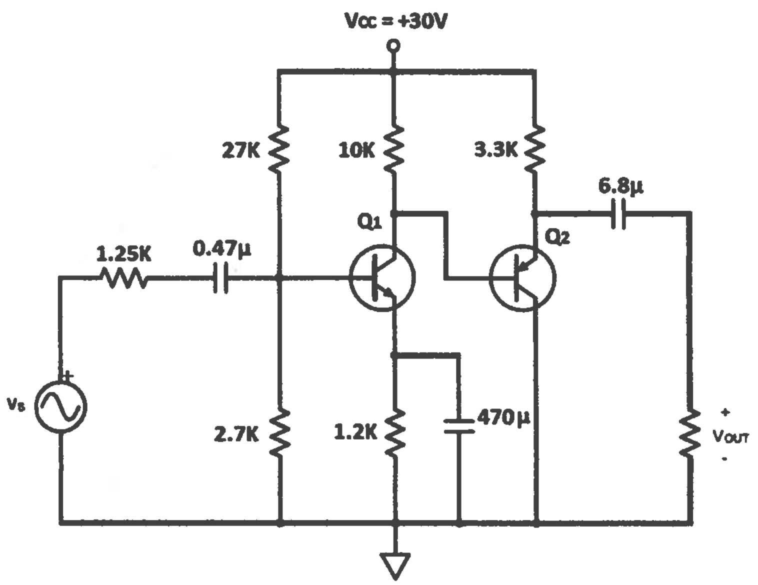
EE 3310/3510 • Exam II • 5 October 2022 43 pts.

NAME SOLUTION

1) Refer to the following circuit:



Which type of transistor is Q_1 (NPN or PNP), and in what amplifier configuration is it used (common-emitter, common-base, or common-collector)?

NPN (+1)

Common-emitter (+1)

Please answer the same questions for Q_2.

PNP (+1)

Common-collector (+1)

Determine V_{B1}, V_{E1}, I_{E1}, I_{C1}, V_{C1}, and V_{CE1} if base current may be assumed negligible due to high β. Check P_{diss1} and verify that the transistor is operating in the active region.

$$V_{B_1} = 30\left[\frac{2.7}{2.7+27}\right] \doteq 2.724\text{ V} \quad (+2)$$

$$V_{E_1} = V_{B_1} - \underset{\text{NPN}}{0.7} = 2.027\text{ V} \quad (+1)$$

$$I_{E_1} = \frac{V_{E_1}}{R_{E_1}} = \frac{2.027}{1.2k} = 1.689\text{ mA} \quad (+2)$$

high-β → $I_{C_1} \sim 1.689$ mA (+1)

$$V_{C_1} = V_{CC} - I_{C_1}R_{C_1} = 30 - 1.689 \cdot 10$$

$$V_{C_1} = 13.11\text{ V} \quad (+2)$$

$$V_{CE_1} = V_{C_1} - V_{E_1}$$

$$= 11.08\text{ V} \quad (+1)$$

> 0.2 V; yes active region (+1)

$$P_{diss_1} = V_{CE_1} \cdot I_{C_1}$$

$$= 11.08 \cdot 1.689$$

$$= 18.71\text{ mW} \quad (+2)$$

Now determine V_{B2}, V_{E2}, I_{E2}, I_{C2}, V_{C2}, V_{CE2}, P_{diss2}, and verify active region under the same high-β assumption.

$$V_{B2} = V_{C_1} = 13.11\text{ V} \quad (+1)$$

$$V_{E2} = V_{B2} + \underset{\text{PNP}}{0.7} = 13.81\text{ V} \quad (+1)$$

$$I_{E2} = \frac{V_{CC} - V_{E2}}{R_{E2}} = \frac{30 - 13.81}{3.3k}$$

$$I_{E2} = 4.906\text{ mA} \quad (+2)$$

$$\therefore I_{C2} \simeq 4.906\text{ mA} \quad (+1)$$

$$V_{C2} = 0\ (\text{ground}) \quad (+1)$$

$$V_{CE2} = V_{C2} - V_{E2}$$

$$= 0 - 13.81 = -13.81 \quad (+1)$$

$|-13.81| > 0.2$V; yes, active (+1)

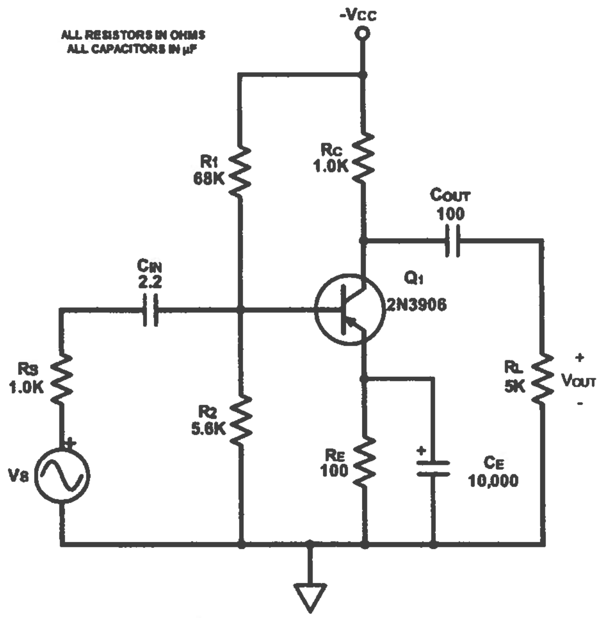
$$P_{diss\,2} = |V_{CE2}| \cdot I_{C2}$$

$$= 13.81 \cdot 4.906$$

$$= 67.75\text{ mW} \quad (+2)$$

21

2) A silicon PNP transistor is used in a common-emitter amplifier configuration. Collector current is known to be 2.4 mA and the transistor has an Early voltage of 220 V and beta 320. Calculate the parameters g_m, r_b, and r_o.



$$g_m = 35 I_C = 35 \cdot 2.4 = 84 \frac{mA}{V} \quad +2$$

$$r_b = \frac{\beta}{g_m} = \frac{320}{84} = 3.81\ k\Omega \quad +2$$

$$r_o = \frac{|V_A|}{I_C} = \frac{220}{2.4} = 91.67\ k\Omega \quad +2$$

Determine the mid-frequency small-signal gains A_{V1} and A_{V2} and the overall gain of the amplifier in dB.

$$R_b' = r_b \| R_1 \| R_2 = 3.81 \| 5.6 \| 68 = 2.194\ k\Omega \quad +1$$

$$A_{V_1} = \frac{V_{be}}{V_s} = \frac{R_b'}{R_b' + R_s} = \frac{2.194}{2.194 + 1} = 0.6869 \quad +2$$

or -3.3 dB

$$A_{V2} = \frac{V_{OUT}}{V_{be}} = -g_m (r_o \| R_C \| R_L) = -84 (91.67 \| 1 \| 5) = -69.37 \quad +2$$

$\hookrightarrow = .8258K$ +1

or +36.8 dB

overall midband gain : $-3.3 + 36.8 =$ 33.5 dB (inverting) +1

Determine the high-frequency input capacitance using Miller's Theorem if C_{BC} = 4.5 pF and C_{BE} = 12 pF. Use it to compute the input HF cutoff frequency. You do not have to compute the output capacitance or cutoff frequency.

Miller Time!

$$C_{BC(IN)} = C_{BC}(1 - A_{V2}) = 4.5(1 - {}^{-}69.37) = 316.7\ pF \quad +2$$

$$C_{IN} = C_{BC(IN)} + C_{BE} = 316.7 + 12 = 328.7\ pF \quad +1$$

$$f_{H(IN)} = \frac{1}{2\pi\, C_{IN} \cdot R_b' \| R_s} = \frac{1}{2\pi \cdot 328.7 \times 10^{-12} (1k \| 2.194k)}$$

$\hookrightarrow 686.9\ \Omega$

$$f_{H(IN)} = 704.9\ kHz \quad +2$$

18