MMI401 Lab 1

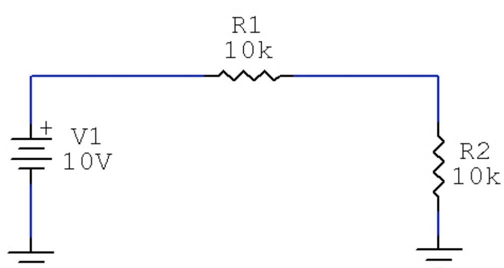
Voltage Dividers, Input/Output Impedance, DC Blocking Caps

The TA will show you how to setup Circuit Maker and find and place the following parts on the Schematic Window:

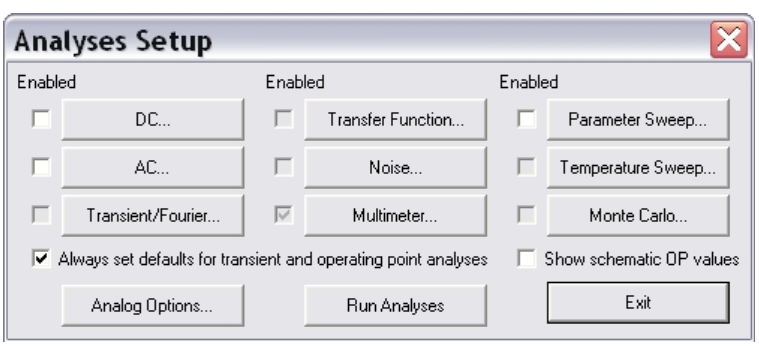
- Resistors
- Capacitors
- Inductors
- Battery for simple DC Source
- Signal Generator for AC Source

Circuit 1: Basic Voltage Divider, DC and AC

Use CM to make the following two circuits:

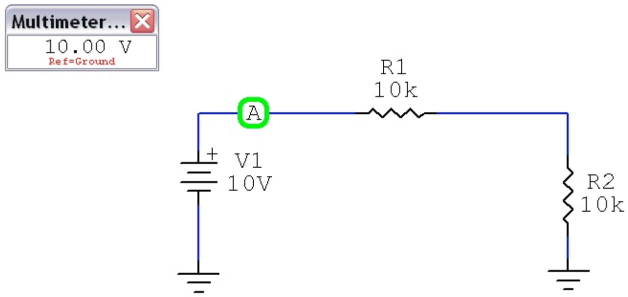


Setup your Analysis to use the Multimeter:

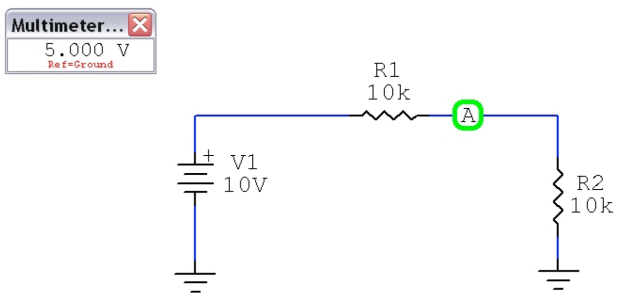


Note that AC is not checked.

Run the Analysis and use the Multimeter to probe the point on the left of the resistor and you will see the input 10VDC from the battery:

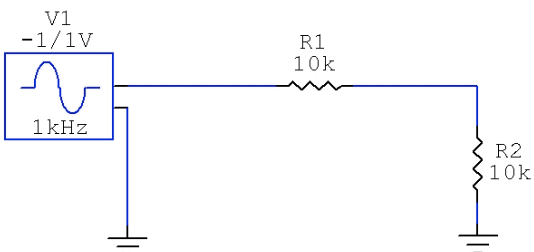


Now probe the other side:



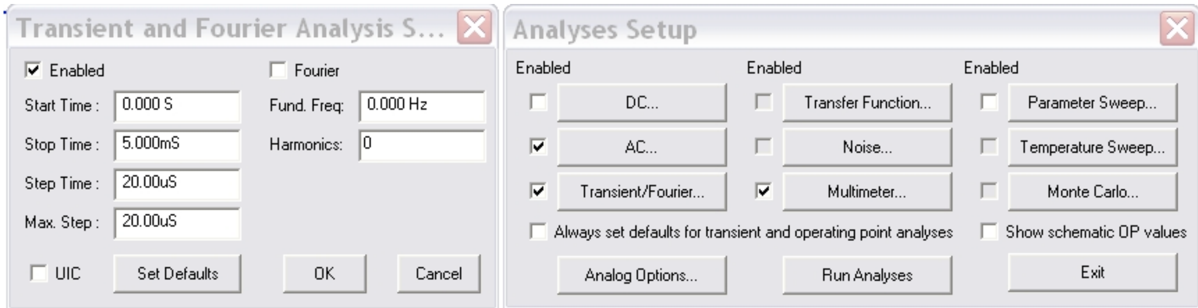
Since R1 = R2, you expect the output voltage to be 1/2 the input so it is.

Next, create the same circuit with an AC source instead of the battery:



Double click on the Signal Generator (AC Source) to check it's peak voltage (1Vp = 2Vpp, thus the -1/1V you see on top). Also, set the frequency to 1khz (1000Hz) and make sure the DC offset is 0.0V. To see the voltage division in AC you need an Oscilloscope, or in CM the Transient Analysis tool. You need to set it up in Analysis Options. It can only be used if there is an AC source in the circuit. Uncheck "Always set default…"

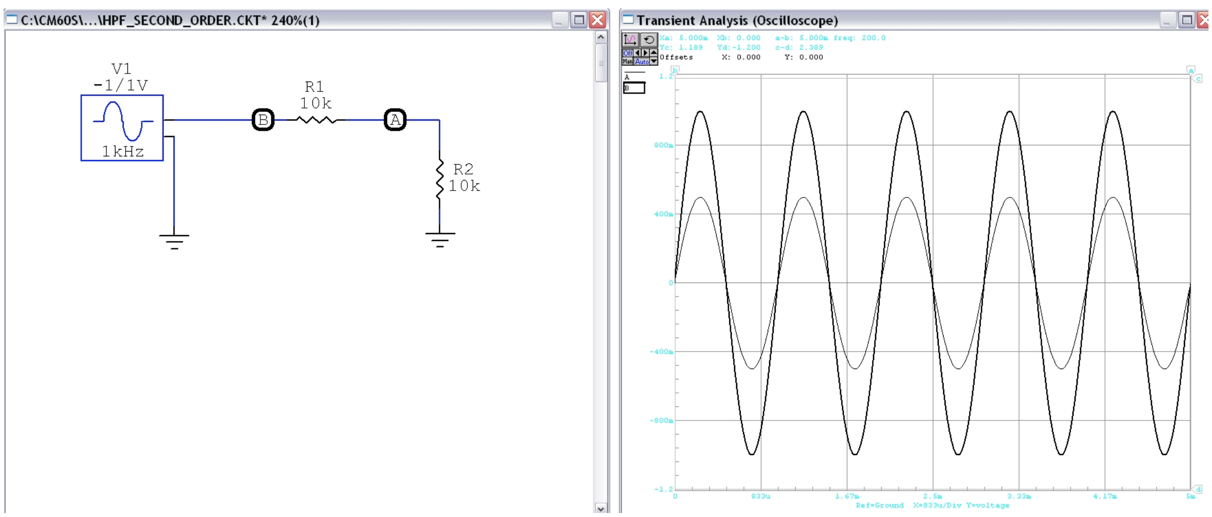
Your Transient Analysis should look like this (which is the normal):



When you run the analysis another window will show that will let you probe AC. You have to:

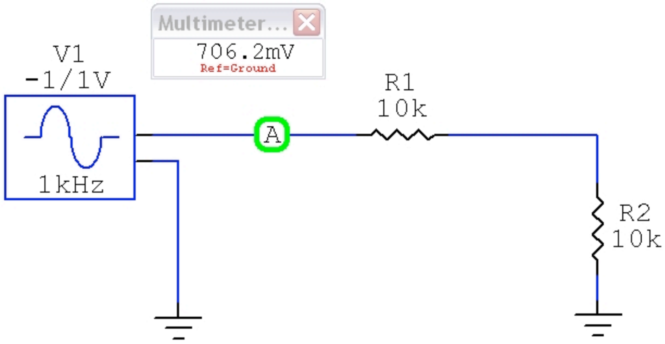
- click the probe toolbar button
- click on the Transient Analysis window
- probe the circuit

You can hold the shift key and probe more than one place in the circuit. Here I have the input and output probed. You can see that the output is half the size of the input:



To remove traces from the plot, just click on the A or B probe points.

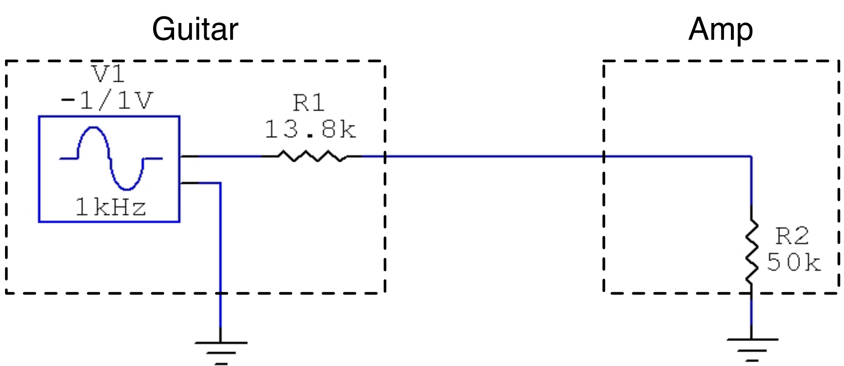
Finally, use the Multimeter to check the AC voltages. If you double click inside the multimeter window, you can change it to AC Vrms. **If you loose or close your windows, you can get them back from the Window menu item.** For the input side you should see this:



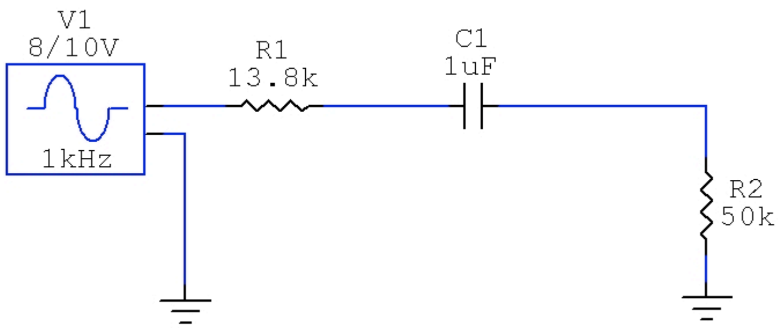
Does it make sense that the voltage is 706.2 mVrms? <u>Why? Discuss this with the T.A.</u>

Circuit 2: Using a Capacitor to remove DC offsets

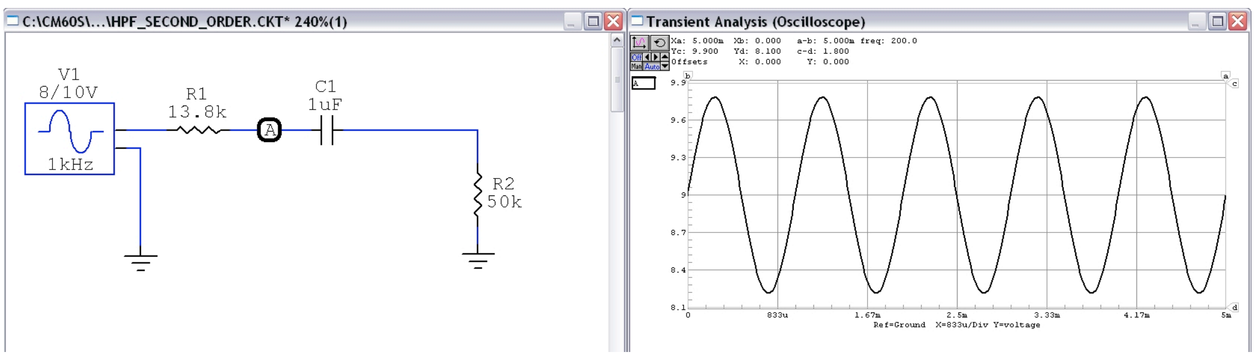
In this circuit, you are going to simulate my Stratocaster guitar with an output impedance of 13.8k connected to an amplifier with an input impedance of 50k. Here is what the simulation would look like, for guitars/basses we use the 1Vp generator to simulate:



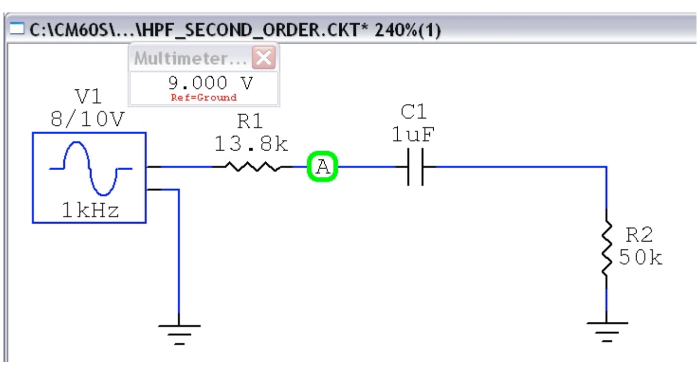
My Strat is actually a Clapton Strat that has an active (battery powered) midrange boost circuit built in (really, it does). My circuit has failed and there is a 9V DC offset biasing up my guitar signal. You simulate this by double-clicking on the signal generator and setting the DC offset to 9V. When you do this, the Sig Gen will read 8/10V at the top (this is confusing, it's not 0.8V, it means the output is swinging between 8V and 10V which is 1Vp (or 2Vp-p) biased up by 9V. That DC offset can cause problems with the Amp as well as a potential shocking hazard. To remove it, we are going to place a capacitor at the output of the guitar, before the input to the amp:



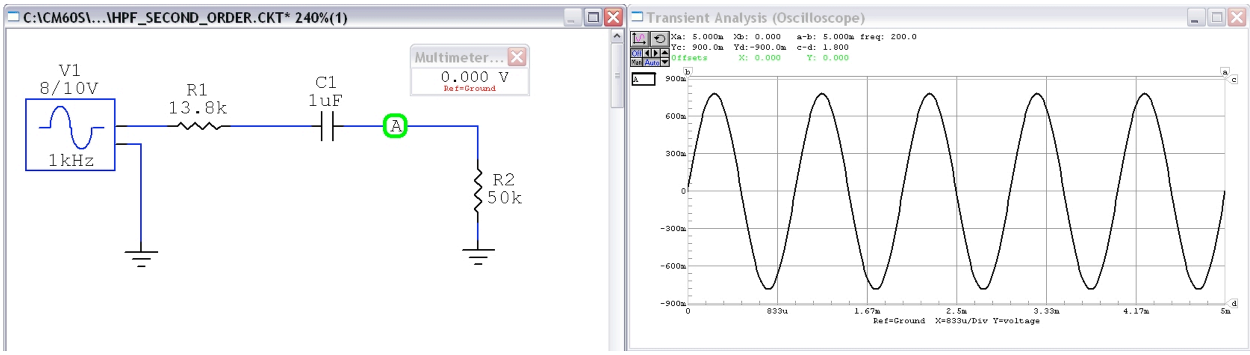
Use the Transient Analysis (scope) tool to probe the output of the guitar (left side of the cap). You will see the DC offset:



You can also see the DC offset by using the Multimeter: remember to double-click inside it to change it to measure DC (Choose “DC Operating Point”):



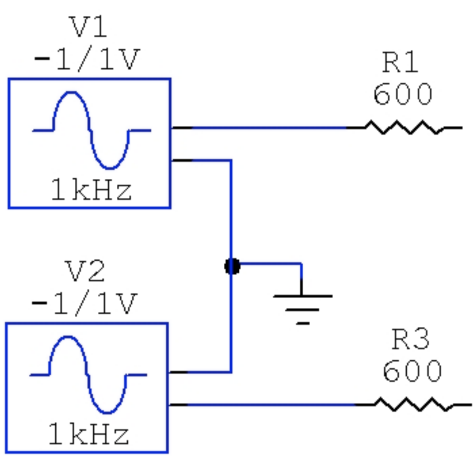
Now probe the other side of the cap to check for DC offset elimination. Here, I have also used the Multimeter to probe the other side, verifying the graph on the right.



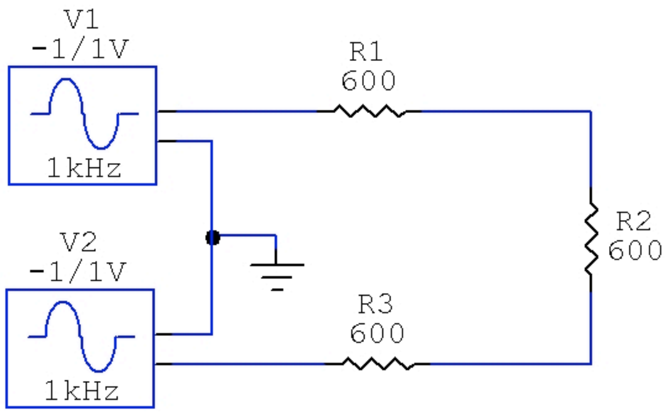
We can also see that the voltage out of the cap is in phase with the source.

Circuit 3: Simulating a Balanced Source

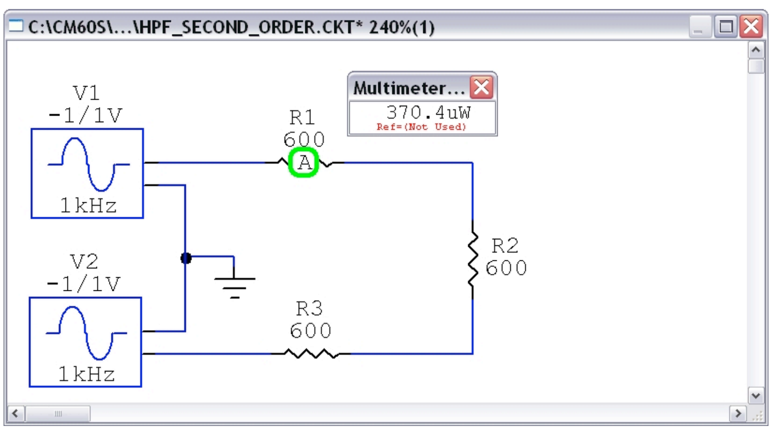
Lastly, you need to learn how to simulate a balanced source, for example the balanced output of a mixing board. Let's say we have an SSL Mixing Board balanced output. It's output impedance is 600 ohms (this means 600 ohms on each output, hot and cold). The way to do that is by wiring the signal generators as shown here with the 600 ohm output impedance resistors:



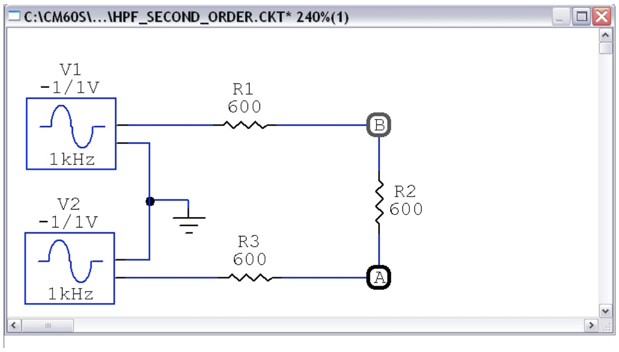
Both sources have 1Vp and 0V DC Offset. In early (telephone) circuits, the two signals drove a load that had the same value as either output impedance, or 600 ohms in this case. The two outputs share the same load and drive it ***differentially***. You can simulate that by connecting another 600 ohm resistor across the output:

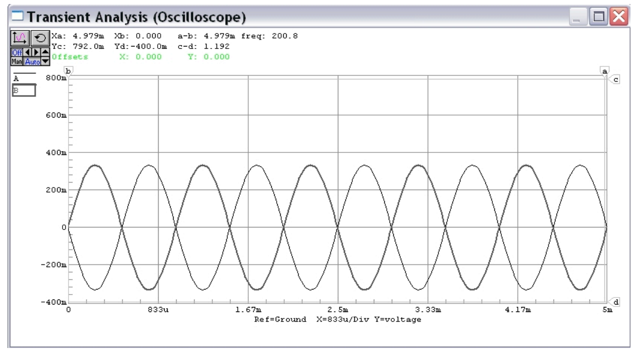


This was done to transfer the *maximum power* from the sources into the load. In the days of tube amps and circuits, maximum power transfer was the goal. To show this, you can use the Multimeter in an interesting way - put it in AC VRMS mode and then hover the probe over either of the source output resistors (R1 or R3 in my circuit above); the probe will change to have a “P” inside it, measuring power. Look at the power dissipated in R1:



You can see 370uW of power dissipated in that resistor. If you check the other one you will see the same. Now probe the 600 ohm load resistor - it also has 370uW of power dissipated. Maximum power has been delivered to the load. Next, look at the Transient Response and probe each side of the load:





But if you look at either output, they aren't 1Vp anymore. What's going on? First, there is a voltage divider - each half of the balanced output sees a voltage divider, R1&R2 and R3&R2, but what does the division look like? The answer is that each output sees 1/2 the load, voltage-wise. So, each output thinks it's driving a 300 ohm resistor. Measure the AC VRMS with the multimeter on each side of the load resistor. You get 235mV. Does this make sense?

Lab Writeup Questions:

These days, we care about maximum Voltage Transfer, not maximum Power Transfer in all but a handful of circuits (generally, these are circuits that couple the output of an amplifier to a speaker, where we want power!).

To get maximum Voltage Transfer, we need to drive a High Impedance load.

1. Why?

Change the load to 100k and re-run the simulation. Use the Multimeter to probe each side of the load. You will get 697mV. Finally, probe the power delivered to the load, you will get 19.53 uW.

2. Why is the power 19.53uW?

3. In Circuit 2 you simulated my guitar driving an amp with a 50k input impedance. Is "loading" occurring? Why or why not?

3. Design Project/Simulation

You are asked to design an unbalanced Pad (attenuator) that will provide 40dB of attenuation which means the output of the pad is 40dB below the input, or Vout/Vin = -40dB. **First**, design this pad. The way to do this is with a voltage divider. There are two resistors but only one known value (-40dB) so the way to do this is to arbitrarily choose a resistor value for one of them, and then calculate the value of the other one to get that -40dB output. Yes, you will have to do some algebra to work backwards.

But what arbitrary value should you try? I can't give you a value but I can give you a range of values; because of the sizes of currents and voltages and power dissipations in small signal analog, we generally wind up with resistor values on the range of 100 ohms to 1M (at the absolute extremes) but we try to keep the values more on the range of 1k to 500k.

To complete this question, show your equations and starting resistor values (it will look really suspicious if you all have the exact same resistor values, so do your own work!).

Next, use Circuit Maker to simulate and prove that your design works. To do this take screenshots of the software showing the Schematic and the Simulations (multimeter and Transient Response window).

Report Guidelines:

This is really a lab to get you working with Circuit Maker; as the semester continues we will put more emphasis on the report. But:

- all reports must be submitted electronically as PDF files. Use Microsoft Word or Apple Pages and then export your document as PDF.
- You will need to use an equation editor (both have MathType, a free add-on for this) to show your calculations.
- You can also use one of many free screen capture utilities (HardCopy Pro is the one I use for PC, Mac has it built in called "Grab") to capture your schematic and other windows.
- **All labs are due in the T.A.'s email Inbox by the beginning of the lab, one week later.**

The project write-ups are always due the following week after the lab, so you have 7 days to get it finished. **Beware - as the semester continues the MUE classroom will get crowded with students working on projects.** And, I do not allow students to use the classroom computers while I am teaching classes (on Tuesdays, I am in that room from 2pm until your class starts at 5pm so waiting until the last minute is not an option unless you have your own Windows machine and do it a home - recommended).

Nate P.

Lab 1

① Voltage Transfer $= \dfrac{Z_{load}}{Z_{load} + Z_{source}}$

To get a high voltage transfer higher impedance loads will get you bigger and bigger ratios.

e.g. $\dfrac{V_{in}}{V_{out}} = \dfrac{500\Omega}{500\Omega + 250\Omega} = \dfrac{2}{3}$ and $\dfrac{V_{in}}{V_{out}} = \dfrac{5000\Omega}{5000\Omega + 250\Omega} = \dfrac{20}{21}$

higher transfer

② $P = \dfrac{V^2}{R}$

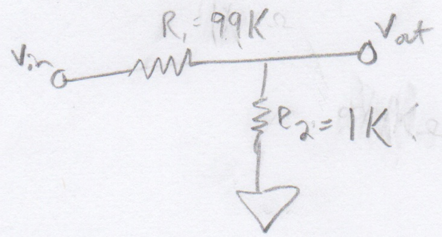
697 from each side

$P = \dfrac{(697\,mV + 697\,mV)^2}{100k\Omega} = 19.53\,\mu W$

③ $\dfrac{V_{in}}{V_{out}} = \dfrac{Z_{load}}{Z_{load} + Z_{source}}$

No because the amp's input impedance of 50KΩ is bigger than the guitar's output impedance of 13.8KΩ.

④ $\dfrac{V_{out}}{V_{in}} = \dfrac{1K}{1K + R_1}$ ← Arbitrary R value



$-40\ dB = 20 \log\left(\dfrac{V_{out}}{V_{in}}\right)$

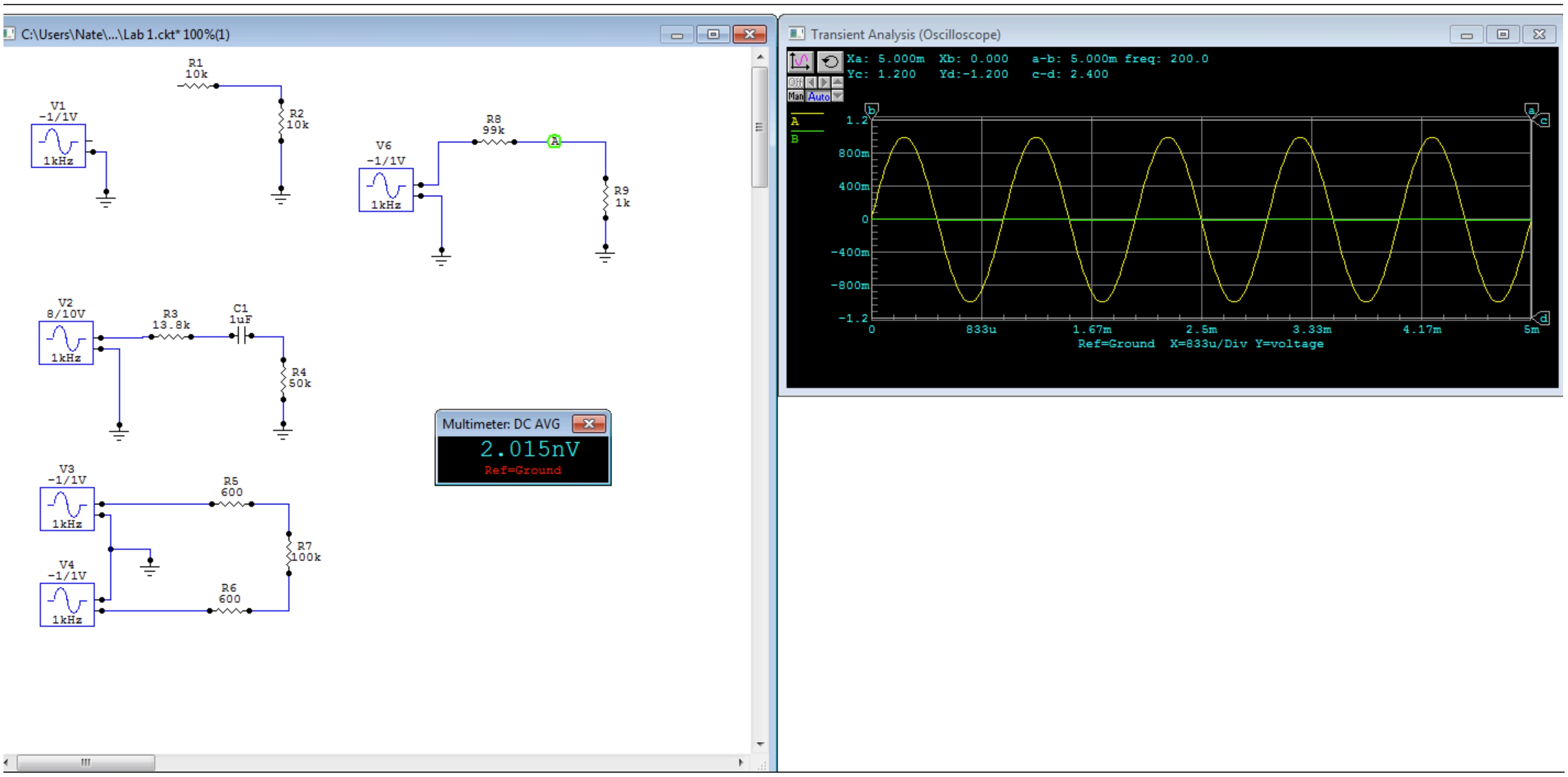
$10^{-2} = \dfrac{V_{out}}{V_{in}}$

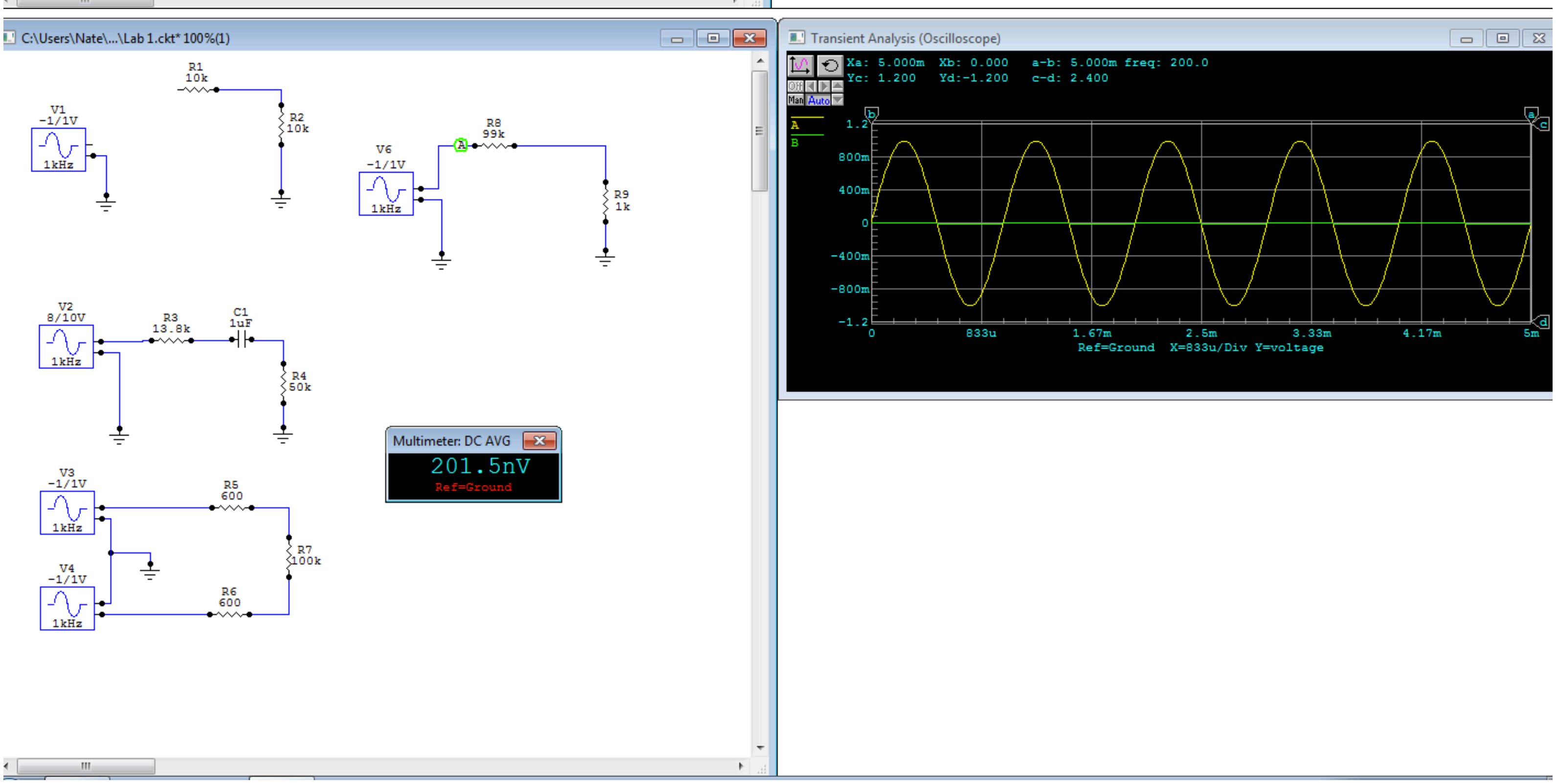
$10^{-2} = \dfrac{1K\Omega}{1K\Omega + R_1}$ $\quad V_{out} = \frac{1}{100} V_{in}$

$10\Omega + .01R_1 = 1K\Omega$

$.01\,R_1 = 990\,\Omega$

$R_1 = 99K$


C:\Users\Nate\...\Lab 1.ckt* 100%(1)
R1 10k
R2 10k
V1 -1/1V 1kHz
V6 -1/1V 1kHz
R8 99k
R9 1k
V2 8/10V 1kHz
R3 13.8k
C1 1uF
R4 50k
V3 -1/1V 1kHz
V4 -1/1V 1kHz
R5 600
R6 600
R7 100k
Multimeter: DC AVG
2.015nV
Ref=Ground
Transient Analysis (Oscilloscope)
Xa: 5.000m Xb: 0.000 a-b: 5.000m freq: 200.0
Yc: 1.200 Yd:-1.200 c-d: 2.400
Ref=Ground X=833u/Div Y=voltage


C:\Users\Nate\...\Lab 1.ckt* 100%(1)
R1 10k
R2 10k
V1 -1/1V 1kHz
V6 -1/1V 1kHz
R8 99k
R9 1k
V2 8/10V 1kHz
R3 13.8k
C1 1uF
R4 50k
V3 -1/1V 1kHz
V4 -1/1V 1kHz
R5 600
R6 600
R7 100k
Multimeter: DC AVG
201.5nV
Ref=Ground
Transient Analysis (Oscilloscope)
Xa: 5.000m Xb: 0.000 a-b: 5.000m freq: 200.0
Yc: 1.200 Yd:-1.200 c-d: 2.400
Ref=Ground X=833u/Div Y=voltage