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EPE 2165—Analog Electronics

HOMEWORK #3—MOSFETs

Question:	1	2	3	4	5	6	Total
Points:	20	10	20	10	20	20	100
Score:							

Issued on: *June 29, 2022*
Due on: July 7, 2022

1. An NMOS transistor that is operated with a small v_{DS} is found to exhibit a resistance r_{DS}. By what factor will r_{DS} change in each of the following situations?

   (a) (5 points) v_{OV} is doubled.

   (b) (5 points) The device is replaced with another fabricated in the same technology but with double the width.

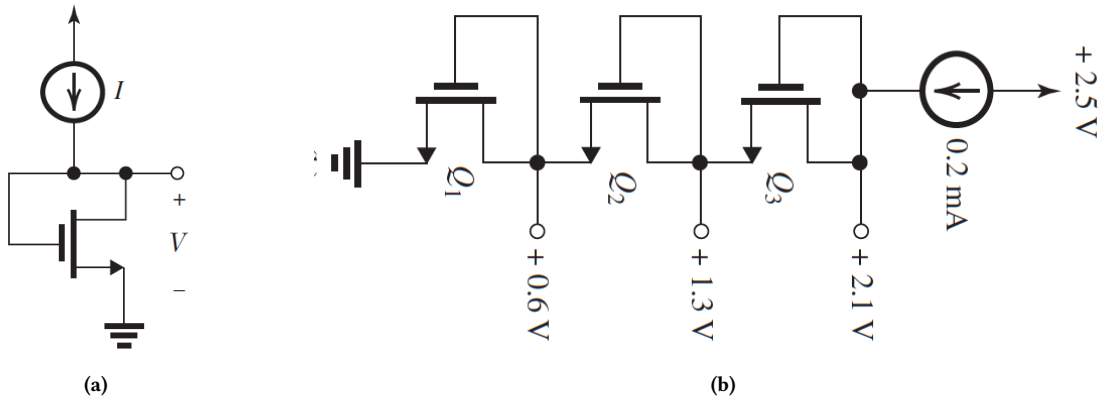
   (c) (5 points) The device is replaced with another fabricated in the same technology but with both the width and length doubled.

   (d) (5 points) The device is replaced with another fabricated in a more advanced technology for which the oxide thickness is halved and similarly for W and L (assume $_n$ remains unchanged)."

2. (10 points) For a particular IC-fabrication process, the transconductance parameter $k' = 400\,\mu A\,V^{-2}$ and $V_t = 0.5V$. In an application in which $v_{GS} = v_{DS} = V_{supply} = 1.8V$, a drain current of 2 mA is required of a device of minimum length of 0.18 $0.18\,\mu m$. What value of channel width must the design use?

3. (a) (10 points) For the circuit shown in Figure 1a, assuming that $\lambda = 0$, show that

$$V = V_t + \sqrt{\frac{2I}{k'_n W/L}} \tag{1}$$



(a) (b)

FIGURE 1

   (b) (10 points) The MOSFETs Figure 1b have $V_t = 0.4V$, $k'_n = 0.4mA/V^2$ and $\lambda = 0$. Find ration W/L of each transistors (Q_1, Q_2 and Q_3) that are required to obtain the reference voltages ($V_1 = +0.6V, V_2 = +1.3V$ and $V_3 = 2.1V$)shown on the circuit.

4. (10 points) Figure 2a has a drain current of 0.1 mA and a drain voltage of $V_D = 0.2V$. The MOSFET has $Vt = 0.2V$, $\mu_n C_{ox} = 400\,\mu A\,V^{-2}$,$L = 0.5\,\mu m$, and $W = 4\,\mu m$. What is the the required values for R_S and R_D? Assume$\lambda = 0$

5. The MOSFET in the circuit of Figure 2b has $V_t = 1V$ and $k_n = 2mA/V^2$, and the Early effect can be neglected.

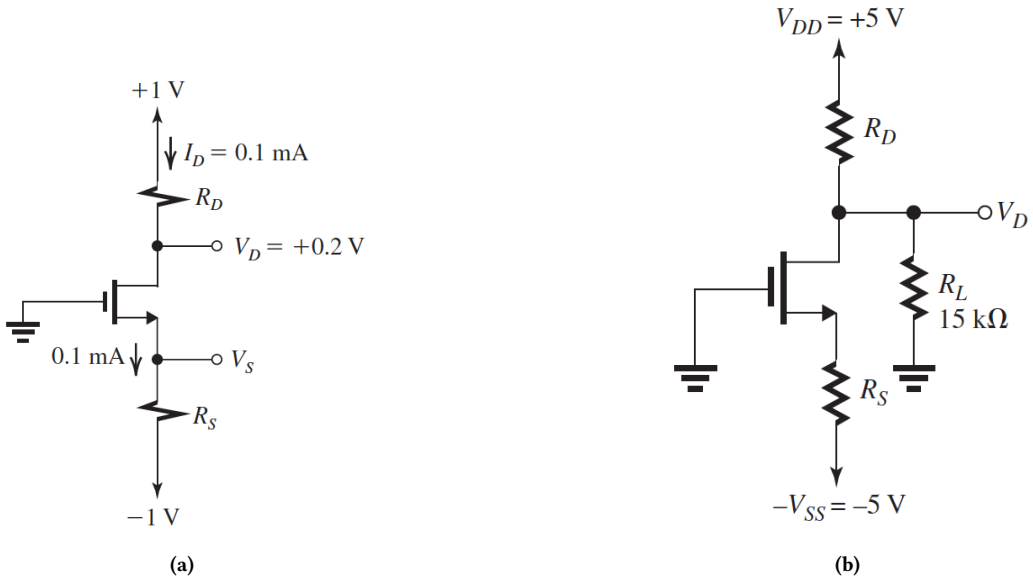


FIGURE 2

(a) (10 points) Find the values of R_S and R_D that result in the MOSFET operating with an overdrive voltage of 0.5V and a drain voltage of 1.5V. What is the resulting I_D value?

(b) (5 points) If R_L is reduced from $15\,\text{k}\Omega$, what does V_D become?

(c) If R_L is disconnected, what does V_D become?

(d) (5 points) With R_L disconnected, what is the largest RD that can be used while the MOSFET is remaining in saturation?

6. The transistors in the circuit of Figure 3 have$k_n = k_p = 2mA/V^2$ and $V_{tn} = -Vtp = 0.4V$. Findv_O for each of the following cases:
   (a) (5 points) $v_I = 0V$
   (b) (5 points) $v_I = 1V$
   (c) (5 points) $v_I = -1V$
   (d) (5 points) $v_I = -2V$

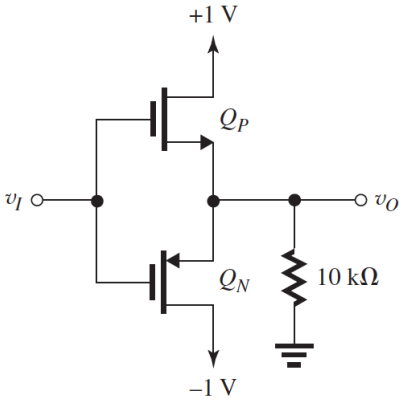


FIGURE 3