Electronics II Exam-2 2021/4/30 Solution

1.

(a) $\frac{R_4}{R_3} = \frac{R_6}{R_5}$

$V_O = \frac{R_4}{R_3}(V_{O2} - V_{O1})$

$V_{O1} = (1+\frac{R_2}{R_1})V_{I1} - \frac{R_2}{R_1}V_{I2}$

$V_{O2} = (1+\frac{R_2}{R_1})V_{I2} - \frac{R_2}{R_1}V_{I1}$

$\Rightarrow V_O = \frac{R_4}{R_3}(1+\frac{2R_2}{R_1})(V_{I2} - V_{I1})$

(b) $\frac{R_2}{R_1} = 2$, $\frac{R_4}{R_3} = 10$, $\frac{R_6}{R_5} = 11$

$V_O = (1+\frac{R_4}{R_3})\left(\frac{R_6/R_5}{1+R_6/R_5}\right) \cdot V_{O2} - \frac{R_4}{R_3}V_{O1}$

$= 11 \times \frac{11}{12} V_{O2} - 10V_{O1}$

$= 10.083\, V_{O2} - 10V_{O1}$

$\begin{cases} V_{O1} = 3V_{I1} - 2V_{I2} \\ V_{O2} = 3V_{I2} - 2V_{I1} \end{cases}$

$\Rightarrow V_O = 10.0833(3V_{I2} - 2V_{I1}) - 10(3V_{I1} - 2V_{I2})$

$= 50.25\, V_{I2} - 50.167\, V_{I1}$

$= A_{cm} \cdot \frac{V_{I1}+V_{I2}}{2} + A_d \cdot (V_{I2} - V_{I1})$

$= (A_d + \frac{A_{cm}}{2})V_{I2} - (A_d - \frac{A_{cm}}{2})V_{I1}$

$\Rightarrow \begin{cases} A_d + \frac{A_{cm}}{2} = 50.25 \\ A_d - \frac{A_{cm}}{2} = 50.167 \end{cases} \Rightarrow \quad A_d = 50.2085, \quad A_{cm} = 0.083$

$CMRR(dB) = 20\log_{10}\left(\frac{50.2085}{0.083}\right) = 20\log_{10}(604.92)$

$= 55.634\ (dB)$

2

$$R_1 = \frac{V_O - V_Z}{I_Z} = \frac{12-5.6}{2} = 3.2\,\text{k}\,\Omega$$

$$\frac{V_O}{V_Z} = \left(1+\frac{R_2}{R_3}\right) = \frac{12}{5.6} \Rightarrow \frac{R_2}{R_3} = 1.143$$

Let $I_R = 2$ mA, $\Rightarrow R_2 + R_3 = \frac{V_O}{I_R} = \frac{12}{2} = 6\,\text{k}\,\Omega$

Then $1.143R_3 + R_3 = 6$, $\Rightarrow R_3 = 2.8\,\text{k}\,\Omega$ and $R_2 = 3.2\,\text{k}\,\Omega$

$$R_L = 6k\Omega, I_{R_L} = 12/6 = 2mA$$

$$\text{Then } I_{R4} = 6mA, R_4 = \frac{15-12}{6} = 0.5k\Omega$$

3

(a) $A_\upsilon = \frac{-R_2}{Z_1}$, where $Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1+j\omega R_1 C_1}{j\omega C_1}$

$$A_\upsilon = \frac{-j\omega R_2 C_1}{1+j\omega R_1 C_1} = \frac{-R_2}{R_1}\cdot\frac{j\omega R_1 C_1}{1+j\omega R_1 C_1}$$

(b) As $\omega \Rightarrow \infty$, $A_\upsilon = \frac{-R_2}{R_1}$

(c) $\left|A_\upsilon\right| = \frac{R_2}{R_1}\cdot\frac{\omega R_1 C_1}{\sqrt{1+(\omega R_1 C_1)^2}}$

Set $\frac{\omega R_1 C_1}{\sqrt{1+(\omega R_1 C_1)^2}} = \frac{1}{\sqrt{2}} \Rightarrow \omega = \frac{1}{R_1 C_1} \Rightarrow f = \frac{1}{2\pi R_1 C_1}$

4.

(a)

For $v_O = 5$ V, $\quad i_L = 5/20 = 0.25$ A

Then, for $I_Q = 0.05$ A when $v_O = 0$, we have

$$I_{DQ} = 0.05 = K\left(\frac{V_{BB}}{2} - |V_T|\right)^2 = (0.20)\left(\frac{V_{BB}}{2} - 1\right)^2$$

which yields

$$V_{BB}/2 = 1.50\text{ V}$$

$$V_{BB} = 3\text{V}$$

(b)

The input voltage for v_O positive is

$$v_I = v_O + v_{GSn} - \frac{V_{BB}}{2}$$

For $v_O = 5$V and $i_{Dn} \cong i_L = 0.25$ A, we have

$$v_{GSn} = \sqrt{\frac{i_{Dn}}{K}} + |V_T| = \sqrt{\frac{0.25}{0.20}} + 1 = 2.12\text{ V}$$

The source-to-gate voltage of M_p is

$$v_{SGp} = V_{BB} - V_{GSn} = 3 - 2.12 = 0.88\text{ V}$$

(c)

$$v_I = 5 + 2.12 - 1.5 = 5.62\text{ V}$$