MOSFET EXERCISES 2017-08-31

1. a) A MOSFET delivers a maximum current of 500 μA/μm at a supply voltage of 1 V. What would be the effective resistance $R_{eff}=V_{DD}/I_{DSAT,max}$ of a 1 mm wide MOSFET?

   b) What if the MOSFET is 5 μm wide. How much current would it be able to deliver and what would be its effective resistance?

   c) What if the MOSFET was 280 nm wide, what would be its maximum current and what would be its effective resistance?

2. a) Calculate the gate capacitance for a 1 mm wide MOSFET in the 65 nm CMOS process if the effective channel length is 60 nm and if the MOS capacitance per unit area is given as 20 fF/μm^2?

   b) What would be the gate capacitance of a 5 μm wide MOSFET if the channel length is 45 nm and C_{ox} is 10 fF/μm^2?

   c) Calculate the gate capacitance for the device above if its channel width is 280 nm!

3. a) The figure shows the regions of operation for an n-channel MOSFET. What are the borderline equations?

   b) Draw the corresponding diagram for a p-channel MOSFET!

4. The model parameters k and V_T for a certain MOSFET technology are given by k=900 μA/V^2 and V_T=0.3 V.

   a) Calculate the gate voltage overdrive V_{GT} if the supply voltage is 1.2 V!

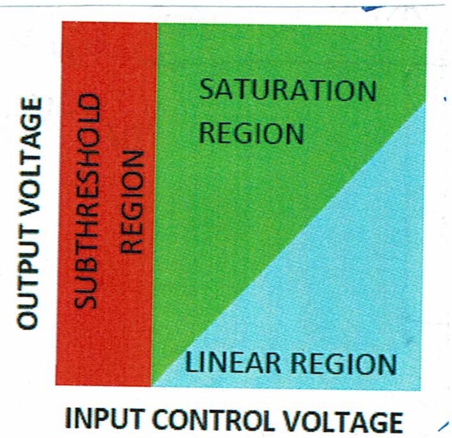
   b) Calculate the saturation current when the gate voltage is equal to the supply voltage, i.e. $V_{GS}=V_{DD}$.

   c) Calculate the saturation voltage, V_{DSAT}, according to the classic square-law MOSFET model. What is the corresponding saturation voltage in the piecewise linear model?

5. Discuss qualitatively why it is not such a good idea to use n-channel devices in pull-up networks.

   a) Quantify using MOSFET square-law model equations!

   b) Discuss the corresponding problem why it is not such a good idea using p-channel devices in the pull-down networks, and quantify using MOSFET square-law model equations!



SOLUTIONS MOS EXERCISE

1 a) $W = 1\,mm$ $I_{max} = 500\,mA = 0.5\,A$ $R_{eff} = 2\Omega$

b) $W = 5\,\mu m$ $I_{max} = 2500\,\mu A = 2.5\,mA$ $R_{eff} = 400\,\Omega$

c). $W = 280\,nm$ $I_{max} = 500 \times 0.280 = 140\,\mu A$ $R_{eff} = 7\,k\Omega$

2. a) $W = 1\,mm$ $C_G = WLC_{ox} = 1000 \times 0.060 \times 20 = 1200\,fF = 1.2\,pF$

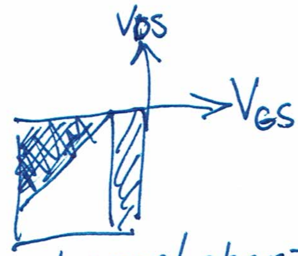
b) $W = 5\,\mu m$; $C_{ox} = 10\,fF/\mu m^2$ $L = 45\,nm$

$C_G = WL\,C_{ox} = 5 \times 0.045 \times 10 = 5 \times 0.45 = 2.25\,fF$

c). $W = 280\,nm$ $C_G = 0.28 \times 0.045 \times 10 = 126\,aF$

3) a $V_{IN} = V_{TN}$; $V_{OUT} = V_{IN} - V_{TN}$

b) $V_{IN} = V_{TP}$ $V_{OUT} = V_{IN} - V_{TP}$



p-channel chart

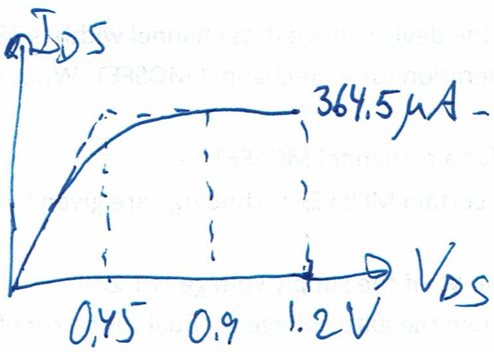
4. $k = 900\,\mu A/V^2$ $V_T = 0.3\,V$

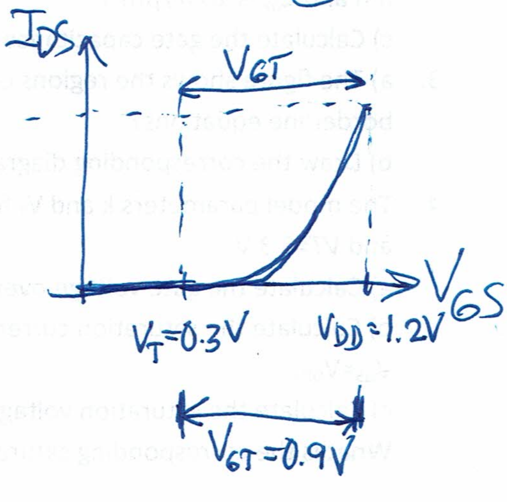
a) $V_{GT} = V_{GS} - V_{TN} = 1.2 - 0.3 = 0.9\,V$

b) $I_{DSAT} = \frac{k}{2} V_{GT}^2 = \frac{900}{2} \times 0.9^2 = 364.5\,\mu A$

c). $V_{DSAT} = V_{GT} = 0.9\,V$

piecewise linear model $V_{DSAT} = \frac{V_{GT}}{2} = 0.45\,V$.

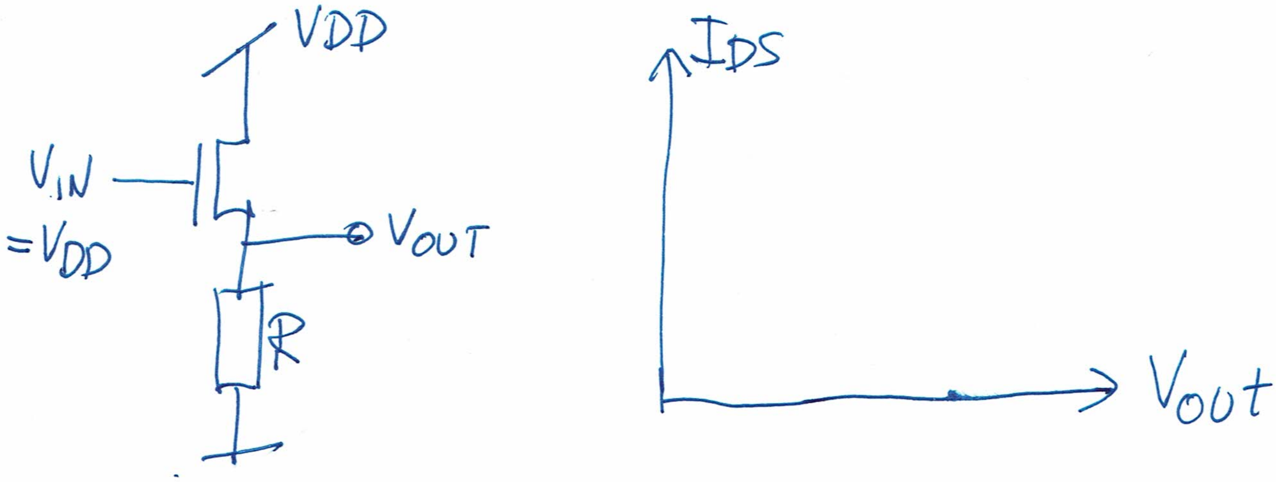




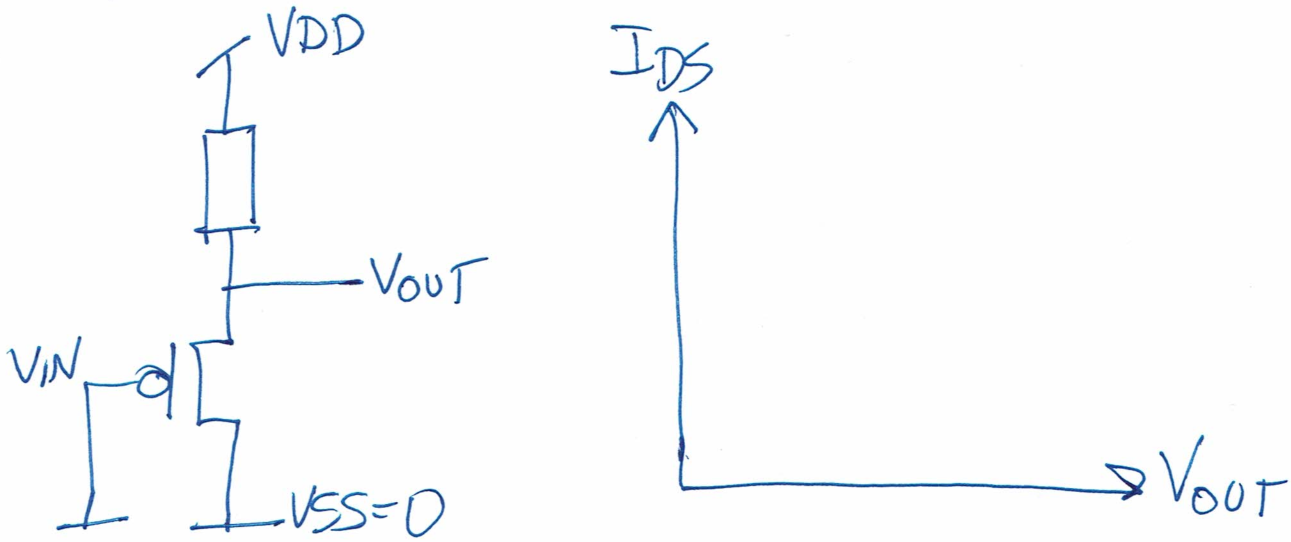
SOLUTIONS: 2 MOSFET EXERCISE

5. Analyze the following situations:

a) n-channel MOSFET as pull-up device



b) p-channel as pull-down device



Suggestion: start by identifying what is MOSFET source and drain.

First approach: check if devices are saturated or not!