DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDRAPRASTHA INSTITUTE OF INFORMATION TECHNOLOGY DELHI

MONSOON Semester | ECE 315/ ECE515: Analog CMOS Circuit Design | 2023 – 2024

Time: 40 minutes. | **Quiz -1** | **M.M.: 20**

Instructions: For the multiple choice type questions, answer with the **correct option only on the provided space in question paper**. **Overwritten/multiple answers** for a question **will not be checked**. There is no negative marking.

Name: ______________________________ **Enr. No.:** ____________________

Part-1 **5×1=5**

1. For a MOSFET in the pinch off region, as the drain voltage is increased, the drain current
(A) becomes zero (B) abruptly decreases (C) abruptly increases (D) remains constant

2. Given the operating point values I_{DQ}= 1.8 mA and V_{DSQ} = 3.1 V for common-source amplifier circuit operating in edge of saturation region, value of the small signal parameter g_m will be (V_T = 1.6, λ = 0)
(A) 1.16×10^{-3} S (B) 0.005 S (C) 0.625×10^{-3} (D) cannot be determined

$$g_m = \frac{2I_D}{V_{GS}-V_{TH}} = \frac{3.6\text{ mA}}{3.1\text{ V}} = 1.16\times10^{-3}\text{ S}$$

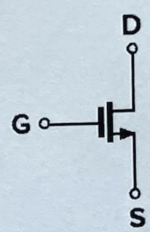


Fig. 1

3. For the MOS transistor in Fig. 1, if $V_{GS}>V_T$ and $V_{DS}<V_{GS}-V_T$, the channel voltage __________ along the length of the transistor, and the charge density __________ as we go from the source to the drain.
(A) remains constant, falls (B) varies, remains unchanged
(C) remains constant, increases (D) varies, falls

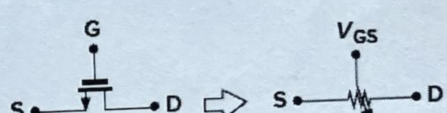


Fig. 2

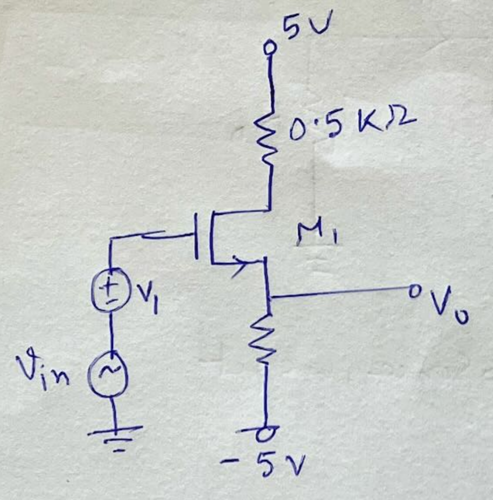
4. R_{DS}(ON) of the MOSFET in Fig. 2 __________ with increasing V_{GS}.
(A) decreases (B) increases
(C) remains constant (D) first increases then decreases

5. In the CS-stage with source degeneration, if the source resistance R_S is bypassed by a capacitor C_S, then ac voltage gain of the amplifier
(A) remains the same (B) increases (C) decreases (D) gain is not affected

Answer:

1	2	3	4	5

Q6.



(a) D.C. Analysis: For the gate to source loop, using KVL

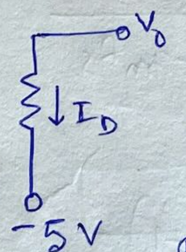
$$V_1 - V_{GS} - V_o = 0$$

for $V_o = 0$, $V_1 = V_{GS}$

Enforcing Saturation condition,

$$I_D = k(V_{GS} - V_T)^2$$

$$= 0.4 (V_{GS} - V_T)^2 \times 10^{-3} \quad \text{——— (1)}$$



Using KVL, $V_o = I_D R_S - 5$

$\therefore I_D = \frac{5}{5K} = 1\,mA$

Putting I_D in (1)

$$1\,mA = 0.4\,mA (V_{GS} - 1)^2$$

$$\text{or } (V_{GS} - 1)^2 = \frac{1}{0.4} = 2.5$$

$$\text{or } V_{GS} - 1 = \pm\sqrt{2.5} = \pm 1.58$$

Check: Taking $V_{GS} = 2.58V$, $V_{GS} > V_{th}$

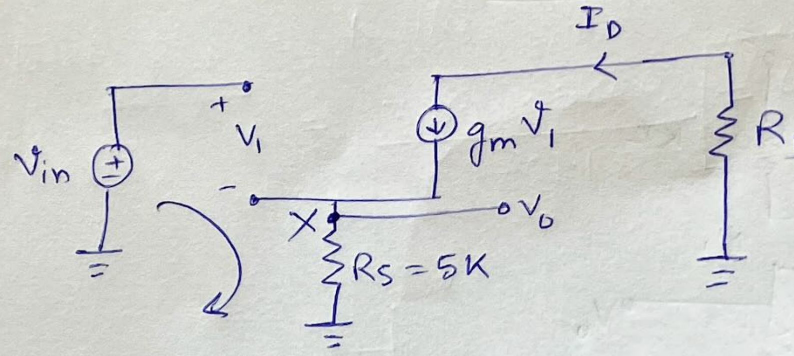
on the outer loop using KVL

$V_{DD} - I_D R_D - V_{DS} = 0$ as $V_o = 0$

or $V_{DS} = 4.5V > V_{GS} - V_{th}$

So $V_1 = 2.58V$

6. (b)



6. (c)

AC Analysis: Using KVL in loop Gate to Source, we get

$$V_{in} - V_1 = V_o$$

Using KCL at node X

$$\frac{V_o}{R_S} = g_m v_1$$

or $$\frac{v_o}{R_S} = g_m (v_{in} - v_o)$$

or $$v_o \left(\frac{1}{R_S} + g_m\right) = v_{in} (g_m)$$

or $$v_o / v_{in} = \frac{g_m}{1/R_S + g_m} = \frac{g_m R_S}{1 + g_m R_S}$$

Here $$g_m = 2K (V_{GS} - V_T)$$

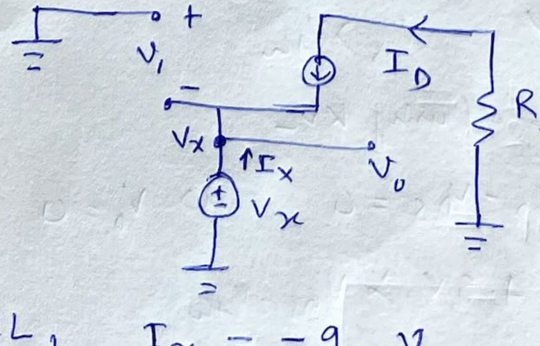
$$= 2 \times 0.4 \times 10^{-3} (2.58 - 1)$$

$$= 1.264 \times 10^{-3}$$

$$\therefore \frac{V_o}{V_{in}} = A_v = \frac{1.264 \times 10^{-3} \times 5 \times 10^{+3}}{1 + 1.264 \times 10^{-3} \times 5 \times 10^{3}}$$

$$= 0.863$$

6. (d)



Using KCL, at node X: $I_x = -g_m V_1$ or $I_x = g_m v_x$

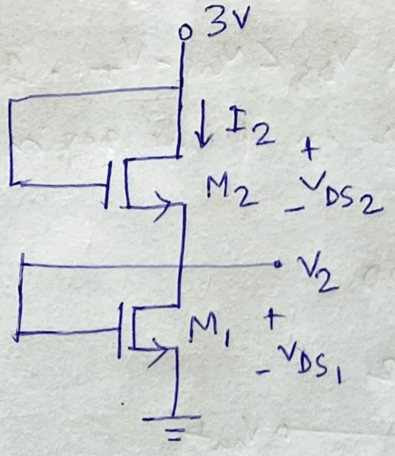
$$\frac{v_x}{I_x} = R_o = \frac{1}{g_m} = \frac{10^{-3}}{1.264} = 791.13\,\Omega$$

Total $R_{out} = R_o \| R_S$

$$= \frac{791.13 \times 5000}{5791.13} \boxed{= 683.05\Omega}$$

Q. 7

a



Using KVL on the outer loop

$$3 - V_{DS2} - V_{DS1} = 0 \quad \text{---} (1)$$

As both transistors are characterized by same device parameters

$$V_{DS2} = V_{DS1}$$

From (1), $V_2 = V_{DS1} = \frac{3}{2}$ Volt

$$\boxed{= 1.5 \text{ Volt}}$$

Check for saturation:

Here $V_{GS} - V_T = V_{DS} - V_T$ [As $V_{GS} = V_{DS}$]

$\therefore V_{DS} > V_{GS} - V_T$

$\therefore$ The transistors are in saturation.

Current $I_2 = \frac{1}{2} \mu_n C_{ox} W/L \, (V_{GS} - V_T)^2$

$$= \frac{1}{2} 20 \times 10^{-6} (3)(1.5 - 1)^2$$

$$= 10 \times 10^{-6} \times 3 \times 0.25$$

$$\boxed{= 7.5 \, \mu A}$$

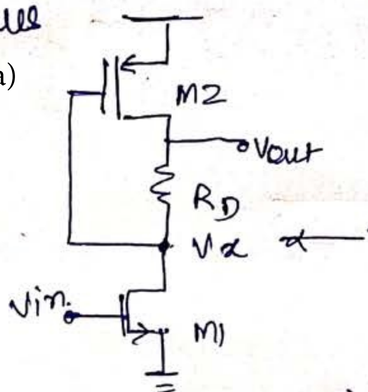
7(b) (4)

No, there is no channel-length modulation in triode region. For channel length modulation, pinch off should occur and $V_{DS} > V_{GS} - V_T$ should be satisfied.

But in triode region $V_{DS} < V_{GS} - V_T$. Therefore channel length modulation should not occur in triode region.

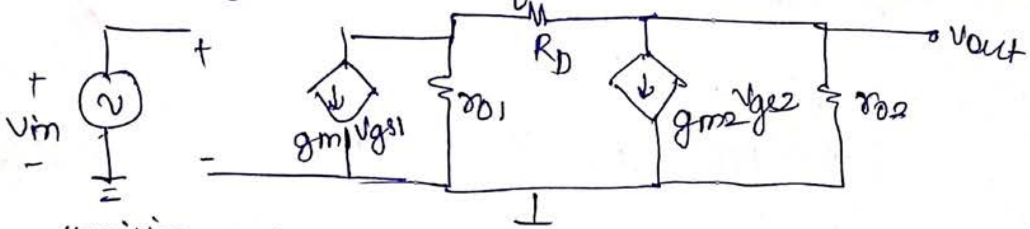
Ques

8 (a)



← Taking this node as Vx

small signal circuit of above circuit as shown below:



8(b) writing KCL. at Vx node,

$$g_{m1}V_{gs1} + \frac{V_x}{r_{o1}} + \frac{V_x - V_{out}}{R_D} = 0$$

(Note: $V_{gs2} = V_x$, $V_{gs1} = V_{in}$)

$$\frac{V_{out}}{R_D} - g_{m1}V_{in} = V_x\left(\frac{1}{R_D} + \frac{1}{r_{o1}}\right) \quad \text{— (1)}$$

writing, KCL at output node,

$$g_{m2}V_{gs2} + \frac{V_{out}}{r_{o2}} + \frac{V_{out} - V_x}{R_D} = 0$$

$$g_{m2}V_x + \frac{V_{out}}{r_{o2}} + \frac{V_{out}}{R_D} - \frac{V_x}{R_D} = 0$$

$$V_{out}\left(\frac{1}{r_{o2}} + \frac{1}{R_D}\right) = V_x\left(\frac{1}{R_D} - g_{m2}\right)$$

$$V_x = \frac{V_{out}\left(\frac{1}{r_{o2}} + \frac{1}{R_D}\right)}{\left(\frac{1}{R_D} - g_{m2}\right)} \quad \text{— (2)}$$

putting eqⁿ (2) into eqⁿ (1)

$$\frac{V_{out}}{R_D} - g_{m1}V_{in} = \frac{V_{out}\left(\frac{1}{r_{o2}} + \frac{1}{R_D}\right)}{\left(\frac{1}{R_D} - g_{m2}\right)} \times \left(\frac{1}{r_{o1}} + \frac{1}{R_D}\right)$$

$$\frac{V_{out}}{R_D} - \frac{V_{out}\left(\frac{1}{r_{o2}} + \frac{1}{R_D}\right)\left(\frac{1}{r_{o1}} + \frac{1}{R_D}\right)}{\left(\frac{1}{R_D} - g_{m2}\right)} = g_{m1}V_{in}$$

$$V_{out}\left[\frac{\left(\frac{1}{R_D}-g_{m2}\right)}{R_D} - \frac{R_D\left(\frac{1}{r_{o2}}+\frac{1}{R_D}\right)\left(\frac{1}{r_{o1}}+\frac{1}{R_D}\right)}{\left(\frac{1}{R_D}-g_{m2}\right)}\right] = g_{m1}V_{in}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m1}(1-g_{m2}R_D)}{\frac{1}{R_D}-g_{m2}-\left[\left(\frac{R_D}{r_{o2}}+1\right)\left(\frac{1}{r_{o1}}+\frac{1}{R_D}\right)\right]}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m1}(1-g_{m2}R_D)}{\left(\frac{1}{R_D}-g_{m2}-\frac{R_D}{r_{o2}r_{o1}}-\frac{1}{r_{o2}}-\frac{1}{r_{o1}}-\frac{1}{R_D}\right)}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m1}(1-g_{m2}R_D)}{-\left[g_{m2}+\frac{1}{r_{o1}}+\frac{1}{r_{o2}}\left(1+\frac{R_D}{r_{o1}}\right)\right]}$$

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{g_{m1}(g_{m2}R_D-1)}{\left[g_{m2}+\frac{1}{r_{o1}}+\frac{1}{r_{o2}}\left(1+\frac{R_D}{r_{o1}}\right)\right]}}$$