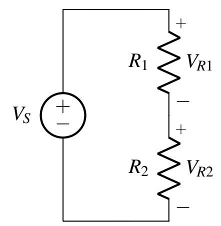
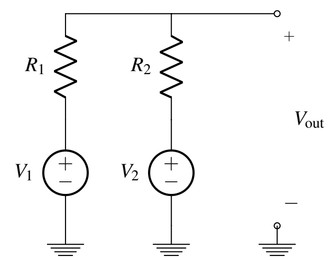
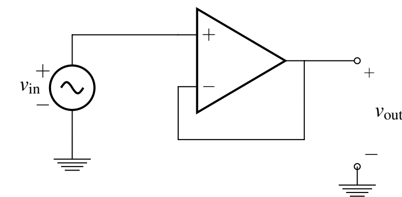
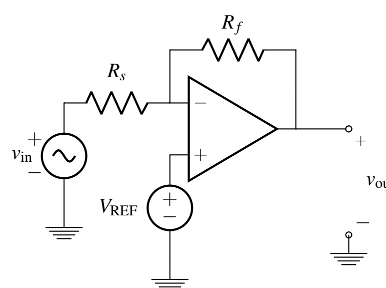
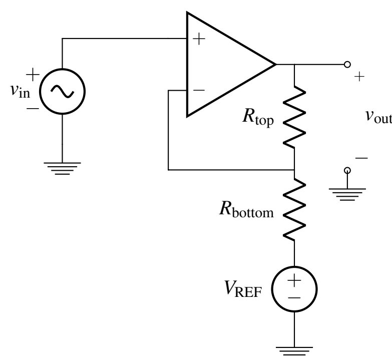
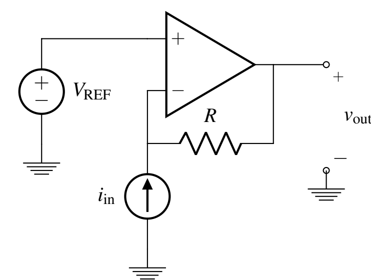
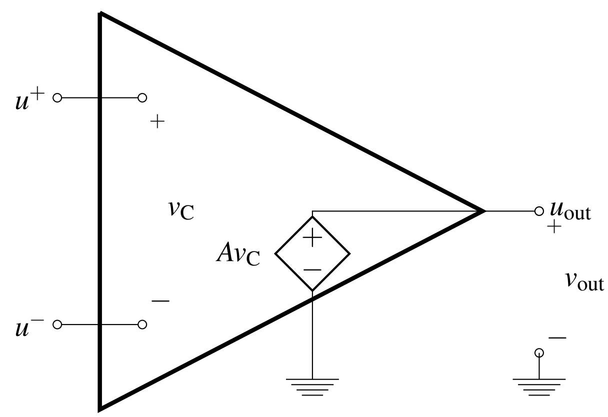
EECS 16A Designing Information Devices and Systems I
Spring 2020 Discussion 10A

For Reference: Example Circuits

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

1. **Op-Amp Rules and Negative Feedback Rule**

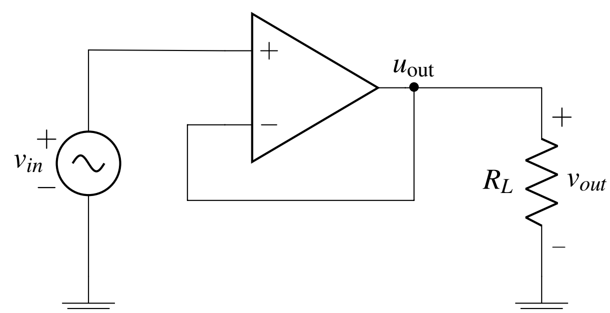
   Here is an equivalent circuit of an op-amp (where we are assuming that $V_{SS} = -V_{DD}$) for reference:



(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:

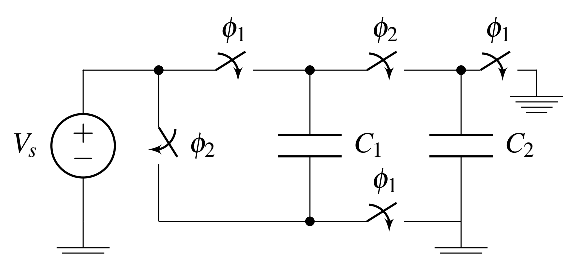


(c) Assuming that this is an ideal op-amp, what is v_{out}?

(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 $A \to \infty$?

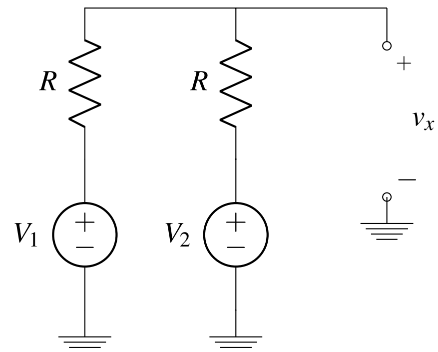
2. Charge Sharing Algorithm

For the switch capacitor circuit below, calculate the value of all node voltages at the end phase 2, as a function of the voltage source V_s and the capacitors C_1, C_2.



3. Dividers for Days

(a) Solve the following circuit for v_x.



(b) You have access to two voltage sources, V_1 and V_2. You can use two resistors (as long as $0 \leq R < \infty$). How would you design a circuit that produces a voltage $v_x = \frac{1}{3}V_1 + \frac{2}{3}V_2$?

(c) You have two current sources I_1 and I_2. You also have a load resistor $R_L = 6\,\mathrm{k}\Omega$. Similar to the first part, you can use whatever resistors you want (as long as they are finite integer values). How would you design a circuit such that the current running through R_L is $I_L = \frac{2}{5}(I_1 + I_2)$?