Read Sections 5.1–8 in Alexander & Sadiku. The problems in this assignment are not ordered by difficulty.

1. Redo Example 5.2 in Alexander & Sadiku for the following component values: $5\,\text{k}\Omega \rightarrow$ ___ $\text{k}\Omega$, $40\,\text{k}\Omega \rightarrow$ ___ $\text{k}\Omega$, $20\,\text{k}\Omega \rightarrow$ ___ $\text{k}\Omega$, and $v_s =$ ___ V.

$v_o/v_s =$            3 pts.
                            0

$i_o =$               3 pts.
                            1
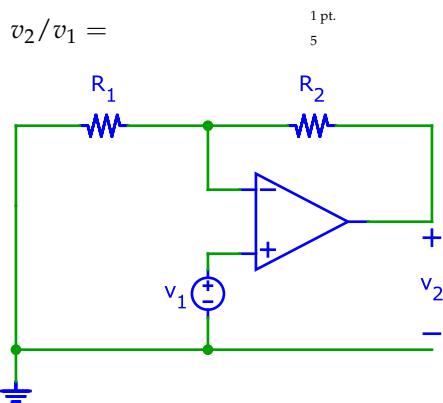
2. Redo Example 5.7 in Alexander & Sadiku for the following component values: $v_1 =$ ___ V, $v_2 =$ ___ V, $R_1 =$ ___ $\text{k}\Omega$, $R_2 =$ ___ $\text{k}\Omega$, $R_3 =$ ___ $\text{k}\Omega$ and $R_4 =$ ___ $\text{k}\Omega$.

$v_o =$             2 pts.
                            2

$v_a =$             2 pts.
                            3

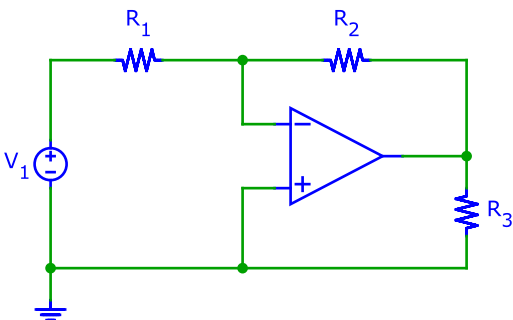3. Redo Practice Problem 5.10 in Alexander & Sadiku for the following component values: $v_1 =$ ___ V and $v_2 =$ ___ V.

$v_o =$             4 pts.
                            4

4. Calculate the ratio $v_2/v_1$. Assume that the operational amplifier is ideal. Use $R_1 =$ ___ $\text{k}\Omega$, $R_2 =$ ___ $\text{k}\Omega$.

$v_2/v_1 =$            1 pt.
                            5



5. Calculate the power dissipated in resistor $R_3$. Assume that the operational amplifier is ideal. Parameter: $V_1 =$ ___ V, $R_1 =$ ___ $\text{k}\Omega$, $R_2 =$ ___ $\text{k}\Omega$, $R_3 =$ ___ $\text{k}\Omega$.
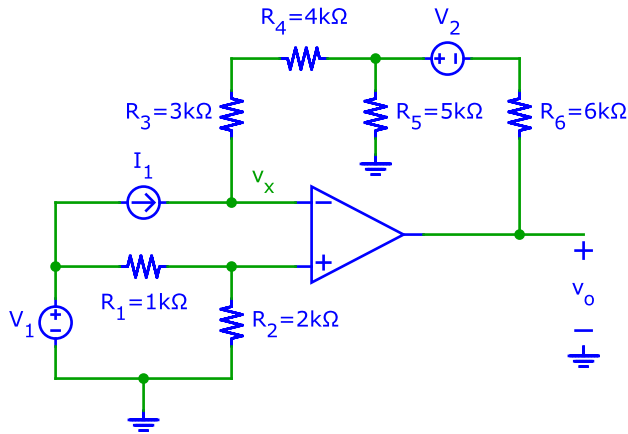
$P_{R_3} =$            1 pt.
                            6



1

6. Find the voltage at node $v_x$ for $V_1 =$     V, $V_2 =$     V, $I_1 =$     mA.

Note: the solution of this problem is trivial!
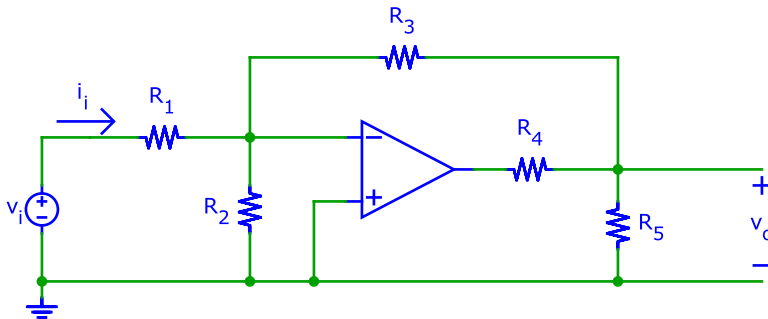
$v_x =$             1 pt.
                     7



7. Calculate the closed-loop gain $A_v$ and input resistance $R_i$ of the circuit below. Use $R_1 =$     kΩ, $R_2 =$     kΩ, $R_3 =$     kΩ, $R_4 =$     kΩ, $R_5 =$     kΩ.

Note: this problem can be solved by inspection.

$$A_v = v_o/v_i = $$     1 pt.
                  8
$$R_i = v_i/i_i = $$     1 pt.
                  9



8. Large resistor ratios are required if a big closed-loop gain $|v_o/v_i|$ is desired in an operational amplifier circuit. E.g. setting the gain of an inverting amplifier to -1000 requires resistors with values $10\,\mathrm{k\Omega}$ and $10\,\mathrm{M\Omega}$ or multiples thereof. Such large resistor values and ratios often exhibit unacceptably large variation, causing error in the closed-loop gain. In integrated circuits, large resistor values occupy a large area, increasing fabrication cost.

The circuit shown below requires resistor ratios that are much smaller than the closed-loop gain. Find the ratio $R_2/R_1$ such that $v_o/v_i =$     . Use $R_1 = R_3 =$     kΩ and $R_2 = R_4$.
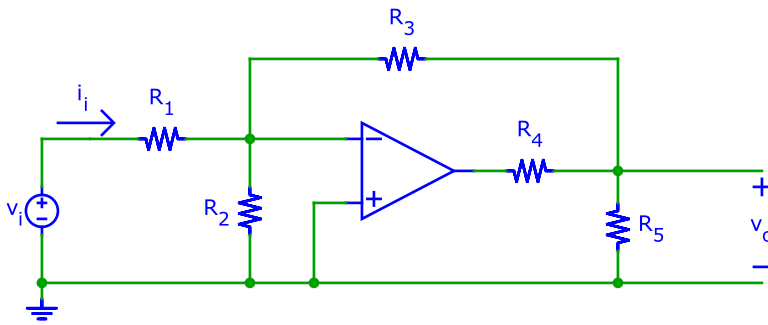
$R_2/R_1 =$            3 pts.
                   10
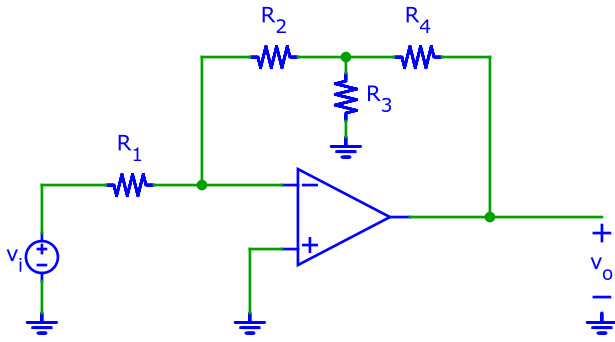
9. Calculate the closed-loop gain $A_v$ and input resistance $R_i$ of the circuit below. Use $R_1 =$ ___ k$\Omega$, $R_2 =$ ___ k$\Omega$, $R_3 =$ ___ k$\Omega$, $R_4 =$ ___ k$\Omega$, $R_5 =$ ___ k$\Omega$.

Note: this problem can be solved by inspection.

$$A_v = v_o/v_i = $$
$$R_i = v_i/i_i = $$
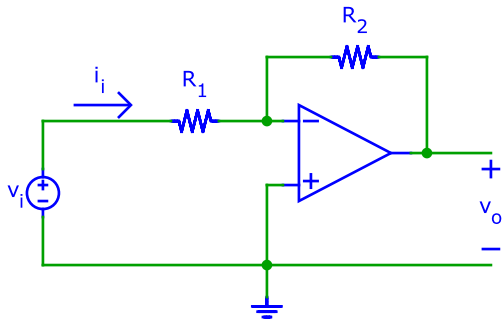
1 pt.
11
1 pt.
12



10. The current into the input of an ideal operational amplifier is ideally zero. Many operational amplifiers come close to this ideal, with leakage currents in the pA or even fA range.[1] This corresponds to a very high input resistance (T$\Omega$ range) that is usually negligible.

High input resistance of the open-loop amplifier (i.e. without feedback resistors) does not always translate into the same characteristic for the closed-loop configuration. Specifically, non-inverting closed-loop configurations retain the high input resistance of the open-loop amplifier, but in inverting configurations the input resistance is determined by the feedback network and therefore much smaller.

The diagram below shows a test circuit. Calculate the input resistance $R_i = v_i/i_i$ for $R_1 =$ ___ k$\Omega$ and $R_2 =$ ___ k$\Omega$.

$R_i =$

1 pt.
13

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[1]This depends on the type of amplifier. In particular, amplifiers with MOS or JFET inputs have very small input currents, while the input current of BJT amplifiers is much larger, often in the $\mu$A range. BJT amplifiers have other advantages, such has higher speed or output current capability and lower offset voltage. If low input resistance is critical, an operational amplifier with either MOS or JFET inputs is preferred.

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