REACTIVE AMP LOAD DESIGN

The designed circuit will serve as a reactive load for a guitar amplifier. The load will simulate the impedance response of a speaker cabinet and will feature a line level output that can be connected to an audio interface. A switch will enables the user to choose between 3 operating modes of $4\Omega,\ 8\Omega$ and 16Ω.

In order to design the circuit at first a reactive load of 8Ω was designed. The load will give the amplifier a similar impedance response as single 8Ω speaker.

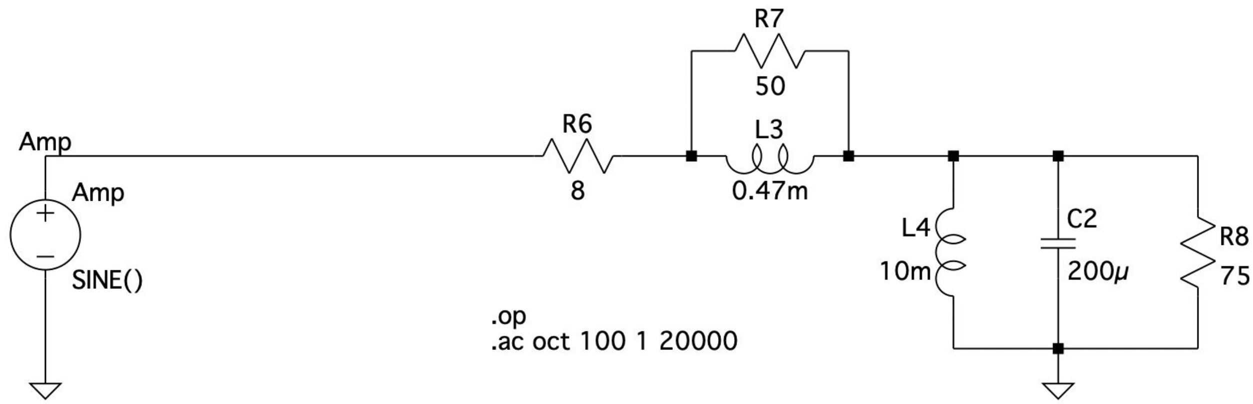

Fig.1 - 8Ω reactive load simulation

The reactive load features a main load resistor $R_1 = 8\Omega$ that keeps the impedance at 8Ω for most of the frequency spectrum (we consider $1Hz - 20kHz$ to be the spectrum of interest since it contains the human hearing spectrum and corresponds with most modern audio interfaces frequency range). A combination of inductive and capacitive elements was used to produce a resonant peak at $100Hz$ and a rising slope at $2kHz$ *to* $20kHz$.

The impedance curve of the simulated load can be seen in figure 2

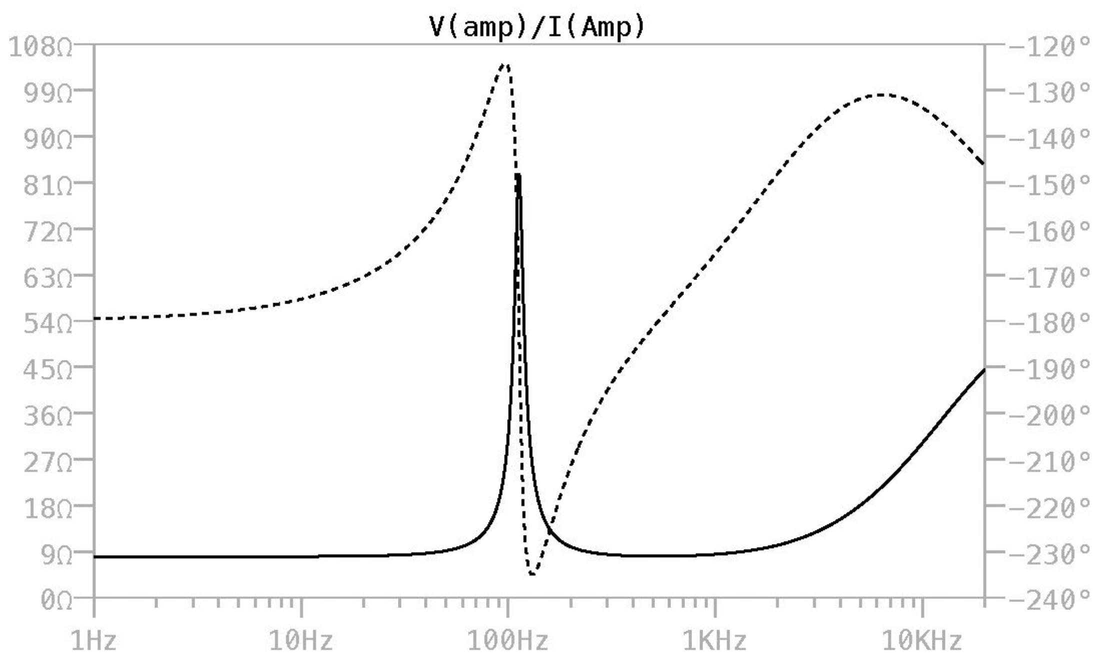

Fig.2 - Impedance response 8Ω load *unbroken line

Since guitar cabinets feature multiple speakers in various configurations there is a variety in amp load ratings, most guitar amplifiers on the market are rated to work with either one of 4Ω, 8Ω or 16Ω speaker loads. To accommodate those amplifier ratings, two 8Ω loads were used in the circuit and a switch was used to select between 3 configurations: parallel(4Ω), single(8Ω) and series(16Ω). In addition, a voltage divider of a $10k\Omega$ resistor and a $1k\Omega$ potentiometer was used to serve as a line level output that can be connected to an audio interface.

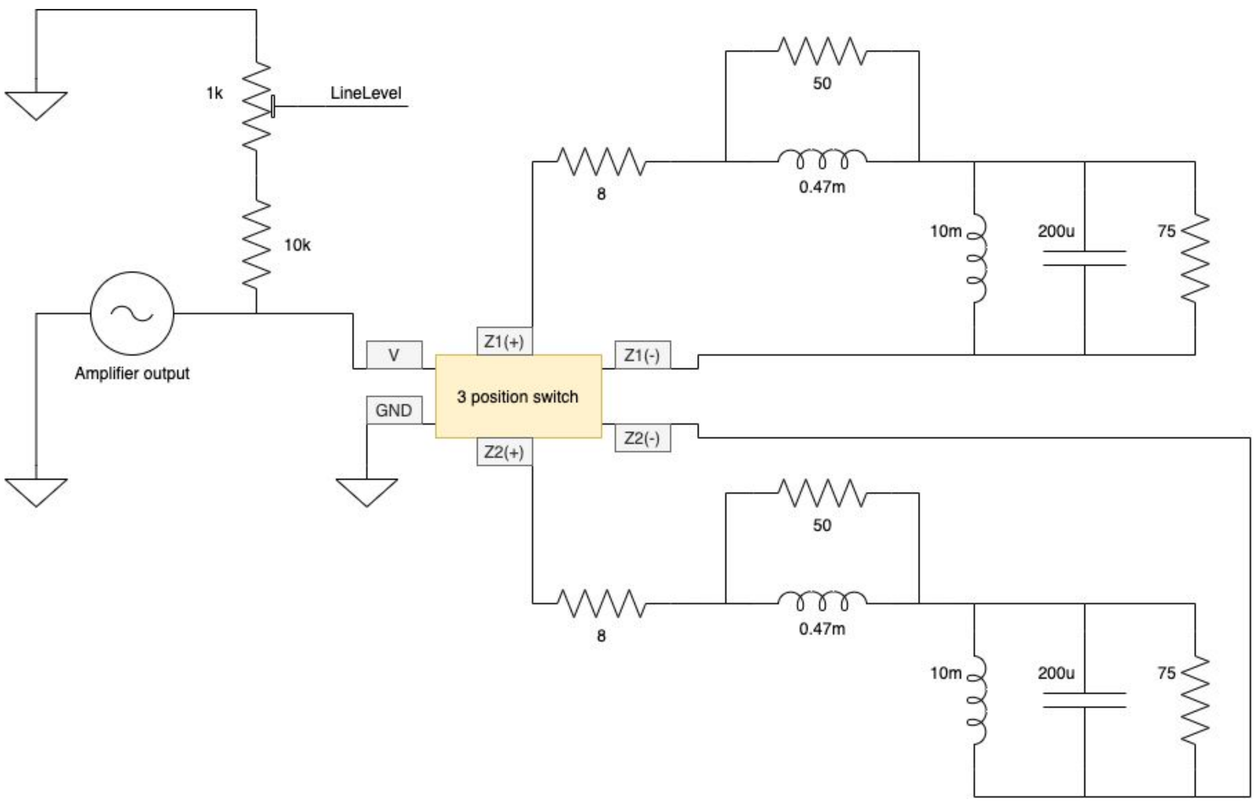

Fig.3 - system schematic

In order to switch between the 3 load configurations a DPDT on-on-on switch was used with the following wiring. The terminal labels correspond with the labels in the system schematic.

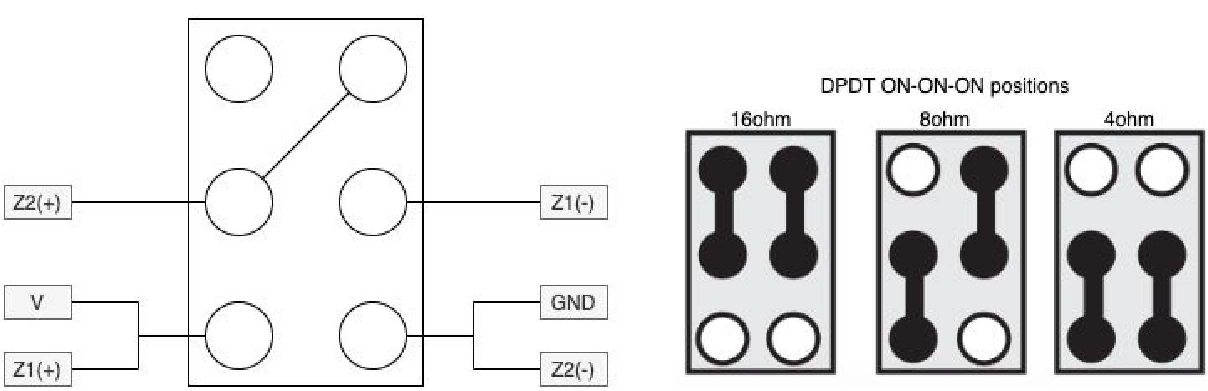

Fig.4 - switch wiring diagram and DPDT positions

A simulation of each one of the configurations can be seen in figures 5-10

To form a 4Ω load, the positive terminals of each load are connected to the amp output while the negative terminals are connected to ground.

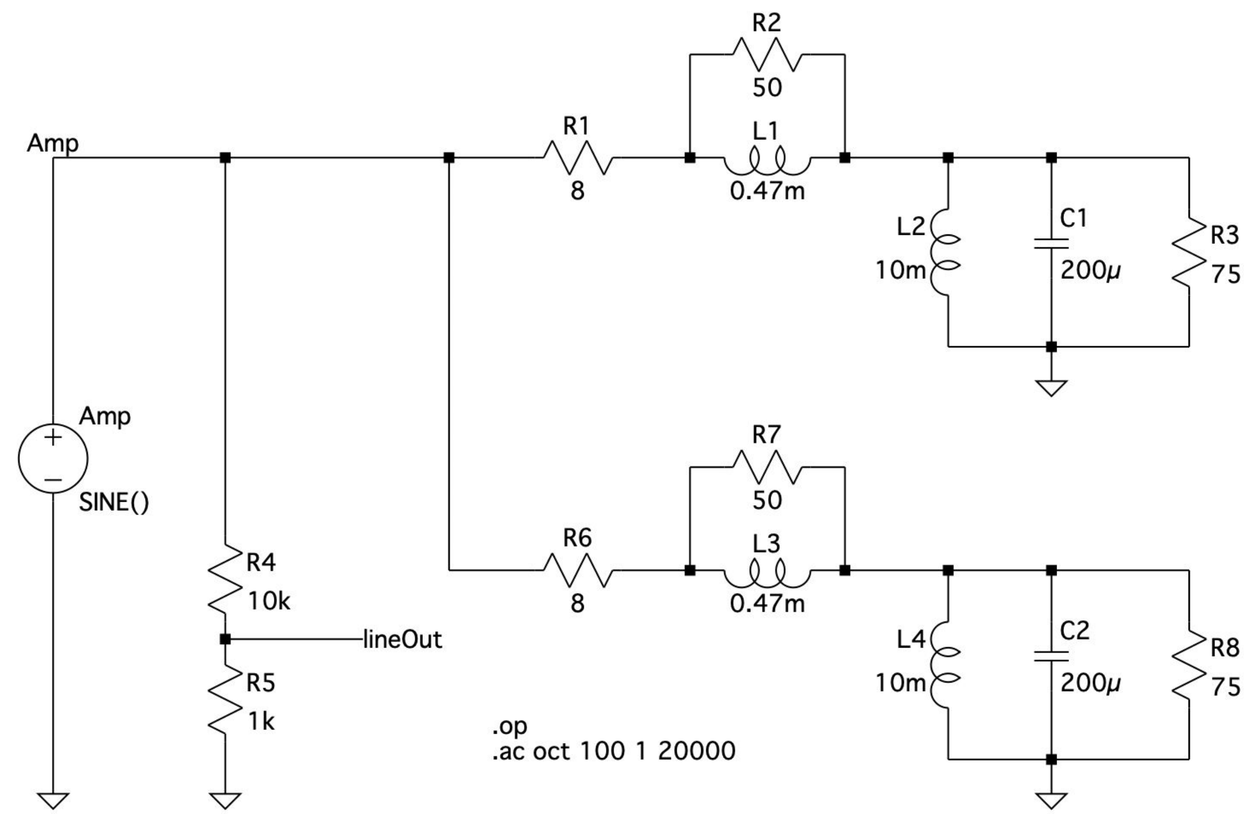

Fig.5 - 4Ω configuration

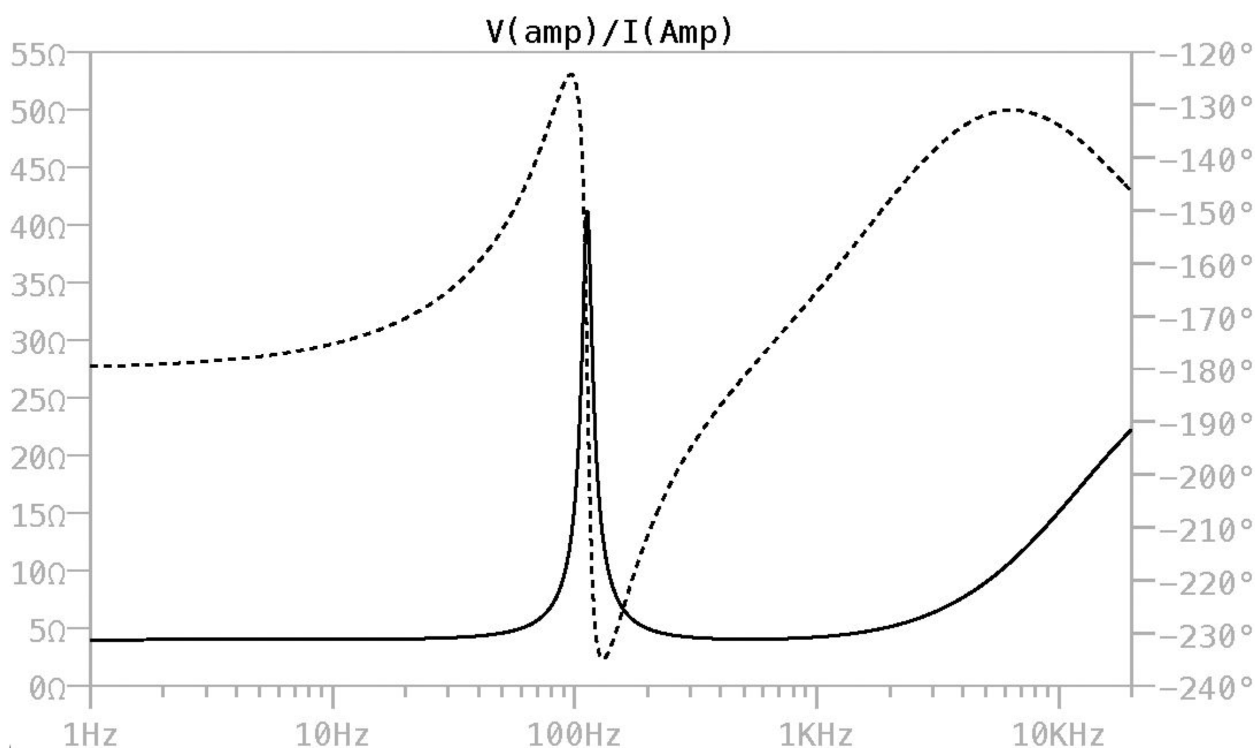

Fig.6 - 4Ω impedance curve *unbroken lines

To form an 8Ω load, the positive terminals of each load are connected to the amp output while only one of the loads has the negative terminals connected to ground. This results in current flow only to one of the loads.

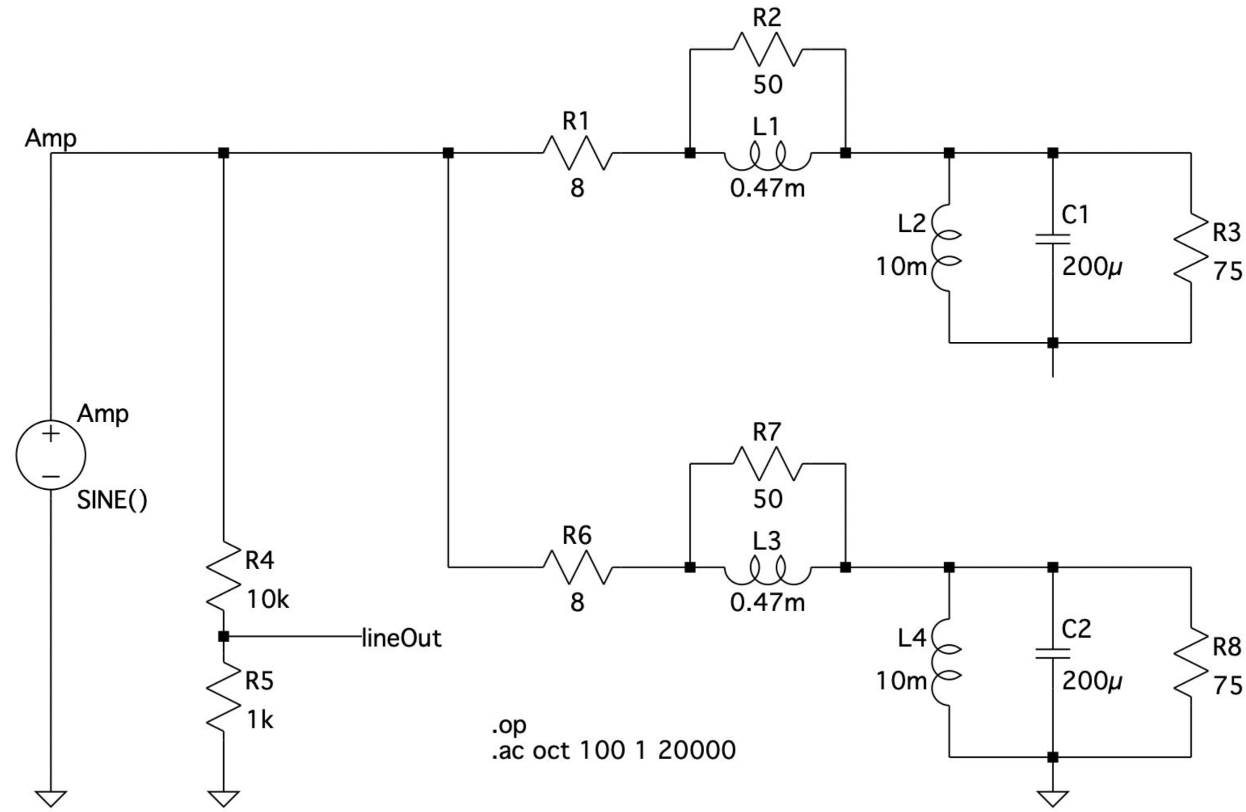

Fig.7 - 8Ω configuration

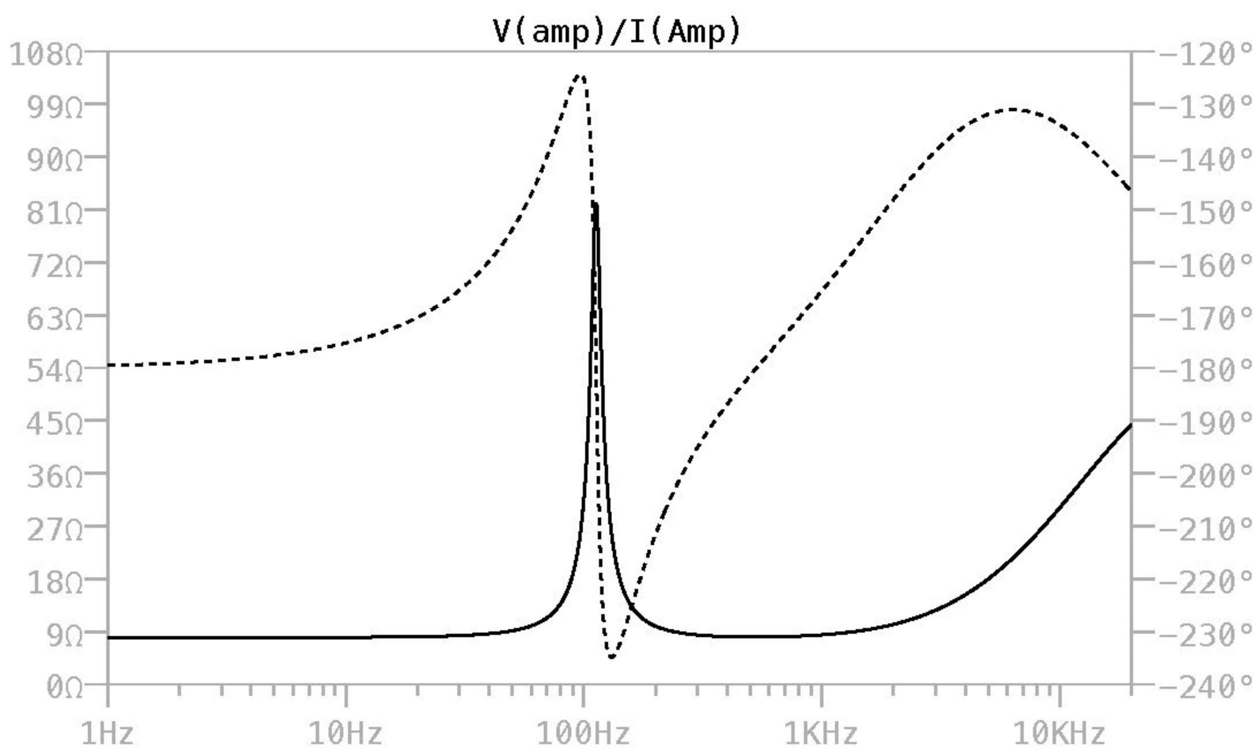

Fig.6 - 8Ω impedance curve *unbroken lines

To form a 16Ω load, the positive terminal of the first load is connected to the amp output, the negative terminal of that load is connected to the positive terminal of the second load, then the negative terminal of the second load is connected to ground.

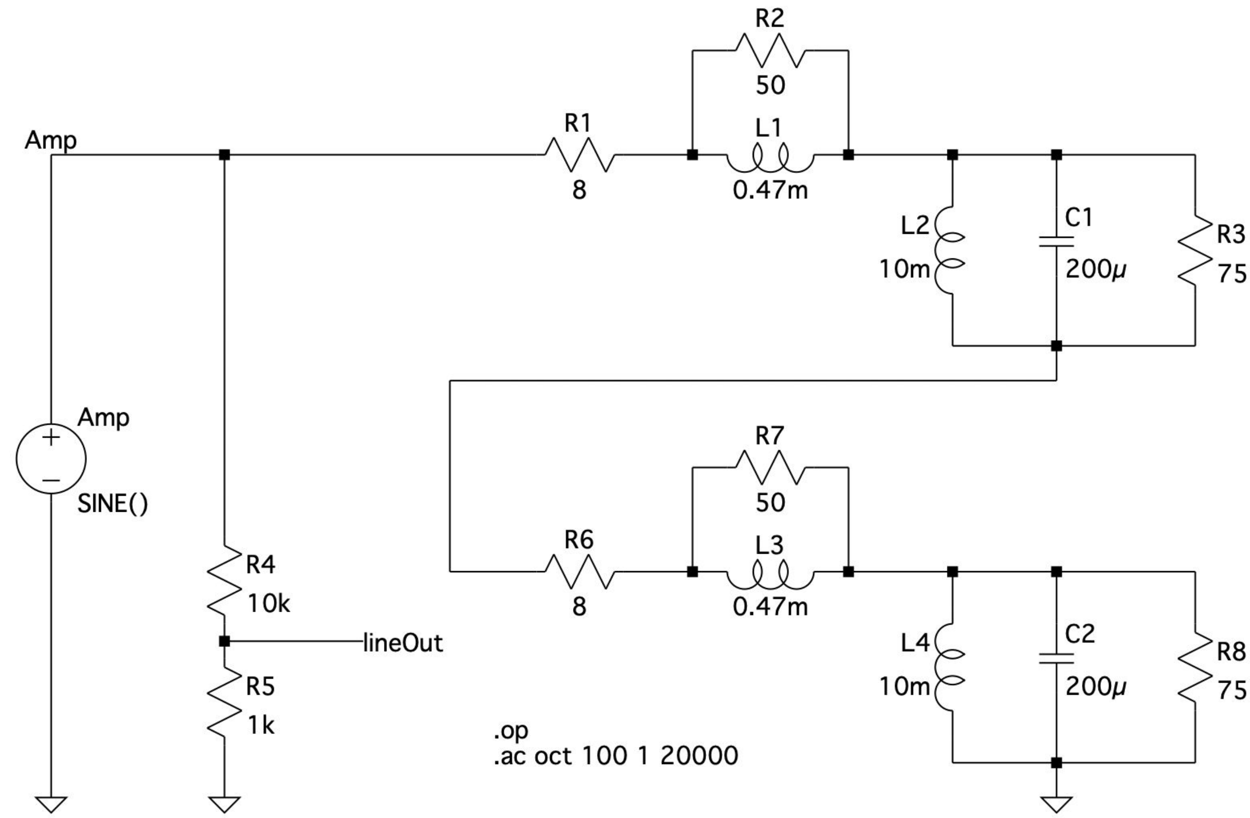

Fig.9 - 16Ω configuration

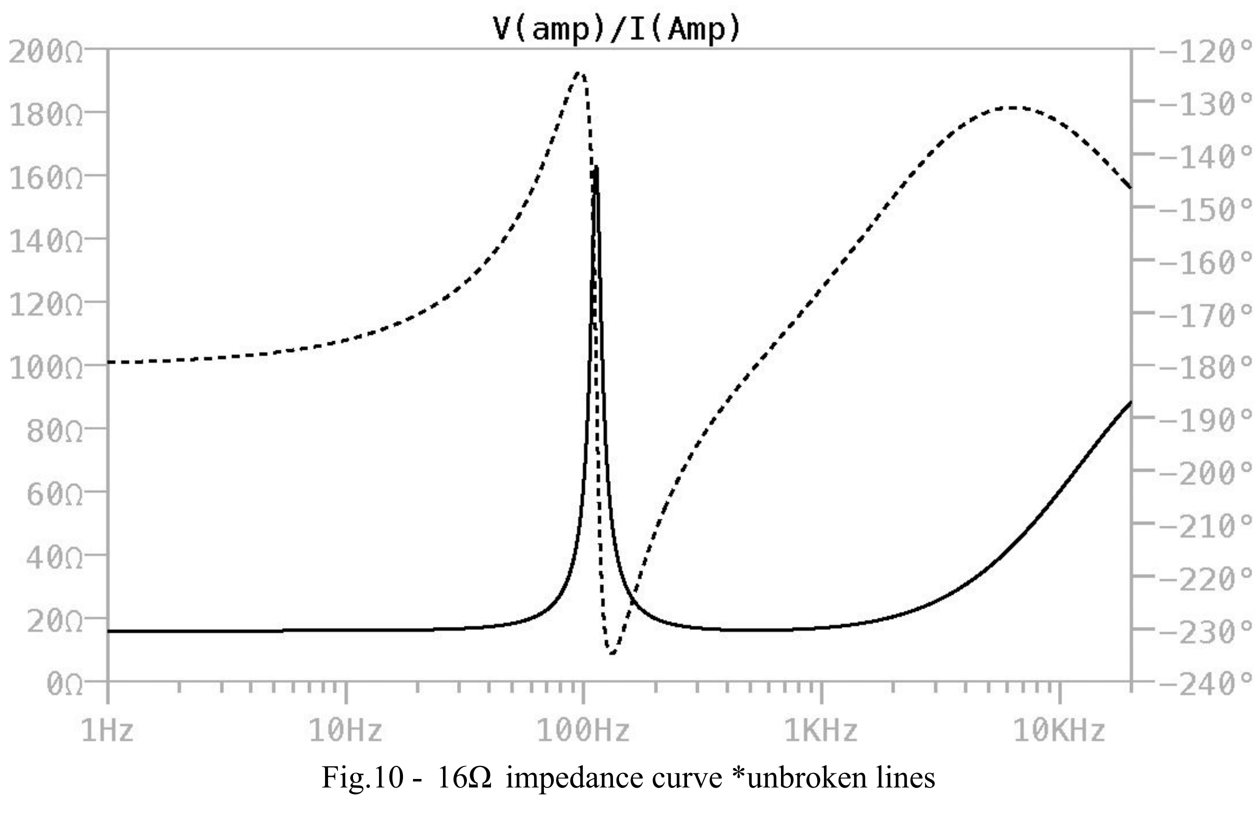

Fig.10 - 16Ω impedance curve *unbroken lines

When choosing the components it was important to make sure that the components are rated to handle the current and voltage that amp will produce, to calculate the maximum current and voltage ratings a maximum of amp power $p_{max} = 100W$ was chosen.
This value was chosen since the majority of tube amps are rated at 100 watts or below.
Since the maximum and minimum impedance values are known from the simulations of the circuit, the equations $v = \sqrt{pr}$ and $i = \sqrt{p/r}$ were used to calculate the max voltage and current

	$r_{min} = 4\Omega$	$r_{max} = 160\Omega$ (Resonant peak of $16\,\Omega$ load)
v	20	126
i	5	.8

Table1 - calculation results

From this table a current rating of $5A$ and a voltage rating of $125V$ was derived, since those are the closest standard ratings. The calculated max voltage is higher by 1 volt but this is ok since it happens only at the resonant peak and only if the amp is driven at its maximum wattage which is not recommended by amp manufacturers in the first place.
Those ratings will be considered when choosing the capacitors, inductors, connectors and switch.
The load resistors needs to be rated at maximum power $100W$,the other resistors can be rated at $50W$ since less current will flow through them (most of the current inside the load will flow through the inductors and capacitors as can be seen in Fig11.

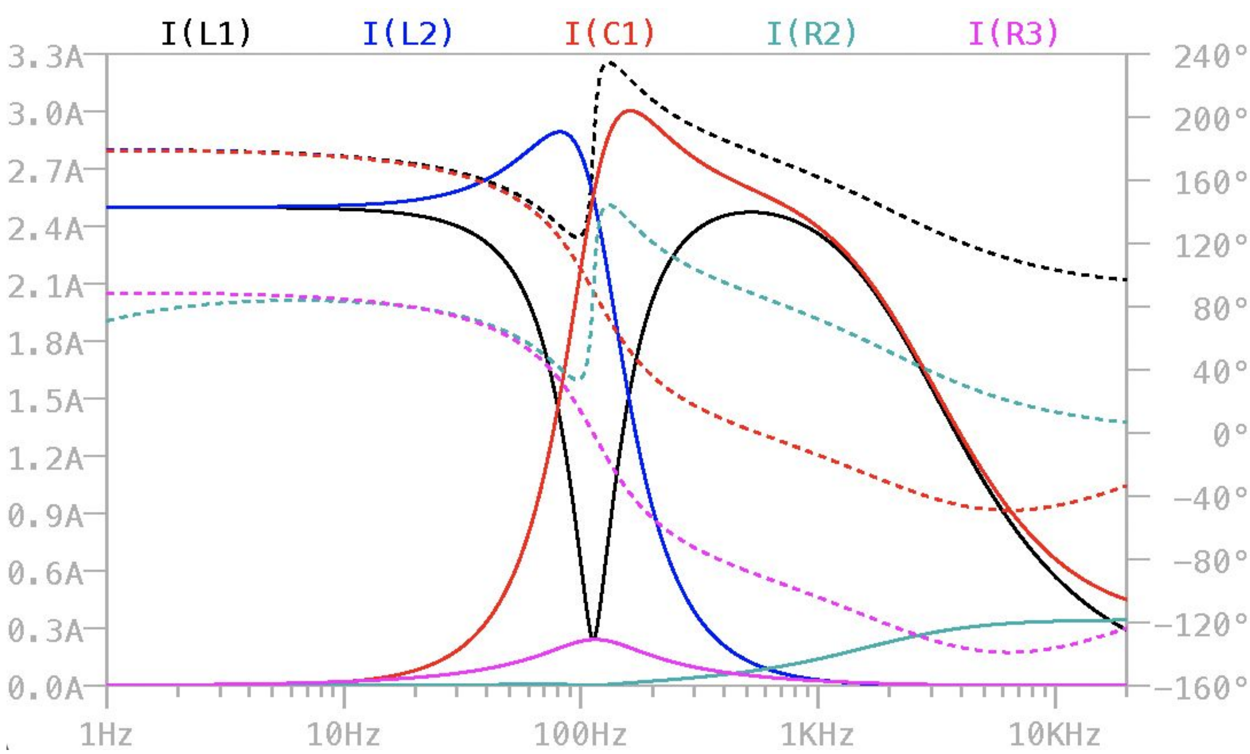

Fig.11 - simulation of current flow in circuit elements (load resistor not included)
*unbroken lines

In order to add a line output a voltage divider of a $10k\Omega$ resistor and a $1k\Omega$ potentiometer was used. The potentiometer will help the user to fine tune the line out voltage in order to stay within the range of the audio interface's ADC.
The current flow to the line output will be very low since the voltage divider resistance is much higher than the load resistance. This will help protect the audio interface when it is connected to the line level output of the circuit. It also means that the voltage divider resistors don't need to have a heat sink and can be rated at lower wattage.

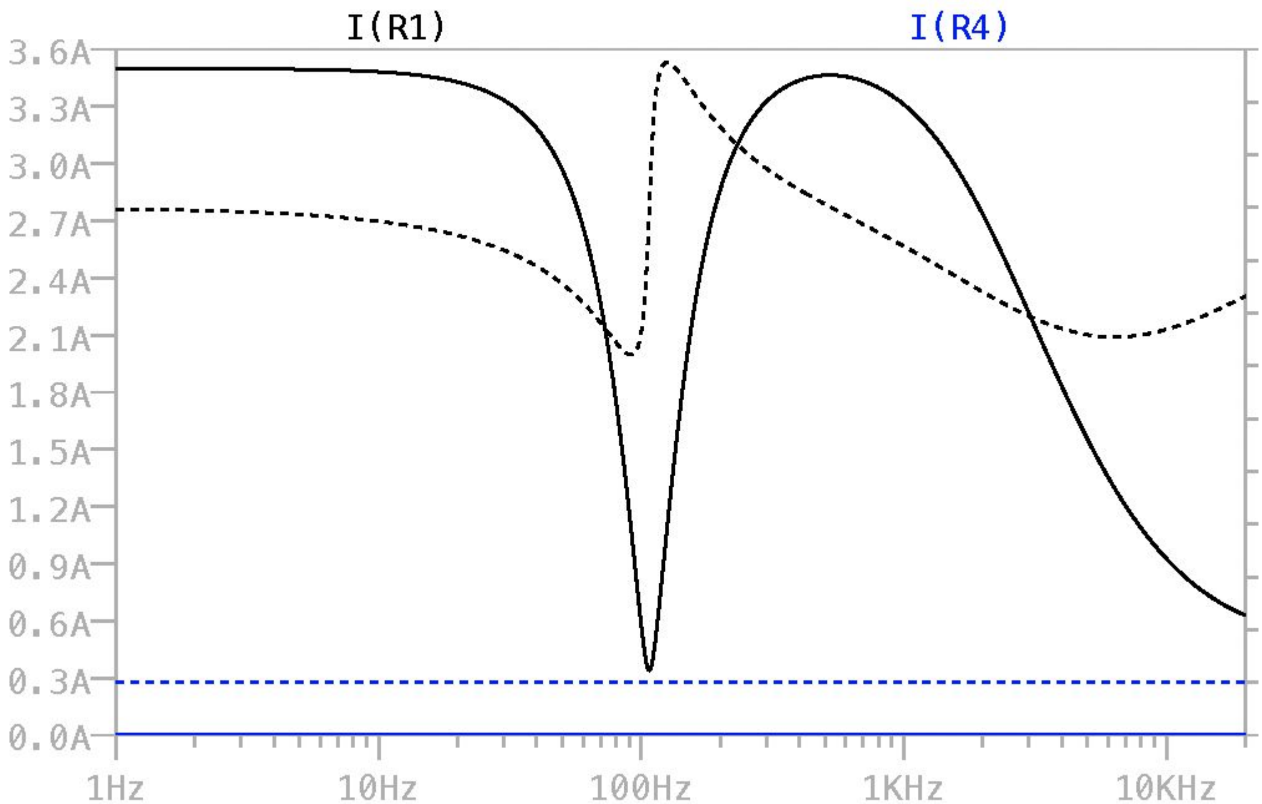

Fig.12 - currents through load resistor(R1) vs. line out resistor(R4) *unbroken lines

After the signal is sampled by the ADC of the user's audio interface the signal is not yet similar to an output from a speaker cabinet. The circuit's main function is to make sure the amp is operating and responding to an impedance curve of a speaker, but the line output of the system is just the output from the amp through a voltage divider. In order to reproduce the sound of a speaker cabinet the signal needs to be convolved with an impulse response of a speaker cabinet. A small program is used to take care of that part.

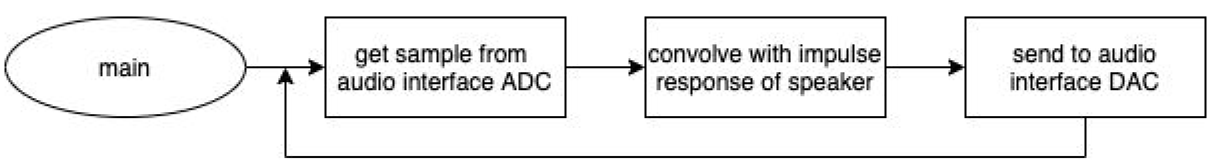

Fig.13 - software flow chart