Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	01 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 3 .
SEMESTER 1, ACADEMIC YEAR 2017/2018
Date: 18 July 2017 Time: 15 minutes

Question:

Consider the **MOSFET differential amplifier** in **Figure 1**. Constant current in the current source is $\boldsymbol{I_1 = 0.6}$ **mA**. The transistor parameters are: $\boldsymbol{K_{n1} = K_{n2} = 0.1}$ **mA/V**^{2}, $\boldsymbol{K_{n3} = K_{n4} = 0.3}$ **mA/V**^{2}, and for all transistors $\boldsymbol{\lambda = 0}$ and $\boldsymbol{V_{TN} = 1}$ **V.**
The maximum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(max)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$ reach the saturation point, while the minimum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(min)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_4}$ reaches the saturation point.
Determine the maximum range of common-mode input voltage, i.e. find $\boldsymbol{v_{CM}}$ **(max)** and $\boldsymbol{v_{CM}}$ **(min)**.
[10 marks]

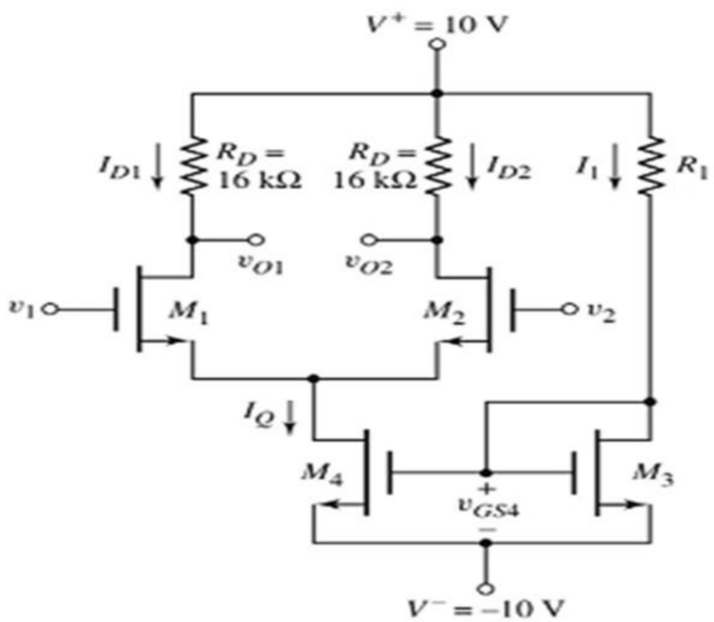

Figure 1

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

; Small signal

Answer:

$\boldsymbol{I_Q = I_1 = 0.6}$ **mA**, $\boldsymbol{I_{D1} = I_Q / 2 = 0.3}$ **mA** **[2]**

$$V_{GS1} = \sqrt{\frac{I_{D1}}{K_{n1}}} + V_{TN} = \sqrt{\frac{0.3m}{0.1m}} + 1 = 2.732\text{V} \quad [1]$$

$\boldsymbol{v_{O1} = V^+ - I_{D1} R_D = 10 - (0.3m)(16k) = 5.2}$ **V** **[2]**

$\boldsymbol{v_{CM}}$ **(max)** $\boldsymbol{= V_{S1}(\text{max}) + V_{GS1} = (v_{O1} - V_{DS1}(\text{sat})) + V_{GS1} = v_{O1} - (V_{GS1} - V_{TN}) + V_{GS1}}$ **[1]**

$\boldsymbol{v_{CM}}$ **(max)** $\boldsymbol{= v_{O1} + V_{TN} = 5.2 + 1 = 6.2}$ **V** **[1]**

$\boldsymbol{v_{CM}}$ **(min)** $\boldsymbol{= V_{S1}(\text{min}) + V_{GS1} = (V^- + V_{DS4}(\text{sat})) + V_{GS1} = V^- + (V_{GS4} - V_{TN}) + V_{GS1}}$ **[1]**

$$V_{GS4} = \sqrt{\frac{I_Q}{K_{n4}}} + V_{TN} = \sqrt{\frac{0.6m}{0.3m}} + 1 = 2.414\text{V} \quad [1]$$

$\boldsymbol{v_{CM}}$ **(min)** $\boldsymbol{= (-10) + 2.414 - 1 + 2.732 = -5.854}$ **V** **[1]**

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Question:

Consider the **MOSFET differential amplifier** in **Figure 1**. Constant current in the current source is $\boldsymbol{I_1 = 0.62}$ **mA**. The transistor parameters are: $\boldsymbol{K_{n1} = K_{n2} = 0.1}$ **mA/V**^{2}, $\boldsymbol{K_{n3} = K_{n4} = 0.3}$ **mA/V**^{2}, and for all transistors $\boldsymbol{\lambda = 0}$ and $\boldsymbol{V_{TN} = 1}$ **V.**
The maximum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(max)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$ reach the saturation point, while the minimum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(min)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_4}$ reaches the saturation point.
Determine the maximum range of common-mode input voltage, i.e. find $\boldsymbol{v_{CM}}$ **(max)** and $\boldsymbol{v_{CM}}$ **(min)**.
[10 marks]

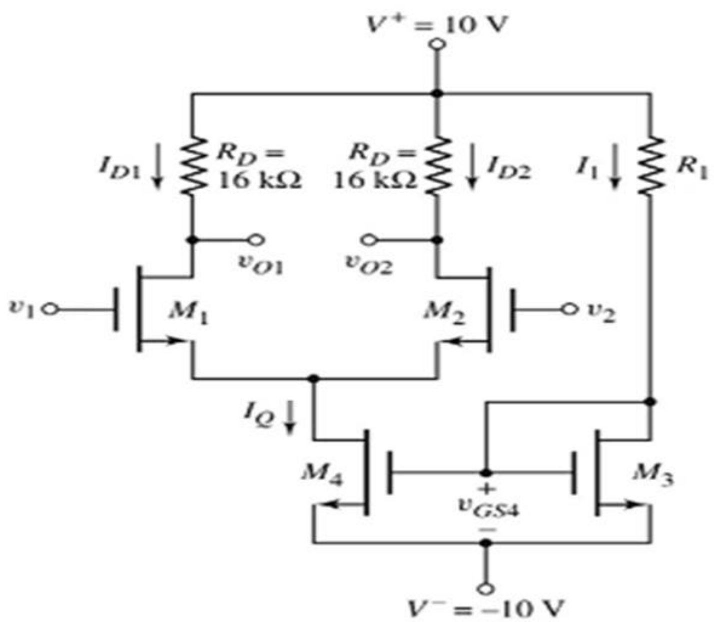

Figure 1

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

; Small signal

DQ

Answer:

$\boldsymbol{I_Q = I_1 = 0.62}$ **mA,** $\boldsymbol{I_{D1} = I_Q / 2 = 0.31}$ **mA** **[2]**

$$V_{GS1} = \sqrt{\frac{I_{D1}}{K_{n1}}} + V_{TN} = \sqrt{\frac{0.31m}{0.1m}} + 1 = 2.76\text{V} \quad [1]$$

$\boldsymbol{v_{O1} = V^+ - I_{D1} R_D = 10 - (0.31m)(16k) = 5.04}$ **V** **[2]**

$\boldsymbol{v_{CM}}$ **(max)** $\boldsymbol{= V_{S1}(\text{max}) + V_{GS1} = (v_{O1} - V_{DS1}(\text{sat})) + V_{GS1} = v_{O1} - (V_{GS1} - V_{TN}) + V_{GS1}}$ **[1]**

$\boldsymbol{v_{CM}}$ **(max)** $\boldsymbol{= v_{O1} + V_{TN} = 5.04 + 1 = 6.04}$ **V** **[1]**

$\boldsymbol{v_{CM}}$ **(min)** $\boldsymbol{= V_{S1}(\text{min}) + V_{GS1} = (V^- + V_{DS4}(\text{sat})) + V_{GS1} = V^- + (V_{GS4} - V_{TN}) + V_{GS1}}$ **[1]**

$$V_{GS4} = \sqrt{\frac{I_Q}{K_{n4}}} + V_{TN} = \sqrt{\frac{0.62m}{0.3m}} + 1 = 2.437\text{V} \quad [1]$$

$\boldsymbol{v_{CM}}$ **(min)** $\boldsymbol{= (-10) + 2.437 - 1 + 2.76 = -5.803}$ **V** **[1]**

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Question:

Consider the **MOSFET differential amplifier** in **Figure 1**. Constant current in the current source is $\boldsymbol{I_1 = 0.64}$ **mA**. The transistor parameters are: $\boldsymbol{K_{n1} = K_{n2} = 0.1}$ **mA/V**^{2}, $\boldsymbol{K_{n3} = K_{n4} = 0.3}$ **mA/V**^{2}, and for all transistors $\boldsymbol{\lambda = 0}$ and $\boldsymbol{V_{TN} = 1}$ **V.**
The maximum common-mode input voltage, v_{CM} **(max)**, is defined as the voltage at the input v_1 when M_1 and M_2 reach the saturation point, while the minimum common-mode input voltage, v_{CM} **(min)**, is defined as the voltage at the input v_1 when M_4 reaches the saturation point.
Determine the maximum range of common-mode input voltage, i.e. find v_{CM} **(max)** and v_{CM} **(min)**.
[10 marks]

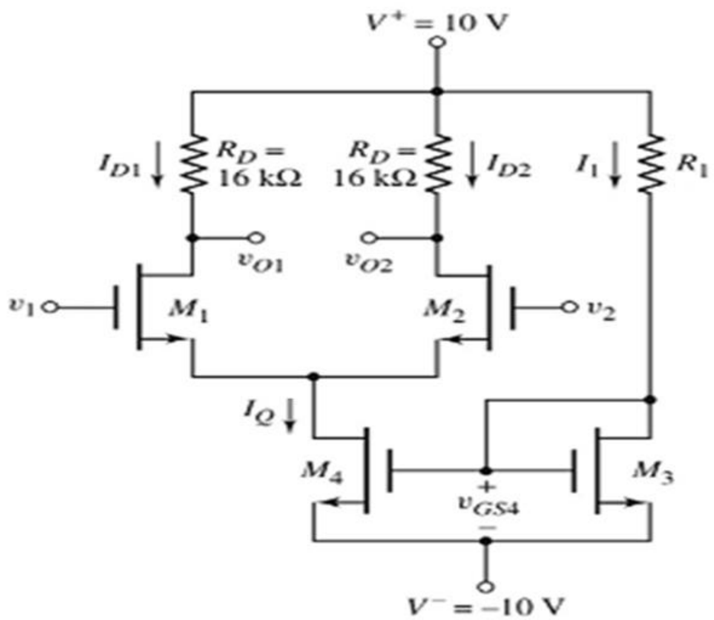

Figure 1

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

; Small signal

Answer:

$\boldsymbol{I_Q = I_1 = 0.64}$ **mA,** $\boldsymbol{I_{D1} = I_Q / 2 = 0.32}$ **mA** [2]

$$V_{GS1} = \sqrt{\frac{I_{D1}}{K_{n1}}} + V_{TN} = \sqrt{\frac{0.32m}{0.1m}} + 1 = 2.788\text{V}$$ [1]

$\boldsymbol{v_{O1} = V^+ - I_{D1} R_D = 10 - (0.32m)(16k) = 4.88}$ **V** [2]

$\boldsymbol{v_{CM}(\max) = V_{S1}(\max) + V_{GS1} = (v_{O1} - V_{DS1}(\text{sat})) + V_{GS1} = v_{O1} - (V_{GS1} - V_{TN}) + V_{GS1}}$ [1]

$\boldsymbol{v_{CM}(\max) = v_{O1} + V_{TN} = 4.88 + 1 = 5.88}$ **V** [1]

$\boldsymbol{v_{CM}(\min) = V_{S1}(\min) + V_{GS1} = (V^- + V_{DS4}(\text{sat})) + V_{GS1} = V^- + (V_{GS4} - V_{TN}) + V_{GS1}}$ [1]

$$V_{GS4} = \sqrt{\frac{I_Q}{K_{n4}}} + V_{TN} = \sqrt{\frac{0.64m}{0.3m}} + 1 = 2.461\text{V}$$ [1]

$\boldsymbol{v_{CM}(\min) = (-10) + 2.461 - 1 + 2.788 = -5.751}$ **V** [1]

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Question:

Consider the **MOSFET differential amplifier** in **Figure 1**. Constant current in the current source is $\boldsymbol{I_1 = 0.66}$ **mA**. The transistor parameters are: $\boldsymbol{K_{n1} = K_{n2} = 0.1}$ **mA/V²**, $\boldsymbol{K_{n3} = K_{n4} = 0.3}$ **mA/V²**, and for all transistors $\boldsymbol{\lambda = 0}$ and $\boldsymbol{V_{TN} = 1}$ **V.**
The maximum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(max)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$ reach the saturation point, while the minimum common-mode input voltage, $\boldsymbol{v_{CM}}$ **(min)**, is defined as the voltage at the input $\boldsymbol{v_1}$ when $\boldsymbol{M_4}$ reaches the saturation point.
Determine the maximum range of common-mode input voltage, i.e. find $\boldsymbol{v_{CM}}$ **(max)** and $\boldsymbol{v_{CM}}$ **(min)**.
[10 marks]

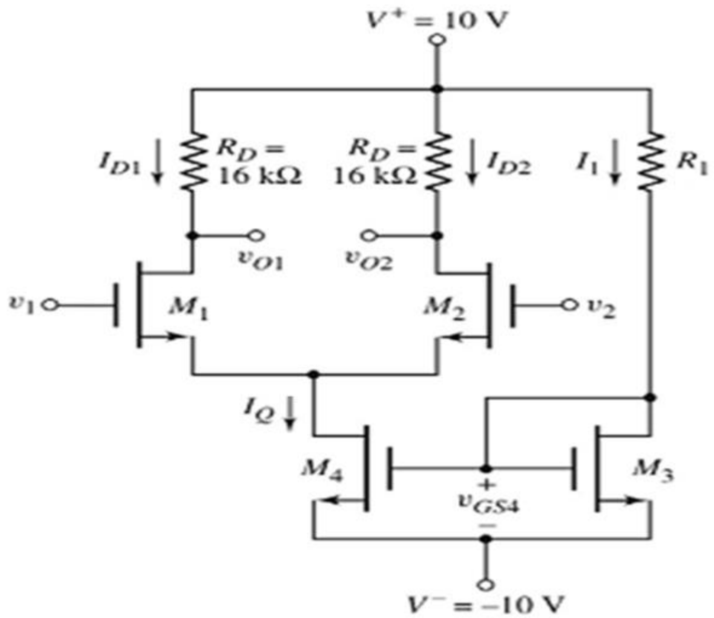

Figure 1

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

; Small signal

Answer:

$\boldsymbol{I_Q = I_1 = 0.66}$ **mA,** $\boldsymbol{I_{D1} = I_Q / 2 = 0.33}$ **mA** [2]

$$V_{GS1} = \sqrt{\frac{I_{D1}}{K_{n1}}} + V_{TN} = \sqrt{\frac{0.33m}{0.1m}} + 1 = 2.816\text{V} \quad [1]$$

$\boldsymbol{v_{O1} = V^+ - I_{D1} R_D = 10 - (0.33m)(16k) = 4.72}$ **V** [2]

$\boldsymbol{v_{CM}\,(max) = V_{S1}(max) + V_{GS1} = (v_{O1} - V_{DS1}(sat)) + V_{GS1} = v_{O1} - (V_{GS1} - V_{TN}) + V_{GS1}}$ [1]

$\boldsymbol{v_{CM}\,(max) = v_{O1} + V_{TN} = 4.72 + 1 = 5.72}$ **V** [1]

$\boldsymbol{v_{CM}\,(min) = V_{S1}(min) + V_{GS1} = (V^- + V_{DS4}(sat)) + V_{GS1} = V^- + (V_{GS4} - V_{TN}) + V_{GS1}}$ [1]

$$V_{GS4} = \sqrt{\frac{I_Q}{K_{n4}}} + V_{TN} = \sqrt{\frac{0.66m}{0.3m}} + 1 = 2.483\text{V} \quad [1]$$

$\boldsymbol{v_{CM}\,(min) = (-10) + 2.483 - 1 + 2.816 = -5.701}$ **V** [1]