation of how the model performed every time it was tested. This will be our accuracy log which will tell us how many times the model was right or wrong. This will help us reach our most optimal version of our machine learning software.

There will come a point where our model is optimal, and here is when testing is most important for our machine learning software. When our model is at its optimal state, we need to start testing random gestures. Up until this point our gesture testing would be primarily linear A, B, C, … Z; however, life isn’t linear, life is random, and nothing truly sticks to a straight linear path. Random gesture testing is key to finding the true accuracy of our machine learning software. We might just call out a random letter and the person wearing the glove will gesture it, or we might have a fishbowl with papers with letters on it to determine what gesture to make, or we might even develop a separate program which generates a random letter and then we gesture it. The point being that here we have reached the point our machine learning testing where it needs to have randomness, we must know that our model can work outside of linearity. We will continue logging our accuracy results at this point because here we will test the trained model several times and checking to see if it keeps its accuracy. Once the model produces accurate results with every testing, we will consider it working and ready for presentation.

#### Threshold Testing

When discussing what our expected outcome of the machine learning prediction model we all agreed that testing should be considered successful at certain thresholds, and we agreed to start small and work our way up. The group decided that we want a sixty percent success rate for our prediction for our model to be considered “working”. But we also did not only want our prediction to simply work, we also wanted them to be successful. So, sixty percent is considered working, and we know from there we improve, our goal is at least a seventy-five percent success rate. Some might think this is low, but for our level of expertise and experience in machine learning we believe this is a realistic number for us. During the project conception phase, we wanted to build a device that was almost flawless, at a success rate of ninety or ninety-five percent; however, after much research we have realized that that might be a little unrealistic, therefore our goal is for three out of four gesture need to be accurate for us to consider our design a success. We have called this Threshold testing, until we reach a fifty percent success rate, we do not consider the model and design as working (even though even at 15% it is working); then, we continue to improve our prediction model until testing shows an accuracy of at least seventy-five percent.

#### Different User Testing

One large challenge we will have is how the data results might differ in a different user’s hand. Within our group alone we compared hands one day and realized we all had different size hands. This could be an issue when we are testing the glove, because there is potential that our training model will get different data from two people with different sized hands: therefore, producing different prediction. We are tackling this problem by having one main person doing the gesture testing most if not all the time. We are aware that this isn’t practical for a real-world device, because again, not everyone has the same sized hand. But using one main glove wearer will help eliminate the probability of not getting true accuracy readings from our design. It has also been agreed that the same person doing the glove testing will present the glove as well. We did state it will be most of the time because we are still curious to see if a different sized hand will get incorrect predictions. So there will be a day where we will all test the glove to see the true impact it has on our prediction models output.

### Projector Display Software Testing

Our Projector will be our device to mainly display our output, the glove does the gestures and creates the data, the PC uses that data and through machine learning makes a prediction, and then the projector will receive the machine learning software’s prediction as input and display it. For the most part any software involved with the projector is straight forward. We just need to make sure the projector receives the correct data from the LCD we are using, and it is in a form it can correctly project onto our display medium. We are going to initially do this wired using a USB connection to the projector device we are designing to make sure our design project works completely. If time permits it, we would like to enable a Bluetooth connection between the PC and the projector to transmit the necessary data.

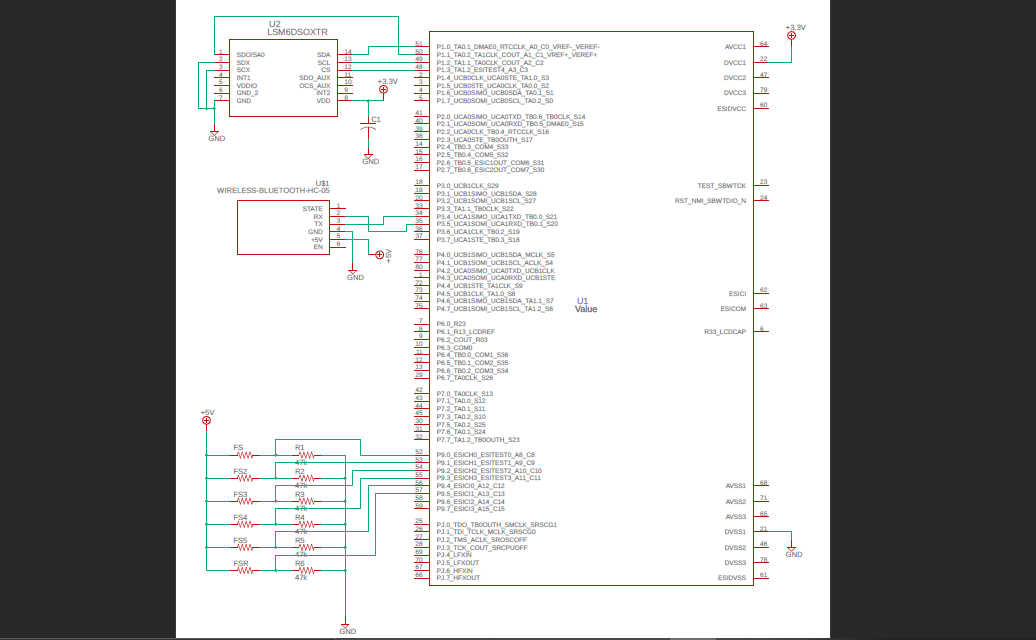
## Schematics

The glove’s schematic is composed of eight different components that make the overall hardware connection. the schematic has the LSM6DSOX (accelerometer/gyroscope), the HC-05 Bluetooth module, the five flex sensors (FS), and one force sensing resistor (FRS) connected to the MSP430FR6989IPN, microcontroller. Starting with The MSP430FR6989IPN with the DVCC1 pin which is connected to a 3.3 V input voltage as it is recommended on the datasheet for it to activate, and the DVSS1 pin is connected directly to the ground. According to the LSM6DSOX’s electrical specifications on the datasheet, The LSM6DSOX must have an input voltage of 3.3 V to operate. It has fourteen pins and we only used the pins that need to be connected to the MCU and be used to make it operate according to the datasheet.

We used seven pins of the LSM6DSOX to make the connection possible. VDD is connected to a 3.3 V power supply with decoupling capacitors of 100nF ceramic connected with the ground. The SDX and SCX pins are connected to the ground, the SDO/SAD pin is connected to P1.1, the SDA pin is connected to P1.0, the SCL pin is connected to P1.2, and finally, the CS pin is connected P1.3 of the MUC. This makes the complete connection of the LSM6DSOX to the MCU.

The HC-05 Bluetooth module has only six pins to make the connection for it to function as it is required by the datasheet. The module required an input voltage of 5 V to operate. On the schematic, the module +5V pin is connected to a 5 V power supply, the GND pin is connected to ground, the RX and TX are connected to pins P3.5 and P3.4 of the MCU. We only used four of the six pins of the HC-05 Bluetooth module to accomplish the full connection to the MCU that is needed to transfer all the data to another Bluetooth receiver. Finally, we have the five-flex sensors and the force sensing resistor connected to the MCU.

The five-flex sensors are connected in series with 47 Kohm resistors connected to the ground. We created a voltage divider between the FSs and the 47 Kohm resistors to get the analog inputs of all the five sensors. They are connected to P9.0 through P9.4 of the MCU’s analog pins. The required input voltage for the FS to operate is 5 V, and they are all connected to a 5 V power supply on the schematic.



*Figure 30: Schematic*

This schematic in *Figure 30* will be the foundation of our glove design that makes up the hardware connection. The schematic was designed by our group member Lens, with a second input and review by Olamijide on the platform EAGLE. This platform has been very helpful in organizing our glove design, giving a clear visual representation of our goal.

### Senior Design 2 - Schematics Update

After careful revision and adjustment due to the constraints faced in getting the right parts needed for the completion of the project, the schematic was updated. All five flex sensors and force sensor are still connected to the same pins, but now LEDs were implemented to display a change in bend of the resistors. A voltage regulator of 5 and 3.3V can be seen in the schematic. Other items in the schematic that can be seen, are the three different power sources implemented. The battery holder, the DC Jack and the pin headers on the rightmost side of the MCU. Those pins are linked via jumper cables to a launchpad with EZ-FET access to turn on the PCB.

Diagram, schematic

Description automatically generated

*Figure 31: Updated Schematic*

A screenshot of a computer

Description automatically generated with low confidence

*Figure 32: Finalized PCB Design*

# Project Prototype Construction & Testing

The main factors that we wanted to display with our demo design was a short-range compact system that can project 3 images with virtually identical brightness in ambient room lighting. We were able to achieve this by creating a simple optical set up using cost effective materials for the display.

The optical demonstration of the projector shown in *Figure 31* included the purchased 3-inch lens, 2 Thorlabs beam splitters, 2 flat mirrors, an android phone flashlight, and a white trifold as the screen. This demonstration was a simplified optical set up that showed that we would be able to amplify and project 3 identical images onto three surfaces. The final system would be configured differently with the addition of various lenses to further amplify images, so this demo was made to be effective in both functionality and cost since these items will only be used in senior design 1. Everything in this set up was cut out and stabilized by hot glue, which was already owned, and carboard which made additional demonstration costs less than $10.

A picture containing graphical user interface

Description automatically generated

Figure 31: Projector demo set up

The structures that held all optical components were made by cutting out panels of dried hot glue that I applied to a flat acrylic surface. Two identical V-shaped panels would be held together by strips of cardboard that were approximately 2 mm wide. These strips were what the components would be resting on while the panels held them in place. Each of the sides were filled and reinforced by hot glue while two strips of cardboard were glued to the bottoms of the structures to create one stable lens holder (*Figure 32*). Holders of three different sizes were made to fit each of the three different optical components used.

A picture containing rectangle

Description automatically generated

Figure 32: Lens holder

The light aperture itself would be used as the image and was aligned and placed at the focal length (10 cm) of the 3” diameter lens. This lens would be used as a collimator for the beam splitters to effectively split and project the images equally. The center of the lens was about 1 cm higher than the height of the aperture, so to correct that we made a platform and a phone strap to ensure that the light would always be vertically aligned. We initially tested the clarity of the collimated image by taking one of the mirrors and aiming the image on to different surfaces of varying distances in the room. The image clarity stayed true to the stated lens focal length, but it was noted that the image was not very clear on surfaces that were closer in proximity. The clarity of the image even reflected across the room and on the ceiling was much sharper than the image that appeared on the trifold that was less than a foot away. It was assumed that since we are working with a defused light source, even after collimation there is still a lot of noise that needs to be corrected by either more lenses to create a more tightly focused system, or an increase in projection distance.

Since this is just the demo, we wanted to just work with the optical components we already had, so we opted to increasing the projection distance by aiming the light source parallel to the trifold center and adding mirrors to aim the image perpendicular to it. The collimated image would bounce off the mirror directly in front of the lens, reflecting the image on to the second mirror. That mirror was then aligned to send the images through the two beam splitters that were angled at approximately 45 degrees to project the images on to the side panels of the standing trifold, whose middle panel was standing about 5 inches away from the second beam splitter.

The optical system being perfectly aligned with the height of the aperture produced images that appeared very low on the screen which was not what we wanted. We wanted the images to be higher up on the screen so that it was easy to see for anybody standing near it. For that reason, we placed small strips of cardboard under the base of the mirrors holders in a way that would angle them upward. We then created an elevated, sloped platform where we placed and properly aligned the beam splitters. This set up was able to project the image at the height that we wanted and increased the image’s traveling distance enough for it to be relatively sharp on the trifold.

It was noticed that there was initially a lot of noise being projected on to the screen, so we also made a pin hole structure that was taped to the lens holder whose hole was cut to be approximately 1 cm in diameter. This was very effective to cutting out noise and making the images sharper. There was also still some diffused light that was directly coming from the flashlight that was showing up on the right panel of the trifold, so we fixed this problem by placing down a cardboard flap that spanned over the phone and the front edge of the lens. We made sure not to make it too long so it wouldn’t block the actual image from projecting. The aperture itself is about 3 mm in height, and the projected image came out to be 15 mm. The collimating lens produced a magnification of 5 which was larger than expected. The original goal of the lens was to be a collimator, but the magnification outcome only benefitted in displaying the demo’s projection capabilities.

Once this set up was complete, we taped all the holders in place so that we would not have to mess with it too much when it came time to present it. The stability of this demo made it easy to set up and travel with since all the optical components could easily be taken out and put back in and everything would still be accurately aligned.

A picture containing night sky

Description automatically generated

Figure 32: Projected Aperture

The projected images from the demo shown above in *Figure 32* is in dim room lighting. When in brighter lighting, the images are visible but not as bright as we would like to be easily visible. The average camera flashlight is 40-50 lumens which is quite low in respect to other light sources such as LEDs. This gives us good insight as to how bright we can make our images even while using such a low powered light source. Moving on from the demo, making our images visible in brighter room lighting was not deemed to be an issue. The camera used to capture this image was not very reliable in displaying how the images look in person, but the main purpose of the demo is still successful. The images are sharper in person, but it is also slightly more noticeable that the center panel is a bit brighter than the side panels. This is due to the beam splitters’ reflectance ratios being 30:70 R/T, which means that the center image would be 40% brightness compared to the identical 30% reflected images on the side panels. We predict is not a huge problem but can most likely be corrected by a filter if we feel it is needed later in our design.

# Administrative Contents

This section describes the administrative parts of our project design. Here we discuss how the logistics of our project were worked out and how we worked as a team to accomplish the best possible design. Here we discuss how we arranged our project budget and decided how the project would be financed. We set our milestones and those are explained below as well. We also have listed suppliers we found to have a lot of our needed components and plan on using them for ordering parts. We Our team was able to quickly come to an agreement on how we would function as a team in the sense of costs, communication, and deadlines. We identified our options and made decisions that would be convenient for all group members. The overall non-technical aspects of our design group would be broken down and discussed below.

## Project Budget and Financing

The project being worked on by group three will be financed by the students involved. The team will be splitting the total cost equally amongst each other. The currently have a maximum budget of $1000 amongst all four of us. We hope to not exceed that budget and will look for cost effective parts to stay within budget. We will not however comprise quality parts for lower cost, our main goal is to have a project that works correctly. Most of the materials needed for our project can be found on amazon or other sites at relatively low prices. Most of our cost will be in the optical components of our projector and sensors for our glove. The table below *(Table 11)* breaks down the main materials we know we will need from the start and includes a miscellaneous section to account for unexpected cost and materials. We understand that cost might be higher or lower when final design is complete. We are also ordering a few extra units for any components which may be faulty or burn out. Our goal is to build a cost-effective device. We started to purchase most of our components towards the end of Senior Design 1, which would allow us to start prototyping and testing all our components at the beginning of Senior Design 2. This was very important for two reasons:

* First, Electrical components are at an all-time low when it comes to availability, especially chips. With this being true we do not want to design a project around a component that is hard or impossible to get, because this could mean an extremely delay in our design timeframe.
* Second, we need to see how much of our budget is being used early on. We could go over quickly and need to be aware if we need to alter our budget or potentially make some spending cuts. We might also have a budget surplus which could allow for extra components for extra testing, which could ultimately lead to better overall project results.

|  |  |  |  |
| --- | --- | --- | --- |
| Item | Retailer | Qty | Cost |
| MCU 1 (For projector) | Amazon | 1 | $120.00 |
| MCU 2 (For Glove) | Texas Instrument | 2 | $3.48 |
| Flex sensors | Adafruit | 10 | $11.66 |
| Force sensors | SparkFun | 2 | $6.95 |
| Bluetooth Module | Amazon | 2 | $9.88 |
| Gloves | Grainger | 2 | $8.34 |
| Accelerometer | Adafruit | 1 | $11.95 |
| PCB | Pcbbuy | 5 | $26.0 |
| Projector Light Source  (Blue Laser Diode) | Amazon | 2 | $18.95 |
| Projector Lenses  (Biconvex Lens) | Surplusshed | 3 | $10.00 |
| Miscellaneous | Other |  | ~250.00 Unexpected cost |
| Estimated Total | Various |  | $629.87 |

*Table 11: BOM*

Below is our projects initial budget and expected bill of materials. This is gather from our initial speculations and our research. As components are order, returned, and damaged (we are expecting damaged part or burnt parts) our budget and bill of material will be updated to reflect to final cost of our project design.

## Facilities and Assembly

When we first got together to discuss our project, we decided to meet at the Atrium in Engineering Building I. Usually that space is jam-packed with students socializing, having meetings and study sessions, and a decent amount of traffic from classes. Due to COVID restrictions it was empty when we first met. Initially we planned on meeting there every week to discuss our project goals and milestones. We however did realize that it was only a matter of time before it would be as busy as before. One of our team members, Keonni, is also a member of UCF’s ROTC, and she suggested we do our meetings in a conference room in the ROTC floor. This is where we met for the rest of our meetings and plan to continue meeting there. Here we had a private space that was free for us to use during our chosen time. We had a large table, plenty of outlets for our computers, and a white board to write out and draw our ideas and concepts. The ROTC floor is located on the second floor of Classroom Building II, and is right next to parking garage H, which makes it easy to park and arrive. We plan on continuing to meet there for all our meetings and even plan to do some possible component testing there, since there is plenty of space and a large conference table.

When it comes to start testing and evaluating our project parts and design, we plan on using the Senior Design Lab. This lab has resources which we can use to begin prototyping our design. The lab has components like resistors and capacitors which we can use to test some of our sensors. Using these prototyping materials will help us make the optimal design before ordering our PCB. The lab also has tools which none of us have at home like an oscilloscope, function generator, and multimeter. Computers are readily available for us if we ever need them, and most software we might need for a design project are available on these computers. The best part about the lab is that we have access to it at any time of the day or evening, so we can have super early sessions or super late sessions if necessary. Another thing we look forward to in using this lab is the chance of running into other students. Even though we will very likely be working on completely different projects, we can share experiences figuring out any issues with general problems across our design or help understand any concepts we might be missing.

As far as building the project the main plan is to find a place where we can build the project in sessions and leave it stored and safe until the next session. We do not want to be constantly transporting our device and risk damaging it. We might find one of our homes to meet up in as the place the build some physical aspects of the project, like the glove or the projector. This will allow us to have a constant place to meet, but where we can store away our work and pick up the following day or week. We understand that there might be tools which we need for our project build which we won’t have in our home. Because of this we plan on taking advantage of the Universities Texas Instruments Innovation Lab which has great equipment free for UCF student to use. Here we have more testing equipment like oscilloscopes, multimeters, and function generators; but there is also a laser cutter, 3D printer, and soldering stations. These tools can be useful for our project, so for the necessary function of our project, and others to potentially add a cosmetic aspect to our design as well. The innovation lab is only open from 10am-6pm on weekdays, so when we plan on using it, we need to schedule ourselves accordingly.

## Suppliers

When it comes to ordering our components for our project design it was very important for us to find the right suppliers. There are a few factors we cared about when looking into a supplier, one being their credibility as a legitimate site and business to ensure we were not buying a fake or incorrect product. With the internet being so vast and accessible to basically anyone with a computer we had to make sure the supplier we order from wasn’t a scam website or a business with a bad reputation. So, to ensure this we used well known websites like Amazon, Sparkfun, Digi-Key, and if necessary Ebay.

Another factor we found important for choosing our suppliers was the speed in which they offered shipping. Being able to order practically anything online is a great milestone of the twenty-first century, literally anything is at our grasp. But we still need to account for the time it takes from ordering the product to processing the order to shipping out the product to the actual delivery of this product. Amazon was determined to be the best option for any component we needed to arrive as quickly as possible. With Amazon’s Prime membership we are able to receive most items within two business days, to add to that the shipping is “free” as it is included in the price of the membership. We kept this in mind for the cases where Amazon offered the component at the same or very similar price.

Amazon is a great supplier that we used for fast shipping, but it didn’t always have all our necessary components in stock and even if it did the stock could be very limited. For this reason, we knew we had to use more suppliers. A lot of our sensor components could be found on SparkFun and Digi-Key, these are two well established websites/companies used for ordering electrical components. We knew we could trust these sites when it came to delivering a promised product. The components were at their lowest price through these suppliers, but shipping was not included, so shipping needed to be calculated into the total cost. These suppliers did offer incentives for ordering all components in one single cart. Their shipping cost was usually per-order not per-item, so if we planned accordingly and ordered most or all our components at once we could save money on shipping. SparkFun offers free shipping for order of one-hundred or more, and Digi-key offers the same option for orders over two hundred.

For the most part we wanted to stick to these three suppliers. We did have Texas instruments as a supplier for their microprocessors and any possible electrical components we might need. eBay was also a supplier we planned on using if we ever couldn’t find a component and needed to order it from a third-party vendor. eBay can be a little risky because there are times when people don’t send out the product they list. eBay does have buyer protection though, so if we did not receive what we were promised we had a guarantee to get a refund. Even with this protection we wanted to ensure we used eBay only if necessary and would check the seller’s ratings to ensure we are receiving a good product. Even with the buyer protection getting a wrong or broken component could set back our time for testing and evaluation, which we want to avoid any unnecessary setbacks.

## Project Milestones:

In project management, activities need to be completed at a timely manner. At the beginning of the Summer 2021 semester, the team spent some time evaluating and discussing the timeline needed for the completion of the project in terms of design, building and testing of the prototype. We wanted to divide the work up in a way which was fair and concise with everyone’s schedule and life load. We understood some of us had full-time jobs and other responsibilities, so we discussed all of this from the beginning. We agreed to be open to ask for help if needed and also provide the help each team member might need to finish their portion of the workload. Meeting deadlines and goals are very important, and we all made an agreement to not procrastinate, and to always give our very best effort.

Table 11 below is a snapshot of this project and its list of tasks with a timescale, and individuals in the team responsible for the completion of the project. The table is currently tentative for the next semester and would be updated at the beginning of the semester.

[Table

Description automatically generated](https://knightsucfedu39751-my.sharepoint.com/:x:/g/personal/jidekay_knights_ucf_edu/EV3BYVsBlblDmkgb0-Sdph0BTN7EVx63qW7HgmaYm7oQIA)

Table 12: Milestones

## Project Tools

To implement a project of this caliber, a productive workflow is needed by using appropriate tools. Various tools were readily available and at our disposal. These tools were provided by the University of Central Florida and on the internet in general. The sections below represent the tools the team will utilize from research all through the completion of the project. Here we go over how we planned for communicating even while in a pandemic and what tools we used to communicate. We discuss our action plan to stay on schedule and not fall behind. If we all played our part the project could run smoothly, and we can develop a design project we would all be happy with.

### Communication

Poor communication could be the largest contributor to team failure. It is an essential skill to have, and our team has ensured to hone it during the course of our design. We used various platforms in passing information to each other about specifications, requirements, tasks, testing etc. It is the most crucial piece of skill needed for this project to work. We made an agreement as teammates and fellow students that we would be open about all our progress and needs. For effective communication we used various methods that would be explained below.

#### GroupMe

GroupMe is a messaging application owned by Microsoft but formerly developed in the year 2010 by Founders Jared Hecht and Steve Martocci. This is a mobile application that can be used as a web application also. This was the premier app we used in setting up communication with each other. We used it as an introduction phase in getting to know each other and setting up our first meeting. We have all used GroupMe in previous courses at UCF, it is extremely easy to use and basically a message/chat platform. Group me is very simplistic in many ways when it comes to features, so we started here, but knew we would like to find a communication platform which would be more useful for our project communication goals.

#### Email

Electronic mail is a process of exchanging messages electronically via the use of electronic devices. It is the most professional way of sending messages. We used this as a platform in communicating with our professors. We used it to asks questions and requesting one on one meetings with the professor whenever we faced a roadblock and needed guidance in ensuring we were on the right track. We considered using email to send files and links if necessary, but ultimately decided against it. Email is a great tool for work and general question, but for a constant back and forth communication device, it is considered very slow. We did however exchange university email addresses in order to have the form of communication in hand if ever necessary.

#### Discord

Discord is a voice over internet protocol (VoIP), instant messaging and distribution platform designed for creating communities called servers. Servers are a collection of chat rooms and voice channels. When we realized we needed a better way of communication, we decided to switch over to discord. As we needed an app with more capabilities, we needed a platform where we could message, as well as stream live feeds and call or talk to each other at the same time when needed.

Discord became our main means of communication. We set up a private channel where we could discuss any topics necessary to the project. We could ask each other questions and make request at any time. Discord allowed us to even create separate threads within our channel that could be dedicated to specific parts of our project and discussion. We were able to make threads which were dedicated to important project files like our paper and excel sheets. We created a thread for distributing research articles that we came across, and even had a thread for links to similar projects which made it easy to reference these whenever needed. Anything we needed to share we would do it through discord.

Another very useful tool for us that Discord offered was the audio communication. Whenever we had a meeting with Dr. Wei, we did it over zoom, so we always did them from our own separate homes. Afterwards we would hope on the audio channel and discuss how we felt about the meeting. We would discuss how we plan on moving forward from the advice and critique we would receive. After our chats we could immediately right out a brief summary of everything we discussed for us to reference on the following weeks.

We also used discord to set up automatic reminders for meetings we had, it provided an opportunity to accept and decline meetings. It provided a one stop access by synchronizing our meetings and adding them to our Google or iCloud calendar, making it easy to get notified without going back and forth amongst the different calendars we had. Setting this up was swift and easy, as every member already had an account set up and used Discord at one point in time as a point of communication for a few other classes we had taken. Discord is available as an app for our phones, so we could get notifications anywhere we were, but also runs on our PC’s for open communication while working on the project from home.

#### Periodic Meetings

Our team came up with the idea to meet up in person every Tuesday at 4pm, to catch up on ideas and to see where everyone was at. By doing so, it put the right amount of pressure on every member to have if not all, but at least almost all the task due for the coming week assigned to each member done. We used discord as our meeting tool to schedule and remind each member of the upcoming meetings and what type of meetings they were. We also used Zoom as our primary means to communicate with our professor whenever it came to meetings about our paper or for any question. We made sure to immediately have a voice-discord meeting after every meeting with the professor they discuss how we felt about the discussion we would have with him and how to implement any advice or critiques we received. There were times when we had to have a last-minute meeting to either work on a aspect of the project that needed immediate attention or because something important needed to be discussed. We would all try to make it to these last-minute meetings, or we tried our best to find a day that could work for most of us if not all of us. We always understood that sometimes we have commitments that need to be kept and would miss a meeting or two if needed, and that was okay, but didn’t want any one of us to make a habit out of it.

## File Preservation and Collaboration

Even with the advancement in technology of today, events occur where technology fails, and there must be measures set in place to prepare for the unexpected. In our case, especially during the research phase where lots of data are being accumulated and stored. We ensured we had all data backed up in real time. We used Microsoft 365 office suites in attaining the maximum security in terms of back up. This was a tool provided by the University of Central Florida, the use of Microsoft Word and Excel were integrated with SharePoint, a web based collaborative platform used for document management and storage. These tools allowed for multiple users to access a file at the same time, making it easy for each member to read and edit the file as well as save whatever changes were added to the file. These files were saved on to the Microsoft OneDrive and can be accessed easily form anywhere in the world, thus eliminating any possibility of our files being lost if or when our computers crashes.

## Division of Labor

For our design project we were named as Group 3. Our design project is name Sign Language Display, and we consist of four members. We believe our group consist of a diverse mix of University of Central Florida student with varying degree paths. Olamijide Kayode is a student of Computer Engineering, Lens Kongolo is a student of Electrical Engineering, Keonni Adams is a student of Optics and Photonic Engineering, and Miguel Cordero is a student of Computer Engineering. Our projects division of labor is dependent on what our degree of pursuit is and any areas we feel comfortable working on.

Keonni Adams is our optical and photonics member therefore she is our optical and photonics expert. Her main focus for the project will be the design of the projector for our display. She will be researching parts, cost, and implementation. Keonni will be in charge of how the projector is designed and constructed, and we have agreed to help her in anyway with any electrical or computer aspects of the projector. Olamijide Kayode is one of our Computer Engineering members, therefore he is one of our Computer Engineering experts, but also acts as our team leader (we never assigned a leader, but Olamijide has always taken charge of our project and meetings). Olamijide has taken it upon himself to overlook the project to make sure we are meeting deadlines and progressing. He will also be helping in the software implementation and the integration of our electrical components working with our software. Miguel Cordero is our second Computer Engineering member; therefore, he is our second Computer Engineering expert. Miguel will focus on the machine learning software for our project and look over most of the programming done. He will also assist with any component testing. Lens Kongolo is our Electrical Engineering member, therefore he is our Electrical Engineering expert. Lens will be focusing on the electrical circuitry of our project and on working with the schematics. Lens main goal is to make sure everything is connected safely and communicates correctly.

## Keonni Adams

Keonni is a Photonics and Optics engineering student. She plans on pursuing developmental engineering for the Air Force or Space Force after completing her bachelor’s degree in Fall 2021. She has always enjoyed her lab courses that incorporated optics and laser technology and she hopes to carry that experience into weapon and space technology in the future.

## Olamijide Kayode

Kayode is studying at UCF’s College of Engineering and Computer Science to earn a Bachelor’s in Computer Engineering. He currently works at United Parcel Services in the Systems Engineering department as a supervisor. Although he has multiple years of managerial experience, he hopes to start a career in hardware engineering or electrical field after graduation. Kayode has a diverse skill set and is well versed with different programming languages both for software and hardware development, he is also experienced with embedded systems and in charge of ensuring the photonics, electrical and the software development parts of the project are in correlation with one another and can yield a seamless outcome.

## Miguel Cordero

Miguel is a Computer Engineering student. He has always enjoyed courses that involved programming and software. He hopes to start a career in software programming after graduation but is open to start in any Computer Engineering position after graduation. Miguel is currently in pursuit of a career to start applying his skills learned in university and also to learn on the field skills. Miguel is in charge of the machine learning software research and development. He has taken a course that worked with machine learning and has some experience with python. Miguel knows the software development for this project will be a challenge, but he believes it will be exciting and help with his career pursuit. Miguel will also help program the devices and sensors we will be using and is open to help in anything electrical. Miguel said he believes the biggest obstacle for him will be developing a well-trained machine learning model and has asked the group to be open to helping with concepts and ideas.

## Lens Kongolo Ngoie

Lens Kongolo Ngoie is an international student at the University of Central Florida, born in 1993 in the Democratic Republic of the Congo. As a teenager, Lens enjoyed working in electrical projects in his country alongside reputed electricians in his city. Lens gained a passion for the electrical field; therefore, he decided to deepen his knowledge of the field. Lens took several classes in Electrical Engineering, which is his major, with a focus on power and renewable energy track. He enjoys designing and solving electrical circuits. Lens plans to work with clean energy companies after he gets his bachelor’s degree. One of Lens’s biggest ambitions is to bring back to his city, on a small scale, then to his country the knowledge he acquired to provide power even to the neglected areas so he can influence and motivate his generation and the generations to come to work together so that the country can have the most stable power it has never had in the past. He is hopeful for what he will bring to his family and community back home.

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## Permission Emails

