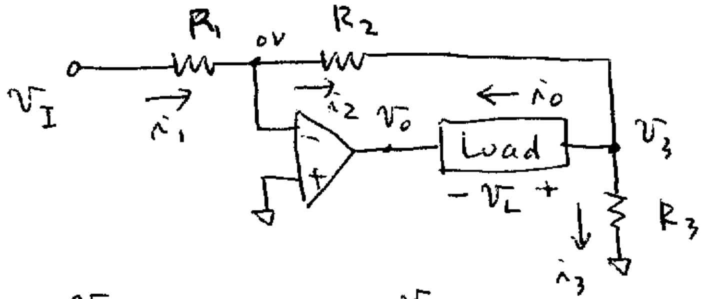
2 장 숙제 해답

2-5



(a) $i_1 = \dfrac{v_I}{R_1} = i_2 = -\dfrac{v_3}{R_2}$, $i_3 = \dfrac{v_3}{R_3}$

$i_2 = i_o + i_3$ 에서 $\dfrac{v_I}{R_1} = i_o - \dfrac{R_2}{R_1 R_3} v_I$

$i_o = \dfrac{v_I}{R_1}\left(\dfrac{R_2}{R_3} + 1\right) = \dfrac{v_I}{R_1/k}$, $k = 1 + \dfrac{R_2}{R_3}$

(b) $R_i = R_1 = 1\,M\Omega$

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

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

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

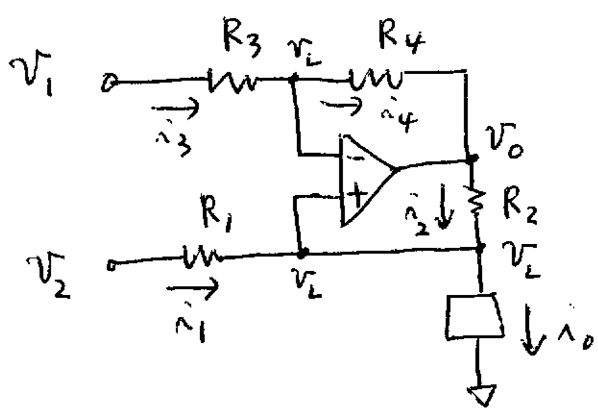
(c) $v_3 = -\dfrac{R_2}{R_1} v_I = v_o + v_L$

$\therefore v_L = -v_o - \dfrac{R_2}{R_1} v_I$

$\dfrac{R_2}{R_1} = 10^{-4}$ 이므로

$\left(-13 - 10^{-4} v_I\right) < v_L < \left(13 - 10^{-4} v_I\right)$

2-9



$$i_1 = \frac{v_2 - v_L}{R_1}, \quad i_2 = \frac{v_o - v_L}{R_2}, \quad i_o = i_1 + i_2$$

$$i_3 = \frac{v_1 - v_L}{R_3} = i_4 = \frac{v_L - v_o}{R_4} \text{ 에서}$$

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

$$i_o = i_1 + i_2 = \frac{v_2 - v_L}{R_1} + \frac{\frac{R_4}{R_3} v_L - \frac{R_4}{R_3} v_1}{R_2}$$

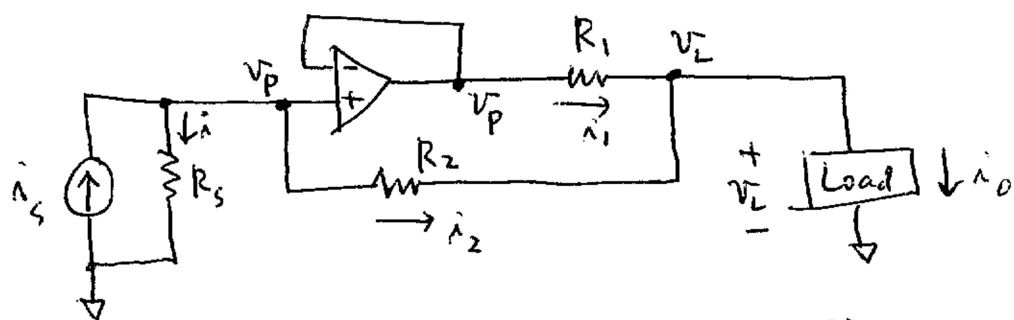
$$= \frac{v_2}{R_1} - \frac{R_4}{R_2 R_3} v_1 + \left(\frac{R_4}{R_2 R_3} - \frac{1}{R_1}\right) v_L$$

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

$$\frac{1}{R_o} = \frac{R_4}{R_2 R_3} - \frac{1}{R_1} = 0 \text{ 에서 } \frac{R_4}{R_3} = \frac{R_2}{R_1}$$

이때, $i_o = \frac{1}{R_1}(v_2 - v_1)$

2-21



$$i = \frac{v_p}{R_s}, \quad i_2 = \frac{v_p - v_L}{R_2}, \quad i_1 = \frac{v_p - v_L}{R_1}$$

$$i_s = i + i_2 = \frac{v_p}{R_s} + \frac{v_p - v_L}{R_2} \quad \text{—— ①}$$

$$i_o = i_1 + i_2 = \frac{v_p - v_L}{R_1} + \frac{v_p - v_L}{R_2} \quad \text{—— ②}$$

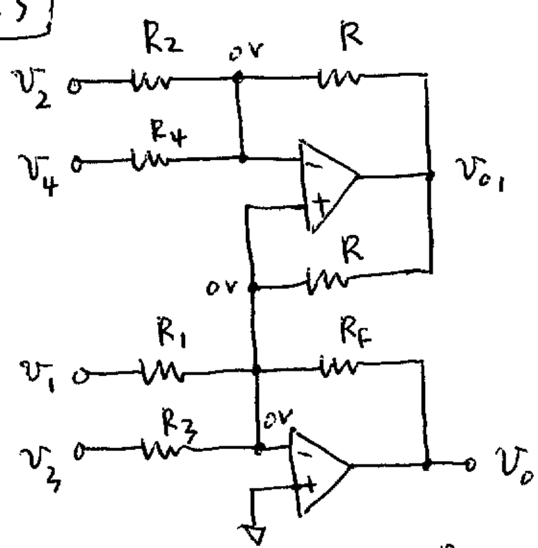
① 에서 $v_p = \frac{R_s R_2}{R_s + R_2} i_s + \frac{R_s}{R_s + R_2} v_L$

따라서 $v_p - v_L = \frac{R_s R_2}{R_s + R_2} i_s - \frac{R_2}{R_s + R_2} v_L$

② 에서
$$i_o = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)(v_p - v_L)$$
$$= \frac{R_1+R_2}{R_1 \cancel{R_2}} \frac{R_s \cancel{R_2}}{R_s+R_2} i_s - \frac{R_1+R_2}{R_1 \cancel{R_2}} \frac{\cancel{R_2}}{R_s+R_2} v_L$$
$$= \left(1 + \frac{R_2}{R_1}\right)\frac{R_s}{R_s+R_2} i_s - \frac{R_1+R_2}{R_1}\frac{1}{R_s+R_2} v_L$$
$$= \left(1 + \frac{R_2}{R_1}\right)\frac{R_2}{R_s+R_2} i_s - \frac{v_L}{R_o}$$

이때,
$$R_o = \frac{R_1}{R_1+R_2}(R_s+R_2)$$
$$A_I = \left(1 + \frac{R_2}{R_1}\right)\frac{R_2}{R_s+R_2}$$

2-25



$$-\left(\frac{v_2}{R_2} + \frac{v_4}{R_4}\right)R = v_{o1} \quad \text{—①}$$
$$-\left(\frac{v_{o1}}{R} + \frac{v_1}{R_1} + \frac{v_3}{R_3}\right)R_f = v_o \quad \text{—②}$$

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

만약 v_2 가 floating 되면, ② 식은 변함이 없고

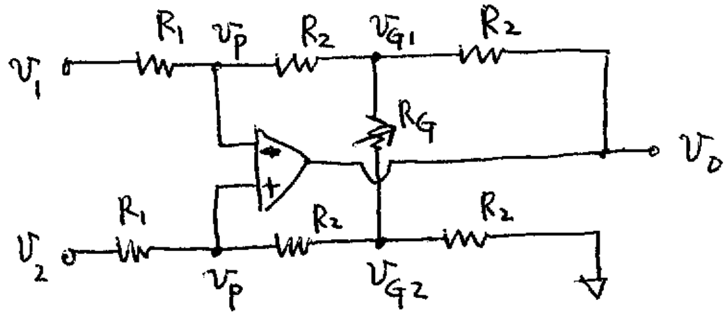
$$-\frac{v_4}{R_4}\cdot R = v_{o1} \Rightarrow v_o = -\frac{R_f}{R_1}v_1 - \frac{R_f}{R_3}v_3 + \frac{R_f}{R_4}v_4$$

만약 v_1 이 floating 되면, ① 식은 변함이 없고

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

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

2-27 (a)



$$\frac{v_2 - v_p}{R_1} = \frac{v_p - v_{G2}}{R_2} \Rightarrow v_2 - v_p = \frac{R_1}{R_2} v_p - \frac{R_1}{R_2} v_{G2} \quad \text{— ①}$$

$$\frac{v_1 - v_p}{R_1} = \frac{v_p - v_{G1}}{R_2} \Rightarrow v_1 - v_p = \frac{R_1}{R_2} v_p - \frac{R_1}{R_2} v_{G1} \quad \text{— ②}$$

① 식 − ② 식 에서 $v_2 - v_1 = \frac{R_1}{R_2}(v_{G1} - v_{G2})$ — ⑤

$$\frac{v_p - v_{G2}}{R_2} = \frac{v_{G2} - v_{G1}}{R_G} + \frac{v_{G2}}{R_2} \quad \text{— ③}$$

$$\frac{v_p - v_{G1}}{R_2} = \frac{v_{G1} - v_{G2}}{R_G} + \frac{v_{G1} - v_0}{R_2} \quad \text{— ④}$$

③ 식 − ④ 식 에서

$$\frac{1}{R_2}(v_{G1} - v_{G2}) = 2\frac{v_{G2} - v_{G1}}{R_G} + \frac{1}{R_2}(v_{G2} - v_{G1}) + v_0 \frac{1}{R_2}$$

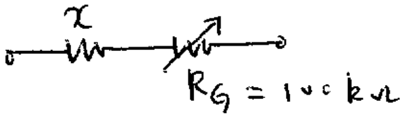
⑤ 식을 대입하면

$$\frac{1}{R_2}\frac{R_2}{R_1}(v_2 - v_1) = 2\frac{1}{R_G}\frac{R_2}{R_1}(v_1 - v_2) + \frac{1}{R_2}\frac{R_2}{R_1}(v_1 - v_2) + v_0 \cdot \frac{1}{R_2}$$

$$\therefore v_0 = 2\frac{R_2}{R_1}\left(1 + \frac{R_2}{R_G}\right)(v_2 - v_1)$$

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

$R_G = 0$ 이 되는 것을 방지하기 위해 R_G 를



로 대치함.

$R_2 = R_1$ 으로 함.

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

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

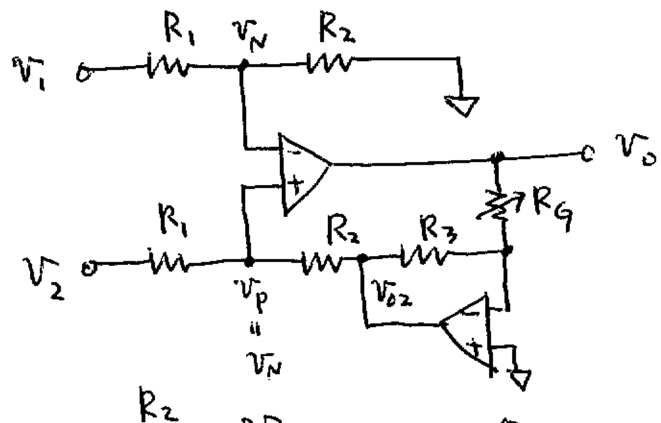
(ii) $R_G = 100\,k\Omega$ 일때, $2\left(1+\frac{R_2}{x+100}\right) = 10$

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

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

$$R_2 = 49 \times 8.89 = 435.61\ k\Omega = R_1$$

2-28 (a)



$$v_N = v_p = \frac{R_2}{R_1+R_2}v_1 \quad \text{—— ①}$$

$$\frac{v_2 - v_p}{R_1} = \frac{v_p - v_{o2}}{R_2} \quad \text{—— ②}$$

$$\frac{v_o}{R_G} = \frac{-v_{o2}}{R_3} \Rightarrow v_{o2} = -\frac{R_3}{R_G}v_o \quad \text{—— ③}$$

① 과 ③ 을 ② 에 대입하면,

$$\frac{1}{R_1}v_2 - \frac{R_2}{R_1}\frac{1}{R_1+R_2}v_1 = \frac{1}{R_1+R_2}v_1 + \frac{R_3}{R_2R_G}v_o$$

$$\frac{R_3}{R_2R_G}v_o = \frac{1}{R_1}v_2 - \frac{1}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right)v_1$$

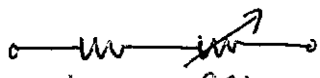
$$= \frac{1}{R_1}v_2 - \frac{1}{R_1}v_1$$

$$\therefore\ v_o = \frac{R_2R_G}{R_1R_3}(v_2 - v_1)$$

(b) $A_{DM} = \dfrac{R_2R_G}{R_1R_3}$, $1 \le A_{DM} \le 100$

$R_2 = R_1 = 100\,k\Omega$ 으로 선택

R_G는 이득이 0이 되는 것을 방지하기 위해



으로 구성.

$R_3 = 1\,k\Omega$ 으로 함.

2-29 (a) $v_1 = 10\cos 2\pi 60t - 5\cos 2\pi 10^3 t$ mV

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

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

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

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

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

$CMRR = 20\log\dfrac{200}{10} = 20\log 20 \simeq 26.02\,dB$

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

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

$v_o = 0.5 \cos 2\pi 60 t \quad + 2.5 \cos 2\pi 10^3 t$, V

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

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

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

$$= -10 A_{DM} \cos 2\pi 60 t + 10 A_{DM} \cos 2\pi 10^3 t$$

$$+ 10005 A_{CM} \cos 2\pi 60 t \quad \text{mV}$$

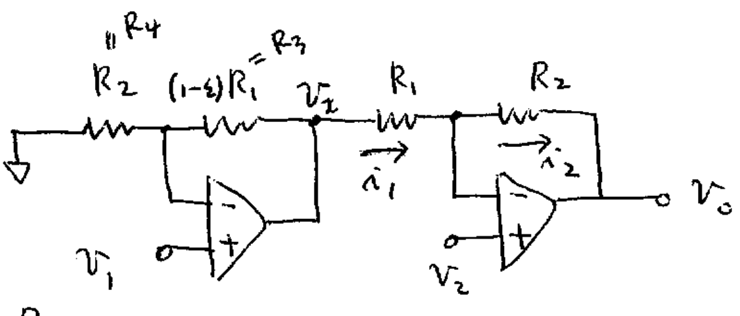
$$\begin{cases} -10 A_{DM} + 10005 A_{CM} = 500 \\ 10 A_{DM} = 2500 \end{cases} \Rightarrow A_{DM} = 250$$

$$A_{CM} = 0.299$$

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

2-35

(a)



$\frac{R_3}{R_4} = \frac{R_1}{R_2}(1-\varepsilon)$ 이므로 $\quad R_4 = R_2$, $R_3 = R_1(1-\varepsilon)$

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

$$i_1 = \frac{v_x - v_2}{R_1} = i_2 = \frac{v_2 - v_o}{R_2} \text{ 에서}$$

$$V_o = V_2 - \frac{R_2}{R_1}(V_x - V_2)$$
$$= \left(1+\frac{R_2}{R_1}\right)V_2 - \frac{R_2}{R_1}V_x$$
$$= \left(1+\frac{R_2}{R_1}\right)V_2 - \frac{R_2}{R_1}\left[1+\frac{R_1}{R_2}-\frac{R_1}{R_2}\varepsilon\right]V_1$$
$$= \left(1+\frac{R_2}{R_1}\right)(V_2 - V_1) + \varepsilon V_1$$

$V_{DM} = V_2 - V_1$, $V_1 = V_{CM} - \frac{1}{2}V_{DM}$ 이므로

$$V_o = \left(1+\frac{R_2}{R_1}\right)V_{DM} + \varepsilon V_{CM} - \frac{\varepsilon}{2}V_{DM}$$
$$= \left(1+\frac{R_2}{R_1}-\frac{\varepsilon}{2}\right)V_{DM} + \varepsilon V_{CM}$$

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

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

$p = 0.01$ 이므로 $\varepsilon = 4p = 0.04$

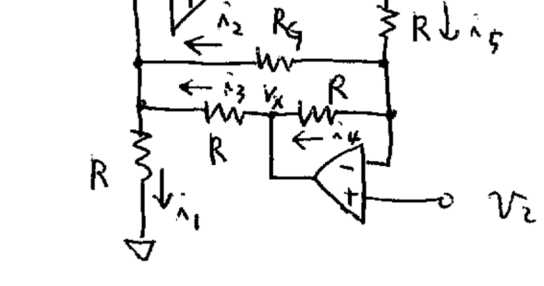
$A_{DM} = 100 - 0.02 = 99.98$

$A_{CM} = 0.04$

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

즉, CMRR이 67.96 dB로 낮아진다.

2-37 (a)



$i_1 = i_2 + i_3$ 에서

$$\frac{v_1}{R} = \frac{v_2 - v_1}{R_G} + \frac{v_x - v_1}{R} \quad —①$$

$i_5 = i_2 + i_4$ 에서

$$\frac{v_o - v_2}{R} = \frac{v_2 - v_1}{R_G} + \frac{v_2 - v_x}{R} \quad —②$$

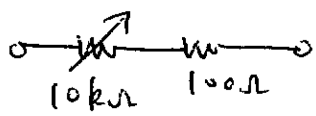
① + ② 에서

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

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

(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

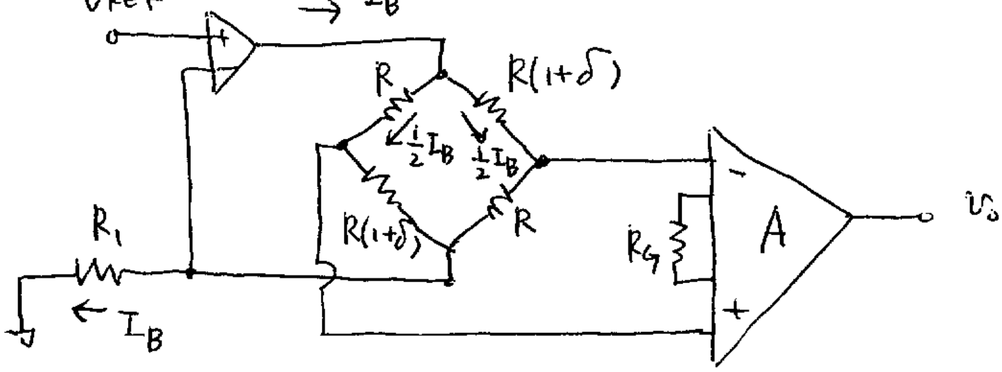


으로 한다.

$R_G = 10\ k\Omega$ 일 때 이득이 10 이므로

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

2-47



$V_{REF} = 2.5\ V$

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

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

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

$R = 100\ \Omega$ 이므로 $I_B = 2.83\ mA$

안전하게 하기 위해 $I_B = 2.5\ mA$ 로 선택

그러면, $I_B = \frac{V_{REF}}{R_1} = \frac{2.5}{R_1} = 2.5\ mA$ 에서

$R_1 = 1\ k\Omega$.

$v_o = \frac{V_{REF}}{2R_1} R \delta A$ 에서

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

$\frac{v_o}{\Delta T} = \frac{2.5}{2} \times 0.000392 \times A = 0.1$ 에서

$A = 204.08$

따라서, R_G 는 IA 의 이득이 204.08 이 되도록 결정한다.