# Vest Free Laser Tag and Texas Star (VFLTTS)

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### *Abstract —* 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 realm of laser tag.

***Index Terms —* Circuits, Electronic Circuits, Microcontrollers, Infrared sensors, Electromagnets, Digital signal processing.**

### I. Background

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 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 MILES and pairing them with detectors, it’s effective for training development. 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. 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. Like radios and phones used by government defense 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 famous 1960s television series and quickly became a worldwide pop-culture phenomenon. With an estimated $10.6 billion in revenue, it is one of the most recognizable and highest-grossing media franchises of all time. 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 titled 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 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. George Carter III, an inventor, 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.

### II. Introduction

For our laser tag part of the blaster, we began looking into adding various “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. The blaster would also have more functionality than what NERF offers currently. Such as taking the reload feature a step further by allowing the user to select from various maximum “magazine” sizes. We are also 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. Enters the Texas Star, a challenging target long enjoyed by shooting enthusiasts that is mounted on a swinging base holding a few 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 untapped potential for a simulation of this for a low cost.

### III. OBJECTIVES & REQUIREMENTS

In this section, we will outline the specific objectives and stretch goals that will enable us to achieve the required functionality and performance of our laser gun system. Our primary objective is to develop a weapon that is highly accurate and reliable, with the ability to engage a variety of targets effectively. To achieve this, we will focus on optimizing the system's power output, beam quality, and thermal management capabilities.

In addition to meeting these core requirements, we have identified several stretch goals that will further enhance the system's capabilities. These include increasing the range of the laser gun system, improving its ability to operate in adverse weather conditions, and enhancing its compatibility with other tactical equipment. We will also explore the potential to incorporate advanced targeting and sighting systems to further improve the accuracy and effectiveness of the weapon.

Ultimately, our goal is to develop a laser gun system that exceeds our initial requirements and sets a new standard for precision weapons in the military, law enforcement, and security sectors. By establishing clear objectives and ambitious stretch goals, we are confident that we can deliver a laser gun system that meets the needs of our customers and exceeds their expectations. Below are the objectives and requirements we’ve selected:

*A. Objectives:*

1) Create Working Laser emitters & receivers on blasters

2) Create laser blasters with variable “magazine” sizes

3) Have a functioning game mode selector

4) Display player health and ammo capacity on the blaster

5) Create working receiver for Texas Star target

6) Create a mechanism on Texas Star Target that allows for plates to be dropped

*B. Stretch Goals:*

1)Unique Rifle Body Design or Other Body Design Variants

2)Sound Effects for Firing, Hit, Reload, Mode Select

3)Various Magazine Sizes

4)Extra space/rails on blasters for accessories

5)Digital Ammo Display

*C. Requirements:*

This section will cover all 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, or a repurposed toy gun with a hollow inside. This will allow room for the microcontroller, LED’s, IR emitter and receiver, etc. The other component 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.

### IV. SYSTEM COMPONENTS

These sections discuss the Laser system and its various components, which are individual physical modules that are either purchased or designed and then integrated to form the final product. The following section offers a partially technical overview of each of these components.

*A. Microcontroller*

We’ve 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 write the code. The microcontroller chosen is also feasible to acquire, which was important in our final decision. Arduino microcontrollers are relatively cheap, have a small form factor, there is an extensive library selection, and are in stock. As a group we are very experienced in the programming language. However, it is not as capable as other options, and has no onboard USB or Bluetooth, but features like these were not a concern in our case.

*B. Electromagnets*

The electromagnet model that was selected is the Adafruit Industries 3873. This particular electromagnet is advertised as having 5Kg of holding force which, according to the datasheet, should be able to hold onto half of the advertised holding force, 2.5Kg or around 5.5lbs in this case, but upon actual implementation has proven to be much stronger than expected. The greater than expected strength of the electromagnets has not had any negative impact on the performance of the targets but had the actual strength of the electromagnets been known the weaker, and cheaper, 2.5Kg holding force magnets could have been used instead.

This particular electromagnet style was chosen not only because of strength and price, but also because it is a simple inductor with power and ground terminals that allow it to be easily integrated into our design. Due to its simple design, it functions much like a small electric motor would, and this is a positive as there are certain requirements when using inductors in this way that are applicable to both cases of an electromagnet and a motor, but the use of motors is much better documented online. The main design factor that had to be included was the inclusion of a kickback diode which will be discussed in a later section.

*C. Infrared Emitter/ Receiver*

For our IR communication components, we chose the Gikfun EK8477. These IR emitters and receivers were chosen because they met the few requirements we had for them, which were that they only need a 5v source, and came as a pair so we could ensure they were compatible with each other to minimize possible complications during board prototyping and programming. Another benefit of choosing these specific boards is that they had mounting holes sized for M3 screws already which makes mounting them inside the blaster much simpler, and the same sized mounting hole was then used on the board for the blaster and target to reduce the number of different parts that needed to be used. These emitters and receivers were also made to function with the Arduino hardware and coding language, making their implementation much easier. The IR signal is transmitted at 38KHz, and the modulation is done by an IR library that was implemented in the code.

### V. Similar Projects and Products

Our blaster design was based on NERF’s AlphaPoint Nerf Laser Ops Pro. This blaster inspired us to combine the emitter and receiver portion of the laser tag gun into the same body. While we were inspired by this product, after buying and experimenting with them we thought we could improve on some aspects of the design as well as adding a simulated Texas Star that was truer to the original than other offerings on the market.

All of the readily available Texas Star toys are intended for either foam dart guns or low-power air rifles, which makes this concept of a laser tag compatible Texas Star to be a unique market offering.

### VI. System Concept

Our laser tag system consists of three team selectors, green, yellow, and red team. Green and yellow are for regular team deathmatch, while red is free for all. Using the fire buttons on the blaster, the player can toggle through, and lock in their mode by pressing the reload button.

Each of these modes has a specific hexadecimal value it is expecting and will be discussed more in Section VIII.

Diagram

Description automatically generated

Fig. 1. Simple system diagram of logic for team selection function

### VII. Hardware Detail

The blaster and target boards use some of the same targets in a few cases to simplify the design of each. They both use the same Arduino nano, resistors, LEDs, and 9v batteries for power.

The blaster as described utilizes both an IR emitter and receiver so that it can perform all the necessary functions of laser tag in a single package. The emitter and receiver both require individual data pins as well as a connection to the nano’s 5v power, and their 5v voltage requirement was the reason they were selected over others. The IR emitter and receiver function much like a TV remote does, by encoding, sending, and receiving hex code, and by doing this it is possible to create game modes that ignore friendly fire, or making it so if there are multi-person teams the teammates cannot damage each other.

The blaster and target both use LEDs and a 220Ω resistor to limit the current through them. The blaster uses single resistors for each pin used as their purpose is to indicate information to the user such as game-mode, health, and ammo count. While it would be possible to use a multi-color LED it was decided not to as the frame of the blaster will have more than enough room for all the components, and having multiple LEDs spaced out will also make it easier for the user to interpret all this information at a glance. The target only utilized two pins for LEDs as it only needs to indicate if it has been hit or not. To accomplish this green and red LEDs are used to indicate no-hit or hit, respectively, and for greater visual clarity at range 3 LEDs are connected in parallel for each indicator color. Only 3 are used as it is both a reasonable amount for the size of the target and how many can be used at once while providing a reasonable and consistent brightness while using one of the Arduino Nano’s digital pins. While smaller surface mount LEDs exist, the larger through hole mount LEDs are far more ideal for brightness and clarity.

The electromagnet(s) used on the target(s) were initially an issue in board testing as the digital pins on the Arduino Nano were insufficient in terms of voltage and/or current supply. While the datasheet claimed that the digital pins should provide 5v, as was required by the electromagnets, when measured by a voltmeter they did not provide this as they fluctuate from 1-4v, and additionally it was suggested that they may not be providing enough current as well, but by this time the issue had been resolved. The solution to this was to add a PN2222 NPN transistor to function as a switch and connect the 5v pin to the source of this, a pin to the gate for control, and the electromagnet to the drain. This was a very quick and easy solution as due to how close the voltage and current are on the gate and source no additional resistance is required.

Both the blaster and targets utilize a switch between the 9v battery and the Vin pin of the Arduino Nano that turns them on and off as well as functioning as a reset. While it would also be possible to program a reset mode into both it is just as easy, especially in the case of the target, to just reset them by turning power off and on again rather than add more code and/or another component to either board.

The blaster utilizes two 4-pin push buttons that function as the trigger and reload button and are also used to select game mode upon boot-up of the blaster. Both buttons are current regulated by a 10KΩ resistor going into ground as they are also connected to a digital pin to provide input to the board and the 5v pin.

### VIII. Software Components

The software used for this project may be broken down into two sections, one for each part of the project: the blaster’s code and the Texas Star’s code.

*A. Blaster Code*

Our code has 5 main functions, “game\_mode”, “LED\_state”, “fire\_detect”, “dead”, and “play”.

The “game\_mode” function runs only on startup, this code allows the player to toggle through the three different team selectors, and then lock in their choice.

The “LED\_state” function runs continuously, to show the appropriate health and ammo remaining for the player. This takes the form of

The “fire\_detect” function also runs continuously, checking for two events, if the player has been shot, or if they have pulled the trigger. Each doing the appropriate action, either decreasing health and flashing a single LED to display that a hit has been detected or decreasing ammo after detecting that the trigger has been pulled. The hit detection here is driven by Arduino’s infrared (IR) libraries that allow for a connected infrared emitter to transmit a hexadecimal value that is then received by an infrared emitter, and this hexadecimal value is specific to the game mode selected to prevent the user from possibly hitting themselves or a teammate if they happen to be playing in one of the team modes. It is important to note here that both the emitter and receiver must be compatible with Arduino hardware and its language.

The “dead” function is a loop that continuously checks if the player's health is zero, and if it is, then the end display is triggered. The play loop runs while the player is alive, once they run out of health all the LED’s turn off and the hit detection LED flashes every second. This signals that the game is over.

Diagram

Description automatically generated

Fig. 2. Simple system diagram of logic for blaster during a session of play.

*B. Texas Star Code*

The Texas Star, or rather the plates of the Texas Star, function in a similar manner to the blaster in means of detecting hits. To be efficient with time as well as having a uniform software design for the entire project, the “fire detect” function was repurposed for its functionality of detecting a preprogramed hexadecimal value and then executing an action in response.

In the case of the plates of the Texas Star when each of them are powered on they initiate their game mode immediately as they have no need for selection, and the green LEDs as well as the electromagnet are turned on. The plate(s) then run through the modified “fire detect” function continuously until a hit is detected. At that point the green LEDs as well as the electromagnets are turned off and the red LEDs are turned on to indicate that the target has been hit.

### IX. Board Design

The blaster’s board is a bit unorthodox as not many of the components are actually connected to the board, rather the board just serves as a hub for all the components to be wired into the Arduino. Due to the need for the blaster to be similar in construction to a pistol to fit the hand of the user, as well as have all of the LED indicators in visible locations, and the controls being easy to access, the components must be connected by wires to the board and placed elsewhere on or within the blaster. This influenced the design by making the board as small as possible while attempting to allocate all the footprints for the components that needed to be placed elsewhere in the blaster, on the outer edge so it would be easier to install the board as well as those components within the body of the blaster.

The target board is very much the opposite of this as the idea when designing it was to line up with the square design of the prototype plates and make the target board larger than it needed to be to create an easy surface to arrange the LED indicators as well as the IR receiver. The target board was designed to be slightly smaller than the plywood square it is installed on to allow the LEDs to be spaced out in a triangle pattern as it makes it more visible to the user.

### X. Conclusion

While all of the functional requirements of the project were met there was only a single goal that was not met, and this was making the Texas Star function as intended. While the individual plates function as required, due to some unfortunate factors the Texas Star cannot be played as intended because when fired upon it is difficult to hit only a single plate. This issue is due to the spread of the infrared beam and could be remedied in a few ways.

The first of these is simply increasing the scale of the Texas Star’s arms. This is a very straightforward solution but could possibly help as the iteration of the Texas Star in this project is in a much smaller form than the original shooting target is based on, and the increased distance between plates could possible make the spread of the infrared beam a negligible issue.

The second solution would be to implement a focusing lens much like the one used by the NERF product that inspired this project, and while this could be a simple fix for some, this project group lacks an optical engineer and thus the knowledge or skills needed to select or create such a lens.

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.

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, it would be more enjoyable and engaging to make a fun product while also learning the process of bringing an invention to life.

### References

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