

EE3122 Analogue Circuit Fundamentals Quiz 1

Solutions

1. Determine the region of operation for the following circuit in Fig. 1, i.e. in cutoff, saturation or triode/ohmic/linear region. You may assume $\lambda=0$, $V_{TP} = -1$ V and $K_p = 250$ $\mu\text{A}/\text{V}^2$ for the PMOS transistor. **(30 marks)**

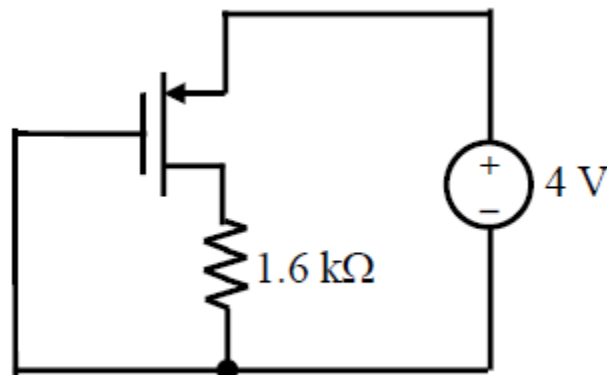


Figure 1

KVL: $4 = |V_{DS}| + 1.6I_D$, where I_D in mA

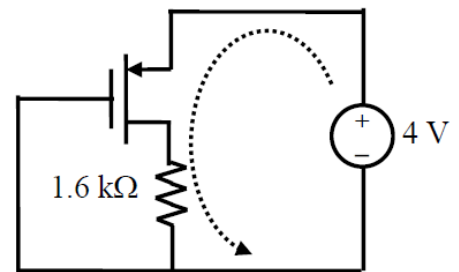
Also, $|V_{GS}| = 4\text{V}$.

Since $|V_{GS}| = 4 > |V_{TP}| = 1$, it is not cut-off.

Assume Saturation region operation,

$$I_D = \frac{K_p}{2} (|V_{GS}| - |V_{TP}|)^2$$
$$= \frac{0.25}{2} (4 - 1)^2 = 1.125 \text{ mA}$$

15 marks



That means $|V_{DS}| = 4 - 1.6 \times 1.125 = 2.2$ V

Since $|V_{DS}| = 2.2 \text{ V} < |V_{GS}| - |V_{TP}| = 4 - 1 = 3 \text{ V}$,

PMOS is not in saturation.

10 marks

Therefore the only conclusion is: it is in triode region, which is also known as ohmic or linear region.

5 marks

2. Determine the region of operation for the BJT in Figure 2 and find all the currents and voltages at the 3 terminals. It is given that $|V_{BE}| = 0.7 \text{ V}$, $|V_{CE(\text{sat})}| = 0.2 \text{ V}$ and $\beta = 200$. (30 marks)

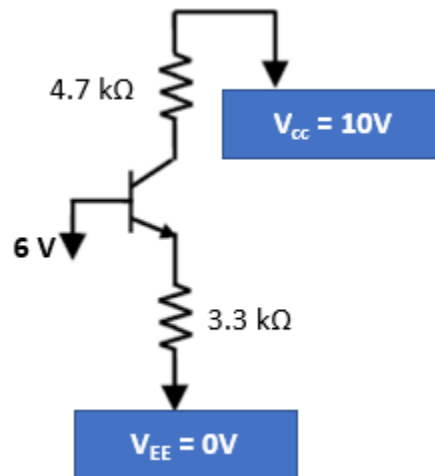


Figure 2

Assume active-mode operation,

$$\begin{aligned} V_E &= V_B - V_{BE} \\ &= 6 - 0.7 \\ &= 5.3 \text{ V} \end{aligned}$$

$$\begin{aligned} I_E &= \frac{5.3}{3.3} \\ &= 1.6 \text{ mA} \end{aligned}$$

Since β is very large,

$$\alpha \approx 1 \Rightarrow I_C \approx I_E = 1.6 \text{ mA}$$

$$\begin{aligned} V_C &= 10 - 1.6 \times 4.7 \\ &= 2.48 \text{ V} \end{aligned}$$

$$\begin{aligned} V_{BC} &= V_B - V_C \\ &= 6 - 2.48 \\ &= 3.52 \text{ V} \end{aligned}$$

15 marks

Wrong assumption $\rightarrow$ Q is in saturation mode

$$V_E = 6 - 0.7 \text{ and } I_E = \frac{5.3}{3.3}$$

$$= 5.3 \text{ V} \quad = 1.6 \text{ mA}$$

5 marks

$$V_C = V_E + V_{CE(SAT)}$$

$$= 5.3 + 0.2$$

$$= 5.5 \text{ V}$$

$$I_C = \frac{10 - 5.5}{4.7}$$

$$= 0.96 \text{ mA}$$

5 marks

5 marks

3. For the amplifier shown in Fig. 3, what is the name of this topology of amplifier (common-X)? Draw the small-signal model for this amplifier and determine expressions of the small-signal voltage gain, input resistance and output resistance. Show all the steps in deriving these equations –just writing down the equations will not be awarded marks. The capacitors can be assumed to be short circuit for the AC small-signal analysis and r_o in the MOS small-signal model can be ignored (i.e. $\lambda=0$). **(40 marks)**

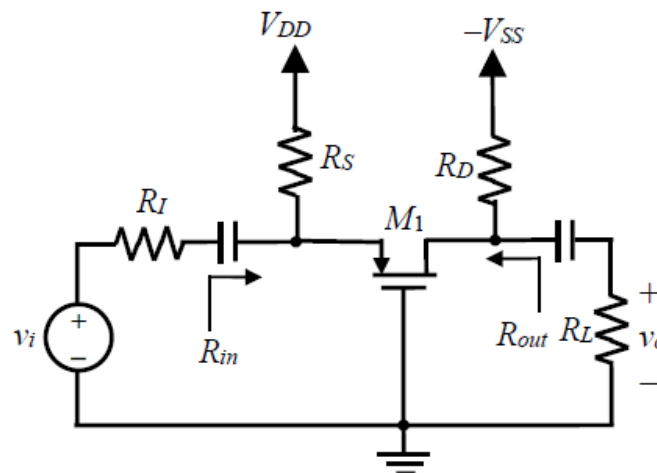
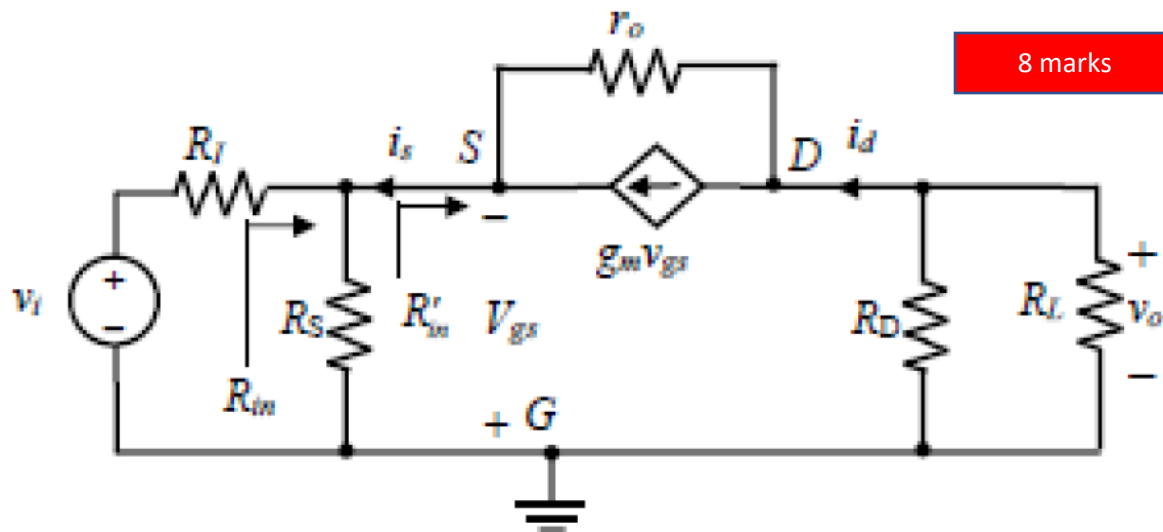


Figure 3

Since Gate is connected to AC ground, this is common Gate.

2 marks

Draw AC model – V_{DD}/V_{SS} are AC ground and capacitors are shorted.



8 marks

Finding Rin

$$R'_{in} = \frac{v_{gs}}{i_s} = \frac{v_{gs}}{g_m v_{gs}} = \frac{1}{g_m}$$

10 marks

$$R_{in} = R_S \parallel R'_{in}$$

Finding Voltage gain

$$A_{vt} = \frac{v_d}{v_s} = \frac{-g_m v_{gs} (R_D \parallel R_L)}{-v_{gs}} = g_m (R_D \parallel R_L)$$

$$A_v = \left(\frac{R_{in}}{R_{in} + R_I} \right) A_{vt}$$

10 marks

Finding Rout

