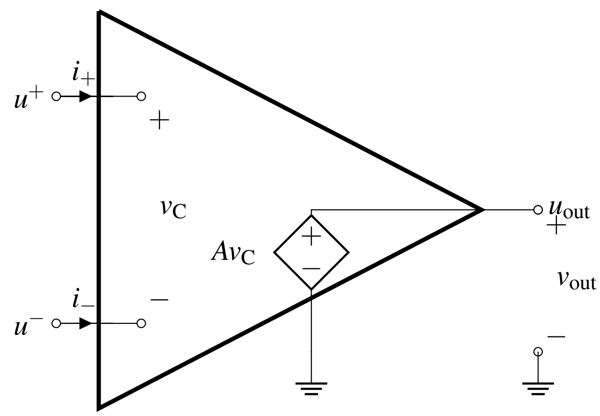
EECS 16A Designing Information Devices and Systems I
Fall 2021 Discussion 10A

1. Op-Amp Rules

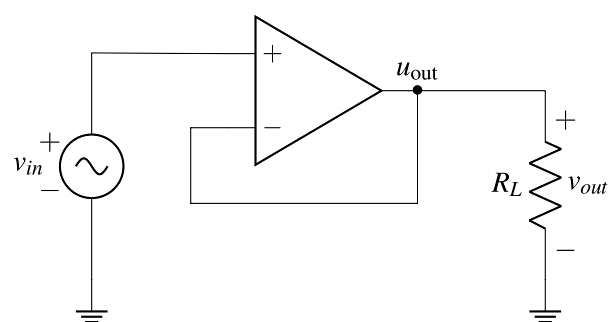
Here is an equivalent circuit of an op-amp (where we are assuming that $V_{SS} = -V_{DD}$) for reference:



(a) What are the currents flowing into the positive and negative terminals of the op-amp (i.e., what are I^+ and I^-)? Based on this answer, what are some of the advantages of using an op-amp in your circuit designs?

(b) Suppose we add a resistor of value R_L between u_{out} and ground. What is the value of v_{out}? Does your answer depend on R_L? In other words, how does R_L affect Av_C? What are the implications of this with respect to using op-amps in circuit design?

For the rest of the problem, consider the following op-amp circuit in negative feedback:

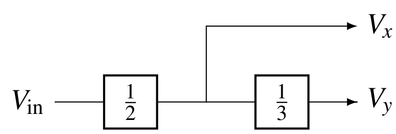


(c) Assuming that this is an ideal op-amp, what is v_{out}?

(d) Draw the equivalent circuit for this op-amp and calculate v_{out} in terms of A, v_{in}, and R_L for the circuit in negative feedback. Does v_{out} depend on R_L? What is v_{out} in the limit as $A \to \infty$?

2. 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:



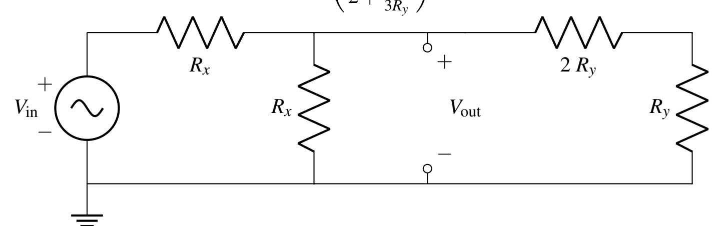
In other words, create a circuit with two outputs V_x and V_y, where $V_x = \frac{1}{2}V_{\text{in}}$ and $V_y = \frac{1}{3}V_x = \frac{1}{6}V_{\text{in}}$.

(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!

