CMR
INSTITUTE OF
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Internal Assessment Test - I

Sub:	**Analog Electronic Circuits and Op-Amps**							Code:	**21EE32**
Date:	02.12.2022 10.15 – 11.45AM	Duration:	90 mins	Max Marks:	50	Sem:	III	Branch:	EEE

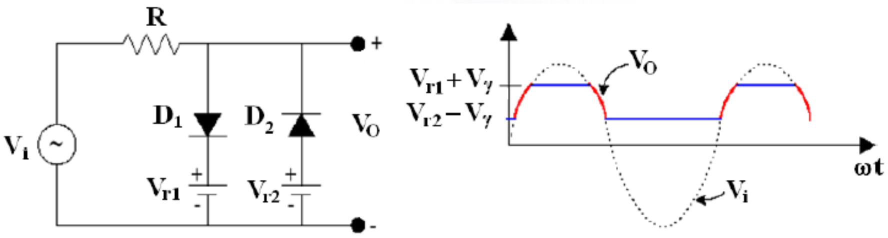
Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1	Explain the operation of double ended clipping circuit with neat circuit diagram and waveforms	10	CO1	L2
2	Derive the expression for stability factors $S(I_{CO})$ and $S(V_{BE})$ for voltage divider biasing circuit.	10	CO2	L3
3	With the help of r_e equivalent model derive an equation for input impedance, output impedance, voltage gain and current gain for emitter follower configuration	10	CO2	L3
4	Design a voltage divider bias circuit using the given parameters: I_c = 1mA, $S(I_{CO})$ = 20, β = 100, V_E = 1V, V_{CE} = 6V and V_{CC} = 12V. Draw its circuit diagram	10	CO2	L6
5	Explain hybrid equivalent model for transistor. Develop h-parameter model for CE, CC and CB configurations.	10	CO2	L2
6	For the transistor connected in CE configuration, determine A_V, A_I, Z_i and Z_o using complete hybrid equivalent model. $R_L = R_S$ = 1KΩ, h_{ie} = 1KΩ, $h_{re} = 2 \times 10^{-4}$, h_{fe} = 100 and h_{oe} = 20μA/V	10	CO2	L3

AEC IAT 1 Solution

1. Double ended clipper

- Two parallel clippers can be combined to form a double-ended clipper:



Input	Diode status	Output
$V_i < (V_{r2} - V_\gamma)$	D_1 OFF, D_2 ON	$V_{r2} - V_\gamma$
$(V_{r2} - V_\gamma) \le V_i \le (V_{r1} + V_\gamma)$	D_1 OFF, D_2 OFF	V_i
$V_i > (V_{r1} + V_\gamma)$	D_1 ON, D_2 OFF	$V_{r1} + V_\gamma$

2. Stability factor

$$S(I_{CO}) = \frac{1+\beta}{1-\beta\frac{\partial I_B}{\partial I_C}}$$

$$V_{Th} = R_{Th} I_B + V_{BE} + I_E R_E$$

But $I_E = I_C + I_B$

$$V_{Th} = R_{Th} I_B + V_{BE} + I_C R_E + I_B R_E$$

Differentiating with respect to I_C, keeping V_{BE} constant,

$$0 = (R_E + R_{Th})\frac{\partial I_B}{\partial I_C} + R_E$$

$$\therefore \frac{\partial I_B}{\partial I_C} = \frac{-R_E}{R_E + R_{Th}}$$

Substituting in the expression for $S(I_{CO})$, we get

$$S(I_{CO}) = \frac{1+\beta}{1+\beta\frac{R_E}{R_E + R_{Th}}}$$

$$= \frac{1+\beta}{R_E + R_{Th} + \beta R_E}(R_E + R_{Th})$$

$$\therefore S(I_{CO}) = (\beta+1)\frac{R_E + R_{Th}}{(\beta+1)R_E + R_{Th}}$$

$$\therefore S(I_{CO}) = (\beta+1)\frac{\left[1+\frac{R_{Th}}{R_E}\right]}{(\beta+1)+\frac{R_{Th}}{R_E}}$$

$$S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}}$$

$$V_{Th} = R_{Th} I_B + V_{BE} + I_C R_E + I_B R_E$$

$$I_B = \frac{I_C}{\beta}$$

$$\therefore V_{Th} = \left(\frac{R_{Th}}{\beta} + \frac{R_E}{\beta} + R_E\right) I_C + V_{BE}$$

$$= \left(\frac{R_{Th} + R_E + \beta R_E}{\beta}\right) I_C + V_{BE}$$

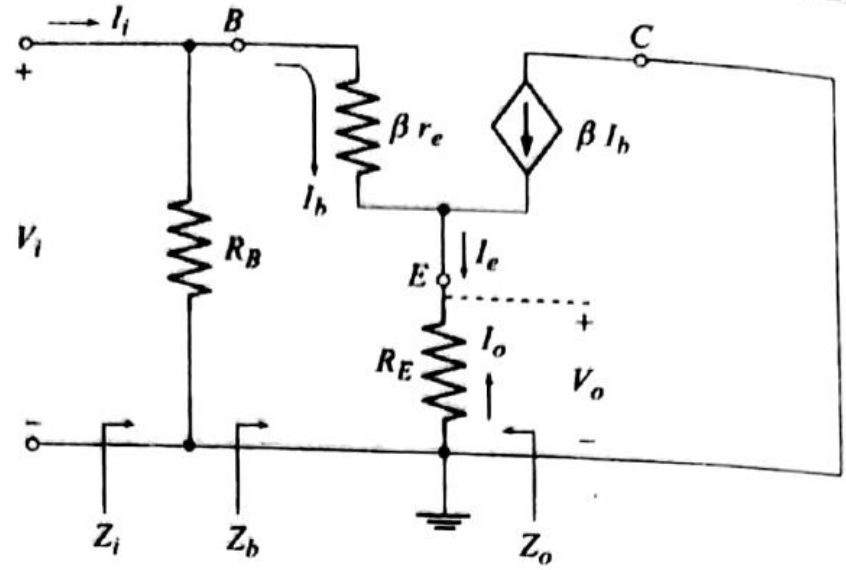
$$V_{Th} = \left(\frac{(R_{Th} + (\beta+1)R_E)}{\beta}\right) I_C + V_{BE}$$

Differentiating with respect to V_{BE}, keeping β constant

$$0 = \frac{R_{Th} + (\beta+1)R_E}{\beta}\frac{\partial I_C}{\partial V_{BE}} + 1$$

$$\therefore S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}} = \frac{-\beta}{R_{Th} + (\beta+1)R_E}$$

3. Emitter follower re model.



Input Impedance

$$V_i = I_b \beta r_e + I_e R_E \Rightarrow I_b \beta r_e + (1+\beta) I_b R_E .$$

$$Z_b = \frac{V_i}{I_b} = \beta r_e + (1+\beta) R_E \quad [\because (1+\beta) \simeq \beta]$$

$$= \beta (r_e + R_E) \quad \because [r_e + R_E \simeq R_E]$$

$$= \beta R_E .$$

$$\boxed{Z_i = \frac{V_i}{I_i} = R_B \| Z_b}$$

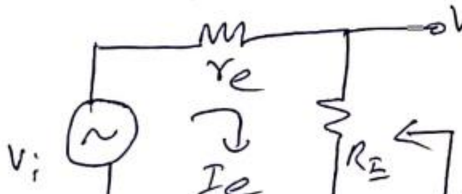
Output Impedance

$$Z_b = \frac{V_i}{I_b} \Rightarrow I_b = \frac{V_i}{Z_b}$$

$$I_b = \frac{I_e}{1+\beta}$$

$$\frac{I_e}{1+\beta} = \frac{V_i}{Z_b} \Rightarrow I_e = \frac{V_i (1+\beta)}{Z_b} .$$

$$I_e = \frac{V_i \beta}{\beta (r_e + R_E)} \Rightarrow V_i = I_e r_e + I_e R_E$$



To find Z_o, Let $V_i = 0$.

$$\boxed{Z_o = r_e \| R_E} = \frac{r_e R_E}{r_e + R_E}$$

Voltage Gain Av = 1

Current Gain

$$V_o = I_e R_E = -I_o R_E \qquad [\because I_e = -I_o]$$

$$\therefore \quad I_o = -\frac{V_o}{R_E}$$

$$\text{Also} \quad I_i = \frac{V_i}{Z_i}$$

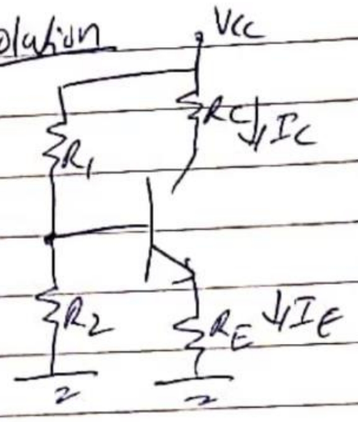
$$\text{Now} \quad A_I = \frac{I_o}{I_i} = \left[-\frac{V_o}{R_E}\right] \div \left[\frac{V_i}{Z_i}\right]$$

$$= -\left[\frac{V_o}{V_i}\right]\left[\frac{Z_i}{R_E}\right]$$

$$\boxed{A_I = -\frac{A_V Z_i}{R_E}}$$

4.

Solution



$I_C \simeq I_E = 1mA.$

$V_E = I_E R_E$

$\therefore R_E = \frac{V_E}{I_E} = 1k\Omega$

$I_B = \frac{I_C}{\beta} = 0.01mA.$

$V_{CC} - V_{CE} - I_C(R_C + R_E) = 0.$

$\therefore R_C = \frac{V_{CC} - V_{CE}}{I_C} - R_E = 5k\Omega$

$$S_{ICO} = (\beta+1)\left[\frac{R_E + R_{Th}}{(1+\beta)R_E + R_{Th}}\right] \Rightarrow \text{Solve to find } R_{Th}$$

$$\rightarrow S(I_{CO})\left[(1+\beta)R_E + R_{Th}\right] = (1+\beta)(R_E + R_{Th})$$

$$2020R_E + 20R_{Th} = 101R_E + 101R_{Th}$$

$$1919R_E = 81R_{Th}.$$

$$R_{Th} = \frac{1919}{81} \times 1 = 23.69 \text{ k}\Omega$$

$$V_{Th} = R_{Th} I_B + I_E R_E + V_{BE}$$

$$V_{Th} = V_{CC}\frac{R_2}{R_1 + R_2}$$

Multiply & Divide by R_1.

$$V_{Th} = \frac{V_{CC}}{R_1}\frac{R_1 R_2}{R_1 + R_2} \Rightarrow \text{Solve to find } R_1.$$

$$\rightarrow V_{Th} = \frac{V_{CC} R_{Th}}{R_1} \Rightarrow R_1 = \frac{V_{CC} R_{Th}}{V_{Th}}.$$

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} \Rightarrow \text{Solve to find } R_2.$$

$$\rightarrow R_{Th}(R_1 + R_2) = R_1 R_2.$$

$$R_{Th}R_1 = R_1R_2 - R_{Th}R_2 = R_2(R_1 - R_{Th}) \quad \Big| \quad R_2 = \frac{R_{Th}R_1}{R_1 - R_{Th}}$$

5.

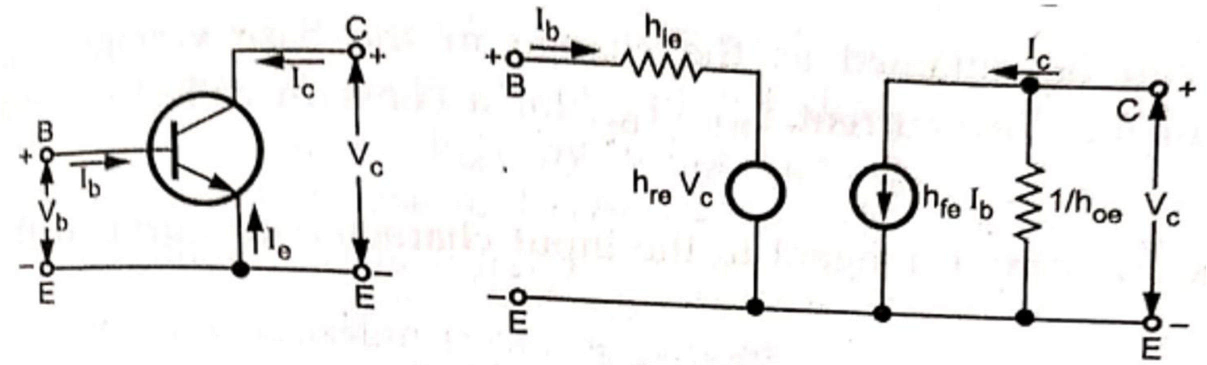
H-parameter model

Parameters are defined in general terms of any operating conditions.

Hybrid means mixed. Here we have mixed parameters.

In hybrid model, the transistor is modelled based on what is happening at its terminals without regard for the physical process taking place inside the transistor.

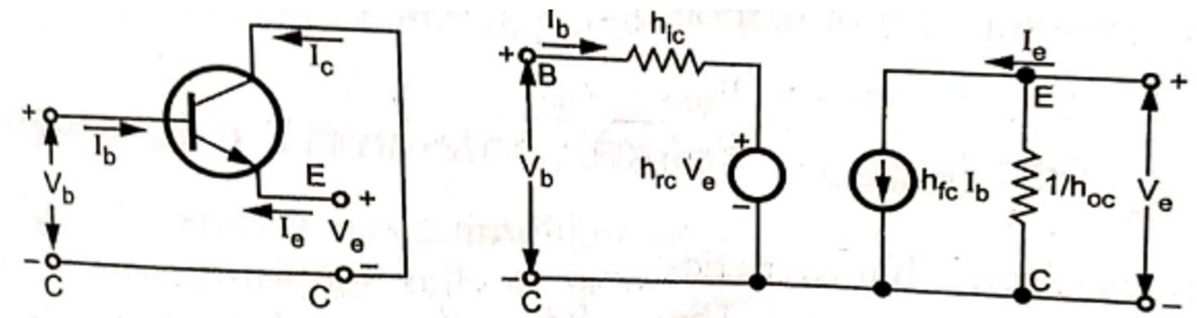
CE Configuration



$$v_1 = h_i i_1 + h_r v_2$$
$$i_2 = h_f i_1 + h_o v_2$$

$$V_b = h_{ie} I_b + h_{re} V_c$$
$$I_c = h_{fe} I_b + h_{oe} V_c$$

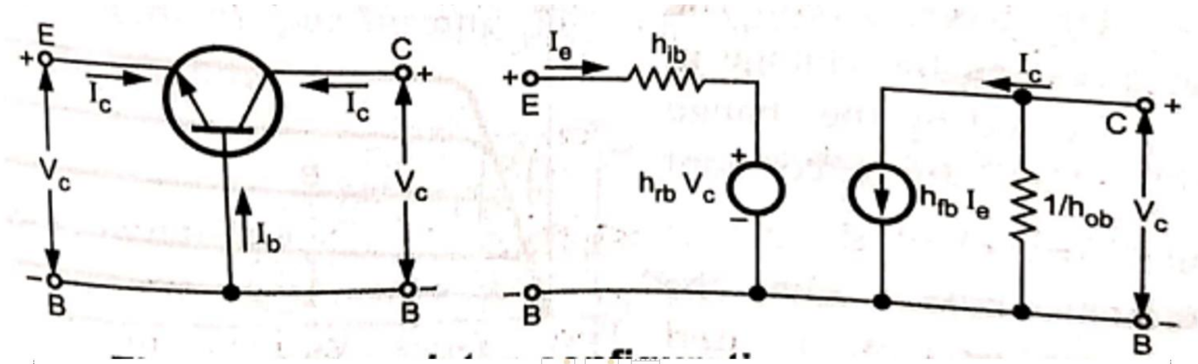
CC Configuration



$$v_1 = h_i i_1 + h_r v_2$$
$$i_2 = h_f i_1 + h_o v_2$$

$$V_b = h_{ic} I_b + h_{rc} V_e$$
$$I_e = h_{fc} I_b + h_{oc} V_e$$

CB Configuration



$$v_1 = h_i i_1 + h_r v_2$$
$$i_2 = h_f i_1 + h_o v_2$$

$$V_e = h_{ib} I_e + h_{rb} V_c$$
$$I_c = h_{fb} I_e + h_{ob} V_c$$

6.

$$h_{oe} R_L = 0.02 < 0.1$$

$$A_I = -h_{fe} = -100$$

$$A_V = \frac{-h_{fe} R_L}{h_{ie}} = \frac{-100 \times 1}{1} = -100$$

$$Z_i = h_{ie} = 1 K\Omega.$$

$$Z_o \simeq 0.$$