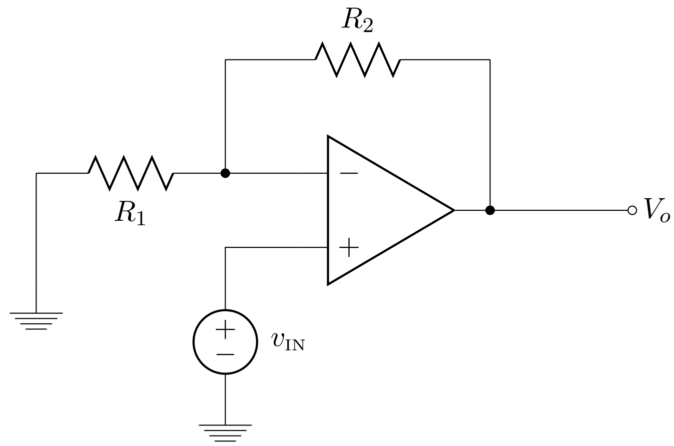
Problem 1. The non-inverting amplifier shown below uses a non-ideal op amp with a finite open-loop gain.



(A) Calculate the *ideal gain* if the op amp has $A \to \infty$, $R_1 = 1\text{k}\Omega$ and $R_2 = 9\text{k}\Omega$.

(B) Calculate the *actual gain* for the values in (A) if the gain is $A = 100\,\text{V/ V}$.

(C) Suppose the op amp has a finite open-loop gain of $A = 1000\,\text{V/ V}$, and it is desired to have an actual circuit gain of $G = 10\text{V/ V}$. What is the ratio $R_2/R1$ that will achieve the desired gain?

(D) Lastly, if the open loop gain varies from 100 to $1000\,\text{V/ V}$, and R_1 is held constant at $1\text{k}\Omega$, what is the range of adjustments needed in R_2 to maintain an actual gain of $G = 10\,\text{V/ V}$?

Problem 2. The *transresistance amplifier* shown below is to be used in a sensor interface. The resistor R_s is an unknown resistance, which will be measured by the following method:

(i) Apply a known potential V_{ref} to the op amp's non-inverting input terminal. Due to the virtual short effect, the same potential (or nearly the same) should then appear at the inverting input terminal.

(ii) Measure the potential V_o appearing at the op amp's output terminal.

(iii) Based on V_o, estimate the value of the current flowing through R_s. The resistance is then

$$R_s \approx V_s/I_s$$

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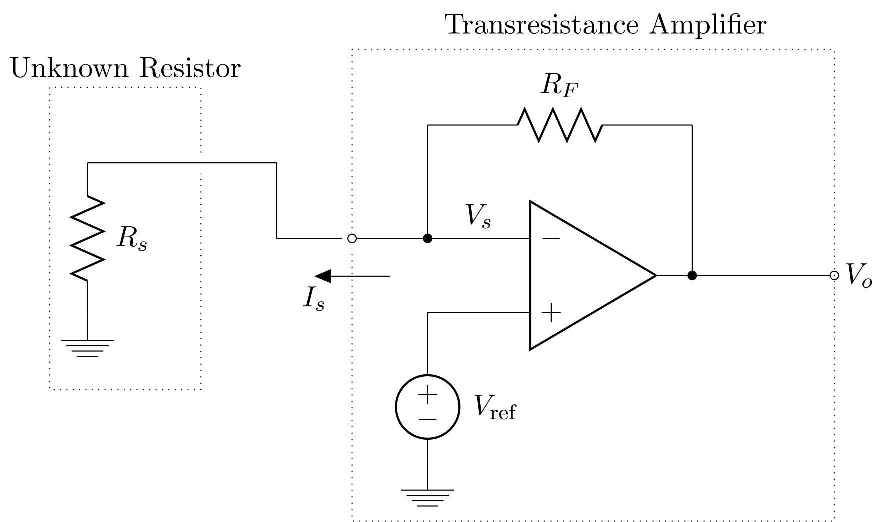

(A) If the op amp is ideal, obtain expressions for these items: V_s, I_s, and V_o. For each item, the left-hand side of your expression should only include R_s, V_{ref} and/or R_F. Finally, obtain an expression for R_s.

(B) Repeat (A) for the case where the op amp has *finite gain* equal to $A\,\text{V/V}$. This time, the left-hand side of each expression should only include R_s, V_{ref}, R_F and/or A.

(C) Suppose the op amp is ideal, $R_s = 1\text{k}\Omega$, $R_F = 2\text{k}\Omega$, and $V_{\text{ref}} = 1\text{V}$. What are the values of V_s, I_s and V_o?

(D) Repeat (C) for an op amp with finite gain $A = 100\,\text{V/V}$

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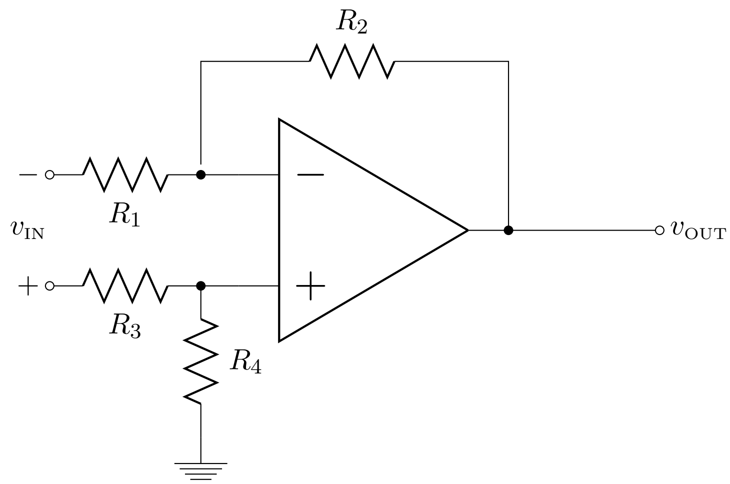
(E) For the circuit described in (C) and (D), suppose R_s can vary between 500Ω and $5\text{k}\Omega$. What is the corresponding range of variation that may be seen in V_o?

(F) Estimate the value of R_s if $V_o = 1.5\text{V}$, $R_F = 10\text{k}\Omega$, $V_{\text{ref}} = 1\text{V}$ and $A \to \infty$.

Problem 3. The difference amplifier shown below uses an op amp, but suffers from mismatch in its resistor values. By design, $R_2 = R_4 = 10\text{k}\Omega$, and $R_1 = R_3 = 1\text{k}\Omega$. In reality, all resistors vary within a $\pm5\%$ tolerance.



For this circuit, recall that there are two signal paths, called the *inverting* path and the *non-inverting* path. The goal is to balance the gains along these signal paths:

$$\text{inverting path}: \quad -G_i = -\frac{R_2}{R_1}$$

$$\text{non}-\text{inverting path}: \quad G_{ni} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)$$

Notice here that G_i is defined as a positive number. Based on these definitions, you can show that the differential gain and the common-mode gain are:

$$A_d = \frac{1}{2}\left(G_i + G_{ni}\right)$$

$$A_{CM} = \left|G_i - G_{ni}\right|$$

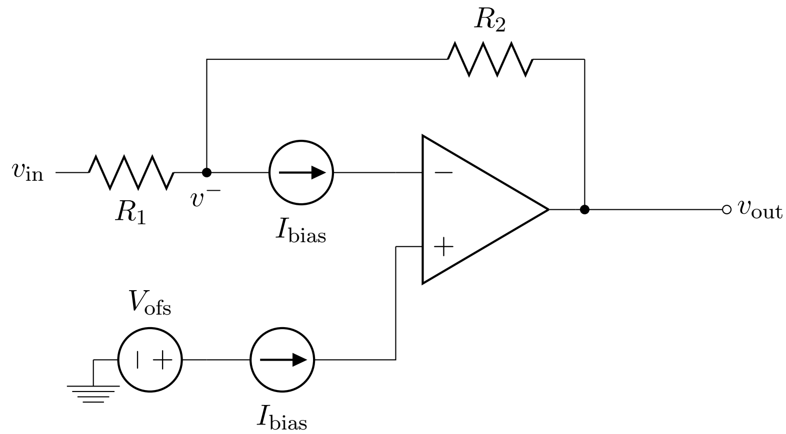
(A) If all the resistors were *perfectly matched* to their specified values, what should be the circuit's differential gain, common-mode gain and CMRR?

(B) Suppose all resistors are mismatched from their specified values as follows:

R_1: 5% too large $\quad R_2$: 5% too small
R_3: 5% too small $\quad R_4$: 5% too large

In this case, calculate the resistor values, the differential gain, the common-mode gain and the CMRR in dB.

Problem 4. A non-inverting op amp configuration is shown below. Also shown are current and voltage sources inserted to model the op amp's non-ideal bias current and offset voltage.



(A) For this problem, suppose that $V_{\text{ofs}} = 0$, $I_{\text{bias}} = 20\mu\text{A}$, and $R_1 = 10\text{k}\Omega$. The op amp's supply rails are at $\pm5\text{V}$, and the op amp has infinite open-loop gain. If the input signal is a sinusoid with peak-to-peak amplitude 10mV, what is the **maximum gain** (i.e. the maximum value for R_2) that can be allowed without saturating the op amp?

(B) For this problem, suppose that $I_{\text{bias}} \approx 0$, $R_2 = 5\text{k}\Omega$, $R_1 = 1\text{k}\Omega$ and the op amp is otherwise ideal. If V_{ofs} varies in the range of $\pm10\text{mV}$, what is the range of DC offset voltages that may appear at V_{OUT}?