HW2_solution

1.

$R_{id} = 2R_1 \Rightarrow 2R_1 = 10k\Omega \Rightarrow R_1 = 5k\Omega$

Assume $R_1 = R_3$, $R_2 = R_4$ Ideal

(a) $A_d = \frac{R_2}{R_1} = 1 \Rightarrow R_2 = 5k\Omega$

$\Rightarrow R_1 = R_2 = R_3 = R_4 = 5k\Omega$ #

(b) $A_d = 5 \Rightarrow R_2 = 25k\Omega$

$\Rightarrow R_1 = R_3 = 5k\Omega$, $R_2 = R_4 = 25k\Omega$ #

(c) $A_d = 10 \Rightarrow R_2 = 50\ k\Omega$

$\Rightarrow R_1 = R_3 = 5k\Omega$, $R_2 = R_4 = 50\ k\Omega$ #

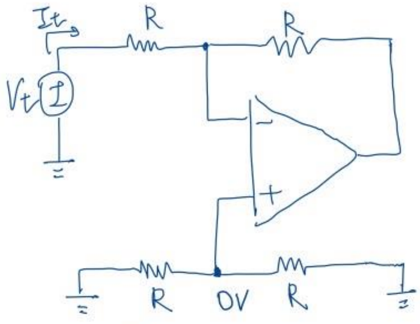
(d) $A_d = 25 \Rightarrow R_2 = 125\ k\Omega$

$\Rightarrow R_1 = R_3 = 5k$, $R_2 = R_4 = 125k\Omega$ #

$$A_{vo} = \frac{R_m}{R_i}$$

2.

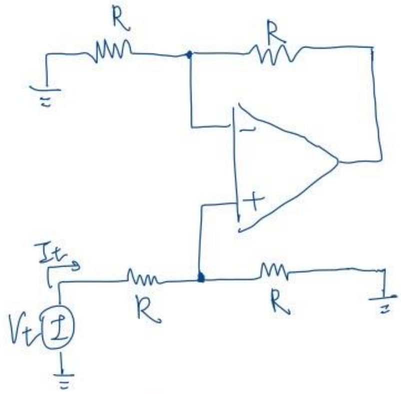
(a)



$$I_t = \frac{V_t}{R}$$

$$\Rightarrow R_{in} = \frac{V_t}{I_t} = R$$

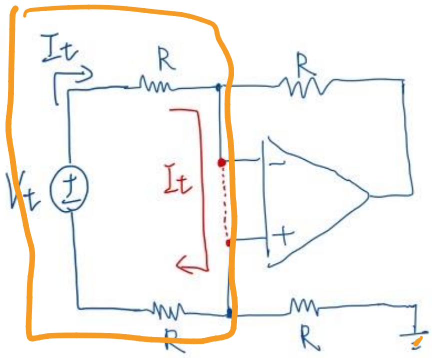
(b)



$$I_t = \frac{V_t}{2R}$$

$$\Rightarrow R_{in} = 2R \ \#$$

(c)

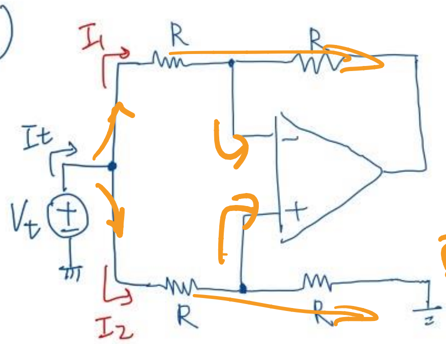


$$I_t = \frac{V_t}{2R}$$

$$\Rightarrow R_{in} = 2R \ \#$$

Differential Mode

(d)



ideal 放大器 輸入不会有电流

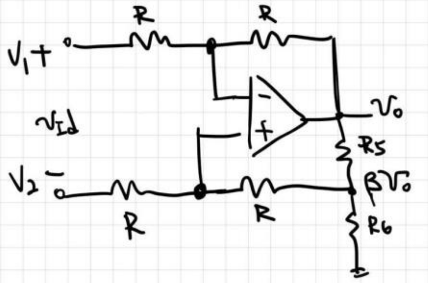
$$I_t = I_1 + I_2$$

$$= \frac{V_t}{2R} + \frac{V_t}{2R} = \frac{V_t}{R}$$

$$\Rightarrow R_{in} = R \ \#$$

Common Mode

(三)



Design $A_d = 10$ V/V

$R_{in} = 2M$

$R, R_5, R_6 = ?$ $(R_5 + R_6) \le \frac{R}{100}$

prove A_d

use superposition

$$V^+ = V^- = \beta V_{o1} \cdot \frac{R}{R+R} = \frac{\beta V_{o1}}{2} \Big|_{V_2=0}$$

$$\frac{V_1 - \frac{\beta V_{o1}}{2}}{R} = \frac{\frac{\beta V_{o1}}{2} - V_{o1}}{R} \Rightarrow V_1 = (\beta - 1) V_{o1}$$

$$\Rightarrow V_{o1} = \frac{V_1}{\beta - 1}$$

$$V^+ = V^- = \frac{V_{o2}}{2} \Big|_{V_1=0}$$

$$\frac{V_2 - \frac{V_{o2}}{2}}{R} = \frac{\frac{V_{o2}}{2} - \beta V_{o2}}{R} \Rightarrow V_2 = (1-\beta) V_{o2}$$

$$\Rightarrow V_{o2} = \frac{V_2}{1-\beta}$$

$$V_{o2} + V_{o1} = \frac{V_1}{\beta - 1} + \frac{V_2}{1-\beta} = \frac{V_2}{1-\beta} - \frac{V_1}{1-\beta}$$

$$A_d = \frac{V_o}{V_2 - V_1} = \frac{1}{1-\beta}$$ #

$R_{id} = 2R = 2M\Omega \rightarrow R = 1M\Omega$ #

$A_d = 10$ V/V $\Rightarrow \beta = \frac{R_6}{R_5 + R_6} = 0.9$

$$\begin{cases} \frac{R_6}{R_5 + R_6} = 0.9 \\ R_5 + R_6 \le R/100 = 10k\Omega \end{cases} \Rightarrow \begin{cases} R_6 = 9R_5 \\ R_5 + R_6 = 10k\Omega \end{cases}$$

$R_5 = 1k\Omega$, $R_6 = 9k\Omega$ #

4. $N_A = 5\times10^{18}$

$$n_i = 7.3\times10^{15}(300)^{3/2} e^{\frac{-1.12}{2\times8.62\times10^{-5}\times300}} \approx 1.5\times10^{10}/cm^3$$

$$N_A \cdot n_p = n^2 = 2.25\times10^{20}$$

$$n_p = \frac{2.25}{5}\times10^2 = 4.5\times10/cm^3$$

$$P_p = \frac{2.25\times10^{20}}{4.5\times10} = 5\times10^{18}/cm^3$$

5. $$n_i = BT^{3/2} e^{-E_B/2kT}$$

$$n^2 = B^2T^3 e^{-E_B/kT}$$

$$I_s \propto T^3 e^{-\frac{E_g}{kT}}$$

$$\Rightarrow \frac{n^2|_{T=305}}{n^2|_{T=300}} = \frac{305^3}{300^3} e^{-\frac{1.12}{8.6\times10^{-5}}\left(\frac{1}{305}-\frac{1}{300}\right)}$$

$$= 2.1$$

6.

$$I_s = Aqn_i^2\left(\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A}\right), \quad A = 100\,\mu m^2 = 100\times10^{-8}\,cm^2$$

$$I_s = 100\times10^{-8}\times1.6\times10^{-19}\times(1.5\times10^{10})^2\left(\frac{10}{5\times10^{-4}\times10^{16}} + \frac{18}{10\times10^{-4}\times10^{17}}\right)$$

$$= 7.85\times10^{-17}\,A$$

$$I = I_s e^{V/V_T}$$

$$= 7.85\times10^{-17}\times e^{750/26}$$

$$= 0.26\,mA \;\#$$

$$1\,\mu m^2 = 10^{-18}\,m^2$$

$$= 10^{-14}\,cm^2$$

$$\mu = 10^{-6} \quad n = 10^{-9}$$

$$Å = 10^{-10}$$