

1<sup>a</sup> for  $V_o = 5V$ ,  $i_L = \frac{5}{10} = 0.5 A$ .

$I_{cq} = 0.2 \times 0.5 = 0.1 A$ . ( $V_o = 0$ )

$0.1 = k \left( \frac{V_{BB}}{2} - 1 \right)^2 = 0.25 \left( \frac{V_{BB}}{2} - 1 \right)^2$

$\frac{V_{BB}}{2} = 1.63V$ .

2<sup>a</sup> As  $V_o = 5V$ ,  $i_{DN} = 0.5 A$ . (NMOS ON)

$0.5 = 0.25 (V_{gsn} - 1)^2$

$V_{gsn} = 1 + \sqrt{2} = 2.414 V$ .

( $V_{gsP} = 3.26 - 2.414 = 0.846 V$ .

PMOS is off)

$\Rightarrow V_i = -\frac{V_{BB}}{2} + V_{gsn} + V_o$

$= -1.63 + 2.414 + 5 = 5.784(V)$  \*

2.

$$v_0 = \left(\frac{333}{20}\right)(v_{01} - v_{02}) = 16.65(v_{01} - v_{02})$$

$$v_{01} = -v_{BE1} = -V_T \ln\left(\frac{i_{C1}}{I_S}\right)$$

$$v_{02} = -v_{BE2} = -V_T \ln\left(\frac{i_{C2}}{I_S}\right)$$

$$v_{01} - v_{02} = -V_T \ln\left(\frac{i_{C1}}{i_{C2}}\right) = V_T \ln\left(\frac{i_{C2}}{i_{C1}}\right)$$

$$i_{C2} = \frac{v_2}{R_2}, \quad i_{C1} = \frac{v_1}{R_1}$$

$$\text{So } v_{01} - v_{02} = V_T \ln\left(\frac{v_2}{R_2} \cdot \frac{R_1}{v_1}\right)$$

Then

$$v_0 = (16.65)(0.026) \ln\left(\frac{v_2}{v_1} \cdot \frac{R_1}{R_2}\right)$$

$$v_0 = 0.4329 \ln\left(\frac{v_2}{v_1} \cdot \frac{R_1}{R_2}\right)$$

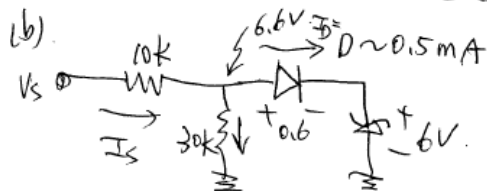
3.

(a).  $v_Z = 6V$ .

$$\frac{v_0}{v_Z} = \frac{10}{6} = 1 + \frac{R_2}{R_1}$$

$$\frac{R_2}{R_1} = 0.667 \quad *$$

$$1 \text{ mA} = \frac{10 - 6}{R_F} \Rightarrow R_F = 4 \text{ k}\Omega \quad *$$



① when  $I_D = 0$

$$I_S = \frac{6.6}{30K} = 0.22 \text{ mA (min)} \quad *$$

② when  $I_D = 0.5 \text{ mA}$

$$I_S = \frac{6.6}{30K} + 0.5 = 0.72 \text{ mA (max)} \quad *$$

4.

See Textbook p.556

$$V_0(V_{I1}) = -\frac{R_F}{R_1} V_{I1}$$

$$V_0(V_{I2}) = -\frac{R_F}{R_2} V_{I2}$$

$$V_0(V_{I3}) = \left(1 + \frac{R_F}{R_1 \parallel R_2}\right) \left(\frac{R_B \parallel R_C}{R_A + R_B \parallel R_C}\right) V_{I3}$$

$$V_0(V_{I4}) = \left(1 + \frac{R_F}{R_1 \parallel R_2}\right) \left(\frac{R_A \parallel R_C}{R_B + R_A \parallel R_C}\right) V_{I4}$$

$$V_0 = V_0(V_{I1}) + V_0(V_{I2}) + V_0(V_{I3}) + V_0(V_{I4})$$

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$$\text{or } V_0(V_{I3}) = \left(1 + \frac{R_F}{R_1 \parallel R_2}\right) \left(\frac{R_B \parallel R_C \parallel R_A}{R_A}\right) V_{I3}$$

$$V_0(V_{I4}) = \left(1 + \frac{R_F}{R_1 \parallel R_2}\right) \left(\frac{R_A \parallel R_C \parallel R_B}{R_B}\right) V_{I4}$$

5.

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

$$V_o = \frac{R_4}{R_3} (V_{o2} - V_{o1}) \quad \text{by (9.52)}$$

$$\begin{cases} V_{o1} = (1 + \frac{R_2}{R_1}) V_{i1} - \frac{R_2}{R_1} V_{i2} \\ V_{o2} = (1 + \frac{R_2}{R_1}) V_{i2} - \frac{R_2}{R_1} V_{i1} \end{cases} \quad \text{by (9.65)}$$

$$V_o = \frac{R_4}{R_3} (1 + \frac{2R_2}{R_1}) (V_{i2} - V_{i1}) \quad \text{XX}$$

$$(b) \cdot \frac{R_2}{R_1} = 1, \frac{R_4}{R_3} = 10, \frac{R_6}{R_5} = 12$$

$$\begin{aligned} V_o &= (1 + \frac{R_4}{R_3}) \left( \frac{R_4/R_5}{1 + R_6/R_5} \right) V_{o2} - \frac{R_4}{R_3} V_{o1} \\ &= 11 \times \frac{12}{1+12} V_{o2} - 10 V_{o1} \\ &= 10.1538 V_{o2} - 10 V_{o1} \end{aligned}$$

$$\begin{cases} V_{o1} = 2V_{i1} - V_{i2} \\ V_{o2} = 2V_{i2} - V_{i1} \end{cases}$$

$$\begin{aligned} V_o &= 10.1538 (2V_{i2} - V_{i1}) - 10 (2V_{i1} - V_{i2}) \\ &= 30.308 V_{i2} - 30.1538 V_{i1} \\ &= A_{cm} \left( \frac{V_{i1} + V_{i2}}{2} \right) + A_d \cdot (V_{i2} - V_{i1}) \\ &= A_{cm} V_{cm} + A_d \cdot V_{d} \end{aligned}$$

$$A_{cm} = 30.308 - 30.1538 = 0.1542$$

$$A_d = \frac{1}{2} (30.308 + 30.1538) = 30.2309$$

$$CMRR (dB) = 20 \log_{10} \left( \frac{30.2309}{0.1542} \right) = 45.8423 \text{ dB}$$