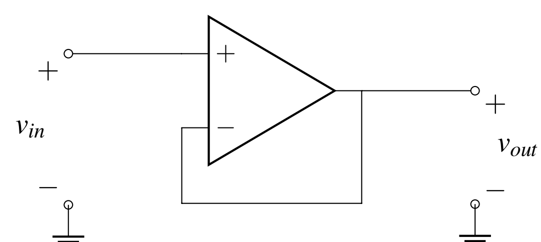
EECS 16A Designing Information Devices and Systems I
Fall 2021 Discussion 10B

1. Testing for Negative Feedback

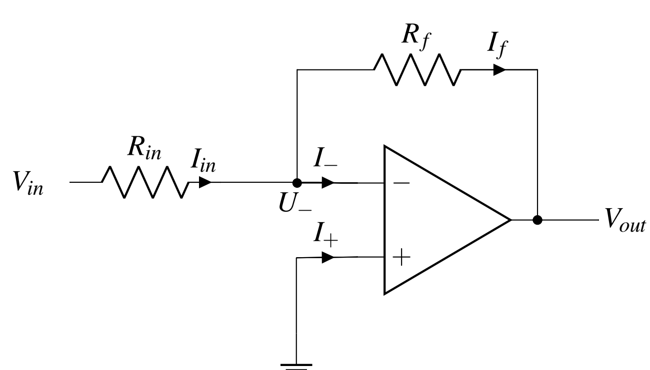
While it is tempting to say "if the feedback voltage is connected to the negative op-amp terminal, then we have negative feedback," this is not always true. Here is a two-step procedure for determining if a circuit is in negative feedback:

- **Step 1: Zero out all independent sources**, replacing voltage sources with wires and current sources with opens as we did in superposition. You do not need to zero out the voltage sources that serve as the power supplies to the op-amp, since they are not treated as signals and almost considered part of the op-amp.
- **Step 2: Wiggle the output and check the loop**. The goal is to see how the feedback loop responds to a change. Assume that the output increases slightly. Check the direction of change of the feedback signal and the error signal from the circuit. Any change in the error signal will cause a new change in the output. This change is the feedback loop's response to the initial change.
  - If the error signal decreases, then the output must also decrease. This is the *opposite direction* we initially assumed, i.e. the loop is trying to correct for the change. So the circuit is in negative feedback.
  - If the error signal instead increased, then the output would also increase. This is the *same direction* we initially assume, i.e. the initial increase lead to further increase. We call this positive feedback.

(a) Show that the voltage buffer circuit is in negative feedback. Note that here v_{in} is acting as a voltage source.



(b) Show that the inverting amplifier circuit is in negative feedback.



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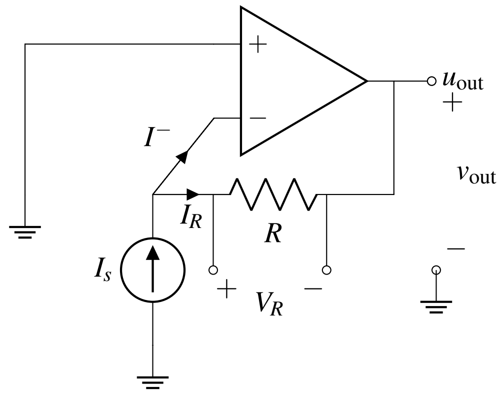
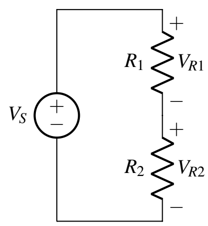
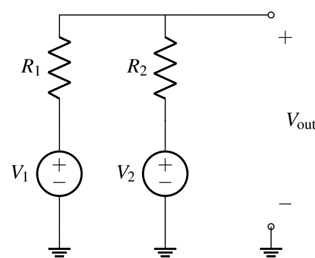
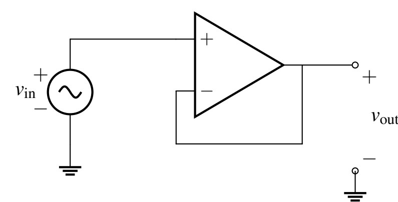
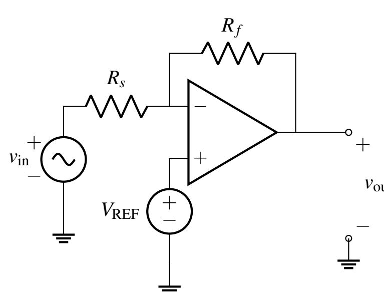
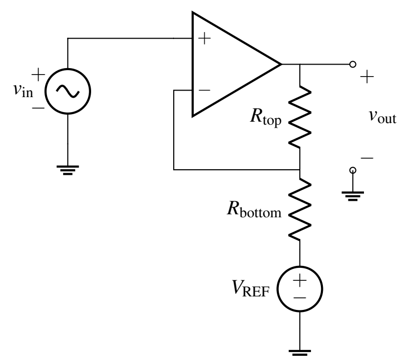
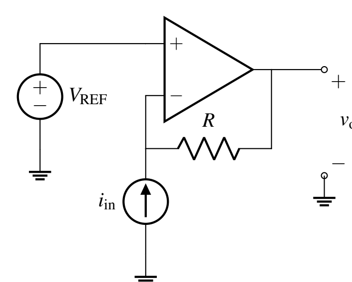
2. A Trans-Resistance Amplifier



Calculate v_{out} as a function of I_s and R.

(For Reference: Example Circuits)

Voltage Divider	Voltage Summer	Unity Gain Buffer
		
$V_{R2} = V_S\left(\frac{R_2}{R_1+R_2}\right)$	$V_{out} = V_1\left(\frac{R_2}{R_1+R_2}\right) + V_2\left(\frac{R_1}{R_1+R_2}\right)$	$\frac{v_{out}}{v_{in}} = 1$
Inverting Amplifier	**Non-inverting Amplifier**	**Transresistance Amplifier**
		
$v_{out} = v_{in}\left(-\frac{R_f}{R_s}\right) + V_{REF}\left(\frac{R_f}{R_s}+1\right)$	$v_{out} = v_{in}\left(1+\frac{R_{top}}{R_{bottom}}\right) - V_{REF}\left(\frac{R_{top}}{R_{bottom}}\right)$	$v_{out} = i_{in}(-R) + V_{REF}$

3. (Practice: Modular Op-Amp Circuits)

Let's design blocks that implement the following operations

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

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