ECE 445 Project Proposal
Lightweight Hybrid Guitar Amplifier

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Motivation

Guitar amplifiers which primarily use vacuum tubes (tube amps) for electronic amplification are desirable to many guitar players because of the way vacuum tubes behave when outside of their linear regimes. However, traditional tube amps that are powerful enough for professional use (usually about 50 Watts) are expensive, heavy, extremely inefficient, and difficult to maintain. These drawbacks are often mediated in lower-priced amplifiers by using "hybrid" designs which feature vacuum tubes in a preamplifier circuit and a pure transistor design for the power amplifier. These designs tend to sound inferior to the amplifiers which use only tubes because the vacuum tube gain stages used in these designs resemble only the first stages of a tube amplifier; there is no tube circuit in those designs which mimic the power amplifier stage of a tube amplifier. The project is to design a hybrid amplifier head which retains the sound of a vacuum tube amplifier, and which is extremely lightweight and efficient. The project will also include a speaker cabinet to go along with the amplifier, which will also be lightweight, with even sound dispersion at several angles of incidence.

1. Introduction

Objectives:

The goal of this design is to create a guitar amplifier head with output power between 35W and 75W, and a matching speaker cabinet with good dispersion characteristics.

The amplifier head will accept a high-impedance audio signal from an electric guitar and amplify it for connection to a speaker cabinet. It will include an entire low-power tube amplifier presented with a resistor load in the preamplifier section, and a solid-state class-D power amplifier for the speaker output, as well as a switching power supply. The preamplifier section will also have controls for gain, equalization, and volume. The speaker cabinet will use lightweight neodymium speakers to convert the electrical energy to acoustic energy, which will disperse in an even way at several angles of incidence and with a frequency response flattering to the guitar sound.

Benefits:

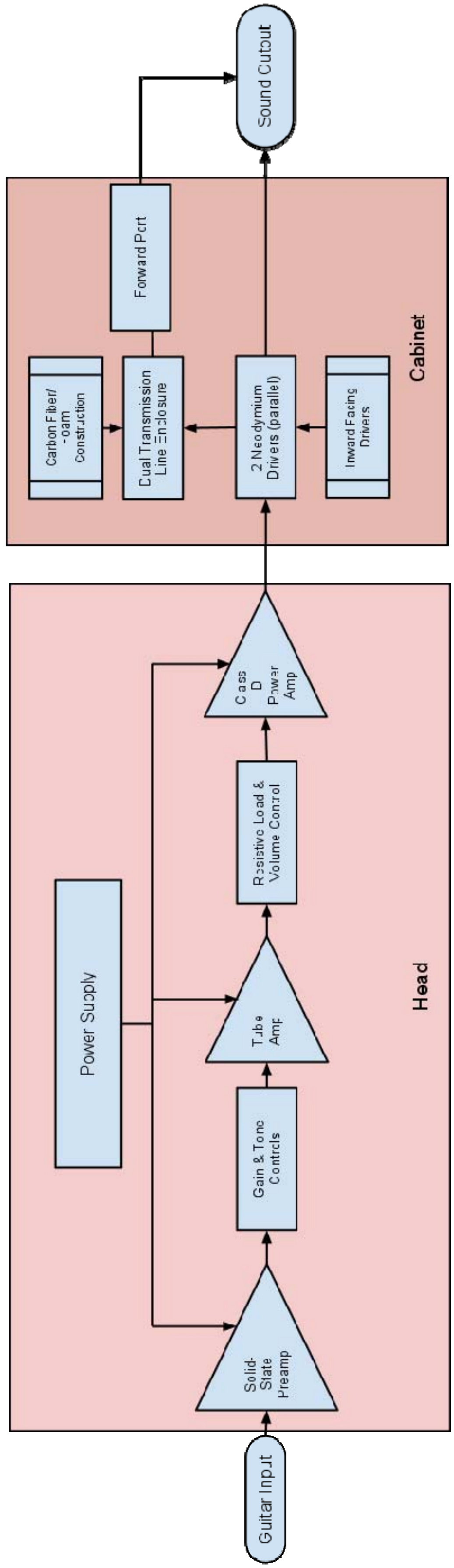
- Improve sound quality over commercially available hybrid amplifier designs
- Reduce weight from conventional tube amplifier designs
- Increase efficiency over conventional tube amplifier designs
- Reduce weight from conventional speaker cabinet designs
- Improve sound dispersion over conventional speaker cabinet designs

Features:

- Versatile "piggyback," "head and cabinet" design
- Controls for amount of distortion, equalization, and volume
- Approximately 50W power output from "head"
- 2 x 10" speaker cabinet

2. Design

Block Diagram:



Block Descriptions:

Head

Power Supply

The power supply accepts power from 120V, 60Hz and using a switching circuit, produces several DC voltage rails to power the rest of the head: +240V for the vacuum tube plate voltage supply, ±18V for the Class-D amplifier, and +12.6V for the tube filaments, logic, and solid state preamp.

Guitar Input

The input signal for the circuit will come from an electric guitar.

Solid-State Preamp

A solid-state preamp circuit using an operational amplifier will present a high impedance to the guitar input signal and ensure that the amplifier has enough gain to drive the tube stages into nonlinear operation.

Gain & Tone Controls

The solid-state preamp will send its output signal to passive bass, middle, and treble tone controls for equalization. A volume potentiometer (labeled "gain") will throw away gain if needed to adjust amount of distortion created in the tube stages.

Tube Amp

Following the gain and tone controls, one 12AT7 vacuum tube (containing two triodes) will be used as an entire tube amp. The first triode will be a common-cathode gain stage, and the second will be a common cathode power amplifier stage, utilizing an output audio transformer. The power output of the power amplifier stage will be about 1 Watt. This block is where distortion may be intentionally created, and the output transformer blocks DC from entering the next stage.

Resistive Load & Volume Control

The tube amplifier will be loaded by a power resistor. A potentiometer and voltage limiting resistor will allow volume adjustment before the class-D power amplifier and prevent driving the class-D power amplifier into distortion.

Class-D Power Amp

A class-D power amplifier, built around a TDA8922B amplifier IC in bridge-tied load configuration, will accept the output from the volume control and amplify it for the speakers.

Cabinet

Neodymium Drivers

Two neodymium drivers will take the signal from the output of the Head and convert this into sound. The neodymium magnets have a larger remanence per square inch than ceramic magnets, thereby allowing for smaller magnets to be used for the same power. Two Jensen Neo 10-100 drivers will be used based on specifications and cost.

Inward Facing Drivers

Each speaker will be directed 17.5 degrees toward the other speaker when looking from above. This will create greater dispersion of sound, especially at higher frequencies where sound beaming is increased.

Dual Transmission Line

Each speaker will have a transmission line enclosure. The enclosure absorbs most of the energy from the back side of the speaker through a tapered port, creating a more clear sound while not adversely loading the drivers as in a sealed cabinet. The length of the port will be ¼ of the resonant wavelength of the driver and will be folded to effectively use space.

Carbon Fiber/Foam Construction

The cabinet will be constructed of a carbon fiber and Kevlar 2x2 twill weave of 3k throw fabric covering rigid insulation foam. This will create a rigid and lightweight cabinet.

Forward Port

The port for the cabinet will vent to the front in phase with the driver, reinforcing the low frequency response of the cabinet.

Sound Output

The audible sound heard by the observer.

Performance Requirements:

- At least 500kΩ input impedance at 1kHz
- Maximum power output from the head at least 35W at 1kHz with less than 1% total harmonic distortion + noise (THD+N) at output of the head when volume set to full and gain set to avoid distortion in tube amplifier
- At least 20% total harmonic distortion at output of the head when presented with 100mV 1kHz input signal, with gain control set to full
- 50W capable drivers
- Capable of withstanding 400 lb load in vertical and horizontal compression
- Minimum of 90 db at 1 meter
- Flat frequency response down to 40Hz with gradual roll off.

3. Verification

Testing Procedure:

1. Test rail voltages produced by power supply with oscilloscope; verify correct voltages within 5%.
2. Apply 1V peak 1kHz sinusoidal input signal through 500kΩ resistor to input of head; verify that voltage at the input exceeds 500mV with oscilloscope to check input impedance.
3. Apply low-impedance 1V peak 1kHz sinusoidal input signal to input of head; apply resistive 8Ω load to output of head. Set all controls to full. Verify correct signal voltages at the beginning of each block with an oscilloscope, beginning with left-hand side of the block diagram.
4. Apply low-impedance 1V peak 1kHz sinusoidal input signal to input of head; apply resistive 8Ω load to output of head. Adjust volume to maximum and gain to THD+N just below 1% (measured with oscilloscope). Verify that voltage across the load is at least 23.66V peak (35W).
5. Apply low-impedance 100mV peak 1kHz sinusoidal input signal to input of head; apply resistive 8Ω load to output of head. Set volume to 12 o'clock position, gain to full. Measure THD+N with oscilloscope, verify that it exceeds 20%.
6. Test thiele small parameters before and after inclusion in cabinet to compare cabinets effect. By measuring the resistance, resonant frequency and nominal impedance of the drivers, the thiele small parameters can be calcualted. Compare these to the values provided by the supplier.
7. Compare sound field of actual cabinet versus simulation provided by the Field 2 plugin for Matlab. Place pressure and particle velocity microphones in 2D Grid Formation level with drivers to generate 2D sound field.
8. Use a spectrum analyzer to generate a flat response white noise signal and measure the output from the cabinet using a microphone.

Tolerance Analysis:

In order to meet the 1% THD+N requirement, the voltage ripple of the 240V power supply should not exceed that which will cause 237mV peak of noise at the output. Approximately one half of the ripple from the 240V rail will be applied to the primary of the output transformer, implying a voltage gain of -6dB. The transformer has a voltage gain of -34.5dB. The class-D amplifier has a voltage gain of +36V. This makes the voltage gain of that ripple from the tube power amplifier to the speaker output a total of -4.5dB. This means that the voltage ripple on the 240V rail from the power supply should be less than 4.5dB greater than 237mV peak, which is 141mV peak, or about 0.12% of the rail voltage, peak-to-peak.

In order to test this ripple, the 240V power supply rail should be viewed with an oscilloscope. Its peak-to-peak ripple should be measured and divided in half to obtain the peak ripple.

4. Cost and Schedule

Cost Analysis:

Labor:

Dream Salary of each team member:		$40	per hour
$40 x 2.5 x 150 hours	=	$15,000	per member
$15,000 x 2 members	=	$30,000	total

Materials:

Item	Spec	quantity	unit cost	total
Head				
Vacuum Tube	12AT7	1	$10.00	$10.00
Output transformer	Hammond 1750A	1	$19.01	$19.01
Power Transformer				$15.00
ICs & transistors				$30.00
Resistors, caps, misc				$30.00
Chassis				$20.00
Tube socket	9-pin, PC mount	1	$2.45	$2.45
Switch, Fuse, Power Jack				$15.00
Jacks		3	$2.50	$7.50
Potentiometers		5	$2.50	$12.50
PCBs		4	$0.00	$0.00
			TOTAL	**$161.46**
Cabinet				
High Density Insulation Foam	8'x4'x1"	2	$12	$24.00
Jensen Neo 10-100 Driver	10" -16 Ohm	2	$112.65	$225.30
Neutrik Locking Jack	black	1	$6	$6.00
Carbon Fiber Part Kit	2 yard kit	1	$142	$142.00
			TOTAL	**$397.30**
			GRAND TOTAL	**$558.76**

Total Cost: Parts and Labor

Labor	$30,000.00
Parts	$558.76
Total	$30,558.76

Schedule:

Week	Task	Lead
2/6	• Read Material On Transmission Line Design	Thomas
	• Determine configuration for switching power supply • Finalize audio signal path design	Jeremy
2/13	• Finalize Transmission Line Design • Create Sound Field Simulation	Thomas
	• Sign up for Design Review • Finalize power supply design • Draw electrical schematics	Jeremy
2/20	• Purchase Cabinet Materials	Thomas
	• Design component layouts • Purchase electrical components	Jeremy
2/27	• Create small mock up of Cabinet	Thomas
	• Acquire PCBs • Acquire amplifier enclosure	Jeremy
3/5	• Begin Carbon Fiber cabinet manufacture	Thomas
	• Wind and test transformers • Assemble power supply	Jeremy
3/12	• Finish Individual Progress Report	Thomas
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3/19	• Spring Break	Thomas

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3/26	• Sign up for Mock-up Presentation	Thomas
	• Test & troubleshoot power supply • Assemble audio signal chain	Jeremy
4/2	• Finish Cabinet Construction	Thomas
	• Test & troubleshoot power supply • Test & troubleshoot audio signal chain	Jeremy
4/9	• Test Frequency Response of Cabinet	Thomas
	• Test & troubleshoot power supply • Test & troubleshoot audio signal chain	Jeremy
4/16	• Test Thiele small parameters inside and outside of cabinet	Thomas
	• Sign up for Demo and Presentation times • Test & troubleshoot power supply • Test & troubleshoot audio signal chain	Jeremy
4/23	• Create Presentation	Thomas
	• Create Presentation	Jeremy