EPE2165—Exam #2

August 10, 2022

1. (20 points) The NMOS transistor in Figure 1 has a threshold voltage $V_t = 0.7V$, $\mu_n Cox = 100\,\mu A/V^2$, $L = 1\,\mu m$, and $W = 32\,\mu m$. If the channel-length modulation effect is neglected, calculate the value of R_D and R_S so that the transistor operates with a current $I_D = 0.4\,mA$ at a voltage $V_D = 0.5V$.

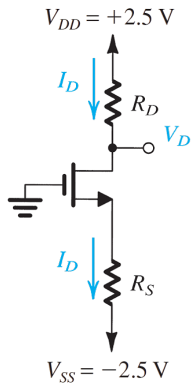


FIGURE 1

Solution:

- The resistor R_D can be calculated with

$$R_D = \frac{V_{DD} - V_D}{I_D} = \frac{2.5V - 0.5V}{0.4} = 5\,k\Omega \tag{1}$$

- The resistor R_S is determined from Equation (2)

$$R_S = \frac{V_S - V_{SS}}{I_D} \tag{2}$$

V_S is unknown at this point. However, it can be computed from V_{GS} and V_{OV} since the transistor is operating in the saturation region (i.e., because $V_D > V_G$). In saturation, the current I_D is given by Equation (3)

$$I_D = \frac{1}{2}\mu_n Cox \frac{W}{L} V_{OV}^2 \tag{3}$$

Consequently, substituting with the known constants, we get (Equation (4))

$$\begin{aligned} 400\,\mu A &= \tfrac{1}{2} 100\,\mu A/V^2 \tfrac{32}{1} V_{OV}^2 \\ &= 1600 V_{OV}^2 \end{aligned} \tag{4}$$

Which implies that (Equation (5))

$$V_{OV}^2 = 0.25V^2 \Leftrightarrow V_{OV} = 0.5V \tag{5}$$

From Equation (5), V_{GS} is given by

$$V_{GS} = V_t + V_{OV} = 0.7V + 0.5V = 1.2V \tag{6}$$

Since $V_G = 0$, the voltage at the source should be instead $V_S = -1.2$. Thus,

$$R_S = \frac{-1.2V + 2.5V}{0.4mA} = 3.25\,\mathrm{k}\Omega \tag{7}$$

2. The BJT in Figure 2 has $\beta = 100$, $V_{CESat} = 0.3V$ and $V_B(on) = 0.7V$. Find V_E, V_C and I_B, I_C and the transistor's mode of operation:

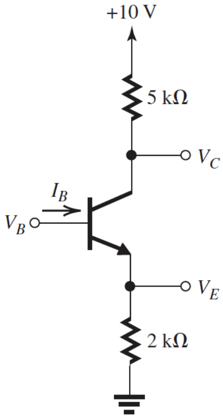
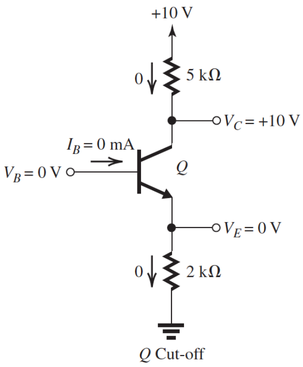


FIGURE 2

(a) (10 points) When $V_B = 0V$

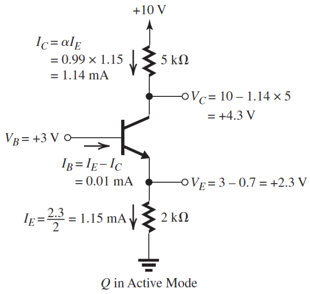
Solution: In this case, the transistor is in cut-off mode. Thus,



- $i_B = I_C = 0$
- $V_E = V_B = 0$
- $V_C = 10V$

(b) (10 points) When $V_B = 3V$

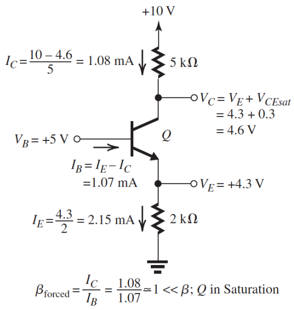
Solution: In this case, the transistor is in the active mode



- $V_E = V_B - V_{on} = 3 - 0.7 = 2.3V$
- $I_E = \frac{V_E}{2k} = \frac{2.3}{2k} = 1.15mA$
- $I_C = \alpha I_E = 0.99 \times 1.15 = 1.14mA$
- $I_B = I_E - I_C = 0.01mA$
- $V_C = 10V - I_C R_C = 4.3V$

(c) (10 points) When $V_B = 5V$

Solution: If we apply the same approach as in (b) above (and assume that the transistor is in active mode), we would notice that $I_C < 0$, which is not possible. Thus, the transistor must be in the saturation mode. In this case:



- $V_E = 4.3V$
- $I_E = 4.3/2 = 2.15mA$
- $V_C = V_E + V_{CESat} = 4.3 + 0.3V = 4.6V$
- $I_C = \frac{10V - 4.6V}{5} = 1.08mA$
- $I_B = I_E - I_C = 1.07mA$