Laser Skeet

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***Abstract* — This report contains information pertaining to the research, design, and testing of the laser skeet system. The laser skeet is an electronic variant for a common sport used by firearm owners that aims to eliminate the use of explosive ammunitions and safety hazards by using re-usable targets and harmless IR technology. Overviews of power systems, PWM controlled signals, optical signal handling and user feedback interface through external controls are provided. The laser skeet is our version of making a safer alternative to modern methods of skeet shooting and overall target practice.**

***Index terms* — regulators, pulse width modulation, phototransistors, infrared, detection, 802.15.4, LCD, RF, low power MCU, sensor networks.**

I. INTRODUCTION

Skeet is an American shotgun game, designed such that the sportsmen can train in accurate shooting of targets from multiple distances and angles, ensuring no angle of practice is missed. The sport consists of a standard shotgun loaded with skeet shots, which are fired at clay targets launched from "houses." The aim of the sport is to accurately shoot every target at every angle in succession; the houses themselves launch targets in different directions and angles to add further challenge to the sport. While this game has designated practice locations such as regulated shooting ranges and sports facilities, metropolitan and suburban use has not found a niche for skeet shooting.

Because of the regulations set out on firearms in public as well as the disturbances they can cause while handled in unregulated areas, it's easily seen why the skeet sport has not caught on more. Newcomers to the sport may not be comfortable handling firearms or even being around them. The common hazards with most live-round sports come from the unsafe use and practice of handling a firearm.

Electronic Skeet provides a safer environment for the users and those whom are participating or spectating the sport by eliminating live rounds and the chances of a mishap associated with firearms. Similar devices exist on the market but only as entertainment rather than re-usable mobile alternatives. We aim to create a product that would allow for further participation in this exhilarating sport while lowering conventional operating costs, hazards and environmental pollution.

II. OVERVIEW

The Laser Skeet system stems from an idea to incorporate all disciplines of those on this team, including our combined interests in printed circuit board (PCB) design, power systems, radio frequency (RF) systems, programming, optics and photonic devices. These interests are met with a series of specifications listed in Table 1 below and are properly achieved using the following information.

TABLE 1
LASER SKEET SPECIFICATIONS

	RIFLE	TARGET
Realistic Weights	<10lbs	<110g
Dimensions	< 50"	~11cmx2cm
IR Transmission	<0.5" spread	Capable of Capturing
IR Effectiveness	15yd	15yd
RF Effectiveness	15yd	15yd
RF TX Power	<10dBm	<10dBm
Standby Power	<75mW	<15mW
Active Power	<1.0W	<500mW

The traditional sport is performed using a standard shotgun or any model firearm the athlete wishes to use and some clay targets with a launcher. Therefore, the Laser Skeet system will be comprised of the two primary devices, the Laser Skeet Rifle acting as the master control portion of the system and the Laser Skeet Target acting as the sensor receiver and transmitter.

Both devices contain independent power supplies that are stepped down for regulated use within the systems to drive the CC1310 MCU, vibration motors, laser, provide stable PWM outputs to speakers and Operational Amplifiers as well as RF and signal filtration. Each device is made from a clear acrylic composite for both durability and light weight; the material is relatively cheap and can be easily manufactured. The Laser Skeet Rifle is powered by 9.6V NiMH battery pack enclosed in the stock end of the rifle to the PCB enclosed in the barrel of the rifle. A power switch activates the CC1310 and readies the pairing mechanism to the skeet target. The CC1310 is the MCU which drives a PWM signal into the output laser, through an operational amplification circuit to perform safe power management and output of the laser. Furthermore, the MCU controls the speakers and motors using PWM signals and bipolar junction transistor (BJT) to provide power to these two interactive systems (see Figure 1).

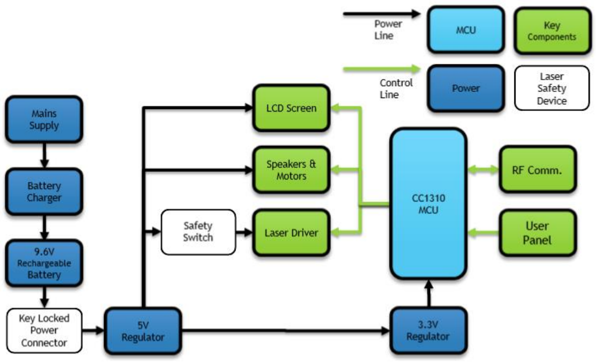

Figure 1 –Block diagram of the Laser Rifle system.

The Skeet Target is powered by two lightweight 3V CR2032 coin cells to drive the phototransistors that filter wavelengths of light to match the one emitted by the rifle, bandpass filtration system to mitigate IR interference of the incoming signal. Another CC1310 MCU is used to detect the incoming message, RF communications to connect to the rifle and communicate with it (see Figure 2).

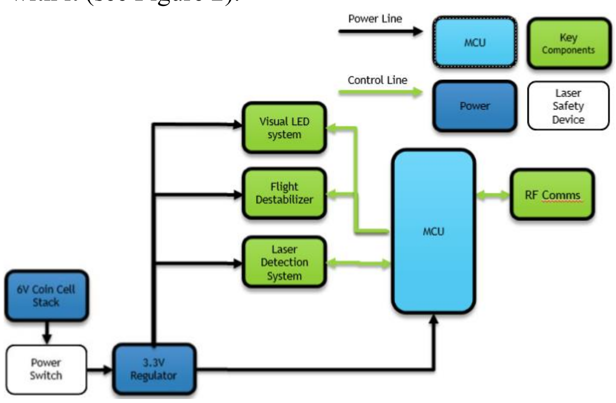

Figure 2 – Block diagram of the Skeet Target system.

The total operations of the system are for the user to shoot the target and the target to transmit back a correct hit. The user will hear a sound and vibration confirming that a shot was made followed by another sound if the target was hit. The target, upon receiving a correct hit, will initiate internal vibration motor controls to oscillate the target and thrown it off a trajectory, to simulate it being shot down. On the rifle's Sharp LCD screen, metrics are displayed showing the accuracy of shots and tracker overall performance.

Safety measures are enacted to correctly abide by the IEEE 802.15.4 [1], US FDA Title 21 [2], FCC CFR Title 47 Part 15 [3], and FL State Statute 790.22 & 790.23 [4].

III. HARDWARE DESIGN

The Laser Skeet system consists of seven major subsystems: Power System, Processor, Software Operations, Laser Transmission, Laser Detection, RF Communication and Peripheral Devices.

The processor component is the CC1310 which is powered differently on both the skeet and rifle devices, but is still commonly responsible on both devices in this project for RF communication, PWM to signal motor and speaker driving circuits. Differences between the devices are the laser transmission and detection circuits of which the rifle acts as a transmitter and the skeet as the receiver, both communicate through 802.15.4.

The power systems for both devices utilizes an input supply to be regulated for the CC1310 to access, as well as supply the mains current for the device's driving needs. Extensive research went in to creating a design that would see the smallest amount of power lost to allow for a game of skeet to continue one charge, as well as meeting the specifications of realistic quality and metrics.

A. Power Systems

Power provided to the laser skeet system is operated under a 9.6V NiMH battery that stores approximately 1600mAh with standard mini-Tamiya connection for easily marketable battery replacements. This main power supply is known to be capable of overcharging and reaching up to 12V for the 5V regulator source via a LM2575TV-5G [5] buck switching voltage regulator seen in Figure 3.

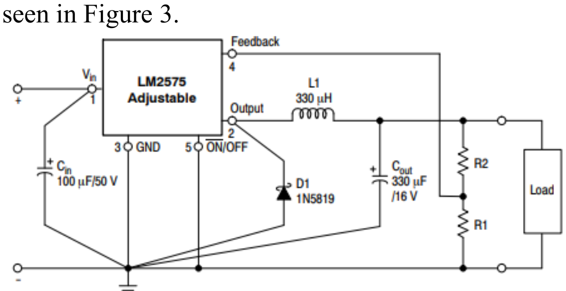

Figure 3 – LM2575 Regulator Circuit

Initially linear regulators were considered for the project due to experiences in lab sections with them working fine. Given Because of the extensive loads during maximum throughput sessions, a better performing power regulator is needed. Which is why the LM7805 was swapped with the LM2575 for higher performances, lower drop-out voltages for longer games, as well as overall power efficiency, see Table 2.

TABLE 2
LM2576 SWITCHING REGULATOR VS. LM7805 LINEAR REGULATOR

Feature	LM2575	LM7805
Operating Voltage	4.25 – 45 V	2 – 40 V
Max. Output Current	3.0 A	2.2 A
Quiescent Current	5 – 9 mA	4.2 – 8mA
Output Options	Adjustable	Fixed
Efficiency	77%	≤ 40%*

*Measurement taken in EEL 4309 Electronics II.

A potentiometer is utilized as the feedback point to safely provide up to 1A of power at a regulated voltage level. This 5V regulated source is used to power the motors within the laser rifle and provide the necessary 0.2A bursts while active.

Power systems within the skeet target and rifle also contain a LM3940-IT LDO Voltage Regulator to obtain a 3.3V reference voltage for the CC1310, Sharp display, speakers, and detection circuit power. Both regulators can supply up to 1.0A of current to properly drive all necessary functions and loads.

The maximum current driving laser rifle was approximately 440mA while the MCU, RF, motors, and laser driver were all in operation, therefore the power regulators can appropriately drive all necessary functions while retaining a low quiescent current of 16mA for the rifle and 8mA for the skeet target.

B. Processor

The rifle controller component is the primary control device and the skeet is a wireless sensor. The primary control device will require a PWM output for the laser control and buzzer, Serial Peripheral Interface (SPI) output for a display, digital inputs/outputs for buttons, and the capacity to handle the wireless communication protocol that is selected for use. The sensor device has an input from the IR laser sensor detector circuit that is used as an interrupt to wake the CPU from low power and transmit the strike message back to the controller. The demands on both devices are close enough that the same device can be used for both.

The CC1310 provides an ARM® Cortex® 48MHz M3 microprocessor four 32bit(or eight 16bit) timers/PWM, two SPI channels, an I2C channels, 12bit ADC, real-time clock, and an analog comparator. It has an integrated Sub-1GHz transmitter and receiver supporting the 915MHz Industrial, scientific and medical (ISM) band. There is a secondary ARM® Cortex® M0+ processor embedded to support the RF communication. For MCU specifications see Table 3 [6].

TABLE 3
CC1310 SPECIFICATIONS

Cost (single / lot)	\$6.57 / ~\$3.00
Flash storage	128KB
RAM	20KB
Max TX power	14dBm
Operating voltage	1.8 to 3.8 V
Min standby current load	0.7 µA
Idle current load	570 µA
Active load	2.5 mA
Transmitting load	23.5 mA
IO load	per load

Demands of the system, the inputs and outputs needed, the requirement for low battery power, and compact size make this job fit for the lower power SOC (system on a chip) microprocessors. Additionally, the need for wireless communication makes having integrated wireless RF also desirable. The Texas Instruments CC1310F128RGZR was selected for the job.

C. Software Operations

For our software development, Texas Instruments' Code Composer Studio IDE is being utilized. The IDE, Software Development Kit (SDK), starter projects used are available from TI without licensing fees. This along with support from the chip manufacture, were reasons using them instead of other options.

Texas Instruments provides the CC1310 MCU as part of their SimpleLink product line. Support for this is provided by the SimpleLink Software development kit. Part of this is TI-Real Time Operating Software (RTOS). The RTOS is a cut down operating system that can best be described as an interrupt handler. The RTOS provides efficient allocation of processor resources necessary to perform the communication functions along with application tasks at the same time. The RTOS also handles the integration of the separate software tasks necessary to coordinate power savings functions. TI-RTOS also provides a standardized method for interfacing with the device’s hardware I/O and pin connections that is not device specific. [7]

The previously described RTOS and drivers are necessary to support the 802.15.4 protocol communication stack provided by TI as part of the SDK. [8] The OS driver calls, MAC Application Programming Interface (API) and starter application from TI are written in C. As such the use of Object Oriented Programming was not practical. C was used to integrate with TI SW. The components of the software can be seen in Figure 4.

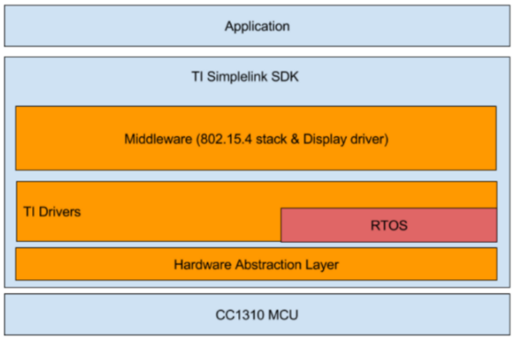

Fig. 4 Application Software Stack

The SW requires and implements three different threads, the OS, the MAC API, and the application. Interaction is handled with semaphores, message queues, interrupts, and registered call back functions using the SDK's Indirect Call Framework (ICALL). This allows abstraction of the protocol stack interaction and allows separation of the functions required to keep the application from causing blocking of stack operations.

Our application is built on Texas Instrument which provides a collector and sensor starter project. It provides the basic star network topology we need for our project. It includes all the files necessary to get the 802.15.4 network up and running. Included in the packages is the logical link control function. This handles the tasks of network detection, node joining, and rejoining. Channel selection, network ID and other options are set in project configuration file /subg/config.h. The MAC API and starter project for each end includes about 125 files each. Changes and additions to handle our needs were done to 8 to 10 files on each end.

The starter application already has a structure in place for handling messages on the 802.15.4 link and for handling application tasks. Our application communication specific needs are added into this existing framework. This is done by defining a new message type format and adding functionality to the application thread to handle it. Our different I/O port configurations needs were added to existing files. The PWM driver was also added to the project and initialized.

The game controller required functionality for button press, display, output controls. The button controls are implemented using OS SW callback functions that occur following pin interrupts. The trigger activation button also includes a timed delay of 80ms to simulate the travel time that an actual shot may take. The delay is also implemented using the OS timer and a callback function.

Outputs for the 100ms burst of PWM to the laser driver, PWM to provide a tone feedback to user, and feedback motor control are likewise implemented through the OS drivers and timers. The display functionality is addressed through the Sharp display driver in the OS.

A game state handler was added to process possible buttons presses. It handles the score counting and display menu control for changing game option, resetting score, network joining, and laser activation. A function was also added to handle updating the display.

The target sensor end utilizes a similar SW structure. It handles the SW callback from the OS then an interrupt is seen on the laser detect input. It then sends the notification message over the RF link through the MAC API. The hit indication also sends an output pulse to activate feedback action. A lockout delay is implemented to prevent multiple detections from one trigger event. The delay is configurable and currently set for 2sec to simulate a flying target being destroyed. The delay is handled with an OS timer and callback function.

The sensor MCU and SW are able to initiate low power mode through the OS when the application and MAC threads are idle. When in low power mode, the MCU is only using about 50µA plus I/O load. Interestingly if an LED is active its 4mA usage dwarfs the MCU's use. As this is the case, LED use should be looked at if trying to extend battery life. The sensor MCU wakes up on laser detect interrupt and periodic timer for network keep alive. The controller MCU is unable to achieve the same low power use due to its need to keep it receiver active and monitoring for sensor messages. As the controller has a larger battery, the 5.5mA minimum draw during reception monitoring is still manageable.

D. Laser Transmission

The following sections are dedicated to the explanation for the selection of the laser diode; the design of the modulation circuit and lens system, and the implemented safety systems and percussions.

1. Laser Selection

Laser selection was determined by two parameters: wavelength and output power. The wavelength was chosen to allow for the least amount of solar interference as possible since this product is designed for indoor and outdoor use. The wavelength chosen was 980 nm since it shows low relative interference and coincides near a local minimum as well as still being in the silicon region, making it relatively inexpensive. ThorLabs offer a line of 980 nm laser diodes of varying output power from 10 mW to 100 mW. The 10 mW laser diode was chosen to increase safety [2].

2. Modulation Circuit

The modulation circuit is designed around a TLV2471CP summing operation amplifier in Figure 5 to keep the laser diode right below threshold current and then bumping it up by PWM from the microcontroller. This component was chosen based on a 1.5 Vμs slew rate for a range of frequencies to be used. The circuit was designed to hold the laser diode at threshold to reduce any possible noise associated with constantly ramping the laser from no current to operating current.

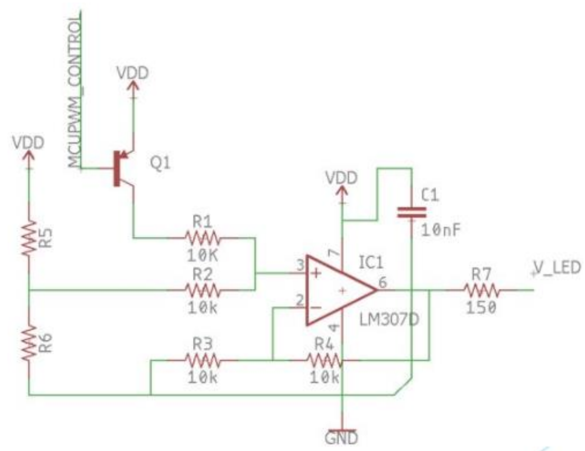

Figure 5 – TLV2471CP Summing Amp Schematic

The amplifier has a straight DC voltage fed through a voltage divider from the voltage regulator and a PWM signal from the microcontroller that passes through a BJT that has its collector connected from the same line as the DC bias to the regulator. A key switch as well as an indicator LED was placed between the voltage regulator and the two inputs to the summing amp, such that the key switch must be turned on for the laser to fire to follow laser safety protocol [2,9,10]. The summing amplifier contains two potentiometers with the first being after the BJT to control the voltage level of the DC bias and the other being placed after the output of the summing amplifier to control the current going to the laser diode, a fuse being used for protection seen in Figure 5. The modulation circuit can easily be modified by adjusting the potentiometer and fuse values for the use of other laser diodes up to an operating current of 80 mA.

3. Lens System

The lens system is designed to correct the laser beam to the desirable shape and can be seen in Figure 6. The laser system is designed to simulate a shotgun as much as possible. The system itself is comprised of three parts designed to collimate, correct, expand, and diverge the laser beam. The first element in the system is a precision molded acrylic aspheric lens fitted into an aluminum holder with a focusing screw for alignment. The next elements in the system are anamorphic prism pairs used to expand the slow axis of the laser beam to create a more circular beam at the target distance. Since the prisms do not correct for beam divergence and are unable to be moved, they are set to magnify the laser beam as much as possible at a magnification of 4x that of the original output. The final elements consist of a beam expander constructed from a biconvex lens and a plano-convex lens with focal lengths of 15 mm and 50 mm respectively for a total magnification of 3.33. The focal lengths are kept small to allow for the beam expander to not take up much space on the rifle. The expanded beam is used to both expand the beam to the size of the barrel and cause it to diverge by moving the plano-convex towards the biconvex lens. A physical stop is used to prevent the plano-convex from moving forward and causing the beam to focus outside of the gun. The entire lens and laser system is contained in a black acrylic box at the end of the gun, so as not to allow for any light to escape from the system.

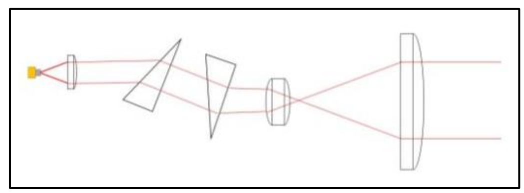

Figure 6 – Laser System, optics used for beam manipulation.

E. Laser Detection

The following sections are dedicated to explaining the design of the hit detection system as well as the placement of the detectors and supporting optics.

1. Photodiode Arrangement

For this project, six photodiodes are placed around the skeet at a 45-degree angle pointing to the ground. The photodiode chosen was the VEMD5080X01 because their peak sensitivity is centered at 980 nm. The original Vishay SFH320-4 detectors consisted of phototransistors since they have higher sensitivity, due to internal gain.

However, they saturated even in low light conditions. The placement of the detectors was chosen to optimize the amount of signal obtained while minimizing solar interference. Each photodiode was covered with an optical bandpass filter centered at 980 nm with Full Width at Half Maximum (FWHM) fixed to 20 nm. Translucent epoxy is used to both affix the photodiode and filter to ensure the devices do not separate, while not blocking the signal light. During testing it was found that solar interference was penetrating the skeet target from angles outside of the wanted range as well as from behind the sensor itself. Mirrored solar shielding was placed around each sensor, except over the bandpass filter, to block any unwanted light. Multiple layers of the shielding as well as painting the target reduced the solar interference.

Each photodiode is fed from the cathode to the inverting terminal of a transimpedance amplifier with the anode going to ground. The six photodiodes are split into two lines of three that are pre-filtered using a high pass filter. Diodes are used on all six photodiode lines to couple them together before pre-filtering, so current generated by the signal is not back fed to the different lines. After pre-filtering, the two lines are combined and fed into the hit detection circuit.

2. Hit Detection System

The hit detection system is comprised of three parts: a bandpass filter, a comparator, and a peak detector. Early in the design, it was assumed that because the skeet target was quite small only a single positive voltage source would be able to fit inside the skeet with the associated detectors and filtration circuits to go along with the communication and visual detection systems. Because of a limited power source, the bandpass filter is comprised of multiple first order high and low pass filters connected with amplifiers to account for attenuation of each amplifier. During testing, the laser diode was shown to work up to 1 kHz without any degradation of the signal. The bandpass filter was designed around the 1 KHz input. The output of the filter is then fed into a comparator circuit to register a hit if the input is above 3.0V. The output of the comparator is fed to a BJT that is linked to both a visible indicator and peak detector. The visible indication is three red LEDs mounted on the outside of the skeet target around the side of the disk. The peak detector raises a flag when there is an output from the comparator that alerts a MCU pin that the skeet target has been hit.

F. Wireless Communication

The rifle and target both need to be in uninterrupted communication for the design to work properly. If connection is interrupted a hit may not register back to the rifle. When the target detects a hit, it will send a message back to the rifle indicating a hit to the MCU.

IEEE 802.15.4 [1] at 915 MHz is the selected wireless protocol and frequency to be used for this design. The CC1310 is designed to be used at this frequency and with this protocol. For this project IEEE 802.15.4 provides a range over 70ft. The 915 MHz frequency is much friendlier to use for designing, as wire length and cross wire talking is not a concern for frequencies in the GHz range. Using a wireless protocol for the implementation of wireless communication is allowed for the project under IEEE 802.15.4 standards. This setup operates at a lower power when compared to Bluetooth or Wi-Fi. For this design the rifle acts as the master node and will establish connection with the target. If the project wanted to evolve into having multiple rifles and targets, a different protocol should be used to handle more connections.

For this project a Johanson Technology 0915AT43A0026 antenna is used for both the rifle and target. This antenna is connected to a node on the RF impedance matching circuitry, following specifications provided by TICC1310 documents. The average gain is -4.0 dBi which is more than enough for the CC1310 to transmit and receive data at a range of 70 ft. The radiation pattern of this antenna allows the signal to be strong enough in any direction, except 30 degrees, from the rear of the stock as seen in Figure 7 [11]. The rear of the stock will have the least chance to be facing directly at the target, which makes this an ideal position to place the non-ideal RF capture point. This hole in the radiation pattern will be pointed up towards the sky on the skeet disc to mitigate a loss in communication.

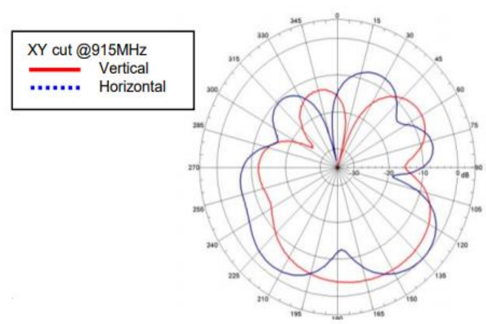

Figure 7 Typical Radiation Performance

Keeping the antenna constant on the rifle and the target allows for a one-time calculation on impedance matching. A template for the impedance matching circuit is provided by T.I. which left a pi-network open for modification to match the 50Ω antenna. Components selected for the impedance matching circuit are kept under a tolerance of 5%, to mitigate error while not increasing cost exponentially. Efforts were made to separate the RF circuit as much as possible from the rest of the PCB. Following tips from TI employees, each grounded component is given their own via to ground instead of sharing nodes to reduce unwanted noise in the RF circuitry.

Under FCC requirement 47 CFR 15.23 [3] these devices are compliant. Since this project is an independent device and not mass produced, much of the requirements to meet standards are bypassed through scholastic testing and use. However, the best engineering practices to the team's ability were used for testing RF outputs.

G. Peripheral Devices

This section is dedicated to addressing the devices used for the user experience. It is necessary to create a device which mimics the real deal, such that the realistic nature and excitement of the sport is not lost.

For the user to know what is happening visually, an LCD screen is utilized. A start-up menu and various shot statistics can be shown on the screen, improving user interaction. The LCD will be mounted on the left side of the barrel and will fold in for protection while not in use. SPI is the chosen form of communication for the display as it was easy to implement with CC1310. SPI also allows for longer wire lengths so the display does not need to be in nearly as close proximity as I2C.

A connection from a 10 wire flat flexible cable to a 10 pin board was needed. This will allow the display to be located away from the PCB. The adapter seen in Figure 8 on the right was connected onto the PCB on the left. This PCB was made and assembled by Proto Advantage. Jumper wires will be connected to the main rifle PCB. This was a cheap alternative to using a long flat flexible cable to connect the rifle to the display.

Figure 8 – Custom LCD PCB, Ribbon to Pin adapter

The display selected for the design is a Sharp Microelectronics LS013B7DH03. This display has a resolution of 126 x 126 pixel which gives a larger area to display what is presented. The display has a larger resolution than the display on the development board and thanks to T.I. a small modification to the code seamless integration. The screen measures 1.28” diagonally making it easily readable under 2 ft by the user. The display shows when the system is operational as well as the game metrics, seen in Figure 9.

Figure 9 – Sharp LCD Screen with initial metrics

People love the experience of skeet shooting which includes the sounds, the sight of a target getting hit, and the recoil when the trigger is pulled. To give the user a fully absorbed experience, motors and speakers were added to recreate the environment in which skeet shooting takes place. To maximize rifle space, these components are embedded within the rifle structure to better provide a more immersive user experience.

The Parallax 28821 vibration motor was the chosen motor for this project as they are inexpensive for their size and contribution. The vibration motors are used to simulate a recoil effect when the trigger is pulled, providing the user with a realistic experience. The vibration motors are installed on the target, so that when a hit occurs, flight destabilization occurs and can be seen by the user. The vibration motors are controlled by a MCU PWM pin on a BJT connecting the motor to a regulated mains power supply. The motor in the rifle is secured tightly in the stock providing a stronger vibration and is kept outside of reasonable distance from the PCB. The wires coming off the terminals for the motors were very thin and ripped off several times during testing, therefore thicker wires were attached to the terminals providing a more secure connection.

A speaker is mounted to the top of the stock of the rifle so that it can clearly be heard by the user while rifle is active. The speaker is controlled by the MCU on a PWM pin, so the desired frequency can be played. Every time the trigger is pulled a low pitch tone is played, if a hit is recorded by the target an RF relay signal is sent and will be followed by a different higher pitch tone indicating the hit. The use of a high pitch tone with the result of a hit provides more engagement for the user, while a low pitch sound without the high pitch tone is equally engaging.

IV. CONCLUSION

Ending a two-semester long journey, the Laser Skeet has become an extensive and well thought out engineering process that extends beyond research, design, development, prototyping and implementation. The experience gained as a team correlates closely with the fieldwork we will encounter daily in our future careers.

Experiences encountered come from time management and the paramount consequences of meeting deadlines. Not only on one individual’s part, but as a team. Although the project was divided into leading roles and supporters, these roles soon disappeared as the entire team would come together when issue arose. Assignments given through the course can be seen as the deadlines and expectations that managers, or potential employers would ask of anyone.

This project enabled the team to utilize knowledge obtained through individual experiences at the University of Central Florida and prepared us for a future in an engineering environment.

ACKNOWLEDGEMENTS

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Recognition is given to Dr. Samuel Richie for his support and guidance in the senior design process. For without his constant assistance and diligence in providing the team with positive feedback, we surely would have not become the competent engineers standing here today.

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BIOGRAPHY

Alexander Spencer will be graduating in May of 2018 with a Bachelor's in electrical engineering. He has accepted a position as Test Engineer with Honeywell Aerospace & Defense in Clearwater, FL. He will spend time in the engineering field and pursue an M.S.E.E. with focus on power management systems and FPGA development.

Sean Brown is a senior electrical engineering student graduating the Spring of 2018. Sean has accepted a position with Lockheed Martin as an Electrical Engineer Associate. He will pursue an M.S.E.E with a focus on RF on a systems level.

Kevin Ratliff a senior student in the computer engineering program at University of Central Florida. Prior work includes telecommunication equipment installation, IT, & network operations. He is looking to expand career options by obtaining a BSCpE.

Clayton O'Rourke will be graduating Spring of 2018 with a bachelor's degree in Photonic Sciences and Engineering. He currently works for Optigrate in central Florida in the glass manufacturing department. He will pursue an Optics M.S. after spending time in the engineering field.