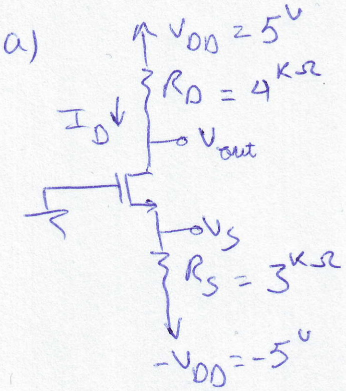
Question 1)

a)



$V_G = 0$

$V_S = -V_{DD} + R_S I_D = -5 + 3I_D$

$V_D = V_{DD} - R_D I_D = 5 - 4I_D$

$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$

$= \frac{1}{2} \times 0.1^m \times 20 \times (0 - (-5 + 3I_D) - 1)^2$

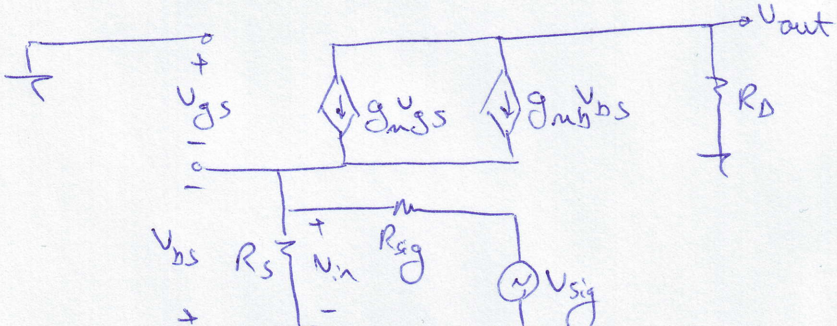
$\Rightarrow I_D = (4 - 3I_D)^2 \Rightarrow 9I_D^2 - 25I_D + 16 = 0$

$\Rightarrow I_D = 1^{mA}$ ✓ $V_S = -2^V, V_D = 1^V$

$\Rightarrow I_D = 1.8^{mA}$ $V_S = 0.4^V \Rightarrow V_{GS} = -0.4 < V_t$ not acceptable

b) input is at Source, output is at Drain $\Rightarrow$ CG amplifier

c)



d) $g_m = \frac{2I_D}{V_{GS} - V_t} = \frac{2 \times 1^{mA}}{0 - (-2) - 1} = 2^{mA/V}$

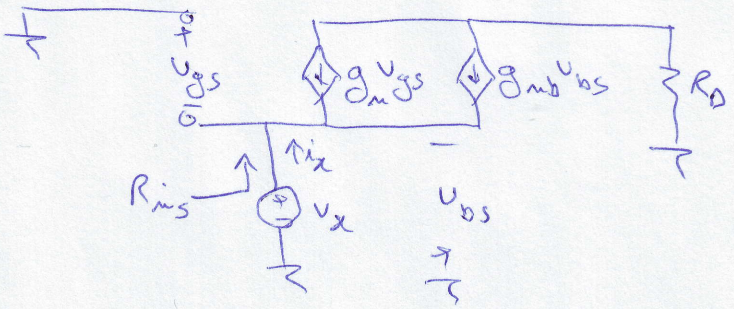
$g_{mb} = \chi g_m = 0.2 \times 2 = 0.4^{mA/V}$

e) $V_{in} = -V_{gs} = -V_{bs}$

$V_{out} = -(g_m V_{gs} + g_{mb} V_{bs}) R_D = (g_m + g_{mb}) R_D V_{in}$

$$\Rightarrow \frac{v_{out}}{v_i} = (g_m + g_{mb}) R_D = (2^m + 0.4^m) \times 4^k = 9.6 \text{ V/V}$$

f)



$$v_{gs} = v_{bs} = -v_x$$

$$i_x = -g_m v_{gs} - g_{mb} v_{bs} = (g_m + g_{mb}) v_x \Rightarrow R_{is} = \frac{1}{g_m + g_{mb}}$$

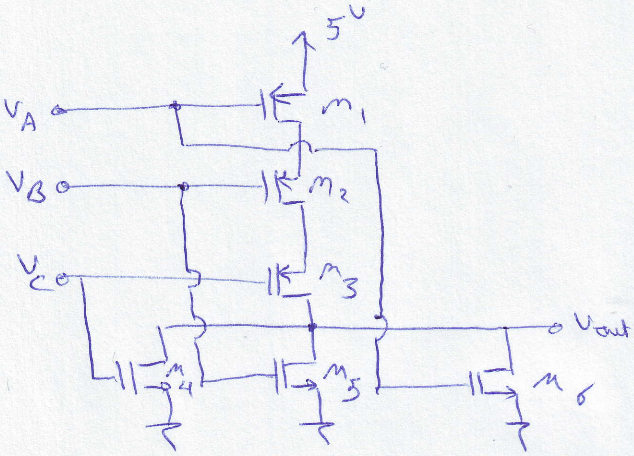
$$R_i = R_S \| R_{is} = R_S \| \frac{1}{g_m + g_{mb}} = 3^k \| \frac{1}{2.4^m} = 366\,\Omega$$

g) $$v_i = \frac{R_i}{R_i + R_{sig}} v_{sig} = \frac{366}{366 + 50} v_{sig}$$

$$\frac{v_i}{v_{sig}} = 0.88 \text{ V/V}$$

$$\Rightarrow \frac{v_{out}}{v_{sig}} = \frac{v_{out}}{v_i} \times \frac{v_i}{v_{sig}} = 9.6 \times 0.88 = 8.45 \text{ V/V}$$

Question 2)

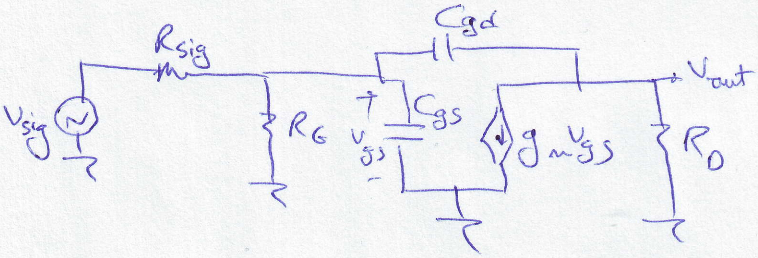


a) $V_A = 0$, $V_B = 0$, $V_C = 0$ $\Rightarrow$ m_1, m_2, m_3 are "on"; m_4, m_5, m_6 are "off" $\Rightarrow$ $V_{out} = 5^v$

b) $V_A = 0$, $V_B = 5^v$, $V_C = 0$ $\Rightarrow$ m_2 is "off"; m_5 is "on" $\Rightarrow$ $V_{out} = 0^v$

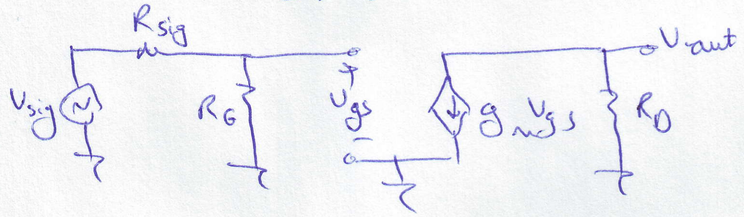
Question 3)

a) at high frequencies C_c and C_s are short circuits.



b) A_M : $C_{gs}, C_{gd} \longrightarrow$ o.c.

$C_c, C_s \longrightarrow$ s.c.



$$\left.\begin{array}{l} V_{gs} = \dfrac{R_G}{R_G + R_{sig}} V_{sig} \\ V_{out} = -g_m V_{gs} R_D \end{array}\right\} \Rightarrow \frac{V_{out}}{V_{sig}} = -\frac{R_G}{R_G + R_{sig}} g_m R_D$$

c) $$\left.\begin{array}{l} f_{C_S} = \dfrac{1}{2\pi C_S R_{C_S}} \\ R_{C_S} = \dfrac{1}{g_m} \end{array}\right\} \Rightarrow f_{C_S} = \frac{1}{2\pi C_S \frac{1}{g_m}}$$

d) $$\left.\begin{array}{l} f_{C_C} = \dfrac{1}{2\pi C_C R_{C_C}} \\ R_{C_C} = R_{sig} + R_G \end{array}\right\} \Rightarrow f_{C_C} = \frac{1}{2\pi C_C (R_{sig} + R_G)}$$

e) $$f_H \simeq \frac{1}{2\pi C_{in} R_{in}}$$

$$C_{in} = C_{gs} \,||\, [C_{gd}(1 + g_m R_D)] = C_{gs} + C_{gd}(1 + g_m R_D)$$

$$R_{in} = R_{sig} \,||\, R_G$$

Question 4)

For an npn BJT in active mode BE junction is in forward bias and BC junction is in reverse bias. Since BE junction is in forward bias, a large number of electrons (majority carriers) from the Emitter region enter the Base region. Since the BC junction is reverse-biased most of these electrons (minority carriers in the P-type Base) are swept into the Collector region Considering that the Base region is very thin. Therefore, a large current flows between the Collector and Emitter region. This current is controlled by a small voltage V_{BE}.