Faculty of Engineering
Benha university
Electrical Eng.Dept.
Dr Hossam Labib Zayed

Microelectronics (E302)
Final-Term Exam (corrective)
Data: 20/5/2014
Time: 3 Hours

Answer the following questions:

Q1:(a) The JFET in the circuit of fig.(1) has $V_p = -3V$, $I_{DSS} = 9mA$ and $\lambda = 0$. Find the values of all resistors so that $V_G = 5V$, $I_D = 4$ mA and $V_D = 11V$. Design for 0.05 mA in the voltage divider.

(b) The basic op amp in fig.(2) is ideal. Find V_o and determine what mathematical operation is performed by the amplifier circuit.

Q2: The MOSFET amplifier circuit of fig.(3) has $K = 1$ mA/V^2 and $V_t = 2V$. Also, $V_{GS} = 5V$, $R_D = 1.33$ KΩ and $V_{DD} = 20V$. Find the dc current I_D , the dc voltage V_D and g_m. If $v_{gs} = 0.5 \sin wt$ V, find v_d and what are the minimum and maximum values of v_D.

Q3: Consider the common gate amplifier shown in fig.(4) with transistor parameter $g_m = 2mA/V$. If $I = 1mA$, $V_{DD} = V_{SS} = 5V$, $R_G = 1$ MΩ, $R_D = R_L = 3kΩ$ using T-model determine the small signal voltage gain $A_v = (v_o / v_i)$, the input resistance R_{in}, and the output resistance R_{out}.

Q4: The circuit in Fig. (5) utilizes an ideal op amp.
(a) Find I_1, I_2, I_3, I_L, and V_x.
(b) If V_o is not to be lower than −13V, find the maximum allowed value for R_L.

Q5: Find the voltage gain v_o/v_i and the differential input resistance of the amplifier shown in fig. (6). Assuming $\beta = 100$.

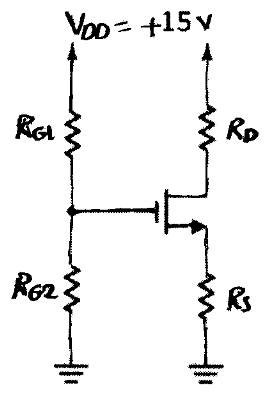


Fig.(1)

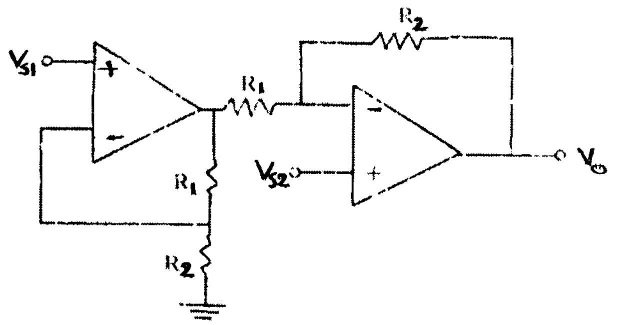


Fig.(2)

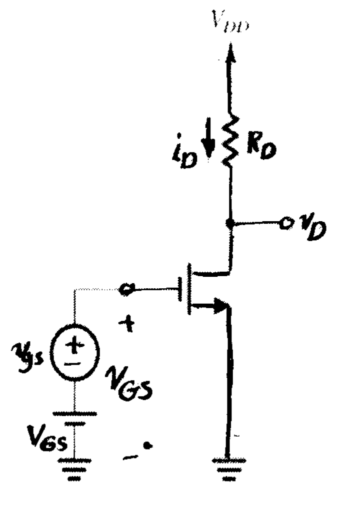


Fig.(3)

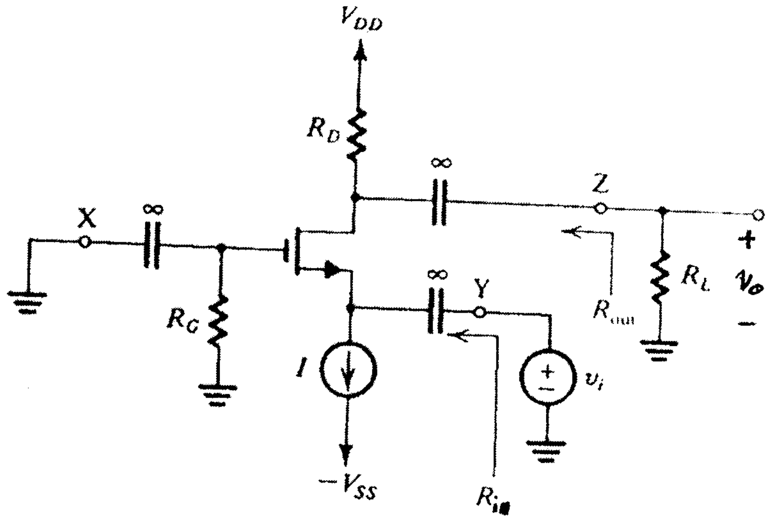


Fig.(4)

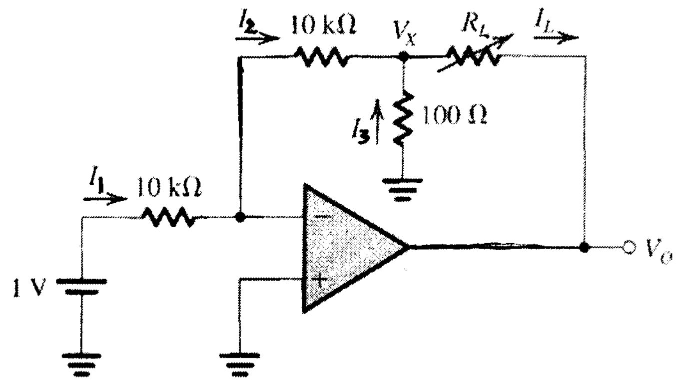


Fig.(5)

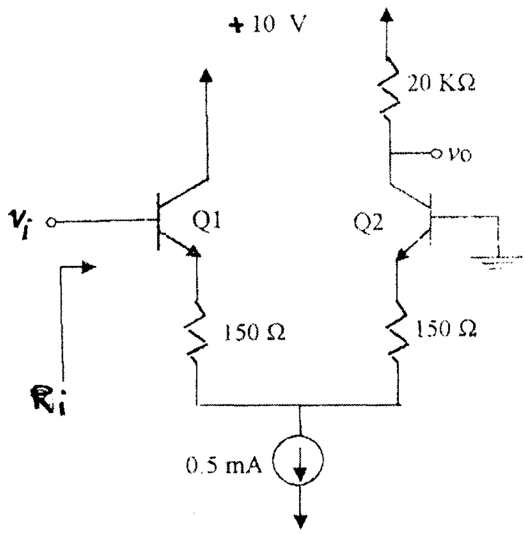
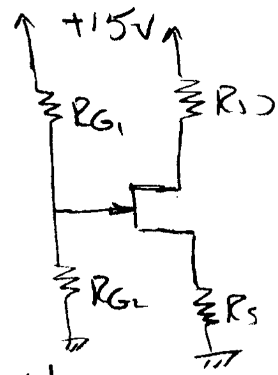


Fig.(6)

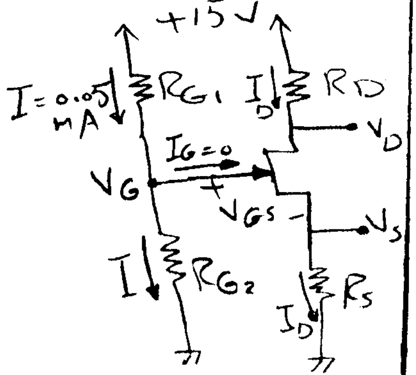
BEST WISHES

Hossam Labib

Q (a) The JFET in the circuit shown has $V_P = -3\ V$, $I_{DSS} = 9\,mA$ and $\lambda = 0$. Find the values of all resistors so that $V_G = 5\ V$, $I_D = 4\,mA$ and $V_D = 11\ V$, design for $0.05\ mA$ in the voltage divider.



Solution



$\because I_G = 0$ & $V_G = 5\,V$

$$R_{G1} = \frac{15-5}{0.05\,mA} = 200\ K\Omega.$$

$$R_{G2} = \frac{5-0}{0.05\,mA} = 100\ K\Omega.$$

$$R_D = \frac{15 - V_D}{I_D} = \frac{15-11}{4m} = 1\ K\Omega.$$

$$V_{DS}\big|_{sat} = V_{GS} - V_P = V_G - V_S - V_P = 5 - V_S + 3$$
$$= 8 - V_S$$

$$V_{DS} = V_D - V_S = 11 - V_S$$

$\because V_{DS} > V_{DS}|_{sat}$ $\therefore$ Tr. In saturation region

$$\therefore I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$4\,mA = 9\,mA\left(1 + \frac{V_{GS}}{3}\right)^2 \Rightarrow \frac{4}{9} = \left(1 + \frac{V_{GS}}{3}\right)^2$$

$$\pm\frac{2}{3} = \left(1 + \frac{V_{GS}}{3}\right) \overset{\times 3}{\Rightarrow} \pm 2 = 3 + V_{GS}$$

$$V_{GS} = \pm 2 - 3 \Rightarrow V_{GS} = -1 \ \ \&\ \ V_{GS} = -5$$

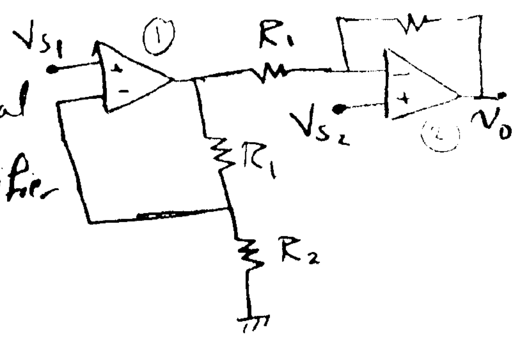
for $V_{GS} = -5\,V < V_P \Rightarrow$ neglected

Then $V_{GS} = -1\ V$

$$\because V_{GS} = V_G - V_S \Rightarrow V_S = V_G - V_{GS} = 5 + 1 = 6\ V$$

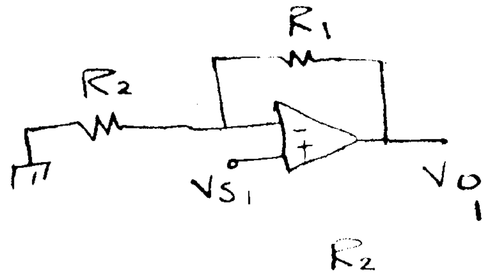
$$\therefore R_S = \frac{V_S}{I_D} = \frac{6}{4m} = 1.5\ K\Omega.$$

Q1(b) The basic op Amp. shown is ideal. Find V_o and determine what mathematical operation is performed by the Amplifier circuit.



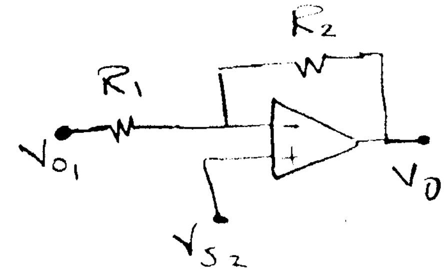
Solution

For op Amp ①



$$V_{O_1} = \left(1 + \frac{R_1}{R_2}\right) V_{S_1}$$

For op Amp ②



$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{S_2} + \left(-\frac{R_2}{R_1}\right) V_{O_1}$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{S_2} - \left(\frac{R_2}{R_1}\right)\left(1 + \frac{R_1}{R_2}\right) V_{S_1}$$

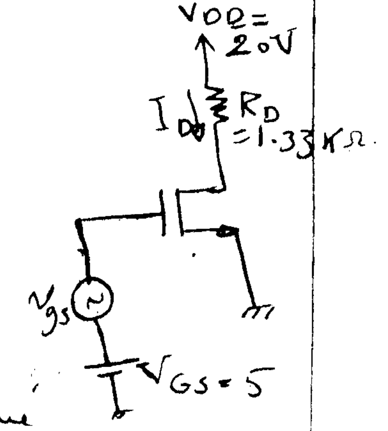
$$= \left(1 + \frac{R_2}{R_1}\right) V_{S_2} - \left(\frac{R_2}{R_1} + 1\right) V_{S_1}$$

$$= \left(1 + \frac{R_2}{R_1}\right) \left(V_{S_2} - V_{S_1}\right)$$

The operation is difference (subtractor) op Amp.

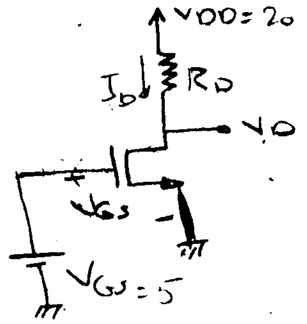
(Q2) The MOSFET of amplifier circuit shown has $K = 1\ mA/V^2$ and $V_t = 2\ V$ ALSO, $V_{GS} = 5\ V$, $R_D = 1.33\ K\Omega$ and $V_{DD} = 20\ V$

Find the dc current I_D, the dc voltage V_D and g_m. If $v_{gs} = 0.5 \sin wt$ find v_d and what are the min. and max. value of v_D.



Solution

DC analysis $\Rightarrow v_{gs} = 0$



$\because$ Tr. in saturation region (Amplifier)

$I_D = K(V_{GS} - V_t)^2 \quad ; \lambda = 0$

$V_S = 0 \quad \& \quad V_G = 5V \Rightarrow V_{GS} = 5\ V$

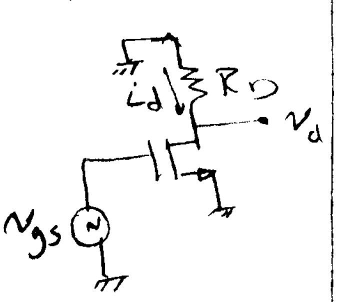
$\therefore I_D = 1m(5-2)^2 = 9\ mA$

$V_D = V_{DD} - I_D R_D = 20 - 9 * 1.33 = 8.03\ V$

$g_m = 2K(V_{GS} - V_t) = 2*1(5-2) = 6\ mA/V$

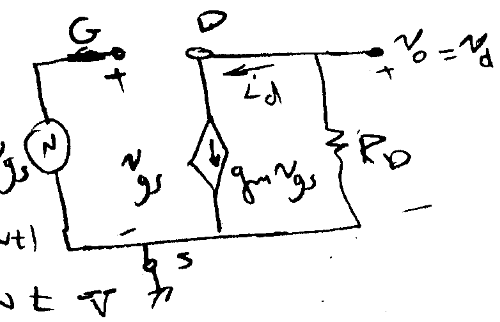
AC Analysis

$V_{GS} = 0 \quad \& \quad V_{DD} = 0$



$r_o = \infty \quad v_d = -i_d R_D$

$v_o = v_d = -g_m v_{gs} R_D$



$v_d = -6*1.33(0.5 \sin wt)$

$= -3.99 \sin wt\ V$

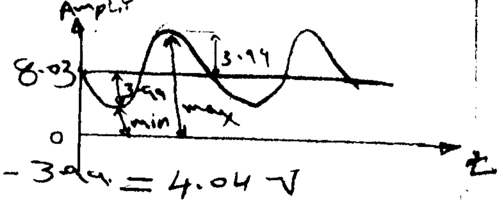
Note

$A_v = \frac{v_o}{v_{gs}} = -g_m R_D = -6 * 1.33 = -7.98\ \frac{V}{V}$

$v_d = v_o \Rightarrow \frac{v_d}{v_{gs}} = -7.98 \Rightarrow v_d = -7.98\, v_{gs} = -7.98 * 0.5 \sin wt$

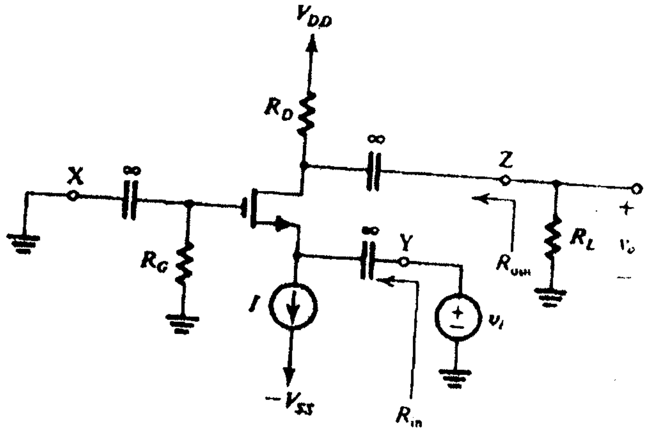
$v_d = -3.99 \sin wt\ V$

$v_D = V_D + v_d = 8.03 - 3.99 \sin wt$



$v_D|_{max} = 8.03 + 3.99 = 12.02\ V \quad \& \quad v_D|_{min} = 8.03 - 3.99 = 4.04\ V$

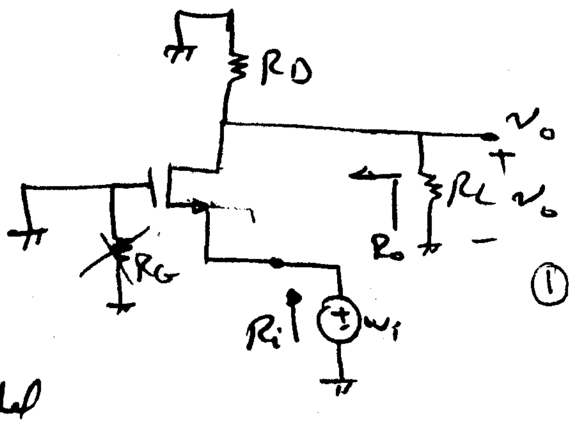
Q3: Consider the common gate amplifier shown in fig. (3) with transistor parameter $g_m = 2mA/V$. If $I = 1mA$, $V_{DD} = V_{SS} = 5V$, $R_G = 1\ M\Omega$, $R_D = R_L = 3k\Omega$ using T-model determine the small signal voltage gain $A_v = (v_o/v_i)$, the input resistance R_{in}, and the output resistance R_{out}.



Solution

$g_m = 2mA/V$

AC Analysis



Using T-model

$R_i = \frac{1}{g_m} = \frac{1}{2\times10^{-3}} = 0.5\ K\Omega.$ → ②

$R_o \Big|_{v_i=0} = R_D = 3\ K\Omega.$ → ②

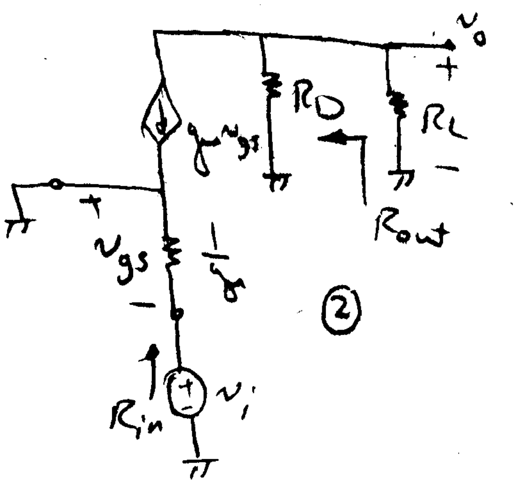
$v_o = -g_m v_{gs}(R_D \| R_L)$ → ①

$v_{gs} = -v_i$ → ①

$v_o = +g_m v_i (R_D \| R_L)$

$A_v = \frac{v_o}{v_i} = g_m (R_D \| R_L)$ → ①

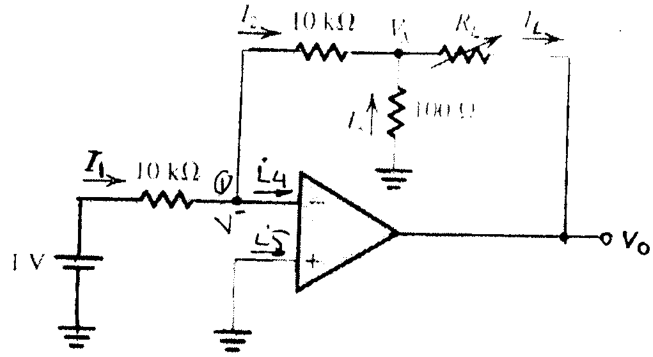
$= 2\times10^{-3}(3K \| 3K) = 3\ V/V$ → ②



Q4: The circuit in Fig.(5) utilizes an ideal op amp.

(a) Find I_1, I_2, I_3, I_L, and V_x.

(b) If V_O is not to be lower than −13 V, find the maximum allowed value for R_L.



Solution

(a) for ideal op Amp:

$i_4 = i_5 = 0$; $v^+ = v^-$; $v^+ = 0 \Rightarrow v^- = 0$

$I_1 = \frac{1 - v^-}{10k} = \frac{1}{10k\Omega} = 0.1\ mA$

at node (1)

$I_1 = I_2 + i_4 \Rightarrow I_1 = I_2 = 0.1\ mA$ ($i_4 = 0$)

$\because I_2 = \frac{v^- - V_x}{10k\Omega} \Rightarrow 0.1m = \frac{0 - V_x}{10k}$

$V_x = -0.1 * 10 = -1\ V$

$I_3 = \frac{0 - V_x}{100} = \frac{+1}{100} = 10\ mA$

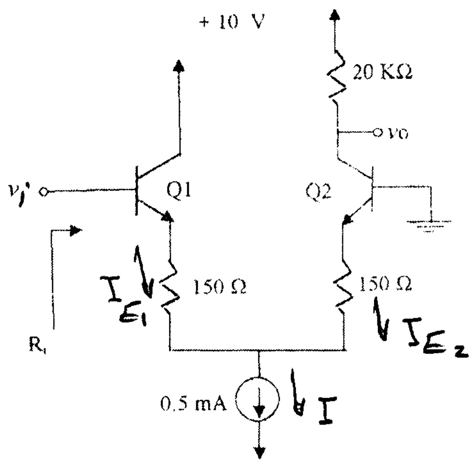
at node (x)

$I_L = I_2 + I_3 = 0.1\ mA + 10\ mA = 10.1\ mA$

(b) $R_L = \frac{V_x - V_o}{I_L} = \frac{V_x - V_o|_{min}}{I_L}$

$= \frac{-1 + 13}{10.1m} = \frac{12}{10.1m} = 1.188\ K\Omega \simeq 1.2\ K\Omega$

Q5: Find the voltage gain v_o/v_i and the differential input resistance of the amplifier shown in figure. Assuming $\beta = 100$.



Soution:

DC Analysis

$$I_{E_1} = I_{E_2} = I_E = \frac{I}{2}$$

$$I_E = \frac{0.5mA}{2} = 0.25mA$$

$$I_C = \alpha I \simeq I_E = 0.25mA \quad ; \quad \alpha = 1$$

$$r_e = \frac{V_T}{I_E} = \frac{25mV}{0.25mA} = 100\Omega$$

$$g_m = \frac{I_C}{V_T} = \frac{0.25mA}{25mA} = 0.01 \text{ A/V}$$

Ac Analysis

$$R_{id} = (1+\beta)(2R_E + 2r_e)$$

$$= (1+100)(2*150 + 2*100)$$

$$= 101 * 500 = 50.5 K\Omega.$$

$$\left|\frac{v_o}{v_i}\right| = \frac{R_C}{2r_e + 2R_E}$$

$$= \frac{20K}{2*100 + 2*150} = 40.$$