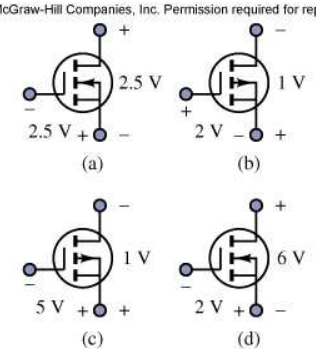
Q1. Problem P11.1

Solution:

Known quantities:

For the transistors shown in Figure P11.1, $|V_T| = 3\,\text{V}$.

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Find:

The operating state of each transistor.

Analysis:

a) This is an n-channel enhancement MOSFET, with $V_T = 3\,\text{V}$. To operate in the triode region, the condition is: $v_{GD} > V_T$. To operate in the saturation region, the condition is: $v_{GD} \le V_T$. To turn the transistor on, the condition is: $v_{GS} > V_T$.

We can compute:

$v_{GS} = -2.5\,\text{V}$, $v_{DS} = 2.5\,\text{V}$, $v_{GD} = v_{GS} - v_{DS} = -2.5 - 2.5 = -5\,\text{V}$

$v_{GS} < V_T$, $v_{GD} \le V_T$.

Therefore, the transistor is in the cutoff region.

b) This is a p-channel enhancement MOSFET, with $V_T = -3\,\text{V}$. To operate in the triode region, the condition is: $v_{GD} < V_T$. To operate in the saturation region, the condition is: $v_{GD} \ge V_T$. To turn the transistor on, the condition is: $v_{GS} < V_T$.

We can compute:

$v_{GS} = 2\,\text{V}$, $v_{DS} = -1\,\text{V}$, $v_{GD} = v_{GS} - v_{DS} = 2 - (-1) = 3\,\text{V}$

$v_{GS} > V_T$, $v_{GD} \ge V_T$.

Therefore, the transistor is in the cutoff region.

c) This is a p-channel enhancement MOSFET, with $V_T = -3\,\text{V}$. To operate in the triode region, the condition is: $v_{GD} < V_T$. To operate in the saturation region, the condition is: $v_{GD} \ge V_T$. To turn the transistor on, the condition is: $v_{GS} < V_T$.

We can compute:

$v_{GS} = -5\,\text{V}$ $v_{DS} = -1\,\text{V}$ $v_{GD} = v_{GS} - v_{DS} = -5 - (-1) = -4\,\text{V}$

$v_{GS} < V_T$, $v_{GD} < V_T$.

Therefore, the transistor is in the triode region.

d) This is an n-channel enhancement MOSFET, with $V_T = 3\,\text{V}$. To operate in the triode region, the condition is: $v_{GD} > V_T$. To operate in the saturation region, the condition is: $v_{GD} \le V_T$. To turn the transistor on, the condition is: $v_{GS} > V_T$.

We have: $v_{GS} = -2\,\text{V}$. $v_{DS} = 6V$ $v_{GD} = v_{GS} - v_{DS} = -2 - 6 = -8\,\text{V}$

$v_{GS} < V_T$, $v_{GD} \le V_T$

Therefore, the transistor is in the cutoff region.

Q2. Problem P11.3

Solution:

Known quantities:

The threshold voltage, V_T = 2 V, of an enhancement-type NMOS that has its source grounded and a 3 V DC source connected to the gate.

Find:

The operating state if:

a) $v_D = 0.5\,\text{V}$.

b) $v_D = 1\,\text{V}$.

c) $v_D = 5\ \text{V}$

Analysis:

As V_{GS} is 3.0V > V_T in all case, it must not in cutoff region

a)
$$v_{DS} = v_D = 0.5\,\text{V}$$
$$v_{GD} = v_{GS} - v_{DS} = 3 - 0.5 = 2.5\ \text{V}$$
$$v_{GD} > V_T$$

The transistor is in the triode region.

b)
$$v_{DS} = v_D = 1\,\text{V}$$
$$v_{GD} = v_{GS} - v_{DS} = 3 - 1 = 2\ \text{V}$$
$$v_{GD} = V_T$$

The transistor is either in the triode or in the saturation region.

c)
$$v_{DS} = v_D = 5\,\text{V}$$
$$v_{GD} = v_{GS} - v_{DS} = 3 - 5 = -2\ \text{V}$$
$$v_{GD} < V_T$$

The transistor is in the saturation region.

Q3. Problem P11.5

Solution:

Known quantities:

The threshold voltage, V_T = 2 V, of an enhancement-type NMOS transistor. i_D = 1 mA when v_{GS} = v_{DS} = 3 V.

Find:

The value of i_D for v_{GS} = 4 V.

Analysis:

Because $v_{GS} > V_T$, $v_{GD} = 0V \le V_T = 2V$, the transistor is in the saturation region:

$$i_D = k \cdot (v_{GS} - V_T)^2 = k \cdot (3-2)^2 = 0.001\ \text{A}$$
$$\Rightarrow k = 0.001.$$

For v_{GS} = 4 V we have:

$$i_D = 0.001 \cdot (4-2)^2 = 4\,\text{mA}.$$

Q4. Problem P11.6

Solution:

Known quantities:

Characteristics of an n-channel enhancement-mode MOSFET operated in the ohmic region: v_{DS} = 0.4 V, V_T = 3.2 V. Effective resistance of the channel, given by: $R_{DS} = \frac{500}{(v_{GS} - 3.2)}\ \Omega$.

Find:

The value of i_D when v_{GS} = 5 V, R_{DS} = 500 Ω, and v_{GD} = 4 V.

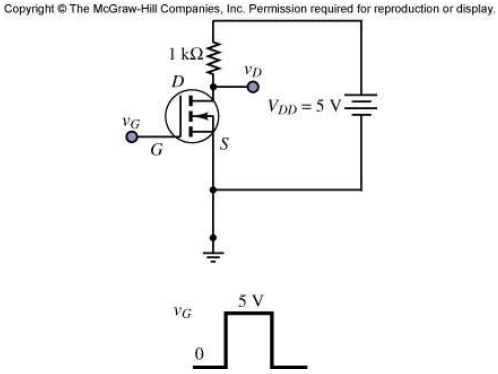
Analysis:

Since $v_{GS} > V_T$, $v_{GD} = 4.6 > V_T = 3.2V$,the transistor is operating in the ohmic region. The effective resistance is: $R_{DS} = \frac{500}{(5-3.2)} = 277.78\,\Omega$.

Since $R_{DS} = \frac{V_{DS}}{i_D}$, we have: $i_D = \frac{V_{DS}}{R_{DS}} = \frac{V_{GS} - V_{GD}}{R_{DS}} = \frac{5V - 4V}{277.78\Omega} = 3.6\,\text{mA}$.

Q5. Problem P11.9

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Solution:

Known quantities:

The threshold voltage, V_T = 1.5 V, of the NMOS transistor shown in Figure P11.9. $k = 0.4\,\text{mA/V}^2$.

Find:

The voltage levels of the pulse signal at the drain output, v_D if v_G is a pulse with 0 V to 5 V.

Analysis:

Since V_T = 1.5 V, with v_G = 0 V, $v_{GS} < V_T$, the transistor is cut off. Therefore, I_D=0A, no voltage drop at $R_{1k\Omega}$, thus v_D = 5 V.

When v_G = 5 V, v_{GS} =5V, so $v_{GS} > V_T$ and transistor is either in the saturation region or triode region:

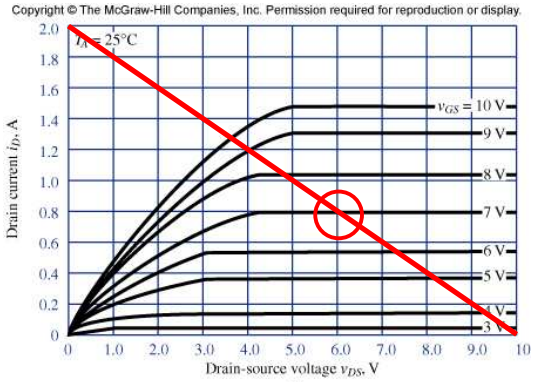
a) Assume NMOS is operating in the saturation region:
$i_D = k\,(v_{GS} - V_T)^2 = 0.4\,(5 - 1.5)^2 = 4.9$ mA. Therefore, v_D = 5V - 4.9mA×1kΩ = 0.1 V. But $V_{GD} = V_G - V_D$ =5V-0.1V= 4.9V > V_T, this assumption is not correct.

b) Assume NMOS is operating in triode region:
$i_D = K[2(V_{GS}-V_T)V_{DS}-V_{DS}^2] = 0.4\,[2(5-1.5)V_D-V_D^2] = 0.4\,[7V_D-V_D^2]$ mA.
Also, $V_D = V_{DD}-i_D R_{1k\Omega}$ = 5V-0.4[$7V_D-V_D^2$] mA×1kΩ.
Then, $0.4V_D^2-3.8V_D+5 = 0$, V_D = 1.578V or 7.922V. Since $V_{GD}=V_G-V_D>V_T$ for triode region, V_D = 1.578V.

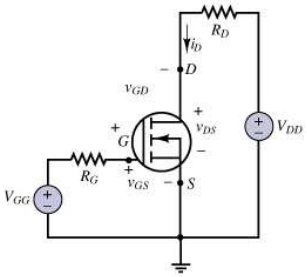
Therefore, NMOS is operating in triode region when v_G = 5 V, and V_D = 1.578V.

Q6. Problem P11.13

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(a)



(b)

Solution:

Known quantities:

The *i-v* characteristic of Figure P11.13(a), and the circuit in Figure P11.13(b): $V_{GG} = 7\,\text{V}, V_{DD} = 10\,\text{V}, R_D = 5\Omega$

Find:

The current i_{DQ} the voltage v_{DSQ}, and the region of operation of the MOSFET.

Analysis:

The operating point can be determined using the load line method.

$$i_D = \frac{V_{DD}}{R_D} - \frac{v_{DS}}{R_D} = 2 - 0.2\,v_{DS}$$

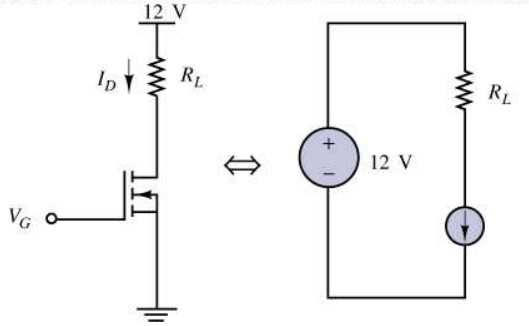
By superimposing the load line on Figure P11.13(a), and by noticing that $V_{GS} = V_{GG} = 7\,\text{V}$, we obtain

$i_{DQ} = 0.8\,\text{A}, v_{DSQ} = 6\,\text{V}$

The MOSFET is in the saturation region.

Q7. Problem P11.17

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Solution:

Known quantities:

The power MOSFET circuit shown in Figure P11.17.

Find:

a) If $V_G = 5\,\text{V}$, find the range of R_L for which the VCCS will operate.

b) If $R_L = 1\,\Omega$, determine the range of V_G for which the VCCS will operate.

Analysis:

The MOSFET should be working in the saturation region, so $v_{GD} < 3 \Rightarrow V_D > V_G - 3$

a) $V_G = 5\,\text{V}$, $I_D = K(v_{GS} - V_T)^2 = 1.5(5-3)^2 = 6\,\text{A}$ so

$$V_D = 12 - R_L I_D > V_G - 3 = 2 \Rightarrow R_L < \frac{10}{6}\,\Omega$$

b) $V_D = 12 - R_L I_D > V_G - 3 \Rightarrow V_G < 15 - R_L I_D = 15 - I_D$

$I_D = K(v_{GS} - V_T)^2 = K(V_G - V_T)^2$

Solve the above inequation, we can have

$-0.181V < V_G < 5.515V$

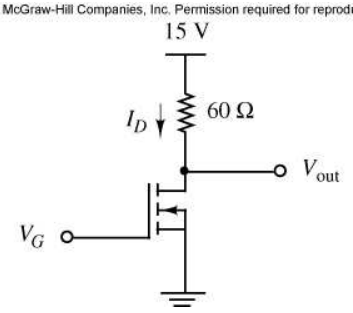
Besides, for saturation region, $V_G > V_T = 3\text{V}$, so

$3V < V_G < 5.515V$

Q8. Problem P11.19

Solution:

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Known quantities:

The Class A amplifier shown in Figure P11.19

Find:

a) Determine the output current for the given biased audio tone input, $V_G = 10 + 0.1\cos(500t)$ V.
Let $K = 2$ mA/V^2 and $V_T = 3$ V.

b) Determine the output voltage.

c) Determine the voltage gain of the $\cos(500t)$ signal.

d) Determine the DC power consumption of the resistor and the MOSFET.

Analysis:

a) The MOSFET should be working at the saturation region

So $i_D = K(v_{GS} - V_T)^2 = 0.002(10 + 0.1\cos(500t) - 3)^2 = 0.002\left(49 + 1.4\cos(500t) + 0.01\cos^2(500t)\right)$
$= 0.002(49 + 1.4\cos(500t) + 0.005\cos(1000t) + 0.005)$ A

b) $V_{out} = V_{DD} - i_D R = 15 - 60 \times 0.002(49 + 1.4\cos(500t) + 0.005\cos(1000t) + 0.005)$ V

c) $gain = \left.\dfrac{V_{out}}{V_G}\right|_{\omega=500} = \dfrac{-60 \times 0.002 \times 1.4}{0.1} = -1.68$

d) We can ignore the cosine part signal when calculating the DC power consumption.

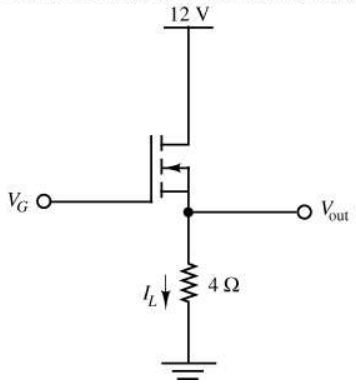
$i_{D_DC} = 0.002(49 + 0.005) = 0.098$ A

$P_R = i_{D_DC}{}^2 \times R = 0.576$ W

$P_{MOSFET} = i_{D_DC} \times v_{DS} = i_{D_DC} \times (V_{DD} - i_{D_DC} \times R) = 0.098 \times (15 - 0.098 \times 60) = 0.894$ W

Q9. Problem P11.20

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Solution:

Known quantities:

The source-follower amplifier shown in Figure P11.20.

$V_G = 9 + 0.1\cos(500t)$ V, $K = 30$ mA/V^2 and $V_T = 4$ V

Find:

a) Determine the load current I_L.
b) Determine the output voltage.
c) Determine the voltage gain of the $\cos(500t)$ signal.
d) Determine the DC power consumption of the resistor and the MOSFET.

Analysis:

The MOSFET should be working at the saturation region, So the $V_{out} = V_S = v_{GS} - V_T = 5 + 0.1\cos(500t)$

a) $I_L = \dfrac{V_{out}}{R} = \dfrac{5 + 0.1\cos(500t)}{4} = 1.25 + 0.025\cos(500t)$

c) $gain = \left.\dfrac{V_{out}}{V_G}\right|_{\omega=500} = \dfrac{0.1}{0.1} = 1$

d) We can ignore the cosine part signal when calculating the DC power consumption.

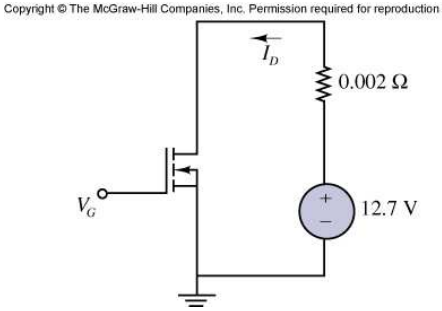
$i_{D_DC} = 1.25$ A

$P_R = i_{D_DC}{}^2 \times R = 6.25$ W

$P_{MOSFET} = i_{D_DC} \times v_{DS} = i_{D_DC} \times (V_{DD} - i_{D_DC} \times R) = 1.25 \times (12 - 5) = 8.75$ W

Q10. Problem P11.21

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Solution:

Known quantities:

The circuit shown in Figure P11.21.

$V_G = 8$ V, $K = 4$ A/V^2 and $V_T = 3$ V

Find:

The discharging current I_D and the required MOSFET power rating.

Analysis:

Obviously, the MOSFET should be working in the saturation region.

$i_D = K(v_{GS} - V_T)^2 = 4(8 - 3)^2 = 100$ A

$P = v_{DS} \times i_D = (12.7 - R \times i_D) \times i_D = (12.7 - 0.002 \times 100) \times 100 = 1250$ W