DEPARTMENT OF ELECTRICAL ENGINEERING, IIT KANPUR

Microelectronics – I (EE210)   Mid-Sem. Exam

Date: 17.2.14   **Max. Marks ~~30~~ 35**

In all the problems assume that BJT has the following characteristics:

$$V_{BE}(ON) = 0.7V; \beta = 100, C_\pi = \frac{2.5\times10^{-10}}{2\pi}F; C_\mu = \frac{2\times10^{-12}}{2\pi}F; r_o = \infty; r_{bb} = 0; V_T = 26mV$$

Q.1 Determine the bias point (I_{CQ}, V_{CEQ}) , mid-frequency small-signal open circuit voltage gain (v_o/v_s), input resistance (R_{in}) and lower cutoff frequency for the amplifier circuit shown in Fig. 1. State three benefits that come from keeping a part of emitter resistance that is not bypassed by a capacitor. ----11

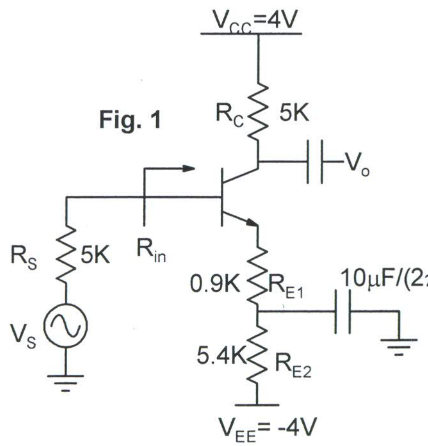


Fig. 1

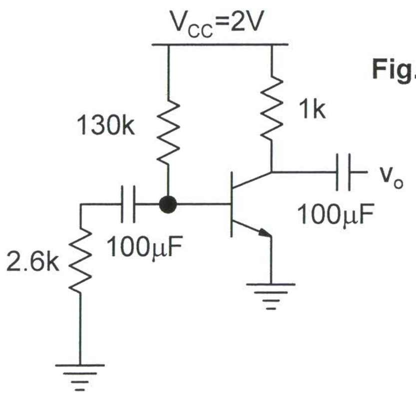


Fig. 2

Q.2 Figure.2 above shows a common-emitter amplifier schematic. The power supply voltage V_{CC} has an ac ripple of peak magnitude 0.2V and frequency 1kHz. Determine the magnitude of resulting ac ripple at the output vo .---~~5~~ 4

Ans.1

$$I_C = \frac{0 - V_{BE} - V_{EE}}{R_{E1} + R_{E2} + \frac{R_S}{\beta}} = 0.52\,mA \quad (1)$$

$$V_C = V_{CC} - I_C R_C = 1.4 \qquad V_E = V_{EE} + I_C(R_{E1}+R_{E2}) = -0.72$$

$$V_{CE} = 2.12V \quad (1)$$

$$r_\pi = \frac{V_T}{I_C}\cdot\beta = 5K \qquad g_m = I_C/V_T = 0.02\,\mho$$

$$A_V = -\frac{g_m R_C}{1+g_m R_{E1}} \times \left(\frac{R_{in}}{R_{in}+R_S}\right) \qquad R_{in} = r_\pi + (1+\beta)R_{E1} = 96\,k\Omega \quad (2)$$

$$= -5 \quad (2)$$

$$f_L = \frac{1}{2\pi C_E R_{eff}} \qquad R_{eff} = R_{E2} \,||\, \left(R_{E1} + \frac{r_\pi + R_S}{\beta}\right) = 843.7\Omega$$

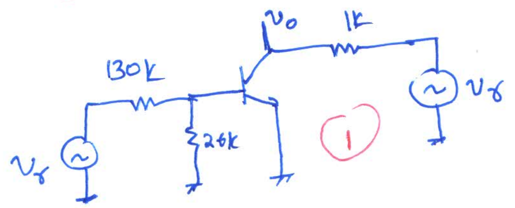
$$= 118.5\,HZ \quad (2)$$

Benefits: (1) Higher R_{in} (1) (2) Smaller f_L (1) (3) Reduced distortion (1)

Ans.2 (1)

$$I_C = \frac{2-0.7}{130K}\times100 = 1mA \Rightarrow r_\pi = 2.6K\Omega \qquad g_m = .0385\,\mho$$

v_r = ripple of 0.2V magnitude



(1)

There are two contributions to v_o. one from the output and the other from the input.

$$v_o = v_r - \left(g_m\cdot10^3\right)\times\frac{2.6K||r_\pi}{(2.6K||r_\pi)+130K} = -0.1238 \simeq 0.12V \quad (2)$$

Q.3 For the amplifier shown in Figure 3 determine a suitable value of R_{C2} such that output voltage swing at 10% second harmonic distortion is 0.8V and overall mid-frequency small-signal open circuit voltage gain Vo/Vs is maximized. Determine also the magnitude of this gain. ----5

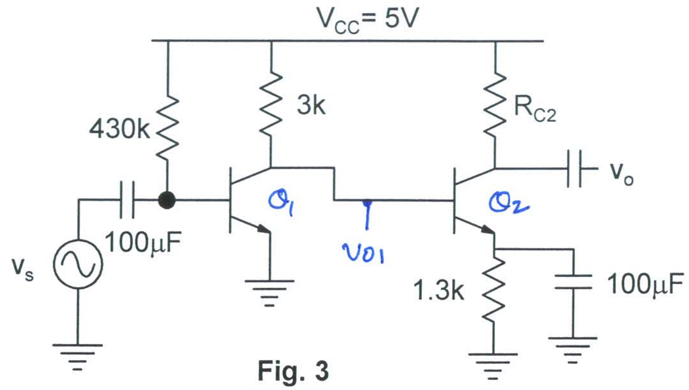


Fig. 3

Q.4 Determine the value of bias current I_O such that output resistance Ro in mid-frequency band is 20Ω . Assume that both transistors have identical characteristics and are biased in forward active mode. -----5

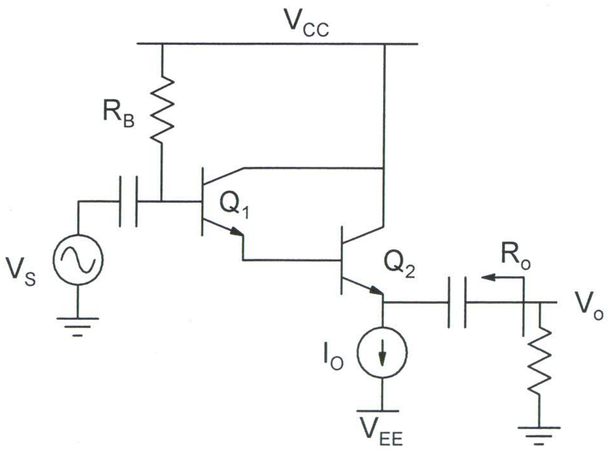


Fig. 4

Ans 3.

$I_{C1} = \frac{5-0.7}{430k} \times 100 = 1mA$ $\qquad V_{C1} = 5-3 = 2V$ $\qquad$ 1

$I_{C2} \approx \frac{2-0.7}{1.3k} = 1mA$

$V_{om} = 0.8V \Rightarrow V_{CE2} \geq 0.8+0.2 = 1V$. $\qquad$ choose minimum

$I_{C2}R_{C2} = 5 - 1 - I_{C2}R_{E2} = 2.7V$ $\qquad$ 2

$R_{C2} = 2.7K\Omega$

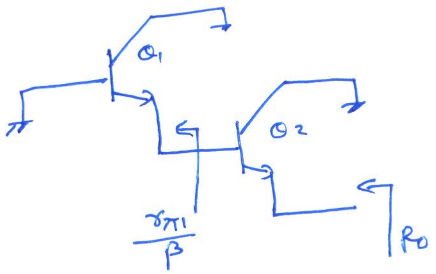
$I_{C2}R_{C2} \cdot \frac{HD2}{2.5} = 1.08 > V_{om}$.

$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_{01}} \times \frac{v_{01}}{v_s}$ $\qquad \frac{v_o}{v_{01}} = -\frac{I_{C2}R_{C2}}{V_T} = -103.84$ $\qquad$ 2

$\frac{v_{01}}{v_s} = -g_{m1} \cdot 3k \| r_{\pi 2}$ $\qquad g_{m1} = 0.0385℧$ $\qquad r_{\pi 2} = 2.6k\Omega$

$= 53.57$ $\qquad A_v = 5.5 \times 10^3$

Ans 4



$R_o = \frac{\frac{r_{\pi 1}}{\beta} + r_{\pi 2}}{\beta}$ $\qquad$ 3

Since $I_{C2} = \beta I_{C1} \Rightarrow r_{\pi 2} = \beta^{-1} r_{\pi 1} \Rightarrow r_{\pi 1} = \beta r_{\pi 2}$ $\qquad$ 1

$R_o = \frac{2 r_{\pi 2}}{\beta} = \frac{2 V_T}{I_O} = 20\Omega$

$I_O = \frac{V_T}{10} = 2.6mA$ $\qquad$ 1

Q.5 Determine the upper cutoff frequency of the two-stage amplifier shown below in Fig. 5. Assume that both transistors have identical characteristics and are biased in forward active mode ------5

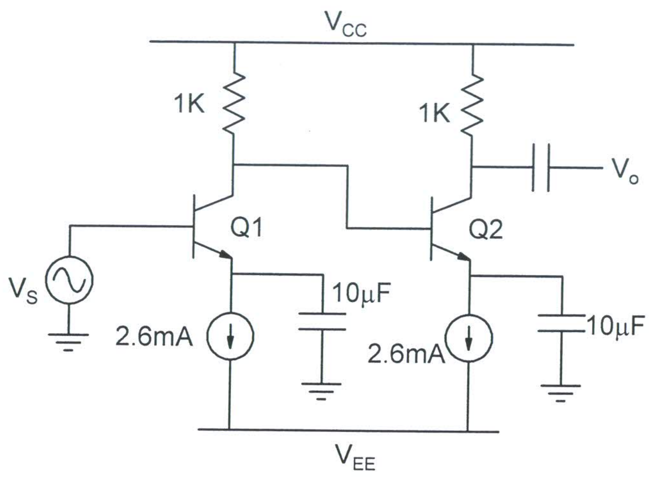


Fig. 5

Q.6 In the circuit shown in Fig. 6 determine collector current of transistor Q1. The PNP transistor Q2 has V_{EB} = 0.7V, identical current gain and other small signal parameters as NPN. Estimate the mid-frequency voltage gain Vo/Vs . ------4 5

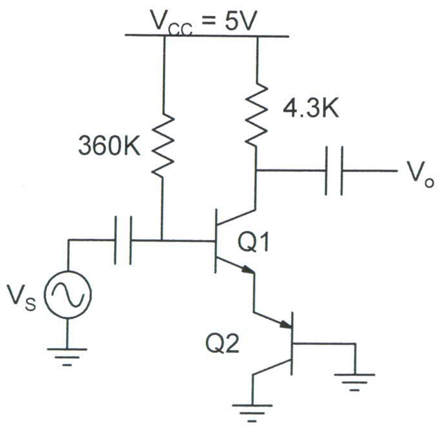
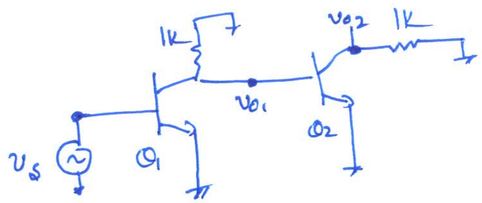


Fig. 6

Ans 5 $r_{\pi1} = r_{\pi2} = \frac{V_T}{2.6mA} \cdot \beta = 1K\Omega$ $g_{m1} = g_{m2} = 0.1 \mho$



$A_{v1} = -g_{m1}\ 1K \| r_{\pi1} = -50$

$A_{v2} = -g_{m2} \cdot 1k = -100$ 1

There are 3 nodes (v_S, v_{o1} and v_{o2}) which contribute to 3-dB frequency.

Input node: $R = 0$ So it will not contribute 1

v_{o1} node $R = 1K \| r_{\pi2} = 0.5K$ $C \equiv C_{\mu1} + C_{\pi2} + C_{\mu2} \times (1 - A_{v2})$

$= \frac{4.5 \times 10^{-10}}{2\pi}$ F

$\tau = RC = \frac{2.25 \times 10^{-7}}{2\pi}$ s. 2

Output node $R = 1K$ $C \approx C_{\mu2} = \frac{2 \times 10^{-12}}{2\pi}$ $f = \frac{1}{2\pi \Sigma\tau} \cong 4.4$ MHz. 1

Ans 6.

$V_{B1} = 0.7 + 0.7 = 1.4$ $I_{B1} = \frac{5 - 1.4}{360K} = 10\mu A$ 1

Assuming Q_1 in forward-Active mode $I_{C1} = \beta I_{B1} = 1mA$

$V_{C1} = 5 - I_C R_C = 0.7$ But $V_{E1} = 0.7$ 1

$\Rightarrow V_{CE1} = 0 \Rightarrow Q_1$ is in saturation region

$\Rightarrow V_C = 0.7 + 0.2 = 0.9V$ 1 $I_C = \frac{5 - 0.9}{4.3K} = 0.95mA$ 1

Since Q_1 is in saturation, voltage Gain will be negligible 1