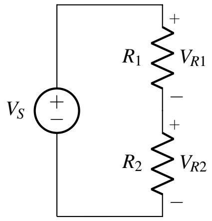
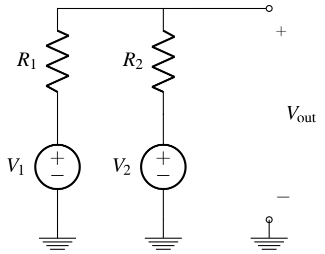
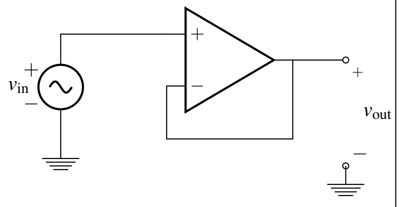
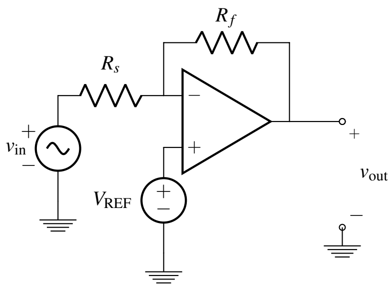
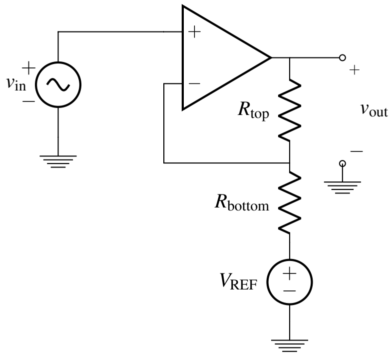
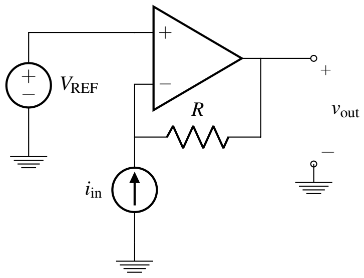
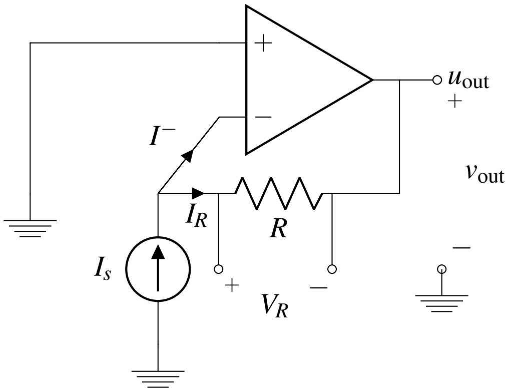
EECS 16A Designing Information Devices and Systems I
Spring 2019 Discussion 9B

For Reference: Circuits Cookbook, Abridged

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

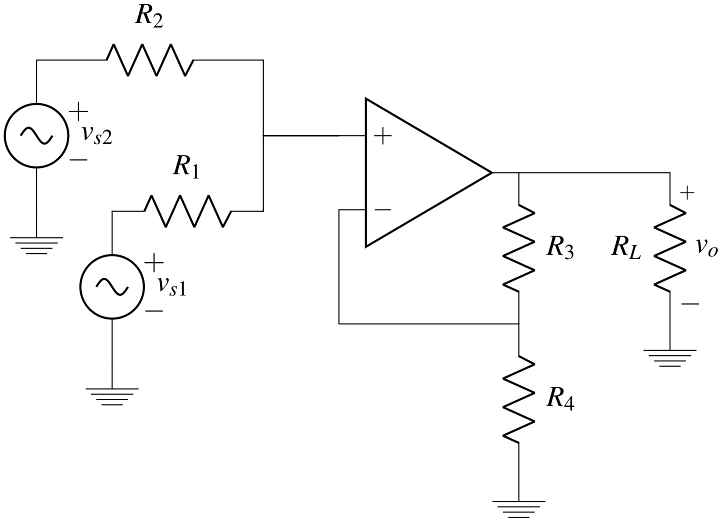
1. A Trans-Resistance Amplifier



(a) Use the Golden Rules to calculate v_{out} as a function of I_s and R.

(b) Use the Golden Rules to implement the same behavior as the above circuit (with a current source), but use a voltage source and a resistor instead.

2. Multiple Inputs To One Op-Amp

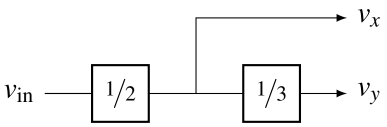


(a) For the circuit above, find an expression for v_o. *(Hint: Use superposition.)*

(b) How could you use this circuit to find the sum of different signals?

3. Modular Circuits

In this problem, we will explore the design of circuits that perform a set of (arbitrary) mathematical operations in order to elucidate some of the important properties and uses of op-amps in negative feedback. In the last discussion, we noticed that voltage dividers are not compose-able, so we will use op-amps instead. Again, recall that we want to implement the block diagram shown below:



In other words, we want to implement a circuit with two outputs v_x and v_y, where $v_x = \frac{1}{2}v_{\text{in}}$ and $v_y = \frac{1}{3}v_x$.

(a) Using an ideal op-amp in negative feedback, modify the design of one of the two voltage divider circuits you built (i.e. the 1/2 block or the 1/3 block), so that the originally intended relationships between v_x and v_{in} as well as v_y and v_x are realized by the resulting overall circuit (where each block is replaced by its individual implementation). Is this configuration enough by itself to attach loads at v_x and v_y?

(b) Now let's assume that we want to expand our toolbox of circuits that implement mathematical operations. In particular, design blocks that implement:

  i. $v_o = 5v_i$
  ii. $v_o = -2v_i$
  iii. $v_o = v_{i_1} + v_{i_2}$

  Pay careful attention to the way you design these blocks, so that connecting any one block to any other block does not modify the intended functionality of any of the blocks.

(c) Check that your designs from part (b) indeed enable a library of compose-able elements (i.e., that you can connect any block to any other block without having the intended functionality be modified) by implementing the block diagram shown below.