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 listeners hold in high esteem, are recordings of vacuum-tube drive amplifiers. The sonic footprint these albums left on the modern musician is considerable - many guitarists refuse to play with amplifiers driven by tube alternatives – the dominant alternative is 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 in magnitudes or 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 leaps and bounds made in BJT technology (in efforts to model the tube amp), and despite the considerable financial benefit to producing solid state amplifiers on a commercial scale, solid state technology still, for the most part, plays second fiddle to vacuum tubes among professional musicians. We believe this is large due to a failure to properly address the sonic aesthetics surrounding vacuum tube amplifiers.

We believe that, if the key musical parameters around the tube amplifier are quantitatively observed, a tube 'effect' can be digitally or analog-ly generated and superimposed onto the signal entering any run-of-the-mill amplifier (solid state, or otherwise). This effects module, along with generating the tube tone, could incorporate other desirable effects such as overdrive, reverb, tremolo, etc. In our proposed solution, we have a small form factor effects module that can superimpose desired effects onto the incoming signal, and then overlay the tube sonic qualities onto the signal prior to output into any amplifier-speaker system. This 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 a boutique vacuum tube amplifier and effects pedalboard rig.

1.3 OPERATIONAL ENVIROMENT

Our effects module 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 module be reasonably water and dust resistant. In a live performance, the guitarist rarely has a free hand to adjust effects parameters - this means that most effects modules have large knobs and buttons that can be operated with one's foot. Some

guitarists will simply put their full weight into compressing and decompressing a switch, thus the module must be encased in a durable enclosure (optimally aluminum) that can withstand ~200lbs/in2 of pressure. Additionally, as the module 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. – This information is necessary in order to design an end product that can withstand the hazards that it is expected to encounter.

1.4 INTENDED USERS AND USES

The intended users would be avid musicians that do not have/ don't want to spend the money for a $1000 + amp but instead a couple hundred dollar amp. They would want the sound quality of tube amplifier, without the cost. These could be most any instrument but would be mostly directed toward strings instruments as our connections and experience is in string instruments.

The effects module would be used in conjunction with an amplifier. The outcome would be to produce a higher quality more smooth sounding output from the effects module that sounds like a tube amplifier. Also the effects module would have a few other effects that can be selected and adjusted.

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions

Will be used in conjunction with any amplifier maintains quality even hours into use. Input would be a TRS monophonic audio jack, or ¼" jack (TRS for short) outputs TRS to an amplifier. Single input and output from device. If applicable only language available is English.

Limitations

Is not operated in temperature outside -30 - 50 degrees Celsius. Cannot be operated in very wet conditions. Cost doesn't exceed $200. Minimal tests were run on wind and percussion, and brass instruments.

1.6 EXPECTED END PRODUCT AND DELIVERABLES

The finished effects module will include several analog effects circuits along with a microcontroller to run all digital effects. This will all be packaged in an painted and decaled aluminum enclosure. This enclosure will have all of 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 signal out of the module.

9V Power supply: to be delivered April 2018

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

User Manual: to be delivered April 2018

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

2. Specifications and Analysis

2.1 PROPOSED DESIGN

The team is implementing a modular device to emulate the effects of a tube amplifier. The device is meant to be an intermediate device between the source signal and an amplifier. The device will combine the use of an ADC, microcontroller, and circuit to achieve the desired tube emulation. Additionally, the module should have a user interface to not only activate the emulation but also control the strength of emulation to the signal.

Functional Requirements:

- On/Off switch
- Emulation strength control
- True bypass while in the off state
- Tube emulation signal response while in the on state

Non-Functional Requirements:

- Small, portable device
- Ease of setup, use, and tear down
- $50 maximum BOM

2.2 DESIGN ANALYSIS

The most important requirement of our project is our device's ability to emulate a tube amplifier. This is currently the main focus of our team, as all other aspects of the project hinge on the tube amplification. Thus far, our team has done multiple tests on two amplifiers: both a solid state and a vacuum tube amplifier. The two spectral responses of the amplifiers are important in assigning technical definitions of what constitutes the "warm" sound that musicians seek. Further detail on what testing has been performed can be found in the results section. This proposed solution is good but in order to start specific design details we need more testing results

3 Testing and Implementation

3.1 INTERFACE SPECIFICATIONS

Software

Matlab analysis of signals will be used to analyze the output waves of a tube amplifier and the output of module device. Specifically, the team will use a Fourier transform analysis to ensure

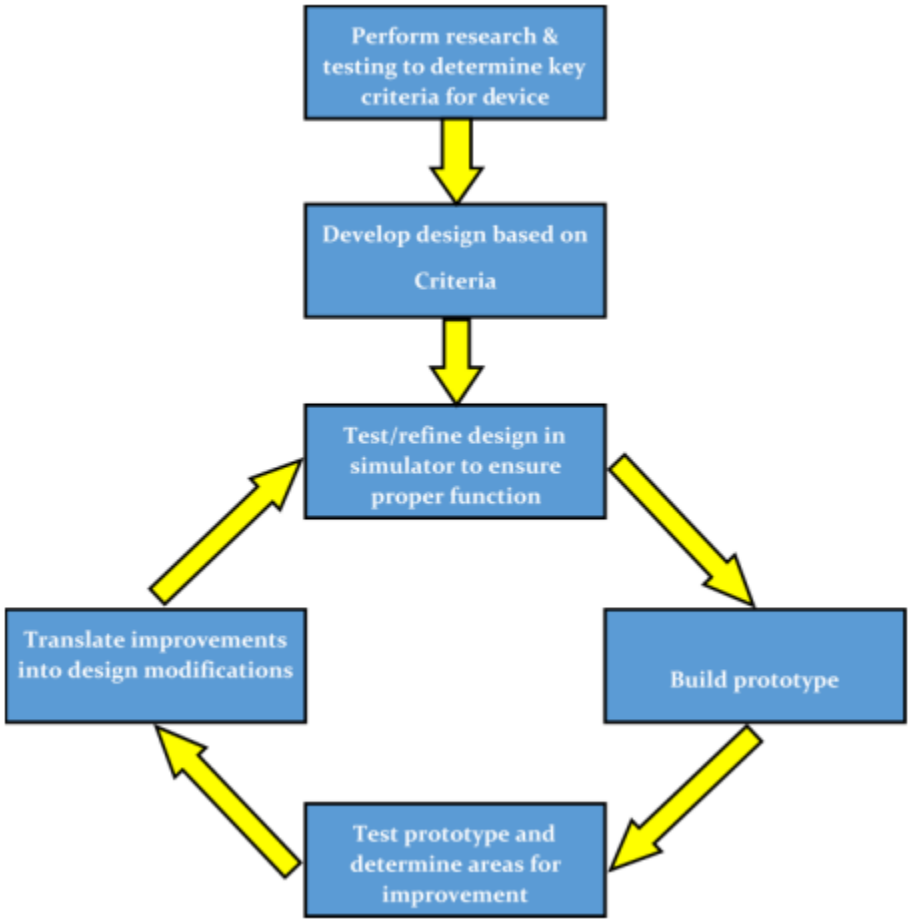
correct frequency response. Additionally, a time analysis will be used to ensure no unexpected distortion is created through the tube emulation device.

3.2 HARDWARE AND SOFTWARE

For our testing environment we used the Fender super champ x2 tube amplifier and fender champion 100watt solid state amplifier. We also used a fender telecaster electric guitar, oscilloscopes, Matlab software, in order to take recordings and analyze sound waves in a quantitative way.

3.3 PROCESS

So far our group 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 our design process to be used. Our group is currently in the top two sections of the process: researching to determine key criteria and developing design based on criteria.



3.4 RESULTS

Test 1

Our first test we took was to recording output from amplifier on microphone then pass sound wave through Matlab. We then got the frequency domain and analyzed dominant frequencies. This test was less than ideal and highly inaccurate due to the quality of recording and setup. We did find some things to improve on

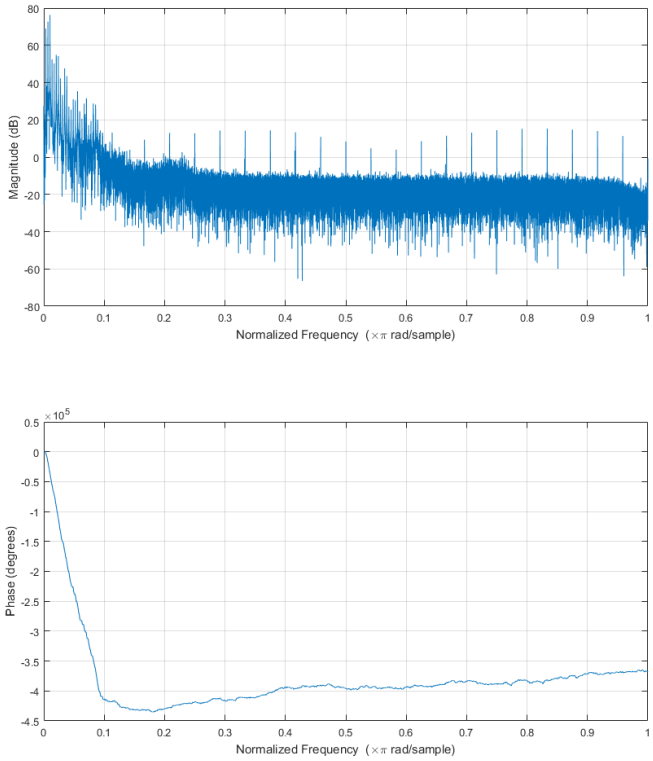


Figure 1: results from test 1 frequency domain of A4 note on guitar

Test 2

The major test we took was pulling directly from amplifier power and wiring waveform to oscilloscope then saving file and revaluating results on Matlab. This 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). We were able to find what we needed to do to make the test environment better and that we would need 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.

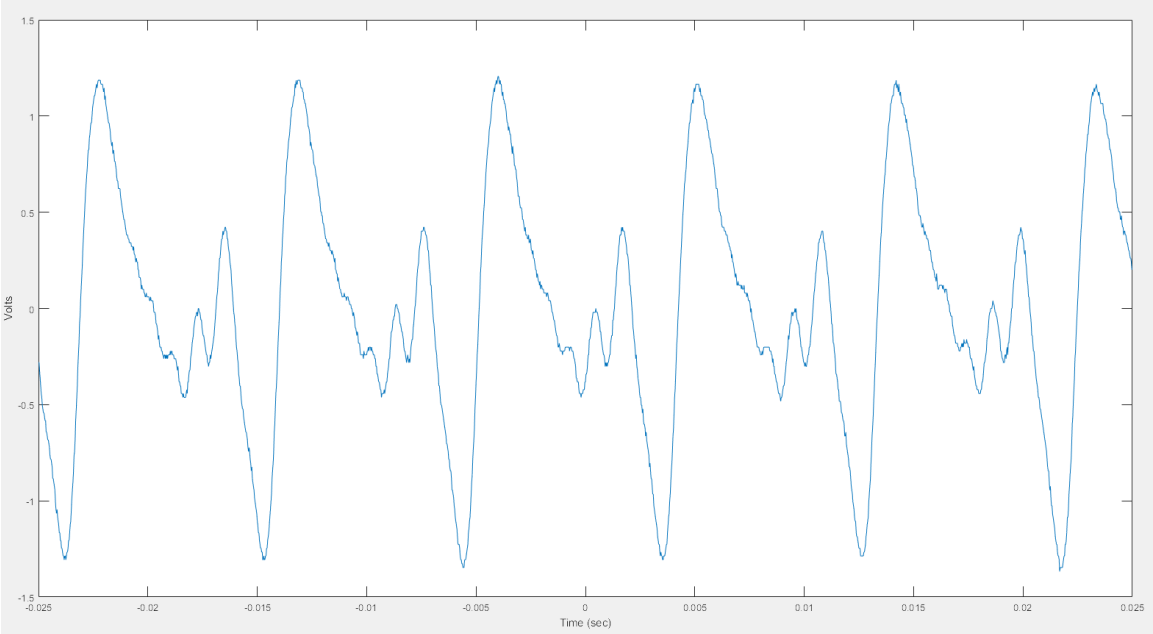


Figure 2: soundwave from oscilloscope in matlab time domain

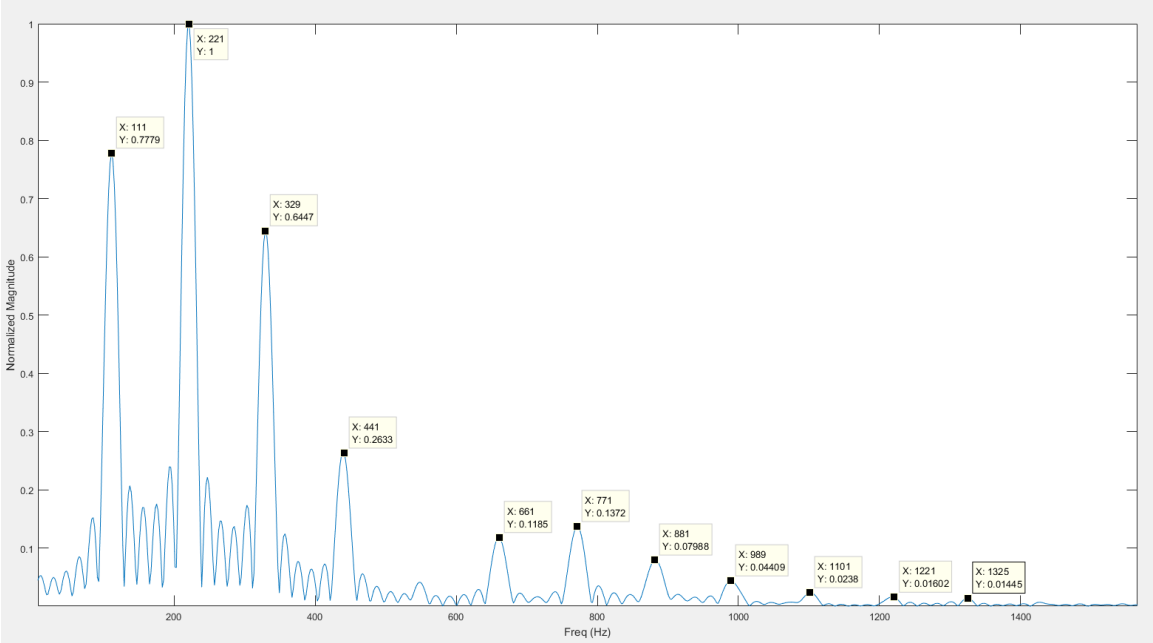


Figure 3: soundwave from oscilloscope in matlab frequency domain

4 Closing Material

4.1 CONCLUSION

With this effects module, we attempt to construct an audio profile that meets the demands of professional musicians, without compromising on cost or ease of use. This includes quantifying and reconstructing the positive textures surrounding vacuum tube amplification, on a modular small signal platform (pre-gain). Given the hardware required to meet this initial task, it simply makes sense to incorporate other effects in our module, such as distortion, chorus, and reverb, among other things. The versatility of our platform allow us to operate as the jack-of-all trades when it comes to superimposed guitar effects, 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

Resources from Business insider that deal with differences between tube amplifier and solid state: http://bi.galegroup.com.proxy.lib.iastate.edu/essentials/article/GALE%7CA126763239/dbc5eb41968832faa3ab08e40c201198?u=iastu_main http://bi.galegroup.com.proxy.lib.iastate.edu/essentials/article/GALE%7CA128177466/7b49cf4d 25d959c3f5493ef4e022d791?u=iastu_main

Articles that deal with some patents of similar architecture. This was used to see a sort of jump board off which we can tell where other people are at on developing a tube amplifier emulator: http://patft.uspto.gov/netacgi/nphParser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearchadv.htm&r=9&f=G&l=50&d=PTXT&S1=Korg&OS=Korg&RS=Korg http://patft.uspto.gov/netacgi/nphParser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearchadv.htm&r=5&f=G&l=50&d=PTXT&S1=Korg&OS=Korg&RS=Korg

4.3 APPENDICES