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MMI 506 – Advanced Audio Electronics

Project 1 – Tube and Solid State Amp Design

Amplifier Design

Overview

The goal of this project was to create a combination of vacuum tubes and solid state components into a single amplifier. This combination is often not approved of by many audiophiles and tube enthusiasts, but it has several benefits and is often used in other capacities. Vacuum tubes are considered a thing of the past for many industries, but still offer some of the best amplification for high end audio applications due to their distortion and tone characteristics. Solid state components also offer a list of benefits, such as the signal clipping abilities of diodes for distortion applications, and the lower price and size compared to their tube counterparts.

Design Idea

For my design, I chose to implement a version of my own personal guitar set up. I run a solid state tube screamer pedal into a peavey 6505+ amp that uses a series of vacuum tubes to create one of the most iconic distorted guitar tones in the industry. But in this project, rather than having the solid state component outside of the amp as a pedal I put the tube screamer into the amp design, complete with its own distortion and tone controls. These extra knobs allow the user to create a unique distortion not typically offered in a tube amplifier. It is extremely common to use the tube screamer with a small amount of soft clipping distortion and a slight tone boost to add color to the tube amp sound. The amp then runs through a class A tube pre-amplifier with two 12AX7's creating the pre amp gain and pre amp volume knobs. In between the two tubes is a Marshall tone stack that provides the user with the option to filter high, middle, and low range frequencies. The signal then runs into a phase splitter and a Class AB push-pull pentode power amp using 6L6GC tubes.

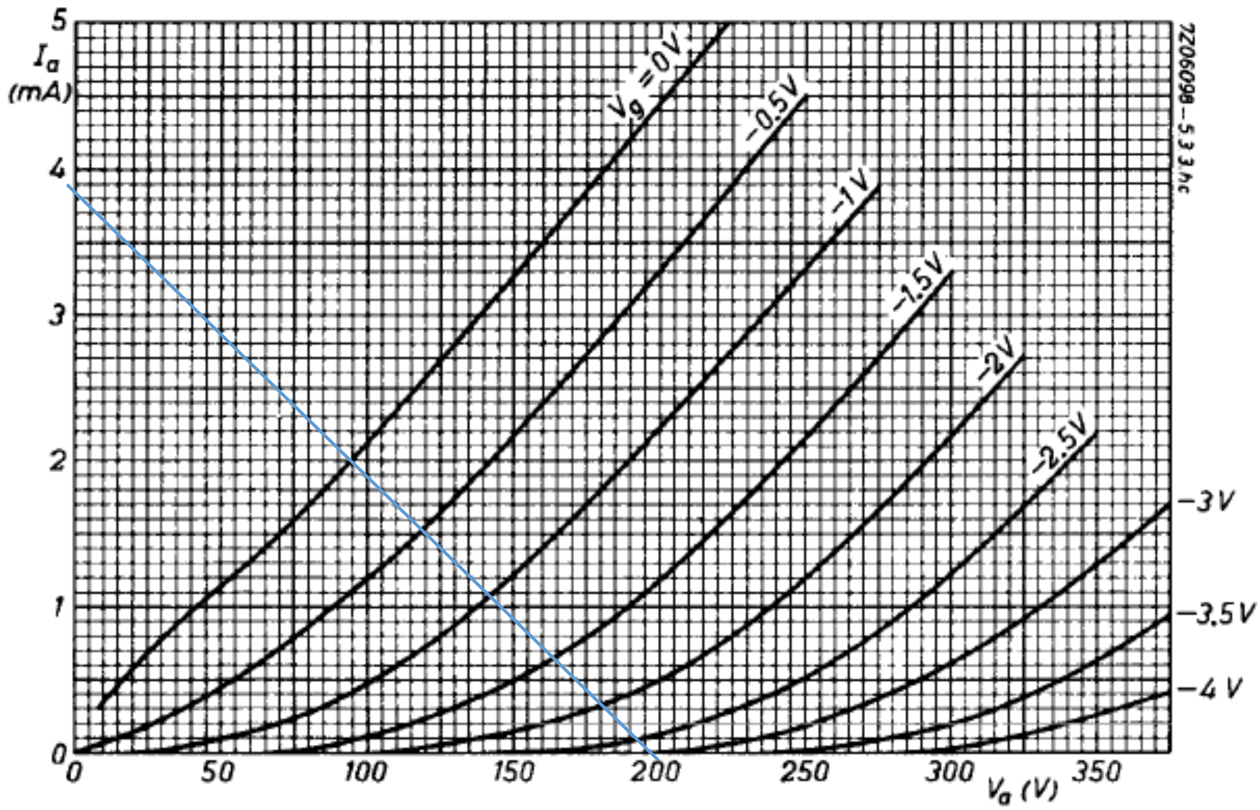
Diode Distortion: The tube screamer diode clipping distortion is one of the most commonly used solid state distortion circuits. In this amplifier I implemented a model of the physical Ibanez tube screamer pedal which allows the user to control a tone knob as well as the gain level. The tone knob creates a low pass filter with a slight resonant hump when it is at its maximum setting.

Pre Amp: The pre amp stage is separated into two different sections, with a marshall tone stack in between them. The “pre amp gain” potentiometer is a voltage divider that controls the input level into the second stage of the pre amp. Setting the drive of the first stage of the pre amp creates an asymmetrical distortion in the output of the second stage.

Tone Stack: For this section I used the Marshall Tone Stack to give the user the option of varying the high, middle, and low frequencies of the amplifiers pre amp stage. Tone stacks are one of the most common components of any guitar amp and critical to let the user create their tone of choice.

Power Amp: I chose to use a class AB push-pull pentode power amp for this design because it is the most common design for both tube and solid state designs. This class also does not have any cross-over or asymmetrical distortion that are caused by Class A and Class B power amps.

Component Designs



- I chose to start with a supply voltage of +200V since it is in the middle of the plate voltage range, and a plate resistor value of 50k Ohms.
- I then calculated the maximum current that could flow: $I_{MAX} = \frac{V}{R} = \frac{200V}{50k\Omega} = 4mA$
- I then placed the load line (blue line on the graph) to be able to see the range of the input voltage swing (0 – 3V) and the plate voltage swing (200V – 300V).
- The Voltage amplification is the ratio of the input grid voltage to the output plate voltage: $A_v = \frac{200V-100V}{-3V-0V} = \ 33.3 = 30.4dB\ of\ Gain$
- I chose a bias voltage that was in the middle of the voltage swing value to keep things simple: $V_{BIAS} = \ -1.5V$

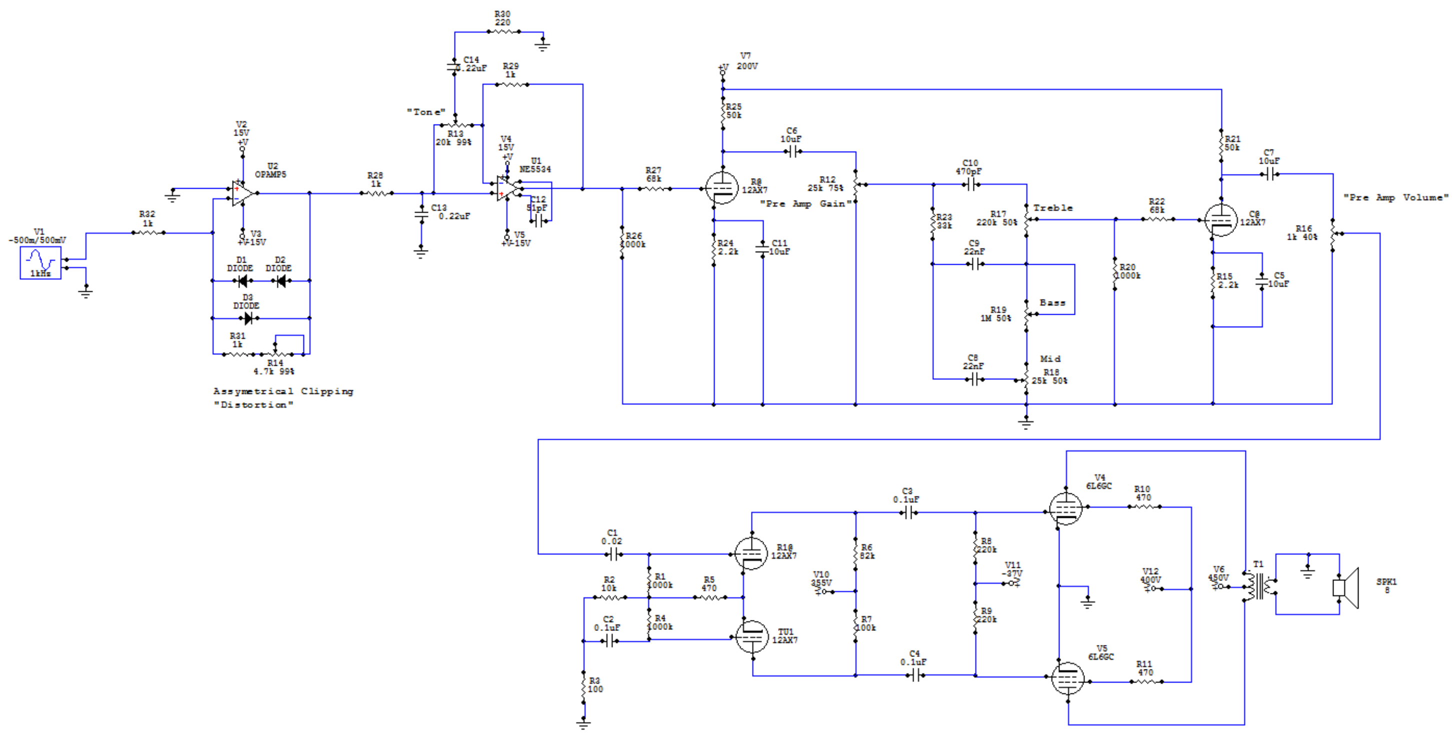
- I then needed to bias the voltage through a cathode self-biasing resistor, where the current of the cathode (I_C) is found by looking at where the load line lined up at the bias voltage (1.5V) in respect to the current: $R_k = \frac{V_k}{I_C} = \frac{1.5V}{0.7mA} = 2.2k\Omega$

- To prevent degenerative feedback I added a capacitor around both of the cathode self-biasing resistors:

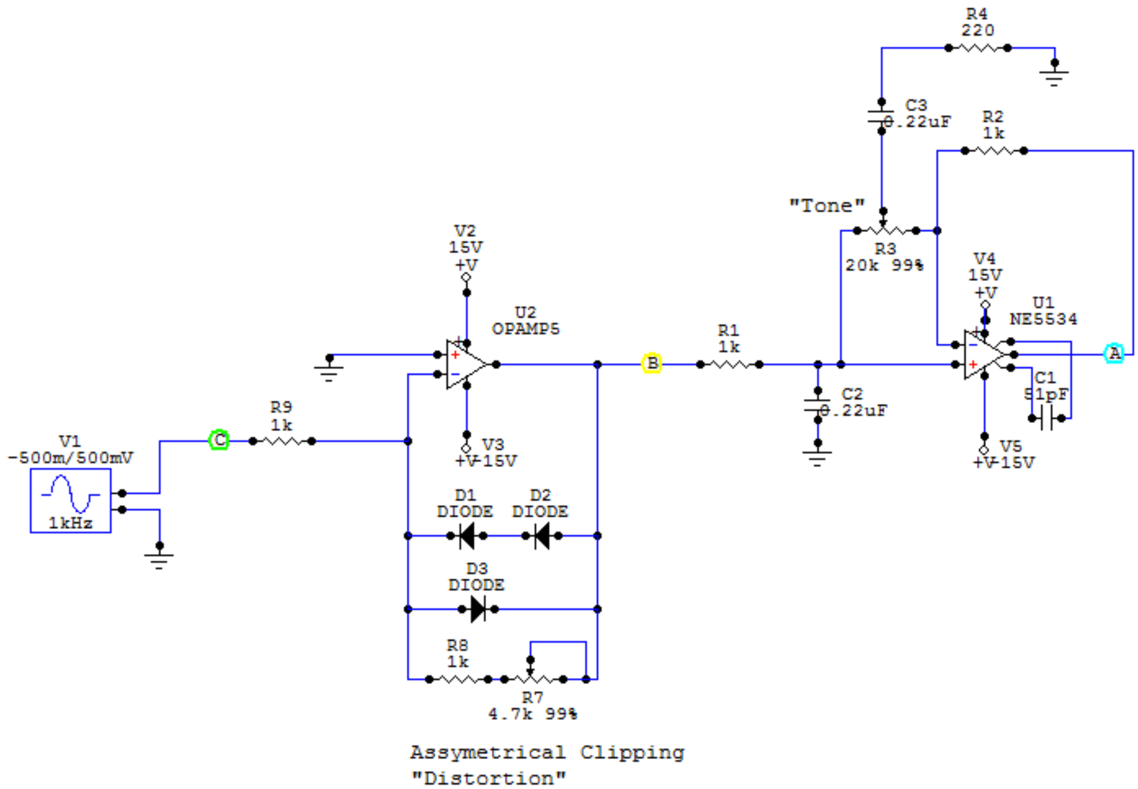
$$X_k = 10\%(R_K) = 220$$

$$C_k = \frac{1}{(\omega)(X_k)} = \frac{1}{(2\pi f)(X_k)} = \frac{1}{(2\pi * 81 * 220)} = 8.9uF = 10uF$$

Schematic

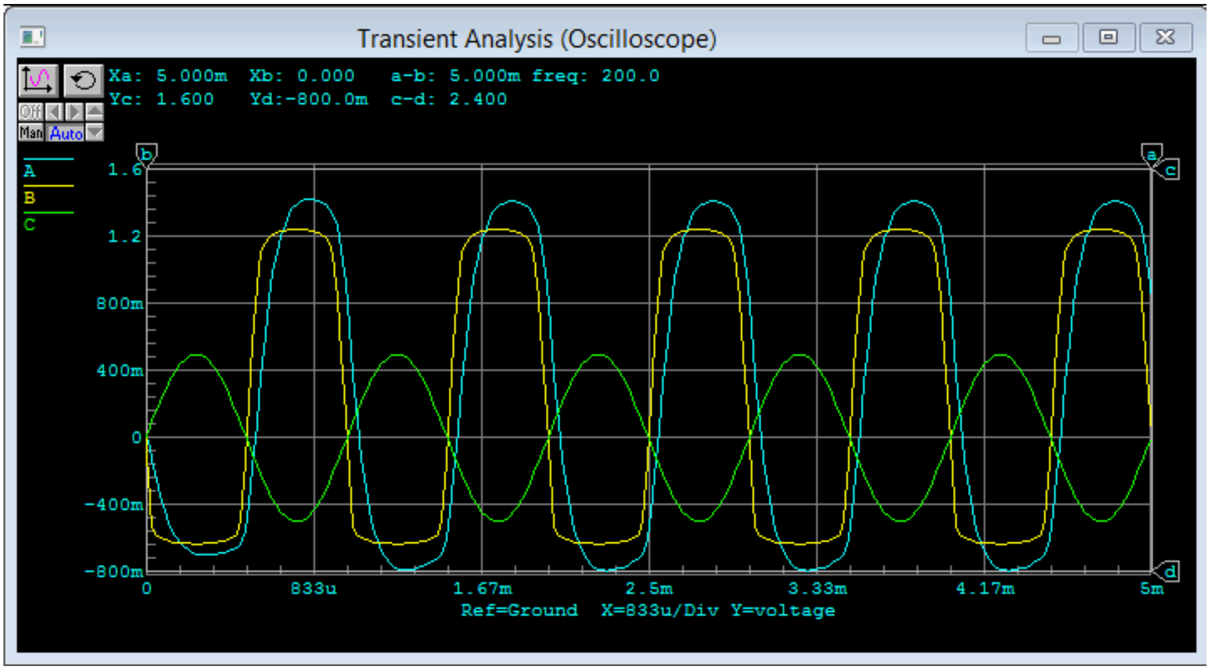


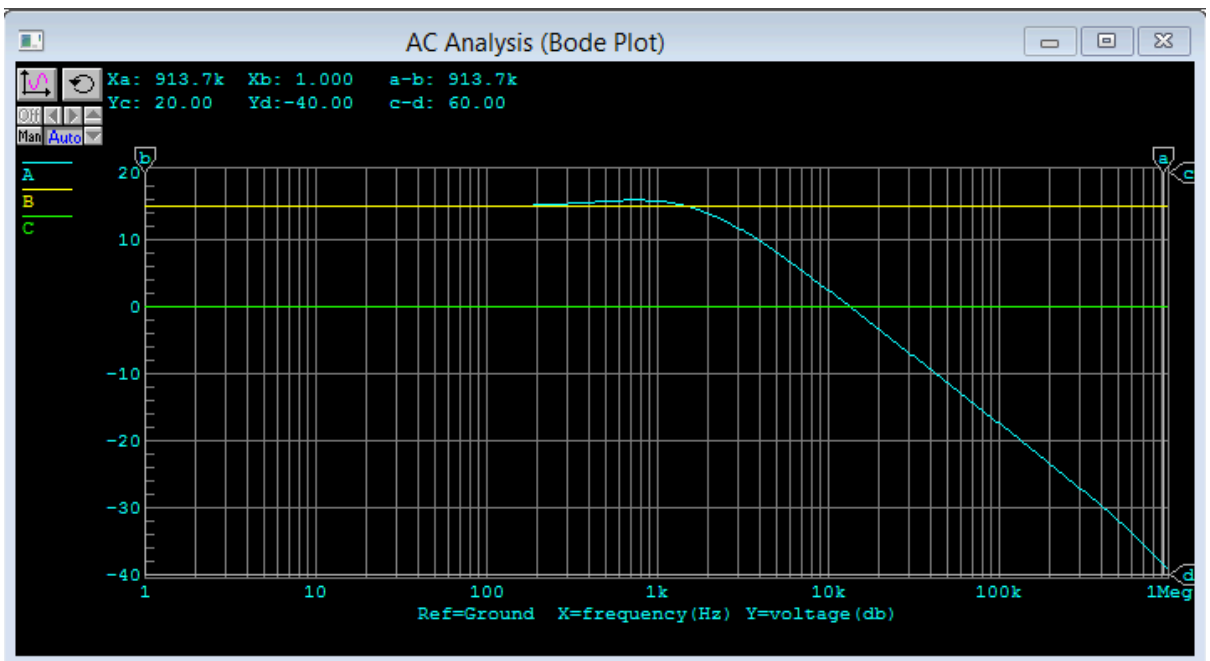
Distortion and Tone



- The two diodes D1 and D2 create asymmetrical clipping of the input signal, with the level of distortion controlled by the potentiometer. This can be seen at the output yellow and blue transients of the circuit below.
- With the tone control set to its maximum value, a low pass filter is created with a slight resonant hump.

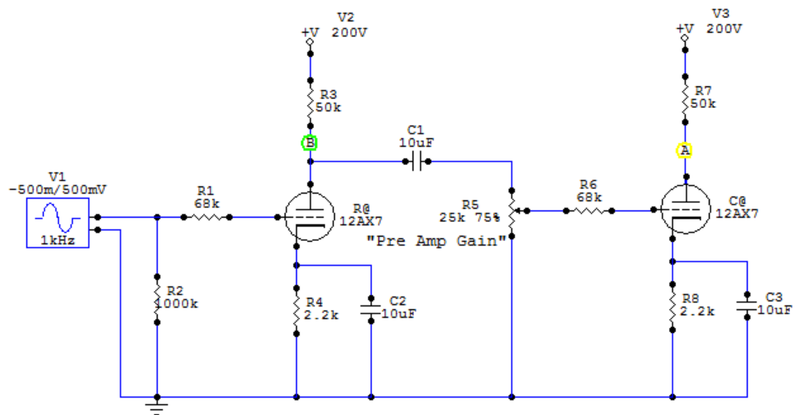
Transient and Frequency Analysis:

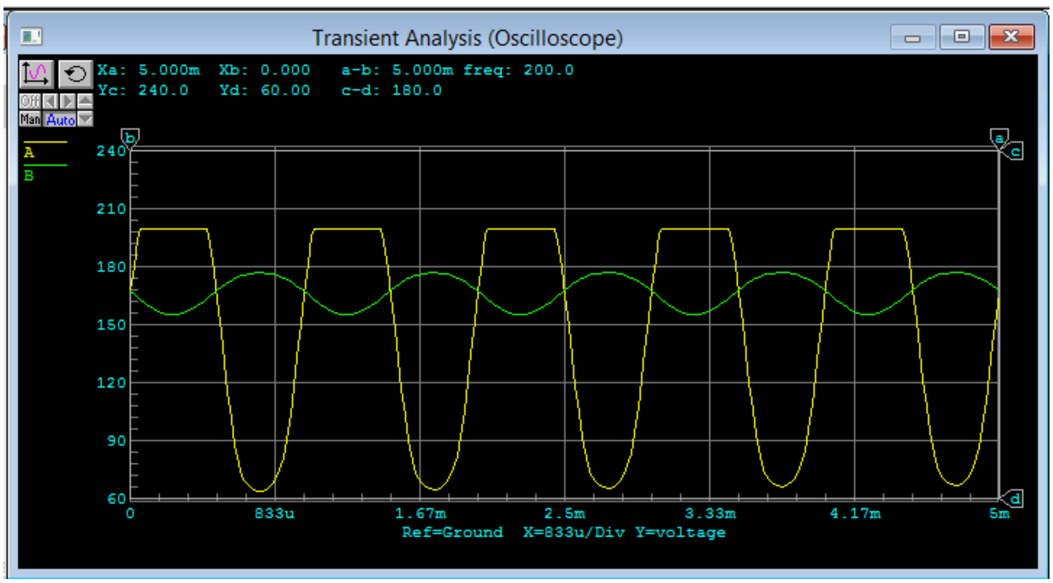




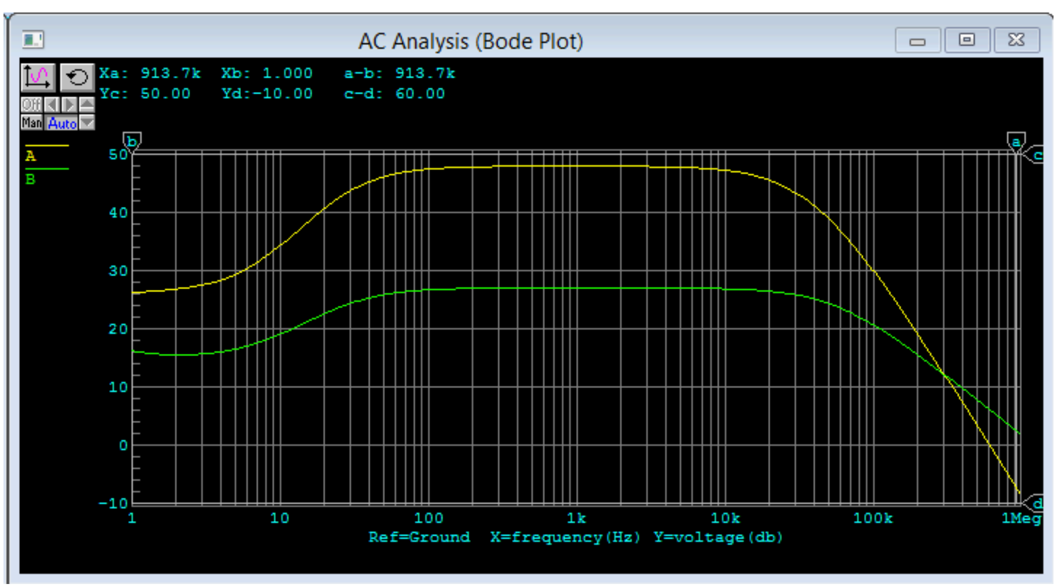
- Cyan Blue = Output of distortion and tone sections
- Blue = Output of distortion section
- Green = Original input signal

Tube Pre Amp

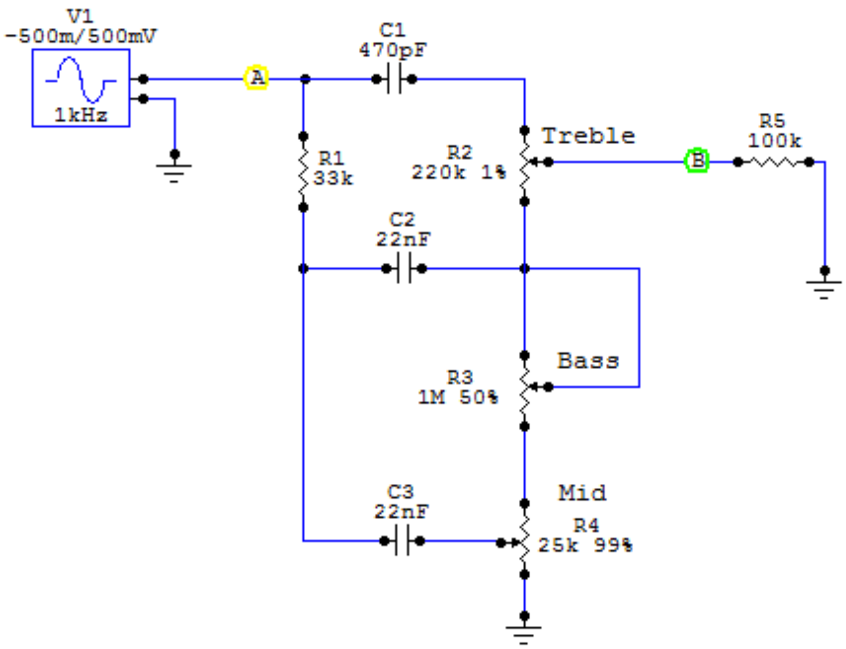


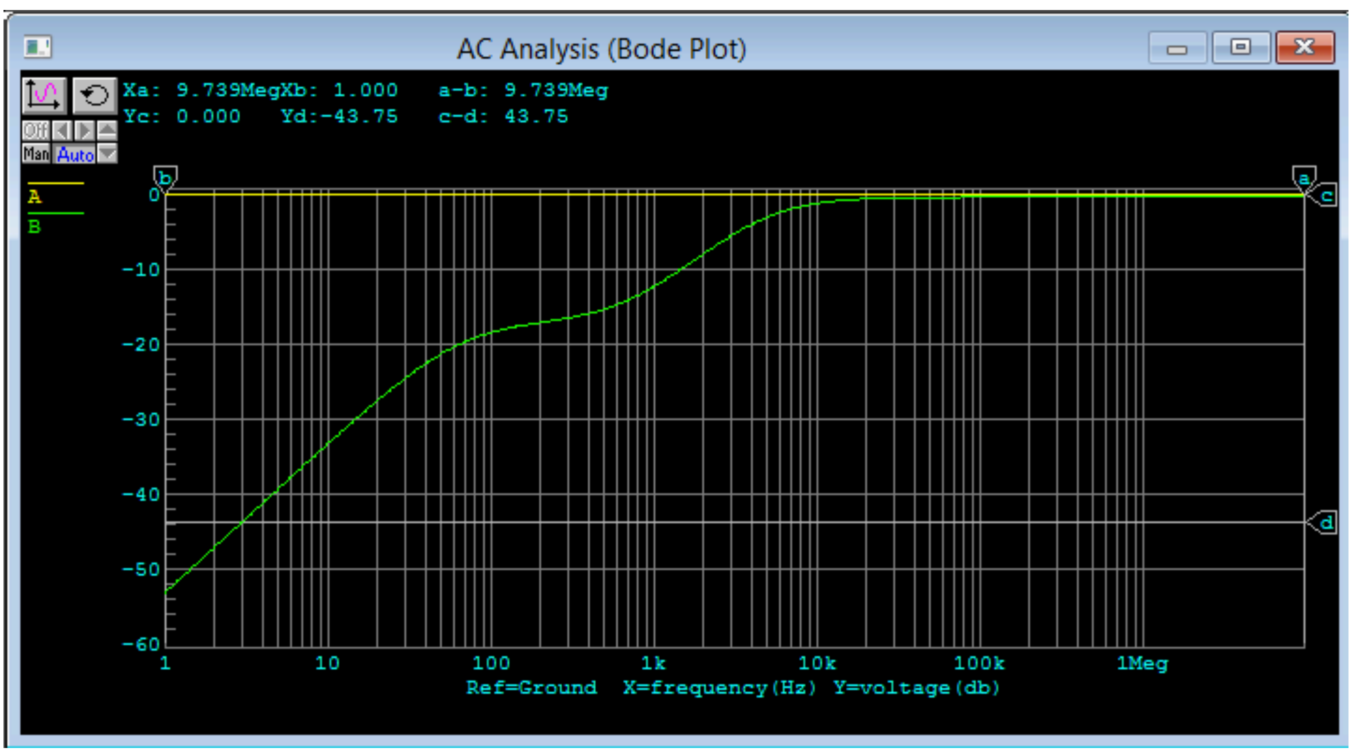


- Yellow = Output of both stages
- Green = Output of first stage



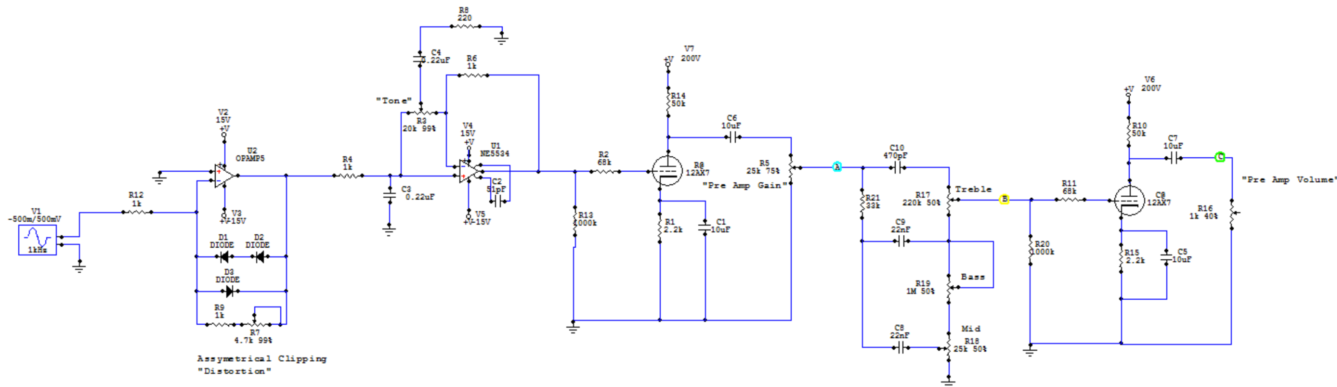
Tone Stack

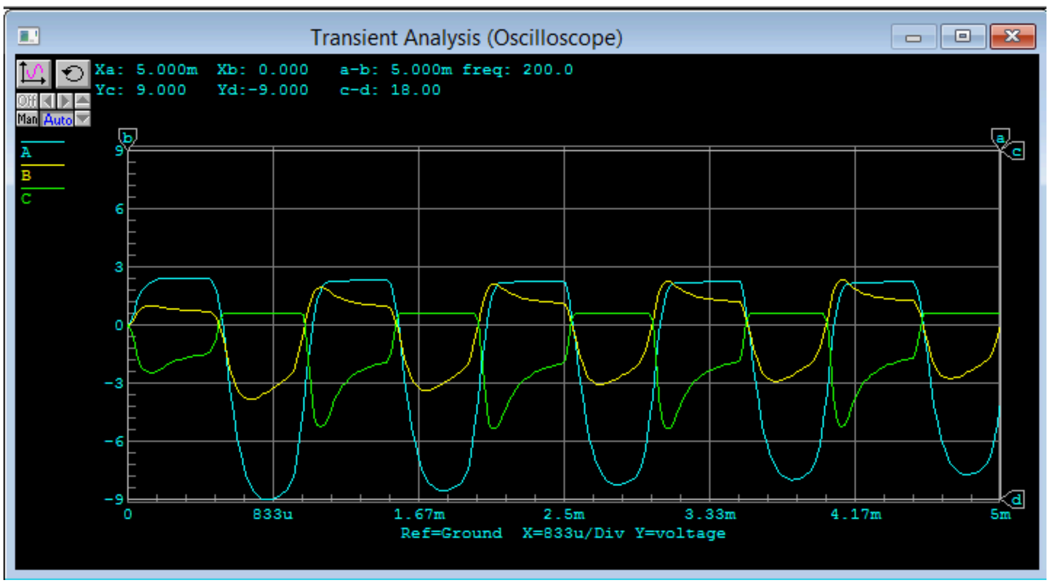


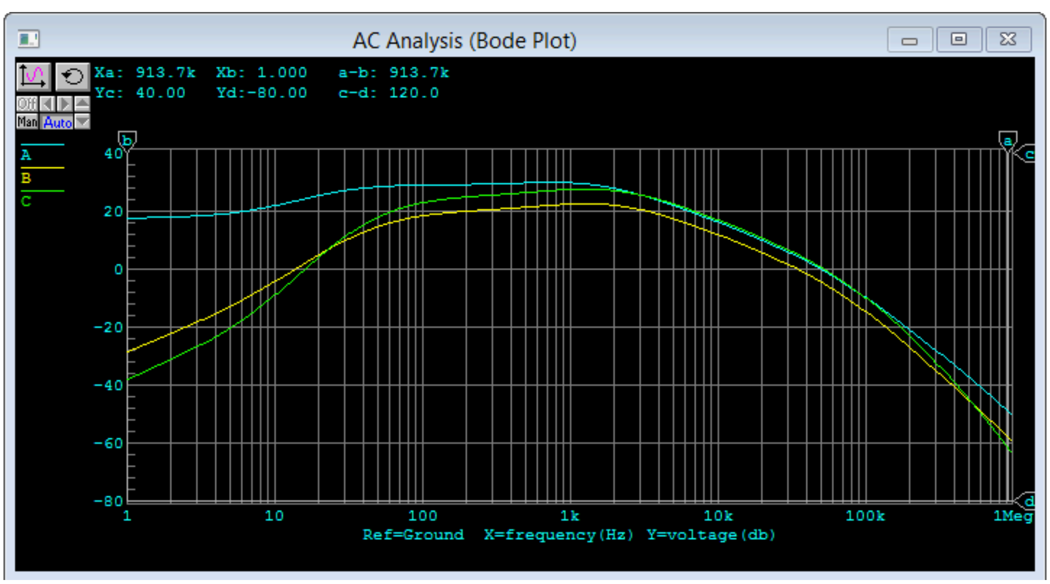


- Yellow = Input Signal
- Green = Output filtered signal

Full Pre Amp Section

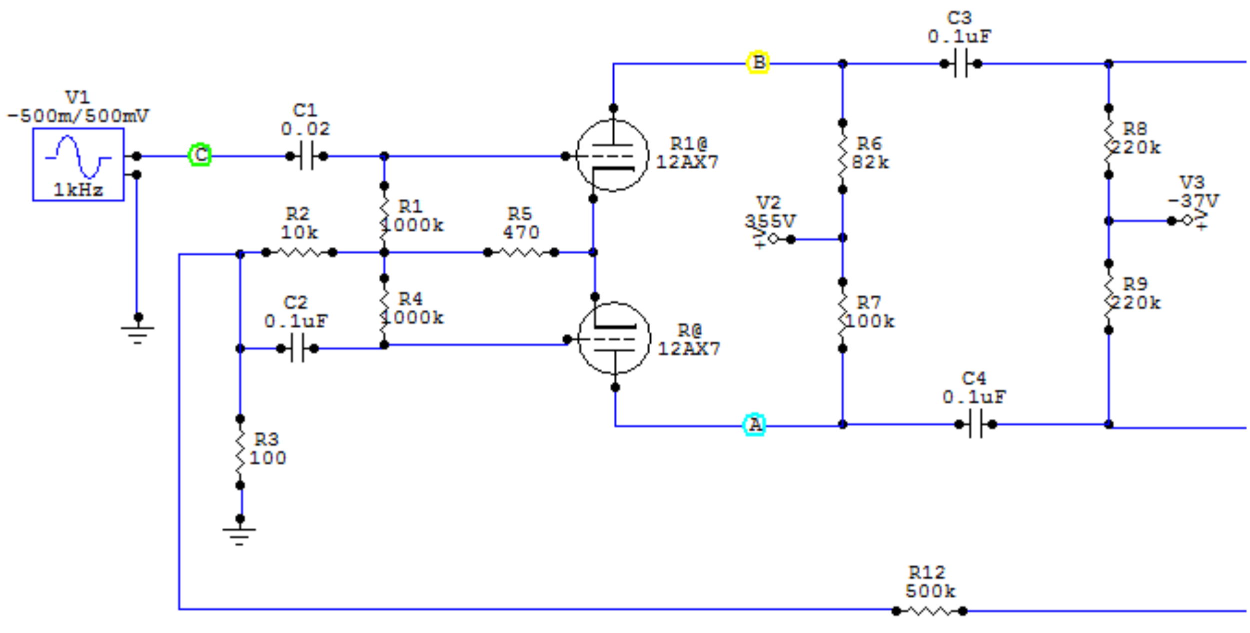


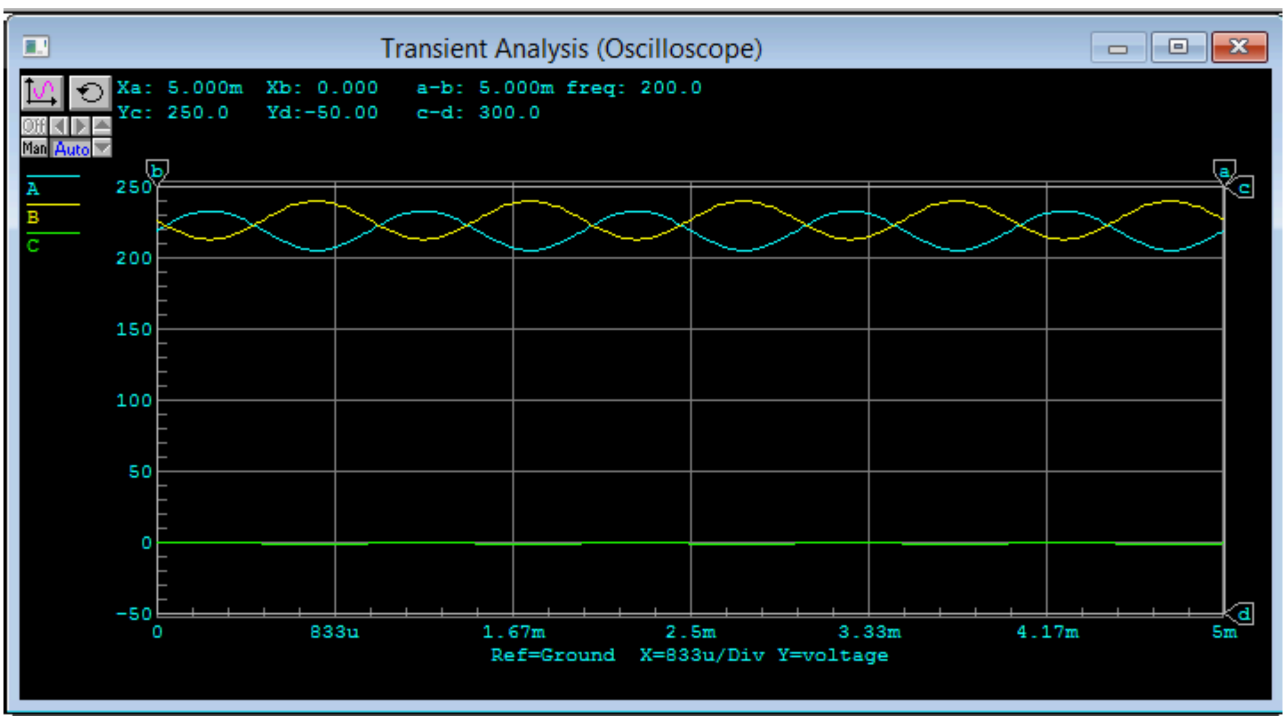




- Green = Pre amp output
- Yellow = before second stage of tube pre amp
- Cyan = After distortion stage and first stage of pre amp

Phase Splitter

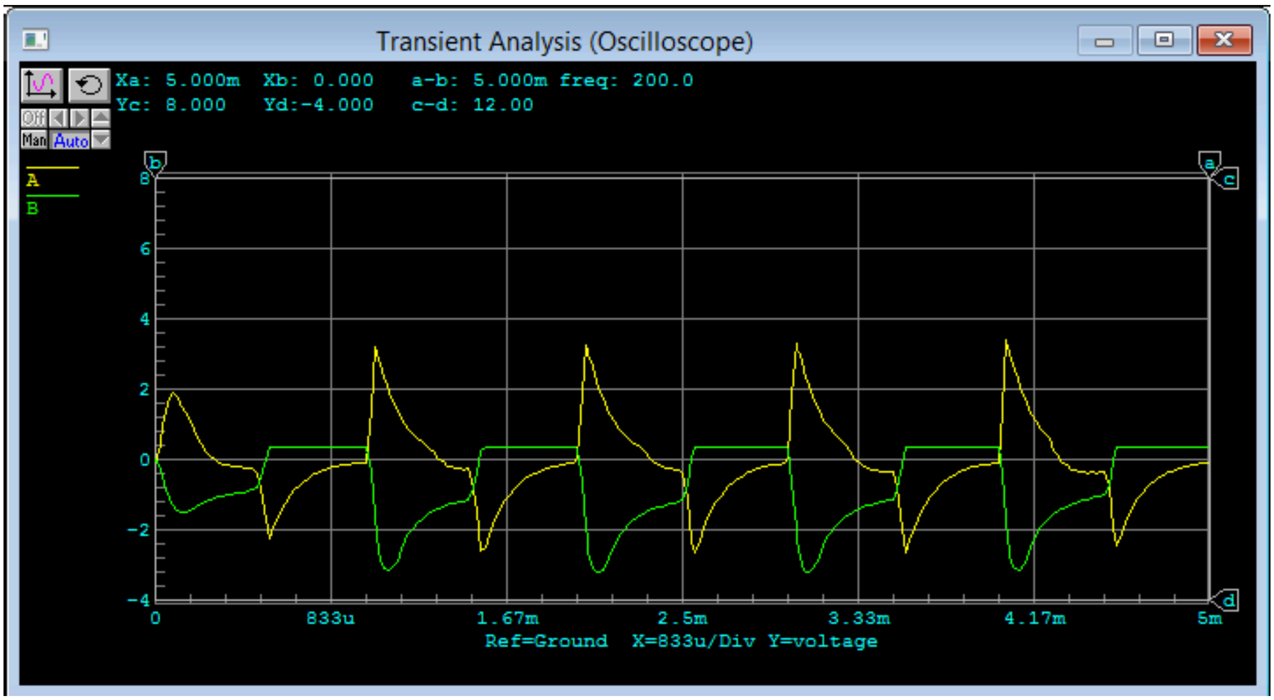


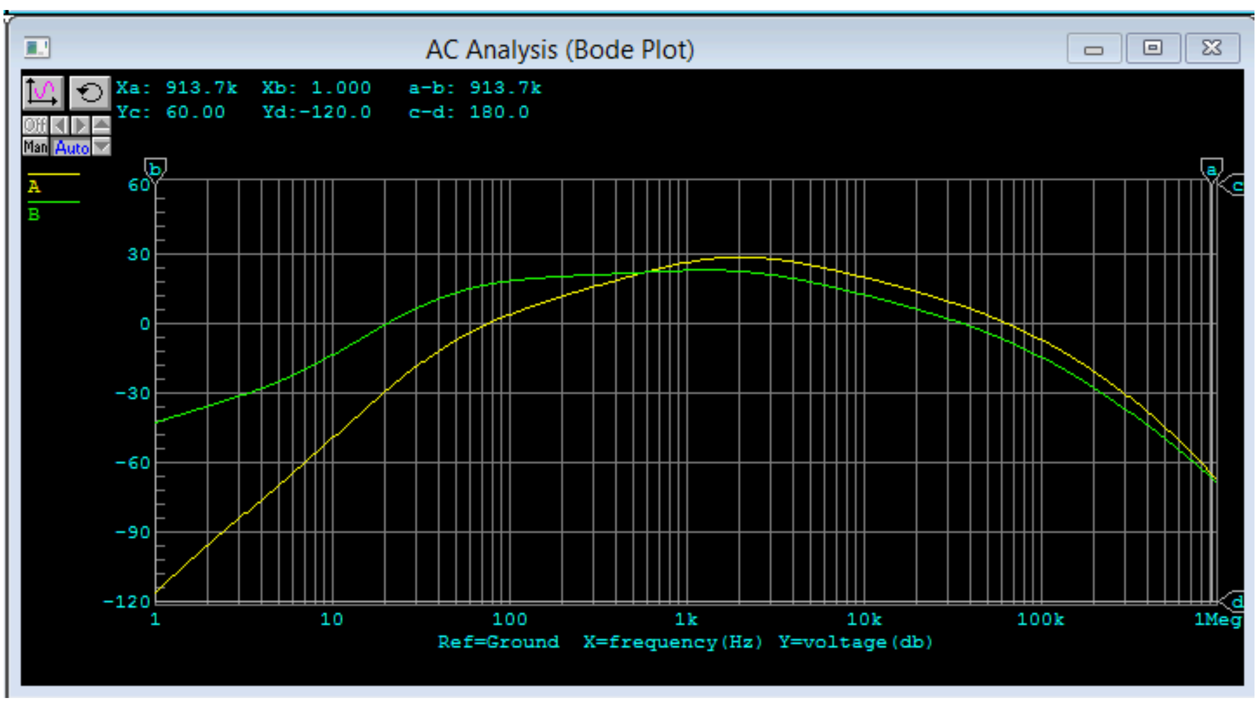


- Green = Input Signal
- Blue & Cyan = split signals, each with inverted phase to each other

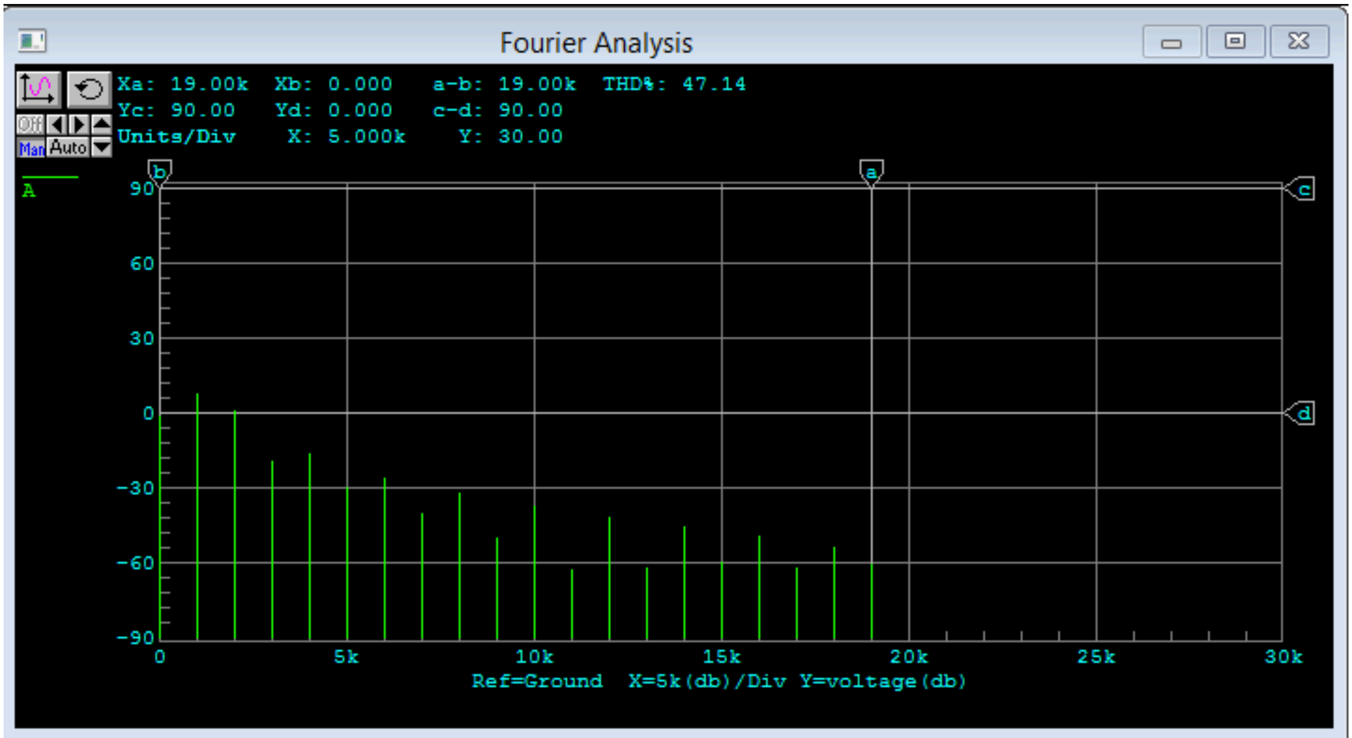
Final Output

High Gain & Random Tone settings





- Yellow = Final Output
- Green = Output of pre amp section = Input to power amp



Fourier Analysis
Xa: 19.00k Xb: 0.000 a-b: 19.00k THD%: 47.14
Yc: 90.00 Yd: 0.000 c-d: 90.00
Units/Div X: 5.000k Y: 30.00
A
90
60
30
0
-30
-60
-90
0
5k
10k
15k
20k
25k
30k
Ref=Ground X=5k(db)/Div Y=voltage(db)