Multi-Effect Sound Pedal Sequencer for Performing Musicians

Project Plan

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Contents

List of Figures:

List of Definitions:

ADC: Analog-to-Digital Converter
DAC: Digital-to-Analog Converter
LCD: Liquid-Crystal Display
WAV: Waveform Audio File Format

1 Introductory Material

1.1 Acknowledgement

Considerable contribution to the planning of this project was made by our client, Dr. Randall Geiger, through technical advice and consultation. Iowa State University contributed equipment that proved vital to our project as well.

1.2 Problem statement

Effect pedals for musicians play a very important role in almost all live performances. However, using multiple effect pedals in series or parallel requires stringing multiple pedals up to each other. While some high-end multi-effect pedalboards do exist, those systems only allow for one dominant effect to be used at a time, which limits the variety of sounds a musician can produce while on stage. Additionally, while attaching individual pedals together would allow for a similar effect, the tradeoff becomes losing dynamic switching, as it would either require stopping the show for a time to switch pedals or would require a large amount of pedals to pull off a show with many diverse effects.

Our solution is to take the general idea of a digital multi-effect pedal, and improve upon the design to allow for effects to be added and changed around in series or parallel, which would allow for many different distinct sound types to be possible. Our pedal would take in a sound, convert to a digital signal, apply the desired effects and configuration, and output the new sound through whatever system (most likely an amplifier) the performer chooses. The sequence and configuration of effects used will be controlled through an app developed to be used on a tablet device, which would send data to the physical board. The configuration settings could be prepared prior to the live performance. This would mean that an entire new set of effect sequences could be programmed to the board with a press of a button in the app.

1.3 Operating Environment

The end product will consist of the pedalboard with a display screen showing the current sequence configuration. The main operation of the pedalboard will be done via foot operation by the user, and thus will be on the ground in a variety of different stages. Therefore, the board must be durable enough to withstand long-term and consistently heavy use (potentially heavy stomping on the switches and also board itself), as well as withstand dusty, wet, and hot conditions, depending on where a set might be played. The re-configuration will be done using a user interface found on a tablet or smartphone device. This UI application would ideally run on a device with above average quality hardware. The primary environmental factor to consider in regards to the UI would be heavy rainfall during outside shows.

1.4 Intended user(s) and intended use(s)

The intended users of our project primarily include performers and hobbyists. Keeping this in mind, we aim to design a product that satisfies both these audiences by including various features in our pedal board. Our design will reduce clutter onstage for performers while also possessing enough memory banks for diverse effect sequence options. We will also design a powerful and easy-to-use UI for our intended users, whether it be for professional or at-home use.

1.5 Assumptions and limitations

There would be a limitation as to the maximum quality of sound that would come from the pedal. The quality would be primarily limited by the ADC chip we use in our circuit to discretize the signal. Using an ADC chip with a very high resolution would ensure the reconstruction process produces a signal very similar to an analog sound. Signal integrity should be maintained at a very high level, as our connections will be short and make use of high quality connectors and wires.

1.6 Expected end product and other deliverables

We will have two deliverables. Our first deliverable will be a pedalboard with 8 switches, arranged in two rows on the board. There will be an LCD display on the board to notify the user as to which effects are in use. Internally, the pedalboard will consist primarily of a raspberry pi, being fed an analog signal that will be converted with an ADC, as well as several switches that will be connected to the pi as well. The pi will then output a signal through a buffer circuit, which can then be connected to an amplifier or other output. Our second deliverable will be a user interface in the form of an Android app that can communicate with our pedal board via Bluetooth. The app will be where a user can configure the effects they want to use in series or parallel. They will also be able to adjust the parameters of effects.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

We will strive to create a user interface that allows in-depth customization, while being simple enough for any musician (hobbyist or professional) to operate. The board will be durable, portable and reliable. We wish to create a seamless blend between robust effect creation and live performance.

2.2 Functional Requirements

- The board must be able to modify a signal as desired. As with other digital pedal technology currently on the market, our pedalboard must as well be able to provide a large range of desired digital pedal effects. This will be done by discretizing an analog signal before reaching the microcontroller, then modifying the signal as desired through an algorithm before sending the sound back out to an amplifier.

- The effects to be implemented must be modular. Individual effects must be configurable to stand alone or work in series or parallel with other effects.

- The pedal must be able to be configured via an app. This is the heart of our product and what separates it from other technology already available. The board must be able to be configured via a mobile app (optimized for tablets), which will allow the user to quickly change the configuration of the sound sequences to be used.

2.3 Constraints Considerations

- There must be no significant delay during reconfiguration of the board.
- There must be seamless switching between effects without unwanted transient sounds that occur from rapid switching in sound effects.
- The UI must be simple enough so that users can learn to navigate it rather quickly.
- The UI will be programmed in Java and possibly make use of a tool to interface between C and Python programming languages.

The industry in which we are targeting does not appear to have any restrictions that would stem from regulatory agencies. Standards will not be particularly limiting for our design. There may be a liability concern, but this would not fall outside the normal issues any electrical device may encounter with user interaction.

2.4 Previous Work and Literature

Pedals are a very common tool to use for sound manipulation in the musical performance domain. While there are existing pedals out there that enable guitarists to implement effects such as distortion, fuzz, wah, delay, etc., these are usually one effect per pedal. Although there are also pedal boards out there where you can set up multiple pedals for the sake of organization, we intend to take this one step further by being able to program multiple interchangeable effects into one pedal board. We also aim to implement these effects digitally for a more refined design without the mess of many wires. The users of this product should be able to easily program the pedalboard of their desired effects using the app we create that connects to the pedal board. This makes for a simple user interface that is intuitive to beginners and professionals. Similar products such as the, Helix Line 6, cost around $1500 and do not offer app-based configuration.

2.5 Proposed Design

There are three main parts for the pedal board: The application, the circuit based around the Raspberry Pi 3, and the physical board.

1. Application

   The app will developed for Android and have three main activities in which the user can play, configure effects, and configure the pedalboard. Each of these activities will be reachable from the app's home screen. "Play" shows a graphical representation of the pedalboard which indicates which effect is active on the board. "Effects" lists all available effects that can be loaded onto the board along with individual "Effect Settings" screen to specify each effect's parameters to determine how it will sound. "Board Configuration" lets the user select a set of 8 effects they wish to save to the board. Several sets can be saved to allow the user different sets of effects for different performances and not have to recreate them. An effect set is selected or created and the effects are determined by the user from the available effects in the "Effects" screen. After changes have been made, when the user taps play, the "Play" screen will display the updated configuration.

   Figure 1 shows the navigation, layout, and overall concept of the application in its early stage.

Figure 1: Representation of framework for navigation and layout of application

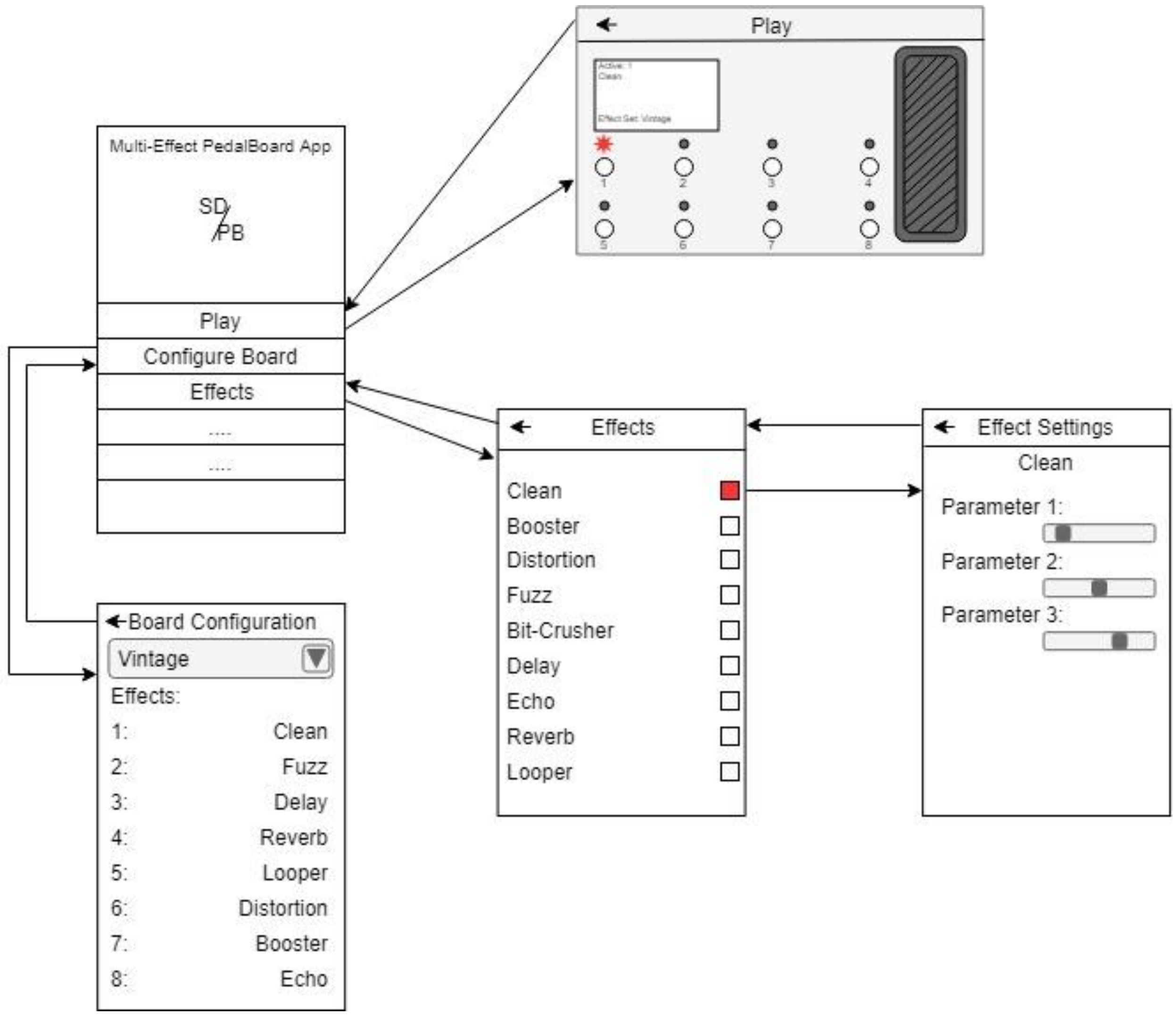
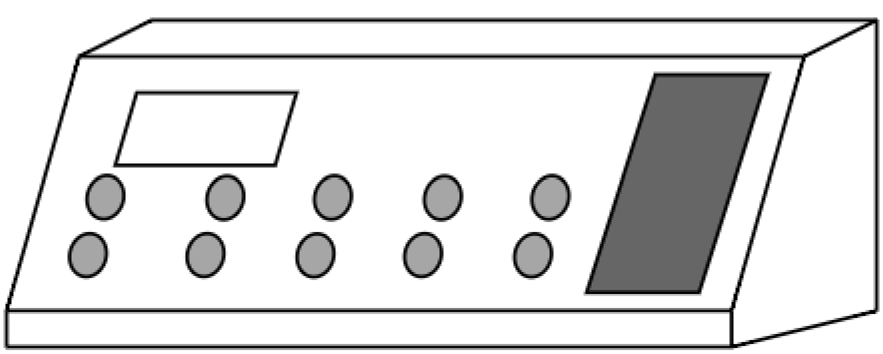


Figure 2: A visual mockup of what the final product will look like



2. Signal handling circuit
    a. ADC and DAC
    b. Raspberry Pi 3B for signal processing
    c. Filters, input protection, power distribution

3. Pedal Board
    a. Change between saved effect configurations with the buttons
    b. Foot pedal for volume control
    c. 2-by-5 button array
    d. LCD for displaying effects list
    e. 2.5-by-1.5 feet

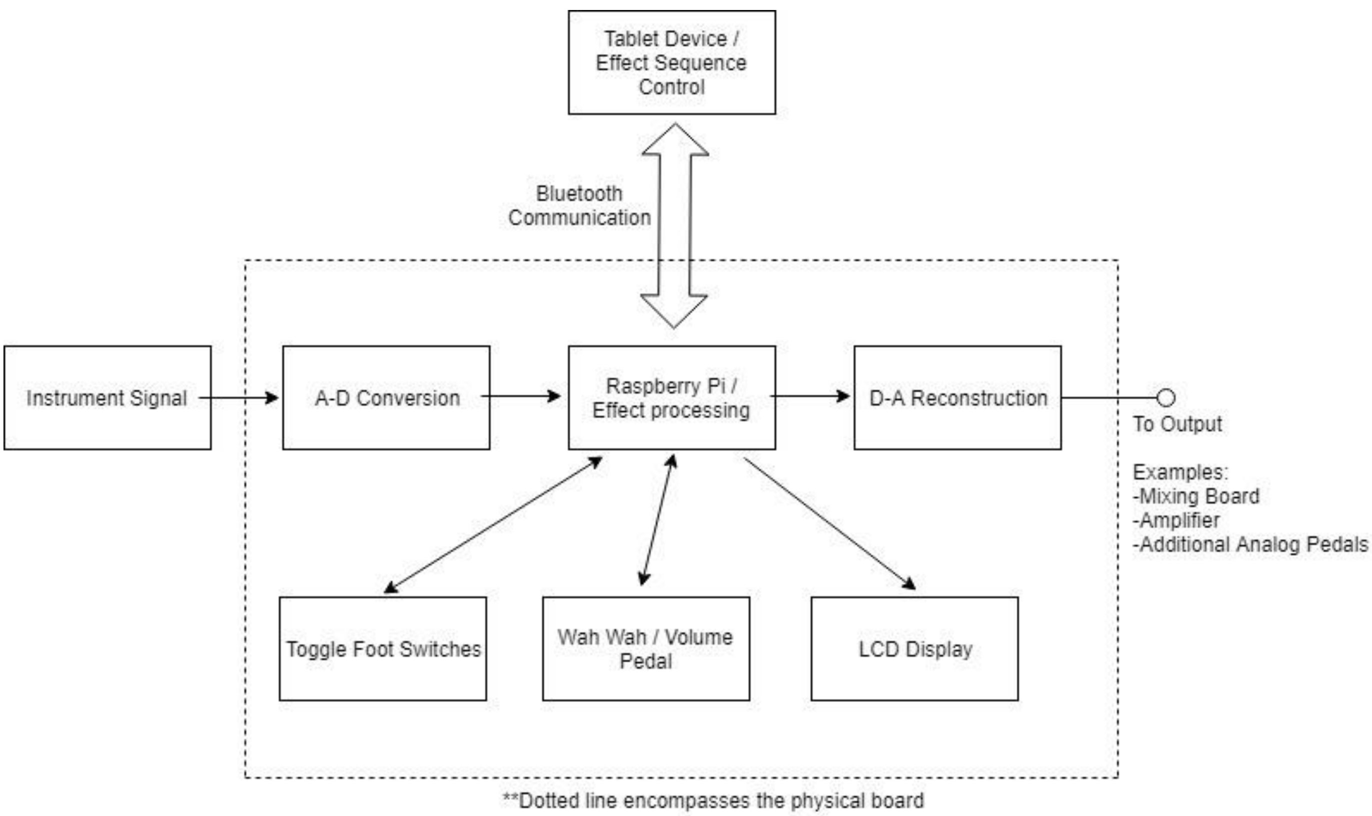


Figure 3: A high-level diagram of our sequencing board system

The goal of this project is to create a multi-effect pedal board that allows the user a higher degree of control over their effects. Typically, artists collect an assortment of effect pedals and they wire them together in sequences of their choosing. The limitations of effect pedals stem from their size and wiring requirements. To create a custom effect sequence from a variety of pedals requires a lot of time to connect the pedals and space to keep them.

With the board we are designing, we will be able to incorporate a multitude of effects housed in a digital library on a microcontroller. Using a GUI, the user will be able to configure their effect sequence and parameters easily and quickly. Once the user has created their custom setup, they are able to save that configuration and assign it to a button on the board. When playing live, the artist is able to change between their custom effects with the press of a button.

The board will utilize digital waveform processing to apply the chain of effects the user has created. The use of a digital device instead of an analog one allows the reduction of space and diverse customization options. The pedalboard will be responsive, easy to use and durable.

2.6 Design Strengths and Weaknesses

One weakness of the proposed design is the digital waveform manipulation. Many audiophiles prefer the sound of an analog system to digital one. However, in a live performance environment signal integrity issues should not cause concerns in comparison to high level household audio equipment. While high-fidelity is preferred, the focus of many live settings is high power systems achieved with large amplifiers. Digital sampling technology has been greatly improved so the introduced noise from sampling is greatly reduced. The digital implementation may be a weakness for sound quality, but the digital process allows us to develop a cheaper, smaller and much more *versatile* board.

A strength that our board has is its ability to interact with an application. This allows the user to make changes with relative ease. The UI will be intuitive so anyone can make changes to their effects. The application also will give a visual representation of the configuration. Another strength of the board will be its durability. The board will be made with water and dust resistant parts, ensuring that the shoes of the performer will not damage the board.

2.7 Technology Considerations

Our pedalboard needs a way to get data from the app and change the effects produced by the pedalboard. It also needs some storage to save these settings. Our solution for this is to use a microcontroller that handles all these responsibilities. We investigated using either the MSP430 or the Raspberry Pi 3 as our two primary options for microcontrollers. We chose to use the Raspberry Pi 3 since the community for it is much bigger than that of the MSP430. We also found effect libraries that our pedalboard can implement. This will save us time in development by not having to create each effects ourselves.

2.8 Challenges

There are many obstacles that must be considered when designing and building the pedal board. The largest challenge is keeping the signal integrity. We want to make sure our ADC is converting the signal at a high enough resolution and frequency to preserve sound quality and avoid aliasing. To ensure that we preserve sound quality, we have opted for a higher resolution ADC. The selection of a higher resolution ADC presents new challenges. The data that the raspberry pi inputs will be serial so we have to account for that when processing the signal. The raspberry pi has enough processing speed where this shouldn't be an issue, however testing will be done to ensure that this is the case. Fabrication of the board itself will be a challenge. Creating the board will be a new experience for most of the team members. Creating a functional and intuitive UI will also be a challenge that requires both GUI design experience and human factors research.

2.9 Safety Considerations

There aren't many safety concerns we need to worry about with this project besides making sure all the wiring and circuitry is done properly in the pedalboard. We will take great care in ensuring the wiring is safe, sturdy, and unlikely to create any fire hazards. Typical electric guitars produce a signal that is far less than 1 Volt. We are not planning to filter the analog signal, and thus no op-amps are planned to be necessary, unless a buffer circuit is decided to be added in the future. We have considered many different potential issues, and decided there is very little safety risk involved.

2.10 Task Approach

We plan on developing the pedalboard and app concurrently. This will make integration between the two easier since we won't be stuck trying to force the app to work with the pedalboard and vice versa. This also provides more time to focus on making the UI for the app clean and intuitive. See 4.3 Appendices for reference to task plan.

2.11 Possible Risks And Risk Management

Acquiring materials is a small concern. We are most concerned with the knowledge and execution required to properly create the pedalboard. We plan on addressing these issues by collecting materials to reinforce our knowledge. We will properly execute the design implementation by using careful planning and measurements for the physical board and using thorough examination of our implementation of the wave manipulation on the Raspberry PI. We plan to extensively test the final prototype to ensure it meets the standards of our client.

2.12 Project Proposed Milestones and Evaluation Criteria

The first key milestone would be to get a prototype of the pedalboard put together. This requires having the wiring properly done in a way that would allow us to switch the order of effects that it is using at one time. Testing this could be done by manually manipulating the effects that the board is set to create. The second key milestone would be to develop an app that which is capable of changing effects with an intuitive UI to encourage the user to want to use this system. The third and last key milestone will be to plug in a guitar to the pedal board and use the app to change the current effects on the pedalboard and hear the change in sound produced from the guitar.

2.13 Project Tracking Procedures

We are using Trello to keep a list of what tasks need to be done next and who is working on them. We will keep it up to date to ensure we know when things like deliverables and weekly status reports are to be finished.

2.14 Expected Results and Validation

We want to have a working pedalboard prototype that is controlled with an app designed specifically for it. We want to have a system that has multiple effects that can be switched between at any time by a guitarist using it. To confirm that our product works, we will plug in a guitar to the pedalboard with the effects preset by the app and go into an amplifier. Then we'll play the guitar and switch between effects and see how it sounds/works.

2.15 Test Plan

Our test plan is to ensure that the effects implemented in software affect a signal as desired, by running a WAV file representation of a guitar output, ensuring that the output is as expected for each case. Unfortunately much of the testing in this case will be subjective, we can't just test circuit values because they do not give us a clear idea of how the effects sound.

After we have ensured that the first set of effects to be used replicate the same effect as intended, we will test the communication functionality between the board and the application for configuring the pedal board. We will test different configurations of sequences to verify that the program correctly configures the raspberry pi.

Once the app has been verified to function properly, live testing will begin. With the board connected to a guitar we can gauge how the board reacts to the input of an analog signal. We will verify that that the ADC/DAC are functioning properly. We plan to take the board to Genre or other musicians and let the play around with it. This will give us an idea of how intuitive our system is and how it sounds when being played live. The feedback from the musicians is incredibly important since they are our target consumer.

2.16 Validation and Acceptance Test

The following tests will allow us to confirm that the design meets the proposed constraints of the client.

The first constraint, an experimental demonstration of the system along with an evaluation of the performance by both the team and guitarists that appreciate the use of effect pedals. This constraint is easy to meet. Genre (a student-run club focused on live-music performances) is an excellent resource to find musicians who can help test each effect. Each design team member has other contacts that they can reach out to. The acceptance criteria needs to be rather strict. A single opinion against a successful replicated effect is enough to warrant a rework of the code.

The second constraint, a graphical interface that can be used to visualize and control the sequencing of the pedals. This constraint will be tested in two ways. The first being a functionality test where we verify that the application does properly configure and interact with the pedal. The second part will be a human factors test. We will have multiple people use the software and get feedback on its design and intuitiveness of the UI.

The third constraint, real-time configuration that can incorporate 6 or more standard pedal effects in sequence and up to 3 effects in parallel. This constraint requires the hardware and software to work correctly and allow for proper configuration. The test required to verify success is simply assigning an effect sequence in the app that would correspond to a button on the board and activating that particular button. This test can be done after all working parts are completed and combined for a prototype.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

The Gantt chart is in the appendices for both semesters.

SEMESTER 1:

The first semester will focus heavily on research, design, and initial prototype building. As we begin to meet with our client, we will begin to set roles and expectations in our group. We will conduct market research to be aware of similar products to ours and brainstorm what we can improve with our design. We will obtain our necessary starting materials, such as the raspberry pi 3 model. We will first learn how to effectively implement algorithms for signal manipulation using this microprocessor. We will be using recordings as signals for the initial testing. Once we can create effects with our initial prototype, we will begin work on our UI. We are planning to make an app that can successfully configure the pedal board with the desired effects.

SEMESTER 2:

The second semester will be dedicated to improving the prototypes for both the board and the UI with cycles of testing and re-design. We will be focusing on the app to make it as refined and intuitive for users as we can. We will also be moving into testing with actual musicians to gain feedback on both the functionality and usability of our final product.

The final milestone of our project will be to plug in a guitar to our pedal board and successfully implement the correct effects in either series or parallel.

3.2 Feasibility Assessment

We will have a pedalboard that will have an app capable of manipulating the effects produced from the pedalboard. The app will have an intuitive design making it easy to use and understand. This design will produce a responsive system that will not have any lag to the sound produced. A challenge will be getting the pedalboard to work with the app we plan to develop. Sending data back and forth over bluetooth won’t be too difficult, but parsing the data one both ends to make it usable might be more difficult.

3.3 Personnel Effort Requirements

Task	Description	Resources
Initial Meeting / Reflection	This covered the first meeting with the client to discuss what their vision and goals were for the project. The group then discussed how to realize those visions.	This process took about 2 hours for each team member, as the meeting and reflection were both team actions.
User/Market Feedback	This is similar to the empathy stage of the design process that was discussed in class. The goal with this action is to form an idea of what types of elements our design should and shouldn't include based on what users find useful in this type of product.	This process will be ongoing for most of the duration of the first semester. Measureable hours so far include an hour for creating a survey to hand to members of the Genre club and talking with them while they filled it out. The team spent another hour discussing the feedback received.
Analog / Digital Implementation Decision	There were two main methods to use to achieve the desired results for this project. We could make use of analog or digital effects. This required a little bit of research and discussion into which would best suit our needs.	This task was completed rather quickly, as one of the main criteria is re-configuring the board. Digital is the most convenient way for the user to do this.
Digital Effect Library	We need to create a large library of effects to be used by the Raspberry Pi. These will be done in C. These effects will be controlled by the UI.	This task was completed quickly, as well. We were able to find a host of effects already programmed and that are open-sourced for us to use. These are a great foundation to begin the prototype.
UI Creation	This will be the bulk of the work needed to complete this project. The interface controls most of the functionality that is unique to our product compared to other similar products already on the market. The UI will allow a musician to upload a new library of 8 effect sequences to the board.	This task is expected to take about four to five weeks between planning and creation. This will take effort from 2 or 3 members for most of the time spent working on it, as it will need to interface with the board. Testing will be done periodically as sections of this are completed.
Prototype	This will be when all the working parts come together. The UI will be ready to manipulate the conversions taking place in the Pi.	This task is expected to take about a week to get everything to communicate effectively and produce the desired effects.

3.4 Other Resource Requirements

We have planned to meet with the College of Design to get information regarding the influence that human factors have on UI design. Information regarding the effect algorithms is required. Information regarding the sampling and modification of digital waveforms.

3.5 Financial Requirements

For the pedalboard construction we require: 8 lockless pushbuttons, 1 foot pedal, 1 LCD, 1 Raspberry PI, 1 16gb micro SD, 1 micro USB cable, 1 HDMI cable, 1 ADC/DAC, some resistors and op-amps to properly route the ADC/DAC, Wood for the case and wire for the connections.

<u>Projected Costs</u>

	Prototype	Final Product
Physical Board	No outer shell - $0	Outer Shell - ~$50
Circuit Components	PI3 - $30 12-bit ADC/DAC - $3/each LEDS/Switches/Caps/etc - $5	PI3 - $30 12-bit ADC/DAC - $7/each LEDS/Switches/Caps/etc - $50 PCB - ~$30
Application	Tablet - $60	Tablet - $60
Total Cost	$101	$234

4 Closure Materials

4.1 Conclusion

Musicians need to be able to transition between effects, quickly and effortlessly, while playing a song in front of a live audience. The musician also requires a durable board that can withstand the pressure of a person depressing the buttons with their feet. The board should also be weather resistant to allow the musician to play at a variety of venues. We propose that we create a multi-effect pedalboard that can be preprogrammed with the artist's effects. This would allow the user the ability to create a board that is customized to their needs and allows for quick and easy transitions between the saved effects. An application will be created to allow the user to implement these effect configurations, while having a simple and intuitive layout for the user. When the board and the application work in tandem, the musician will have an effective tool for creating and transitioning between effects.

4.2 References

Raspberry Pi effect libraries:
Ray. "How to Start Programming Pedal-Pi." ElectroSmash, 27 Apr. 2017, www.electrosmash.com/forum/pedal-pi/202-how-to-start-programming-pedal-pi?lang=en.

"Dual PWM Circuits." *Open Music Labs*, Flingco Sound System, www.openmusiclabs.com/learning/digital/pwm-dac/dual-pwm-circuits/index.html

4.3 Standards

IEEE 151-1965 Standard Definitions of Terms for Audio and Electroacoustics

IEEE 1241-2010 Standard for Terminology and Test Methods for ADC

IEEE 1118.1-1990 Standard for Microcontroller System Serial Bus

IEEE 802.15.1-2005 Standard for Information technology-- Local and metropolitan area networks--Specific requirements

IEEE 145-2013 Standard for Definitions of Terms for Antennas

IEEE 1789-2015 Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers

4.4 Appendices

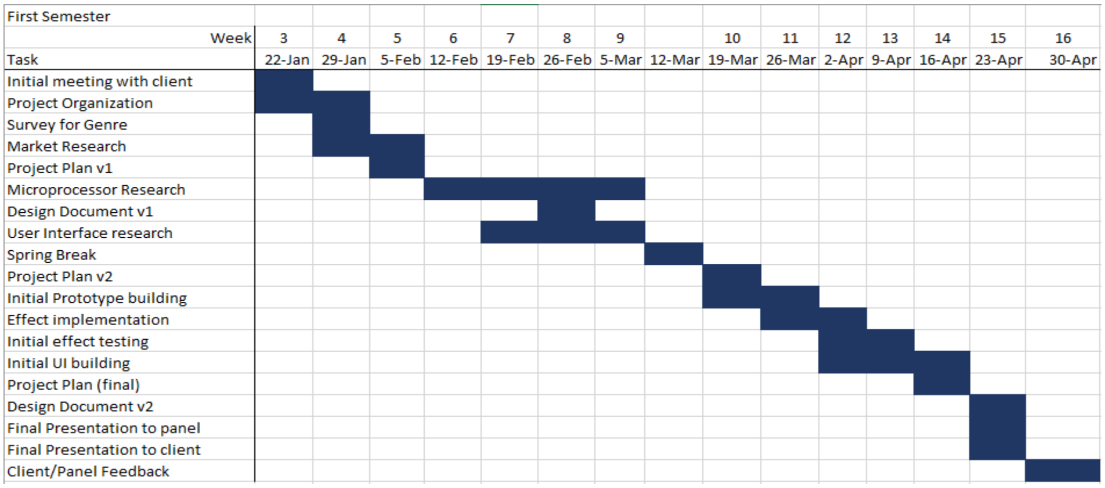


Figure 4: A Gantt chart detailing our project schedule for the scope of 491 (first semester)

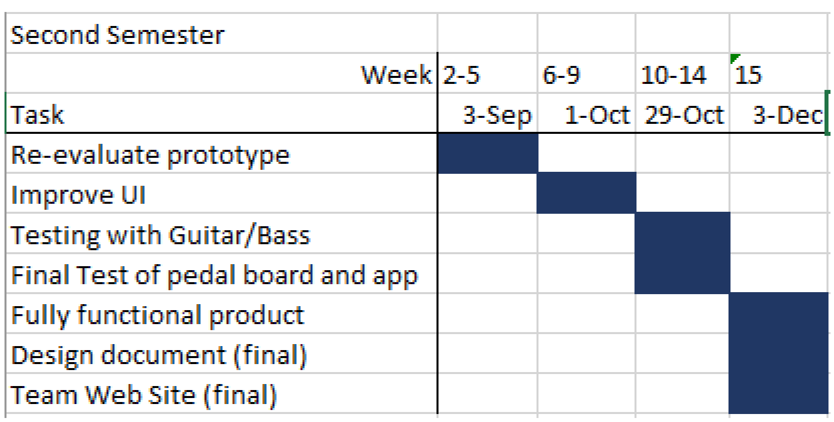


Figure 5: A Gantt chart detailing our project schedule for the scope of 492 (second semester)