ECE 207 – OP AMP CIRCUITS – INVESTIGATION 8
NEGATIVE GAIN OP AMP CIRCUITS

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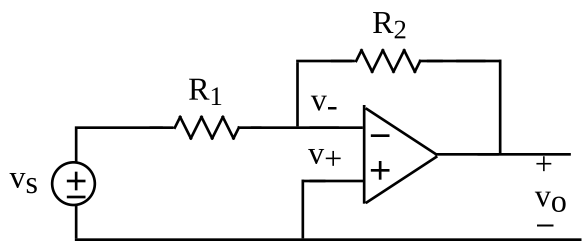
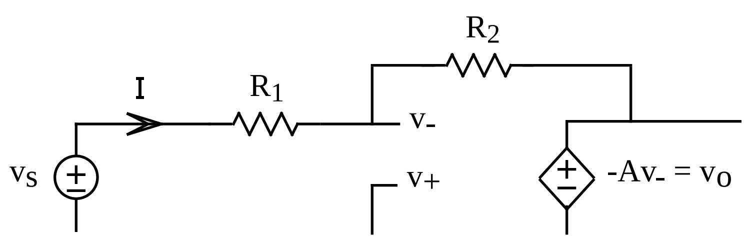
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

From the last Investigation we know how to analyze positive gain op amp circuits. The objective of this investigation is to analyze the following basic negative gain op amp circuit



We call this a negative gain op amp circuit because, as we will see, v_O is equal to a negative constant times v_S . As we will see, its operation is very similar to that of the positive gain op amp circuits in the last investigation.

1. The objective of this first problem is to calculate V_O in an example where the op amp is operating in its linear active region with $V_S = 2$ volts, $R_1 = 1K$, $R_2 = 2K$ and $A = 10^5$
   a. Draw the corresponding negative gain op amp circuit
   b. Redraw your circuit in part (a) with the op amp replaced by its linear equivalent circuit as follows



   c. From inspection of the equivalent circuit in part (b) we see that the value of V_- at the input to the op amp depends on V_O. And so negative gain op amp circuits have feedback just like positive gain op amp circuits do. Writing out the equations we have

$$V_o = A(V_+ - V_-) = A(0 - V_-) = -A(-R_1 I + V_s) = -A\left(-R_1 \frac{V_s - V_o}{R_1 + R_2} + V_s\right)$$

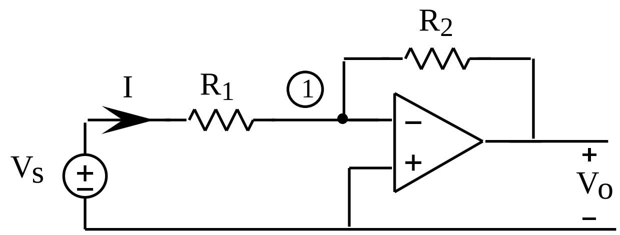
   Make use of this equation to find V_O.
   d. Make use of your result in part (c) to find the voltage gain $G = V_O/V_S$
   e. Make use of your result in part (c) to find the differential input $(V_+ - V_-)$

2. From Problem (1) we see that when a negative gain op amp circuit is operating in its linear active region and the op amp itself has a large gain A as it does for real op amps with gains on

the order of 10^5 then

$$V_+ - V_- \approx 0$$

and so for all practical purposes we can assume $V_+ = V_-$ when writing our circuit analysis equations - just like we can for positive gain op amp circuits. The objective of this problem is to make use of this result to show that voltages and currents like V_O and I in negative gain op amp circuits as follows



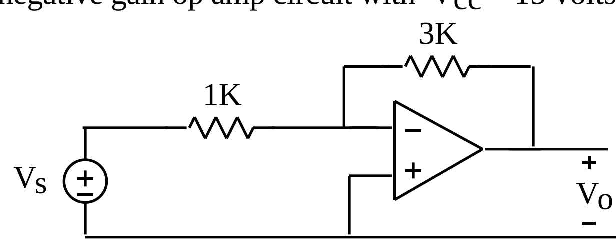
are independent of the op amp gain A when the op amp is operating in its linear active region.

a. Find I as a function of the resistors and the input V_S assuming A is large

b. Find $G = V_O/V_S$ assuming A is large by simply writing the node equation at node 1

3. Given the negative gain op amp circuit of Problem (2)
   a. Sketch I as a function of R_1
   b. Sketch I as a function of R_2
   c. Sketch V_O as a function of R_1
   d. Sketch V_O as a function of R_2

4. Given the following negative gain op amp circuit with $V_{CC} = 15$ volts



   a. Find V_O when $V_S = 4$ volts. Is the op amp in saturation.
   b. Find V_O when $V_S = 6$ volts. Is the op amp in saturation.
   c. Sketch $v_O(t)$ when $v_S(t) = 4 \cos(2\pi\, 1000t)$
   d. Sketch $v_O(t)$ when $v_S(t) = 6 \cos(2\pi\, 1000t)$

5. Math Review - Use the cookbook method to find and sketch x(t) satisfying

$$x' + 2x = 0 \qquad x(3) = 2$$

for $t \geq 3$. Express your answer in the form $ke^{-2(t-3)}$