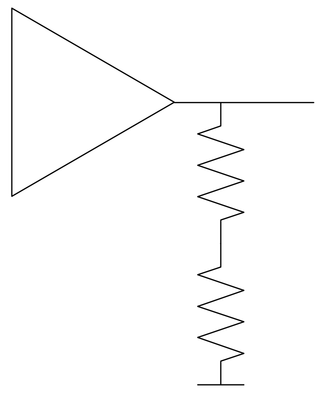
Amplifiers and Mixers

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



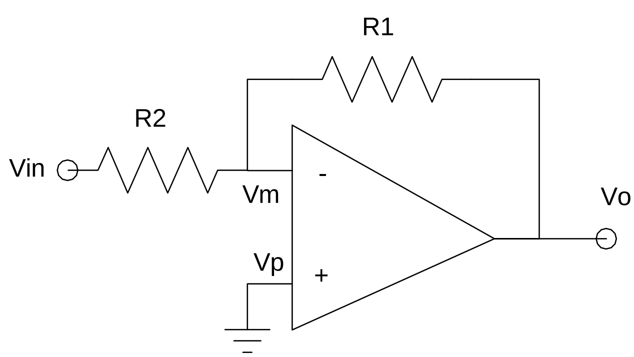
Running a time-domain simulation for 3ms (3 cycles)

Here, you can see

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

You can also use this circuit to mix Katy Perry with Iron Butterfly or whatever you like.

Inverting Amplifier



Inverting Amplifier

Problem: Find the gain from Vin to Vo:

Write the node equations. There are three voltages, so we need three equations:

(1) Vp = 0V

(2) Vp = Vm = 0V

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

Solving:

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

This is an inverting amplifier.

Note that for the ideal op-amp model to be valid, the current into the + and - inputs (20nA) needs to be negligible. Assuming 1V signals, that means R2 and R1 must be much less than 50M Ohms.

Also note that for the output to be valid, R1 must be much more than the output impedance of the op-amp (75 Ohms).

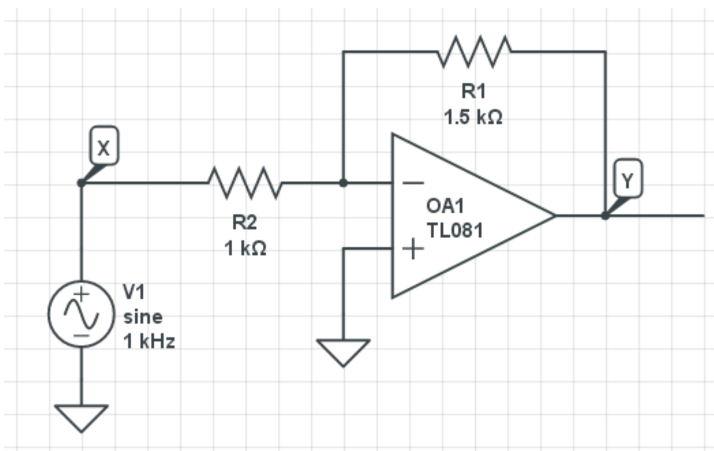
Picking resistors between 1k and 1M tends to work fairly well for 741 and LM833 op-amps. Outside this range, the model will break down a little.

Example: Deign a circuit with a gain of

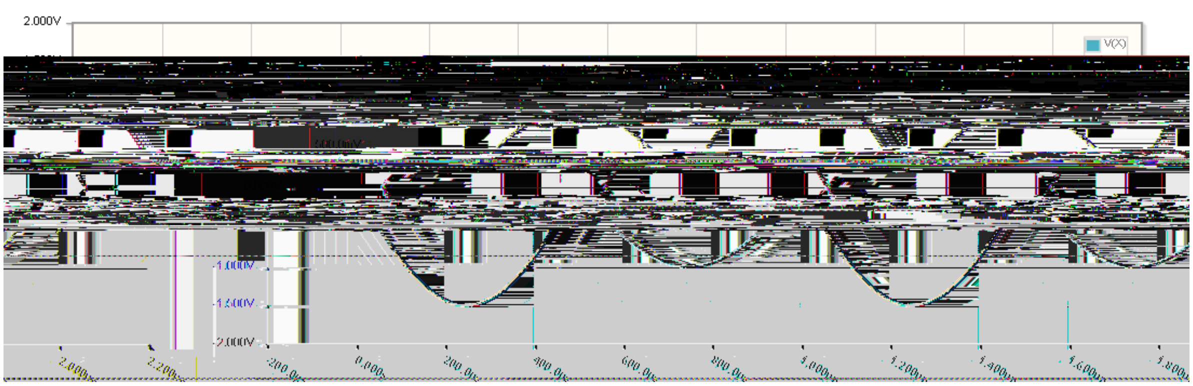
$$y = -1.5x$$

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

CircuitLab Simulation:



Simulation Results:

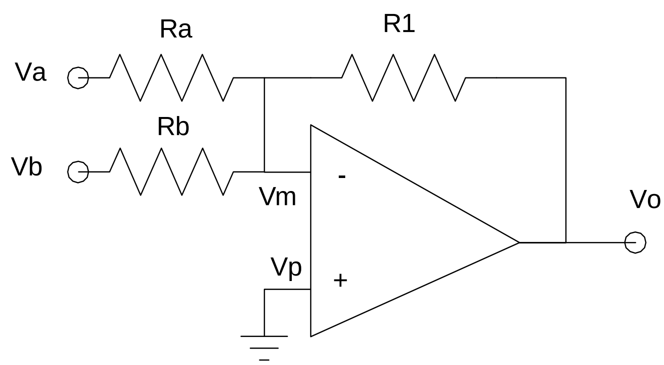


Note the following:

- 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:



Summing Amplifier

Again, there are three voltage nodes so we need to write three equations to solve for 3 unknowns:

(1) Vp = 0V

(2) Vp = Vm = 0V

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

Solving:

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

A second way to solve for the output is to use superposition. With two inputs in a linear circuit, you know the output will be

$$V_o = k_1 V_a + k_2 V_b$$

Use superposition. First, let Vb = 0 and solve for Vo. This is the non-inverting amplifier from before (Vm = Vb = 0V, so there is no current lost in Rb).

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

Next, let Va = 0 and solve for Vo. Again by symmetry

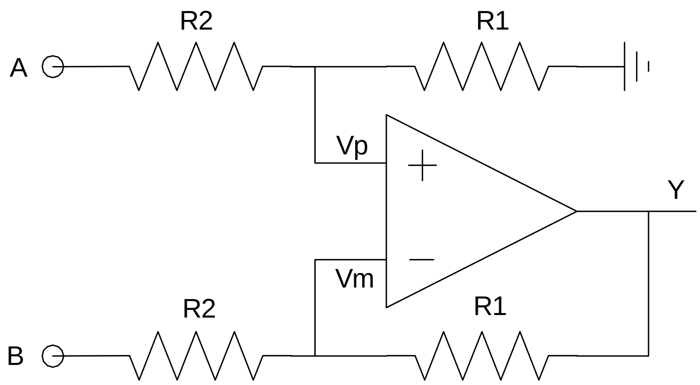
$$V_o = \left(-\frac{R_1}{R_b}\right)V_b$$

Using superposition, the total output will be the sum of these two answers:

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

This allows you to add two signals together as a mixer.

Instrumentation Amplifier:



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

To derive the transfer function, write the voltage node equations:

$$V_p = V_m$$

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

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

Solving gives

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

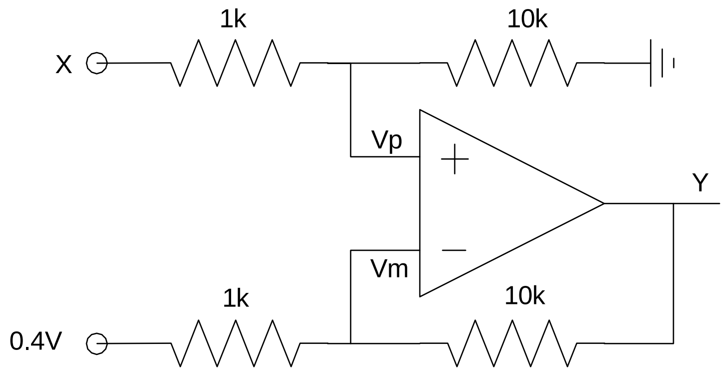
Instrumentation Amplifier Example 1: Design a circuit to implement

$$Y = 10X - 4$$

Rewrite as

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

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



Y = 10X - 4

With this circuit, you can implement almost any function.