

ECE 320 - Homework #7

Mosfet Switch, Op-Amp Amplifiers

MOSFET Switch

One of the MOSFET's that CircuitLab has is an IRF1047. It's specifications are

- $\max(I_c) = 100A$ continuous
- $V_{gs(th)} = 4V$ (max)
- $R_{ds} = 7.8m\Omega @ I_{ds} = 78A @ V_{gs} = 10V$
- \$0.53 each

1) Determine the transconductance gain, k_n , for this MOSFET.

- Assume $V_{tn} = 4.00V$

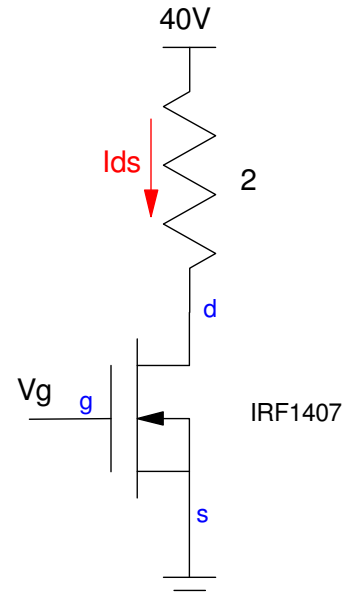
R_{ds} is the Ohmic region

$$V_{ds} = 0.0078\Omega \cdot 78A = 0.608V$$

$$I_{ds} = k_n \left(V_{gs} - V_{th} - \frac{V_{ds}}{2} \right) V_{ds}$$

$$78A = k_n \left(10V - 4V - \frac{0.608V}{2} \right) 0.608V$$

$$k_n = 22.508 \frac{A}{V^2}$$



2) Determine the voltages and currents for the following circuit when $V_g = 5V$

Assume Ohmic. This gives 2 equations for 2 unknowns

$$I_{ds} = k_n \left(5 - 4 - \frac{V_{ds}}{2} \right) V_{ds}$$

$$V_{ds} + 2I_{ds} = 40$$

There is no solution (it's not ohmic)

Assume saturated

$$I_{ds} = \frac{k_n}{2} (V_{gs} - V_{th})^2$$

$$I_{ds} = \frac{22.508}{2} (5V - 4V)^2 = 11.254A$$

$$V_{ds} = 40 - 2I_{ds} = 17.492V$$

Check: To be in the saturated region

$$V_{ds} > V_{gs} - V_{th}$$

$$17.492V > 5V - 4V$$

Check your result in CircuitLab

- Change the parameters of an IRF1407 to match the data sheets ($k_n = 22.5 \text{ A/V}^2$)

BS170	Datasheet	Buy
BSS138	Datasheet	Buy
FDN337N	Datasheet	Buy
IRF1407	Datasheet	Buy
IRF3205	Datasheet	Buy
IRF3710	Datasheet	Buy
IRF520	Datasheet	Buy
IRF540	Datasheet	Buy

name:	M1	Part#:	IRF1407		
K_P:	22.5	A/V ²	V_TO:	3.91946	V
LAMBDA:	0	1/V	R_G:	4.94006	Ω
R_D:	0.00208	Ω	R_S:	0.00443	Ω
C_ISS:	5600p	F	C_OSS:	800p	F

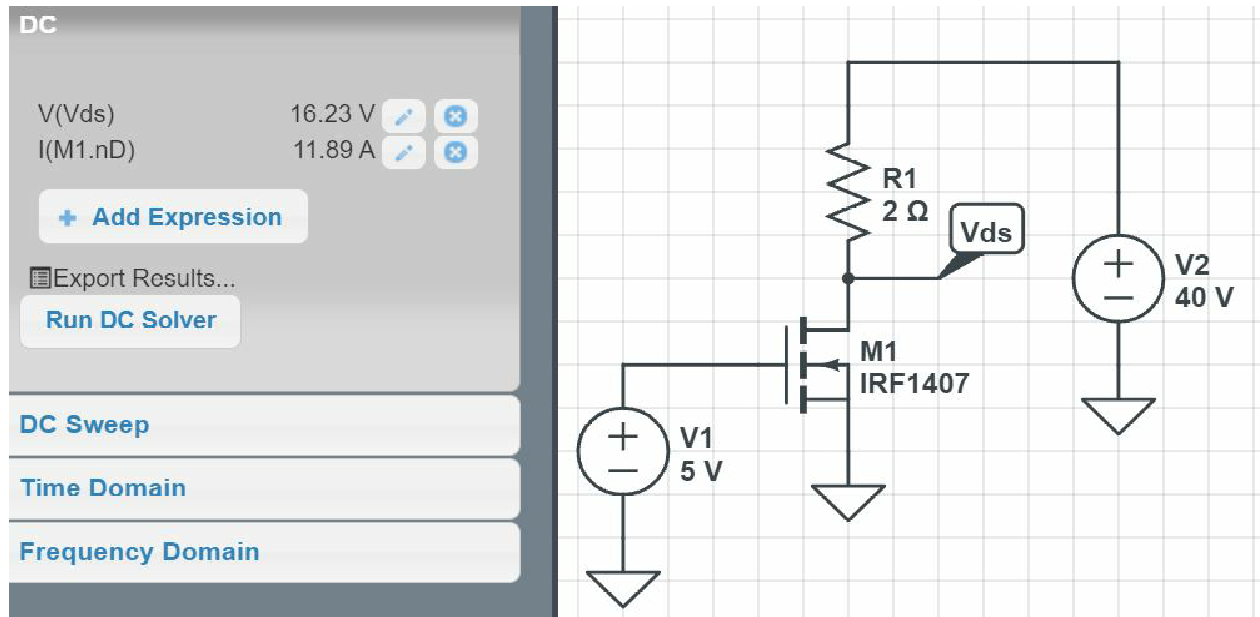
Save Custom Device Model

Import SPICE Model

View All MOSFETs In Stock

Input Capacitance (DS short @ AC)

Simulate:



The results are somewhat close (11.89A vs. 11.25A)

3) Determine the voltages and currents for the following circuit when $V_g = 10V$

Assume ohmic

$$I_{ds} = k_n \left(V_{gs} - V_{th} - \frac{V_{ds}}{2} \right) V_{ds}$$

$$(1) \quad I_{ds} = 22.5 \left(10V - 4V - \frac{V_{ds}}{2} \right) V_{ds}$$

$$(2) \quad V_{ds} + 2I_{ds} = 40$$

Solving 2 equations for 2 unknowns

$$V_{ds} = 0.149V, I_{ds} = 19.926 A$$

correct solution

$$V_{ds} = 11.895V, I_{ds} = 14.053A$$

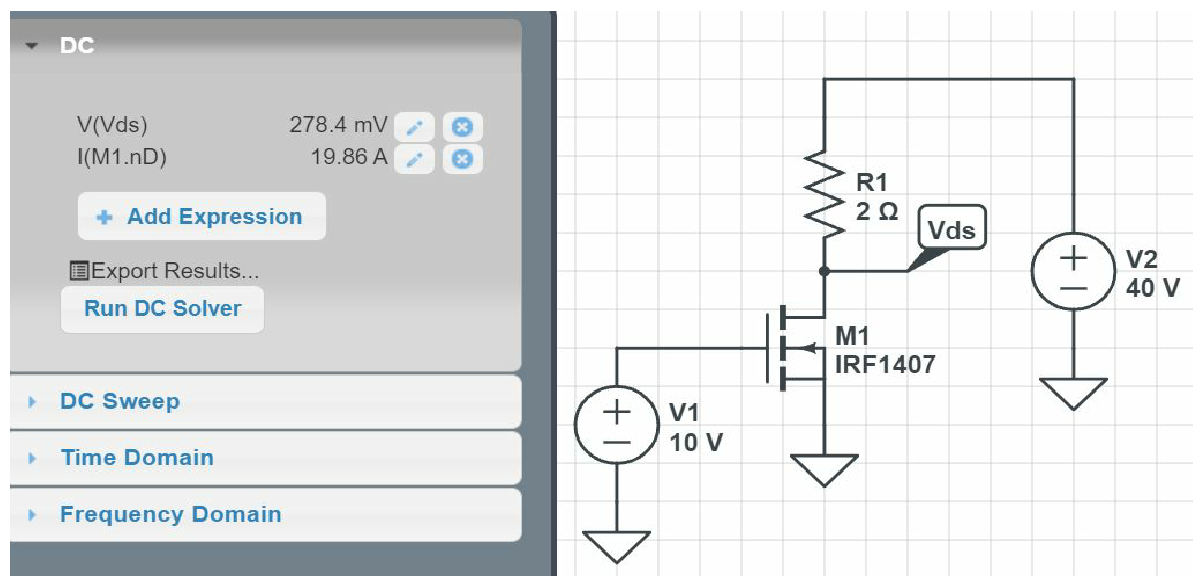
stray solution

Checking that you're in the ohmic region:

$$V_{ds} < V_{gs} - V_{th}$$

$$0.149V < 10V - 4V$$

Check your result in CircuitLab



CMOS Logic

4) Design a CMOS gate to implement the function: $f(A, B, C, D)$

Y(A,B,C,D)		CD			
		00	01	11	10
AB	00	1	0	1	x
	01	1	0	0	1
	11	1	1	1	0
	10	x	1	x	0

Circle the zeros

- This gives the logic for the n-channel MOSFETs.
- You could also circle the ones - giving the logic for the p-channel MOSFETs

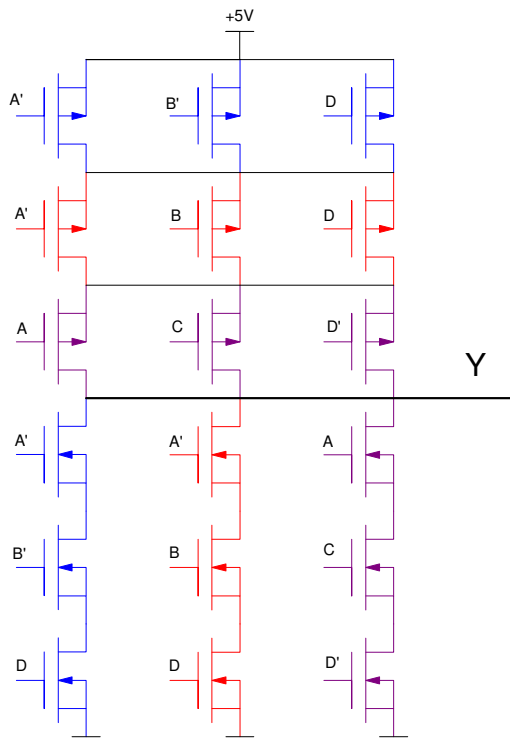
$$\bar{Y} = \bar{A}\bar{C}D + \bar{A}BD + A\bar{C}\bar{D}$$

This is the logic for the n-channel MOSFETs

- When turned on, Y is tied to ground
- Series is and
- Parallel is or

The p-channel comes from DeMorgan's law

$$Y = (A + C + \bar{D})(A + \bar{B} + \bar{D})(\bar{A} + \bar{C} + D)$$



Op-Amp Amplifiers & Mixers

5) Design a circuit to implement

$$Y = 2X$$

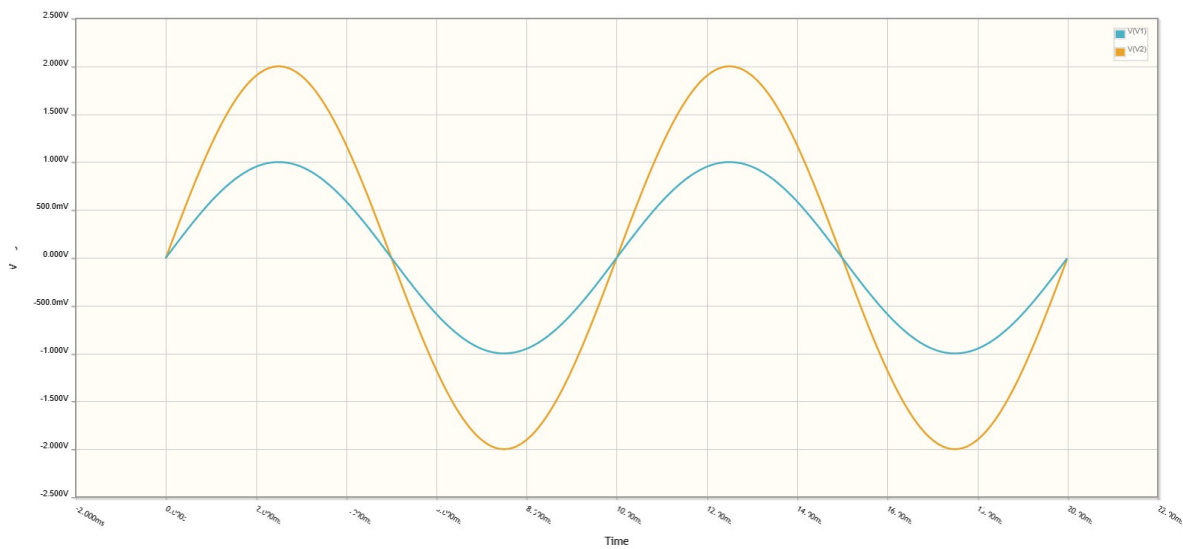
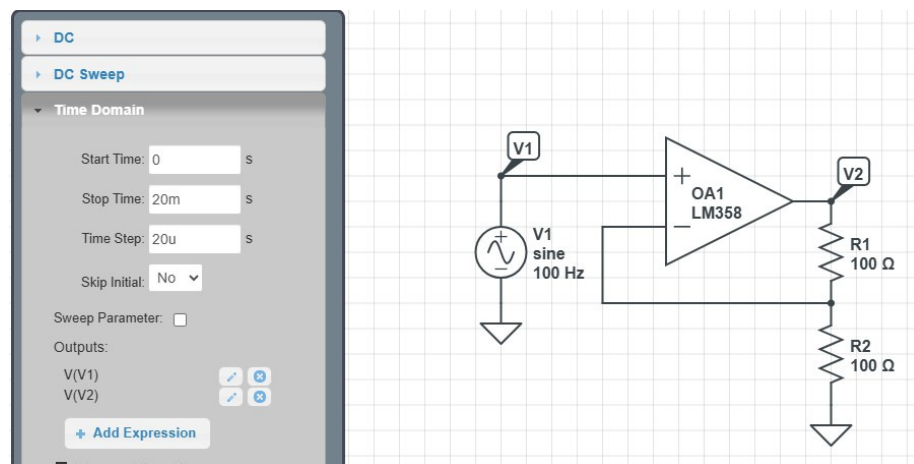
Verify your design in CircuitLab

- Let X be a 1Vp 100Hz sine wave
- Check that Y is a 2Vp, 100Hz sine wave

Use the non-inverting amplifier

$$\text{gain} = 2 = \left(1 + \frac{R_1}{R_2}\right)$$

Let $R_1 = R_2 = 100 \text{ Ohms}$



6) Design a circuit to implement

$$Y = -2X$$

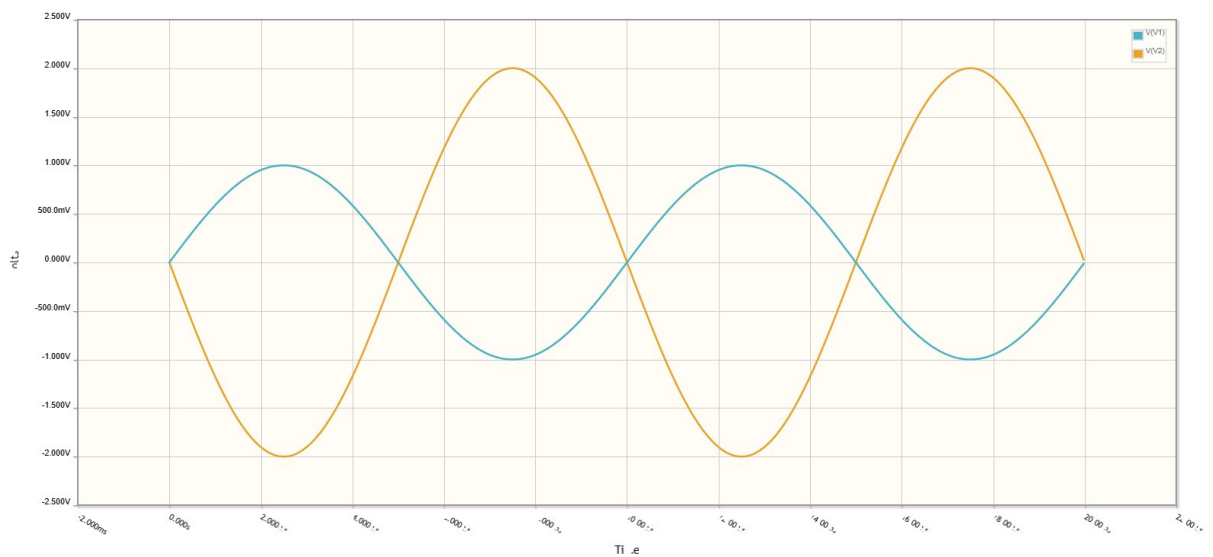
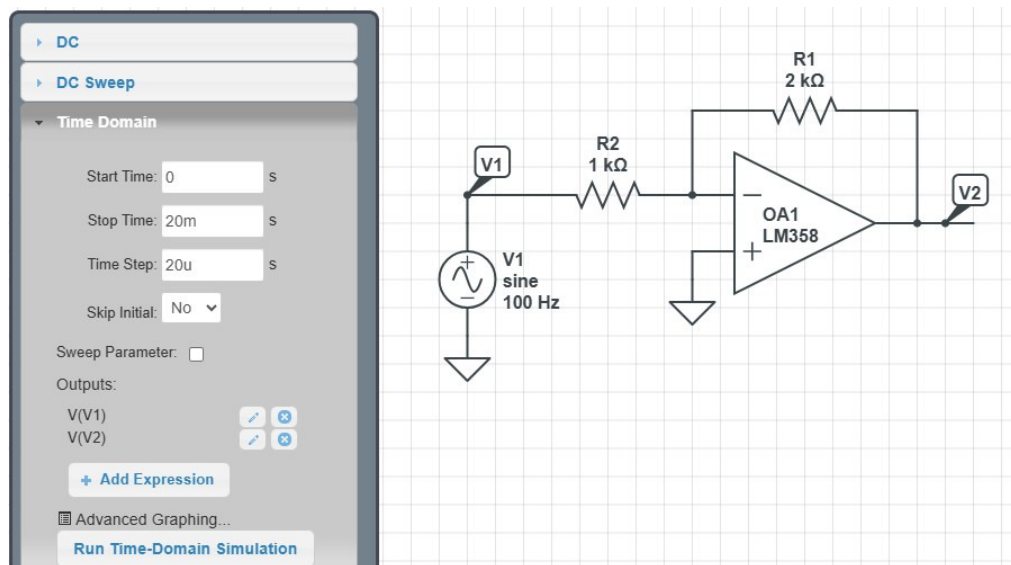
Verify your design in CircuitLab

- Let X be a 1Vp 100Hz sine wave
- Check that Y is a 2Vp, 100Hz sine wave that's 180 degrees out of phase

Use an inverting amplifier

$$\text{gain} = -\left(\frac{R_1}{R_2}\right)$$

Let $R_2 = 1\text{k}$, $R_1 = 2\text{k}$



7) Design a circuit to implement

$$Y = 3A + 4B + 5C$$

Create a dummy variable that's a weighted average

$$X = \left(\frac{3A+4B+5C}{12} \right)$$

Use three resistors to create a weighted average. Let the nominal resistance be 60k (arbitrary)

$$R_a = \left(\frac{60k}{3} \right) = 20k$$

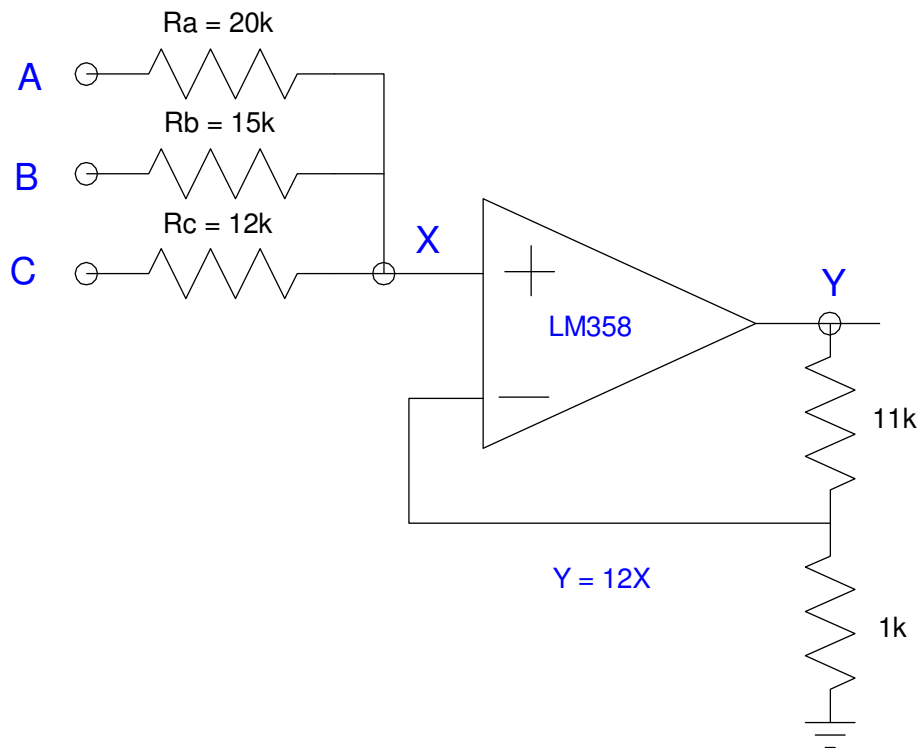
$$R_b = \left(\frac{60k}{4} \right) = 15k$$

$$R_c = \left(\frac{60k}{5} \right) = 12k$$

Add a non-inverting amplifier with a gain of 12

$$Y = 12X$$

note: There are other solutions



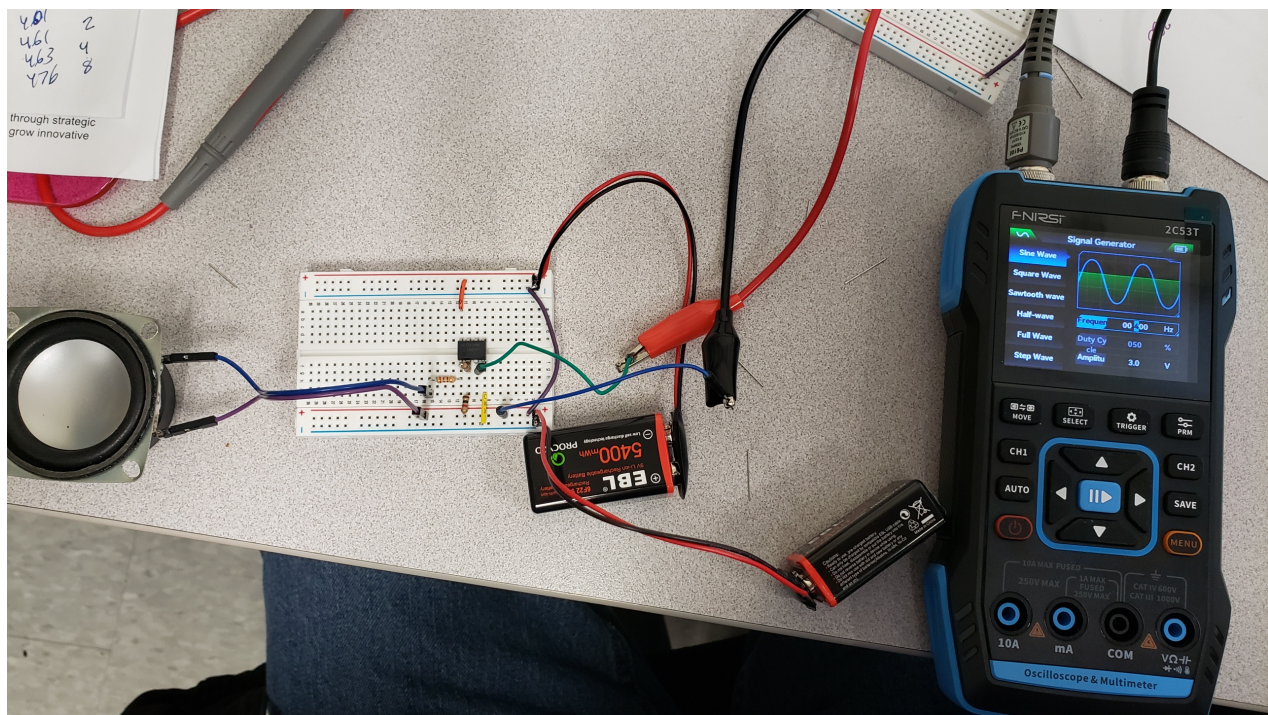
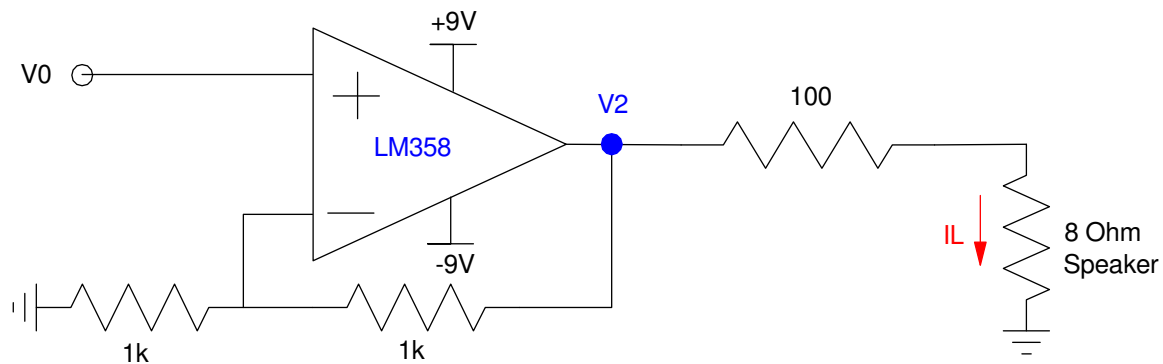
Lab (Hardware)

8) Built the following circuit using your lab kit. Power the op-amp with $\pm 9V$ using two 9V batteries.

- Include a photo of your breadboard circuit for full credit

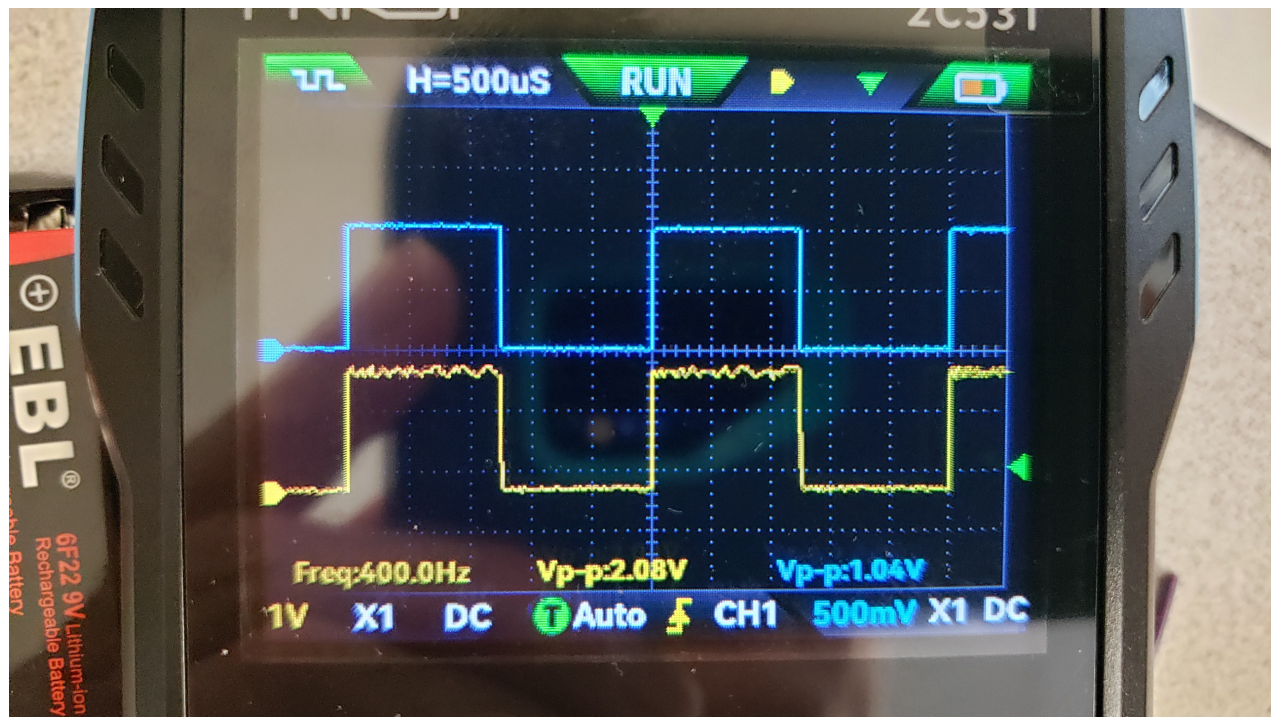
Verify that this circuit has a gain of $+2.000$

- Apply 2V DC signal at V0
- Measure the voltage at V2
- Compute the currents in the circuit

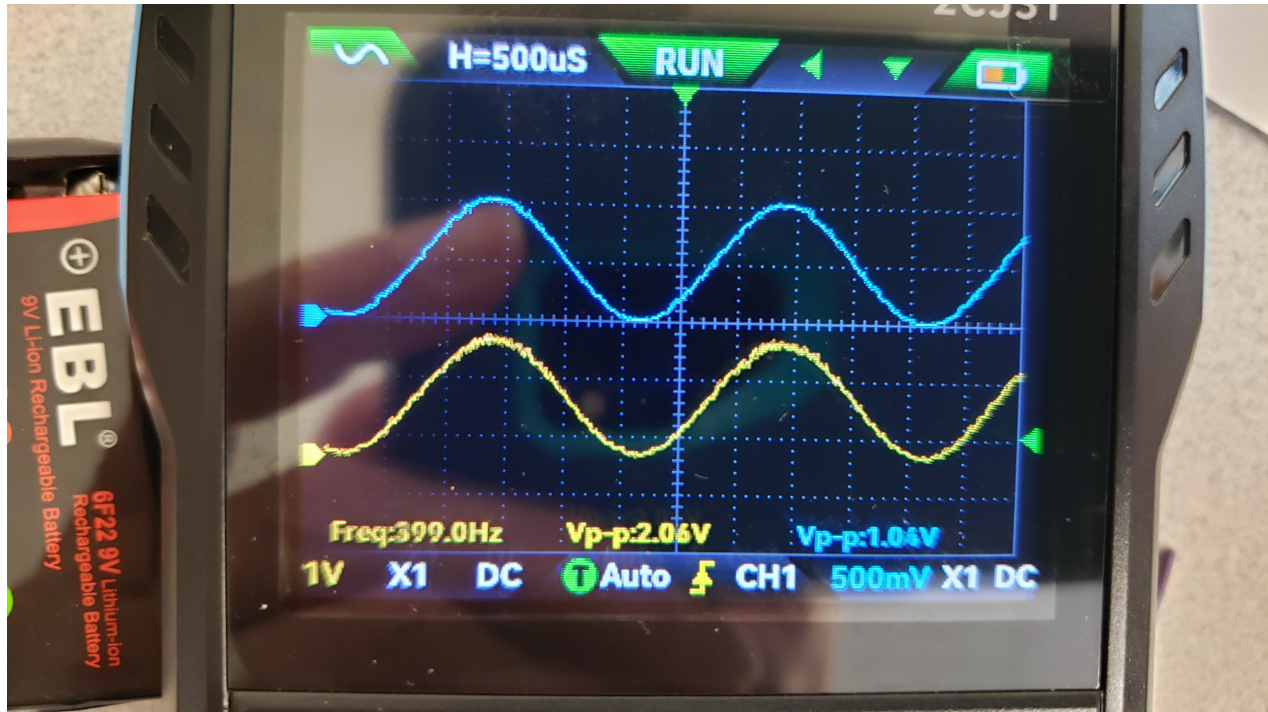


Apply a square wave in

- Note that the output of the amplifier is 2x the input



- 9) Change V0 to a 200Hz 1Vp sine wave
- Measure the voltage at V2 using your FNRSI oscilloscope
 - Include a photo of the oscilloscope reading



- 10) Change V0 to be the audio signal from your cell phone or computer playing a YouTube video
- Verify this amplifier works (sound plays on the speaker)
 - A YouTube video or a photo of the output voltage at V2 measured with an oscilloscope works for this

It's a very quiet signal you can barely hear - but it's there

