UCF Senior Design 1 Final Document

VFLTTS
(Vest Free Laser Tag and Texas Star)

Department of Electrical Engineering and Computer Engineering
University of Central Florida
Lei Wei/ Samuel Richie

Group 22

Chace Arrington	Computer Engineer	chacearrington@knights.ucf.edu
Reneau Augusma	Computer Engineer	raugusma@knights.ucf.edu
James Gossett	Electrical Engineer	james.gossett@knights.ucf.edu

Table of contents:

1.0 Executive Summary

Laser tag has been around for quite a while and is a hobby or outing activity enjoyed by many to this day. Recently NERF developed a way to make the game much more compact by integrating the receiver, usually located in a vest, and building it into the gun.

Laser tag was invented in 1982 by George Carter III. It was inspired by movies like Star Trek and Star Wars. After George Carter finished designing and building the blasters, sensors, and arenas, the first game was played in 1984. It wasn't until 1986 that laser blasters were available on the open market. Blasters contain an emitter of collimated infra-red beams of light that is highly directional. The sensors are infra-red receivers that absorb the light and use optical filters to detect the signal. These blasters use infrared rather than real lasers for a few reasons: even cheap lasers can still cause eye damage, infrared emitters and receivers are cheaper, and lasers may cause distractions in game. Especially since games are often played in dark environments. At the end of laser tag games, you get a stat sheet with how you did, and who shot you. This is possible due to the fact that each gun emits a specific beam of infrared light, which can be differentiated by the sensor.

The Nerf blaster has a single shot, IR burst, with each pull of the trigger and registers hits with lights and sounds. It also has a status bar for health and ammo capacity. While the blaster has unlimited ammo, there is a reload button for when your magazine runs out. Nerfs blaster also has two different game modes, team deathmatch, or free for all. (Figure 2)

For our laser tag part of the blaster, we have been looking into adding a few different "game modes", to increase the capabilities of the blaster. One of which being a health based game mode, where every player has a set amount of health, with their blaster turning red once they run out. Another option would be keeping score, counting how many times a player has been "shot". There will be a toggle switch for selecting game modes, or switch to target shooting. (Figure 1)

The blaster additionally would have more functionality than what NERF offers currently. Such as taking the reload feature a step further by allowing the user to select from variable maximum "magazine" sizes such as a six shot mode for a revolver-like experience, and a magazine size more reflective of modern firearms. We are planning on implementing multiple features of the Nerf blaster: health and ammo status, reload button, different game modes, team selector, lights or sounds to visual or audible feedback.

To take this cheap access to laser tag to the next level there must be more than one kind of activity that can be done with it. Enter the Texas Star, a challenging target long enjoyed by shooting enthusiasts that is mounted on a swinging base holds a number of plates that fall off as they are hit causing the target to swing erratically as more are removed. The real version of this target is quite expensive with even lower end models costing around $300, but with the low cost and wide availability of electronics in the present day there is an untapped potential for a simulation of this for a low cost. (Figure 3)

The Texas Star target would work by having a simple PCB in each plate that's only functions would be detecting the laser from the gun, signaling that it has detected the laser, and then releasing itself from the Star via an electromagnet. This would put it ahead of what is currently offered as the target for laser guns are more of an afterthought, whereas this device would simulate the physical aspects and size of what it is modeled after.

These plates will be affixed to the arms of the main body via 5 volt electromagnets with a holding force of 5.5 lbs. This means that the magnets will be able to support 1 pound, and this should be more than enough for our minimal electronic components and 3D printed plate. As a form of redundancy each plate will also be equipped with LEDs that will light up when a plate has been hit. This redundancy feature allows us to account for two points of failure that can exist in our system that are parallels to the same in the real-world target. The first point of failure comes about if the electromagnet does not release when struck leaving the plate on the target, and the actual texas star sometimes does this if you are using a lower power round and hit the plate at a non-optimal spot. The second point of failure is the opposite, plates flying off due to too much force being produced by the swinging of the star and overriding the holding force of the connection. The LED hit confirmation also mirrors a real-world factor of using this target such that in using a real Texas Star one can see if the plate was struck by checking for the impact of the bullet on the plate.

2.0 Project Description

Laser tag has been around for quite a while and is a hobby or outing activity enjoyed by many to this day. Recently NERF developed a way to make the game much more compact by integrating the receiver, usually located in a vest, and building it into the gun.

Laser tag was invented in 1982 by George Carter III. It was inspired by movies like Star Trek and Star Wars. After George Carter finished designing and building the blasters, sensors, and arenas, the first game was played in 1984. It wasn't until 1986 that laser blasters were available on the open market. Blasters contain an emitter of collimated infra-red beams of light that is highly directional. The sensors are infra-red receivers that absorb the light and use optical filters to detect the signal. These blasters use infrared rather than real lasers for a few reasons: even cheap lasers can still cause eye damage, infrared emitters and receivers are cheaper, and lasers may cause distractions in game. Especially since games are often played in dark environments. At the end of laser tag games, you get a stat sheet with how you did, and who shot you. This is possible due to the fact that each gun emits a specific beam of infrared light, which can be differentiated by the sensor.

The Nerf blaster has a single shot, IR burst, with each pull of the trigger and registers hits with lights and sounds. It also has a status bar for health and ammo capacity. While the blaster has unlimited ammo, there is a reload button for when your magazine runs out. Nerfs blaster also has two different game modes, team deathmatch, or free for all. (Figure 2)

For our laser tag part of the blaster, we have been looking into adding a few different “game modes”, to increase the capabilities of the blaster. One of which being a health based game mode, where every player has a set amount of health, with their blaster turning red once they run out. Another option would be keeping score, counting how many times a player has been “shot”. There will be a toggle switch for selecting game modes, or switch to target shooting. (Figure 1)

The blaster additionally would have more functionality than what NERF offers currently. Such as taking the reload feature a step further by allowing the user to select from variable maximum “magazine” sizes such as a six shot mode for a revolver-like experience, and a magazine size more reflective of modern firearms. We are planning on implementing multiple features of the Nerf blaster: health and ammo status, reload button, different game modes, team selector, lights or sounds to visual or audible feedback.

To take this cheap access to laser tag to the next level there must be more than one kind of activity that can be done with it. Enter the Texas Star, a challenging target long enjoyed by shooting enthusiasts that is mounted on a swinging base holds a number of plates that fall off as they are hit causing the target to swing erratically as more are removed. The real version of this target is quite expensive with even lower end models costing around $300, but with the low cost and wide availability of electronics in the present day there is an untapped potential for a simulation of this for a low cost. (Figure 3)

The Texas Star target would work by having a simple PCB in each plate that’s only functions would be detecting the laser from the gun, signaling that it has detected the laser, and then releasing itself from the Star via an electromagnet. This would put it ahead of what is currently offered as the target for laser guns are more of an afterthought, whereas this device would simulate the physical aspects and size of what it is modeled after.

These plates will be affixed to the arms of the main body via 5 volt electromagnets with a holding force of eleven pounds. This means that the magnets will be able to support somewhere between one and two pounds, and this should be more than enough for our minimal electronic components and 3D printed plate. As a form of redundancy each plate will also be equipped with LEDs that will light up when a plate has been hit. This redundancy feature allows us to account for two points of failure that can exist in our system that are parallels to the same in the real-world target. The first point of failure comes about if the electromagnet does not release when struck leaving the plate on the target, and the actual texas star sometimes does this if you are using a lower power round and hit the plate at a non-optimal spot. The second point of failure is the opposite, plates flying off due to too much force being produced by the swinging of the star and overriding the holding force of the connection. The LED hit confirmation also mirrors a real-world factor of using this target such that in using a real Texas Star one can see if the plate was struck by checking for the impact of the bullet on the plate.

2.0.1 Background History

The history behind laser Tag stems back to its initial use as a training resource for the United States military and other armed forces called MILES or the Multiple Integrated laser engagement system developed in the 1970s - early 1980s where it is still used as a training tool in the present day. The essential goal of the tool was to create a system design that simulates the real life weapons, weapon characteristics and effects of a family of weapon systems including infantry, armor and aircraft, with an initial design of eleven systems such as tank guns, rifles and missiles.

Using the MILES tools and pairing them with detectors, it is effective for training development if it could easily allow combat squadrons to simulate fighting each other through good and even harsh conditions without causing physical bodily harm to one another. MILES systems used a laser module which was mounted to the barrel of a real weapon, a blank-firing adaptor for the weapon, and an integrated receiver consisting of sensors on the helmet and load-bearing vests of the soldiers. As stated briefly in research… “Different versions of MILES systems are available to both US and international militaries. The capabilities of the individual systems can vary significantly but in general all modern systems carry information about the shooter, weapon and ammunition in the laser. When this information is received by the target, the target's MILES system uses a random number roll and a casualty probability lookup table to determine the outcome. For example, a MILES transmitter emulating an M16 rifle cannot harm an armored personnel carrier (APC), but could still "kill" a commander visible in the hatch of the vehicle.”

Similar to radios and phones used by the government programs initially, the Laser Tag system wasn’t initially thought of as a mass produced product for the public until the global success of the Movie Franchise Star Trek. Star Trek is an American science fiction media franchise created by the American T.V. screenwriter and producer Gene Roddenberry, which began with the eponymous 1960s television series and quickly became a worldwide pop-culture phenomenon. The franchise has expanded into various films, television series, video games, novels, and comic books. With an estimated $10.6 billion in revenue, it is one of the most recognizable and highest-grossing media franchises of all time. As stated with the success of Star Trek came the need for public souvenirs, toys and accessories mimicking resources used within the movie franchise especially after the release and success of a similar futuristic franchise Star Wars, so in 1979 the Star Trek franchise developed the first laser toy ever when they released the Star Trek Electronic Phaser Guns and Star Trek Super Phaser II Target Game sets were released by competing toy companies such as South Bend for recreational uses with the primary purpose of marketing the movie Star Trek: The Motion Picture. This initial device used infrared light and a corresponding sensor as its system.

After the development and success of the Star Trek phaser guns and the Star Wars and Star Trek franchises, George Carter III, an inventor whose initial invention was a dirt-track grand prix concession car course in Phoenix called the Baja Raceway, began the process of creating the very first arena laser tag system in 1982 that rapidly rose in popularity.He thought of this idea back in 1977 when the movie Star Wars inspired him. He wanted to create a scored version of the Star Trek phaser gun game and opened the first Photon center in Dallas, Texas, on March 28th, 1984 and caused such a demand that the market quickly became glutted with laser toys. This led to Carter being honored by the International Laser Tag Association on November 17th, 2005.

Laser tag toys began to take off in 1986, starting with Photon toys. Later, Lazer Tag toys came out from a company called Worlds of Wonder, and similar toys came out from various other companies. However, as people’s love for games wore off, these companies, including Photon, went out of business later in the 80s to early ‘90s as the tread turned into a fad. Laser tag arenas slowly went out of business as well. Sadly, that includes the original one started by George Carter. It is only in more recent years that laser tag came back—again—from the brink of official game extinction, and we are all so glad it did! Laser tag is now used for fun games, team building exercises, and the best birthday parties. Fed by social media, the industry has seen huge growth in the last few years. New technologies have driven a surge in innovative designs, but the game is still generally played with taggers and receivers.

2.1 Project Motivation and Goals

There are lots of different laser tag systems on the market nowadays, from arcade and specifically designed arenas, to good old fashioned backyard fun. For our project we were looking into creating an at home laser tag system, and shooting range. Our blaster will share many features with products that already exist, as well as a few new ones of its own. The blaster will not be anything revolutionary, however the Texas Star will be a fairly new idea.

In the current market there are and have been toy versions of challenge targets like the Texas Star, but they always seem to fall short of the mark of being a true adaptation of the real thing, often resulting in simulated movement by mechanical motors or target plates that simply fold out of the way. With our project we seek to create a true simulated Texas Star experience with all the hallmarks of the real thing to give users an enjoyable and authentic-feeling experience.

2.2 Objectives

- Create Working Laser emitter/receiver on blaster
- Create laser blaster with variable “magazine” sizes
- Have a functioning game mode selector
- Display player health and ammo capacity on the blaster
- Create working receiver for Texas Star target
- Create a mechanism on Texas Star Target that allows for plates to be dropped

2.3 Stretch Goals

- Rifle Body Design or Other Body Design Variants
- Sound Effects For Firing, Hit, Reload, Mode Select
- Variable Magazine Size
- Extra space/rails for accessories
- Digital Ammo Display

2.4 Project Requirements

- Texas Star Target
    - Five targets Mounted on swinging base 3 feet across and holds plates that can fall off as they are hit by Laser Gun
    - Plates of the Texas Star Target are attached by Five respective electromagnets
    - Receives emitted Laser transmitted from Gun
    - Star Target stands 4 feet tall

- Laser Gun
    - Emits Laser from Gun that will be aimed at Texas Star Target
    - Receives emitted Laser that allows Gun to be self contained
    - Each laser Gun fires a single-shot IR beam up to 200 FEET (60.96 METERS)
    - Reload feature that allows the user to choose a maximum “magazine” size from 15-17 shots as well as a minimum magazine size of 1 shot

2.4.1 Functional Requirements

This section will cover all of the features of our project, and how each component should end up working. In order to make a laser based shooting game, as well as a functional texas star, we will need to design multiple systems that will work together. The main part of the project being the blaster itself. The blaster will be 3D printed, probably in multiple pieces, with a hollow inside. This will allow room for the microcontroller, LED’s, IR emitter and receiver, etc. The other big part of our project is the Texas Star. The Texas Star will consist of five independent plates, each with their own small microcontroller that will be able to “detect” when they have been hit, and drop away from the system. This would then cause the target to spin since it will no longer be balanced, which increases the difficulty in clearing the star as fast as possible.

2.4.1.1 Laser Gun

The laser blaster must produce an IR beam, meaning we can not just use a laser as the emitter. Some lasers are very powerful, and can even damage peoples eyes. To avoid this and make our product safe for use, we will use an IR emitter and receiver. IR is undetectable by the human eye, and has no risk of damaging people's eyes. The beam also needs to be concentrated, both for distance and accuracy. We will not have to deal with which exact photodiode was hit, just as long as one is, the system will register a hit.

The blaster should also be responsive to inputs, such as trigger pulls. When a trigger pull is detected by the microcontroller, it should trigger then the infrared emitter to turn on for a certain amount of time, resulting in a shot being fired. Within the code on the microcontroller it should check and display how much ammo is available, and subtract one after each shot is taken.

Physically speaking, the blaster itself will need to contain inside of it a power supply, microcontroller, IR emitter, and lens to focus the light. The blaster will need to be rugged enough to be able to withstand swinging and acceleration, so that the internal components stay in place and remain functional.

2.4.1.2 Texas Star

The Texas Star has two big functional requirements that we will need to meet. Being able to detect when a plate has been hit, and trigger the electromagnet to release the plate. In order to identify hits, each of the five plates will have an IR receiver and a small circuit board whose only purpose is to disable the electromagnet when a hit is detected.

The target consists of 5 different plates, where each will have their own IR receiver, microcontroller, and electromagnet. For the target to function correctly, when each plate detects a hit, that plate should drop away from the system. Upon detecting a hit, LEDs within the plate will light up to confirm that that plate has indeed been hit, and these LEDs will remain on until the target is reset.

2.4.1.3 Microcontroller

For our project there will be a total of six to seven microcontrollers. We will make three different blasters, one for each member of the group to test. Each of the five plates on the Texas Star will have its own microcontroller. The ones used in the blaster will basically be for controlling every aspect of laser tag, and mode selector. While the Texas Star's microcontrollers will just have to detect a hit, and release the electromagnet. For this element, we decided to base our design off of the Arduino ATmega328P. There are tons of other microcontroller platforms that we could have chosen to use, each with different attributes. One of the main reasons we chose to go with the Arduino ATmega328P, is that it is cheap and in stock. Due to the pandemic, and other factors, certain electronic components are still hard to find.

Microcontroller	Pros	Cons
Arduino	• Cheap • Small form factor • Experienced in program language • Extensive library selection • In stock	• Not as capable as other options • No onboard USB • No onboard Bluetooth
MSP430	• Cheap • Very power efficient • More extensive control/ capabilities • Onboard indicator LED's	• Not in stock • Less experienced in the program language • No onboard USB • No onboard Bluetooth

Raspberry Pi	• Onboard USB 3.0 connections • Onboard video • Used more as a learning tool • Bluetooth 5.0	• More expensive due to supply issues • Less experienced in the program language

Table 1: Microcontroller Pros and Cons

The main functions of the microcontroller in the blaster will be sending and receiving IR signals. Every trigger pull should cause the microcontroller to enable the IR emitter and keep track of how many shots are left. The blasters microcontroller will also handle every aspect of laser tag, as well as the mode selector. The Texas Stars microcontroller will function in a way that once a hit is detected, it will deactivate the electromagnet, causing the plate to drop.

Model	ATmega328P	MSP430FR6989	Raspberry PI
Clock Speed	16 MHz	16 MHz	1 GHz
Vsupply (V)	1.8-5.5	1.8-3.6	1.8-3.3
Current draw (mA)	0.5-1.4	1.6	540
Storage	4 KB	Unified with RAM	4 GB
RAM	8 KB	128 KB	1 GB

Table 2: Microcontroller Specifications

The Arduino ATmega328P is a very solid choice for our project. It has enough processing power for what we are looking for, as well as a small power draw. The onboard storage and RAM is a little on the lower end, but we believe it will be sufficient for our applications.

The MSP430FR6989 is another good option for us. However, we didn’t feel as comfortable programming it. Even though it has very similar clock speeds, required voltages, and power draw, the complicated programming language is ultimately why we choose to go with a different platform.

The Raspberry PI had the highest clock speeds, storage, and RAM of any of the options. But we felt that it was way overkill for what we were looking at doing. There are a ton of features that it offers that we just don't have a need for, such as hdmi, and usb connections.

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage	7-12V
Analog input pins	6
Digital I/O pins	14
PWM Digital I/O pins	6
DC Current per I/O pin	20mA
Flash Memory	32 KB
Clock Speed	16 MHz
Size	68.6 x 53.4 mm
Weight	25 g

Table 3: Full Technical Specs for an Arduino ATmega238P

After reviewing the pros and cons, from Table 1, of each microcontroller, as well as the exact specifications of each chip,from Table 2, we have decided to go with the Arduino ATmega328P. Arduino is a platform that our group feels extremely comfortable in programming with. There are also plenty of online libraries and guides to help us along the way. A big reason we decided to use the Arduino ATmega328P instead of the MSP430 is that the MSP430 is out of stock, and has a very long lead time. The ATmega328P is in stock now.

During the actual construction of the prototype, the stock ATmega328P as well as USB connectors for them was fluctuating, and the decision was made instead to purchase and use the entire Arduino Nano boards which utilize the same core processor. With these being available in great numbers with two-day shipping it made building the prototypes much less threatened by online stock and shipping lead times.

2.4.1.4 Electromagnet

For our project, we will use electromagnets to hold the plates of the target. We have to find an electromagnet that is strong enough to hold the plates to the target, while not being excessively strong either. We estimate that each plate will weigh around two pounds, so with that in mind the magnet should have a holding force around 5 lbs just to be safe. The DFR0794 electromagnet has a holding force of 3 kg, which is about 6.6 pounds. We choose these magnets because they are relatively cheap, and operate at 5V.

2.4.2 Non Functional Requirements

This section will outline the features of each component that the project does not need to be considered functional. These requirements consist of things such as, quality of life, aesthetics, and conveyance of use.

2.4.2.1 Laser Gun

The laser gun should have an appearance similar to a real firearm, while also being obvious that it is just a toy. Meaning that the body itself can resemble a real gun, except that if it does, it would have to have an orange tip. According to federal law, airsoft guns should be equipped with a minimum 6 millimeter wide orange tip. This law is in place to make it easier to differentiate between a real firearm and an airsoft or laser tag gun.

For our prototype of the laser gun we intend to go above and beyond what is currently being offered on the market. While similar products to ours focus on function we intend for our blaster to have a good deal of form as well. Our laser gun controller will be shaped in such a way to give the user good ergonomics and make the device much more comfortable to handle. This has also been a consideration when mapping the layout of the laser gun controller as we are housing the power supply, which is one of the heaviest parts of the system, in the pistol grip to allow the user to have good control over the center of gravity of the controller.

We will also be adding a section of picatinny rail to the top of the laser gun controller. This will allow for the mounting of many different optic options, and especially adjustable ones so that the user can ensure the laser gun is shooting where they are aiming at. This is much more effective than trying to create some kind of rudimentary fixed sighting system that neither the manufacturer ,nor the user, have any way of adjusting.

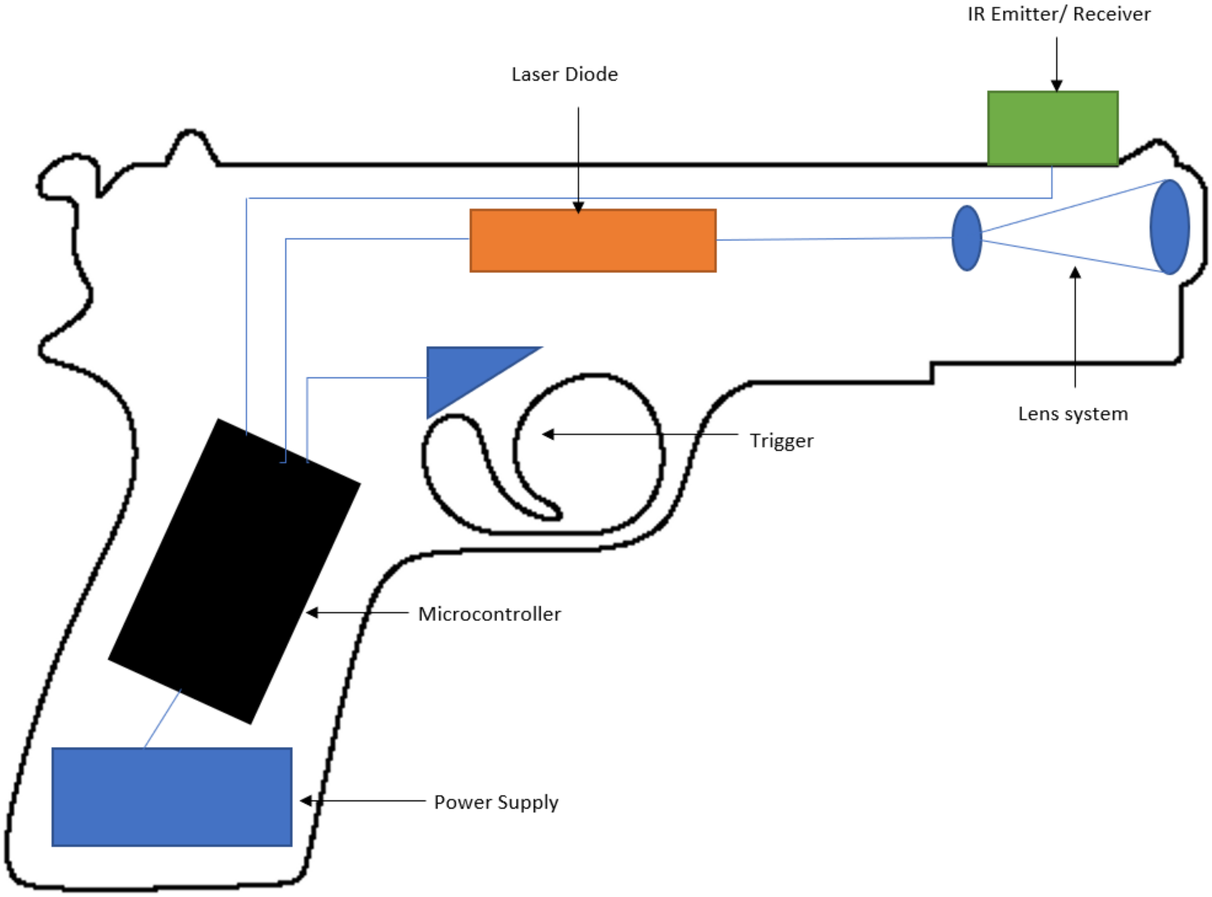


Figure 1: Approximate Blaster Design

2.4.2.2 Texas Star

A Texas Star is a shooting target that has five plates that need to be cleared as fast as possible. Each of these plates will have an IR receiver, circuit board, and electromagnet. But as far as non functional components, the exact look and size doesn't really affect the performance in any way. We are planning on making each target plate about six inches diameter, and the whole target will stand 4 feet tall.

While it is ideal for the Texas Star to spin it is not a function requirement for the reason that the mechanical design of the Texas Star is not part of the proof of concept of our design. While

we understand roughly how the components of the star need to be made so that it will spin, we are not well-educated in that field. What we are trying to simulate in our design is the action of the bullet hitting the plate and causing it to fall from the Texas Star. So, if the final design of the Texas Star does not spin as the real one does, we may choose to either leave it in its dysfunctional state, or add a simple DC motor that will spin the Texas Star and there will at least be a moving target to challenge the user.

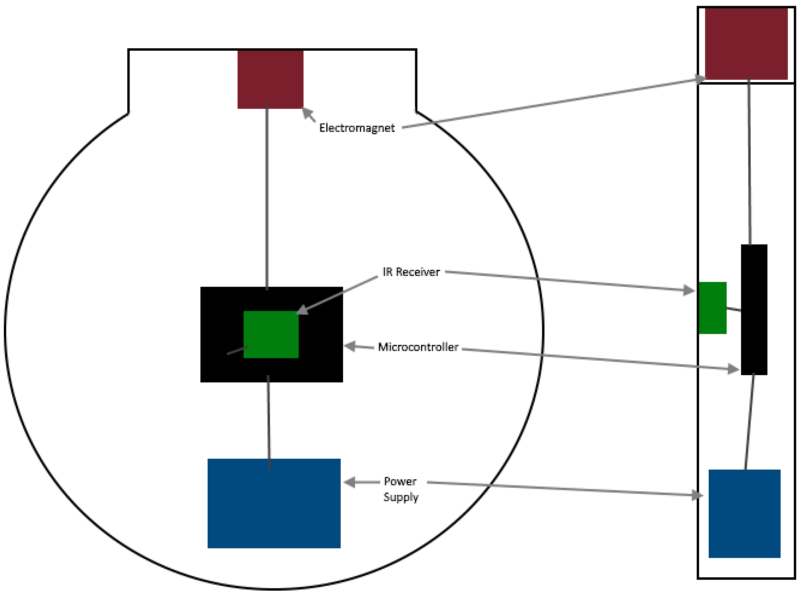


Figure 2: Approximation of Plate Design

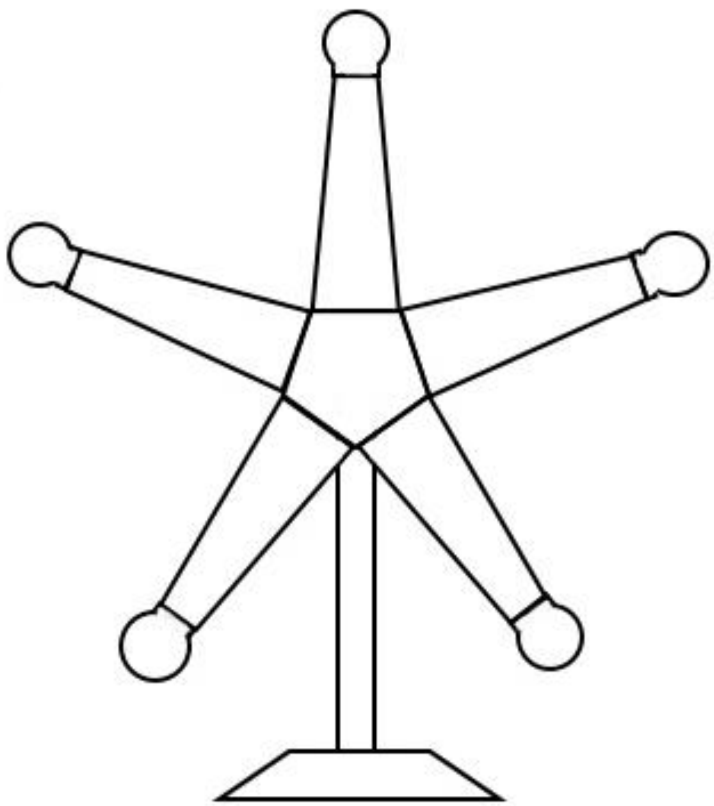


Figure 3: Approximation of Texas Star Design

2.4.2.3 Microcontroller

The microcontroller will consist mainly of functional requirements. There is not really anything functional to figure out. The blaster will have to be able to detect a trigger pull, which would then cause the IR emitter to turn on for a short amount of time, be able to detect a hit and reduce the health accordingly. It will also have an ammo counter for every time you fire, and have to reload once the player runs out of ammo. The blaster will have a mode selector for if the player chooses team mode, free for all, one in the chamber, or target shooting modes.

For the Texas Star the microcontroller will only need to take input and perform a few actions in response. These actions include: switching on LEDs and turning off the electromagnet. In addition the microcontroller must remain on and keep the electromagnet on until the IR beam from the blaster is detected.

2.4.3 Functional and Non-functional Requirements: Addendum

By meeting these functional requirements, Our system is able to provide an engaging and interactive shooting experience for users.The system should provide real-time feedback to the user, indicating whether the laser gun has hit the target or not. The user should also be able to control the speed and direction of the Texas star using the microcontroller.The system should include 5 electromagnets, each powered by a 5-volt battery, capable of generating enough magnetic force to operate the Texas stars functionality.The system should be controlled by an Arduino ATmega328P microcontroller, which will serve as the brain of the system, allowing for real-time control of the electromagnets and Laser gun.The system should include a functional Laser gun that is capable of emitting, receiving and can be aimed at a target. The laser gun should be triggered by a button connected to the microcontroller soldered onto our board as well. Our final design ended up being an edited shell of an already made Laser Gun called the *NERF Laser OPS PRO* which was always an option initially. The system should also include a functioning Texas star, which is a target used in shooting sports. The Texas star should be mounted on a pivot point and rotate when hit by a laser beam making the difficulty of each shot harder once a leg of our star was disassembled from the system which also worked as we initially thought.

2.5 Quality of House Analysis

QFD: House of Quality C. Battles. (2011, May). QFD House of Quality Template. Schrodinger's Ghost.com [Online]. Available: http://www.schrodingersghost.com/?cat=54.

Project: Vest Free Laser Tag and Texas Star

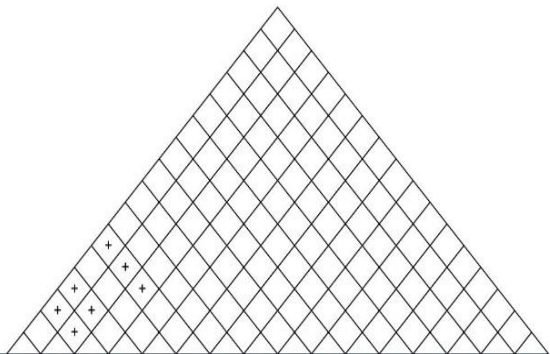
Revision: Original

Date: 10/6/22

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

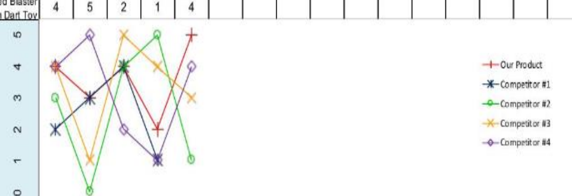
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Category	Weight	Customer Requirements (Explicit and Implicit) \ Engineering Requirements	1 Create Working Laser emitter/receiver	2 Have a functioning game mode select	3 Create working receiver for Texas Sta	4 Create a mechanism on Texas Star Ta	5 Create laser blaster with variable "mag	6	7	8	9	10	11	12	13	14	15	16	Our Product	Best Choice Products Set of 4 Infrared Laser Tag Gun Set for Kids	X-Shot Laser Tag - 4 Laser Tag Guns & 360° Sensor Goggles -	Laser X Revolution Two Player Laser Tag Gaming Blaster Set	Worker MOD Nightingale Motorized Blaster with Orange Muzzle Short	Row #
		Direction of Improvement	▲	◇	◇	▲	▲																	
Safety	8	Customer shall choose laser blaster with variable "magazine" sizes	●	○	●	●	○												4	2	3	1	5	1
	2	Customer shall choose a game mode	●	○	●	●	●												3	2	1	5	3	2
	4	Customer shall have a displayed player health and ammo capacity on the blaster	○	●	○	●	●												1	2	4	0	3	3
		Plate lights up from feedback of the shot hit	○	○	●	▽	○																	4
																								5
																								6
																								7
																								8
																								9
																								10
																								11
																								12
																								13
																								14
																								15
																								16

Customer Competitive Assesment

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Target	Target for Functional Requirement #1	Target for Functional Requirement #2	Target for Functional Requirement #3	Target for Functional Requirement #4	Target for Functional Requirement #5											
Max Relationship	9	9	9	9	9											
Technical Importance Rating	#REF!	#REF!	#REF!													
Relative Weight	#REF!	#REF!	#REF!													
Weight Chart	#REF!	#REF!	#REF!													
Our Product	4	3	4	2	5											
Best Choice Products Set of 4 Infrared Laser Tag Gun Set for Kids & Adults w/ Multiplayer	2	3	4	1												
X-Shot Laser Tag - 4 Laser Tag Guns & 360° Sensor Goggles - Ultimate Laser	3	0	4	5	1											
Laser X Revolution Two Player Laser Tag Gaming Blaster Set	4	1	5	4	3											
Worker MOD Nightingale Motorized Blaster with Orange Muzzle Short Foam Dart Toy	4	5	2	1	4											



Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Template Revision: 0.9 Date: 4/23/2010
Christopher Battles

2.6.1 Project Description Summary

In section 2 we discussed the essential elucidation of the project system such as our non-functional requirements like the Quality of House analysis necessary for our design and microcontroller which consist mainly of functional requirements. There is not really anything functional to figure out. The blaster will have to be able to detect a trigger pull, which would then cause the IR emitter to turn on for a short amount of time, be able to detect a hit and reduce the health accordingly. It will also have an ammo counter for every time you fire, and have to reload once the player runs out of ammo. The blaster will have a mode selector for if the player chooses team mode, free for all, one in the chamber, or target shooting modes.

We also discussed our Texas Star which we said is a shooting target that has five plates that need to be cleared as fast as possible. Each of these plates will have an IR receiver, circuit board, and electromagnet. But as far as non functional components, the exact look and size doesn't really affect the performance in any way. We are planning on making each target plate about six inches diameter, and the whole target will stand 4 feet tall. The design of our Laser Gun which should have an appearance similar to a real firearm, while also being obvious that it is just a toy. Meaning that the body itself can resemble a real gun, except that if it does, it would have to have an orange tip. In our Functional Requirements sections we discussed our laser gun which in regards to our output laser blaster should produce an IR beam, meaning we can not just use a laser as the emitter.

Some lasers are very powerful, and can even damage peoples eyes. To avoid this and make our product safe for use, we will use an IR emitter and receiver. IR is undetectable by the human eye, and has no risk of damaging people's eyes. The beam also needs to be concentrated, both for distance and accuracy. We will not have to deal with which exact photodiode was hit, just as long as one is, the system will register a hit.

The blaster should also be responsive to inputs, such as trigger pulls. When a trigger pull is detected by the microcontroller, it should trigger then the infrared emitter to turn on for a certain amount of time, resulting in a shot being fired. Within the code on the microcontroller it should check and display how much ammo is available, and subtract one after each shot is taken.

The Texas Star has two big functional requirements that we will need to meet. Being able to detect when a plate has been hit, and trigger the electromagnet to release the plate. In order to identify hits, each of the five plates will have an IR receiver and a small circuit board whose only purpose is to disable the electromagnet when a hit is detected. For our project there will be a total of six to seven microcontrollers. We will make three different blasters, one for each member of the group to test. Each of the five plates on the Texas Star will have its own microcontroller. The ones used in the blaster will basically be for controlling every aspect of laser tag, and mode selector. While the Texas Star's microcontrollers will just have to detect a hit, and release the electromagnet. For this element, we decided to base our design off of the Arduino

ATmega328P. There are tons of other microcontroller platforms that we could have chosen to use, each with different attributes. One of the main reasons we chose to go with the Arduino ATmega328P, is that it is cheap and in stock. Due to the pandemic, and other factors, certain electronic components are still hard to find. Overall this section was effectively able to overview our Laser tag system to its entirety adequately.

2.6.2 Project Description Summary Addendum

Overall, we discussed the functional requirements for our Laser Tag system, including the laser gun, Texas Star target, and microcontroller. For the laser gun, our functional requirements included the ability to detect trigger pulls, emit an IR beam when fired, and detect hits on the target using an IR receiver. The gun also needed to have an ammo counter and a mode selector for different game modes. Additionally, we emphasized the importance of safety and chose to use an IR emitter instead of a laser to avoid potential harm to users' eyes. We also outlined the functional requirements for the Texas Star target, which included the ability to detect hits on each of the five plates and trigger the electromagnet to release them. To achieve this, we incorporated an IR receiver and circuit board on each plate to disable the electromagnet when a hit was detected. Finally, we discussed our choice of microcontroller for the system, which was based on the Arduino ATmega328P. The microcontroller was responsible for controlling all aspects of the laser tag game, including the laser gun, Texas Star target, and mode selector. We chose this microcontroller due to its availability and affordability, given the challenges of obtaining electronic components during the pandemic. In conclusion, our Laser Tag system successfully met all of its functional requirements, including the ability to detect hits, emit IR beams, and track ammo count. We also achieved our goal of creating a safe and engaging game for users.

3. Research related to Project Definition

For this section of our senior design document, we will look into the various subsystems necessary for a laser tag system. In this section, we will research similar projects that have been done in the past, or similar products that already exist. Which will help in the design and execution of our Laser Tag and Texas Star. Through our research, we will see what has, and hasn't worked in the past, and the most efficient way to accomplish the desired results. This will allow us to build our project in the most efficient way. There are already tons of different laser tag systems on the market, but we choose to model or off of the Nerf Laser Ops Pro.

3.1 Similar Projects and Products

There are all sorts of different laser tag systems on the market nowadays. Most laser tag systems are the type where the blaster and the vest are separate. Just about every place a person can go to play laser tag, uses this system. However, we will be focusing on integrated systems. Like the NERF Laser Ops Pro, it is a relatively new technology where the hit receiver is attached to the top of the gun, instead of wearing a vest. This method makes it so players can't just shoot over or around walls, they have to actually engage in player to player. We will be heavily basing our project off of this. The Nerf blaster has a health system, ammo and reload system, game mode selector, and LED and sound hit indicators. We are planning to have very similar features with our project.

Figure 4: Nerf Laser Ops Pro

Another laser shooting technology is called LaserHit. They are a company that allows firearm training from your own home. LaserHit uses a special ammo cartridge that produces a laser and gives you a score based on your accuracy. Their technology basically just turns a real gun into a laser gun for safe training at home. This is similar to our Texas Star idea, but instead of getting a score for accuracy, you'd just have to clear all the plates as fast as you can.

There have been a few other laser shooting projects in the past couple of years. Such as “Laser Target Gallery” and “Wirelessly Connected Laser Shooting Gallery”. Both of these projects focused solely on target shooting and accuracy. The Texas Star part of our project will be pretty similar to those two, but the laser tag portion is entirely different.

For our project we were essentially planning on taking the chip from an Arduino Uno and recreating our own board. However, Arduino already makes something like this, it's called the Arduino Make Your UNO Kit. It comes as a blank circuit board, with all components we would need. You would then have to follow the directions and solder all the components onto the board, giving you a fully functional Arduino Uno. We will still have to design our own, but this will greatly help us in deciding how to lay out our board and what exact components we'd need to buy. The kit will tell us the exact resistors, diodes, various capacitors, socket and microcontroller that we will need. The full schematic and datasheets are posted online, which should really assist us in designing our board. Basically keep the parts we actually need, and remove the rest that we don't.

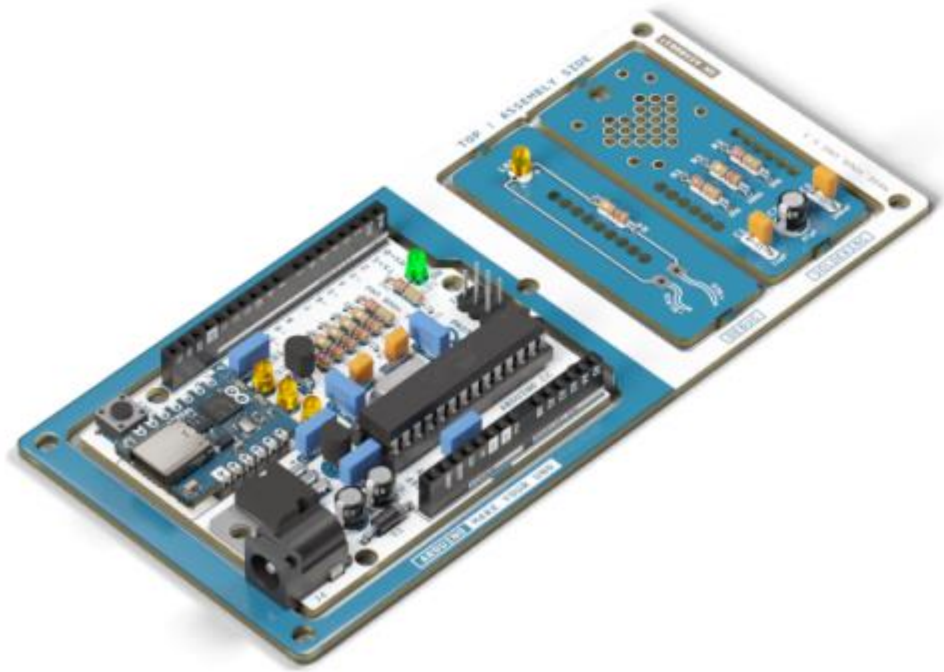


Figure 5: Arduino Make Your UNO

3.2 Relevant Technologies

IR transmitters and receivers have been around for years, and there are multiple ways of sending and receiving IR. Remotes use IR receivers, such as the TSOP1738, which can sense modulated IR pulses and convert them into electrical signals. An IR LED emits infrared light, which can not be seen by the human eye, but can be seen by a receiver.

There are various ways to detect infrared light, using: IR LEDs, diodes, photoresistors, and transistors. Photoresistors have a relatively slow response time. Below we will talk a little about how each one works, as well as their strengths and weaknesses.

3.2.1 Laser Diode

Laser Diodes are Light Amplification by Stimulated Emission of Radiation, which are typically p-n junction semiconductor devices. Laser Diodes are the most popular type of laser produced. They are very similar to Light Emitting Diodes (LEDs), with a few drawbacks. Due to the small surface area of Laser Diodes, thermals become a concern. Figure 5 shows the common structure of a PN junction Laser Diode.

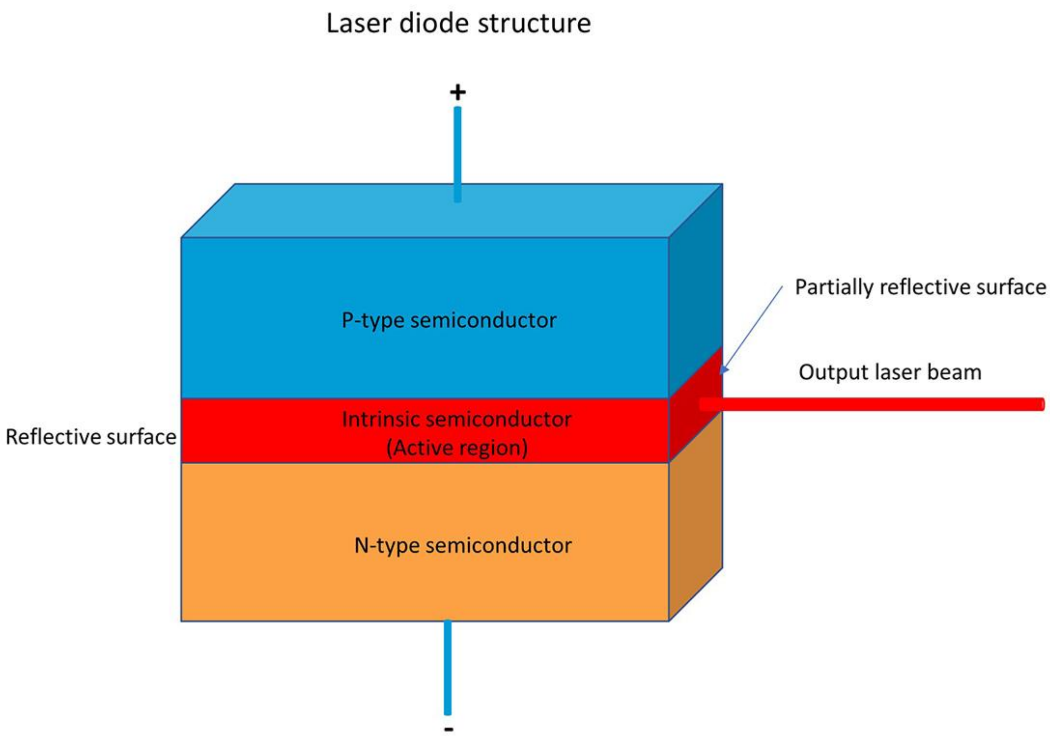


Figure 5: Structure of a Laser Diode

3.2.2 Ways to Sense Light

In this section we will talk about various ways to sense light. There are many different ways to sense light, including photoresistors, photodiodes, and phototransistors. We will discuss how each functions, and some possible intended purposes of each.

Photoresistors:
A photoresistor, also known as light dependent resistors (LDR), is a passive component that has a decrease in resistance, when there's an increase in light intensity. The resistance is the inverse of the light intensity. Meaning, when they are in very bright light, their resistance value can drop to just a few ohms, while in the dark, the resistance value is at a maximum of up to 1 Mega ohm.

There are two types of photoresistors, intrinsic and extrinsic. Intrinsic photoresistors use undoped materials, such as silicon or germanium. Photons that hit the photoresistor, cause the electrons to move from the valence band, to the conduction band. This results in more free electrons carrying current, resulting in lower resistance. Extrinsic photoresistors are doped with impurities, which create a new energy band above the existing valence band. The electrons require less energy to move between bands due to the lower band gap. This results in the extrinsic photoresistor being sensitive to different wavelengths of light. However, both types will have a decrease in resistance, with an increase in light intensity.

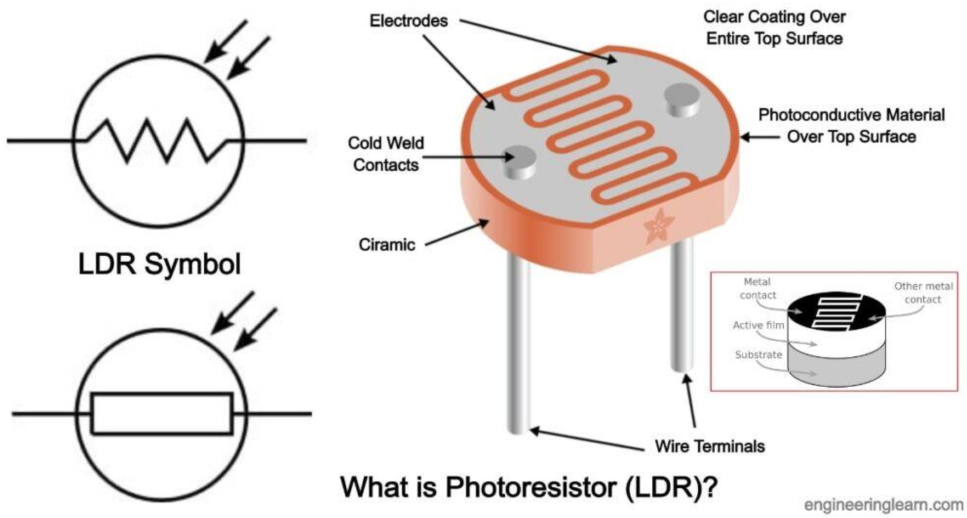


Figure 6: Structure of a Photoresistor

Photodiode

A photodiode is a P-N junction, semiconductor device, that converts light into electrical energy. The P layer has an abundance of holes, while the N layer has an abundance of electrons. Photodiodes can be made from a variety of materials, Silicon, Germanium, and Indium Gallium Arsenide. Each material has different properties, response time, noise levels, and sensitivity. A depletion region is formed from diffusion of electrons that move from the N layer to the P layer, and the diffusion of holes from the P to N layers. This results in a region where no free carriers exist. An electric field is created across the depletion region due to built in voltage. Allowing current to flow in one direction, anode to cathode. A photodiode can be forward biased, however the current will flow in the opposite direction. As a result, most photodiodes are reverse biased, or not biased.

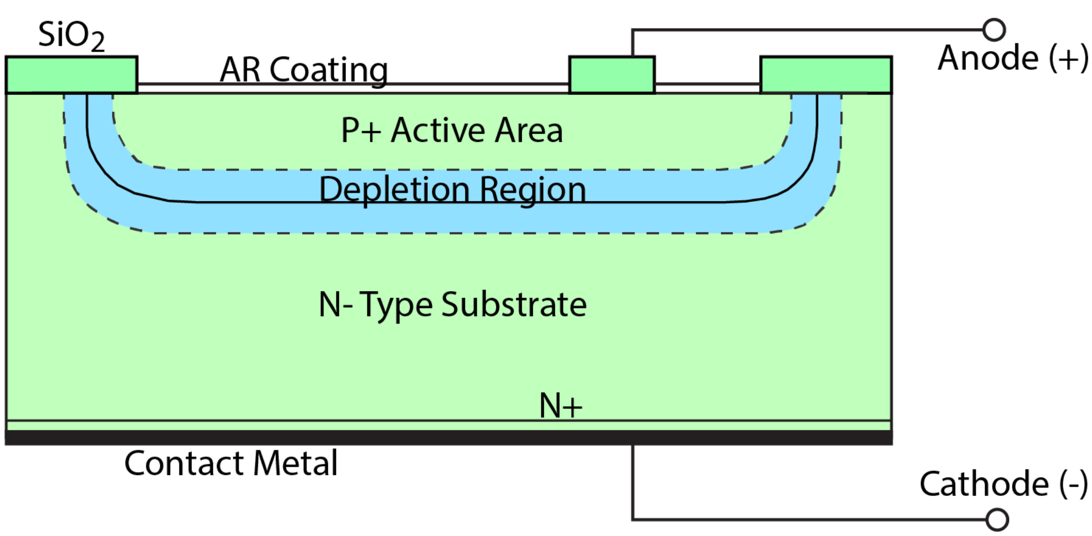


Figure 7: Structure of a Photodiode

Phototransistor

A phototransistor is a semiconductor device that is capable of sensing light levels, and altering the current flowing through the emitter and collector according to the light it receives. While a phototransistor and a photodiode are both capable of sensing light, the phototransistor is more sensitive because it is a bipolar transistor. This makes a phototransistor more suitable in a number of different applications. While all bipolar transistors are light sensitive, phototransistors are a specialized type of bipolar transistors. They have been optimized for being sensitive to light, which makes them ideal for light sensing applications.
Phototransistors are widely available, and can be obtained at a very low cost.

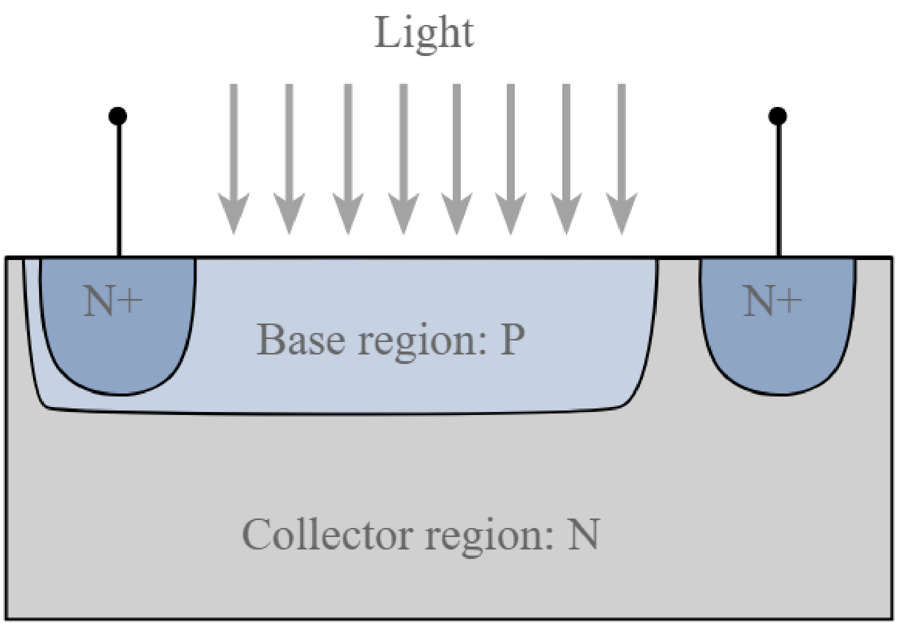


Figure 8: Structure of a Phototransistor

3.3 Strategic Components and Part Selections

In this section we will discuss possible parts and components that we will use in our project. The first major decision is which microcontroller platform we would be using. The three main ones available are Arduino, Texas Instruments MSP430, and Raspberry Pi. Each has positives and negatives for what we are trying to accomplish. We will discuss the differences later in this report. Due to the global pandemic, and ship shortages over the last few years certain electronic devices are still very hard to find. However, at the end of the day we have decided to base our project around the Arduino Uno Rev3. We choose this one because at the time of looking, many integrated circuits are still unavailable or have very long lead times. The Arduino Uno Rev 3 comes as an integrated circuit, or as a PIC microcontroller. We chose to use this due to the fact that they are actually in stock.

The exact microcontroller is the ATMEGA328P-PU Arduino Bootloader. This chip operates at 5V, allows for 14 digital pins, 6 of which are PWM, 6 analog input pins, 32KB of memory. In order to attach this to our board, we will use an ED281DT, which is basically just a 28 pin socket for the ATMEGA328P-PU Arduino Bootloader to slot into. We chose the ATMEGA328P because it has all of the features we will need, is actually in stock, and we feel very comfortable in the programming environment. For this project, we will need to create three of the exact same board, one for each blaster. As well as a slightly simplified board for the targets. While the boards in the blasters themselves are going to be fairly complex, the targets will be more straightforward. They will just have to detect a hit, and activate the electromagnet. Which will cause the plate to drop off, and the system to start spinning.

For the emitter and receiver, we will use the TSOP38238 IR receiver and the TSAL6200 emitter. The receiver has an operating voltage of 2.5-5.5V, transmission range of 45 meters, which is about 50 yards. A carrier frequency of 38KHz. The emitter has an operating voltage of 1.35V, with a wavelength of 940nm.

3.4 Software Comparison

In this section we will discuss how our software compares to other products out there. We will focus on the Nerf Laser Ops because it is the most similar to our project goals. The Nerf laser blaster has many features that we are looking into implementing into our own design. When you first turn on the blaster, you have to first select which game mode you are going to play, whether that be team mode or free for all. The mode/ team you are selecting is displayed by an LED on top of the blaster. Red is red team, blue is blue team, and purple is free for all. Their blaster also has a health and ammo status leds, indicated by green being all good, yellow being low ammo or health, and red being out of ammo or extremely low health. The blaster also has a built-in ammo counter, and reload button to simulate real life. On the side of the blaster is a speaker for audible recognition, both when shots are fired and when you get hit. Alongside the speaker sounds when you get hit, the top of the blaster also lights up.

For our design we are planning to implement a large number of these in our project. We are looking to have a similar game mode system, team vs team, free for all. However, ours will differ in that we will have a game mode called one in the chamber, where you only get one shot each time you reload. This is a popular mode from various first person shooter games. Another way ours will differ is that we will have a mode just for target shooting. Our target will be a texas star, which will require completely different circuit boards and code from the blaster. Each plate of the texas star will have its own mini board, to basically detect and hit, and release the magnet that's holding it to the stand. Our blaster will also have a led indicator for health and ammo, just as the Nerf blaster does. At this time, we are not planning to implement a speaker into our design. But we will have LEDs on the blaster that light up when shot.

3.5 Research Summary

To summarize our vital research section of this document We've discussed There are all sorts of different laser tag systems on the market nowadays. Most laser tag systems are the type where the blaster and the vest are separate. Just about every place a person can go to play laser tag, uses this system. However, we will be focusing on integrated systems.

Like the NERF Laser Ops Pro, it is a relatively new technology where the hit receiver is attached to the top of the gun, instead of wearing a vest. This method makes it so players can't just shoot over or around walls, they have to actually engage in player to player. We will be heavily basing our project off of this. In our project we were essentially planning on taking the chip from an Arduino Uno and recreating our own board. However, Arduino already makes something like this, it's called the Arduino Make Your UNO Kit. It comes as a blank circuit board, with all components we would need. IR transmitters and receivers have been around for years, and there are multiple ways of sending and receiving IR. Remotes use IR receivers, such as the TSOP1738, which can sense modulated IR pulses and convert them into electrical signals. An IR LED emits infrared light, which can not be seen by the human eye, but can be seen by a receiver.

We also inspected research on our Laser Diodes which are Light Amplification by Stimulated Emission of Radiation, which are typically p-n junction semiconductor devices. Laser Diodes are the most popular type of laser produced. Research in our programming was done in section 3 as well. The Nerf laser blaster has many features that we are looking into implementing into our own design. When you first turn on the blaster, you have to first select which game mode you are going to play, whether that be team mode or free for all. The mode/ team you are selecting is displayed by an LED on top of the blaster. Red is red team, blue is blue team, and purple is free for all. Their blaster also has a health and ammo status leds, indicated by green being all good, yellow being low ammo or health, and red being out of ammo or extremely low health. The blaster also has a built-in ammo counter, and reload button to simulate real life. On the side of the blaster is a speaker for audible recognition, both when shots are fired and when you get hit. Alongside the speaker sounds when you get hit, the top of the blaster also lights up. We also discussed possible parts and components that we will use in our project. The first major decision is which microcontroller platform we would be using.

The three main ones available are Arduino, Texas Instruments MSP430, and Raspberry Pi. Each has positives and negatives for what we are trying to accomplish. We will discuss the differences later in this report. Due to the global pandemic, and ship shortages over the last few years certain electronic devices are still very hard to find. However, at the end of the day we have decided to base our project around the Arduino Uno Rev3. We choose this one because at the time of looking, many integrated circuits are still unavailable or have very long lead times. The Arduino Uno Rev 3 comes as an integrated circuit, or as a PIC microcontroller. We chose to use this due to the fact that they are actually in stock. The exact microcontroller is the ATMEGA328P-PU Arduino

Bootloader. This chip operates at 5V, allows for 14 digital pins, 6 of which are PWM, 6 analog input pins, 32KB of memory. In order to attach this to our board, we will use an ED281DT, which is basically just a 28 pin socket for the ATMEGA328P-PU Arduino Bootloader to slot into. We chose the ATMEGA328P because it has all of the features we will need, is actually in stock, and we feel very comfortable in the programming environment.

For this project, we will need to create three of the exact same board, one for each blaster. As well as a slightly simplified board for the targets. While the boards in the blasters themselves are going to be fairly complex, the targets will be more straightforward. They will just have to detect a hit, and activate the electromagnet. Which will cause the plate to drop off, and the system to start spinning. A photoresistor, also known as light dependent resistors (LDR), is a passive component that has a decrease in resistance, when there's an increase in light intensity. The resistance is the inverse of the light intensity. Meaning, when they are in very bright light, their resistance value can drop to just a few ohms, while in the dark, the resistance value is at a maximum of up to 1 Mega ohm. This overview of our required research is essential to our design.

3.6 Research Addendum

Research is a crucial aspect of any project, especially when it comes to designing a complex system such as an integrated laser tag game. In our senior design project, we have performed extensive research on various aspects of laser tag technology to create an integrated laser tag system. One of the significant areas of research we conducted was on different laser tag systems available in the market. We found that most laser tag systems use separate blasters and vests, but we focused on integrated systems like the NERF Laser Ops Pro. We were impressed by the top-of-gun hit receiver design that promotes player-to-player engagement, and we incorporated this design in our project. We also researched different microcontroller platforms to determine the most suitable for our project. The Arduino, Texas Instruments MSP430, and Raspberry Pi are the three main platforms available. After analyzing the pros and cons of each platform, we decided to use the Arduino Uno Rev3. This decision was based on the availability of integrated circuits and our comfort level with the programming environment. Our research also included an in-depth study of laser diodes, which are the most popular type of laser produced. We explored the various components we would need for our project, such as IR transmitters and receivers, which have been around for years, and there are multiple ways of sending and receiving IR. Additionally, we examined the features of the NERF laser blaster, which we plan to implement into our design. The blaster has various features such as health and ammo status LEDs, a built-in ammo counter, and a reload button. We also researched possible parts and components we will use in our project, such as the ATMEGA328P-PU Arduino Bootloader microcontroller chip, which operates at 5V, has 14 digital pins, 6 analog input pins, and 32KB of memory.Finally, we researched the components required for the targets in our game. We will use photoresistors, also known as light-dependent resistors (LDR), to detect a hit and activate the electromagnet, which will cause the plate to drop off, and the system to start spinning. Overall, our research was essential to our design, and we used the information to make informed decisions about our project's components and features.

4. Related Standards and Realistic Design Constraints

In section 4 of this document we'll be looking at an overview of relatable standards and design constraints for laser gun system's in today's society. For this section we'll be using a numerous of resources in order to adequately display the different standards of components that we utilized in our system. This will be important as it will help to highlight the set of rules that the design must follow to be consistent with society and the users that will seek to utilize the laser gun.

4.1 Standards

In this portion of section 4 we'll discuss standards on various topics related to the successful build of a laser gun system. In section 4.1 titled *Standards* we'll be looking at an overview of standards used today including titles of current versions of standards used currently and in the past. We'll also be referencing the American National Standards site for relatable standards considered in the U.S. The first standard to speak on is the safety of the group while working with light sensors. As referenced from the American National Standards, the IEC 60825 - Safety of Laser Products Package provides requirements on the safety of various laser equipment and uses for them. It is supported with a compliance checklist, manufacturers checklist and a user's guide. The Safety of Laser Products Package is suitable for providers / recipients of laser service and manufacturers of laser products used in various industries not limited to: research, education, medical and consumer products. ANSI/ESD S20.20-2021
Protection Of Electrical And Electronic Parts, Assemblies And Equipment (Excluding Electrically Initiated Explosive Devices).

This document applies to organizations that manufacture, process, assemble, install, package, label, service, test, inspect, transport, or otherwise handle electrical or electronic parts, assemblies, and equipment susceptible to damage by electrostatic discharges greater than or equal to 100 volts human body model (HBM) and 200 volts charged device model (CDM). Also, protection from isolated conductors is handled by limiting the voltage on isolated conductors to less than 35 volts.

As shown above, the importance of this standard is implemented to ensure that the laser gun created is safe and protectant against any user who wishes to engage with the gun. Without this standard in place, the proposed artifact could pose a serious safety risk to anyone using it. While developing the laser gun, it will be imperative that we design the structure and handle the electrical internals with this in mind.

This next standard is used as a guide to measure methods of laser modules; the DS/IEC 62595-2-4:2020 Display Lighting Unit - Part 2-4: Electro-Optical Measuring Methods Of Laser Module specifies the electro-optical measuring methods of laser modules with multiple laser devices and an optical output for various displays and display lighting applications which require photometric and colorimetric measurements, covering the wavelength range of 380 nm to 780 nm. The module has multiple laser devices such as edge-emitting laser diodes (LDs), vertical cavity surface-emitting laser diodes (VCSELs), or photon up-conversion laser devices including second-harmonic generation (SHG). Due to our need for a phototransistor we will also need to have a standard associated to the topic as well here the IEC 60747-5-7:2016 which specifies the terminology, the essential ratings and characteristics as well as the measuring methods of photodiodes (hereinafter referred to as "PDs") and phototransistors (hereinafter referred to as "PTs"). The next standard that will be vital is a standard associated in PCB and other schematics. The DS/EN 61690-2:2001 Electronic Design Interchange Format (EDIF) - Part 2: Version 4 0 0

This document defines the syntax and semantics for EDIF Version 4 0 0, IEC 61690-2. EDIF Version 4 0 0 addresses EDIF Level 0 and Level 1. EDIF Version 3 0 0 provides support for Connectivity and Schematics; EDIF Version 4 0 0 offers additional capability by providing support for the representation of Printed Circuit Boards (PCBs) and Multi-chip Modules (MCMs) including technology rules and assembly drawings. For our magnets we'll be referencing the AS/NZS 61000.4.1:2006 for Electromagnetic Compatibility (EMC) - Testing And Measurement Techniques - Overview Of IEC 61000-4 Series (FOREIGN STANDARD).

4.1.1 Requirement Standards

We'll now take a closer look at several requirement standards needed to achieve a successful, efficient, and effective Laser Gun System that are used in today's tech world. In this section we'll be discussing soldering standards developed by the IPC titled J-STD-001 where we'll showcase the requirements that J-STD-001 lists out in terms of assembly such as assembly cleaning, assembly protection, and assembly inspection. Numerous in-depth explanations to essential considerations for soldered electronic products including but not limited to Cleaning maintenance and residue requirements, Relevant materials, components, and equipment, Wire and terminal connections, Coating, encapsulation, and adhesives, assembly and soldering requirements, and surface mounting and through-hole components.

General Part Mounting Requirements are also apart of our soldering standards section as several different mounting part requirements are given in this section of the standard such as parts should be mounted so that their markings and reference designators are visible, parts should be mounted with sufficient clearances between themselves and the PCB in order to make adequate cleaning possible, when both through-hole and surface mounted components are used on one PCB, all through-hole components should be mounted on a single side of the PCB, while surface mounted components can go on either side, all components should be mounted and soldered using a process compatible with that specific part, especially if the part is temperature sensitive.

Another standard we'll be analyzing is the IPC's PCB standard. There are several variations of standards related to PCBs indicating the essential steps associated for every stage of the PCB production development process such as the testing processes, designing and manufacturing stages. With our current project PCB standards will be essential to ensure that our board is of the best quality using up to date and relevant standards and components are compatible while attached. The laser standards section is one of the most essential standards within this document due to its emphasis on safety. The need for the standard is associated with the negative results that are made when the laser light is amplified causing radiation to be emitted that is dangerous to humans. Laser standards are approved, classified and recognized by the U.S. Food and Drug Administration as well as the International Electrotechnical Commission (IEC).

4.1.1.1 Soldering Standards

In section 4.1.1 we'll discuss current standards used in today's tech workforce. The following is a look at our first standard that we'll look into is the IPC standard regarding Soldering and component mounting standards that refers to the soldered equipment and electronics titled J-STD-001. Originally released in 1992 as J-STD-001A and has been implemented into multiple different amendments throughout the years and currently under the version title J-STD-001H. Which inaugurates essential soldering practices to present the best and efficient quality and reliability of the soldered products. Within the J-STD-001 standard are numerous in-depth explanations to essential considerations for soldered electronic products as well as products that are non-electronic:

- Cleaning maintenance and residue requirements
- Relevant materials, components, and equipment
- Wire and terminal connections
- Coating, encapsulation, and adhesives
- Assembly and soldering requirements
- Surface mounting and through-hole components

Below will describe the relevance of each standard, the importance, and how it relates to the process of designing the laser gun.

Cleaning Maintenance and Residue Requirements

It's imperative when the laser gun is constructed that the space where the parts are soldered is free of any mechanical debris and cleaned routinely to prevent cross-contamination of metals. If not, then it's possible that the gun could be exposed to environmental hazards or extremities that could render it unsafe. Additionally, while outlandish in nature, the laser gun may take on additional properties that once weren't exclusive, such as flammability or even toxicity.

While there are various ways to ensure that the laser gun is cleaned, including **ultrasonic cleaning** (a process that utilizes sound waves of high frequency to clean deeper parts within the scrubbing solution), the methods will be chosen that will keep the proposed laser gun within standards.

Relevant Materials, Components, and Equipment

Just as important as the cleaning of the materials while undergoing construction is the usage of relevant materials that will help the laser gun to perform at its best. Especially in a post-pandemic world where the relevance of the chip shortage is in full effect, it's even more important that materials are chosen in an efficient manner for development. There's a fine balance that must be achieved between component limitation and gluttony - keeping this in mind will cement the laser gun's design and efficiency. Alongside the materials that are used to develop the gun, it's important that the design and utilization is validated amongst the group to keep in line with the standards of artifact design.

In designing and developing the laser gun, this standard will be adhered to in the utmost importance. Given the finite set of resources the group has access to, it will be a given that the equipment is used to its fullest potential.

Wire and Terminal Connections

With the design of the laser gun, there won't be too many wires that'll need to be connected as the silhouette is purely mechanical - however, for the connections that will need to be made, the security amongst the wires will need to adhere to this standard not only for compliance with J-STD-001, but for the safety of the individuals who plan to use the gun. Wires are extremely sensitive and the potential for energy disruption is especially high. The team is aware of the electrical issues that can arise from incorrect connections, including flammability, that can potentially lead to death, so the importance for this standard to be followed increases tenfold.

Again, with the team's focus on hardware and mechanical connections as opposed to wires, the hope is that this standard will be one that's less likely to be broken. Still, the need to have knowledge of and adherence to the standard is important as safety of the users in using the gun is paramount.

Coating, Encapsulation, and Adhesives

Moving potentially in line with the first standard, the coating, encapsulation, and adhesives used in attaching the components of the laser gun will be followed in parallel. When one thinks about this, it makes sense as well; a clean surface is necessary for the laser gun to be developed without residue cross-contamination and only when the surface is clean should additional coatings or adhesives be applied. Of course, when applying these materials, the team will need to make sure that what's used on the laser gun is documented, validated, and approved amongst the head. Additionally, adhesives used on the gun should be minimal as well since the laser gun will follow a free-flow like design that will keep the utilization of these materials to a minimum.

The case that will be used to encapsulate the laser gun is the most important part as it encompasses the standard in its entirety in terms of what the team will need to follow. In addition to cleaning the surface and constructing the gun with limited contamination, the case will also be compliant with J-STD-001.

Assembly and Soldering Requirements

Perhaps the most important standard for the team to follow, assembling the gun will require pristine care and precision when soldering parts together. In addition to the joining of parts, the security and fitment of each component will need to be analyzed, inspected, calculated, and arranged in crucial detail to limit the amount of soldering errors encountered. The requirements that J-STD-001 lists out in terms of assembly can be dissected into the following: assembly cleaning, assembly protection, and assembly inspection.

Assembly Cleaning: while this was touched on in previous standards, it's worth reiterating that with each attachment and soldering of each part that the laser gun is cleaned thoroughly to remove generated residue from the process.

Assembly Protection: thought of as a two-fold process, when the artifact is assembled, there needs to be protection against the covering of the laser gun used to promote durability and protection against any environmental factors that could cause quality to deteriorate. Through the team's research, resources and materials were discovered that could aid in this protection, one of them including chemical heat-protectant strippers, helping to clean off resident flux left from soldering practices.

Assembly Inspection: when all is said and done, the assembly will need to undergo a critical inspection that will help to validate that the constructed parts fall within all of the assembly standards explained above. In theory, if one kept up with cleaning the residue of the soldiering job and reinforcing attachments then the assembly would pass inspection. Figure 5 below shows a pictorial representation of an assembly that would pass inspection with the validations laid out and multiple assemblies below that fail inspection for various reasons.

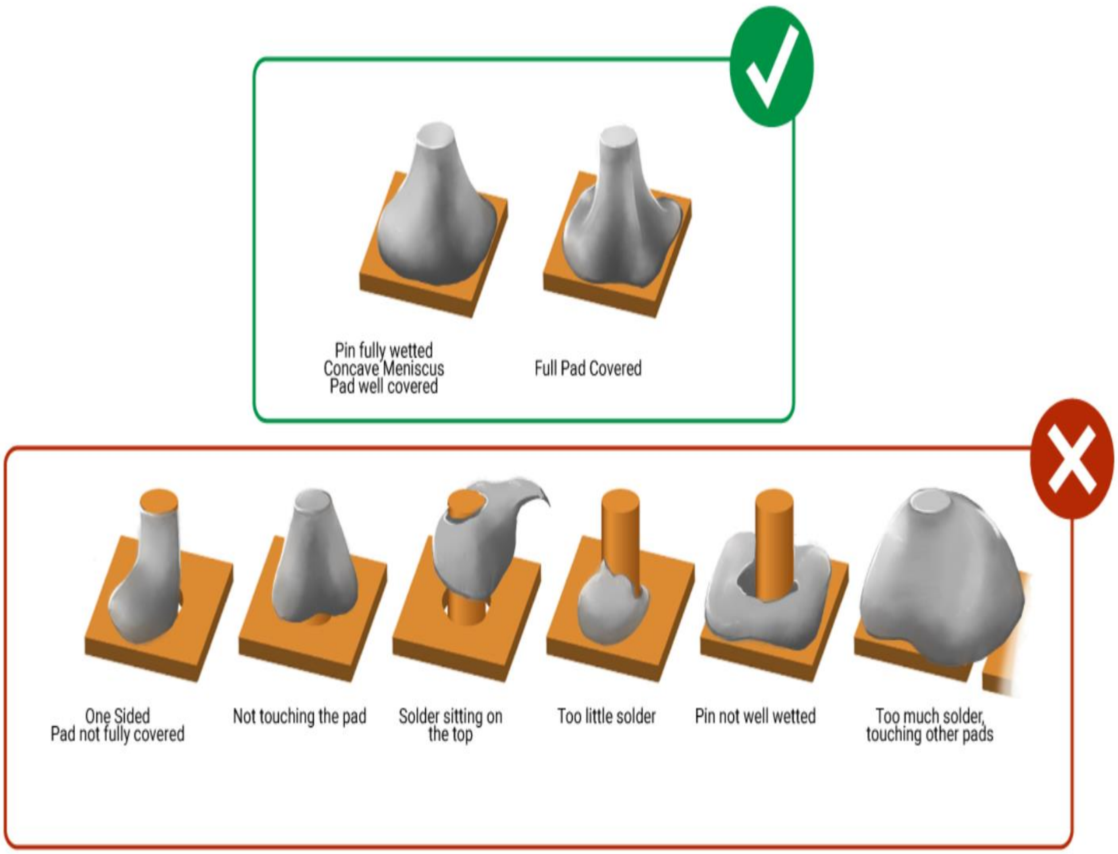


Figure 9: Examples of assemblies that would pass/fail inspection.

Surface Mounting and Through-Hole Components

Before expanding on the approach that would be used for the laser gun's construction, it's important that the distinction between surface mounting and through-hole components is made. Through-hole component mounting refers to the process where the components run through the hole. There are advantages to this type of construction, ranging from artifacts that would be better suited to handle environmental trauma to frames to the ease of testing that may be beneficial to provide proof-of-concept reflections of the artifact. In situations where the customer may prefer a tangible item to gauge engineering decision on, through-hole mounting would grant the builders the ability to quickly swap breadboards and resume working.

Surface mounting, on the other hand, follows a paradigm native to the term, mounting the components on the surface. In following this method of construction, the team is granted a slew of improvements, including:

Quicker setup times. With mounting components on the surface, one wouldn't need to map out a component path of attachment like the through-hole construction mechanism since the surface would serve as the structure for the component flow. This can prove advantageous when needing to ramp up quickly and deliver value for artifacts.

Reduced board cost. As the through-hole name suggests, the developer would need to drill holes through the PCB in order to attach the components necessary. Surface mounting simply avoids this - because the process of attaching components to the surface is relatively simple, capital isn't required to utilize robotic or automation technology to perform the drilling of the holes. Manual labor can be used to attach components, granting greater flexibility of construction across the board and, in conclusion, cheaper overhead costs.

More compact design. Surface mounting, by nature, is more flexible and lightweight than through-hole mounting because components can be rearranged anywhere on the surface to accommodate design. Different from the former, which requires a defined path to create the holes for component mapping, this can translate to creative PCBs that will support efficiency in form and fashion.

With the above outlined, one can determine that the team will follow surface mounting as the component design paradigm as iterations on the PCB won't be as likely for a more frame-intensive artifact. Regardless, the standards must be adhered to in mounting the components, including cleaning of the artifact and verification of parts used.

With the standards described, the document will now be analyzing the IPC standard available to the public for free, J-STD-001ES, located in the IPC website. Additionally, we'll look at best practices used while soldering components, defined below:

Flux*:* If used, flux should be in accordance with IPC standard J-STD-004: "Requirements for Soldering Fluxes," or an equivalent standard.

This material is used to help aid in cleaning up soldering residue so the solder can produce a more uniform connection and flow throughout artifact connections. While the specific material was not reiterated in *Cleaning Maintenance and Residue Requirements*, it serves as an important tool that the team will be leaning on for development of the laser gun.

Soldering Tools and Equipment*:* Soldering tools and equipment should be selected, used, and maintained in such a way that their use will not damage or degrade components in a way that would prevent them from performing their intended functions.

Through access to the labs provided for our team to develop the laser gun, the practice is one that seems matter-of-fact. Regardless, the materials and equipment used will be stored and cared for to ensure that the structural integrity of them will not be compromised.

Lighting*:* The surface of workstations used for soldering should be well-lit, and the standard states that they should be illuminated to at least 1000 lumens per square meter.

The team understands the importance of well-lit, clearly visible areas for performing soldering jobs and upon connecting parts together, will keep the lighting to the aforementioned metrics listed.

Thermal Protection*:* The heat sensitivity of a component should be identified before it is soldered. When hand soldering, tinning, or reworking a heat sensitive component, measures need to be taken to protect the component. Examples given in the standard of measures that include: a heat sink, a thermal shunt, or preheating.

Touched on a bit in *Assembly and Soldering Requirements,* the laser gun will be constructed with the utmost focus in assembly protection. Thermal protection is important as the wire components inside are sensitive to heat, so the team will be sure to design with protection in mind.

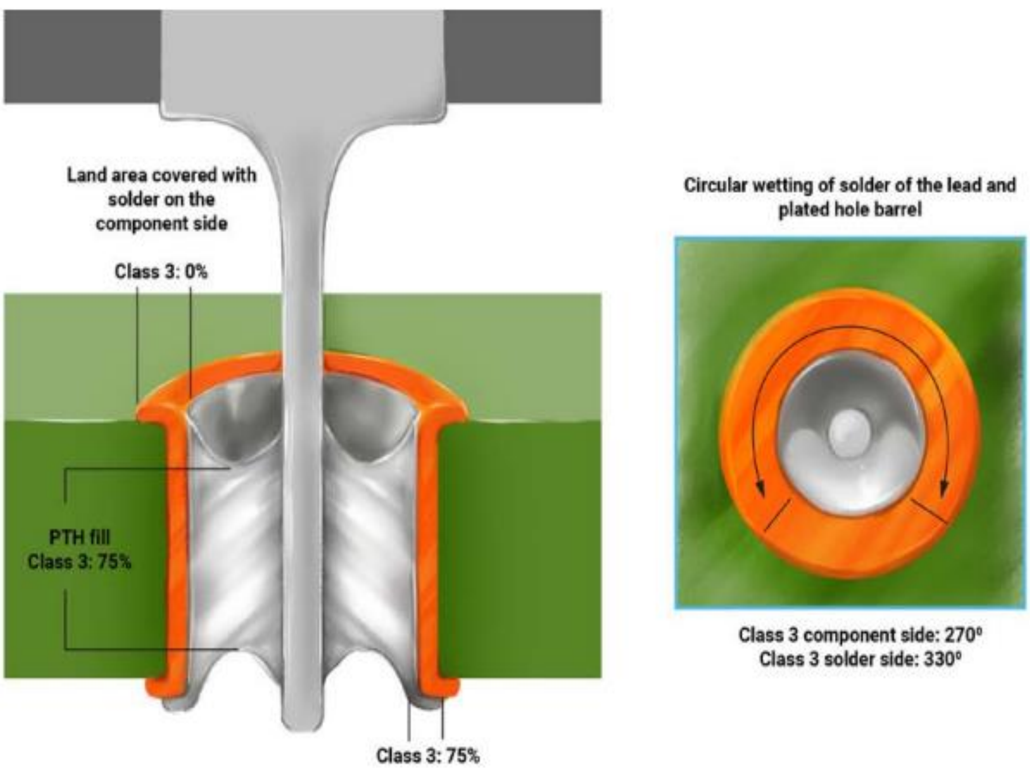


Figure 10: The internals of the solder working with land, showing the structure and fill.

General Part Mounting Requirements*:* A number of different part mounting requirements are given in this section of the standard, so they will be listed briefly below:

- Parts should be mounted so that their markings and reference designators are visible.
- Parts should be mounted with sufficient clearances between themselves and the PCB in order to make adequate cleaning possible.
- When both through-hole and surface mounted components are used on one PCB, all through-hole components should be mounted on a single side of the PCB, while surface mounted components can go on either side.
- All components should be mounted and soldered using a process compatible with that specific part, especially if the part is temperature sensitive.

Solder: Solder alloys permitted by J-STD-001ES are Sn60Pb40, Sn62Pb36Ag2, or Sn63Pb37. High temperature solder alloys such as Sn96.3Ag3.7 may be used only where specifically shown by approved engineering drawings. All soldiers listed in the standard are alloys of tin combined with silver and/or lead. A comparison of lead solder versus lead- free solder will be done below. The standard also states that other solder alloys that are of the same level of quality may be used if all other standards are met and all evidence of quality is reviewed and approved by the user prior to its use.

Lead Solder vs. Lead-Free Solder*:* Both lead solder and lead-free solder have pros and cons that will need to be weighed before making the final decision on which solder to use. Lead solder is still in use in the United States, although it is declining in use due to safety concerns, especially since it was banned in most consumer electronics sold in the European Union in 2006. Lead solder has been used heavily in PCB production because it cools more slowly than other metals, causing less joint cracking, it wets joints well, providing a good electrical connection, and it has a lower melting point than any lead-free alternative,meaning it is less likely to damage heat-sensitive electronic components.

If our group wishes to extend our RoHS compliance beyond components to solder, a lead-free solder will need to be used. The main benefit to lead-free solder is that it is safer, but its main drawback is that it does not have a stable melting temperature, and its melting range is higher than that of lead solder, which can damage PCBs and electronic components.

4.1.1.2 IPC PCB Standards

The Next standard we’ll be discussing is the IPC PCB standard accredited by the American National Standards Institute (ANSI). IPC was originally founded in 1957 called the Institute of Printed Circuits and later changed to Institute of Interconnecting and Packaging Electronic Circuits once it added services that integrated electronic assemblies and packaging from bare boards, its current title now IPC was instilled in 1999. With over 3,000 associates in various areas of the electronics industry within the world, such as board manufacturing companies, suppliers, assembly companies, and design companies. The standards are produced, edited and later voted by a committee of volunteers.

In regards to standards associated with PCBs there are several variations indicating the essential steps associated for every stage of the PCB production development process such as the testing processes, designing and manufacturing stages. With our current project PCB standards will be essential to ensure that our board is of the best quality using up to date and relevant standards and components are compatible while attached as well.

Although IPC standard documents are available for funds for over one hundred US dollars we are able to analyze one available standard by IPC which is both relatable and applicable to our own Laser Gun System titled IPC-221A, is given as a standard that "...establishes the generic requirements for the design of organic printed boards and other forms of component mounting or interconnecting structures." It also covers essential discussions including electrical properties, thermal management, holes and interconnections, quality assurance, materials selection, component and assembly issues and general circuit feature requirements.

4.1.1.3 Laser Standards

Class 4	▪ Unsafe for eye ▪ Unsafe for skin
Class 3B	▪ Unsafe for eye ▪ Safe for skin
Class 3R	▪ Generally safe for eye and skin under specials conditions
Class 2M	▪ Unsafe for eye with viewing aids ▪ Safe for skin
Class 2	▪ Safe with (0,25s) aversion response including viewing aids ▪ Safe for skin
Class 1M	▪ Unsafe for eye with viewing aids ▪ Safe for skin
Class 1	▪ No precautions required

Figure 11: Laser class standard.

In section 4.1.1.3 Laser Standards we'll be discussing standards associated with our laser light. With our laser light being amplified it creates a small and narrow beam of light we'll be using within our Laser Gun system. The need for a standard is associated with the negative results that are made when the laser light is amplified causing radiation to be emitted that is dangerous to humans. As mentioned in numerous sections regarding laser emission within this document, light when concentrated to a small area and focused in a single direction creates a very high intensity achieving tasks needed to run our Laser Gun System.

Lasers have been classified on their safety based on each of the various output power levels, and their potential at each power level to cause injury to a person's eyes and/or skin. These classifications are recognized by the U.S. Food and Drug Administration (FDA) which according to usa.gov “is responsible for protecting the public health by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation”., as well as the International Electrotechnical Commission (IEC). Both organizations recognize four major hazard classes (I to IV for FDA, 1 to 4 for IEC), as well as a few subclasses (IIa, IIIa, and IIIb for FDA, and 1M, 2M, 3R, and 3B for IEC). Labeling for classes II-IV are required to have a warning symbol that gives the output power and class of the laser. The different laser classes are outlined below in Table 14, alongside examples of products they are used in, and a description of the hazard that each class presents to the human eye or skin. Though these classes are not explicitly stated as “standards,” they are essentially standards, and will be considered as such for the purpose of this project.

Class FDA	Class IEC	Laser Product Hazard	Product Examples
I	1, 1M	Considered non-hazardous. Hazard increases if viewed with optical aids, including magnifiers, binoculars, or telescopes.	• laser printers • CD players • DVD players
IIa, II	2, 2M	Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids	• bar code scanners
IIIa	3R	Depending on power and beam area, it can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. The risk of injury increases when viewed with optical aids.	• laser pointers
IIIb	3B	Immediate skin hazard from direct beam and immediate eye hazard when viewed directly.	• laser light show projectors • industrial lasers • research lasers
IV	4	Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard.	• laser light show projectors • industrial lasers • research lasers • medical device lasers for eye surgery or skin treatments

Figure 12: FDA & IEC Laser Classes

Class 1

Class 1 laser is incapable of causing an injury during normal use. Lasers can be Class 1 because they are very low power or because the beam is fully enclosed. The operators of Class 1 lasers do not need to take any precautions to protect themselves from laser hazards. The Class 1 limits for visible lasers under the ANSI Standard vary with laser wavelength. Visible lasers with wavelengths longer than 500 nm have a class 1 limit of 0.4 mW. The Class 1 limit for visible lasers with wavelengths shorter than 450 nm is 40 mW. Power limits have been increased from earlier versions of the ANSI Standard because we now know that they had been set lower than necessary for safety. The CDRH Class 1 limit is 0.4 microwatts for the entire visible area. The power limits have not yet been changed since it took effect in 1976. Class 1 limits under the IEC 60825-1 Standard agree with the ANSI Standard for the visible and near infrared, but they may be slightly different in the UV or far IR.

Class 2

Class 2 lasers must be visible. The natural aversion response to bright light will cause a person to blink before a Class 2 laser can produce an eye injury. The average time for a human aversion response to bright light is 190 ms. The maximum aversion time is always less than 0.25 s. The only protection you need from a Class 2 laser is to know not to overcome the aversion response and stare directly into the beam. This has been done, and people have burned their retinas doing it.

Class 3R

Class 3R lasers are “Marginally Unsafe.” This means that the aversion response is not adequate protection for a direct exposure of the eye to the laser beam, but the actual hazard level is low, and minimum precautions will result in safe use. The CDRH Standard (FLPPS) allows only visible lasers in Class IIIa. The CW power is limited to 5 mW.

If the laser has a small beam so that more than 1 mW can enter the pupil of the eye, it carries a DANGER label. If the beam is expanded to be large enough that only 1 mW can pass through the pupil, the laser carries a CAUTION label. (This category of expanded beam laser is in Class 2M in the new classification scheme.) The ANSI Standard has the same limits for visible Class 3R lasers as the old ANSI Class 3a and CDRH IIIa. It also allows invisible lasers in this class.

An invisible laser with 1 to 5 times the Class 1 limit is a Class 3R invisible laser under the ANSI Standard. The only precautions required for safe use of a Class 3R laser are that the laser user must recognize the level of hazard and avoid direct eye exposure.

Class 3B

Class 3B lasers are hazardous for direct eye exposure to the laser beam, but diffuse reflections are not usually hazardous (unless the laser is near the class limit and the diffuse reflection is viewed from a close distance). The maximum average power for a CW or repetitive pulse class 3B laser is 0.5 W. The maximum pulse energy for a single pulse Class 3B laser in the visible and near IR varies with the wavelength.

For visible lasers the maximum pulse energy is 30 mJ. It increases to 150 mJ per pulse in the wavelength range of 1050-1400 nm. For the ultraviolet and the far IR the limit is 125 mJ. Class 3B lasers operating near the upper power or energy limit of the class may produce minor skin hazards. However, this is not usually a real concern. Most Class 3B lasers do not produce diffuse reflection hazards. However, single pulse visible or near IR Class 3B lasers with ultrashort pulses can produce diffuse reflection hazards of more than a meter. Your laser safety officer will perform a hazard analysis.

Class 4

Class 4 lasers are powerful enough that even the diffuse reflection is a hazard. The lower power limit for CW and repetitive pulsed Class 4 lasers is an average power of 0.5 W. The lower limit for single pulse Class 4 lasers varies from 0.03 J for visible wavelengths to 0.15 J for some near infrared wavelengths. Class 4 lasers require the application of the most stringent control measures.

Class 1M & 2M

Class 1M and Class 2M lasers have the same hazards as Class 1 and Class 2 lasers when viewed with the unaided eye. If these lasers are viewed with magnifying or collecting optics, more light enters the eye and the hazard is greater. These lasers can be viewed safely using optical instruments only if appropriate laser safety eyewear or filters are used.

Previous versions on the IEC 60825 Standard included some diverging laser beams in M classes. This applied to the diverging beams from optical fibers. The 2014 version of this standard does not include diverging beams in M classes. It is in agreement with the ANSI Standard, which never included diverging beams.

4.1.2 Design impact of relevant standards

Due to our design being original we will face many challenges hurdling standards associated with some of our components and the overall system. Although it is our goal to stay within the means of the U.S. standards and the American National Standards it is vital that we prepare beforehand of the potential impact our design will take compared to relevant standards. In section 4.1.1, one of the relevant standards that will impact our design is the phototransistor although this will be our first encounter with a phototransistor it's understood how the standards set in the U.S. will impact our design for our Laser Gun System and Texas star target.

Another impact on our design by Standards would be the electromagnets needed on our Texas star target. There will be more impacts on our design as we go along as this is inevitable. Reference module 4.1 Standards "Search at www.ansi.org" in order to follow along on the certain standards we've mentioned in earlier sections.

While the standards and design impacts were expanded on deeply in 4.1.1.1, the challenges that the team will have to brace themselves for will be handling the phototransistor. Attaching the phototransistor, while it would be challenging, wouldn't be the toughest part - it would resolve to ensure that the artifact falls within the protectant standards defined earlier. The artifact, not only needing to be thermal resistant, would also need to be easily assembled with care to the soldering procedure followed. With it being such a lightweight piece, it's imperative that the team explores the necessary avenues possible to secure the phototransistor.

In theory, using a surface mounting design (SMD) could help support this effort since the laser gun structure would be more forgiving towards attaching the transistor haphazardly. If explored, the possibility could then extend to other components of the gun that would prove challenging to attach.

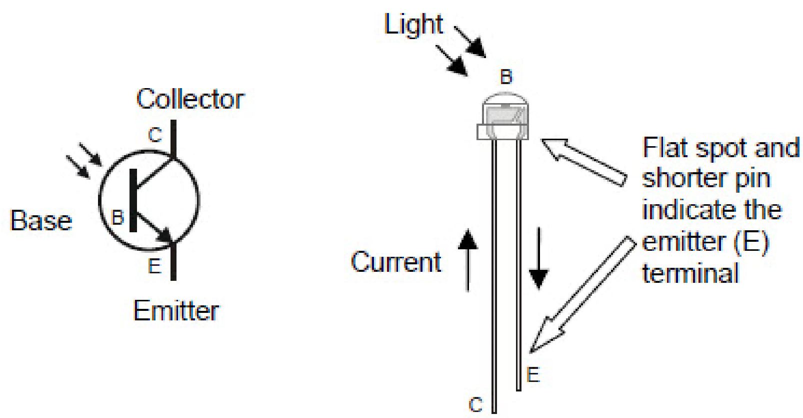


Figure 13: Example of a phototransistor.

4.2 Realistic Design Constraints

In section 4.2 we analyze the design constraints of our System. The most crucial design constraint that we'll discuss is the 5 volt constraint of our design. Not going above or below our design's specific output voltage will be troublesome since we'll need to find an efficient way to containerize the voltage output while maintaining the form-fitting design that will drive the laser gun. The tradeoff from functionality versus power will be substantial, and it's something that will need to be discussed with the team to help determine the best approach moving forward. To help explain the conflict, below lists potential pros and cons of prioritizing each paradigm over the other.

The pros of using a **functionality-focused approach** are important to consider when designing the structure for the laser gun - for one, the intuitivity of interacting with the laser gun will provide a better, more seamless experience. With functionality in mind, we can make decisions that will drive the user, resulting in improved satisfaction, ease of comfort and use, and ultimately, a design that just makes sense. Additionally, if the team develops with function as a priority, gaps may be identified that could snowball into vastly transformed improvements for the design of the gun. It's important, however, to keep in mind the setbacks that may arise from a functionality-centric direction; for starters, while the functionality of the laser gun would prove satisfactory, frustrations could arise from customers if they find themselves constantly needing to supply power due to the voltage not being satisfied. Recharging the laser at an increased frequency could develop into an annoyance in the future and totally destroy the innovations made in ergonomics.

Transitioning into a **power-based approach** will help to alleviate the concerns raised about power loss. With a laser gun that has a “charge once, use anywhere” use case, satisfaction would be derived from the portability and battery life of the gun. Additionally, more power would mean that the functionality and reliability of the embedded components would be increased, promoting longevity throughout the board. Having a laser gun that could stand through the test of time would be monumental for the team and would really showcase the knowledge of maximizing usage of all the volts available for the gun. On the other hand, committing to the maximum voltage constraint allocated could result in producing a design that isn’t ergonomic to the user. It would be tough to advertise to the user the benefits of using our laser gun if the design was bulky or inefficient in nature.

While power is an important constraint to discuss, another design constraint plaguing the team is the size of the internal components. From our microcontroller to our laser emitter/receiver diodes the components located within our gun must be within the size of our design criteria. It’s crucial that all parts meet the size requirements to fit within our hardware and within the standards in the U.S. in order to be successful. When one thinks about this, there exists a relationship between the size of the components and the power consumption used. Intuitively, larger components would resolve to higher power consumption, with the reverse holding true for smaller components. With this in mind, the parallelism between the size of the components and the power used would be instrumental in directing the design decisions made of the laser gun - knowing this, unless development proves otherwise, it would be better for the group to try to keep the parts as small as possible. It’s understood that the process of doing so would be easier said than done, as there needs to be an existence between the size of parts and the strength produced.

The electromagnets in our design will all need to have a large enough holding force to allow the plates to remain attached to the arms of the Texas Star while it is in motion. For this we have determined that a magnet with a holding force of 11 pounds would be more than enough. This holding force will allow the magnet to reliably hold an object of 2 pounds, which should exceed the weight of the plate and allow for the excess strength to help counteract the focus produced by the spinning of the plate. The challenge with this, consequently, comes from finding a sized electromagnet that can sustain the holding force, and through development, could make the optimistic approach of maintaining smaller dimensions unattainable.

4.3 Standards Summary

To conclude this section Standards are essential in the developing and testing plans of projects and systems around the world. Due to our design being original we will face many challenges hurdling standards associated with some of our components and the overall system. Although it is our goal to stay within the means of the U.S. standards and the American National Standards it is vital that we prepare beforehand of the potential impact our design will take compared to relevant standards. We've discussed soldering standards developed by the IPC titled J-STD-001 where we'll showcase the requirements that J-STD-001 lists out in terms of assembly such as assembly cleaning, assembly protection, and assembly inspection. Numerous in-depth explanations to essential considerations for soldered electronic products including but not limited to Cleaning maintenance and residue requirements, Relevant materials, components, and equipment, Wire and terminal connections, Coating, encapsulation, and adhesives, assembly and soldering requirements, and surface mounting and through-hole components.

General Part Mounting Requirements was also apart of our soldering standards section as several different mounting part requirements are given throughout the section of the standard such as parts should be mounted so that their markings and reference designators are visible, parts should be mounted with sufficient clearances between themselves and the PCB in order to make adequate cleaning possible, when both through-hole and surface mounted components are used on one PCB, all through-hole components should be mounted on a single side of the PCB, while surface mounted components can go on either side, all components should be mounted and soldered using a process compatible with that specific part, especially if the part is temperature sensitive. We'll be concluding our analysis with the IPC's PCB standard.

There are several variations of standards related to PCBs indicating the essential steps associated for every stage of the PCB production development process such as the testing processes, designing and manufacturing stages. With our current project PCB standards will be essential to ensure that our board is of the best quality using up to date and relevant standards and components are compatible while attached. The laser standards section is one of the most essential standards within this document due to its emphasis on safety.

The need for the standard is associated with the negative results that are made when the laser light is amplified causing radiation to be emitted that is dangerous to humans. Laser standards are approved, classified and recognized by the U.S. Food and Drug Administration as well as the International Electrotechnical Commission (IEC). Summarizing our realistic constraints with the most crucial design constraint that we'll discuss is the 5 volt constraint of our design.

Not going above or below our design's specific output voltage will be troublesome since we'll need to find an efficient way to containerize the voltage output while maintaining the form-fitting design that will drive the laser gun. The tradeoff from functionality versus power will be substantial, and it's something that will need to be discussed with the team to help determine the best approach moving forward. To help explain the conflict, below lists potential pros and cons of prioritizing each paradigm over the other. While power is an important constraint to discuss, another design constraint plaguing the team is the size of the internal components.

Lasers have been classified on their safety based on each of the various output power levels, and their potential at each power level to cause injury to a person's eyes and/or skin. These classifications are recognized by the U.S. Food and Drug Administration (FDA) which according to usa.gov "is responsible for protecting the public health by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation"., as well as the International Electrotechnical Commission (IEC). Both organizations recognize four major hazard classes (I to IV for FDA, 1 to 4 for IEC), as well as a few subclasses (IIa, IIIa, and IIIb for FDA, and 1M, 2M, 3R, and 3B for IEC).

From our microcontroller to our laser emitter/receiver diodes the components located within our gun must be within the size of our design criteria. It's crucial that all parts meet the size requirements to fit within our hardware and within the standards in the U.S. in order to be successful. When one thinks about this, there exists a relationship between the size of the components and the power consumption used. Intuitively, larger components would resolve to higher power consumption, with the reverse holding true for smaller components. With this in mind, the parallelism between the size of the components and the power used would be instrumental in directing the design decisions made of the laser gun - knowing this, unless development proves otherwise, it would be better for the group to try to keep the parts as small as possible.

5. Project Hardware and Software Design

The following section describes a detailed description of the block diagrams used as guides that we carried out during Senior Design 1. We will discuss the objectives and motivations of each diagram within the description, along with all the supplies, programming techniques and materials that will be used, other materials needed, the setup of the test (including the testing environment), and finally, the results of each test.

We will first analyze both our Hardware and software block diagrams separately showcasing the steps needed respectively including specifications. We'll later discuss the 3D aspects of our design from the Printing and modeling specifications required for the success of our design. We'll also go in depth on the various components of our system such as the design of our Laser Gun and our themed Texas Star Target.

The laser gun system has different pieces amongst itself that allows it to be both efficient and effective. We'll be going into depth on the gun's power supply which for this system will be utilizing the Automatic power control APC mode connecting to our laser diode package. The Microcontroller mentioned is the MSP430fr6989 used in previous courses in our undergraduate curriculum as well as a great mcu developed by Texas Instruments. The laser emitter diode and laser receiver diode portions of section five relates to the diodes vital to both emit the light source from our laser gun system and receiving the laser hit from a laser onto both our Texas star target as well as our Laser gun system used to create a player vs. player game mode. Another essential portion of this section is our lens and aperture section which requires information needed for our laser gun systems lens component.

Both cleanliness and effectiveness is discussed throughout the portion. A block diagram is a graphical representation of a system – it provides a functional view of a system. Block diagrams give us a better understanding of a system's functions and help create interconnections within it. Block diagrams derive their name from the rectangular elements found in this type of diagram. They are used to describe hardware and software systems as well as to represent processes. Block diagrams are described and defined according to their function and structure as well as their relationship with other blocks.

As this group consists of two Computer engineering majors it's natural for the two to take the lead on the essential programming to achieve an effective Laser Gun System which is showcased in the roles directed for each task needed in the software diagram. All members of this group have interest in hardware design and components. Since this is a three man group there is only one electrical engineering major within the group so it is natural that he takes the lead in terms of hardware development tasks and the other two members support indicating how the hardware development task roles were assigned.

5.1 Hardware Block Diagrams

In section 5.1 we'll be analyzing the hardware block diagram that showcases the required Hardware specifications and objectives needed to achieve to develop or Hardware design. This diagram is separated between three sections: one of the sections is for the Texas star where we'll discuss the breakdown of our components needed to achieve the functions required of our Texas star target from a laser receiver to a brief overview of a function of our Texas Star which is the magnet attached detaching indicating it's received a "hit" from our associated laser gun. Another section in our hardware diagram is for our gun's components in our blocks we have an overview of essential functions to the success of our laser gun system such as the beam contacting the receiver and alerting the user that he has been eliminated. The final portion of our Hardware block diagram is the initial hardware configurations needed to start the Laser tag game. Although all members of this group have interest in hardware design and components there is only one electrical engineering major within the group so it is natural that he takes the lead in terms of hardware development tasks and the other two members support.

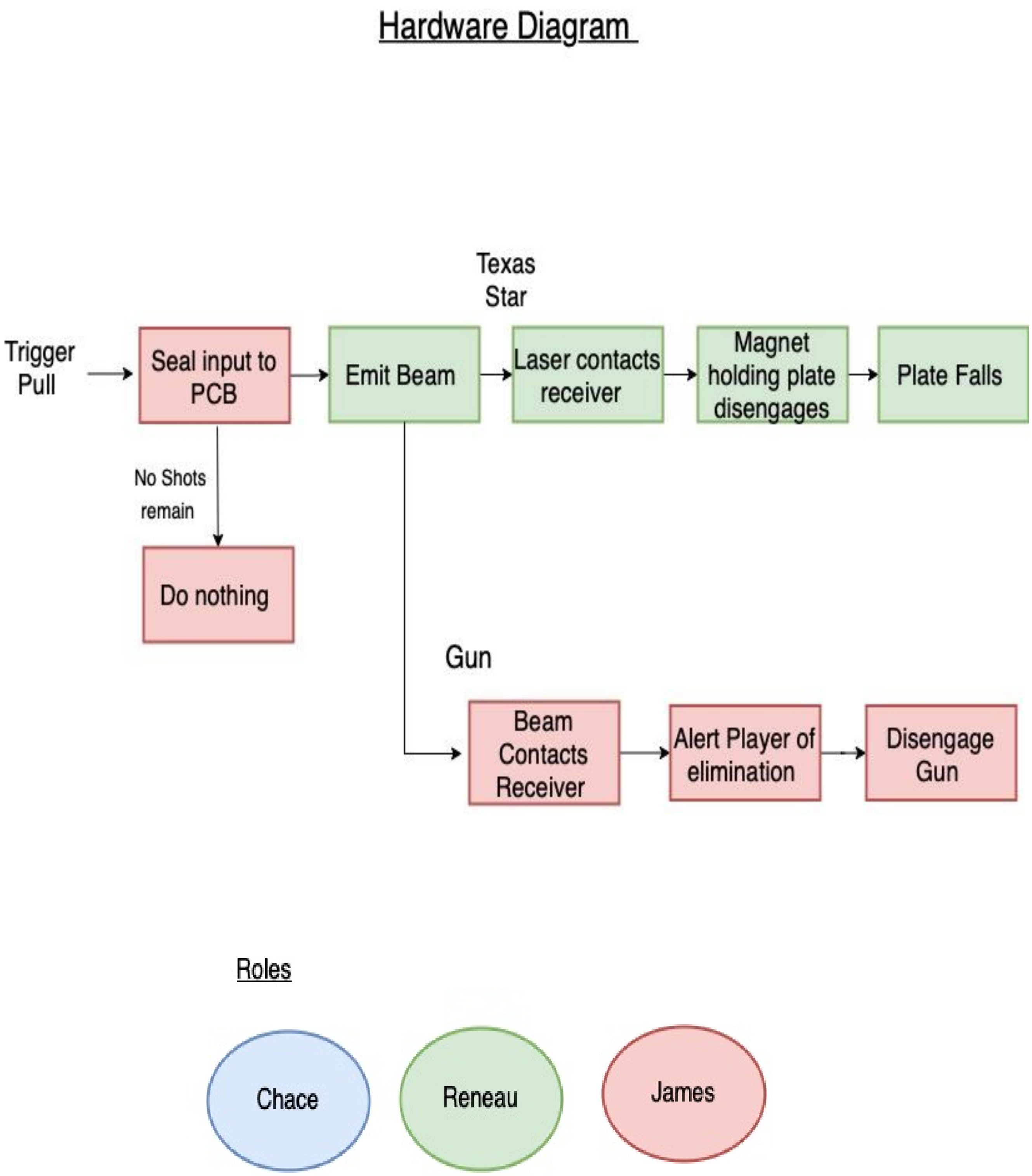


Figure 14: The Hardware Block Diagram describing the flow of the laser gun

5.2 Software Block Diagrams

Our Software Block diagram describes an accurate depiction of the required software specifications and procedure needed to be achieved to program our Laser Gun's system. We've separated our current Software diagram into three portions: calculating bullet count, preparing trigger pull, and hit detection. When viewing the diagram below, portions of pseudo code and conditionals drive the flow of states from the time the trigger is pulled to the moment a hit is detected. *Gun Firing* indicates the need for the source code logic to fire the trigger and the steps that follow. Followed by the connecting logic called *Texas Star* allowing for the recognition of a hit on a target located on the Texas Star and dismemberment of the Star's magnet. The third portion of the Diagram *Reload* indicates the reload logic of our Gun system and the specifications behind our reload requirements. As this group consists of two Computer engineering majors it's natural for the two to take the lead on the essential programming to achieve an effective Laser Gun System.

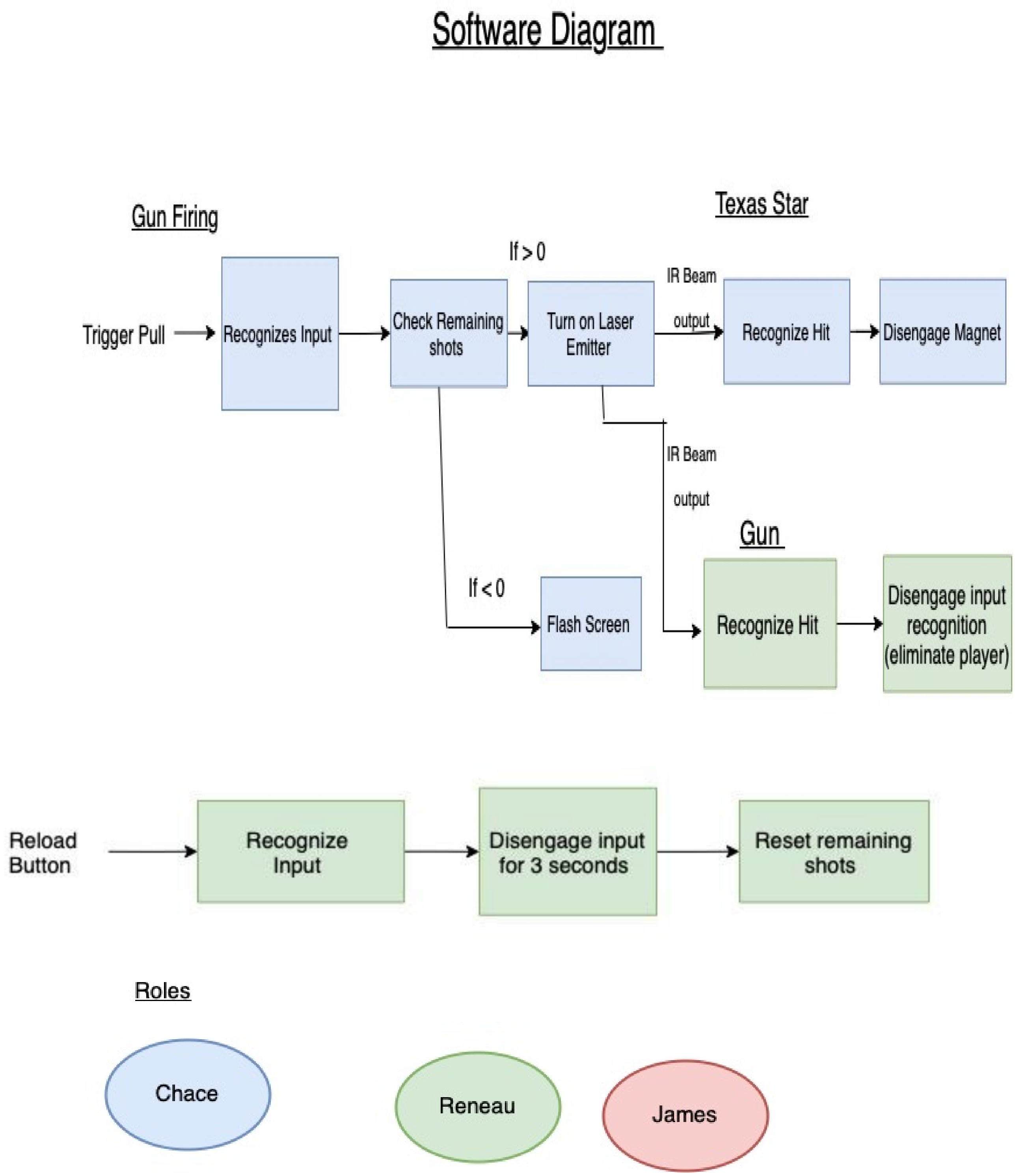


Figure 15: The Software Block Diagram explaining the different phases of the laser gun.

5.3 3D Printing and Modeling

For this project we will utilize both 3D modeling Hardware and Software to bring our project to life. Thanks to the recent hobbyist 3D printing boon we are able to fabricate precision parts from 3D filament to use in our prototype. The parts must be modeled and while there are many options available we have narrowed it down to one we believe to be the most fitting.

5.3.1 3D Modeling Software

For creating the 3D model of the blaster as well as the bodies of the plates we will be using Blender, a free and open-source modeling software. In addition to these two initial reasons we have selected Blender as it has vast libraries of pre-existing models to learn from as well as a wealth of online tutorials for how to use it. Additionally as it is also used by artists to create 3D sculptures or modes the program has a much more organic and intuitive interface and tools than something more technical that AutoCad, and will allow us greater creative freedom when sculpting the body of the blaster.

Additionally, we felt that AutoCad was not optimal for this project as what we are 3D printing is static and thus the mechanical precision of AutoCad would not be put to use in this project. Rather since what we are doing is more sculpting frames than modeling parts it makes much more sense to use a software like Blender that lends itself better to these kinds of applications.

Any model in Blender can be turned into a printable file by converting that model into a mesh object. A mesh object is made up of three pieces that can be thought of as if they are parts of a square:

- Vertices: these can be thought of as the corners of a square
- Edges: these would be the sides of a square that join the vertices
- Face: this would be the interior part inside the borders created by the vertices and edges.

While it is easy to think of them as a square, the mesh objects can be created by a minimum of three vertices and a recommended maximum of 4. The reason for the limited number of vertices is that when the file is exported all of these mesh objects are converted into triangles. With these being the only constraints it can be imagined how one would create a mesh object from a sphere by creating a group of meshes that slowly taper into a point to approximate the object.

5.3.2 3D Modeling Hardware

While we plan to use a 3D modeling software, such as AutoCad, for designing the blaster, we will use a 3D printer to bring it to life. An Ender 3 Pro to be exact. There are loads of different 3D printers on the market nowadays, such as: Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), Digital Light Process (DLP), Multi Jet Fusion (MJF), PolyJet, Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM).

However, there are pretty much only two types that are easily accessible, and applicable for us, SLA and FDM. Stereolithography (SLA), is a process that uses a vat of liquid photopolymers resin that can be cured or hardened. The build plate moves in small increments as the liquid polymer is exposed to light from UV lasers, where cross-section are then created layer by layer. The process repeats until a model is created. SLA is often used in creating miniatures, are really anything that needs an extremely high accuracy that most FDM printers can not achieve.

The other type of 3D printing that we considered is FDM. FDM 3D printers work by extruding thermoplastic filaments, such as ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), through a heated nozzle, which melts the material and applies the plastic layer by layer to a build whatever object you tell it. Each layer is laid down one at a time until the part is complete. FDM is one of the most popular types of 3D printers, especially among hobbyists due to its simplicity. While there are lots of different FDM printers, we will be using the Ender 3 Pro. The Ender 3 Pro is a good entry level printer that has everything you'd need to make accurate prints, without an extremely high price tag. The Ender 3 and Ender 3 Pro are among the most popular FDM printers for hobbyists, partially due to the fact that so many mods exist to improve the printer.

Since we will be using a FDM 3D printer, the next decision is what kind of material we will use. There are currently eight different standard filaments, each with different attributes. Such as: PLA, ABS, PETG, Nylon, Carbon Fibre, PVA, HIPS, TPU, and Polypropylene. The ones that are most applicable to us are PLA and ABS. These two are some of the most common types for 3D printing filaments. PLA is pretty common for home use, because it is cheap and the easiest filament to work with. There is no need to worry about exact temperature and humidity. PLA is stronger and stiffer than ABS. ABS is weaker and less rigid, but is also tougher and lighter. Which makes it better for prototyping.

We are planning on making three identical blasters, each roughly twelve inches long, eight inches high, and three inches thick. We also plan to 3D print the main body of the plates that will be the functional part of the Texas Star, and these will need to be around

5 inches in diameter to provide an adequate target. We estimate the total price to print the three blasters, and five plates to be about a full roll of PLA, which costs $25.

5.4 Laser Gun System

In this section we'll be discussing the essential components and criteria required to successfully build our Laser Gun system's design. We'll briefly speak on the Lens and aperture needed, the microprocessor we've decided as a group for our system, and the Laser diodes necessary to develop an effective laser gun.

Overall, this section is vital to the success of system design, without a general understanding of such topics the chances of completing such a system would be in jeopardy. In section 5.4.1 *Power Supply* we'll be analyzing the use of a Power supply. We'll need one that cooperates with our laser emitter and receiver diodes. This power supply has two modes, the Automatic power control (APC) and the Constant current (CC). With APC mode it is usually used in smaller laser emitter and receiver diodes around the sizes of 5.6 mm - 9 mm. However with the APC mode there is a need for an additional component called the photodiode which will be linked into the inside of the laser diode package.

Section 5.4.2 *Microcontroller* we'll be overviewing our decision-making choosing our microcontroller for our Laser Gun System and the different options available to choose from. For this system we'll be using the MSP430fr6989 device used in our Junior Design 3926L and Embedded Systems 4742C courses part of our undergraduate curriculum.

For Section 5.4.3 and 5.4.4 Laser Emitter/Receiver Diode we discuss the impact of the diodes on our system as well as the importance of their functions. In section 5.4.5 Lens and aperture we analyze our understanding of lens and effects of aperture on lens to emit the necessary laser specifications from our lens.

5.4.1 Power Supply

The Power Supply needed for our System is necessary to supply electrical power to our load. With our power supply its main function is to convert its electric current given from a source to the system for its precise voltage, frequency and current needed to power the system's load. This essential step is important to power our Laser Gun System in order to showcase the full functionality of our system. For our particular power supply we'll need one that cooperates with our laser emitter and receiver diodes. This power supply has two modes, the Automatic power control (APC) and the Constant current (CC). With APC mode it is usually used in smaller laser emitter and receiver diodes around the sizes of 5.6 mm through 9 mm.

However with the APC mode there is a need for an additional component called the photodiode which will be linked into the inside of the laser diode package earlier mentioned. The photodiode later creates an output signal which helps determine the magnitude and adjust the current supply creating a constant output of power through time and changes of temperature. The Constant Current (CC) does not need the additional component as the APC however a given level of current is set to the diode. Another difference would be that the diode's output power will vary depending on the change in temperature in regards to the Constant Current.For our design we'll be utilizing a power supply on Automatic power control equipped with the photodiode linked to the laser diode package. Below is the MAX3669 Power Control system associated with an Automatic Power Control framework.

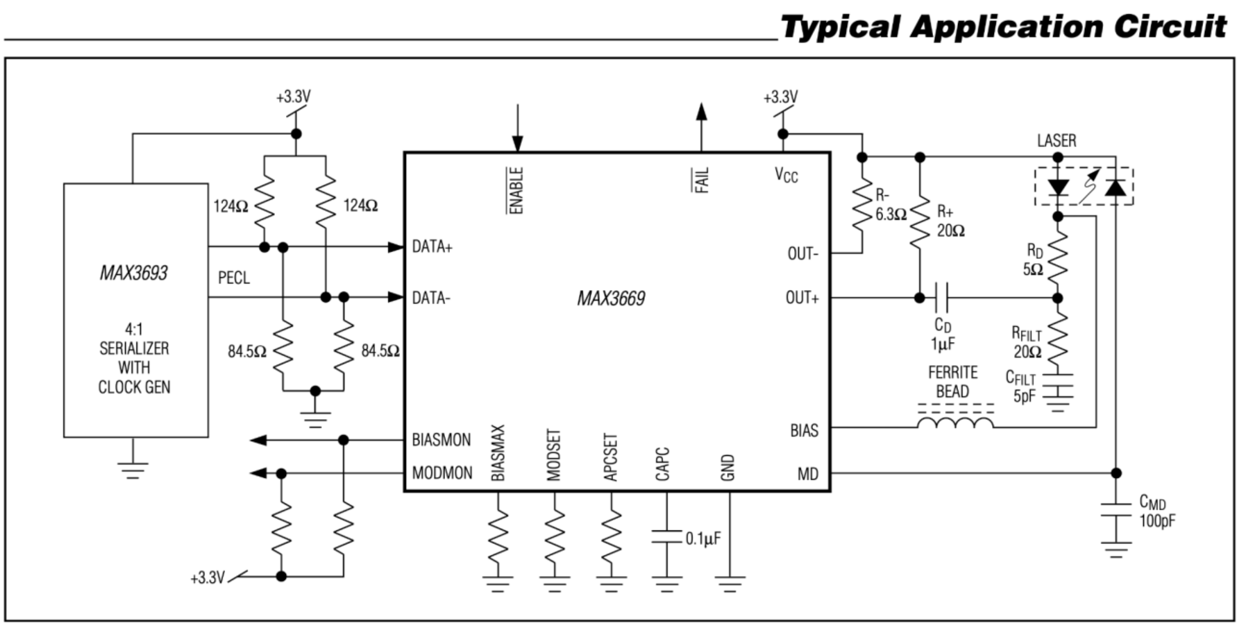


Figure 16: The MAX3663 schematic, similar to MAX3669

5.4.2 Microcontroller (talk about the different options and why we picked it)

When designing an electrical system it's essential to decipher between the need for a microprocessor or a microcontroller although both have similar functions the microcontrollers ability to keep all peripherals internal to the chip sets itself apart from the microprocessors need for external peripherals. Microcontrollers integrate important computing components in one chip. Utilizing bus controls, I/O peripheral ports, memory and interrupt controls as just some of the components integrated in its chip. Microcontrollers are used in various electrical systems in today's society such as office

machines, most remote controllers, toys such as this system here appliances, and many more. For this system we initially thought to use the MSP430fr6989 device used in our Junior Design 3926L and Embedded Systems 4742C courses as part of our undergraduate curriculum.
Being familiar with this microcontroller gives us a sense of “ coming full-circle” using past lectures and lessons as both resources and for nostalgia as well. The MSP430fr6989 LaunchPad development kit is a Texas Instruments electrical product embedded microcontroller which uses Rotary senses, uses 128KB of Ferroelectric Random Access Memory, ultra-low power of non-volatile memory as well as a high speed write access and endurance.

However, we’ve further discussed amongst the group and decided against using a MSP microcontroller because with the Arduino family of microcontrollers the simplicity of the Arduino language will pair well with our code’s simplicity. While the TI-MSP could offer greater power over what happens in our design it would add an unnecessary degree of complication and possibly lengthen the time it takes to wraith the code. The microcontroller chosen is also feasible to acquire which was important in our final decision.

According to *www.embeddedschools.in* a website used to possess an unparalleled track record of offering a blend of both conventional and digital training techniques. There are five different types of Microcontrollers that can be categorized based on components and functions. Here’s an excerpt defining the different microcontrollers from the site:

PIC Microcontroller

PIC Stands for Peripheral Interface Controller which is a kind of microcontroller component used in the development of electronics, computer robotics, and similar devices. Even though the PIC was produced by Microchip technology and based on hardware computing architecture, here the code and data are placed in separate registers to increase the input and output. Pic has a built-in data memory, data bus and dedicated microprocessor for preparing all I/O purposes and methods.

ARM Microcontroller

ARM stands for Advanced RISC Machine. It’s the most popular Microcontrollers Programming in the digital embedded system world, and most of the industries prefer only ARM microcontrollers since it consists of significant features to implement products with an excellent appearance. It is a cost sensitive and high-performance device which has been used in a wide range of applications such as Industrial Instrument control systems, wireless networking and sensors, and automotive body systems, etc.

8051 Microcontroller

Intel created 8051 microcontrollers in 1981. It is an 8 bit microcontroller. It’s made with 40 pins DIP (Dual inline package), 4kb if ROM storage and 128 bytes of RAM storage, 2 16 bit timer. It consists of four parallel 8 bit ports, which are programmable as well as addressable as per the specification.

AVR Microcontroller

AVR stands for Alf and Vegard's RISC Processor. It was the modified Harvard architecture machine, where program and data were stored in the separate physical memory system that appears in different address spaces, but having the ability to browse information from program memory victimization in particular directions. AVR isn't an associate degree signifier and doesn't symbolize something specially.

MSP Microcontroller

MSP stands for Mixed Signal Processor. It’s the family from Texas Instruments. Built around a 16 -bit CPU, the MSP is designed for low cost and respectively, low power dissipation embedded statements. The controller's appearance is directly related to the 16-bit data bus, and seven addressing modes and the decreased instructions set, which allows a shorter, denser programming code for fast performance. The Range of Microcontroller is an IC chip that executes programs for controlling other devices or machines. It is a micro-device which is used for control of other device machines that’s why it’s called Microcontrollers Programming.

As stated earlier in the section the selected microcontroller for our is a variation of the MSP microcontroller titled MSP430fr6989.

5.4.3 Laser Emitter Diode

The Laser Emitter diode is a semiconductor which uses electrical currents through a diode to generate and emit a lasing state at a diode’s junction of a system. In our design we will need to integrate laser emitter diodes in both our Laser Gun systems configured to emit at the command of a trigger pull by a user and cooperate with the amount of ammo set by the user and distance the distance of the target is required as well. There is also a need for an understanding of a phototransistor and photoresistors. The two different photoresistors intrinsic and extrinsic are different in need, function and material. Silicon and germanium are some of the undoped materials in intrinsic photoresistors while the latter doesn’t. Unlike intrinsic photoresistors Extrinsic photoresistors create a new energy band above the current valence band. As earlier mentioned in section 3.2.2 Ways to Sense Light.

The infrared emitter diode we have selected is the Vishay TSAL6200 High Power Infrared Emitting Diode. We are sourcing this emitter from Amazon where it is packaged in an eight-pack that includes four of these emitters as well as four Vishay TSOP38238 Infrared Receivers. This bundle deal costs $11.88 which makes the price per component of these emitters very high at about $1.50 as singles can be bought on Digikey for fifty-six cents, but since we only need two of them and the next largest quantity of them on Digikey is 10, the price in addition to the short delivery offered by Amazon Prime makes the cost acceptable.

The TSAL6200 is an infrared emitting diode which operates on a low forward voltage while being able to reliably output both high radiant power and high radiant intensity. It is able to output a peak wavelength of 940 nm and has applications for use in infrared remote control units, but most importantly is suited for free air transmission systems.

5.4.4 Laser Receiver Diode

The Laser Receiver diode is required in both our Laser Gun System and Texas star target. It is vital for our Laser Gun system due to the function of our gun that allows it to be "hit" by another laser gun incorporating a player vs. player game mode to our system. The laser receiver diode is also needed in our Texas star target as a phototransistor. The Phototransistors function by emitting current proportional to the amount of light that they absorb. For our Laser receiver diode we'll be using a working voltage output of five volts and an output form meant for digital output. This component is a foundational component of our system which is referenced in many sections of this document.

The infrared receiver we have selected for our design is the Vishay TSOP38238 IR Receiver. This receiver is not only cheap and readily available, but can also be sourced from Amazon as a pack of 4 that also includes 4 Vishay TSAL6200 infrared emitters that were discussed in the prior section. This is ideal as we will need a good number of each of these and they are very crucial to the build so the short lead times of Amazon Prime are a massive convenience. They retail as a pack of eight with the emitters for $11.88 before taxes, and that means each emitter costs about $1.50, which is slightly higher than Digikey's price but an added thirty cents for as short as one day delivery is a good tradeoff.

The receiver consists of a photodiode which receives the infrared input and passes this input through an Automatic Gain Control (ACG) circuit then through a Band-Pass Filter, and after this the input signal is demodulated and may be passed directly to a microcontroller. The ability to connect this receiver directly to a microcontroller to pass a demodulated signal is incredibly convenient for the design of our blaster. The direct supply of the signal allows for us to differentiate the input and thus in conjunction with the infrared emitter discussed previously will allow us to program multiple game modes using different frequencies. For instance if the blasters are set to a mode where there are teams the teammates should not be able to damage each other, and by differentiating frequencies it is possible to create and implement such a feature.

5.4.5 Lens and Aperture

In section 5.4.5 we'll be discussing the Lens and aperture we've used in our Laser Gun system. Our understanding of this topic is essential to emit the necessary laser specifications from our lens. Aperture is the opening area of a lens diaphragm which can widen or shrink in allowing light to pass; this is essential to the width and intensity of our light source. The lens we've decided on is a double-convex magnifier lens with a 21 mm radius. The cleanliness of our lens is necessary to the effectiveness of our laser gun. Because of that this is the most vital component to keep safe, clean and away from harm's way than any other component in this system. In some laser systems around the world air quality and moisture is a concern when dealing with lenses. Overall, we'll be utilizing our understanding of how the aperture of our lens affects our laser gun system and ensuring our cleanliness and quality of our lens will be beneficial to our system.

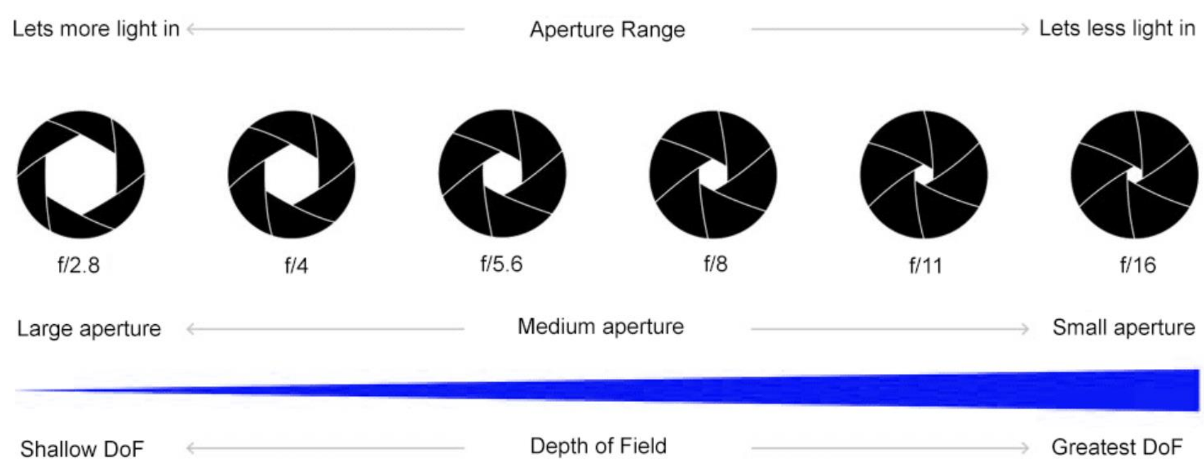


Figure 17: Lens and Aperture

5.4.6 Design of Housing

This section will discuss our plans for the design for the housing of the electronics that when combined make a complete blaster. The housing serves a dual function as it not only holds the electronics in a stable position to prevent them from being damaged as well as holding them in an optimal position, but also serves as the interface between the user and the microcontroller inside. It is for this reason that it is not only important to design the interior of the housing well to protect the electronics, but also to design the exterior well as to allow the user to use the blaster effectively and comfortably.

The interior of the housing will be designed to hold in place our: finalized printed circuit board design which includes a infrared emitter, a power supply, a button that will function as the trigger, an additional button to be used to trigger a “reload”, and a focusing element for the infrared emitter. It will not provide a protective casing for these components but also allow them to be secured as to prevent them from moving around from the inside and becoming damaged in that way.

The exterior of the blaster will be designed in such a way that is comfortable for a user of reasonable size to use comfortably and accurately. Upon inspection of the Nerf Laser Ops Pro, we found the construction and weight of the gun to be both bulky and poorly weighted. The grip was far too large and did not fit in any of our hands very well. The balancing of the gun was also very poor as the entire system is powered by four AA batteries that are stored at the front of the gun, and in addition to this with the design of the gun is best described as an oversized pistol the weighting is very front heavy and unwieldy even in adult-sized hands. However we found the least convenient part of Nerf’s gun to be the sighting system. The sighting system that is implemented in this case tries to use the infrared receiver as a front sight, but this causes the sighting of the gun to be quite difficult, and in our use of this format that is not a sacrifice that can be made.

To remedy these issues our solutions to each are as follows. To fix the issue of the grip we will shrink it down to be of comparable size to real handguns that are on the market today so that each of us find it comfortable to use. To solve the weight issue we have a simple solution for this which is just to mount the power source in the grip of the blaster, which will balance the weapon by concentrating the bulk of the weight where the user is placing their hand.

The relocation of the battery pack will cause us to make another change in layout that diverges from Nerf’s design which is the relocation of the reload button. While Nerf implemented the reload control as a large button on the bottom of the grip, we would instead implement the reload function as two buttons on both sides of the grip near where the user thumb would rest, more akin to where the magazine release is on modern handguns. This would allow for not only ambidextrous operation but it would also allow for the user to perform a reload without the use of a second hand.

To overcome the issue of creating a reliable sight we have decided to forgo adding a fixed sight to the blaster and add a Picatinny Rail instead. This picatinny rail is a military standard accessory mounting system featured on both real and airsoft weapons. This will allow for the user to mount the sight of their choice, and even gives the user the option to mount adjustable optics to better refine their aim.

5.5 Texas Star Target

The following section contains our plans for and schematics of the Texas Star target. Our design for how the target will work will be discussed in both the function of the electronics as well as the mechanical function. The electronics used, and the basis of each will be explained as well as diagrams for the types of special components will be given as well.

The Texas Star targets will be designed and 3D printed using PLA. This will provide them with enough strength to survive drops, while also remaining lightweight. The base of the target will be constructed out of wood, giving it a nice and solid base.

5.5.1 Target Materials

The plates of the Texas Star will be specially designed and 3D printed using the filament discussed in prior sections. The purpose of this is to allow for proper support of the PCB as to prevent it from being damaged during the drop as well as reducing the weight. The weight must be controlled to keep the cost, and voltage requirements of the project down due to the amount of holding force that a reasonably priced electromagnet has. Our selected electromagnet can hold around 2 to 2.5 pounds reliably.

The arms of the Texas Star will be made from a light plastic to allow for the plates to be the harvest portion on the arm so that as the fall the target spins as designed. The arms will connect to a slightly denser center piece that will in turn be affixed to a metal post. This post will be inserted into a pair of ball bearing mounts that will allow the Texas Star to produce the spinning motion. These mounts will be affixed to a wooden base that will outweigh the combined weight of all the other components to prevent the swinging motion of the Texas Star from moving itself any other way than the way it is intended to.

5.5.2 Infrared Receiver

In our project the Infrared Receiver will be powered until the input from the Blaster is detected. To detect the beam emitted by the blaster, the plates on the Texas Star will utilize infrared receivers to detect the IR beam that is being projected onto them.

The infrared receiver we have selected for our design is the Vishay TSOP38238 IR Receiver. This receiver is not only cheap and readily available, but can also be sourced from Amazon as a pack of 4 that also includes 4 Vishay TSAL6200 infrared emitters. This is ideal as we will need a good number of each of these and they are very crucial to the build so the short lead times of Amazon Prime are a massive convenience. They retail as a pack of eight with the emitters for $11.88 before taxes, and that means each emitter costs about $1.50, which is slightly higher than Digikey’s price but an added thirty cents for as short as one day delivery is a good tradeoff.

While these receivers are intended for infrared-based remote control systems they will serve our needs well. They require a very low supply current and can function off of a supply voltage from 2.5 V to 5.5 V which is ideal for our design being at our desired 5 volts. Additionally, they have improved immunity to ambient light and are insensitive to supply voltage ripple.

The receiver consists of a photodiode which receives the infrared input and passes this input through an Automatic Gain Control (ACG) circuit then through a Band-Pass Filter, and after this the input signal is demodulated and may be passed directly to a microcontroller. The ability to connect this receiver directly to a microcontroller in addition to its small size with the head being 5x7x4.8 mm makes it a good fit for our design.

5.5.3 Electromagnets

For our design the electromagnet we have selected is the Adafruit Industries 3873. This five volt electromagnet produces around 11 pounds (or 5 kilograms) of holding force, and this allows the electromagnet to pick up an object weighing a fifth to a tenth of its maximum holding force. In our case this means that at the minimum the electromagnet should be able to pick up an object weighing around two pounds. We are sourcing five of these particular electromagnets from Digikey where they retail for just under 10 dollars each. While these may not be the cheapest electromagnets Adafruit provides a clear and simple datasheet as well as having extensive support in the form of guides available on their website.

The electromagnet itself has a diameter of approximately 0.8 inches. While some may not consider this size idea it suits our design well as an increased surface area will aid in making sure the target remains stable and does make any unwanted turns while the Texas Star is in motion. The electromagnet’s manual suggests a material that is very ferromagnetic, and for this any kind of galvanized or mild steel will work fine, but more ferromagnetic varieties of steel are available, such as ferritic steel, if these options do not yield a strong hold.

The included datasheet includes a warning that since this electromagnet is a coil, or inductor, that when the current is quickly added or removed from the component there is a large spike in voltage that could potentially damage the electromagnet. For this we will employ the use of an anti-kickback diode connected parallel with the electromagnet to protect it from any voltage spikes.

For our project we chose to use only a single electromagnet for each plate as a means to reduce the total number of points of failure. An alternative method of affixing the plates to the arms would be to connect multiple smaller electromagnets instead of a single large one. This could possibly result in the same effect, but again there is going to be twice the risk of component failure.

However, since no one in the group has extensive experience with electromagnets we can only speculate on this. If our single magnet design proves inefficient running trials with multiple smaller magnets used to affix a single plate could possibly yield better results. However we will not buy the smaller ones at first as a contingency because electromagnets are on the costly side and have developed into one of if not the most expensive part of this entire project.

Electronic locks that retract themselves upon being hit could also be used for our prototype, but they are often slow and this presents a large problem for them. Because of the nature of the Texas Star the plates must quickly detach from the target in order for the game to work properly, and the often sluggish electronic bolt would simply not be up to the task.

There is an additional issue with the electronic locks as well in that mounting them could prove quite difficult. While the electromagnets can mount vertically at the ends of the plates, making the process of detaching, once the electromagnet has been deactivated, a very straightforward one. In the case of these electronic bolts the system to not only keep it mounted but to also allow it to decouple from the arms of the Texas Star would have to be more complicated, and the more complex a design in this case, the more likely it is to fail.

5.5.4 Plate Design

The plates in our project are going to be what the user will shoot the blaster at in order to cause the Texas Star to function. The plates themselves in addition to being the targets will also be the housing for the PCB. There will be five targets made which will be exact copies of one another so that they may be placed on any arm of the target. They will be circles that are 4 inches in diameter with a flat protrusion that will allow for them to connect to the Texas Star.

The plates will contain an infrared receiver that will be fixed in the center of the circle, and to increase the tolerance for a hit a conical section of the target around the phototransistor will be hollowed out and lined with a reflective material as to reflect signals that hit close to the center as the objective is to hit the plate and not just the dead center of it. There will also be a piece of darkened plastic placed over the previously mentioned section as well as the phototransistor that will reduce chances of having an accidental activation by cutting down on noise that could be detected by the phototransistor. In addition to cutting down on noise this plastic pane will also serve to protect the phototransistor as well as the reflective lining from any damage it could sustain or any debris that could build up around the sensor when the plate falls from the tree during use.

The flat portion of the plate will house the electromagnet which is the mechanism that will allow for the plate to detach itself after it has been hit with the IR beam from the blaster. In addition to this point of connection there will be two additional posts that will fit into holes in the end of the arms. These posts are to provide extra security to the plate when the target begins to swing so that they remain facing the front as intended, and will reduce the possibility that the forces produced by the target swinging will exceed the holding force of the electromagnet. This connection and stabilization method is represented in the illustration below:

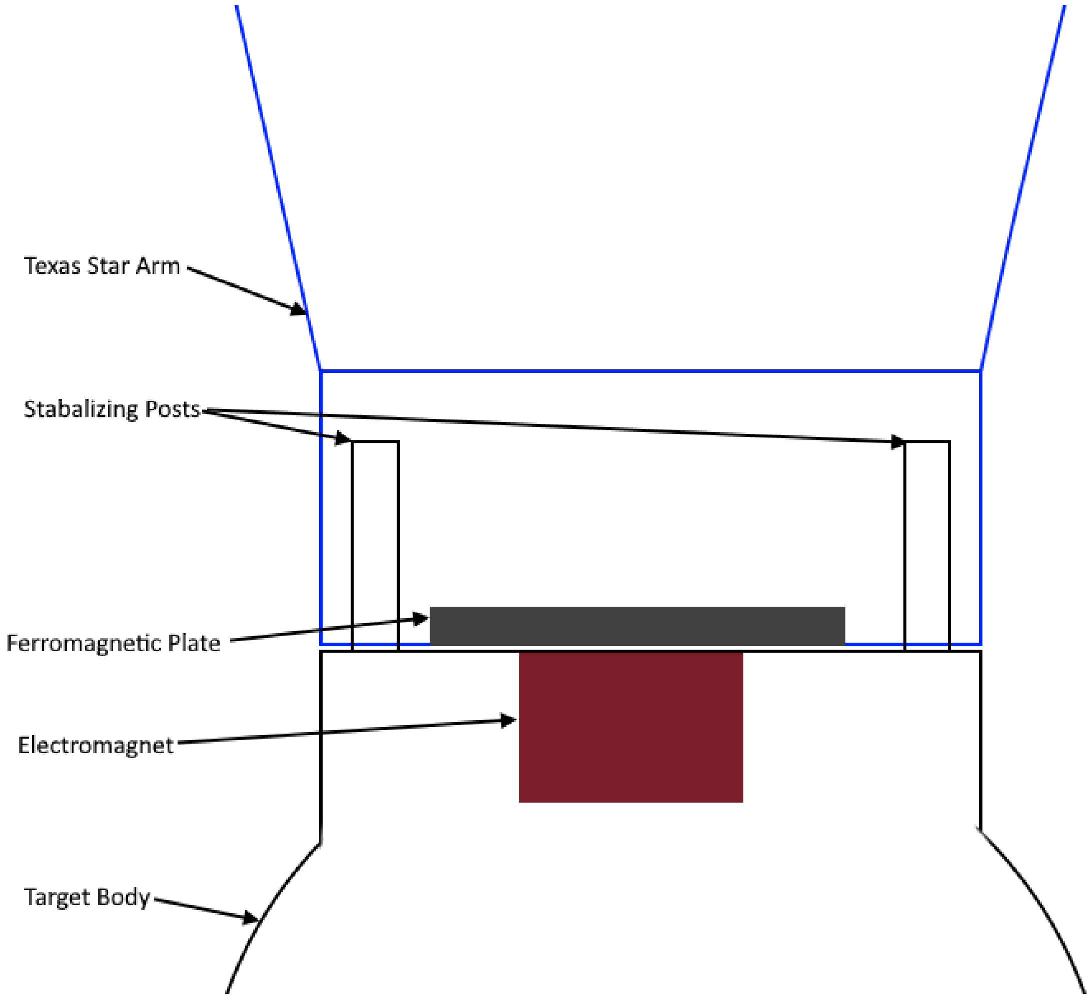


Figure 18: Pictorial Realization of Plate Connection

The plates will remain on after they have fallen from their respective arms to allow the user to confirm that they indeed hit their target.

After play has concluded the user may reset the plates by switching them off and back on again via a standard slide switch. The Slide switch we have selected is the TE 1825232-1, and it was chosen because it was both cheap and is well in stock. We are sourcing this part from Digikey and we are buying a bulk pack of 10 of them which costs $0.431 per switch. The switch is also angled 90 degrees from the pins which is also going to be helpful as the switch will likely be mounted on the rear side of the plate. The style of input was important for the plate since it will be subject to several impacts. For instance a button would be a poor choice for the plate design because it could much more easily be activated when it hits the ground either being pushed by some object or simply pushed down due to the force and angle of impact with the ground. This would be catastrophic for the design of the plate because the user would not be able to confirm a hit if the plate were turned off because the LEDs turning red is our method for confirming that the plate did indeed register a hit.

5.5.5 Material Durability

The plates will be printed out of PLA, the same as the gun controller. While the PLA is a great material for the gun it has both advantages and disadvantages in the case of the plates for the Texas Star.

PLA was chosen because it is a good balance of cost, strength and print quality and in addition to that one of the group members also owns a 3D printer and has experience working with PLA. This provides us a great advantage in prototyping and testing as we can cut, sand, and modify the initial prints of the plates without fear of damaging them and having to replace them at the cost of wasting time waiting in line in the engineering lab, or waiting for them to be shipped from a print shop. Additionally we can make several versions of the plate to test designs of the plate itself.

This would also allow us to experiment with methods and materials to reduce the effect of the impact with the ground on the plates. These methods will involve changes in shape and assembly as well as materials like rubber that can be used to coat non-critical surfaces such as the outside edges. We hope these coating materials will make our plates more impact resistant, but we do not expect them to be impervious to damage from impacting the ground.

There is a tradeoff with any damage reduction method and it is that the plates must not exceed the 2 pound weight limit of our electromagnets, and thus the amount of additional material that can be added is limited. This in particular is an issue with methods such as adding rubber coating. Unlike 3D printed PLA this kind of coating must be applied like paint and can become dense after only a few coats adding a good deal of weight.

While we could concoct a working prototype that is drop resistant out of the PLA, save the design, and have it shipped off to a print shop to have it printed in a more durable material like resin, and use that in the final design, that could add on to lead times particularly if it is happening near the project deadlines. On top of that we would also have to remove the PCBs as well as all of the other attached components and transfer them over to the new plate chassis without damaging them.

Considering all of this information we have resolved to take a more moderate path. Seeing as we are only creating a prototype, and are more focused on the electronics aspect of this project over the materials, it would make sense to just test a few styles of plate chassis for drop resistance, choose the best of them, and then install all of our hardware in that design.

Additionally, to ensure that our prototype works successfully up to and during our demonstration, we will be taking precautions such as providing a padded surface for the plates to land on after falling as to reduce the damage sustained by the plate, and more importantly the electronics inside.

5.5.6 DC Motor

While the inclusion of a DC motor is not in our initial design it is a favorable addition in the event that the mechanics of the Texas Star target prove to be troublesome. While it is the desired outcome that our design for a laser-tag version of the Texas Star functions similarly to its real-life counterpart, it is not a sure thing as we have to make more concessions due to this being an electronic approximation that has to meet certain design criteria due to the inclusion of electronic control as compared to its purely mechanical base that we have drawn inspiration from.

The main issue lies in calculating the focus behind what makes the mechanical Texas Star function, as it relies on the plates situated to the ends of the target to provide balance to the structure while they are all attached, but as the plates are removed the loss of each one causes the Texas Star to spin more erratically. However, in the mechanical version of the Texas Star these plates are made out of very heavy armored steel that is locked in place with just enough tension to stay affixed to the arm and then is removed when subjected to the force of a bullet impacting it. In contrast our plates cannot be as heavy as they must be suspended via an electromagnet that cannot support beyond around 2.5 pounds.

So, the issues that could prevent our design from functioning as required all have one thing in common: they do not pertain to the circuit design of this project and thus are out of the scope of the project. So, if the trials of the Texas Star prove to us that it will take more than a minor redesign of the weighting and/or structure of a few parts it will be within our best interests to forfeit this goal. While it is possible for us to make the calculations and do the research and design necessary to have the Texas Star function as we hoped it would, this is not an efficient use of our time as we are not setting out to demonstrate our abilities to create a mechanical device.

Therefore, to create a target that still presents a challenge to the user by creating moving multiple targets we have a simple but effective solution. Since the arms and body of the Texas Star are already on a pole that runs through the mounted ball bearings we can simply attack the end of this pole to a 12-volt DC motor that would just spin it at a constant rate, thus still giving the user a challenging moving target.

While in theory it sounds as if these would be easier targets that is not necessarily true because while the Texas Star does swing erratically it also tends to come to a near halt at points as at the apex of the swing it has either just enough or almost enough inertia to make a full rotation instead of its typical parabolic pattern. Most shooters who use this target know this and it would quickly become apparent to even a new user, and users of the target will often wait for this chance to take a much easier shot. So, while our modified version would move at a constant speed it would always be in motion, making this an equal challenge for the user.

For this potential workaround we have selected the FBA_TRS-775W Micro DC motor. It is a 12-volt motor that can produce up to 12000 RPM at its brush. While the motor is small it is also light and cost effective, coming in at less than $20, which makes it ideal for a possible fix to potential issues, should they arise. While the Texas Star will not be able to utilize the full 12000 RPM that this motor's brush can produce, it does not need to as that would certainly exceed the average user's ability to see, much less hit, the plate targets of the Texas Star. Instead the motor will just be used to move the Texas Star at a moderate rate that we will determine in trials after it is installed.

As this motor is powered by a coil, much like the electromagnets used in the design of the plates of the Texas Star, it will need to be protected from kickback, or sudden changes in voltage, as these could produce surges in voltage large enough to damage and/or destroy the motor. Thankfully, because of the nature of this component, the ability to vary the speed is often desired and DC motor speed controllers are widely available and prevent the DC motor from experiencing the previously mentioned instantaneous current changes. The speed controller we have selected is the RioRand RRPDMSCSGSPC, a 12-40 volt speed controller that is not only economical but also has a small footprint that makes it ideal for installing onto our Texas Star after it has already been fully assembled.

Both of the previously mentioned components will be sourced through Amazon if needed, and both also happen to be eligible for Amazon Prime. This is also another benefit that makes sourcing them from Amazon over Digikey, or any other provider, the logical choice as these components are a contingency plan they will not be ordered in advance like the rest so the low shipping time in the case that we do need them will not slow down our development of our prototype.

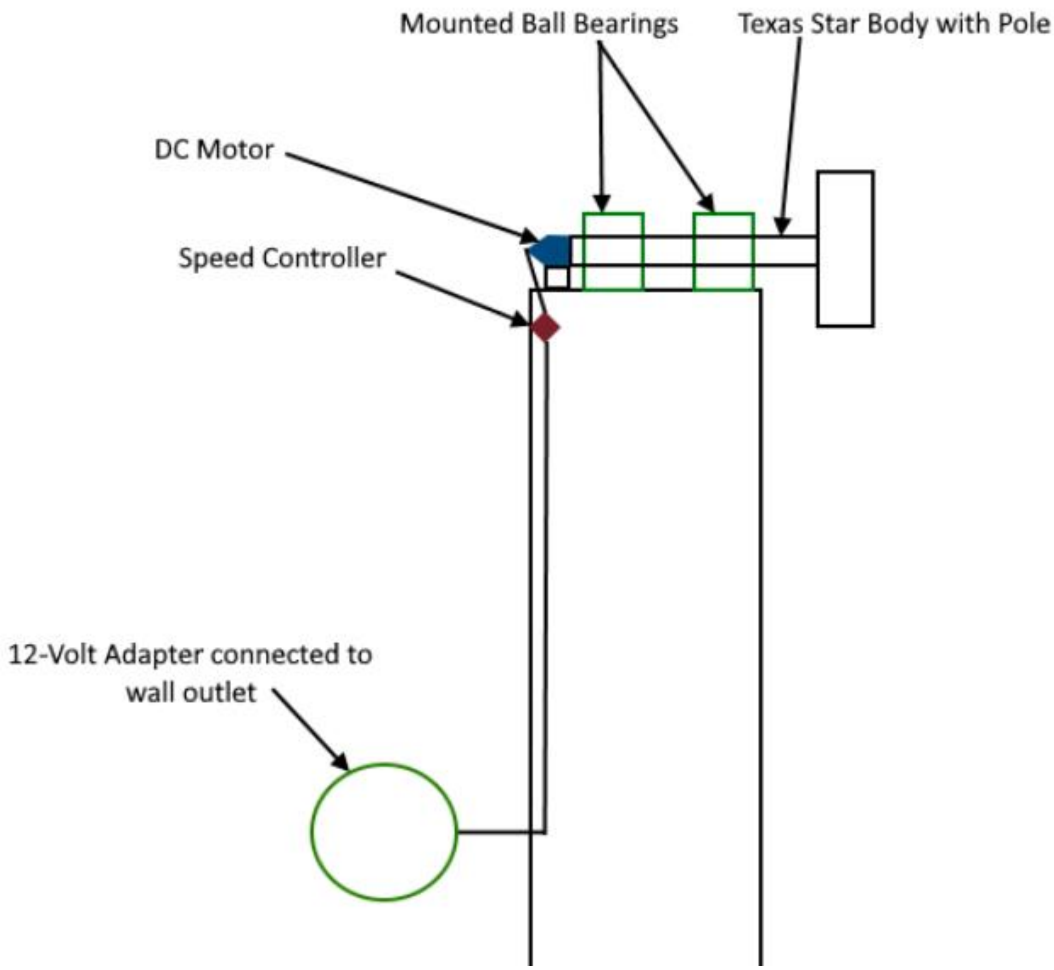
To attack the DC motor along with its supporting components, we will implement the following design. First, connect the motor to the pole connected to the body of the Texas Star that is in the mounted ball bearings. Next, Mount the speed controller to the rear of the Texas Star's stand so that it is not at risk of damage. Lastly, connect these two components together and attach them to a 12-volt wall adapter that will act as the source of power for this motor. Below is an illustrated approximation for the design detailed above.

5.6.1 Project Design Summary

In Section 5 we've discussed an overview of our Project design plan. We began with analyzing both our Hardware and software block diagrams separately showcasing the steps needed respectively including specifications. We'll later discuss the 3D aspects of our design from the Printing and modeling specifications required for the success of our design. We'll also go in depth on the various components of our system such as the design of our Laser Gun and our themed Texas Star Target. We then discussed our utilization of both 3D modeling Hardware and Software to bring our project to life. Thanks to the recent hobbyist 3D printing boon we are able to fabricate precision parts from 3D filament to use in our prototype. For creating the 3D model of the blaster as well as the bodies of the plates we will be using Blender, a free and open-source modeling software. In addition to these two initial reasons we have selected Blender as it has vast libraries of pre-existing models to learn from as well as a wealth of online tutorials for how to use it.

Figure 19: Approximation of Addition of DC Motor

There are only two types of 3D modeling hardware that are easily accessible, and applicable for us, SLA and FDM. Stereolithography (SLA), is a process that uses a vat



of liquid photopolymers resin that can be cured or hardened. The build plate moves in small increments as the liquid polymer is exposed to light from UV lasers, where cross-section are then created layer by layer. The process repeats until a model is created. SLA is often used in creating miniatures, are really anything that needs an extremely high accuracy that most FDM printers can not achieve. The other type of 3D printing that we considered is FDM. FDM 3D printers work by extruding thermoplastic filaments, such as ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), through a heated nozzle, which melts the material and applies the plastic layer by layer to a build whatever object you tell it.

We also overviewed our laser gun system within the chapter which is important to power our Laser Gun System in order to showcase the full functionality of our system. For our particular power supply we'll need one that cooperates with our laser emitter and receiver diodes. This power supply has two modes, the Automatic power control (APC) and the Constant current (CC). With APC mode it is usually used in smaller laser emitter and receiver diodes around the sizes of 5.6 mm through 9 mm. However with the APC mode there is a need for an additional component called the photodiode which will be linked into the inside of the laser diode package earlier mentioned.

As mentioned throughout the section When designing an electrical system it's essential to decipher between the need for a microprocessor or a microcontroller although both have similar functions the microcontrollers ability to keep all peripherals internal to the chip sets itself apart from the microprocessors need for external peripherals. Microcontrollers integrate important computing components in one chip. Utilizing bus controls, I/O peripheral ports, memory and interrupt controls as just some of the components integrated in its chip. Microcontrollers are used in various electrical systems in today's society such as office machines, most remote controllers, toys such as this system here appliances, and many more.

Also mentioned is the Laser Emitter diode is a semiconductor which uses electrical currents through a diode to generate and emit a lasing state at a diode's junction of a system. In our design we will need to integrate laser emitter diodes in both our Laser Gun systems configured to emit at the command of a trigger pull by a user and cooperate with the amount of ammo set by the user and distance the distance of the target is required as well. There is also a need for an understanding of a phototransistor and photoresistors. The two different photoresistors intrinsic and extrinsic are different in need, function and material. The Laser Receiver diode is required in both our Laser Gun System and Texas star target. It is vital for our Laser Gun system due to the function of our gun that allows it to be "hit" by another laser gun incorporating a player vs. player game mode to our system. The laser receiver diode is also needed in our Texas star target as a phototransistor.

While discussing the Lens and aperture we've used in our Laser Gun system. Our understanding of this topic is essential to emit the necessary laser specifications from our lens. Aperture is the opening area of a lens diaphragm which can widen or shrink in allowing light to pass; this is essential to the width and intensity of our light source. The lens we've decided on is a double-convex magnifier lens with a 21 mm radius. The cleanliness of our lens is necessary to the effectiveness of our laser gun. Because of that this is the most vital component to keep safe, clean and away from harm's way than any other component in this system. In some laser systems around the world air quality and moisture is a concern when dealing with lenses.

In regards to our hardware design it is separated between two sections interior and exterior with the interior of the housing will be designed to hold in place our: finalized printed circuit board design which includes a infrared emitter, a power supply, a button that will function as the trigger, an additional button to be used to trigger a "reload", and a focusing element for the infrared emitter. It will not provide a protective casing for these components but also allow them to be secured as to prevent them from moving around from the inside and becoming damaged in that way. The exterior of the blaster will be designed in such a way that is comfortable for a user of reasonable size to use comfortably and accurately. Upon inspection of the Nerf Laser Ops Pro, we found the construction and weight of the gun to be both bulky and poorly weighted. The grip was far too large and did not fit in any of our hands very well. The balancing of the gun was also very poor as the entire system is powered by four AA batteries that are stored at the front of the gun, and in addition to this with the design of the gun is best described as an oversized pistol the weighting is very front heavy and unwieldy even in adult-sized hands.

The arms of the Texas Star will be made from a light plastic to allow for the plates to be the harvest portion on the arm so that as the fall the target spins as designed. The arms will connect to a slightly denser center piece that will in turn be affixed to a metal post. This post will be inserted into a pair of ball bearing mounts that will allow the Texas Star to produce the spinning motion.

In section 5.5.2 and 5.5.3 we overviewed our infrared receiver and magnets, The infrared receiver we have selected for our design is the Vishay TSOP38238 IR Receiver. This receiver is not only cheap and readily available, but can also be sourced from Amazon as a pack of 4 that also includes 4 Vishay TSAL6200 infrared emitters. This is ideal as we will need a good number of each of these and they are very crucial to the build so the short lead times of Amazon Prime are a massive convenience. They retail as a pack of eight with the emitters for $11.88 before taxes, and that means each emitter costs about $1.50, which is slightly higher than Digikey's price but an added thirty cents for as short as one day delivery is a good tradeoff. While these receivers are intended for infrared-based remote control systems they will serve our needs well. They require a very low supply current and can function off of a supply voltage from 2.5 V to 5.5 V which is ideal for our design being at our desired 5 volts. The electromagnet itself has a diameter of approximately 0.8 inches. While some may not consider this size idea it suits our design well as an increased surface area will aid in making sure the target remains stable and does make any unwanted turns while the Texas Star is in motion. The electromagnet's manual suggests a material that is very ferromagnetic, and for this any kind of galvanized or mild steel will work fine, but more ferromagnetic varieties of steel are available, such as ferritic steel, if these options do not yield a strong hold.

We also discussed the plate design of our Texas star target. The plates themselves in addition to being the targets will also be the housing for the PCB. There will be five targets made which will be exact copies of one another so that they may be placed on any arm of the target. They will be circles that are 4 inches in diameter with a flat protrusion that will allow for them to connect to the Texas Star. The plates will contain an infrared receiver that will be fixed in the center of the circle, and to increase the tolerance for a hit a conical section of the target around the phototransistor will be hollowed out and lined with a reflective material as to reflect signals that hit close to the center as the objective is to hit the plate and not just the dead center of it. There will also be a piece of darkened plastic placed over the previously mentioned section as well as the phototransistor that will reduce chances of having an accidental activation by cutting down on noise that could be detected by the phototransistor.

5.6.2 Project Design Addendum

In Section 5 of our senior design project, we discussed the detailed project design plan. Firstly, we analyzed the hardware and software block diagrams separately and discussed the necessary steps and specifications. We also discussed the 3D printing and modeling specifications required for the success of our design. In addition, we went into depth on the various components of our system, such as the design of our Laser Gun and our themed Texas Star Target. We utilized both 3D modeling hardware and software to bring our project to life, thanks to the recent hobbyist 3D printing boon. For creating the 3D model of the blaster, as well as the bodies of the plates, we initially thought to use Blender, a free and open-source modeling software but decided on using an already used Laser Gun body due to our struggle to settle on a design and simplicity of the premade body. We also discussed the two types of 3D modeling hardware that are easily accessible and applicable for us - SLA and FDM. We considered Stereolithography (SLA), which uses a vat of liquid photopolymers resin that can be cured or hardened. The other type of 3D printing we considered was FDM, which works by extruding thermoplastic filaments through a heated nozzle. Furthermore, we provided an overview of our laser gun system and the power supply needed to operate it. We used a power supply that cooperates with our laser emitter and receiver diodes and has two modes, Automatic power control (APC) and Constant current (CC). We also discussed the need for a microcontroller when designing an electrical system and its ability to integrate important computing components in one chip. We explained the Laser Emitter diode, which uses electrical currents through a diode to generate and emit a lasing state at a diode’s junction of a system. In addition, we discussed the need for a phototransistor and photoresistors and their different functions. The Laser Receiver diode is vital for our Laser Gun system and Texas star target, as it is required for the function of our gun that allows it to be “hit” by another laser gun, incorporating a player vs. player game mode to our system. We also discussed the Lens and aperture used in our Laser Gun system, which are essential to emit the necessary laser specifications from our lens. Aperture is the opening area of a lens diaphragm that can widen or shrink in allowing light to pass. The lens we’ve decided on is a double-convex magnifier lens with a 21 mm radius, which is crucial to the effectiveness of our laser gun. Lastly, we provided details on the hardware design and the separation between the interior and exterior sections. All of the overview we researched was used in finalizing our Laser gun which we were happy with in the end. The interior of the housing is designed to hold in place our finalized printed circuit board design, which includes an infrared emitter, a power supply, a button that will function as the trigger, an additional button to be used to trigger a “reload,” and a focusing element for the infrared emitter and receiver. The exterior of the blaster is designed in such a way that it is comfortable for a user of reasonable size to use comfortably.

6. Project Prototype

We plan for our prototype to properly represent the functionality of a product we could take to market, or show to a board of directors as a proof of concept of what can be done with existing technology. In section 6.1 *Integrated schematics* we focus on the importance of such schematics in our design planning stages. In our Laser Gun system’s design planning the software we’ve decided to use is one that is a part of our Undergraduate curriculum as this software was vital in completing the Junior Design course 3926L which is a prerequisite to this senior design course.

The Autodesk software EAGLE is an electronic design automation software which allows users to design printed circuit boards easily by connecting schematic diagrams, component placements and PCB routing all on a software that we are familiar with.We’ll also be discussing within this section our PCB vendor and assembly which is essential process of our laser gun system there are several steps needed to assemble a printed circuit board such as applying solder paste, Component Placement,the need for a reflow oven, Inspection,Through-Hole Part Insertion, and final inspection and cleaning. The last portion of section 6 the final coding plan is detailed where all members of the group will be responsible for completing different parts of the code.

To manage the possibility of using different processors for different parts of the product Visual Studio Code will be used with extensions to help manage the different libraries associated with each. Due to the straightforward nature of our approach to coding, we will be doing much of the debugging with the physical prototype in-hand while running it off of a microcontroller to test the code.

6.1 Integrated Schematics

Integrated schematics are a necessity when designing an electrical system. The integrated schematics show a digital view of the Circuit board we’ll need to physically design, so developing the integrated schematics as similar to the final product as you can ensures success in printing out our final models of the circuit board. For our project the software we’ve decided to use is one that is a part of our Undergraduate curriculum as this software was vital in completing the Junior Design course 3926L which is a prerequisite to this senior design course.

The Autodesk software EAGLE is an electronic design automation software which allows users to design printed circuit boards easily by connecting schematic diagrams, component placements and PCB routing all on a software that we are familiar with. Because of our familiarity we feel as though this is the software that we'll choose in order to print our circuit board in Senior Design 2. Eagle is also available free to students which allows us to remove the cost of the software from our budget. Below is an example of a Printed circuit board designed on Eagle:

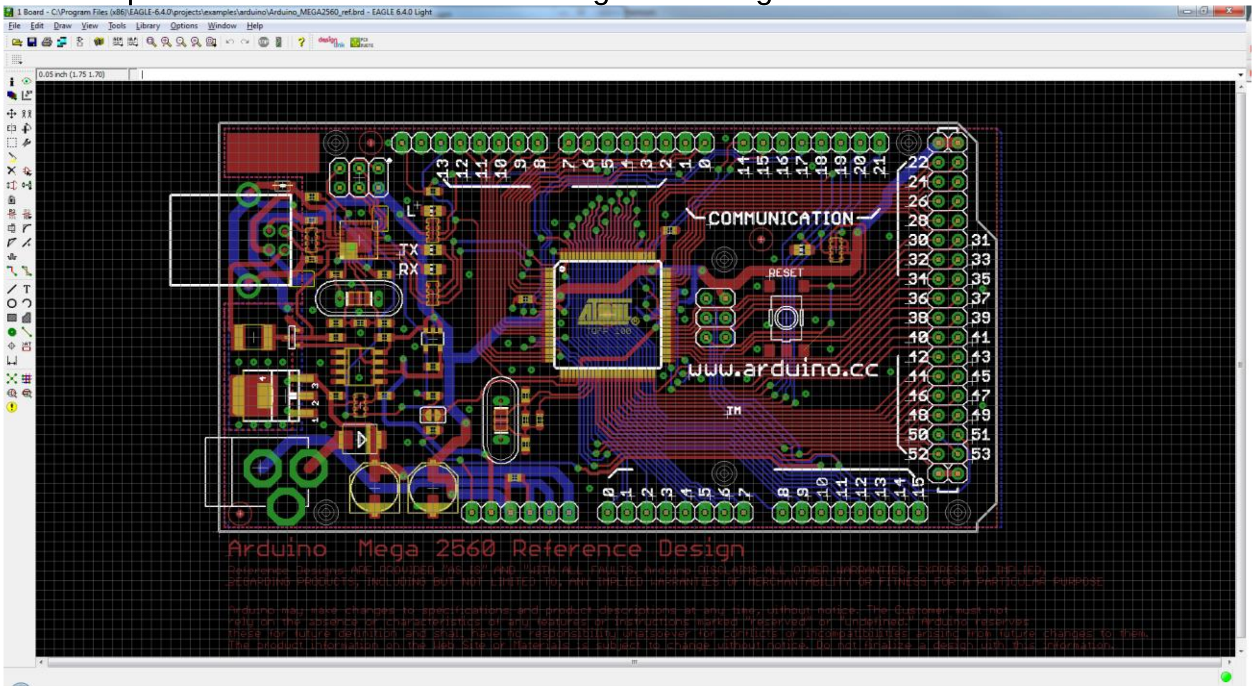


Figure 20: Arduino Uno Layout

6.2 PCB Vendor and Assembly

In this section we will talk about where we plan on getting the PCB from, and how we are going to assemble it. There are numerous different vendor options for our Printed circuit board all of which will be assembled on campus at the University of Central Florida's senior design lab where there is a soldering machine and reflow oven available and capable of assembling components that are needed for our printed circuit board. Although no member of this team has prior knowledge and/or experience with the soldering process needed for a printed circuit board we are grateful for the opportunity given to us during our Junior Design course at the University of central florida which gave us the prior option to solder a PCB during the course curriculum. According to www.4pcb.com a site known for leading the PCB industry in quality and innovation the following is the essential steps in the assembly process of the printed circuit board [18]:

- **Solder Paste**: If you're following a traditional PCB assembly process, the first step is the application of solder paste.

- **Component Placement**: In the traditional PCB assembly process, the next step is to place the components on the board. This can be done manually, or it can be done with the assistance of machinery (pick and place systems). In THT assembly, components are placed by hand, which requires incredible precision. In the SMT process, robotic systems place components on the board.

- **Reflow**: In the traditional PCB assembly process, the next step is reflow, which is when the solder is first melted and then resolidified. The board and all its components move through an oven, which heats the solder, liquifying it and ensuring that connections are formed before the board moves into a cooler, where the solder is cooled.

- **Inspection**: The next step in the traditional PCB assembly process is a visual inspection of the board, soldering, and components.

- **Through-Hole Part Insertion**: The traditional process requires that through-hole insertion be done manually, after the reflow and inspection process. Soldering is also often done manually, but it may be done using wave soldering.

- **Final Inspection and Cleaning**: The final step in the traditional PCB assembly process is a final inspection of the board, the solder points, and the components, and a cleaning to ensure that debris or excess solder is removed.

6.3 Final Coding Plan

As of the writing of this document we plan to use Arduino microcontrollers to bring our project to life. We have chosen this because as a group we feel that we have the most proficiency with the Arduino language.l However, because of the shortages still occurring in the consumer electronics industry our plans may have to change based on what is available for us to purchase.

All members of the group will be responsible for completing different parts of the code. To manage the possibility of using different processors for different parts of the product Visual Studio Code will be used with extensions to help manage the different libraries associated with each.

Due to the straightforward nature of our approach to coding, such as the lack of bluetooth or other wireless connectivity, we will be doing much of the debugging with the physical prototype in-hand while running it off of a microcontroller to test the code. The straightforwardness of our project was also another factor in the selection of the Arduino family of microcontrollers as the simplicity of the Arduino language will pair well with our code's simplicity. While the TI-MSP could offer greater power over what happens in our design it would add an unnecessary degree of complication and possibly lengthen the time it takes to write the code, therefore pushing back our testing and completion of the prototype.

Code functionality will also be recycled where at all possible not only to save time, but also to reduce debugging issues. If everything uses similar methods for coding it will be much easier to weed out problems that have been solved before, as well as preventing any unforeseen errors by testing and applying fixes to other parts of the code where processes are similar.

6.4.1 Project Prototype Summary

In this section we talked about how we plan on creating a functioning prototype that we could take to market. In section 6.1 Integrated schematics, we focused on the importance of schematics in our current design planning stages. We will use Autodesk Eagle for designing our custom circuit boards. Eagle is a software that allows users to design printed circuit boards with ease by connecting schematic diagrams, component placements, and PCB wire routing, all on a software that we are familiar with from taking Junior Design. Once we design the board there are still many steps left to assemble the circuit board. Such as applying solder paste, Component Placement,the need for a reflow oven, Inspection,Through-Hole Part Insertion, and final inspection and cleaning. In section 6.3 Final Coding Plan, we talked about how each member of the group will be responsible for programming certain aspects of the project.

The use of integrated schematics is essential when designing electrical systems. These schematics show a digital view of the circuit board that we are physically designing. For this project we decided to use a program that we learned as part of our undergraduate curriculum, as this software was vital in completing Junior Design. Eagle will allow us to fully build and design our circuit virtually due to its extensive libraries and part selections. Once we have our board layout all finalized, we will then have to send it off to be built. When we receive the blank board back, we will then have to attach all of our components to the blank board.

There are numerous different vendors that offer services such as custom printed circuit boards. Regardless of which one we decide to go with, all of the boards would then be assembled on campus in the senior design lab. The lab has multiple soldering stations, as well as a reflow oven. Even though no one in our group has experience in designing, purchasing, and assembling custom circuit boards, we look forward to furthering our knowledge.

At this moment our group still plans on using the Arduino ATmega328P to bring our project to life. Our group chose this microcontroller because we felt the most comfortable programming with Arduino. All members of our group will be responsible for completing different parts of the code. Due to the nature of our approach, troubleshooting will be done with the prototype in hard, see what is and isn't functioning as intended.

6.4.2 Project Prototype Addendum

To summarize our senior design project, we planned on creating a functioning prototype that we could take to market. To achieve this goal, we emphasized the importance of integrated schematics, which provide a digital view of the circuit board we are physically designing. We decided to use Autodesk Eagle, a software that we learned as part of our undergraduate curriculum, to design our custom circuit boards. Once we finalized our board layout, we sent it off to be built and assembled with a non-associated manufacturer in China.
Although none of us have experience in designing, purchasing, and assembling custom circuit boards, we are excited to learn more about the process. We also planned on using the Arduino ATmega328P microcontroller, which we are familiar with, to bring our project to life. Each member of the group would be responsible for completing different parts of the code, and we troubleshooted the prototype to ensure everything is functioning as intended. Overall, we were confident in our approach and our project came to fruition.

7. Testing Plan

In this section we will discuss how we plan on testing the various aspects of our blaster. Including the laser, light intensity, phototransistor response, texas star’s hit detection and drop mechanism. As well as the blasters functionality, including, game mode selector, ammo counter/ reloading, the health and ammo display, gameplay test of the laser tag and Texas Star systems. Testing each component independently is very important, not for just making sure each piece works correctly, but also this should reduce the number of problems we find when we put all the different systems together. It is very important that we test each aspect of our project because if just one component does not function as intended, it may lead to other problems.

7.1 Testing of Laser

To test the IR laser we will be testing it in two ways. The first of these will also be testing the phototransistor as we will just shine the IR laser at the phototransistor and measure to see if there is a response, this is the least robust of the two tests as one or both components could be nonfunctional.

The second method for testing is far more robust, but requires the use of an additional device. Unfortunately, due to the nature of infrared it is outside the spectrum of light humans can observe so we cannot simply use our eyes to confirm the function or position of the IR laser when it is projected. Thankfully technology exists that allows us to overcome this hurdle, and it is known commonly as night vision or infrared cameras.

Night vision works by using digital cameras that record infrared light rather than visible light, and this is usually used in combat or hunting roles as infrared light is emitted when heat is radiated from ,in these cases, humans or animals. However, as weapon-mounted lasers have become common, militaries faced an issue when trying to utilize night vision; the lasers they were normally using were not visible when the soldiers were using the night vision alone to see. So the solution was to use a weapon mounted laser that was in the infrared spectrum. Thankfully after many years monoculars that allow you to see in the infrared spectrum are widely available for $100 or less and are commonly used by hunters to spot animals in low light conditions. We plan to use one of these monoculars to not only ensure that the IR laser is working, but to also allow us to affix functional sights to the blaster that lets the user reliably aim the weapon.

7.1.1 Light Intensity

In this section we will talk about how we are going to measure the light intensity based on the aperture and lens systems. We will have to experiment with what size and type of lens we should use to focus our IR beam. Depending on the aperture of the lens, the beam generated could be very different. We will have to find one that has a wide enough cone to be detected at reasonable ranges, but not too wide to the point where there is no accuracy required. There are lots of different ways that someone can measure light intensity. This can be measured using a power meter.

Since we are using inferred instead of lasers, there is no risk of eye injury. Focusing a laser can cause serious eye injuries, but inferred doesn't have any risk.

7.1.2 IR Receiver Response

After testing the intensity of our IR emitter we will then use it, in addition to a spectrum analyzer, to measure the output signal generated by the infrared receiver in response to having the infrared beam projected onto it. While we could measure the output in response to varying intensities of infrared light, that would be out of the scope of our project as we are only interested in looking for the specific output caused by the infrared beam produced by the laser diode we have selected for use in our blaster. However, we will also conduct tests to determine the infrared receiver's response to ambient light indoors as well as outdoors to determine if there is a significant amount of noise that could prove troublesome if we do not account for it in our design. While the datasheet claims that the infrared receiver is resistant to noise we still must test fringe cases as when dealing with infrared light there are many sources of noise that vary with environment and location.

For example heat sources output infrared radiation, and this could possibly create noise that would then exceed what the infrared receiver is capable of suppressing. So tests such as holding a heat source at varying distances from the infrared receiver and checking for noise that is large compared to the output generated by our infrared emitter would help us gain valuable insight about what conditions to avoid when using this system.

7.2 Testing of Texas Star

The testing of the Texas Star can be broken down into two sections. The first is testing that the IR beam from the blaster is actually making contact with the plate and causing the phototransistor to produce a change in current that the microcontroller can recognize and react to. The second test is ensuring that the plates actually disconnect themselves from the arms of the Texas Star when they register a hit. In section 7.2 we'll be discussing our hit detection on each plate where we discussed two methods one is the same as the tests for the laser described above: by using an IR monocular we will be able to tell if the IR laser from the blaster is making contact with the phototransistor. The second method is not only for testing purposes but also allows for us to have a more robust hit detection system. Once the plate recognizes that it has been hit the electromagnet will be switched off and the rotational energy of the moving Texas Star combined with gravity will cause the plate to fall to the ground.

To prevent damage to the electronics when the plate falls to the ground the target will be constructed in such a way that the PCB will not be absorbing the energy from the impact. To aid in protecting the PCB as well as whatever surface the plate is falling onto there will be a rubber coating on the edges of the plate.

7.2.1 Hit detection on each plate

The hit detection on each plate will be confirmed initially by current probe, but later in the project as pieces are fabricated and the circuitry is harder to reach we have other methods of confirming hits. One is the same as the tests for the laser described above: by using an IR monocular we will be able to tell if the IR laser from the blaster is making contact with the phototransistor.

The second method is not only for testing purposes but also allows for us to have a more robust hit detection system. For this the design for the plates will have LEDs in them that will be turned on when the plate detects that it has been hit with the IR laser. This creates a more robust system because even if the electromagnet system works flawlessly there may be fringe cases where the target is spinning so fast or in such a manner that the plate does not dislodge properly, but this is not a catastrophic failure as it is possible to encounter this error with the actual Texas Star. Rather this is a way to confirm in these fringe cases that the system did work and the plate was hit, much like one would check the real-life plate for a bullet impact in the case it did not release itself from the target.

The test will be considered a success so long as the LED changes its color from green to red to confirm that it is hit. This can be reaffirmed by the use of an infrared camera, and if both of these are true then the plates will pass this test.

7.2.2 Drop mechanics

As previously stated each plate will be affixed to the end of an arm of the Texas star via an electromagnet, and provided additional stability by two posts that will be inserted into holes at the end of each arm to prevent undesired rotation of the target that would cause it to face away from the user. These posts will be made out of the same PLA as the rest of the target to reduce weight and cost, unless initial testing proves for the filament to be too fragile to withstand the focus generated by the spin of the target. In this case we would install posts of a more durable material onto the existing plate while trying to not add excessive weight or cost to the design.

Once the plate recognizes that it has been hit the electromagnet will be switched off and the rotational energy of the moving Texas Star combined with gravity will cause the plate to fall to the ground. To prevent damage to the electronics when the plate falls to the ground the target will be constructed in such a way that the PCB will not be absorbing the energy from the impact. To aid in protecting the PCB as well as whatever surface the plate is falling onto there will be a rubber coating on the edges of the plate.

This test will be considered a test if the plates disengage the electromagnet when detecting a hit as described in the previous section. If the electromagnet disengages and this coincides with the hit detection on the plate ⅔ times then the test will be considered successful. The plate does not need to fall from the Texas Star for a successful test as there may be physical forces outside of the scope of our project that cause this.

7.3 Blaster functionality

In this section we will cover how we plan to test each aspect of our blaster and Texas Star. Every aspect needs to be tested to ensure that it is working properly. The main systems are the game mode selector where we will be breaking colors into six different

LED meanings , ammunition counter/ reloading mechanic which as long as the ammo value is not zero, every time the trigger button is pressed, decrease the ammo count by one. If the reload button is pressed, reset the ammo value to the maximum value. If the ammo value is between six and twelve, the LED should be green. If it's between one and five, the LED should be yellow.

In health and ammunition display As long as the ammo value is not zero, every time the trigger button is pressed, decrease the ammo count by one. If the reload button is pressed, reset the ammo value to the maximum value as well as a way to test the gameplay as a whole including requirements of the laser tag guns this project was inspired from claim to have a range of up to 225 feet, and while this may be similar to the standard laser tag version of our design, the Texas Star introduces an entirely different mode with different rules.

In addition to this, even if the Texas Star did function at the full range it may not be useful at this range as hitting a target six-inches in diameter from over 200 feet would be difficult to do using only the naked eye. So it is important to combine the data that we extract from the following testing strategies with a reasonable range for shooting the target without any assistance from magnified optical aiming devices.

7.3.1 Game mode selector

In order to test the game mode selector, we will set up an Arduino Mega, with just a single button and an LED. Each time the button is pressed, it should change the LED's color. When the system turns on the LED will just be set to green, but once a button is pressed, the LED should cycle through each game, which each have their own specified color.

Color:	LED Meaning:
Green	System Startup
Red	Red Team
Blue	Blue Team
Purple	Free for all
Yellow	One in the Chamber
White	Target Shooting

Table 3: Status LED Meaning

7.3.2 Ammo counter/ Reloading

For testing the ammunition counter, and reloading mechanic we will set up the same Arduino Mega with an LED and two buttons, one representing the trigger and one representing the reload. The system will print the number shots remaining to the terminal. Let's say a full starting clip is twelve shots. As long as the ammo value is not zero, every time the trigger button is pressed, decrease the ammo count by one. If the reload button is pressed, reset the ammo value to the maximum value. If the ammo value is between six and twelve, the LED should be green. If it's between one and five, the LED should be yellow. If the ammo is zero, then the LED should turn red. All of this can be set up and tested on a sample board and added to the complete system code later.

No matter the value of the ammo counter the system should still reload if the input is given by the user. Even on a full magazine the process should still occur as there is no reason to stop the user from doing this and they should be allowed to reload as frequently or infrequently as they desire.

We must also test for a very common issue in electronics: button bouncing. In our selection of buttons we decided to make the most cost effective choice. It will be important to monitor the frequency of bouncing in the preliminary stages of testing, and as early as breadboard setups.

It is important to identify this issue quickly and either eliminate it through debouncing code or buy higher quality buttons that are less prone to bounce. Button bouncing is something that must be eliminated from this project as our prototype will be moving around almost all the time and that will expose us to more chances of it happening. Additionally, if the button were to bounce and cause the trigger of the gun controller to be pulled twice in an amount of time that is quicker than a human’s reaction time that would give one user an unfair advantage against another and possibly cause two hits to occur when there should have been only one.

For this reason button debounce must be a near non-existent occurrence. For this test if the button bounces less than three times out of one hundred pushes then we will consider this test a success. If this does not succeed through debounce programming then we will simply order buttons with built in debounce.

7.3.3 Health and Ammo display

In order to test the health and ammo display, we will use the same Arduino Mega again, as well as the hit detection system and two LED’s. Let's say a full starting clip is twelve shots. As long as the ammo value is not zero, every time the trigger button is pressed, decrease the ammo count by one. If the reload button is pressed, reset the ammo value to the maximum value. If the ammo value is between six and twelve, the LED should be green. If it's between one and five, the LED should be yellow. If the ammo is zero, then the LED should turn red.

Color	Remaining Ammo Count
Green	Greater than 6
Yellow	Between 1 and 5
Red	Empty, must reload

Table 4: Ammo Count LED Color Meanings

7.3.4 Gameplay Test

In this section we will discuss how we will actually test the real mechanics of the game, both how the laser tag system will be tested, and how the Texas Star will be tested. The actual gameplay is very important because at the end of the day, it is a game and should function as one. We will have to test every aspect of gameplay, from just making sure the basic principles of laser tag are functioning, to the Texas Star responding to being hit.

Starting with laser tag, our blaster will have to be able to cycle through the different modes efficiently, as well as being able to emit and detect hits. It is very important that we test the laser tag system because if that does not function, then nothing else will. We will also have to test the Texas Star to ensure that when a hit is detected, drop the plate. We will have to experiment with accuracy a little bit so that a shot can’t hit two or more plates in one go.

7.3.4.1 Laser Tag Test

Our laser tag game should be playable in many different environments. Whether that be indoor or outdoors, bright areas or dark areas, it should function in both. We will have to test casual game play in both environments to ensure that the system functions correctly in both. We will start with standing still, gun to gun shooting, to ensure that all previous parts still function. Then once that is confirmed to work we can move on to actually running different matches and game modes, ensuring that each one works as intended. We will likely find quite a few issues here and there that will need to be fixed.

The general method of testing the game modes is to try and mix and match the modes on the blasters to one that does not match with the purpose in which you are trying to apply it. For instance if both blasters are set to be on the blue team they should not accept the emitted infrared signal from each other, and while there is such a thing as friendly fire in real life we must consider that the beam expands at distance and would cause more complications if we implemented a friendly fire system.

Another test would be to put one blaster in Free for All mode and another on one of the teams. The two different frequencies emitted by each of the blasters should not be accepted as valid input by the other as they are not intended to be used in conjunction.

7.3.4.2 Texas Star Testing

For testing the Texas Star most of it would be testing the hit detection and the drop mechanism. We would also need to test to see if distance affects the accuracy or the detectability of the plates themselves. We would have to test six feet away from the target, then fifteen feet, and so on until we find a distance that no longer works as the system is intended to work.

While the laser tag guns this project was inspired from claim to have a range of up to 225 feet, and while this may be similar to the standard laser tag version of our design, the Texas Star introduces an entirely different mode with different rules. In addition to this, even if the Texas Star did function at the full range it may not be useful at this range as hitting a target six-inches in diameter from over 200 feet would be difficult to do using only the naked eye. So it is important to combine the data that we extract from the following testing strategies with a reasonable range for shooting the target without any assistance from magnified optical aiming devices.

This would then allow us to determine a recommended distance for use in which the blaster still works as intended. While this would likely be less than the functional range for use in the modes that pit player against player due to the clustering of multiple targets in a relatively small area, it would allow for the user to have realistic expectations and use our design without malfunction due to the expansion of the infrared beam.

Since the blasters have a Texas Star Mode it then implies we ensure that the Texas Star plates only accept the frequency that is output by the blaster when in the appropriate mode. In this testing we would of course try to ensure that this is the case.

As we are going outside of the norm of how these laser tag systems are typically used this section of the project has the potential to prove much more difficult than expected. In typical laser tag scenarios it is not common to have five targets grouped such a short distance from each other as we have in the case of the Texas Star, and in addition to the erratic motion we intend for the Texas Star to exhibit when in use. It is because of these reasons that the difficult situation may arise that multiple plates are being hit after only a single function of the blaster. If this were to be a prevalent issue there may be solution such as just installing a motor to turn the Texas Star at a constant speed to test if the erratic swinging motion is the cause of the failure to function properly, and from this we could implement one of or all of the following solutions:

- Add darkened pieces of plastic or other translucent material that could act as a sort-of resistor to the infrared beam, such that the beam would have to be much closer to the photodiode for the signal to be accepted.
- Change the frequency of the infrared signal we are shooting at the target, by shifting the frequency it may be possible to avoid physical modification to the design.
- Make the tolerances of accepted signals tighter, as to reduce the chances of having a less direct signal be received by the photodiode on the plate.
- Make the Texas Star swing slower or faster: while this is the most simple solution it may be possible to avoid any major modification by just changing the speed at which the Texas Star moves could possibly solve this problem.

However, if this issue occurs very rarely, say once every twenty full games and no more than once per game, we believe it to be acceptable to call this a fringe case and ignore it. This could be written off as similar to the real target as there are a few situations in which the bullet could split and strike two plates, the bullet strikes the plate in just such a way it knocks another loose, and other such phenomena.

The next function to test after this would then be the speed and pattern in which the Texas Star moves as the plates are dropped from it. While we intend for the target to be a decent challenge it should not be difficult to the point where it would be too difficult for a new user to reliably make hits on the targets, but not so slow that it does not present a challenge to a regular user. So if we find that the movement pattern and or speed does not satisfy both of these cases it may be better to affix an electrical motor that just spins the Texas Star at a constant speed.

If the Texas Star is able to consistently spin and react for a gameplay session lasting a minimum of 20 seconds for ⅔ tries then we will consider this a success and forgo the addition of an electric motor to the design.

7.4.1 Testing Plan Summary

In this section we went over all the different aspects of our project that we will need to test to ensure everything is working properly. Once we have our circuit all laid out and designed, we will prototype our design using a breadboard. We will also use the breadboard to test a majority of our functionality. With the breadboard we will be able to test the trigger pulls, the health and ammo displays, the reload mechanics, the player to player hit detection, game mode selector, and many more. Once we test a majority of our parts using the breadboard, we can move on to actually assembling the final products and testing and modifying the design.

We will test the IR emitter in two different ways, using a photoresistor to get a rough idea of intensity. As well as an IR receiver diode. The next thing we will have to test is the light intensity, based on various apertures and lens systems. The beam will need to be focused in such a way that it will have a high accuracy, even at further distances.

The Texas Star will have to be tested for hit detection, and if the plates can be dropped away from the system. We have a couple different back up ideas in case the electromagnets don't work out. The first being that once a plate is hit, it will just light up, alerting the user that they hit the target. The second is that we could attach a motor to the target, which will cause the whole system to spin at a constant speed.

Testing the blaster mechanics is really the biggest part since our project is laser tag first. We will have to test every aspect of the blaster, including, game mode selection, ammo counting and reloading, the health and ammo display, as well as testing the physical gameplay. All of these systems will have to work simultaneously or else our project will have issues. For us to test the actual gameplay, we will play in different environments, indoors and outdoors.

7.4.2 Testing Plan Addendum

In order to ensure the success of our project, testing was an integral part of our plan. As mentioned previously, we began testing by prototyping our design using a breadboard, allowing us to test a majority of our functionality, including the trigger pulls, health and ammo displays, reload mechanics, player to player hit detection, and game mode selector. This enabled us to ensure that all of our systems are working together as intended before moving on to the final assembly and modifications. One crucial component that requires extensive testing was the IR emitter. We tested the emitter's intensity using both a photoresistor and an IR receiver diode, and tested the beam's accuracy at various distances. We also tested the Texas Star for hit detection and the ability of the plates to be dropped away from the system. We had backup plans in place in case the electromagnets did not work as expected, including lighting up the plates or attaching a motor to the target but thankfully we were able to integrate it into our system. Testing the blaster mechanics was the most critical aspect of our project, as it is the foundation of the laser tag gameplay. We tested every aspect of the blaster, including game mode selection, ammo counting and reloading, health and ammo displays, and physical gameplay. To ensure that our system worked seamlessly, we played in different environments, both indoors and outdoors. By doing so, we became confident that our project was ready for implementation and can provide a fun and engaging experience for users. In conclusion, our testing plan was comprehensive and essential to ensuring the success of our project. Through breadboarding, testing the IR emitter and Texas Star, and extensive testing of the blaster mechanics, we assure you that our laser tag system is functional, reliable, and fun to use.

8. Administrative Content

In this section of our senior design document, we will discuss the steps we took to follow the project milestones and stay on track during Fall 2022 and Spring 2023 semesters. For Fall 2022, each milestone is listed, as well as the date in which we plan to have it completed by. The major categories are then broken into subtasks, including which team is responsible for completing that task. The estimated amount of time is also shown with a start and end date. For Spring 2023, each major milestone is listed, but no due date for each as of yet since we haven't received information about it yet. Once we do, we can go in and update the table.

We will also go over our initial budget and initial Bill Of Materials. These are subject to change when we actually start ordering and testing parts, but as of now we believe we cover most of our bases.

8.1 Milestone Discussion

Number	**Task**	**Start**	**End**	**Status**	**Responsible**
Senior Design 1					
1	**Ideas**	8/23/2022	9/1/2022	Complete	Group
2	**Project Selection and Role Assignment**	9/5/2022	9/9/2022	Complete	Group
	Project Record				
3	Initial Divide and Conquer	9/9/2022	9/16/2022	In Progress	Group
4	Final Document	9/16/2022	9/30/2022	In Progress	Group
	Engineering Analysis, Documentation, Design				
5	IR emitter and receiver for Laser Guns	9/16/2022	11/4/2022	Researching	James
6	IR receiver for Texas Star	9/16/2022	11/4/2022	Researching	James
7	Design PCB for power delivery	9/16/2022	11/4/2022	Researching	James
8	Write code for hit detection	9/16/2022	11/4/2022	Researching	Chace

9	Write code for reload	9/16/2022	11/4/2022	Researching	Reneau
10	Write code for ammo capacity	9/16/2022	11/4/2022	Researching	Reneau
11	Write code for Health bar	9/16/2022	11/4/2022	Researching	Reneau
12	Write code for laser tag or target shooting mode	9/16/2022	11/4/2022	Researching	Reneau
13	Mechanism to drop plates once hit is detected	9/16/2022	11/4/2022	Researching	Chace
14	Design Gun model/ layout	9/16/2022	11/4/2022	Researching	Chace
15	Design Texas Star	9/16/2022	11/4/2022	Researching	Chace
	60 Page Senior Design Draft	9/30/2022	11/4/2022	In Progress	Group
16	Cover Page and Summary	9/30/2022	10/14/2022	In Progress	Group
17	Technical objectives, goals, specifications	9/30/2022	10/14/2022	In Progress	Group
18	Research and investigation	9/30/2022	10/21/2022	In Progress	Group
19	Design overview	9/30/2022	10/21/2022	In Progress	Group
20	Explicit Design	9/30/2022	10/28/2022	In Progress	Group
21	Project Summary and Conclusion	9/30/2022	10/28/2022	In Progress	Group
22	Appendices	9/30/2022	10/28/2022	In Progress	Group
	100 Page Report Submission	9/30/2022	11/18/2022	In Progres	Group

				s	
23	Finalize Cover Page and Summary	11/4/2022	11/11/2022	In Progress	Group
24	Finalize Technical objectives/ Goals	11/4/2022	11/11/2022	In Progress	Group
25	Finalize Design overview	11/4/2022	11/11/2022	In Progress	Group
26	Finalize Project Summary and Conclusion	11/4/2022	11/18/2022	In Progress	Group
27	Finalize Appendices	11/4/2022	11/18/2022	In Progress	Group
28	**Final Document**	9/30/2022	12/6/2022	In Progress	Group
29	**Order and Test Parts**	11/1/2022	12/6/2022	Researching	Group
Senior Design 2					
30	**Built Prototype**	1/9/2023	1/13/2023		
31	**Test and Redesign**	TBA	TBA		Group
	Test Laser Tag System	TBA	TBA		Group
	Test Texas Star System	TBA	TBA		Group
32	**Finalize Prototype**	TBA	TBA		Group
33	**Peer Presentation**	TBA	TBA		Group

Table 5: Milestone Discussion

8.2 Budget and Finance Discussion

In this section we will talk about our budget, and parts list. For this project, we were hoping to get all of the parts for less than $400 total. Considering our initial budget is already $357, it is looking like that will probably go over. We are aware that part of the budget has to include buying parts and testing to see what works and what does not work. As well as buying duplicates of certain pieces that might be more likely to fail.

	Part	**Description**	**Unit Price**	**Amount**	**Total Price**
Laser guns:	Nerf Laser OPS	Nefs Laser Tag gun for reference of what parts to get	21	1	21
	IR Emitter/ Receiver	To sensor IR signals	10	8	9
	Misc	Buttons, switches, resistors, etc	20	1	20
	Battery pack	Power the guns	6	3	18
	Body of Gun	Find or create model/ 3D print	5	3	15
	PCB	Control power delivery	20	3	60
	LED's	Pack of 25 various colors	5	1	5
	ATMEGA328P-PU Arduino Bootloader	Integrated Circuit	8	6.75	54
	ED281DT	Socket	8	0.318	2.544
				Total:	204.544
Texas Star:	2"x4"x96"	Target Stand	4.25	4	17
	1" bearing	Pillow Block Ball Bearing	2	11	22
	1" bolt	Mounts star to bearing	3	1	3
	3/8" bolt	Mounts bearing to frame	0.33	4	1.32
	LED's	Pack of 25 various colors	5	1	5
	PCB	Detects hits	10	5	50
	Infrared Sensor	To sense IR signals	2	5	10
	Electromagnets	Affix and detach plates from star	5	5	25
	IR Monocular	Allow us to view IR beam from gun	57.9	1	57.9

	Misc	Buttons, switches, resistors, etc	20	1	20
				Total:	211.22
				Grand Total:	415.764

Table 6: Initial Budget

8.3 Bill Of Materials

In this section we show our Bill Of Materials. It is our current plan for parts that we will end up using in our final project. As the semester goes on, we will update it with any material changes, or new materials added.

Part	Description	Vendor	Quantity	Unit Price	Total Price
TSOP38238	IR Receiver	Amazon	4	1.5	6
TSAL6200	IR Emitter	Amazon	4	1.5	6

Apex RC Products #2931	Battery Pack	Amazon	5	2	10
Adafruit Industries 1119	Tactile Switch Buttons	Digikey	10		15
ATMEGA328P-PU Arduino Bootloader	Integrated Circuit	Digikey	8	6.75	54
ED281DT	Socket	Digikey	8	0.318	2.544
FBA_TRS-775W	DC Motor	Amazon	1	15.89	15.89
RRPDMSCSGSPC	DC Motor Controller	Amazon	1	9.99	9.99
PGN - UCP205-16	1" Pillow Block Ball Bearing	Amazon	2	11	22
Adafruit Industries 3873	Electromagnet	Digikey	5	9.95	49.75
1825232-1	Slide Switches	Digikey	10	0.431	4.31
RG-BK-4	Breadboard	Amazon	2	5.99	11.98
				Total:	195.484

Table 7: Bill Of Materials

8.4 Project Operations

In this section we will discuss how our project will function. The game will start once the player selects a mode. If they could pick multiplayer modes such as: team deathmatch, free for all, one in the chamber. Or they could pick the shooting range mode, which will only target the Texas Star. The steps of the game, as well as troubleshooting issues with understanding how the game will function.

8.4.1 Laser Tag Game Modes Setup

At the start, a player will have to select which mode they would like to play. Whether that be teams, free for all, shooting range, or any other modes we include. The user will be able to choose their mode by using a dedicated button to cycle through the available modes and once they have cycled to their desired mode they may lock into it by depressing the reload button. Once a mode has been selected the players may begin. If they choose some sort of multiplayer laser tag, they can then start and play a normal game of laser tag. Each blaster will display the player's health and ammo, and alert the player if they run out of health.

To enter the team-based mode users will need to cycle through the modes until the LEDs are either red or blue. The color of the LED will let the user know which team they are on. There are no restrictions on team size, save for the fact that there will need to be a minimum of one person on each team for the game to be played. This is because this mode lacks “friendly fire” or the ability to damage one’s teammates, and because of this you will actually need somebody on the opposing team in order to play the game, but the users may choose the dispersion of players between teams so long as there is a minimum of one member per team. Each player has a starting health amount that is decreased each time their blaster registers a hit from a user that is on the enemy team. Once the user’s health has been reduced to zero they are eliminated from the match and their blaster will no longer be able perform any function until it is turned off and back on again, from which the user begins the selection process again.
The round will end when one of the two teams has been eliminated via the enemy team reducing each of their health to zero.

In the free for all mode each user is able to damage every other user. Unlike the team-based mode there is nothing to stop a player from damaging another provided that one or both of them has not been eliminated. Each player has a starting health amount that is decreased each time their blaster registers a hit from one of the other user’s blasters. Once the user’s health has been reduced to zero they are eliminated from the match and their blaster will no longer be able perform any function until it is turned off and back on again, from which the user begins the selection process again. The free for all game mode is over when all or only one player is left, and if there is only one user who has not been eliminated they will be declared the winner.

8.4.2 Texas Star Game Mode Setup

If the player chooses the shooting range, then the Texas Star system will be used. The goal would be to clear the star as fast as possible. To set up the target itself, the plates must be switched on and attached one at a time. The user will know the plate is on because the LEDs on the plate’s side which houses the infrared sensing diode will light up green. Once the plate is turned on the electromagnet will be active and the player should affix the plate to the end of an empty arm, being careful to slot the posts into the holes and allowing for the electromagnet to make full contact with the ferromagnetic plate, ensuring that the electromagnet is able to use its full strength.

Once the player has hit a target, a counter will begin which will display how fast the target was cleared. Ideally, after a target is hit, it should release from the system, which would then cause the system to spin. The spinning motion would cause an increase in difficulty, because now the player would have to hit a moving target. The targets will be released from the system via their electromagnets being turned off. However, in the case that a target is het and registers it, but does not release the players will still be able to confirm they hit their target by looking at the LEDs on the sensing side of the plate. These LEDs that were green at startup will be red if the plate detected a hit, and remain red until the plate is switched off.

8.4.3 Results

Once a round of laser tag is played, the player or team that runs out of players will all receive a message saying that their team has been eliminated. There will not be a post game screen for points kept as the only real objective of the laser tag modes is to eliminate all of the enemies. Points are not valuable in these modes as they are war games and the only result that matters is the elimination of the opposition.

In the target mode that utilizes the Texas Star the user's gun controller will keep track of how long it took them to hit all of the targets. The users could play this mode competitively if they wished, comparing times, or they could compete against themselves to try and beat their best time. This mode also does not utilize points as the Texas Star is meant to be a test of both speed and accuracy simultaneously as the user must hit all of the targets as fast as possible, but still must be accurate enough to hit the plates while they are moving.

8.4.4 Troubleshooting

In order to help players understand the game, we will create a written list of rules and directions. Including how to turn the blasters on, walking them through the game mode selectors, and explaining the basis of how it works.

We will also provide the players with the knowledge they need to effectively make use of our project. In the case of the laser gun controller we will provide them with instructions on how to utilize the controller and access all of its functions. These instructions will inform players on how to operate access all the functions and features of the laser gun controller such as:

- How to turn on the laser gun controller
- How to cycle through game modes
- How to select a game mode
- The features of each game mode
- How to interpret the round count LED
- How to reload
- How to play each mode
- How to know when you are eliminated
- How to Know when you've won

In the case of the texas star there will be less functions but all the same we will provide instructions on the following topics:

- How to turn on the plates
- How to mount the plates to the arms
- The objective of the Texas Star
- How to use the laser gun controller with the Texas Star
- How to know when a plate has been hit
- What to do if a plate does not fall
- Tips and tricks for beginners on how best to hit all the plates

In the Final design of the Laser Blaster Controller if there is any error the best course of action is to simply reset the controller by turning it on and off again and checking its connection to the battery as well. If the wrong team has been chosen at startup this mistake can be fixed in this way.

In the case of resetting the targets the idea is the same except that the targets have no power switch and the battery will just have to be unplugged then reconnected to reset the plate.

8.5 Administrative Content Summary

This section dealt with all the administrative issues in our project. Topics like budgeting costs of materials, management of time, objective deadlines, the electronic components required for this prototype, the setup of the devices, troubleshooting issues, and what results the users can expect.

The bill of materials and budget discussion tables include our estimated costs of the project. The bill of materials includes all the major electric components we require for our prototype, and how much they cost per unit, and how much they will cost us at the end of the day. The budget discussion table includes our estimated costs for other more minor or common components like resistors and such, but it also includes materials that we will require for testing our project.

The remaining sections pertain to how we should communicate knowledge from us about the project that would be relevant to the end user of it.

9. Summary and Conclusion

In this section we will review our project summary, what it will take for us to have a successful project and what our next steps are. Our project is a new take on laser tag, which has been around for years. The real twist though is the Texas Star implementation.

9.1 Project Summary

The idea for our project began as just a single bullet point when the group was just two members the day after the first lecture, but with the addition of only a third member it quickly became the forerunner for being selected as it either intersected with our personal hobbies, seemed like the most fun out of all the options, or seemed like a reasonable amount of work for a group that was at three quarters capacity. Additionally, this idea was selected as we felt that as computer and electrical engineering have a much larger overlap with the consumer market than most other engineering disciplines, why should we try to come up with some life altering product? We are engineers, not humanitarians, and we've been tasked with something that will take the better part of a year to complete so why not have fun with it? That was the thought process that pushed us to combine our interests in shooting sports with our knowledge in electronics, and because of this we have created a project that allows us to have fun while we learn the finer points of bringing a design to life.

9.2 Project Success and Next Steps

Moving Forward into Senior Design 2 our goal will be to complete all of our objectives ahead of schedule. Since we already have a good framework and the main parts of our projects share the same foundations as well as simple and repeatable design we should be able to push forward into next semester at an accelerated pace. Going forward into Senior Design 2 we can categorize what needs to be accomplished into three general sections, that being: design, testing, and assembly.

The design aspect comprises both the hardware and software aspects of the design. First we will need to finalize the design of the required printed circuit board(s) that will allow both our blasters and plates to work. We will complete a much more rigid and final design for all the components, committing to a design for them on a program like EasyEDA or Eagle so that the printed circuit board can be assembled, while also making sure the desired parts can actually be sourced before we commit to putting them in our final PCB design. While at the same time we must also be open to changing the design should parts suddenly become unavailable, and while this is certainly not ideal it is the way things have to be in a post-COVID world why the industries are possibly still in recovery.

On the Software part of the design we will have to complete the code that serves as the backbone of this project. The most basic parts of the code like the infrared detection will be shared between the code for the plates and the blasters, and from there we can diverge. The plates' code will need to be expanded to cause the detection of the infrared beam to switch off the electromagnet and activate LEDs to confirm the hit. The blaster's code will be more extensive as it not only needs its basic functions but these need to be expanded upon and modified to fit the different modes. The first part to be completed will give the blaster the functionality to "shoot" by emitting an infrared beam and also the basis for a "magazine" that limits how many times the blaster will function before a reload is required, and this will suffice for the Target mode. This will be expanded as some modes like Free for All and Teams will require a health/life system and the integration of the hit detection to work, and the One in the Chamber mode will have a modified magazine size.

The last part of the design stage that will need to occur after the design of the hardware is the design of the housing systems for both the plate and the blaster. Once the dimensions for the printed circuit boards and other components are finalized then the internal portion of the blaster and plate housing may be finalized, but the exterior and general look can be worked on at the same time as the initial hardware and software development as it can always be scaled and reshaped at any point before it is finalized and printed.

Next is the testing portion, and for this there are a few different kinds of tests that need to be conducted. The first of these is tests on the actual components to ensure they are actually functional from the supplier. While this is just a small precaution it is one that can save us a lot of time and stress down the line. The second kind of testing will also be on the hardware, but in these tests we will be specifically testing the response and output of the infrared receivers and emitters respectively. While the manufacturers will provide their expected ranges it is best to be prudent and confirm these both with isolated components as well as testing them in a mock up of our final design.

With the testing of the hardware concluded and a good range of values of input and output we can then fine tune our software and begin testing our system in full and making adjustments as needed. Once the software has been integrated with the hardware, we can conduct a full test on the system and confirm it works as intended.

After all the testing has been completed we can move onto the final phase which is assembly. The first step of this is to complete and assemble the printed circuit boards, and this will most likely be done via the oven located in the junior design lab. Once this is completed and we confirm it is functional then the interior dimensions of the housings for the blasters and plates may be finalized and printed via a 3D printer owned by one of our group members. After printing all that is left is to assemble the components inside the housing as well as building the body for the Texas Star.

9.3 Concluding Thoughts

Completing Senior Design 1 has given us all valuable insight to what the task of getting a product to the market actually entails. Going from brainstorming for an idea to bring to life to actualizing the design of the prototype, creating tests, and selecting the parts that best fit our needs.

As electrical and computer engineers this has all been a valuable experience that we can all benefit from in our future careers if even just to a small degree as understanding not only what parts are needed for a project for a design, but also how to source them and make sure they are compatible as well.

However, chief among the skills we learned that has not been mentioned yet is learning how to work among a team of your peers. While all of us have worked in internship positions, and that has helped a great deal to manage expectations of each other, it is much different than working in a group like this where everyone comes in at level footing to apply their own knowledge compared to learning from others with more experience than you.

This creates an environment where everyone must divide and conquer in order to prosper, and this is a skill that is not often used or taught in our time at college. In many such cases group projects are often dreaded, particularly in general education classes, because it is inevitable that one to almost all of your group members are going to not put in any work and lay the burden of one or more people on top of your workload, but in this project there is no room for any of this behavior as everyone must contribute or fail. The inclusion of a peer review is also good insurance against one member dragging the group down.

All of us in this group are very excited to move on to the actual building phase of our project in Senior Design 2. While the experience we have taken from Senior Design 1 is invaluable, typically fun for engineers lies in getting hand-on and manifesting a tangible product and not so much administrative needs.

That being said we are all brimming with anticipation for assembling and testing our idea we have spent a whole semester planning and our entire college career waiting for. This will also be a new experience for most of us as we all took Junior Design at different times, and for some of us that meant at the least not being able to create our own board for that project, while for others it meant not being able to get hands on with a project like that at all due to being during the peak of the COVID-19 pandemic. So this should prove both a fun and novel experience for all group members as we finally get to take a product from start to prototype.

We also are looking forward to taking these designs from drawings to physical form that we can interact with and hand tune to our liking, as well as play the game we have spent so long designing.

We hope to end up with a project we can say we took pride in designing as well as had fun with. We also hope that we can take the lessons we learned in this class with us into the workforce as we leave UCF behind to begin our careers as fully fledged engineers.

Now that the design has been finished and looking back at this paper all the members of the group feel accomplished to deliver on a prototype of this project that met all of the functional requirements without any of the functional alterations needed. While The Texas Star has some issue due to the spread of the IR beam this is within acceptable parameters as the size of the target itself could always be built in a more updated prototype, but the target plates themselves function perfectly.

Appendix A References

[1] "Arduino Tutorial: IR Transmitter and IR Receiver". https://mschoeffler.com/2021/05/01/arduino-tutorial-ir-transmitter-and-ir-receiver-hx-m121-hx-53-ky-005-ky-022-keyes-iduino-open-smart/

[2] "Use an IR Remote Transmitter and Receiver with Arduino". https://create.arduino.cc/projecthub/electropeak/use-an-ir-remote-transmitter-and-receiver-with-arduino-1e6bc8

[3] "Photoresistors". https://eepower.com/resistor-guide/resistor-types/photo-resistor/#

[4] "Photodiodes". https://www.teamwavelength.com/photodiode-basics/

[5] "Phototransistor". https://www.electronics-notes.com/articles/electronic_components/transistor/what-is-a-phototransistor-tutorial.php

[6] "Block Diagram" https://www.microtool.de/en/knowledge-base/what-is-a-block-diagram/#:~:text=A%20block%20diagram%20is%20a,in%20this%20type%20of%20diagram.

[7] "Blender". https://all3dp.com/2/blender-3d-printing-tutorial/#:~:text=Enter%20Blender%2C%20a%20wonderfully%20accessible,creating%20your%20own%20printable%20objects.

[8] "Laser Diodes". https://www.laserfocusworld.com/detectors-imaging/article/16548556/laser-diodes-require-the-right-power-source

[9] "TI MSP430FR6989". https://www.ti.com/product/MSP430FR6989#product-details

[10] "WHAT IS THE DIFFERENCE BETWEEN THE APERTURE AND F-STOP" https://maratstepanoff.com/aperture-in-photography/

[11] "ATMEGA328P-PU Arduino Bootloader" https://www.digikey.com/en/products/detail/universal-solder-electronics-ltd/ATMEGA328P-PU-Arduino-Bootloader/16822123

[12] "Arduino Uno Rev3"

https://store-usa.arduino.cc/products/arduino-uno-rev3?gclid=Cj0KCQiAgribBhDkARIsAASA5buuauXLwzj0LTEORXOlzqawReOyIBnhtXoJ2oH50Tj-UYN1ZRDaEW0aAgY8EALw_wcB

[13] “ED281DT” https://www.digikey.com/en/products/detail/on-shore-technology-inc/ED281DT/4147600

[14] “Easyeda” https://easyeda.com/editor

[15] “Laser safety class descriptions” https://lasersafetyu.kentek.com/laser-safety-rich/should-there-be-a-class-5-laser

[16] “FDA purpose” https://www.usa.gov/federal-agencies/food-and-drug-administration

[17] “Different Microcontrollers used today” https://embeddedschool.in/different-types-of-microcontroller-programming-used-in-embedded-systems/

[18] “PCB Assembly process” https://www.4pcb.com/blog/the-pcb-assembly-process-and-what-you-should-know/

[18] “Vishay TSOP38238 IR Receiver Datasheet” https://www.digikey.com/en/products/detail/vishay-semiconductor-opto-division/TSOP38238/1681362

[19] “Vishay TSAL6200 IR Emitter Datasheet” https://www.digikey.com/en/products/detail/vishay-semiconductor-opto-division/TSAL6200/1681339?utm_adgroup=Infrared%2C%20UV%2C%20Visible%20Emitters&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Optoelectronics&utm_term=&utm_content=Infrared%2C%20UV%2C%20Visible%20Emitters&gclid=Cj0KCQiA99ybBhD9ARIsALvZavW0fns-hnCFp2jkCiNtV7fEscfGYzQIqVePoTWXzux795_C87Q_wsEaAk2KEALw_wcB

[20] “Arduino Make Your Uno” https://store-usa.arduino.cc/products/make-your-uno-kit?gclid=CjwKCAiAyfybBhBKEiwAgtB7fpGvJM688ltbBHNFxp_gueeHM-umY_mwPeAgaK8CBZmXElqO5RdNsBoCBB8QAvD_BwE