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# **Amplifiers and Mixers**

## **EE 206 Circuits I**

### **Jake Glower - Lecture #14**

Please visit [Bison Academy](#) for corresponding lecture notes, homework sets, and solutions

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# **Amplifiers and Mixers**

With op-amps, you can build a wide variety of amplifiers and mixers.

This covers some of the common ones we'll use.

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# Noninverting Amplifier

Voltage node equations

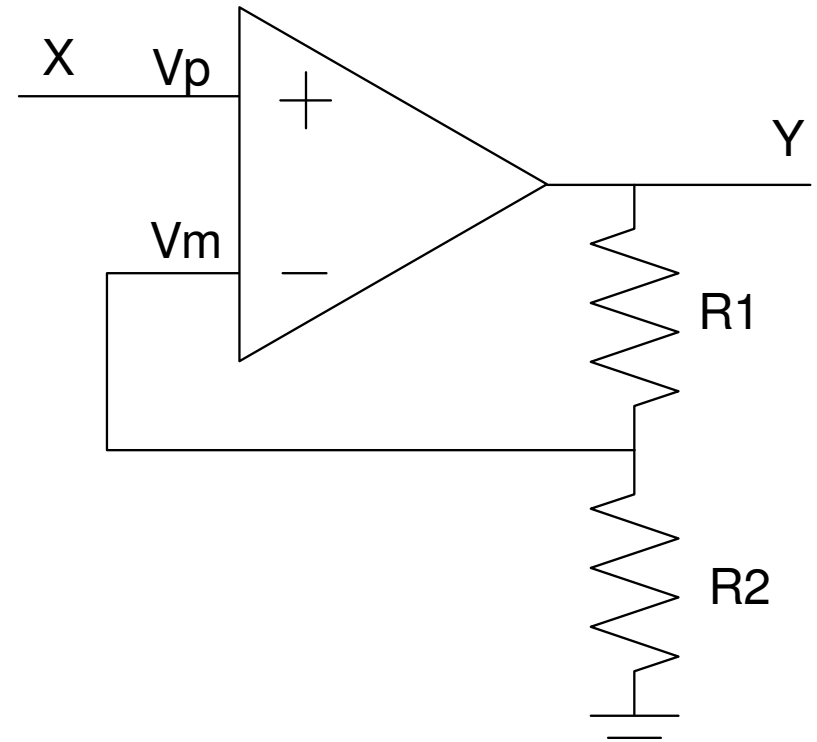
$$V_p = X$$

$$V_m = V_p$$

$$\left(\frac{V_m - Y}{R_1}\right) + \left(\frac{V_m}{R_2}\right) = 0$$

Solving

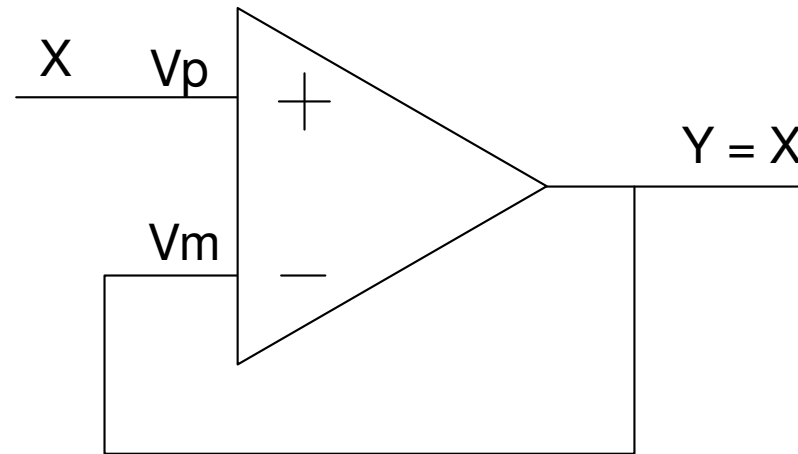
$$Y = \left(1 + \frac{R_1}{R_2}\right) X$$



# Buffer

- A special case
- $R2 = \text{infinity}$ ,  $R1 = 0$

$$Y = X$$

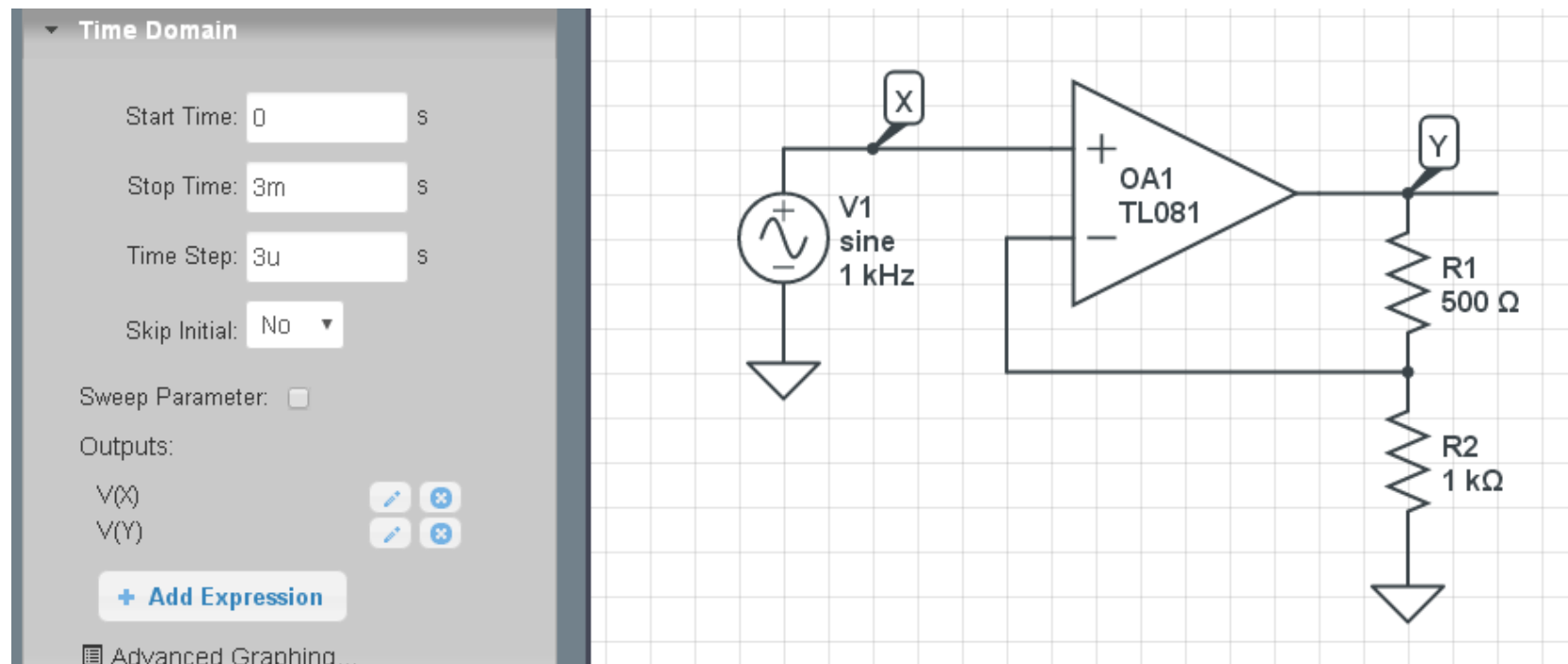


Example: Design a circuit to implement

$$y = 1.5x$$

Solution: For a gain of 1.50

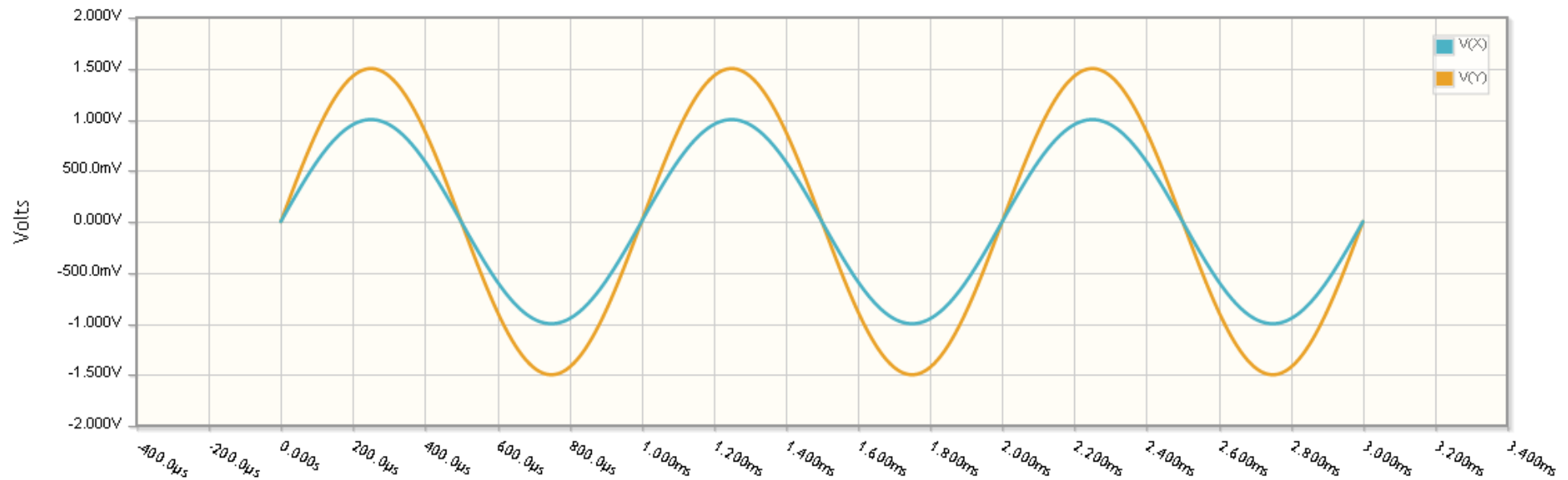
$$\text{gain} = 1 + \left( \frac{R_1}{R_2} \right) = 1.5$$



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Running a simulation for 3ms (3 cycles) gives the following result.

- The output is 1.5x the input (  $Y = 1.5 X$  )
- They are in phase ( the gain is positive )
- A sine wave is used to show that the gain of 1.5 works from -1V to +1V



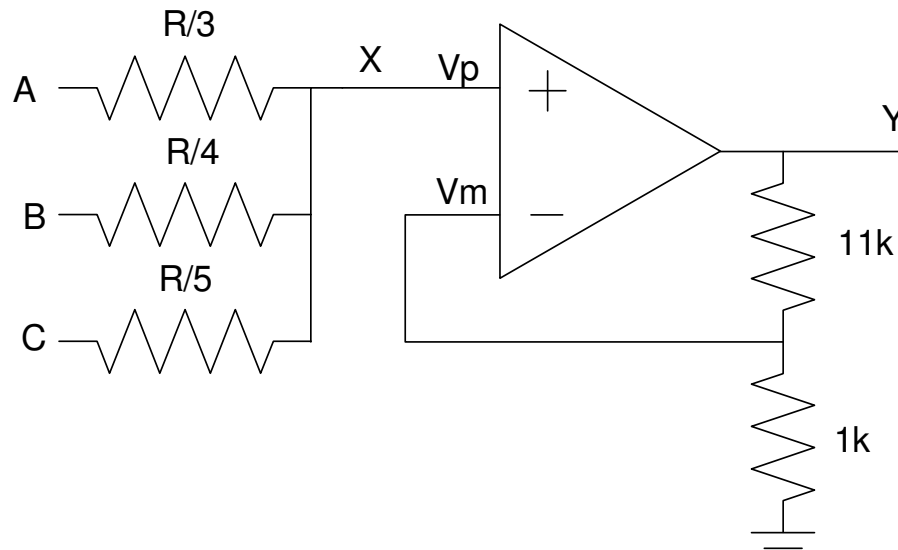
# Non-Inverting Summing Amplifier:

Design a circuit to implement

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

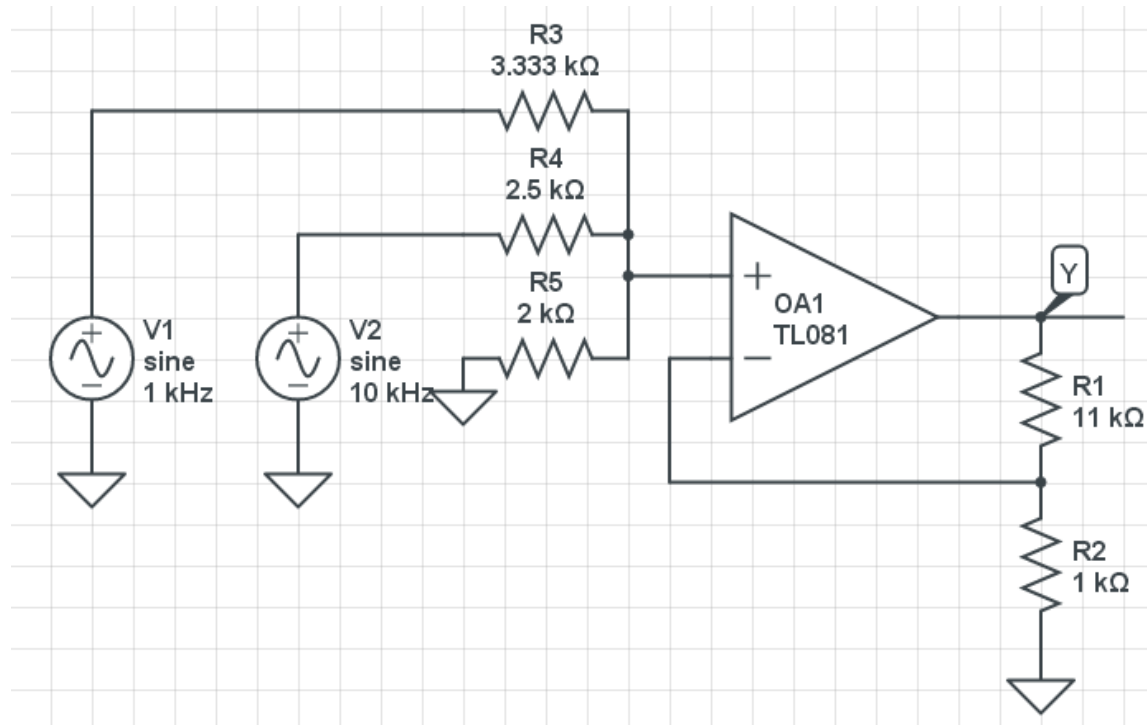
Rewrite this as

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



## Checking in CircuitLab: Use three inputs

- 1V @ 1kHz
- 1V @ 10kHz (10x different so you can see the difference at Y)
- 0V (getting too many signals to see what's going on)

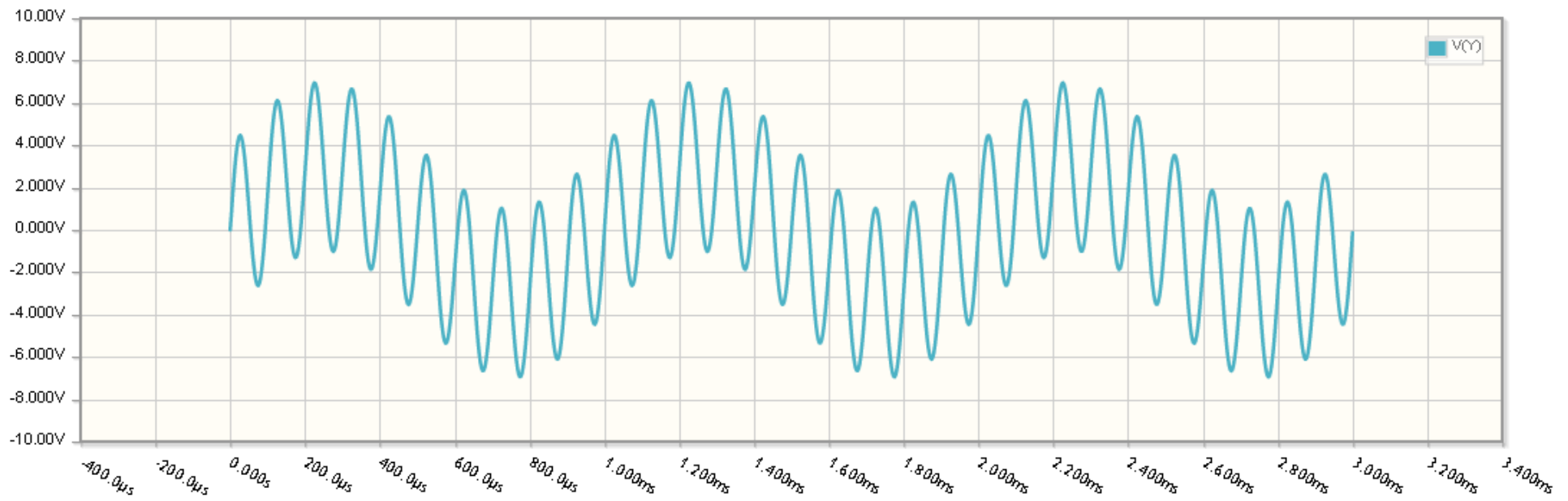




## Running a time-domain simulation for 3ms (3 cycles)

Here, you can see

- The 1kHz sine wave (envelope), mixed with
- A 10kHz sine wave.



# Inverting Amplifier

$$V_p = 0V$$

$$V_p = V_m = 0V$$

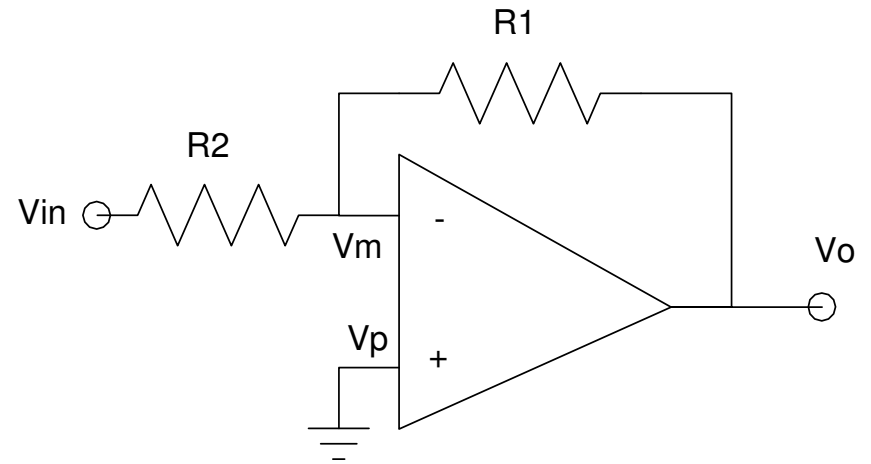
$$\left( \frac{V_m - V_{in}}{R_2} \right) + \left( \frac{V_m - V_o}{R_1} \right) = 0$$

Solving:

$$V_o = \left( -\frac{R_1}{R_2} \right) V_{in}$$

Limitations:

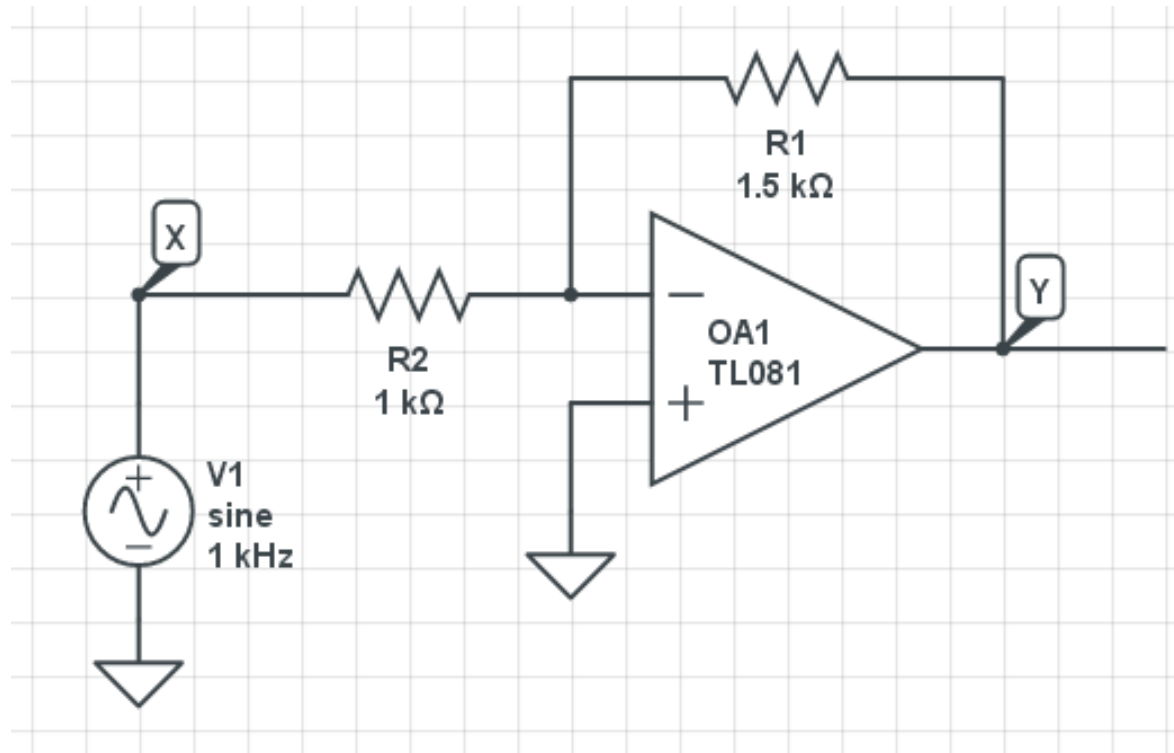
- $R_1$  and  $R_2 \ll 50M$
- $R_1$  and  $R_2 \gg 200$  (current  $< 50mA$ )



Example: Design a circuit with a gain of

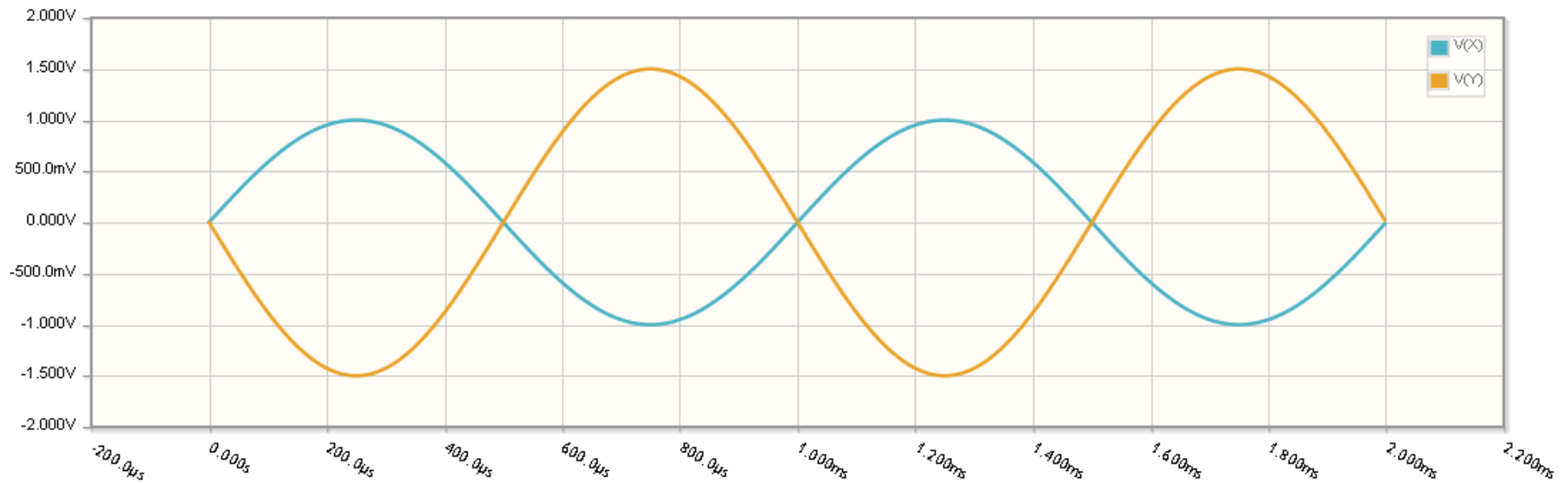
$$y = -1.5x$$

Solution: Let  $R1 = 1500$  and  $R2 = 1000$  Ohms.



## Simulation Results:

- The amplitude of Y is 1.5x the amplitude of X (as desired)
- Y is 180 degrees out of phase from X (the gain is -1.5)



## Summing Inverting Amplifier:

A slight variation is the summing amplifier:

$$V_p = 0V$$

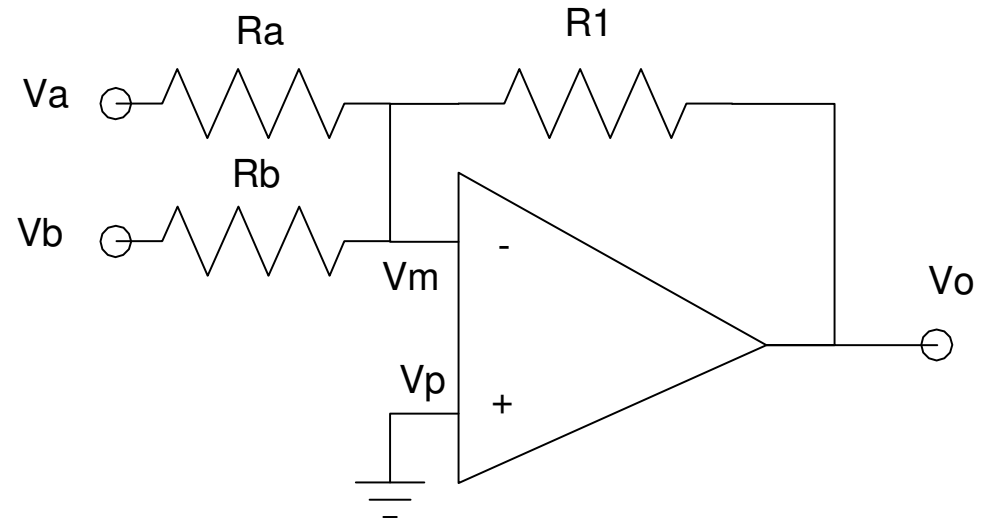
$$V_p = V_m = 0V$$

$$\left( \frac{V_m - V_a}{R_a} \right) + \left( \frac{V_m - V_b}{R_b} \right) + \left( \frac{V_m - V_o}{R_1} \right) = 0$$

Solving:

$$V_o = \left( -\frac{R_1}{R_a} \right) V_a + \left( -\frac{R_1}{R_b} \right) V_b$$

Superposition also works



# Instrumentation Amplifier:

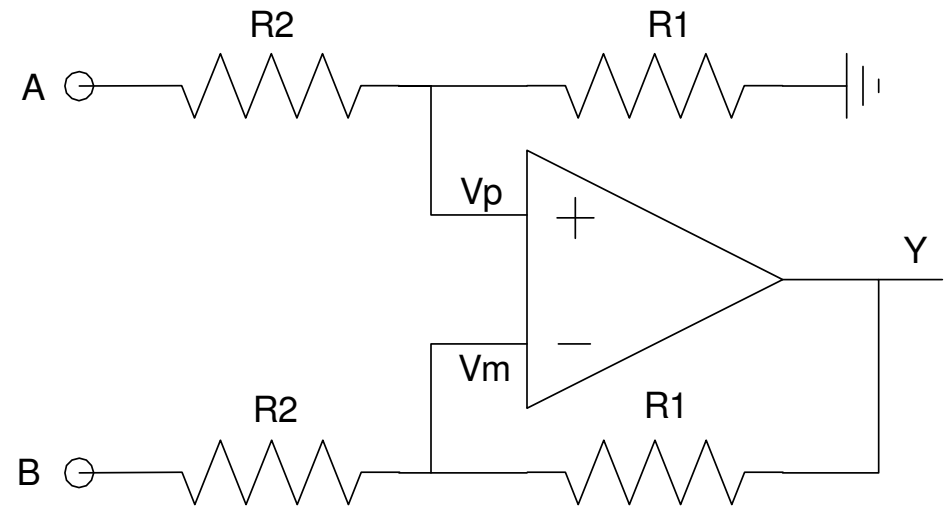
$$V_p = V_m$$

$$\left( \frac{V_p - A}{R_2} \right) + \left( \frac{V_p}{R_1} \right) = 0$$

$$\left( \frac{V_m - B}{R_2} \right) + \left( \frac{V_m - Y}{R_1} \right) = 0$$

Solving gives

$$Y = \left( \frac{R_1}{R_2} \right) (A - B)$$



Design a circuit to implement

$$Y = 10X - 4$$

Rewrite as

$$Y = 10(X - 0.4)$$

$$Y = \left( \frac{R_1}{R_2} \right) (A - B)$$

