ECE 321 - Homework #1

Op Amp Amplifiers, Push-Pull Amplifiers. Due Monday, April 3rd
Please email to jacob.glower@ndsu.edu, or submit as a hard copy, or submit on BlackBoard

For all problems, assume you are using

- LM833 Op Amps (max current = 50mA)
- 2SC6144 transistors (β = 200, 10A max, |Vbe| = 0.7V), or
- TIP112 / TIP117 NPN and PNP power transistors (for a push-pull amplifier).
  - β = 1000, 3A max, |Vbe| = 1.4V

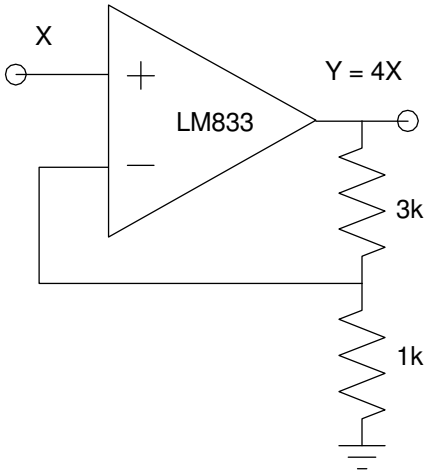
Amplfier:

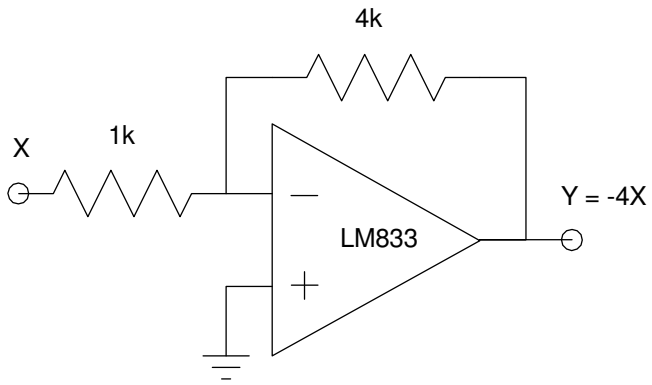
1) Design a circuit to implement

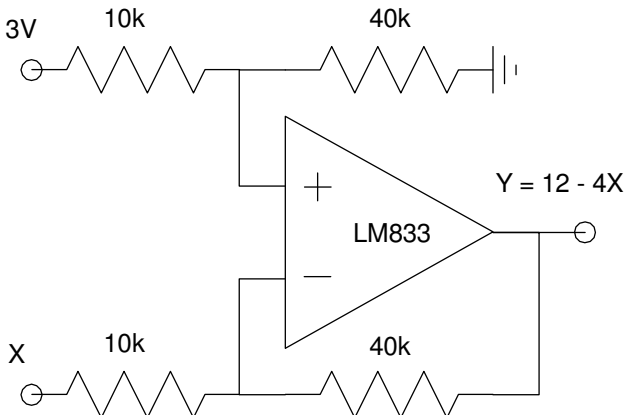
a) Y = +4X

b) Y = -4X

c) Y = 12 - 4X = 4 (3 - X)







Mixer

2) Design a circuit to mix three signals together:

- Y = 6A + 3B + 7C

Do this in two steps

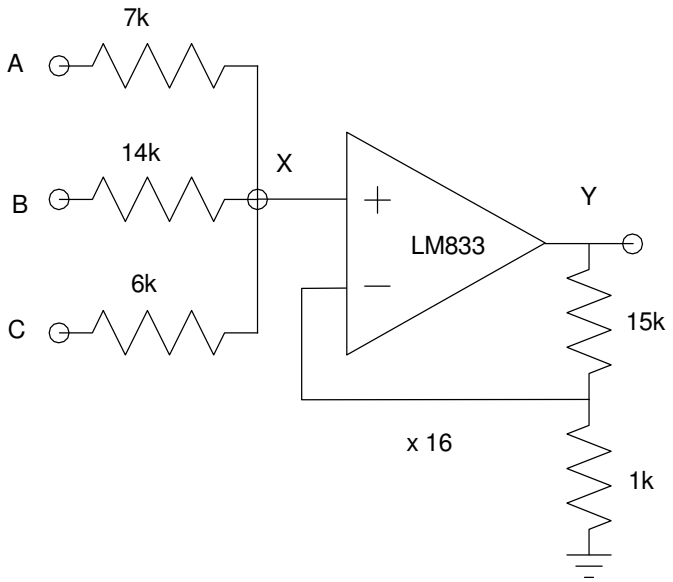
$$X = \left(\frac{6A+3B+7C}{16}\right)$$

$$Y = 16X$$

Create X using a weighted-average circuit

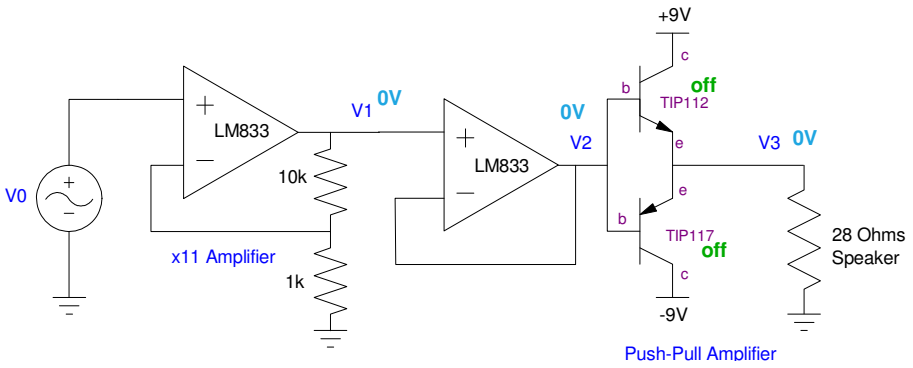
Create Y using a non-inverting amplifier

(there are other solutions)

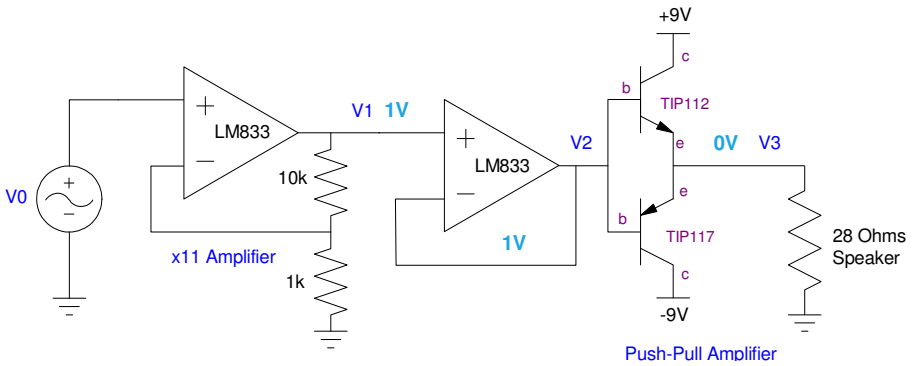


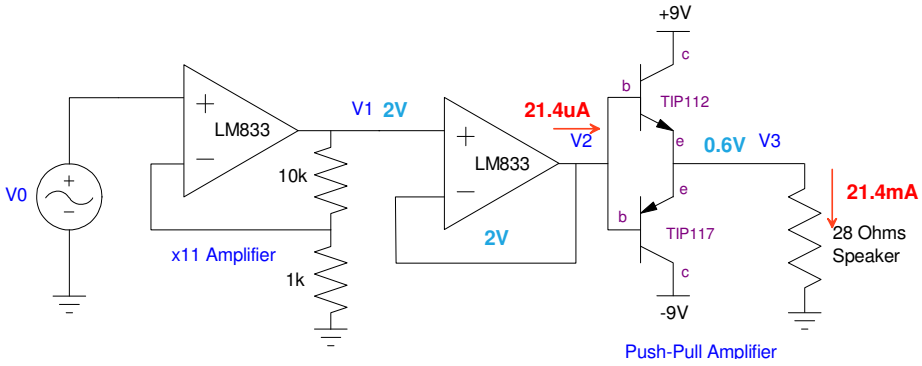
Push-Pull Amplifier with Crossover Distortion

3) For the circuit below, calculate the voltages and currents when V1 = { +0V, +1V, +2V}



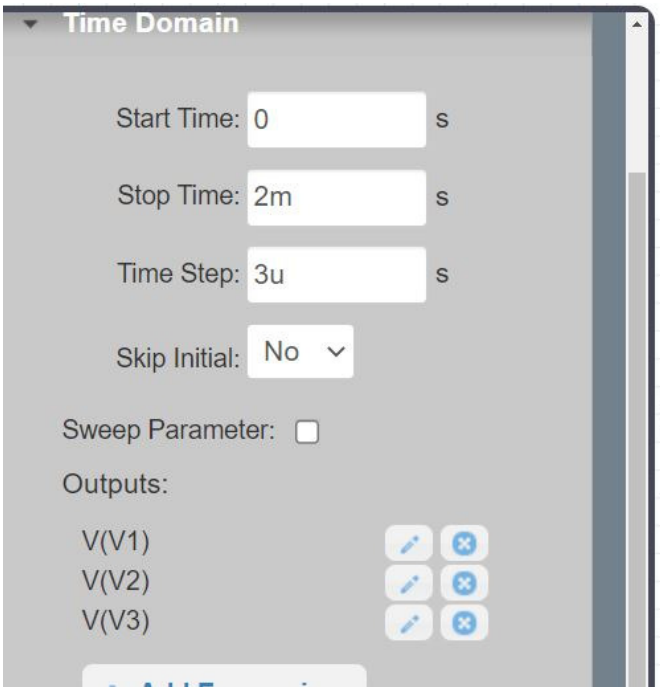
Problem 3-5: Amplifier with Crossover Distortion

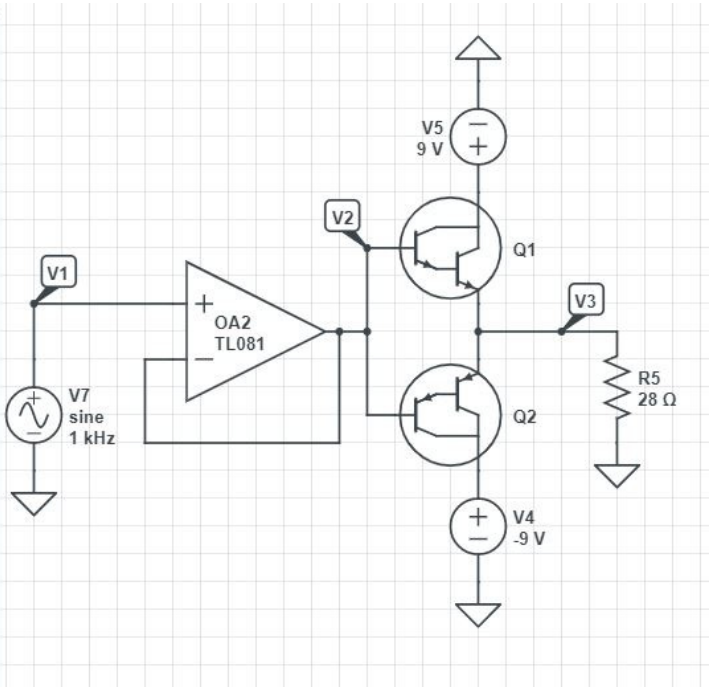


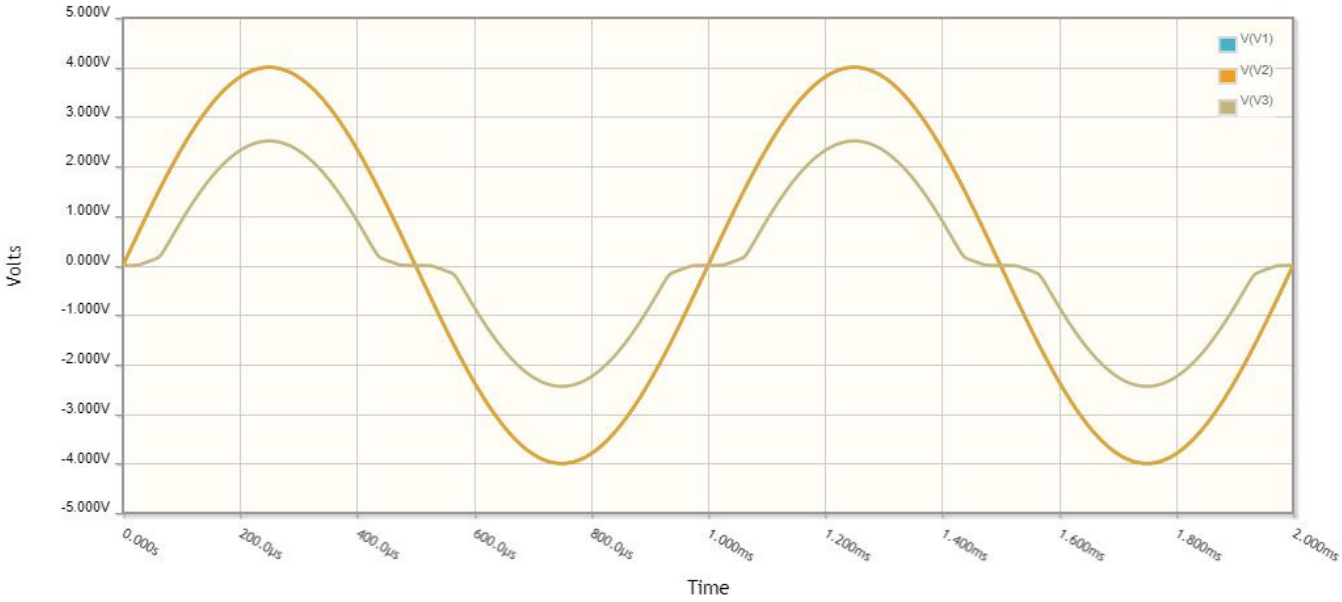


4) Simulate in CircuitLab with

- V1 being a 4Vpp sine wave at 1kHz, or
- V0 being a 363mVpp sine wave at 1kHz (same result)

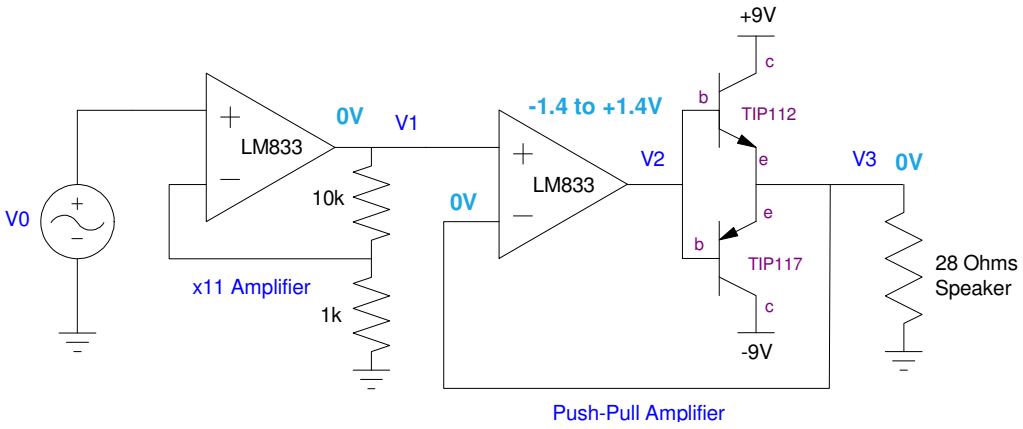




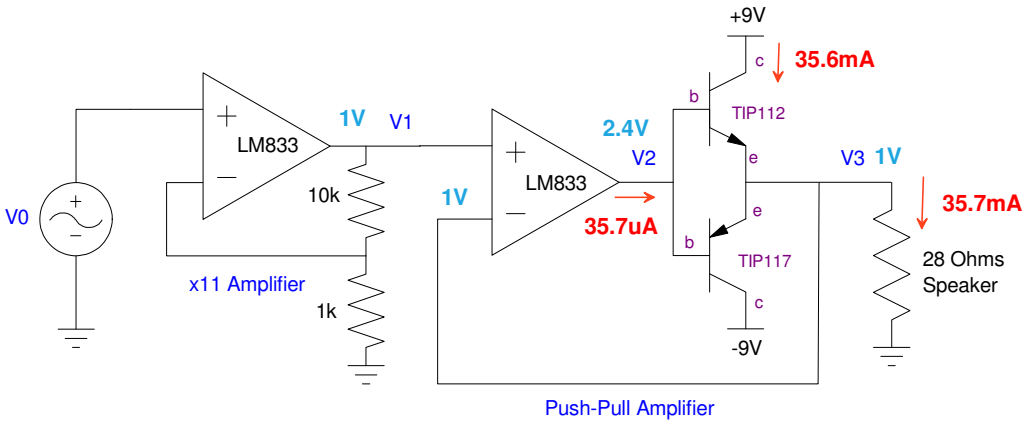


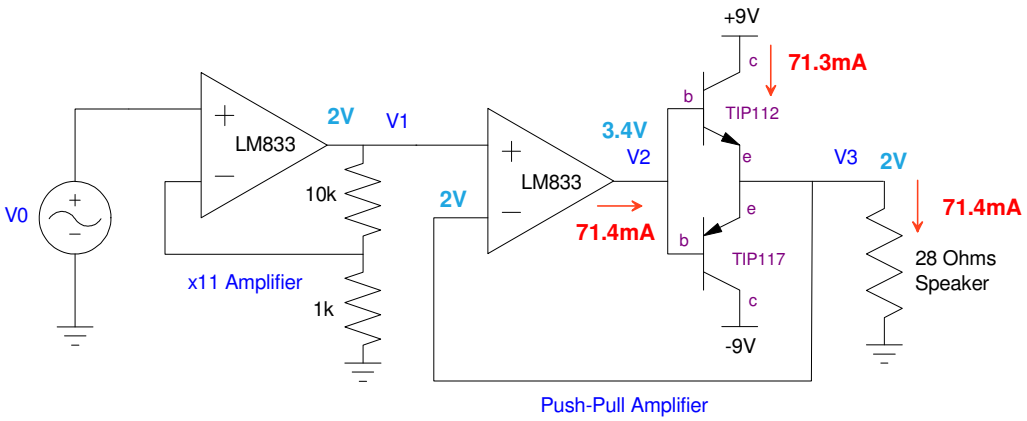
Push-Pull Amplifier without Crossover Distortion

5) For the circuit below, calculate the voltages and currents when V1 = {+0V, +1V, +2V}



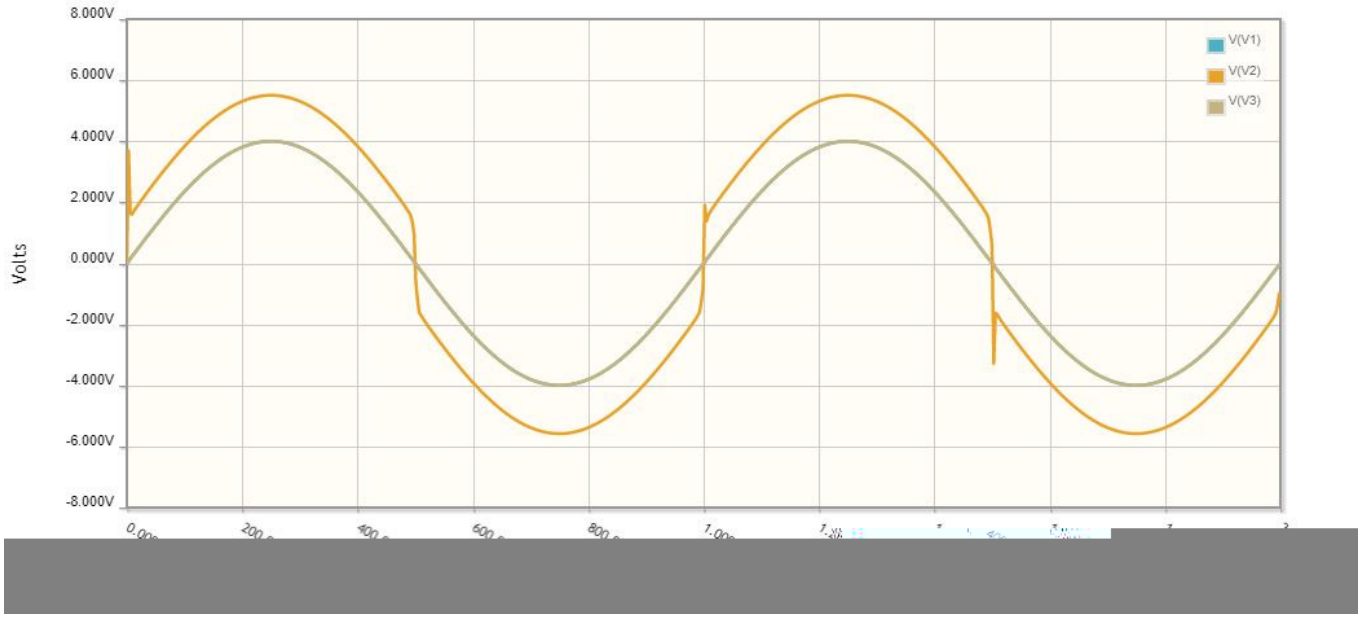
Problem 5 -6: Amplifier Withour Crossover Distortion



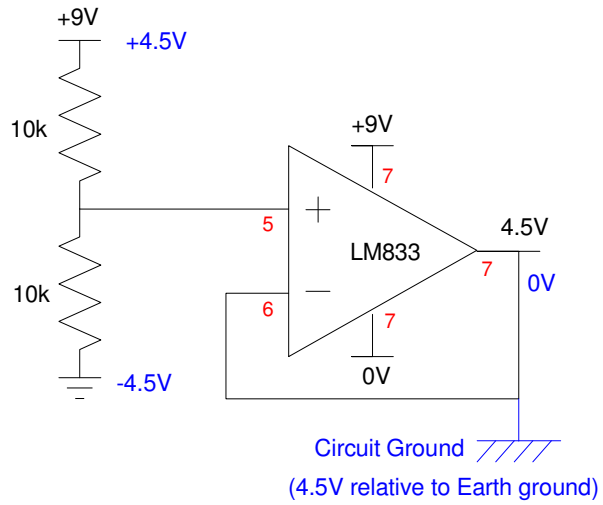


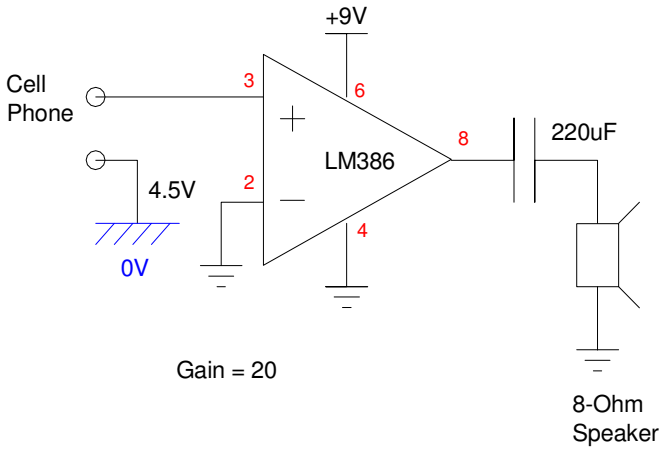
6) Simulate in CircuitLab with

- V1 being a 4Vpp sine wave at 1kHz, or
- V0 being a 363mVpp sine wave at 1kHz (same result)



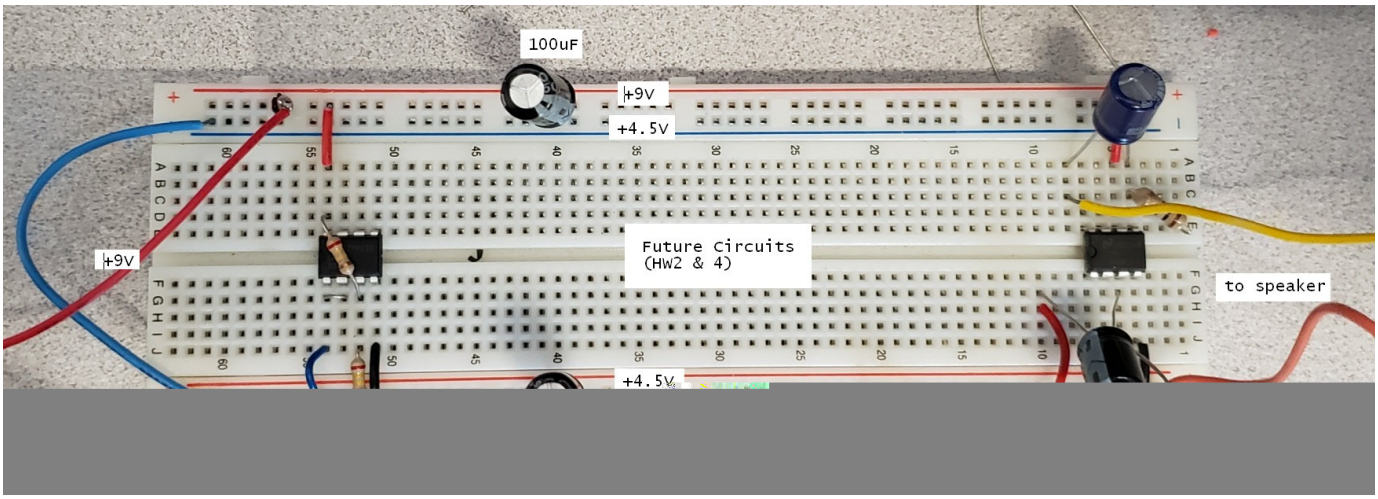
An LM386 is a 700mW audio amplifier (essentially a push-pull anmplifier on a chip - provides better sound quality).





7) Build the two circuits above on a breadboard using a 9V battery (or any 6-12VDC power source)
   - Creating a 4.5V reference signal (acts as circuit ground) capable of sourcing / sinking up to 25mA
   - A gain of 20 audio amplifier (LM386)

Include photo of your resulting breadboard circuit.



8) Check the functioning of the 4.5V reference source (LM833) under load. Measure the output votlage with

- No load on the output.
- The output connected to +9V through a 220 Ohm resistor (sinking 20.5mA)
- The output connected to 0V through a 220 Ohm resistor (sourcing 20.5mA)

Checking the +4.5V signal

- No-Load: 4.58V
- 220 Ohms to +9V: 4.60V (sink 20.0mA)
- 220 Ohms to ground: 4.56V (source 20.7mA)

Comment: The op-amp creates a 4.5V signal which can

- Source or sink 20mA (measured)
- Source or sink 50mA (data-sheets for LM833)

The output impedance of the op-amp appears to be

$$R_{out} \approx \left(\frac{0.02V}{20mA}\right) = 1\Omega$$

9) Check the functioning of the audio amplifier (LM386) under load (connected to an 8-Ohm speaker). Connect the input to a function generator (cell phone app preferred). Measure the gain when the input is

Go to OnlineFunctionGenerator.com to output a sine wave from my computer...

200Hz sine wave

- Vin = 19.1mVrms signal from the computer
- Vout = 347mVrms voltage across the speaker
- gain = 18.2

1kHz sine wave

- Vin = 19.2mVrms
- Vout = 383mVrms across speaker
- gain = 19.94

5kHz sine wave

- Vin = 19.0mVrms
- Vout = 372mVrms across speaker
- gain = 19.57

note: Keep your circuit together - we'll use it for the next few weeks.