Fayoum University- Faculty of Engineering- Communications & Electronics Department
Electronics 2nd year

FINAL EXAM
January 22th 2009
TIME ALLOWED: 3 Hours
Dr. Rania Ahmed Abul Seoud

Total Marks: - 70

Question 1: (20 marks)

(a) Draw the low frequency and mid-band small signal model for the shown amplifier in Fig.1 if $R_S = 100\Omega, R_4 = 1.3K\Omega, R_D = 4.3K\Omega$, $R_3 = 100K\Omega$, $C_1 = 4.7\mu F$, $C_2 = 1\mu F$ and $g_m = 5mA/V$.(7 marks)

(b) Drive the expression of the mid-band gain and the low frequency gain of the amplifier .Assume $r_{ds} = \infty$.(7 marks)

(c) What are the lower-cut off frequency (using short-circuit time constant method)? (6 marks)

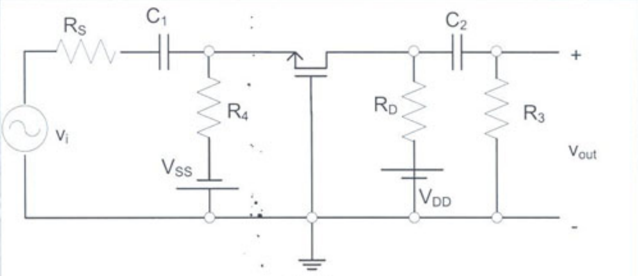
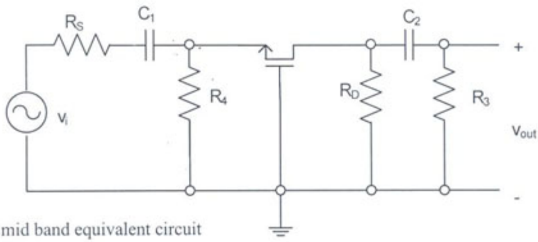


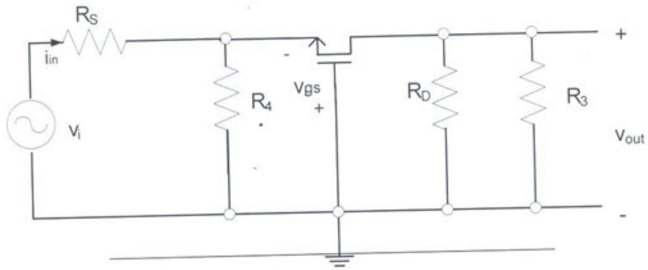
Fig.2

Solution:

(a) The low frequency equivalent circuit



The mid band equivalent circuit



(b) The mid band frequency gain

$$v_{out} = -g_m v_{gs}(R_3//R_D)$$

$$v_{gs} = v_g - v_s = 0 - v_s = -v_s$$

$$v_s = v_{in} - i_{in}R_S$$

$$i_{in} = -g_m v_{gs} - \frac{v_{gs}}{R_4} = -v_{gs}\left(g_m + \frac{1}{R_4}\right)$$

$$\therefore v_{gs} = -(v_{in} - i_{in}R_S) = -v_{in} - v_{gs}R_S\left(g_m + \frac{1}{R_4}\right)$$

$$v_{gs} = \frac{-v_{in}}{1 + R_S\left(g_m + \frac{1}{R_4}\right)}$$

$$\therefore A_{MF} = \frac{v_{out}}{v_{in}} = \frac{+g_m(R_3//R_D)}{1 + R_S\left(g_m + \frac{1}{R_4}\right)} = 13.06$$

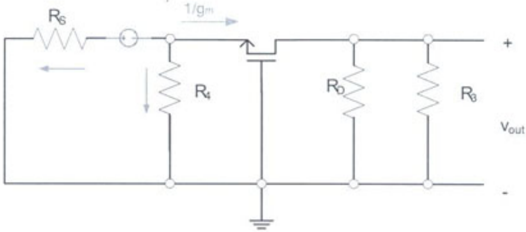
(c) The voltage gain of the amplifier

$$A_{LF} = \frac{A_{MF} \times S^2}{(S + w_{LC1})(S + w_{LC2})}$$

We have two zeros at $S = 0$; $(w = 0)$

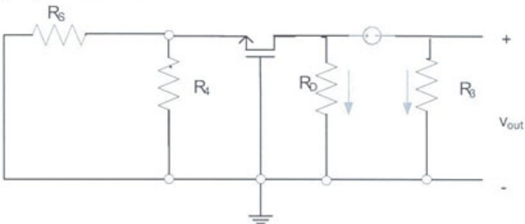
The poles are generated due to the presence of the external capacitors; to get the poles locations we will use the short circuit time constant method;

The pole generated from C1



$$w_{LC1} = \frac{1}{C_1 R} = \frac{1}{C_1\left(R_S + \left(R_4 // \frac{1}{g_m}\right)\right)}$$

(d) The pole generated from C2



$$w_{LC2} = \frac{1}{C_2 R} = \frac{1}{C_2(R_D + R_3)}$$

$$f_{LC1} = \frac{1}{2\pi C_1\left(R_S + \left(R_4 // \frac{1}{g_m}\right)\right)} = 123.8\ Hz$$

$$f_{LC2} = \frac{1}{2\pi C_2(R_D + R_3)} = 1.526\ Hz$$

The overall lower cut-off frequency

$$f_L = \sqrt{f_{LC1}^2 + f_{LC2}^2} = 123.81\ Hz$$

Question 2: (15 marks)

Consider the cascode circuit in Fig.2 with the following components, $R_s = 4\ K\Omega$, $R_1 = 18\ K\Omega$, $R_2 = 4\ K\Omega$, $R_E = 3.3\ K\Omega$, $R_C = 6\ K\Omega$, $V_{CC} = 15\ V$, $r_\pi = 1000\Omega$. Assume that Q_1 and Q_2 are of the same type so $I_E = 1mA$, $\beta = 100$, $C_{be} = 1\ pF$, $C_{bc} = 13.9\ pF$, and neglect r_o. Calculate the mid band gain $A_{mid\text{-}band}$, the high frequency gain A_H and by using open-circuit time constant method calculate f_H.

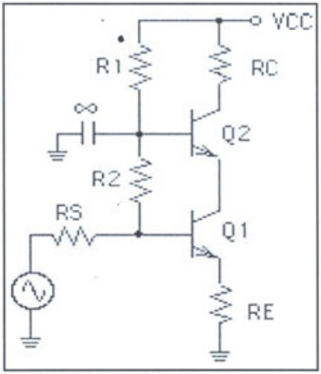
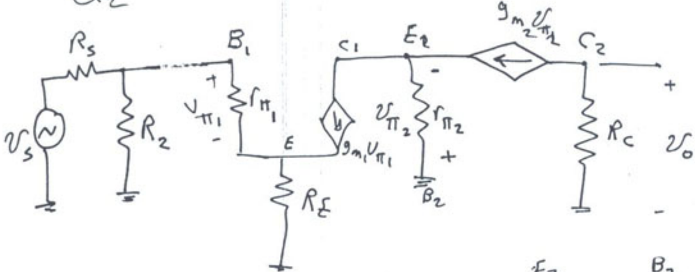
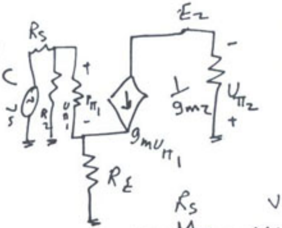


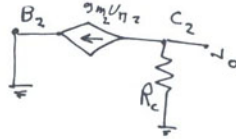
Fig.2

Solution:

Q2



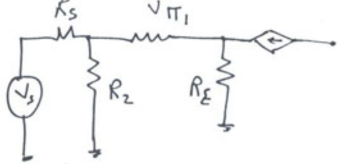




$* \; v_o = -g_{m_1} v_{\pi_2} R_C$

$* \; v_{\pi_2} = g_{m_1} v_{\pi_1} \frac{1}{g_{m2}}$

$* \; v_{\pi_1} = i_{b_1} r_{\pi_1}$



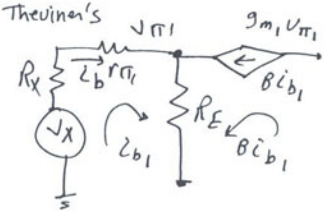
mesh eq.

$$v_X = i_{b_1}(R_X + r_{\pi_1} + R_E) + R_E B i_{b_1}$$

$$v_X = i_{b_1}\left[R_X + r_{\pi_1} + R_E(B+1)\right]$$

$$v_{\pi_1} = \frac{v_X r_{\pi 1}}{R_X + r_{\pi_1} + R_E(B+1)}$$

Thevenin's

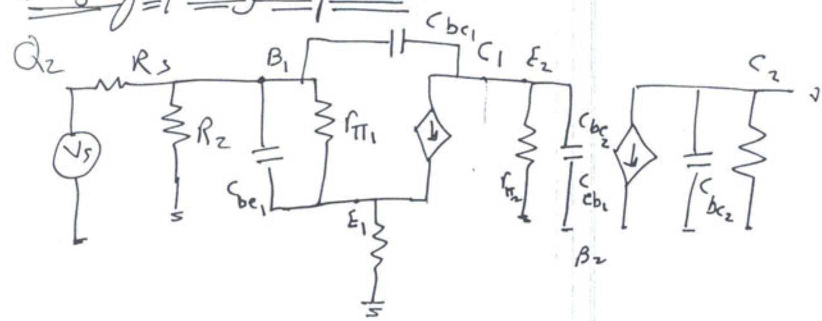


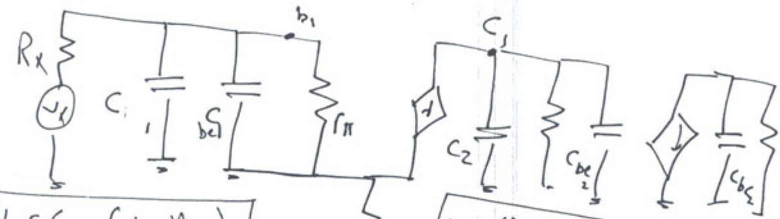
$$v_{\pi_1} = v_S \frac{(r_{\pi_1} // (B+1)R_E)}{(r_{\pi_1} // (B+1) R_E) + (R_2 // R_S)}$$

$$A_v = \frac{V_{out}}{V_s} = \frac{V_{out}}{v_{\pi 2}} * \frac{v_{\pi 2}}{v_1} * \frac{v_{\pi 1}}{v_s} =$$

$$A_v = -g_m R_C \frac{[r_{\pi_1} // (B+1)R_E]}{[(r_{\pi 1} // (B+1) R_E] + (R_2 // R_S)]}$$

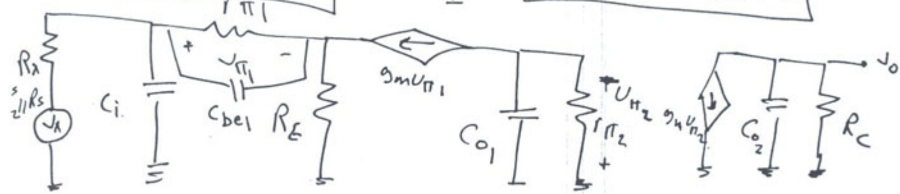
* high frequency Responce :o





$C_1 = C_{bc1}(1 - A)$
$C_2 = C_{bc_1}(1 - A^{-1})$

$A = \frac{v_{c1}}{v_{b1}} = -\frac{\alpha r_{e2}}{r_{e2} + R_o}$



C_i

$C_{o1} = C_2 + C_{be_2}$

$A_H =$

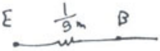
$$f_H = \frac{1}{\sqrt{\left(\frac{1}{f_{H C_i}}\right)^2 + \left(\frac{1}{f_{H C_{o1}}}\right)^2 + \left(\frac{1}{f_{H C_o}}\right)^2}}$$

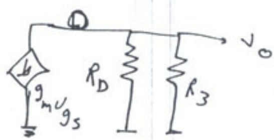
$v_o = -g_m v_{\pi_2} \left(R_C \| \frac{1}{sC_o}\right)$

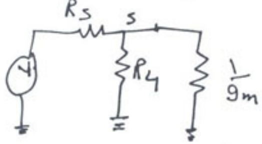
$v_{\pi_2} = g_m v_{\pi_1} Z$

$Z = r_{\pi_2} \| \frac{1}{sC_{o1}}$

Q_2







$$A_{Mid\text{-}band} = \frac{\beta^2 \left[R_2 // \left[(\beta+1)(r_e+R_E)\right]\right] * R_C}{(\beta+1)^2 (R_E+r_e)\left[R_S + R_2 // \left[(\beta+1)(r_e+R_E)\right]\right]}$$

$$= \frac{g_m^2 r_{e_2} r_{e_1} \left[R_2 // (\beta+1)(r_e+R_E)\right]}{(R_E+r_{e_1})\left[R_s + R_2 \left[\text{[illegible]}// (\beta+1)(R_E+r_e)\right]\right]}$$

$$A_H(s) = A_{Mid\text{-}band} \frac{}{(1+sC_{bc}R_c)(1+sC_{c_1}(R_s//R_2))(1+sC_{\delta}(r_e))(1+s}$$

$$\left[C_{be}\left(\frac{(R_s//R_2)}{(\beta+1)} + R_E\right)//r_e\right]$$

Question 3: (20 marks)

a) For the feedback amplifier shown in the figure Fig.3, drive expressions for A, β, A_f, R_{inf}, R_{of}. Neglect r_{ds} and the body effect, $g_{m1} = g_{m2} = 5mA/V$, $R_D = 10\ K\Omega$, $R_s = 10\ K\Omega$ and $R_f = 10\ K\Omega$. (2 marks per one)

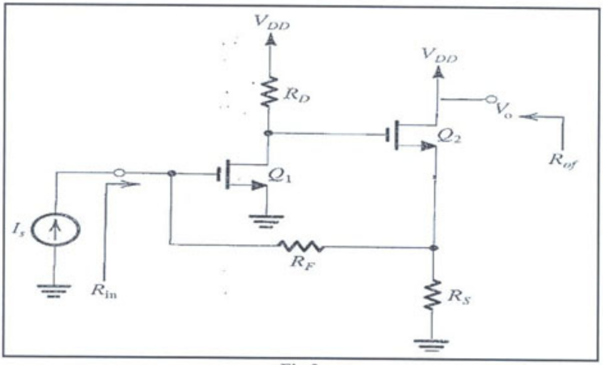
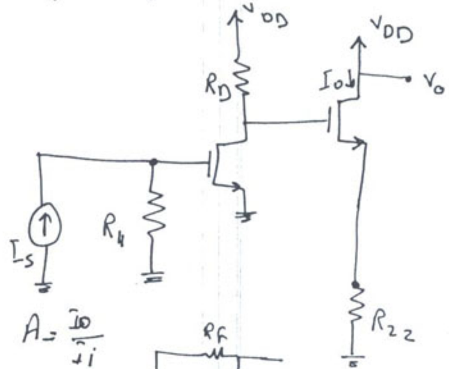


Fig.3

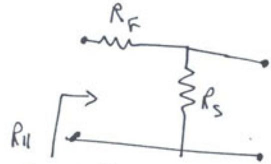
Solution:

Q3

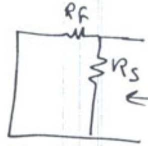
a] shunt-series → (1 mark)



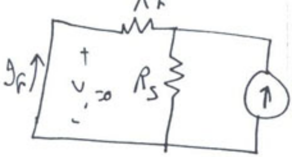
$A = \frac{I_o}{i_i}$



$R_{11} = R_F + R_S$



$R_{22} = R_F // R_S$



$I = \beta_s \frac{I_F}{I_o}$

$$\beta = \frac{-R_S}{R_F + R_S}$$

$$R_{oF} = (1 + A\beta) R_o$$

$$R_{iF} = \frac{R_i}{(1 + A\beta)}$$

$$A_f = \frac{A_F}{1 + A\beta}$$

$$A = \frac{I_o}{g_s} = \frac{-g_m R_D (R_F + R_s)}{1/g_m + R_F // R_S}$$

$$R_i = R_F + R_S$$

$$R_o = \frac{1}{g_m} + R_F // R_S$$

b)Let the output of Q2 be taken as the voltage at the source of Q2 as shown in the figure Fig.4. Find the expressions for A, β, A_f, R_{inf}, R_{of}. Neglect r_{ds} and the body effect, g_{m1}= g_{m2}= 5mA/V, R_D= 10 KΩ, R_s= 10 KΩ and R_f= 10 KΩ. (2 marks per one)

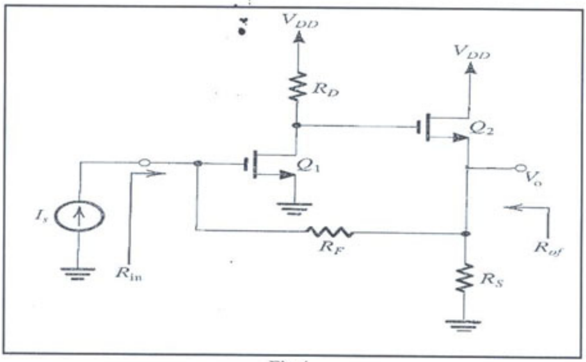
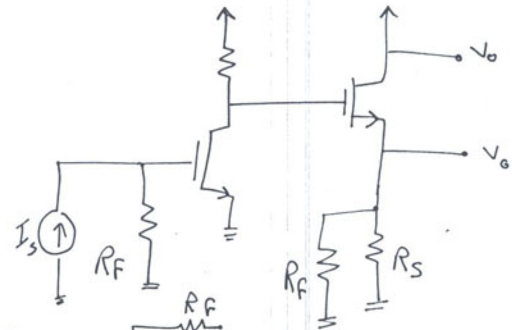


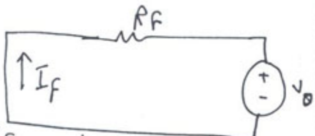
Fig.4

Solution:

Q_3 [b] shunt-shunt → (1 mark)



$R_{11} = R_F$ $\qquad A = \frac{V_s}{I_i}$ $\qquad R_{22} = R_F$



$$*\beta = \frac{I_F}{V_o} = \frac{-1}{R_F}$$

$$A_f = \frac{A}{1 + A\beta}$$

$$R_{iF} = \frac{R_i}{(1 + A\beta)} \Rightarrow R_i = R_F$$

$$R_{oF} = \frac{R_o}{(1 + A\beta)} \Rightarrow R_o = R_F \,||\, R_s \,||\, \frac{1}{g_m}$$

$$\boxed{A = \frac{-g_m R_D R_F (R_F \,||\, R_s)}{1/g_m + R_F \,||\, R_S}}$$

Question 4: (15 marks)

A two stage feedback circuit is shown in the figure Fig.5. Assume that both transistors are identical and have a $\beta = 100$, $r_\pi = 1000\Omega$, $R_E = 2\ K\Omega$, $R_1 = 5\ K\Omega$, $R_C = 10\ K\Omega$, $V_{CC} = 15\ V$, and neglect r_o. Use the method of feedback analysis to find A, β, A_f, R_{inf}, R_{of}. (3 marks per one)

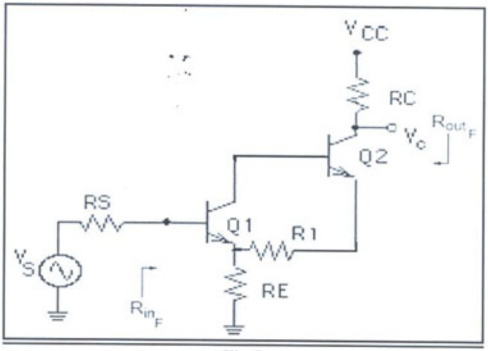


Fig.5

Solution:

Good Luck

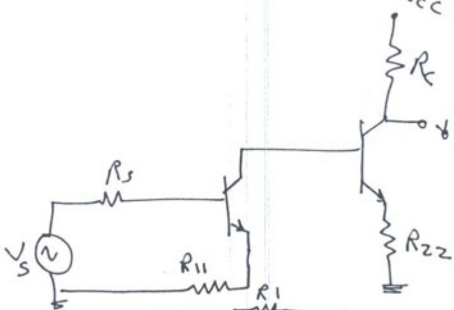
Q4 Series-series (1 mark)

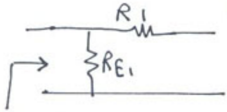
$$A = \frac{I_o}{v_i}$$

$$A_f = \frac{I_o}{V_s} = \frac{A}{1+A\beta}$$

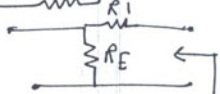
$$R_{if} = R_i(1+A\beta)$$

$$R_{of} = (1+A\beta)R_o$$

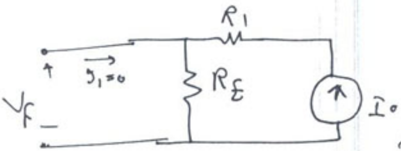




$R_{11} = R_E$



$R_{22} = R_1 + R_E$



$$\beta = \frac{v_f}{i_o} = R_E$$

$$R_i = (\beta+1)(r_e + R_E)$$

$$R_o = R_E + R_1 + r_e$$

$$A = \frac{1}{R_s + r_e + R_E}$$