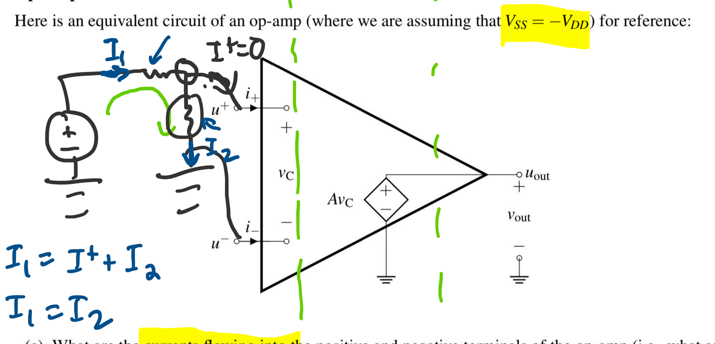
EECS 16A Dis 10A Notes

Saturday, October 30, 2021 5:12 PM

Feedback form: tinyurl.com/anusha16afeedback

1. Op-Amp Rules

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



$I_1 = I^+ + I_2$

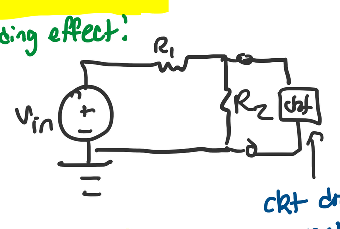
$I_1 = I_2$

(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?

$I^+ = I^- = 0$

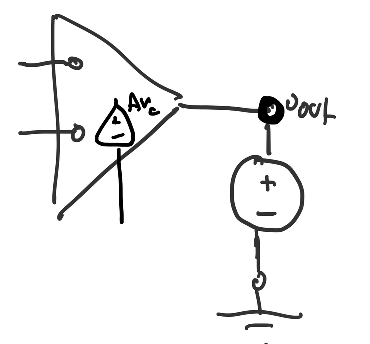
No loading effect

Loading effect:



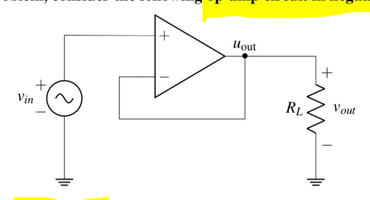
ckt draws current - changing expected behavior

(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?



No loading effect

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

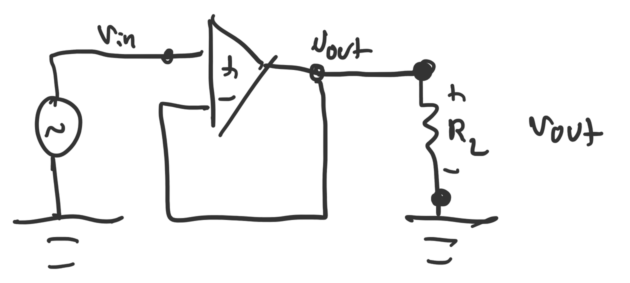


(c) Assuming that this is an ideal op-amp, what is v_{out}?

$V^- = V^+$ (Golden Rule #2)

$\boxed{V_{out} = V_{in}}$

(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 $A \to \infty$?



$v_{out} = v_{out} - 0$

$A \cdot v_c = A \cdot (v_{in} - v_{out})$

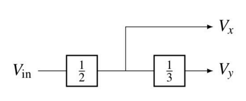
$v_{out} = A \cdot v_c$

$v_{out} = A \cdot (v_{in} - v_{out})$ $\quad v_{out} = \underbrace{\left(\frac{A}{1+A}\right)}\, v_{in}$

As $A \to \infty$, $\frac{A}{1+A} \to 1$ $\quad \boxed{v_{out} \approx v_{in} \text{ As } v_{out} \to \infty}$

2. Modular Circuit Buffer

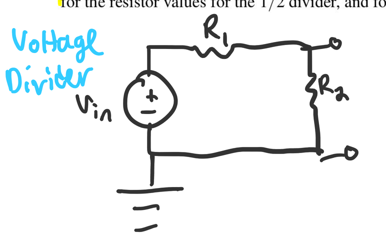
Let's try designing circuits that perform a set of mathematical operations using op-amps. While voltage dividers on their own cannot be combined without altering their behavior, op-amps can preserve their behavior when combined and thus are a perfect tool for modular circuit design. We would like to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



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

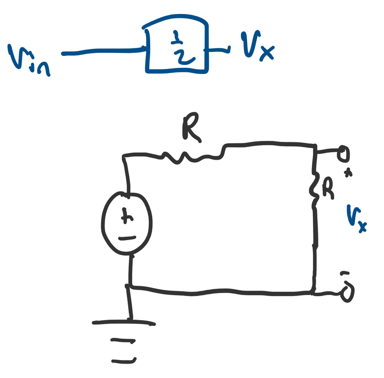
(a) Draw two voltage dividers, one for each operation (the 1/2 and 1/3 scalings). What relationships hold for the resistor values for the 1/2 divider, and for the resistor values for the 1/3 divider?

Voltage Divider



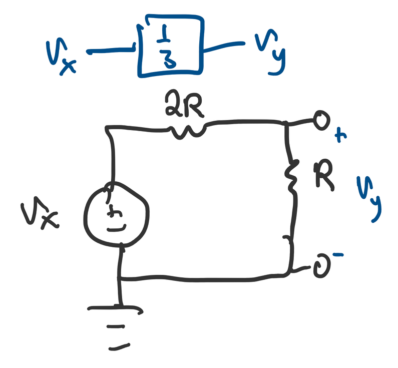
$V_{out} = \left(\frac{R_2}{R_1+R_2}\right) V_{in}$

$V_{in} \to \boxed{\frac{1}{2}} \to V_x$



$V_x = \frac{1}{2} V_{in}$

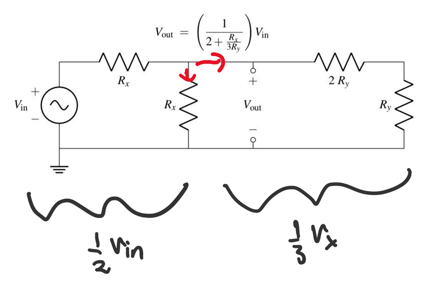
$V_x \to \boxed{\frac{1}{3}} \to V_y$



$V_y = \frac{1}{3} V_x = \frac{1}{6} V_{in}$

(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 $6V_{in} = 3V_x = V_y$)?

HINT: The following circuit and formula may be handy:



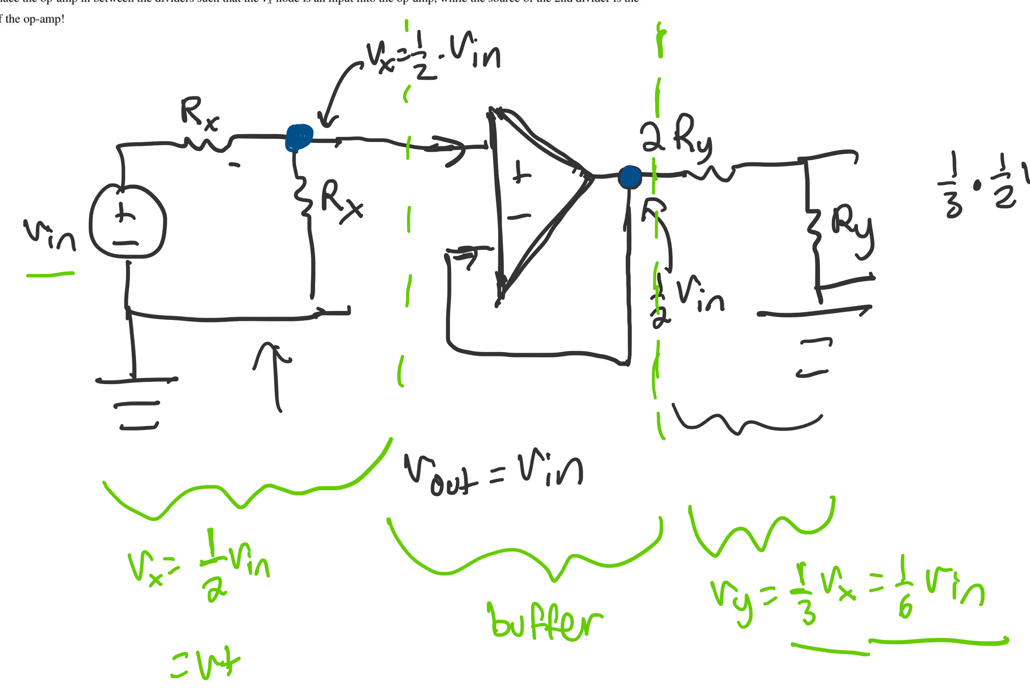
Loading effect - current is being drawn by the $\frac{1}{3}$ voltage divider ckt

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

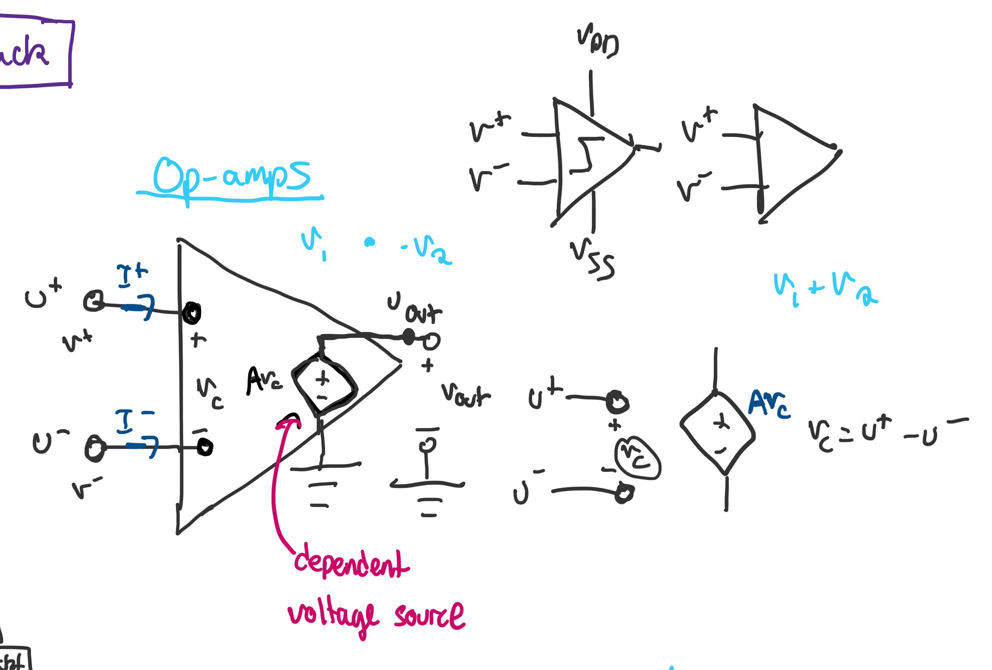
$\neq \frac{1}{2} V_{in}$

(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 $V_x = (1/2)V_{in}$ and $V_y = (1/3)V_x = (1/6)V_{in}$.

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!

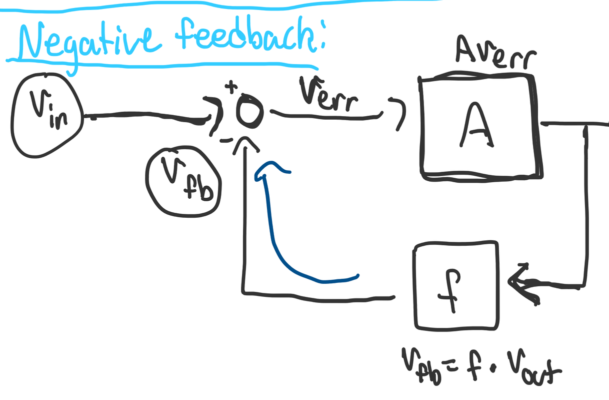


$\frac{1}{3} \cdot \frac{1}{2} V_{in} = \frac{1}{6} V_{in}$



Lecture Recap

Negative feedback:



$V_{fb} = f \cdot V_{out}$

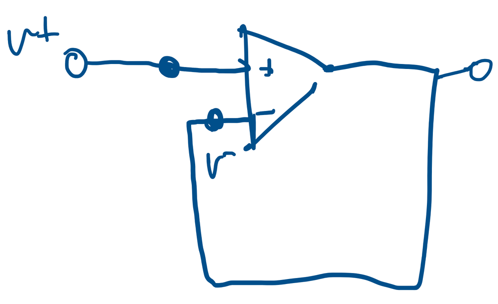
$V_{err} = V_{in} - V_{fb}$

$V_{out} = A \cdot V_{err}$

$V_{fb} = f \cdot V_{out}$

$V_{err} = V_{in} - V_{out}$

Op-amp in negative feedback



$V^- = V^+$

$V_{out} = V_{in}$

$V_{out} = A \cdot V_{err}$

$= A(V_{in} - V_{fb})$

$= A(V_{in} - f \cdot V_{out})$

$V_{out} + A \cdot f V_{out} = AV_{in}$

$V_{out} = \left(\frac{A}{1+A \cdot f}\right) \cdot V_{in} \cdot f$

$A \sim 100k$

As $A \to \infty$, $\left(\frac{A}{1+Af}\right) \to \frac{1}{\frac{1}{A}+f} \xrightarrow{A\to\infty} \frac{1}{f}$ $\quad V_{out} = \frac{1}{\cancel{f}} \cdot V_{in} \cdot \cancel{f}$ $\quad \boxed{V_{out} = V_{in}}$

Golden Rules for Op-Amps:

1. $I^+ = I^- = 0$
2. If in negative feedback, $u^+ = u^-$

Questions:

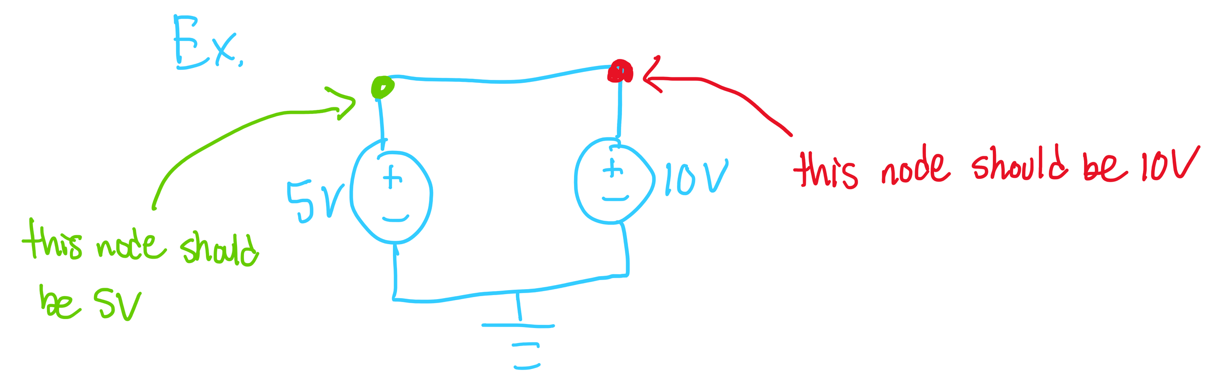
1. How are dependent sources modeled in real life?

Dependent sources are not items that are found in lab kits.
Rather, they model the behavior of more complex devices (bipolar junction transistor).
Take EE 105 to learn more!

2. Can ideal voltage sources be connected in parallel?

Ideal voltage sources w/ different voltage values can't be connected in parallel.

Ex.



$5 \neq 10$