Analogue Electronics 1 (EE204FZ)

Tutorial 1 (Solutions)

Q1.

1. (D)
2. (C)
3. (B)
4. (D)
5. (A)

Q2.

1.

The two types of MOSFETs are depletion-type MOSFETs and enhancement-type MOSFETs.

In depletion-type MOSFETs, when there is no voltage on the gate, a conduction channel still exists between the source and the drain, and the transistor is in the "ON" state. When a gate voltage is applied, depending on its polarity, it can either reduce the number of charge carriers in the channel (the MOSFET is said to operate in the depletion mode which is also its most common mode of operation) or increase the number of charge carriers in the channel (the enhancement mode of operation). In the depletion mode of operation, the channel conductivity decreases while in the enhancement mode of operation, the channel conductivity increases.

For enhancement-type MOSFETs, when there is no voltage on the gate, there is no conduction channel. Thus, the transistor is in the "OFF" state. A channel is only created by the application of a voltage to the gate. The greater (the absolute value of) the gate voltage is, the better the device conducts.

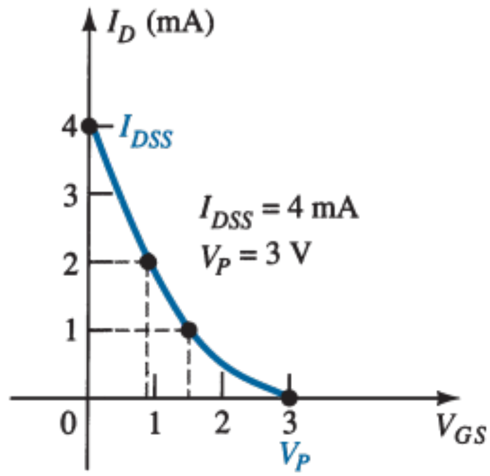
2.

Cut-off region: When $V_{GS} < V_T$, no channel is induced and the MOSFET is in the cut-off region. No current flows.

Triode region: When $V_{GS} \geqslant V_T$, a channel is induced and current starts flowing if $V_{DS} > 0$. A MOSFET is in the triode region as long as $V_{DS} < V_{GS} - V_T$. A MOSFET in the triode region behaves like a 'tunable resistor' whose resistance can be modified by changing V_{GS}.

Saturation region: When $V_{GS} \geqslant V_T$ and $V_{DS} \geqslant V_{GS} - V_T$, the channel is in saturation and the drain current is almost constant. There is very little or no increase in the drain current when V_{DS} is further increased.

Q3.



Q4.

No current flows into the gate terminal ($I_G = 0$). Hence, R_1 and R_2 are connected in series between V_{DD} = +10 V and the ground.

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = \left(\frac{4.7\ \text{M}\Omega}{10\ \text{M}\Omega + 4.7\ \text{M}\Omega}\right)(10\ \text{V}) = 3.20\ \text{V}$$

The source terminal is on the ground. $V_{GS} = V_G - V_S = 3.20$ V.

The MOSFET equation is $I_D = k(V_{GS} - V_T)^2$ (we group all the device parameters into k). Rearranging it and inserting the datasheet values, we have,

$$k = \frac{I_D}{(V_{GS} - V_T)^2} = \frac{3\ \text{mA}}{(4\ \text{V} - 2\ \text{V})^2} = 0.75 \times 10^{-3}\ \frac{\text{A}}{\text{V}^2}$$

Using this k value and V_{GS} = 3.20 V we can calculate the drain current going through the MOSFET,

$$I_D = k(V_{GS} - V_T)^2 = \left(0.75 \times 10^{-3}\ \frac{\text{A}}{\text{V}^2}\right)(3.20\ \text{V} - 2\ \text{V})^2 = 1.08\ \text{mA}$$

Now solve for V_{DS},

$$V_{DS} = V_{DD} - I_D R_D = 10\ \text{V} - (1.08\ \text{mA})(1.0\ \text{k}\Omega) = 10\ \text{V} - 1.08\ \text{V} = 8.92\ \text{V}$$

Q5.

No current goes through the ideal voltmeter and no current goes into the gate terminal ($I_G = 0$). It means that no current goes through resistor R_G. Hence, $V_{DS} = V_D = V_G = 8.5$ V.

$$I_D = \frac{V_{DD} - V_D}{R_D} = \frac{15\ \text{V} - 8.5\ \text{V}}{4.7\ \text{k}\Omega} = 1.38\ \text{mA}$$