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UCDenver CSCI 4287

Spring 2019

Final Design Document

The LazerBoy Entertainment System:

Final Design Document

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Proposed Project Description - Background:

- Do you miss playing Duck Hunt? Are you sad your original copies of Area 51, Virtua Cop, and House of the Dead 2 don't work on your flatscreen television? Did your generation skip lightgun-based video games entirely?

Introducing:

The LazerBoy Entertainment System

Proposed Project Description - Summary:

- The LazerBoy Entertainment System is a game platform which allows players to shoot lasers at photosensitive targets and enjoy a variety of game modes.

Proposed Project Description - LazerGuns:

- LazerGuns are the controllers players use to interact with the LazerBoy Entertainment System. The LazerGun available at product launch will be the model M9B2. The LazerGun M9B2 consists of one 6 mm Class IIIa red laser, an Arduino Nano microcontroller, momentary switches for the trigger and slide, and an audio system for generating sounds related to the operation of the gun. The components will be integrated into children's toy non-projectile roleplaying guns which resemble United States Armed Forces standard issue Beretta M9 pistols. These toys are neither dangerous nor realistic, and they are not intended to cause fear or to assault another person (see: University of Colorado at Denver Student Code of Conduct §E.21). The Arduino Nano microcontroller will be connected to special circuitry designed to intercept the switches and interface with the audio controller components built into the children's toy (see: LazerGun M9B2 schematic on page 7 of this document). The microcontroller in each LazerGun M9B2 employs three outputs and two inputs and uses an input interrupt to enable an interrupt timer which manages switches and the duration of the laser pulse. Future LazerGun models may support different configurations and features. Physical appearance is subject to change.

Proposed Project Description - LazerTargets:

- LazerTargets are photosensitive devices designed to detect when a player has fired a LazerGun accurately and handle these events in the context of gameplay. Each LazerTarget consists of one or more arrays of photoresistors, a microcontroller, a speaker, a communications module, one or more status LEDs, one or more pushbutton switches and optional additional electronic circuitry. LazerTargets can function as independent modules for quick play, or they can be used in tandem with other LazerTargets for coordinated gaming for one or more players. Each LazerTarget employs at least three outputs and two inputs.

Proposed Project Description - The LazerDirector:

- The LazerDirector is a microcontroller which uses communication modules to coordinate interactions between the LazerGuns and the LazerTargets, depending on the game mode. It employs one input and one output for each LazerTarget active in the system as well as a configuration of user-interactive input and output components. At this time the LazerDirector is still in the conceptualization stage and might not be ready for product launch at the same time as the LazerGun and LazerTarget systems.

Proposed Requirements / States - LazerGun:

- The LazerGun will be powered on by inserting a USB battery into a compartment located inside the grip. Pulling back (i.e. “racking”) the slide at any time while powered on will cause the LazerGun to emit a racking slide sound and to switch the current state. A “cooldown”, “recharge”, or “reload” function which restricts the player from firing rapidly immediately after having already fired the LazerGun rapidly may or may not be implemented.

- ***Initial (Safety) State:*** The LazerGun will enter the Safety state as soon as it receives power. In this state, pulling the trigger will cause the LazerGun to only emit the racking slide sound.

- ***Semi-Automatic State:*** If the player racks the slide once within a predetermined duration, the LazerGun will enter the Semi-Automatic state. In this mode, pulling the trigger will cause the LazerGun to emit one laser pulse as well as emit a sound of the gun firing. This will not occur again until the player pulls the trigger again.

- ***Three-Round-Burst State:*** If the player racks the slide twice within a predetermined duration, the LazerGun will enter the Three-Round-Burst state. In this mode, pulling the trigger will cause the LazerGun to emit three laser pulses in succession as well as emit three sounds of the gun firing in succession. This will not occur again until the player pulls the trigger again.

- ***Fully-Automatic State:*** If the player racks the slide three times within a predetermined duration, the LazerGun will enter the Fully-Automatic state. In this mode, pulling the trigger will cause the LazerGun to emit a continuous succession of laser pulses as well as emit a continuous succession of sounds of the gun firing. This will occur for the entire duration during which the player holds down the trigger, and will cease when the player stops holding down the trigger.

Proposed Requirements / States - LazerTarget:

- A LazerTarget will be turned on as soon as it receives power. A red led on the target will light on to indicate that the target is powered on and ready to be used. In addition, the same push button switch will be used to switch between two modes: Independent and Active. If the player decides to switch into Independent mode, he/she will need to press the push button twice within a predetermined duration. In this case the status led will blink for a short duration. Timing and button event handling will be accomplished using timer and input interrupts.

- ***Initial (Discovery) State:*** Push button is pressed one time. Power led and status led are on and their colors are red and blue. LazerTarget will try to establish communication with the LazerDirector; it will send “READY’ signal to director and wait a predetermined duration for its response. If the response is received from the director in time, the target will be switched to Active mode. The color of status led will be changed to green. Otherwise, it will stay on blue, and the LazerTarget will switch to Independent mode.

- ***Active State:*** The color of status led is green. LazerTarget will receive direction from the LazerDirector. Direction will be dependent on the active game program. A typical game program will cause the the target to send a “HIT” signal to the director if a player fired a LazerGun and hit the target. The status led and speaker may indicate the successful shot. The LazerTarget will then wait for further direction from the LazerDirector.

- ***Independent State:*** The LazerTarget will enter the Independent State if the push button is pressed twice within a predetermined duration or communication between the LazerTarget and the LazerDirector was not established within a predetermined duration. The color of the status led is then blue. If the target is hit, the status led will start blinking and the speaker will indicate that a hit has occurred. When the push button on the target is pressed one time, the LazerTarget will switch to the Discovery State. Future LazerTarget models may support multiple gametypes in the Independent State.

Proposed Requirements / States - LazerDirector:

- The LazerDirector will turn on as soon as it receives power. Since the LazerDirector is still in the conceptualization stage, the final configuration of user-interactive input and output components and their ability to switch the LazerDirector's state has not yet been decided.

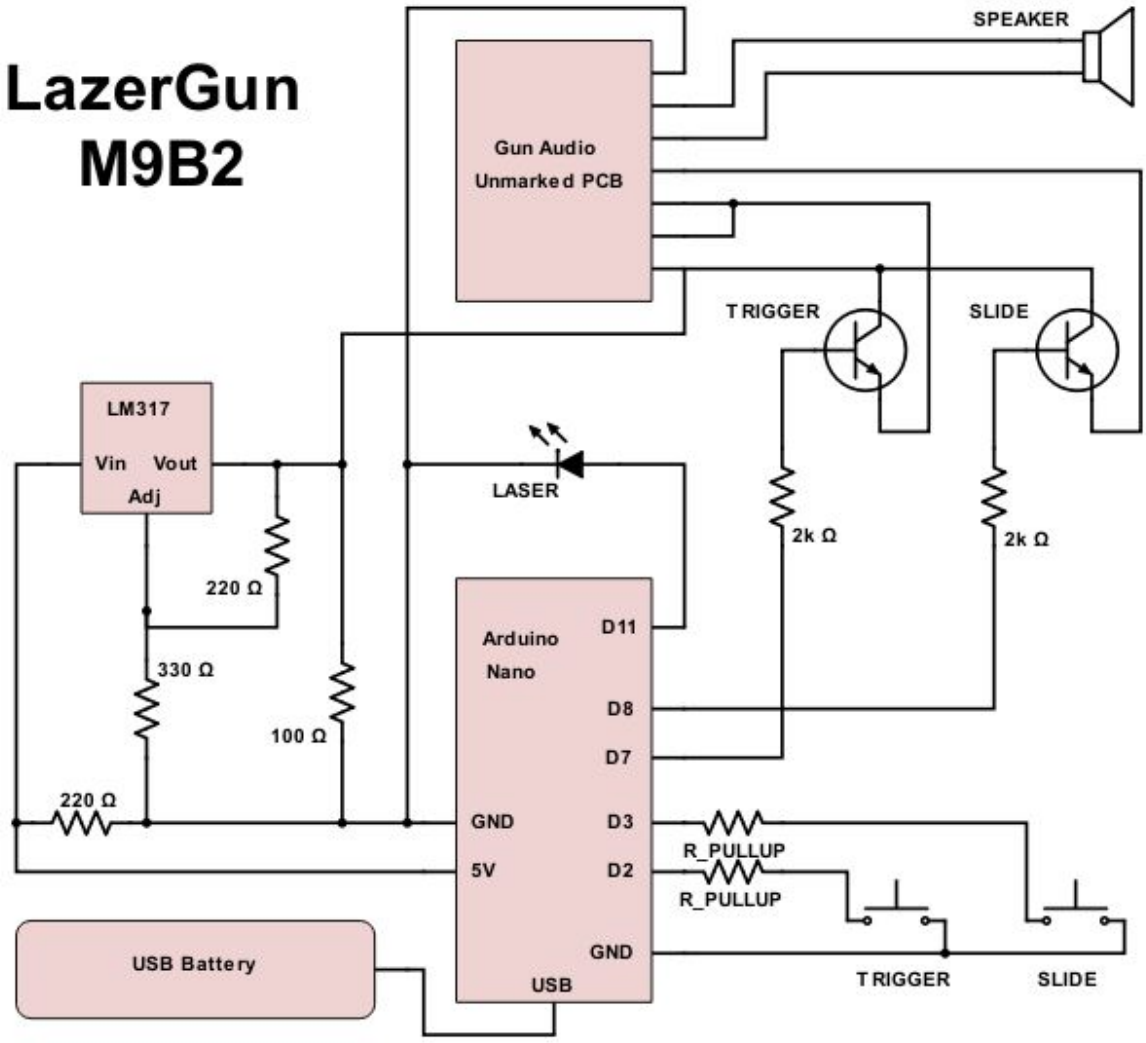
- ***Initial (Discovery) State:*** The LazerDirector will immediately begin scanning for available LazerTargets also in the Discovery State. If LazerTargets are found, the LazerDirector will enter the Selection State. If no targets are found, the director will remain in the Discovery State.

- ***Selection State:*** The player(s) will be permitted to select a gametype using user-interactive input and output components. Once a game has been selected, the LazerDirector will enter the Uplink State.

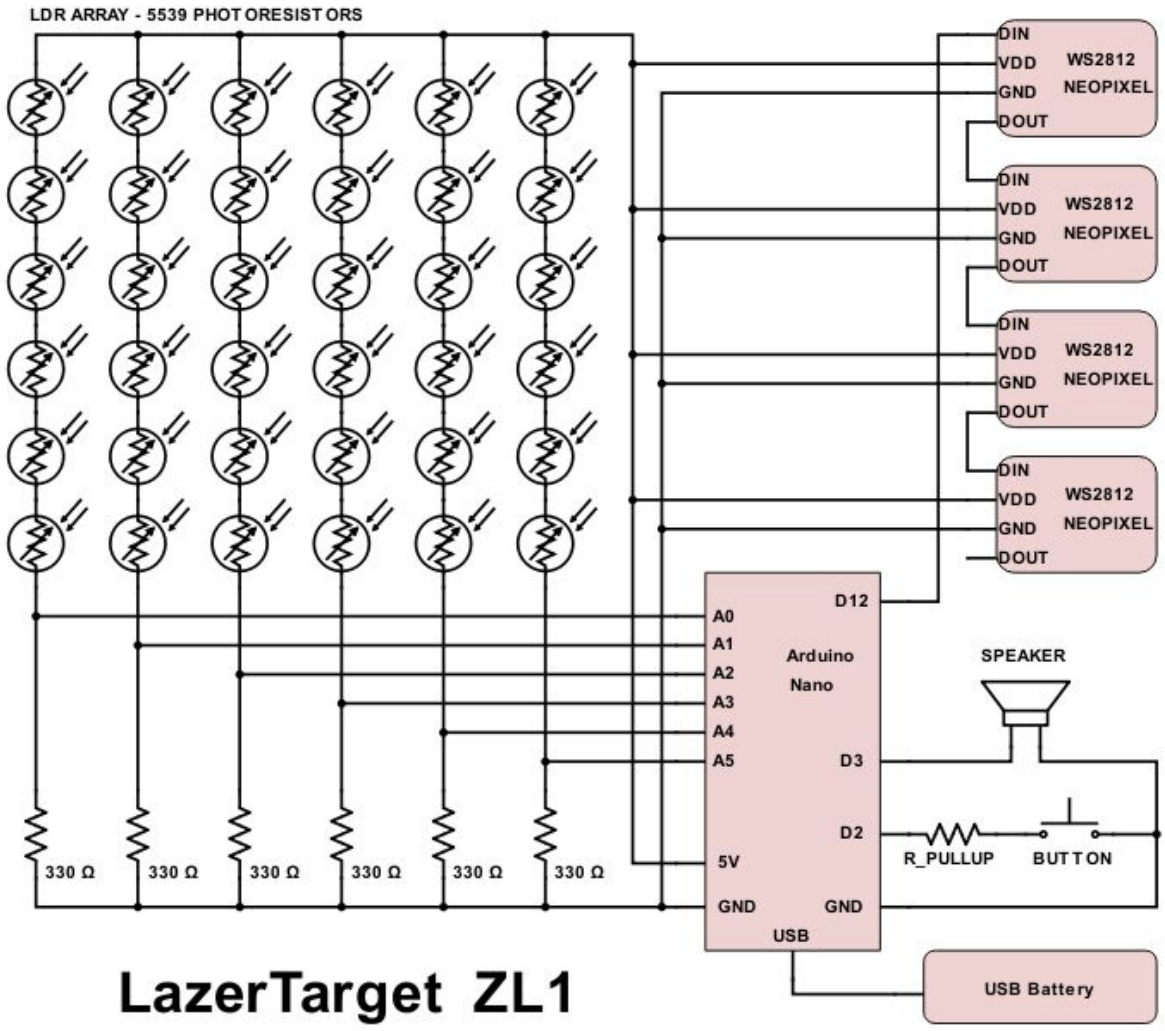
- ***Uplink State:*** The LazerDirector will establish communication with each participating LazerTarget which is in Active mode and upload all game parameters necessary to play the game successfully. Once all data has been sent to the targets, the LazerDirector will enter the Coordination State.

- ***Coordination State:*** The LazerDirector will now start the game. The director will coordinate all LazerTargets to provide a seamless gameplay experience. If a game ends normally, the LazerDirector will return to the Selection State.

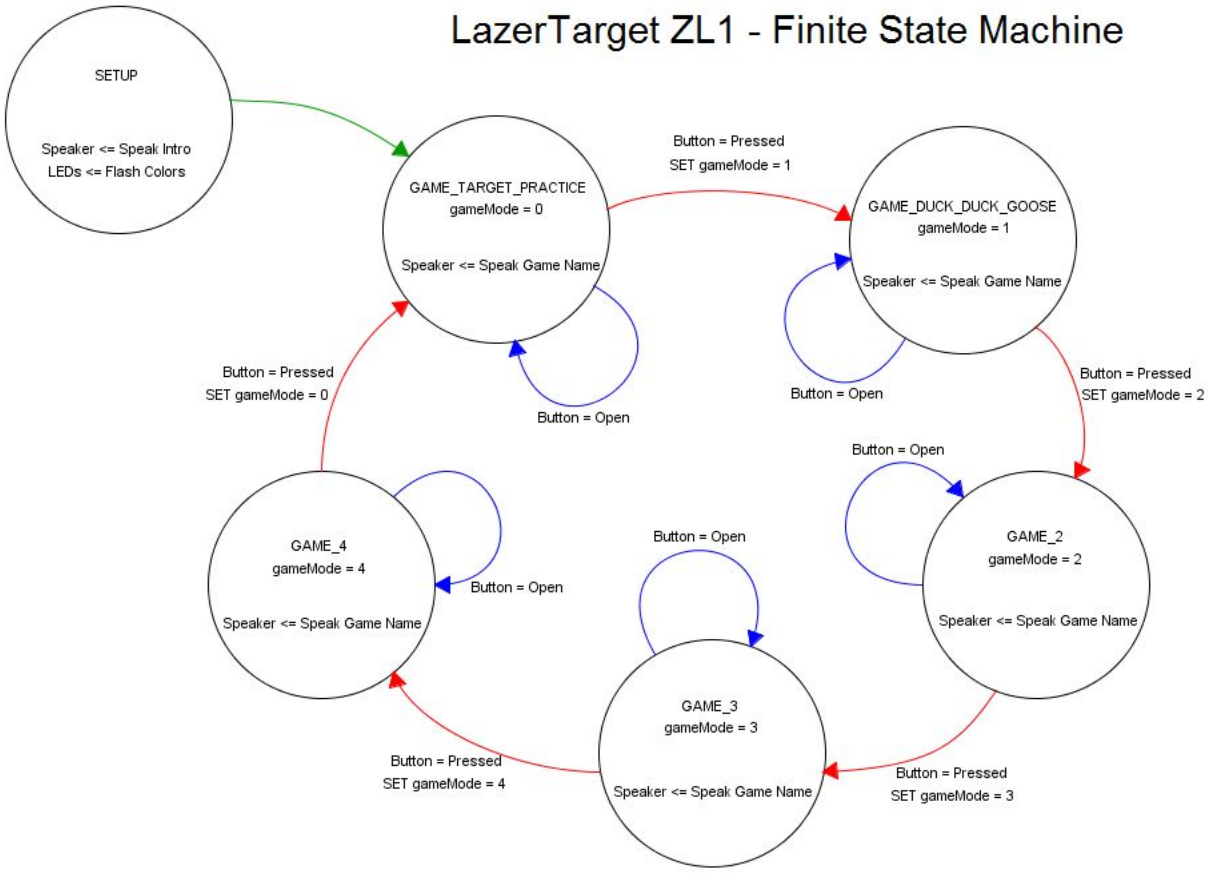
Implemented High-Level Design - Hardware Schematic - LazerGun M9B2:



Implemented High-Level Design - Hardware Schematic - LazerTarget ZL1:



Implemented High-Level Design - Finite State Machine- LazerTarget ZL1



Implemented High-Level Design - Pseudocode - LazerGun M9B2:

```
// MAIN LOOP
    // ON FIRE LASER EVENT
        // FIRE LASER
        // GENERATE FIRE LASER SOUND
        // CLEAR DO FIRE LASER FLAG
        // DECREMENT MAGAZINE CAPACITY
    // ON TRIGGER DEBOUNCE TIMER EVENT
        // IF TRIGGER PIN HIGH
            // CLEAR TRIGGER DEBOUNCE DO EVENT FLAG
            // SET TRIGGER RESET TIMER COUNT AS MAX COUNT
            // ENABLE TRIGGER RESET TIMER
        // ELSE
            // IF FIRING MODE IS THREE ROUND BURST
                // FOR SHOT 1 TO 3
                    // IF MAGAZINE CAPACITY NOT EMPTY
                        // FIRE LASER
                        // GENERATE FIRE LASER SOUND
                        // DELAY FOR LASER PULSE DURATION
                        // STOP FIRING LASER
                        // DELAY FOR REPEATING SOUND DURATION
                        // STOP FIRE LASER SOUND
                        // DELAY FOR REPEATING RESET DURATION
                        // DECREMENT MAGAZINE CAPACITY
            // ELSE IF FIRING MODE IS FULLY AUTOMATIC
                // WHILE TRIGGER IS HELD
                    // IF MAGAZINE CAPACITY NOT EMPTY
                        // FIRE LASER
                        // GENERATE FIRE LASER SOUND
                        // DELAY FOR LASER PULSE DURATION
                        // STOP FIRING LASER
                        // DELAY FOR REPEATING SOUND DURATION
                        // STOP FIRE LASER SOUND
                        // DELAY FOR REPEATING RESET DURATION
                        // DECREMENT MAGAZINE CAPACITY
                    // CLEAR TRIGGER DEBOUNCE DO EVENT FLAG
                    // RESET TRIGGER RESET TIMER COUNT AS MAX COUNT
                    // ENABLE TRIGGER RESET TIMER
            // ELSE
                // CLEAR TRIGGER DEBOUNCE DO EVENT FLAG
                // RESET TRIGGER DEBOUNCE TIMER COUNT AS MAX COUNT
                // ENABLE TRIGGER DEBOUNCE TIMER
            // IF MAGAZINE CAPACITY EMPTY
                // SET FIRING MODE TO SAFETY
    // ON TRIGGER RESET TIMER EVENT
```

```
        // CLEAR TRIGGER RESET DO EVENT FLAG
        // STOP FIRE LASER SOUND
        // ENABLE TRIGGER INPUT
    // ON RACK SLIDE EVENT
        // GENERATE RACK SLIDE SOUND
        // CLEAR DO RACK SLIDE FLAG
    // ON SLIDE DEBOUNCE TIMER EVENT
        // IF SLIDE PIN HIGH
            // CLEAR SLIDE DEBOUNCE DO EVENT FLAG
            // SET SLIDE RESET TIMER COUNT AS MAX COUNT
            // ENABLE SLIDE RESET TIMER
            // ENABLE TRIGGER INPUT
        // ELSE
            // RESET SLIDE DEBOUNCE TIMER COUNT AS MAX COUNT
            // ENABLE SLIDE DEBOUNCE TIMER
    // ON SLIDE RESET TIMER EVENT
        // CLEAR SLIDE RESET DO EVENT FLAG
        // STOP RACKING SLIDE SOUND
        // ENABLE SLIDE INPUT
// END LOOP


// INTERRUPT SERVICE ROUTINE FOR TRIGGER SWITCH INPUT
    // IF MAGAZINE CAPACITY IS EMPTY
        // SET FIRING MODE TO SAFETY
    // IF FIRING MODE IS SAFETY
        // DISABLE TRIGGER INPUT
    // IF TRIGGER INPUT ENABLED
        // IF FIRING MODE IS SEMI AUTOMATIC
            // SET FIRE LASER FLAG
        // DISABLE TRIGGER INPUT
        // SET TRIGGER DEBOUNCE TIMER COUNT AS MAX COUNT
        // ENABLE TRIGGER DEBOUNCE TIMER
        // SET LASER RESET TIMER COUNT AS MAX COUNT
        // ENABLE LASER RESET TIMER
// END TRIGGER SWITCH ISR


// INTERRUPT SERVICE ROUTINE FOR SLIDE SWITCH INPUT
    // IF SLIDE INPUT ENABLED
        // IF MODE SELECTION WINDOW TIMER ENABLED
            // SET FIRING MODE TO SEMI AUTOMATIC
        // ELSE
            // INCREMENT FIRING MODE
        // SET MAGAZINE CAPACITY TO MAGAZINE MAX CAPACITY
        // SET MODE SELECTION WINDOW TIMER COUNT AS MAX COUNT
        // ENABLE MODE SELECTION WINDOW TIMER
        // DISABLE SLIDE INPUT
```

```
        // SET DO RACK SLIDE FLAG
        // SET SLIDE DEBOUNCE TIMER COUNT AS MAX COUNT
        // ENABLE SLIDE DEBOUNCE TIMER
// END SLIDE SWITCH ISR


// INTERRUPT SERVICE ROUTINE FOR TIMER1
    // IF TRIGGER DEBOUNCE TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // SET DO EVENT FLAG
        // ELSE
            // DECREMENT COUNT
    // IF SLIDE DEBOUNCE TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // SET DO EVENT FLAG
        // ELSE
            // DECREMENT COUNT
    // IF TRIGGER RESET TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // SET DO EVENT FLAG
        // ELSE
            // DECREMENT COUNT
    // IF SLIDE RESET TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // SET DO EVENT FLAG
        // ELSE
            // DECREMENT COUNT
    // IF LASER RESET TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // DO NOT SET DO EVENT FLAG
            // STOP FIRING LASER
        // ELSE
            // DECREMENT COUNT
    // IF MODE SELECTION WINDOW TIMER ENABLED
        // IF COUNT <= 0
            // DISABLE TIMER
            // DO NOT SET DO EVENT FLAG
        // ELSE
            // DECREMENT COUNT
// END TIMER1 ISR
```

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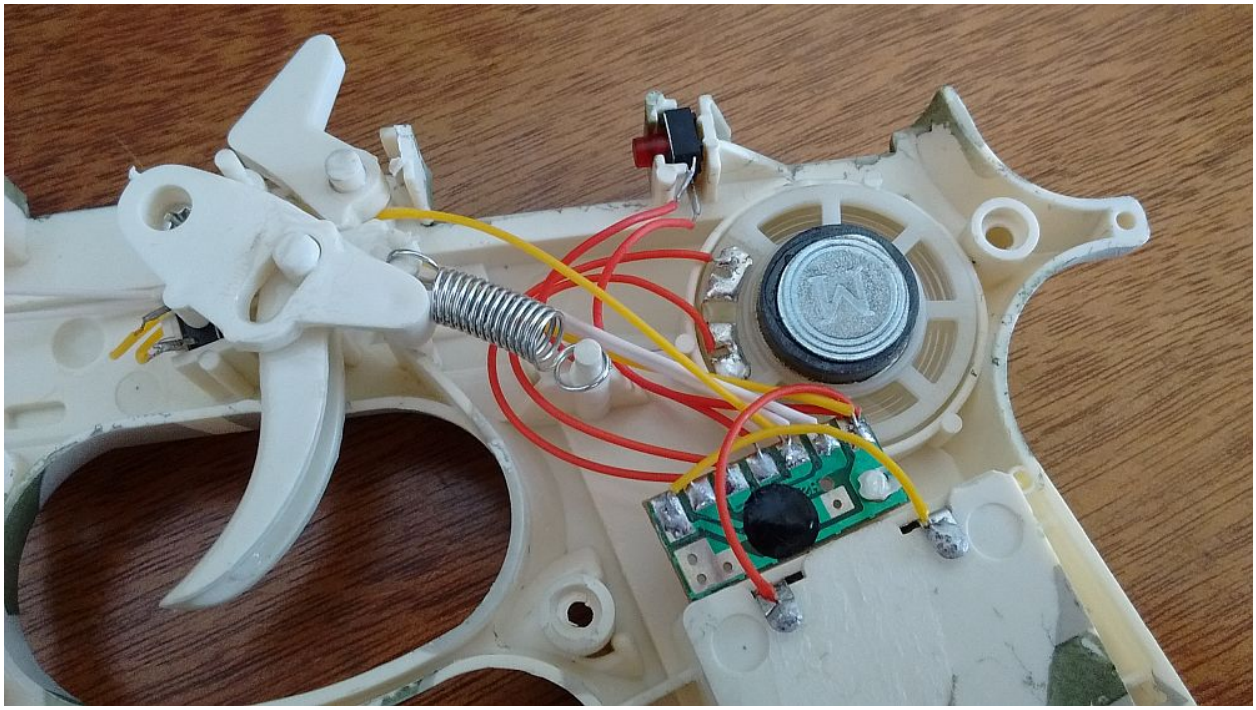
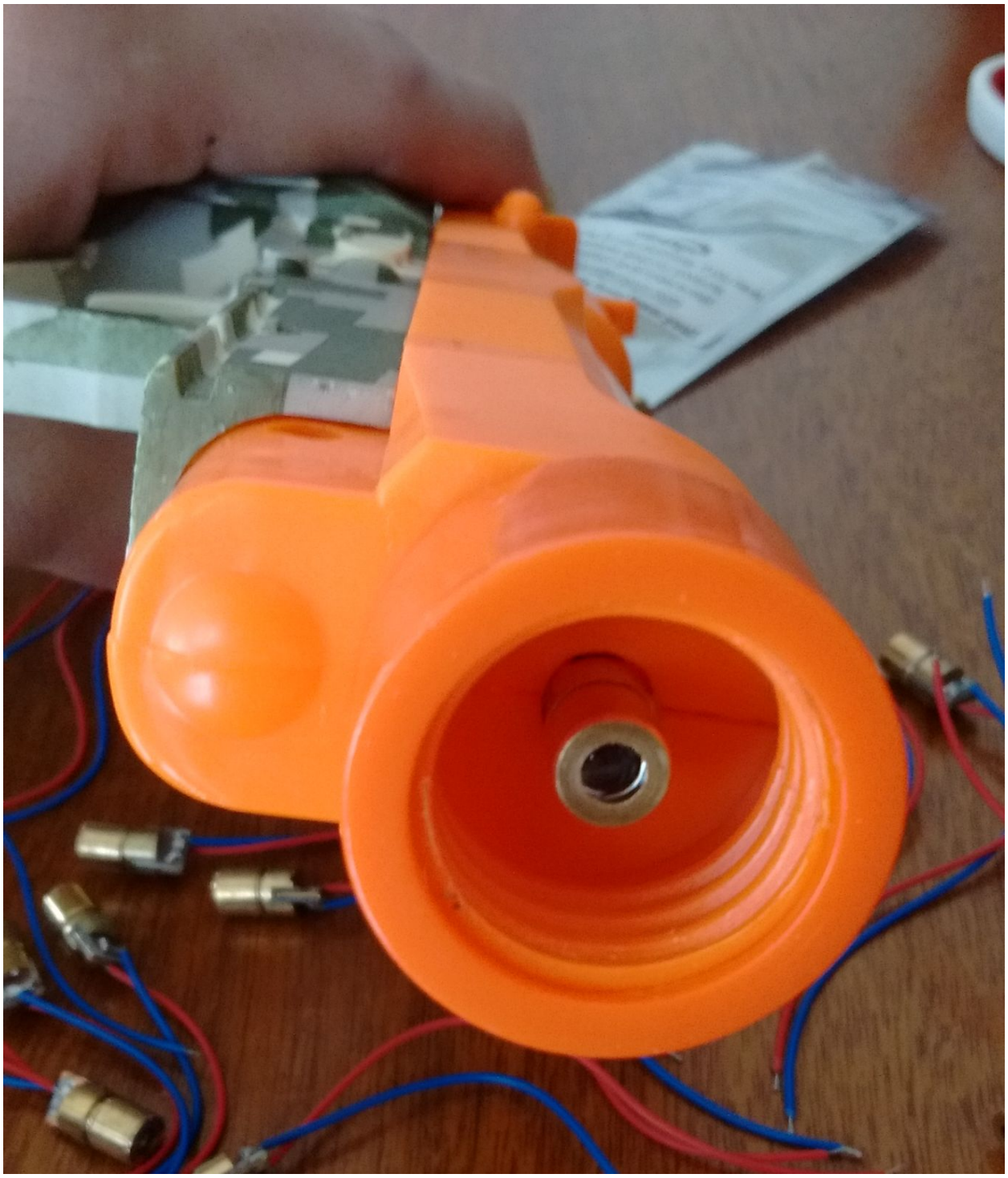
Implemented High-Level Design - Photos - Building the LazerGun M9B2:

00. This inexpensive children's toy was chosen for the LazerGun frame.

01. The inside of the toy. The first piece to be removed was the small lever which pushes the slide backward when the trigger is pulled. The long white wire is going to the muzzle switch which is activated by the mock suppressor included in the package. When this switch is activated, the gun makes a sound upon firing which is ideal for imitating a sci-fi lasergun.



02. The gun doesn't come with any instructions for interfacing with this 3 volt audio controller PCB containing unspecified combinatorial logic circuits.

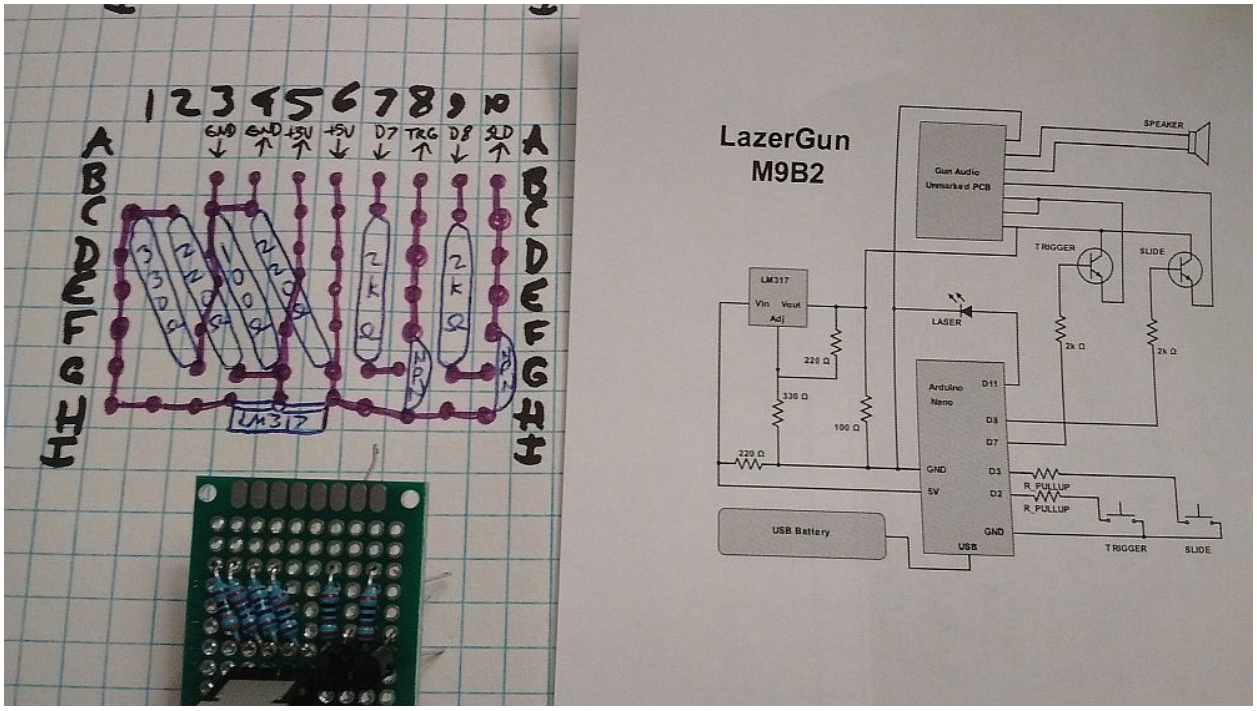


03. Fortuitously, these inexpensive 5 mW laser modules fit perfectly in the hole in the muzzle designed to accept the mock suppressor.

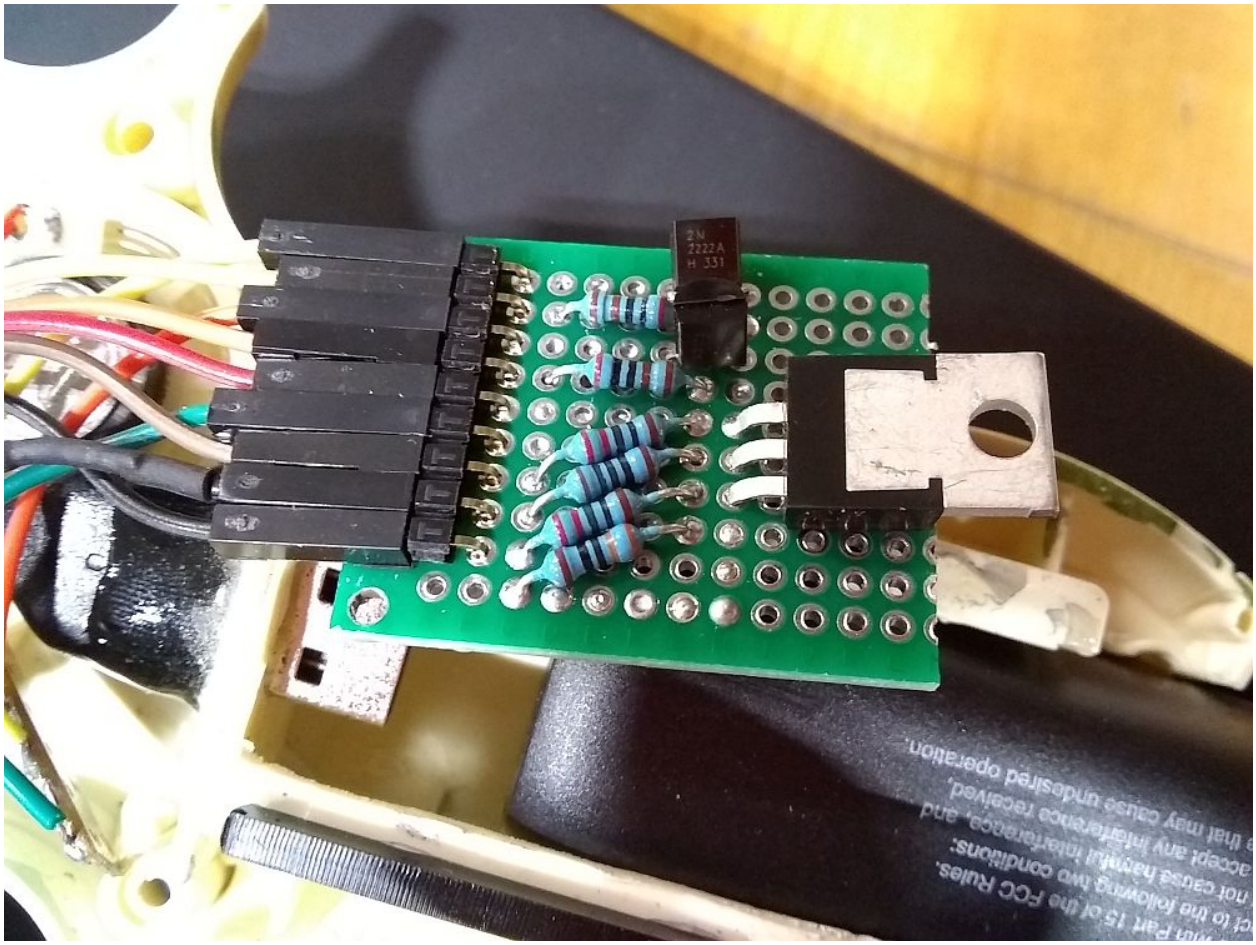
04. Extensive testing was required to determine the electrical and logic characteristics of the unmarked audio controller PCB. One of the switch inputs turned out to be reverse-biased against another switch input, which was an unexpected finding. The Arduino Nano was selected for the microcontroller at this stage because the ESP8266 did not fit inside the gun's frame.

05. About to dremmel out the AA battery compartment to make room for this USB battery. Having power to the microcontroller is crucial to the success of the LazerGun, and at this point there was no guarantee this battery would fit.

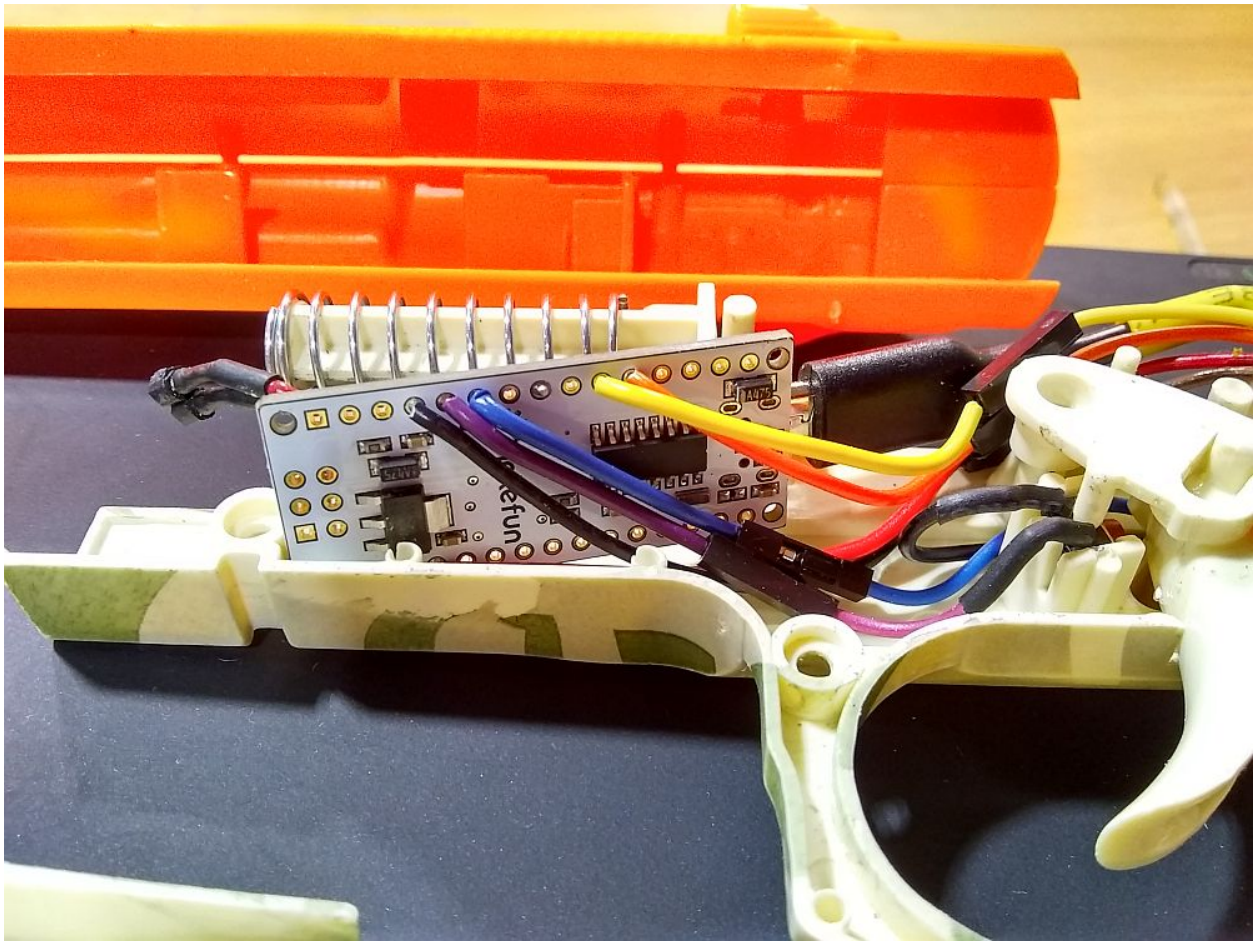
06. The original intended battery layout did not fit, but after much effort this layout successfully allowed insertion of the battery "magazine". The idea was, to put the LazerGun into battery, put the battery into LazerGun.



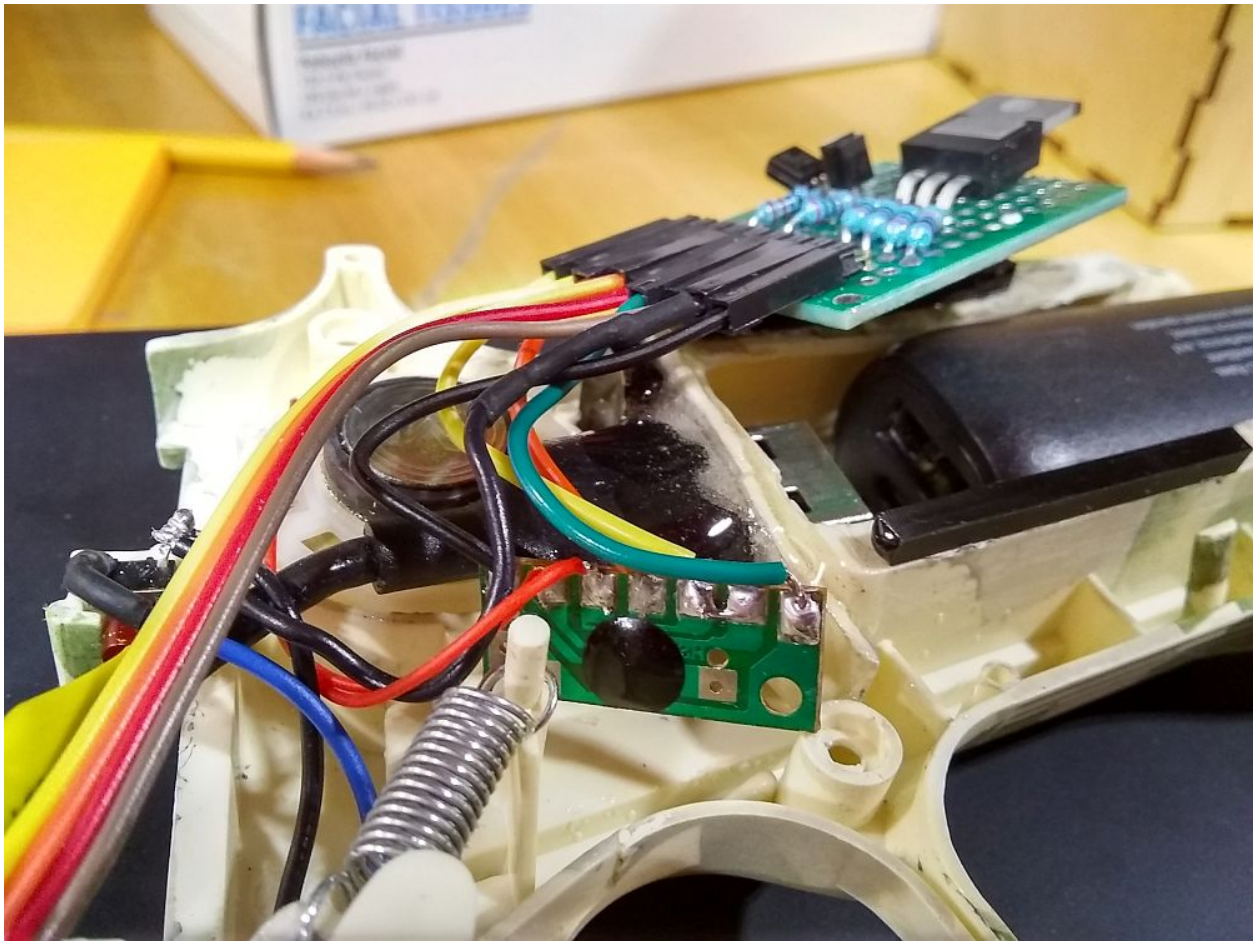
07. After considerable effort and a bit of circuitbending, the schematic on the right was produced. The audio controller board will be powered by 3v downregulated from the Nano's 5v rail, and then fed 5v logic signals. Figuring out that this approach works correctly was the hard part. The harder part was designing a board to interface between the Nano and the audio controller and still fit inside the gun's frame.



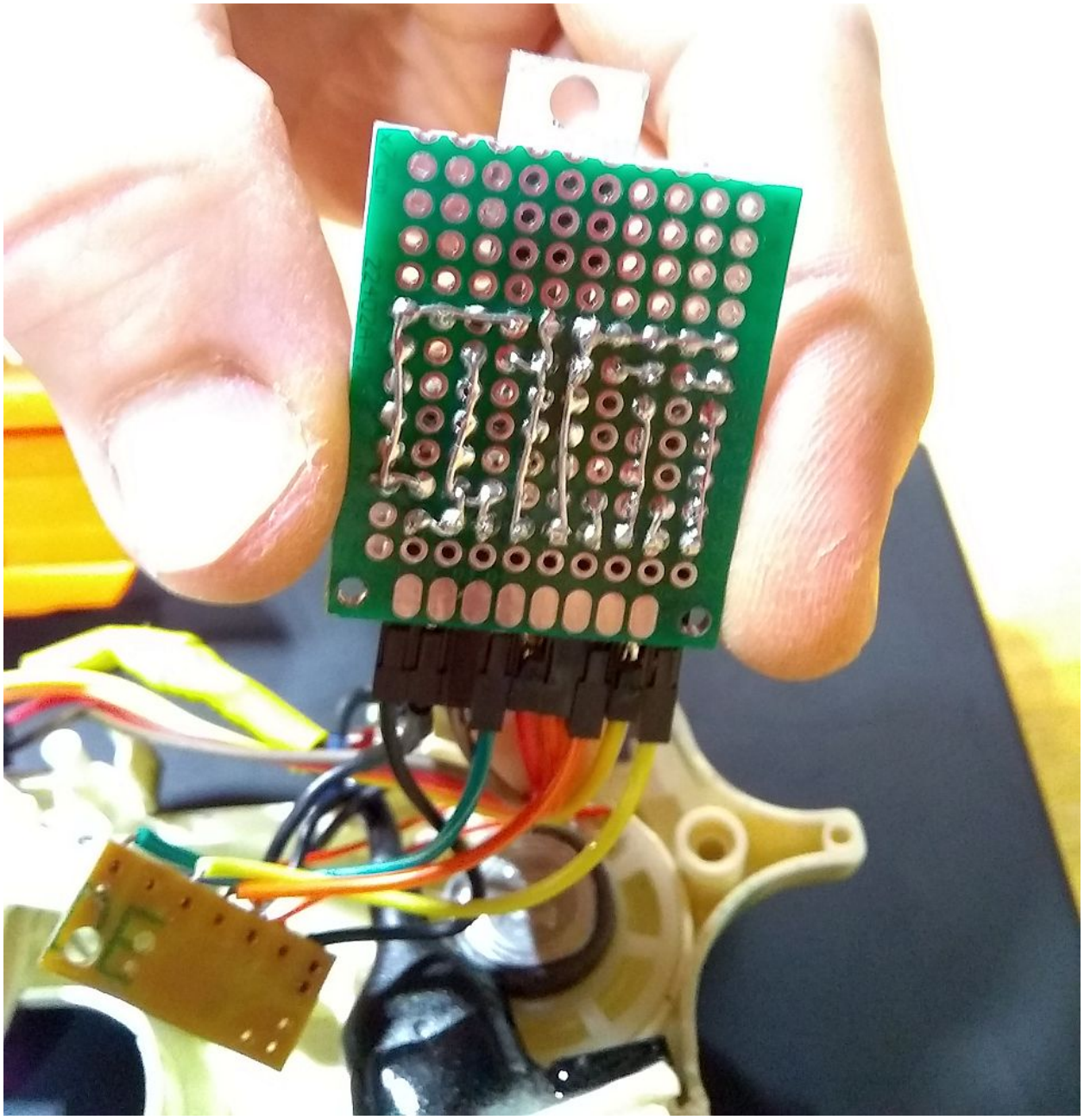
08. The finished audio interface board. Two of the resistors do nothing other than drain just enough current to prevent the USB battery from turning itself off due to underutilization (which had been a problem).



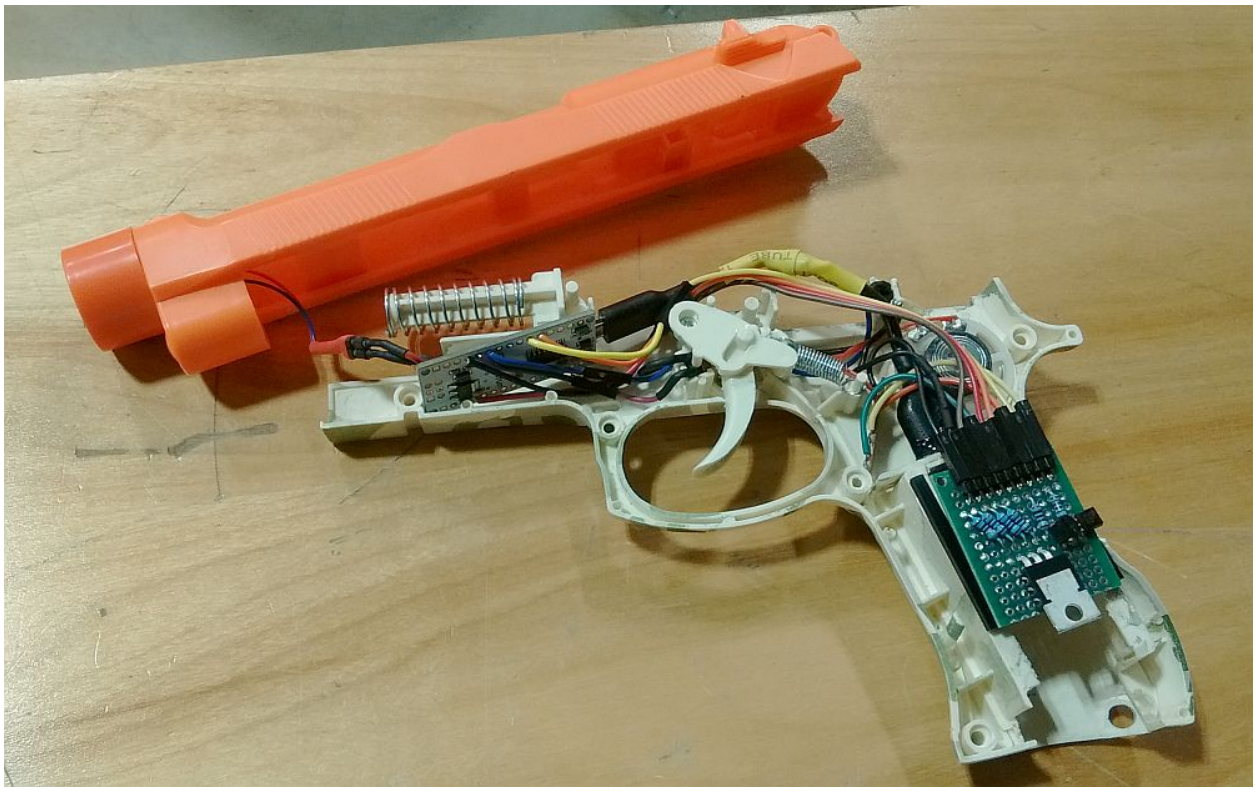
09. Headers for the audio interface board consist of solid-core wire soldered directly to the Arduino Nano microcontroller. On the other side of the Nano is the header for the laser.



10. The audio controller PCB, speaker, and momentary switches are the only hardwired components that are not designed to be disconnectable if necessary.



11. WARNING: this product contains lead, a chemical known to the state of California to cause cancer and birth defects or other reproductive harm.



12. The complete LazerGun M9B2 fully connected. The M9B2 was the most difficult project ever built by designer Brian Sumner to date. Writing the firmware to fully realize the M9B2's vision was not difficult at all, comparatively speaking.

13. The assembled LazerGun M9B2 is fully functional and still attractive (despite losing battles with isopropanol, epoxy, and a heatshrink gun). This gun is ready to interact with the LazerBoy Entertainment System.

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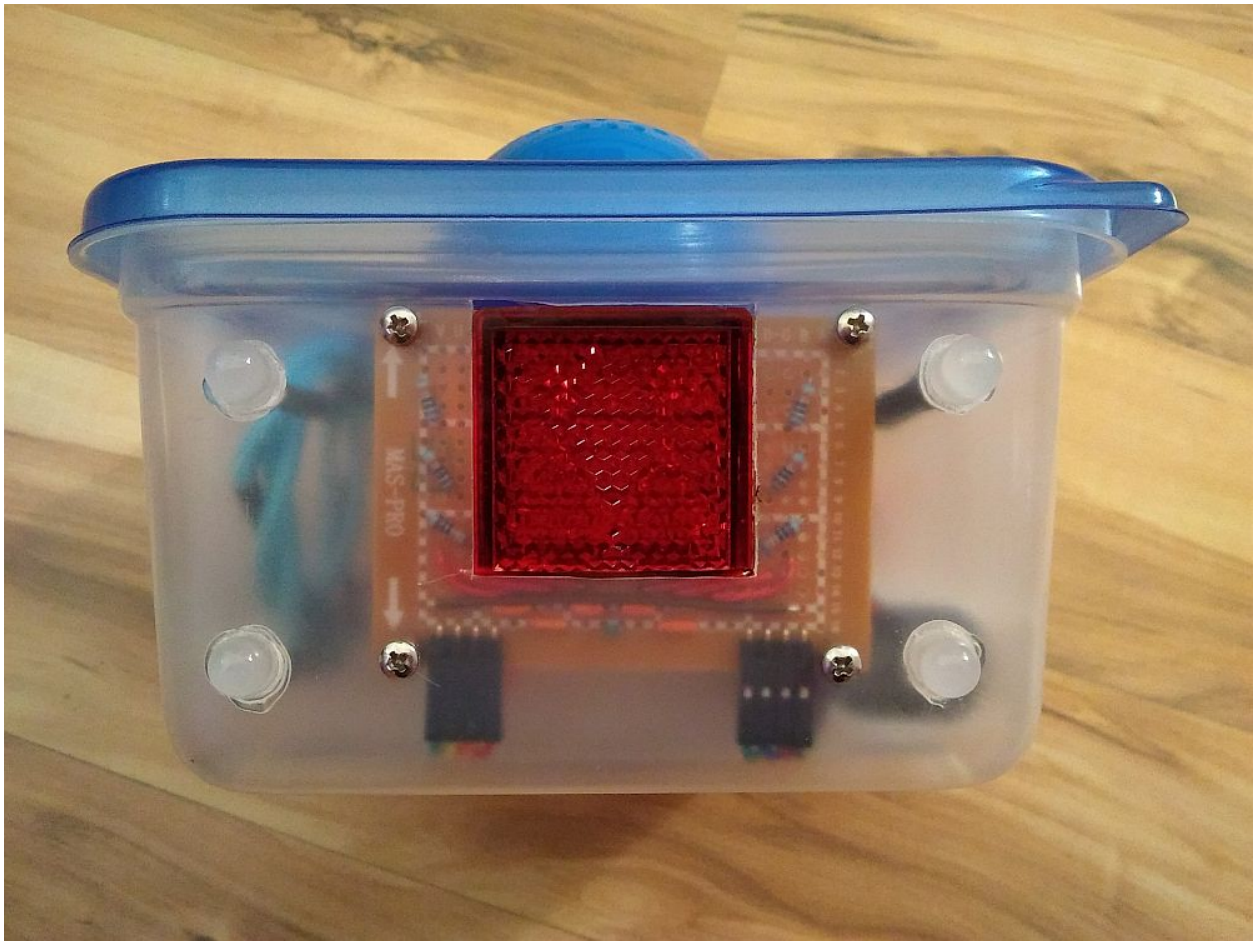
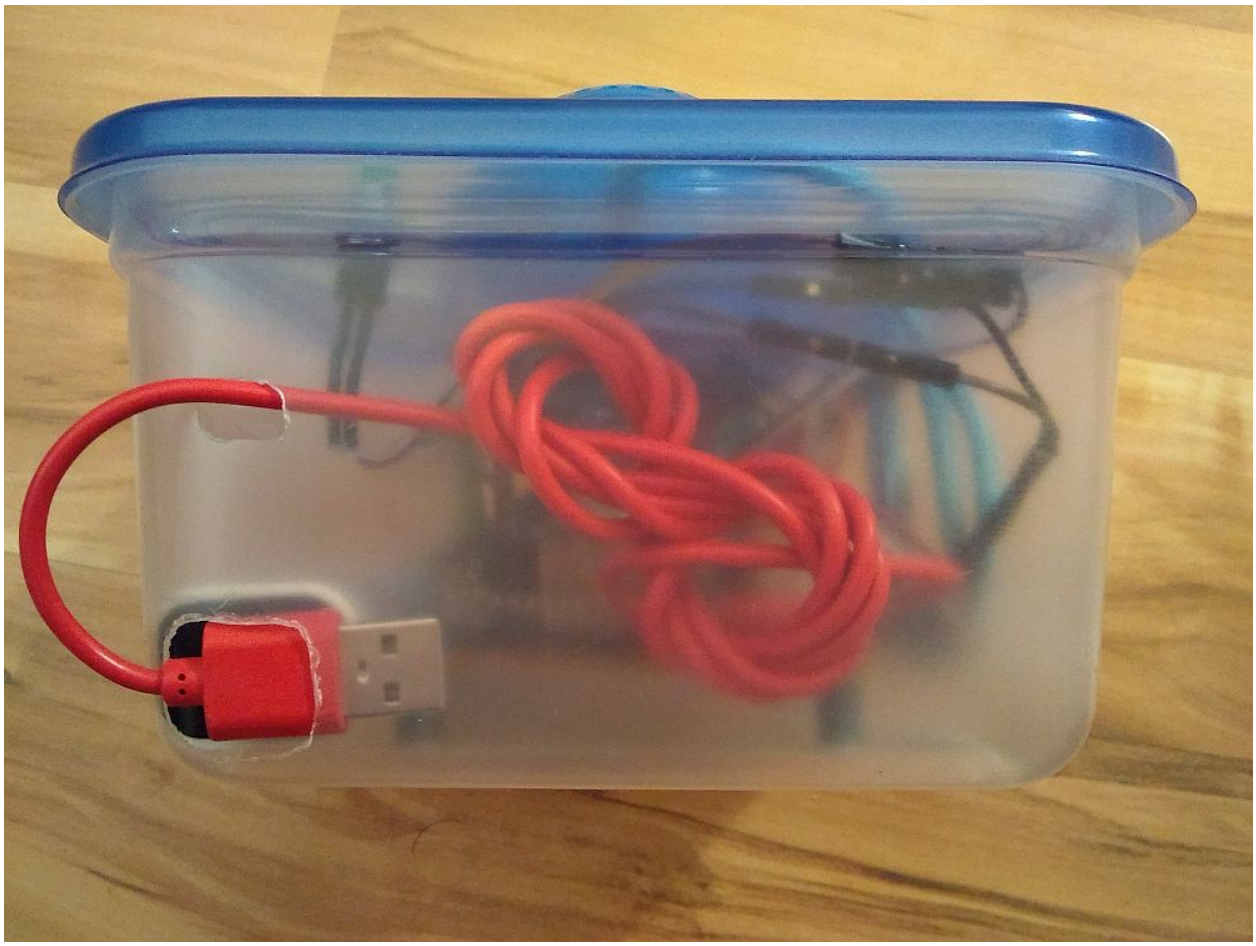
Implemented High-Level Design - Photos - LazerTarget ZL1:

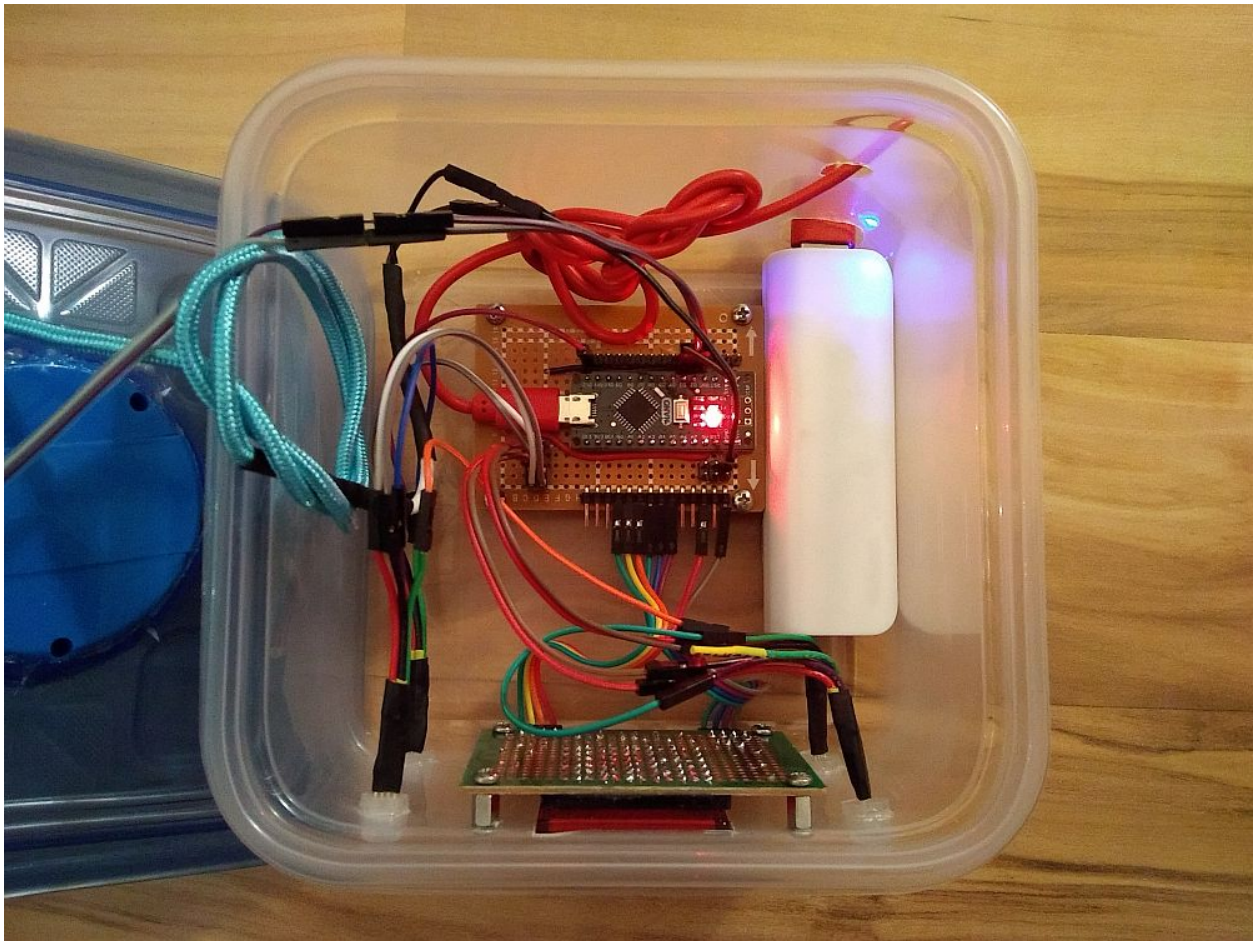


00. Front of LazerTarget ZL1. The red lens over the laser detector is the reverse side of an automotive reflector. The front side cannot be used or it will reflect the laser directly back to the player's eye (which was discovered quite by accident).

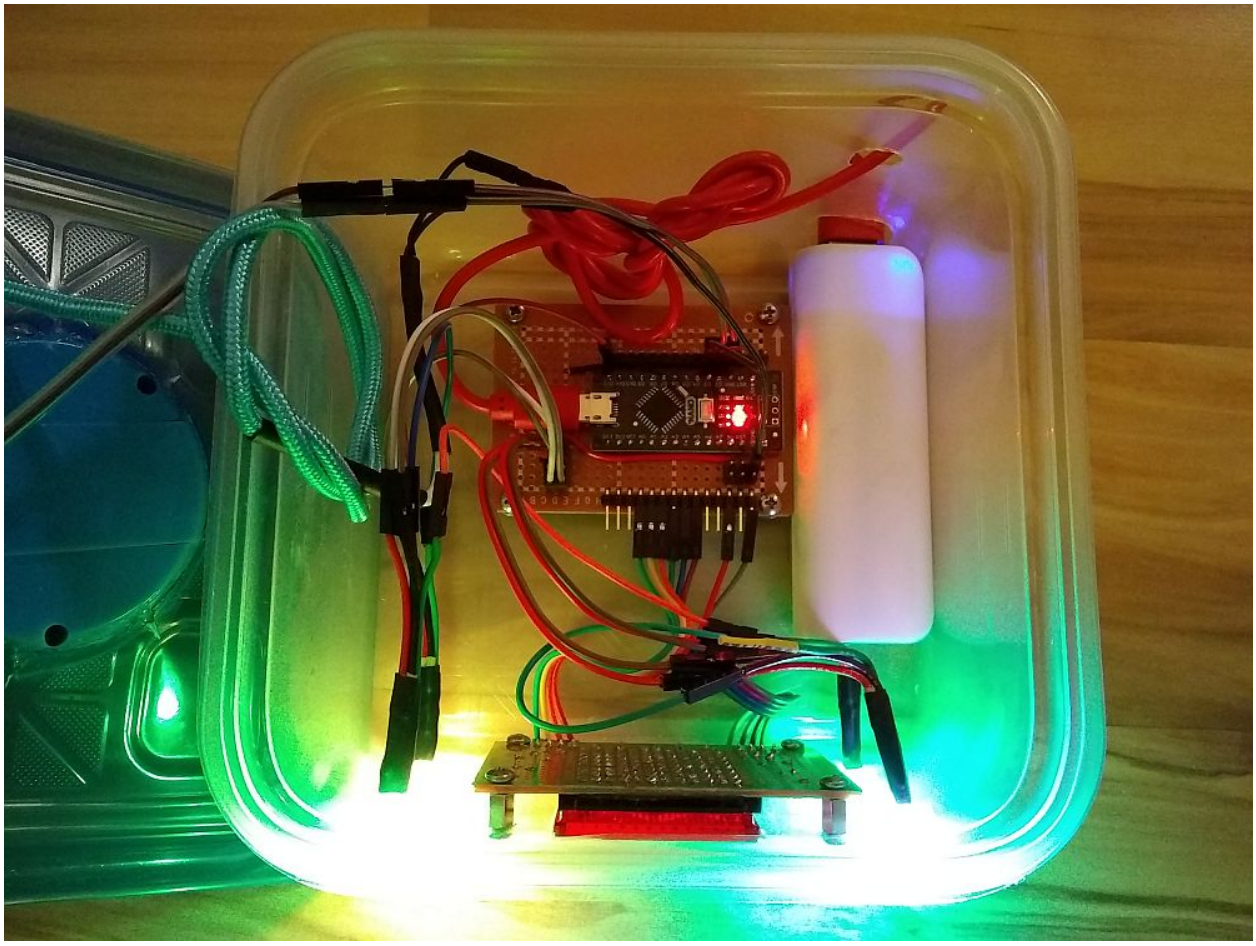
01. Top of the LazerTarget ZL1. Yes, “ZL” does refer to the brand of this particular container.



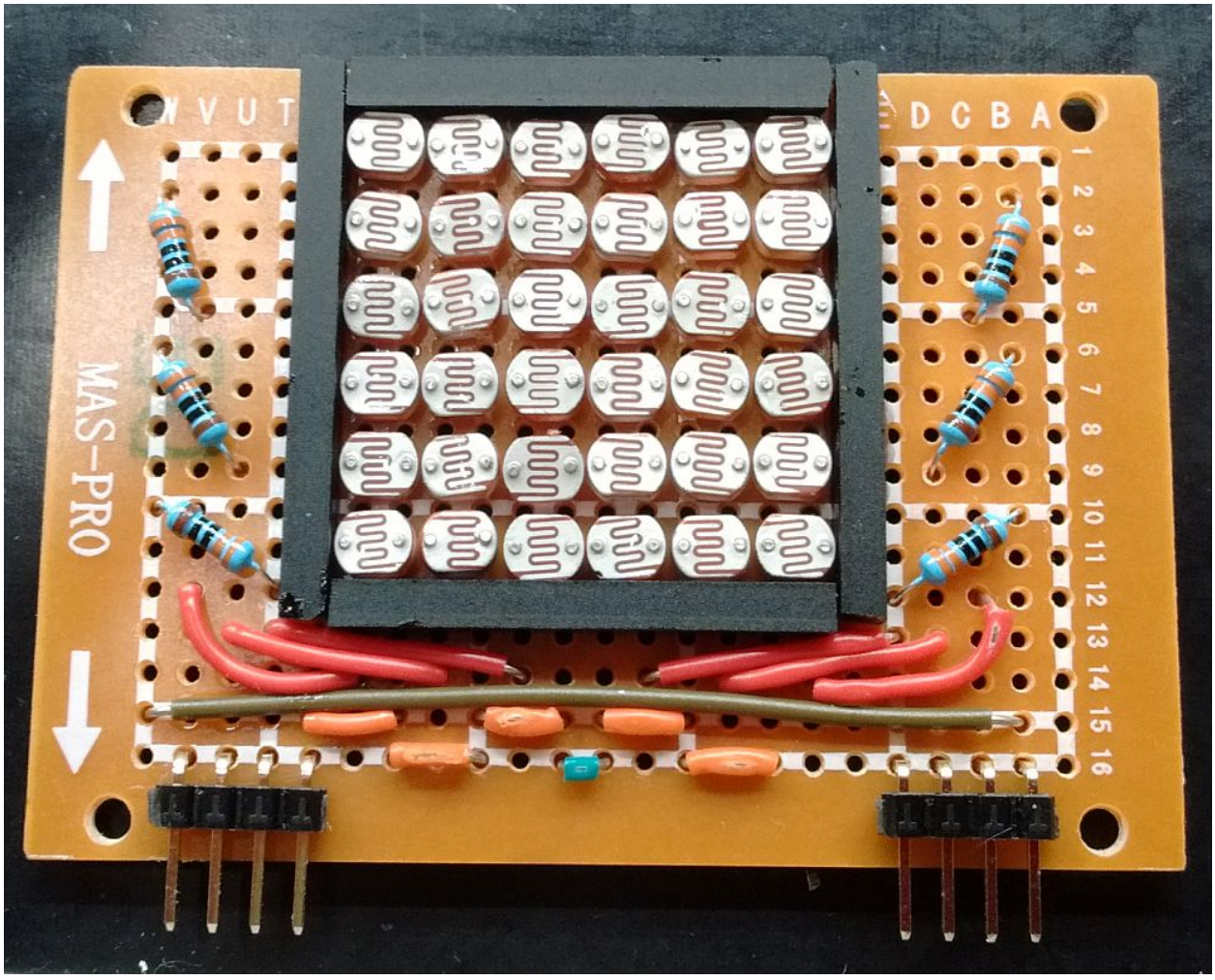
02. Back of the LazerTarget ZL1. The power cord is tucked into its storage area conveniently behind the USB battery.



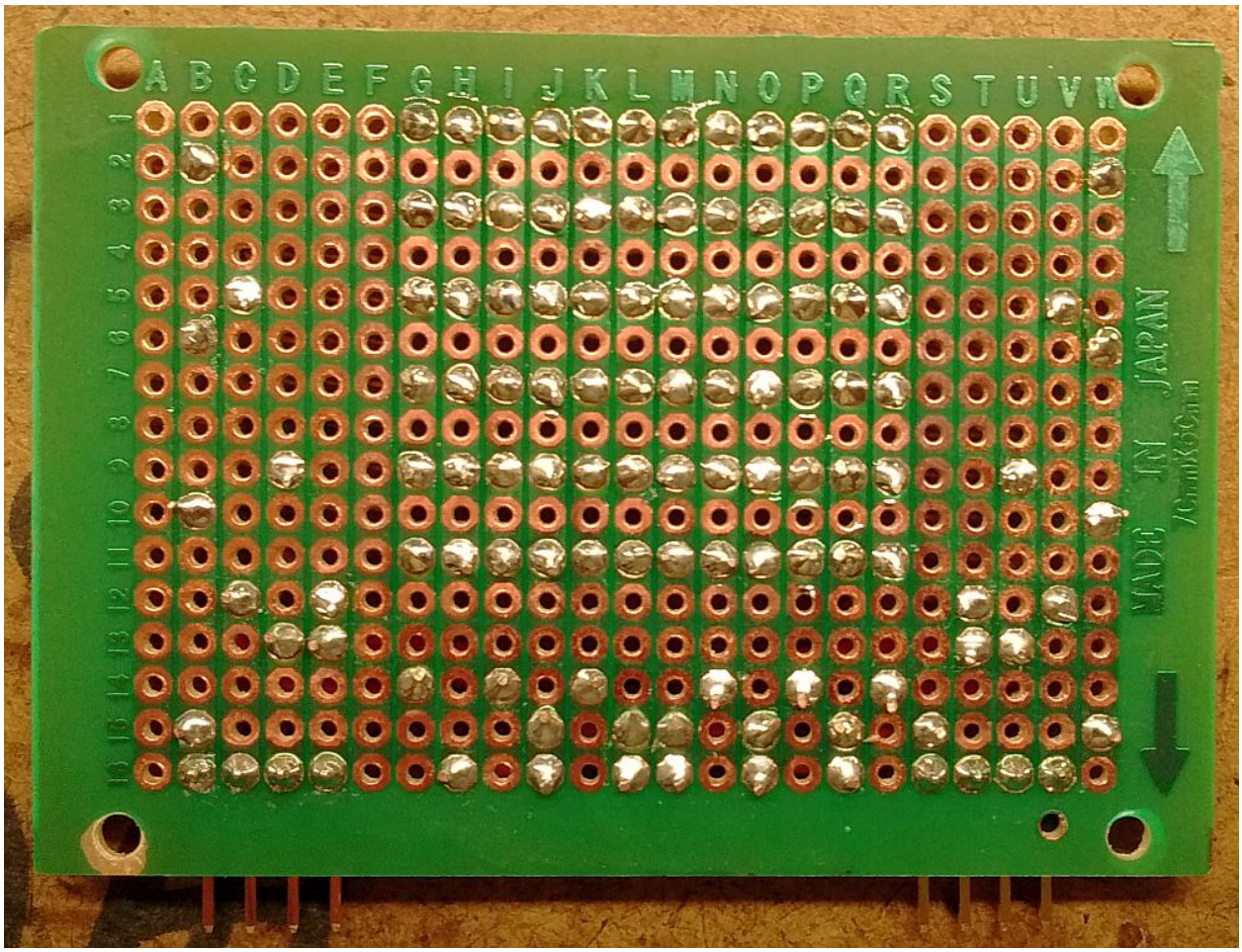
03. Inside of the LazerTarget ZL1 while powered on. All components utilize disconnectable headers.



04. Inside of the LazerTarget ZL1 with RGB LEDs active.



05. The laser detector board before the lens was attached. The sensor consists of 36 LDR 5539 photoresistors in six parallel lines with voltage dividers.



06. Back of laser detector board. Stripboard was chosen for its simplicity when connecting components in parallel.

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