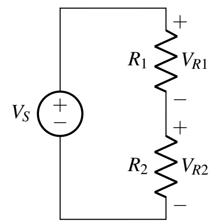
EECS 16A Designing Information Devices and Systems I
Fall 2020 Discussion 11A

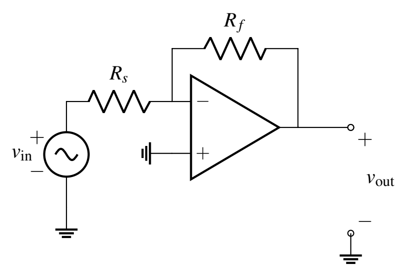
Reference: Op-Amp Example Circuits

Voltage Divider



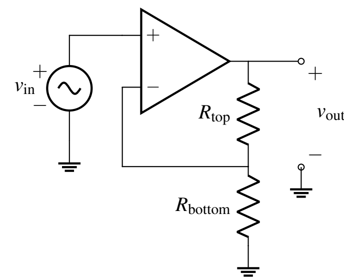
$$V_{R_2} = V_S \left(\frac{R_2}{R_1+R_2} \right)$$

Inverting Amplifier



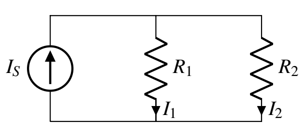
$$v_{out} = v_{in} \left(-\frac{R_f}{R_s} \right)$$

Noninverting Amplifier



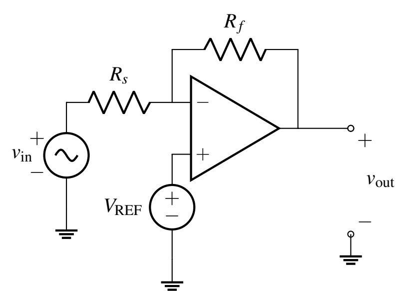
$$v_{out} = v_{in} \left(1 + \frac{R_{top}}{R_{bottom}} \right)$$

Current Divider



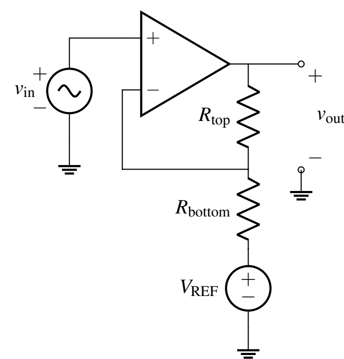
$$I_1 = I_S \left(\frac{R_2}{R_1+R_2} \right)$$

Inverting Amplifier with Reference



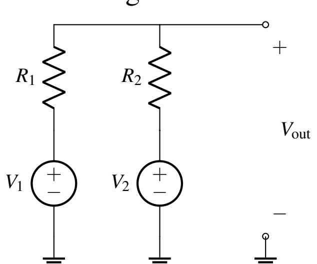
$$v_{out} = v_{in} \left(-\frac{R_f}{R_s} \right) + V_{REF} \left(\frac{R_f}{R_s} + 1 \right)$$

Noninverting Amplifier with Reference



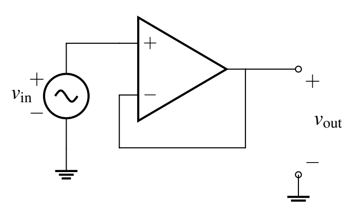
$$v_{out} = v_{in} \left(1 + \frac{R_{top}}{R_{bottom}} \right) - V_{REF} \left(\frac{R_{top}}{R_{bottom}} \right)$$

Voltage Summer



$$V_{out} = V_1 \left(\frac{R_2}{R_1+R_2} \right) + V_2 \left(\frac{R_1}{R_1+R_2} \right)$$

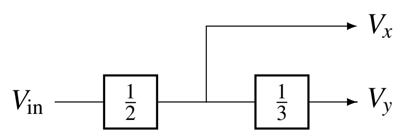
Unity Gain Buffer



$$v_{out} = v_{in}$$

1. Modular Circuit Buffer

Let's try designing circuits that perform a set of mathematical operations using op-amps. While voltage dividers on their own cannot be combined without altering their behavior, op-amps can preserve their behavior when combined and thus are a perfect tool for modular circuit design. We would like to implement the block diagram shown below:



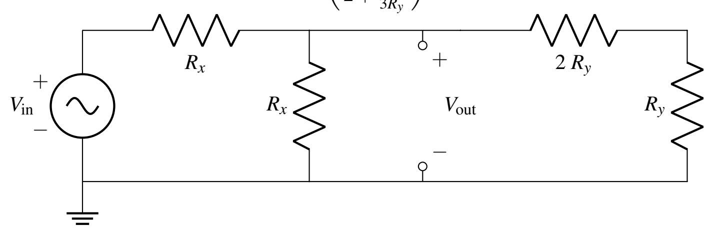
In other words, create a circuit with two outputs V_x and V_y, where $V_x = \frac{1}{2}V_{\text{in}}$ and $V_y = \frac{1}{3}V_x = \frac{1}{6}V_{\text{in}}$.

(a) Draw two voltage dividers, one for each operation (the $1/2$ and $1/3$ scalings). What relationships hold for the resistor values for the $1/2$ divider, and for the resistor values for the $1/3$ divider?

(b) If you combine the voltage dividers, made in part (a), as shown by the block diagram (output of the $1/2$ voltage divider becomes the source for the $1/3$ voltage divider circuit), do they behave as we hope (meaning $6V_{\text{in}} = 3V_x = V_y$)?

HINT: The following circuit and formula may be handy:

$$V_{\text{out}} = \left(\frac{1}{2+\frac{R_x}{3R_y}}\right)V_{\text{in}}$$



(c) Perhaps we could use an op-amp (in negative-feedback) to achieve our desired behavior.
Modify the implementation you tried in part (b) using a negative feedback op-amp in order to achieve the desired V_x, V_y relations $V_x = (1/2)V_{\text{in}}$ and $V_y = (1/3)V_x = (1/6)V_{\text{in}}$.
HINT: Place the op-amp in between the dividers such that the V_x node is an input into the op-amp, while the source of the 2nd divider is the output of the op-amp!

2. Modular Op-Amp Circuits

Let's expand our toolbox of op-amp circuits that perform mathematical operations by designing blocks that implement the following operations

(a) Scale the input voltage so that: $V_{\text{out}} = +5\ V_{\text{in}}$

(b) Scale and invert the input voltage so that: $V_{\text{out}} = -2\ V_{\text{in}}$

(c) Sum two input voltages together so that: $V_{\text{out}} = V_{\text{in}_1} + V_{\text{in}_2}$

Use the reference above for help!
Would connecting any of these blocks together modify their intended functionality?

