Parkinson's Freezing Of Gait Device

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Statement of Disclaimer

Since this project is a result of a class assignment, it has been graded and accepted as fulfillment of the course requirements. Acceptance does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

Abstract

This report details the work done by Cal Poly Electrical Engineering student, Megan Gerlach, Mechanical Engineering student, Austin Krause, and Biomedical Engineering student Berizohar Padilla on a project developing a device to help people with Parkinson's disease freezing-of-gait. Freezing-of-gait (FoG) is classified as the "temporary involuntary inability to take a step or initiate movement"[1]. This device will be mountable to a wide variety of walkers and canes and will alleviate specific instances of FoG by the activation by the user of different therapies integrated into the device. The therapies employed by the device go as follows: a laser line projected onto the floor in front of the user, a metronome beat frequency, MP3 playback capability, and voice recording playback capability.

The team worked with local man with Parkinson's, Jack Brittle, who aided in design development and testing. The team was sponsored by QL+, a non-profit organization dedicated to improving the lives of disabled Veterans through initiating, creating and supporting medical innovations. The team worked under the supervision and direction of Dr. John Ridgely, a Cal Poly Mechanical Engineering Professor, specializing in Mechatronics.

Chapter 1
Introduction

Team Members

Megan Gerlach is a 4th year Electrical Engineering student graduating in Fall 2015. Growing up in the San Francisco Bay Area, she gained an interest in the sciences at a young age. But it wasn't until she came to Cal Poly where her passion for engineering was sparked. She hopes to continue with electrical design after graduation, more specifically within the medical industry. This project was a fitting introduction into the medical side of her career interests.

Austin Krause is a 5th year Mechanical Engineering major graduating this June. Having grown up in Montana and Wyoming's Rocky Mountains, he enjoys snowboarding, backpacking, and mountain biking. For high school, he went to the Thacher School, a college preparatory boarding school in Ojai California. Upon graduation, he wanted to hold onto the California lifestyle and study engineering so Cal Poly was a great match. Upon graduation, he is eager to uses is degree to work in the solar energy field with photovoltaic and/or solar thermal systems.

Berizohar Padilla is a 5th year biomedical engineer graduating in the fall. She is passionate about global health and product development for unrepresented communities. Currently, she works as a STEM tutor and mentor for Allan Hancock College in Santa Maria, CA. She also teaches robotics and STEM classes for kids at Allan Hancock as well as in Santa Ana, CA. Her passion for engineering helps her work with developing communities providing educational information for parents and kids. Currently she is helping organized the first STEM Girl conference in Santa Maria. She is a single mom who has plans to continue for her master in biomedical engineering. She really loves hand on projects, hiking, road trips, books and overall spending time with her six year old daughter.

Sponsor

This project was organized, monitored, and funded by QL+, a not-for-profit organization dedicated to improving the lives of veterans through innovation and engineering advancements.

Customer

Jack Brittle, a Korean War veteran and President of the local Parkinson's Association for SLO county, has made it his life's work to improve the lives of sufferers of freezing-of-gait. With a strong mechanical engineering background and a wealth of first hand knowledge on the subject, Jack's direction and patient assistance was paramount to the success of this project. He has in the past, and continues now, to work with students from the QL+ program at Cal Poly on projects that improve the quality of life for him and others who have Parkinson's disease and suffer daily from its effects.

Advisors

John Ridgely is a professor in the mechanical engineering department at Cal Poly who closely advised the team through the duration of the project. His expertise in mechatronics and design were extremely valuable assets to the product development.

Dr. Lily Laiho is a professor in the biomedical engineering department at Cal Poly and is the school's representative/advisor for the QL+ program and project lab. Her experience working with teams from the program as well as in the development of biomedical devices in a general sense provided valuable insight for the team throughout the project.

Chapter 2
Background

Parkinson's Disease
Parkinson's disease (PD) is the second most common neurodegenerative disorder, behind Alzheimer's, affecting 7-10 million people worldwide[7]. It is caused by the brain's inhibited ability to produce dopamine. The symptoms that result are tremors, rigidity, bradykinesia (slowness of movement), shuffled steps, retropulsion (propensity to uncontrollably fall backwards), trouble blinking and swallowing, hallucinations, and, our primary focus, Freezing of Gait[1]. The average age to be diagnosed is 62-years old. There is currently no cure for PD, only treatments and therapy to reduce symptoms and improve quality of life. These include: pharmaceuticals, deep brain stimulation, meditation, physical therapy, and musical therapy[1]. A defining characteristic of PD is its varying and unpredictable nature in terms of severity, progression and presence of symptoms. This holds true and applies to Freezing of Gait symptoms as well.

Freezing-of-gait
According to the Parkinson's Foundation, Freezing of Gait (FoG) is the "temporary involuntary inability to take a step or initiate movement"[1]. Like other symptoms of Parkinson's, there is no cure for FoG, and current pharmaceuticals prove to have limited effectiveness.[3] Researchers have identified several common circumstances that trigger FOG episodes such as: crowds, turning corners, close steps, changes of floor texture, crossing borders (between inside and outside), turning in a circle, and divided attention.[3]

Freezing is an especially bothersome symptom for Parkinson's patients because it puts a restriction on the places they can go and terrain they can travel; this limits the person's independence, mobility, and socializing capabilities. Some studies have suggested that these limitations can influence the disease's progression, and can lead to depression.[4] Doctors, patients and caregivers must remain active in utilizing all possible therapies to combat the elusive FoG.

Existing Technology
Visual: Lights and Markings

The most common therapy for FoG is the use of a light or laser to project a line onto the floor. This also includes other similar floor markings, such as a line of tape. When the line is projected on the floor in front of the feet of a person with Parkinson's (PWP), it gives their brain a target and a focal point that they can step to and resume normal gait.[3] These therapies are quite effective, but typically inconvenient for everyday situations as it is difficult to place a line on the ground at any given moment. They are mostly only used during therapy sessions.

Visual: Virtual Glasses

A more sophisticated approach is the use of glasses that project a virtual checkerboard grid onto the floor[2]. The purpose of the glasses is to simulate a step pattern that a PWP can follow and work to regain the rhythm of a normal gait. The glasses seem to be a great way to control FoG[2]; however, they are not readily accessible to the public. Expensive and unrealistic, the glasses are only used as a therapy method along side a doctor or healthcare professional in a scheduled appointment.

Auditory: Metronome and Musical Beats

The metronome is a fairly effective auditory aid to help with FoG[3]. The beat helps a PWP overcome the mental barrier of FoG by giving them a rhythm to follow. Another approach has been simple music beats that are constant and work as a metronome, but with a more rhythmic approach.

Auditory: Counting and Verbal Cues

Some other therapists have used simple counting aloud as a therapy in its own sense. The approach is similar to keeping timing while teaching somebody to dance[6]. Also, it has been shown that talking to a PWP in a constant, uniform voice helps them overcome episodes of FoG.

Tactile Methods

There are additional therapies currently being developed that involve tactile cues. Dr. David Hilgart from the University of Delaware is the patent holder for a foot-mounted device that sends vibrations into the patient's feet to cue resumption of a normal gait. It is called the PD Shoe. The vibration on the foot acts as a trigger for the PWP to continue walking.
Even though several therapies exist and have been effective, it is important to understand that FoG is a changing disease, and the brain becomes accustomed to any given therapy. A PWP struggles with the therapies effectiveness over time; what might have worked last week might not work again this week. Thus, variation in therapy is as important as the therapy itself (Filippi, MD).

Problem Definition

Therapies exist to alleviate specific intances of freezing-of-gait in the form of visual, auditory, and tactile cues. Often times, it is hard to predict the effectiveness of a therapy at any given time. There is no device readily available that successfully integrates a variety of these therapies that is both portable and affordable.

Customer Requirements

The following items outline the specifications that were given by the customer, which were utilized to develop a set of engineering specifications. The complete table with specifications and subsystems is included in **Appendix B**.

Chapter 3
Design Approach

Design Specifications

Initial Ideation
At the beginning of our design process, we did not want to limit ourselves in our ideation. We had access to the work done on the first-generation prototype, but were given the task of taking its proof of concept, and designing a device that would maximize its universality. We determined this is accomplished by making the device accessible, usable, and effective to the maximum number of people who suffer from FoG. We considered eliminating the use of a walker altogether, considering some people with Parkinson's do not require the use of a walking aid. After conducting research and developing our design requirements, we began to formulate possible solutions that would most closely meet these requirements and fulfill our team's objective. In the conceptual prototyping process, we streamlined the number of design ideas to investigate to three: a fanny pack-style waist mounted device, a wrist mounted device, and a foot/shoe mounted device.

Conceptual Prototyping
In order to select a final design, we created a series of questions that we knew would be of significant importance in achieving our end goal:
Would the users be willing and comfortable wearing a fanny pack-type device in public, and would this be an effective location for the device? Is it possible to get a device small and light enough to be comfortably worn on a wrist, especially considering the typical age and physical strength or our customer? Is a foot or shoe mounted device feasible considering the small number of options for mount locations and space availability? How would the user operate this device?

Top Concept Development
Before more general market research was conducted to obtain feedback from our target users, we looked to our sponsor for feedback. The sponsor strongly suggested using a walker-mounted device as our primary focus. This advice refocused our attention to two points: 1) our main customer, Jack Brittle uses a walker, and knows a sizeable demographic who wish to use a device to be mounted on their walker 2) The work of the first-generation can be a stepping stone to further improve a new device. Thus, we adapted our idea to fit with these suggestions: Design a device that is universal, low cost, and manufacturable, which can be adapted and transferred to any walker or cane. This will be accomplished in two steps: first, the design of the device itself, and then, mounting the device on walker/cane. The diagram below (Figure X) shows the main improvements to be made from the previous generation and the objective we hope these improvements will achieve.

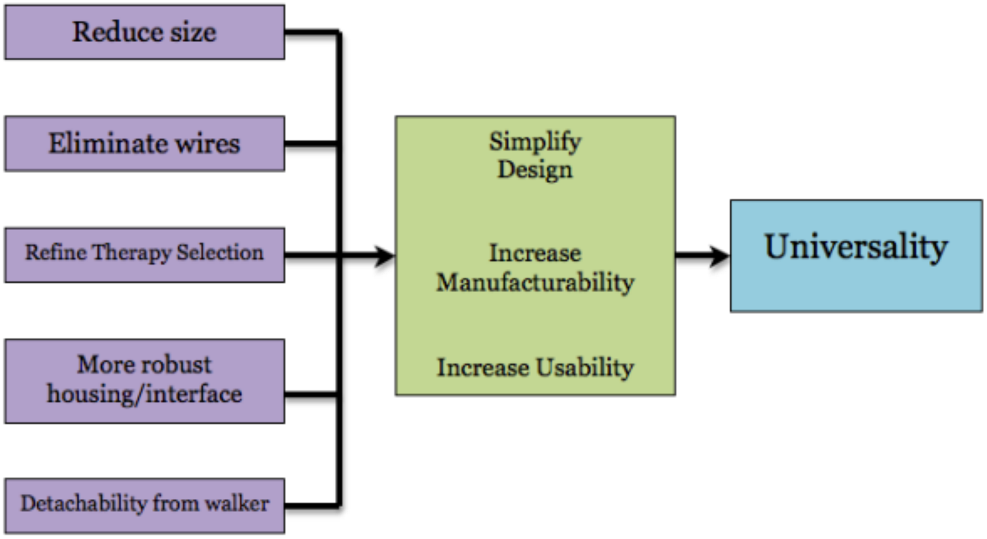


Figure 1: Features chosen for improvement for next generation

Chapter 4
Final Design

Overall Description and Layout

Our next step was to develop the specifications for the different subsystems of our new design. By utilizing literature reviews, contacting experts in the field of interest, and completing decision matrices we have refined our subsystem selection. The decision matrices are located in **Appendix B**.

Therapy Selection

As previously mentioned, our focus is universality, which Stride Rhythmics qualitatively defined as a minimum of three therapy options for users. This is an important, or perhaps the most important, aspect of the device. The research conducted about therapy options was thorough and extensive, so we feel comfortable and confident with our final selection.

Visual Cues-

Line projection: One of Jack Brittle's specifications was a green line; our research indicated that projecting a line on the floor is a cue currently being utilized to alleviate FoG. The first generation walker also included this form of therapy, but the line was dim and not visible outdoors. Thus, we decided to include a green line projection as the first form of therapy; the color of the line is important as well as the shape. Following the rationale that FoG is a brain disorder and that we are predisposed to associate green with go, we feel that a straight green line is the most effective visual cue option.

Tactile Cues-

Vibration: One of the tactile therapies use on the first generation was vibration on the handles. Through our extensive literature review we could not find anything suggesting that such type of therapy is effective. Thus, we reached out to Jack and many experts in the field. Jack's input was that this therapy is hardly used to regain gait and that only vibration on the lower extremities is helpful. We heard back from two experts who specialize in FoG, and both confirmed that vibration on the hands would not be useful. Therefore, we decided to look for an alternative therapy that could be implemented instead.[14]

Auditory Cues-

Metronome: Our customer, as well as several others affected by PD, can successfully use a metronome as a form of therapy for FoG. We decided this is an important option for our user. The metronome in our device will play through speakers and it will act as one of three auditory cues.

Custom recording: The third form of therapy is another auditory cue; however, because we learned that FoG therapies must be versatile, we decided to add a customizable component. The voice recorder capability will allow the user to record the voice of their therapist or any verbal cue that helps when a FoG episode is present

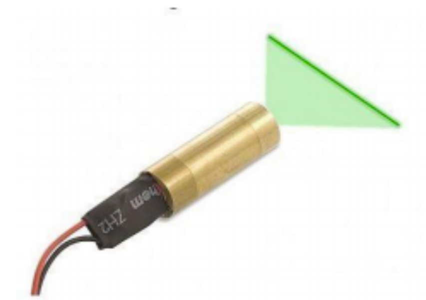
Music: The forth and final form of therapy integrated into the device is a small MP3 player with several music selections that allow the user to choose a song that will allow them to resume a normal gait. The team was given feedback from Jack as well as song suggestions that will be readily available on the device created.

Component Selection

The next step in design was selecting the components to be used to effectively build the device with our desired outcomes.

Laser

In the decision matrix for our line projector (**Appendix X),** we compared a green laser line, a red laser line, and a green LED light. We wanted to investigate an LED combined with an optical system because it would be a safer, less expensive option. The decision matrix, however, yielded that the green laser line is the best option for the visual cue subsystem of our device. We began researching green lasers and sent out product inquiries to Apinex and Laser Tools Co., both manufacturers of lasers, and asked which of their products they felt would be able to project a line 20 cm long (projected length) a distance of 1 meter. From these inquiries and research, we selected the Apinex GMCW02L. The laser requires 3 volt DC power and draws up to 300 mA of current (although testing indicated the laser we chose- the 1 mW option- draws significantly less). For this reason however, it required circuitry that uses a MOSFET as a switch to obtain direct power from the battery that is regulated with an LDO linear regulator. The schematic including the regulator selected and simulations for the can be seen in **Appendix E** and **Appendix F**. Additionally, a simple schematic for the MOSFET switch including the transistor chosen can be seen in **Appendix E**.



Specifications :

Laser Class :	II, IIIa, IIIb
Wavelength :	532nm
Output Power :	<1mW, <5mW, <10mW, <20mW, <30mW, <50mW
Output Mode :	Continuous
Input Voltage :	3V DC
Operation Current :	<300mA (<600mA for the 50mW)
Operation Temp. :	20°C - 30°C
Beam :	Line (90° fan angle)
Divergence :	1.4mrad
Expected Lifetime :	> 3000 hours
Case Material :	Brass
Length :	31mm
Diameter :	12 mm

Figure 2: Laser selected with specifications

Power Source

When choosing a power source, a main requirement was the ability to safely recharge the battery. The system requires 7-12 volts to power the microprocessor. We decided to use a standard lithium ion battery due to their reliability and effectiveness for the size. Due to the nature of lithium ion batteries however, this requires to add a an extra protection feature to recharge the battery effectively and safely. We decided to use a small recharge module that accepts a standard 5-volt USB wall charger to micro B adapter to safely charge a single cell lipo battery. Because we chose to use this module for charging, it limited our battery to a single cell. This provides 3.7 volts but due to the 7 volt requirement of the microprocessor, we added a buck-boost converter chip with appropriate circuitry to step up the 3.7 volts to about 9 volts. The schematic and simulated results can be found in **Appendix E**.

Speakers

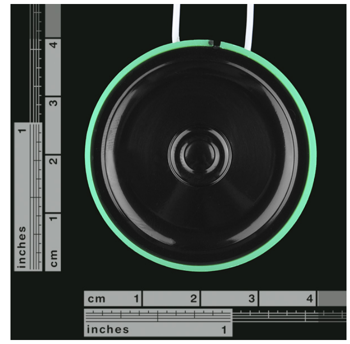


Figure 3: Speaker selected

The speaker we have selected is the Sparkfun 0.5W (8 Ohm) Speaker, shown in **Figure 3**. This is slightly larger in size than a piezo speaker, but will also produce a higher quality and louder sound. After preliminary testing, it was determined that the speaker on its own was not loud enough for universal use. We decided to add an amplifier IC with circuitry to amplify both speakers, one sourced from the MP3/Metronome and the other that is sourced from the voice-recording module.

Microprocessor

For the processing of our device, we have selected the RedBoard programmed with Arduino Uno, shown in **Figure 4**. When making our board selection, we narrowed it down to the Arduino Uno microprocessor and the Raspberry Pi A+. We ultimately selected the Arduino because there are several hardware accessories available to enhance the functionality of the board and contains more ports for analog/digital interface than the Raspberry Pi.

Additional Hardware Accessories

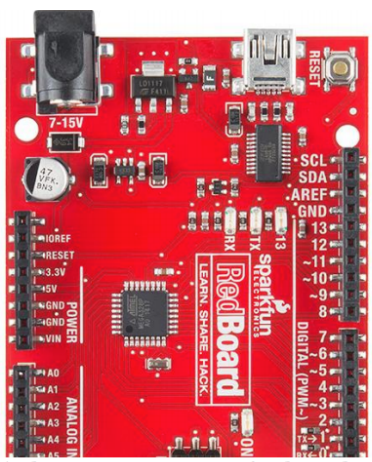


Figure 4: RedBoard programmed with Arduino Uno

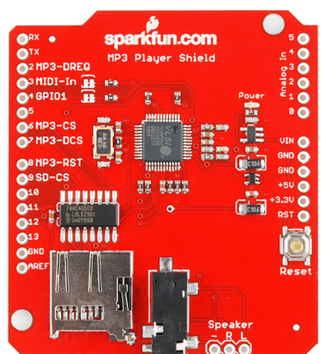


Figure 5: MP3 Player Shield

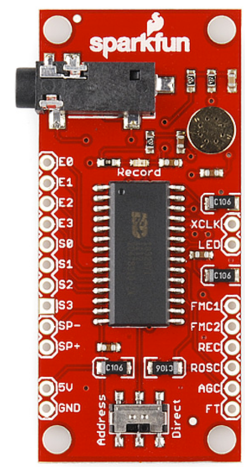


Figure 6: Voice Recording Breakout Board

The Redboard is compatible with a number of additional boards and modules that allow for greater functionality. Two were chosen for the device. One, is the MP3 Player Shield offered through SparkFun that allows for MP3 decoding, selection, and storage of music files. The second is the Voice Recording Module which comes with an included microphone and speaker port to allow the user to record and play their recording. Detailed schematics of these boards and the hardware added to allow for functionality are shown in **Appendix E**. **Figure 5** and **Figure 6** above show the two boards.

Power Analysis

As stated in the Component Selection section, a standard 3.7-volt lithium ion battery is used to power the device. This will required a step-up voltage conversion as well as an LDO regulator to ensure different modules of our device safely operate at their rated voltages. The battery we chose to use is a rechargeable lipo battery rated at 1200 mAh. Shown below in **Table 1** is the estimated current draw broken into each subcomponent. Using this information, we have estimated how long the battery will last.

Table 1—Power requirements for device used to estimate total hours of use

Component (per part)	Current Draw:
Laser	300 mA
Speaker	191.7mA
MP3 Shield	
VS1053b audio decoder	60 mA + 15 mA 5 mA + 11 mA no load, standby
Voice Recorder Breakout	
ISD1900	30 mA record/playback 10 uA standby
RedBoard	
Atmega microcontroller	.2 mA active .1 uA power down *All MAX values

9 V rechargeable battery (mAh) =	1200
Total Current (active-mA) =	596.9
Total Current (standby-mA) =	16.00011
TOTAL Avg Current (mA) = (Active for 10% of use)	74.090099
Hours of Use=	16.19649611

Key Functional Modules Within Device

There are a few key modules of separate hardware that are controlled by the main processing unit. Four major buttons provide the interface required with the user. They are simple digital input ports on the Arduino board.

The first separate hardware unit is the Voice Recorder Breakout board. It requires two inputs driven by the processor to control if it is recording or playing.

The second additional hardware module contains the power amplifiers. We chose to use a NJM386 low voltage audio power amplifier. It operates at a voltage of 4 to 12 v and allows for a 20 dB gain with relatively few external components. The detailed schematic for this circuitry as well as a simulation can be seen in **Appendix E** and **Appendix F** the data chip for the IC is located in **Appendix G.**

The third noteworthy electronic module is the combination of a MOSFET and LDO regulator to power and control the laser. We chose the MCP1700 Low-dropout regulator to step-down the 3.7 volts from the battery to just under 3 volts- the requirement to drive the laser. Additionally, a standard JFET was chosen (the IRLZ44) to take a digital output from the processor and allow current to switch on only if driven by the user. The schematic for this circuitry can be found in **Appendix E.** The data sheets for these two chips are located in **Appendix G.**
Finally, a switching headphone jack is used to allow the user to plug in headphones or use the speakers as an audio source. A standard potentiometer is also included to allow volume control. The schematic for this is found in **Appendix E**.

Block Diagram

The modules are connected as shown in the following diagram (Figure 7). The microprocessor controls both the voice recorder board as well as the laser module. However, the battery directly powers the laser module. One speaker is driven by the MP3 shield while the other is driven by the voice recorder breakout board.

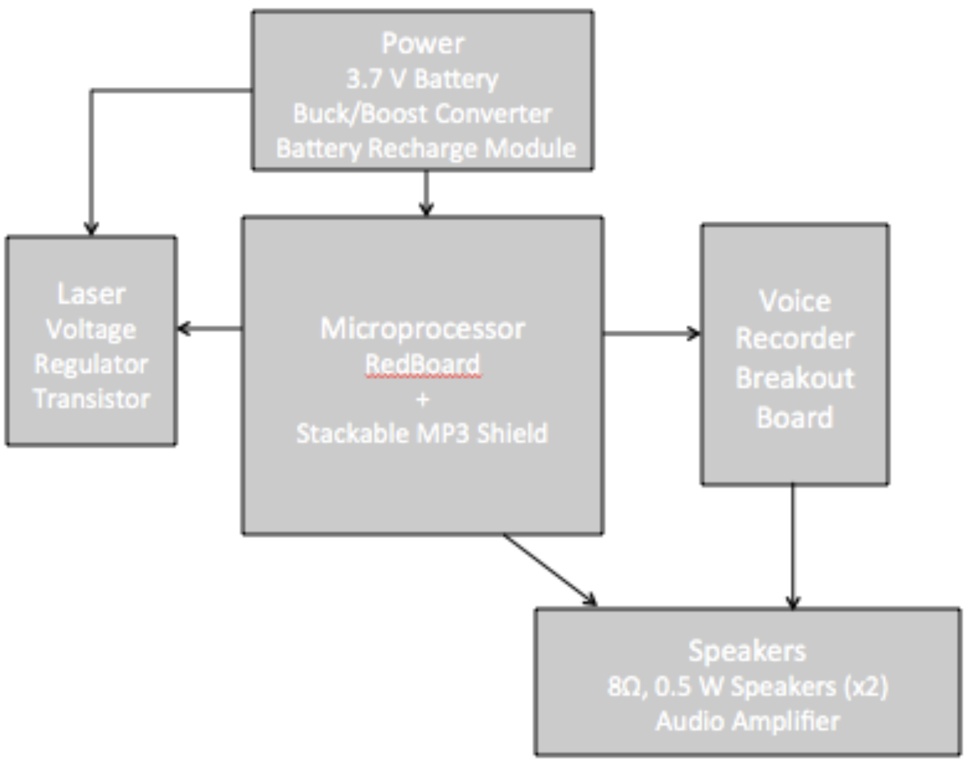


Figure 7: Block Diagram

Housing

To house the electronics in the most durable and simple way, we designed two separate enclosures. One holds the main processing unit and supporting hardware and the other holds the laser. They are connected through a main power line. **Figure 8** shows the two separate enclosures connected with a cord.

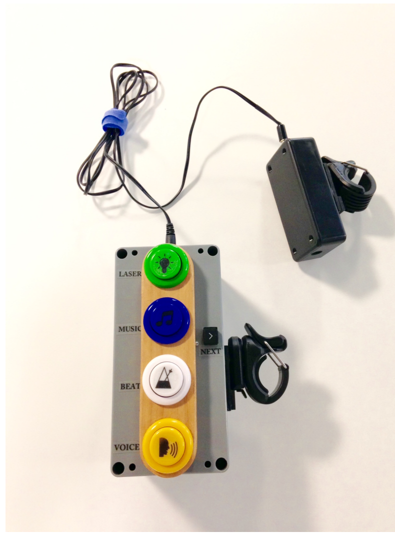


Figure 8: Main housing unit along with laser housing unit

For the housings of this device, prefabricated electronic enclosures were modified to accommodate the required internal and external components. Originally, the team created 3D models in SolidWorks that could be 3D printed in small quantities and had the ability to be adapted to injection mold casts if a large a situation arose where the device would be mass-produced. However, several factors led the team away from this decision:

1. The manner in which material is dispensed in the 3D printing process often produces components that have compromised strength and durability. The FoG device must be able meet specifications detailing strength and durability, as it will likely undergo rough and heavy use

2. The startup and operating costs to 3D print is quite expensive. The use fee to utilize the 3D printer at Cal Poly is approximately $70. Pre-existing enclosures are quite affordable.

3. Printing an entire housing is a long process and would take many hours.

Although 3D printing and injection molding would produce a device housing that would be more reproducible, it did make sense from an engineering perspective for this iteration of the device. The modified pre-existing electronic enclosures used on this prototype are robust and meet the outlined specifications.
The enclosure used for the main device housing was manufactured by Bud Industries and supplied by Allied Electronics. The specifications for this housing are listed in **Table 2**. The

enclosure housing the laser module was manufactured by manufactured and supplied by RadioShack. The specifications for this enclosure are also shown in **Table 2.**

Table 2—Specifications for pre-modified housing enclosures.

Specification	Main Housing	Laser Module
Model Number	PN-1333-DG	270-1802
Dimensions	6.3” x 3.15” x 3.35”	4.0” x 2.0” x 1.125”
Material	High Impact ABS	ABS
Color	Dark Gray	Black
Weight	9.8 oz.	1.2 oz.
Provided hardware	(4) M4 x 20mm screws	(4) #4-5/8 screws
Cost/unit (1 unit)	$13.13	$3.99
Cost/units (100 units)	$8.79	$3.99

Mount System

The mount is an important aspect of this device, as it is tied closely to the idea of universality. In order for the device to be truly portable and usable on a variety of different walkers and canes, it must be easily adjustable, rotatable, and mountable to a range of tubing diameters, all in a simple and straightforward fashion. In maintaining simplicity, the team aimed to have the device me mounted in less than 10 seconds and be adjustable in 2 steps or left. This likely meant no screws other hardware, which would also be difficult for a user or caretaker with limited motor skills or experience using tools.

Initial ideation led the team to design a mechanism that would utilize a grip clip, similar to one that holds a broom on the wall that was attached to a set of circular plates that had teeth in interferences that would allow the user to rotate the clip, therefore the device, 360 degrees around the fixed mount. An exploded assembly of this design is shown in **Figure 9.** With the grip clip itself able to rotate around and slide along the axis of the walker or cane frame, this give the device 3 degrees of motion to position the main housing and properly aim the laser.

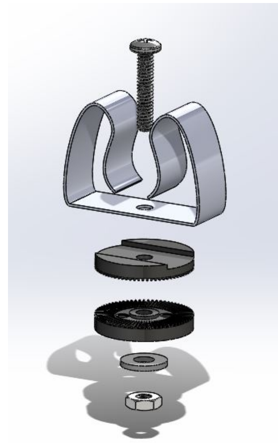


Figure 9: Initial design iteration for mount system

This design, however ultimately failed to meet the specifications outlined in the early stages of the design process. Here is why:

1. The grip clips could not maintain a sufficiently strong grip on the range of common diameters. Over time, this would only get worse due to fatigue.

2. It would be hard to get the precision necessary on the teeth of the rotator plates by 3D printing, not to mention the high cost to print.

3. The metal on metal contact of the grip clips on the walker/cane caused slight damage. Several coatings were tested to combat this, as well as increase the friction and force of the grip, but they did not adhere to the grip clip and would peel off over time.

The next design approach was to find an existing mount system and integrate it onto our device. This strategy found a lot more success. After testing multiple systems, the team ultimately selected a mount system that is designed for mounting bike lights to bikes. This system is the "Universal Mounting Bracket" shown in **Figure 10** and produced by a company named Serfas® that specializes in bike lights and other bike accessories.

Figure 10: "Universal Mounting Bracket" designed and manufactured by Serfas©

This system utilizes a rubber strap and cam-locking latch to attach to the walker or cane. The length of the strap is adjustable, which allows it to mount to the specified range of tubing diameters. It is rotatable, and can easily mount in less than 10 seconds. The caveat to using this mount system is that Serfas® holds a patent on the system (US patent 8,132,764) so this system could not be used if the device was to be marketed and sold. It, however, works great for the prototype.

In order to use this mount bracket for this device, internal mount slides were manufactured, which can slide into the slot and fix the device to the bracket. This mount slide is shown in **Figure 11** and detailed in **Appendix H**.

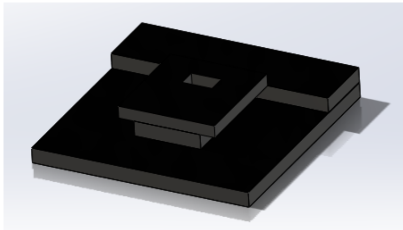


Figure 11: Mount slide to accommodate Serfas© bracket to device housings

With this simple and dynamic mount setup, there are a variety of locations for the main device housing and laser module to be mounted on walkers, rollators and canes. **Figure 12** shows some examples of these locations, allowing for optimal use for the user.

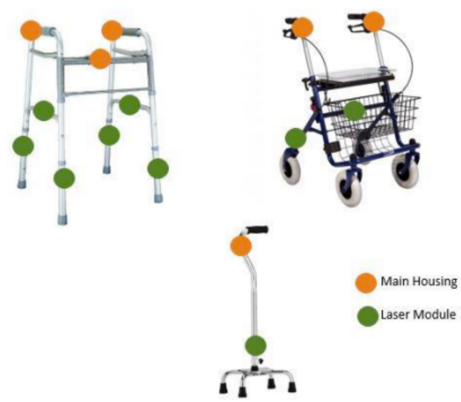


Figure 12: Possible locations for mounting main device housing and laser module

Safety Consideration

A major safety consideration for the device was the laser used, to ensure no accidental improper use of the laser was possible. A device of this type can lead to injury. In the early stages of design, the team hoped to use a more powerful laser to maximize visibility and effectiveness of the visual stimulation. It was planned to equip the laser module of the device with a mercury switch to guarantee the laser would not turn on if tilted in an unsafe direction (possibly in the eyes of the user or others in the nearby vicinity of the user). Through testing, it did not seem possible to incorporate a surefire way consistent enough to guarantee safety. For this reason the team opted to use a lower power laser as a safety precaution in the final design.

Cost and Final Component Breakdown

A detailed Bill of Materials with the prices and sources of all components in the final design of the device is included in **Appendix D**.

Chapter 5
Product Realization

Material and Part Sources
The sources for our materials included various websites and stores specializing in electronics and simple manufacturing. Electronic parts were ordered from SparkFun (for the Arduino and its accessories), Digikey (for specific IC's and electronic components like resistors and capacitors needed) and RadioShack and Amazon (for parts needed to physically build the device such as wires and crimps). The laser was specially ordered for our given requirements from a company named Apinex.

To modify the existing enclosures and adapt them to successfully house the components, Inserts were manufactured using a 12"x24" sheet of machinable, 1/8" thick ABS plastic, purchased from McMaster-Carr for $14.07. These inserts are detailed in **Appendix H.** ABS plastic was selected because it is cheap, strong and easily machined.

Equipment
The equipment required to build the electrical components of the device was limited to relatively standard electrical equipment. This includes: a soldering iron, crimp for wired connections, a multimeter for intermittent testing and wire cutters/strippers.

The modifications to the enclosures were done using mostly basic tools and power tools, including a drill press, band saw, drill bits, files. Often, an alternative method would be to laser cut the access holes and different pieces necessary to manufacture the inserts. The laser cutter was not employed for the manufacture of this prototype due to the low availability of the laser cutters on campus.

Prototyping and Manufacturing
The realization of this design, as with most designs, began with a prototyping stage. As a finished project it is a first, yet reliably useable, prototype that serves as a functional product for our main customer Jack as well as proof of concept to be tried out and tested among his friends. His plans for the future of the project as well as steps needed for volume production will be noted in the closing chapter. The first stage of electrical prototyping involved a solder-less breadboard to incorporate the needed external components with the micro-processing board. A test circuit was built with simple push buttons to ensure working and tested code. The test circuit created is shown in **Figure 13**.

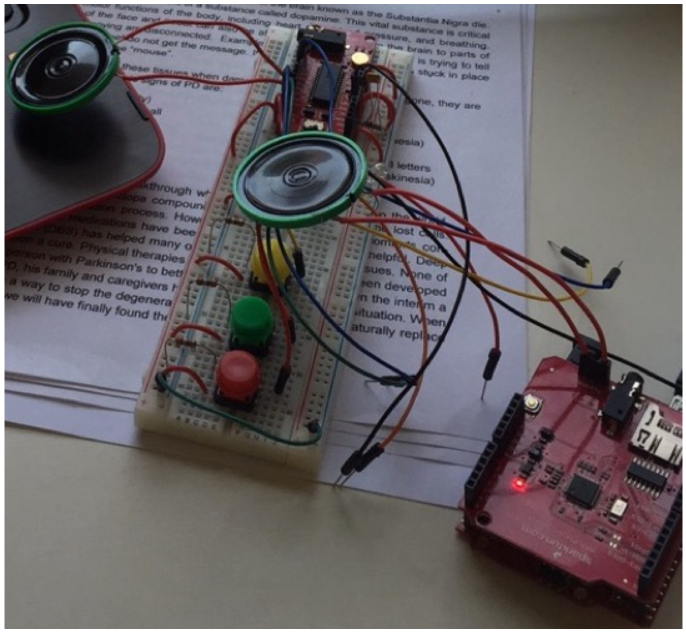


Figure 13: Test circuit with simple switch buttons

The pin-out diagram shown in **Figure 14** describes the function of the input/output pins on the microprocessor and relates to the code in **Appendix G**.

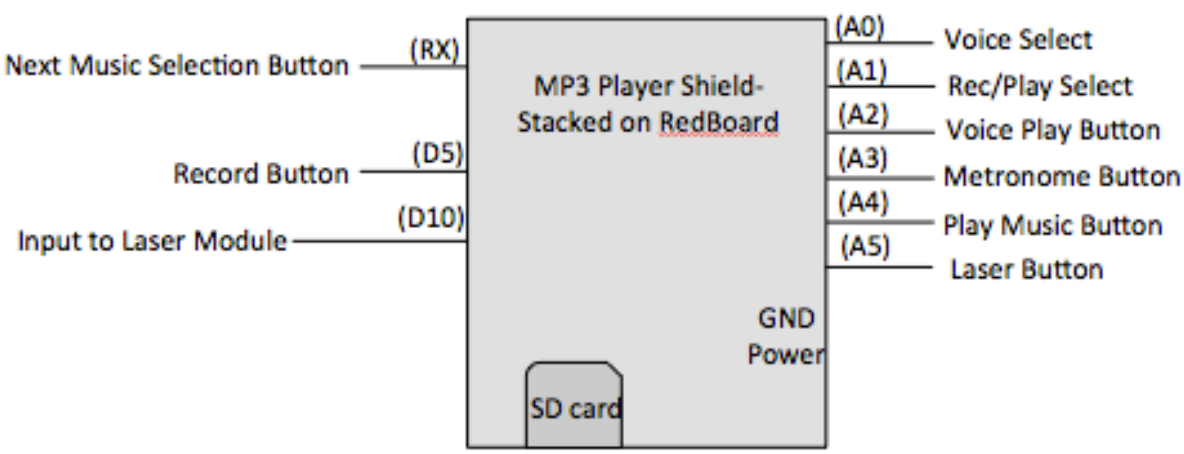


Figure 14: Pin-out diagram

The prefabricated enclosures described in earlier sections were modified using several methods. **Table 3** has a list of every modification to the housing necessary to facilitate the components of the device, the equipment and material used, the estimated duration of the step, and alternative methods available.

Table 3—Modifications made to prefabricated electronic enclosures.

	Modification	Method	Equipment/Tools	Duration (hours)	Alternative Method
	Cut hole for DC jack	Power tools	Drill press, 5/16" drill bit	0.1	Laser cut
	Cut laser projection access hole	Power tools	Drill press, 3/8" drill bit	0.1	Laser cut
	Manufacture laser support plate	Power tools, assembly	Drill press, band saw, belt sander, 0.5 sq. ft. ABS plastic (1/8" thickness), Devcon® plastic welding epoxy	1.25	Laser cut/epoxy or 3D print
	Cut speaker holes	Power tools	Drill press, 1.5" hole saw, small file	0.5	Laser cut
	Cut audio jack access hole	Power tools	Drill press, 7/32" drill bit	0.1	Laser cut
	Cut potentiometer access hole	Power tools	Drill press, 5/16" drill bit	0.1	Laser cut
	Cut hole for DC jack	Power tools	Drill press, 5/16" drill bit	0.1	Laser cut
	Cut holes for mounting PCB standoffs	Power tools	Drill press, 5/64" drill bit	0.5	Laser cut
	Cut hole for "Next" button	Power tools	Drill press, 3/8" drill bit, small files	0.5	Laser cut
	Manufacture USB chip support	Power tools, assembly	Band saw, belt sander, 0.25 sq. ft. ABS plastic (1/8" thickness), Devcon® plastic welding epoxy	1	Laser cut/epoxy or 3D print
			Total	**3.35**	

Locations and dimensions for each modification and insert manufacture are detailed in **Appendix H.**

Schedule and Time Frame

Attached is the Gantt Chart detailing the timeline for the project, located in **Appendix C**.

Chapter 6
Design Verification

Testing Method

Mount Grip

An important aspect of the device is that it could fix to the walker or cane in a strong, sturdy fashion. To ensure a firm connection, the team specified that the mount grip would need to withstand a torque of 1 ft-lb. To verify this, a grip test was setup. In the test, the mount was connected to the walker with a 6-inch extension arm that could support weights, and exert a torque about the axis of the mount. The amount of weight added to the extension arm would determine the amount of torque about the axis, in foot-pounds. Unfortunately, the data from these tests, which were also in a logbook and in a flash drive, were lost in a theft to one of the team members. However, the results showed the mount could sustain a 1 ft-lb or torque on diameters ranging from ¾" to 1 ¼". At the design diameter of 1", the mount could withstand up to 2 ft-lb of torque.

Figure 15: Mount grip test performed in lab

Laser Safety

Originally, for the laser to be used as the visual therapy on the device, the team selected a laser that operated at 5 mW of output power, which classifies it as a Class IIIa laser under that ANSI laser classification. Lasers in this classification can have the potential to cause eye damage. This laser was selected to maximize the environments in which the laser would be visible and the therapy would be effective. However, in order for this laser to be used, safety mechanism would need to be in place to protect the user and others from eye damage, without fail.

Several safety mechanisms were considered. Mechanical doors were designed, but proved to be unreliable and compromised the function of the laser therapy. An accelerometer was considered but, in the name of maintaining simplicity, discarded. The optimal choice for safety mechanism was the use of a mercury switch that would break the circuit powering the laser when the laser module was tilted past a certain angle from vertical.

Two mercury switches were selected to test their average angle of disconnect and reliability: the Omega Au46 and the Tile-type STSP 2P. Unfortunately, the actual data of these test results, which were in a logbook and on a flash drive, were lost in the theft to one of the members of the team. However, the tests showed that the average angle the mercury switches would turn off the laser was around 98° upward from vertical, for both mercury switches. This angle was determined unsafe for the mercury switches to be employed as the safety mechanism. In addition, there were runs during the testing in which the mercury switches would not split the connection at all.

The team concluded that the only way to ensure the device would be completely safe and not endanger the user or anyone else to eye damage was to have a completely safe laser. For this, the team selected a less powerful laser: the same model of Apinex laser but with an output power of 1 mW. This classifies the laser as a much safer Class II.

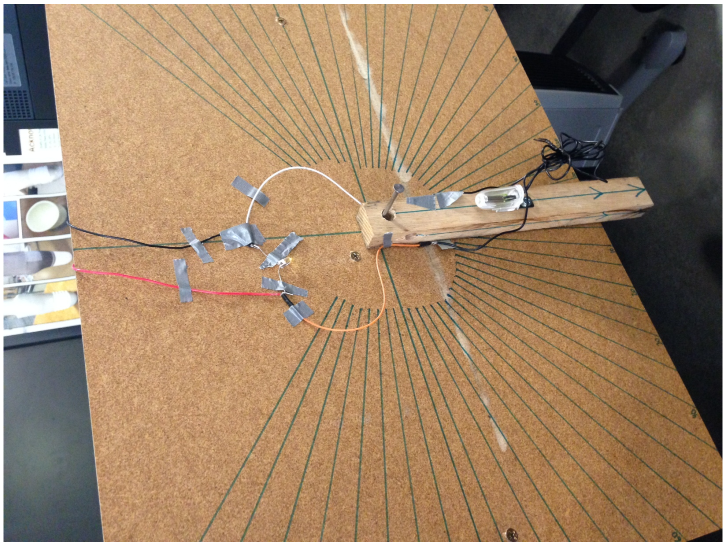


Figure 16: Testing of the mercury switch safety feature

Laser Visibility

The visibility of the laser was initially an important design specification after consulting with the customer. After the necessary change in the power of the laser, we felt the need to test the visibility with the new lower power laser. The laser was tested indoors in the lab and was visible from more than four feet. Once tested outside, the laser was visible in the shade from the same distance, but became more difficult to see from farther distances in the sun. It was determined that the user would most likely use the laser within two feet of the ground (mounted towards the bottom of the walker) and in *most* cases of sunlight (some surface textures and colors may be harder to see than others) from two feet, the laser will be visible. Below in **Figure 17** the lab portion of the test is shown.

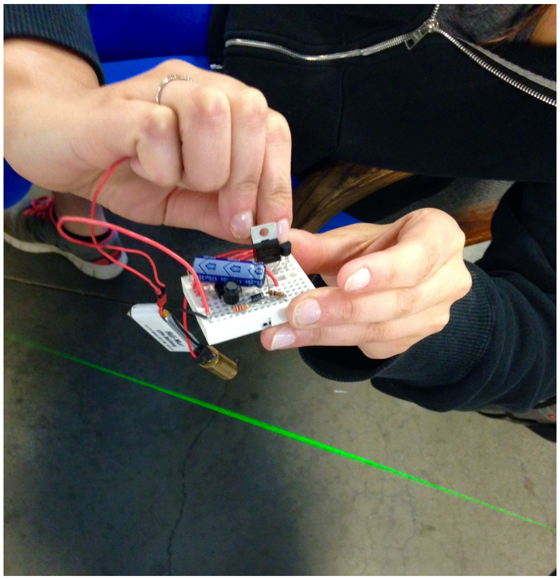


Figure 17: The laser was tested indoors as well as outdoors at different distances from the ground

Battery Life

Another test performed was the battery test. We successfully charged the battery fully to yield 3.7 volts. Additionally, the Buck-Boost converter circuit was tested and 9 volts were yielded. It was found that the laser actually draws significantly less current than its rating which will allow the battery to last longer than originally estimated.

User Compatibility

The ease of which our target customer is able to use the device is an important aspect of this project and was considered highly throughout the design process. While the team could not get direct feedback from Jack and members of the Parkinson's Association due to travel and other circumstances, the next step of testing is to get input from users who use the device and test how easily they operate it.

Chapter 7
Conclusion and Recommendations

The design of the device has been modified and developed significantly since its early stages. In the following month we hope to get more feedback from customers, most specifically Jack, about the ease of use and user compatibility.

Manufacturing wise, there are many opportunities for growth with coming generations of the device. A custom printed circuit board would significantly decrease the space occupied by the electrical components and allow for simpler reproduction. Additionally, for mass production custom molds for the enclosures would increase efficiency. And finally, although it will be important to maintain the integrity of the properties of the micro-switches/arcade buttons, a custom keypad for the buttons allows for more rapid replication.

Going forward, several recommendations can be made to improve the device in the next generations. As stated previously, a positive next step would be the creation of a custom printed circuit board. Some modifications to the circuitry first, however, are recommended. The audio quality can be improved in a few simple ways, such as: switching to a better quality amplifier IC (the LM386 runs on such a low voltage that it affects the quality of sound), improve the power and quality of the speakers, shield the speakers within the device to allow for amplification. There currently is one speaker for each source in the device. A more efficient way to play the sound would be with a single stereo speaker system that accepts inputs from the several sources. In addition to the quality of sound, the option for headphones was allowed with a simple but rugged connector. In the future, a direct line from the board to the headphone jack would allow for more reliability.

Along with improvements to the circuitry, there are possible modifications to the user interface. Arcade buttons with micro-switches were chosen due to the ease of pressing a button and reliability of that button press. They however, require a lot of space, so a similar but smaller alternative will decrease the overall size and weight requirements.

With the design and manufacture of a prototype for the Parkinson's Freezing of Gait device, critical insight and

Appendices

Appendix A: References

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3. Frazzitta, G., Maestri, R., Uccellini, D., Bertotti, G., & Abelli, P. (2009). Rehabilitation treatment of gait in patients with Parkinson's disease with freezing: a comparison between two physical therapy protocols using visual and auditory cues with or without treadmill training. Movement Disorders, 24(8), 1139-1143.
4. Hélie, Sébastien, Erick J. Paul, and F. Gregory Ashby. "A neurocomputational account of cognitive deficits in Parkinson's disease." Neuropsychologia 50.9 (2012): 2290-2302.
5. "Medications for Motor Symptoms."(2013). National Parkinson Foundation. N.p., n.d. Web. Nov. 2014.
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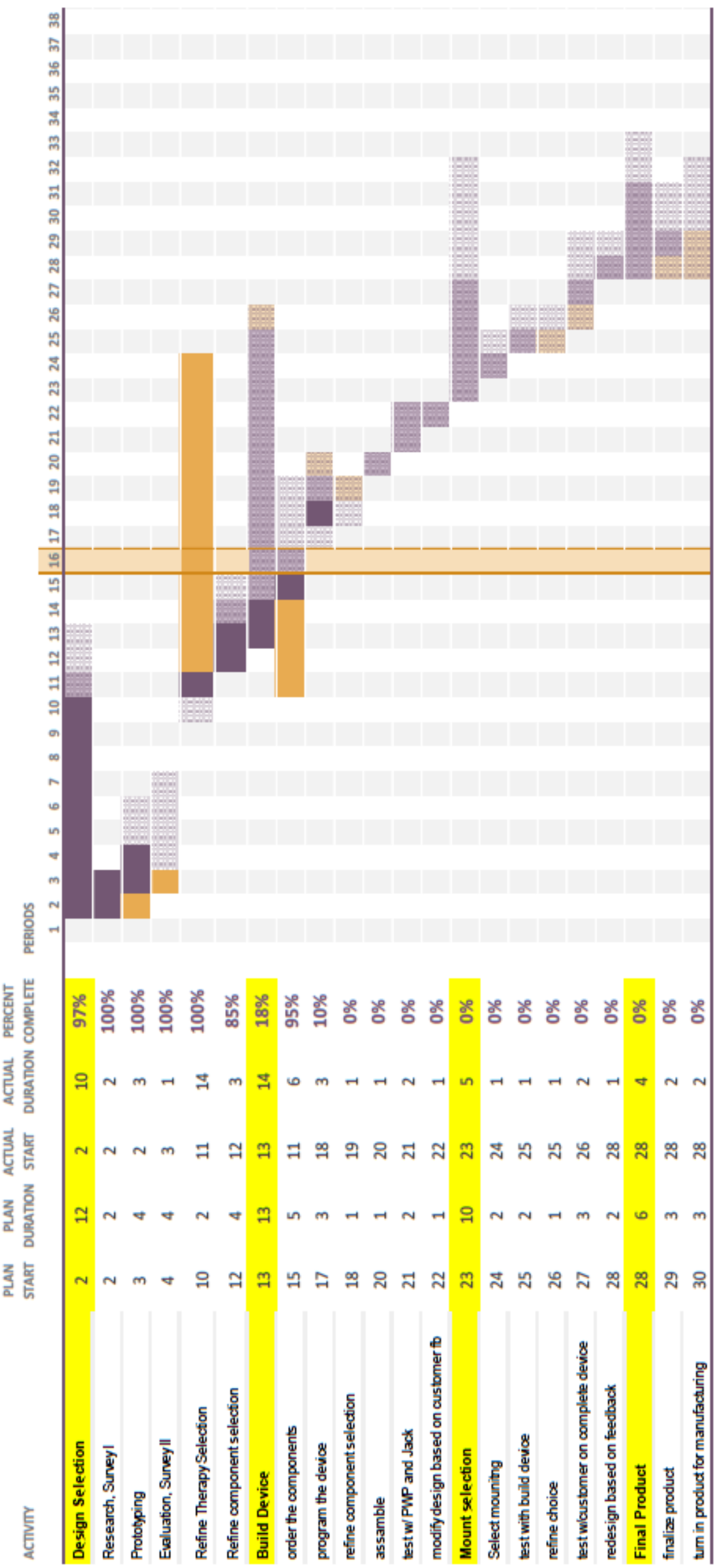
Appendix B: Decision Matrices

Project Name	Freezing-of-Gait Device	Engineering Requirements														
System Functions	Potential Solutions (From Convergent Thinking Exercise)	Best Benchmark from QFD	Mounts in < 10 sec	Components can withstand 50 lb force	Weighs < 8oz	Protrudes no more than 3 in from device	Compatible with 0.5"-1.5" bar	Tightened Grip can withstand 15 ft-lb torque	Less than or equal to 3 total pieces	Adjust angle and position in 2 actions or less	Costs less than $40	Weighted Sum +	Weighted Sum -	Weighted Sum S	Total Score	Specification Weighting Check
	Specification Weight		17	10	5	6	20	15	11	12	4					100
Device Mount	Holster-type, Cradle-mount	S	S	+	-	+	S	+	-	-	S	31	28	41	15.3	
	Device-attached Grip-clips		+	-	+	-	S	-	S	+	+	38	31	31	16.3	
	Magnetized Base-mount		+	S	-	+	S	-	S	-	-	23	36	41	-0.7	

		Engineering Requirements													
System Functions	Potential Solutions	Best Benchmark from QFD	Easy to use by costumer (buttons)	customizable arrangement (180-rotational angle)	safe	Projection Distance (>1 m)	keeps the device protected	Power Consumption (Operating current <300 mA)	minimal cable attachment	one housing only	Weighted Sum +	Weighted Sum -	Weighted Sum S	Total Score	Specification Weighting Check
	Specification Weight		20	25	15	12	12	7	5	4					100
Housing	One housing w/ adjustable mount	S	+	-	S	-	S	S	+	+	27	20	28	15	
	One main housing/ laser housing with extension to main house		+	+	S	+	S	S	-	S	27	13	35	25	
	one main house/ one laser house		-	+	-	s	+	-	S	-	16	37	22	-14	

		Engineering Requirements										
System Functions	Potential Solutions	Best Benchmark from QFD	Easy to use (one button command)	Has been proven effective (PWP have used it before)	safe (safety measures are needed)	Can work on demand	Can be integrated w/ in current system (no additional devices)	cost efficient (less than $50)	allows for variability/ easy to acquire	Weighted Sum +	Weighted Sum -	Weighted Sum S	Total Score
	Specification Weight		25	25	16	8	10	8	8				
	Vibration on handles		S	-	S	S	-	S	S	0	16	52	-0
Therapy selection	Line projection		+	+	-	+	+	S	+	45	10	13	39
	metronome	S	+	+	S	+	+	+	+	58	0	10	61
	Auditory cues (music/ voice recording)		S	+	S	+	+	+	+	51	0	17	56
	Visual cues (other than laser)		-	+	S	S	-	-	S	11	25	32	-4

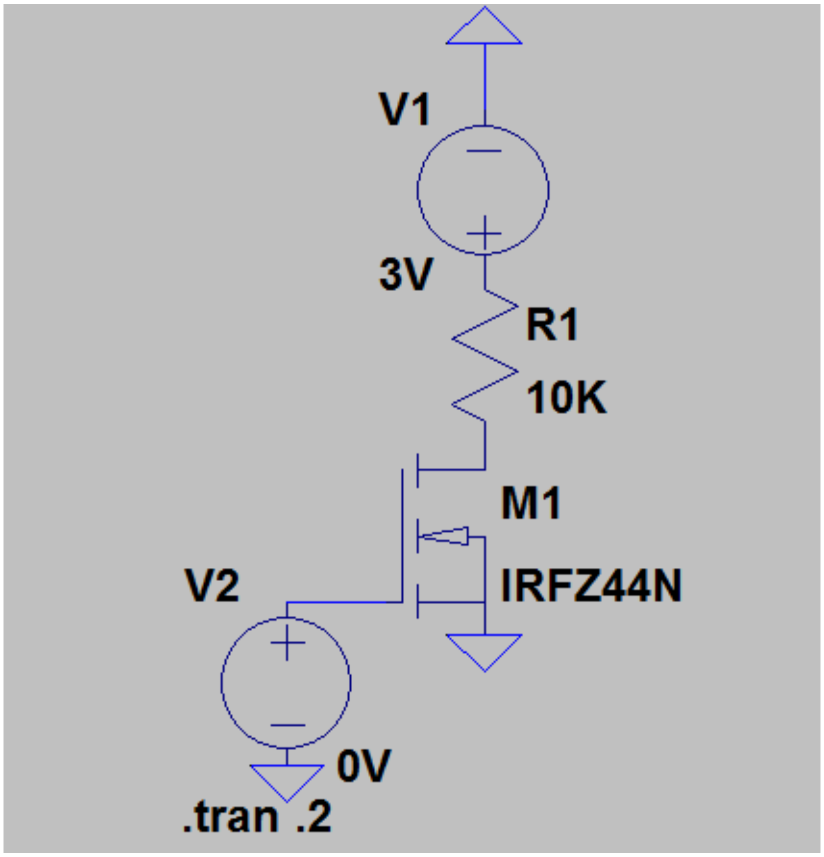
Appendix C: Gantt Chart



Appendix D: Bill of Materials

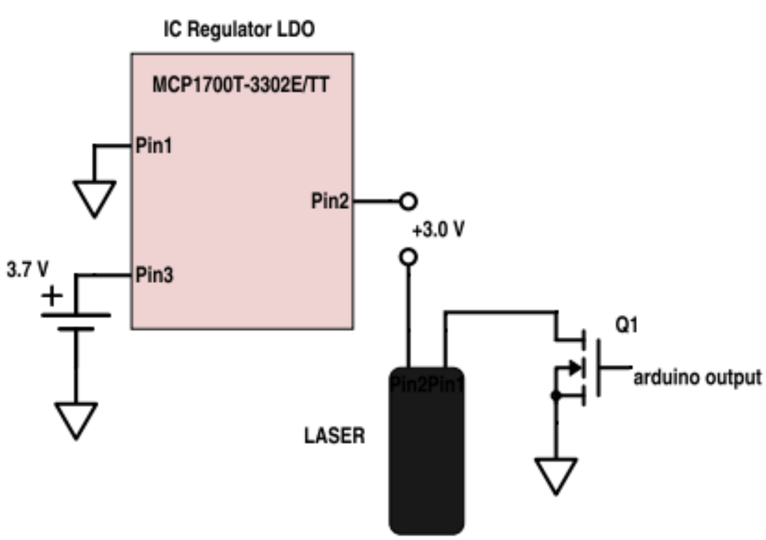
Part	Description	Part Number	Quantity	Price per Unit	Net Cost	Supplier
1	SparkFun RedBoard	DEV-12757	1	19.95	19.95	SparkFun
2	SparkFun MP3 Player Shield	DEV-10628	1	39.95	39.95	SparkFun
3	Thin Speaker	COM-10722	2	0.95	1.9	SparkFun
4	8-Pin Stackable Header	PRT-09279	2	0.5	1	SparkFun
5	6-Pin Stackable Header	PRT-09280	2	0.5	1	SparkFun
6	Micro SD card	SDSDQUAN-008G-G4A	1	7.35	7.35	Amazon
7	SparkFun Voice Recorder Breakout	BOB-10653	1	19.95	19.95	SparkFun
8	Laser Module	GM-CW02L	1	49.5	49.5	Apinex
9	Heli-Max LiPo 1S 3.7V Battery	HMXP1016	1	12.99	12.99	Amazon
10	MCP1700 LDO Regulator	MCP1700-3302E/TO-ND	1	0.44	0.44	DigiKey
11	IRLZ44 N-Channel MOSFET	IRLZ44PBF-ND	1	2.04	2.04	DigiKey
12	NJM386 Low Voltage Audio Power Amplifier	NJM386D-ND	2	0.91	1.82	DigiKey
13	TP4056 LiPo Battery Charging Module	B00QGVP944	1	5.99	5.99	Amazon
14	Dual Mini Prototype Board	276-0148	1	2.49	2.49	Radio Shack
15	Panel Mount Phone Jack	274-0246	1	2.99	2.99	Radio Shack
16	Main housing material (ABS)	PN-1333-DG	1	8.79	8.79	Allied Electronics
17	Laser housing material (ABS)	270-1802	1	3.99	3.99	Radio Shack

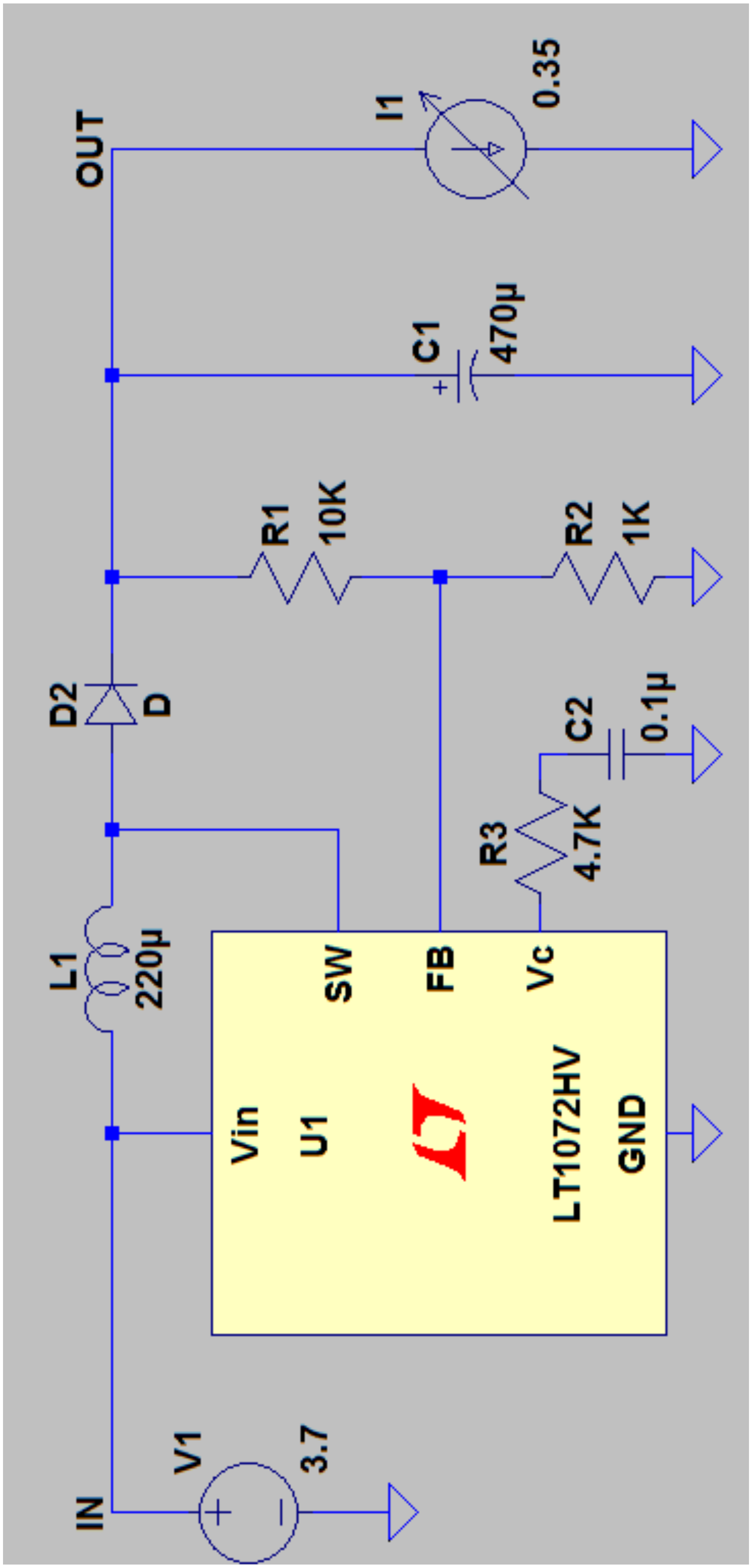
Appendix E: Schematics



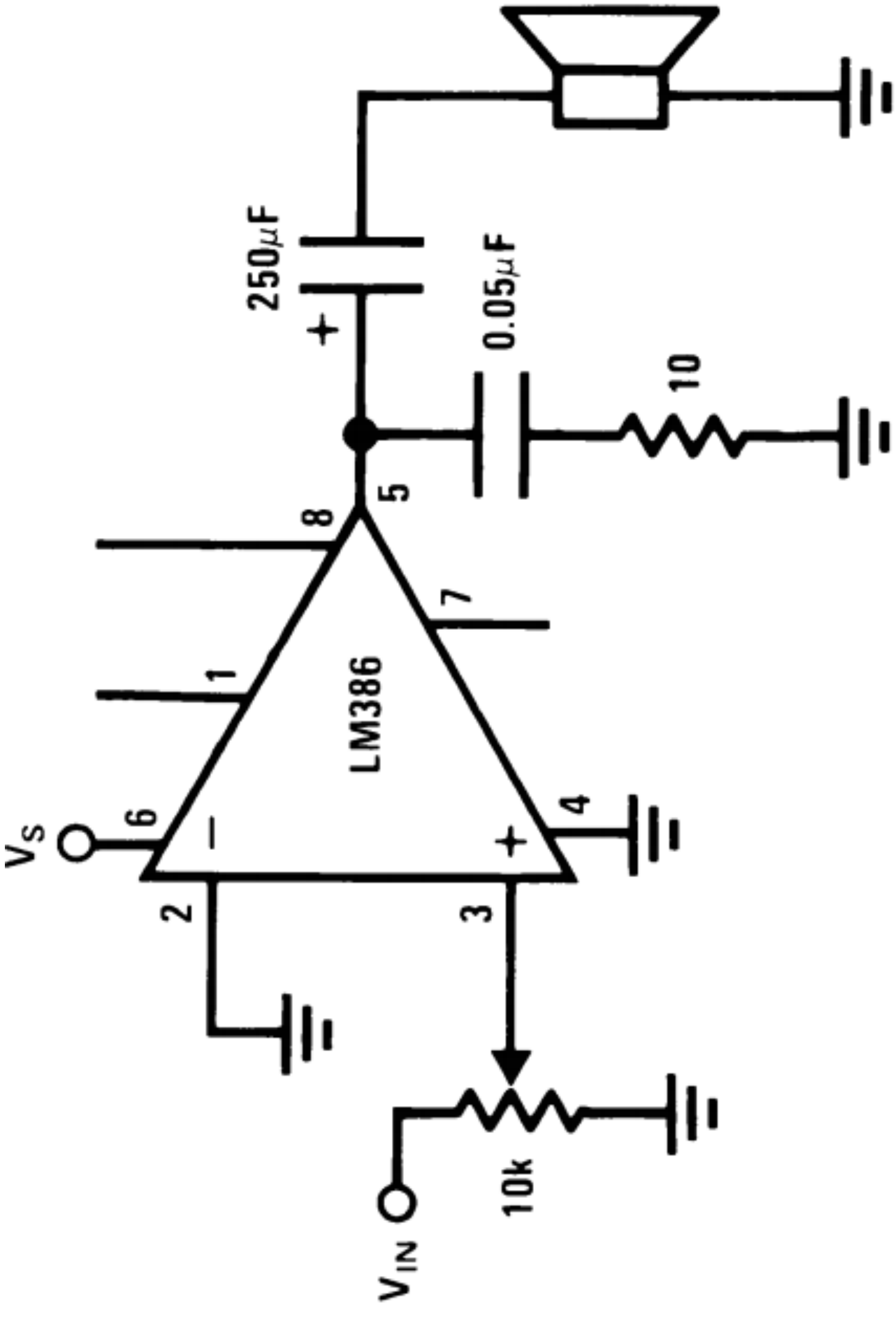
Laser Module schematic (a 3V voltage source stands in place of the LDO regulator that behaves in a similar way, yielding 3VDC)

Laser Module schematic with LDO regulator and pinouts shown

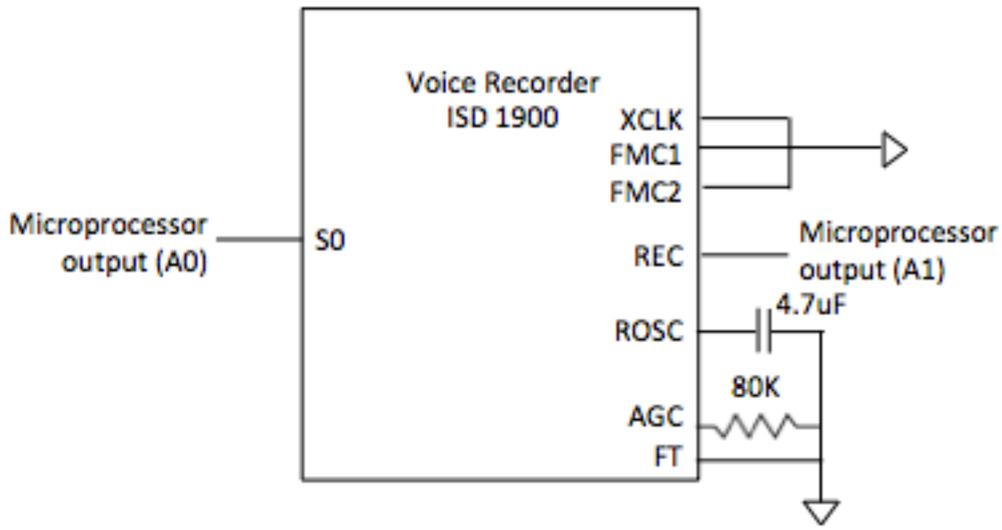




Buck-Boost Converter schematic: The resistive divider network allows for an adjustable output voltage. Our circuit aims to provide 9 V.



Audio Amplifier schematic: pinout with external components shown. This circuit allows for a 20 dB gain



Schematic for the voice recorder breakout board. Hardware controls how many recordings the user wants to save. This schematic is set for one.

Appendix F: Simulations

Simulation of the Buck/Boost converter: Steps up 3.7 V to about 9 V

Appendix G: Data Sheet Links

Microprocessor (ATmega328)
https://www.sparkfun.com/datasheets/Components/SMD/ATMega328.pdf

Voice Recorder/Playback Device (ISD1932)
https://www.sparkfun.com/datasheets/BreakoutBoards/BOB-09579-ISD1900.pdf

Audio Decoder (VS1053b) https://www.sparkfun.com/datasheets/Components/SMD/vs1053.pdf

Speaker http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Components/General/8ohm%200.25w

LDO regulator (MCP1700) http://ww1.microchip.com/downloads/en/DeviceDoc/20001826C.pdf

Power amplifier (NJM386) http://www.njr.com/semicon/PDF/NJM386_E.pdf

Buck-Boost converter (LT1072) http://cds.linear.com/docs/en/datasheet/1072fc.pdf

Appendix G: Code

```
// libraries
#include <SPI.h>
#include <SdFat.h>
#include <SdFatUtil.h>
#include <SFEMP3Shield.h>
#include <Bounce2.h>

/**
* \breif Macro for the debounced NEXT pin, with pull-up
*/
#define B_NEXT  A4

/**
* \breif Macro for the debounced PLAY/STOP pin, with pull-up
*/
#define B_PLAYSTOP  A5

/**
* \breif Macro for the debounced PLAY METRONOME pin, with pull-up
*/
#define B_PLAYMET  1


/**
* \breif Macro for the Debounce Period [milliseconds]
*/
#define BUTTON_DEBOUNCE_PERIOD 20 //ms



/**
* \brief Object instancing the SdFat library.
*
* principal object for handling all SdCard functions.
*/
SdFat sd;

/**
* \brief Object instancing the SFEMP3Shield library.
*
* principal object for handling all the attributes, members and functions for
the library.
*/
SFEMP3Shield MP3player;

/**
* \brief Object instancing the Next Button.
*/
```

```
Bounce b_Next  = Bounce();

/**
* \brief Object instancing the Play/Stop Button library.
*/
Bounce b_PlayStop  = Bounce();

/**
* \brief Object instancing the Play/Stop Button library.
*/
Bounce b_PlayMet  = Bounce();

/**
* \brief Index of the current track playing.
*
* Value indicates current playing track, used to populate "x" for playing the
* filename of "track00x.mp3" for track000.mp3 through track254.mp3
*/
int8_t current_track = 1;
int playMode = LOW;

//declare metronome track
int8_t met_track = 5;
int metMode = LOW;
//----------------------------------------------------------------------------------
-----------------


// set pin numbers:
const int recButton = A0;       // the number of the RECORD button pin
const int playButton = A1;      // the number of the PLAY button pin
const int selectPin = A2;       // the number of the SELECT pin for Voice
Recorder
const int recplayPin = A3;      // the number of the REC/PLAY select pin for
Voice Recorder
const int buttonPin = 10;      // the number of the LASER input pin
const int laserPin = 5;        // the number of the LASER output pin



// These variables will change
int selectState = HIGH;        //state of the select mode for voice recorder
int recplayState = LOW;        // state of the rec/play select mode for voice
recorder
int playButtonState = LOW;    // current state of the play button
int recButtonState = LOW;      // current state of the record button

int laserState = LOW;         // the current state of the output pin of laser
int buttonState;              // the current reading from the input pin of
laser
```

```
int lastButtonState = HIGH;   // the previous reading from the input pin of
laser

//Debounce variables
long lastDebounceTime = 0;  // the last time the output pin was toggled
long debounceDelay = 50;    // the debounce time; increase if the output
flickers



void setup() {
 pinMode(recButton, INPUT);
 pinMode(playButton, INPUT);
 pinMode(selectPin, OUTPUT);
 pinMode(recplayPin, OUTPUT);
 pinMode(buttonPin, INPUT);
 pinMode(laserPin, OUTPUT);
 pinMode(B_NEXT, INPUT_PULLUP);
 pinMode(B_PLAYSTOP, INPUT_PULLUP);
 pinMode(B_PLAYMET, INPUT_PULLUP);


   // set intital playback mode-- OFF
 digitalWrite(selectPin, HIGH);
 digitalWrite (recplayPin, HIGH);

 //set initial mode of laser-- OFF
 digitalWrite(laserPin, laserState);

 //debounce and initialize MP3 Player
 b_Next.attach(B_NEXT);
 b_Next.interval(BUTTON_DEBOUNCE_PERIOD);
 b_PlayStop.attach(B_PLAYSTOP);
 b_PlayStop.interval(BUTTON_DEBOUNCE_PERIOD);
 b_PlayMet.attach(B_PLAYMET);
 b_PlayMet.interval(BUTTON_DEBOUNCE_PERIOD);

 if(!sd.begin(9, SPI_HALF_SPEED)) sd.initErrorHalt();
 if (!sd.chdir("/")) sd.errorHalt("sd.chdir");

 MP3player.begin();
 MP3player.setVolume(10,10);

}


void loop() {
 //read the current state of the RECORD and PLAY buttons
 playButtonState = digitalRead(playButton);
 recButtonState = digitalRead(recButton);
```

```
//turn on recording mode when button is held down
while (recButtonState == HIGH) {
  digitalWrite(recplayPin, LOW);
  digitalWrite(selectPin, LOW);
  return;
}

//turn on voice recording if play button is pressed
if (playButtonState == HIGH) {
  digitalWrite(recplayPin, HIGH);
  digitalWrite(selectPin, LOW);
}

//otherwise, turn playbakc and recording off
else{
  digitalWrite(selectPin, HIGH);
}


// read the state of the LASER button
int reading = digitalRead(buttonPin);

// If the switch changed, due to noise or pressing:
if (reading != lastButtonState) {
  // reset the debouncing timer
  lastDebounceTime = millis();
}

if ((millis() - lastDebounceTime) > debounceDelay) {
  // whatever the reading is at, it's been there for longer
  // than the debounce delay, so take it as the actual current state:

  // if the button state has changed:
  if (reading != buttonState) {
    buttonState = reading;

    // only toggle the LASER if the new button state is HIGH
    if (buttonState == HIGH) {
      laserState = !laserState;
    }
  }
}

// set the LASER:
digitalWrite(laserPin, laserState);

// Save the reading
lastButtonState = reading;
```

```
  // Start of MP3 Player code
   if (b_PlayStop.update()) {
    if (b_PlayStop.read() == HIGH && playMode == LOW)  {
      MP3player.playTrack(current_track);
      playMode = HIGH;
    }
    else if (b_PlayStop.read() == HIGH && playMode == HIGH)  {
     MP3player.stopTrack();
     playMode = LOW;
    }
  }

  if (b_Next.update()) {
    if (b_Next.read() == HIGH) {
      current_track++;
      MP3player.stopTrack();
      MP3player.playTrack(current_track);
    }
  }

  if(current_track >= 4) {
        current_track = 0;
       }


   if (b_PlayMet.update()) {
    if (b_PlayMet.read() == HIGH && metMode == LOW)    {
      MP3player.playTrack(met_track);
      metMode = HIGH;
    }
     else if (b_PlayMet.read() == HIGH && metMode == HIGH)   {
     MP3player.stopTrack();
     metMode = LOW;
    }
  }
}
```

Appendix H: Drawings

Detailed drawings are on the following pages.