Homework for Chapter 2

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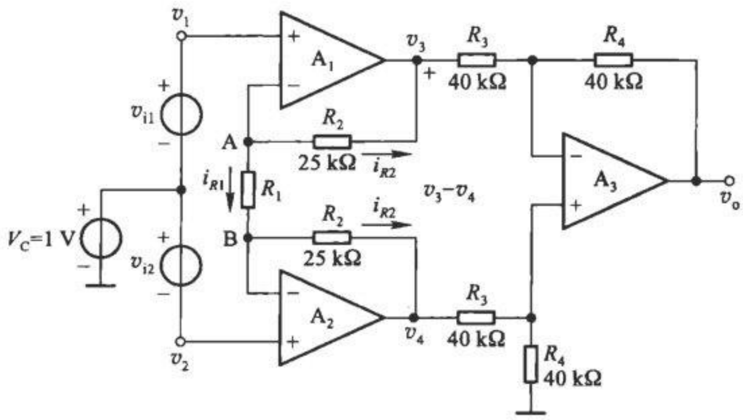
2.4.4 INA2128 型仪用放大器电路如图题 2.4.4 所示，其中 R_1 是外接电阻。(1) 它的输入干扰电压 $V_C=$



图题 2.4.4

1 V（直流），输入信号 $v_{i1}=-v_{i2}=0.04\sin\omega t$ V，输入端电压 $v_1=(V_C+0.04\sin\omega t)$ V，$v_2=(V_C-0.04\sin\omega t)$ V，当 $R_1=$ 1 kΩ时，求出 v_3、v_4、v_3-v_4 和 v_o 的电压值；(2) 当输入电压 $V_{id}=V_1-V_2=0.018\,66$ V 时，要求 $V_O=-5$ V，求此时外接电阻 R_1 的阻值。

Solution for Q1 Since A_1 and A_2 are ideal operational amplifiers

$$v_A = v_1 = V_C + v_{i1}$$
$$v_B = v_2 = V_C - v_{i2}$$

Now we currents around A_2 can be calculated

$$i_{R2} = i_{R1} = \frac{v_A - v_B}{R_1} = \frac{v_{i1} + v_{i2}}{R_1} = 0.08 \sin \omega t \text{ mA}$$

$$v_3 = v_A + i_{R2} R_2 = (1 + 2.04 \sin \omega t) \text{ V}$$
$$v_4 = v_B - i_{R2} R_2 = (1 - 2.04 \sin \omega t) \text{ V}$$

(I noted that the arrow below the first R_2 counted from top to bottom might be opposited)
We can then calculate the input voltage of A_3

$$V_{A3_{input}} = \frac{R_4}{R_3 + R_4} v_4 = (0.5 - 1.02 \sin \omega t) \text{ V}$$

For R_4, I assume the current direction is from left to right.

$$i_{R4} = \frac{v_3 - V_{A3_{input}}}{R_3} = \frac{0.5 + 3.06 \sin \omega t \text{ V}}{40 \text{ k}\Omega}$$

Finally

$$v_o = V_{A3_{input}} - i_{R_4} R_4 = -4.08 \sin \omega t \text{ V}$$

Solution for Q2 Since A_1 and A_2 are ideal operational amplifiers

$$v_A = v_1 = V_C + v_{i1}$$
$$v_B = v_2 = V_C - v_{i2}$$

Now we currents around A_2 can be calculated

$$i_{R2} = i_{R1} = \frac{v_A - v_B}{R_1} = \frac{v_{i1} + v_{i2}}{R_1}$$

$$v_3 = v_A + i_{R2} R_2 = V_C + v_{i1} + \frac{v_{i1} + v_{i2}}{R_1} R_2$$
$$v_4 = v_B - i_{R2} R_2 = V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2$$

(I noted that the arrow below the first R_2 counted from top to bottom might be opposited)
We can then calculate the input voltage of A_3

$$V_{A3_{input}} = \frac{R_4}{R_3 + R_4} v_4 = \frac{R_4}{R_3 + R_4} \left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right)$$

For R_4, I assume the current direction is from left to right.

$$i_{R4} = \frac{v_3 - V_{A3_{input}}}{R_3} = \frac{\left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right) - \frac{R_4}{R_3 + R_4} \left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right)}{R_3}$$

Finally

$$\begin{aligned} v_o &= V_{A3_{input}} - i_{R_4} R_4 \\ &= \frac{R_4}{R_3 + R_4} \left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right. \\ &\quad - \frac{\left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right) - \frac{R_4}{R_3 + R_4} \left(V_C - v_{i2} - \frac{v_{i1} + v_{i2}}{R_1} R_2 \right)}{R_3} R_4 \end{aligned}$$

When $V_1 - V_2 = v_{i1} + v_{i2} = 0.01866$ V, $v_o = 5$ V, we can solve for R_1

$$R_1 = 186 \ \Omega$$