

Multi-Effect Sound Pedal Sequencer for Performing Musicians Final Project

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List of Definitions:

ADC:	Analog-to-Digital Converter
DAC:	Digital-to-Analog Converter
LCD:	Liquid-Crystal Display
WAV:	Waveform Audio File Format
OS:	Operating System
UI:	User Interface
UX:	User Experience

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. Lee Harker and ETG played an integral part in the final stages of the design and assembly.

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 is designed to take in an audio signal, convert that to a digital signal, apply the desired effects and configuration, and output a reconstructed signal through whatever system (most likely an amplifier) the performer chooses. The sequence and configuration of effects used are controlled through an app developed on a tablet device, which sends data wirelessly to the physical board. The configuration settings are designed to be prepared prior to a live performance. This means that an entire new set of effect sequences can be programmed to the board with the press of a button in the app.

1.3 Operating Environment

The end product consists of the pedalboard with a display screen showing the current sequence configuration. The main operation of the pedalboard is done via foot operation by the user, and thus will be on the ground in a variety of different stages. Therefore, the enclosure is 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 is done using a user interface found on a tablet or smartphone device. This UI application can run any any recent version of the Android OS. 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, our product works to satisfy both these audiences by including various features in our pedal board. Our design reduces clutter onstage for performers while also possessing enough memory banks for diverse effect sequence options. Our UI application is also powerful and easy-to-use for our intended users, whether it be for professional or at-home use.

1.5 Assumptions and limitations

There is a limitation as to the maximum quality of sound that would come from the pedal. The quality is primarily limited by the ADC chip we use in our circuit to discretize the signal. Using an ADC chip with a high resolution would ensure the data conversion process produces a signal very similar to an analog sound. Signal integrity is maintained by including high fidelity interconnect components and by keeping connections as short as possible.

Additionally, the processing power and clock speeds of the Raspberry Pi, the ADC chip, and the DAC chip, can create a delay between a signal being sent and the signal being processed and sent from the DAC. We were able to minimize this delay to 56 microseconds, which is small enough that the delay should not be noticed by performers or audiences, alike.

1.6 End product and other deliverables

We have two deliverables. Our first deliverable is a pedalboard with 8 preset switches and 3 effect-specific looper switches, arranged in one row on the board. There is an LCD display on the board to notify the user as to which effects are in use. Internally, the pedalboard consists primarily of a raspberry pi, being fed an analog signal converted with an ADC, as well as several switches that are connected to the pi as well. The pi then outputs a signal through a buffer circuit, which can then be connected to an amplifier or other output. Our second deliverable is a user interface in the form of an Android app that can communicate with our pedal board via Bluetooth. The app is where a user can configure the effects they want to use in series or parallel. They are also able to adjust the parameters of effects.

2 Our Approach and Statement of Work

2.1 Objective of the Task

Our main objective in this project is to create a durable, portable, and reliable pedal board, along with a user-friendly application as an interface to the board. We also strived to create a seamless blend between robust effect creation and live performance.

2.2 Functional Requirements

- The board must be able to accept, modify, and output 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.
- The input impedance has to be high and the output impedance has to be relatively low. This is to allow for maximum voltage transfer between systems, and this is the standard used in virtually all guitar setups. Maximum voltage transfer is important, as it helps maintain signal integrity through a system that could potentially consist of 5 or more different stages, including our designed board.

2.3 Constraints Considerations

- There must be no significant delay during reconfiguration of the board via the Android app.
- 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, as input and output impedance are fairly easy to control with how we implemented the design.

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 was developed for Android and has three main activities in which the user can play, configure presets, and configure the pedalboard. Two of these activities are reachable from the app's home screen, and one is accessed within the 'configure presets' activity. "Play" shows a numerical representation of presets on the board, each of which can be selected to change the preset on the board, as though the pushbutton was pressed. "Preset Configuration" shows a list of presets that are configured on the application, with options to upload to or download from the board itself. When selecting a preset and editing it, the "Preset Edit" activity allows the user to select the sequence of effects to configure the preset with, as well as configuring specific options within each effect. Figure 1 shows the navigation, layout, and overall concept of the application in its early stages.

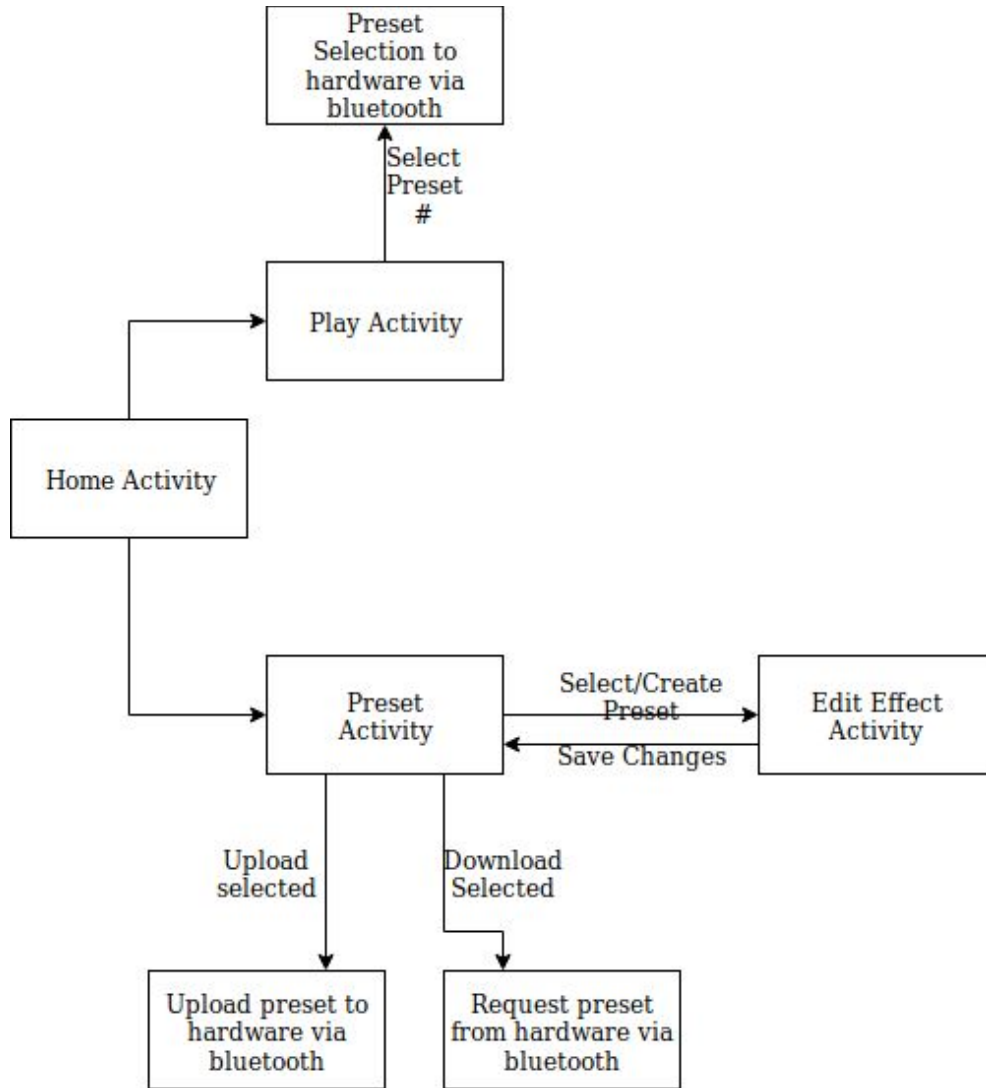


Figure 1: Representation of framework for navigation and layout of application

2. Signal handling circuit
 - a. ADC and DAC for data conversion processes
 - b. Raspberry Pi 3B for signal processing
 - c. Filters and output buffer

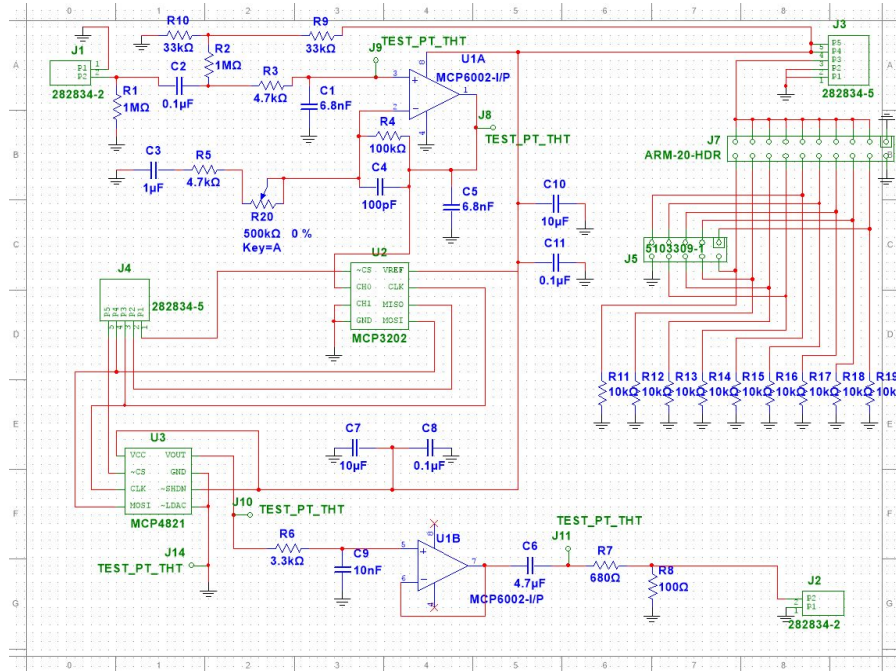


Figure 2: Multi-Sim Schematic

3. Pedal Board
 - a. Change between saved effect configurations with the buttons
 - b. 1 row of 8 switches, 1 row of 3 switches
 - c. LCD for displaying effects list
 - d. 27 inches by 11 inches

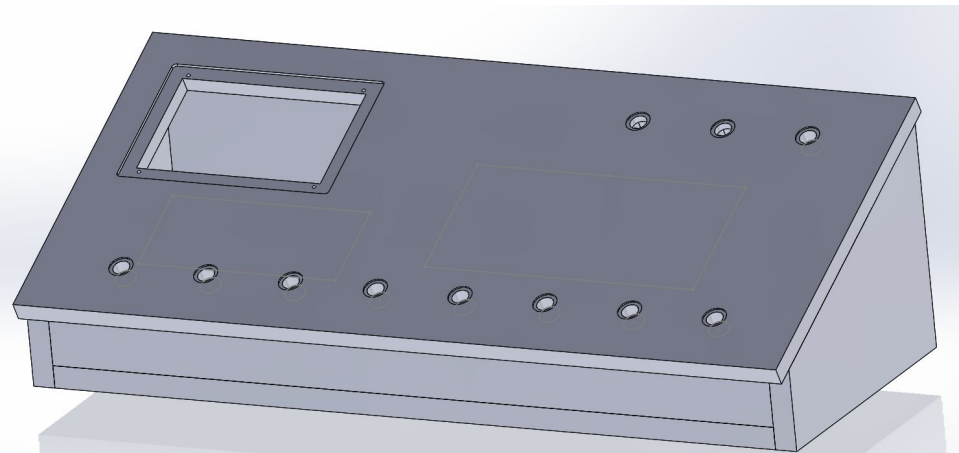


Figure 3: A Solidworks assembly of what the final product looks like

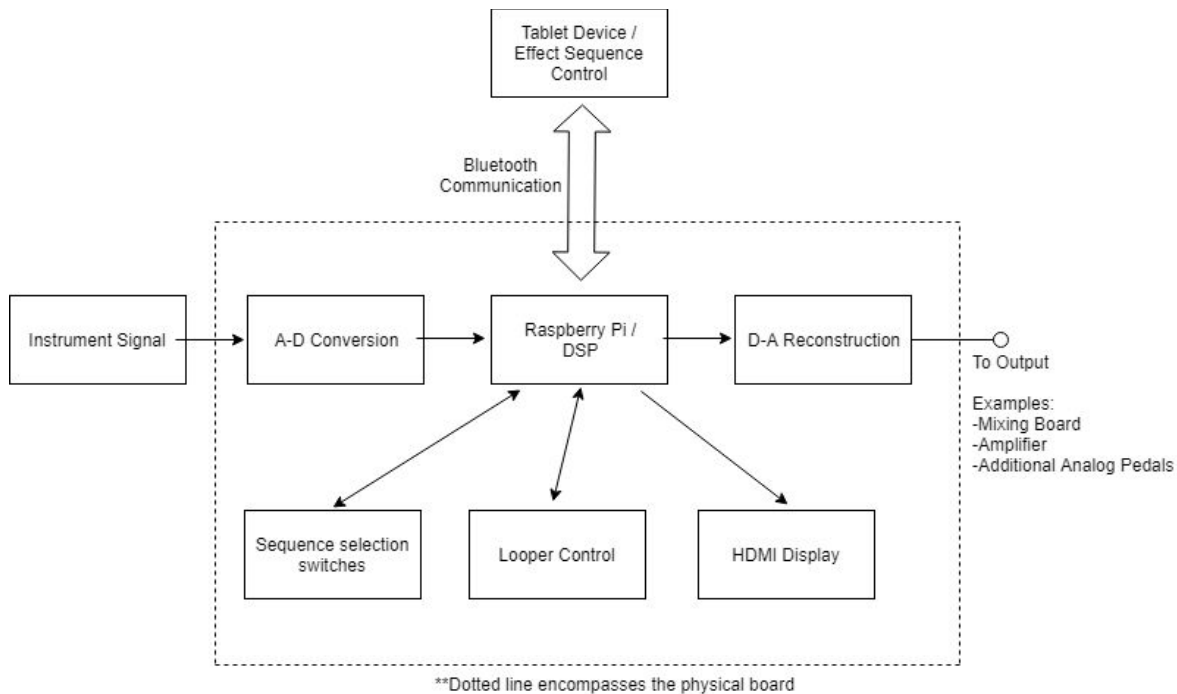


Figure 4: A high-level diagram of our sequencing board system

The goal of this project was 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 designed, we are able to incorporate a multitude of effects housed in a digital library on a microcontroller. Using a GUI, the user is 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 utilizes 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 is intuitive enough so anyone can make changes to their effects. The application also gives a visual representation of the configuration. Another strength of the board is its durability. The board is 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 and take inspiration from. These factors saved us time in development by not having to create each effect from scratch.

2.8 Challenges

During our time designing and building our pedalboard, we came across a multitude of obstacles. The largest challenge we faced was maintaining signal integrity. We wanted to make sure our ADC was converting the signal at a high enough resolution and frequency to preserve sound quality and avoid aliasing. To accomplish this, we utilized a higher-resolution ADC, but this choice came with its own set of constraints. The serial input that the Raspberry Pi can utilize to accept the signal has an upper limit, so we have to account for delays in accepting, processing, and outputting the signal. Using some optimizations, as well as ensuring the ADC and DAC can run freely of each other, the delay in total processing time was 56 microseconds, small enough that it would not be noticeable to the human ear, which is sufficient for our use.

Related to ADC signal integrity, another challenge we had to deal with was maintaining proper signal integrity when processing the signals, namely when summing and outputting the signals. For summing signals, we found that converting the signal to have a reference value of 0 (rather than 2048, since it is a 12-bit digital signal), summing and averaging the signals, then adding back the reference signal (2048) would suffice for this purpose. One downside to this entire design is that frequency cannot easily be maintained when accounting for drops in processing speed, which can occur by either the Pi itself, the ADC, or the DAC. These drops can cause minor fluctuations in frequency, but only occur when heavy summing is used (such as in loopers), and therefore do not pose a significant issue to our design.

Fabrication of the board as a whole also proved to be a major challenge, as creating and fabrication of a circuit board, as well as the display, foot-switches, and other such components, is something none of us had any experience in. Learning to use Solidworks required a fairly large time investment, which was important in getting the top panel milled out to create a clean

looking final product. Creating an innovative UI was also a challenge for similar reasons, as it required a lot of research into UX design in order to come up with a intuitive design.

2.9 Safety Considerations and Risk Management

There aren't many safety concerns we needed to worry about with this project besides making sure all the wiring and circuitry is done properly in the pedalboard. We took 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 (typically 250 mVpp). We have considered many different potential issues, and decided there is very little safety risk involved.

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.

2.10 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 does not degrade a signal beyond an acceptable level for a live performance is a subjective measurement.

2.11 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.

Data conversion will be tested on an oscilloscope and verify multiple stages of the complete circuit. Figure 5 shows the input signal to the ADC and also the output signal of the DAC after a low-pass filter. Filter designs were simulated using ADS and can be seen below in

Figure 6. The amplitude varies due to mismatches in ADC/DAC reference voltages and also the gain of each filter used.

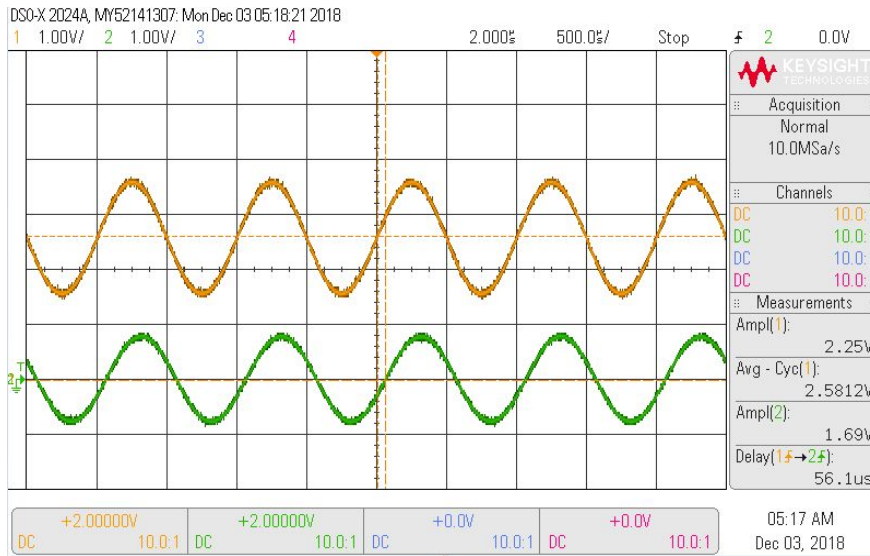


Figure 5: Oscilloscope trace of final testing

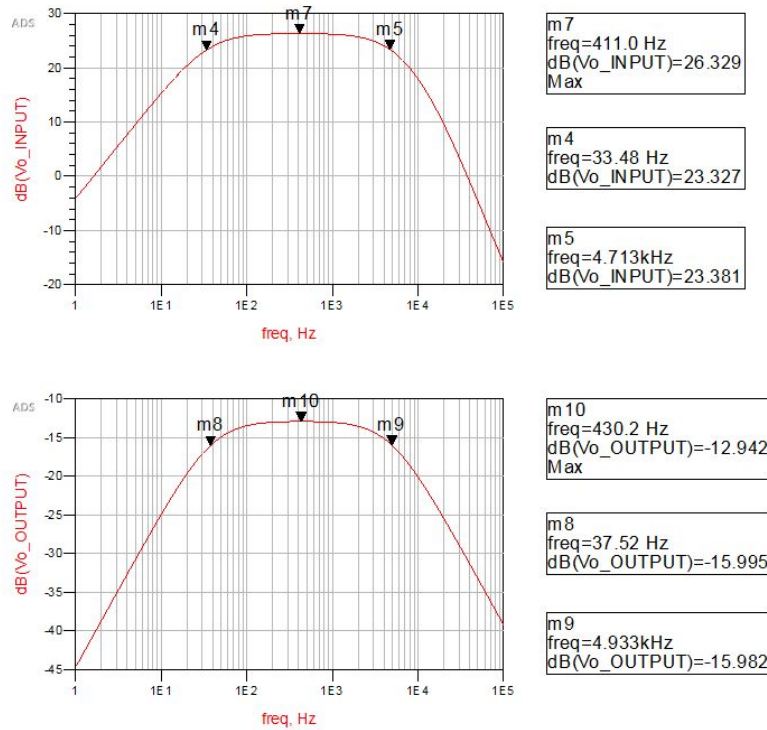


Figure 6: Input and Output filter responses

2.12 Validation and Acceptance Criteria

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. The acceptance criteria for testing the effects is subjective.

The hardware will also be tested to verify that the filter responses attenuate and pass frequencies as expected. This is to be tested with a function generator and oscilloscope, and the acceptance criteria is as follows: The passband should not drop below 1 dB of the desired gain/attenuation factor. Each filter will be tested individually. The output signal will be tested to fall within a reasonable range that a guitar amplifier would typically expect. The amplitude of the output signal should have a value in the range of 200-300 mVpp with an input voltage of 250 mVpp. The acceptance criteria for this test was +/- 50 mVpp. The mass quantity of different volume controls in concert settings allow for a large acceptance criteria in this test.

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 3 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 focused heavily on research, design, and initial prototype building. As we began to meet with our client, we began to set roles and expectations in our group. We

conducted market research to be aware of similar products to ours and brainstormed what we can improve with our design. We obtained our necessary starting materials, such as the raspberry pi 3 model. We then learned how to effectively implement algorithms for signal manipulation using this microprocessor. We used recordings in .wav files as signals for the initial testing. Once we could create effects with our initial prototype, we began work on our UI application.

SEMESTER 2:

The second semester was dedicated to improving the prototypes for both the board and the UI with cycles of testing and re-design. We focused on the app to make it as refined and intuitive for users as we can, as well as finalizing the functionality of the application as a whole. The final milestone of our project was to plug in a guitar to our pedal board and successfully implement the correct effects in either series or parallel.

3.2 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.	One group member spent an hour 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 was 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 allows a musician to upload up to 8 presets onto the board.	This task took the majority of the second semester to accomplish, between 2 group members. The bluetooth functionality and initial communication was finalized in the last weeks of the first semester, and the effect sequencing was completed a few months into the second semester. Testing took another month to remove many issues.
Circuit Design	This step included designing filters with the desired frequency responses, while adding a bias network at the input and a DC blocking cap to remove the bias at the output. This is due to the ADC and DAC input limitation of being positive values, while typical audio signals oscillate centered at zero. The programming aspect of running the ADC and DAC also took a considerable effort in debugging the bit strings required for proper operation.	The circuit design took the longest. This was worked on for the majority of both semesters and was finalized about 5 weeks prior to the end of the semester. The PCB design included in this step took an additional week to finalize.
Prototype	This is when all the working parts come together. The UI is ready to manipulate the conversions taking place in the Pi.	This task took about 2 weeks to get the parts list and circuit board finalized, and another week to get the board assembled after the parts had all arrived. Testing took

		another few days to verify the prototype worked as intended.
Enclosure	The top panel of the enclosure was designed in Solidworks to be submitted to ETG to be milled in the machine lab. This provided a method for obtaining a final product that would look cleaner and provide a longer lasting solution.	This task took about 3 weeks between learning fundamental Solidworks operations and using woodworking tools to construct the housing

3.3 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.

3.4 Financial Requirements

The total cost of this project was \$550. For the pedalboard construction we require: 11 momentary contact pushbutton switches, 1 LCD display, 1 Raspberry PI 3, 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. For a detailed BOM, please refer to the appendix for a screenshot of the excel sheet. The cost of everything for the final product is just slightly over \$400. Costs of materials for testing and prototyping that are not included in the final product figure, fell around roughly \$150.

Physical Board	Enclosure Hardware - \$50
Hardware Components	PI3 + power supply - \$48 12-bit ADC/DAC/Op-Amp - \$3/each Switches - \$60 Display - \$80 Interconnects - \$25 Circuit Components - \$10 PCB - \$40 + 20\$ shipping
Application	Tablet - \$60
Total Cost	\$402

3.5 IEEE 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 Standard for Wireless Personal Area Networks

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

4.3 Appendices

Appendix I: Operation Manual

1. Setup

To set up the board, have the guitar cord plugged into the jack on the left of the board, and have the amplifier plugged into the jack on the right of the board. Have the Multi Effect Pedal App application installed onto an android device that is bluetooth paired with the internal raspberry pi (one should be provided with the prototype). Plug the black power cord into a wall socket. The display should show a raspberry pi boot screen at this time. Wait until the display shows a simple white screen with a preset name showing.

2. Using the board

Once the board has booted up, the first preset will be loaded. You can now play your instrument utilizing the preset corresponding to the leftmost pushbutton (as graphically shown on the display). You can press any of the 8 pushbuttons to switch to that specific preset. There are additionally 3 looper pushbuttons, in the top-right corner of the board. These buttons, when held down, activate the looping functionality of specific effects, correlating to the first, second, and third layers respectively.

3. Using the Application

Start the application normally. Ensure that the bluetooth is shown to be connected on the home screen.

a. Changing presets via the app

To change presets via the app, tap the “Play” button, then select one of the 8 presets listed to change the preset to. Preset 1 corresponds to the leftmost preset button, while preset 8 corresponds to the rightmost preset button.

b. Creating presets

To create a new preset, press the “Configure” button. In the top left corner, press “New Effect”, then type the name you want the preset to have at the bottom, and hit “Create”. The effect should now be listed in the middle of the app.

c. Editing presets

To edit a preset, tap the preset you want to edit, then press the “Edit” button at the bottom. This will take you to a new activity to edit the preset. By default, three effects will be shown in a row, each set to the “Clean” effect.

Each column refers to one 'layer' of the preset. In the processor, the leftmost column of effect(s) are processed, then summed. The second layer of effects are then processed and summed, using the signal from the first layer (or the origin if it is configured as such). The third layer of effects are processed in a similar fashion, and said output on the third layer is what is outputted to the amplifier. To add or remove effects from a column, press the "add/remove" buttons below the column.

Tap an effect to get a configuration menu on the lower half of the screen. Tap the "Effect" option to switch between the various effects. Each effect has its own set of configurable options, each explained to you in the application itself. The "weight" option sets the weight of that effect against other effects in that column. Make sure at least one effect in the column has a weight of 1 or more, otherwise that column will not produce any sound, and you may not hear anything from the board itself. You can set the effects in the second column to receive a signal from the origin, rather than the default option of from the first column. Likewise, you can set the effects from the third column to receive a signal from the origin, first column, or the second column (default). Hit "done" when you are finished to save your configuration for that specific effect. To save the preset as a whole, press the "Save" button at the top.

d. Uploading/Downloading presets

On the "Configure" screen, tap the "Download" button at the top right to bring up a dialog box. Select the preset from the board you want to download, then press OK. The board will then send the preset to the application, where the application will then store the preset. If a preset on the app matches the name of the preset on the board, the preset will be overwritten.

To upload a preset to the board, select the desired preset and hit "Upload" at the bottom. A dialog box will come up, where you will need to select the preset you want to write to, and hit OK. The preset will then be written to the board. If the current set preset is the same preset as the one you upload, the preset will be reloaded automatically.

Appendix II: Scrapped versions/Ideas

On the application side, one idea that we could have implemented was the ability to upload presets to the application from an external file. The preset files themselves are very human-readable, so getting simple txt files to store the preset would be trivial. However, the idea was scrapped as it did not seem to be very useful, and would have added confusion in having two upload sources, especially when recreating a preset is trivial.

One hardware-side idea that was scrapped was to have a bypass jack, much like many professional boards contain, that ignore the processor entirely and simply pass the guitar signal straight to the amplifier. This was scrapped as it added unneeded complexity to the circuit board, and it was obvious that using a simple "Clean" preset would provide a nearly identical scenario.

One software-side idea that was scrapped was to have the output signal go through an auxiliary output, rather than from a DAC. This was actually implemented early on in order to test the signal processing, and used the PortAudio library to accomplish. This was commented out in

the code once the ADC/DAC was implemented, and ultimately scrapped as a whole once it was unneeded and it was shown that the library is very processor and RAM-intensive.

Appendix III: Code

To view the full source code of both the software and the Android application, a download of the most recent version of our git repository is available at <https://tinyurl.com/ycrmjg9z>.

List of Figures:

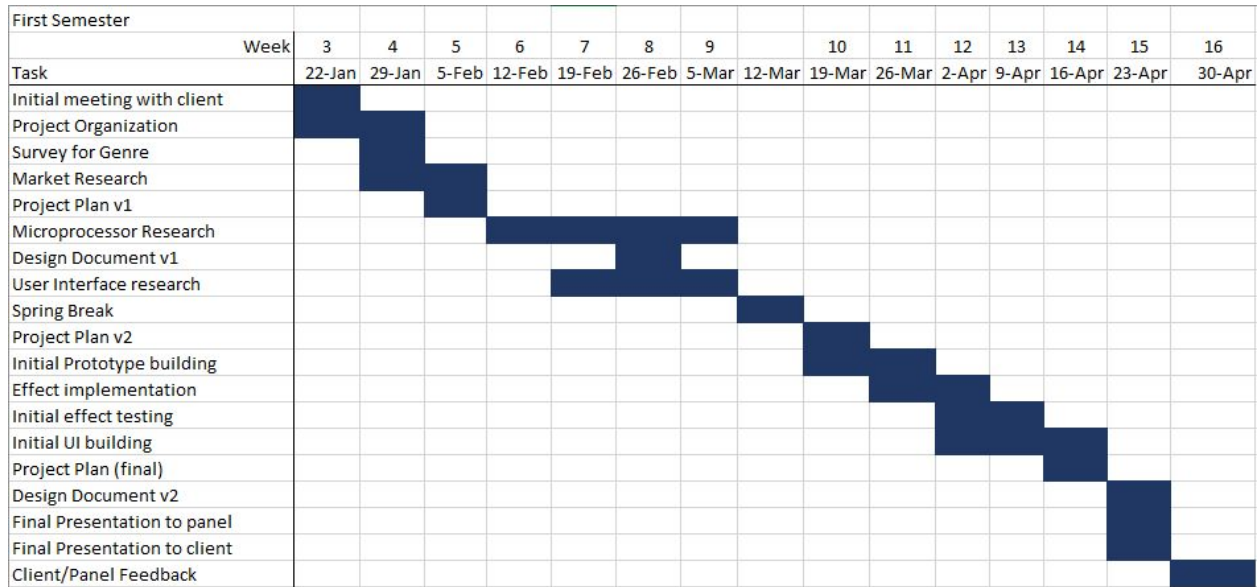


Figure 7: A Gantt chart detailing our project schedule for the scope of 491 (first semester)

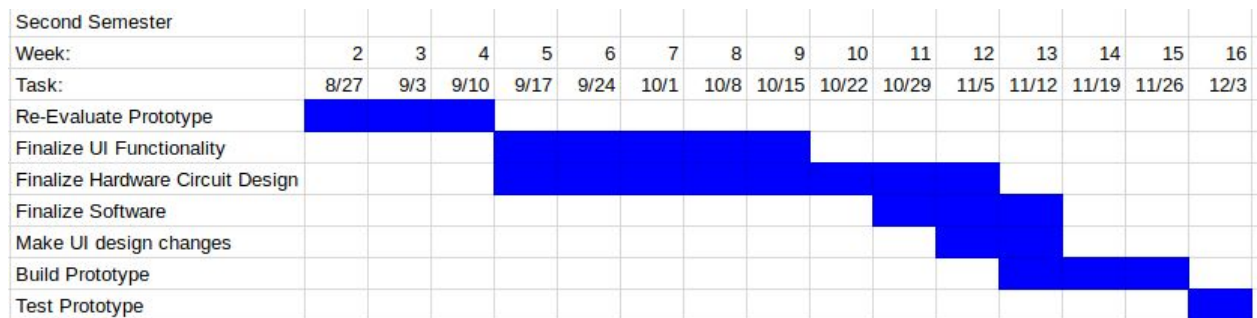


Figure 8: A Gantt chart detailing our project schedule for the scope of 492 (second semester)

	A	B	C	D	E	F	G
1	Link	Digikey #	Description	Quantity	Schematic	Cost/unit	Net cost
2							
3	https://www.adafruit.com/product/285	N/A	40 pin Pi Shield	1		20	20
4	https://www.adafruit.com/product/109	N/A	Power Supply	1		15	15
5	https://www.adafruit.com/product/109	N/A	Power barrel to micro USB adapt	1		2	2
6	https://www.adafruit.com/product/109	N/A	micro USB splitter	1		3	3
7	https://www.adafruit.com/product/109	N/A	7" HDMI display	1		80	80
8	https://www.adafruit.com/product/109	N/A	HDMI Cable	1		4	4
9							
10		** CONNECTORS & SWITCHES **					
11							
12	https://www.digikey.com/product-detail/en/SC2546-ND	SC2546-ND	1/4 " instrument cable jack	4		2.85	11.4
13	https://www.digikey.com/product-detail/en/451-1199-ND	451-1199-ND	foot switch	12		6	72
14	https://www.digikey.com/product-detail/en/WM13944-ND	WM13944-ND	2 pin terminal block .250"	4	J1, J2	1.44	5.76
15	https://www.digikey.com/product-detail/en/ED2583-ND	ED2583-ND	5 Pin terminal block .200"	4	J3, J4	1.37	5.48
16	https://www.digikey.com/product-detail/en/MKC20A-ND	MKC20A-ND	20 pin ribbon cable header	2	J7	1.2	3.6
17	https://www.digikey.com/product-detail/en/3M11932-ND	3M11932-ND	20 pin header socket	2	J7	0.8	3.6
18	https://www.digikey.com/product-detail/en/3M156030-ND	3M156030-ND	10 pin ribbon cable header	2	J5		
19	https://www.digikey.com/product-detail/en/30310-6002HB-ND	30310-6002HB-ND	10 pin header socket	2	J5		
20	https://www.digikey.com/product-detail/en/A27936CT-ND	A27936CT-ND	Quick Connect Crimp	30		0.2	6
21							
22		** ICs **					
23							
24	https://www.digikey.com/product-detail/en/MCP6002-I/P-ND	MCP6002-I/P-ND	MCP6002 Op-Amp	2		0.5	1
25	https://www.digikey.com/product-detail/en/MCP3202-BI/P-ND	MCP3202-BI/P-ND	MCP3202 ADC	2		3	6
26	https://www.digikey.com/product-detail/en/MCP4821-E/P-ND	MCP4821-E/P-ND	MCP4821	2		2.5	5
27	https://www.digikey.com/product-detail/en/AE9986-ND	AE9986-ND	8 pin IC socket	6		0.75	4.5
28							

Figure 9: First half of the BOM

29		** RESISTORS **					
30							
31	Digikey	RNF14FTD10K0CT-ND	10k metal film	30	R11, R12, R13	0.1	3
32	Digikey	1.00MXBK-ND	1 M metal film	6	R1, R2	0.1	0.6
33	Digikey	S4.7KCACT-ND	4.7k 1% 1/4 W Metal film	6	R3, R5	0.1	0.6
34	Digikey	RNF14FTD100KCT-ND	100k 1% 1/4 W metal film	3	R4	0.1	0.3
35	Digikey	S3.3KCACT-ND	3.3k 1% 1/4 W metal film	3	R6	0.1	0.3
36	Digikey	RNMF14FTC33K0CT-ND	33k 1% 1/4 W metal film	3	R9, R10	0.1	0.3
37	Digikey	S680CACT-ND	680 Ohm 1% 1/4 W	3	R7	0.1	0.3
38	Digikey	RNF14FTD100RCT-ND	100 Ohm 1% 1/4 W	3	R8	0.1	0.3
39	Digikey	200XTR-ND	200 Ohm 1% 1/4W	3	(R8)	0.1	0.3
40	Digikey	S300CACT-ND	300 Ohm 1% 1/4 W	3	(R8)	0.1	0.3
41	Digikey	987-1532-ND	500k Trimmer Potentiometer	3	R20	1.5	4.5
42							
43		** CAPACITORS **					
44							
45	Digikey	493-10944-1-ND	1 uF electrolytic 20% 50V	3	C3	0.3	0.9
46	Digikey	493-10942-1-ND	4.7 uF electrolytic 20% 50V	3	C6	0.3	0.9
47	Digikey	493-10359-1-ND	10 uF electrolytic 20% 50V	6	C7, C10	0.4	2.4
48	Digikey	445-8392-ND	6.8nF ceramic 5% .098 pitch	6	C1, C5	0.4	2.4
49	Digikey	399-9867-1-ND	0.1 uF ceramic 5% .100 pitch	9	C2, C8, C11	0.45	4.05
50	Digikey	BC5129-ND	100pF ceramic 5% .098 pitch	3	C4	0.22	0.66
51	Digikey	399-9712-ND	10nF ceramic 5% .098 pitch	3	C9	0.36	1.08

Figure 10: Second half of the BOM