Modular Pedalboard

A Senior Project submitted to

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(NSME)

at

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1 Introduction - TR

Effects pedals are essential in shaping a guitarist's unique sound. By stepping on a foot switch, a circuit activates and modulates a guitar's signal with effects such as distortion, reverb, or delay. To manage multiple effects, guitarists often use a pedalboard - a metal panel designed to organize, house, and power the pedals in series. However, the arrangement of these pedals significantly impacts the guitar's tone, adding a layer of complexity to the act of "tone chasing". For instance, placing a "wah" pedal before a fuzz pedal produces a distinctly different sound than placing it after, a topic often discussed in guitar communities.

1.1 Background - TR

A populated pedalboard such as the one shown in Figure 1 consists of a wide range of secondary components:

- **Pedalboard:** A customizable platform built with gaps for cable management, and a dedicated slot for a power supply unit.
- **Power Supply Unit (PSU):** A power supply block with multiple isolated ports capable of delivering varying voltages to fit the demands of individual effects pedals. A single daisy-chained power supply may be used instead if it suits the power demands of the effects pedals.
- **Effects Pedals:** A circuit engaged by a stomp switch that modulates an input signal with a desired effect before passing the output signal to another system (Either amp or other effects pedal).
- **Cables:** Patch cables are used for passing both input and output signals. Power cables are connected to each effects pedal from the PSU or daisy-chained from a single 9V supply.

Figure 1: An Anonymous Reddit User's $1000 Pedalboard [1]

1.2 The Main Problem - TR

After a guitar signal goes through a pedalboard's effects chain, the final signal is passed to an amplifier for sound output. However, outside factors could have compounding impacts on the frequency response of the final signal, resulting in unwanted noise. A proposed solution would be to use 3D printed materials with adequate EMI shielding effectiveness. The main advantages of using a 3D printed composite come from being lightweight, corrosion resistant, and cheap to process [2]. For example, PLA + Graphene is a promising choice for electromagnetis shielding in 3D printing environments, meeting the 15 DB shielding effectiveness requirement for commercial applications [2]. Output signal noise can be directly targeted through a numerous methods, including:

- **Dedicated Noise Gate Pedals:** With adjustable thresholds, these effects pedals can be added to the end of an effects chain to cut off noise frequencies. When more adjustable features are added, these pedals can become expensive.
  - *Example:* The Boss NS-1X pedal is a noise suppressor pedal with a mode selector, built-in reduction indicator, and adjustable threshold, dampening, and decay knobs [3].

- **Built-In Simple Noise Gates:** To save pedalboard space, a noise gate can be built at the output of other effects pedals [4].
  - The noise gate is implemented with Junction Field Effect Transistors (JFETs), which "pinch" a signal given negative voltage, cutting off flow between source and drain terminals.
  - Useful application in Distortion pedals, which are known to generate large amounts of noise by intentionally boosting the gain of a guitar signal until clipping occurs.

Lastly, with different tones accessible through different permutations of guitar pedals, live musicians must rearrange pedals during live performances to suit the tonal needs across different songs. On a traditional pedalboard, pedals are connected to each other through patching cables, with each pedal requiring its own power supply. This means that rearranging a pedalboard would entail disconnecting and reconnecting power, input, and output cables. This leads to a downtime between songs that adds up over time, which could lead to cutting songs out of a planned set entirely.

1.3 Project Objective - TR

To address the outlined problems, this project focuses on developing a central controller for each pedal that acts as a board, signal carrier, and power supply

The primary objectives of this project are to:

1. Design and prototype a central controller capable of signal carrying and supplying power.
2. Design and create a distortion pedal with a built-in noise gate using industry standard measurements to ensure wide-scale compatibility with existing pedals.
3. To improve musician time management and expenses.

This project focuses solely on the aforementioned objectives. While there exists some pedals with unique dimensions and power demands, they are beyond the scope of this study. The results will provide support for industry standards and lay a foundation for future development in wide-scale compatibility.

1.4 The Adopted Approach - TR

Current trends in guitar pedal innovation tend to utilize digital circuits and integrated digital signal processing (DSP) cores to do advanced, high-performance audio processing. Commercial products such as the Neural DSP Quad Cortex utilize 6 built-in DSP cores and a neural network to capture and create simulation models for pedals and amplifiers.[5] This project positions itself as an analog hardware foundation onto which future digital control could be layered.

This project addresses the economic barrier-to-entry for guitar pedal setups by prioritizing affordability for entry-level musicians. A daisy-chained power bus is adopted to minimize costs and energy footprint, as opposed to utilizing fully-isolated inputs for each pedal; a singular power supply will be sufficient for the entire system. A 3D-printed PLA enclosure for the distortion pedal and central controller is used as a cost-effective and easily-available medium to design, implement, and configure chassis prototypes.

2 Methodology

2.1 Design & Implementation Challenges - Guitar Pedal - TR

The circuit design of choice is heavily inspired by the BOSS SD-1 model, which has been subject to widespread reverse engineering and modding by guitar pedal enthusiasts [6]. The circuit acts as a baseline for a wide array of possible modifications ranging from volume boosting, midrange frequency dampening, and noise gating [4].

This project's pedal design is a Boss SD-1 modification from Tobias Almqvist and David Nordberg's student thesis that details the addition of a muting circuit modification; The muting circuit filters common noise frequencies in guitar signals [4] and has an adjustable threshold potentiometer in the event that noise levels exceed tolerable magnitude in the original design.

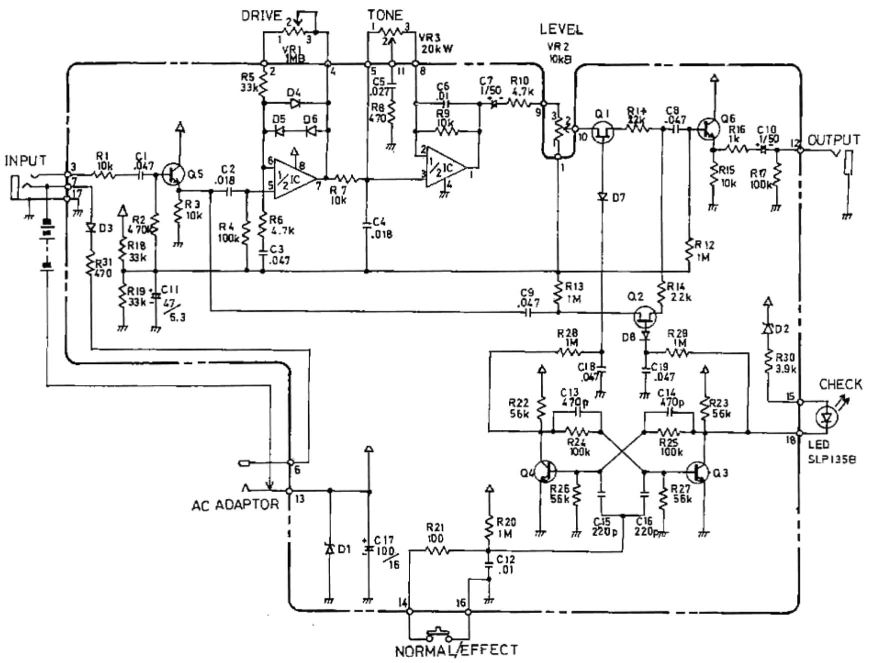

Figure 2: Schematics for the BOSS SD-1 Distortion Pedal [6]

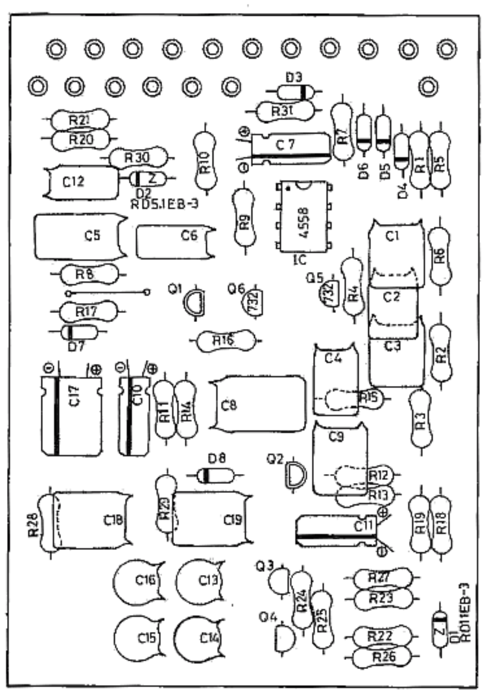

Figure 3: PCB for the BOSS SD-1 Distortion Pedal [6]

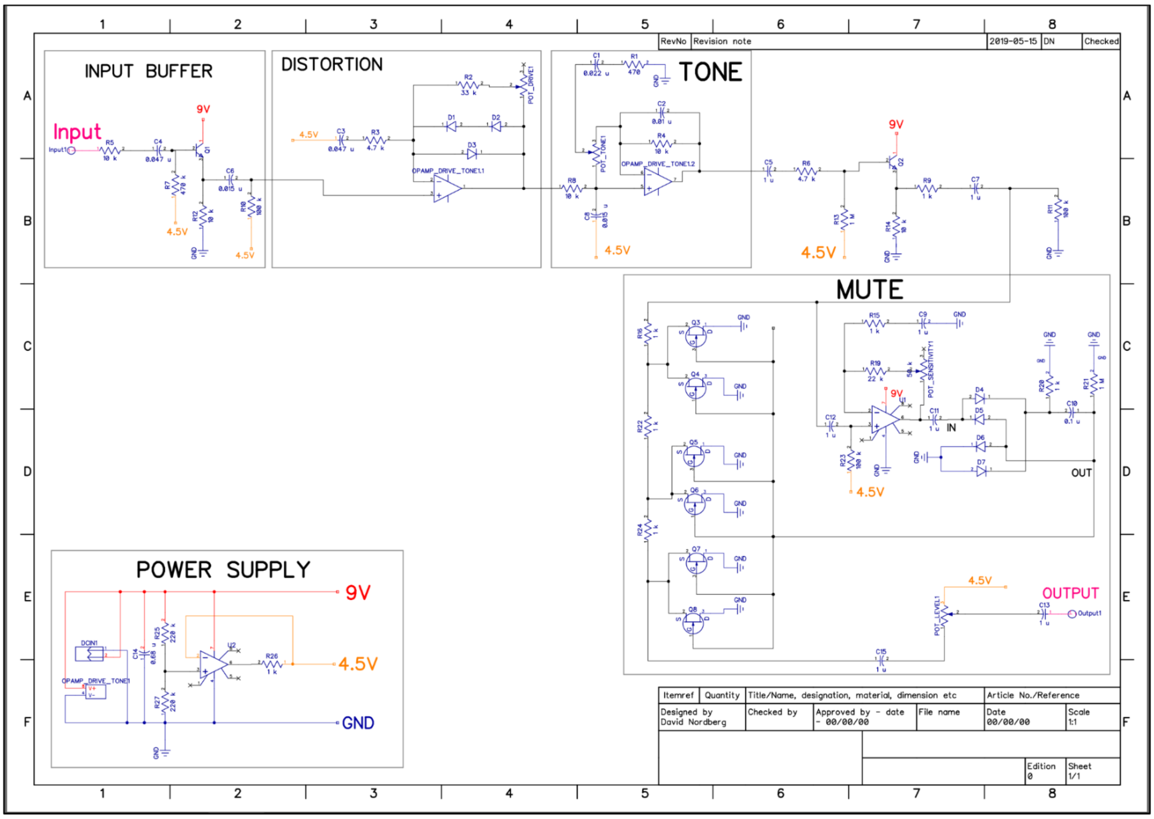

Figure 4: Schematic of a Boss SD-1 With an Added Noise Gate [4]

Almqvist and Nordberg's thesis details future work to improve upon their project, with the most notable being an enclosure for their circuit and the implementation of a three pole double throw switch. Utilizing their schematic, their PCB was redesigned to fit within an industry standard enclosure size (1590BB), as showcased in Figure 5, Figure 6, Figure 7, Figure 8. As it stands, their design uses a two pole double throw switch, which enables true bypass when the pedal is off. However, there is no indicator for an on/off state. This problem is solved with the usage of a three pole double throw switch, which enables the addition of an enclosure LED to the third switch.

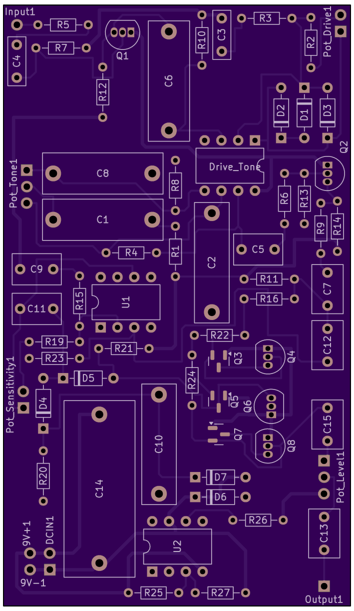

Figure 5: Frontal View of the Designed PCB

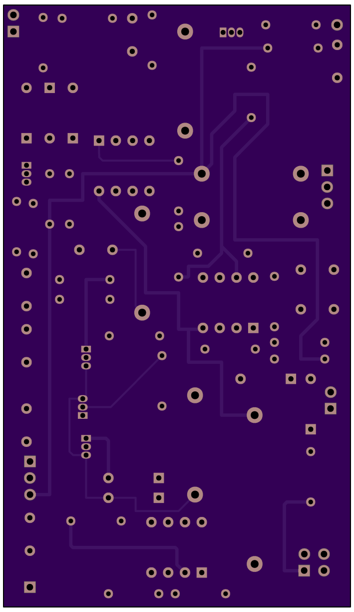

Figure 6: Back View of the Designed PCB

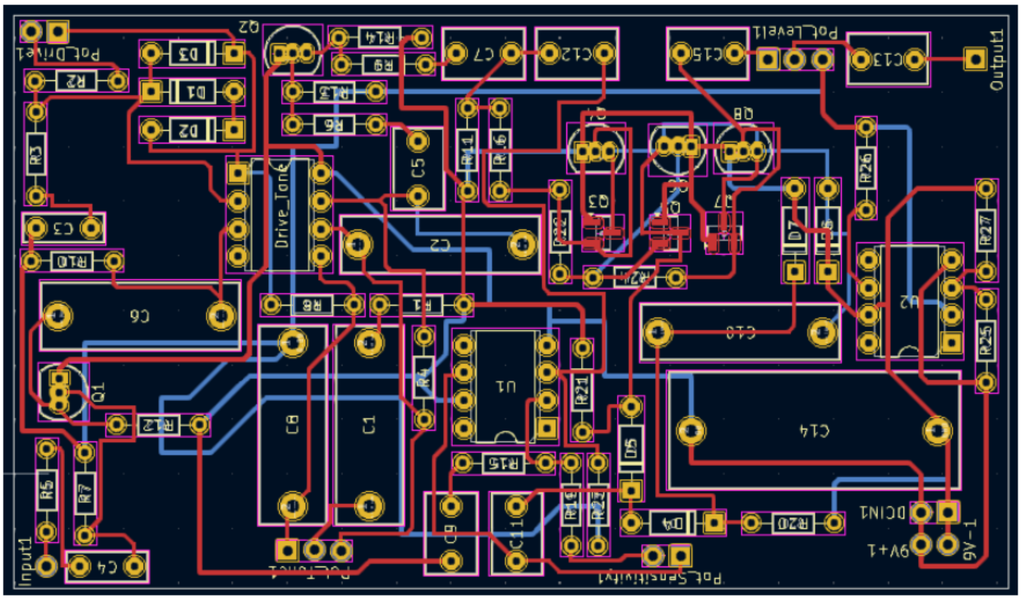

Figure 7: Back View of the Designed PCB

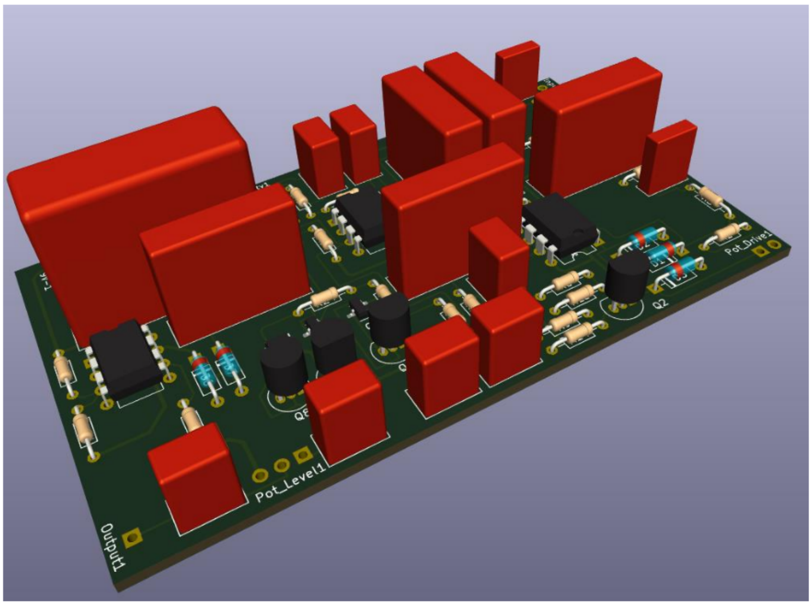

Figure 8: Back View of the Designed PCB

In an ideal environment, the pedal distorts the guitar signal while providing the clarity of the original signal. Additionally, the output signal should be effectively noiseless. However, not all electronic components are manufactured precisely to specified parameters, and these minor fluctuations will accumulate.

2.2 Design & Implementation Challenges - Central Controller - MC

There are plenty of pedal-boards available on the market today, whether they are made by companies or individuals. The designs are often simple, because these boards simply act as support and consolidation for multiple effects. However, as more pedals are added to achieve a more complex signal output, cable management becomes increasingly time-intensive. This can be detrimental during live performances, where long pauses between songs can negatively affect audience satisfaction.

Thus, the primary goal of the Modular Pedal-board is to reduce setup time by consolidating the cable management of multiple guitar pedals and streamlining the setup process. Additionally, it offers easy swapping and rearranging of modules through protruding pins and receiving ports. The overall system is shown in Figure 9

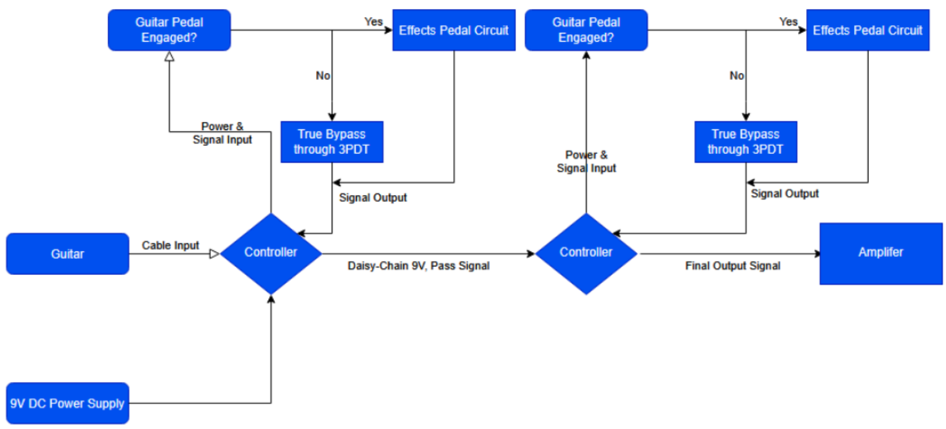

Figure 9: Modular Pedalboard System Overview

The most important section of the three sections that make up the Central Controller is the connector piece. This section houses the most components and holds the actual Guitar pedal in place and can be said to be the main selling point of the project as it is the core of our main objective. It is built around the dimensions of the a standard guitar pedal with human intuitiveness in mind. The shape helps the user figure out the basic set up of the device which reduces the chance of user error and accidents as seen in Fig 10 for the Top view of the Connector. The power cable comes out of the top most hole in the with enough slack to allow the cable to reach either side of the pedal to accommodate for differing power ports. The Amps cords holes are aligned wit the sides and allow for fluent cord design to the following connector.

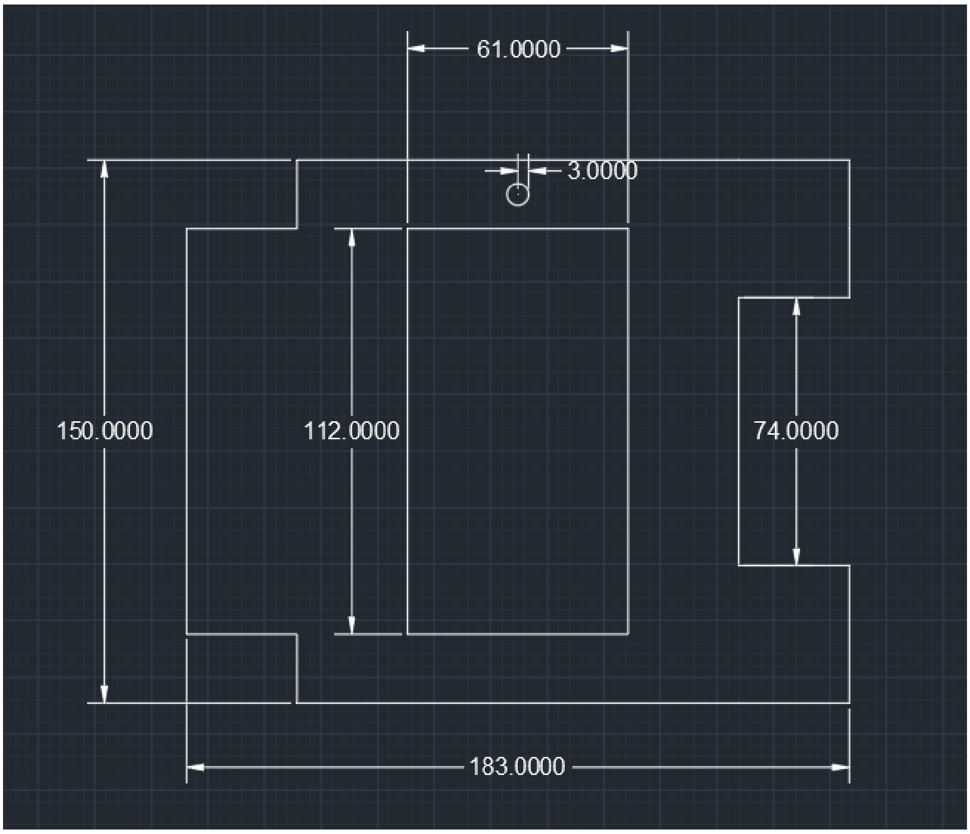

Figure 10: Central Controller - Connector Top view

As for the Left protrusion and Right indent as seen in Figure 11, the left and right view of the connector. The left protrusion will house the Female Amps and power couplings, which will the be routed to their proper inputs. The right indent has a small protrusion which houses the Male couplings which will connect to either a following Connector piece or the ending AMP/Output. The indents and protrusions server to major purposes, one as a safety mechanism and to initiate human intuitivism. As if they are inserted the wrong way, both design aspects will blocks each other from forming a connection, along with protecting the possible sensitive Power Component inside each Connector.

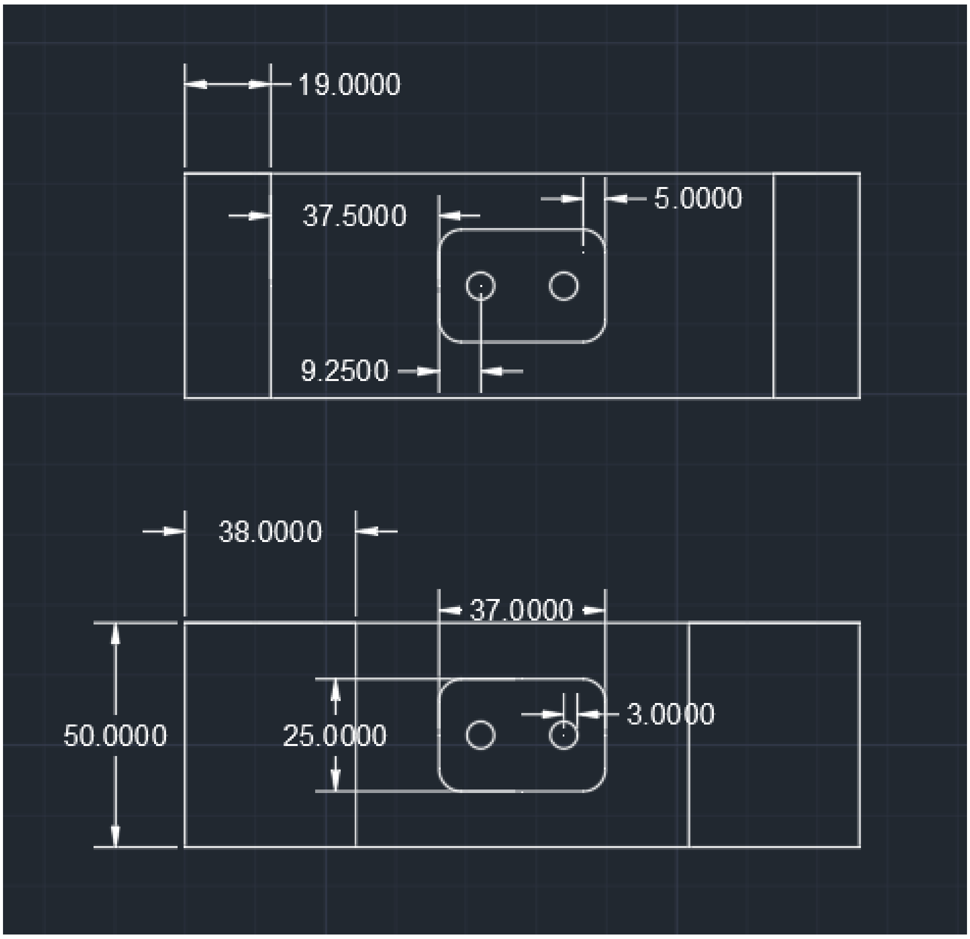

Figure 11: Central Controller - Connector Left and Right Views

In the 3D mock up of the connector pedal a few more details that the schematics displayed poorly, the first being the top surface's rectangular divot where a pedal will be placed. This along side the (second securing method) will keep the pedal secure during configurations.

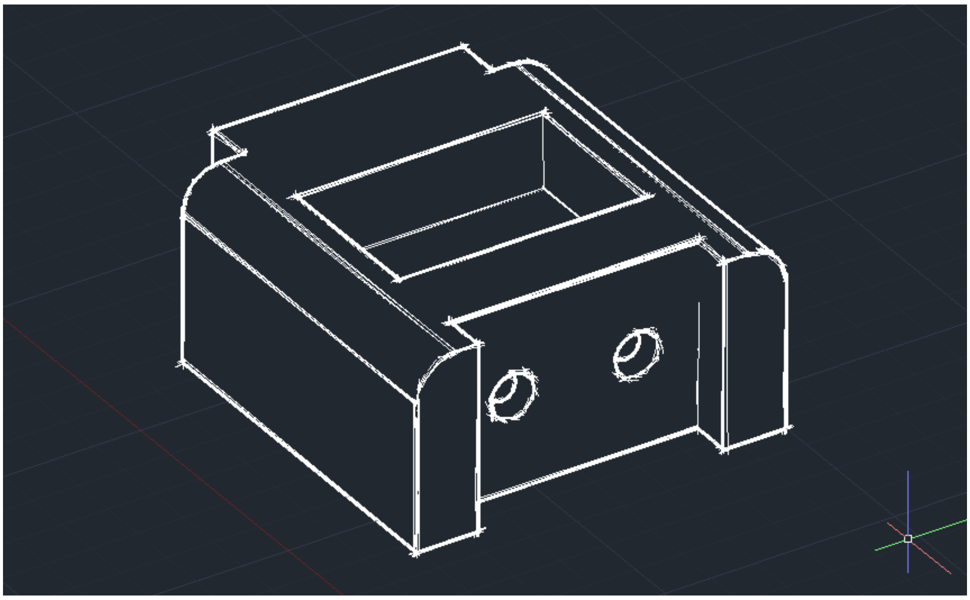

Figure 12: Central Controller - Connector Left and Right Views

Unfortunately, late during the design phase, a hard drive failure resulted in all design files for the central controller being lost. This setback prompted a change in CAD tool to Fusion 360, leading to the finalized design for the central controller seen in Figure 13.

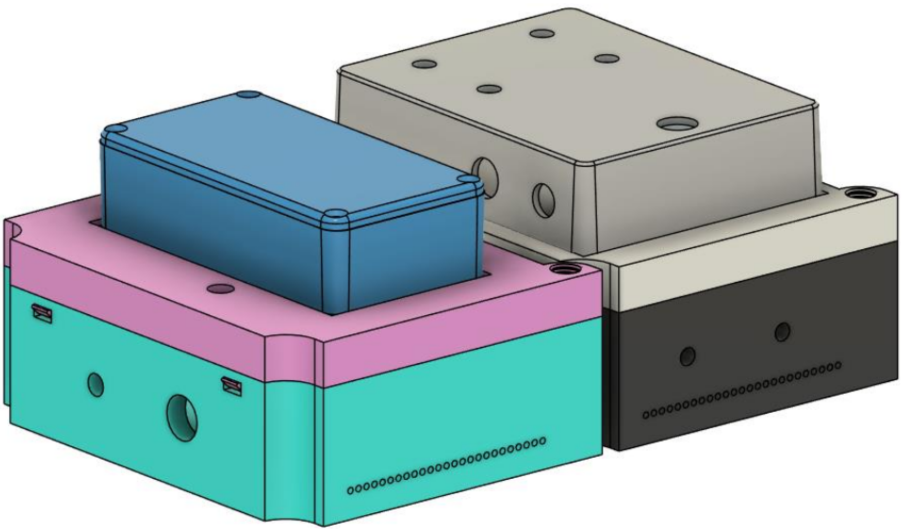

Figure 13: Finalized Central Controller with Mounted Placeholder Pedals

Ports for 9V DC barrels and mono 1/4" audio cables are placed along the left wall of Figure 13. The male counterparts are mounted on the other side, thus creating a connecting mechanism that passes signal and power. Additionally, venting holes were placed along the top and bottom edges of the controller for heat management.

The pedal-board is compatible with most third-party pedals on the market. Although we are designing and producing a functional guitar pedal, most musicians already have their own, and the main product is the modular pedal-board itself. Therefore, we needed to adhere to the standard measurements and power ratings that most pedals use, which are 112 mm x 61 mm x 31 mm and 9-volt power[7].

Along with the usage on standard pedal-board accessories such as 9V power cables and patch cables. This would allow users to use their already purchased equipment along with our own. Alternative designs come from the usage of different enclosure sizes. In Figure 13, the black and white central controller was designed to fit a 1590BB enclosure, while the pink/teal controller is designed for a 1590B enclosure. Both of which are industry standard sizes.

2.3 The Impact of Time Constraints - TR

The time constraints of this project manifested mainly through parts delivery times and refinement of each design implementation. Parts came in three primary shipments: Pedal electronics, controller I/O and cables, and the manufactured PCBs. A unique challenge came in the lack of official CSUB campus vendor for PCB fabrication. Initially, sufficient equipment was thought to be available through a milling machine in a fabrication lab. However, the double-sided nature of the distortion pedal PCB necessitated more specialized equipment which were only available through outside vendors. Ultimately, PCB fabrication was delayed due to time spent establishing a suitable vendor. While ordered within the month allocated for parts ordering as shown in Figure 14, parts arrived later than expected and created more time constraint.

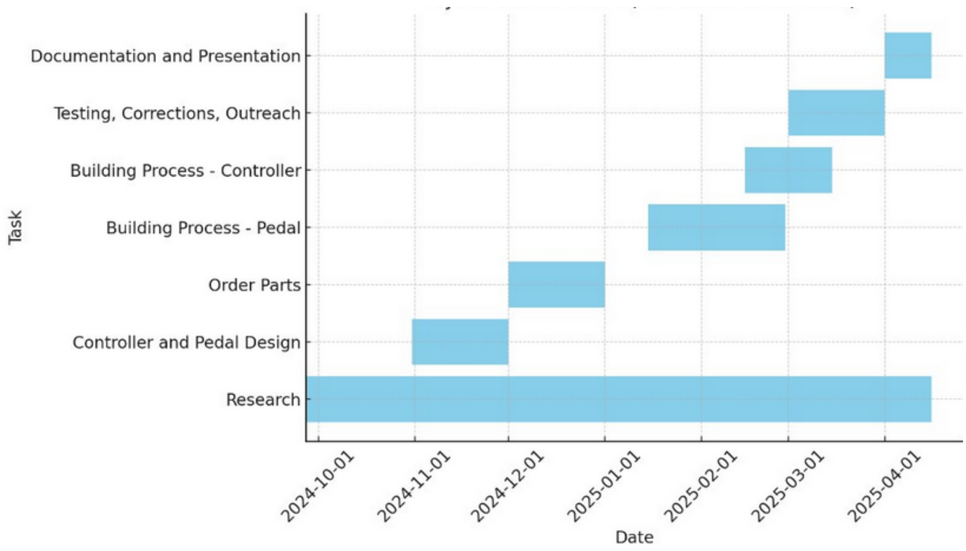

Figure 14: Project Gantt Chart

2.4 Required Knowledge - TR

The design and implementation of the distortion pedal demanded knowledge of analog circuits, soldering, signal processing, electronic design automation (EDA), and simulation methodologies. The distortion pedal utilized OPAMPs to boost an input signal, diodes to clip the signal, and transistors for further gain to create its distinctive sound. Creating the PCB demanded knowledge in EDA software workflow. This meant learning schematic construction, footprint and symbol assignment, and PCB copper trace configuration. Additionally, the schematic must undergo simulation within a SPICE simulator to verify expected behavior through sending test inputs and monitoring output signals.

The central controller design required knowledge in CAD design, soldering, and power systems. The central controller underwent iterations through multiple CAD software, and the hardware needed precise soldering and wiring to negate ground loops.

2.5 Required Hardware & Software - TR

- 3D Printer
- PLA Filament for 3D Printers
- Resistors - 470, 1k, 4.7k, 10k, 22k, 100k, 220k, 470k, 1M, 10M

- Transistors - N-channel JFET, NPN BJT
- Capacitors - 0.01u, 0.015u, 0.022u, 0.047u, 0.1u, 0.68u, 1u, 100uf
- Diodes - 1N4148, 1N4001
- OPAMPs - RC4558 and TL072
- Potentiometer - Linear and Logarithmic 100k
- Jacks - 1/4", 2,1mm
- Customized PCB Board
- Power Transformer - FS12-090-C2
- Breadboards
- Soldering Iron
- Lead-Free Solder
- Soldering Flux
- Wires - 22AWG
- Patch Cables - 1/4"
- XLR Cables
- 9V DC Power Supply - TruTone 1-Spot [8]
- Multi-Plug Cable - TruTone Multi-Plug Cable [8]
- DC Power Barrel Plug Connector Cable, 2.1mm x 5.5mm Male Female
- Ableton Live 12 Standard - Software [9]
- Microphone - Shure SM57 [10]
- USB Audio Interface - UA Volt 2 [11]

- KiCAD - PCB Design Software and Circuit Simulator [12]
- Fusion 360 - CAD software [13]
- MultiSim - Circuit Simulation [14]
- Voltage Regulator - LM7909
- Guitar
- Amplifier

2.6 Existing Technology Limitations - TR

A major limitation was encountered during the construction of the distortion pedal circuit. Upon troubleshooting, it was revealed that the OPAMPs used for the pedal's power supply and muting circuit (TL061) were insufficient for holding a 4.5 V bias voltage as virtual ground to the rest of the circuit. With a max source current of 250 microamps, the IC was simply unable to meet the load of clipping diodes, transistors, and other OPAMPs. This resulted in the drive and muting stage of the circuit being completely inactive, while the tone and volume stage remained functional. The TL061 OPAMP had to be replaced by the TL072 in order provide sufficient supply current and restore drive and muting functionality.

2.7 Team Member Contributions - TR

In this project, each team member was assigned an entire objective in order to provide a clear distinction of contribution:

1. Martin Caballero: Design and prototype a central controller capable of signal carrying and supplying power.
2. Tom Regpala: Design and create a distortion pedal using industry standard measurements to ensure wide-scale compatibility with existing pedals.
3. To improve musician time management and expenses.

- Tom Regpala: Outreach with local musicians to evaluate modular pedalboard compatibility.
- Martin Caballero: Create and analyze data on overall project cost efficiency and time saved.

4. Martin Caballero (Added objective): To design and create a 9V DC power supply

The central controller was successfully implemented, being able to pass audio and power signal while acting as a platform for 1590B-1590BB pedals, as shown in Figure 15. The distortion pedal, at the time of the final demo, demonstrated half functionality through a clear guitar input and output signal with adjustable volume and tone, shown in Figure 16. However, thorough troubleshooting highlighted in Figure 17 showed an insufficient OPAMP IC as the cause for lack of distortion and muting. The third objective will be explored through a cost and performance analysis later within this report. As for the power supply, an implementation was successfully created and was able to supply 9V, though current leakage was present.

Figure 15: The Complete Central Controller with Two Mounted Pedals.

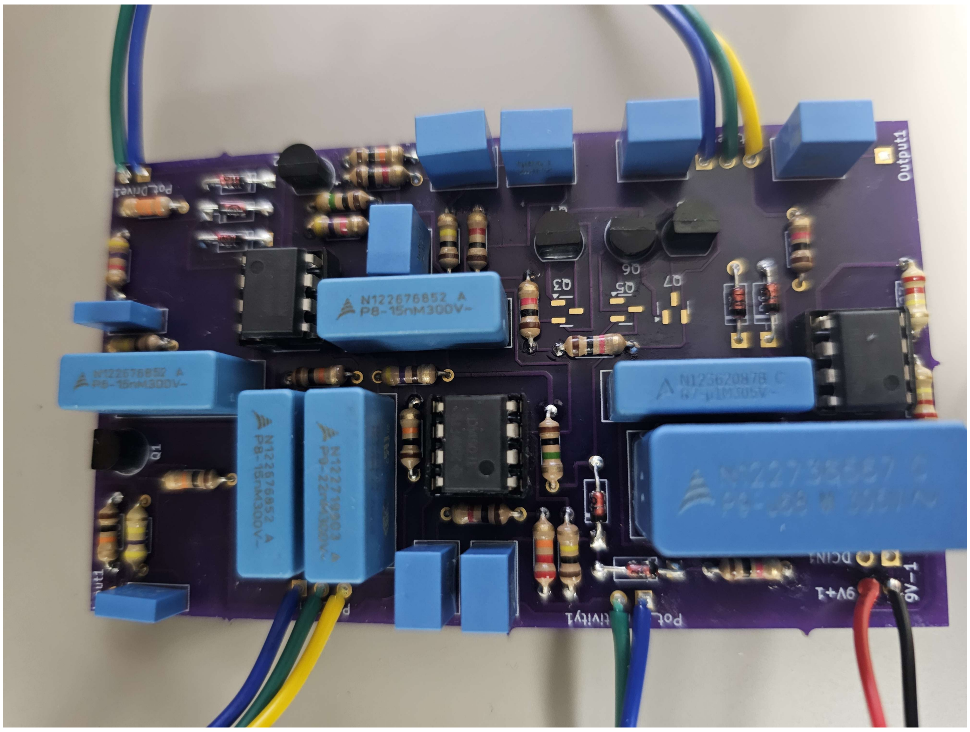

Figure 16: The Fully-Populated Distortion Pedal PCB

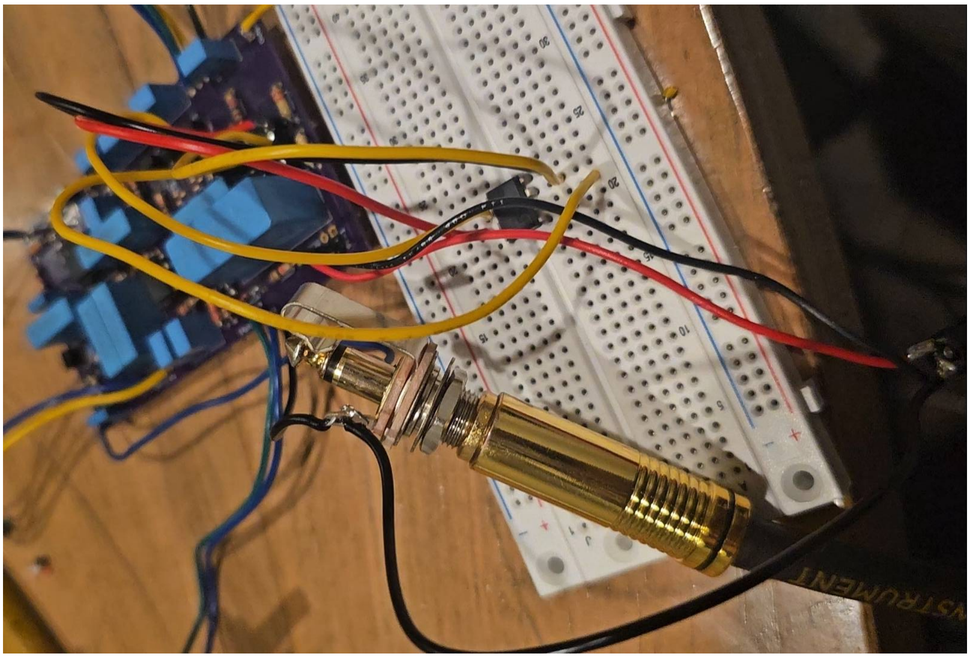

Figure 17: PCB OPAMP IC Troubleshooting Setup

3 Product Results - MC

For validation, a function generator sent a 60Hz sine wave through the controller's signal input and an oscilloscope probed the output. While both pedals were off, the output was expected to match the input. While a pedal was on, a distorted waveform consistent with the effect used was expected. This behavior is shown through Figure 18

Figure 18: Left: A Sine Wave output verifying true bypass to the dual-controller output. Right: A modified wave from an engaged fuzz pedal, indicating mounted pedals are routed through controllers

Time management was further validated through five time trials of both the a conventional board and the modular board.

Table 1: Time Trials for Reconfiguring a Two-Pedal Setup

Trial	Conventional Board	Modular Board	Δs	Improvement (%)
1	18.5 s	11.0 s	7.5	40.5
2	18.2 s	10.5 s	7.7	42.3
3	18.7 s	11.2 s	7.5	40.1
4	17.9 s	10.3 s	7.6	42.5
5	18.5 s	11.2 s	7.3	39.5
Mean	**18.36 s**	**10.84 s**	**7.52**	**41.0**

Similarly, a multimeter was used to measure the outputs of each DC barrel jack in order to both verify polarity and 9V DC daisy-chaining.

The Errors and issues that came form the controllers mostly stemmed form design oversights and prototype construction mistakes. Most of these mistakes were learned and ironed out with the first controller. As previously mentioned, This controller was the prototype with the most problems. These errors were caused by inexperience in both Fusion 360 design for a new product, and soldering wires, jack, and ports. Oversight in the Fusion 360 design caused the initial placements for the audio input and output to be very cumbersome when handled. This made the soldering process more complex than needed and made mistake more likely as well.

These mistakes were ironed out during the creation of the second pedal, where the Audio inputs and outputs locations were changed. Along with more experience soldering wires, this led to an optimal prototype with very little performance issues. The lessons learned from the second pedal were then used to deconstruct, modify, and rebuild the first prototype controller, bringing it into working condition alongside the second prototype.

The power supply was first simulated in NI MultiSim and can be viewed in Figure 19 . since the addition of a power supply was a late addition, it was decided to be simple and focused in scope. Providing a steady and stable 9V with an output of at least one Amp. To match the 9v power supply we ordered for testing.

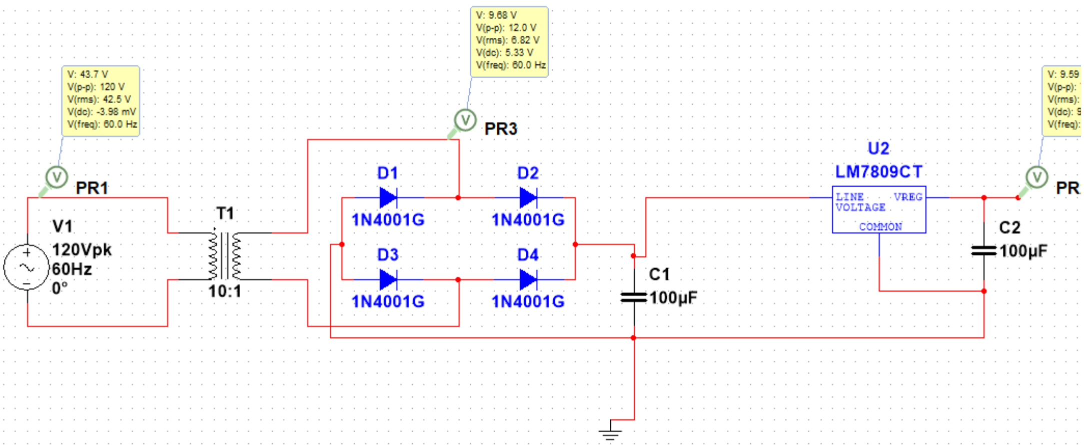

Figure 19: Power Supply circuit

The construction of the of the power supply was done on a PCB, unlike the distortion pedal, a custom PCB was not order. This was due to the time constraints and budget constraints, as both were already stretched to the limit. The overall power supply consist of a Transformer, a diode rectifier, capacitors, and a Voltage regulator. The Transformer takes in the US standard of 120 volts at 60hZ, and steps it down to 12 volts at 60hz. This power is then routed to the bridge rectifier and turned into a DC signal removing the 60hz aspect. Then its circulated through a 100uf capacitor to smooth out the signal and reduce noise, and then a voltage regulator. Which limits the out put voltage from 12 volts to 9 volts, and ran through one last 100uf capacitor smoothing out the signal before being outputted. An overview can be seen in Figure 20.

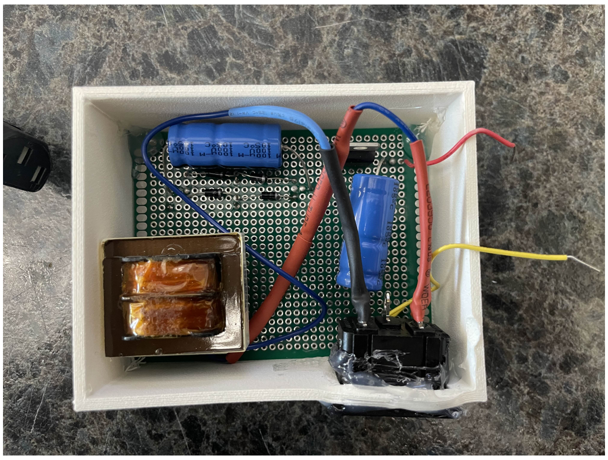

Figure 20: Project 9V Power Supply - Top View

Once constructed, testing would be done to confirm that the power supply would output 9 volts. Using the power cable of a spare monitor for power, testing was conducted on each component of the power supply to ensure proper operation. After recording a steady and stable 9V reading using a Multimeter, shown in Figure 21, testing was considered a success.

Figure 21: Power Supply Testing

To secure the power supply, an open enclosure was modeled and printed for the dimensions of the PCB it was built on. A hole was cut out to fit the AC power input for the power supply, Both the figure below shows both the cable used and AC input outlet used for the power supply.

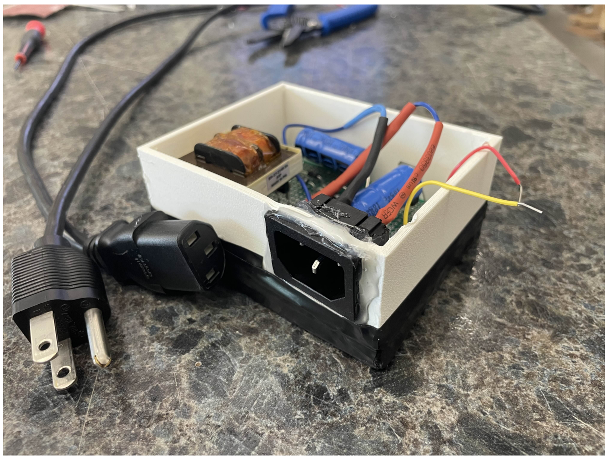

Figure 22: Project 9V Power Supply - Side View

As for errors and issues faced when dealing with the making of the power supply, there were few. The biggest hurdles were soldering the transformer in the proper formation and issues testing the device. The first is easily explained by a misinterpretation of the part's data sheet. The Transformer acquired is made of international use, meaning it can both step down 120volt/60Hz U.S standard and 220volt/50hz EU standard as well. In order to use the U.S standard for the transformer, both its input and output ports needed to be soldered in parallel. during initial soldering, only the input ports were soldered in parallel. This lead to little to no voltage output to the circuit. Once the misinterpretation was cleared, the output was easily soldered together and the transformer was working properly. The second issue was more logistical than complex. Due to safety concerns and lack of a means to provide the Power Supply circuit 120 Volts, its was difficult to measure or test the power supply. At first a function generator was used to provide the transformer 10 volts of AC power, but this proved to be insufficient. As only a singular volt would be supplied to the circuit, which would be stopped by the charging capacitors. Thus, causing the power supply to read zero volts. This was found out when measuring the different components of the Power Supply and capacitor one was slowly discharging was little voltage it had stored. Therefore, power was entering the circuit, but not enough to make it past the internal resistance of the power supply. After a quick safety brief, it was decided to plug the circuit into a Surge protectors, and cover as much exposed metal as possible before plugging in the device as a safety precaution. Once everything was soldered in place and safety measures were taken, the device was plugged in and it read a full 9.04 volts.

4 Cost and Sustainability Analysis - MC

4.1 Prototype Design and Production Cost - MC

The overall cost of the project prototype can be varied, some of the more expensive pieces of equipment that is needed for prototyping and testing test have already been acquired either through our partners such as CSUB's Fab Lab who provide a wide array of tools such as 3D printers and soldering irons, or a member of the team has instruments and programs on hand for personal use which can be allocated towards the project.

However, a rough estimate of 200 - 355 dollars depending on the components and amount that is procured, These involve the "loose" components that were provided by the Fab Lab. Thus, it must be said that the estimated cost may not reflect the true cost, as the main work area for this project, the CSUB Fab Lab, has a stockpile of valuable electronics which can be used, further lowering the project cost.

4.2 Device Cost in Mass Production - MC

As for a Mass production Consumer product, it will come out much cheaper than the protyping cost. As the parts were bought for an individual usage, the parts bought for mass production would be acquired for a cheaper price per unit. but also more easily assembled now that certain design restraints are now in place for the product. To estimate a cost of a mass produced product would be around 25-30 dollar, per unit, from the parts required alone.

4.3 Cost Saving - MC

Pedal-Boards today can vary in price range based on their different design aspects, As the average board could be priced from 100-400 dollars. The closest product to that of the Modular pedal board, priced itself in the 300 dollar range. However, their customer base differs from The Modular-Peadalboard.

It does need to stated that these pedal boards are made to house multiple Guitar pedals at once. Whereas, The modular pedal board's Controllers are made to house a singular Guitar pedal per unit.

4.4 Change in Emissions through Process Change - MC

Manufacturing the modular pedalboard involves assembling circuit boards and soldering components. Energy consumption, chemical usage during board fabrication, and emissions from soldering all have environmental implications. To help mitigate impacts, careful consideration will be given to efficient manufacturing methods and using lead-free solder.

4.5 Change in Use Patterns - MC

Resource efficiency and conservation is achieved through using electronics that can be broken down to scrap or recyclable. Additionally, documentation will be outlined detailing recycling practices for the consumer, such as labeling applicable components and recycling practices.

4.6 Impact on Natural Resources - MC

Eventually, the pedal or controller may reach end-of-life due to device wear. At the obsolete stage, proper disposal and recycling is an important consideration offloaded to the consumer. To address this, guidance through provided documentation or establishing a take-back program ensures that electronics and plastics can be recovered and reused.

4.7 Environmental Regulation - MC

By adopting sustainable design principles, the modular pedal-board project can further reduce its environmental impact while providing musicians with a solution that is not only convenient, but also environmentally responsible. Being modular in design, the pedal-board layout is optimized by having strictly the amount of central controllers to match effects pedal amount; capacity is one-to-one and no space is wasted. Additionally, a the design supports a circular economy, where upgrading certain parts rather than disposing the entire unit is encouraged. Sustainable design principles also involve planning for end-of-life such as labeling components for recycling and providing repair documentation.

4.8 Impact on Individuals - MC

The pedal-board was designed with Human intuition in mind, the shape of the separate pedal-board modules were chosen so they could only be put together in one way. in order to prevent human error and possible unforeseen consequences. Other features are in the works to help the user handle the Pedal-board, while already discussed in the design section of this paper, small effects like finger groves for grips, or the beveled sides of the product are examples of this.

Accommodations for Users with Disabilities have been made once a controller has been put together So a user can be provided options for hands-free operation, such as foot switches with tactile feedback for users with visual impairments. Ensure connectors and controls are easy to handle for users with limited dexterity. An ergonomic design was kept in mind, to ensure the pedal-board can be easily operated while standing or sitting to minimize strain during use.

4.9 Impact on Community - MC

Factors pertaining to climate adaptation are outside of the scope of this project. The report does not address significant adaptation strategy issues such as infrastructure improvement, water management, or natural land use.

4.10 Future Change in Consumption Patterns - MC

Sustainable design principles call for strict adherence to California's Restrictions on the use of Certain Hazardous Substances (RoHS) law [15]. In the context of this project, compliance with this law is done through using lead-free solder for manufacturing circuit boards. Additionally, transparent communication through RoHS documentation could also influence consumer choices toward the modular pedal-board due to being a sustainable product.

4.11 Automation Analysis - MC

Automation was outside the scope of this project. The report does not address Automation strategy issues.

4.12 Job Creation - MC

While job creation was not in the scope of this project. The modular pedal-board does, in theory, lower the cost of entry for musicians. As the Modular pedal board would be a more cost efficient option for new artist who are unable to afford costly boards or production teams.

4.13 Safety and Health Concerns - MC

Identification and mitigation of hazards during the modular pedal-board project is the most crucial requirement for ensuring safety and reliability. Potential hazards are electrical shock, fire hazards, and toxic gas from burning materials. Before these issues can be addressed, risk assessments must first determine which hazards would be identified on the basis of a detailed analysis of the components and usage settings of the project. For instance, electrical faults can arise from both inadequate insulation and power connectors with substandard design. The following series of mitigation address these concerns: this includes proper grounding, adequate insulation of circuits, and using materials that don't help spread flame. Compliance with UL 1310 safety standards for low-voltage power sources further establishes compliance and minimizes hazards.

Another major concern when it comes to safety is the likelihood of toxic fumes from vaporizing filaments. The risk from this can be addressed by using certified non-toxic, flame-retardant plastics. Besides, structural precautions, such as thermal cutoffs, may be incorporated into the board in such a way that prevents overheating and checks the risk of ignition. The design ensures easy access and clear labeling to minimize user error for less experienced users.

4.14 Regulation Constraints - MC

The following are possible regulations and safety standards the Modular pedal-board may all under, and thus should be taken into consideration. These are along the lines of various electrical standards, Power supply guidelines, and material safety in electronics

1. Electrical Standards

- International Electro technical Commission (IEC) 61010: Safety requirements for electrical equipment for measurement, control, and laboratory use [16].
- UL 508A: Covers industrial control panels, including components like power supplies and wiring [17].
- NFPA 70 (National Electrical Code): Provides guidelines for safe electrical design, installation, and inspection to protect people and property from electrical hazards [18].

2.Power Supply Guidelines

- IEC 62368-1: Covers the safety of audio, video, and IT equipment, including power supplies.
- UL 1310: Safety standards for Class 2 power units, focusing on limiting energy output to prevent electrical shocks and fire hazards.

3. Material

- UL 94: Flammability standards for the plastic casings or housings used in resistors or other electrical components.
- IEC 61000 Series: Addresses electromagnetic compatibility (EMC) to ensure electrical components do not emit or are susceptible to excessive electromagnetic interference.
- ANSI/CAN/UL 2904: Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers

5 Results - TR

This project set out to develop a modular pedalboard capable of consolidating secondary purchases into an economically sound solution. The Modular Pedalboard achieves that goal by unifying audio IO, power distribution, and pedal platform support through a central-controller module. Compatibility is further tested through a purpose-built SD-1-derived distortion pedal with an integrated noise-gate stage. Additionally, live trials with two pedals showed the average reconfiguration time drop from 18.36s (conventional board) to 10.84s – a 41.0% improvement.

No current commercial solution integrates mechanical docking, audio I/O, and power in a singular form factor. By meeting industry pedal dimensions (1590B/BB) and standard 2.1 mm centre-negative power, the design directly welcomes existing industry standards, offering a low-cost option for entry-level musicians and professionals—translating to less barrier to entry and more stage time.

In summary, the Modular Pedalboard validates a novel, sustainable approach to pedal management that is faster, quieter, and cheaper than traditional boards, while laying a clear roadmap for scaling into more digital-oriented modules.

5.1 Future Work - TR

- Add additional voltage rails (12 V, 18 V) or integrate switch-mode converters within each module to support power-hungry digital pedals.

- Embed Bluetooth, IoT, or USB-C integration for programmable switching of enabled/disabled modules.
- Add LED status indicators for power and signal on each controller.

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