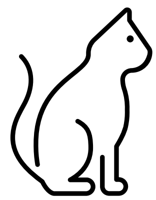
Senior Design I

Interactive Cat Toy



Project Documentation

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Group 25

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1. Executive Summary

In the world today, it is estimated that the domestic cat population exceeds 400 million; and that 373 million cats around the globe are kept as pets. (1-1) Here in the USA, it is estimated that there are 93.5 million cats kept as pets, with about one-third of all US households having at least one pet cat. (1-2) This provides for a large number of pet owners looking for toys to entertain their fun-loving felines.

Pet cat toys are a great way to help an owner enjoy time with their cats and have fun. Finding the right toy to really thrill a cat; however, can be a tough challenge. For our Senior Design class project our team decided to design and build an Interactive Cat Toy that meets this challenge. It is well documented, that cats are enamored by the scent of catnip; they love to play with light beams; and they are drawn to the shape, subtle sounds and motions that are similar to those of small animals. Our team will work to bring these entertainment worthy elements creatively to life with our Interactive Cat Toy.

For our Interactive Cat Toy our team will conduct thorough research to investigate and identify the latest technologies to select the best components to build our toy and express our toy's features. Then we will utilize our engineering education and skills to develop a computerized electrical operating system for our toy. We will work to meet optimal requirement specifications and to carefully design within various constraints for all aspects of our design. We will also strive to meet industry standards, from the global community, pertaining to our project. This design strategy was introduced to us by our Senior Design class professors, Dr. Samuel Richie and Dr. Lei Wei. We will follow this design strategy with the goal of producing a fun Interactive Cat Toy that both pet cats and their owners can enjoy together.

The design of our Interactive Cat Toy will go beyond the scope of electrical and computer engineering. To aid us in the design areas outside of our educational focus, we are gratefully employing the help of a professional mechanical engineer and author, Le Phan, and the help of an experienced seamstress, Sonja Steinke. Within the scope of electrical and computer engineering we, as students, are very limited in our design experience. To compensate for this, we will be seeking advice and input from our professors and from experienced professionals. Bob Meizlik, a senior software architect experienced with electronic device development is kindly advising us with regard to various part selections and important design considerations.

2. Project Description

Our Senior Design team's Interactive Cat Toy will be a whimsical plush toy, modeled after a real-life animal. We will be incorporating elements into this fun toy that we have found are key to domestic cat entertainment. With understanding from team members having experience with pet cats and from performing research we have identified many cat attracting elements.

Taking direction from our Senior Design class professors, Dr. Samuel Richie and Dr. Lei Wei, we established three levels for our project design: Basic Design, Advanced Design and "Stretch Goal" Design. Once successful in pulling together components to develop a basic cat toy prototype, we will endeavor to incorporate more technically advanced features for an advanced cat toy prototype. Having sound design completed for an advanced level will allow us to move forward to incorporate "stretch goal" features into our project design.

The Basic Design features that we are planning to build into this toy are lighting, motion, scent, sound and rechargeable powering features. For the basic design our cat toy will display a single-colored light signal pattern across a light strip on the skin of the toy. It will perform a singular attractive animal-like motion and also shake a catnip pouch to disburse the scent of catnip into the air. Further for this basic level, our toy will employ a speaker to emit a singular animal sound.

We plan for our Advanced Design model to have adjustable feature settings, controllable through a smart phone application. Features that would be controllable through this app include multiple-colored and multiple-patterned lighting effects, along with controllable motion and sound options. This advanced level toy design will also include a motion sensing activation.

Our "Stretch Goal" Design features that we have considered incorporating into our design would employ a video camera and an existing speaker. The video camera would allow the cat's owner to watch video of their pet interacting with the toy through the smart phone application. The audio speaker would allow the pet owner to transmit their voice through the toy to speak to their pet via the app.

It is our goal to build our Senior Design class project, utilizing our engineering education from the University of Central Florida, to the best of our ability. With soundly engineered incorporation of good, fun features into our Interactive Cat Toy, we believe that our toy will become a favorite for cat lovers, and their cats, across the globe!

Senior Design Project - Planned Features

Basic Design Features

- ☐ Lighting Effects
    - ➢ Single colored light display

- ☐ Sound
    - ➢ Singular animal sound

- ☐ Motion
    - ➢ Subtle bodily movement
    - ➢ Catnip pouch shaker

- ☐ Rechargeable Battery
    - ➢ Easy plug-in to repower

Advanced Design Features

- ☐ Phone Application
    - ➢ Capable of adjusting motion.
    - ➢ Capable of changing sound.
    - ➢ Capable of switching light color and display signals

- ☐ Motion Detection
    - ➢ Toy will activate when motion detected.
    - ➢ Activation will occur when motion is within 1 foot

- ☐ Lighting Effects
    - ➢ Multi-colored light display
    - ➢ Multiple light patterns available

"Stretch Goal" Design Features

- ☐ Video Camera Accessory "Kitty Cam"
    - ➢ Cat owner will be able to view video, from a wall mounted camera, via a smart phone application.

- ☐ Speaker
    - ➢ Cat owner will be able to project voice from the toy and speak to pet through the phone application.

2.1 Motivation

With the estimated amount of 373 million pet cats around the World, our team recognizes that there is a useful need for cat toys that a pet cat owner can enjoy seeing their kitty cat play with. These toys need to be of good quality engineering that incorporates features that entertain a frisky feline with hours of enjoyment. This need is the main source of motivation for our team to design and build an Interactive Cat Toy for our Senior Design class project.

Veterinarians say that cat toys are good for cats' health in several very beneficial ways. An Editorial from Chewy, published in 2016, gives many important reasons for pet playtime. The first reason they give in saying that playtime is very good for your pet is that "regular activity can help ensure your pet maintains a healthy weight", they go on to say "play can help boost your pet's mood, prevent boredom and relieve pet stress"; additionally they say playtime leads to better behaved pets" by helping them release their "bottled-up energy" and finally they say with pet playtime "you'll form stronger bonds" with your pet. (2.1-1) We believe our Interactive Cat Toy will help pet owners enjoy all these playtime benefits.

As engineering students, designing and building this interactive pet cat toy serves to fulfil the requirement to design and build an electronic device for our Senior Design class. This is a requirement for us to meet in order to graduate from The University of Central Florida's College of Engineering and Computer Science with a Bachelor's Degree in Engineering. Through designing and building this Interactive Cat Toy we are able to utilize and display our engineering education and skills that we have attained.

Being that our team is composed of two Computer Engineering (CPE) and two Electrical Engineering (EE) students, we believe that we will be able to combine our knowledge to create a well featured Interactive Cat Toy product to showcase our engineering education that we have received here at the University of Central Florida. We hope to see the integration of all our knowledge and skills, that we have accumulated over the long course of our studies, to work together to successfully complete our project.

As we work on this project we are also motivated to gain as much new educational understanding as we can with this hands-on design and build experience. Our computer engineering teammates will be focused on embedded and application program design. Our electrical engineering teammates will be focused on circuit design and power management. All teammates will be working with the hardware selection and design. The extent of this project experience is a priceless learning and experience gaining opportunity.

A final motivation for our project is our team members' affinity for cats. Aliza has three pet cats (*Gracie, Dandy and Twinkle*) that she would love to see enjoying the fruits of our labor. Liz is glad to be able to help design this toy *in loving memory* of her precious cat Aaliyah, who passed away in November of 2020. Joseph has never had a pet, but he is fond of little "gatos" and is glad to be part of making a toy that will bring them enjoyment. Vu has a corgi, and while not sure that his dog will like our cat toy, he really likes cats and hopes our project will be successful in entertaining others with their pet cats.

2.2 Goals and Objectives

Our team has three main goals for our Interactive Cat Toy. First, we will work to design our toy so that it is highly entertaining to cats. Secondly, we will endeavor to make our toy as safe as possible. Thirdly, we will aim to build a robust design for our toy so that it will hold up to potentially harsh treatment for a reasonable amount of time. We plan to implement these goals at every level of our toy design.

Our primary objective of designing and building an Interactive Cat Toy that will be highly entertaining to pet cats will require experience with and understanding of felines. Cats can be finicky and indifferent, so attaining the objective of entertaining a cat will require incorporation of key features. In selecting and designing our key cat entertaining features we will use the experience of our teammates who have had pet cats along with research into professional veterinarian and cat caregiver advice.

Our secondary, but most highly important, objective is for our team to design a safe toy that will hold up to potentially rough cat play. Keeping in mind that our toy is actually an electrical device, we will work to design the toy with the utmost care in implementing the best safety factors that we can. We will look to industry standards to assist us with these safety factor designs.

Our third objective is to design and build a cat toy that can withstand rough cat play and last for a reasonable amount of time. We will take measures to design the exterior skin of our toy with the most durable material that we can. Then we plan to design an interior chassis that will sturdily support features and enclose the toy's electrical circuitry with strategically placed padding to cushion any significant battering. We will work to make the toy as robust as we can so that it will not easily break when engaged in rough play.

2.3 Related Work

There is an enormous variety of electronic pet cat toys available today. By looking into related products and their design we are able to learn a lot about the capabilities and features that exist. We can then incorporate the best of these attributes into our cat toy design. A search of the internet allowed us to look at some of the best rated electronic cat toys available while we considered the design options for our Senior Design project.

According to Best Review's Guide, PetDroid's Robotic Cat Toy was ranked #1 in 2021, when our senior design project got started. This toy is on their list of the "10 BEST Interactive Robotic Toys of September 2021". (2.3-1) They say the ranking for this top ten list is based on 112 million consumer reviews. This toy also took high rankings on many other websites and came up as a top seller for Amazon.

Figure 2-1: PetDroid's Robotic Cat Toy

Good Housekeeping ranked this Interactive Cat Toy as 12th out of 15 of their best selected toys in December of 2020. (2.3-2) They point out several attributes, to the toy, that are helpful considerations. Their review points out that the toy will roll "on carpet, tile and wood floors and will move in a similar way to natural prey". (2.3-2) They also mention the benefits of the toy's various attachments, "so your cat can play with a crinkle ball one day, a ribbon another and a feather the next, to keep them from getting tired of it". (2.3-2) This is very helpful in reminding us to make sure our toy has various options to keep cats from getting bored with our toy.

This cat toy, by PetDroid, is an abstract geometrically shaped robot. The toy uses the features including wheeled motion to move and spin about, attractive attachments to lure cats into play, and LED lighting that can catch any cat's attention. The features are adjustable and this toy provides lots of food for thought when considering attractive and adjustable features for our Interactive Cat Toy project.

On the PetsRadar Buying Guide for the “Best Automatic Laser Cat Toys”, the Felix & Fido Playdot ranks as the “Best overall”. (2.3-3) Their guide says that “the best automatic laser cat toys offer a fun and exciting play session that will keep your kitty physically and mentally stimulated” and say that “the best cat toys have plenty of fun options”. (2.3-3) They list pluses and minuses for the toy with pluses being “hard to knock over”, “manual and automatic modes”, “stays on for 30 minutes”; and the minuses being “batteries run down quickly”. The brief overview of this toy was very helpful in giving us more to consider for our senior design project.

Figure 2-2: Felix & Fido Playdot

The manufacturers, Felix & Fido, say the Playdot can be placed on a flat surface and set to one of three automatic settings (slow, fast, advanced); or it can be hand-held and manually directed. They clearly explain their automatic settings in their product details: “slow-speed mode, where the Playdot automatically rotates the led light at a slow speed in a basic circular motion”, “fast-speed mode, where the led will move in a basically circular motion, but at a faster speed”, advanced mode, “where “the machine will switch between the fast and slow modes as well as "freeze" the light every so often so the cat feels like it can "pounce"” and a final mode which “holds the light in one place and you can use this as a handheld toy to interact with your cat while they play”. (2.3-4) Understanding the settings of this popular cat toy can help us to establish the best settings for our Interactive Cat Toy project.

The Playdot’s sole entertainment for cats is its laser pointing feature. Research shows that domestic cats are drawn into engaging in play with moving dots of laser light and there are countless videos of cats playing with laser light points online. According to HillsPet.com “playing with laser pointers is a fun cardio activity” for cats (2.3-5) and this is also confirmed by many other pet care sites. So seeing the Playdot built for the laser pointing feature is not surprising. Our toy design takes into consideration the enticing quality of laser light play to cats.

Another electronic cat toy with rave reviews is Potaroma's Floppy Fish. People Magazine says, "This Flopping Fish Toy Is Winning Over the Attention of Cats (and their owners) Everywhere". (2.3-6) The toy is listed as "an overall best-seller in Amazon's Cat Nip toys category". (2.3-6) Good Housekeeping ranks the toy 6th in their list, "15 Best Cat Toys". (2.3-2) So it was fitting that we looked at this toy while considering our pet toy project.

Figure 2-3: Potaroma's Floppy Fish

The features that people positively remarked on about this toy fish is its realistic animal design and flipping motion, its motion detection and its USB recharging feature. These are all features that our team initially discussed while brainstorming features that we would like to see in our project toy, prior to seeing this type of toy online. On the flip side of the reviews, some people stated that this fish was noisy, that the tail movement was too rough for their pet, and that the realistic looking skin cover was thin and cheaply made. While creating our project design we will take into consideration the comments from both the positive and negative reviews.

Our investigation of the current top-rated cat toys clearly reveals what features are favored by pet owners to entertain their fun-loving felines. Key features are repeated between many cat toys. These features include the use of laser light beams, mock animal motions and sounds, attractive luring attachments, realistic animal modeling and the use of catnip. Our investigation allowed us to compile this list of features to use for our consideration during our cat toy design process.

After examining the related works of current Interactive Cat Toys on the market, we are able decide on a unique combination of features for our pet cat toy design to make our product most enjoyable for pet owners and their little friskies.

2.4 Requirements Specifications

Our Interactive Cat Toy will have certain requirements specifications that will be necessary for product acceptability, safety and optimal performance. Requirements will exist on every level of our design and will include specifications for dimensions, run time, response time, voltage and current levels, volume, range of motion, sensing capabilities, lighting measures, etcetera.

Requirements Specifications for our project are based on market/industry standards and constraints within our design. Standards refer to acceptable product specifications often based on consumer approval and scientific case studies. Constraints refer to limitations resulting from product design including the sizing of our toy and the power requirements of our components; to name a few limiting factors. Industry standards and Constraints for our project are further detailed in Section 4 of this report. Research into the latest industry standards, scientific case studies on cats and a study of consumer reviews online revealed many necessary requirements for our Senior Design project.

The most important requirements specifications for our Interactive Cat Toy involve product safety, as we will be fabricating a device that's main function will be to entertain a living creature. During our design process we will work to ensure that our project is in compliance with industry standards for safety. We will also check the product labels of our selected components for comments on safety standards such as RoHS compliance to ensure that hazardous materials are not incorporated into the fabrication of our toy.

Reports from veterinarian's studies involving felines are a good source for safety factors for us to adhere to with requirements specifications for our toy design. Since our project design involves lighting effects, we wanted to choose the safest option of illumination for our feline friends. Studies reveal that LEDs are safer for cat's vision, than the popularly used lasers in cat toys, so we are employing LEDs for our lighting feature. According to veterinarians; however, prolonged exposure to blue LED light can pose a risk for a cat's health (as it does for human health) in disrupting their circadian rhythm, a body's 24 hour biological rhythmic cycle. Therefore we will limit the use of this color, which is also emitted undetectably through bright white LED light. For safety purposes we will limit the brightness of our lighting effects to between 100 and 200 lumens with the use of LEDs.

Further sampling of various scientific case studies on domestic cats revealed that color choices for our toy's features could impact a cat's enjoyment of our toy. Veterinarians recommend yellow-green and blue-violet colored toys for pet cats, as these are believed to be the hues that are most prominently detectable in the range of feline vision. We will utilize this information within our design process, and use it to set requirements specifications for our lighting effects that we will employ to entice a cat into play.

Consumer reviews for various cat toys reveal the likes and dislikes of pet owners when it comes to toy features. Many toys have servo motors that actuate motion within their design. We noted that many online consumers complained about the loud mechanical noises that the motors or gears in their automated cat toys made. We will require our motors and/or gears to produce low noise within our cat toy. This gives us a requirement specification that the noise should not amount to much more than a whisper ranging at under forty decibels.

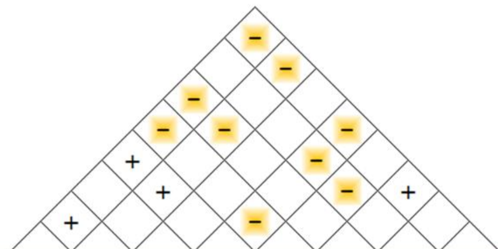
Some specific requirements specifications for our project design are listed in the table below. While we have a long list of requirements specifications for our project's design, the table below lists just the mainly important requirements specifications for our project. The three highlighted specifications will be able to be clearly demonstrated, within 15 minutes, during our Senior Design presentation.

Table 2-1: Specific Project Requirements Specifications		
Component	**Parameter**	**Specification**
Battery	Run Time on Full Battery Charge	> 60 min
Feature Components		
Lighting Effect	Light Output	100 - 200 lumens
Lighting Effect	Illuminate Yellow Color	≤ 5 seconds
Speakers	Volume	≤ 60 dB
Motor(s)	Low Noise	< 40 dB
Motion Detector	Detection Distance	≤ 2 feet
Phone Application	Whole System Delay Time	< 30 seconds

2.5 House of Quality

A House of Quality diagram (**Table 2-2**) is particularly important when establishing the requirements that are needed between the marketing team and the engineering team. This allows the two teams to understand the tradeoffs that will be needed to create the ideal product. The House of Quality below shows the correlations between the requirements from the engineers, the relationship of the requirements of the engineering team compared to the marketing team requirements, and the direction of improvement from the engineering team's requirements.

Table 2-2: House of Quality



Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	Light Weight	Small Dimention	Sound Clearity	Power Output	Cost	Mobility Range	RGB LEDs	Smooth Motion
					Column #	1	2	3	4	5	6	7	8
					Direction of Improvement	▲	◇	◇	▲	◇	◇	◇	▼
1		14%	4	9	Durable	●	●			○			
2		14%	4	3	Affordable / Low Cost	○				▽			
3		7%	2	3	Easy Application UI				○	▽		○	○
4		3%	1	9	Rechargeable / Battery Life	○		●	○				
5		17%	5	9	Fun for cats	○	●	○			●		
6		14%	4	9	Small Form	●	●				●		
7		14%	4	9	Sounds			●		○			
8		10%	3	9	Lighting Effects							●	
9		7%	2	3	Movement	○							▽

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

2.6 Hardware Block Diagram

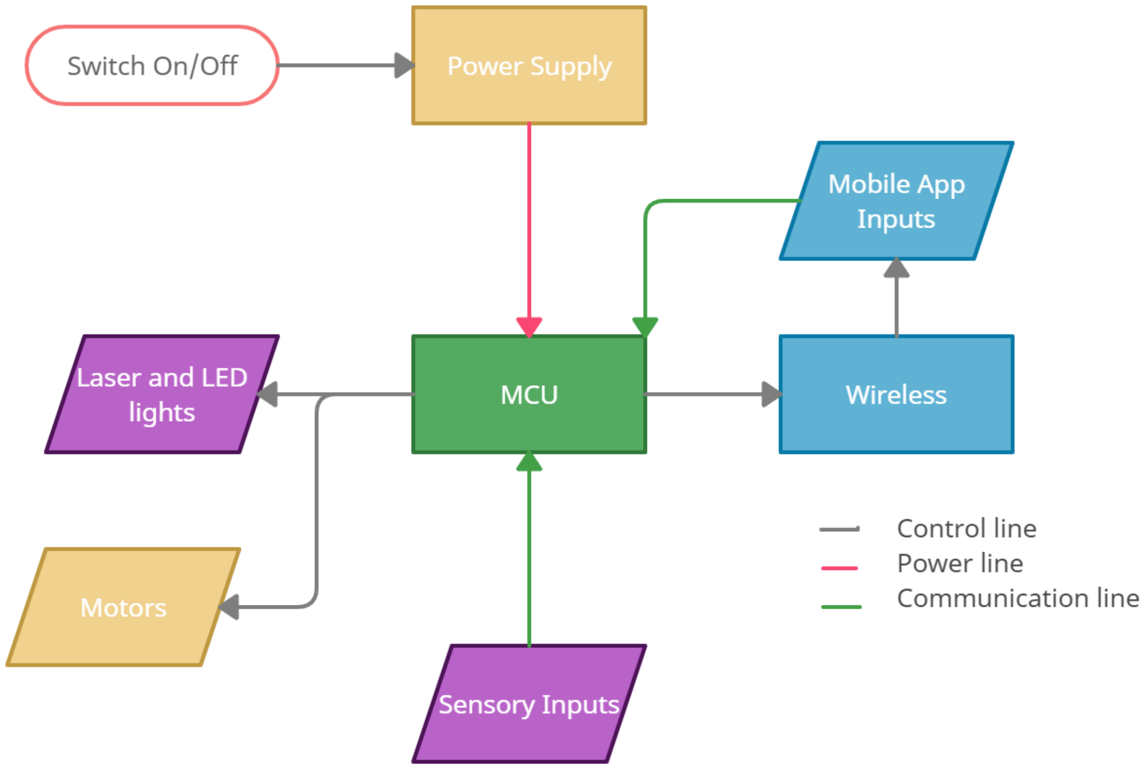


Figure 2-4: Hardware Block Diagram

2.7 Software Diagram

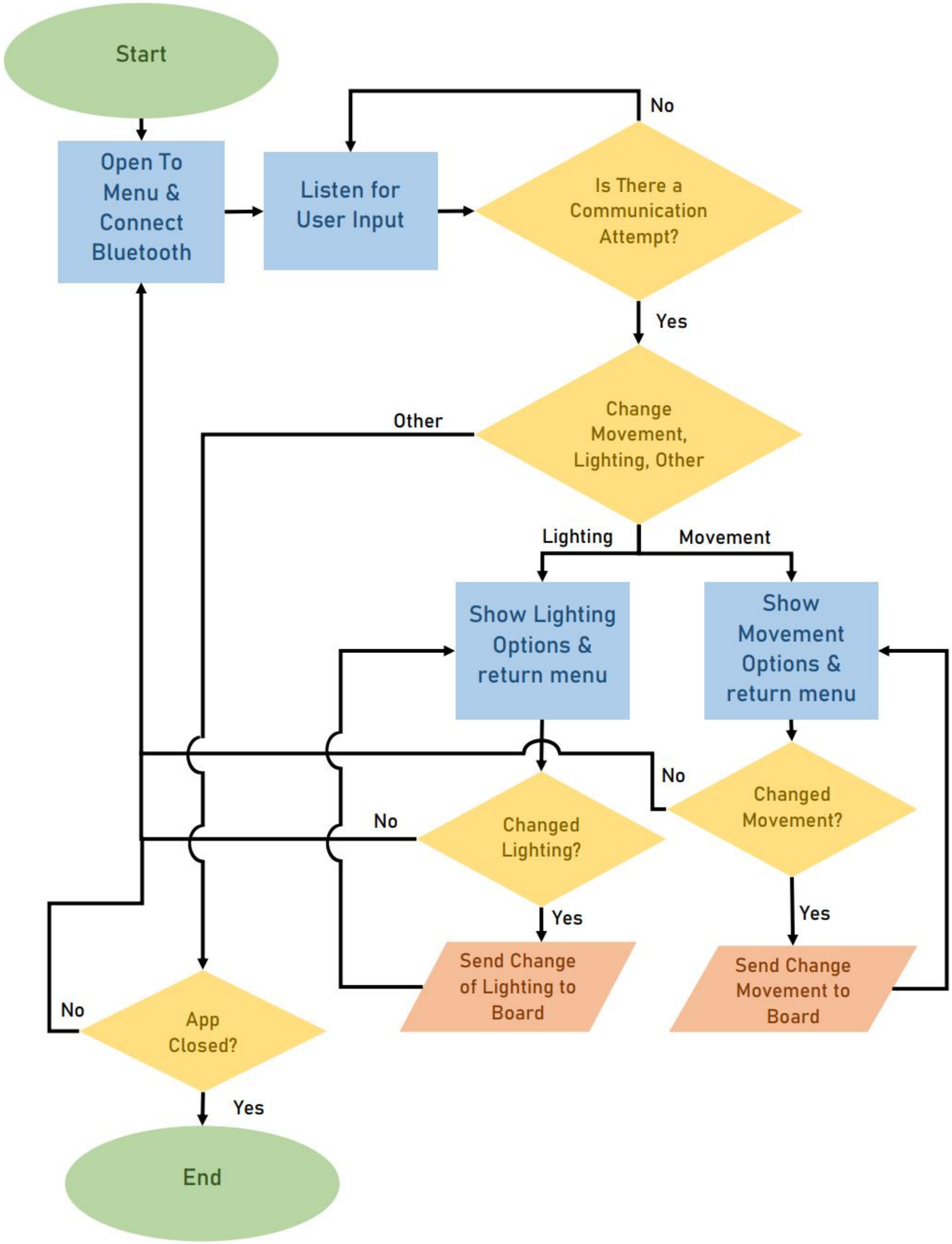


Figure 2-5: Software Flow Chart

3. Technology Investigation & Part Selection

To properly execute the design of our Interactive Cat Toy we will first perform an investigation of the most current technology available for the needed components of our project design. We will then perform a search to find parts that meet the latest technology and are available for us to acquire. Then we will compare the available parts according to factors that are important to our project design. Finally, we will select the parts that will best meet the needs of our project. In order to perform our part research we will search local and online suppliers; and we will also consult with our professors, other professional engineers and trade specialists.

Building our project design will require the acquisition of a various number of components. We will need to search for parts from fabrics, to motors, to microcontrollers. We will also need to use a 3-D printer to fabricate some mechanical parts for our project. Finding the best parts for our project will require a detailed investigation into the current designs and latest technologies available. All this will be considered and detailed in our "Technology Investigation" in section 3.1 of this report.

After completing our technology investigation we will move forward to our part selection phase, this will be detailed in section 3.2 of this report. We will use the investigation and comparison data to make the best part selections possible. Section 3.3 of this report will give a detail of all of the parts we selected.

Following part selection we will begin the procurement of our necessary parts. As we acquire each part we will test them for successful usability within our project design. Should a part not meet a proper usability factor, we will move to acquire the next best part that was determined from our investigation, or we will launch a new investigation into better parts based on our usability findings.

The current market, during our 2021-22 school year, may pose some difficulty in our acquisition of parts as the Coronavirus Pandemic has slowed the world supply chain. For some industries many supply shelves are empty, resulting in suppliers listing "out of stock" notices for many parts. Suppliers of our parts include local stores and online vendors. Some of these suppliers are dependent on world trade, as many electrical device parts are made in other countries.

The Coronavirus Pandemic has caused many issues that have slowed the world's supply chain. Among the issues created by the pandemic is the shortage of essential delivery workers. This is hindering the supply chain as International ships are being held up from delivering their cargoes to

American ports. International ships are lining up off our coasts waiting for delivery workers to take their cargoes.

One of the main suppliers of electronics parts in the United States, Adafruit Industries, is currently getting assistance from Digi-Key for their sales. While Adafruit is busy working with pandemic assistance they are getting help from other suppliers to serve their customers. A message from the Adafruit Industries' website reads as follows:

> *"Adafruit is currently making face shields and making/shipping critical components and electronics for COVID-19 related efforts and testing.*
>
> *While we're helping the fight against COVID-19, Digi-Key is assisting Adafruit getting products delivered to customers via the Digi-Key site.*
>
> *Thank you Digi-Key!" (3.2-1)*

The world's supply chain slow-down may affect the availability of some of the parts that we will need for our project. We will attempt to purchase our parts as soon as possible and while items are in stock. Should the supply of a needed part be affected, we will move to select the next best option. We also plan to be prepared to make adjustments to our design if necessary.

3.1 Technology Investigation

In order to build the best version of our Interactive Cat Toy that we possibly can, we will investigate the current technology that will allow us to implement our design plan. We will further compare the details and features of similar components, available on today's market, that can be used to build our project. We will create and use data tables to simplify our comparisons and ease our part selection process. These data tables will be presented in each of the following sections that investigate the various parts that we need.

For our Senior Design I class, Dr. Richie encouraged us to perform a technology investigation for our part search, rather than performing "part research". This would allow us to find what technology is already on the market for our specific purposes rather than doing research into figuring out how to design a necessary part. While part research could require an enormous amount of time, technology investigation allows us to more quickly find a part to perform the tasks we need to have done.

While we will be selecting prefabricated parts for use, from our technology investigation, we will still be engineering the computer and electrical system design for our Interactive Cat Toy project. This will require in-depth understanding of electrical and computer engineering practices.

3.1.1 System Controllers (Vu)

The system controller is one of the most important components of the Interactive Cat Toy. It has the role of distributing appropriate signals and voltage to other components of the toy. It also acts as a medium for communication between components, receiving data and inputs and producing outputs. Furthermore, the controller makes it possible for us to implement functions, change parameters, and program whatever we want into those other components. The controller also provides the ability to connect the users and the toy using the user's phone application and the controller's wireless communication features like Wi-Fi or Bluetooth.

There are many specifications that we need to investigate in order to select the most suitable controller for this project. There are many controllers with various abilities and capabilities. A wrong controller might be too big, require too much voltage, or be too weak to be able to handle the tasks and the functions. Therefore, searching for the right controller requires us to understand what the toy needs and what it does not need, in order to satisfy the constraints and the standards that we have for the toy.

The first specification is the dimension of the controller. The dimension of the controller, including the board it is attached to, must be small enough to fit inside the exterior skin and the chassis of the toy. Considering the possible exterior skins and chassis, the controller along with its board must be smaller than 6 inches in length and 4 inches in width. The second specification is the amount of pins available to be able to connect to other components, such as but not limited to battery, motor, light strip, and motion detector. We initially believe that around 20 pins are sufficient enough for the toy.

The processor power and its maximum frequency are also considered when selecting a controller. Since this is a small toy, we do not need a powerful processor or extremely high frequency; therefore, most of the current controllers on the market are able to deliver the necessary speed. With system memory, we also do not need a large memory. However, flash memory is needed so that the data within the memory can be erased and reprogrammed if needed. The controller that is suitable for this project is limited to its programmable languages. The programming language has to be a language that one of our group members is already familiar with, such as C/C++ and Python.

From our search, we stumbled across three controllers with the most potential of being successful for the project. The Raspberry Pi Pico is known for its small and compact design and known as the miniature version of Raspberry Pi 4 Model. It uses RP2040 microcontroller which is dual-core Arm Cortex M0+. The Raspberry Pi Pico is great for beginners using well-known programming languages, C and MicroPython.

Figure 3-1: Overall view of Raspberry Pi Pico

The second controller we found is the Trinket M0+ from Adafruit. The processor used for this controller is 32-bit Cortex M0+, which is similar to the Raspberry Pi Pico. The Trinket M0+ is similar to an Arduino microcontroller. We can even use Arduino IDE to program this controller.

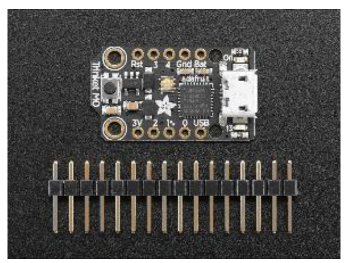


Figure 3-2: Trinket M0

The last controller we found is a Peripheral Interface Controller, known as PIC, which is designed by Microchip. Specifically, we notice that PIC18F16Q40 is most suitable for our project from the PIC family product. This 8-bit PIC is known for its compact design and cheap manufacturing process. However, the PICs use MPLAB IDE software, which no member is familiar with.

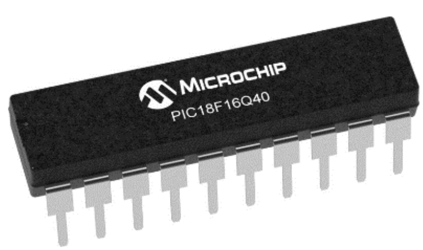


Figure 3-3: Peripheral Interface Controller, PIC18F16Q40

3.1.2 Printed Circuit Boards (Vu)

With Printed Circuit Boards (PCBs), we can easily customize and cater to the needs of our project by going online and using PCB design software such as Autodesk EAGLE, SolidWorks, and Fusion 360. Once our project design is complete with one of these software programs, we would then, send our PCB design to manufacturers and order our board to be fabricated from their website.

There are also other methods of using circuit boards without manually designing one. Some controllers come attached to a specifically designed PCB. For example, the Raspberry Pi Pico is a RP2040 microcontroller attached to a small board. The Trinket M0+ is also a microcontroller attached to its own board. These prefabricated boards have installed pins and ports in anticipation of various uses. Using these types of boards requires no additional PCB design work, and it is very convenient for the user. However, for this project, an additional printed circuit board is likely to be needed to stack with these specific types of boards due to the amount of features that our project will support.

The last method we can use for printed circuit boards is that we can order a pre-made circuit board. They are readily available on the market in many forms. There is one board we could potentially use from Amazon that is called Gikfun Protoboard GK1009. It has the dimensions of 1.3 x 1.8 inch, and 1/16" thick. This sizing would be ideal for our project's small hardware space. These boards are made mainly for prototyping, but are sturdy enough with through-plated holes to support soldering of a projects electronic components.

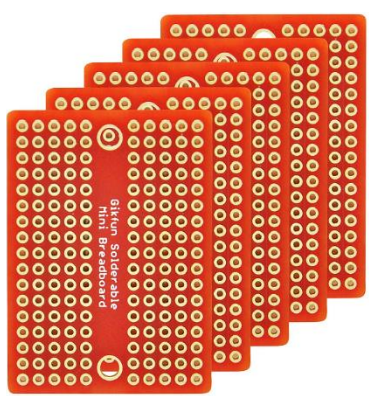


Figure 3-4: Gikfun Protoboard GK1009

3.1.3 Wireless Components (Joseph)

A phone application, or an app, will be an advanced feature for our Interactive Cat Toy. This advanced feature will allow a cat owner to select fun lighting displays and control toy movements. A "stretch goal" for our application would also allow a pet owner to communicate to their furry friend(s) through a speaker on the toy. In order to make all this possible, our toy will require the ability to send signals wirelessly to the app. A necessary component for our toy to have will be a wireless module.

There are many ways to transfer data wirelessly. This could make it a hard decision to determine which type of wireless modules to use. We must keep in mind where we are going to use it and why we are going to transfer data. The three main types of wireless communication technology are Wi-Fi, Bluetooth and Zigbee.

The first wireless communication system that we looked at was Wi-Fi. Many Wi-Fi communication controllers have a data rate of up to 600 Mbps maximum with a range between 20 - 40 meters. What makes this controller an excellent choice is that its cost is low and it is easy to activate. What makes Wi-Fi controllers not so good of a choice is that it is not good with power consumption. Alternative wireless components offer better energy conservative options.

The second wireless communication technology that we considered was Bluetooth. Bluetooth's way to transfer data is effective if we exchange data in a small range, between 50 - 150 meters. Though, the data rate is quite low, compared with wi-fi, at 1Mbps. For the purposes of our toy's app, this should be more than sufficient. Bluetooth is a great option for low power consumption and a good level of security.

Zigbee is another IOT communication protocol, it is quite similar to Bluetooth. Like Bluetooth, Zigbee offers low power consumption. Besides this low power consumption; however, Zigbee also offers high security and high scalability. Zigbee's range is less that Bluetooth's, being between 10-100 meters maximum. The data rate, for Zigbee, measures around 250 Kbps.

From the three types of wireless communication technologies that we have investigated, we consider that using Bluetooth will be the best option for our Interactive Cat Toy. Bluetooth offers us just what we believe that we need, since it has a great amount of data rate at a low cost with low power consumption. These capabilities of Bluetooth will make it more usable for features, and it will not consume too much power, allowing us to use that power for other toy features. Therefore, we will only compare Bluetooth modules in our comparison table for part selection.

Two very popular Bluetooth modules are the HC-06 and HC-05 modules. These two modules are good to consider because they are really small in size and this will be perfecto to implement into our toy. The HC-06 and the HC-05 Bluetooth modules are not compatible with the IOS platform and therefore not compatible with iPhones. They do; however, work with Android phones and can work within an app via a computer.

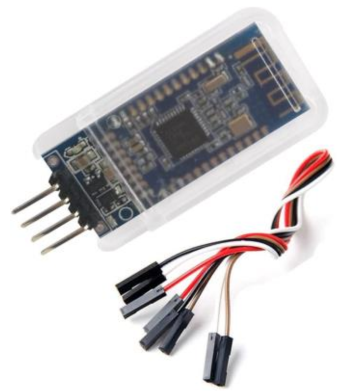


Figure 3-5: DSD Tech Bluetooth Module

The HC-05 Bluetooth module usually comes with 6 pins, KEY/En, VCC, GND, TXD, RXD, STATE. With this module we can check if the device is on thanks to pin STATE and for the KEY/En pin we can choose how we would like to transmit the data either command mode or data mode. The baud rate in command mode is 38400 bps and for data mode is 9600 bps. This module can be used as a master and slave Bluetooth device. This could possibly allow for multiple pet toys to one day sync with one another.

The HC-06 Bluetooth module is a little bit different from the previous one because this device come with 4 pins which are VCC, GND, TXD, RXD, it doesn't include the KEY/En and STATE. The big difference between this module with the previous one is that this one can only be use as a slave while the HC-05 can be used as a master and slave Bluetooth device.

A third Bluetooth component that we considered was Adafruit's Bluefruit LE UART Friend – Bluetooth Low Energy (BLE) module. This module is compatible with both iOS and Android devices; however, it does not have the same power of a regular Bluetooth module. It has a lower bandwidth and will not stream audio or video. This module may be good for our Advanced Design and be capable of allowing a pet owner to send a command to the microcontroller to change a lighting effect. But, it will not meet the needs for the features of our "Stretch Goal" Design level since it will not steam audio or video.

3.1.4 Batteries (Liz)

Battery choice for our Interactive Cat Toy project is very important. We will need for our battery to power our toy for a good length of time to supply proper entertainment for cats in a given day. We expect that a battery should provide a minimum of one to four hours of play with a full-charge and this will be our goal to attain. Similar toys on the market employ rechargeable batteries and provide chargers. We will need to select a battery with similar convenience considerations.

A rechargeable battery seems to us to be the most cost effective and convenient option for a toy that will be used on a regular basis. Because rechargeable batteries are also better for the environment than disposable batteries, we also feel that this makes a better choice for our power source. So, we will investigate rechargeable battery technology that is available today for use with our Interactive Cat Toy.

Battery Power Supply

When searching for batteries for our cat toy we will need to ensure that our needed power supply is met. Based on Ohm's Law, we know that the power can be calculated using the simple equation of P = VI. Thus, we will make special note of a battery's voltage rating and its current capacity, as indicated by its mAh value.

> *"The capacity of batteries is indicated as XXXX mAh (milliampere/hour). The formula for calculation is as follows:*
>
> *Capacity (milliampere/hour) =*
>
> *discharge (milliampere) x discharging time (hour)*
>
> *E.g. Take a Ni-MH rechargeable battery with a capacity of 2000 milliampere/hour. If you insert this battery into an appliance which consumes 100 milliampere current continuously, the operating time of the appliance will be around 20 hours mathematically."* (3.1.4-1)

By calculating the approximate mA usage for each electrical component in our toy we will be able to mathematically calculate the mAh necessary to power our toy. Along with the voltage rating, this value will be a great help to us for selecting which battery we will use for our cat toy.

Types of Batteries

Since our cat toy is robotic in its design, advice and recommendations for finding the best type of battery for our toy was largely available on robotics' websites on the web. (*Thankful to God for the World Wide Web!*) The most highly recommended rechargeable battery for small robotic devices was the NiMH battery. Close secondary recommendations were given for the Li-Ion batteries. There are many other types of batteries on the market that could be used within our design, but they are less suitable than NiMH or Li-Ion batteries, so we will not consider them for use within our project design.

Nickel-metal hydride (NiMH) batteries are highly recommended for use with robotic toys. NiMH batteries have a high electrical capacity (≈2000 mAH for AA batteries) and come in convenient standard sizes. They are also rechargeable and capable of a large number of recharging cycles. NiMH batteries can be completely depleted and recharged, they also have no memory effect so they can be partially depleted and recharged many times over without loss of energy capacity. NiMH batteries are also considered relatively safe, while they may "pop if overcharged or short circuited" (3.1.4-2), they do not explode like Li-Ion batteries do. Top rated NiMH batteries on the market include Panasonic's Eneloop battery. Eneloop NiMH batteries offer up to 2100 recharging cycles and claim to retain "70% capacity after ten years in storage". (3.1.4-3)

Lithium Ion (Li-Ion) batteries are also highly recommended for use with robotic toys. Li-Ion batteries also have high electrical capacity, higher than NiMH batteries due to the more highly reactive material that they are composed of , with approximately 2200 mAh per AA battery. Li-Ion battery packs have the advantage over other batteries with their ability to be more compact in size and thus fitting more easily into small electrical devices. This will be a big consideration for our cat toy since the volume for us to fit all of our electrical hardware into is relatively quite small.

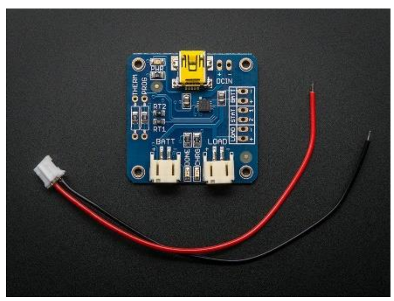
On the downside, Lithium batteries are well known for their volatility. However, newer Li-Ion batteries on the market are built with safety protections in place. A highly rated Lithium-Ion battery that is manufactured by EBL and sold on Amazon boasts that it "supports over-charged, over-discharged, over-voltage, over-current and short circuit protection" and "ensures complete safety for you and your devices" (3.1.4-4) But, even with these safety factors in place, we are still quite unsure if this battery source would be safe for a toy that could be wildly mauled by a rough-housing tomcat. The possibilities that come to mind of that combination are a bit scary since Li-Ion batteries can explode if they are damaged.

Comparisons of NiMH and Lithium batteries have give-and-takes, for us to consider for our robotic toy. NiMH batteries are lower in cost, offer more charging cycles, come in standard battery sizes and are less likely to explode than lithium batteries. Lithium batteries are smaller in size and have more energy with higher voltages than NiMH batteries, but they pose some risks that we may not want to take with a precious pet kitty.

Battery Chargers

The appropriate charging mechanism will be significant to a pet owner's convenience. Selecting a charger that is commonly used on the market for other devices will be helpful. Having a charger that a pet owner can use with other devices would be beneficial to them. We will aim to utilize the best recharging system that we can for our Interactive Cat Toy.

Chargers popularly used today involve USB plugs. USBs are well liked because of their interoperability with other devices. Utilizing a USB compatible charger for our toy could allow a pet owner to even charge their toy through their computer's USB port, which would be a handy convenience. Technology that will support USB charging of a device is readily available on the market. IC module boards ready to be plugged into a project PCB are available for Li-Ion and NiMH batteries. Using this type of charger will limit our power supply voltage to around 4.5 V.



https://cdn-shop.adafruit.com/1200x900/259-00.jpg
Figure 3-6: Adafruit's USB Li-Ion / Li-Poly Charger Board

Some batteries come prepackaged with charging accessories, like the Gecoty NiMH battery below. It may be possible to incorporate this design in with our PCB with a switch. We will test this possibility in our Senior Design Lab. This battery provides 7.2 V, a good amount for our design.

Figure 3-7: Gecoty Ni-MH Battery Pack with Charging Cord

3.1.5 Speakers (Aliza)

After studying the behaviors of cats when they are playing and looking at top cat toys on the market, we noticed that sounds play a significant role in the enjoyment of the cat's play time. Noises not only gain a cat's attention to a toy, but noises also seem to bring out a cat's natural instinct to want to "kill" the toy they are playing with. Thus, implementing a speaker into our design would benefit our design to help bring even more enjoyment to a cat's playtime.

Considering the auditory range of humans and cats, we find that it is documented that humans hear sound in a range of frequencies from 20 Hz to 20 kHz and cats hear sound in a range of frequencies from 55 Hz to 77 kHz. Cats are therefore able to hear on a broader range of frequencies, including on an ultrasonic level, as compared to their human owners. But we would like for our toy to be enjoyable to both pet owners and their cats so we will work to keep sounds that emanate from our toy in a frequency range that both can hear and enjoy. We will do this by modulating sounds similar to low volume human speaking.

While conducting our previous research for this report regarding other cat toys on the market, in section 2.3, we found that many pet owners complained about the loud noises that came from their pet's toys. We will work to keep the volume to an enjoyable level for our toy. The decibel level for a human whisper to normal conversation is between 20 – 50 dB. We will work to keep our speaker volume within this range. Luckily there are smart phone applications that measure sounds in decibels to help us with this.

When choosing the speaker for our toy project, we will take into account many different factors. One factor being what the speaker will be outputting exactly. In our case the audio will only be playing a simple array of animal noises, and possibly the sound of a bell. For these sounds to be enjoyable we must have a good volume range for our speaker, between 20 – 50 dB, and good tonal clarity. We must also take into account the speaker's shape and size, or its dimensions. We need to select a speaker that will be small enough to fit well into our electrical component casing, but not so small that it will not be able to be heard through the exterior skin of our toy.

Investigating the available speaker technology for our toy design, we found three speakers that seemed like a good fit for our design. We found that speakers are rated by their impedance and their wattage. We also found that speakers require an amplifier to convey sound. To understand how these parameters apply, experts use the analogy of a pipe with water running through it. They say that the impedance gives us the idea of the diameter of the pipe… a smaller impedance means a larger diameter thus letting more water to flow through it. The amplifier is like a water pump that sends the water through the pipe. The wattage rating tells us how much power the speaker can hold up to without burning out. This is the max amount of power a speaker should take from an amplifier.

The first speaker we will consider is called the STEMMA Speaker from Adafruit. This is actually a speaker attached to a small circuit board that includes an amplifier and a volume control that can be adjusted with a screwdriver. This board comes ready to be plugged in for use in a project like ours. We will just need to purchase the appropriate JST cable to connect with our PCB.

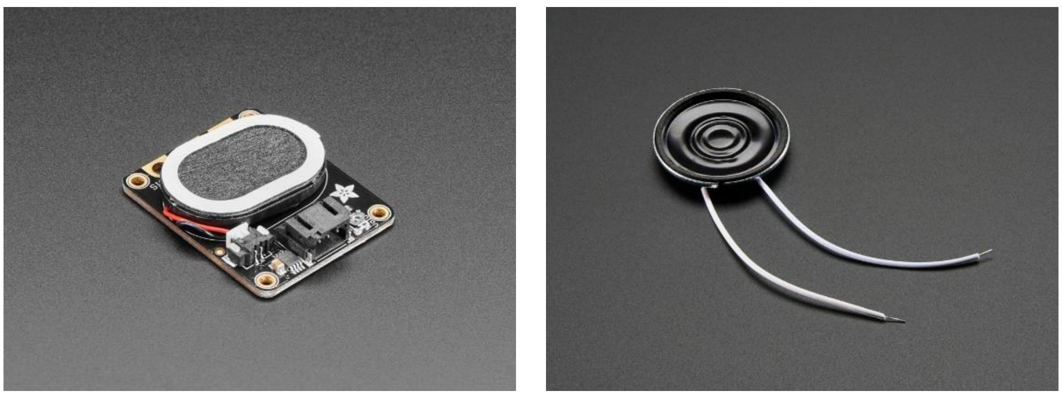


Figure 3-8: STEMMA Speaker & Metal Speaker Respectively

The second speaker we will consider is a simple Mini Metal Speaker from Adafruit Industries. This speaker comes wired up, but will need an amplifier board to connect into our project. This speaker is only 1” in diameter so its sizing is within a good range for our project.

The third speaker we found to consider for our Interactive Cat Toy was Soberton Inc.’s SP Dynamic Speaker Unit. This is another 8 Ohm speaker, with a Wattage rating of 800 mW, or 0.8 W. This speaker is a bit small than the Mini Metal Speaker and denoted as a Micro Speaker. This speaker also comes with wire leads and will require an amplifier.

All the speakers we have considered seem like good candidates for our project, having compact dimensions and good power ratings. With their power ratings for wattage being between a 0.5 and a 1 W power rating, we will need to be careful when designing our circuit and using these speakers that the power fed to them does not exceed this amount and burn our speakers. Determining the good volume level and clarity of sound from the speakers will need to be investigated in our Senior Design Lab.

3.1.6 Motors (Liz)

Our project design requires us to use motors, to facilitate movements for our Interactive Cat Toy. Since cats are instinctive hunters of small animals, we will employ a motor to produce movement within the body of the toy to mimic subtle motions of a small animal. We will also employ the use of a motor to produce shaking of a catnip pouch, in order to release the catnip scent into the air and attract a feline's attention.

We will investigate different motor types to determine which will be best suited for our bodily motion and shaker features. Our search for a motor for our Interactive Cat Toy will be limited to DC motors, as our toy will be operating off of a DC power supply. "A DC motor is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields." (3.1.6-1)

Motors found of common use in robotic toys like the one we are designing include small sized brushed & brushless DC motors, servo motors and stepper motors. Each of these motors produce different types of rotational motion for us to utilize. Standard DC motors produce continual 360° rotational motion when power is applied to them, servo motors supply angular position controlled rotational motion (commonly within 180°) and stepper motors avail high precision position control "in steps" with 360° rotational motion. Either of these types of motors could be used within our project design so we will compare one of each of these types of motors.

Standard DC motors come in both brushed and brushless versions. We are considering a brushless DC (BLDC) motor because it offers a quieter output with its 360° rotational motion. Control of this type of motor is a bit complex though as it involves increasing, decreasing, and reversing power to the motor. This aspect could prove to be too difficult to implement into our project design for the purpose of creating subtle bodily movements for our toy. However, this motor could possibly be useful for shaking our catnip pouch with a creatively designed mechanism. But design of our mechanical parts will determine if a continuously turning BLDC motor will be a viable choice for any of our features. We will consult Le Phan, our teams' sponsoring mechanical engineer to determine the feasibility of this possibility.

Servo motors are DC motors with some additional parts, that allow for angular position control. "The technical definition of a "Servo Motor" is a motor which employs negative feedback to control motor speed and/or position." (3.1.6-1) This position control makes servo motors a good option for use in robotics, and being that our cat toy will have robotic features, it will also be a good option for use in our toy. A fault that could arise with a servo motor; however, is that the “feedback mechanism in the servo will actively try to correct any drift from the target position” (3.1.6-1) and this could possibly cause a “jitter” (3.1.6-1) effect in our toy. This would not be desirable for our project. We do not anticipate that this will occur for the subtle movements that we are looking to create with the motor, but we will look for this occurrence in testing of our hardware. If it becomes an issue Adafruit, a supplier of servo motors, recommends switching to a stepper motor.

The sizing of available servo motors on the market today make this motor an appealing option for our cat toy design. Because we have a small volume in which to fit all of our electronic hardware, micro servo motors are the most appealing for us. Adafruit Industries, Inc., along with many other vendors who cater to small project designs like the one we are building, offers a good variety of these “micro” servo motors like the one pictured below. Micro servo motors come with both plastic and metal gears, with the metal gears being more durable.

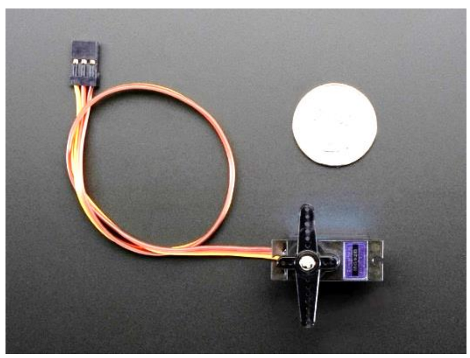


Figure 3-9: Adafruit’s Micro Servo Motor

Stepper motors are also DC motors, but they offer the precision of rotational positioning in “steps”. These motors are very useful in machines where high precision positioning is important. For our cat toy this is not a necessity, but a stepper motor could offer the functionality we would need for creating the subtle animal like motions that we would like for our Interactive Cat Toy. We will consider a stepper motor for integration into our project design. But with this consideration we will also need to consider a down side to stepper motors which is their high current draw due to their high torque produced from holding a position. This could be an issue for our power supply, as it could require a larger capacity battery.

The selection of motor(s) that we will use for our Interactive Cat Toy project will depend on many different factors. We will explore these factors further in section 3.2.6.

3.1.7 Lighting Effects (Aliza)

Moving on to our cat toy design's lighting effects. For our cat toy we want to add an assembly of lights that we can program to show off a light display down the back of the body on our toy design, giving our toy an extra element of fun for our feline friends. We intend to offer a show of light that attracts a cat, similar to the way a laser pointer attracts them, into play. Cats chasing laser pointer lights is a well-documented form of favored fun for cats. We will employ lighting different from a laser though, we will use LEDs because they are safer for the eyes and use less power.

We plan for our basic design of our lighting effects feature to illuminate a single colored and single signal patterned display. The advanced design for this feature of our cat toy will include offering multiple lighting colors along with multiple light signaling patterns. The advanced design will be controllable through a smart phone application.

With lighting design ideas in mind, we realized that we needed to not only do an investigation into the available technology for the components we need, but also to do an investigation to understand the visual capabilities that cats have. In an article on the 'Litter-Robot Blog' the publisher provides information about the vision of a cat, stating that cats have a smaller range of colors that they are visually able to see. According to the 'Litter Robot Blog', colors that are most prominent and easy to see in a cat's vision are blue-violet hues of color; followed by yellow-green hues of color, which are slightly less easy for cats to see. 'Litter Robot' says that red and orange hues of color are not prominent at all in a cat's vision, so they are unable to see those colors at all. "You're likely wondering how your cat cannot detect red hues even though a favorite play toy is the bright red laser pointer. Your cat is detecting the rapid movement of the light and not the color itself" (3.1.7-1) says 'Litter Robot'. Doctors of Veterinary Medicine with VCA Animal Hospitals concur this information about the visible light spectrum for cats and say, "*Your cat will enjoy yellow and blue toys more than red ones." (3.1.7-2)* We will use this information in our final cat toy design. We will lean more toward employing the use of blue-violet and yellow-green lighting effects for our cuddly kitties.

Available on today's market are programmable LED lights that use the RGB color code, which allow you to display multiple colors from combinations of red, green, and blue. Red, green, and blue are the primary colors for lights, with them you can create a broad array of colors. There are also programmable LED lights that only allow you to change the brightness of the light, while the color is unchangeable. For the purposes of designing our cat toy we will investigate the technology that is available which offers us the ability to program LEDs to display various colors.

Multiple lighting color and signal pattern displays can be accomplished with “addressable” LEDs. These LEDs are individually programmable and can be coordinated through a microcontroller that we will embed in our cat toy’s PCB. These LEDs come in various shapes.

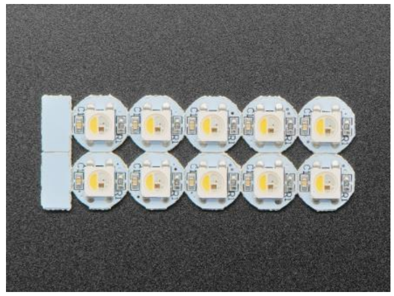


Figure 3-10: Adafruit’s NeoPixel RGBW Mini Button LEDs

The NeoPixel RGBW Mini Button LEDs available through Adafruit are simply a set of ten ultra-bright SK6812 LEDs. SK6812 LEDs have one RGB LED and one white LED on a mini circuit board. The buttons have a programmable 32-bit color range with 24 bits for RGB and 8 bits for white lighting. These buttons also have a built-in driver providing constant current which works in minimizing the possibility of burn-out of the LEDs. These buttons are able to be joined together in one row and connected to just 1 pin per wire on our project PCB.

Figure 3-11: Banggood’s 5M WS2811 RGB IP68 LEDs

Banggood’s 5M WS2811 RGB IP68 LED Pixel Module Strip Light with 3-Key Controller is similar to a string of “Christmas tree lights”. This will save us the trouble of wiring each LED together as for the mini button LEDs. This string of lights already comes with its own controller programmed to select colors and signaling patterns.

Adafruit’s NeoPixel Digital RGB LED strip is more of a straight ‘string-like’ line with RGB LEDs running down it. The strip has 60 LEDs per meter with one every 0.65 inches, where they can be cut to size based on project needs. These are WS2812 LEDs on a strip that allow for a good bit of flexibility in coding. The LEDs are encased in a waterproof sheath.

Figure 3-12: Adafruit's NeoPixel Digital RGB LED Strip

Each type of LED that we are investigating have different fashions on how to program them. Banggood's strip of WS2811 LEDs cannot be programmed individually. Which brings us to the set back of having to change the color to all the LEDs in the line all together to the same exact color. Not allowing us to change each LED in the line separately. So this makes Banggood's 5M WS2811 RGB IP68 LEDs less desirable for our project design.

Adafruit's button and strip LEDs could be programmed separately. These were the SK6812 and the WS2812 LEDs.

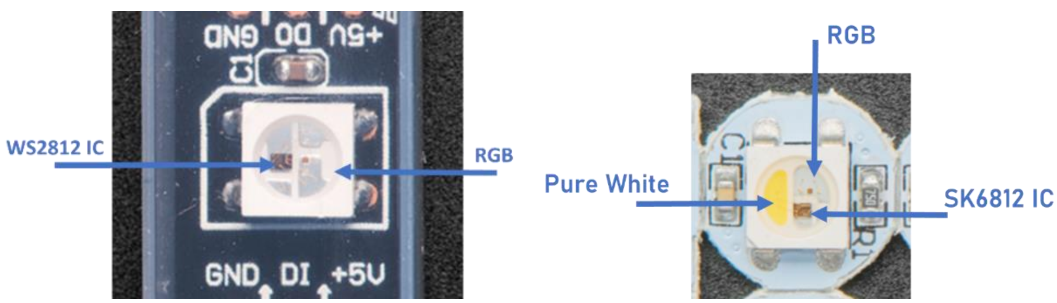


Figure 3-13: WS2812 LED vs SK6812 LED light Set Up

The SK6812 LED and the WS2812 LED are both similar in the instance that they both allow you to separately change each LED in the line to a different color. But the main difference between the SK6812 LED and the WS2812 LED is that the SK6812 LED has a voltage independent color and brightness over a wide range. This allows the LEDs to not be affected when there is a voltage supply drop. Another major difference is that the SK6812 allows for you to use the pure white LED that is connected to each LED.

3.1.8 Motion Sensors

For an advanced feature with our Interactive Cat Toy, we would like to employ a motion detector. We want our toy to utilize this sensor when a cat approaches it so that it can activate and entice the cat into play. We plan to program the toy to display an animal-like movement and/or to display lighting when motion is detected.

Types of Sensors

There are many motions sensors on the market, but every sensor is different and used for different cases. With this in mind we realize we need to be careful at this time to choose our sensor for this project because while sensors may be detecting movement it might be differently from what we are expecting.

The three sensors that we will investigate for use within our cat toy will be the PIR, ultrasonic, and knock sensors. Implementing correct placement for a sensor within a project is critical for the sensor to work effectively. We will test sensors and their placement in our Senior Design Lab to determine which sensor will work best for our purposes within our project design.

A knock sensor, also known as a shock or vibration sensor, "detects vibrations or shocks from knocking or tapping it" (3.1.8-1). Within this sensor a spring acts like a switch. When it receives the shock of a tap it briefly closes allowing its circuit to be signaled (by switching from high to low). This could be an ideal sensor for our toy, since cats like to tap an object before engaging in play with it.

The "passive infrared (PIR) sensor recognizes infrared light emitted from nearby objects". (3.1.8-2) The sensor uses "a pair of pyroelectric sensors" so it can detect "heat energy in the surrounding environment". (3.1.8-2) "When the signal differential between the two sensors changes" (3.1.8-2), that is when the sensor triggers. This could be an excellent choice if we would like to detect general movement of a cat in the area surrounding our toy.

Ultrasonic sensors work a little bit differently than an infrared sensor. Instead of using infrared sensing this device uses sound waves. These sound waves are just above the range of human hearing at 20 kHz, that is why the term ultrasonic is used. Usually, these devices are made of two parts, transmitter and receiver, but sometimes they are made with a single unit called a transceiver. "Sound waves are emitted by the ultrasonic sensor" and "if there is an object in front of it" then sound waves will bounce back to the receiver. (3.1.8-3) Depending on how long it will take those waves to bounce back to the receiver it can calculate the distance to the object. “Distance is then estimated by the time interval between sensor and object.” (3.1.8-3)

The ultrasonic sensors have an advantage over other sensors, in that ultrasonic sensors are unaffected and unhindered by the color of objects or sunlight being detected, as IR sensors are. Ultrasonic sensors are typically used for proximity detectors, anti-collision detection and liquid level sensing, but they are also sometimes used as motion detectors for people. It will be left up to us to do tests to see if this sensor can also be used as a motion detector for cats.

Available Sensors

Adafruit sells a version of an ultrasonic sensor that they say can be used for motion sensing. They say this sensor could work well for motion sensing up to 8 feet away. The sensing mechanisms do need to be directly facing their target; however, so workable placement of this sensor in our cat toy could be difficult to establish. This would be a great sensor for a more stationary device.

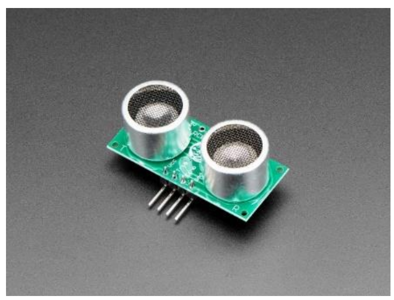


Figure 3-14: Adafruit’s Ultrasonic Distance Sensor

Another sensor we are considering is a PIR sensor module. This sensor detects motion within a 120° cone of space around it. A module we found from Adafruit detects motion within 7 meters, but also has adjustable sensitivity. It comes with an extension cord to allow for optimal placement which will be an important for a cat toy that will not remain stationary. We will need to place a sensor of this kind in a place on the toy where if it were to be left upside down the sensor would still function.

Adafruit sells Fast/Medium/Slow Vibration Sensor Switches, and refers to them as “The "poor man's" accelerometer/motion sensor!” (3.1.8-4). These are small canister modules with spring switches inside them. This would allow for our toy to activate when it is tapped or knocked by a cat. It would function as a motion detector, a little differently from what we had in mind for this feature, but it would be a good alternative option for our toy.

3.1.9 Video Cameras (Liz)

A “Stretch Goal” feature that we will aim to include in the design of our Interactive Cat Toy will be a video camera that captures video of a pet cat in play. Our concept is to enable the cat’s owner to view their video through the toy’s phone app. It will be a real stretch We think this would be quite an awesome feature for this cat toy.

There are many camera modules available on the market today. Many camera modules are developed for use with development boards from companies like Raspberry Pi, SparkFun or Arduino. With all that is available, matching a camera to its proper interface and integrating it into a design project seems like a real challenge. Luckily, we have decided to use the Raspberry Pi Pico microcontroller board and it is compatible with many modules.

Camera modules come with various features and specifications for us to consider. Following is a list of some of the items we will look at in order to select the best camera module for our project:

- Camera Resolution
- Color display
- Power Consumption
- Interface Compatibilities
- Data Communication Methods
- Features.
    - Live Video Streaming
    - Still Color Photography
    - Motion Sensing for Activation
    - Adjustable focus, Auto-Brightness and Auto-Contrast.

The resolution of a camera is an important factor. For a digital camera resolution refers to the number of pixels that a camera uses to capture an image. So, with higher resolution we obtain a better picture quality. Video Graphics Array, VGA, and HDMI are typical standards for camera resolutions incorporated for use with many cameras on the market. Resolution will be an important deciding factor for us to use in selecting the best camera for our project.

Available Cameras

ArduCam is a company that prides itself on providing platforms for camera modules that make them easier for consumers to use in electronic projects. They offer their ArduCam for Raspberry Pi Pico Camera, HM01B0 QVGA Camera Module, a camera module that comes installed on a board ready to use with the Raspberry Pi Pico microcontroller board. This camera offers “ultra-low” power usage, motion sensing activation, and monochrome video. All these are features we are looking to implement to achieve our “stretch goal” camera feature.

Figure 3-15: ArduCam QVGA Camera Module

Digi-Key sells the Himax HM01B0 camera by itself without a board that adds additional features to it. To incorporate it into any project would require some adaptors. However, this camera is the same camera embedded into the ArduCam camera module for the Pico Board. Installing this camera by itself may not offer all of the amenities that an enhanced fashioned board does, but it does offer the ability to insert only the camera which is smaller than a thumbnail into a project. Allowing this very small camera module to be placed in a device where room for electronics is an issue, as in our cat toy, could make this camera module the necessary choice for a project.

Figure 3-16: Himax Camera Module

A TTL Serial JPEG Camera with NTSC Video is sold through Adafruit. Its descriptive name is a mouthful, but it says a lot about the qualities of the camera. This camera comes with the ability to communicate via a TTL (transistor – transistor logic) serial link which is compatible with the HC-05 Bluetooth Module. The video from this camera is automatically compressed and ready to transport.

Figure 3-17: TTL Serial JPEG Camera with NTSC Video

3.1.10 Exterior Skin (Liz)

For the exterior design of our Interactive Cat Toy, our team decided to employ the look of a small animal that cats typically like to play with in nature. Wanting to be creative, we decided to model our toy after something less common than a mouse, on today's market. Having group members experienced with pet cats, we were able to easily identify small animals that cats play with for us to model.

Brainstorming and discussion helped us narrow our choices to two types of small animal models. The first small animal that we decided to model for our project was a squirrel, and the second was a lizard. After drawing squirrel and lizard body shapes, we purchased sturdy outdoor material and had our animal skins sewn together by a seamstress. Below are pictures of our first skin prototypes.


Figure 3-18: Squirrel and Lizard Skin Prototypes

Each skin was designed with a similar body shape. This will enable us to design the hardware for both skins, as we take the time to decide which animal skin we will select. It's a tough choice, so we are having difficulty deciding, we like them both! Having interchangeable skins may be a feature that we consider using.

There are elements to each of these designs that we can compare to make our selection easier. We will utilize the comparison table in section 3.2.10 of this report to analyze the attributes of each skin, in hopes of making the selection of the best skin for our project as obvious as possible.

Consideration will also need to be given to the sizing of the other hardware that will be required for our project. Integration of all the components for our project will help us determine the type of skin we will select for our final product.

3.1.11 **Chassis and Joint(s)** (Liz)

Our project cat toy will require a chassis, *or framework*, to support the lighting and movable toy parts; and to encase the electrical hardware. The chassis can be put together from parts that can be purchased separately along with parts that can be fabricated on a 3-D printer; or it can be wholly built from parts fabricated on a 3-D printer. Determination of the route that we take to build our framework depends on the ease and cost of bringing the necessary parts together.

For components that are fabricated on a 3-D printer we have the assistance of a professional mechanical engineer, Le Phan. Le will be designing and printing the mechanisms that create motion for our toy and possibly also printing other components of the mechanical framework. Le will be utilizing his own 3-D printer or will be using a 3-D printer made available to students at UCF.

Because our cat toy will most likely be played with in a rough manner we will need to design and insulate parts to withstand breakage as best we can. To protect the electrical and mechanical parts of our cat toy from damage during playtime, we can use foam padding around the parts and can also instill an inner lining to the exterior skin that is padded with poly-fill.

Important for us to consider for the 3-D printing for our Interactive Cat Toy will be the material that we select for fabrication. Typical material used in 3-D printing includes polylactic acid, or polylactide, (PLA) and polyethylene Terephthalate Glycol (PETG) filament. These filaments come in spools or in pellets and are fed into a 3-D printer where they are melted and fed through a feed tube for printing.

Figure 3-19: PETG 3-D Printing Filament

“PETG is a less rigid material (more elastic) than the PLA: it is easier to bend it and it is less fragile than the PLA”. (3.1.11-1) This makes PETG a good filament for us to consider using. A more malleable part may stand up better to rough cat play. So it seems that PETG should be the 3-D printing material that we should use. However, there are other factors to consider for our selection of filament which will include the capabilities of the 3-D printer itself. The temperature at which PETG needs to be melted for printing is higher than the temperature for PLA.

Parts that are needed for our chassis and can be purchased include a box to enclose the electrical hardware. Based on our current skin prototypes this box will need to be within the $lxwxh$ dimensions of: 3.75 x 2.5 x 1.25 inches. Some manufacturers of circuit boards sell cases that enclose the boards and have openings for various ports. Should we be able to find a case that will be compatible with our PCB and hardware design, purchasing it would save us time from designing and 3-D printing a case.

Table 3-1: Electrical Box Comparison Table

Product Description	Black Box	Aluminum Box
Vendor/ Manufacturer	Digi-Key Hammond Mftg.	Adafruit
Product ID	DK: HM362-ND	2229
Manufacturer ID	1591MBK	--
Dimensions Max: 4 x 2.5 x 1.25	3.34” x 2.21” x 1.03”	3.9” x 2.6” x 1” *
Component Access Ports	0	drillable**
Cost	$5.52	$7.50

* Because the body cavity of our toy is oval in shape, it may be preferable to design and print an enclosure for our electrical hardware, that measures 6” x 3”. The shorter width should allow for padding and zipper closure.

* The drillable aluminum box from Adafruit can have custom holes created for plug-ins to a circuit board. This box will also fit within the body cavity of our toy.

3.2 Part Selection

Our "Part Selection" process for our project is based on our "Technology Investigation" from the previous section 3.1 of this report. In that section we investigated different technologies that are available today for the parts and features that we need to build our Interactive Cat Toy. We also identified different parts that are available for us to purchase so that they can possibly be used in the construction of our design. From this technology investigation we discovered key features of each part, that are important to our design, and listed them in comparison tables in this section of our report to aid us in our part selection process.

In the sections that follow we further detail and consider aspects of each part that are most relevant to the design of our Interactive Cat Toy. For proper part selection we will also need to employ various tests to determine which parts will best meet the needs within our project. These tests will be detailed in Section 5.1.2 of this report, entitled Hardware Testing. It will be very important during our testing process to ensure that all of our parts are functioning correctly and will be interoperable, so that our design can be properly integrated. Based on our considerations, and experimentations, we will make every effort to select the very best available components.

We will consider part selections for our project including components that will be necessary for all levels of our design, from our "Basic Design" to our "Advanced Design", and also to our "Stretch Goal Design". This will allow us to have a good overview of the parts available to us and the capabilities for our design. While considering our part selections, we expect the feasibility of our conceptual design to become clear. Selecting our parts will require that we make sure the parts not only successfully deliver performance of our design features, but also that the parts fit into our overall design, are interconnectable with other parts, and operate within power specifications that are achievable for our power supply.

Our part selections will be limited to dimension constraints, compatibility, market availability and cost. Being mindful of possible constraints and limitations to obtaining preferred parts, we plan to be prepared to make adjustments to our design if necessary. The desired quality of our toy design could be affected due to our having to choose "the next best option" for a part. We will do our best to make compensation within our design for any necessary substitutions we may need to make over what we believe would be a better part selection, while still working to produce the best Interactive Cat Toy that we possibly can.

3.2.1 System Controller Selection (Vu)

Selecting a right controller can determine the overall success for our Interactive Cat Toy Project. It will impact how effective the toy will be. How frequent the programming bugs will happen? How many extra components do we need to ensure that the cat toy will behave as expected? How much time will we need to spend on the microcontroller and its connections to other components? These questions need to be asked for every potential controller that we come across. From section 3.1.1, we shorten the list of potential controllers to three.

Table 3-2: Controller Comparison Table

Product Description	Raspberry Pi Pico	Trinket M0	PIC18F16Q40
Vendor/ Manufacturer	Digi-Key / Raspberry Pi	Adafruit	Microchip
Vendor ID #	2648-SC0915	--	--
Processor	Dual-core Arm Cortex M0+	ATSAMD21E18 32-bit Cortex M0+	8-bit PIC
Dimensions	21 mm × 51 mm	27 x 15.3 x 2.75 mm	7.2 x 5.30 x 1.73 mm
Operating Voltage	1.8–5.5V DC	Up to 16V input	1.8–5.5V DC
Watts / Amps	@ 5V ≈ 92.8mA	--	--
Pins	26 GPIO pins	5 GPIO pins	20 pins
Memory size	264 KB SRAM, 2 MB flash memory	32 KB RAM, 256 KB flash memory	64 KB flash memory
Max frequency	133 MHz	48 MHz	64 MHz
Programmable language(s)	C/C++, Python	CircuitPython, Arduino IDE	MPLAB IDE
Cost	$4.00	$8.95	$2.24

The PIC18F16Q40 is a Peripheral Interface Controller from Microchip. This PIC is considered to be very simple and easy to implement into the printed circuit board. It has most of the required power and speed specifications, while having a very small dimension of 7.2 x 5.30 x 1.73

mm. The PIC has sufficient pins, with 20 pins to connect with other components for a the project. The PIC's 64 KB flash memory and 64 MHz frequency are more than enough for this project as well. There are currently a lot of PIC18F16Q40 in stock with Digi-Key, with a unit price of $2.24. However, its programming language, MPLAB IDE, will require us to learn before we can code the controller. This is a downside to this microcontroller that makes us consider our other options.

The Trinket M0+, on the other hand, is much easier to program, with the programmable languages of CircuitPython and Arduino IDE. Our members have experienced firsthand with other Arduino controllers and boards so that programming this controller will not be too much of a challenge. The Trinket M0+ controller is also considered to be powerful. It has a 32-bit processor and a maximum frequency of 48 MHz. It also has a relatively large memory size, with 32 KB RAM and 256 KB flash memory. Its operating voltage is also impressive, with up to 16 V input allowed. This Trinket M0+ is relatively big, with a dimension of 27 x 15.3 x 2.75 mm. The price point of this controller is higher than the other two controllers, at $8.95 from Adafruit. However, the specification that makes us be wary of this controller is the number of pins that it has. This Trinket M0+ only comes with 5 GPIO pins, which might not be enough for the number of components that we are thinking of implementing. Due to this we will move on to consider another controller.

Out of the three controllers in section 3.1.7, Raspberry Pi Pico is the best option for the project. Its specifications and parameters satisfy nearly all of our needs for the cat toy. The Raspberry Pi Pico controller with Dual-core Arm Cortex M0+ is impressive with its processor power. The processor is 32-bit with maximum frequency of 133 MHz. It also has the largest memory out of the three, with 264 KB SRAM and 2 MB flash memory. The Pico microcontroller has 26 multi-function GPIO pins that will be extremely useful for the number of components that we have intended for our Senior Design project. The programmable languages for the Pico, of C/C++ and MicroPython, are very easy to use. Raspberry Pi also has much assistive material available. The castellated holes and modules on the Pico board are convenient for us to solder easily onto carrier boards.

Furthermore, this controller has several exclusive features that possibly helps it to out-perform the other two controllers. It has different channels that can be used for various functions: 2 SPI, 2 I2C, 2 UART, 3 12-bit ADC, and 16 controllable PWM channels. There is a temperature sensor. Low-power sleep and dormant modes are useful to have a longer battery life. The only downside of this controller is that its dimension, 21mm x 51mm, is also large. However, considering the size of the exterior skin and the chassis, this should not be a problem.

3.2.2 Printed Circuit Board Selection (Vu)

Due to the requirements of the Senior Design project, the printed circuit boards must be self-designed and printed. There are many vendors and manufacturers who allow the users to submit a PCB design file and customize the sizes and the number of layers needed. In the comparison table below, we list three PCB development options for our project.

Table 3-3: PCB Comparison Table

Product Description	**PCB for specific controller**	**Build-your-own PCB**	**Gikfun Protoboard GK1009**
Vendor/ Manufacturer	Raspberry Pi or Adafruit	PCBWay	Amazon
Dimensions	Varies, same with the MCU	Varies	1.3 x 1.8inch, 1/16" thick
Customizable	No	Yes	Yes
Layering	No	Yes	Yes
Soldering required	No	Yes	Yes
Cost	Included with MCU price	$5 for 10 pcs	$9.28 for 5 pcs

The PCB design we select must allow us to cascade with other boards and components. The Raspberry Pi Pico controller board that we selected from section 3.2.7, is a small board in which the microcontroller is attached. This small board has castellated holes and modules for easy soldering; in order to make it simple to incorporate into a PCB design.

One option we can look into before we design the PCB is premade circuit board. The Gikfun Protoboard GK1009 from Amazon is a good starting point. Using this board, though not customizable, we can have a clearer idea of what the PCB design would look like.

The vendor we chose to buy the printed circuit boards from is PCBWay. The online service of buying customized PCB prototypes becomes an easy process on PCBWay's website. You can select the dimensions, layers, and thickness of the board, and choose the quantity of PCBs that you want. Next, you just need to upload your PCB design file, whether it is from SolidWorks or Autodesk EAGLE. After you pay for the products, they have an option for real-time fabrication tracking and delivery tracking, which is very useful for managing this project. The price of the PCB from this vendor is reasonable; you can get 10 pieces with 1-2 layers for $5.00.

3.2.3 Wireless Component Selection (Joseph)

The wireless component that we have decided to use for our Interactive Cat Toy is a Bluetooth communication module. A Bluetooth module will allow our toy to connect to a smartphone app and enable a user to control multiple features of the cat toy. We selected Bluetooth out of the three technologies that we investigated, being Wi-Fi, Bluetooth and Zigbee. We made this selection because Bluetooth is better with power consumption compared to Wi-Fi, and because Bluetooth has a better data rate than Zigbee. Therefore, our wireless component comparison table is restricted to only evaluating Bluetooth communication modules.

Table 3-4: Wireless Component Comparison Table

Product Description	**HC-05**	**HM-10 Bluetooth Module**	**Bluetooth Low Energy**
Vendor/ Manufacturer	Amazon / DSD tech	Amazon / DSD tech	Adafruit
Vendor ID	B01G9KSAF6	B074VXZ1XZ	2479
Dimensions	26.9 x 13 x 2.2 mm	1.5 x 0.6 x 0.1 in	21 x 32 x 5 mm / 0.8" x 1.26" x 0.2"
Operating Voltage	3.6 - 6V	3.6 - 6V	5V safe input with 3.3 Voltage regulator
Watts/Amps	30mA	30mA	Avg: 1.86 mA Peak: 15.2 mA
Transmission speed	2.1 Mbps	2.1Mbps	not listed
Operating frequency	2.4 GHz	2.4GHz	not listed
Phone Compatibility	Android	iPhone, Android	iPhone, Andriod
Cost	$9.99	$11.49	$17.50

The first wireless communication module that we considered for use with our Interactive Cat Toy was the HC-06 Bluetooth module. Along with this module we also considered the HC-05 module. We investigated both modules for the purpose of best understanding the technology and features that we could employ with our toy design. We found that the HC-05 module was superior to the HC-06, having more features.

The HC-05 Bluetooth module usually comes with 6 pins, KEY/En, VCC, GND, TXD, RXD, STATE. With this module we can check if the device is on thanks to pin STATE and for the KEY/En pin we can choose how we would like to transmit the data, either command mode or data mode. The baud rate in command mode is 38400 bps and for data mode is 9600 bps. The HC-05 module has the capability of being used as a master or slave device, making it able to expand our toy network. The HC-06 Bluetooth module is a little bit different from the HC-05 because this it only comes with 4 pins which are VCC, GND, TXD, RXD, it doesn't include the KEY/En and STATE. The big difference between this module with the previous one, though, is that this one can only be used as a slave, while the HC-05 can be used as a master and slave Bluetooth device.

During our investigation, we found that the HC-05 and HC-06 Bluetooth modules are compatible with Android software, but not with iOS software. This means that iPhone users could not connect to our application. This would restrict a large amount of pet owners from being able to use our toy's app. Gaining our understanding of the compatibility limitations of the HC-05 and HC-06 Bluetooth modules lead us to find the HM-10 Bluetooth module. The HM-10 Bluetooth module is compatible with both IOS and Andriod software. This module can also serve as a master or slave device. The HM-10 module comes with 4 pins for VCC, GND, TX and RX. This device is based off the HC-04 model of Bluetooth module.

Another Bluetooth Module that we investigated was a Bluetooth Low Energy (BLE) module from Adafruit. Unfortunately, we found that the low energy protocol will not allow for streaming video, that is one way that it is kept a low energy module. The module could be used to send an occasional still photo, though, so it had some potential for consideration.

There are many options for Bluetooth communication out there, but we consider that the best choice for our project will be the *HM-10 Bluetooth module*. This module will allow us to create a usable smartphone application for use with a larger audience than the HC-06 and HC-05. Also, having this module being able to serve as Master or Slave, it will be able to connect to other modules allowing for networking for our Interactive Cat Toy project. This networking prospective could open a channel for us to realize our "stretch goal" features and more for our toy design.

3.2.3.1 "Stretch Goal" Wireless Selection (Joseph)

Should we be able to work up to building our project prototype to include our "Stretch Goal" feature design we will require the use of a Wi-Fi communication module. While we are using a low energy Bluetooth module for our main plush toy component for our project, a Bluetooth communication module is not powerful enough to stream video. A Bluetooth module will suffice for app control of our main plush toy component because only basic commands will be transmitted wirelessly in that case. Transmitting video to our application from our "Kitty Cam" accessory will require a higher powered communication device like a Wi-Fi module.

Because this Wi-Fi module will be used in the "Kitty Cam" accessory to our Interactive Cat Toy, the extra power usage will not create an issue for power drain from our main toy component. This accessory will be a completely separate component operating off of its own internal power source and electrical circuit. A design complexity that does arise from employing a Wi-Fi module for this feature is that we will need to work around is having input from two wireless communication modules to our one smartphone application. Programming for this complexity may prove too difficult to work out within our limited class time.

We choose Wi-Fi for our "Stretch Goal" feature, as opposed to other wireless communication options, because its cost is low and it is easy to activate. Also, Wi-Fi's data rate of up to 600 Mbps will be sufficient for our video transmission to our phone application. For our project we believe the most adequate Wi-Fi module will be small, powerful and compatible with a Raspberry Pi Pico microcontroller; since we will be employing a Pico for our Kitty Cam accessory.

Wi-Fi modules available on the market include development boards or SOCs (system on a chip) that employ Wi-Fi chips. These boards include convenient amenities for ease of connectivity within projects like ours. We looked at two kinds of these modules that employ the ESP8266 Wi-Fi microchip.

The first module we considered was the WeMos D1 Mini. It has 11 digital input/output pins along with analog inputs and outputs and can be programmed using a USB communication port. The module is programable in C using an Arduino IDE. The module does not need too much voltage to work, it can operate with just 3 V. Based on the specs of this device we found that it has a frequency band of 2.4GHz. The WeMos D1 Mini has a preloaded NodeMCU software which is an open source platform which can connect objects and allow to transfer of data using the Wi-Fi protocol.

The second module we considered was the ESP-01. The ESP-01 is like a small computer that offers Wi-Fi connectivity with or without the use of a microcontroller. It has an LED that lets the user know when data is transferring. The ESP-01 also works nicely with NodeMCU or Arduino IDE, allowing the user an extensive variety of options for programming this module. Having the built in UART that can be used for TTL (transistor-transistor logic) serial communication, this has few disadvantages that we might consider like high power consumption at higher frequency and noisy. Advantages to this module; however, include its low cost and most importantly its compatibility with microcontrollers.

From the two Wi-Fi modules that we considered, we found that the WeMos D1 Mini would be the most practical module to use for our project. With this module's ease of connectivity through its multiple I/O pins available on the board, and its lower cost; the WeMos D1 Mini became the obvious best choice.

Table 3-5: Wi-Fi Component Comparison Table

Product Description	**ESP - 01**	**WeMos D1 Mini**
Vendor/ Manufacturer	Espressif	Banggood / Geekcreit
Vendor ID		1264245
Dimensions	25 x 15 mm	34 x 26 mm
Operating Voltage	3.3 V	3 V
Watts/Amps	12 mA	12 mA
Flash Memory	1 Mbytes	4 Mbytes
Cost	$6.59	$ 3.99

3.2.4 Battery Selection (Liz)

Choosing the right battery for our Interactive Cat Toy project depends on the power usage of each component that will be integrated into our design. The battery will need to supply a constant voltage large enough to meet the operational voltages of each component. The battery will also need to supply ample current for each component to properly operate.

In order to select the right battery for our project we will begin by determining the needed power for each component in our design. We will use the common nominal values of voltage and mAH that are given by manufacturers as our basis for these values. For components where these values are not provided we will use educated rough estimates. Then per our professor, Dr. Wei's, instruction we will add a 30% margin to the values of our voltage and current estimates. This will allow for consideration of the loss of voltage and current to other circuit components.

The voltage rating for our battery selection will need to be sufficient to supply the largest valued operating voltage of the components within our design (taking into account that it may be possible to boost voltage for a component if necessary). We will also take into consideration a need for additional voltage to cover "a margin for negative voltage peaks and drop-off voltage on regulator(s) and cables" (3.2.7-1). We will be careful in our selection of the voltage rating as too high of a voltage could burn out components within our circuit, and too low of a voltage application could damage components like a servo motor also.

The total current needed will equate to the sum of the currents that will be consumed by each component. The needed current for each component will be based on an estimate of current required to run the component during toy operation and will be measured in mAH, milliamp hours. Most batteries on the market today provide current ratings in mAH. We will be conservative in our estimates of current values, as to minimize the possibility of damaging a sensitive component. We understand that too much current could damage a component like LEDs.

Most components that we will use provide data sheets with measured values for power usage, which is very convenient for our power calculations. However, values are not always made available. For example, "servo currents usually are not specified". "The average current a servo consumes in actual operation will be somewhere between the two extremes *[of idle and stall current]* and will depend on how active the servo is in the application." So, "it's good to keep a few estimates in mind. A standard servo will have a stall current around one amp, a micro servo will need a few hundred milliamps" and in general a servo's idle current "should be in the few dozen to one or two hundred milliamp range". (3.2.7-2) Since we are using micro servos in our toy project, we will assume the current necessary during play time for our toy will be around 88 mAH based on averaging these estimates.

The Component Power Usage Chart below is based on very rough estimates for power usage values for each of our components. We keep in mind that that each component could be damaged by the improper application of a voltage or current, so we understand that proper careful testing of our circuit design will need to be carried out to avoid causing damage to any of our components.

Table 3-6: Component Power Usage Chart		
Component	Voltage (V, DC)	Current (mA)
Basic Design		
Controller	1.8 – 5.5	93
Speaker (animal sounds)	2 - 5.5	30
Motor (head)	4.8 - 6.6	90
Motor (catnip)	4.8 - 6.6	90
Lighting	5.3	60
30% Margin (per Dr. Wei)	+ ≈ .3 V	109
Total Needed	≈ 6 - 7 V	472
Advanced Design		
Motion Detector	5 - 20	65
Blue Tooth	3.3 - 6	30
30% Margin	+ ≈ 1 V	29
Total Needed (w basic design)	≈ 6 - 7 V	596
"Stretch Goal" Featured Design		
Speaker (pet owner comm)	2 - 5.5	30
Video Camera	5	75
30% Margin	+ ≈ 1 V	32
Total Needed	≈ 6 - 7 V	733

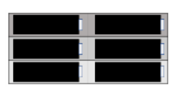
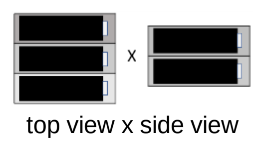
Based on the very rough power calculations above, our toy will require a 6-7 Volt battery that supplies about 733 mA to properly operate. If we would like our toy to operate, with all of its components active, for three hours on a charge; we will need a 6-7 Volt battery with about 2200 mAH. All of the batteries we compared in the technology investigation section of this report could serve as a source of this power requirement.

Table 3-7: Battery Comparison Table			
Product Description	**8 Pk Eneloop AA NiMH**	**Gecoty Ni-MH Battery Pack**	**LITHIUM-ION Battery Pack**
Vendor/ Manufacturer	Amazon/ Panasonic	Amazon / Gecoty	Digi-Key / Jauch Quartz
Vendor ID	ASIN: B00JHKSN5I	ASIN: B0727NJ2MF	1908-LI18650JP2S1P+PCM+2WIRES70MM-ND
Manufacturer ID	BK-3MCCA8BA	10	LI18650JP2S1P+PCM +2 WIRES 70MM
Voltage	1.2 V per battery	7.2 Volts	7.2 Volts
mAh	1900-2000 per battery	2400	3250 mAH
Dimensions	std AA	85 x 51 x 14.5 mm 3.34 x 2 x 0.57"	2.72" L x 1.50" W x 0.79" H
Wired for PCB	No will need wired holder	Yes	Yes
Charger Included ?	No	Yes, wall chgr	No
Cost	$18.99	$25.00	$27.01

The first battery in our comparison table is the Eneloop AA NiMH battery. These batteries provide 1.2 V and 2000 mAH per battery. We would need to package several of these batteries together to meet our voltage needs. Six of these batteries would supply 7.2 V and 12,000 mAH. This would provide enough voltage and plenty of current to run our toy for about 16 hours of blissful playtime. We could realize this packaging with the use of a six-count AA battery holder.

Figure 3-20: Eneloop AA Batteries from Amazon and Battery Holder from Memory Protection Devices, Inc.

Battery holders come in many configurations. The shape and size of our cat toy, along with the dimensions of the other electrical components, will dictate the type of battery holder that we will need for our project.

Table 3-8: Battery Holder / Packaging Comparison Table			
Product Description	**6 Count AA Battery Holder**	**6 Count AA Battery Holder**	**6 Count AA Battery Holder**
Vendor/ Manufacturer	Digi-Key / MPD	Digi-Key / MPD	Digi-Key / MPD
Vendor ID	BH36AAW-ND	BH16AAW-ND	BH26AAW-ND
Manufacturer ID	BH36AAW	BH16AAW	BH26AAW
Dimensions	110 x 49.5 x 16.9 mm 4.33 x 1.95 x .67 in	156.5 x 25.7 mm 6.16 x 1.02 in	58.4 x 45 x 29 mm 2.3 x 1.7 x 1.14 in
Configuration	single layer 2 x 3 	single layer 3 x 2 	double layer 1x3x2 
Accessories	wire leads	wire leads	wire leads
Cost	$4.17	$2.22	$2.43

Initially we consider that the single layer 2 x 3 battery holder will be best for our toy as it could fit along the bottom of the chassis case in an enclosed compartment. We will consider this configuration in lab testing.

The next battery in our comparison table is the Gecoty Ni-MH Battery Pack. This package is very appealing to our toy design because it already comes packaged and wired for re-charging. This battery pack pales in comparison to 6 Eneloop AAs though, providing only 2,400 mAH, to the amount of energy that the Eneloop AAs provide, of 12,000 mAH. But, with the Gecoty NiMH battery having its 2,400 mAH, this battery will still provide about 3.5 hours of play time for a cat with all of our features (basic - stretch) in operation. Simplification of our design with this package makes this battery well worth considering for use in our cat toy.

The final battery in our comparison chart is a Lithium-Ion Battery Pack. We are taking this type of cell into consideration because it claims to have good safety protocols in place to keep the battery from exploding as lithium-ion batteries have the reputation of doing. That would definitely not be appealing to any pet owner. However, the new safety measures claim to make this battery as safe as a standard NiMH battery.

Lithium-ion batteries are typically preferrable for use in electronic design because of their compact size, which would be great for fitting into our cat toy's limited hardware space. This battery is just 2.72 x 1.5", which is substantially smaller than our other battery package dimensions. The lithium-ion battery also provides 7.2 V and 3,250 mAH, putting it right in the middle range of power supply between our other two batteries. With 3,250 mAH this battery would operate our toy, with all its "stretch features" for about 4.5 hours. This should be plenty of time to wear even the most rambunctious kitty-cats out.

Two out of our three batteries that we are comparing will require a charger.

Table 3-9: Charger Comparison Table

Product Description	**Common AA Wall Battery Charger**	**USB Li-Ion/Li-Poly Charger Board**	**Rechargeable NiMH Battery with Charger**
Vendor/ Manufacturer	Amazon / EBL	Adafruit	Amazon / Gecoty
Vendor ID	B0148675WM	ID #259	ASIN: B0727NJ2MF
Manufacturer ID	808-AA23008	na	10
Dimensions	7.81 x 3.33 x 2.56 inches	1.3 x 1.4 x 0.3in	12.1 x 7.8 x 5.2 cm 4.76 x 3.07 x 2.05"
#Chging Ports	up to 8	na	na
Battery Compatibility	NiMH AA, AAA	Li-Ion	NiMH
Voltage	up to 12 V	up to 4.5 V	
Comes with:	na	JST cable	Yes, wall chgr
Cost	$22.99	$12.50	$25.00

As a first consideration, we decided to include a common AA Wall Battery Charger into our comparison table. This just gives us the idea of what is available for a standard sized AA NiMH battery as compared to other charging options for batteries. This also would give us the option of encouraging use of rechargeable batteries without building a charging system into our toy. A pet owner could simply remove the batteries from the toy, recharge them and then replace them.

Secondly, we considered charger board modules while specifically looking at the specifications for the Li-Ion/Li-Poly Charger Board. It is very tempting to look at this option because the Li-Ion battery offers a good combination of power supply and compact dimensions that would be very good for our cat toy design. We may need to take a second look at the safety of the Li-Ion battery given these superior features.

These charger boards offer convenience in being readily able to be attached to a PCB and to be able to incorporate switching between battery charging and powering of our toy. However, the voltage ratings for these boards do not meet our total power supply needs. It could be possible to utilize multiple charger boards for our project but this could require extensive time to develop a safe design to accommodate such a PCB configuration. So, we will not elect a charger board as a first choice for our project.

Finally, with our charger comparison table, we felt it necessary to include and take another look at Gecoty's Ni-MH Battery Pack, which comes ready to be attached to a USB charging cord. The combination of this battery pack, with its 7.2 V, 2400 mAH power supply and its attached charger, seems ideal for our project needs (with the slight disadvantage of it being slightly larger than our other battery options). So, based on all of our comparisons we selected the Gecoty Ni-MH Battery Pack as the best possible power source for our toy.

The operating time that this battery should provide, based on our mathmatical analysis, seems like a reasonable amount of time for a cat to play on a given battery charge. We consider that the toy may not be engaged in active play for an entire 3.5 hours and the toy may go dormant until reactivated by its motion sensor conserving power, so the toy could possibly remain charged for a whole day of kitty play.

Another reason we chose this battery is because the charging ready packaging is too good to pass up, with the simplifications it will allow for our design. Finally, and most importantly, we chose this battery because it is reputed as safer to use in toys, over Li-Ion batteries, we would not want to cause any harm to a anyone's precious pet cat.

We only hope the Gecoty Ni-MH Battery Pack works as well as it claims to and doesn't actually cause more work for us. ;)

3.2.5 Speaker Selection (Aliza)

In this section we will be going through the process of choosing the ideal speaker for our cat toy design. Three speakers that our design would be compatible with are listed in the comparison table below. These speakers have multiple similarities which bring them into the spectrum of use within our design, but they also have differences which can either set back or enhance our design.

Table 3-10: Speaker Comparison Table

	STEMMA Speaker	**Mini Metal Speaker**	**Dynamic Speaker**
Vendor	Adafruit	Adafruit	Digi-Key
Manufacturer	Diodes Inc	AricZhu	Soberton Inc.
Part Number	3885	1890	SP-1605
Dimensions	37 x 30.5 x 7.2 mm 1.46" x 1.2" x .28"	Diameter: 28mm 1.1"	Diameter: 16mm .63"
Weight	7.5g	8g	N/A
Operating Voltage	2.0 - 5.5 V	.25 V	.89V
Watts/Amps	1 Watt	0.5 Watts	0.8 Watts
Impedance	8 Ohm	8 Ohm	8 Ohm
Frequency Range	not listed	600 Hz – 10 KHz	300 Hz – 8 KHz
Volume Control	Screwdriver adjustable	-	-
PCB Connection	Need additional wire purchase	attached wires	attached wires
Shape	Oval / Stadium	Circle	Circle
Accessories	Class D Amplifier	-	-
Datasheet with EagleCAD File	Yes	No	No
Cost	$5.95	$1.95	$1.73

First comparing the size of the three speakers in our comparison table, we see that the STEMMA speaker is the largest. This may be of some concern with the limited space that we have in our toy for circuitry. However, the included amplifier and adjustable volume control on board with this speaker makes up for the larger size. Size is a big component in finding the right speaker for our design. Because our design is a cat toy, we are restricted to small components.

The next main component to consider for all three speakers is their impedance. The STEMMA Speaker, Metal Speaker, and Dynamic Speaker all have an 8 Ohm impedance. The impedance works hand-in-hand with the Wattage to produce the speaker's audible volume. With the STEMMA speaker having the highest Wattage, it will produce the largest volume. For our cat toy we are not looking to produce loud sounds, so the larger volume ability isn't something we care to have. The higher wattage will help to make the speaker less susceptible to burning out; however, and this is a big plus. The STEMMA speaker will be more robust for our cat toy.

Moving onto comparing the speaker prices. While both the Metal Speaker and the Dynamic Speaker are priced at less than $2.00, the STEMMA Speaker is priced just under $6.00. This makes the STEMMA speaker $4.00 more than the other two speakers, and about three times the cost of the other speakers. Production on a large scale with this type of cost difference would probably be affected by economic constraints; however, for the purposes of our prototyping this cost difference is negligible. When we get to the Economic Constraints of this report we will go into deeper detail on why the cost is an important factor in our decision making of our design.

Datasheets for all three speakers are available on their respective vendor websites. All the data sheets come with detailed drawings of the speaker components, but only the STEMMA speaker datasheet comes with a link to its EagleCAD file. This file will be a good benefit to simplifying our PCB design.

With each step of our research into finding the right speaker for our design, the STEMMA Speaker stands out as the best fit for our Interactive Cat Toy. This is due to several superior factors that will provide success in our design. Adafruit's STEMMA Speaker comes prepackaged with an amplifier and a volume control on a platform that will be able to be connected to our circuitry with a good amount of stability. The STEMMA Speaker is also more robust than the other speakers that we compared and it comes with a datasheet that supplies more beneficial information to assisting us in our design process.

3.2.6 Motor Selection (Liz)

For our project, we could employ any of the motors that were included in our technology investigation in section 3.1.2 of this report. We could use a standard brushless DC motor, a servo motor, or a stepper motor. Either of these types of motors could be used within our design, with properly programmed controls, for the purpose of creating body movement or catnip shaking. So our part comparison table includes one of each type of these motors.

In selecting the best motor for our Interactive Cat Toy, we are mainly concerned with three parameters. These parameters are the operating power requirements, the physical dimensions and the ease of control programming for the motor.

Table 3-11: Motor Comparison Table

Product Description	**Brushless DC Motor**	**Micro Servo Motor**	**Stepper Motor**
Vendor/ Manufacturer	BC Robotics	Adafruit/ Tower Pro	Digi-Key / Adafruit
Vendor ID	ROB-211	#2307	1528-1366-ND
Manufacturer ID	A2212/15T	n/a	#858
Dimensions	40 x 27.5 mm 1.73” x 1.1” *length x Diameter*	1.4” x 0.5” x 1.2”	29 x 28 mm 1.14” x 1.1” *length x Diameter*
Range of Motion	360° 930 RPM/Volt	≈ 180°	360°
Operating Voltage	2 - 12 V DC	5.0 ≈ 6.6 V	5 V DC
Watts/Amps	109 W	not given*	not given*
Accessories	motor mount +	3 Horns included	mounting plate
Cost	$12.95	$11.95	$4.95

* Values for current not typically given for motors due to variable use.

The first motion that we will be incorporating into our project design will be to have the tail, of our toy, to move up and down. The simplest mechanical implementation of this movement is to move a joint up and down within a range of about 0 - 45°. A high degree of precision will not be necessary for this motion, but the motion will need to be subtle so it will entice, but not scare, our furry feline friends. A servo or a stepper motor could be an appropriate motor for this motion. Both of these types of motors allow for good position control.

The servo motor offered a range of motion compatible with the needs of our project with the ability to be easily programmed for motion control. The stepper motor offered a high precision position control, but it could drain too much current from our power supply, even while not in use, and lower our toy's operating time. The brushless DC motor seemed capable of offering a quieter delivery of motion but lacks the ease of position control. With time limitations for our class project, figuring the control for the brushless DC motor could put us behind schedule for other things.

Adafruit's Micro Servo Motor, with metal gears, seemed as if it will best serve the purpose of creating the head and/or tail movement that we would like for our cat toy. Its compact dimensions, motor horn accessories and simplified control connectivity make this the most appealing motor for us to employ. Our design team is also most familiar with working with servo motors over all of the other motors that we considered using.

The second motion that we have incorporated into the design of our Interactive Cat Toy is the shaking of a catnip pouch. This will send the scent of this cat attracting herb into the air. This motion depends heavily on the speed at which our motor will be able to rotate and shake the catnip pouch. This feature could also be able to be accomplished with any of the motors that we compared in our technology investigation. However, the servo motor again is most appealing for our use because of our team's experience and its ease of implementation.

We could possibly employ just one servo motor to serve to move the tail and shake the catnip pouch at the same time. In nature animals typically display alternating rapid and slow bodily movements. Using this behavior as a model for our cat toy design, the rapid movement could serve to sufficiently shake the catnip in order for its scent to be released, while the slower movement would just serve to move the tail. Should one motor not be sufficient to perform the two tasks of the bodily movement and shaker function, we will need to consider using two motors, or discontinuing to pursue the shaker function. Two motors may not fit into our limited hardware space. We will investigate different motor capabilities during our hardware testing in the lab and record the results in section 5.1.2 of this report.

3.2.7 Lighting Effect Selection (Aliza)

Lighting Effects will give our design an extra layer of enjoyment that both humans and cats can enjoy together. As discussed in section 3.1.7 'Lighting Effects' of this report, we discussed about the differences in the visual color spectrum of cat's vs human's eyesight. While most humans can see Red, orange, yellow, green, blue, indigo, and violet colors (with exception to those who are color blind); scientific studies say that cats can only vividly see blue, violet, yellow, and green hues of colors. Knowing this information, we can incorporate those colors as the main four colors to use as preset lighting effects, but we can still have the option of having red and orange hues for human enjoyment. To incorporate all these hues of colors into our lighting effects, we will be looking at lights that use the SK6812 , WS2811, and the WS2812 RGB LEDs.

Table 3-12: Lighting Comparison Table

Product Description	**NeoPixel RGBW Mini Button LEDs**	**5M WS2811 RGB IP68 LEDs**	**NeoPixel Digital RGB LED Strip**
Vendor/ Manufacturer	Adafruit	Banggood	Adafruit
Product ID	4776	1346213	1461
Dimensions	9.1 mm x 9.1 mm x 3.1 mm	5.0 m	12.5 mm x 4.0 mm x 16.7 mm
Operating Voltage	5.0 V	6.5 V	5.3 V
Watts/Amps	70 mA each	1.0 µA	21 W / 60 mA each
LED Used	SK6812	WS2811	WS2812
LED Count	10 pack	50 LEDs	60 LED/meter
Individual Control / Addressable	yes	no	yes
Weight	0.3 g	39 g	n/a
Cost	$4.95	$22.99	$24.95

Looking at the operating voltage for each individual LED (SK6812 LED, WS2811 LED, and the WS2812 LED) we notice that they are all within the same range of 5 to 7 volts to operate properly. This is very important to look at when adding to our device. If we use a voltage too high for the specific LED we might fry it, making it unusable. But these ranges for voltage are reasonable for use within our toy design, we will just need to be careful in implementing voltage division or voltage regulation when necessary.

Equally important to consider with LEDs is the current usage. Both of Adafruit's LEDs that we are comparing utilize a good amount of current with 60 – 70 mA each. We will need to program our LEDs with care with this type of current draw so as not to use up our battery too quickly. We may need to only illuminate one LED at a time. But these current ratings are also reasonable for our design.

After some consideration we realize that Banggood's string of LEDs, in our comparison, drops out of the running against Adafruit's button and strip LEDs. Being that Banggood's LEDs are not individually programmable makes them undesirable for our project. So, this leaves us to consider only the lighting effects in our comparison table that we have found with Adafruit.

Both of the LED products in our Lighting Comparison Table, from Adafruit, are individually programmable. They also have very similar power usage. At $4.95 for 10 LEDs, the button LEDs are a little more costly than the strip of LEDs at $4.15 for 10 LEDs.

After going over all the information that we gathered in our technology investigation and in our comparison table of each lighting effect option that would benefit our Interactive Cat Toy design, the team has decided to select to work with Adafruit's NeoPixel Digital RGB LED strip. This lighting product seemed to us to be the best possible option for our toy. Having the LEDs in a strip that can be cut to a custom size to fit into our cat toy is the biggest benefit of this product for our project design. With this product also having the WS2812 LEDs, it will allow us to reach all the array of color hues that a cat and its owner's vision is capable of seeing and enjoying. On top of that this LED strip allows us to adjust the individual LEDs for more fun lighting effects.

We believe the addition of Adafruit's entertaining NeoPixel Digital RGB LED strip to our Interactive Cat Toy will bring our design to the next level of cat toys. We think it will give pet cat owners an exciting new toy experience to enjoy with their kitties.

3.2.8 Motion Sensor Selection (Joseph)

We believe that adding the advanced feature of motion sensing to our Interactive Cat Toy would be a big plus. We think that having the toy respond to a cat's presence would be convenient and entertaining. However, being that our toy will require sensors to detect a cat, which is a relatively small animal, we understand that actual realization of this feature could be difficult. We found various types of motion sensing technology available and compare three types in the table below.

Table 3-13: Motion Detector Comparison Table

Product Description	PIR & Mini-PIR Sensors	Ultrasonic Distance Sensor	Medium Vibration Sensor Switch
Vendor/ Manufacturer	Adafruit	Adafruit	Adafruit
Product ID	189 4871	4007	2384
Dimensions	24*32*25 mm 13.8 mm diameter	45*20*15mm	5 mm diameter by 0.2" height
Operating voltage	5 -20 V 3 - 12 V	5V	none
Signal output voltage	0v –3.3V	--	na
Current consumption	65mA not given	15mA	none
Current when is not active	50μA not given	--	open
Sensitivity range	7 m / 120° cone 5 m / 100° cone	2cm-400cm / 15° cone	0 ft - Tap Sensor
Delay time	5sec - 5min 2 secs	--	--
Working frequency	--	40Hz	--
Contact Time	na	na	2 - 2.5 ms
Cost	$9.95 $3.95	$3.95	$0.95

The first type of motion sensor that we decided to consider for our Interactive Cat Toy is the PIR sensor. We investigated modules for both a regular sized sensor and a mini sensor. PIR sensors are usually used to detect the movement of humans, so we are unsure of how these sensors will work with cats. We will conduct testing to determine if using a PIR sensor for our cat toy will be successful. The parameters of the PIR sensors make them seem ideal, conceptually, for our project and we would like to employ them. We will test both the standard sized PIR and mini sized PIR for our toy design. The mini sized PIR has the advantage of better power consumption and its smaller size over the standard PIR, but the size of the mini could affect its detection of a cat.

The next type of motion sensor that we considered for use with our toy project was an Ultrasonic Distance Sensor. This sensor has advantages over the PIR sensors, for detecting a cat, because this sensor works in sensing a solid object rather than reflections from infrared waves. Infrared sensors can lose proper sense of motion in certain settings such as in direct sunlight or in a warm area. They also can neglect to sense a creature moving by it if there is not enough heat being given off by the creature. An Ultrasonic Distance Sensor also has its own limitations, though. This sensor has a significantly smaller range of motion detection than a PIR sensor has, with its cone of detection being only 15° while the PIR sensors have a much larger cone of detection of 100-120°. So a workable placement of this sensor within our cat toy would be much more difficult that the placement for a PIR sensor.

The final type of motion sensor that we realized that we could employ for our cat toy is a Vibration Sensor (also known as a knock, or tap sensor). This sensor would detect when the cat toy is tapped. This could be a good alternative sensor to use for our toy. Our initial design idea was to have our toy activate when a cat walks by it in order to call the cat's attention to engage in play. The Vibration Sensor would require that the cat is already interested and engaging with the toy. So, we will keep this sensor in mind as a back-up activation feature but we will look to employ other sensors.

We will conduct testing to determine which the sensors will actually work best in detecting a cat. We realize that a conceptual ideal like using a motion detector for a cat may not be able to be implemented successfully in the real world, and that we may have to modify our feature designs. We do hope, though, to be successful in implementing this fun feature for our cat toy.

At this time we will choose to use a PIR sensor to implement the motion detecting feature for our Interactive Cat Toy. We will work to place one or more of these sensors into our toy in hopes for this feature to be solidly established.

3.2.9 Video Camera Selection (Liz)

Adding a camera feature to the design of our Interactive Cat Toy project is a "Stretch Goal" that will require a good bit of engineering. Since our cat toy is not intended to remain stationary, but to be engaged in active play, implementing a feature like video recording within our project design will be a *real stretch*! We are up to this challenge if time permits, once we have our other levels of design complete. We think it would be great to have a Kitty-Cam for a pet owner to see their cat at play via our app on their smartphone or their computer.

Table 3-14: Video Camera Comparison Table

Product Description	**QVGA Camera Module**	**Compact Camera Module**	**TTL Serial JPEG Camera with NTSC Video**
Vendor/ Manufacturer	Amazon / Arducam	Digi-Key / Himax	Adafruit
Vendor ID	B093KBQB1C	3367-HM01B0-MNA-00FT870-ND	397
Manufacturer ID	HM01B0	HM01B0-MNA-00FT870	--
Dimensions	2.09 x 1.69 x 0.75 inches	0.787" L x 0.492"	32 x 32mm 1.26 x 1.26 in
Operating Voltage	1.5 – 2.8 V	1.5 - 3 V	Operating: 5 V Comm: 3.3 V
Watts/Amps	4 mW	.003 - 1.7 mA	75 mA
Resolution	5 megapixels	324 x 324 104.98 KPixels	VGA 640x480 QVGA 320x240 QQVGA 160x120 307.2 KP, 76.8 KP, 19.2 KP
Frame Speed	30 – 60 fps	up to 60 fps	VGA 30 fps
Color	Monochrome	Monochrome	Monochrome Video Color Photos
Misc	made for Raspberry Pi Pico	requires adapters	requires adapters
Cost	$12.99	$16.17	$39.95

During our technology investigation we found three camera modules that would work well with our project. We learned, in our investigation, that for cameras there are many factors to take into account in selecting the best camera for a project. We evaluate some of these factors in our comparison table for three camera modules. All three of these camera modules have the potential of serving the needs we have to realize our concept Kitty-Cam feature.

First, we consider resolution, as it is one of the most important factors for any type of picture imaging or video. Each camera offers a resolution that will produce a decent video quality. The ArduCam camera module offers the best resolution, though, with its 5 megapixels. This puts the ArduCam module's pixel count at millions more than the competition, so we anticipate that this camera will produce very high-quality imaging. So, resolution puts this camera in the lead for our consideration for our project's Kitty-Cam. *Adafruit's TTL Serial JPEG Camera with NTSC Video* comes in second in this category.

Power consumption is another very important consideration, and again the ArduCam module comes out on top. While the power usage is equivalent to the Himax camera alone, it beats out Adafruit's camera module with its ultra-low power consumption. Adafruit's camera module comes in last for power consumption from our comparison table. Having ultra-low power consumption is a real plus for a camera module for our project, as it will allow longer kitty videoing.

Interface Compatibility was a third important factor to consider for our camera selection. The ArduCam camera module is the best in this category too (Adafruits module is 2nd). This camera module is ready for use, being specifically built to interface with the Raspberry Pi Pico microcontroller board. Detailed instructions are even given, along with the datasheet provided, for wiring this camera module up with the Pico.

Based on our comparisons of the information we gathered during our technology investigation, the video camera module that we believe will be most compatible with our project design, is the *ArduCam for Raspberry Pi Pico Camera, HM01B0 QVGA Camera Module*. This is because it ranked first in all the categories we evaluated it in. The second runner up is *Adafruit's TTL Serial JPEG Camera with NTSC Video*

A good camera module in combination with our HC-05 Bluetooth module, will possibly deliver the "stretch goal" feature that we would like to implement in our cat toy. If successful, our pet owner will be able to see live video of their beloved pet streamed from our Interactive Cat Toy to its accompanying phone app.

3.2.10 Exterior Skin Selection (Liz)

Selecting the exterior skin for our Interactive Cat Toy from our initial skin prototypes was a tough choice for us. Everyone on the team thought the squirrel was cute, and we really liked the lizard skin as well. So, we decided to keep both designs to have interchangeable skins for our toy.

Table 3-15: Exterior Skin Comparison Table

	Squirrel	**Lizard**
Dimensions	Body: 7 x 4.5	Body: 7 x 4.5
Color	Brown/Tan	Green/White
Light Strip Fabric	Tan	White*
Cat Attraction Test	Good (*with catnip*)	
Cost	$20	$20

So, our one Interactive Cat Toy design will have *two interchangeable skins*, one resembling a squirrel and one resembling a lizard. This will be a nice additional feature to our toy, adding the ability to throw one skin in the wash when it is dirty and having an additional one to keep kitty's play time going.

The size and shape of the body of each toy skin have been redesigned to be exactly the same. While the heads, tails and feet of each skin have been designed differently to resemble their respective animal model shapes. Thankful to have Grandma Sonja willing to do all this sewing for us. :)

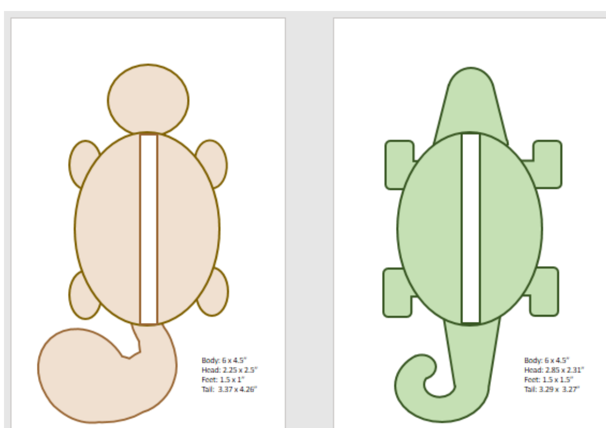


Figure 3-21: Redesigned Toy Skin Sketch Ups

3.2.11 Chassis and Joint Selection (Liz)

For our chassis, we will require special shaped components that will be made easiest by 3-D printing. With our toy having a specialized custom shape, not common to standard devices, components that will correctly fit our toy are not readily available on the market. While we could make do with components that are available, they may be difficult to fit together with our exterior skin and this would not provide for quality design. So, we have decided that custom design and 3-D printing of these parts will be best.

Table 3-16: 3-D Print Filament Comparison Table

Product Description	PLA	PETG
Vendor/ Manufacturer	Amazon.com / Hatchbox	Amazon.com / Hatchbox
Vendor ID	ASIN: B00J0GMMP6	ASIN: B014VM9724
Manufacturer ID	3D PLA-1KG1.75-WHT	3D PETG-1KG1.75-WHT
Dimensions	1.75mm diameter X 1KG (2.2 lb)Spool	1.75mm diameter X 1KG (2.2 lb)Spool
Color	White	White
Recommended Nozzle Temperature	180° - 210° C 356° - 410° F	230° - 260° C 446° - 500° F
Cost	$22.99	$23.99

Our chassis will need to fit properly into our toy skin and be able to support our design features; all while housing our power supply and electronic hardware. The chassis will need to hold a strip of LEDs along the back of our toy in order to support our lighting feature and it will also need to support components that enable our motion features.

Le Phan, the professional mechanical engineer advising and sponsoring our group, suggested that the 3-D printing for this chassis should be done using PETG filament. PETG has better flexibility over other filaments and will hold up better to rough cat play. We are glad to have Le's advising and do select to follow his recommendation to use the PETG filament for our project. Le will be assisting us with the design of the chassis and will be doing the 3-D printing for the project.

3.3 Parts Selection Overview

The table below shows an overview of the major parts that we have selected for our team to use in building our Interactive Cat Toy project. While many general electrical parts for circuit building will also be employed into the fabrication of our cat toy, we have omitted those here.

These parts are selected based on our educational determinations as to which component we believe will work the best for our project. These determinations so far are based on specifications given by vendors and manufacturers of these components. Further scrutiny of these parts individually and then within our circuit design will take place as we move forward in our design process.

As we move forward with design and testing for our project, we may find the need to replace any of these parts for a better option. We are aware that our concept of a part may not work in a real product and re-design and new part selection may be necessary.

Table 3-17: Part Selection Overview

Part #	Part Description	Vendor	ID #	Added to Group Stock	Cost
Basic Design Components					
1	Raspberry Pi Pico	Digi-Key	2648-SC0915	11/16/21	4.00
2	PCB	PCB Way	To be designed. Cost est'd.		50.00
3	Gecoty NiMH 7.2V Battery Pack	Amazon	B0727NJ2MF	11/16/21	15.99
4	STEMMA Speaker	Adafruit	3885	11/16/21	5.95
5	Micro Servo Motor	Adafruit	2307	11/16/21	11.95
6	NeoPixel RGB LED Strip	Adafruit	1461	11/16/21	24.95
7	Squirrel & Lizard Skins	Various	na	11/16/21	40.00
8	PETG 3D Printer Filament	Amazon	B014VM9724	11/16/21	23.99
Advanced Design Components					
9	HM-10 Bluetooth Module	Amazon	B074VXZ1XZ	11/23/21	11.49
10	PIR Sensor	Adafruit	189	11/16/21	9.95
Stretch Goal Design Components					
11	QVGA Camera Module	Amazon	HM01B0	11/23/21	12.99
12	Wi-Fi Module	tbd	tbd	tbd	--
Total Cost					**211.26**

3.4 Decision Matrix

This Decision Matrix in **Table 3-1** was formed following a team brainstorming meeting and does not follow a specific order. The table helped us to formulate decisions about our project design.

Each category has a rating out of 5, where 1 is the worst and 5 is the best. Each feature belongs to one of the following sub-categories: Primary Feature (P), Motor/Mobility (M), Application (A), Wireless Connection (W), Skin/Shape Prototype (S), and Others (O).

Table 3-18: Decision Matrix

Features	Cost	Ease of Use	Durability	Marketability	Total
Laser Pointer (P)	3	3	3	4	13
LED Lighting Effects (P)	4	4	3	3	14
Catnip pouch shaker (P)	3	4	2	3	12
Hinge tail movement (P)	2	2	2	4	10
Non-Mobile (M)	5	5	5	2	17
Mobile (M)	2	3	3	4	12
Color control (A)	5	5	5	3	18
Tail movement (A)	4	4	5	5	18
Video to owner (A)	4	4	4	4	16
Light pattern signals (A)	5	5	5	3	18
Toy mobility (A)	3	3	4	5	15
Blue-Tooth (W)	4	4	4	3	15
Wi-fi (W)	2	4	5	5	16
Lizard (S)	3	4	3	4	14
Squirrel (S)	3	4	3	4	14
Chassis (S)	2	3	3	5	13
Glitter fabric (S)	2	5	4	4	15
Sensor (O)	4	4	2	5	15
Speaker (O)	2	5	3	3	13

4. Design Standards and Constraints

This section will discuss standards and constraints that will shape the design of our Interactive Cat Toy Project. There are many standards and constraints that we, the designers and engineers, must consider to ensure the overall success of the project. They are either required or optional based on the merits of ethics, politics, economics, environment, regulations, performance, management, etc.

4.1 Standards

Standards are expectations and requirements created by consensus within a market, for a product. Standards are helpful to us because they make it simple for us, as product designers, to meet the needs of the clients and the industry. Standards are developed by many individuals and organizations within their respective areas of expertise. Organizations such as the National Information Standards Organization (NISO), the International Organization for Standardization (ISO), and the American National Standards Institute (ANSI) ensure appropriate standards.

For our Interactive Cat Toy Project, the design needs to satisfy the standards mentioned in this subsection in order to achieve satisfactory quality and produce successful results. This project will mainly use standards from the Institute of Electrical and Electronics Engineers Standards Association (IEEE SA). IEEE SA is an organization that oversees the standards used for the technologies developed by electronics and electrical engineering. We will also use standards from the Institute of Printed Circuits (IPC) and the American Society for Testing and Materials (ASTM).

Standards are high priority for consideration in product design so we will continue to update our search for standards during our entire design process. Should we be made aware of additional standards that become required for our project, we will work to insure they are met. As standards are being created on an ongoing basis, we expect that it may be possible for new standards to become applicable for us. We also expect that we may find standards that we did not find with our initial research.

Our research for standards will commence with the various Standard Development Organizations (SDOs) that we are familiar with, like IEEE. Standards from IEEE SA and ASTM are made freely available to us, as students, through our library at UCF. We will rely on the internet to provide us with access to other standards documentation. The pricing of standards vary substantially. Some SDOs offer memberships to view their library of standards.

We may obtain additional standards information as we purchase components for our project design. We will review product labeling or product datasheets for possible references to any necessary standards.

The proceeding sub-sections are titled with the reference number and name of each standard that has been found to be relevant to our project design. Within the sub-sections, the standard is summarized and related to our project design.

4.1.1 IPC-2221A - Generic Standard on Printed Board Design

Integration of all the electronic features of our Interactive Cat Toy will be accomplished through the use of a Printed Circuit Board (PCB). From an engineering standpoint, the PCB is the main component of our senior design project. IPC is a Standards Development Organization (SDO) that is accredited by ANSI and is globally recognized for its electronic standards regarding printed circuit boards. IPC's main goal being to "build electronics better".

This IPC standard provides guidelines on different aspects and properties (mechanical, electrical, material, components, and interconnections) for printed circuit board design. IPC-2221A also tackles other general procedures of designing PCBs, such as but not limited to layout, spacing, and quality assurance.

The IPC-2221A standard will be a helpful set of guidelines for us to design the circuit board for our senior design project. IPC-2221A documentation is available through many engineering libraries. A free copy of this standard is currently available online in a PDF format, at http://www-eng.lbl.gov/~shuman/NEXT/CURRENT_DESIGN/TP/MATERIALS/IPC-2221A(L).pdf . Though it is available to access for reading purposes only, it is not free to print.

4.1.2 ASTM F963-17 - Standard Consumer Safety Specification for Toy Safety

This ASTM standard provides specifications for battery operated toys. These specifications are intended to prevent toy hazards and tackle safety issues that are not readily recognizable by the public and the users. They also include guidelines to minimize potential hazards of the application of the toy. In addition, this standard covers the nature of mental and physical hazards that could occur when the users do not use the toy as intended.

While our Interactive Cat Toy is intended for play with domesticated cats; we recognize that it may be utilized by a child. This ASTM Specification includes standards "for toys intended for use by children under 14 years of age". (4.1.2-1) We will consider the standards within this specification and make sure that our toy is in compliance.

The full text of this ASTM specification was available to us through the UCF Library. Through the library students have access to the PDF with UCF's ASTM Compass membership.

4.1.3 Directive 2011/65/EU - Restriction of Hazardous Substances (RoHS)

Many of the vendors that supply the electronic components that we will require for our Interactive Cat Toy claim RoHS compliance. This brought the RoHS standard to our attention. This standard restricts use of hazardous materials in electronic components that pose health and environmental risks.

"EU RoHS specifies maximum levels for the following 10 restricted substances. The first six applied to the original RoHS while the last four were added under RoHS 3, which took effect July 22, 2019.

- *Cadmium (Cd): < 100 ppm*
- *Lead (Pb): < 1000 ppm*
- *Mercury (Hg): < 1000 ppm*
- *Hexavalent Chromium: (Cr VI) < 1000 ppm*
- *Polybrominated Biphenyls (PBB): < 1000 ppm*
- *Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm*
- *Bis(2-Ethylhexyl) phthalate (DEHP): < 1000 ppm*
- *Benzyl butyl phthalate (BBP): < 1000 ppm*
- *Dibutyl phthalate (DBP): < 1000 ppm*
- *Diisobutyl phthalate (DIBP): < 1000 ppm"* (4.1.3-1)

RoHS originated in the EU and is a worldwide industry standard for electrical components.

4.1.4 IEEE 802.15.4-2020 - IEEE Standard for Low-Rate Wireless Networks

We will be integrating a wireless component into the design of our project. This component will communicate between our cat toy and our phone application. Standards for wireless communications will apply. IEEE's Standard for Low-Rate Wireless Networks is one standard we will work to comply with.

This standard, defined by geographic region, outlines the use of low-rate wireless networks such as Bluetooth and Wi-Fi for personal use networks. These low-rate wireless networks are specifically standardized for fixed or mobile electronics with none-to-little battery consumption.

"The PDF of the standard is available at no cost to the general public at https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=68 compliments of the IEEE GET program." (4.1.4-1)

4.1.5 IEEE 2410-2021 - IEEE Standard for Biometric Privacy

It is our goal to design and implement the use of a phone application to control features built into our cat toy. Standards apply to phone applications. With the use of a mobile application and its programming language, Java, clients are concerned about the vulnerability of their personal identity and data. To protect client's personal information while using such applications, standards like IEEE's Standard for Biometric Privacy (SBP) have been created.

This IEEE standard includes specifications that comply with GDPR, CCPA, BIPA and HIPAA regulations. The standard calls for the use of homomorphic encryption. "Homomorphic encryption ensures the biometric payload is always one-way encrypted with no need for key management and provides full privacy by ensuring plaintext biometrics are never received by the SBP server." (4.1.5-1) Components are available for the implementation of this standard.

The documentation for this standard is available in PDF version from the IEEE SA. Through the UCF library's subscription to IEEE Xplore we were able to access the standard documentation in its entirety.

4.1.6 IEEE 2030.2.1-2019 - IEEE Guide for Design, Operation, and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems

We plan to utilize a rechargeable battery for our Interactive Cat Toy. Thus we will need to comply with standards relating to batteries. This IEEE standard tackles "the design, operation and maintenance" (4.1.6-1) of battery energy storage systems (BESS). The standard also includes different engineering and safety issues regarding BESS.

This standard applies to several types of batteries including but not limited to lead acid batteries, lithium-ion batteries, flow batteries, and sodium-sulfur batteries. As the design of our project moves forward, we will most likely select one of these types of batteries to power our cat toy.

This standard is available for purchase through IEEE.org. It can also be accessed with a subscription to IEEE Xplore. This standard's documentation was available to us through the UCF Library's subscription to IEEE Xplore.

4.1.7 Python Enterprise Proposal (PEP) 8 - Coding Convention for Python

Coding for our microcontroller will require the use of the MicroPython programming language. MicroPython is a low-level programming language based on Python and utilizes a subset of the Python libraries. MicroPython was adapted from Python for use with microcontrollers and embedded systems.

The PEP 8 standard establishes guidelines for coding in Python. These guidelines are aimed at making the code easy to read and work with.

4.1.8 Android Developers - Core App Quality Guidelines

Standards for mobile apps on an Android platform must be adhered to for an app to be approved for launch to public use by Google. These standards include guidelines for usability and appearance. An app must have proper ability to avoid crashing. Security and privacy measures for user information must be solidly implemented. Appearance of the app must be consistent with general Android app design.

As we will be developing an application for our Interactive Cat Toy we will be required to adhere to these standards. Failure to comply could result in our not gaining approval for publishing the application.

4.1.9 Java Code Conventions

The code that we will use within the Android Studios IDE for building our smart phone application will mainly be the Java programming language. Standards for writing code with Java have been created to allow for clear readability of the code. The authors of these code conventions suggest that readability is vital to the maintenance of the code.

4.2 Constraints

Within this section we will go through the multiple constraints that our cat toy design needs to have outlined in order to make it a successful design. Constraints are the challenges and obstacles every project needs to overcome to be successful. Without consideration of the constraints that are potential for a project, a team may run into difficulty and hold ups in manufacturing, marketing or sales.

For our project cat toy design, we will need to evaluate the following constraints: Minimalistic Dimension Constraints, Economic and Time Constraints, Experience Constraints, Environment Constraints, Health and Safety Constraints, Social Constraints, Ethical and Political Constraints. After lining out these constraints producing our cat toy design will become smoother. Understanding these constraints will also help us to produce a product that is best suited to our current global community.

4.2.1 Minimalistic Dimension Constraints

Because we are creating a cat toy that the majority of cats will need to enjoy, we must understand how cats enjoy playing naturally. A domesticated cat plays as if they are hunting for their food. In the wild cats are predators that survive off pray that is smaller in size than they are. Knowing this we must make a cat toy that satisfies their wild instinct to hunt.

This aspect of hunting smaller pray is crucial to finding the dimension constraints of our toy. After doing research it is known that the average height of a domesticated cat is between 9 to 10 inches (23 to 25 cm) tall. The average length of a domestic cat is about 18 in (46 cm) head-to-body. (4.2.1-1) This brings us to know that we need to make our cat toy much smaller than 9 inches in height and 18 inches in length. Our dimensions will be constrained to less than 5 inches in height and 17 inches in length, ensuring our cat toy will be smaller in size than an average domesticated cat.

Because our cat toy will need to be similar in form to a real life animal form, the length and height will also put constraints on the width. Overall the toy dimensions will put constraints on our hardware dimension. We will have to limit the dimensions of our hardware design to fit properly within the toy. Overall integration of our project is discussed in Chapter 6 of this report.

4.2.2 Economic and Time Constraints

Moving onto the economic constraints of our design. As a team we know that we have to find our budget within our own resources. If we were to have a sponsor, we would be able to utilize their provided resources as well. However, with our cat toy we will be using the resources the four members can produce. After discussing the type of product that we will be creating (an electric cat toy) and the parts to achieve the said creation, we made up the rough estimate of less than $500. This allows each member to only need to bring forth $125 of their own funds. View our budget in section 7.1 Project Budget and Financing of this report, to see exactly how we broke down each part and came to the economic constraints of our project

Economic constraints tie to time constraints for the ordering and supply of the parts that we will need to build this project. Because of the Coronavirus Pandemic supply lines for parts have been slowed. So ordering our parts with ample time ahead of Senior Design class deadlines is crucial.

Other time constraints for this project involve the fabrication of hardware that we will conduct ourselves. The skins for our toy are being sewn by a seamstress and require a two week turn around time. So each time we redesign a skin, this will need to be taken into account. Design and fabrication times for the mechanical parts of our toy are yet to be determined, but we will keep in mind that time constraints will be related to these processes also.

4.2.3 Experience Constraints

Our group's experience constraints will affect our designing of our Interactive Cat Toy. Taking into account that our group consists of Computer and Electrical Engineers, we will need to gain some help from other areas when we venture outside of the scope of our engineering specialties. We will be welcoming the assistance of Le Phan, a mechanical engineer who will help us design and fabricate the mechanical parts of our toy design. His experience and knowledge as a mechanical engineer will help us further our experiences. We will also be employing the assistance of a seamstress, aka Grandma Sonja to all the group members, to fabricate the skin of our toy.

Working with others outside of our own fields will help us understand the realistic procedures of integrating workmanship in order to make a working electronic device. Being able to talk and interpret with one another will help us broaden with our communication skills.

4.2.4 Environmental Constraints

Environmental constraints will be a large part of what will make our toy solely an indoor cat toy. With different weather conditions across the world, we are constrained to only being able to test our device outside in Florida weather conditions. To help make this device capable of being used in more than Florida weather like conditions we will constrain our device to being only recommended for use with an indoor cat. This will insure that even if a customer purchases our device in an environment opposite of Florida, for example Toronto Canada, our device will work for them inside.

We will also need to take into consideration the indoor environments where cats may be playing with our toy. Different types of flooring a customer might have could be a consideration we need to make for some of the features of our toy. Whether there be wood, tile, laminate, or carpet flooring; we have to make sure our product is capable of functioning in the majority of cat owner households. Another constraint with flooring will be making sure we are marketing our design as an indoor toy and not an outdoor toy.

4.2.5 Health and Safety Constraints

There are health and safety constraints that will be important to make appropriate modification for within our project design. We will be considering battery safety, safe lighting effect design and safest overall material design.

Should we decide on having a laser built into our Interactive Cat Toy, we need to take into account that an animal and/or a person will be around the device while it is operating. This understanding implies that constraint will need to be adhered to with the angle of our laser direction out of the cat toy. The laser will be required to be positioned in a downward angle to ensure that the laser will never point up and into a pet or person's eyes. Even short term exposure of an eye to the direct beam of a laser light can cause irreparable damage.

With a moving design capable of multiple functions, the device will have a lot of small parts built into our cat toy design. Multiple small parts can lead to multiple small parts falling off and being eaten by a cat. This could pose a choking hazard and is critical to prevent from happening at all. This leads to the design needing a protective casing around the toy's hardware mechanism. This casing can be as simple as making sure that the fabric used in our design is hard to destroy for a cat. We can even have a 3D frame built around the main device before placing it into the fabric.

Another health and safety constraint exists with the selection of our power source for our toy. While obtaining the most compact battery may be best for reducing the dimensions of our electronic components, this may not be the safest. Some of the most compact batteries available on the market have volatility due to their makeup. Lithium-Ion batteries are well know to explode when damaged. We will consider it a constraint to use any such battery for our interactive cat toy.

4.2.6 Social Constraints

A social constraint we will consider is that we will be only catering to average sized domesticated breeds of cats and possibly some small dogs. The majority of cat owners are not typically owners of larger, stronger cat breeds such as Savannah cats; which are typically twice the size of the average domesticated cat. This will place the constraint of our toy being recommended for average sized domestic cats and similar sized pets.

The social constrains for our design are more forgiving due to the design being a cat toy. However, online reviews of other mechanized cat toys mention that gear noises tended to be very loud and annoying, affecting social interaction with the toy for some consumers. We will attempt to limit noise from the motion aspects of our toy design with this in mind, as a social constraint that consumers have made mention of the need for the design of a more quieter cat toy from what is available on the market with electronic cat toys today.

4.2.7 Ethical and Political Constraints

Both ethical and political constraints in our design work very similarly. Taking into account that our device has voltage running through it we will have to make sure the electrical current does not exceed 10-milliamps (10mA). According to the article Electrical Safety: Safety & Health for Electrical Trades. (4.5.7-1) Currents that exceed a 10-milliamp (10mA) current can paralyze muscles. To ensure that this does not happen to our customers the device will be less than a current of 10-milliamp (10mA) and a voltage of 10.

The second ethical and political constraint of our cat toy design will be utilization of a rechargeable battery. This will eliminate the consumer from throwing away multiple dead batteries every time a charged battery is needed. Without the need of batteries, the design will allow our cat toy to have less of a carbon footprint.

Moving us onto our next topic that leans more towards the ethical side of constraints, which is copyright, trademarks or patents. This is an issue with any design, we do not want to overlap too far into a design that could potentially lead to an unnecessary lawsuit. This means that we will have to constantly consider every implementing into our cat toy, and assure that it has not been done before or have a copyright, patented, or trademark that is issued with it.

Finally reaching to our last constraint within the ethical and political section, the implementation of our phone application. To allow us to utilize the mobile function of our device, we will be using a phone application. It is ethically wrong to require a user to allow access to their microphone, camera, or even location without their consent. With the application we will have to place the terms of service and the privacy policy, to describe to our consumers that that data is not being used for any other purpose than our cat toy.

4.2.8 Manufacturability Constraints

Manufacturability constraints will affect how the design will be able to be developed, built, and finally produced. We are not a manufacturing company, so we are limited to the distributors that cater to customers that are not buying in huge bulk quantities. We will be utilizing local stores such as Michael's, Joann Fabric's, Home Depot, Lowes, etc. We will also need to use websites such as Amazon, Adafruit, Digi-Key, etc. These distributors will provide us with limited resources alone, but when together we will be able to produce our device.

4.2.9 Sustainability constraints

While we are designing our cat toy, we will have to work to make our device sustainable towards cats. Cats are natural born hunters, so we must make the casing of our device hard enough to withstand being smacked, dropped, and bit by a cat. Our device has to sustain being dropped from a maximum of 3 ft off the ground. Because cats are not throwers, we can overlook our device being chucked across a room. But cats do tend to hit or "whack" toys around, thus our cat toy will have to be bumped around to make sure no parts get loosened and unscrewed.

Another aspect that our cat toy will have to sustain is the ability to hold a charge. Because we are designing our device to be rechargeable, we must make sure that it recharges at a reasonable rate and last for a reasonable amount of time. If the device runs out of power within 20 minutes, then the consumer will be unpleased with the constant recharging. Our device will have to last for a minimum of 1 hour, giving their feline friend an hour of enjoyment.

5. Project Design (Liz)

The overall project design for our Interactive Cat Toy includes three levels of design, which incorporates both hardware and software design. Our three levels of design include a Basic Design, an Advanced Design and a "Stretch Goal" Design to incorporate various features. Our hardware design envelops the exterior skin over an interior supportive structure and the electrical components. Our software design involves both embedded system and application programming to operate various functions of our toy. Our hardware design aims to create an enticing, fun and robust toy for pet cats and their owners to enjoy. Our software design aims to enhance our hardware design by enabling control of fun toy features.

We will aim to complete the design of our Interactive Cat Toy project to support our Basic Design features first. Then we will move forward to create a project design that incorporates our planned Advanced Design features. Subsequently we will work to further create a project design to incorporate "stretch goal" features that we believe would make our cat toy really awesome for cats and their owners!

The Basic Design of our cat toy includes features that we believe should be included into a base model for our toy. The Basic Design will be controlled by a switch that will select different modes of toy operation. The Basic Design that our hardware and software will support for our Interactive Cat Toy includes the following features, as detailed in Section 2 of this report:

Basic Design Features

- ☐ Lighting Effects
  - ➢ Single colored light display
- ☐ Sound
  - ➢ Singular animal sound
- ☐ Motion
  - ➢ Subtle bodily movement
  - ➢ Catnip pouch shaker
- ☐ Rechargeable Battery
  - ➢ Easy plug-in to repower.

The Advanced Design of our cat toy includes the improvement or addition of various features; including a smart phone application that will allow a pet owner to select optional feature expressions for their pets. This design level will require additional engineering work with both hardware and software design. The Advanced Design will also require additional parts to be purchased and to be built into our toy. The features that we plan to have provided with our Advanced Design include the following:

<u>Advanced Design Features</u>

- ☐ Phone Application
  - ➢ Capable of adjusting motion.
  - ➢ Capable of changing sound.
  - ➢ Capable of switching light color and display signals

- ☐ Motion Detection
  - ➢ Toy will activate when motion detected.
  - ➢ Activation will occur when motion is within 2 feet

- ☐ Lighting Effects
  - ➢ Multi-colored light display
  - ➢ Multiple light patterns available

The "Stretch Goal" Design of our cat toy includes features that will really be a stretch for us to incorporate into our toy design, but that will really enhance our toy design to the next level. For our project, these stretch goal features will require substantially more detailed engineering work with both hardware and software design for us to realize them beyond concept for our toy. The features that we plan to bring in to play with our Interactive Cat Toy's "Stretch Goal" Design include the following:

<u>"Stretch Goal" Design Features</u>

- ☐ Video Camera
  - ➢ Cat owner will be able to view video of their cat in play via our smartphone application, from wall mountable accessory to our toy.
  - ➢ Cat owner will be able to move camera up, down, left and right to obtain desired viewing angle.

- ☐ Speaker
  - ➢ Cat owner will be able to project voice from the toy and speak to pet through the phone application.

5.1 Hardware Design (Liz)

The hardware design for our Interactive Cat Toy is composed of three distinct layers. These layers include the material exterior skin, an inner protective chassis and the electronic circuit components. Each layer requires an individual design focus that includes the purpose of integrating with every other hardware layer.

Hardware Design Layers

1. Exterior Skin
2. Protective Chassis
3. Electronics

The first layer of our toy's hardware design is the toy's exterior skin. For our toy we will have two interchangeable skins, one shaped like a squirrel and one shaped like a lizard. These skins will be made of outdoor fabric that is lined and filled to cushion our chassis from rough cat play. The skins will each have a pocket, with a zipper closure, in which the chassis will be kept.

The next layer of our toy's hardware design is the chassis. The chassis structure will house all of our electrical components and our power supply. The chassis will also support a hinged arm, or two, that will produce toy movement. The back of the chassis will hold the LED strip that will produce the toy's lighting effect. The chassis will be custom designed for these purposes and will be fabricated on a 3-D printer.

The final layer in our hardware design will be composed of the electronics. The electronic layer will include our PCB, micro-controller, power supply and all the electrical components that support our toy's features. The electronic components that will support our toy's features include an addressable RGB LED strip, servo motor(s), speaker(s), a motion sensor, a wireless module and a camera. This layer will be the most delicate layer and will be enclosed in the chassis for protection.

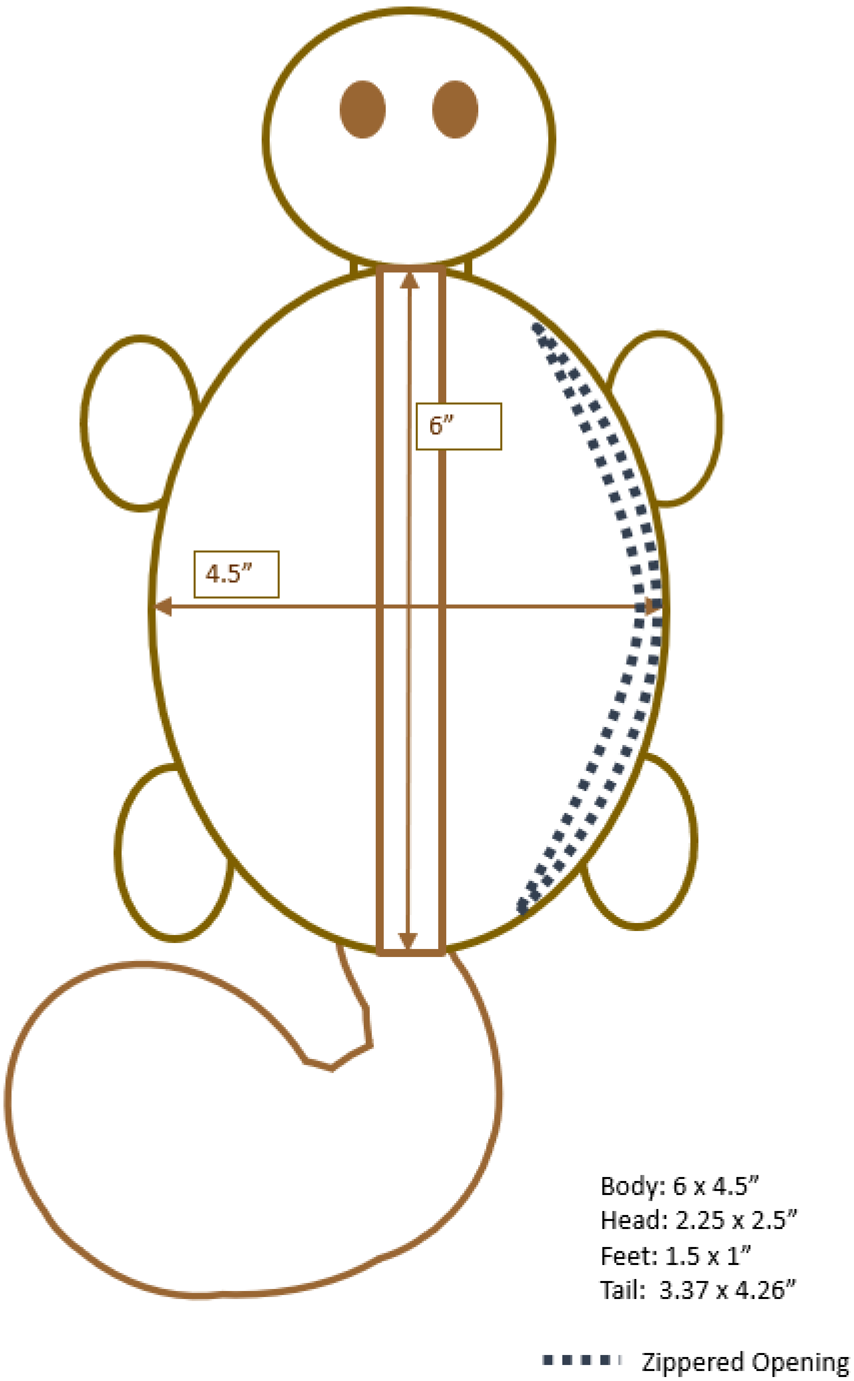
We will initially design schematics for all of the hardware layers of our Interactive Cat Toy based on ideal conceptual and theoretical values. Then we will test each hardware component in our Senior Design Lab to obtain actual measures. With our actual measured values, we will then refine, or redesign, our schematics. This will allow us to move forward with our plans to fabricate or build each layer. Once each layer has been through this detailed design process, we will follow a plan for the integration of all of our toy's hardware layers to produce our final Interactive Cat Toy prototype.

5.1.1 Hardware Schematics (Liz)

5.1.1.1 Hardware Layer #1: Exterior Skin

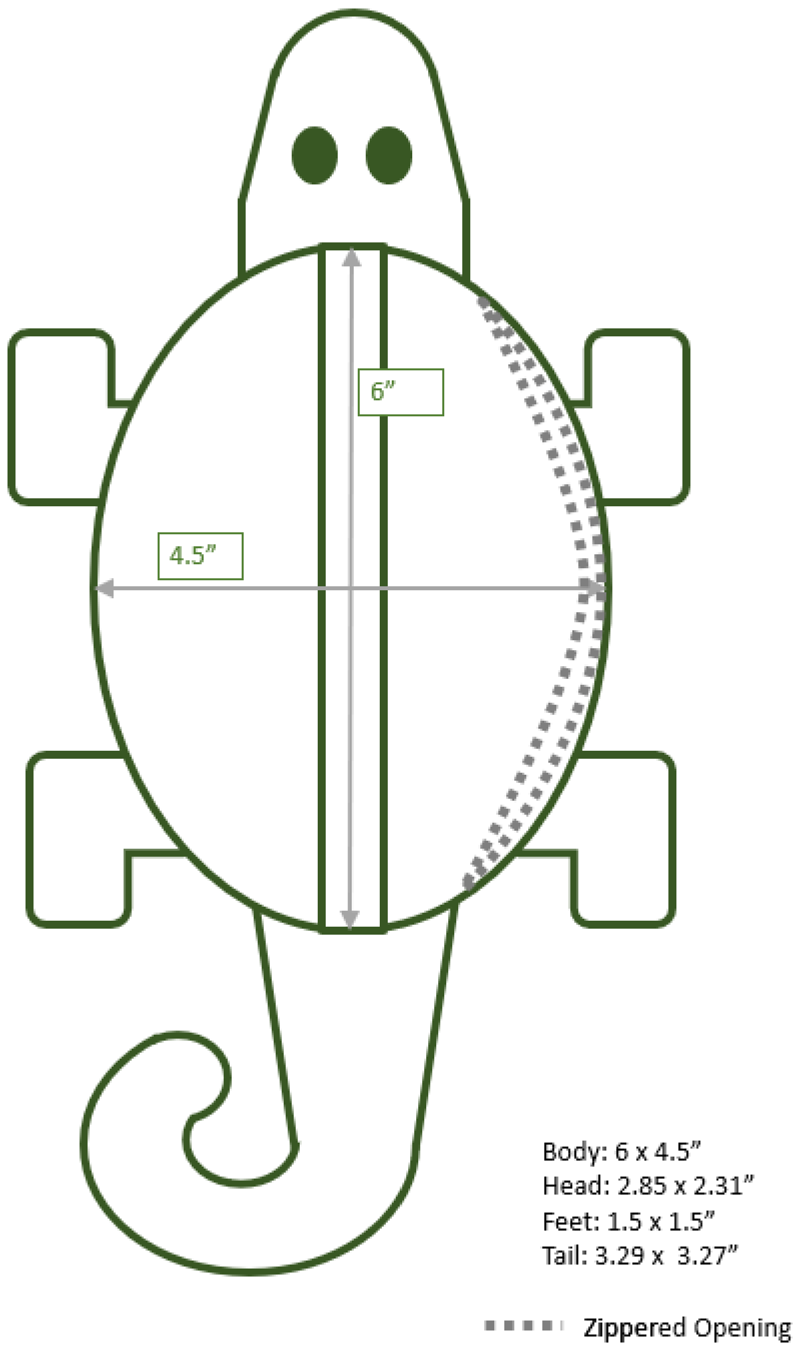
(1 of 2 interchangeable skins)

Figure 5-1: Squirrel Skin Schematic



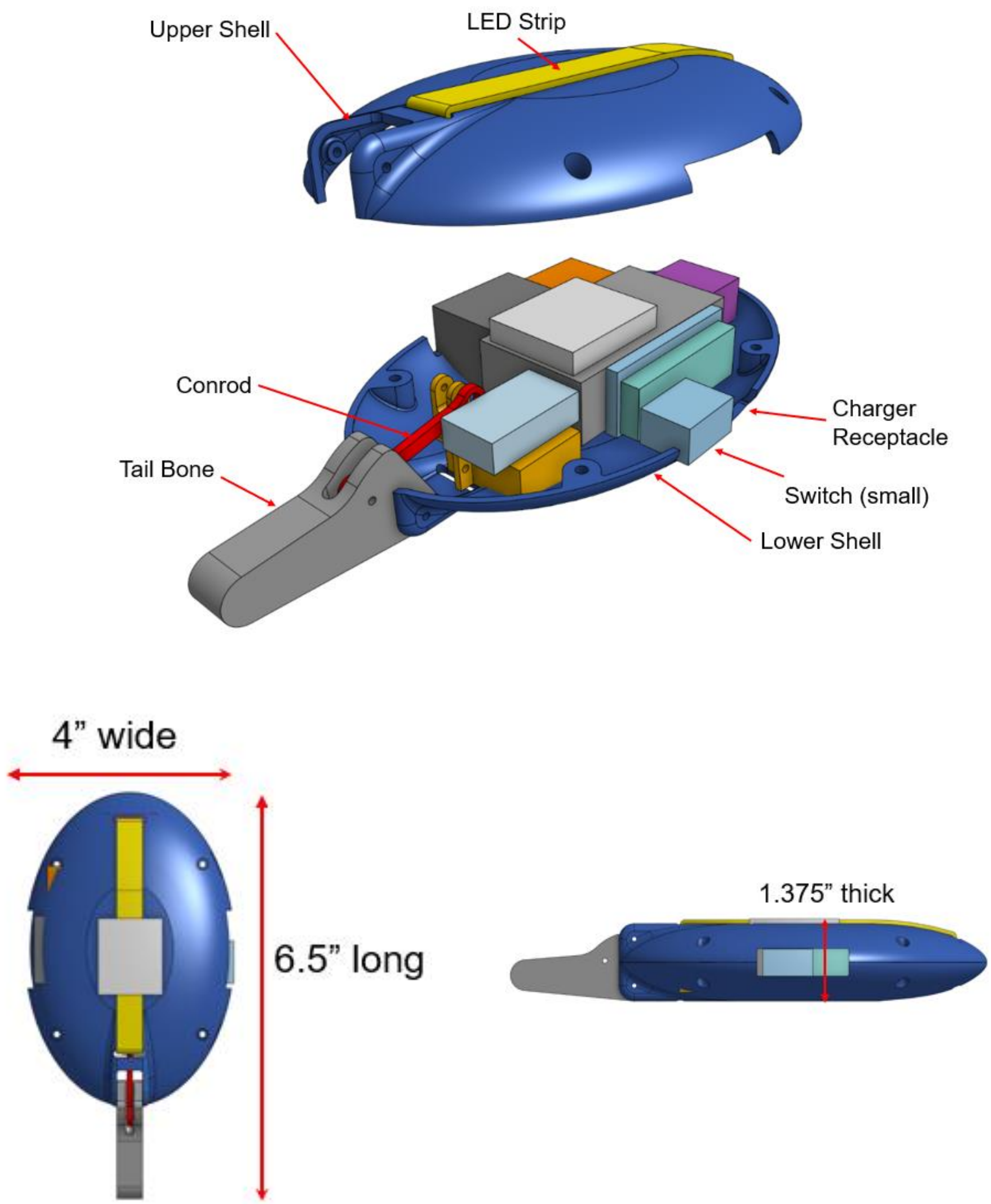
(2 of 2 interchangeable skins)

Figure 5-2: Lizard Skin Schematic



5.1.1.2 Hardware Layer #2: Protective Chassis

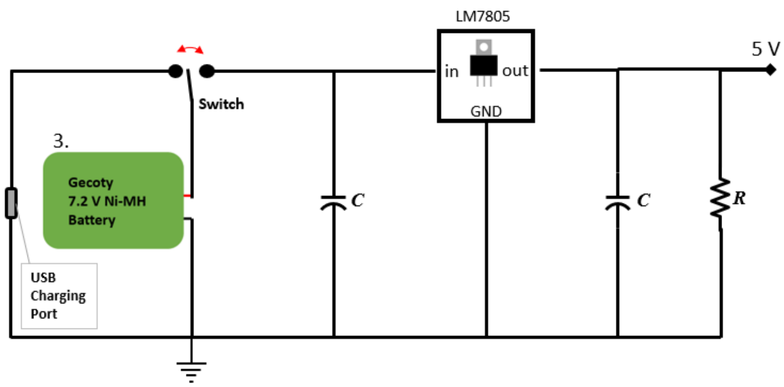
Figure 5-3: Protective Chassis Schematic



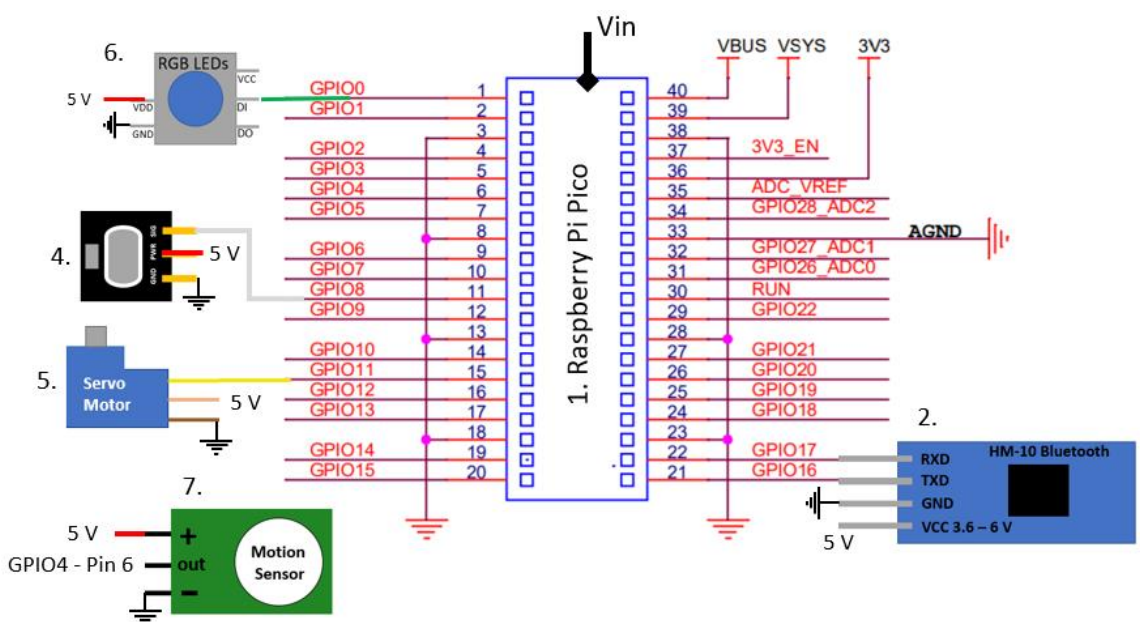
Mechanical Design Courtesy of Le Phan, Mechanical Engineer and Author

5.1.1.3 Hardware Layer #3: Electronics

Figure 5-4: Electronic Hardware Schematic



a. Power Supply with Voltage Regulation.



b. Wiring for Power Supply and Components to Microcontroller

1. Raspberry Pi Pico Microcontroller Board
2. HM-10 Bluetooth Module
3. 7.2 V Battery Pack
4. STEMMA Speaker
5. Micro Servo Motor
6. NeoPixel RGB LED Strip
7. Motion Sensor

Our current electronics hardware schematic includes our circuit design for (a.) our power supply; and (b.) pin allocations involved with power, ground and signal for each component with the Raspberry Pi Pico Microcontroller Board. This schematic is not drawn to scale, but it is drawn for ease of visibility to give the idea for our wiring strategy. As we move forward in our design process; we will work to develop this schematic into the working prototype of our Interactive Cat Toy.

Our first electronic hardware schematic includes the circuit design required to supply 5V of electricity to the Raspberry Pi Pico microcontroller from our rechargeable battery. Since batteries do not commonly come with 5 V ratings, a voltage regulating circuit is required for our design. In order to produce 5 V from an LM7805 linear regulator, we must connect a battery to the input rated with at least 7 V. For this, we selected the Gecoty 7.2 V NiMH battery.

Concerns for our battery selection currently exist due to its weight and size. This battery weighs about 200 grams which is twice as heavy as the whole weight of an equivalent cat toy. The floppy fish cat toy only weighs a total of about 100 grams with its light-weight lithium battery; however, lithium batteries come with extreme warnings of being explosive. One consumer review for the floppy fish cat toy claimed that the device almost set their house on fire… so we are avoiding the lighter weight lithium batteries to go with the heavier and safer NiMH battery with our design for now. We will be looking for design possibilities to reduce weight of our power supply going forward.

The second electronic hardware schematic includes our strategy for wiring of our power supply and components to the Raspberry Pi Pico microcontroller. This schematic may be rearranged as we work to fit our components into our 3-D printed chassis. Wiring of our components to the microcontroller may also require the addition of general circuit components such as a resistor to minimize the chance of burning out our LED strip, etc.

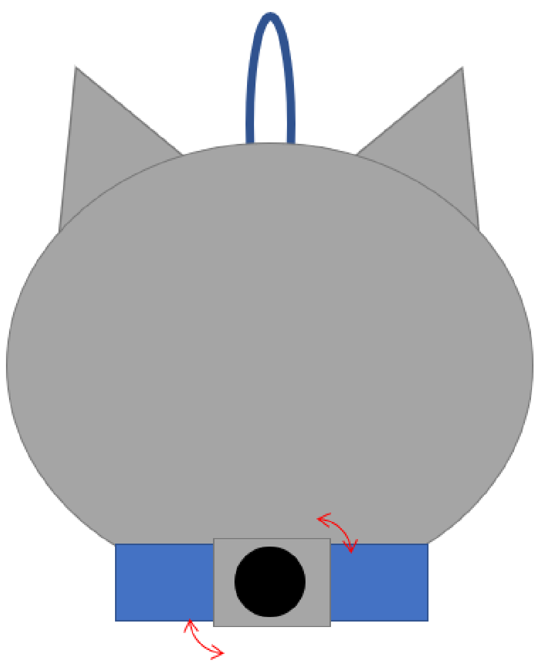
Further research, calculations and testing for our entire circuit design, including all of our toy’s feature components, will be done in an attempt to avoid future component or system failures. This will include research into including proper heat sinks within our circuit, as necessary. We plan to continue this process during the building and redesign phase of our project through the beginning of our Senior Design II class next semester. Through this process we anticipate that the hardware schematics for our project will evolve into a final successful working design. Utilizing schematics in this way is proving to be a good tool for helping our team in our project design process.

5.1.2 Stretch Goal Feature Design

For our Senior Design project, our professors encouraged us to aim high in our design concepts by developing "stretch goals" for our project design. We thought that bringing video into our phone application would be a great feature for our toy to have, in giving our pet owners an extra level of amusement.

A design plan that we formulated to turn this conceptual idea into a working feature for our toy was to construct an accessory for our toy that had a camera built into it. We designed a wall mountable cat shaped accessory with a collar that has a pendant on it. The camera would be placed inside of the pendant on the collar. This pendant will be designed to turn left, right, up and down. This would allow the pet cat owner to aim the camera, by way of the phone application, to get the video that they would like.

Figure 5-5: Stretch Goal Feature Design



<u>Stretch Goal Feature</u>

- Camera is in pendant on collar.
- Pendant can move right, left, up and down to aim camera.
- Camera aim is controllable with app.

We believe that this accessory can be designed for our toy, but we are not sure that we will have the time to complete it in the limit of our class time. This accessory to our toy would require additional application programming and a more robust wireless module from the Bluetooth module that we will use to just communicate commands to our cat toy. This is because Bluetooth is a low energy mode for wireless communications and the low energy mode is not compatible with streaming video.

For us to realize this “stretch goal” feature we will need to employ the stronger wireless communication scheme of Wi-Fi. This is where it becomes a real stretch for us as inexperienced undergraduate students. Incorporating Wi-Fi into a device that is already designed for Bluetooth will be a challenge.

First, we are not sure that our device will perform well with the high-power usage of the Wi-Fi in comparison to the Bluetooth. We previously decided not to employ Wi-Fi into our design because it would significantly shorten the operation time that the battery could support due to the larger draw of power from the Wi-Fi. So we move to consider using a Wi-Fi module in the accessory and a Bluetooth module in the plush toy. This now brings us to question as to finding out if the app can communicate with two different types of wireless modules and produce the features we would like it to. We believe that it can in theory, but not sure if we can figure out how to implement such a scheme.

We consulted with our sponsor, Le Phan, about our “stretch goal” feature. As a highly experienced mechanical engineer he was able to quickly observe our design and hear our plans for it and determine its mechanical feasibility. Le determined that the mechanical fabrication of this stretch goal concept is attainable and could be obtained within a brief timeframe. However, implementing the electrical control of movement of the camera will require some detailed electrical and computer engineering.

We moved on to consider the electrical and computerized components necessary to make this accessory successful. The use of the following components should allow us make this accessory a great kitty-cam for pet owners.

<u>Necessary Stretch Goal Feature Components</u>

1. Raspberry Pi Pico
2. Camera Module
3. Wi-Fi Module
4. Actuator (for movement of camera)
5. Battery

Integration of this camera accessory with our Interactive Cat Toy would be a thrill to see. Though, we understand that this integration into use with the phone application for our current project design along with developing a good control design will be tough. We look forward to the challenge of finding out if this stretch goal feature is realizable for our project.

5.1.3 Hardware Breadboard Testing (Vu, Liz)

Testing of all the components that we have selected to be incorporated into our Interactive Cat Toy is a vital step in building our team's working project prototype. In this section of our report we will detail the types of testing that we will employ for each of our selected components.

The Electrical Engineering students on our team will conduct tests on all of the components that have been selected for the project individually to make sure they are functioning as they should be according to their ideal working specifications. Once each part has been tested by itself and shown to be functioning in good working order the parts will be incorporated into the toy's circuit design for further system testing.

Future system testing will include the components being tested connectively on a breadboard to ensure a properly functioning toy circuit. This will enable us to make adjustments to our toy design, if necessary.

5.1.2.1 Controller Testing

Testing the Raspberry Pi Pico needs to be very intricate and detailed. First, we need to test whether the voltage levels within the pins of the control board to see if they are correct, so that we can wire the correct voltage for other components. There are three voltage levels on the Raspberry Pi Pico: 5V, 3V3, and GND. For the voltage testing, we used Hantek Handheld Oscilloscope to measure the DC voltage level of the voltage pins. Using pin 3 as GND reference, we measure pin 1, also known as Vbus pin, and pin 5, which is 3V3_OUT pin. Using the DMM function of the oscilloscope, we measure pin 1 to have 5.03 V, and pin 5 to have 3.28 V. These are within the acceptable range of voltage levels; therefore, the voltage pins of the controller are working as intended.

Moreover, we need to test the code on the controller so that it sends correct signals. For this testing and future project design, we will code the controller using MicroPython through Thonny IDE. Testing the communication signals of the Raspberry Pi Pico is much more complex. We will need to test the controller individually, then we will start connecting other components with the controller and test to see if the code works. Raspberry Pi's MicroPython is installed, and Thonny IDE is used.

The following are some tests to be carried out:

Pin 25 is reserved for the onboard LED. Write code to turn the LED on/off, toggle and blink using the timer interval.

Use an external LED light and 330 ohms resistor. Connect resistor and the LED light in series to a pin and close the loop with GND pin. Write code to turn the toggle the LED, and blink using the timer interval. Try to control the brightness of the LED using Pulse Width Modulation.

Implement a small button to an I/O pin and wire the button to a voltage pin. Write code to turn the LED on/off by clicking the button.

The Raspberry Pi Pico successfully completed all the basic tests. However, the controller still needs to test its connection to other components.

5.1.2.2 Wireless Module Testing

Our Bluetooth module can be tested by connecting it to the Raspberry Pi Pico board and then lighting an LED through an easily established smart phone application, like "the Serial Bluetooth Terminal App from the Google Play store" (5.1.2.6-1).

The Bluetooth module is connected to the Raspberry Pi Pico by connecting its Tx pin to a UART Rx (pin 2) pin on the Pico, then connecting the Rx pin on the Bluetooth to the UART Tx (pin 1). Then VCC on the Bluetooth is connected to the 5V VBUS on the Pico, and the GND is connected to GND.

The app is set up to follow the simple commands to switch an LED on and off. A simple code for blinking an LED can be found on GitHub (5.1.2.6-1) This code can be modified and downloaded to the Raspberry Pi Pico.

Once this is done the app can be connected to the Bluetooth module by simply powering up the Pico board and look for the connection to the Bluetooth module in the app. Then we will be able to toggle the LED off and on.

5.1.2.3 Battery Pack Testing

Connecting the Gecoty Ni-MH battery to the Raspberry Pi Pico is simple and necessary to keep the controller and other components powered when not plugged into a PC host. Having an external battery requires the controller to automatically execute and runs the code. For MicroPython, the Raspberry Pi Pico will automatically run main.py file when it is powered on and not connected to USB. The battery is connected to Vsys pin and the GND pin adjacent to it.

A possible problem that may arise with the Gecoty Ni-MH battery is that it supplies 7.2 V, which can fry the Raspberry Pi Pico. Therefore, it is necessary to have a DC-DC converter or a linear voltage regulator in order to ensure that the battery only supplies 5 V or less to the Raspberry Pi Pico. More tests need to be carried out to ensure the safety, the performance, and the efficiency of the Gecoty Ni-MH battery.

5.1.2.4 Speaker Testing

Testing the STEMMA speaker is quite complicated and different from testing other components. In order to code the speaker, extra programming, files, and libraries are required. The MicroPython is not fully compatible with the speaker. According to Adafruit, STEMMA speaker requires CircuitPython, along with its libraries, in order to work. Although it also uses the same IDE, CircuitPython requires the user to reset the Raspberry Pi Pico and puts in a different UF2 file from the UF2 file for MicroPython. This will erase the UF2 file for MicroPython; therefore, the codes specifically for MicroPython will not work. Luckily, the majority of CircuitPython is derived from MicroPython, and the majority of these two languages are the same. One biggest difference of using CircuitPython on the Raspberry Pi Pico is that, when its UF2 file is pasted to the controller, CIRCUITPY hard drive will appear on the PC host. The appearance of the hard drive makes it easy to copy and paste additional codes, libraries, and audio files into the Raspberry Pi Pico.

The STEMMA speaker has a 3-pin JST socket, for voltage, ground, and signal. Male-male header cables can be connected to the JST socket, and, similar to the LED strip, the three wires are connected the controller. The black wire is connected to the GND pin, the red wire is connected to Vbus pin, and the white wire is connected to GPIO pin 0.

The interactive cat toy project plans to use MP3 files as audio inputs for the speaker. Hence, we need to write a code and put a sample MP3 file in the CIRCUITPY hard drive to test the speaker and the code. Adafruit provided an MP3 audio sample code specifically for RP2040, the microcontroller used in Raspberry Pi Pico.

Figure 5-6: MP3 Audio Sample Code for RP2040

```
import board
import audiomp3
import audiopwmio

audio = audiopwmio.PWMAudioOut(board.GP0)

decoder = audiomp3.MP3Decoder(open("slow.mp3", "rb"))

audio.play(decoder)
while audio.playing:
    pass

```

The STEMMA speaker, when connected to the Raspberry Pi Pico, amplifies and emits the audio file “slow.mp3” that was copied into the CIRCUITPY hard drive. However, the audio is distorted. The code and the speaker need to be adjusted in order to play quality sound of the MP3 audio file.

5.1.2.5 Motor Testing

We selected the high torque micro servo motor as the component to be used in our toy. The overall look of the servo motor is compacted. Connected to the servo motor are three wires, orange, red, and brown. The orange wire is the signal wire, where we use Pulse Width Modulation to control the angle in which the servo will be turning. The red wire is our voltage input, while the brown wire is the ground. All three wires are connected to the Raspberry Pi Pico. The red wire is connected to 3V voltage pin, brown wire is connected to GND pin, and, for the test, we will use pin 15 as the signal.

Figure 5-7: Duty Cycle Control Code

```
from machine import Pin, PWM
import utime

servo = PWM(Pin(15))

servo.freq(50)

duty = 500000

while True:
    while duty <= 3000000:
        servo.duty_ns(duty)
        utime.sleep(1)
        duty = duty + 100000
```

The servo motor can only turn 180°. Thus, we need to select and calculate the appropriate duty cycles in order to turn the motor for the respective angles. A good PWM cycle for a servo motor is 50 Hz. Calculating and selecting the right duty cycle is quite tricky. For the servo motor, we try to brute force the duty cycle onto the code to see what angle corresponds to how much nanosecond of the duty cycle.

From the code above, the PWM is used for pin 15 under the name servo. Initially, the duty cycle value is set at 500,000 nanoseconds. While the code in on and the duty cycle is below 3,000,000 nanoseconds, the code sets the duty cycle for the PWM, sleeps for one second, and then increments the duty cycle for 100,000 nanoseconds. Theoretically, the servo will start at 0°, and then turn itself every second until it reaches 180°.

Through initial testing of the high torque micro servo (MG92B), we find it concerning regarding its safety issues. The code does not work on the servo. Furthermore, the servo sometimes causes the controller's USB host to shut down. In this case, my PC sometimes shutdowns and has to restart. Luckily, we also have another micro servo (SG90) to test on. This time, the SG90 works perfectly fine and as expected. The SG90 also tested to see the minimum and maximum values of the PWM's duty cycle. We found that 500,000 nanoseconds is about 0°, and 3,000,000 nanoseconds is about 180°.

Although the results of MG92B are quite worrying, we need to take more time to test the component. However, if the servo keeps on failing, we might have to reevaluate our motor choice and pick a different servo motor. The SG90 servo motor is a great alternative.

5.1.2.6 Lighting Effect Testing

We will use a 10-LED WS2812B LED strip to test with the Raspberry Pi Pico. The WS2812B strip has a single pin for each LED where you can change the color based on the RGB value. To connect to the controller, the LED strip has three wires. The red wire is connected to VBUS (5V), the black wire is connected to GND pin, and the green wire is connected to the GPIO pin 0.

Using MicroPython, the code configures the LED strip using the existing library of the Raspberry Pi and writes functions to set and update the LED color using pixel array and state machine. For the test, we will set the color of the LED strip to red, blue, green, and white. After running the program, the code successfully sets the LED light to the desired color.

Figure 5-8: LED RGB Color Codes

```
#Color based on RGB (R,G,B)
red = (255,0,0)
green = (0,255,0)
blue = (0,0,255)
white = (255,255,255)
```

5.1.2.7 Sensor Testing

The motion sensor is also very simple to test. The PIR sensor (HC-SR501) detects motion through infrared radiation. Whenever the sensor detects motion, the sensor outputs high voltage (3.3 V). When no motion is detected, the sensor outputs low voltage (0 V). Using CircuitPython, by configuring the sensor and the pin, the machine reads the pin value of

TRUE (high voltage/1) or FALSE (low voltage/0). The following is a simple code written to test the PIR sensor:

Figure 5-9: PIR Test Code

```python
import board
import digitalio
import time

led = digitalio.DigitalInOut(board.LED)
led.direction = digitalio.Direction.OUTPUT
pir = digitalio.DigitalInOut(board.GP0)
pir.direction = digitalio.Direction.INPUT

led.value = False
time.sleep(2)

while True:
    if pir.value:
        led.value = True
        print('Motion detected!')
    else:
        led.value = False
        print('Motion not detected!')
    time.sleep(2)
```

The code reads the PIR value every 2 seconds. The onboard LED will turn on and the machine prints "Motion detected!" if the sensor detects motion. The PIR sensor works as intended. What we observe from testing the sensor is that the sensor and the code only detect large motion. Although we do not want the sensor to be overly sensitive, adjusting the sensitivity should be looked at further.

5.1.2.8 Camera Testing

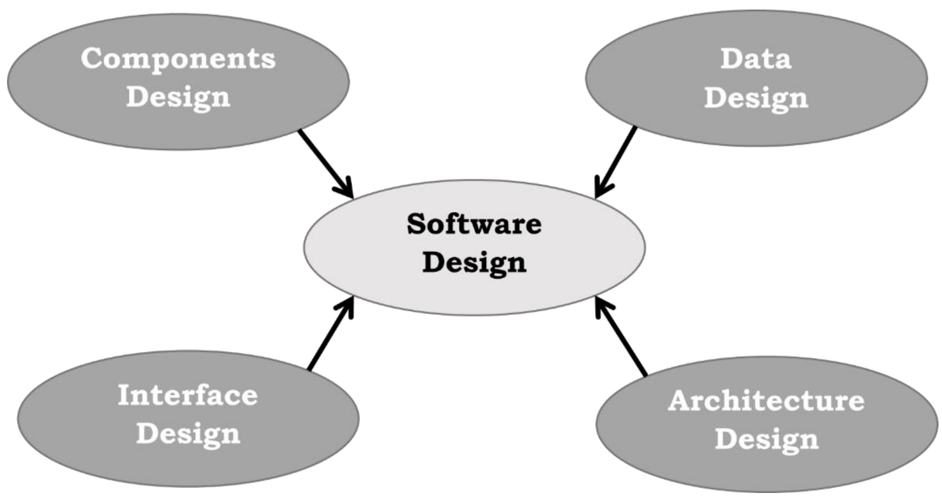
The camera module that we selected for our "Stretch Goal' feature within our project is the Arducam QVGA Camera. A QVGA camera will only utilized a "Quarter" of the amount of pixels that a full VGA camera will. Therefore, we will need testing with our app to determine if the picture quality is clear enough to enjoy. We will test this model to determine if we will actually need the full VGA camera module through testing of this component with the phone application that will be designed for our project.

This cameral module can be connected directly to the Raspberry Pi Pico with careful attention given to the eight pins it requires. Software and driver files from the Arducam website can then be configured along with a computer. Executing the programming, when proper files are done being set-up, streams video onto a computer via a USB Serial Device port. This will be tested along with streaming via Wi-Fi to our smart phone application.

5.2 Software Design (Aliza)

In this section we will go over the software design of our cat toy. But first, we need to know what software design exactly is. Software design is made up of the software specifications intended to accomplish the code needed to achieve the resulting functions in the design of our cat toy. Data design, architecture design, interface design, and components design are four of the major parts that make up software design (see the figure below.

Figure 5-10: Software Design
Including Data Design, Architecture Design, Interface Design, and Components Design

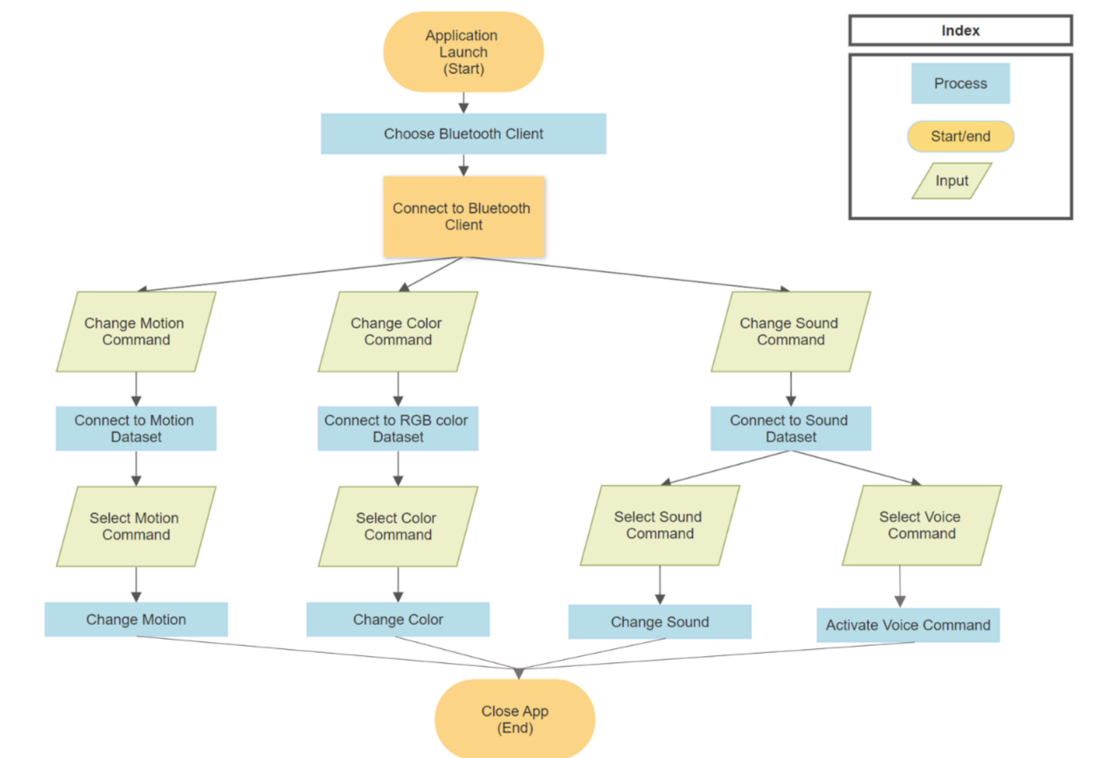


Data design is the specific data collected that will be implemented into the system. The cat toy will hold the datasets of sounds, RGB color codes, and movement patterns. The sound dataset will be compiled of cat enticing noises such as the sounds of birds chirping / singing, the jingle of small bells, mice squeaking, etc. While the RGB color codes dataset will be comprised of the vast array of colors that the RGB LED can emit. With three different primary light colors (Red, Green, and Blue) that can each achieve 256 different brightness levels, the RGB LED will be able to emit over sixteen million different colors. Finally, the movement dataset will be a collection of different “beats” of motion.

Architecture design helps to keep away from major flaws or problems in the software during development. It functions like the blueprints of a building, but instead of a building it functions for the system and software development project. For the basic design features in our device, we will be using the either C/C++ or Micro Python as our programming language, this is essentially our foundation of software design. With either language we will program the cat toy to move, light up, and produce sound. As for the advanced feature in our design, we know that the phone application must talk to the cat toy via a wireless device on the toy. This would have us program the device to take commands from the app allowing the user to change the movement, lighting, and the sound being produced.

Interface design provides the maximum usability and user experience. This will mostly be used for the application feature, which is one of our advanced design features to our cat toy design. The interface design is the software that communicates with itself and to the user. The user interface is composed of three main interfaces: Graphical User Interface, Voice-Controlled User Interface, and Gesture-based User Interface. Our design will only need to focus on the Graphical User Interface. Figure 5-11 provides the information required for the interface for our design.

Figure 5-11: App Control Flow Chart



Component Design helps to describe how each component communicates with each other to make the design function properly. Our cat toy will be using the microcontroller to communicate with each of the different components in our device. The three main components it will communicate with are the lights, speaker, and the motor. In addition to the Bluetooth device, which will then communicate with the phone application, this is for the advanced feature for or design. While with our stretch goal we will add an accessory to our toy that will stream video, for which Bluetooth is not compatible. So the accessory to our cat toy will have its own Wi-Fi communication module to send the video feed to the app while our plush toy will have a Bluetooth communication module to receive commands from the app.

5.2.1 Embedded System Software (Aliza)

Embedded system software is the programming tools in embedded devices that facilitate the functioning of the components within electronic machines and devices. The software allows for the management of the machines (or the hardware devices) without compromising the efficiency of the device.

Embedded software is intended to optimize the working of an electronic device. Specifically, embedded system software refers to the software that engages each component embedded in the circuitry of an electronic device by way of a controller. The controller allows electrical signals to pass through it based on software specifications to control different aspects of different components within a circuit. This is a great scheme that allows for the design of a plethora of electronic devices with a numerous variety of features.

5.2.1.1 Microcontroller Software

After a careful technology investigation, our group decided to use the Raspberry Pi Pico microcontroller for our cat toy design. With its many GPIO pins and other features, this microcontroller will allow for our many features to be controlled by embedded software.

This microcontroller allows us to use either the C or Micro Python programming languages. To access the microcontroller for each device we will need a programming line similar to what is shown below in Figure 5-12. This allows us to access the library of the current device that is being connected or accessed. In the Figure 5-12 case we are connecting to a servo motor.

Figure 5-12: Accessing the library of a servo motor

```
from machine import Pin, PWM
```

5.2.1.2 Motion Control Software

For the motion control software, we must import the servo motor's library to access its motion capabilities. This connection is described in more detail in section 5.1.2.2 of this report. So now let's look at what we want the servo to actually do for our design. Our cat toy design calls for the tail to move in an up and down motion, and not from side to side. This means the servo motor needs to move a total of 90 degrees from its resting position to simulate a wagging like movement. To go about doing this we must know how the servo grabs its positioning.

Positioning of the servo motor is described using nanoseconds, this means we must find the initial position and the secondary position that is needed to create the wagging like motion for our cat toy. As stated in 5.1.2.2 of this report, to access the position of 0 degrees in the servo we must set it at 500,000 nanoseconds and to reach 180 degrees we would set it to 3,000,000 nanoseconds. This would set the 90 degrees mark at 1,500,000 nanoseconds. The following figure displays the code that will enable initializing the 0 degrees and 90 degreed positions.

Figure 5-13: Code to have the tail "wag" using Micro Python language

```
# Access libraries
from machine
import Pin, PWM
import utime

# Connects servo to pin
servo = PWM(Pin(15))

# Sets frequency
servo.freq(50)

# Sets the initial position of the Servo motor
# to the middle and 90 degrees from initial position
MID = 500000
MAX = 1500000

# Set initial duty cycle to 0 degrees
servo.duty_ns(MID)

# Place into while loop To move tail
while True:
    servo.duty_nd(MID)
    utime.sleep(1)
    servo.duty_nd(MAX)
    utime.sleep(1)
```

As shown in Figure 5-13, the code sets up a loop to have the servo motor move between 0 degrees and 90 degrees, with a one second pause between each move, this creates the simulation of the tail wagging. To allow the advanced goal of the application to access the motion the pause time or sleep time will have to be modifiable. Meaning we will have to create a variable so that it can take in any number that is given. The ability to modify the pause time will allow the user to essentially change the speed of the tail wag using the application.

Figure 5-14: Code to change “rhythm” of Tail Wag in Micro Python

```
# Check to see if switch location is 1
if switch == 1:

# Place into while loop To move tail
while True:
    servo.duty_nd(MID)
    utime.sleep(1)
    servo.duty_nd(MAX)
    utime.sleep(1)

# If switch location is not 1 then must be 2
else:
    while True:
        servo.duty_nd(MID)
        utime.sleep(1)
        servo.duty_nd(MAX)
        utime.sleep(1)
        servo.duty_nd(MID)
        utime.sleep(0.5)
        servo.duty_nd(MAX)
        utime.sleep(0.5)
```

We could also set up different loops that will allow for different ‘rhythms’ of tail wagging. The figure above shows the basic code to make this happen. This can be used when we have a switch that has 3 positions, one of which being off. It can also be used in our advanced design. We can set up multiple rhythms and have the application define which rhythm is selected by the user.

Our cat toy is meant to mimic a real small animal and they sometimes exhibit rapid tail wagging. We could use this movement as a model to occasionally use to shake the scent of catnip into the air to attract a cat.

5.2.1.3 Lighting Control Software

The lighting control software will manage expression of the color and signal pattern of the LEDs on a strip down the back of our Interactive Cat Toy design. Our Basic Design will be controllable with a switch on the toy with multiple settings. Our Advanced Design will be controllable through a phone application. Both design levels will require custom embedded software.

The addressable RGB LED strip allows for specific coding for the lighting of each LED individually. Using the WS2812 LED allows for us to use a wide range of colors in the application for the advanced part of our design. Figure 5-15 shows the configuration of the WS2812 that allows you to then begin adjusting the RGB (Red, Green, and Blue) colors and their brightness on the LED.

Figure 5-15: Code for setting up the WS2812 LEDs

```
# WS2812 LED Configuration
led_count = 16 # number of LEDs
PIN_NUM = 10 # pin connected to WS2812 LEDs
brightness = 0.5 # 0.1 = darker, 1.0 = brightest

@rp2.asm_pio(sideset_init=rp2.PIO.OUT_LOW,
             out_shiftdir=rp2.PIO.SHIFT_LEFT,
             autopull=True, pull_thresh=24) # PIO configuration

# define WS2812 parameters
def ws2812():
    T1 = 2
    T2 = 5
    T3 = 3
    wrap_target()
    label("bitloop")
    out(x, 1)               .side(0)    [T3 - 1]
    jmp(not_x, "do_zero")   .side(1)    [T1 - 1]
    jmp("bitloop")          .side(1)    [T2 - 1]
    label("do_zero")
    nop()                   .side(0)    [T2 - 1]
    wrap()
```

For our cat toy design, we will want its lighting feature to change depending on which location the switch is on similar to how the servo motor changes (described in section 5.3.1.2). For our basic design our toy will be controlled using a switch. If the switch is in position two the LEDs will shine Yellow and if the switch is in position three the LEDs will be blue. Figure 5-16 shows code that will be used to make this switch between yellow and blue displays. The advanced design of our toy will allow the user to choose, using a smart phone application, a wider selection of colors as well as the ability to have multiple colors on the line of WS2812 LEDs (power permitting). This action will be done by using a for loop and checking which LED it is currently on to fill that specific LED with the color desired.

Figure 5-16: MicroPython Code for Switching LED Colors Based on Switch Location

```
# color specifications
red = (255,0,0)
green = (0,255,0)
blue = (0,0,255)
yellow = (255,255,0)
cyan = (0,255,255)
white = (255,255,255)
blank = (0,0,0)
colors = [blue,yellow,cyan,red,green,white]

if switch == 1:
# fills all the WS2812 LEDs to yellow
    pixels.fill(yellow)
else:
# fills all WS2812 LESs to blue
    pixels.fill(blue)
```

5.3.1.4 Sound Control Software

In this section we will discuss the Sound Control Software and how we will go about emitting sound out of the speaker of our toy. First, we must turn the wav data of the sound we are using into a static array. With the two switch locations we will need to create two sounds into static arrays. Figure 5-17 shows a part of a static array, these numbers when put together produce a melody.

Figure 5-17: Example of a song converted into a static array

```
#define WAV_DATA_LENGTH 38151

uint8_t WAV_DATA[] = {
    151,151,150,144,152,164,162,146,141,155,157,137,113,118,150,182,
    193,184,164,149,148,153,159,159,152,142,133,128,129,135,141,138,
    128,114,103,100,106,119,138,163,189,211,225,230,224,208,187,162,
    136,113,93,80,74,78,89,106,126,147,166,182,192,195,193,184,
    170,152,133,114,98,87,82,83,90,100,114,130,146,160,172,180,
    184,183,178,169,159,148,137,127,118,112,109,109,111,116,124,133,
    142,151,158,164,167,167,164,158,149,138,126,115,104,96,91,90,
    92,98,106,116,127,139,149,157,163,166,166,163,158,152,145,138,
    131,125,121,119,119,121,124,130,136,144,151,157,162,166,166,165,
    160,153,144,133,122,111,101,94,90,90,93,99,108,118,129,140,
```

After setting up both of the sounds we will be using into static arrays we have to go about pushing it to the speaker to produce the sound for the cat to hear. Figure 5-18 shows how we will go about doing this. In addition to showing how the code produces the sound through the speaker, it shows how it will tell which location the switch is on. This is done in a similar way that both the servo motor and the WS2812 LED code determine which function to present.

Figure 5-18: Code showing how sound is produced in MicroPython

```
if switch == 1:
    decoder = audiomp3.MPDecoder(open("music1.mp3","rb"))

    while true
        while audio.play:
            pass
else:
    decoder = audiomp3.MPDecoder(open("music2.mp3","rb"))

    while true
        while audio.play:
            pass
```

5.2.2 Application Platform (Joseph)

Integrating a smart phone application (an app) into use with our Interactive Cat Toy is a part of our Advanced Design plan for our project. With a smart phone app for our Interactive Cat Toy, we will be offering a variety of changeable feature options along with streaming video. A pet owner will be able to select different lighting effects, different sound effects, and be able to open a camera that they can move by the controls in the app to view live video of their pet.

We are currently planning to use *Android Studio's Integrated Development Environment (IDE*) to build our application with the Java programming language. Most of the features can be coded through Java so it will be our main language. This application will be accessible by use of an Android phone or by use of a computer.

We selected the Android Studio IDE because it seems like the simplest and fastest way to build a smartphone application. The IDE has a well organized user interface, sample code for common application design and various testing methods. With this IDE we believe that we can develop a good working application for our cat toy.

Should time permit, within the period of our taking this Senior Design class, we will also develop an app for iOS software that will be accessible on iPhones. The iPhone app would be coded with XCode.

5.2.2.1 Application's Wireless Communication

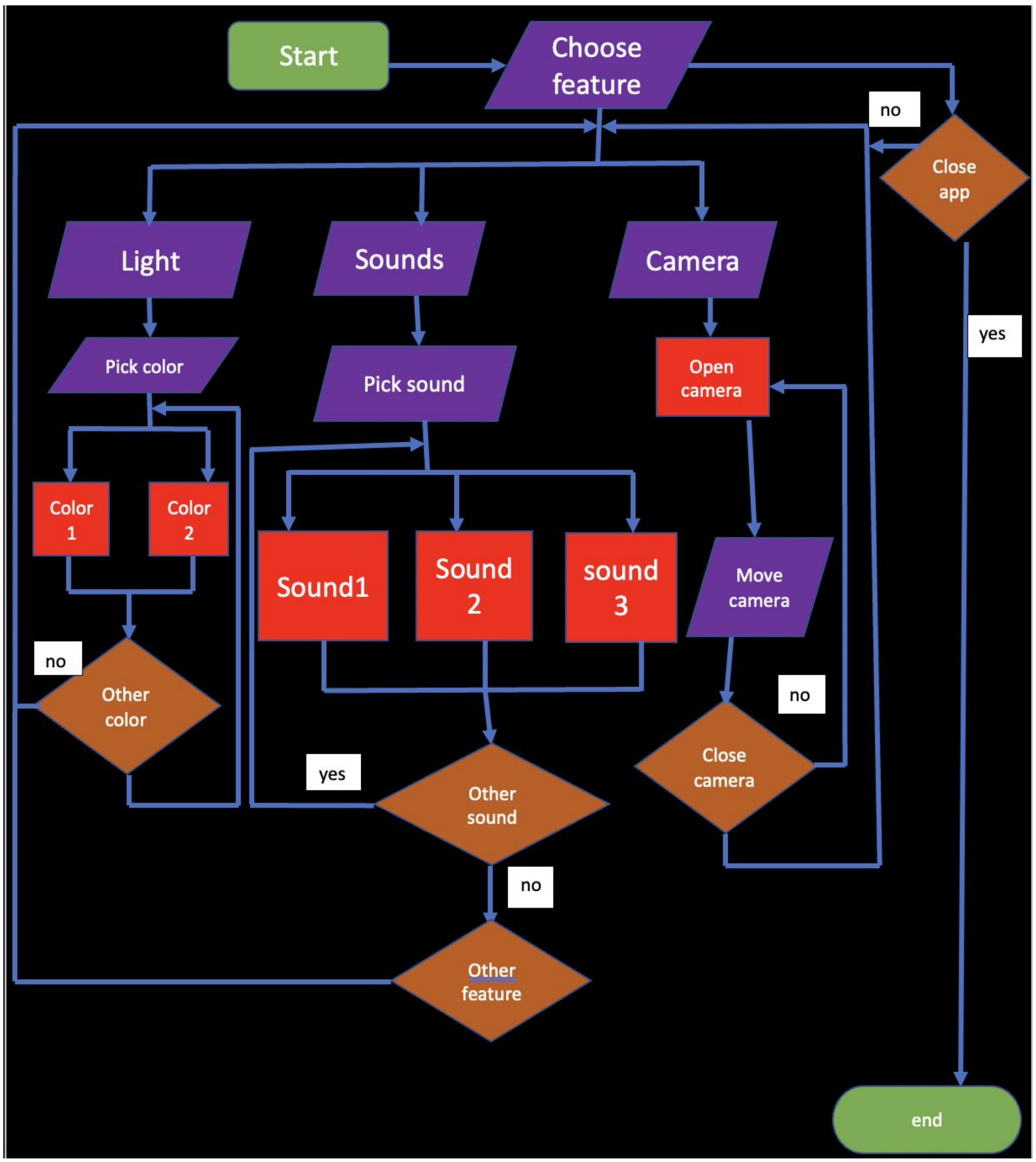
For our application to be successful, it will rely on wireless communication with our Interactive Cat Toy. Bluetooth will be the mode of wireless communication between our plush toy and the application. Bluetooth is able to support the communication of commands. So through our application a pet cat owner can select the feature options they would like and they will be communicated to our toy through Bluetooth wireless communication.

For our Stretch Goal feature of having a camera transmit video of a pet cat to an owner through our app, Bluetooth wireless communication will not suffice. Bluetooth is a low energy mode of wireless communication and is not suitable for streaming video. For this application feature, Wi-Fi wireless communication will be necessary. So for our toy's wall mountable camera accessory we will have a Wi-Fi wireless module that handles the video transmission to our application.

5.2.3 Application Software Design (Joseph)

Below is a flowchart for how we will create our app with the conditions and inputs/outputs it needs to follow. Purple boxes represent inputs/outputs, orange boxes represent the condition statements, red represents the actions that the application will command the toy to follow.

Figure 5-19: Application Software Flowchart

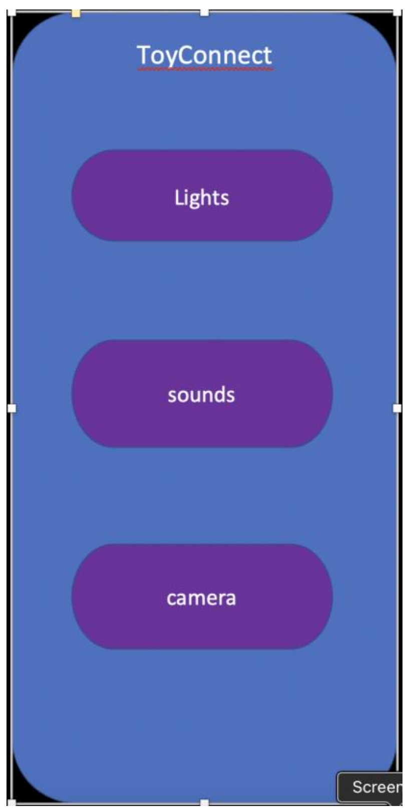


The programming of the application for our Interactive Cat Toy will basically put forth an interface for a pet cat owner to adjust features for the cat toy. For our Stretch Goal feature the programming will allow a pet owner to see an interface where they can view video of their cat and adjust the direction of the cameras aim (up, down, right and left). Another stretch goal feature would transmit the pet owners voice from the app through the toy, so that an owner can communicate with their pet.

Within our application design we will focus on the graphic user interface so the app will appear friendly, fun and easy to use for pet owners. We will aim to make the app basic and straight forward. The picture below shows how we plan for the home screen of our app to appear.

We believe that a user-friendly app requires a very simplistic appearance with well-defined option buttons. The app programming should support an app that a user takes very little time to understand how to navigate and utilize the app. The programming for this simplistic appearance should be easy to write, as there are many templates available as examples for us to follow.

Figure 5-20: Smartphone Application Home Screen Design



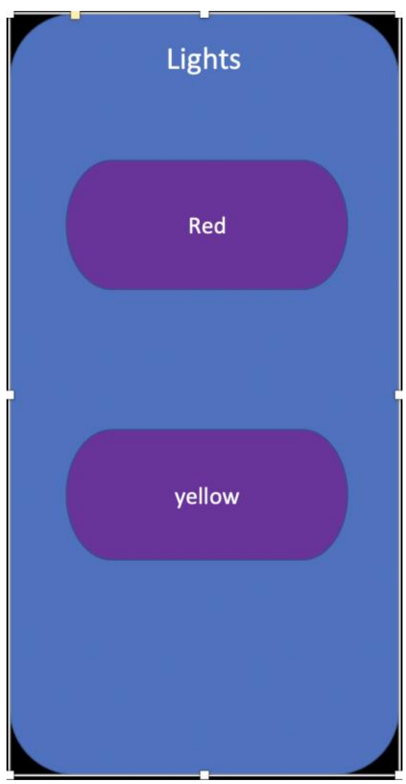
5.2.2.2 Lighting Interface

Our goal for when the user opens our Interactive Cat Toy App is for them to first see the different features that they will be able to work with. The first option for our app users will be to control our toy's lighting effects. A user can press the light button and a new screen will open to offer the user different color lighting displays to choose from.

To be able to program this feature we will need to be able to connect to our Raspberry Pi Pico microcontroller and signal it to adjust the lighting according to our app users selections. We will do research into the best way to implement this command. We will rely of information from component data sheets in order to understand specific language to obtain the desired lighting colors and patterns.

The following picture depicts an example of how our Lighting Selection interface will appear for our app users.

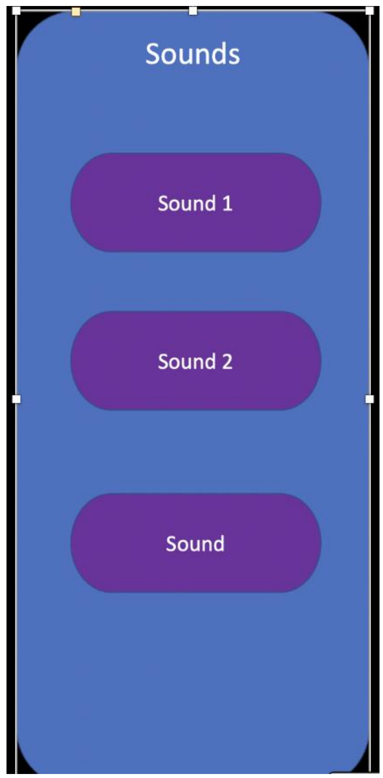
Figure 5-21: Lighting Selection Interface



5.2.2.3 Sound Interface

Next, we would like for our users to be able to control the sound feature of our cat toy with our app. An app user will be able to choose different sounds they would like for our toy to make to get the attention of their playful kitties. Programming for this feature will require compiling a dictionary of each sound that we would like to emulate through key : value pairs. After having the dictionary ready sounds can be selected.

Figure 5-22: Sound Selection Interface



5.2.2.4 Camera Interface

The camera feature is part of our Stretch Goal design. With the application an owner will be able to view video of their pet. They will be able to turn the camera to an angle that best captures their cat and then sit back and watch. For this app to work, our camera accessory for our toy will have its own Raspberry Pi Pico attached to a Wi-Fi module. Our application programming will need to connect with the camera accessory's Pico to control camera motion and receive streaming video to display in the app. This will be a fun app for an owner to use to observe their furry companion at play.

5.2.4 Software Testing (Aliza, Joseph)

Testing software is one of the most important elements in designing a properly functioning device. This section will describe how we will be testing the software for our project cat toy and the smart phone application that will accompany it. Both software testing procedures will show how the software corresponds with and enables the motion, lighting, and sound functions of our cat toy. The application software will have additional testing from the embedded software that will examine the graphical user interface (GUI) and the wireless connection.

5.2.4.1 Embedded Software Testing

Embedded systems are the electronically controlled devices where software and hardware are tightly coupled. (5.2.4.1-1) Our embedded software testing will ensure that code written into our microcontroller will perform the task it is written to perform. To test the design features of our cat toy we will have to test to ensure each feature is functioning properly.

We will connect each of our project's feature components to our Raspberry Pi Pico microcontroller and test them with our written software on a breadboard. We will ensure that the component's response to the code from the Pico is consistent with our planned outcome.

We will test our lighting strip of WS2812 LEDs to illuminate the correct color and signal pattern that our code is intended to express. We will test the servo motor to ensure that the microcontroller's code sets it at the correct duty cycle to move our cat toy's tail in a rhythmic way that will entice a cat. We will also ensure that code from our microcontroller can excite the speaker to produce audible sound that we would like it to produce. Finally, we will ensure that our microcontroller can send and receive data through our Bluetooth module, and possibly a Wi-Fi module if we attain to developing our stretch goal design.

These tests will help to make sure that our cat toy device is working to the potential that it was designed for. The embedded software is key to making every component work as it should and in connection with the other components.

5.2.4.2 Application Software Testing

Application software testing will enable us to make sure that our Interactive Cat Toy can be controlled via our smart phone app as our project design specifies. Testing of application software will involve testing that the GUI of the application responds correctly when prompted; and testing that the desired output of our feature components is expressed correctly.

First, we will need to make sure that our application can connect to our Raspberry Pi Pico microcontroller through our Bluetooth module (and our Wi-Fi module for our stretch goal features). This connection is crucial to the functioning and testing of the software for our phone application.

For our GUI, testing will involve selecting options by tapping virtual buttons on our app's screen. We will test to ensure that the app proceeds correctly through options and screens as our design requires. In the case, for our lighting effects, one screen will allow the user to select that they would like to see lighting options. Once they tap the lighting effect button it will take the user to another screen with multiple buttons that allow for them to pick different colors. With our selected application building platform our GUI can be tested via simulation before it is installed on a phone.

Once the GUI's software has been tested for proper set up of the applications command screens, we will move on to testing the communication of the application with the microcontroller. We will ensure that the microcontroller properly receives and sends commands to each of the feature components that our application will control. We will test to ensure that the software to control the application feature is correctly written to gain the desired feature outcome. Again, using lighting as an example, we will ensure that our application color selections properly correspond through the Raspberry Pi Pico microcontroller to change the LEDs to the correct color within an appropriate time. We will do similar application software testing with our speaker, motor and camera for our stretch goal feature.

For our stretch goal feature our toy will have an accessory "kitty cam" that will connect to our application via Wi-Fi. We will test our applications GUI to ensure it properly displays camera feature options starting from the main home screen. From the main screen we will test the camera button, once the camera button is pressed it should automatically open to the camera screen. Our camera screen will allow a pet cat owner to see live streamed video of their pet. There will be control buttons on the camera screen to move the camera up, down, left and right. We will test these camera moving buttons to ensure that they do in fact follow the application software commands to correctly implement movement of our kitty cam. Also, our camera has a motion sensor that we would like to employ, time permitting, to activate the camera to begin streaming video for a pet owner to see their kitty in action, this will take a good bit of proper software programming and testing to ensure proper workability.

6. Project Integration (Liz)

Our Interactive Cat Toy project is composed of three conceptual levels of design Our concept levels include a Basic Design level, Advanced Design level and "Stretch Goal" Design level. Within these levels of design are several *layers* of design. Utilizing our team's electrical and computer engineering educational understanding and skills, each layer has been designed in preparation for overall project integration with the other layers. The goal of this integration is to bring everything together to make an enjoyable toy for cats and their owners.

<u>Basic and Advanced Design</u>

The Basic and Advanced Design levels include five focused *layers* of design. These five layers of design are three material hardware layers and two computer system software layers. The three physical hardware layers include the plush toy's exterior skins, an inner protective chassis and an electronics layer. The system software layers include the embedded system software and our application software.

Exterior Skin Integration

The two interchangeable exterior (squirrel and lizard) skins for our Interactive Cat Toy, are designed with careful measures so that they will be able to properly envelope the toy's interior chassis and electronics. Since the electronic components and their connections will need some cushioning from rough cat play, these skins have also been carefully designed to include padding to protect these parts.

A zippered opening is designed for the skins in order to allow for a pet owner to access a switch to turn the cat toy on; and to access a port for recharging the toy's battery. The zippered opening will also allow for the chassis to be removed and switched between the skins. Closure of the zippered opening is designed to make it difficult to be opened during play by a pet so that the inner chassis and electronic hardware is protected.

The exterior skins are also designed to support exhibition of our cat toy features. A white strip of polyester belting fabric is sewn down the back of each skin to allow for our lighting feature to be emphasized. Through these strips of fabric our lighting effects will be visible. These strips of fabric will also protect the LEDs from potential damage from direct contact.

The tail of each exterior skin will have a hollow area in which a lever, that is attached to the chassis, can be inserted. This will allow for the lever to move the tail up and down to entice a cat into play. The hollow in each skin's tail will also allow a catnip pouch to be inserted and shaken, to release the scent of catnip into the air to entice a cat.

Design of our exterior skins for our Interactive Cat Toy required our team to strategically calculate dimensions, shaping and material choice. Using these criteria for our design make our exterior skins well suited and ready for integration with our overall project design.

Protective Chassis Integration

The protective chassis of our Interactive Cat Toy will fit inside the toy's exterior skin and house the electronics. So, the chassis makes up the middle layer of our hardware and its integration into our project provides very important support for our toy design. The chassis provides protection for the toy's electronic components, and also provides fixtures to support our toy's features. It is being custom designed and 3-D printed, by our sponsor Le Phan, to seamlessly integrate within our project design.

The chassis will contain all the electronic components to fit as compactly and strategically as possible. We will use a strategy that allows for the most convenient electronic component lay out. This will be important to provide for ease in wiring and accessing components. The chassis wall will support the on-switch and a port to plug in the toy's battery charger. Along with these provisions, the chassis will have built-in foam padding to protect the components from damage.

To support our toy's features, the chassis wall will provide mounting for a speaker and an LED light strip. For our motion feature, a lever will be attached to the chassis. The lever will fit into the hollow in the tail of our toy's skin, to raise it up and down; and it will be controlled by a servo motor from the electronics layer.

The chassis' integration is vital to our project's successes. By providing protection of our electronic components and support of our features it is a significantly important part of our overall project design.

Electronics Integration

The electronics layer for our Interactive Cat Toy is the core hardware layer for our project and will be housed within the protective chassis. This layer will contain all the electronic components necessary to power and control the various features of our toy. Integration of the electronic layer into the toy design is essential for the toy to function properly. Careful attention to design within the electronic hardware layer is also crucial to our project. Within the electronic layer we will design circuitry for our power supply, a switch, and our microcontroller's connections to toy features based on the different levels of our toy design.

Our battery will need to be carefully integrated into the toy's electronic circuit in order to adequately supply power to our toy, but not to burn out the electronic components. Voltage regulation will need to be employed to step down voltage to a safe and usable level for use by our microcontroller. The wiring of the components to the microcontroller will then need to be carefully planned to allow for proper control of the feature components. Wiring will also need to be carefully planned to provide for proper fit of the electronic components for suitable integration into the chassis.

The electronic hardware design of our cat toy will rely on the integration of a switch into our circuitry to turn our toy on and off. When the switch is in the "on" position it will allow the battery to power the toy. When the switch is in the "off" position it will enable charging of the battery. For the "Basic Design" of our cat toy the switch will also be integrated into the circuitry as a selector that allows a user to choose between modes of operation.

The "Advanced Design" for our project will rely on a smart phone application to give control of certain toy features to a pet owner. This level of design requires the integration of a Bluetooth module into our electronic circuitry, that will open a line of communication between our toy and the app. This integration will also involve application software programming.

The overall integration of our electronic hardware layer with the other layers within our project design will require efficient electrical and computer engineering. Besides well-planned wiring of the components, the electronic hardware will also require proper programming of embedded and application software to function properly. This layer in our project is the most demanding layer of our educational understanding as electrical and computer engineering students.

Embedded Software Integration

Embedded system software will control the expression of our Interactive Cat Toy's features. The software will control transmission of electronic power signals from the microcontroller to our feature components. This software will also process received electronic signals, by the microcontroller, from various electronic circuit components. Components, from which the microcontroller will receive signals include our switch, motion sensor and Bluetooth communication module. Proper integration of embedded software into our Interactive Cat Toy will enable the desired expression of our toy features.

The embedded software for our project will be programmed into a microcontroller. This microcontroller will be strategically connected to our toys electronic components by way of General Purpose In/Out (GPIO) pins that will be used to accommodate all of our features. The microcontroller will be embedded (or layered) onto a PCB that will take care other functions (such as voltage regulation and switching) and will be integrated into the electronics layer of our toy design. Thus, the embedded software programing is integral to the overall design of our project.

Application Software Integration

Application software will be integrated into our Interactive Cat Toy design with the implementation of our "Advanced Design" model. This software will enable a pet owner to select certain feature options through an app, on their smart phone. The pet owner's feature selections will be communicated from their smart phone app, through a Bluetooth communication module, to the toy's microcontroller. The microcontroller, in turn, will communicate commands to feature components to express the desired option. In this way, the integration of the application software will essentially impact all the layers of our overall toy design.

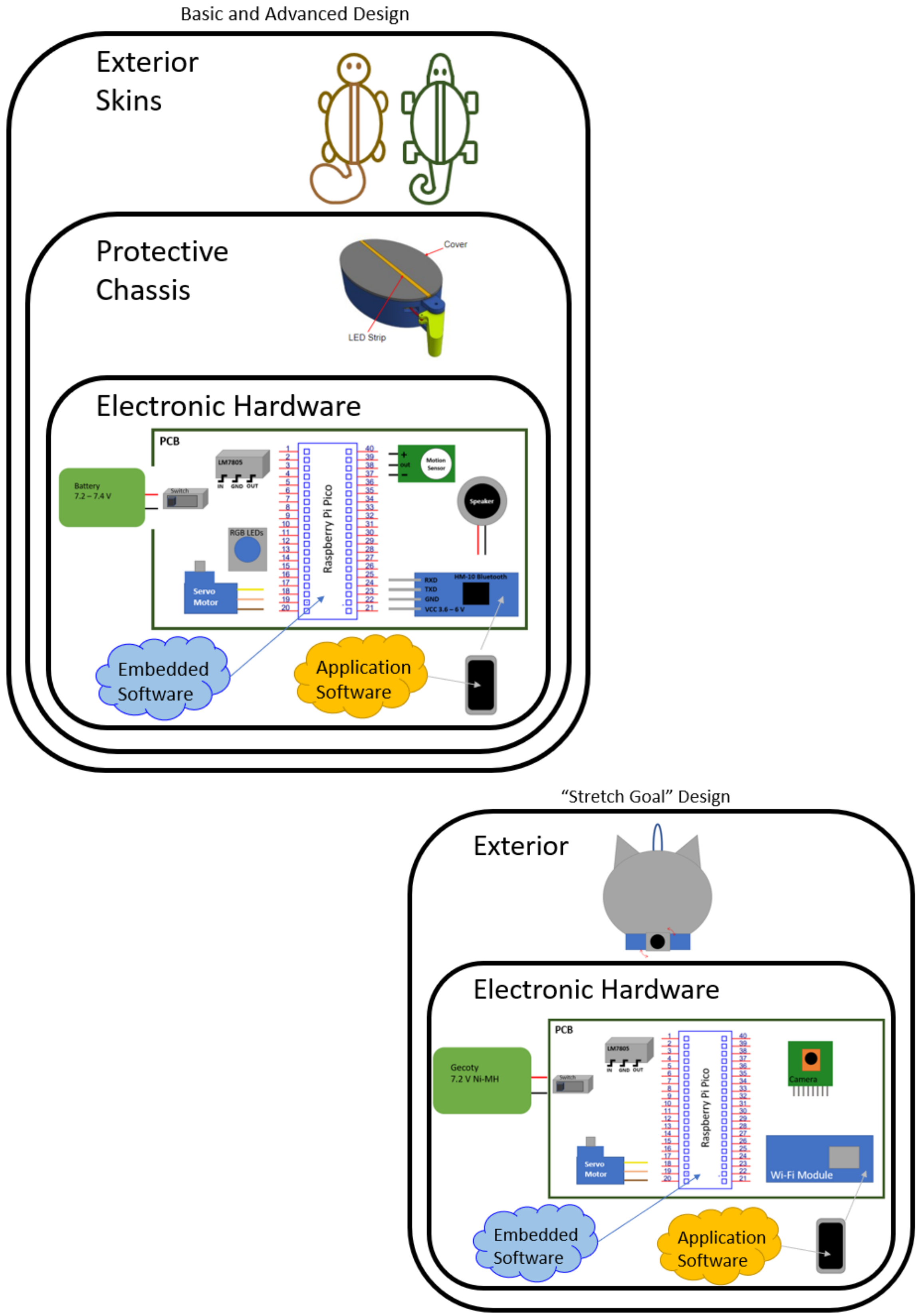
"Stretch Goal" Design

The "Stretch Goal" Design of our Interactive Cat Toy includes all of the layers of the Basic and Advanced Design concept levels, plus additional layers of design for a video camera accessory (a kitty cam) to the toy. The video camera accessory for our toy will have two layers of hardware design along with two layers of software design. These layers have been designed to be integrated within the toy's accessory to bring our "Stretch Goal" Design to realization.

The hardware layers for our "Stretch Goal" Design include the exterior of the accessory and an electronic hardware layer. The exterior layer of this accessory is shaped like the head of a cat for aesthetics, but inside it will integrate with an electronic hardware layer that will support video streaming to our toy's smart phone application.

The software layers for this design level will also include embedded and application software. The embedded software will be integrated with the electronics and the application software through the accessory's microcontroller. The integration of the application with both our plush toy and its kitty cam will bring our whole project design together as a unified package.

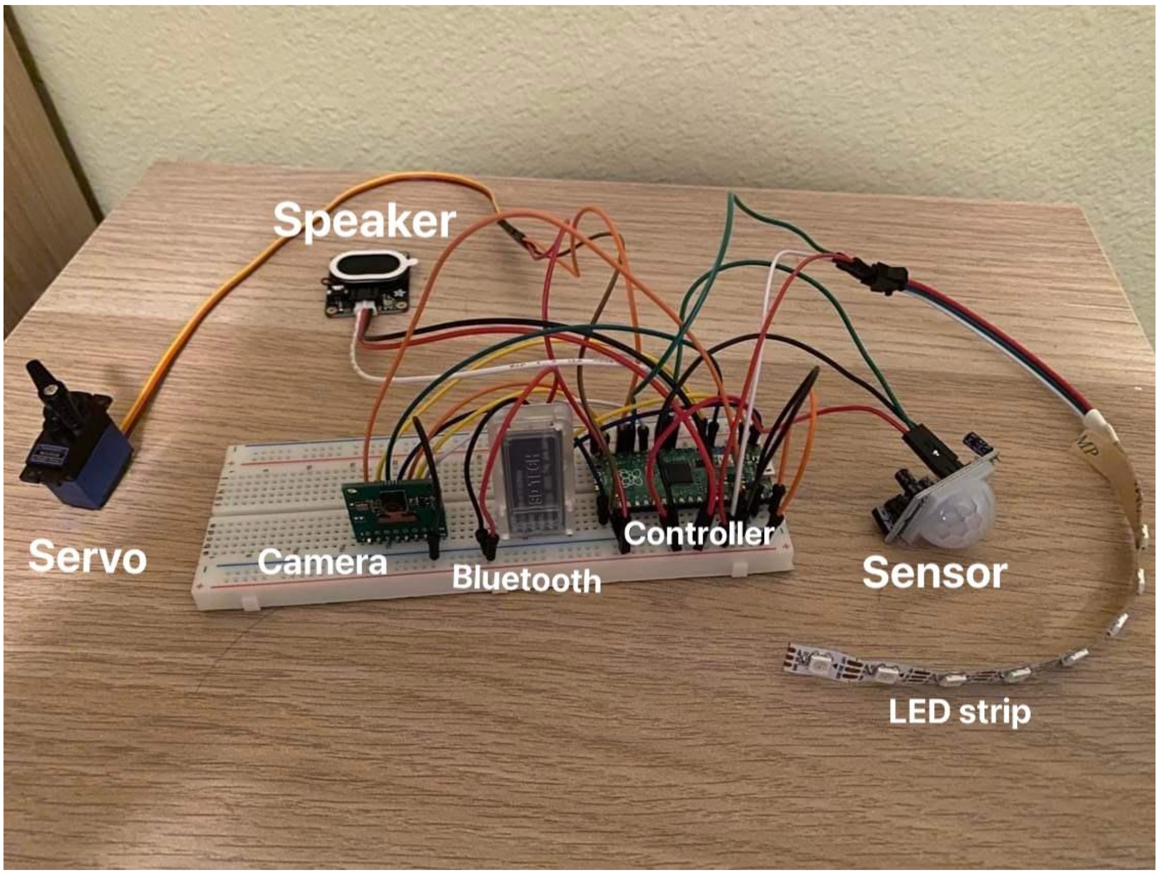
Figure 6-1: Project Integration Venn Diagrams



6.1 Printed Circuit Board Design (Vu)

For our project's printed Circuit board (PCB design, we will use the educational version of Eagle 9.6.2 PCB design software. In order to make sure that the design has the correct components, we downloaded Raspberry Pi Pico's footprint from Ultra Librarian and uploaded it to Eagle's library folder.

Figure 6-2: Prototype Circuit

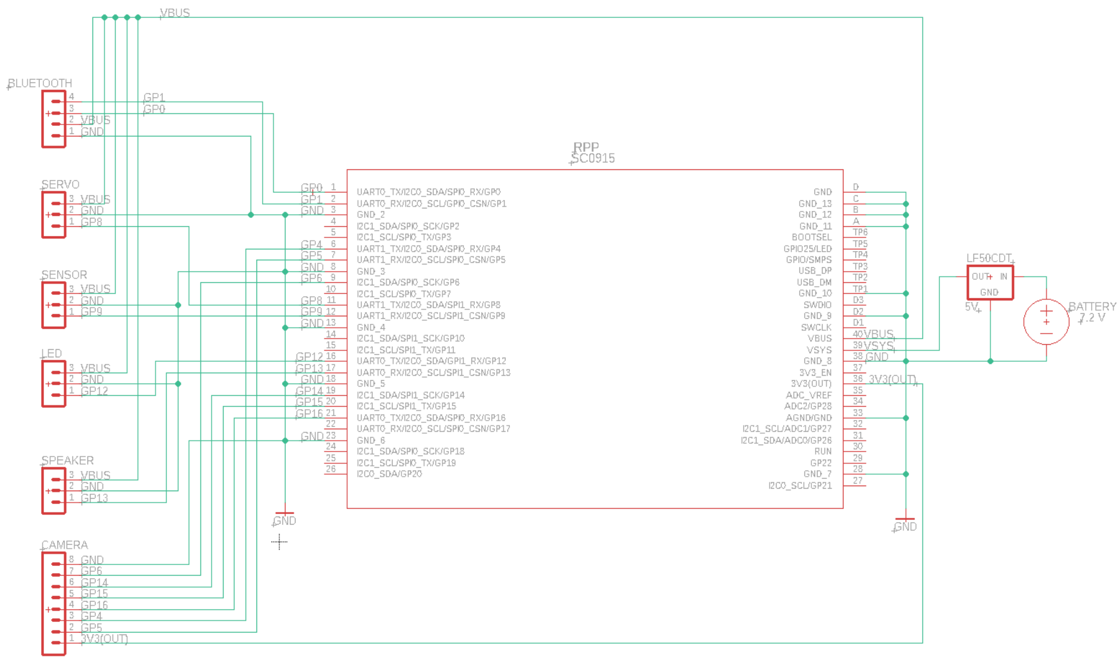


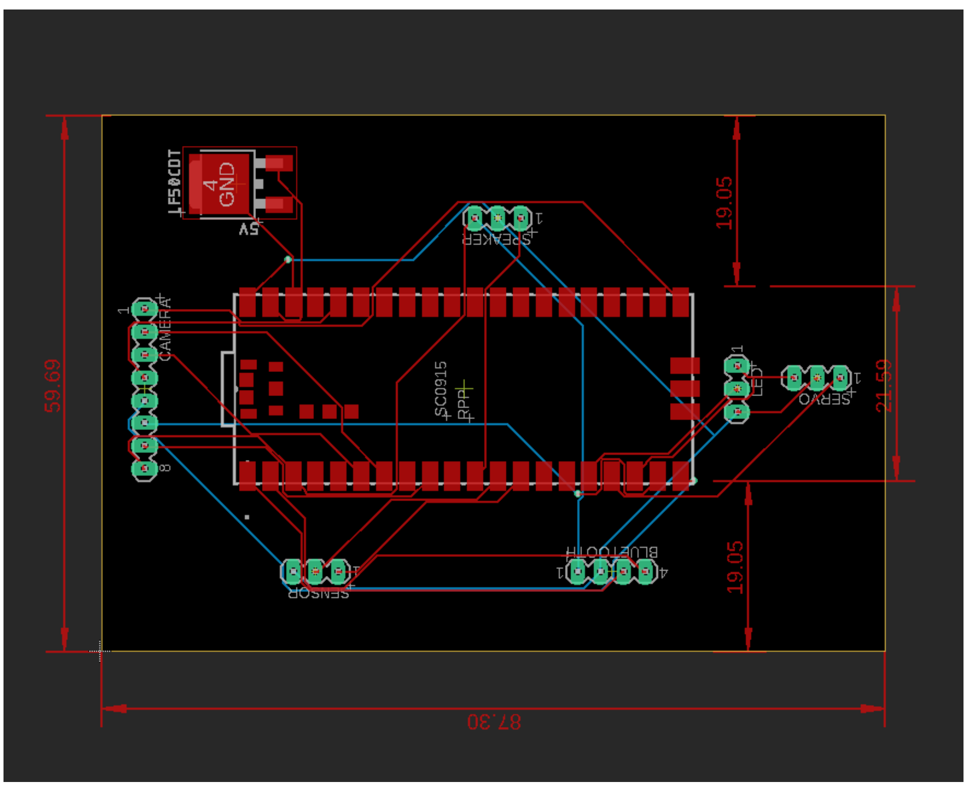
The figure above shows a prototype circuit built on a solderless breadboard with all of the components including the camera, which is a stretch goal component. This prototype shows the wiring and how all the components can be connected to the controller. This setup is used to design the printed circuit board.

The two images below are the schematic and the board design using Eagle software. All components are replaced with pin headers for easy connection when the circuit board is printed. Furthermore, a 5V LDO voltage regulator was added and connected in parallel with the battery. The voltage regulator used in the actual prototype might change.

Regarding the board design, the dimension is in millimeter. Furthermore, the dimension and the placements of the pin headers are not final.

Figure 6-3: Eagle PCB Schematic and Board Design





6.2 System Testing (Vu, Liz)

System testing of our Interactive Cat Toy will include the testing of our power source and our feature components, in combination with our design specific embedded software programming for our microprocessor. Our system testing will observe each individual component's operation in connection with all the other components within our project design. This will involve us connecting all of the electronic components to the microcontroller and ensuring that they can, in conjunction, produce the desired output for our design.

The system testing for our feature components will be conducted by order of our successive design levels; Basic Design, Advanced Design and "Stretch Goal" Design. For system testing we will be working to confirm that our hardware and software will work together to produce the desired output according to our project's design. This system testing will be conducted throughout our prototype fabrication process.

Power Source System Testing

System testing for our rechargeable power source will entail ensuring that the battery fits well within the design of our toy and that it can be switched between convenient recharging and proper powering of our device. This system testing will ensure proper integration of our power source into our overall project design.

Feature Component System Testing

Beginning with our Basic Design model, we will need to confirm that our embedded software correctly controls the hardware for our feature components. We will also need to confirm that a switch is able to properly select the "on" and "off" modes for our toy.

The features that will require system testing that will be expressed for our Basic Design model include the following:

<u>Basic Design Features</u>

- ☐ Lighting Effects
  - ➢ Single colored light display
- ☐ Sound
  - ➢ Singular animal sound
- ☐ Motion
  - ➢ Subtle bodily movement (move tail up and down, slow)
  - ➢ Catnip pouch shaking (rapid tail movement)

Next, for our Advanced Design model we will need to perform system testing to confirm that the embedded software can work with the hardware to implement the advanced functions. This system testing will also require our embedded software to be tested in connection with our application software through a Bluetooth communication module.

Advanced Design Features

- ☐ Phone Application
  - ➢ Adjusts lighting, sound and motion effects.
- ☐ Motion Detection
  - ➢ Toy will activate when motion is detected.
- ☐ Lighting Effects
  - ➢ Multi-colored and multiple light patterns effects.

Our final "Stretch Goal" Design level for our project will require system testing for our "Kitty Cam" accessory. This system testing will involve testing of embedded software with a secondary microprocessor along with the accessory's own electronic hardware and Wi-Fi communication with application software. Following are the features that will also require system testing with our "Stretch Goal" project design level:

"Stretch Goal" Design Features

- ☐ Video Camera Accessory "Kitty Cam"
  - ➢ Video viewing through smart phone application.
- ☐ Speaker
  - ➢ Voice projection from app, through the plush toy.

6.2.1 Design Concerns Identified with System Testing

With our system testing so far, we have identified areas of concern for our project design. These areas of concern involve all of our feature components, so that we will need to give special attention to working around these concerns within our project design. We will work to design around these concerns or replace components with different options as needed.

The battery that we have selected to use for our project design brings with it special design concerns. Our power source selection includes the use of a 7.2 V NiMH rechargeable battery. This type of battery is large and heavy in comparison to other rechargeable batteries. At 200 grams it is twice the size of an equivalent Lithium-Ion battery pack at 100 grams. However, this battery was selected due to it being safer for use with toys than other rechargeable batteries. Development of our circuit design will be required to compensate for the design concerns we have with our battery. With system testing we may decide to strategically place the battery within the chassis of our toy to distribute the weight evenly in the body of our toy, or we may choose to use a smaller 3.7 V NiMH battery and boost voltage to supply the 5 V that we need for our microcontroller to create a 5 V rail for our feature components.

The STEMMA speaker that we have chosen for our toy design emitted a crackled and distorted sound during initial hardware testing. We are working to adjust the code and volume in hopes of still using this speaker due to its ease in wiring. Another draw back for this speaker that we have found; however, is the shape of the speaker and the need to mount it so that it will transmit sound from the hardware layer within the chassis through the exterior skin so that it can produce amusement for both a cat and its owner.

The PIR motion sensor does not seem that it will be able to function as we intended for our toy. Initial hardware testing showed that the sensor only detected movement of large bodies. Further system testing showed that it may not detect motion at all when covered by the exterior skin of our toy. We will still conduct further system testing on this component to determine if we will need to choose a different sensor. We are considering a "knock" sensor as a replacement.

While designing our "Stretch Goal" features, we came to find that the Bluetooth module that we will be using for our main toy component is not suitable for video streaming with our toy's camera accessory; therefore, we will need to do further research to find a Wi-Fi module. This will in turn require our app to communicate to two different types of wireless modules for our application to perform the functions that we would like for our overall project design which includes our "Stretch Goal" features. In considering using only Wi-Fi modules for both of our toy components, we find that Wi-Fi is not suitable for our main plush toy as we will only require commands to be transmitted to it and a Wi-Fi module will cause too much power drain from the battery.

Thus far, our system testing has been valuable in helping us to find areas of concern within our project design. We will put these findings to good use in assisting us to obtain components that are better suited for our project's needs. We hope to continue to work with the strengths of our design as we incorporate better techniques or components for the weaknesses in order to fabricate a successful final working prototype for our senior design project.

7. Administration

Our Senior Design Team, which has been given the designation of "Group 25", is composed of four engineering students from the University of Central Florida's College of Engineering and Computer Science. Of the four students, two are computer engineering students and two are electrical engineering students.

Each teammate within our group is in agreement that we are equally responsible for the overall administration of our project. We also agree that we are each individually responsible for the tasks that we have been specifically assigned by concurrence of the team. We have set up a system of checks and balances, as can be seen on our work distribution table under section 7.3, so that we can ensure the quality of all of our work.

Our team meets on a weekly basis to discuss progress, issues and task planning. Our team meetings and general communications are conducted over Discord. The Discord application allows our team to hold group meetings with voice and video options; and to engage in group text communications. Our team also utilizes Microsoft Teams to organize and share our documentation and to view and work on documentation simultaneously. We also use the planner function within Microsoft Teams to remind us of upcoming project due dates.

The Senior Design class professors, Dr. Samuel Richie and Dr. Lei Wei have made themselves available to assist our group with our design, by offering available office hours for us to meet with them as needed and by corresponding with us by email as our questions arise. Dr. Wei is more specifically our group's mentor, as he has been designated to provide guidance for most of the odd numbered groups. As we reach different milestones for our Senior Design 1 documentation, Dr. Wei schedules meetings with our group to discuss our progress and to give us guidance. The professors have given us documentation guidelines that will help us to ensure our successful completion of our project design for Senior Design I, and the building of our project for Senior Design II.

Proverbs 15:22 (NIV) says that *"Plans fail for lack of counsel, but with many advisers they succeed."* (7-1) Taking this advice from the Proverbs, our group is actively seeking advice throughout our project design process from our professors, industry professionals and family members with specialized skills. We are also seeking advice from online sources that specialize in areas of expertise that pertain to our cat toy design.

We have been encouraged by our class professors to seek advice and assistance in areas of our project that are outside the scope of Electrical and Computer Engineering. For any portion of our project's fabrication that is beyond this scope, we are allowed to employ the assistance of an industry professional in that specific area. For example, we are able to have a mechanical engineer design and fabricate needed mechanical parts for our project. We are also able to employ a seamstress to assist in sewing a fabric skin. We did both of these.

We are gratefully employing the assistance of Le Phan, a mechanical engineer and author. Le is our sponsor and will be assisting us with the design and fabrication of the mechanical parts for our project. Le has many years of mechanical engineering experience and notably worked with the mechanical design of the Avatar ride at Walt Disney's Animal Kingdom. Le is also the author of a book entitled "How to Design Mechanisms that last a Lifetime: Practical Applications of Gruebler's Count", that was published in November of 2020. Le hosts a YouTube channel with fun educational videos that give examples of how to apply the techniques that he describes in his book. Le's channel can be viewed at the following web address: https://youtube.com/channel/UCEYqGvJE61nq9rFS-z_2sSA.

We also gratefully acquire the assistance of a seamstress in order to sew together the skins of our Interactive Cat Toy. Sonja Steinke, AKA Grandma Sonja, has volunteered her services for this project task, and we are very appreciative of her. Grandma Sonja has more than fifty years of experience designing and sewing patterns. She will be assisting us with designing and fabricating the exterior skin; along with stuffing, lining and inserting a zippered closure for our project. She is not aware yet, but we are considering having interchangeable skins which will give her a bit more work to do… we will have to take Grandma out for dinner when this is all over.

In addition to having the help of professionals in the areas beyond our fields of study, we obtained approval from Dr. Wei to also obtain guidance from an electronics professional. This approval was strictly limited to only obtaining guidance and not having any electrical or computer design work done for our project. We gladly accept these parameters.

Bob Meizlik, a Senior Software Architect and an experienced electronic device designer has made himself available to us for technical questions and advice. Bob has worked for large companies including Pan American Airways and Microsoft. He is currently working in the biomedical engineering field and helping to develop medical diagnostic tools. Bob is very helpful to us in recommending various part selections and pointing out important electrical factors we need to take into account. Being knowledgeable in the electronics field, he is familiar with the latest technology like Bluetooth modules which will require less energy for our design. We are very appreciative for Bob's valuable advice.

7.1 Project Budget and Financing

As our project is currently in the design stage, costs estimates are based on web searches and in-store pricing. We expect that our total cost estimate will be changing throughout the design process, including into our Senior Design II class. We expect that our actual costs will not be realized until the completion of our project. Our cost estimates will; however, be sufficient for us to set a budget for our project.

Table 7-1 shows our Bill of Materials. This table is commonly known in the engineering world as the "BOM", as we have found. This table details the parts that we will need to purchase and the estimates of the costs of those parts for our project. Our cost estimates are rounded *up* to the nearest dollar for convenience.

Initial cost estimates suggest that our project can be built for under $300. This is taking into consideration parts that will be needed to build our project, inclusive of not only our basic features, but also our "stretch goal" features. So, we are planning ahead of time to be able to implement these "stretch goals" and to cover the costs for them.

Group members plan to finance the project and to each contribute one-fourth of the cost. To simplify financing each group member will be purchasing the part that they will be doing the research and design for, initially. This will give us freedom to purchase and test parts as we go along. When a more expensive cost arises for a part, each member will contribute funds for its purchase.

We understand that our project may face the need to be redesigned if a part does not properly work, or fit, as expected. We subsequently realize that to buy extra parts will mean additional costs to us as a team. Each of us takes this into consideration and is willing to help cover additional costs as needed.

The Bill of Materials will not include the cost for parts that will not be used in building our final project prototype. Costs for our team will go beyond the Bill of Materials to include the costs of parts that are tested during the design phase of our project but not utilized in the building of our project. Parts may not be used because they do not function in the way that we expected them to for our project; or a part may break and need to be replaced. We will only account for parts used, so that our BOM will only show the cost to build one working project prototype. The BOM will not show financial losses due to parts breaking, or not functioning as desired.

This Bill of Materials will be reviewed and updated by the team as a whole as we complete our part selections. As we update this table, we will have a better idea of the actual cost to build our Interactive Cat Toy project. It will also enable us to ensure that we are fairly sharing the costs of building our device.

Table 7-1: Bill of Materials

Part #	Part Description	Vendor	ID #	Added to Group Stock	Cost
Basic Design Components					
1	Raspberry Pi Pico	Digi-Key	2648-SC0915	11/16/21	4.00
2	PCB	PCB Way	To be designed. Cost est'd.		50.00
3	Gecoty NiMH 7.2V Battery Pack	Amazon	B0727NJ2MF	11/16/21	16.00
4	STEMMA Speaker	Adafruit	3885	11/16/21	6.00
5	Micro Servo Motor	Adafruit	2307	11/16/21	12.00
6	NeoPixel RGB LED Strip	Adafruit	1461	11/16/21	25.00
7	Squirrel & Lizard Skins	Various	n/a	11/16/21	40.00
8	PETG 3D Printer Filament	Amazon	B014VM9724	11/16/21	24.00
Advanced Design Components					
9	HM-10 Bluetooth Module	Amazon	B074VXZ1XZ		12.00
10	PIR Sensor	Adafruit	189	11/16/21	10.00
Stretch Goal Design Components					
11	QVGA Camera Module	Amazon	HM01B0		13.00
12	Wi-Fi Module				10.00
Circuit Components & Misc.					
13	Voltage Regulator		LM7805		1.00
14	Switch				1.00
Total Cost					**224.00**

7.2 Project Milestones for Senior Design I & II

Keeping track of our project milestones will allow us to ensure that we are progressing as we should in the design process for our project. Table 7-2, below, depicts the milestones for both Senior Design I & II.

Table 7-2: Project Milestones

Project Milestones		
Senior Design I		
Dates	**Task Description**	**Status**
Aug 24 - 26	Group Organization	Complete
Aug 24 - Sept 8	Project Selection	Complete
Sep. 10	Divide and Conquer (V1) - 10 page	Complete
Sept 8 - Dec 11	Technology Investigation & Design	Complete
Oct 1	Divide and Conquer (V2)	Complete
Nov 5	60 page Draft Senior Design I Documentation	Complete
Nov 19	100 page SD I Report Submission	Complete
Nov 19 - Dec 7	Review of All Documentation	Complete
Dec 7	Final Document Due	Complete
Senior Design II		
Dates	**Task Description**	**Status**
Jan 10	Build Prototype	
TBD	Testing & Redesign	
TBD	Testing & Redesign	
TBD	Peer Presentation	
TBD	Finalize Prototype	
TBD	Final Report	
TBD	Final Presentation	

7.3 Work Distribution

With our team, "Group 25", being composed of two computer and two electrical engineers we were able to evenly divide the work for our project with regard to electrical and computer engineering tasks. **Table 7-3** below displays how the workload will be distributed.

The team member assigned as a "primary" to a task will be responsible for ensuring that task is completed successfully. The team member(s) that are assigned as "secondary" under a titled task will assist in ensuring that the task is completed successfully. **Table 7-4** displays the responsibility of each team member with regard to documentation for our Senior Design Report.

Table 7-3: Primary/Secondary Responsibilities

	Structural Design	**PCB Design**	**Power Supply**	**Application Software**	**Embedded Software**
Grabowski	S			S	P
Lopez	S			P	S
Nguyen	S	P	S		S
Vargas	P	S	P		

P - Primary S - Secondary

Group 25:

Aliza Grabowski	Computer Engineering, CPE
Joseph Lopez	Computer Engineering, CPE
Vu Nguyen	Electrical Engineering, EE
Elizabeth Vargas	Electrical Engineering, EE

Table 7-4: SD I - Documentation Work Distribution

Work Description	Documenting Team Member	Due Date	Page Count	
Executive Summary (1-2 pgs)	Elizabeth Vargas	10/1/21		1
Project Description (10 pages)	Elizabeth Vargas	10/1/21		2
Motivation, Goals & Objs	Elizabeth Vargas	10/1/21		2
Related Work	Elizabeth Vargas	10/1/21		3
Requirements Specifications	Elizabeth Vargas, Joseph Lopez	10/1/21		2
House of Quality	Aliza Grabowski	10/1/21		1
Project Block Diagram	Vu Nguyen	10/1/21		1
Software Flow Chart	Aliza Grabowski	10/1/21		1
Tech. Inv. and Comp. (10-15 pg)	& Part Selection (30 - 40 pg) E.V.	11/5/21	2	1
Speakers	Aliza Grabowski	11/5/21	2	2
Motors	Elizabeth Vargas	11/5/21	2	2
Lighting LEDs / Laser	Aliza Grabowski	11/5/21	3	2
Wireless Communication	Joseph Lopez, Elizabeth Vargas	11/5/21	2	4
Motion Sensor	Joseph Lopez, Elizabeth Vargas	11/5/21	2	2
Video Cameras	Elizabeth Vargas	11/5/21	2	2
System Controller	Vu Nguyen	11/5/21	2	2
PCB	Vu Nguyen	11/5/21	1	1
Battery	Elizabeth Vargas	11/5/21	3	6
Toy Skin, Chassis and Joints	Elizabeth Vargas	11/5/21	3	2
Part Selection Overview	Elizabeth Vargas	11/19/21		1
Decision Matrix	Vu Nguyen	10/1/21		1
Standards and Constraints	(10 - 15 pages) (Vu)	10/1/21		.25
Standards	Vu Nguyen, Elizabeth Vargas	10/1/21		4.75
Constraints	Aliza Grabowski	10/1/21		5
Project Design (25-30 pages)	Elizabeth Vargas	11/19/21		2
Hardware Design Write-Up	Elizabeth Vargas	11/19/21		1
Hardware Schematics	Elizabeth Vargas	11/19/21		5
Stretch Goal Feature Design	Elizabeth Vargas	11/19/21		2
Hardware Testing	Vu Nguyen, Elizabeth Vargas	11/19/21		6
Software Design	Aliza Grabowski	11/19/21		2
Embedded System Software	Aliza Grabowski	11/19/21		4.5
Application Platform	Joseph Lopez	11/19/21		1
Application Software Design	Joseph Lopez	11/19/21		4
Software Testing	Aliza Grabowski, Joseph Lopez	11/19/21		2
Project Integration (10-15 pgs)	Elizabeth Vargas	12/7/21		5
PCB Design	Vu Nguyen	12/7/21		2
System Testing	Vu Nguyen, Elizabeth Vargas	12/7/21		3
Administration (5-10 pages)	Elizabeth Vargas	10/1/21		2
Budget and Financing	Elizabeth Vargas	10/1/21		2
Milestones	Elizabeth Vargas	10/1/21		1
Work Distribution Table	Elizabeth Vargas	10/1/21		2
Conclusion (2-3 pages)				
Conclusion Write-Up	Aliza Grabowski, Elizabeth Vargas	12/7/21		2
Total Page Count				123.5

8. Conclusion (Aliza, Liz)

Senior Design I afforded our team, “Group 25”, the priceless experience of designing a working electronic device. This exercise required intensive research and development of our group’s conceptual design model for our Interactive Cat Toy project. This experience was a significant challenge that required us to utilize all of our electrical and computer engineering skills obtained within our educational program from the University of Central Florida’s College of Engineering and Computer Science.

The combined research completed by our team members for our device, within this report, has allowed our Interactive Cat Toy to really transform from a conceptual model into an intricately designed prototype. We hope our final product will be captivating for our target consumers and their pet cats. The cat toy design changed in many beneficial ways during our documentation process from the very first idea that was initially pitched; which was a simple idea of a cat toy that points a laser. Now, the cat toy design is a more complex design, with multiple features. The design has the feature to “wiggle” its tail, to display eye catching LED lighting down its back, express cat enticing sounds, and the advanced feature of a phone application connection. All these features are incorporated into our design to capture a pet cat's playful attention.

The look of our product has changed as we have progressed in our design process, with all the features that were incorporated into the cat toy. One of the major changes was the physical size of the toy. With each component added to the project we had to take into account that it also would increase the design size of our toy. A major change from our original project concept was to switch from using laser powered lighting for our toy. We wanted the features to marry together nicely, but the laser required a taller device which would have affected the size of our toy even further. Laser lighting also posed health and safety constraints that made laser lighting incompatible with our cat toy design. For these reasons we chose to incorporate safer and more compact LED lighting instead. The LEDs blended into the toy design with our other features more perfectly and more seamlessly. The last major change that our team decided to make was in relation to the exterior skin of our toy. Originally, we planned for our cat toy to just have the appearance of one small animal, our first idea being a squirrel. But after further prototyping of other animal models, we found it hard to select between a squirrel and a lizard skin for our project. So, we decided to keep both skin designs and to make them interchangeable as an added feature for our Interactive Cat Toy.

With the completion of this report and the combined research contributed to within these pages, we will be able to achieve our goals for our senior design project next semester. Utilizing a format given to us by our class professors, we completed the extensive research which we placed into developing our cat toy design to help our group progress smoothly. The study of standards, as presented in section 4.1, will help us meet the expectations and the requirements of both our target clients and the industry. We'll also make use of the flow charts designed within this report, two being the Hardware Block Diagram (Section 2.6) and the Software Diagram (Section 2.7). These specific charts will help make sure we implement all the features we have planned for within our toy design.

Since our documentation structure required us to design a printed circuit board that would support our device's electrical circuitry and hardware components, we conducted a considerable amount of research into understanding the how the connection of each of our components would properly work with our microcontroller, a Rasberry Pi Pico. With this being done we will be able to focus on making the toy features work during next semester's prototype building and redesigning phase, for our senior design project, during our Senior Design II class.

The system testing, that we were encouraged to do for our Senior Design I class, is an additional aspect of our completing a well-design electronic device. This document's structure, provided by our class professors, directed us to analyze our hardware components through breadboard testing, as seen within section 5.1.3. The section will provide us with a checklist of how things should work when the parts or features are implemented into our design as we move forward to build our cat toy. For our advanced feature the software testing in section 5.2.4, will provide our checklist for how the application should communicate and interact with the design. Testing and redesign of the hardware and software components of our project will continue into next semester as we work to build a final working prototype for our Interactive Cat Toy.

This extensive learning experience has broadened our understanding of what exactly goes into developing a well-designed computerized electronic device. Taking the time to design and build our project, with all of its features including motorized movement, display of varied lighting effects, sound output, smartphone application synchronization, and video streaming provided us with a good comprehensive educational experience. Further, learning to design our circuit to provide ample powering and battery recharging capabilities, programming our embedded microcontroller to properly signal our toy's components to express toy features and developing a smartphone application to control toy features took our engineering education to the next level. This hands-on senior design class project is truly a valuable experience that we appreciate being afforded to us from the University of Central Florida. GO KNIGHTS!!!

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10. Appendix B - Copywrite Permissions

Fig. 2-1 PetDroid's Interactive Robotic Cat Toy - Approved Picture Usage

amazon | Deliver to Liz Chuluota 32766 | All | Hello, Liz Account & Lists

All | Customer Service | Outdoor Recreation | Shopper Toolkit | Pet Supplies | Health & Household | Gift Cards | Sports & Fitness | Beauty & Personal Care | Amazon Basics | Buy Again | Subscribe & Save

YOUR CONVERSATION WITH

PetDroid

Oct 2, 2021 11:23 AM

Hello!
I am a student at the University of Central Florida enrolled in senior design. I am requesting permission to use a picture of PetDroid's Interactive Robotic Cat Toy (ASIN : B07WHSGF4T) in a report that I am writing for the class. Specifically the picture with this current link: [link removed]
The report will not be formally published, but may be reproduced for class or on the university's website.
It would be greatly appreciated if a PetDroid Representative could email me back to grant permission for me to use this picture.
Sincerely, Elizabeth Vargas

Oct 3, 2021 4:25 AM

Of course you can use our pictures.Thank you.
Linda

Thank you for your feedback!

Oct 3, 2021 2:07 PM

Thank you very much! Your Interactive Robotic Cat Toy looks like a fun toy!

Message received and being processed.

Fig. 2-2 Felix & Fido Playdot

Permission to Use Picture From Your Website

EV Elizabeth Vargas
Tue 11/23/2021 11:36 AM
To: info@felixfidopets.com

Dear Felix and Fido Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request to use a picture from your website, https://www.felixfidopets.com/, for my senior design report. The report shall not be published. A copy of the picture is below.

Please respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig. 2-3 Potaroma’s Floppy Fish

Request for Permission to Use Picture from Website :)

Customer-Service <customer@potaroma.com>
Mon 12/6/2021 4:58 AM
To: Elizabeth Vargas

Hello,

We grant you the permission to use the pictures. Thanks for asking.

Best Regards,

Potaroma

Sent from my iPhone

------------------ Original ------------------

From: Elizabeth Vargas <evargas@knights.ucf.edu>
Date: Mon,Dec 6,2021 5:40 PM
To: customer@potaroma.com <customer@potaroma.com>
Subject: Re: Request for Permission to Use Picture from Website :)

To Any Representative Concerned,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request to use a picture from your website, https://potaroma.com/, for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A copy of the picture is below.

It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-1 Raspberry Pi Pico

YOUR CONVERSATION WITH
Seeed Studio Official

Nov 21, 2021 4:44 PM

Dear Seeed Studio Representative,
I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. The link for the picture is below.
Raspberry Pi Pico
[link removed]
It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.
Thank you for your time!
Sincerely,
Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Nov 22, 2021 12:54 AM

Hello Elizabeth
Thank you for coming to us. You can use that picture. And wish you success in your presentation.
Best regards
Seeed

Fig 3-2 Trinket MO

Permission to Use Picture from Adafruit.com

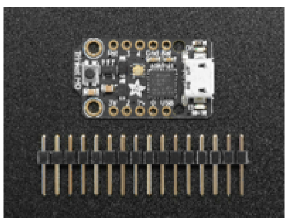
phillip torrone <pt@adafruit.com>
Mon 11/22/2021 8:31 AM
To: Elizabeth Vargas
Cc: press@adafruit.com

totally ok, please do!

Elizabeth Vargas
Mon 11/22/2021 6:37 AM
To: press@adafruit.com

Dear Adafruit Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A copy of the picture is below.


https://cdn-shop.adafruit.com/970x728/3500-01.jpg

Please respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-3 P1C18F15Q40

Academic@microchip.com
Mon 11/22/2021 11:27 AM
To: Elizabeth Vargas

Elizabeth,

Thanks for mentioning Microchip in your report. Academic use of our published content is generally covered under our standard copyright policy. You can find more details here:

http://www.microchip.com/about-us/legal-information/copyright-usage-guidelines

Good luck with your report!

Dave
Microchip Academic Program

Elizabeth Vargas
Sun 11/21/2021 4:59 PM
To: Academic@microchip.com

Dear Microchip Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. The link for the picture is below.

https://www.microchip.com/content/dam/mchp/mrt-dam/ic-images/pdip/20-lead-g6x/PIC18F16Q40-G6X-Regular.jpg

It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-4 Gikfun Protoboard

Dear Gikfun Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A description of the picture is below.

Gikfun Protoboard 1009

It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-5 DSD Tech Bluetooth Module

Inquiry from Amazon customer Liz Vargas

From: DSD TECH Direct 11/23 17:04:19

Dear Elizabeth,
The DSD TECH Team agreed that you use our product pictures.
There will be no restrictions for learning and research.
we support you.
If you have any other questions,please feel free to contact us.

Regards

Dear DSD Tech Representative, I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. The link for the picture is below. https://m.media-amazon.com/images/I/61PW2uyXUML._AC_SL1001_.jpg Please respond to this email at your earliest convenience, to grant your permission for this request. Thank you for your time! Sincerely, Elizabeth Vargas College of Engineering and Computer Science Electrical Engineering Undergraduate University of Central Florida

6:44 AM

Figure 3-6: Adafruit's USB Li-Ion / Li-Poly Charger Board

Permission to Use Website Picture

phillip torrone <pt@adafruit.com>
Mon 11/22/2021 8:32 AM
To: Elizabeth Vargas
Cc: press@adafruit.com

totally ok, please do!

Elizabeth Vargas
Mon 11/22/2021 6:25 AM
To: press@adafruit.com

Dear Adafruit Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A copy of the picture is below.

https://cdn-shop.adafruit.com/1200x900/259-00.jpg

Please respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-7 Gecoty Ni-MH Battery Pack

Gecoty Ni-MH Battery Pack,Upgrade 7.2V 2400mAh Recharge AA Battery Pack with Standard Charge Cable,SM 2P Plug for RC Car,Truck,Tank, Boat,High Capacit

YOUR CONVERSATION WITH
Gecoty

College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida
[e-mail address removed]

Dec 6, 2021 9:25 PM

Hello, as long as the pictures are not used for commercial purposes and do not maliciously slander our products and brand reputation, you can use some related pictures, thank you.

Fig 3-8 Adafruit's STEMMA Speaker 3885 & Metal Speaker 1890
& Fig 3-10 Adafruit Button LEDs 4776 & Fig 3-12 &13 Adafruit LEDs 1461

Adafruit Industries <support@adafruit.com>
Sat 10/30/2021 11:52 AM
To: Aliza Grabowski

totally OK, approved :)

Reply | Forward

On Sat, Oct 30, 2021 at 11:48 AM Aliza Grabowski <contact_us_forms@adafruit.com> wrote:
contactname : Aliza Grabowski
email address : alizarosebud@knights.ucf.edu
message text : Hello,
I am a Computer Engineer at University of Central Florida. I am currently a senior working on my senior design project. I am writing to request to use a few pictures from your website, for the class report. The report shall not be published, but may be reproduced in class or on our university's website.
The links to the pictures for use of my senior design report:
1. https://www.adafruit.com/product/1461?length=1
2. https://www.adafruit.com/product/4776
3. https://www.adafruit.com/product/3885
4. https://www.adafruit.com/product/1890
Your prompt response will be greatly appreciated.
Thank you in advance
Aliza Grabowski
Client IP: 65.126.49.34

Fig 3-9 Adafruit's Micro Servo Motor

phillip torrone <pt@adafruit.com>
Fri 10/15/2021 12:45 PM
To: Elizabeth Vargas
Cc: Adafruit support <support@adafruit.com>

yep, this is all OK, thanks for emailing

> On Oct 15, 2021, at 12:41 PM, Elizabeth Vargas <contact_us_forms@adafruit.com> wrote:
>
> contactname : Elizabeth Vargas
> email address : evargas@knights.ucf.edu
> message text : I am an electrical engineering student at the University of
> Central Florida. Currently, I am enrolled in Senior Design I and working on
> an electrical design project. I am writing to request to use a picture from
> your website, for a class report. The report shall not be published, but
> may be reproduced in class or on our university's website. The link for the
> picture is: https://nam02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fcdn-shop.adafruit.com%2F970x728%2F2307-02.jpg&data=04%7C01%7Cevargas%40knights.ucf.edu%7Cc6e389b01c7f4a39877508d98ffb2307%7C5b16e18278b3412c919668342689eeb7%7C0%7C1%7C637699131050224428%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C2000&sdata=y04d7vP%2FgTX4FK0kMq5BmIYF2dFv7T47jOUhRguu6rw%3D&reserved=0
> Your promt reply to grant permission for this request will be greatly
> appreciated!
> Sincerely, Elizabeth Vargas

Fig 3-11 Banggood's 5M WS2811 RGB IP68 LEDs

androidservice@banggood.com
Mon 11/8/2021 9:32 AM
To: Elizabeth Vargas

Dear customer,

Thank you for your contact.

You can use the picture of item 1346213 from your website, please rest assured.

https://WWW.banggood.com/5M-WS2811-RGB-IP68-Full-Color-50PCS-Bulbs-LED-Pixel-Module-Strip-Light-with-3keys -Controller-DC5V-p-1346213.html?Dckf=O_Gao

If you have any other inquiries, please do not hesitate to contact us at any time, we will be glad and will serve sincerely for you. Goodbye and Have a good day!

Thanks and best regards!

Customer Service

Banggood

13:57:54

Dear Banggood Representative,
I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture (https://usa.banggood.com/5M-WS2811-RGB-IP68-Full-Color-50PCS-Bulbs-LED-Pixel-Module-Strip-Light-with-3keys-Controller-DC5V-p-1346213.html?cur_warehouse=CN&rmmds=search) from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website.

Banggood 13:57:55

Oh! I will continue to study hard on your question. Could you please write a short&brief message of your concern here in English? 😊

Gao 14:03:30

It's my pleasure to help you.

Gao 14:04:54

As for this issue, I need to confirm with related colleagues first and we will email to you within 12-24 hours. Would you like to wait for reply by email first if you wouldn't mind?

14:05:37

sure my email is evargas@knights.ucf.edu

Gao 14:05:44

We will reply as soon as possible after check, please rest assured.

We are always happy to help you anytime. Is there anything else I may assist you with?

Fig 3-14 Adafruit's Ultrasonic Distance Sensor

Request for Permission to Use Picture from Adafruit Website

phillip torrone <pt@adafruit.com>
Mon 12/6/2021 6:57 AM
To: Elizabeth Vargas

totally ok to use :)

Elizabeth Vargas
Mon 12/6/2021 5:17 AM
To: phillip torrone <pt@adafruit.com>

Dear Adafruit Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. The link for the picture is below.

https://cdn-shop.adafruit.com/970x728/4007-00.jpg

Please respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-15 Arducam for Raspberry Pi Pico Camera, HM01B0 QVGA Camera Module

EV

Elizabeth Vargas

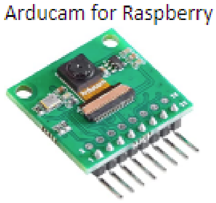
Tue 11/23/2021 12:36 PM

To: linda@uctronics.com

Dear UCTRONICS Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your Amazon website storefront for my senior design report. The report shall not be published; but may be reproduced in class or on our university's website. The link for the picture is below.

Arducam for Raspberry Pi Pico https://m.media-amazon.com/images/I/61YuEZgGDoS._AC_SX425_.jpg



Please respond to this message, at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-16 Himax Camera Module HM01B0-MNA-00FT870

Permission for Picture Use [#14101491]

O Orders@digikey.com
Tue 11/23/2021 2:15 PM
To: Elizabeth Vargas

Hello Elizabeth Vargas,

Thank you for your email.

Please note you do have our permission to use the picture from our website.
Please do not hesitate to contact us if you have any questions or concerns.
Thank you,
Shawntel Ignaszewski
Global Customer Support
DIGI-KEY ELECTRONICS
701 Brooks Ave South
Thief River Falls, MN 56701 USA
+1 800 344 4539 x 13021
+1 218 681 7979
Click here for more information on our ***Quote Self-Service*** options
Are you using all of the benefits of a ***registered user****?*

--Original Message--

From: evargas@knights.ucf.edu
Date: 11/23/2021 11:45 AM
To: sales@digikey.com
Subject: Permission for Picture Use

Dear Digi-Key Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my class project report. The report shall not be published; but may be reproduced in class or on our university's website. The link for the picture is below.

https://media.digikey.com/Photos/3367-Himax/MFG_HM01B0-ANA_MNA-00FT870.jpg

Please respond to this message, at your earliest convenience, to grant your permission for this request.

Thank you for your time!
Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-17 Adafruit's TTL Serial JPEG Camera - Picture Use Approved

phillip torrone <pt@adafruit.com>
Wed 11/3/2021 5:26 PM
To: Elizabeth Vargas
Cc: press@adafruit.com

feel free to, thanks for checking!

Elizabeth Vargas
Wed 11/3/2021 5:25 PM
To: press@adafruit.com

Dear Adafruit Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from your website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A copy of the picture is below.

https://cdn-shop.adafruit.com/970x728/1386-07.jpg

It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas

Fig 3-19 Overture PETG 3-D Printing Filament - Picture Use Approved

Permission to Use Picture from Amazon Website

O3 OVERTURE 3D <service@overture3d.com>
Wed 11/3/2021 9:44 PM
To: Elizabeth Vargas

Hi Elizabeth Vargas,

Thank you so much for reaching out and sure , you are authorised. Here's the original pic and hope can help you

EV Elizabeth Vargas
Wed 11/3/2021 5:08 PM
To: service@overture3d.com

Dear Overture Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request to use a picture fron your Amazon store website for my senior design report. The report shall not be published, but may be reproduced in class or on our university's website. A copy of the picture is below.

https://m.media-amazon.com/images/I/61UiUOGaqvL._SL1001_.jpg

It would be greatly appreciated if you could respond to this email at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Sincerely,

Elizabeth Vargas
College of Engineering and Computer Science
Electrical Engineering Undergraduate
University of Central Florida

Fig 3-20 Eneloop Batteries

Chat with Amazon Customer Service - Work - Microsoft Edge

https://www.amazon.com/message-us?ref_=fs_hub_gateway_mu&paradigm=foresight&muClientName=f.

5:53 AM

Panasonic BK-3MCCA8BA eneloop AA 2100 Cycle Ni-MH Pre-Charged Rechargeable Batteries, 8 Pack

5:53 AM

Messaging Assistant | Customer Service

Looks like this item was delivered on Wednesday, Nov 10.

Could you confirm what went wrong, so I can help?

5:53 AM

Something else

5:53 AM

Messaging Assistant | Customer Service

Type a little about what you'd like help with so I can get you to the right place.

5:53 AM

Never mind, I'm all set

I am writing to request permission to use a picture from the Eneloop store website for my class project report at the University of Central Florida. The report shall not be published; but may be reproduced in class or on our university's website. The picture is of an 8 pack of AA Eneloop batteries. Please respond to this message or email me at evargas@knights.ucf.edu to grant permission for this request. Thank you!

Chat with Amazon Customer Service - Work - Microsoft Edge

https://www.amazon.com/message-us?ref_=fs_hub_gateway_mu&paradigm=foresight&muClientName=f..

AyessaEmmanuel | Customer Service

Yes, you can use this photo for education purposes but make sure you'll put your resources regarding with the picture.

6:07 AM

Thank you very much!

6:07 AM

AyessaEmmanuel | Customer Service

You are welcome.

Fig 3-20 Battery Holder from Memory Protection Devices, Inc.

Request for Permission of Product Picture Use

DL

Daniel Lynch <dan@memoryprotectiondevices.com>
Fri 1/28/2022 7:15 AM
To: Elizabeth Vargas

Dear Elizabeth,

Thank you for your request. I am granting you permission to use one of our images from our product line. Please make sure that the image is not used for any commercial purposes. If possible also I would like to get a copy of your project showing our holder.

Respectfully Yours,

Daniel B Lynch Sr
General Manager
Memory Protection Devices, Inc.
200 Broadhollow Road, Suite 4, Farmingdale, NY 11735-4814, USA
Tel: (631) 249-0001 ext 5791, Fax: (631) 249-0002
Email:dan@memoryprotectiondevices.com
Website: www.batteryholders.com - www.memoryprotectiondevices.com
Follow us on: Twitter - Instagram - Linkedin
MEMORY PROTECTION DEVICES, INC.
an ISO 9001 manufacturer

Request for Permission of Product Picture Use

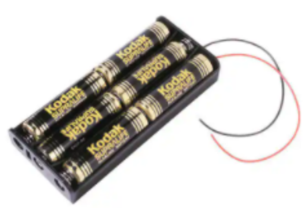
EV

Elizabeth Vargas
Thu 1/27/2022 2:33 PM
To: info@memoryprotectiondevices.com

Dear MPD Representative,

I am an electrical engineering student at the University of Central Florida. Currently, I am enrolled in Senior Design I and working on an electrical design project. I am writing to request permission to use a picture from the Digi-Key website, of one of your products, for my class project report. The report shall not be published; but may be reproduced in class or on our university's website. The link for the picture is below.

https://media.digikey.com/Photos/Memory%20Protection%20Photos/MFG_BH36AAW.jpg



Please respond to this message, at your earliest convenience, to grant your permission for this request.

Thank you for your time!

Elizabeth Vargas
Electrical Engineering Undergraduate
College of Engineering and Computer Science
University of Central Florida

11. Appendix C - Datasheets

****FAIR USE DISCLAIMER****

This report is for non-profit educational and research purposes only.

Datasheets herein are referenced with credit to their originator(s).

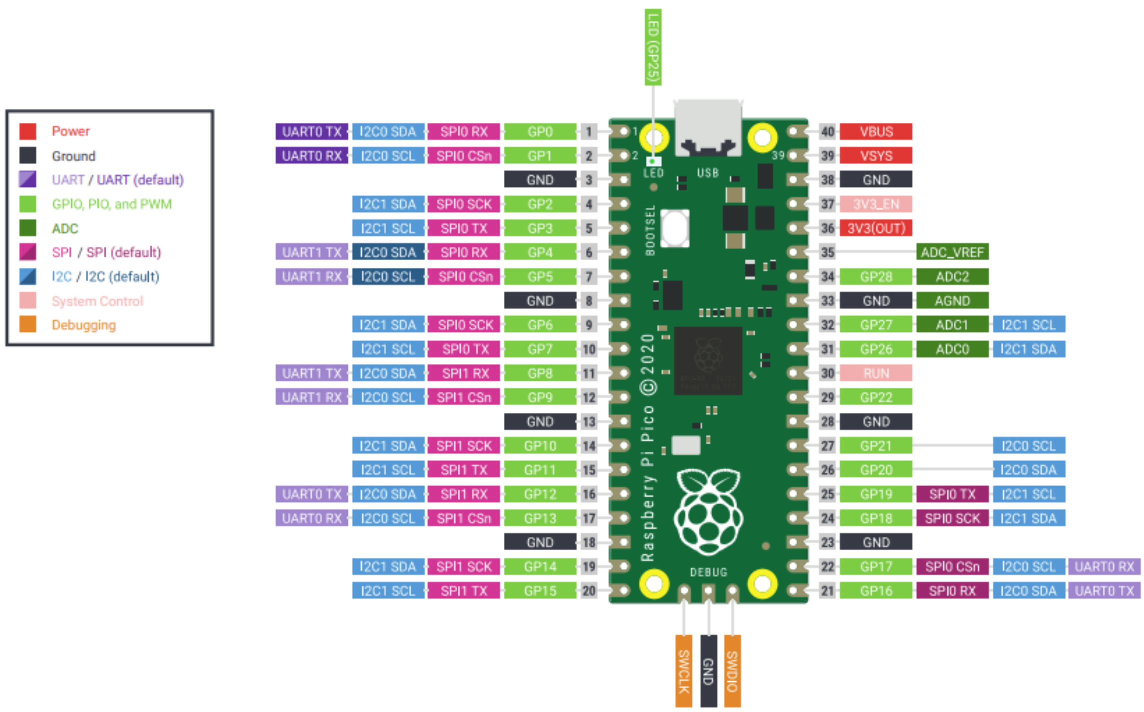
Fair Use

In accordance with *Section 107 of the Copyright Act of 1976*, allowance is made for "fair use" for purposes such as criticism, comment, news reporting, teaching, scholarship, and research.

This fair use does not constitute copyright infringement.

https://www.copyright.gov/title17/92chap1.html#107

Raspberry Pi Pico Datasheet



Raspberry Pi

https://datasheets.raspberrypi.com/rp2040/rp2040-datasheet.pdf

Arducam's SPI Camera Module for Raspberry Pi Pico

https://manuals.plus/m/eb6423386eae77a9e6b138c71d3fe4fe88d56e3f246c4096e91bcc90b492b0ba

Adafruit Stemma Speaker Datasheet

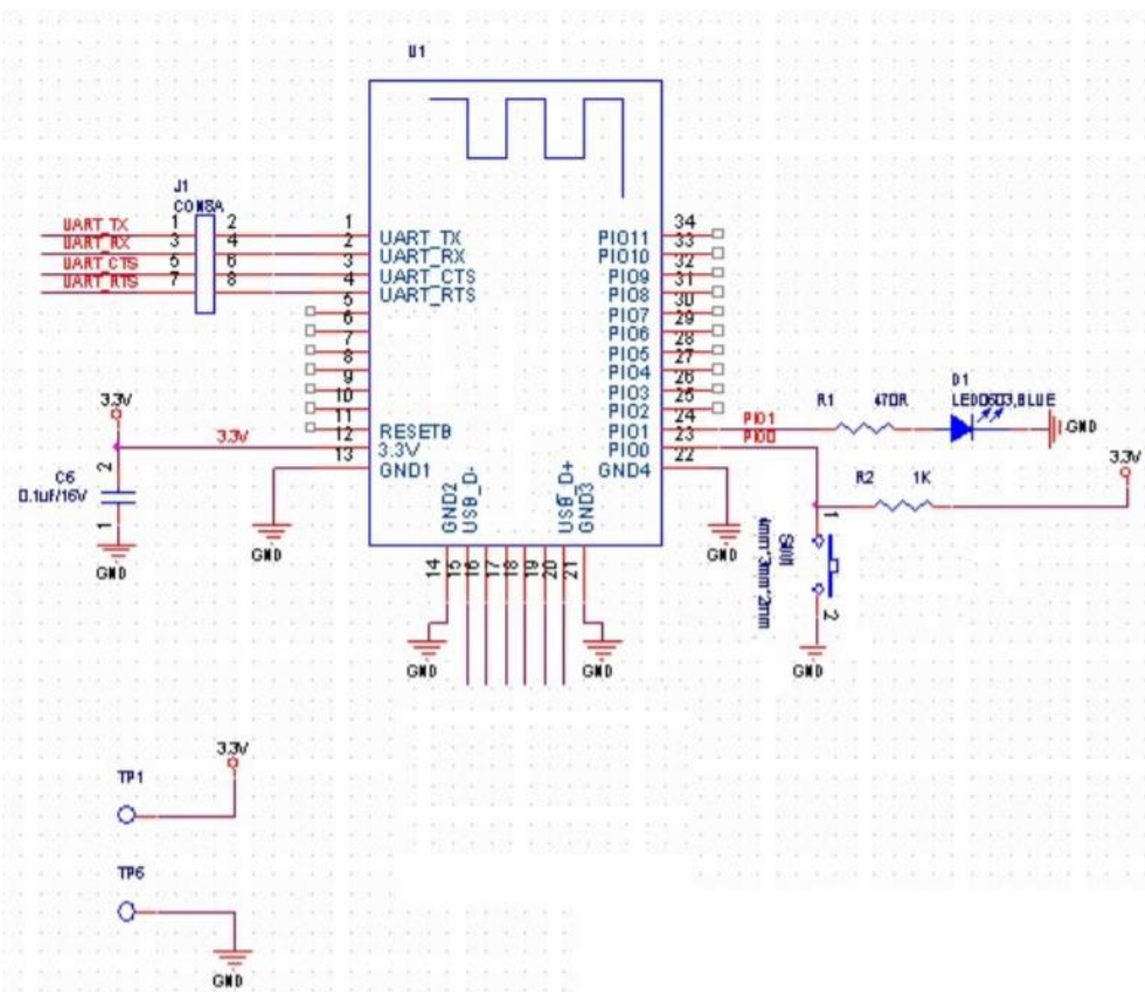
https://media.digikey.com/pdf/Data%20Sheets/Adafruit%20PDFs/3885_Web.pdf

Adafruit's PIR Motion Sensor Datasheet

https://cdn-learn.adafruit.com/downloads/pdf/pir-passive-infrared-proximity-motion-sensor.pdf

DSD TECH HM-10 Bluetooth Module Datasheet

HM Bluetooth module datasheet



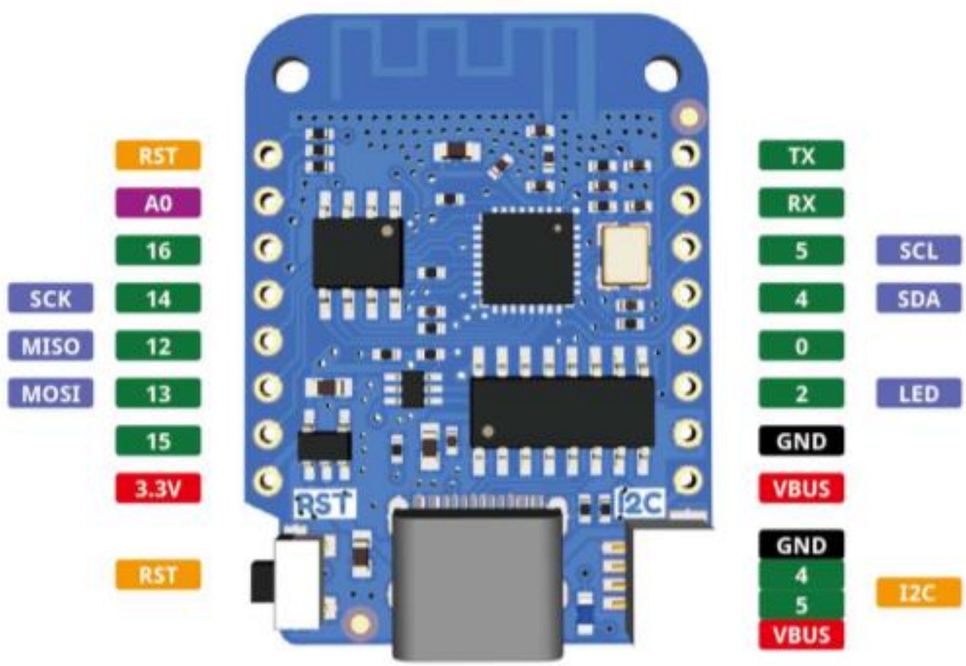
6.2 HM-10 Size

WEMOS - LOLIN D1 Mini Datasheet

Technical specs

Operating Voltage	3.3V
Digital I/O Pins	11
Analog Input Pins	1(3.2V Max)
Clock Speed	80/160MHz
Flash	4M Bytes
Size	34.2*25.6mm
Weight	3g

Pin

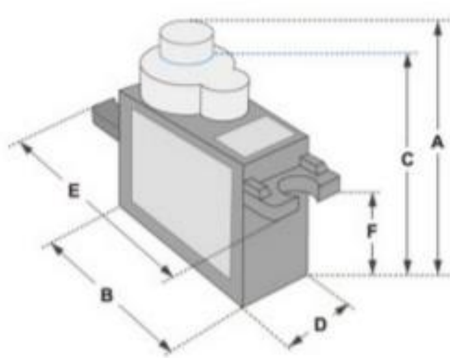


https://www.wemos.cc/en/latest/d1/d1_mini.html

Tower Pro Micro Servo Motor Datasheet

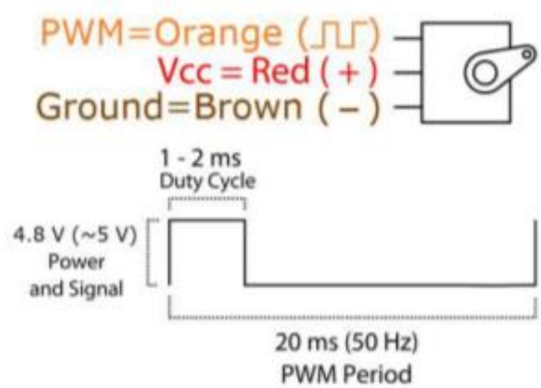
SERVO MOTOR SG90 **DATA SHEET**

Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kind but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6

Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is middle, is all the way to the right, "-90" (~1ms pulse) is all the way to the left.



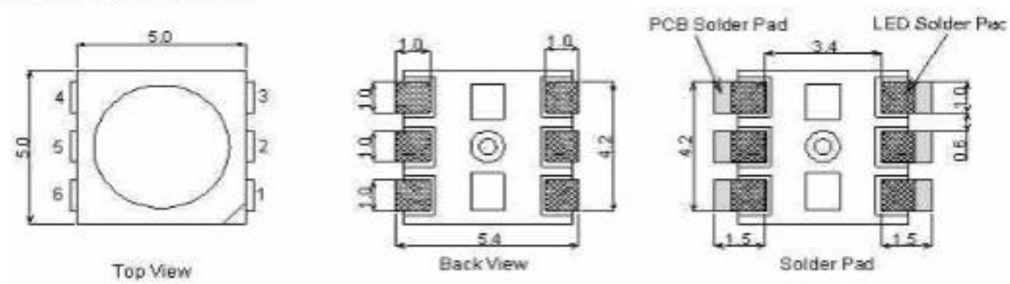
Worldsemi WS2812 RGB LED Datasheet

Worldsemi

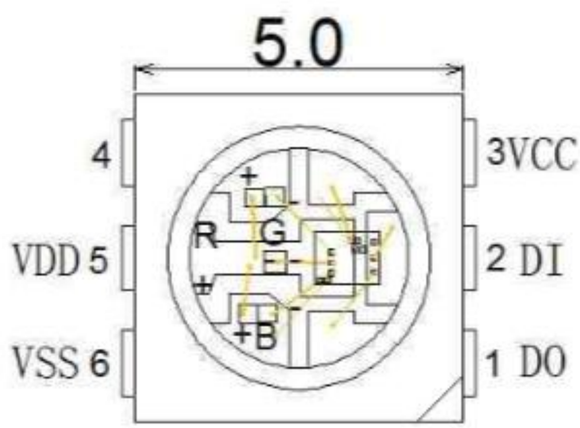
WS2812

Intelligent control LED
integrated light source

Mechanical Dimensions



PIN configuration



PIN function

NO.	Symbol	Function description
1	DOUT	Control data signal output
2	DIN	Control data signal input
3	VCC	Power supply control circuit
4	NC	
5	VDD	Power supply LED
6	VSS	Ground

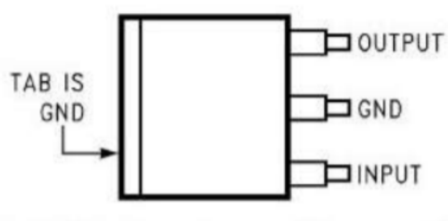
Absolute Maximum Ratings

http://www.world-semi.com

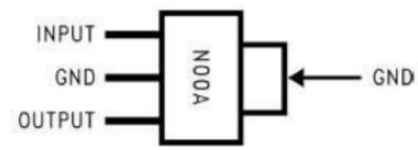
Texas Instruments LM7805 (& family) Voltage Regulators Datasheet

5 Pin Configuration and Functions

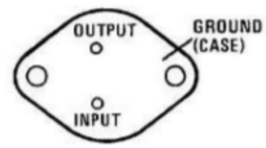
LM7805 and LM7812 KTT Package
3-Pin DDPAK/TO-263
Top View



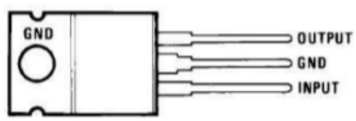
LM7805 DCY Package
4-Pin SOT-223
Side View



LM340K-5.0 NDS Package
2-Pin TO-3
Top View



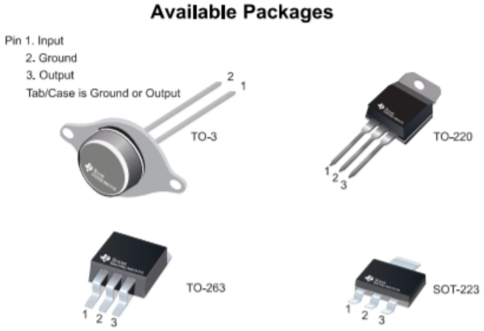
LM7805, LM7812, and LM7815 NDE Package
3-Pin TO-220
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
INPUT	1	I	Input voltage pin
GND	2	I/O	Ground pin
OUTPUT	3	O	Output voltage pin

Available Packages

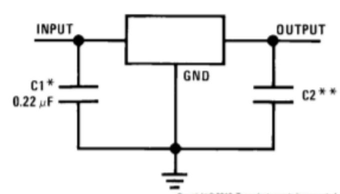


Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM340x LM7805 Family	DDPAK/TO-263 (3)	10.18 mm × 8.41 mm
	SOT-223 (4)	6.50 mm × 3.50 mm
	TO-220 (3)	14.986 mm × 10.16 mm
	TO-3 (2)	38.94 mm x 25.40 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Fixed Output Voltage Regulator



*Required if the regulator is located far from the power supply filter.
**Although no output capacitor is needed for stability, it does help transient response. (If needed, use 0.1-μF, ceramic disc).