Multi-Effect Sound Pedal Sequencer for Performing Musicians

Project Plan

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

1 Introduction

1.1 Acknowledgement

Considerable contribution to this project was made by our client, 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 Specifications and Analysis

2.1 Proposed Design

We are proposing that the most efficient way to re-configure a sequence of effects that musicians want to use be done via an app, rather than manually changing the order of pedals in use. Our design will include an instrument cable port to plug a guitar straight into it. The input signal will be filtered and offset with a summing op-amp circuit for use with a unipolar ADC, which will communicate with a raspberry Pi 3 via a SPI bus. The Pi will handle all DSP to be done, which is controlled by the Android app. The musician could configure the pedal board to use up to 3 effects in series and 3 effects in parallel in each preset option. Once the signal has been manipulated, it is sent to a DAC through the second SPI channel on the raspberry pi. The DAC will convert the signal back to the analog domain, and from there, the musician can plug in a second instrument cable and route the signal to a typical guitar amplifier. For larger shows, this could also be fed into a mixing panel, prior to being sent to the amplification system of a venue. For user customization, thr GUI will let the user 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 following figures show what the end product is planned to look like:

Figure 1 - The physical board, housing the internal components

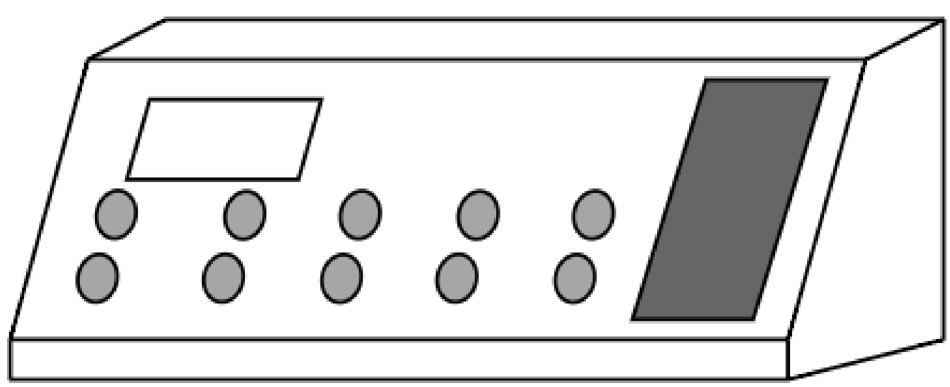


Figure 2 - High level diagram of hardware

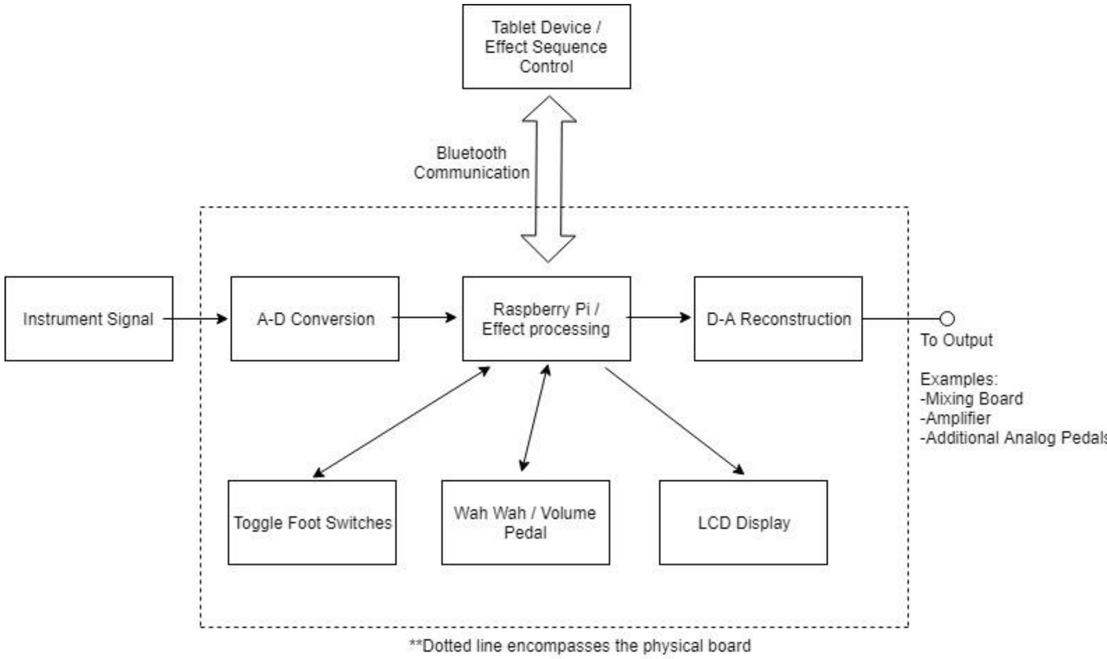


Figure 3 – Conceptual UI for the app

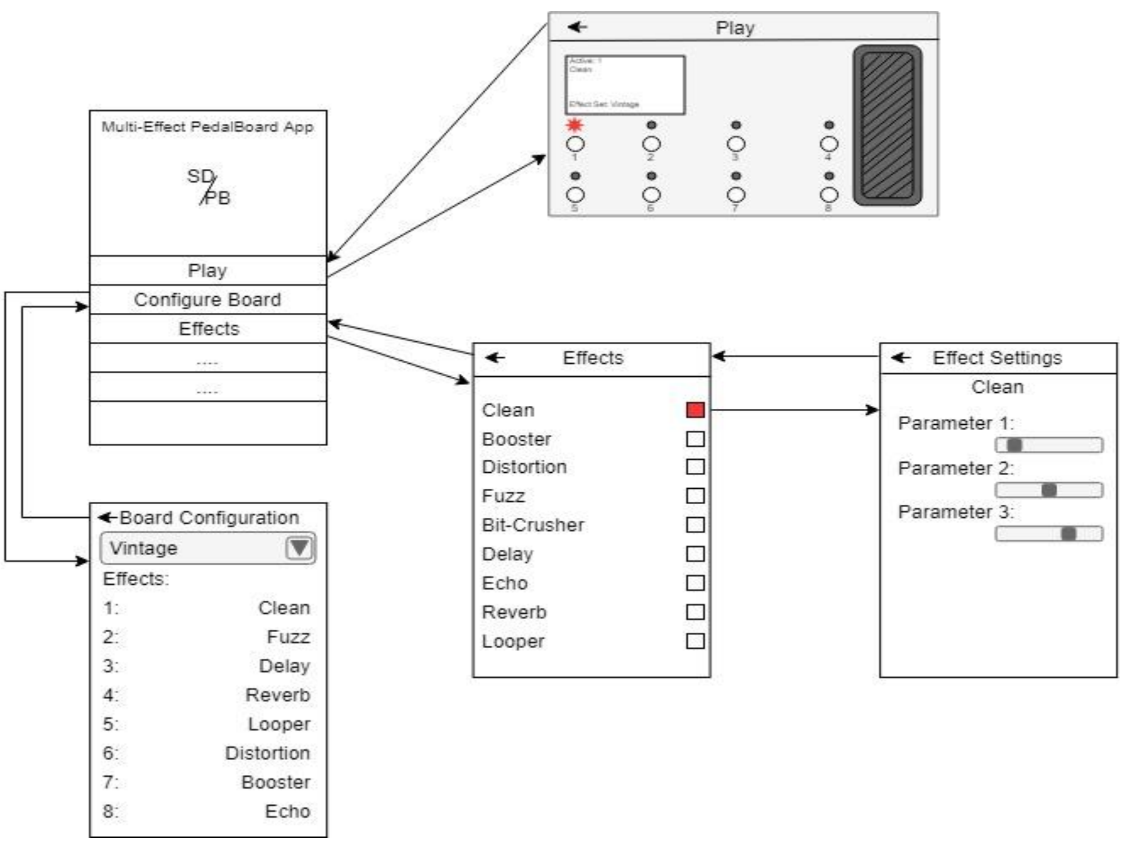
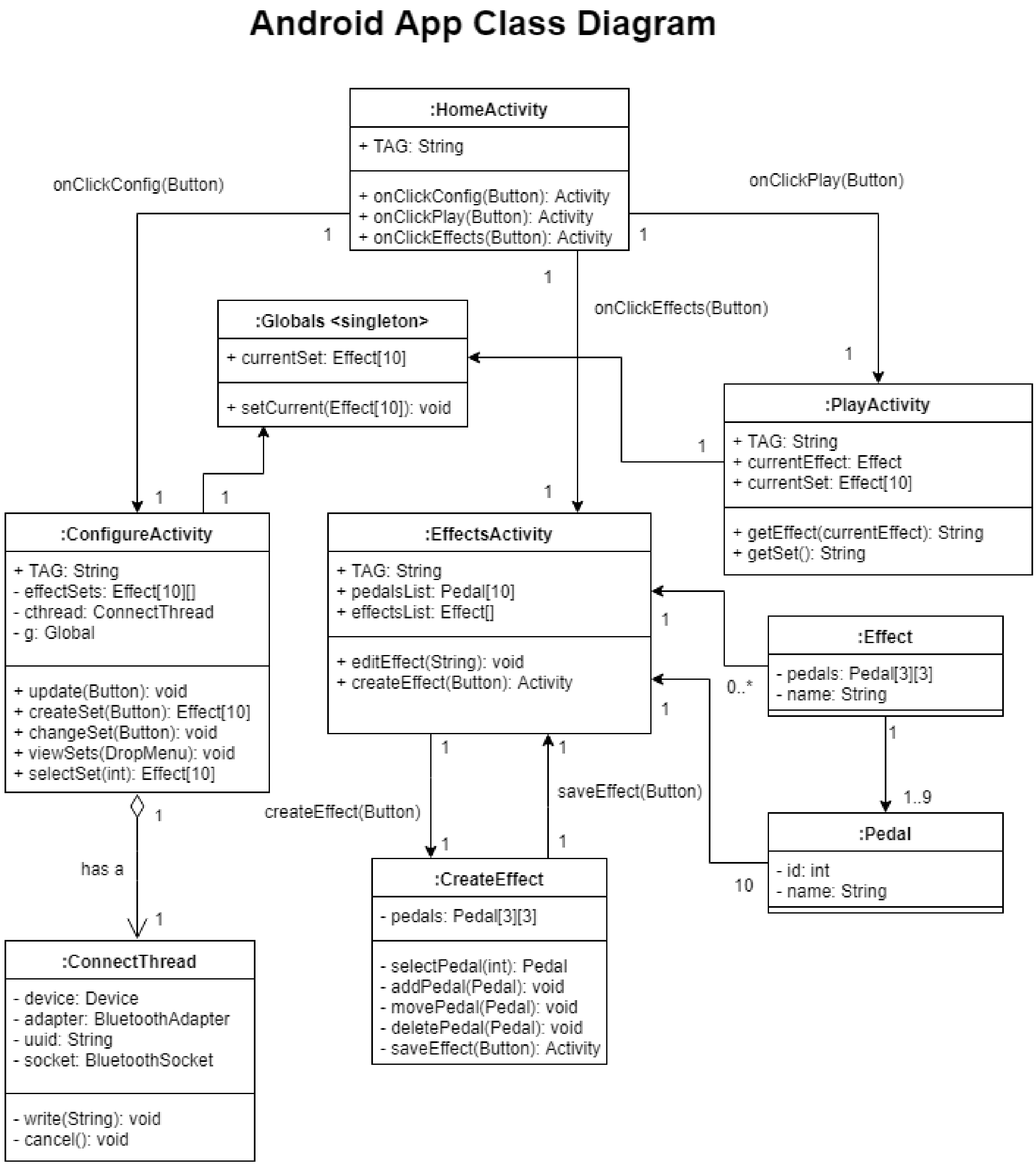


Figure 4 - Class diagram for the app



2.2 Design Analysis

The main differentiator in our design vs what has already been done is the ability to reconfigure the board with an app. Other similar products allow users to create libraries of effects, but in order to change the effect library available on the board, the musician must kneel down and use the interface on the actual board itself, using knobs to navigate between menus. Our board's ability to interact with an application 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. Similar products also cost over five times what we expect our product to cost.

There is a tradeoff in using a digital design with audio signals. The process of digitizing a signal introduces a type of distortion that can be very noticeable if the resolution is not high enough. Many audiophiles swear that analog technology is the *only* acceptable technology in signal processing when it comes to music. However, with rapidly improving technology, digital sampling has come a long way. It is becoming harder and harder to differentiate between analog and digital sound quality. This may be a potential problem with our design, although we are convinced with enough attention to detail and high quality resolution (e.g. making full use of the reference range on the ADC and DAC and choosing a high sample rate), we can produce a sound incredibly close to the analog counterpart.

3 Testing and Implementation

3.1 Interface Specifications

The user interface must include intuitive navigation between pages. Effects should be given obvious names that most guitarists would be familiar with. The communication link between the app and board would need to be done using the android device, which would be the same process as device pairing with any smartphone device.

3.2 Hardware and software

We will be using the Raspberry Pi 3 which will be integrated into the pedalboard to control the effects being used. To control/change these effects produced by the Raspberry Pi, we will have it communicate with an Android app over Bluetooth. The app will have an intuitive design that both hobbyists and professionals can make desired use out of. This app will have a field in which the user can drag and drop specific effects, shown as individual pedals, and specify the order or sequence in which they manipulate the sound signal. Whether the effects are put in sequence and/or in parallel, this design will provide the Raspberry Pi with the ability to create a large range of effects/tones. Software to be used in the design will include extensive C libraries, Python for some of the signal processing, RFCOMM to assist with the bluetooth communication between the app and board.

3.3 Functional Testing

Functional testing will include the implementation of effects onto the raspberry pi, the communication between the pedal board and the app, and the successful manipulation of a live signal in real time. We will test the effects we found for the Raspberry Pi by using WAV file recordings of a guitar and making use of the PortAudio software to stream the output signal through the audio jack on the Pi. Testing the communication between the board and the UI will consist of sending data to the pi to control which effect the WAV file is being processed with. In addition, there are two main functionalities to test with the hardware. We will need to test that the analog signal is reaching the ADC input and that the ADC is digitizing the signal to a binary bitstream to the Pi. The second functionality to test will be the bit stream out of the Pi post-processing and the conversion back to analog. We will set up two separate test benches for these once the small components (resistors, capacitors, etc) have been finalized.

3.4 Non-Functional Testing

Testing for performance will occur intermittently throughout the project. Specific non-functional testing will consist of testing for delay or noise in the input vs output signals and usability of the app. The criteria for these tests are planned to be subjective with no no strict cut off between what determines a success and failure. In general, a high percentage (>90% is ideal) of people should find the app user-friendly and find the resulting sound representative of a guitar.

3.5 Process

The sound signal type we chose to go with is digital and not analog. Digital effects are growing in popularity due to being cheaper and the fact that digital technology has gotten much better in the past few years. Blind tests show that digital effects are nearly indistinguishable from analog. This is our reasoning to this design decision. Using the Raspberry Pi, we plan on first getting the effect libraries to work with a digital signal and make sure the output is correct. Development of the app will be done concurrently with the development of the hardware to ensure they integrate easily and properly instead of forcing one to work with the other since commitment to one design has been made. After we get communication between the Raspberry Pi and the app and can change the active effects on the Raspberry Pi, we will begin integrating the system into a pedalboard which consists of a box frame and switches. These switches will be wired to the Raspberry Pi and indexed to the Pi's effect memory bank in order to change between the effects present on the board at that moment. Testing will be done along the way of course, but after this final prototype step is complete, we will conduct thorough testing throughout the system to ensure system integrity.

3.6 Results

When the project is finished, our plan for analyzing whether we have succeeded or not will be based on extensive, subjective research. The nature of this type of product limits the usefulness of simulations, because signal integrity is the core of this project. While a single cold-solder joint would likely not impact the sound quality, many compounding small factors like a cold-solder joint could affect the resulting signal. We are planning a market analysis with a comparison to analog pedals. Our target surveyees will be performing musicians with extensive experience with analog pedals.The process will include playing through both our device, as well as devices that ours is supposed to model digitally. With those two different setups, surveyees can rate whether or not there is a noticeable difference in sound quality between the analog and digital counterparts. The use of statistic distributions to model success rates would be somewhat irrelevant, as our test is mostly opinion-based. We are striving for roughly 90% of people expressing that our device successfully models the analog counterparts in a concert setting.

We modeled our circuit first on a breadboard. We will eventually move to a PCB for our final prototype. We will be assisted by the ETG in Coover for surface mount soldering. With our breadboard, we have been able to test sound integrity of the output through headphones. One challenge we ran into was audible noise at the output of the circuit. We are researching the cause of this.

A big obstacle to overcome was getting a bluetooth connection running between the Pi and the app. After some research, we found out we needed to use the RFCOMM bluetooth protocol in order to send the correct type of data to the Pi. After some trial and error, we were able to get a connection running which allowed us to send commands to the Pi. Issues following includes losing the bluetooth connection when they orientation of the app on the tablet changed and when the user leaves the "Play" activity. The orientation change killed the current activity process and refreshed it causing the connection to break for a small amount of time. Our plan to solve this two problems with bluetooth connectivity is to turn the bluetooth connection into a service so it can be used across the entire app. This is the next process to undertake in the development in the app.

4 Closing Material

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.

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