MMI401 Lab 5

Basic Op-Amps

By now you are proficient with Circuit Maker. This Lab will have you use CM to verify some of the classroom things we've been doing.

You will need to open the **TL081 Op-Amp** data sheet on the wiki. The op-amp circuits will all use this device. In Circuit Maker, you find it under Op Amp 5 and 5A; be careful. They provide you with 2 versions which flip the inverting and non-inverting inputs. You have to pick the one you need for your situation. You can not flip the op amps unless you also flip the rails which you don't want to do - we want the positive rail to always be on top.

1) Design a simple inverting op-amp circuit with:
   - Av = 40dB.
   - Rails = +/- 15V

Use the data sheet to find the bandwidth of your amplifier at this gain. Use Circuit Maker to verify that this is the correct bandwidth. **Submit** your proof in your report.

2) Increase the gain of your op-amp to 60dB. Again, verify that the Bandwidth of the amplifier matches the theoretical bandwidth the data sheet gives you. **Submit** your proof in your report.

3) Alter your design as follows:
   - Av = 40dB
   - Rails = Single Supply +9V

Question to ponder in Lab: Why do you need DC Coupling Caps on the input and output of this amplifier?

The input coupling cap forms a HPF with the input impedance of the amplifier. **Calculate** the value of the Capacitor you will need to get a low frequency -3dB point suitable for use in a 6-string Guitar effects pedal. Connect the output of the op amp to a 100k load, via the output coupling cap.

Use Circuit Maker and **submit** screenshots to

a) verify your calculation for the Low Frequency cutoff
b) verify that the input pin is biased up to the correct value and that the output signal is riding on this bias voltage
c) use the multi-meter (double click in it and select DC Operating Point) to verify that there is indeed a virtual short between the (-) and (+) input pins of the op-amp.

4) Add the HF Compensation Cap (aka Anti Squeal Cap) to your feedback path. It forms a LPF in the loop and will shrink the bandwidth even more. Adjust (tweak) the value of the cap so that your upper -3dB point is right at 20kHz; you should now have an amp with a LF cutoff for a 6-string guitar and HF cutoff of 20kHz. **Submit** your CM Plots in your report.

5) **Question**: Why is this amp flawed for use with a standard 6-string electric guitar? **Submit** the answer in your report.

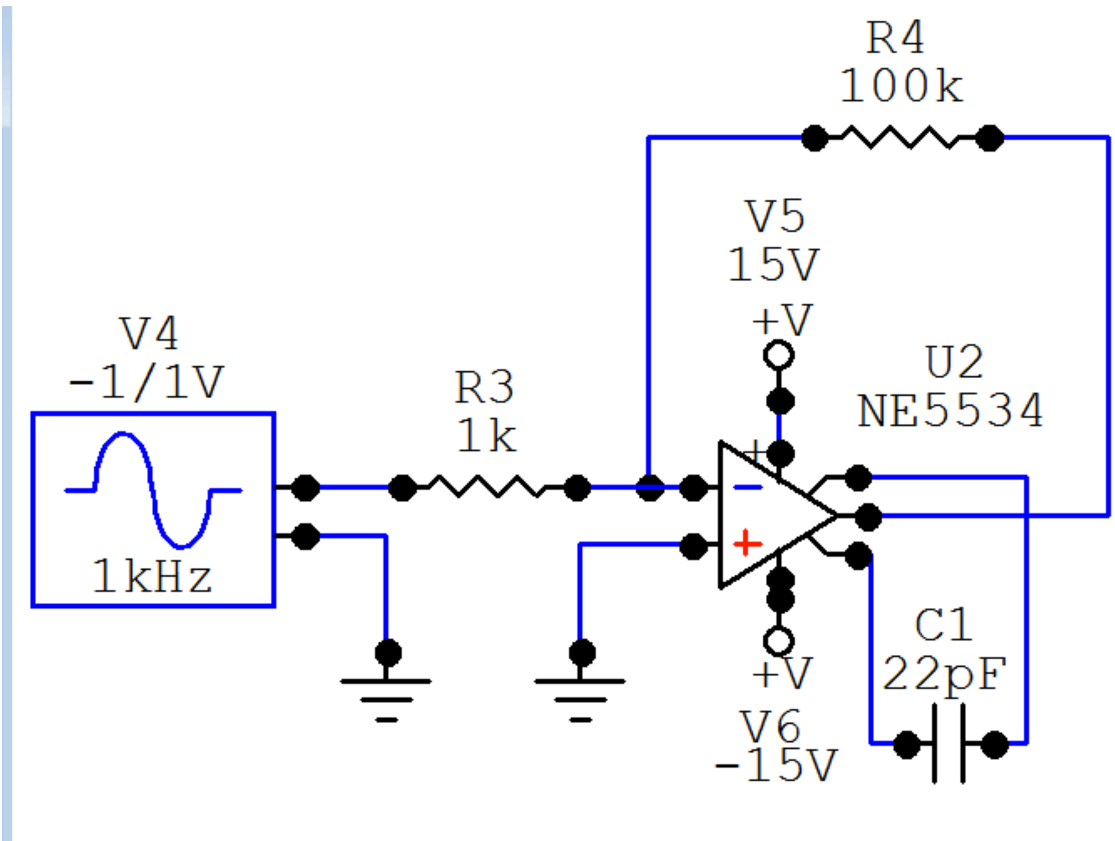
6) Fix the design to work with the standard 6-string electric guitar and have the same gain and single supply as before. **Submit** your CM Plots in your report along with a brief explanation as to why this fixes the issue in 5).

7) Finish the design by making the gain adjustable with a potentiometer to match these specs:
   - Minimum Gain = 6dB
   - Maximum Gain = 40dB

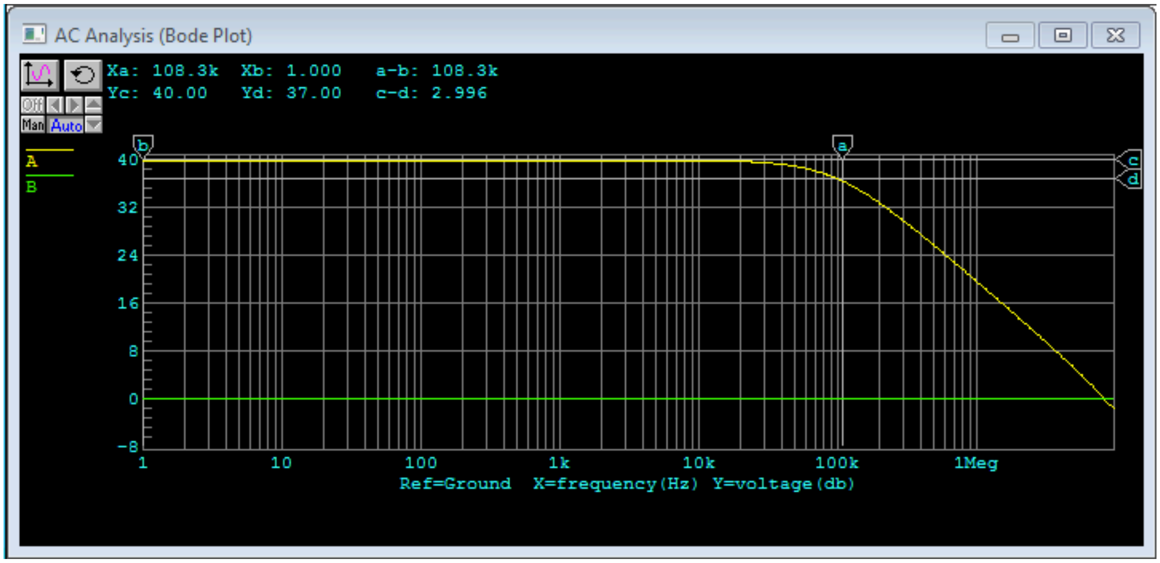
Lab 5

Circuit 1:

$$dB = 20\log\left(\frac{Vout}{Vin}\right)$$
$$40 = 20\log\left(\frac{Vout}{Vin}\right)$$
$$\left(\frac{Vout}{Vin}\right) = 10^2$$
$$R_f = 100k, R_i = 1k$$

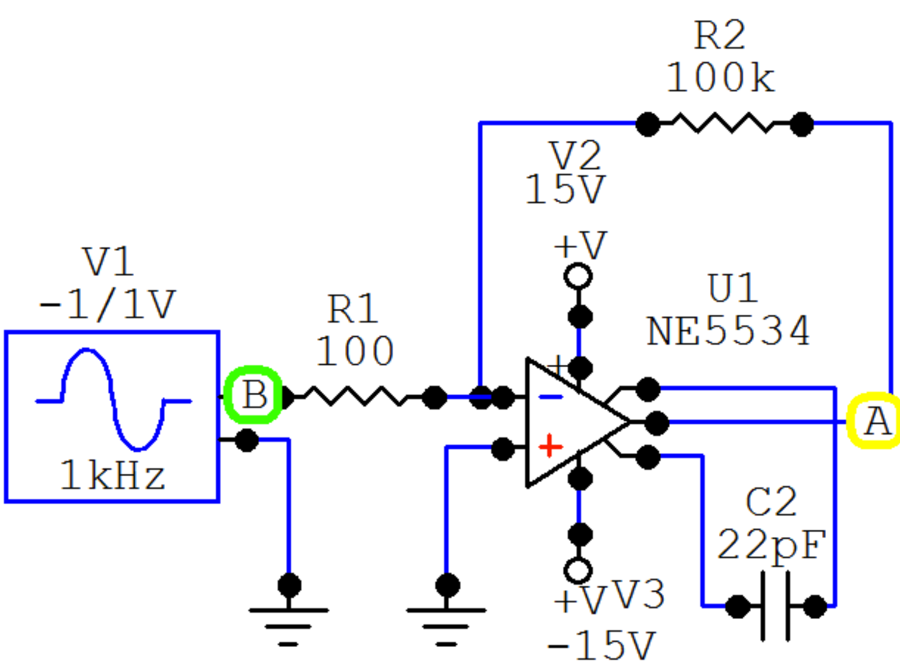


40dB of gain with a bandwidth of about 100kHz

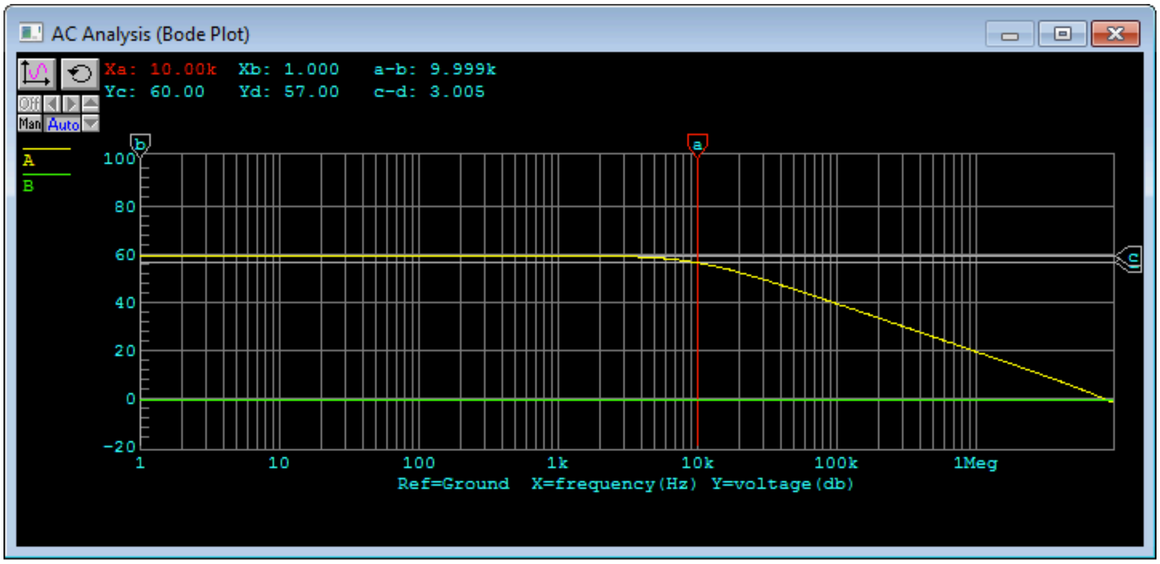


Circuit 2:

$$dB = 20\log\left(\frac{Vout}{Vin}\right)$$
$$60 = 20\log\left(\frac{Vout}{Vin}\right)$$
$$\left(\frac{Vout}{Vin}\right) = 10^3$$
$$R_f = 100k, R_i = 100$$



Marker ‘c’ showing 60dB of gain with marker ‘a’ showing the bandwidth to be approximately 10kHz.



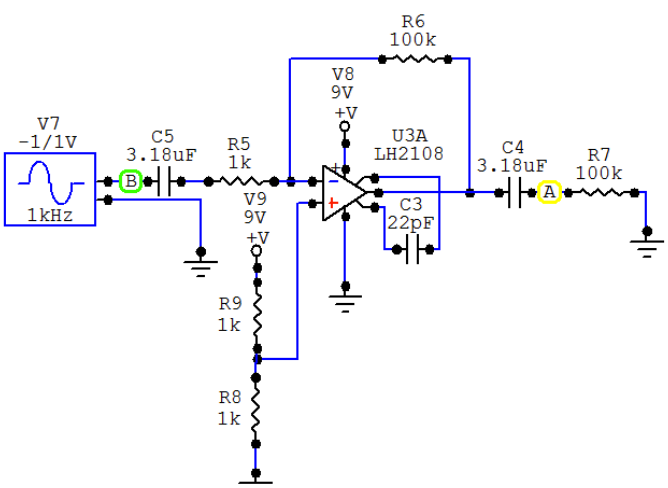
Circuit 3:

$$f_c = \frac{1}{2\pi RC}$$

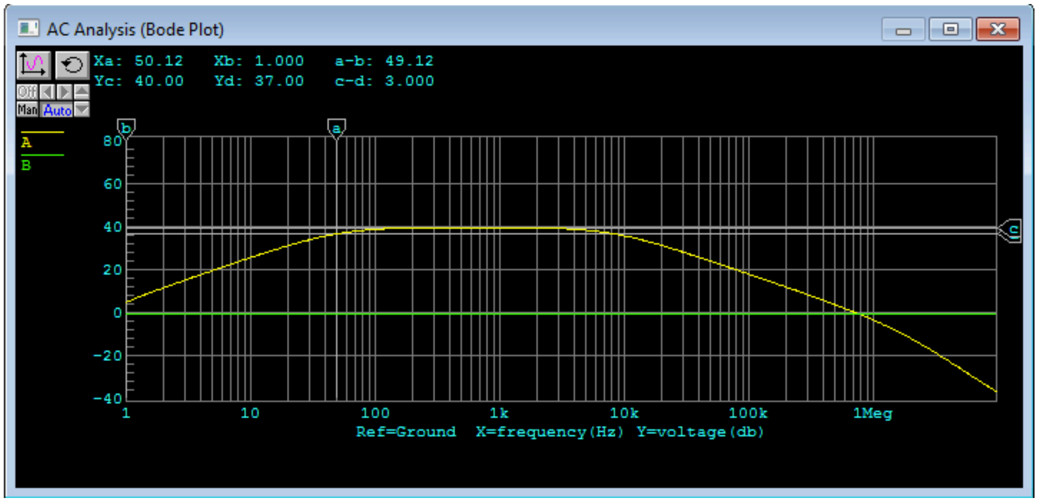
$$C = \frac{1}{2\pi R f_c}$$

*Cutoff frequency is arbitrarily below 80Hz since that is the lowest string on a guitar

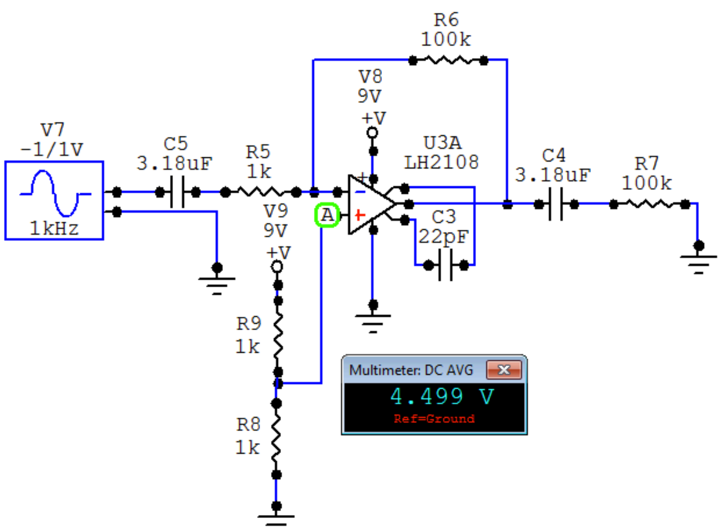
$$C = \frac{1}{2\pi(1k\Omega)(50Hz)} = 3.18\mu F$$

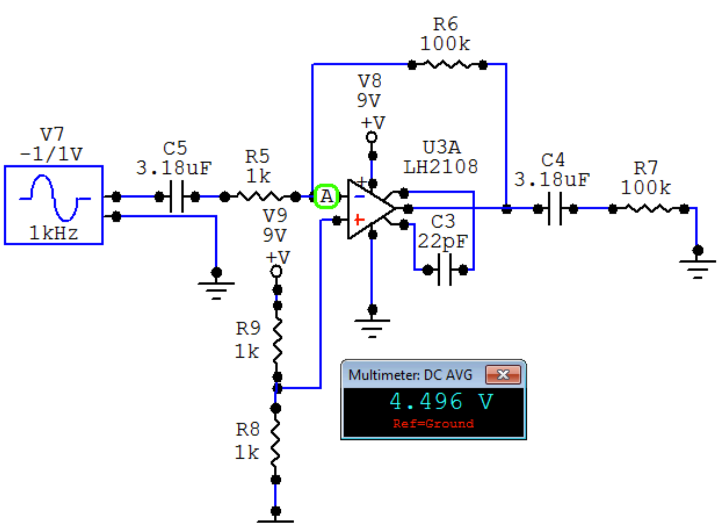


The cutoff frequency of the HPF formed is approximately 50Hz, as calculated.



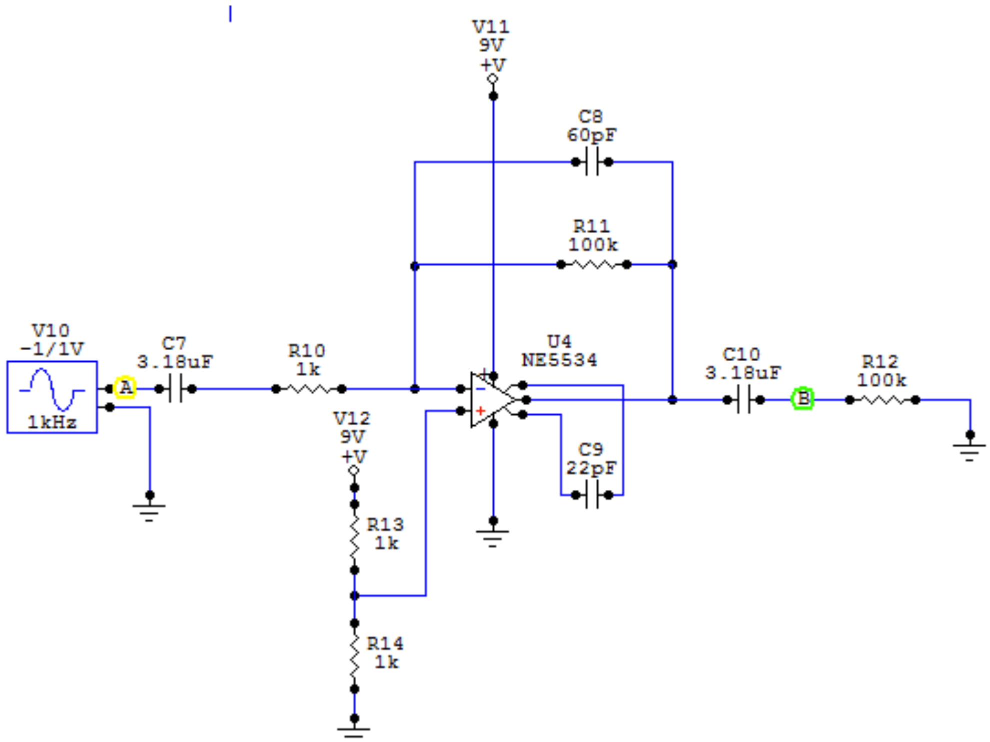
The multimeter shows us that there is a short between the inputs of the amp equal to half of the +9V supply source.



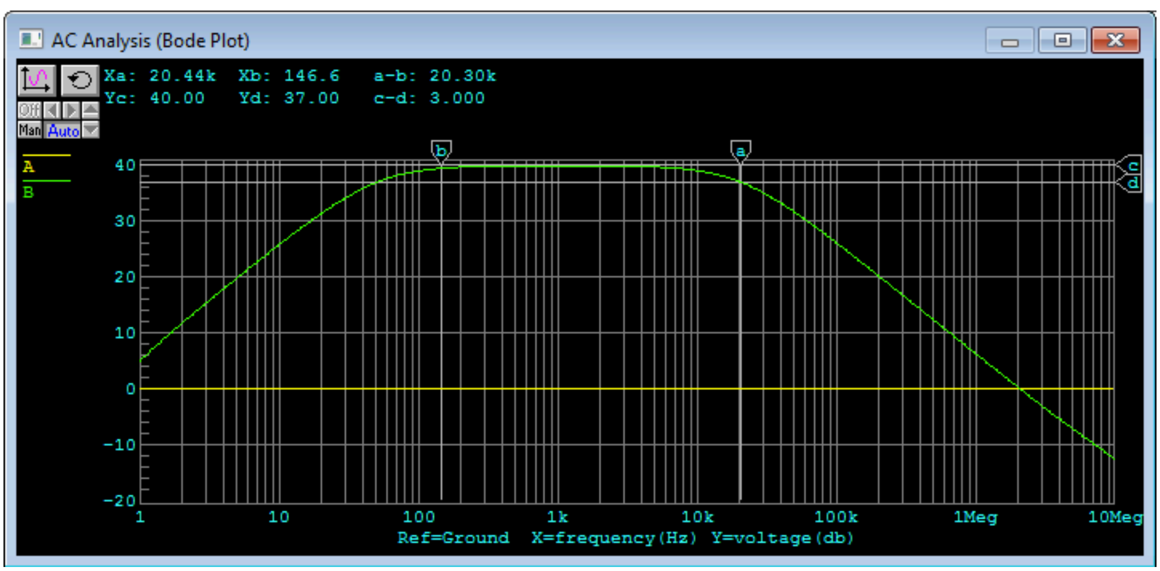


Circuit 4:

I found that an anti-squeal cap at about 60pF produced a HF cutoff of about 20kHz. The amp should now function for all sonic frequencies.



Marker 'a' shows the -3dB cutoff of the amp at 20kHz.



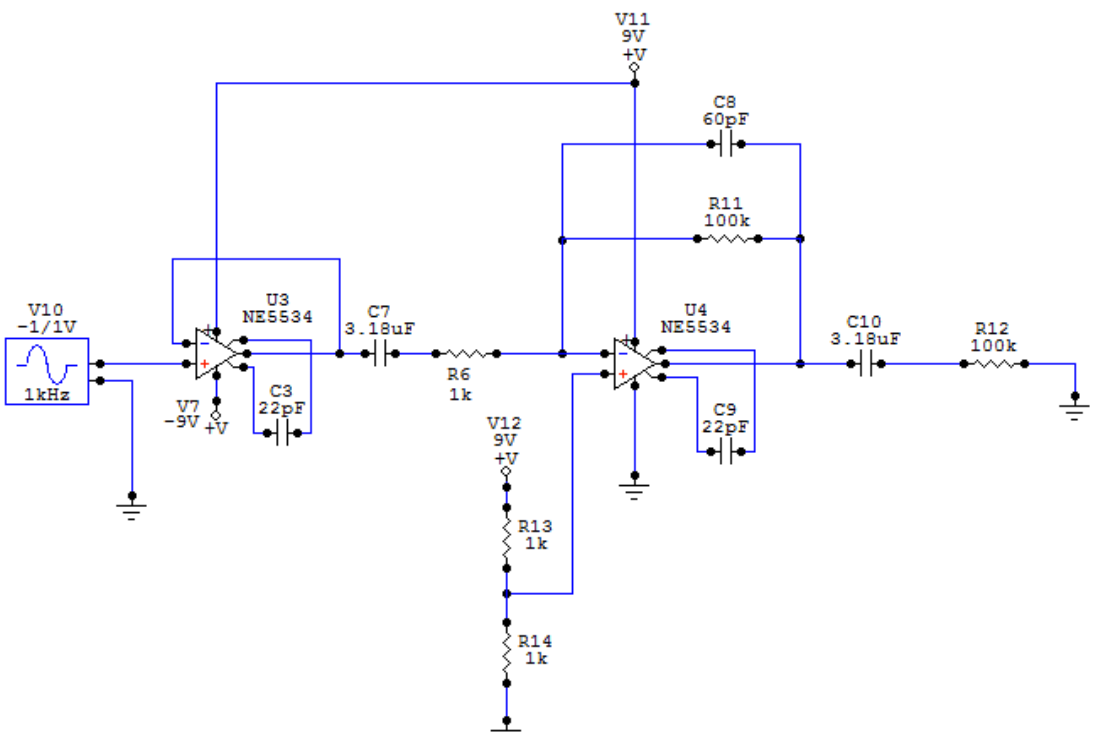
Question 5:

Why is this amp flawed for use with a standard 6-string electric guitar?

A typical guitar drives an output load impedance of at least 100k ohms. The input impedance of the amp is approximately 1k ohms (the miniscule cap value is negligible). Since the input impedance of the amp *should* be at least 10x the output of the guitar this system will massively load the guitar's output (since you would need at least 100k * 10 = 1000k input impedance of the amp which is much higher than the 1k the amp currently runs on). The solution is to add a unity gain buffer before the input of the amp so that the very high output impedance of the guitar will be fed into the unity gain buffer and the low output impedance of the unity gain buffer will be fed into the amp.

Circuit 6:

A unity gain buffer attached to the input to prevent loading:



Circuit 7:

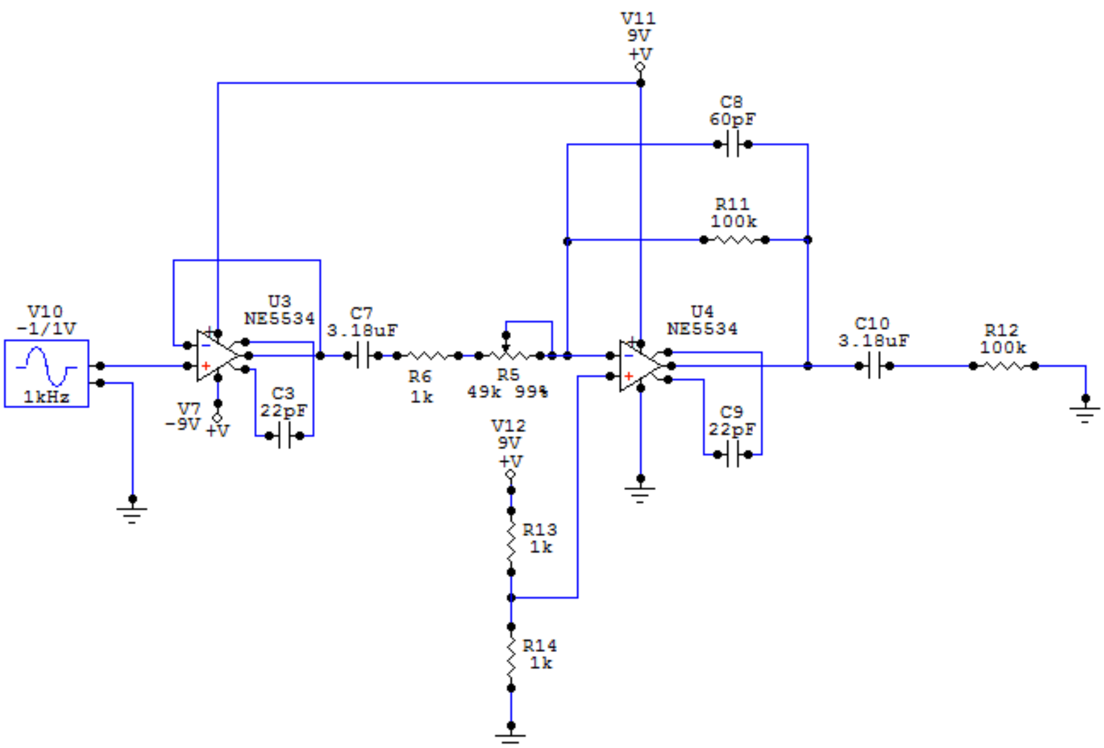
A variable resistor placed at the input set at 49k ohms will allow for a minimum gain of 6dB and a maximum gain of 40dB to be achieved. When the variable resistor is set at 100% all of the signal will bypass it and the original 1k resistor will be Ri and there will be the original 40dB of gain. When the variable resistor is set to 0% all of the signal will pass through the combined 50k ohms of both resistors and that will be Ri.

$$dB = 20\log\left(\frac{Vout}{Vin}\right)$$

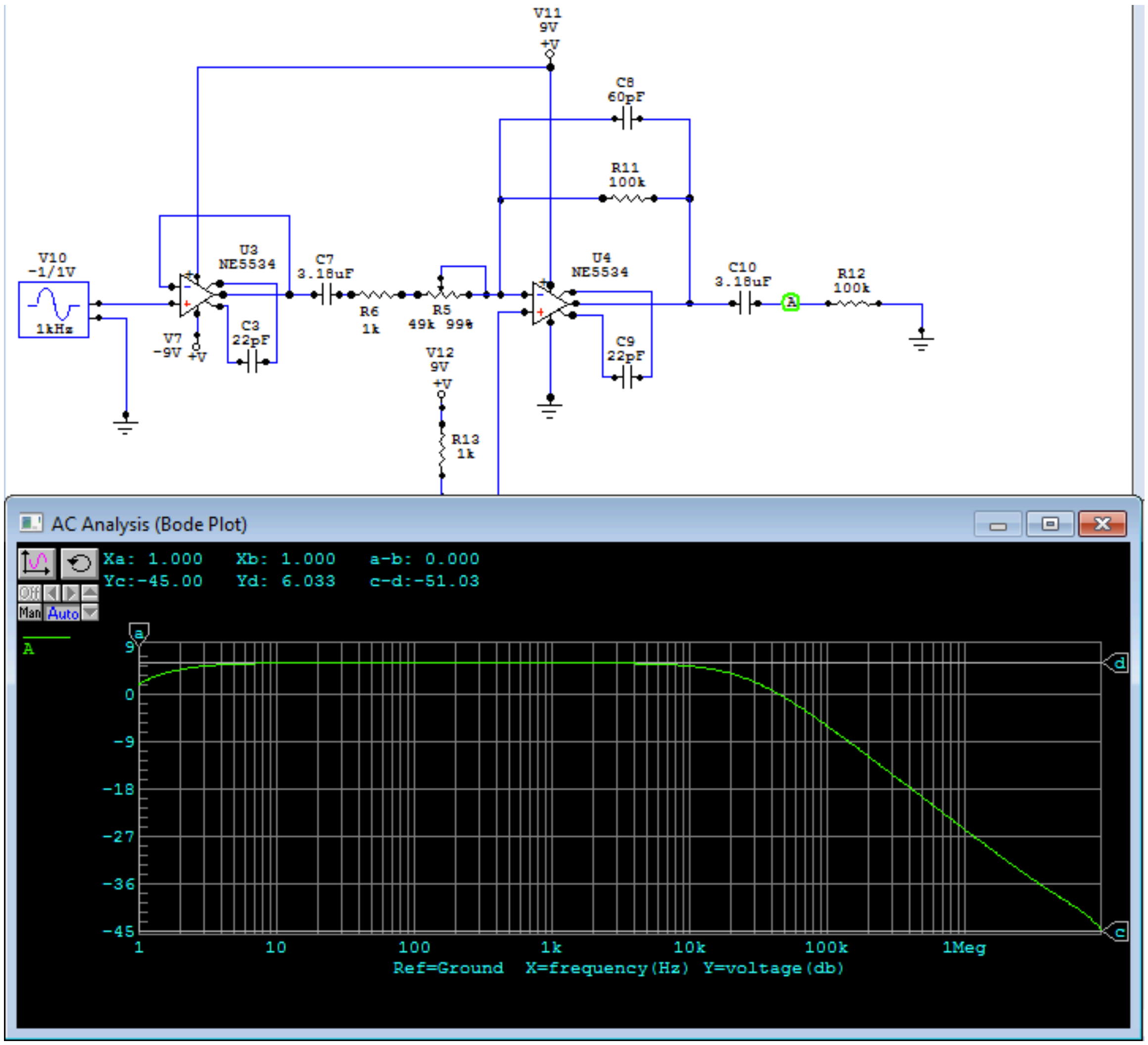
$$6dB = 20\log\left(\frac{Vout}{Vin}\right)$$

$$\left(\frac{Vout}{Vin}\right) = 10^{.3} \approx 2$$

$$R_f = 100k \;\; R_i = 50k$$



The variable resistor set to 99% and marker ‘d’ showing 6dB of gain.



The variable resistor is set to approximately 0% and marker 'd' showing the original 40dB of gain.