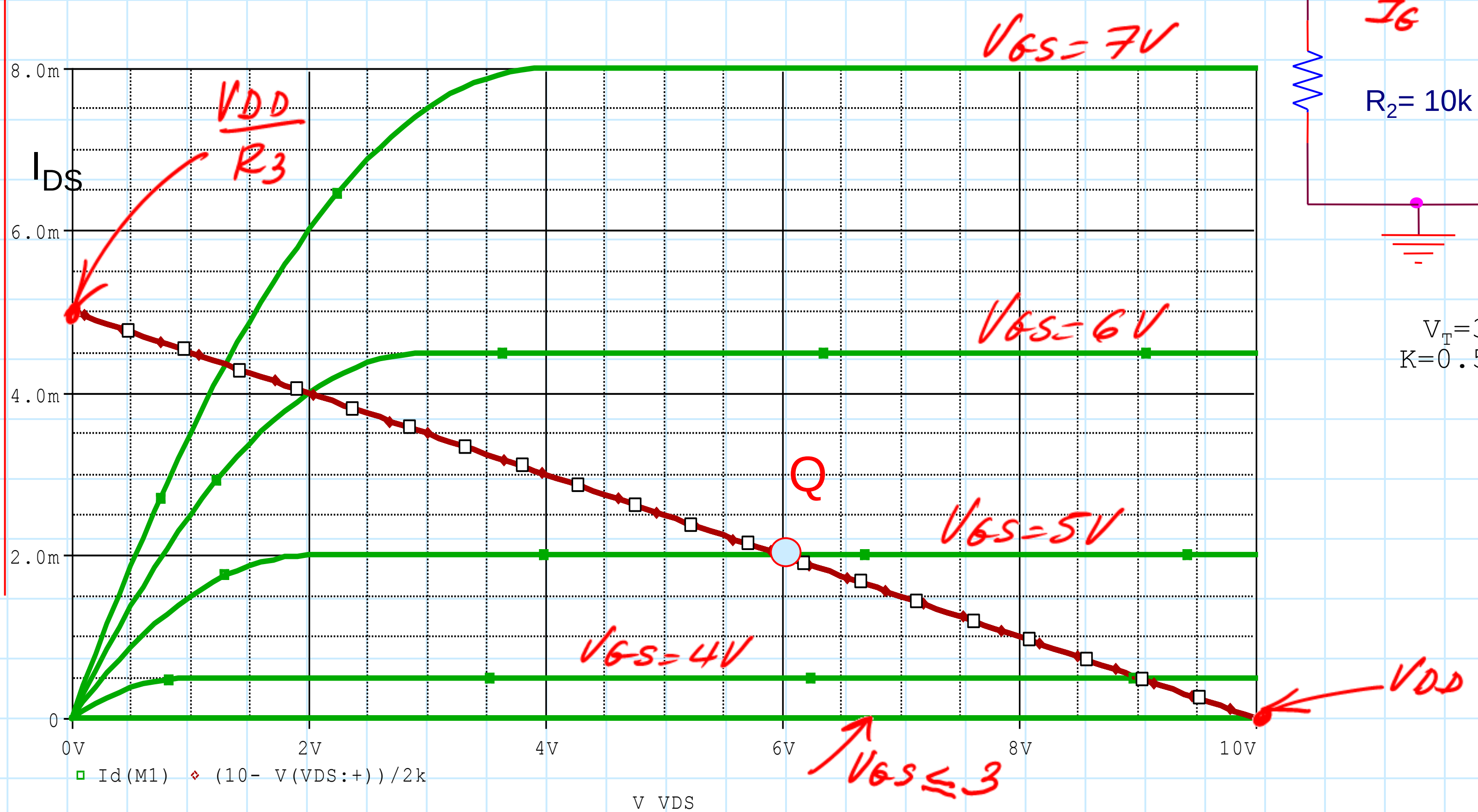
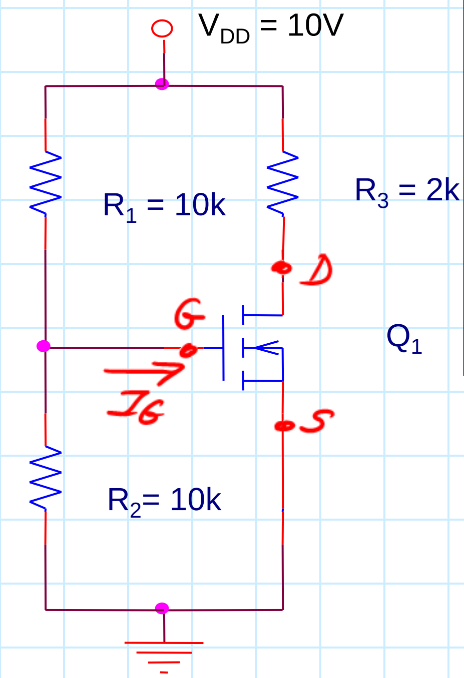
The load line

$V_{GS} = V_{DD} \frac{R_2}{R_1 + R_2} = 5V$

Load line: $\mathbf{V_{DS} = V_{DD} - I_{DS} \times R_D}$

The quiescent point (Q) is determined by intersecting the characteristic curve of MOSFET and the load line.



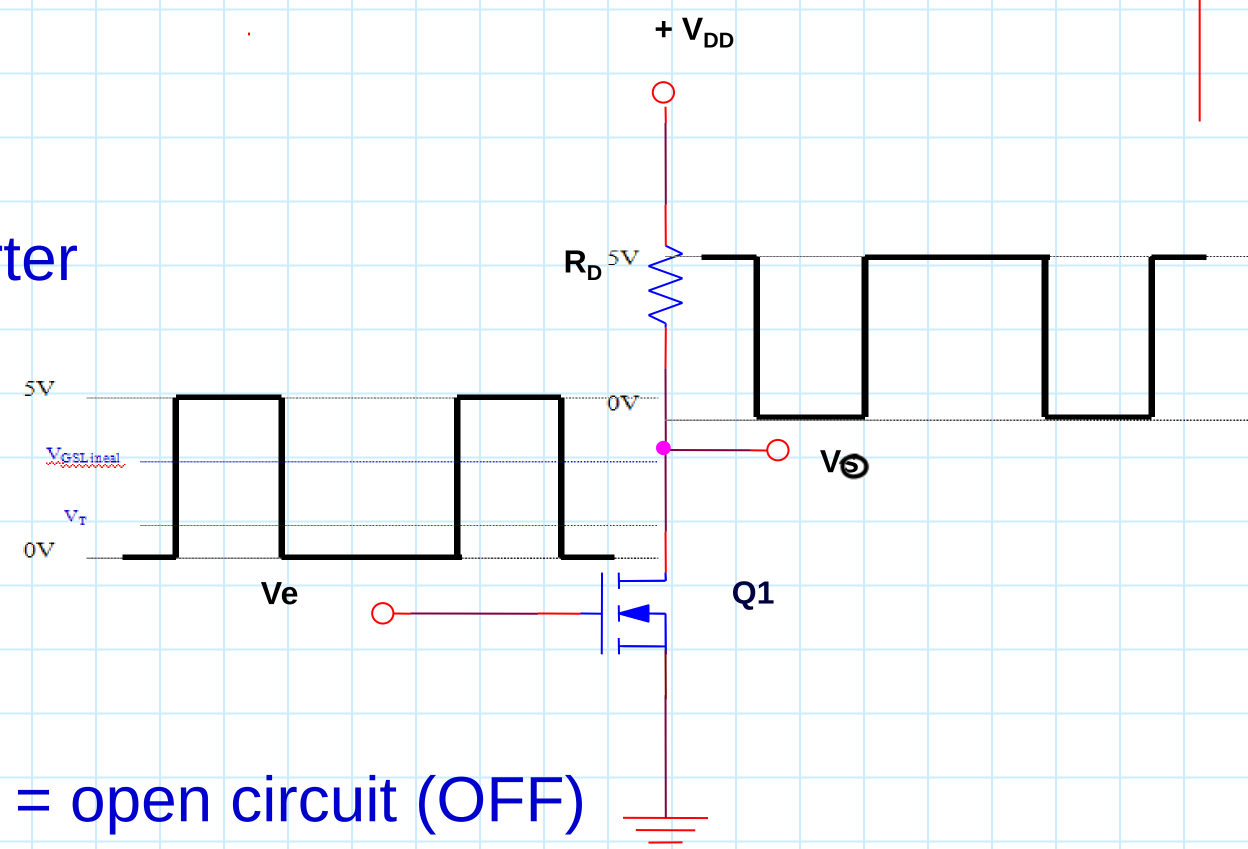


V_T=3V
K=0.5mA/V^2

2.3 The MOSFET in switching mode

- The transistor operates between cut-off and linear regions

NMOS inverter



$Ve = V_{GS}$

Two state:

$Ve < V_T$ → Mosfet = open circuit (OFF)

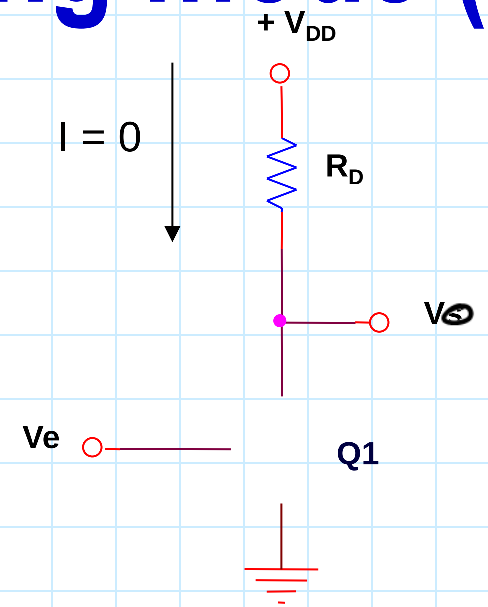
$Ve = V_{DD}$ → Mosfet ≈ R_{on} (very low resistance - ideally a closed switch-ON)

The MOSFET in switching mode (2)

$Ve = V_{GS}$

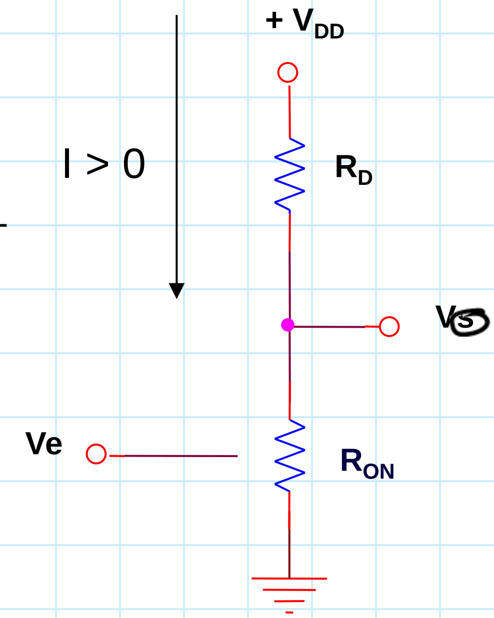
Two state:

- $Ve < V_T \rightarrow$ Cut-off $\rightarrow V_{OH} = V_{DD} =$ “1”



- $Ve = V_{DD} \rightarrow$ Mosfet $\approx R_{on}$

$$R_{ON} \approx \frac{1}{2 \cdot K(V_{GS} - V_T)} \; ; \; V_{OL} = V_{DD} \times \frac{R_{ON}}{R_D + R_{ON}}$$

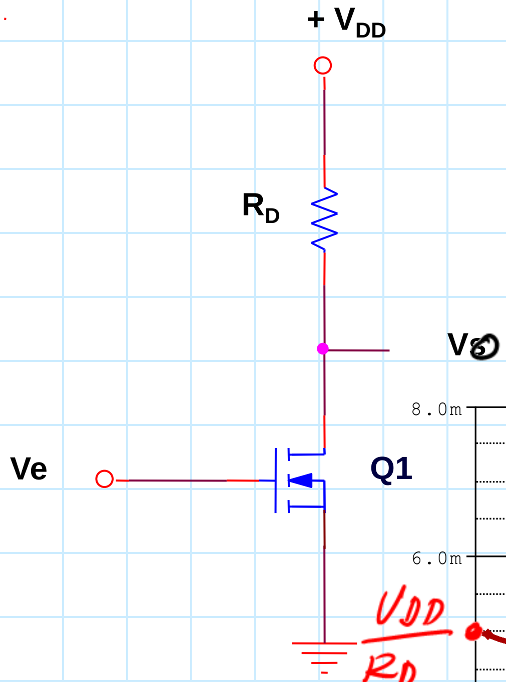


if $R_{on} << R_D \rightarrow V_{OL} \approx 0V =$ “0”

There is static power consumption (I > 0)

The MOSFET in switching mode (3)

NMOS inverter:



Load line= Loop D-S equation (output loop)

$V_{DD} = I_D R_D + V_{DS}$

$R_D \uparrow \Rightarrow$ Better V_{OL}

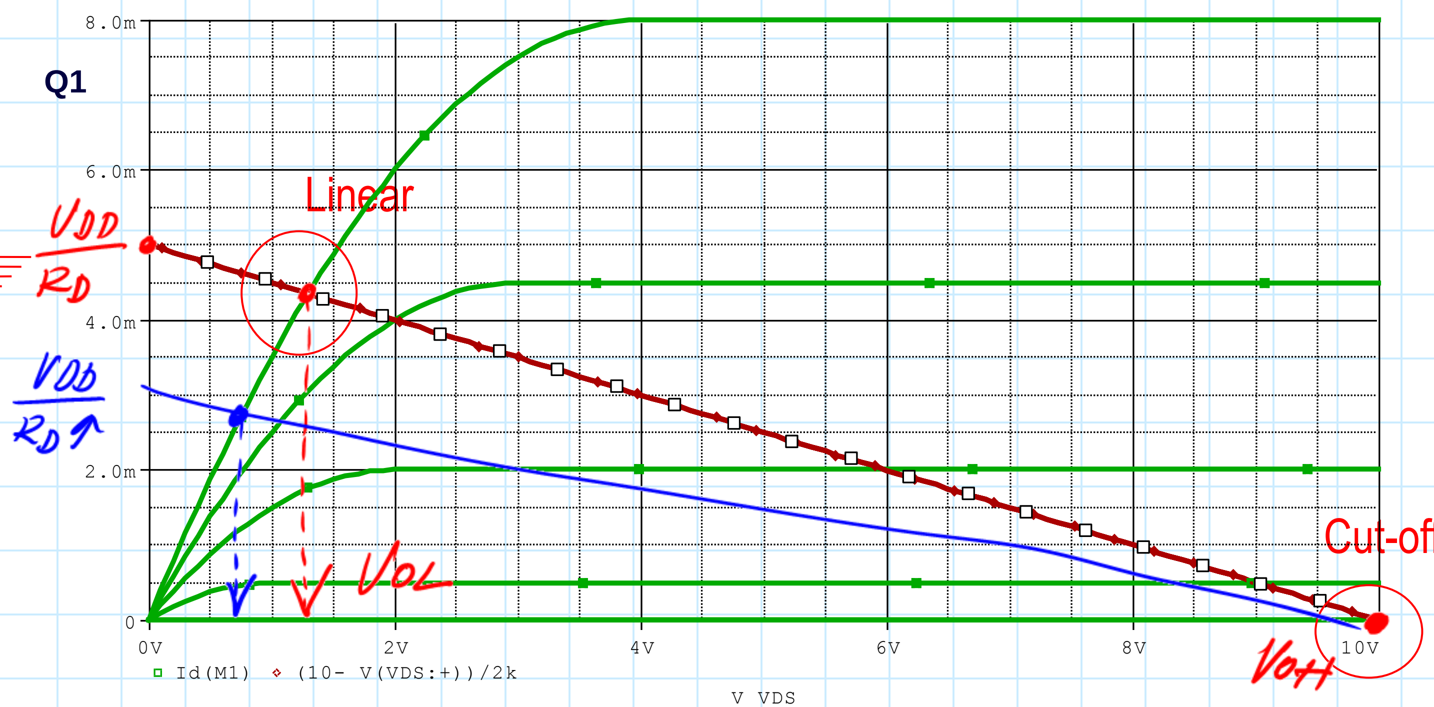
BUT

Less speed

Intersection points:

Vertical axis→ $I_D = V_{DD}/R_D$

Horizontal axis→ $V_{DS} = V_{DD}$



The MOSFET in switching mode (4)

Example:

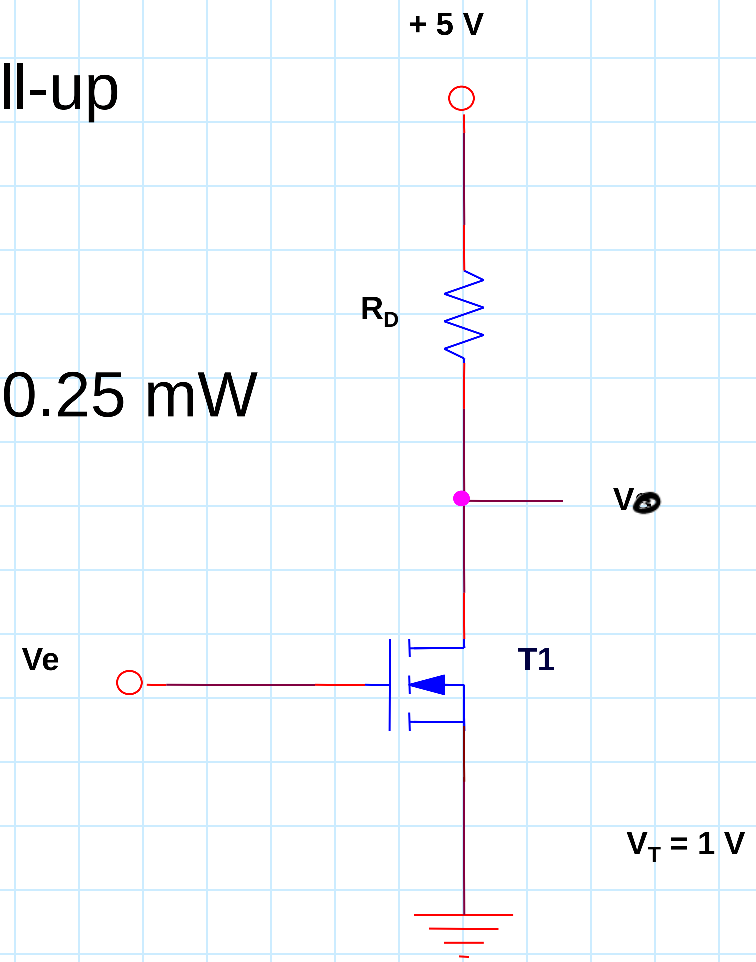
Design an NMOS inverter with pull-up resistor

Data:

Power consumption at low level = 0.25 mW

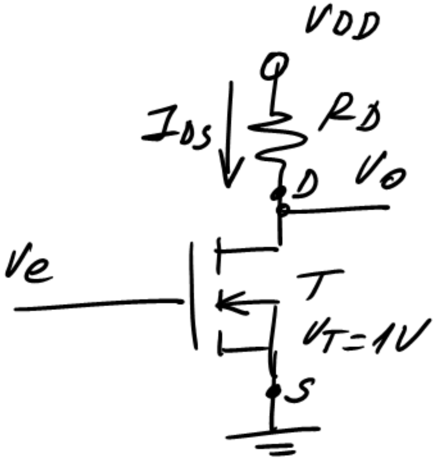
V_{OL} = 0.5V, V_{OH} = V_{DD} = 5V

Transistor: V_T = 1V



Find out R_{on} and K

Design exercise



$V_{OL} = 0.5V$

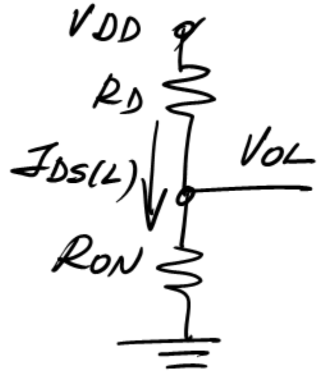
$V_{OH} = V_{DD} = 5V$

$P_L = 0.25mW$

LOW LEVEL: $V_O = V_{DS} = V_{OL} = 0.5V$

$P_L = V_{DD} \cdot I_{DS(L)}$; $I_{DS(L)} = \dfrac{P_L}{V_{DD}} = \dfrac{0.25}{5} = 0.05mA$

$$\boxed{R_D = \frac{V_{DD} - V_{OL}}{I_{DS(L)}} = \frac{5 - 0.5}{0.05} = 90K}$$



$$R_{ON} = \frac{V_{OL}}{I_{DS(L)}} = \frac{0.5}{0.05} = 10K$$

$$R_{ON} = \frac{1}{2K(V_{GS} - V_T)} \Rightarrow K = \frac{1}{2R_{ON}(V_{GS} - V_T)}$$

$V_{GS} = 5V \Rightarrow$

$$\boxed{K = \frac{1}{2 \cdot 10 \cdot (5-1)} = 12.5\,\mu A/V^2}$$