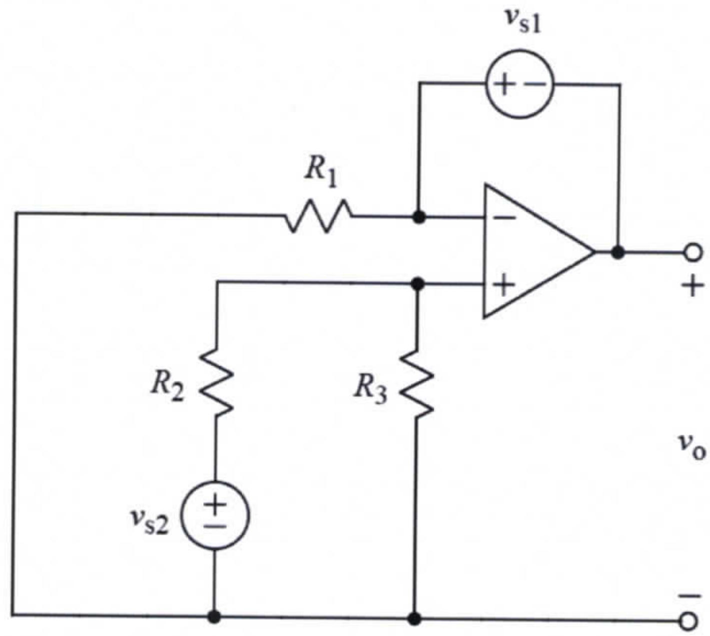
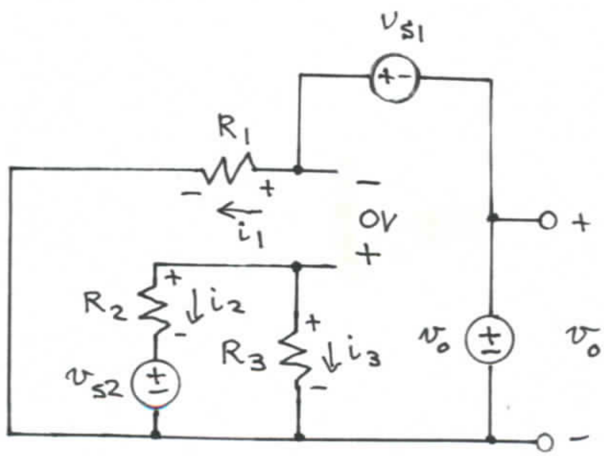
EXAM #1 prob 3 solution

Ex:



The op-amp operates in the linear mode. Using an appropriate model of the op-amp, derive an expression for v_o in terms of not more than v_{s1}, v_{s2}, R_1, R_2, and R_3.

sol'n: Using Kirchhoff's and Ohm's laws, we start by labeling the directions of voltage and current measurements. One possibility for the labeling is shown below. We also replace the op-amp with a voltage source v_o.



Now we write eq'ns for v-loop and i-sums, making sure we have a v-loop that passes through the 0V drop that we assume exists across the inputs of the op-amp.

v-loop on left: $+i_1 R_1 + 0V - i_2 R_2 - v_{S2} = 0V$

v-loop lower middle: $+v_{S2} + i_2 R_2 - i_3 R_3 = 0V$

v-loop outside: $+i_1 R_1 - v_{S1} - v_o = 0V$

The only node not connected to another node by only a v-source is at the + input of the op-amp.

$$i_2 = -i_3$$

Now we solve the eq'ns to find an expression for v_o.

Substitute for i_3 in 2nd v-loop.

$$v_{S2} + i_2 R_2 + i_2 R_3 = 0V$$

We can solve for i_2.

$$i_2 (R_2 + R_3) = -v_{S2}$$

or

$$i_2 = -\frac{v_{S2}}{R_2 + R_3}$$

Now we can use i_2 to find i_1 from the 1st v-loop.

$$i_1 R_1 + 0V - -\frac{v_{S2} R_2}{R_2 + R_3} - v_{S2} = 0V$$

or

$$i_1 = \frac{v_{S2}}{R_1}\left(1 - \frac{R_2}{R_2+R_3}\right) = \frac{v_{S2}}{R_1}\left(\frac{\cancel{R_2}+R_3-\cancel{R_2}}{R_2+R_3}\right)$$

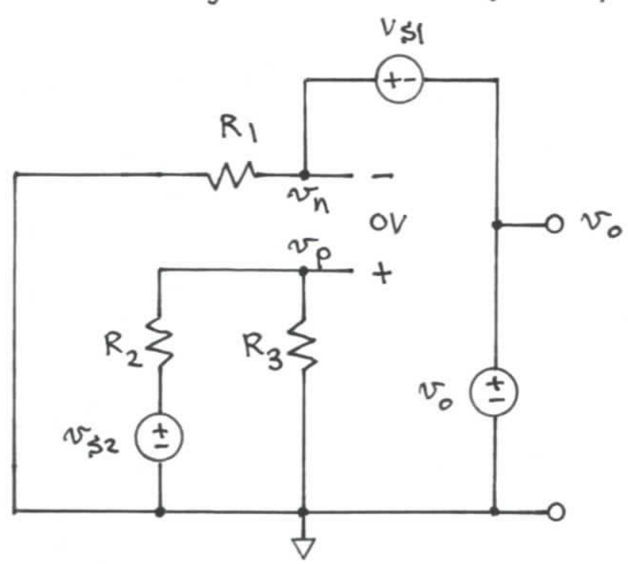
or

$$i_1 = \frac{v_{S2}}{R_1}\frac{R_3}{R_2+R_3}$$

Using this value for i_1, the outer v-loop yields an expression for v_o.

$$v_o = i_1 R_1 - v_{S1} = v_{S2}\frac{R_3}{R_2+R_3} - v_{S1}$$

An alternative approach is to use the Node-V method. We assume a 0V drop across the op-amp inputs, and we start by finding node voltage v_p.



We have v-divider consisting of v_{S2}, R_2, and R_3.

$$v_p = v_{S2}\frac{R_3}{R_2+R_3}$$

The v_n node has the same voltage as v_p.

$$v_n = v_p$$

We would normally now use an i-sum at the v_n node, but we see that v_o differs from v_n by v_{s1}.

$$v_o = v_n - v_{s1}$$

or

$$v_o = v_p - v_{s1}$$

or

$$v_o = v_{s2} \frac{R_3}{R_2 + R_3} - v_{s1}$$