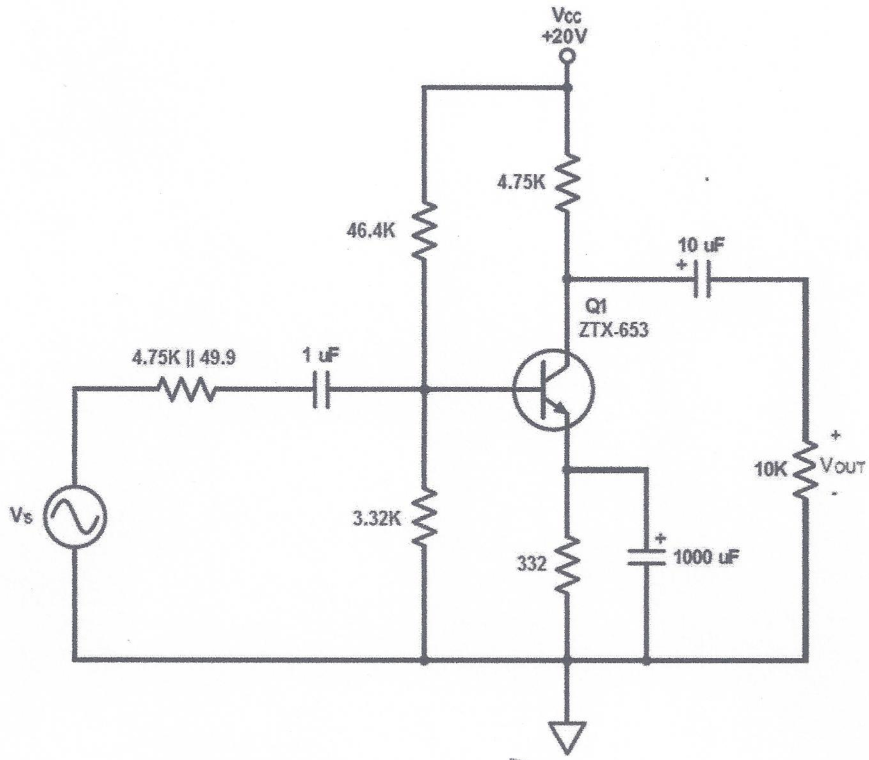
BME-ISE 3512 • Exam V • 15 April 2020 NAME SOLUTION

Determine the D.C. operating point of the following circuit (I_C and V_{CE}) if base current may be assumed negligible. Check P_{diss} and verify that the transistor is operating in the active region.



$$V_B = 20\left(\frac{3.32}{3.32+46.4}\right) = 1.335\,V \quad (+1)$$

$$V_E = V_B - 0.7 = 0.6355\,V \quad (+1)$$

$$I_E = \frac{0.6355}{332} = 0.001914$$

or $1.914\,mA$ (+1)

$$\therefore I_C \approx 1.914\,mA \quad (+1)$$

$$V_C = 20 - 1.914m \cdot 4.75k = 10.91V \quad (+1)$$

$$\therefore V_{CE} = 10.91 - 0.6355 = 10.27\,V \quad (+1)$$

$$P_{diss} = 1.914m \cdot 10.27 = 19.66\,mW \quad (+1)$$

$V_{BE} = 0.7V$
$V_{CE} > 0.2V$

yes, active (+1)

Calculate the parameters g_m, r_b, and r_o if β = 200 and the Early voltage $|V_A|$ is 250 V. Include a unit with each answer.

$g_m = 35 I_C = 35 \cdot 1.914 = 67 \text{ mA/V}$ (+2)

$r_b = \frac{\beta}{g_m} = \frac{200}{67} = 2.985 \text{ k}\Omega$ (+2)

$r_o = \frac{|V_A|}{I_C} = \frac{250}{1.914} = 130.6 \text{ k}\Omega$ (+2)

Determine the mid-frequency gain A_V and A_V(dB).

$$r_b' = 46.4k \parallel 3.32k \parallel 2.985k$$

$$= 1.520k \quad +1$$

$$R_S = 4.75k \parallel 49.9 = 0.04938\,k \quad +1$$

$$\therefore\ V_{be} = V_s \left(\frac{1.520}{1.520 + 0.04938} \right) = 0.9685\,V_s \quad +1$$

$$R_C' = 130.6k \parallel 4.75k \parallel 10k = 3.143k \quad +1$$

$$V_{OUT} = -g_m V_{be} \cdot R_C' = -67 \cdot 0.9685 V_s \cdot 3.143k$$

$$A_V = \frac{V_{OUT}}{V_s} = -203.9 \quad +1$$

or 46.2 dB inverting +1

Determine the high-frequency input and output capacitances using Miller's Theorem if C_{BC} = 5.6 pF and C_{BE} = 24 pF. Compute the input and output HF cutoff frequencies and the approximate overall high-frequency cutoff, f_H.

gain between V_{be} and V_{OUT} :

$$-g_m \cdot R_c' = -67 \cdot 3.143 = -210.6 \quad +1$$

$$\therefore C_{BC(IN)} = 5.6\,(1 - -210.6) = 1185\ pF \quad +1$$

$$C_{IN} = 1185 + 24 = 1209\ pF \quad +1$$

$$f_{H(IN)} = \frac{1}{2\pi \cdot 1209p \cdot 0.04783k} = 2.752\ MHz \quad +1$$

$R_s \parallel R_b'$

$= 1.520k \parallel 0.04938k = 0.04783k$ +1

$$C_{BC(OUT)} = 5.6\left(1 - \frac{1}{-210.6}\right) \cong 5.6\ pF \quad +1$$

$$f_{H(OUT)} = \frac{1}{2\pi \cdot 5.6p \cdot \underbrace{3.143k}_{R_c'}} = 9.042\ MHz \quad +1$$

$$f_{H(IN)} \gg f_{H(OUT)}$$

$$\therefore f_H \sim 2.752 MHz \quad +1$$

Compute the three LF cutoff frequencies and the approximate overall low-frequency cutoff, f_L.

$$R_{CE} = \frac{1}{g_m} \| R_E = \frac{1}{67m} \| 332 = 14.28\,\Omega \quad (+1)$$

$$f_{CE} = \frac{1}{2\pi \cdot 14.28 \cdot 1000 \times 10^{-6}} = 11.14\text{ Hz} \quad (+1)$$

$$R_{COUT} = R_L + (R_C \| r_o) = 10k + (4.75k \| 130.6k)$$

$$= 14.58k \quad (+1)$$

$$f_{COUT} = \frac{1}{2\pi \cdot 14.58k \cdot 10\mu} = 1.091\text{ Hz} \quad (+1)$$

$$R_{CIN} = R_S + R_b' = .04938k + 1.520k = 1.569k \quad (+1)$$

$$f_{CIN} = \frac{1}{2\pi \cdot 1\times10^{-6} \cdot 1.569k} = 101.4\text{ Hz} \quad (+1)$$

= dominant pole; $f_L \approx 101.4$ Hz

(+1)