Senior Design Project - High Level Design

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1 Introduction

As senior electrical engineering majors this semester, we have been tasked with developing a solution to a real-world problem by applying the knowledge and skills we have acquired over the past three years. This task is designed to help us bridge the gap between theoretical learning and practical problem solving, which will provide us with experience with designing and developing products that incorporate electrical devices, systems, and engineering knowledge. The project is intended to simulate the challenges that we will likely face in our future careers, and this will be our first opportunity to demonstrate our abilities to solve these problems as many electrical engineers do across the world.

Furthermore, this project emphasizes the importance of teamwork, which mirrors the way teams of engineers work together in professional engineering environments. In order to meet the project requirements, we must create a solution that demonstrates what we have learned while incorporating or improving existing technologies. Lastly, we have been given a budget of five hundred dollars, which ensures that our solution is cost-effective and practical.

Considering these specifications, our group has decided to design and create a portable laser tag system called Galactic Laser Operations (GLO). This solution provides the perfect platform to showcase our technical abilities and knowledge as it will incorporate many electrical components and subsystems, including sensors, wireless communication systems, power management and delivery systems, and integrated software. The laser tag system will provide a sufficient test to our team, as we will have to contemplate how to most effectively solve numerous engineering challenges such as signal

processing, embedded systems, user interface, and circuit design, all while staying within the five hundred dollar budget. We believe that this project aligns with the goals of the senior design class, as it simulates a real-world engineering problem, allowing us to come up with our own creative solution that applies the theoretical knowledge we have picked up, while also allowing us to develop our ability to collaborate with others.

2 Problem Statement and Proposed Solution

Laser tag is a fun and engaging activity that has long been enjoyed by many people all over the world. It combines strategy, teamwork, athleticism, competition, and fast-paced action, making it a great way for friends and family to spend time together. Traditionally, laser tag has only been available at dedicated facilities with specialized equipment. These venues have provided this unique experience to players for years, however, the landscape of entertainment has greatly shifted in recent times. The rise of at-home entertainment options, including streaming services, gaming systems, and virtual reality goggles, has led consumers to become accustomed to entertainment they can enjoy in the comfort of their own homes. As a result, traditional laser tag venues have experienced a decline in popularity, with many opting for more convenient options compared to these at-home alternatives. While the idea of at-home laser tag systems has emerged as a more favorable alternative, current market offerings are far too expensive to be a justifiable purchase for the average consumer. For example, one of the leading at-home laser tag companies, Laserwar, sells its most basic kit for over $1,200 (Laserwar). This kit includes two laser tag guns and two headbands. Furthermore, many at-home kits lack the quality and immersive aspects that have made laser tag enjoyable for so many people. This has left a significant gap in the market for a product that delivers the same entertainment value as traditional laser tag while in the convenience of one's home at an affordable price.

Therefore, our project aims to revolutionize the classic laser tag experience by creating a portable system that can be played anywhere. The kit will include two laser blasters that detect hits through infrared LED transmitters, IR receivers, and a microcontroller. The blasters will include both

the transmitter and receiver modules, as well as lights, sounds, and haptic feedback to let the user know when they have been hit or when the game has concluded. The system will also include a web interface that all the blasters will wirelessly communicate back to. The web interface will be used to set the game mode, the game timer, and track scores.

3 System Requirements

Before our group can go about solving the problem outlined above, we must first set some system requirements to be met. By meeting these requirements, we can ensure that our product is a success and will deliver on the promises of a fun, affordable, and portable laser tag system. These requirements take various forms with physical requirements, safety requirements, technical capabilities, and important features. The requirements are organized into sections based on which subsystem they are a part of: blaster module, user interface, transmitter, receiver, or control software.

Blaster Module

- Houses user interface system
- Houses IR transmitter and receiver system
- Must be lightweight and comfortably fit in the User's hand
- Must clearly be a toy
- Must correctly distinguish between hits and non-hits
- Must house the microcontroller
- Must house the battery pack

Microcontroller

- Must take input from IR sensors & trigger and output to lights, speakers, laser emitter, buzzer
- Must modulate the laser emitter

Transmitter

- IR emitter and laser emitter that fires when the actuator is stimulated
- Minimal spread from IR laser, directional at a distance of 30 feet or less

Receiver

- Must correctly detect hits and relay data to microcontroller

User Interface

- The actuator should be easy to stimulate
- Have lights, buzzers, speakers to give feedback
- Must keep track of health, received hits, and transmitted hits
- ON/OFF switch

Battery Module:

- Must last at least 24 game hours

Web Server/ Control Software

- Must be able to start the game
- Keeps track of the time, and communicates with the other blasters at a range of 30 feet
- Send out a signal to all modules
- Ability to set and start the timer
- Outputs game information to a screen

4 System Block Diagram

Block diagrams are useful tools in the planning and prototyping phase of developing a product. They are used to break down complex systems and simplify them into individual components, and show how they are all interconnected.

4.1 Overall System:

The overall system will comprise of two main components, the blasters and the web server. The blaster modules will be subsequently broken down into other subsystems, such as the transmitter subsystem, receiver subsystem, and the user interface subsystem. The web server will be where the blaster modules communicate back to, and will display game score and control the game. The block diagram for the overall system can be seen in **Figure 1.**

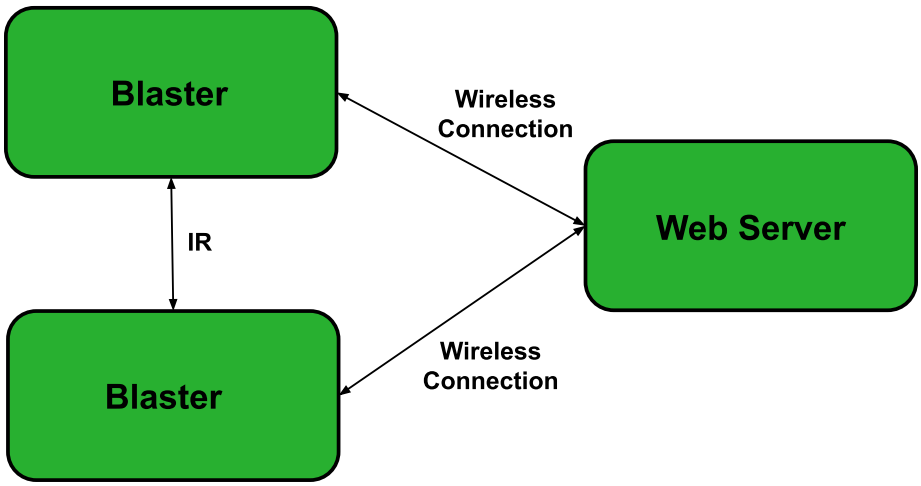

Figure 1. Overall System Block Diagram

4.2 Blaster Module Description and Interface Requirements:

The blaster module is the part of the product that will be responsible for shooting the laser and detecting when the player has been hit. It must fit comfortably in the user's hand, have an actuator, and include a buzzer, lights, and speakers.

4.2.1 Transmitter Subsystem

The transmitter subsystem is a critical component responsible for the conversion of input signals into modulated infrared light. The actuator will be an element that the user interfaces with, such as a button or switch, that starts the signal transmission. Additionally, a blaster sound will be transmitted through a speaker upon the same interaction with the actuator. A driver circuit will be used to amplify and module the signal and prepare it for transmission. The IR LED will emit the modulated infrared light that corresponds to the input signal. We intend to demonstrate that the IR LED can send a modulated signal upon the stimulation of the actuator. The block diagram for the transmitter subsystem is shown in **Figure 2**.

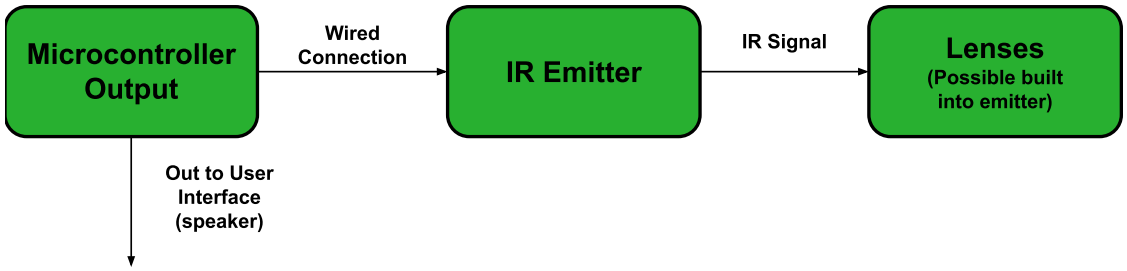

Figure 2. Transmitter Subsystem Block Diagram

4.2.2 Receiver Subsystem

The receiver subsystem will consist of components that will receive and process the transmitted signal. An IR receiver module will be used to detect infrared light. An amplifier and filter circuit will be used to

enhance the strength of the received signal and ideally isolate the modulated signal from any ambient noise. Signal processing will be used to decode the signal and forward it along to the user interface subsystem for application-specific use, like scoring. We intend to demonstrate that the signal from the IR LED can be sufficiently received and processed. The block diagram for the receiver subsystem is shown in **Figure 3**.

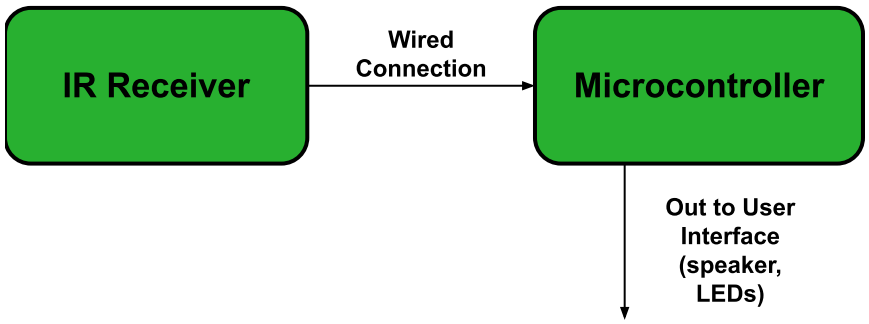

Figure 3. Receiver Subsystem Block Diagram

4.2.3 User Interface Subsystem

LED indicators will light up and buzzers will vibrate to signal that a player has been hit. They could also be used to indicate the amount of shots left in the blaster. A speaker will also be used to play noises when shots are fired, and when the player is hit by another player. It could also be used to start or end game modes. The User Interface also encompasses all buttons that the user could be interacting with, such as the trigger or potential reload. The block diagram for the user interface subsystem is shown in **Figure 4**.

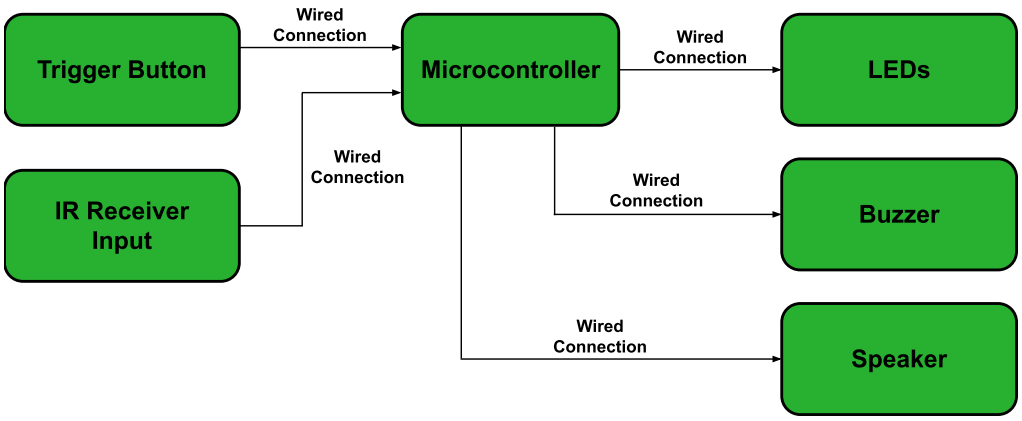

Figure 4. User Interface Subsystem Block Diagram

4.2.4 Power Subsystem

The power subsystem will take power from the AA batteries, regulate it to any necessary voltages, and distribute it to the other subsystems requiring power. The block diagram for the power subsystem is shown in **Figure 5**.

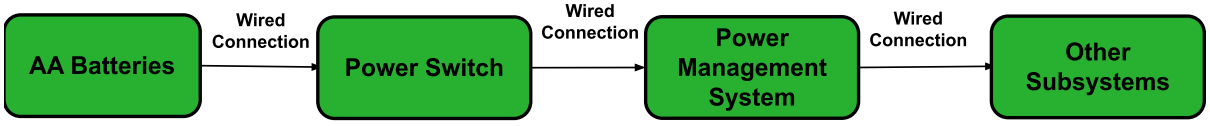

Figure 5. Power Subsystem Block Diagram

4.3 Web Server/ Control Software

A game tracker will be used to update scores, track game progress, and log winners/losers on a connected web server. The microcontrollers will transmit information over WiFi to be stored on the local web server. The block diagram for the web server subsystem is shown in **Figure 6**.

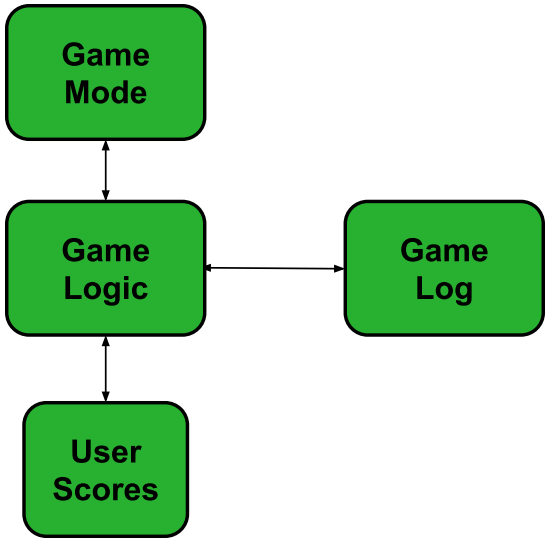

Figure 6. Web Server Subsystem Block Diagram

4.4 Future Enhancement Requirements:

Since we only intend to make two modules for the purpose of Senior Design demonstration, a future goal is to make additional modules that would allow the players to select teams. This would add the extra complexity of ensuring that you cannot be blasted by your own teammate. Additionally, adding a user interface or screen on the blaster to display stats could be an enhancer. More LED lights can be added to the outside of the blaster for a more sleek design.

5 High-Level Design Decisions

5.1 Receiver

Purpose:

Detect incoming IR signals from the other blaster, amplify and filter the signals, and forward 'hit' data to user interface subsystem and control software. This system must detect hits from 30 feet or less and be able to differentiate between sunlight/room lighting and IR signals from the other blaster.

Components:

- IR receiver modules: on the front and each side of the GLO Blaster to amplify detection coverage
- Amplification circuit (built into PCB): Amplifies signals to ensure detection by Microcontroller
- Microcontroller: relay the results to other subsystems like User interface and control software

5.2 User Interface

Purpose:

Provide feedback to users on current game standings and allow users to select from various game modes

Components:

- LED indicators: Signal hits visually to the user
- Buzzers: Provide haptic feedback for hits

- Speaker: Include audio for actions such as blasting and being blasted

5.3 Transmitter

Purpose:

Emit a directional IR signal at least 30 ft after the user shoots their blaster. Add modulation to help differentiate IR emitter and other sources. Emit a class 1 directional laser diode at least 30 ft for aiming purposes.

Components:

- IR Emitter: Modulated to transmit signals when the actuator is pressed
- Amplification Circuit: Amplifies signal and ensures proper modulation (built into PCB)
- Actuator: A trigger or button that serves as user interface for initiating the signal transmission
- The directionality and power of the emitter chosen is crucial. If the emitter is not directional enough, it will make the game too easy by allowing for hits even when the blasters are not aimed at each other. If the power is too low, the blasters will have too short a range, or need to be used only in low light (or both).

5.4 Control Software

Purpose:

Manage game settings, track game status, and communicate with blasters for scoring. This system will use WiFi for reliable communication with blasters.

Components:

- Team web server: Allows users to select game mode and Displays scores upon completion of a game
- Microcontroller: Communicates wirelessly with the team web server to upload scoring data and download game mode data

5.5 Power

Purpose:

Provide power to all subsystems while meeting portability requirements

Components:

- Voltage regulators (built into PCB): Ensure consistent and correct power delivery to all components.
- Battery pack: Allows for battery input

5.6 Electronic Housing

Purpose:

Provide a durable, aesthetically pleasing enclosure for all electronic components

Components:

- Blaster shell: Lightweight and comfortable outside that is appealing to the eye and can clearly be identified as a toy with bright colors. Manufactured using a durable material
- Component Mounts: Internal mounts or brackets to securely hold all internal components and allow access to battery replacement
- Openings: Allow for IR transmission/reception, speaker emissions, and actuator placement

6 Known Unknowns

Our high-level design for this laser tag project includes several areas where we are aware of our current gaps in knowledge. These "known unknowns" will require further investigation, research, and testing during design and prototyping phases. Below, we outline these areas and how we aim to address them for this project's success.

Ensuring player safety is a top priority for this team. We will need to conduct research and test power levels for IR LEDs that will provide effective communication while remaining a safe option for direct or indirect exposure to players' or bystanders' eyes. There is continued debate about whether to use IR LEDs or lasers as the primary transmitter source. Lasers appear to provide greater accuracy, but there is safety concern associated with their use in a game environment. According to sources online, Class 1 lasers are safe for this application, so we will use a laser diode with a power of less than 0.4 mW. Additionally, the standard of safety for an LED light for long-term exposure appears to be 100 W/m^2, or 10 mW/cm^2. Further investigation is needed to analyze the tradeoffs between the two options, including factors like safety, effectiveness, and cost.

While we understand the need to design enclosures and mounts for the components of this project, the exact CAD requirements currently remain undetermined. We need to determine the dimensions, materials, and manufacturing process required to create a comfortable and functional design. We will likely use 3D printing as the manufacturing process. As a result, we will also likely use PVA for simplicity and cost-effectiveness. The housing should allow the actuator to be pressed, while also leaving the receivers and transmitters accessible to allow the signals to leave and enter the device.

A significant technical challenge that we anticipate is ensuring that the IR transmitters and receivers will reliably work together at the required distances. Testing is necessary to ensure the effective range and the accuracy of response in various environments, such as indoors, outdoors, and in various lighting conditions.

At this moment, it is unclear whether modulation of the IR signal will be necessary to distinguish out signals from ambient IR noise, such as sunlight or indoor lighting. Additionally, since we are only planning to make 2 devices, it is not necessary to modulate the signals to distinguish players of different teams. If modulation is required, or if we decide to implement it regardless of necessity, we will need to determine the ideal technique for modulation to ensure signal clarity. This will include selecting the appropriate hardware or software setup for modulating the transmitter and demodulating the receiver. Potential options include using a microcontroller with pulse-width modulation (PWM) capabilities or using dedicated IR communication chips with a designated signature.

Another one of the project goals is to incorporate a web server for score tracking and game management. The scope of this, including how the web server communicates with the physical devices, remains undecided. Some options available to ESP32 microcontrollers include Wi-Fi or Bluetooth communications. The platform and framework, such as local hosting or a cloud-based solution, will need to be determined for the web server.

7 Major Component Costs

Part	Cost per	Quantity	Total Cost
Field study / market research (optional)	$15.00	5-7 (Dr. and Mrs. Schafer are invited)	$75.00 ($105 max)
Battery (AA)	$0.84	8	$6.72
Battery holder	$0.875	8	$7.00
LEDs, IR (test)	$2.00	5	$10.00
LEDs, IR (final)	$2.00	2	$4.00
Sensors, IR (test)	$2.00	5	$10.00
Sensors, IR (final)	$2.00	2	$4.00
Speaker	$1.50	2	$3.00
Vibration motor (LRA)	$5.00	2	$10.00
Actuator (push button)	$3.00	2	$6.00
ON/OFF switch (slide)	$1.00	2	$2.00
Total cost			$62.72
Optional total cost			$137.72 ($167.72 max)

8 Conclusions

In conclusion, our senior design project aims to solve the problem of a lack of options for a system that provides all of the joy and excitement of laser tag within the comfort of one's own home for an affordable price. This project will serve as the culmination of four years of hard work and studying by applying the concepts and theory we have learned in our courses up to this point to a real-world problem in an environment that simulates how engineers solve problems every day. The system comprises two main subsystems, the blaster and the web server. The blaster is then broken down into three other subsystems, transmitter, receiver, and user interface, each with their unique requirements and features. We have already come up with many ideas on how to realize our product, but we know that there are still many unknowns that will need to be figured out for our project to be successful. Lastly, given the time and budget constraints of the project, there are many features that we would like to add, but may not be achievable, so we have come up with some future enhancements that others may want to consider in the future. In all, our project will be successful if the listed system requirements are met in a satisfactory manner, the costs do not exceed the budget allowed, and the team successfully works together to implement the outlined solution.

References

"LASERWAR Laser Tag." *Top 6 Home Laser Tag Sets*, laserwar.com/equipments/laser-tag-at-home.

Accessed 15 Dec. 2024.