

EE3122 Analogue Circuit Fundamentals Tutorial 4

Q1.(a) Assume Q is active

$$V_E = V_{EB} + V_B = 0.7 + 1 = 1.7 \text{ V}$$

$$I_E = \frac{V_{CC} - V_E}{R_E} = \frac{6 - 1.7}{10k} = 0.43 \text{ mA}$$

$$I_C \approx I_E$$

$$\therefore V_C = I_C R_C = 0.43 \text{ mA} \times 10k = 4.3 \text{ V}$$

As $V_C > V_B$, the device will be saturated.
 $\Rightarrow$ Assumption is invalid.

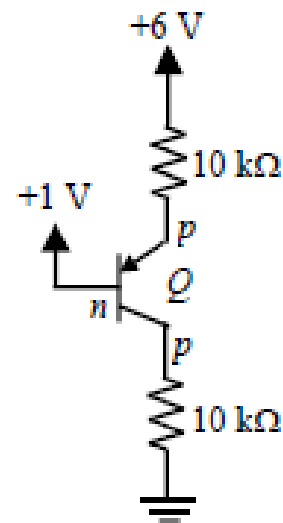
With $V_{CE(SAT)} \approx 0.3 \text{ V}$, $V_{EB} = 0.7 \text{ V}$

$$V_E = V_{EB} + V_B = 0.7 + 1 = 1.7 \text{ V}$$

$$V_C = V_E - V_{CE(SAT)} = 1.7 - 0.3 = 1.4 \text{ V}$$

$$I_C = \frac{V_C}{R_C} = \frac{1.4}{10k} = 0.14 \text{ mA}$$

$$I_B = I_E - I_C = 0.43 - 0.14 = 0.29 \text{ mA}$$



(b) Assume Q is active

$$V_E = V_B - V_{BE} = -20 - 0.7 = -20.7 \text{ V}$$

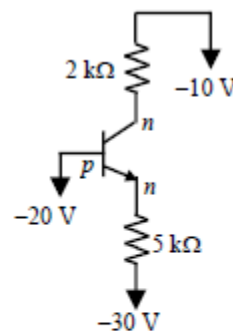
$$I_E = \frac{V_E - V_{EE}}{R_E} = \frac{-20.7 - (-30)}{5k} = 1.86 \text{ mA}$$

$$I_C = \left(\frac{\beta}{\beta + 1} \right) I_E = \frac{100}{101} \times 1.86 = 1.84 \text{ mA}$$

$$I_B = \frac{I_C}{\beta} = \frac{1.84 \text{ mA}}{100} = 0.0184 \text{ mA} = 18.4 \mu\text{A}$$

$$V_C = V_{CC} - I_C R_C = -10 - 1.84 \text{ mA} \times 2k = -13.68 \text{ V}$$

As $V_C > V_B$, Q is indeed active.



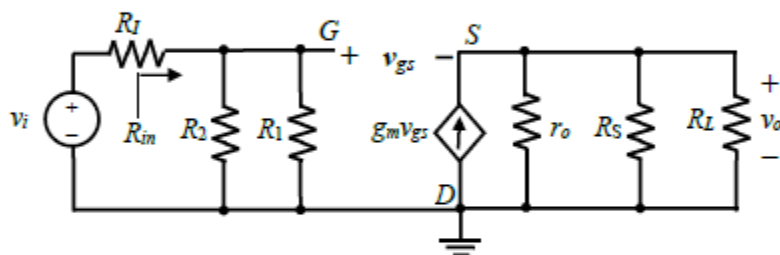
Q2. Here, we approximate r_o but exact calculation including V_{DS} is fine, of course.

$$g_m = \sqrt{2K_n I_D} = \sqrt{2 \times 0.001 \times 1.87m} = 1.93mS$$

$$r_o \cong \frac{1}{\lambda I_D} = \frac{1}{0.02 \times 1.87m} = 26.7k\Omega \gg R_S$$

Note: $g_m \approx \sqrt{2K_n I_D}$ and $r_o \approx \frac{1}{\lambda I_D}$ if $\lambda V_{DS} \ll 1$

Small signal equivalent circuit:



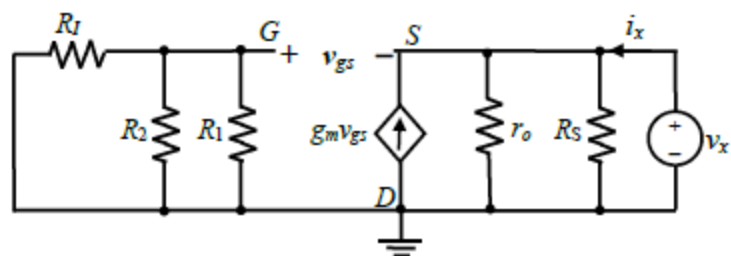
$$R_{in} = R_1 \parallel R_2 = 1.2M \parallel 910k = 517.54k\Omega$$

$$A_{vt} = \frac{v_s}{v_g} = \frac{g_m v_{gs} (r_o \parallel R_S \parallel R_L)}{v_{gs} + g_m v_{gs} (r_o \parallel R_S \parallel R_L)} = \frac{g_m (r_o \parallel R_S \parallel R_L)}{1 + g_m (r_o \parallel R_S \parallel R_L)}$$

$$= \frac{1.93m (26.7k \parallel 3k \parallel 250)}{1 + 1.93m (26.7k \parallel 3k \parallel 250)} = 0.31$$

$$A_v = \left(\frac{R_{in}}{R_{in} + R_I} \right) A_{vt} = \frac{517.54k}{517.54k + 100} \times 0.31 = 0.31$$

Output resistance:



$$g_m v_{gs} + i_x = \frac{v_x}{r_o \parallel R_S}$$

$$\therefore v_{gs} = -v_x,$$

$$i_x = \frac{v_x}{r_o \parallel R_S} + g_m v_x = \left(\frac{1}{r_o \parallel R_S} + g_m \right) v_x$$

$$R_{out} = \frac{v_x}{i_x} = r_o \parallel R_S \parallel \frac{1}{g_m} = 26.7k \parallel 3k \parallel \frac{1}{1.93m} = 434.6\Omega$$