19MA20059

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Basic EC — Test 4

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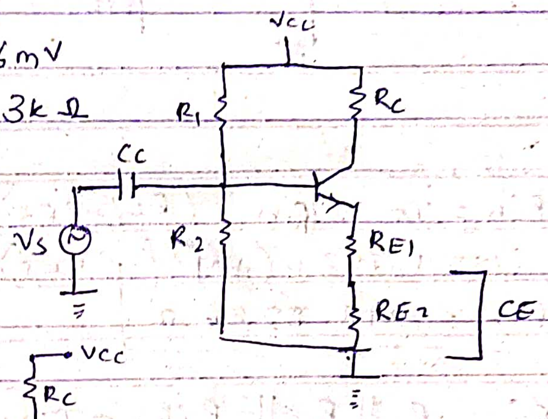
Q4) $\beta = 100$ $\quad V_{BE(ON)} = 0.7V$ $\quad V_T = 26mV$

$R_1 = 20k\Omega$ $\quad R_2 = 10k\Omega$ $\quad R_C = 3k\Omega$

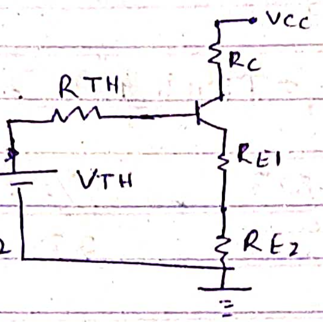
$R_{E1} = 1k\Omega$ $\quad R_{E2} = 1.1k\Omega$

$C_C = C_E = 10\mu F$, $\quad V_{CC} = 12V$



a) DC Analysis

Equivalent Circuit



$$R_{TH} = \frac{R_1R_2}{R_1+R_2} = \frac{20\times10}{20+10} = \frac{20}{3}k\Omega$$

$$V_{TH} = \frac{R_2(V_{CC})}{R_1+R_2} = \frac{\cancel{10}}{\cancel{30}} \times \cancel{12}\,4 = 4V$$

$$V_{TH} = I_B R_{TH} + V_{BE(ON)} + \underbrace{\cancel{I_E}}_{(\beta+1)I_B}(R_{E1}+R_{E2})$$

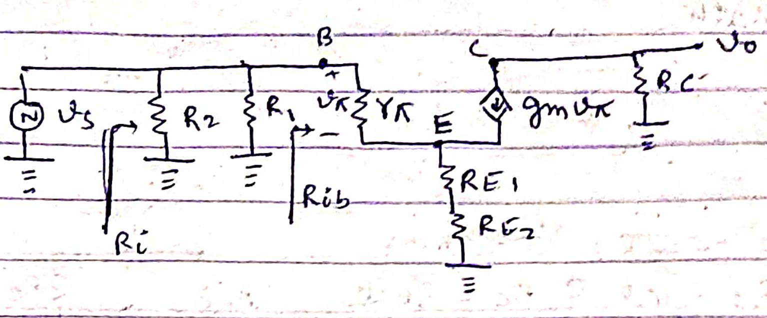
$$4 = \cancel{I_B\left(\frac{20}{3}+1+1.1\right)}\ \frac{20}{3}I_B + 0.7 + (1.1+1)(101)I_B$$

$$4 - 0.7 = 218.766\,I_B \implies I_B = 0.01508\,mA$$

Now $\quad r_\pi = \frac{V_T}{I_B} = \frac{26mV}{0.01508mA} = 1723.6\,\Omega = 1.723k\Omega$

$$g_m = \frac{\beta}{r_\pi} = \frac{100}{1.723k\Omega} = 58.017 \text{ milli-mho}$$

b) $V_A = \infty \Rightarrow r_o = 0$



$R_1 = 20k\,\Omega$

$R_2 = 10k\,\Omega$

$R_{E1} = 1k\,\Omega$

$R_{E2} = 1.1k\,\Omega$

$r_\pi = 1.723k\,\Omega$

$g_m = 58.017$ milli-mho

$R_C = 3k\,\Omega$

$R_{ib} = r_\pi + (\beta+1)(R_{E1}+R_{E2})$

$= 1.723 + (101)(1.1+1)$

$\boxed{R_{ib} = 213.823k\,\Omega}$

$R_i = R_1 \| R_2 \| R_{ib} = R_{TH} \| R_{ib} = \frac{20}{3} \| 213.823$

$= \dfrac{\frac{20}{3} \times 213.823}{\frac{20}{3} + 213.823} = \dfrac{20/3 \times 213.823}{220.489}$

$\boxed{R_i = 6.465k\,\Omega}$

c) CE not connected

$\frac{v_s}{i_b} = R_{ib} \Rightarrow i_b = \frac{v_s}{R_{ib}}$

$v_\pi = i_b r_\pi = \frac{v_s r_\pi}{R_{ib}} = \frac{v_s(1.723)}{(213.823)} = v_s(8.058\times10^{-3})$

$g_m v_\pi = (58.017)\, v_s(8.058\times10^{-3})$ milli-mho-volt

$= 467.5009\, v_s \times 10^{-3}$ mA

$0 - v_o = g_m v_\pi R_C = 467.5009 \times 3\, v_s$

$-v_o = 1402.5029\, v_s$ mV

$v_o = -1.4025\, v_s$ mV

gain $\boxed{A_v = \frac{v_o}{v_i} = \frac{-1.4025\, v_s}{v_s} = -1.4025}$

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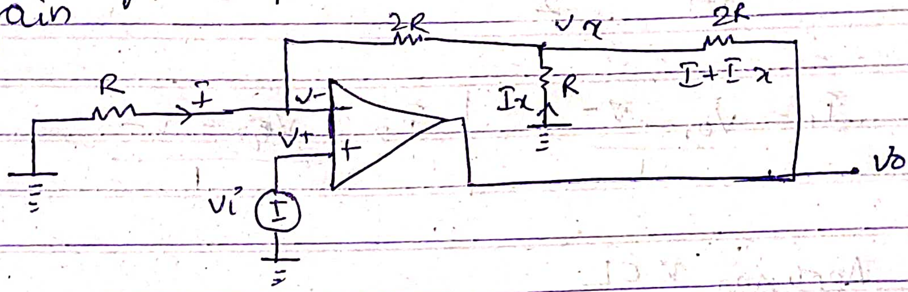
When CE is connected, Rib decreases as R_{E2} is bypassed in AC circuit.

As a result v_π increases. Hence $i_c = g_m v_\pi$ also increases

Due to increase in $g_m v_\pi$, overall voltage gain of the circuit $\left(A_v = \frac{v_o}{v_i}\right)$ increases.

Hence, attaching capacitor CE results in increase of voltage gain

Q3)



$$V_+ = V_i$$

$$V_- \simeq V_+ = V_i \quad \text{(Virtual ground)}$$

$$I = \frac{-V_-}{R} = \frac{-V_i}{R}$$

$$V_x = V_- - I(2R) = V_i - 2R\left(\frac{-V_i}{R}\right) = 3V_i$$

$$I_x = \frac{-V_x}{R} = -\frac{3V_i}{R}$$

$$I + I_x = \frac{-V_i}{R} - \frac{3V_i}{R} = \frac{-4V_i}{R}$$

Now $V_o = V_x - (I + I_x)\,2R = 3V_i - 2\cancel{R}\left(\frac{-4V_i}{\cancel{R}}\right) = 3V_i + 8V_i$

$$V_o = 11V_i$$

$$\boxed{\text{Gain} = A_v = \frac{V_o}{V_i} = \frac{11\cancel{V_i}}{\cancel{V_i}} = 11}$$

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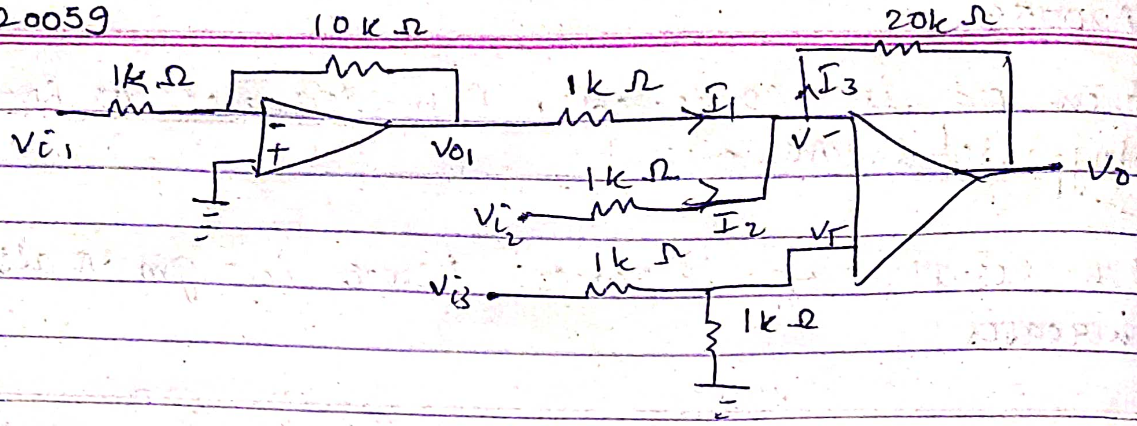
Q2)



$V_{o1} = -10V_{i1}$

$V_+ = \frac{V_{i3}}{1+1} = \frac{V_{i3}}{2} \cong V_-$

$I_1 = \frac{V_{o1} - V_-}{1}$ | $I_2 = \frac{V_{i2} - V_-}{1}$

Applying KCL

$I_3 = I_1 + I_2 = (V_{o1} + V_{i2} - 2V_-)$

$V_o = V_- - I_3 \times 20\,k\Omega = V_- - (V_{o1} + V_{i2} - 2V_-)\times 20$
$= 41V_- - 20V_{o1} - 20V_{i2}$

$$\boxed{V_o = \frac{41}{2}V_{i3} + 200V_{i1} - 20V_{i2}}$$

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Q1) b) $C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.9 \times 8.85 \times 10^{-12}}{8 \times 10^{-9}} = \cancel{4.21} \; 4.3164 \; mF/m^2$

c) $k_n' = \mu_n C_{ox} = 450 \times 10^{-4} \times 4.3164 \times 10^{-3}$

$\boxed{k_n' = 1.9422 \times 10^{-4} \; f/V}$

$\boxed{k_n = \frac{k_n'}{2} \frac{W}{L} = 1.9422 \times 10^{-4} \times \frac{10}{2} = 9.711 \times 10^{-4} \; F/V}$

d) $I_D = k_n (V_{GS} - V_{TN})^2$

$100 \times 10^{-6} = 9.711 \times 10^{-4} \times (V_{GS} - 0.7)^2$

$= \therefore (V_{GS} - 0.7)^2 = 0.012976$

$\Rightarrow \boxed{V_{GS} = 1.021 \, V}$

a) n-channel MOSFET

b) $V_{DS}^{(sat)} = V_{GS} - V_{TN} = 1.021 - 0.7 = 0.321 \, V$

$\boxed{\therefore V_{DS}^{(sat)} = 0.321 \, V}$