Sound Effect Devices for Musicians

DESIGN DOCUMENT

Team Number

39

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1 Introduction

1.1 ACKNOWLEDGEMENT

Dr. Randall Geiger and Dr. Degang Chen have served as technical advisors on this project – they have acted to guide us in direction and pace, and motivated us in our pursuit of understanding of the project's material. Dr. Geiger and Dr. Chen acted to fuel our ambition and turn our curiosities into reality. This acknowledgement is intended to serve as our expression of gratitude to our advisors, without whom project progress would surely suffer.

1.2 PROBLEM AND PROJECT STATEMENT

In the audio amplification world, particularly with respect to electric guitar signal amplification, musicians have historically chosen to use amplifiers driven by vacuum tube technology. Up until around the 1970s, vacuum tubes dominated the audio market, and many of the 'classic' rock albums that listeners hold in high esteem are recordings of vacuum-tube drive amplifiers. The sonic footprint these albums left on the modern musician is considerable, and many guitarists refuse to perform with amplifiers driven by tube alternatives – the dominant alternative being the BJT solid state amplifier – solely because of the 'classic' tones associated with vacuum tubes.

There are significant advantages to utilizing solid state technology for guitar amplification. Solid state devices are significantly more power efficient than vacuum tubes, and the physical footprint of BJTs are magnitudes of order less than that of vacuum tubes. Additionally, solid state technology is far more resilient to abuse – both physical and electrical – than tubes. Perhaps most importantly, BJTs are significantly less expensive than vacuum tubes.

Despite the advances made in BJT technology (in efforts to model the tube amplifier) and the considerable financial benefit to producing solid state amplifiers on a commercial scale, solid state technology still, for the most part, is undervalued to vacuum tubes amongst professional musicians. The team believes this is largely due to a failure to properly address the sonic aesthetics surrounding vacuum tube amplifiers.

The team believes that, if the key musical parameters around the tube amplifier are quantitatively observed, a tube 'effect' can be modelled and reproduced. In the proposed solution, the team designs an emulator that can impose vacuum tube amplifier characteristics onto the incoming guitar signal. The solution offers an all-in-one module that addresses the tone demands of guitarists while maintaining a comparatively less convoluted and expensive package compared to the boutique vacuum tube amplifier.

1.3 OPERATIONAL ENVIROMENT

The vacuum tube emulator will be built to survive in the often harsh environment musicians (particularly performing musicians) use their equipment in. Often, musicians play in adverse weather conditions, necessitating that the emulator be reasonably water and dust resistant. Additionally, as the emulator will operate at nontrivial voltages (~9V) and currents (~300mA), sufficient low impedance ties from chassis ground to earth ground will be engineered to avoid any shock risk to users, as well as to protect the module from ESD. The operating environment information is necessary in order to design an end product that can withstand the hazards that the device is expected to encounter.

1.4 INTENDED USERS AND INTENDED USES

Users

The intended users would be avid musicians that either do not have or do not want to spend the money for a $1000+ amplifier, but instead are looking for affordable and high quality emulator to be used in conjunction with a standard amplifier. Users want the sound quality of tube amplifier, without the cost. The proposed type of emulator could be used in conjunction with most any instrument, but would be mostly designed for and marketed towards electric guitars, as the teams' musical connections and experience is in the guitar domain.

Uses

The emulator would be intended for use with an external power amplifier, addressing both the tonal and power demands of the user.

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions

The emulator will be used in conjunction with any amplifier, and will maintain quality even hours into use. The input is to be a TRS monophonic audio jack, and ¼" jack output TRS to the desired amplifier.

Limitations

The emulator is not operated in temperatures outside of -30 to 50 degrees Celsius. Additionally, the device cannot be operated in excessively wet conditions. The cost will not exceed $500.

1.6 EXPECTED END PRODUCT AND OTHER DEVIVERABLES

Emulator

The finished emulator will include a microcontroller to run all algorithmic processes. The device will all be packaged in a painted and decaled aluminum enclosure. The enclosure will have all of the necessary adjustment knobs and switches mounted on the top panel for ease of access. A female ¼'' jack on the left panel will be designated for the input signal, and a female ¼'' jack, mounted on the right panel of the enclosure will be provided for the output signal of the emulator.

9V Power Supply

The package will also include a 3rd party 9V power supply for driving the emulator. The product is designed around the parameters of the power supply included. Consequently, the team encourages users to use the power supply included, as the electronics will be designed to operate around the supply voltage, current, noise rejection, and grounding parameters surrounding the supply.

User Manual

A user's manual shall be included with the package. The manual will cover topics such as emulator set up, proper use of the device, instructions of how to adjust parameters of the emulator, limitations of the device, device safety, etc. The manual will be cleanly illustrated, delivered in small form factor, as it is intended to be carried along with the emulator for troubleshooting and tuning purposes.

2 Specifications and Analysis

2.1 PROPOSED DESIGN

The team intends to develop a device that emulates the non-linear characteristics of a vacuum tube amplifier. The device is intended to serve as a processing tool for instruments. The device will combine the use of an ADC, microcontroller, and circuit to achieve the desired tube emulation. Additionally, the module will have a user interface that provides basic shaping controls that musicians are used to (bass, treble, etc.).

Functional Requirements

- On-board implementation of tube emulator model (DSP)
- Ability to drive a passive loudspeaker (power amplification stage)
- User controls for tube emulator parameters
- On/Off switching capability

Non-Functional Requirements

- Small, portable device
- Ease of setup, use, and tear down
- Maximum cost of $500.

2.2 DESIGN ANALYSIS

Overview

The most important requirement of the project is the device's ability to emulate a tube amplifier. This is currently the main focus of the team, as all other aspects of the project depend on the tube amplification. Thus far, the team has done multiple tests on two amplifiers: both a solid state and a vacuum tube amplifier. The tests consist of acquiring coherently sampled data from amplifier outputs and instrument inputs. The data was then processed in software to perform a frequency-domain analysis. The frequency responses of the two types of amplifiers are instrumental in developing model parameters for the emulator. Further detail on what testing has been performed can be found in the results section. Once sufficient data is collected, the team will begin designing the emulator profile in software.

Methodology Assessment

The overall methods of this design process can be broken down into several categories of technical overviews, each with their own strengths and weakness:

1. Frequency-Domain Analysis
   The underlying strength of acquiring spectral response of amplifier data is that the inherent differences between the two types of devices is more easily observed. However, relying on developing an emulator that operates on spectral data is impractical because of difficulties

associated with implementing a real-time FFT based program.

2. Transient Analysis
   Transient based analyses of audio devices make it difficult to distinguish behavioral differences. However, if a robust method can be obtained, it is easier to implement this method in real-time processing program.

3. Method for Data Recording
   In the current environment, a 24bit, 192ksps ADC is being used to acquire amplifier data. These are excellent specifications for capturing all relevant frequency components for audio signals. However, once the measurements are converted into digital data, they must be compressed using the mp3 format. This results in some degradation in effective resolution due to the fact that the mp3 format is a lossy compression.

2.3 INTERFACE SPECIFICATIONS

The interface for this device is intended to mimic the typical interface for a guitar amplifier. The user will have easy access to several knobs that control the basic wave-shaping parameters. The device will also offer a basic ON/OFF toggle switch.

3 Testing and Implementation

3.1 HARDWARE AND SOFTWARE

Testing Hardware

The testing environment the team used was the Fender Super Champ x2 tube amplifier and Fender Champion 100watt solid state amplifier. Additionally, the team used a Fender Telecaster electric guitar, oscilloscopes, MATLAB software, in order to take recordings and analyze sound waves in a quantitative way.

Testing Software

MATLAB will be used for the analysis of signals such as the output waveforms of tube amplifiers, solid state amplifiers, and normalizing input waveforms. Specifically, the team will apply Fourier analysis and coherent sampling to analyze the spectral response of said devices. Additionally, transient analyses will be used to ensure no unexpected distortion is created through the tube emulation device.

Device Hardware

The device will revolve around a typical read/modify/write DSP system. The system includes the use of audio ADC, a microcontroller (suitable for audio applications) and an audio DAC.

Device Modeling Software

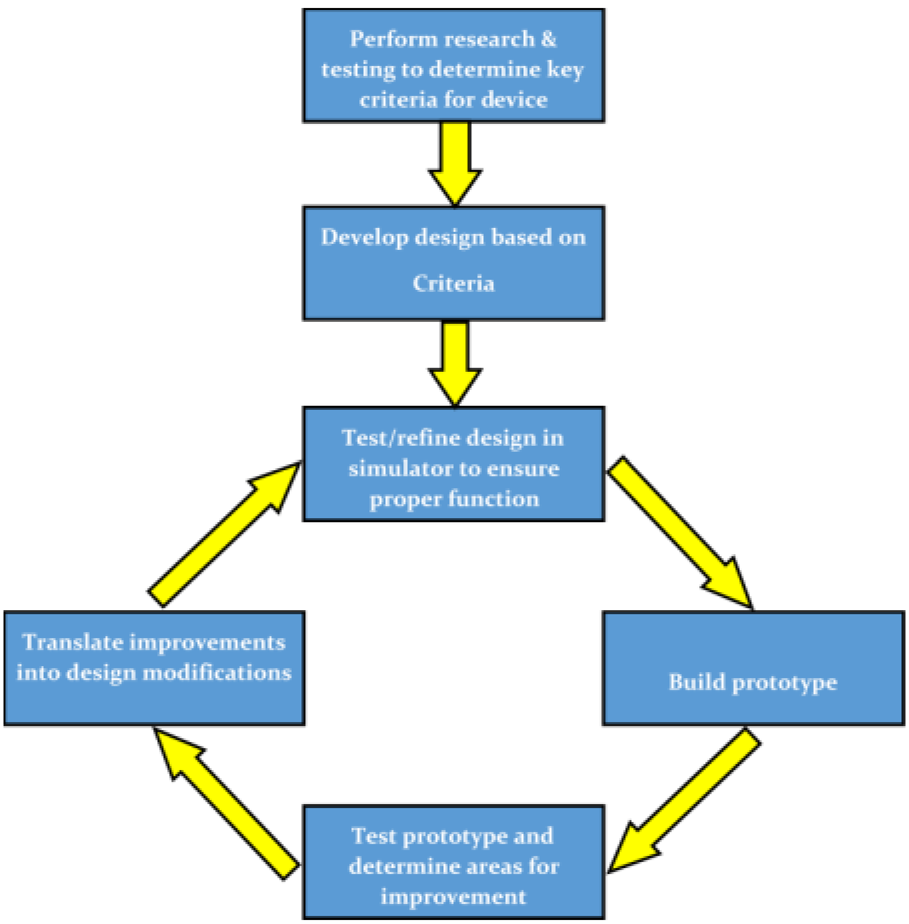
A language for embedded systems, specifically C, will be used to develop the tube emulator profile. The project requires the use of C because of the hardware implementation requirements.

Traditionally, it is easier to develop audio processing software in object oriented languages such as C++. However, starting the development in an embedded language saves time exporting the code to a microcontroller.

3.2 TESTING PROCESS

So far the team has begun testing to determine the key characteristics of the coveted vacuum tube sound. The testing is further detailed in the results section. A diagram is included below of the design process to be used. The team is currently in the top two sections of the process: researching to determine key criteria and developing design based on criteria.

Figure 1: Flow Chart of Overall Process



3.3 NON-FUNCTIONAL TESTING

The emulator will need to be evaluated for its usability and ease of changing parameters. The testing will likely be accomplished by having a set of professional musicians try the product and give feedback on aspects that are undesirable. Additionally, as the emulator profile is being made the team will use a test bench to evaluate performance aspects.

3.4 RESULTS

Test 1

The first test we took was to recording output from amplifier on microphone then pass sound wave through MATLAB. The team calculated the frequency domain and analyzed dominant frequencies. The test was less than ideal and highly inaccurate due to the quality of recording and setup, however the team found necessary improvements in data retrieval and analyze was needed.

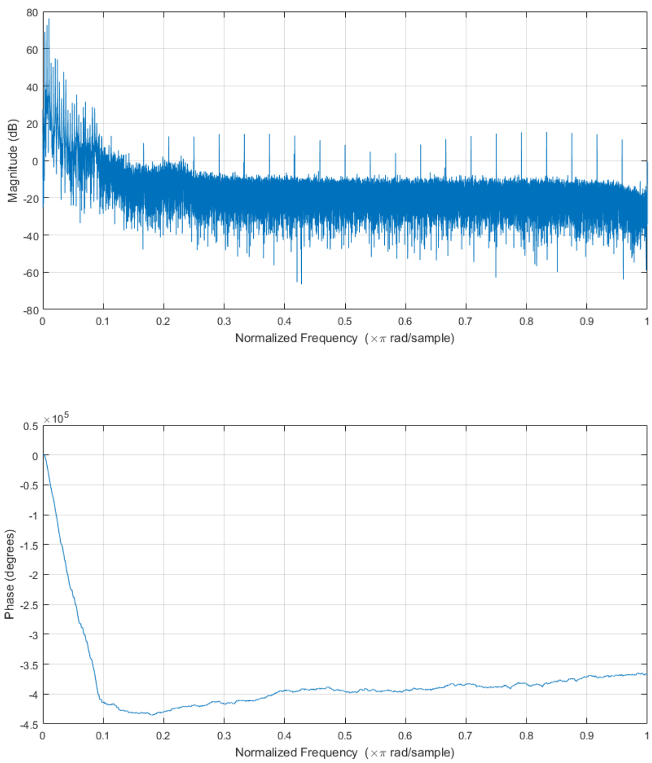


Figure 2: results from Test 1 frequency domain of A4 note on guitar

Test 2

The second major test the team took was pulling directly from amplifier power and wiring waveform to oscilloscope then saving file and revaluating results on MATLAB. The test was much more consistent than the first but still inaccurate due to oscilloscope sample size being only 8 bit (or 12 effective bits with oversampling). The team was able to find what was needed to do to make the test environment better and that it was necessary to purchase some equipment to do so. Specifically a 24 bit 196 kHz 4 channel recorder and an ABC - Y splitter in order to get samples on all speakers and record them simultaneously.

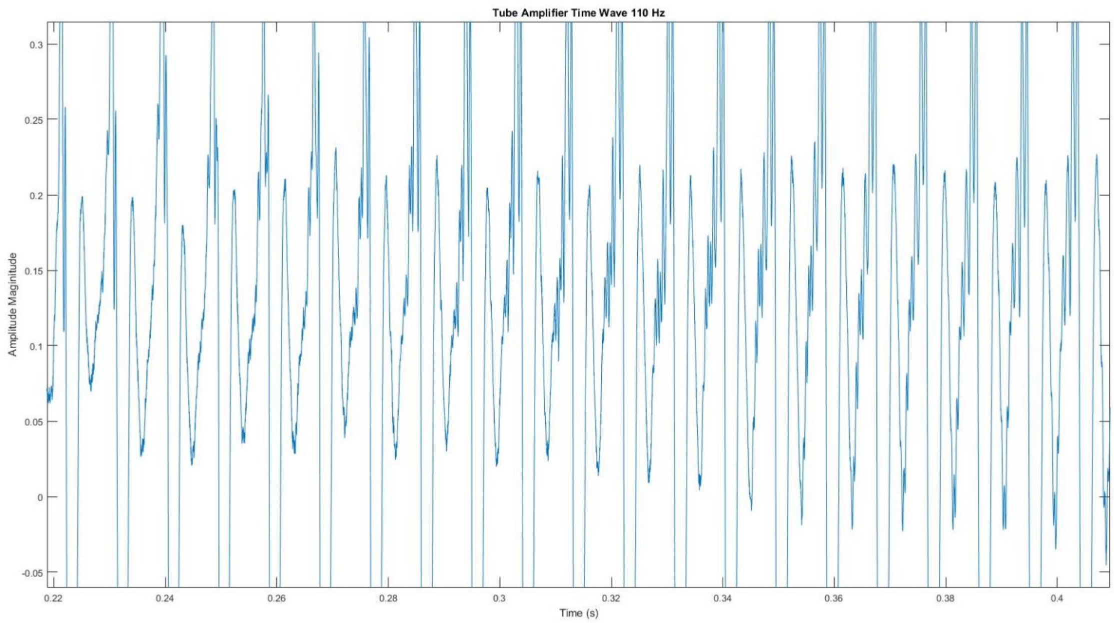


Figure 3: Soundwave from Oscilloscope in MATLAB Time Domain

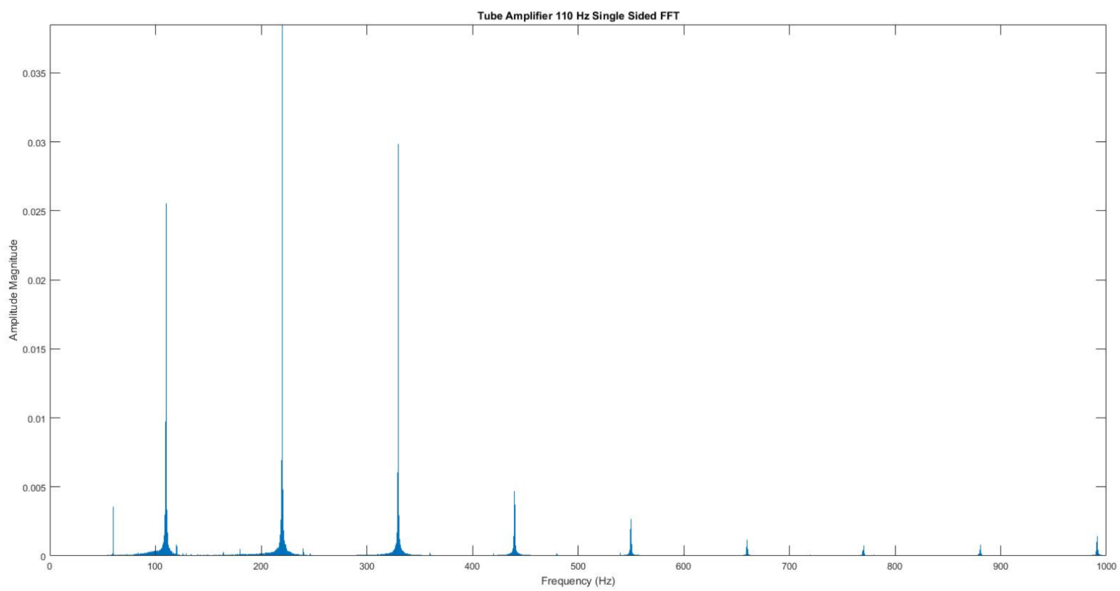


Figure 3: Soundwave from Oscilloscope in MATLAB Frequency Domain

3.5 ISSUES AND CHALLENGES

Many issues have come up and been reconciled while other issues have recently been revealed and now will be challenges for the project in the future. One issue that has already been resolved is the need for a better understanding of spectral responses and their interpretation and accurate create. One challenge that still needs to be reconciled is an algorithm that using actual results and modulates it to become desired value. Another issue is real time device, because the team's goal is to use it in audio application, the team will try to find a way to evaluate input modulate it and output sound to a passive speaker all in a timespan that will be unnoticeable to the user.

4 Closing Material

4.1 CONCLUSION

The proposed emulator attempts to construct an audio profile that meets the demands of professional musicians, without compromising on cost or ease of use. The design includes quantifying and reconstructing the positive textures surrounding vacuum tube amplification, on a modular small signal platform (pre-gain). The versatility of the platform allow the product to operate as universal when it comes to user-defined tube emulation, negating the need for musician to spend thousands of dollars on top of the line equipment, whose greatest advantage is the use of archaic technology.

4.2 REFERENCES

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