Amplifiers and Mixers

EE 206 Circuits I

Jake Glower - Lecture #14

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.

Noninverting Amplifier

Voltage node equations

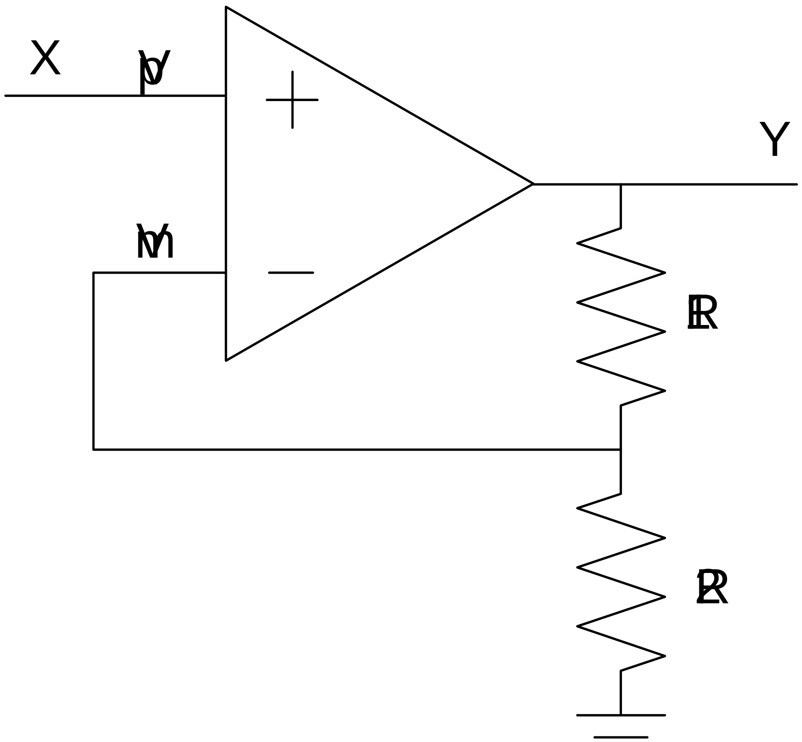
$$V_p = X$$

$$V_m = V_p$$

$$\frac{V_m - Y}{R_1} + \frac{V_m}{R_2} = 0$$

Solving

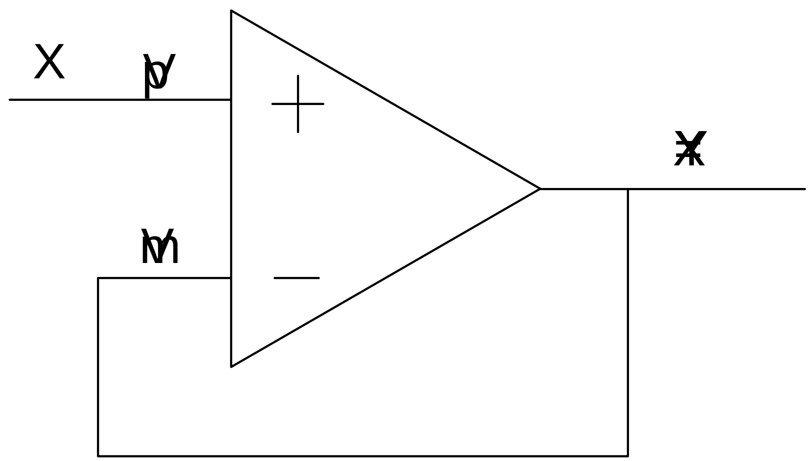
$$Y = \left(1 + \frac{R_1}{R_2}\right) X$$



Buffer

- A special case
- R2 = infinity, R1 = 0

$$Y = X$$

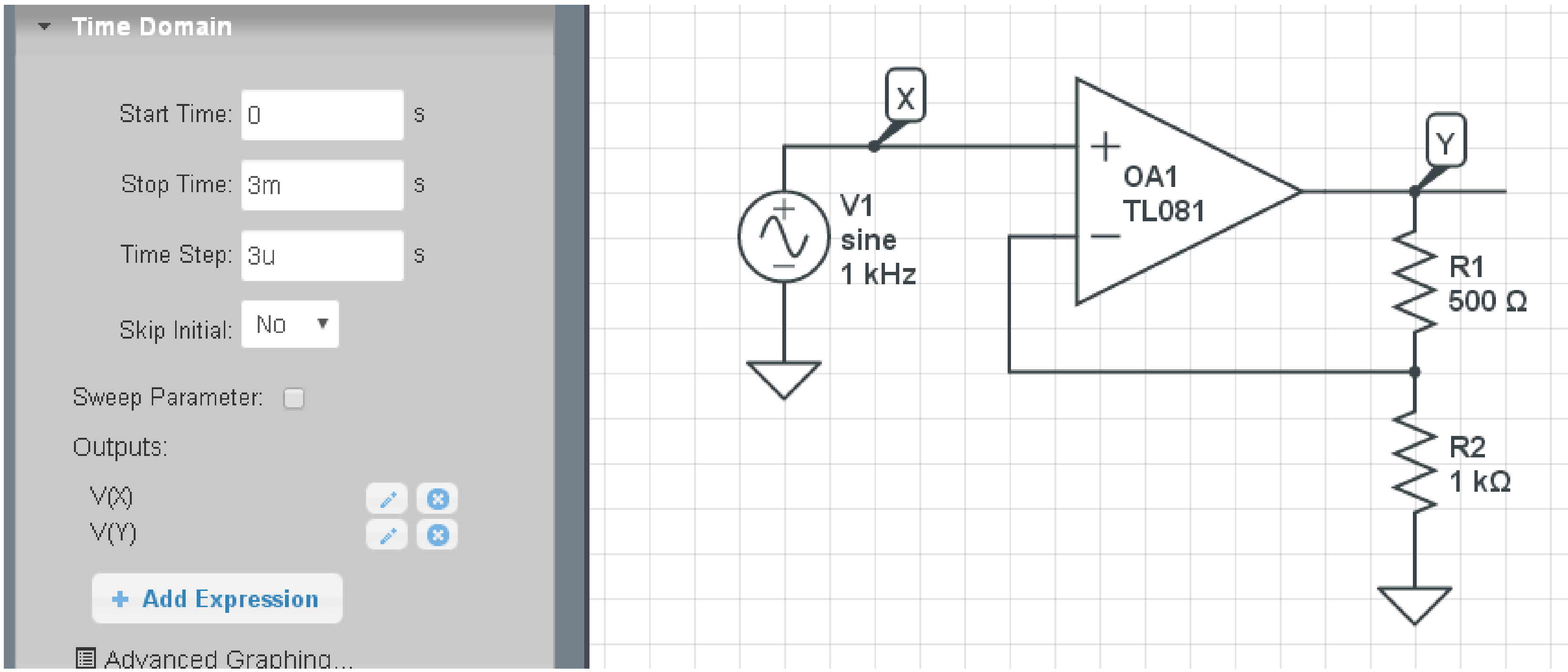


Example: Design a circuit to implement

$$y = 1.5x$$

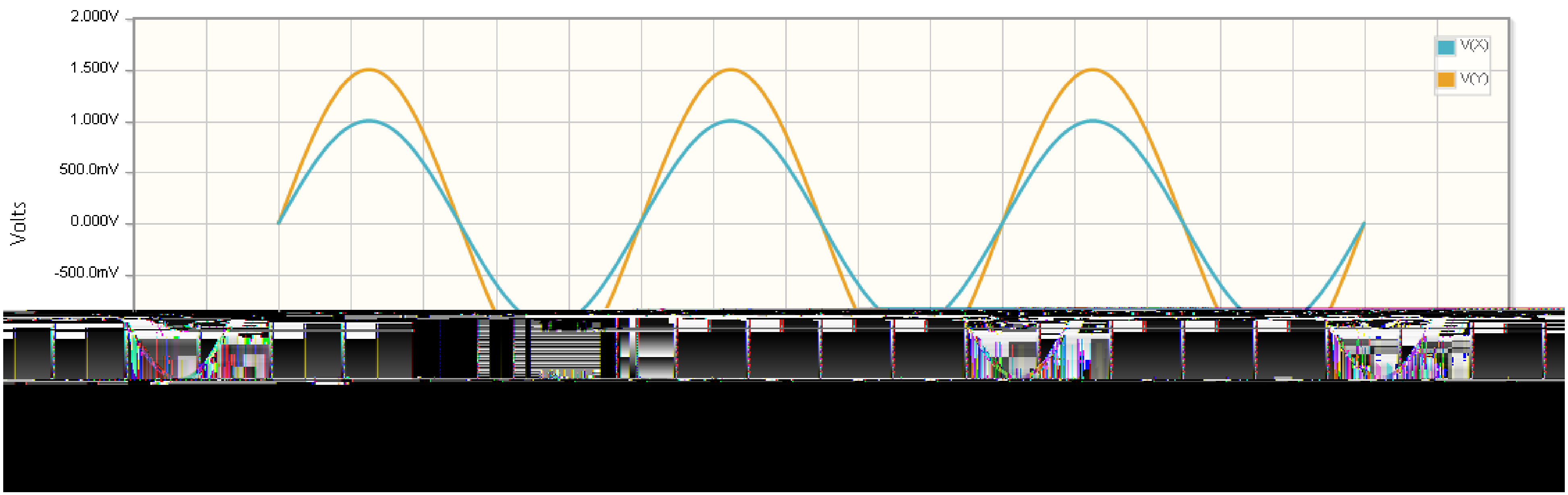
Solution: For a gain of 1.50

$$\text{gain} = 1 + \frac{R_1}{R_2} = 1.5$$



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



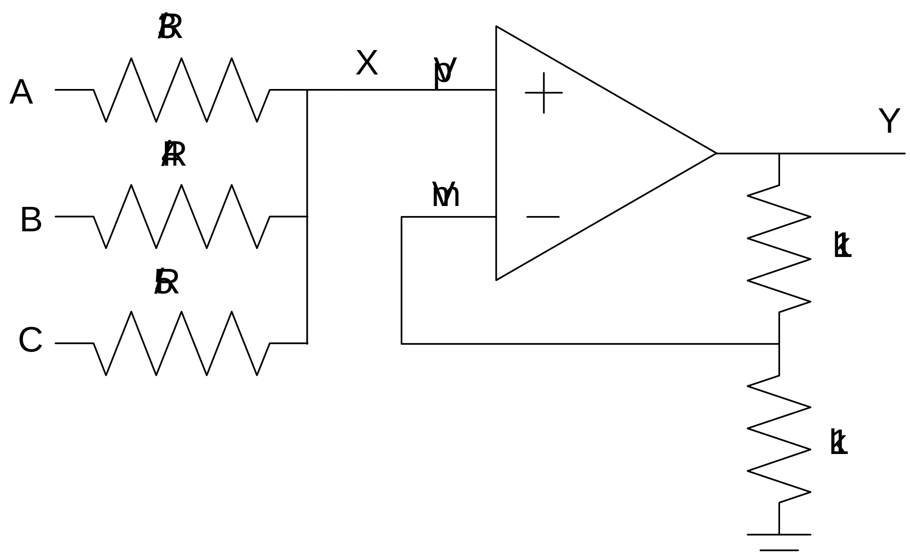
Non-Inverting Summing Amplifier:

Design a circuit to implement

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

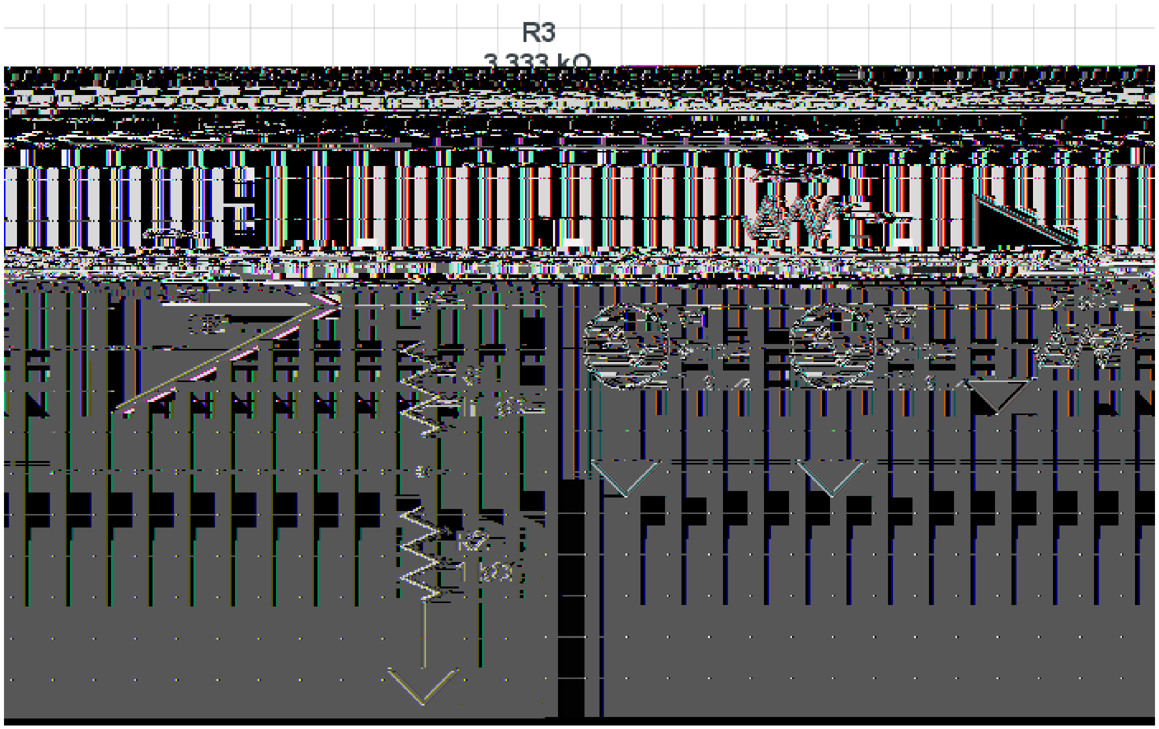
Rewrite this as

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



Checking in CircuitLab: Use three inputs

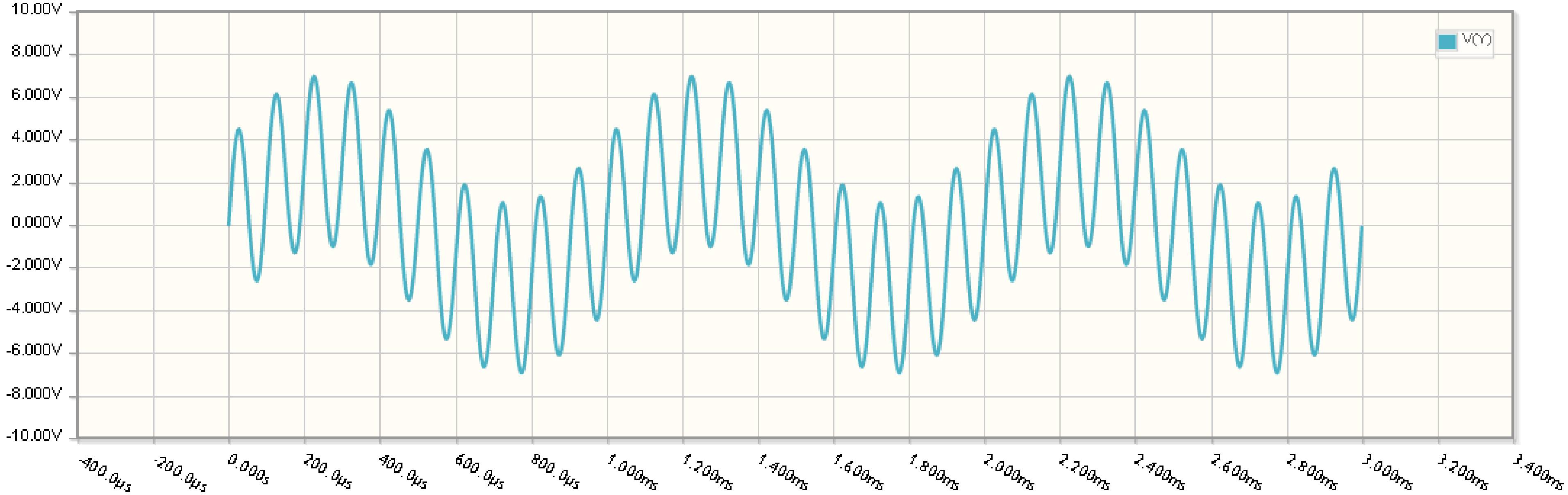
- 1V @ 1kHz
- 1V @ 10kHz (10x different so you can see the difference at Y)
- 0V (getting too many signals to see what's going on)



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

Here, you can see

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

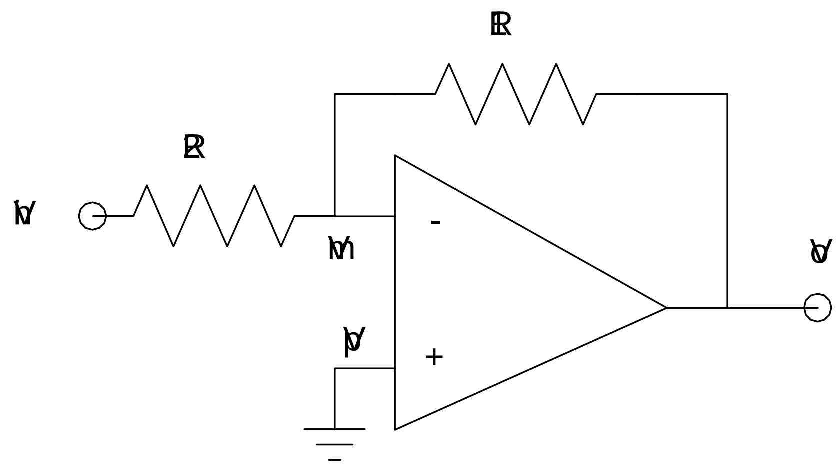


Inverting Amplifier

$V_p = 0V$

$V_p = V_m = 0V$

$$\frac{V_m - V_n}{R_2} + \frac{V_m - V_o}{R_1} = 0$$



Solving:

$$V_o = -\frac{R_1}{R_2} V_n$$

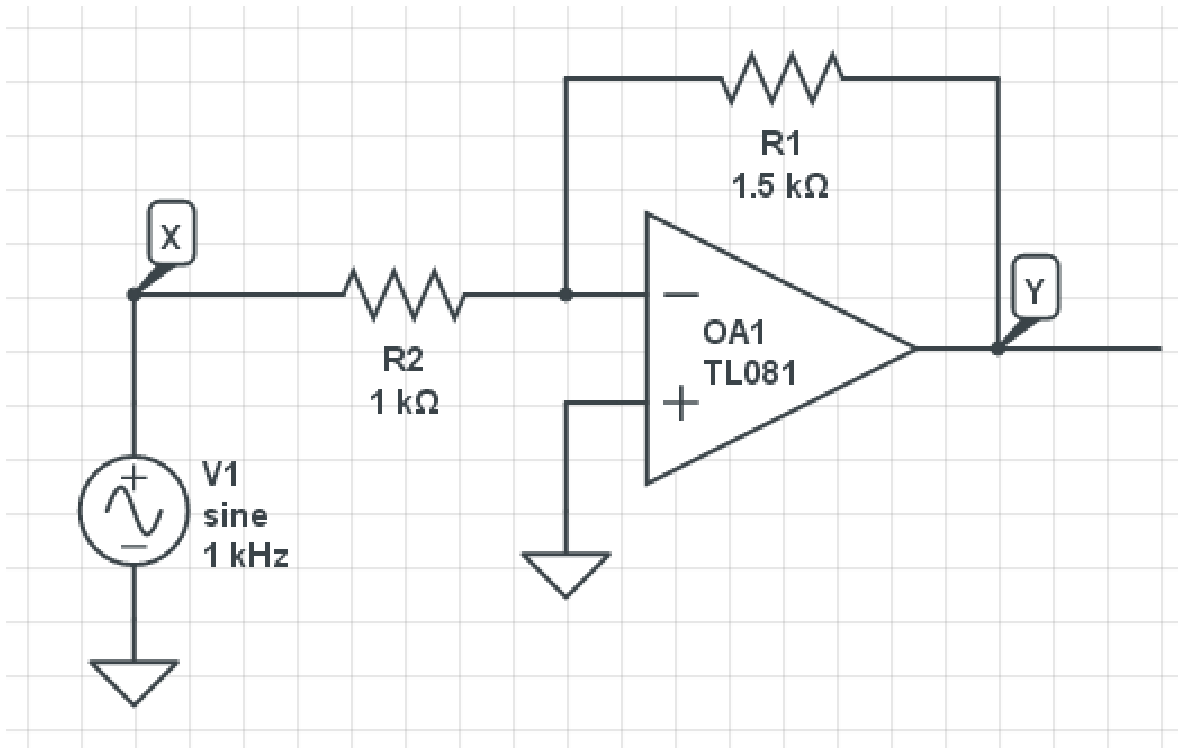
Limitations:

- R1 and R2 << 50M
- R1 and R2 >> 200 (current < 50mA)

Example: Deign a circuit with a gain of

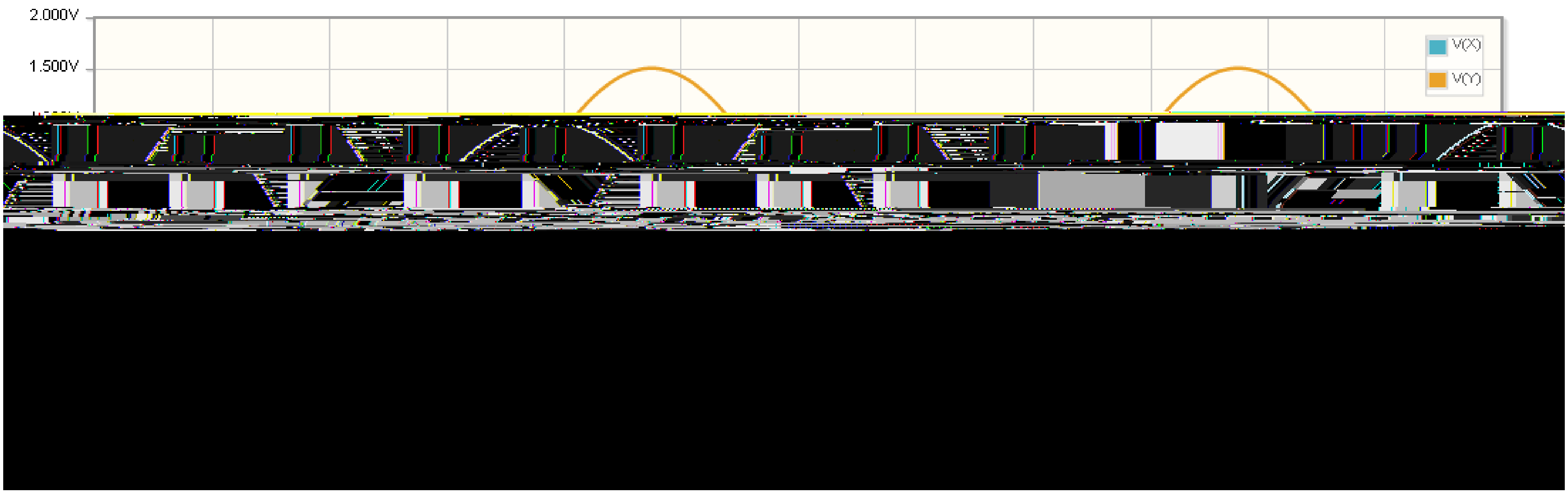
$$y = -1.5x$$

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)



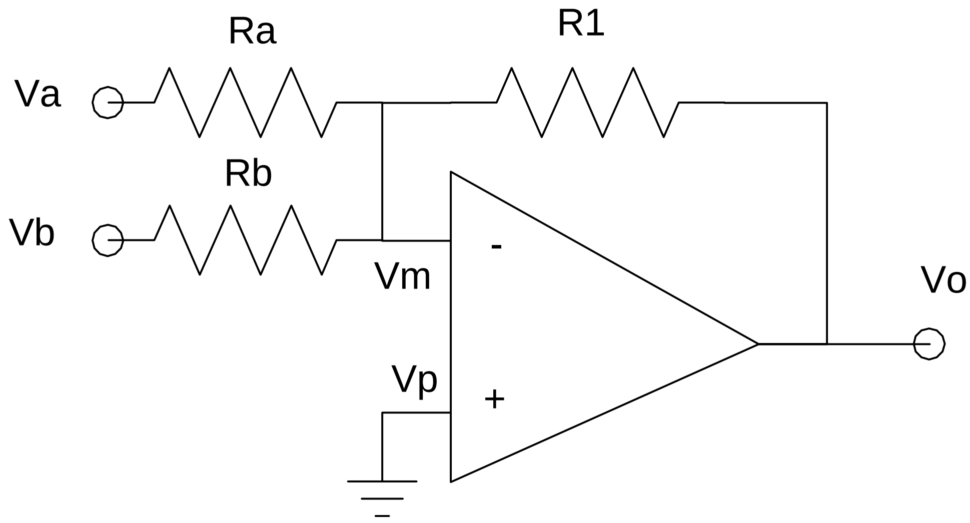
Summing Inverting Amplifier:

A slight variation is the summing amplifier:

$$Vp = 0V$$

$$Vp = Vm = 0V$$

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



Solving:

$$V_o = -\frac{R_1}{R_a} V_a + -\frac{R_1}{R_b} V_b$$

Superposition also works

Instrumentation Amplifier:

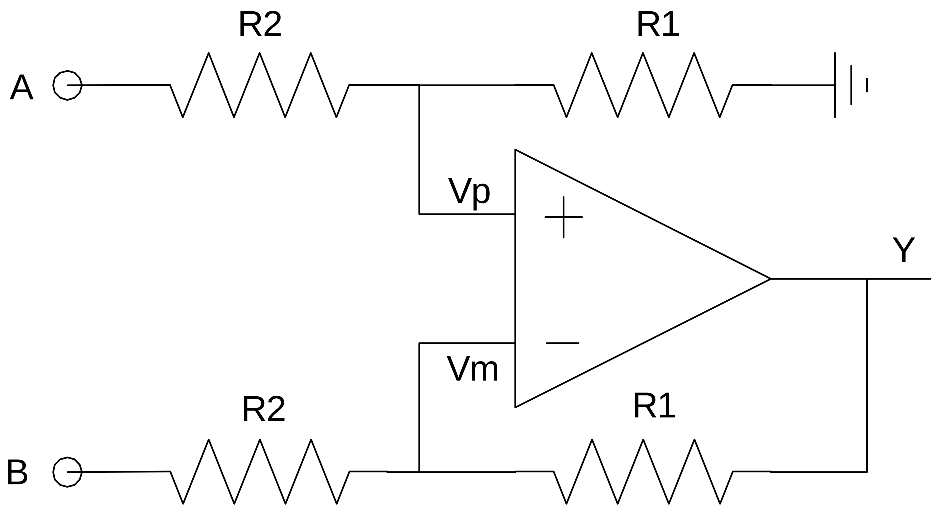
$$V_p = V_m$$

$$\frac{V_p - A}{R_2} + \frac{V_p}{R_1} = 0$$

$$\frac{V_m - B}{R_2} + \frac{V_m - Y}{R_2} = 0$$

Solving gives

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



Design a circuit to implement

$$Y = 10X - 4$$

Rewrite as

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

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