

Analog Electronic Circuits (UEC309)

By



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Subject: Analog Electronic Circuits (UEC301)

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Topic of today's Lecture : Small Signal Model and Operation of BJT-I

Key points

- ✓ Process of Small signal analysis
- ✓ Small Signal parameters
- ✓ Low frequency small signal model
- ✓ Low frequency small signal operation

Contents of this lecture are based on the following books:

- *Jacob Milman & C.C.Halkias, "Integrated Electronics Analog and Digital Circuit and Systems" Second Edition.*
- *Adel S. Sedra & K. C. Smith, "MicroElectronic Circuits Theory and Application" Fifth Edition.*
- *Robert L. Boylestad & L. Nashelsky, "Electronic Devices and Circuit Theory" Eleventh Edition.*



Small Signal Model and Operation of BJT-I

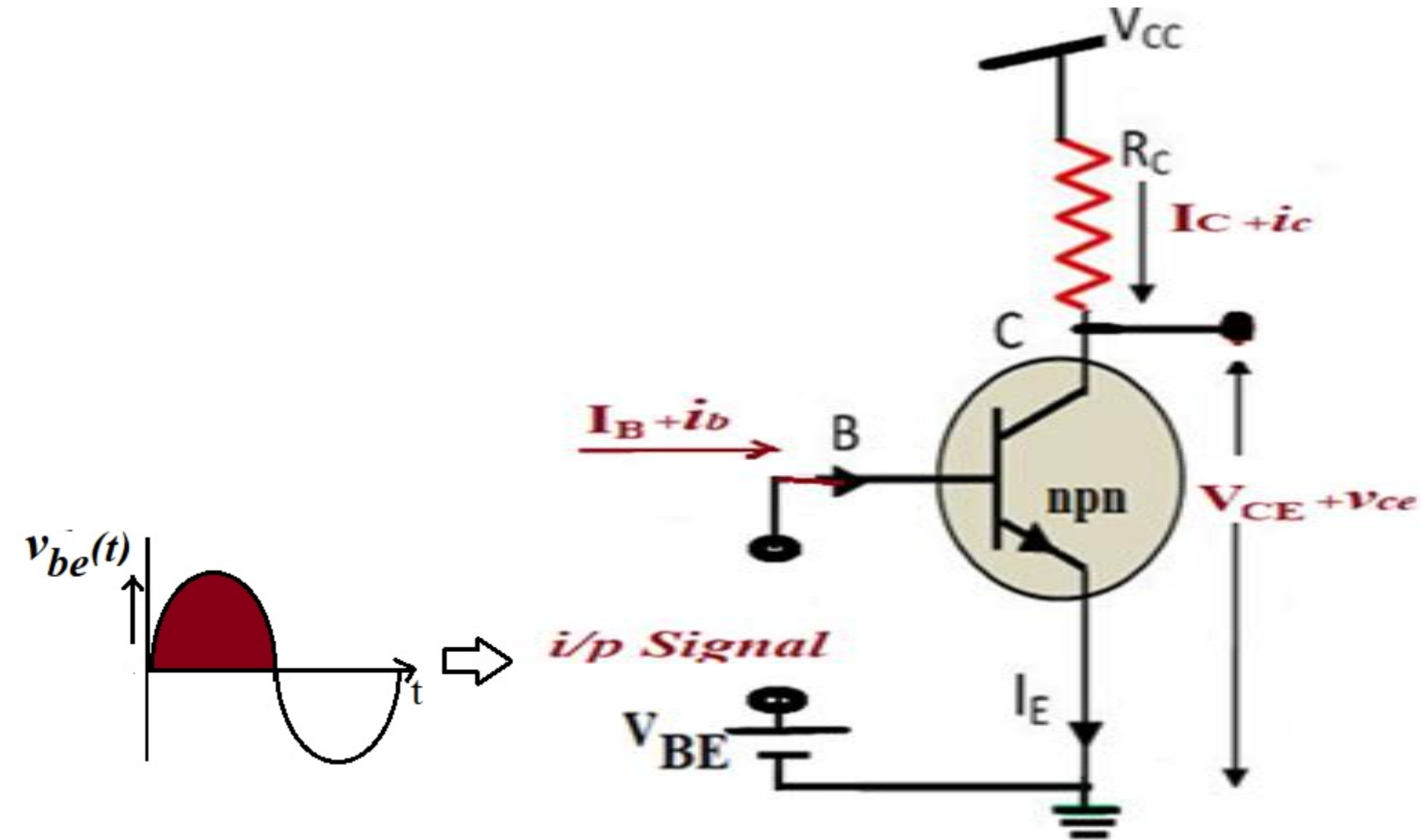


Figure 1:CEC based circuit to illustrate the small signal operation.

Process of Small signal analysis

1. Determine the dc operating point (I_{CQ} and V_{CEQ}) under dc analysis.
2. Calculate the small signal parameters : i_c , i_b , i_e , g_m etc.
3. Eliminate the dc source by replacing each dc voltage source by a short ckt and dc current source with an open circuit.
4. Replace the BJT with one of its small signal equivalent circuit models.
5. Analyze the resulting transistor based circuit to determine voltage gain, output resistance and input resistance.



Small Signal parameters

DC currents and voltages

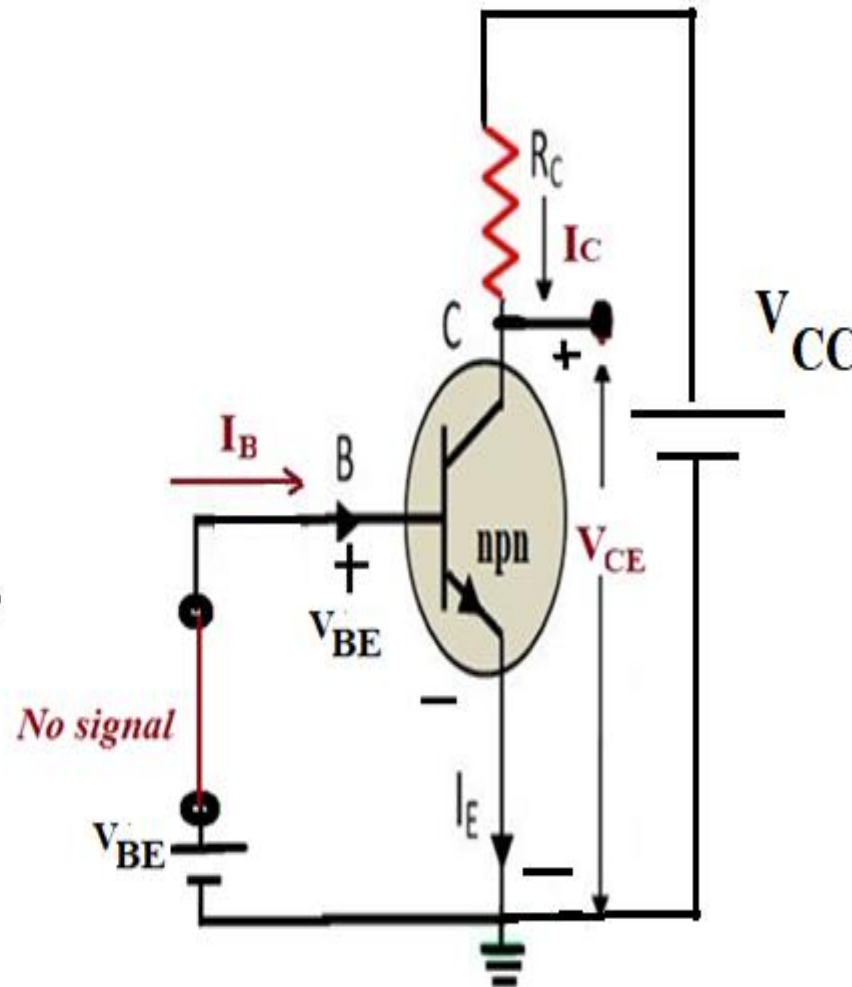
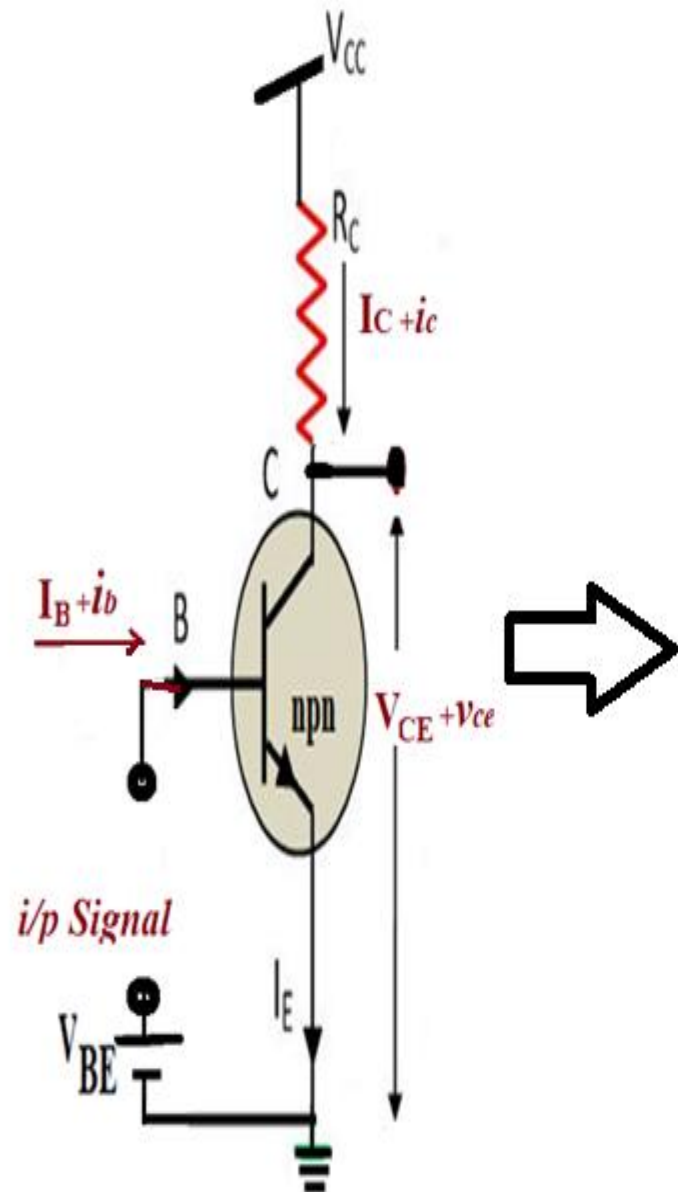


Figure 3: An equivalent CEC based circuit for dc bias analysis.

$$I_C \cong I_S e^{V_{BE}/V_T} \dots\dots\dots(1)$$

$$I_E = I_C / \alpha \dots\dots\dots(2)$$

$$I_B = I_C / \beta \dots\dots\dots(3)$$

$$V_{CE} = V_{CC} - I_C R_C \dots\dots\dots(4)$$



Figure 2:CEC based circuit.

The collector current and Transconductance

$$v_{BE} = V_{BE} + v_{be} \dots\dots\dots(5)$$

$$i_c \cong I_S e^{v_{BE}/V_T} = I_S e^{(V_{BE} + v_{be})/V_T} \dots\dots(6)$$

$$i_c = I_S e^{V_{BE}/V_T} e^{v_{be}/V_T} \dots\dots\dots(7)$$

From Eq.(1)

$$i_c = I_C e^{v_{be}/V_T} \dots\dots\dots(8)$$

Now, if $v_{be} \ll V_T$

$$i_c = I_C \left(1 + \frac{v_{be}}{V_T}\right) \dots\dots\dots(9)$$

$$\{i_c = I_C + i_c\}$$

$$i_c = I_C + \frac{I_C v_{be}}{V_T} \dots\dots\dots(10)$$

$$i_c = \frac{I_C v_{be}}{V_T} \dots\dots\dots(11)$$

$$i_c = g_m v_{be} \dots\dots\dots(12)$$

$$g_m = \frac{I_C}{V_T} \dots\dots\dots(13)$$

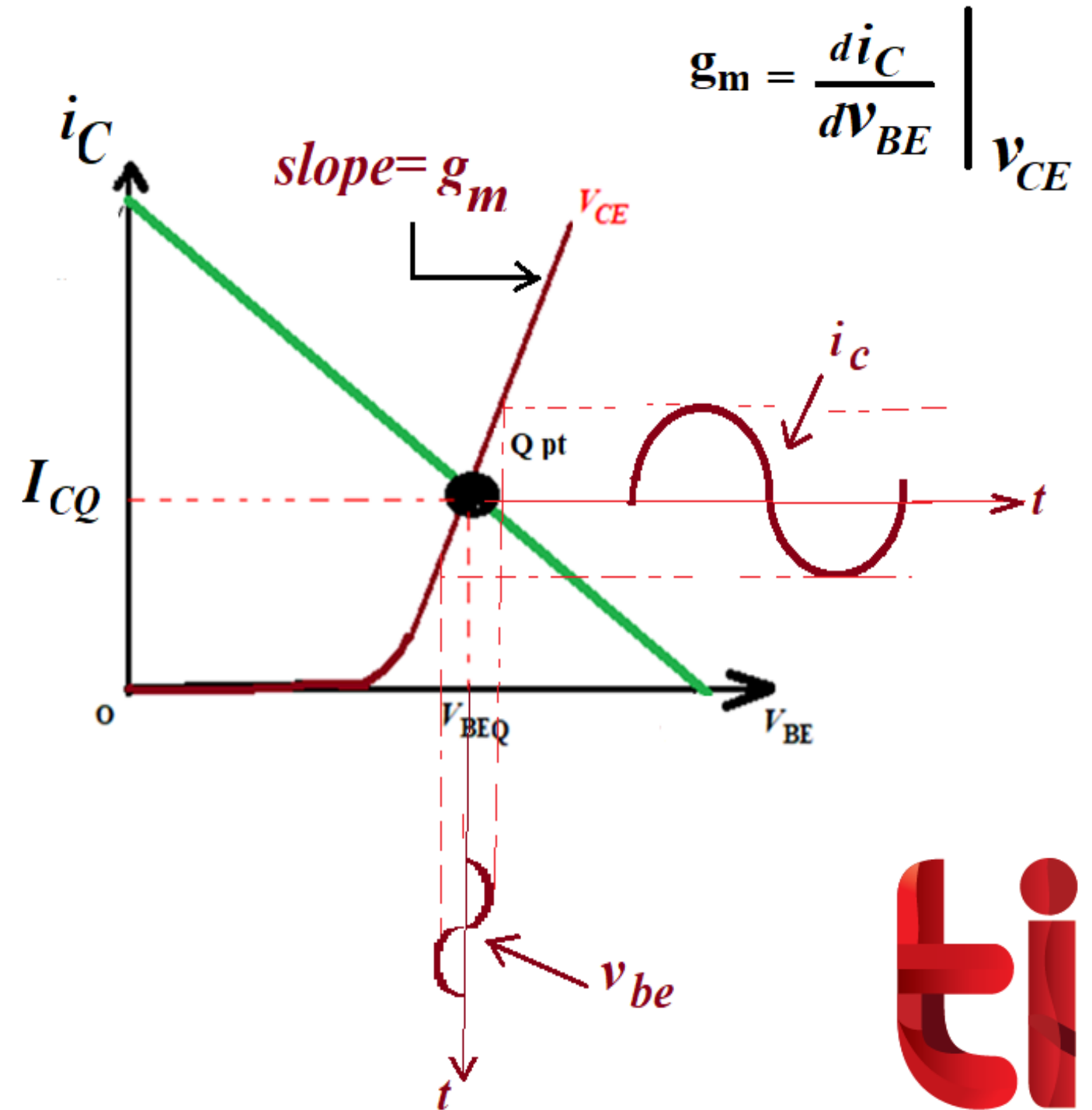
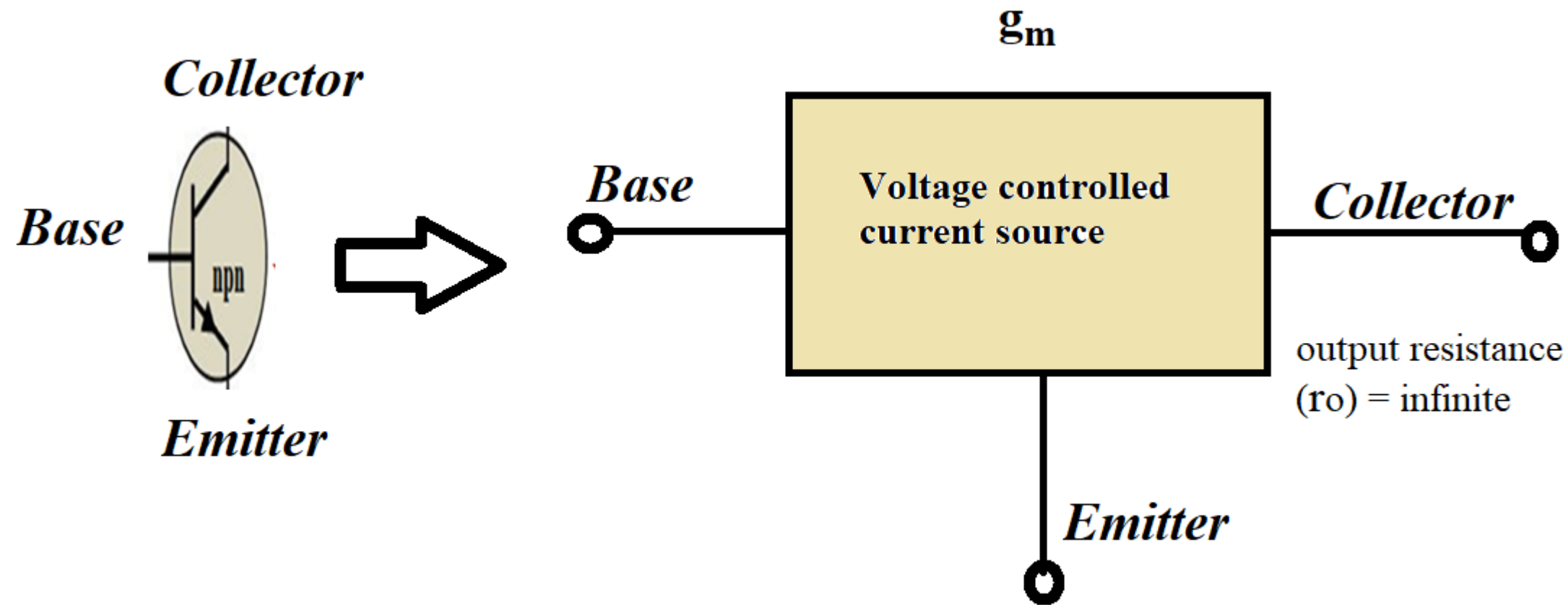


Figure 4: Linear operation of the transistor under small signal condition.



If $v_{be} \ll V_T$



The Base current and the Input resistance at the Base

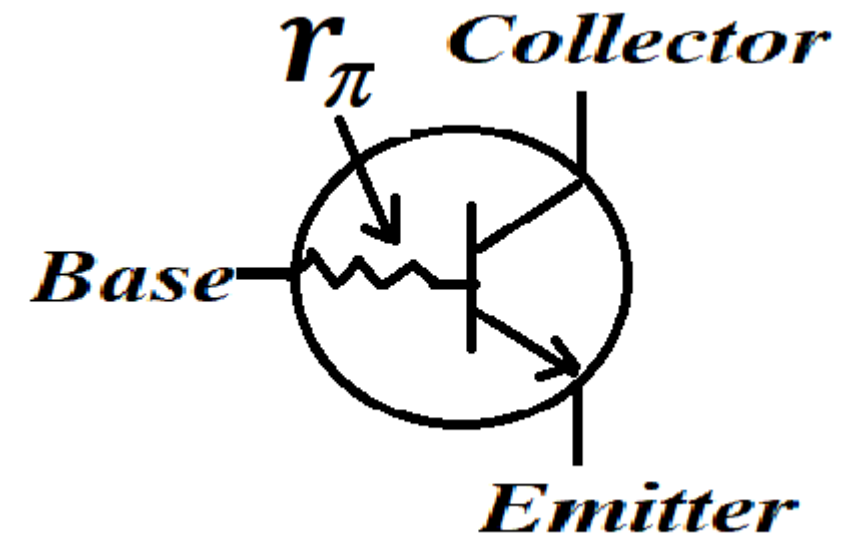
$$i_b = \frac{i_c}{\beta} = \frac{I_C}{\beta} + \frac{I_C v_{be}}{\beta V_T} \dots\dots\dots(14)$$

$$i_B = I_B + i_b \dots\dots\dots(15)$$

$$i_b = \frac{I_C v_{be}}{\beta V_T} \dots\dots\dots(16)$$

$$i_b = \frac{g_m v_{be}}{\beta} \dots\dots\dots(17)$$

$$r_\pi = \frac{v_{be}}{i_b} = \frac{\beta}{g_m} \dots\dots\dots(18)$$



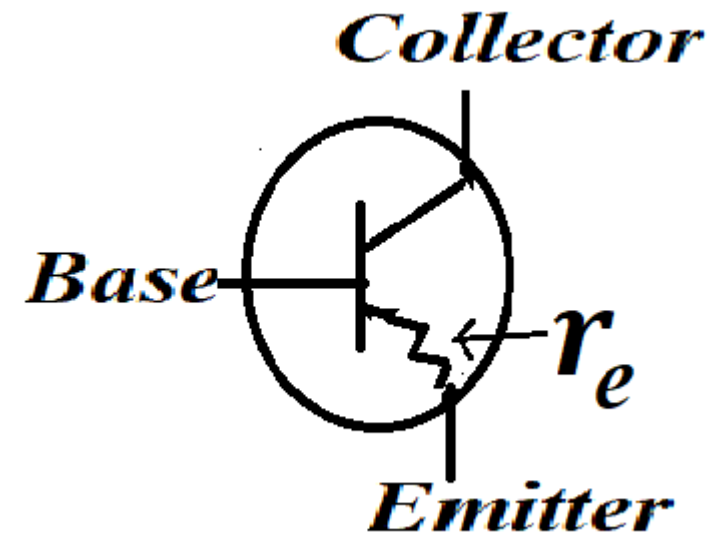
The emitter current and the Input resistance at the Emitter

$$i_E = \frac{i_c}{\alpha} = \frac{I_C}{\alpha} + \frac{i_c}{\alpha} \dots\dots\dots(19)$$

$$i_E = I_E + i_e \dots\dots\dots(20)$$

$$i_e = \frac{i_c}{\alpha} = \frac{I_C v_{be}}{\alpha V_T} = \frac{I_E v_{be}}{V_T} \dots\dots\dots(21)$$

$$r_e = \frac{v_{be}}{i_e} = \frac{\alpha}{g_m} \dots\dots\dots(22)$$



The Relationship between r_e and r_π

$$v_{be} = i_e r_e = i_b r_\pi \dots\dots\dots(23)$$

$$r_\pi = \frac{i_e}{i_b} r_e \dots\dots\dots(24)$$

$$r_\pi = \frac{i_b + i_c}{i_b} r_e = \frac{i_b(1 + \beta)}{i_b} r_e = (1 + \beta) r_e \dots\dots\dots(25)$$

Low frequency Small signal model

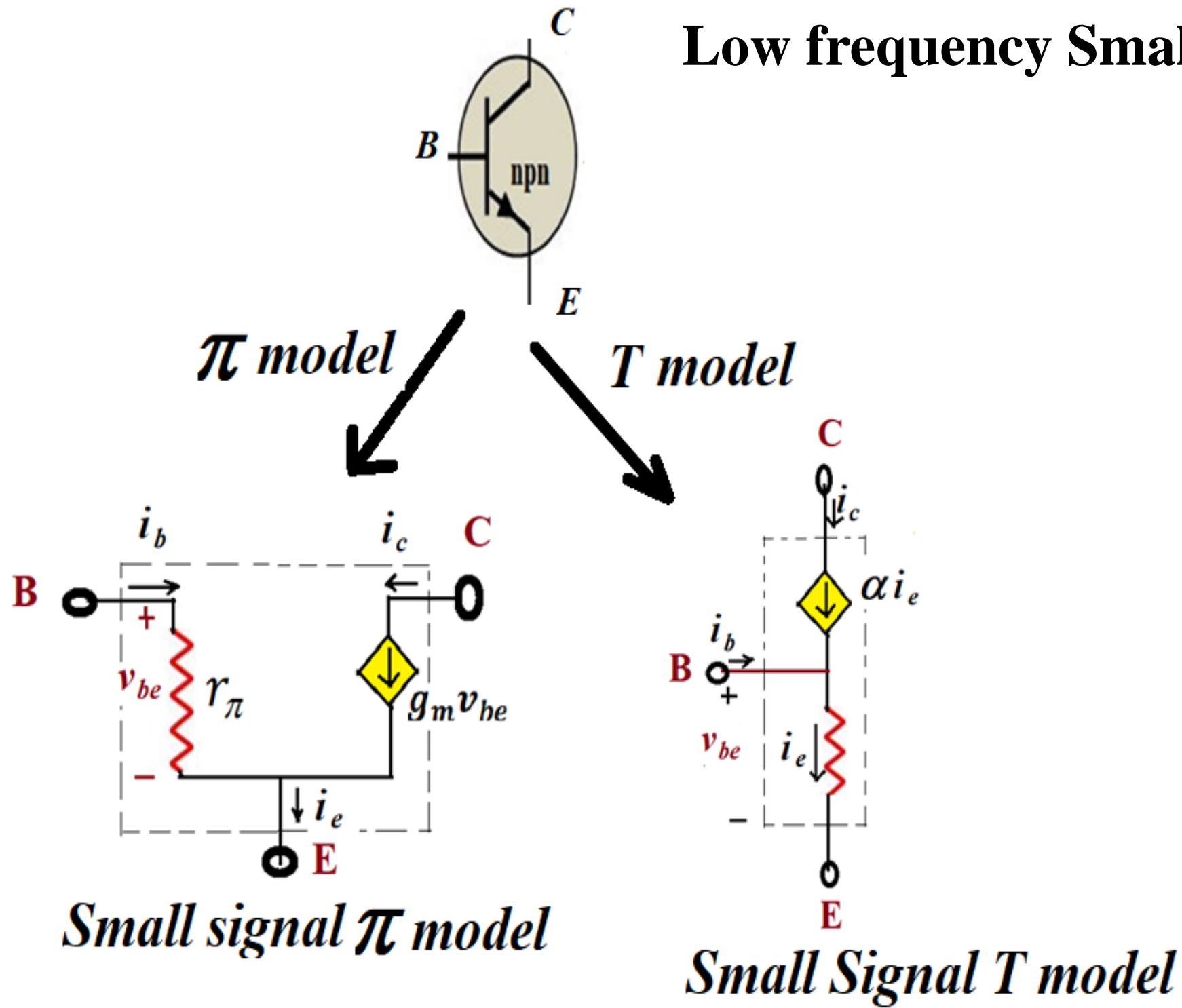


Figure 5:Low frequency Small signal equivalent models.



Low frequency small signal operation

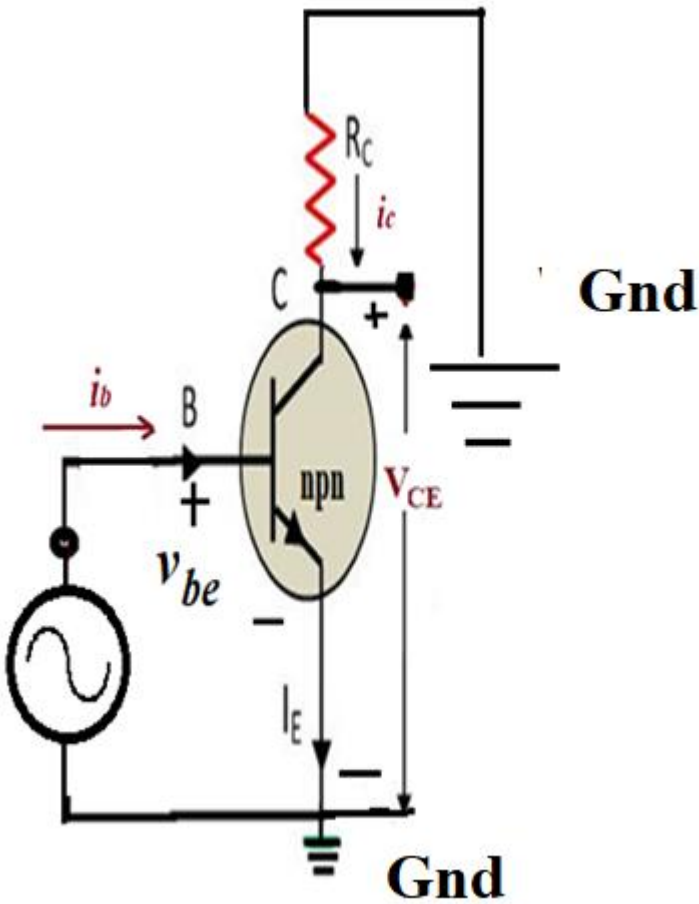


Figure 6:The amplifier CKT with dc sources eliminated.

Voltage gain

$$v_o = i_o R_C = -i_c R_C = -g_m v_{be} R_C \dots\dots\dots(26)$$

$$A_v = \frac{v_{ce}}{v_{be}} = -g_m R_C \dots\dots\dots(27)$$

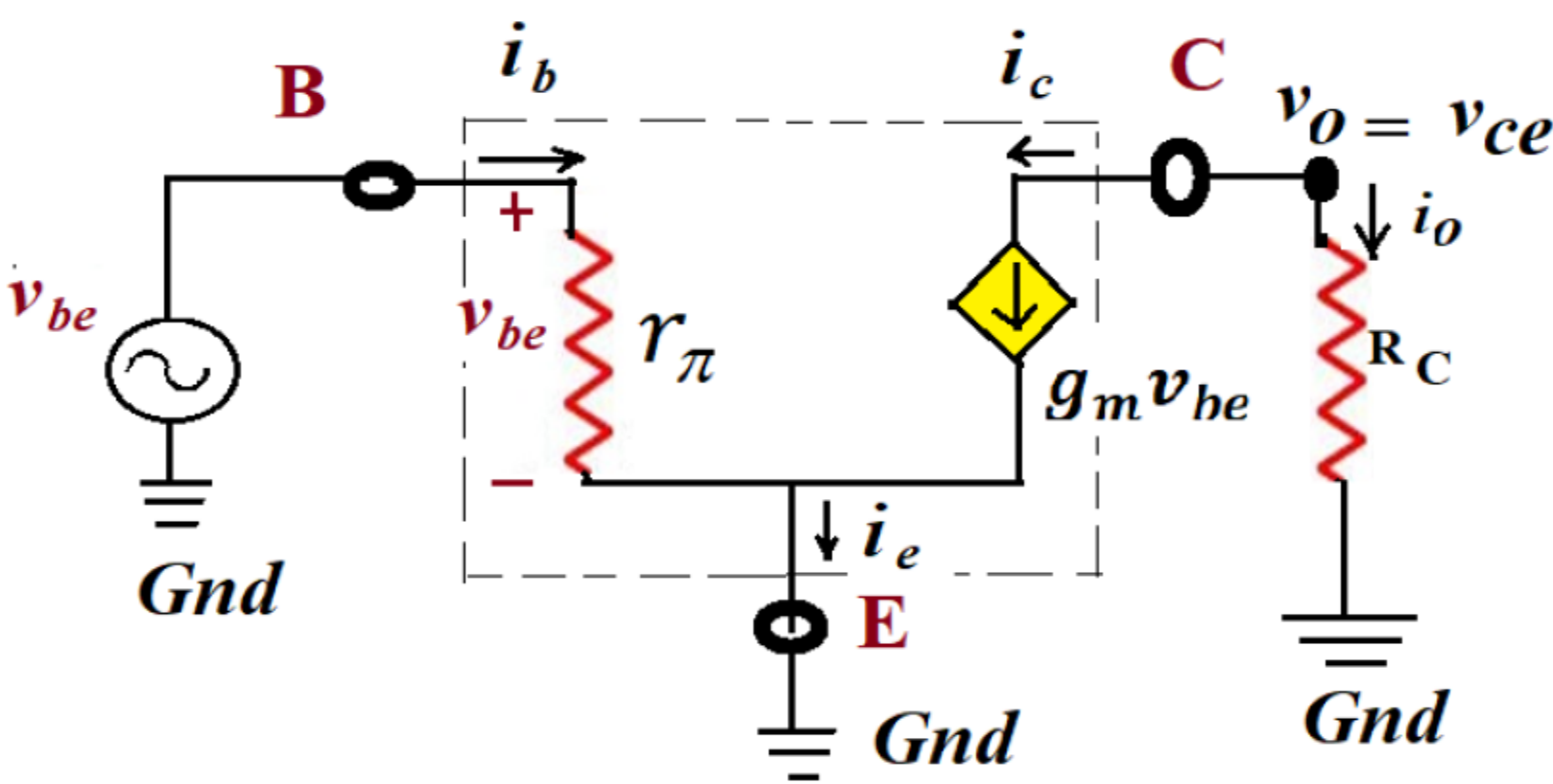


Figure 7:Small signal equivalent CKT of Fig.6.



Thank You

