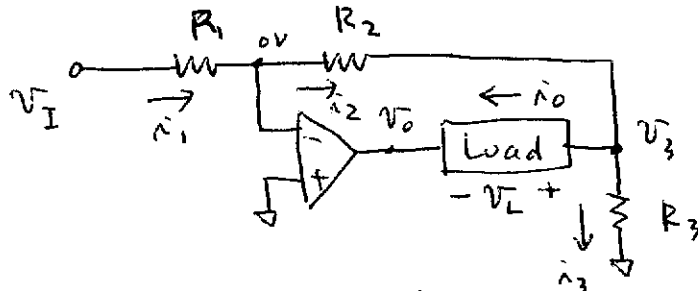


2 장 $\frac{1}{3}$ 제 해 풀

2-5



(a)

$$i_1 = \frac{V_I}{R_1} = i_2 = -\frac{V_3}{R_2}, \quad i_3 = \frac{V_3}{R_3}$$

$$i_2 = i_0 + i_3 \quad \text{or} \quad \frac{V_I}{R_1} = i_0 - \frac{R_2}{R_1 R_3} V_I$$

$$i_0 = \frac{V_I}{R_1} \left(\frac{R_2}{R_3} + 1 \right) = \frac{V_I}{R_1/k}, \quad k = 1 + \frac{R_2}{R_3}$$

(b) $R_i = R_1 = 1 \text{ M}\Omega$

Sensitivity = $\frac{1}{R_1} \left(\frac{R_2}{R_3} + 1 \right) = 1 \text{ mA/V}$

$$\frac{R_2}{R_3} + 1 = 1000 \Rightarrow \frac{R_2}{R_3} = 999$$

5% 저항을 이용하면, $R_2 = 100 \Omega, R_3 = 91 \text{ k}\Omega$

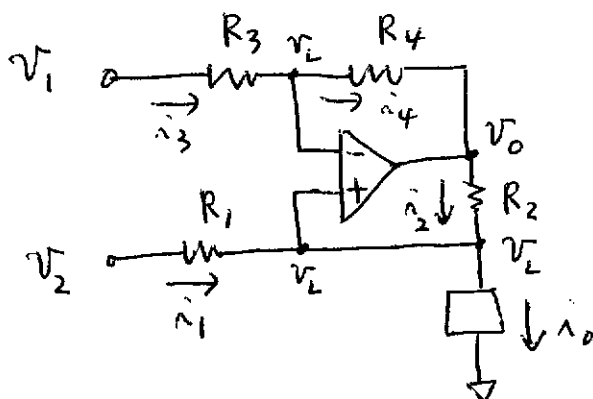
(c) $V_3 = -\frac{R_2}{R_1} V_I = V_0 + V_L$

$$\therefore V_L = -V_0 - \frac{R_2}{R_1} V_I$$

$$\frac{R_2}{R_1} = 10^{-4} \text{ 이라면}$$

$$\left(-13 - 10^{-4} V_I \right) < V_L < \left(13 - 10^{-4} V_I \right)$$

2-9



$$\dot{i}_1 = \frac{v_2 - v_L}{R_1}, \quad \dot{i}_2 = \frac{v_0 - v_L}{R_2}, \quad \dot{i}_0 = \dot{i}_1 + \dot{i}_2$$

$$\dot{i}_3 = \frac{v_1 - v_L}{R_3} = \dot{i}_4 = \frac{v_L - v_0}{R_4} \text{ или}$$

$$v_0 = \left(1 + \frac{R_4}{R_3}\right) v_L - \frac{R_4}{R_3} v_1$$

$$\dot{i}_0 = \dot{i}_1 + \dot{i}_2 = \frac{v_2 - v_L}{R_1} + \frac{\frac{R_4}{R_3} v_L - \frac{R_4}{R_3} v_1}{R_2}$$

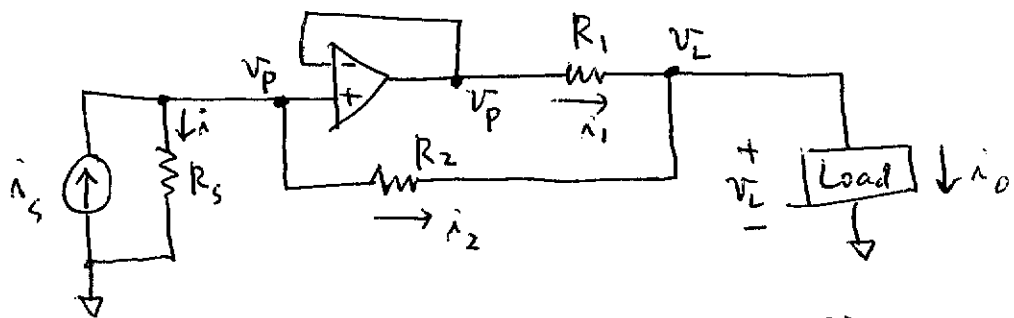
$$= \frac{v_2}{R_1} - \frac{R_4}{R_2 R_3} v_1 + \left(\frac{R_4}{R_2 R_3} - \frac{1}{R_1}\right) v_L$$

$$= \frac{v_2}{R_1} - \frac{R_4}{R_2 R_3} v_1 + \frac{v_L}{R_0}$$

$$\frac{1}{R_0} = \frac{R_4}{R_2 R_3} - \frac{1}{R_1} = 0 \text{ или } \frac{R_4}{R_3} = \frac{R_2}{R_1}$$

$$\text{или, } \dot{i}_0 = \frac{1}{R_1} (v_2 - v_1)$$

2-21



$$\dot{i}_s = \frac{v_p}{R_5}, \quad \dot{i}_2 = \frac{v_p - v_L}{R_2}, \quad \dot{i}_1 = \frac{v_p - v_L}{R_1}$$

$$\dot{i}_s = \dot{i} + \dot{i}_2 = \frac{v_p}{R_5} + \frac{v_p - v_L}{R_2} \quad \text{--- ①}$$

$$\dot{i}_0 = \dot{i}_1 + \dot{i}_2 = \frac{v_p - v_L}{R_1} + \frac{v_p - v_L}{R_2} \quad \text{--- ②}$$

$$\text{① или } v_p = \frac{R_5 R_2}{R_5 + R_2} \dot{i}_s + \frac{R_5}{R_5 + R_2} v_L$$

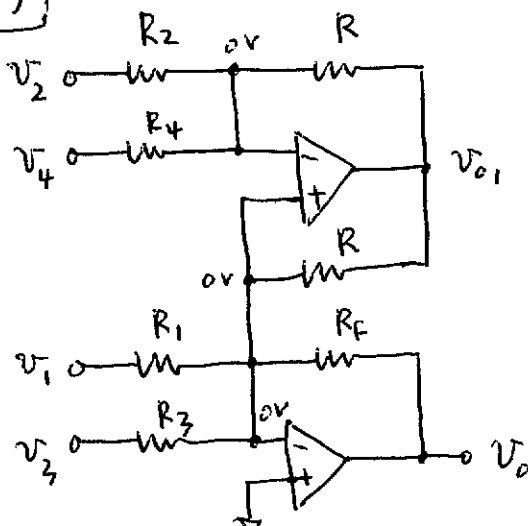
$$\text{или } v_p - v_L = \frac{R_5 R_2}{R_5 + R_2} \dot{i}_s - \frac{R_2}{R_5 + R_2} v_L$$

$$\begin{aligned}
 \textcircled{2} \text{ VIKI} \quad i_0 &= \left(\frac{1}{R_1} + \frac{1}{R_2} \right) (v_p - v_L) \\
 &= \frac{R_1 + R_2}{R_1 R_2} \frac{R_5 R_2}{R_5 + R_2} i_s - \frac{R_1 + R_2}{R_1 R_2} \frac{R_2}{R_5 + R_2} v_L \\
 &= \left(1 + \frac{R_2}{R_1} \right) \frac{R_5}{R_5 + R_2} i_s - \frac{R_1 + R_2}{R_1} \frac{1}{R_5 + R_2} v_L \\
 &= \left(1 + \frac{R_2}{R_1} \right) \frac{R_2}{R_5 + R_2} i_s - \frac{v_L}{R_0}
 \end{aligned}$$

$$\text{V/CCH, } R_0 = \frac{R_1}{R_1 + R_2} (R_5 + R_2)$$

$$A_I = \left(1 + \frac{R_2}{R_1} \right) \frac{R_2}{R_5 + R_2}$$

2-25



$$- \left(\frac{v_2}{R_2} + \frac{v_4}{R_4} \right) R = v_{o1} \quad \text{--- (1)}$$

$$- \left(\frac{v_{o1}}{R} + \frac{v_1}{R_1} + \frac{v_3}{R_3} \right) R_F = v_0 \quad \text{--- (2)}$$

$$\therefore v_0 = - \frac{R_F}{R_1} v_1 - \frac{R_F}{R_3} v_3 + \frac{R_F}{R_2} v_2 + \frac{R_F}{R_4} v_4$$

פתרון v_2 is floating input, (2) is the condition $v_2 = 0$

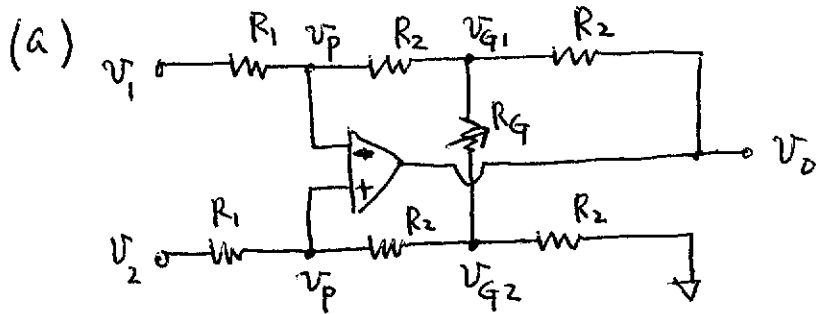
$$- \frac{v_4}{R_4} \cdot R = v_{o1} \Rightarrow v_0 = - \frac{R_F}{R_1} v_1 - \frac{R_F}{R_3} v_3 + \frac{R_F}{R_4} v_4$$

פתרון v_1 is floating input, (1) is the condition $v_1 = 0$

$$- \left(\frac{v_{o1}}{R} + \frac{v_3}{R_3} \right) R_F = v_0 \Rightarrow v_0 = - \frac{R_F}{R_3} v_3 + \frac{R_F}{R_2} v_2 + \frac{R_F}{R_4} v_4$$

따라서, 어느 한 입력이 floating 되면 출력에서
 그 입력을 0으로 하면 됨 그러나 문제 1.31의 해법은
 어느 한 입력이 floating 되면 나머지 입력에 대한
 이득이 달라짐.

2-27



$$\frac{V_2 - V_p}{R_1} = \frac{V_p - V_{G2}}{R_2} \Rightarrow V_2 - V_p = \frac{R_1}{R_2} V_p - \frac{R_1}{R_2} V_{G2} \quad \text{--- ①}$$

$$\frac{V_1 - V_p}{R_1} = \frac{V_p - V_{G1}}{R_2} \Rightarrow V_1 - V_p = \frac{R_1}{R_2} V_p - \frac{R_1}{R_2} V_{G1} \quad \text{--- ②}$$

$$\text{①} \times - \text{②} \times \text{에서 } V_2 - V_1 = \frac{R_1}{R_2} (V_{G1} - V_{G2}) \quad \text{--- ③}$$

$$\frac{V_p - V_{G2}}{R_2} = \frac{V_{G2} - V_{G1}}{R_G} + \frac{V_{G2}}{R_2} \quad \text{--- ④}$$

$$\frac{V_p - V_{G1}}{R_2} = \frac{V_{G1} - V_{G2}}{R_G} + \frac{V_{G1} - V_0}{R_2} \quad \text{--- ⑤}$$

③ × - ④ × 에서

$$\frac{1}{R_2} (V_{G1} - V_{G2}) = 2 \frac{V_{G2} - V_{G1}}{R_G} + \frac{1}{R_2} (V_{G2} - V_{G1}) + V_0 \frac{1}{R_2}$$

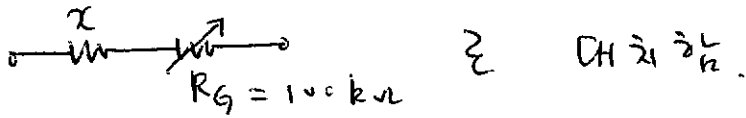
⑤ × = 대입하면

$$\frac{1}{R_2} \frac{R_2}{R_1} (V_2 - V_1) = 2 \frac{1}{R_G} \frac{R_2}{R_1} (V_1 - V_2) + \frac{1}{R_2} \frac{R_2}{R_1} (V_1 - V_2) + V_0 \frac{1}{R_2}$$

$$\therefore V_0 = 2 \frac{R_2}{R_1} \left(1 + \frac{R_2}{R_G} \right) (V_2 - V_1)$$

$$(b) A_{DM} = 2 \frac{R_2}{R_1} \left(1 + \frac{R_2}{R_G} \right)$$

$R_G = 0$ 이 되는 x 은 R_G 이 0 이 되는 x 이다. $R_G \approx 0$



$$R_2 = R_1 = 2 \frac{R_2}{R_1}$$

$$(i) R_G = 0 \text{ 일 때, } 2 \left(1 + \frac{R_2}{x} \right) = 100$$

$$\frac{R_2}{x} = 49$$

$$(ii) R_G = 100 \text{ k}\Omega \text{ 일 때, } 2 \left(1 + \frac{R_2}{x+100} \right) = 10$$

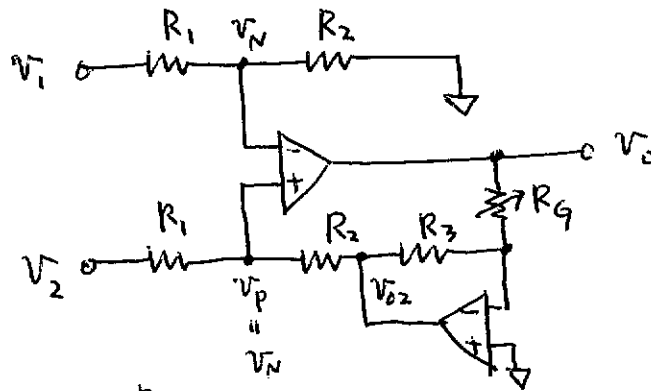
$$\frac{R_2}{x+100} = 4$$

$$\therefore x = \frac{400}{45} = 8.89 \text{ k}\Omega$$

$$R_2 = 49 \times 8.89 = 435.61 \text{ k}\Omega = R_1$$

2-28

(a)



$$v_N = v_P = \frac{R_2}{R_1 + R_2} v_1 \quad \text{--- ①}$$

$$\frac{v_2 - v_P}{R_1} = \frac{v_P - v_{02}}{R_2} \quad \text{--- ②}$$

$$\frac{v_0}{R_G} = \frac{-v_{02}}{R_3} \Rightarrow v_{02} = -\frac{R_3}{R_G} v_0 \quad \text{--- ③}$$

①과 ③을 ②에 대입하면,

$$\frac{1}{R_1} v_2 - \frac{R_2}{R_1} \frac{1}{R_1 + R_2} v_1 = \frac{1}{R_1 + R_2} v_1 + \frac{R_3}{R_2 R_4} v_o$$

$$\frac{R_3}{R_2 R_4} v_o = \frac{1}{R_1} v_2 - \frac{1}{R_1 + R_2} \left(1 + \frac{R_2}{R_1}\right) v_1$$

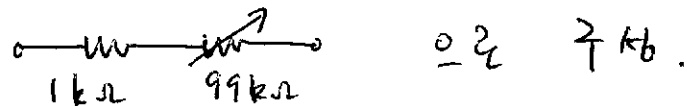
$$= \frac{1}{R_1} v_2 - \frac{1}{R_1} v_1$$

$$\therefore v_o = \frac{R_2 R_4}{R_1 R_3} (v_2 - v_1)$$

$$(b) A_{DM} = \frac{R_2 R_4}{R_1 R_3}, \quad 1 \leq A_{DM} \leq 100$$

$$R_2 = R_1 = 100 \text{ k}\Omega \text{ 으ㄴ 선택}$$

R_4 은 이 $\frac{R_3}{R_2}$ 이 0 이 되는 것 을 방지 하기 위하



$$R_3 = 1 \text{ k}\Omega \text{ 으ㄴ } \frac{1}{10}$$

2-29

$$(a) v_1 = 10 \cos 2\pi 60t - 5 \cos 2\pi 10^3 t \text{ mV}$$

$$v_2 = 10 \cos 2\pi 60t + 5 \cos 2\pi 10^3 t \text{ mV}$$

$$v_o = 100 \cos 2\pi 60t + 2000 \cos 2\pi 10^3 t \text{ mV}$$

$$v_{CM} = 10 \cos 2\pi 60t \text{ mV}, \quad v_{DM} = 10 \cos 2\pi 10^3 t \text{ mV}$$

$$v_o = A_{DM} v_{DM} + A_{CM} v_{CM}$$

$$A_{DM} = \frac{2000}{10} = 200, \quad A_{CM} = \frac{100}{10} = 10$$

$$CMRR = 20 \log \frac{200}{10} = 20 \log 20 = 26.02 \text{ dB}$$

$$(b) \quad v_1 = (10.01 \cos 2\pi 60t) \times 10^3 - 5 \cos 2\pi \times 10^3 t \quad \text{mV}$$

$$v_2 = (10.00 \cos 2\pi 60t) \times 10^3 + 5 \cos 2\pi \times 10^3 t \quad \text{mV}$$

$$v_o = 0.5 \cos 2\pi 60t + 2.5 \cos 2\pi \times 10^3 t \quad \text{V}$$

$$v_{CM} = \frac{1}{2} (v_1 + v_2) = (10.005 \cos 2\pi 60t) \times 10^3 \quad \text{mV}$$

$$v_{DM} = v_2 - v_1 = -10 \cos 2\pi 60t + 10 \cos 2\pi \times 10^3 t \quad \text{mV}$$

$$v_o = A_{DM} v_{DM} + A_{CM} v_{CM}$$

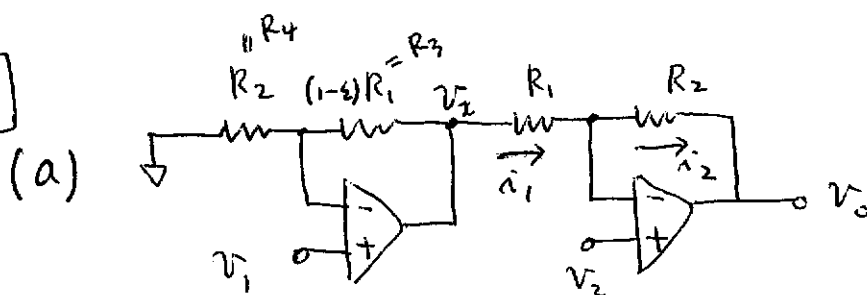
$$= -10 A_{DM} \cos 2\pi 60t + 10 A_{DM} \cos 2\pi \times 10^3 t + 10005 A_{CM} \cos 2\pi 60t \quad \text{mV}$$

$$\begin{cases} -10 A_{DM} + 10005 A_{CM} = 500 \\ 10 A_{DM} = 2500 \end{cases} \Rightarrow A_{DM} = 250$$

$$A_{CM} = 0.299$$

$$\text{CMRR} = 20 \log \frac{250}{0.299} \doteq 58.44 \text{ dB}$$

2-35



$$\frac{R_3}{R_4} = \frac{R_1}{R_2} (1-\epsilon) \quad \text{or} \quad R_4 = R_2, \quad R_3 = R_1 (1-\epsilon)$$

$$v_x = \left(1 + \frac{(1-\epsilon)R_1}{R_2} \right) v_1$$

$$i_1 = \frac{v_x - v_2}{R_1} = i_2 = \frac{v_2 - v_o}{R_2} \quad \text{or} \quad (1-\epsilon)$$

$$\begin{aligned}
 v_o &= v_2 - \frac{R_2}{R_1} (v_x - v_2) \\
 &= \left(1 + \frac{R_2}{R_1}\right) v_2 - \frac{R_2}{R_1} v_x \\
 &= \left(1 + \frac{R_2}{R_1}\right) v_2 - \frac{R_2}{R_1} \left[1 + \frac{R_1}{R_2} - \frac{R_1}{R_2} \varepsilon\right] v_1 \\
 &= \left(1 + \frac{R_2}{R_1}\right) (v_2 - v_1) + \varepsilon v_1
 \end{aligned}$$

$$v_{DM} = v_2 - v_1, \quad v_1 = v_{CM} - \frac{1}{2} v_{DM} \quad \text{이러지}$$

$$\begin{aligned}
 v_o &= \left(1 + \frac{R_2}{R_1}\right) v_{DM} + \varepsilon v_{CM} - \frac{\varepsilon}{2} v_{DM} \\
 &= \left(1 + \frac{R_2}{R_1} - \frac{\varepsilon}{2}\right) v_{DM} + \varepsilon v_{CM}
 \end{aligned}$$

$$\therefore A_{DM} = 1 + \frac{R_2}{R_1} - \frac{\varepsilon}{2}, \quad A_{CM} = \varepsilon$$

$$(b) \quad A = 1 + \frac{R_2}{R_1} = 100$$

$$p = 0.01 \quad \text{이러지} \quad \varepsilon = 4p = 0.04$$

$$A_{DM} = 100 - 0.02 = 99.98$$

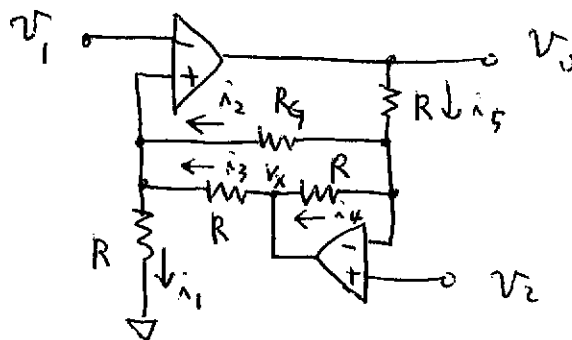
$$A_{CM} = 0.04$$

$$\therefore CMRR = 20 \log \frac{99.98}{0.04} \doteq 67.96 \text{ dB}$$

$\frac{2}{7}$, CMRR 이 67.96 dB 이 $\frac{u}{2}$ 아진다.

2-37

(a)



$$\dot{I}_1 = \dot{I}_2 + \dot{I}_3 \text{ 미시}$$

$$\frac{v_1}{R} = \frac{v_2 - v_1}{R_G} + \frac{v_x - v_1}{R} \quad \text{--- (1)}$$

$$\dot{I}_5 = \dot{I}_2 + \dot{I}_4 \text{ 미시}$$

$$\frac{v_0 - v_2}{R} = \frac{v_2 - v_1}{R_G} + \frac{v_2 - v_x}{R} \quad \text{--- (2)}$$

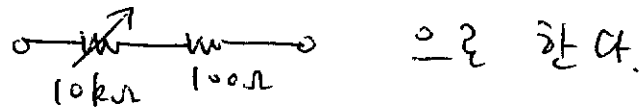
① + ② 미시

$$\frac{v_0 + v_1 - v_2}{R} = 2 \frac{v_2 - v_1}{R_G} + \frac{v_2 - v_1}{R}$$

$$\therefore v_0 = 2 \left(1 + \frac{R}{R_G} \right) (v_2 - v_1)$$

(b) $A_{DM} = 2 \left(1 + \frac{R}{R_G} \right) = 10 \sim 100$

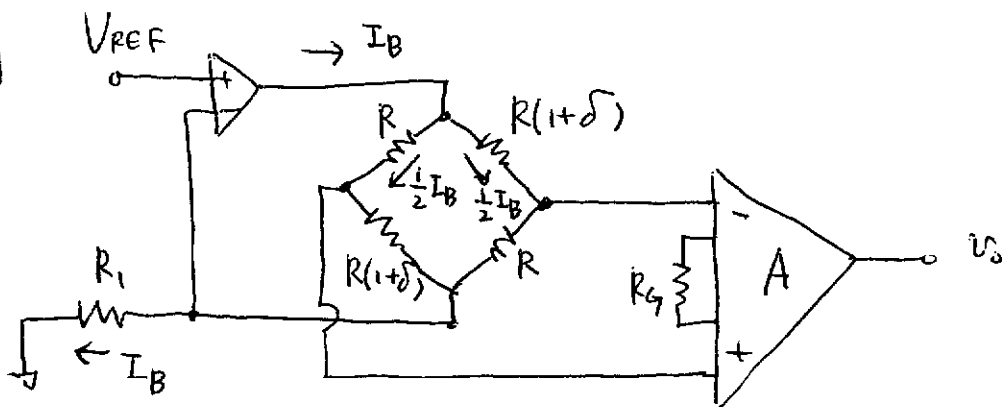
$R_G = 0$ 이 되는 것을 방지하기 위해 R_G 는



$R_G = 10 \text{ k}\Omega$ 일 때 이 $\frac{C}{T} = 1$ 이므로

$$1 + \frac{R}{10.1} = 5 \Rightarrow R = 40.4 \text{ k}\Omega$$

2-47



$$V_{REF} = 2.5 \text{ V}$$

$$\text{Sensitivity} = 0.1 \text{ V}/^{\circ}\text{C}$$

$$\text{Pt RTD : } \begin{cases} 0^{\circ}\text{C} \text{ 일 때 } R = 100 \Omega \\ \alpha = 0.00392 / ^{\circ}\text{C} \\ P_{RTD} < 0.2 \text{ mW} \end{cases}$$

$$P_{RTD} = \left(\frac{1}{2} I_B\right)^2 R = \frac{R}{4} I_B^2 = 0.2 \times 10^{-3} \text{ mW} \quad \text{미시}$$

$$R = 100 \Omega \text{ 이므로 } I_B = 2.83 \text{ mA}$$

안전하게 하기 위해 $I_B = 2.5 \text{ mA}$ 를 선택

$$\text{그러면, } I_B = \frac{V_{REF}}{R_1} = \frac{2.5}{R_1} = 2.5 \text{ mA} \quad \text{미시}$$

$$R_1 = 1 \text{ k}\Omega.$$

$$V_o = \frac{V_{REF}}{2 R_1} R \alpha A \quad \text{미시}$$

$$= \frac{2.5}{2 \times 10^3} \times 100 \times 0.00392 \times A \times \Delta T$$

$$\frac{V_o}{\Delta T} = \frac{2.5}{2} \times 0.000392 \times A = 0.1 \quad \text{미시}$$

$$A = 204.08$$

따라서, R_1 는 $1 \text{ k}\Omega$ 이고 I_B 는 2.5 mA 이 되도록
결정한다.