Keyboard DJ Set

ECE 445 Design Document - Fall 2024

Project #45

Manas Gandhi (manaspg2)

Jack Prokop (jprokop2)

Milind Sagaram (milinds2)

TA: Sainath Barbhai

I. Introduction

I.I Problem

DJ boards have become the “hot topic” of today’s music industry, with the tool giving way to many of the greatest artists of our generation, including *John Summit* and *Twinsick*. However, despite their popularity, traditional DJ boards pose significant barriers to entry for aspiring DJs. Three key issues stand out with these boards: the lack of portability, complexity for beginners, and high costs.

1. **Lack of Portability:** DJ boards are usually bulky, heavy, and cumbersome to transport. In fact, DJs typically need full suitcases to be able to carry them around. This poses difficulties for DJs who wish to practice in outdoor settings or perform at smaller, more intimate events. The weight and size of these boards make them impractical for travel, limiting their use to stationary setups like studios or large venues as well.
2. **Complexity for Beginners:** Standard DJ boards feature an overwhelming array of controls, including turntables and lots of knobs, sliders, and buttons. This complexity creates a steep learning curve for those new to DJing.
3. **High Cost:** Traditional DJ boards are expensive, often priced at $300 or more [1]. For many individuals who are simply exploring the hobby or wanting to learn the basics, this price point is prohibitive. The cost of entry is a significant barrier, especially for younger audiences or those with limited disposable income.

I.II Solution

To overcome these limitations of traditional DJ boards, we want to create a portable, user-friendly, and affordable DJ board. Our solution aims to make DJing accessible to beginners and enthusiasts by addressing the core issues of portability, ease of use, and cost:

1. **Portability**: The DJ board will be lightweight and compact, allowing users to easily transport it to different locations, whether it's a park, a friend’s house, or a small event.
2. **Simplified Interface**: Designed with beginners in mind, our DJ board will feature a minimalistic control scheme. Instead of overwhelming users with too many knobs and buttons, it will provide just the essential controls.
3. **Affordability**: By leveraging cost effective hardware and focusing on essential features, the DJ board will be priced significantly lower than traditional models.

I.III Visual Aid

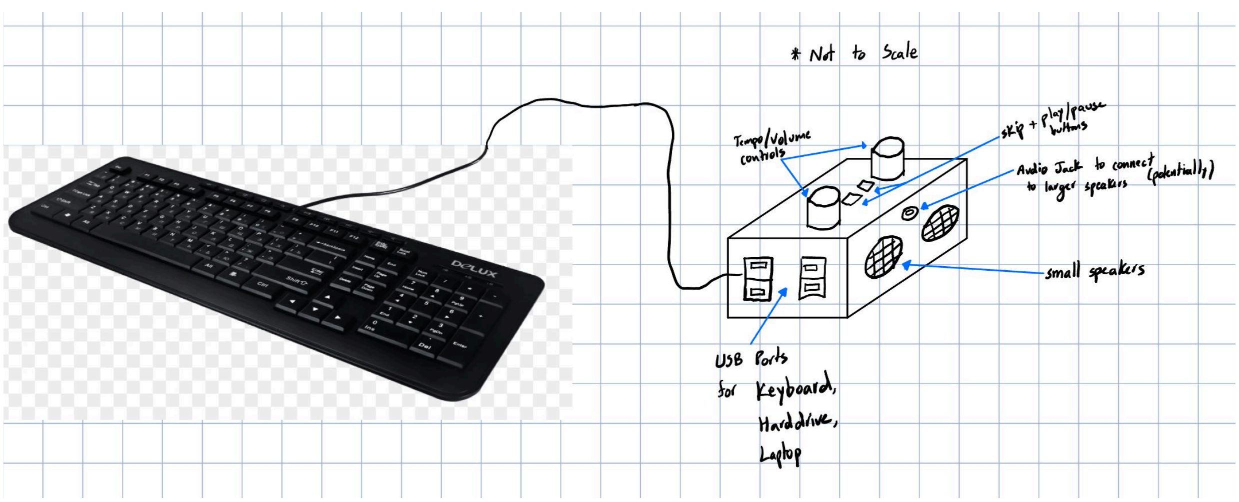

Figure 1: Visual Aid of DJ Set/Box

In this board, we will have a “DJ box” that contains the PCB with all the buttons and knobs. The user will be able to turn the knobs, which are displayed at the top of the DJ box. The speakers will be at the front of the box to output music that is being played, and there are USB ports on the side to connect up the keyboard and other needed components. The buttons will be placed in the middle of the knobs to provide easy access. Overall, it is pretty clear from this design how portable the DJ board will be - it just requires transportation of the DJ Box, a keyboard, and a laptop, all of which can fit in a backpack instead of a large suitcase.

I.IV High-Level Requirements

To consider our project successful, it must meet the following requirements:

1. **Simultaneous Track Playback:** Our DJ board must be capable of playing two tracks simultaneously, allowing users to transition between songs or mix them together. This feature is essential for replicating the core functionality of traditional DJ equipment, enabling smooth transitions and creative layering of audio tracks.
2. **Precision Tempo Control:** The DJ board must support the ability to increase or decrease the tempo of each track by at least 3 beats per minute (BPM). This level of precision will give users the flexibility to fine-tune the speed of the music, allowing for smooth beat-matching.
3. **Dynamic Volume Adjustment:** The DJ board must allow users to adjust the volume of each track by at least 10 decibels (dB) in both directions (increase or decrease). This ensures that users can balance audio levels during live performances or practice sessions.

II. Design

II.I Block Diagram

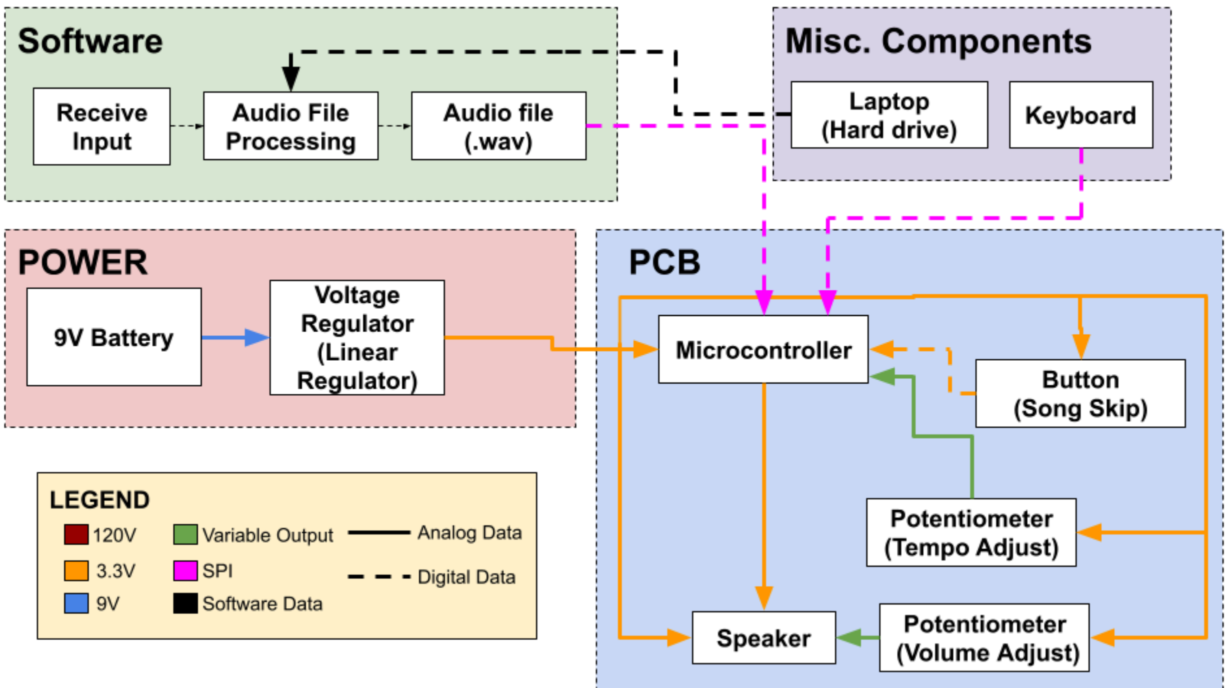

Figure 2: Keyboard DJ Set Block Diagram

II.II Physical Design

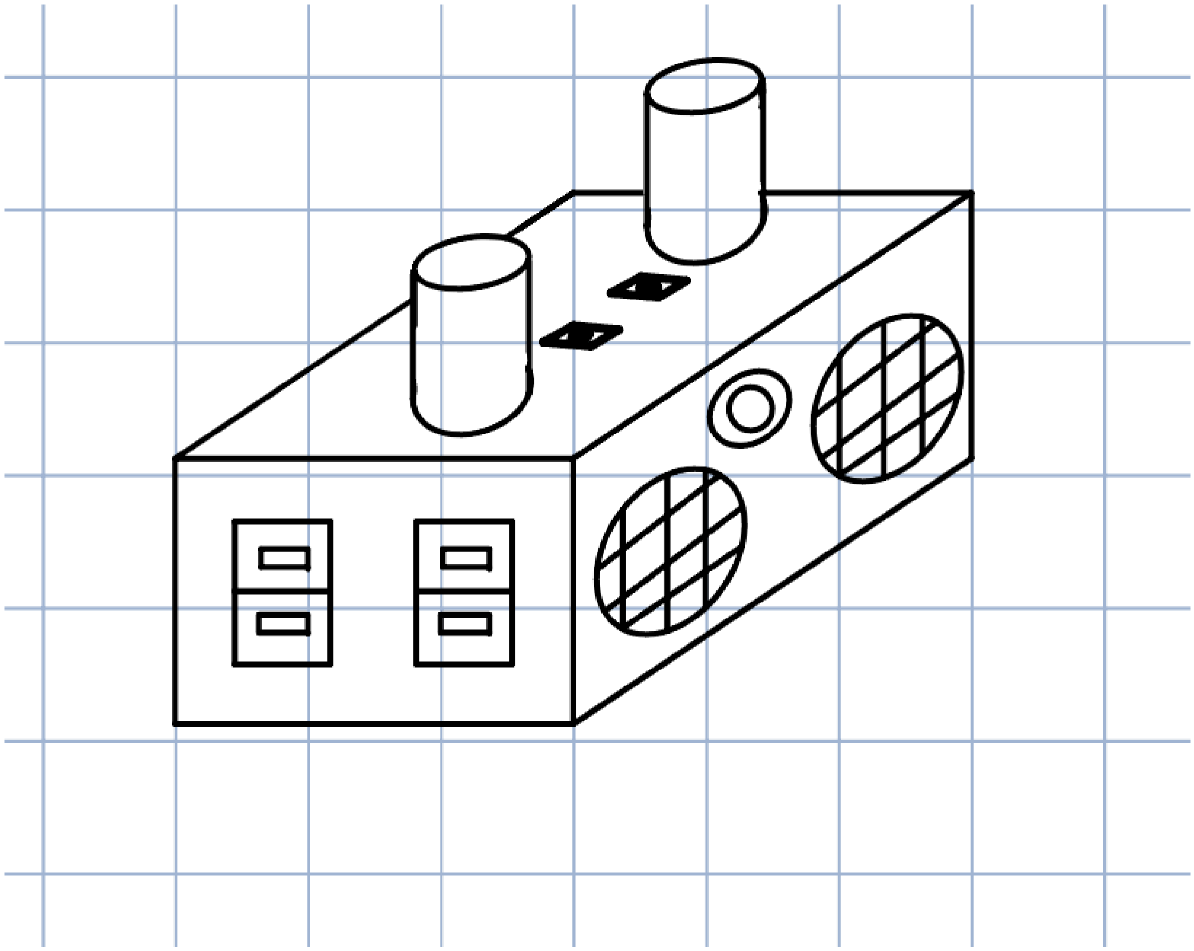

Figure 3: Physical Desing of DJ Set/Box

Above is the physical design for the DJ box that will contain the DJ board. We can see the two knobs for volume and tempo at the top, the buttons for play/pause and skipping a song. The USB connection ports are on the side of the box for the keyboard/laptop connections, and the speakers are in the front to play music. The overall idea of the physical design is to make it look like almost like a boombox or stereo, as this kind of “retro” style appeals to today’s generation.

II.III Subsystem 1: Microcontroller

The microcontroller will be mounted on a custom-designed printed circuit board (PCB), serving as the "brains" of the system. It plays a central role in managing and controlling all the inputs and outputs necessary for the system to function. On the input side, the microcontroller will receive signals from multiple sources. These include commands from the keyboard when the user presses buttons to select notes or actions, as well as audio signals from the laptop, such as music files or live streams that need processing. These inputs are crucial in determining the sound that will be played through the speaker.

On the output side, the microcontroller processes these inputs and sends the resulting audio signals to the speaker for playback. It ensures the quality and timing of the audio output are precise, maintaining the overall performance of the system. The software running on the microcontroller includes essential algorithms for audio processing, such as converting sound signals into digital formats or generating .wav files. It also manages port I/O, facilitating communication between the keyboard, speaker, and other components. Overall, the microcontroller is vital for running the software, executing audio processing tasks, and delivering the final sound output in a seamless and efficient manner.

Components:

Component	Part Number	Quantity	Unit Cost
Microcontroller	ESP32-S3 module	1	$3.48
Resistor	RMCF0805JG10K0	8	$0.10
Capacitor	CL21B105KBFNNNG	4	$0.10

II.IV Subsystem 2: Buttons

The buttons will be part of a keyboard interface, allowing the user to perform various operations on a song, such as skipping tracks, pausing, or adjusting playback. Each time a button is pressed, it sends an input signal indicating the desired action. These inputs represent the user's commands and are essential for controlling how the audio behaves. The keyboard essentially provides a direct way for the user to interact with the system, ensuring they can easily manage song playback or other operations as needed.

Once the input is received from the keyboard, it is transmitted to the microcontroller, which acts as the central processor. The microcontroller runs the software and audio processing algorithms that interpret these inputs and execute the corresponding actions. For example, when a skip button is pressed, the microcontroller processes the command and skips the current song to the next one in the playlist. Other operations, like rewinding, pausing, or adjusting volume, are similarly handled. The microcontroller ensures that all inputs are correctly processed, and the system responds promptly to the user's commands.

Components:

Components	Part Number	Quantity	Unit Cost
Keyboard	Rii RK907	1	$9.99

II.V Subsystem 3: Volume and Tempo Control

To control the tempo and volume of the audio, we will incorporate potentiometers into the design. These are adjustable dials that allow the user to fine-tune these aspects based on their preferences. The position of the dial will determine the level of volume or the speed of the tempo, giving the user direct control over these parameters in real-time.

The output from each potentiometer is sent as a signal to the microcontroller, which interprets the input and adjusts the audio accordingly. Whether the user is increasing the volume or slowing down the tempo, the microcontroller processes this information and modifies the audio file before transmitting it to the speaker. This ensures that the system responds accurately to the user's adjustments, providing a seamless listening experience.

Components:

Component	Part Number	Quantity	Unit Cost
Potentiometer	P160KN2-0QA25B10K	2	$1.83

II.VI Subsystem 4: Power

The power subsystem is composed of three key components: a battery and a voltage regulator. Together, these elements ensure that each part of the system receives the appropriate power it needs for smooth operation. The battery serves as the main power source, and will be 9V. It will handle the charging and discharging to maintain reliable power output.

The voltage regulator plays a crucial role in distributing the correct voltage to different subsystems. For instance, the microcontroller requires a 3.3V power rail to function properly, so the power subsystem must supply exactly 3.3V to it. The rest of our components only require 3.3V, but if other components in the system require different voltage levels, such as 5V, the power subsystem must provide the correct voltage for those components as well. This ensures that each subsystem operates efficiently with the power it requires.

Components:

Components	Part Number	Quantity	Unit Cost
9V Battery	3046-9V-ND	1	$4.45
Voltage Regulator	AZ1117CD-3.3TRG1	1	$0.44

II.VII Subsystem 5: Software

The software subsystem is divided into two essential components: drivers and audio processing algorithms. The drivers are responsible for controlling the input and output ports of the microcontroller. They ensure that the microcontroller's pins are correctly configured to receive input signals, such as those from the keyboard or potentiometers, and to send output signals to devices like the speaker. This allows for smooth communication between the microcontroller and the hardware components, ensuring the system operates as intended.
The audio processing algorithms handle various functions related to manipulating the audio files (.wav files). These algorithms are designed to perform tasks such as speeding up the song, skipping tracks, adjusting the volume, and executing other audio-related operations. By integrating these algorithms, the software subsystem ensures that the microcontroller can process user inputs and modify the audio playback accordingly, delivering a seamless and responsive audio experience.

II.VIII Subsystem 6: Laptop

The laptop subsystem is solely responsible for hosting the music files, and act as a hard drive. This will store all the songs the user has to select from, and the user will be able to select the song that they want to be played from the DJ board. The laptop (hard drive) will send the music files to the software, which will handle the rest of audio editing.

III. Requirements and Verification

II.II Requirements & Verification

II.II.I Microcontroller

Requirements	Verification
I. Must be able to handle Keyboard, Potentiometer, and Button Inputs II. Must send information from PCB components to software	I. The microcontroller will receive the correct voltage from the components, which we can measure within the microcontroller software II. Software will go to the appropriate state when respective components are activated

II.II.II Buttons

Requirements	Verification
I. Keyboard and Push Buttons must only register one input per click	I. For Push Buttons, voltage measurements can be taken to ensure proper digital signal functionality II. For Keyboard Inputs, a driver on the microcontroller will receive the inputs

	and we can display the inputs through a serial terminal on a computer connected to the microcontroller to verify that the correct keycodes are sent and received through the driver

II.II.III Volume and Tempo Control

Requirements	Verification
I. When the potentiometers are adjusted, the DJ board must respond appropriately, by adjusting the volume and tempo accordingly	I. The system must increase and decrease the volume by 10 decibels (dB), measured by a decibel meter II. The system must increase and decrease the tempo by 3 beats per minute (bpm), measured by a metronome

II.II.IV Power

Requirements	Verification

<u>Battery:</u> I. Supply +9V ± 5% Voltage with 500mA current draw II. Must last for up to 2 hours <u>Linear Regulator:</u> I. Voltage must be regulated to +3.3 V ± 5% at 500mA draw	<u>Battery:</u> I. Use an oscilloscope and multimeter to verify a consistent voltage at the specified level II. We will operate the DJ Box for 2 hours and measure the voltage provided with a multimeter and oscilloscope during operating time <u>Linear Regulator:</u> I. Voltage must be regulated to +3.3 V ± 5% at 500mA draw

II.II.V Software

Requirements	**Verification**
I. Must be able to adjust the tempo of the song with a latency of less than .5 seconds	I. We will timestamp the input tempo change and execution of the tempo-adjusting software and verify the latency over a serial terminal on a laptop connected to the

	microcontroller. II. Alternatively, we can use a metronome to detect the live tempo of a song and measure the delay of the tempo change.

II.II.VI Laptop

Requirements	Verification
I. Must be able to store at least 2 songs on the laptop (hard drive) II. Must be able to send the selected audio files to the software	I. We will select a song and check if that song goes to the software and gets played on the speaker

II.II Tolerance Analysis

II.II.I Microcontroller (ESP32-S3 Module)

The ESP32-S3 operates at 3.3V with a maximum current of around 500 mA. To ensure proper functionality, we need to make sure the power supply is constantly delivering 3.3V ± 5%. As such, as the power supply's voltage tolerance is ±5% of 3.3V = 3.135V to 3.465V.

II.II.II Resistors (RMCF0805JG10K0)

These resistors will be used for pull-up/down functions and setting reference voltages.
A 10kΩ resistor with a tolerance of ±5% means the actual resistance could vary between 9.5kΩ and 10.5kΩ. This will be fine for the design, as the functionality of pull-up/down of the resistor will not be affected, as the high voltage and low voltage will still have a clear difference.

II.II.III Capacitors (CL21B105KBFNNNG)

The capacitors will be used for filtering and for other mechanisms. With a nominal value of 1µF and ±10% tolerance, the capacitance will range between 0.90µF and 1.10µF.

II.II.IV Keyboard (Rii RK907)

A typical USB keyboard consumes about 100mA. The ESP32-S3 and the power system need to be able to handle this load without significant voltage drops or instability.

II.II.V Potentiometers (P160KN2-0QA25B10K)

With a 10kΩ potentiometer, the tolerance will be ±10%, meaning the range is from 9kΩ to 11kΩ. This range will not critically affect the system, as the volume and tempo will only change slightly, to an unnoticeable amount.

II.II.VI Power System (9V Battery and Voltage Regulator AZ1117CD-3.3TRG1)

The 9V battery supplies power and the voltage regulator steps it down to 3.3V for the microcontroller and other components. These components will require the most tolerance, as they tend to vary in output. A typical 9V battery will range from 9V to around 6V when depleted. The voltage regulator should be able to provide a steady 3.3V output across this input range. The AZ1117 voltage regulator has a dropout voltage of about 1.15V [2], so it requires at least 4.45V input to maintain 3.3V output.

II.II.VII Push Buttons (2223-TS02-66-70-BK-160-LCR-D)

These buttons are going to be debounced in software or with capacitors, and the current ratings are 160mA. This has a tolerance of ±5%, meaning the current rating can be between 152mA and 168mA, which is supported by the microcontroller GPIO pins, so we do not need to worry.

IV. Cost and Schedule

IV.I Cost Analysis

IV.I.I Labor Cost:

We estimate that each group member will put 10 hours per week into the project in order to get it done. This will be over the next 7 weeks, so each member will put in 70 hours, and in total, our group will put in 210 hours in order to complete the project. A typical entry-level engineer makes around $100,000 a year in salary, which comes out to roughly $50 per hour. The labor cost of this project will be $50 per hour * 3 people * 70 hours per person * 2.5 overhead factor = $26,250 in labor costs. A summary is included below:

Name	**Hourly Rate**	**Hours**	**Total**	**Total x 2.5**
Milind Sagaram	50	70	$3,500	$8750
Manas Gandhi	50	70	$3,500	$8750
Jack Prokop	50	70	$3,500	$8750
Total	150	210	$10,500	$26,250

IV.I.II Parts Cost:

We estimate the cost of our project to be $35.22, which falls well short of the $150 our group will be given. Additionally, many of our parts will be sourced from the Electronic Services Shop at the ECEB, which will be free of cost to us. These parts include the microcontroller, resistors, capacitors, voltage regulators, and other components. With this, we will have north of $115 to spend on other equipment, research and development, or other costs. A summary is included below:

Component	**Part Number**	**Quantity**	**Unit Cost**
Microcontroller	ESP32-S3 module	1	$3.48
Resistor	RMCF0805JG10K0	8	$0.10
Capacitor	CL21B105KBFNNNG	4	$0.10
Keyboard	Rii RK907	1	$9.99
Potentiometer	P160KN2-0QA25B10K	2	$1.83
9V Battery	3046-9V-ND	1	$4.45
Voltage Regulator	AZ1117CD-3.3TRG1	1	$0.44
Push Buttons	2223-TS02-66-70-BK-160-LCR-D	2	$0.12

In total, the cost of the project will be $26,285.46 with labor and materials costs included.

IV.II Schedule

Project Component	Estimated Completion Date
Design Review	10/8

Preliminary PCB Design Review	10/11
PCB Final Design Completion	10/18
PCB Components Soldered	11/1
ESP-32 Drivers Completion	11/1
Audio Processing Algorithms Completion	11/15
Integration and Full Test Completion	11/21

V. Ethics and Safety

V.I IEEE & ACM Code of Ethics

V.I.I Privacy and Data Security (ACM Code 1.6) [3]:

Issue: The software might need to interact with personal files on a user's device, including music libraries. Our design must prevent unauthorized access to the user's music or other personal files.

Solution: The proposed software will prioritize the protection of user privacy and data security. While the software may require access to personal music files, we will implement measures to prevent unauthorized access or disclosure. This includes obtaining explicit user consent for data collection and storage, and adhering to industry-standard data security practices. Such practices might involve encryption, secure data transmission protocols, and regular security audits.

V.I.II Intellectual Property (ACM Code 1.5) [4]:

Issue: Users could potentially use the software to play/mix copyrighted music without authorization, violating intellectual property laws.

Solution: We will include disclaimers encouraging users to comply with copyright regulations and offer placed to legally obtained music files that can be used.

V.I.III Honesty and Integrity (IEEE Code 7.8.I) [2]:

Issue: Ethical guidelines also mandate transparency in communication. We must avoid misleading claims about the functionality or features of the DJ set.

Solution: All documentation, including advertising or promotional materials, will clearly represent the capabilities of the system.

V.II Safety

Our project does not pose any major security risks, beyond soldering and power supply management.

V.II.I Power Supply and Electrical Safety

The DJ board will be powered by a low-voltage 9V battery to avoid the use of high-voltage power supplies, which pose a significant risk of electric shock or fire. We will make sure to only use manufacturer-approved batteries, store them in cool and dry environments when not in use, and inspect them for damage before ever plugging them in. By following these safety restrictions, we will ensure that we have no issues with electrical safety

V.II.I Soldering

When soldering, we will make sure that we have personal protective equipment including safety glasses and soldering iron stands. We will also make sure that we have completed the required training before engaging in any activity that includes high heat, sharp blades, or other health hazards.

VI. References

[1] Amazon.com Inc. (n.d.). Dj Board [Amazon.com]. Retrieved from https://www.amazon.com/dj-board/s?k=dj+board

[2] DiDiodes Incorporated. (n.d.). document number: DS36736 Rev. 7 - 3 [SNIPPET] AZ1117 1A LOW DROPOUT LINEAR REGULATOR [Data sheet]. https://www.diodes.com/assets/Datasheets/products_inactive_data/AZ1117.pdf

[3] Association for Computing Machinery. (n.d.). *ACM Code of Ethics and Professional Conduct*. ACM. https://ethics.acm.org/

[4] Institute of Electrical and Electronics Engineers. (n.d.). *IEEE Code of Ethics*. IEEE. https://www.ieee.org/about/corporate/governance/p7-8.html