The goal of this assignment is to test your concept and knowledge of:
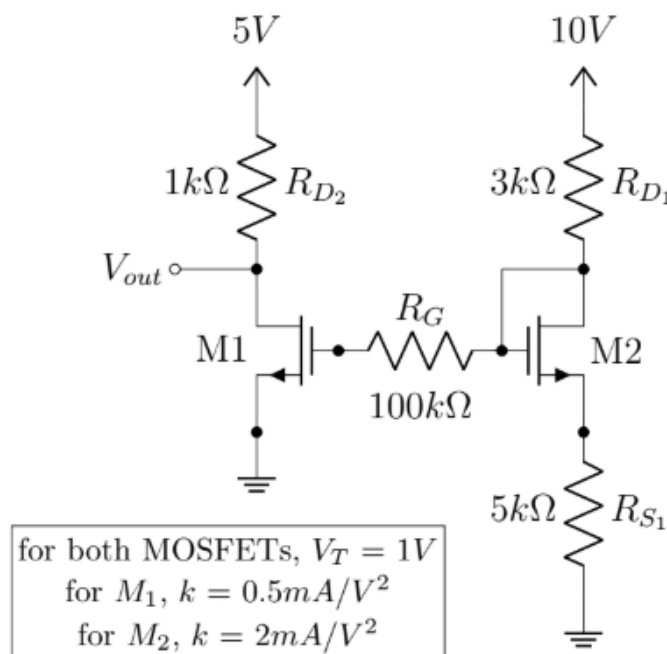- MOSFET Circuits
- MOSFET Logic Gates

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1. [5 marks] Analyze the circuit in the figure and answer the following questions:

(i) Show that, if the MOSFET, M2 conducts current, it will operate in the saturation mode. [Hint: You don't need to solve the circuit]

(ii) Calculate the values of Vout, I_{RD1}, and I_{RD2} using the method of assuming states. You must validate your assumptions.
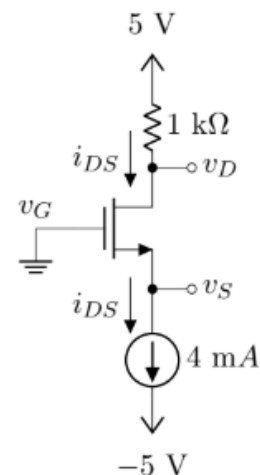

for both MOSFETs, $V_T = 1V$
for M_1, $k = 0.5mA/V^2$
for M_2, $k = 2mA/V^2$

2. [3 marks] Implement the following logic functions using MOSFETs where A, B, C, D, E are boolean inputs.

(i) $f = \overline{A.B.C + D.E}$ (ii) $g = A.B.(C + D)$

3.[5 marks] Analyze the circuit to find v_S. Here, use the Method of Assumed State. You must validate your assumptions. [Hint: assume v_S = x]

VT=1

k=4mA/V^2

4. [7 marks]

Joy and Nirmol were designing an inverter circuit with MOSFET for their project. Joy designed the following circuit. However, Nirmol said that the designed inverter circuit would malfunction. When they tested the circuit, it malfunctioned. For logic HIGH input, the output was also logic HIGH instead of logic LOW. Nirmol modified the value of R_D to a larger value, and eventually it fixed the issue.
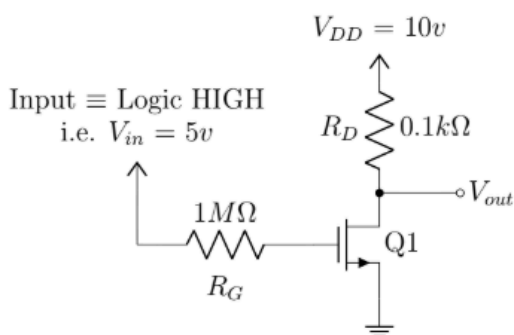
For Input	
Voltage Level	Logic Level
$V_{in} = 0v$	LOW i.e. '0'
$V_{in} = 5v$	HIGH i.e. '1'

For Output	
Voltage Level	Logic Level
$V_{out} > 5v$	HIGH i.e. '1'
$V_{out} < 5v$	LOW i.e. '0'

MOSFET Equations

Cut-off Mode

$I_{DS} = 0$

Triode Mode

$I_{DS} = k \left[V_{OV} V_{DS} - \frac{1}{2} V_{DS}^2 \right]$

Saturation Mode

$I_{DS} = \frac{1}{2} k V_{OV}^2$

MOSFET Parameters

$V_T = 1v, \; K = 4mA/v^2$

Inverter Circuit of Joy and It's Corresponding Voltage Level, Logic Level

(a) [CO1] **State** the conditions to verify the assumptions regarding the Saturation Mode of a MOSFET.

(b) [CO2] **Analyze** the circuit shown above and **calculate** the value of V_{out} using the method of assumed states. You must **validate** your assumption. **Determine** whether Nirmol was correct or not.

(c) [CO2] Nirmol changed the value of R_D to $1k\Omega$. Now, **Analyze** the modified circuit and **calculate** V_{out}. **Determine** whether the the inverter was working properly after the modification.

(d) [CO3] **Design** the inverter circuit by choosing a suitable value of R_D such that, the MOSFET operates at the edge of saturation. [Hint: At the edge of saturation, $V_{DS} = V_{OV}$]