

Analog Electronic Circuits (UEC301)

By



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Subject: Analog Electronic Circuits (UEC301)

Faculty name: Dr. Mayank Kumar Rai (Associate Professor & Course Coordinator)

Topic of today's Lecture : High frequency hybrid Model and Operation of BJT

Key points

- ✓ The BJT capacitances
- ✓ The high frequency hybrid Model
- ✓ The high frequency operation of BJT

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.



The BJT capacitances

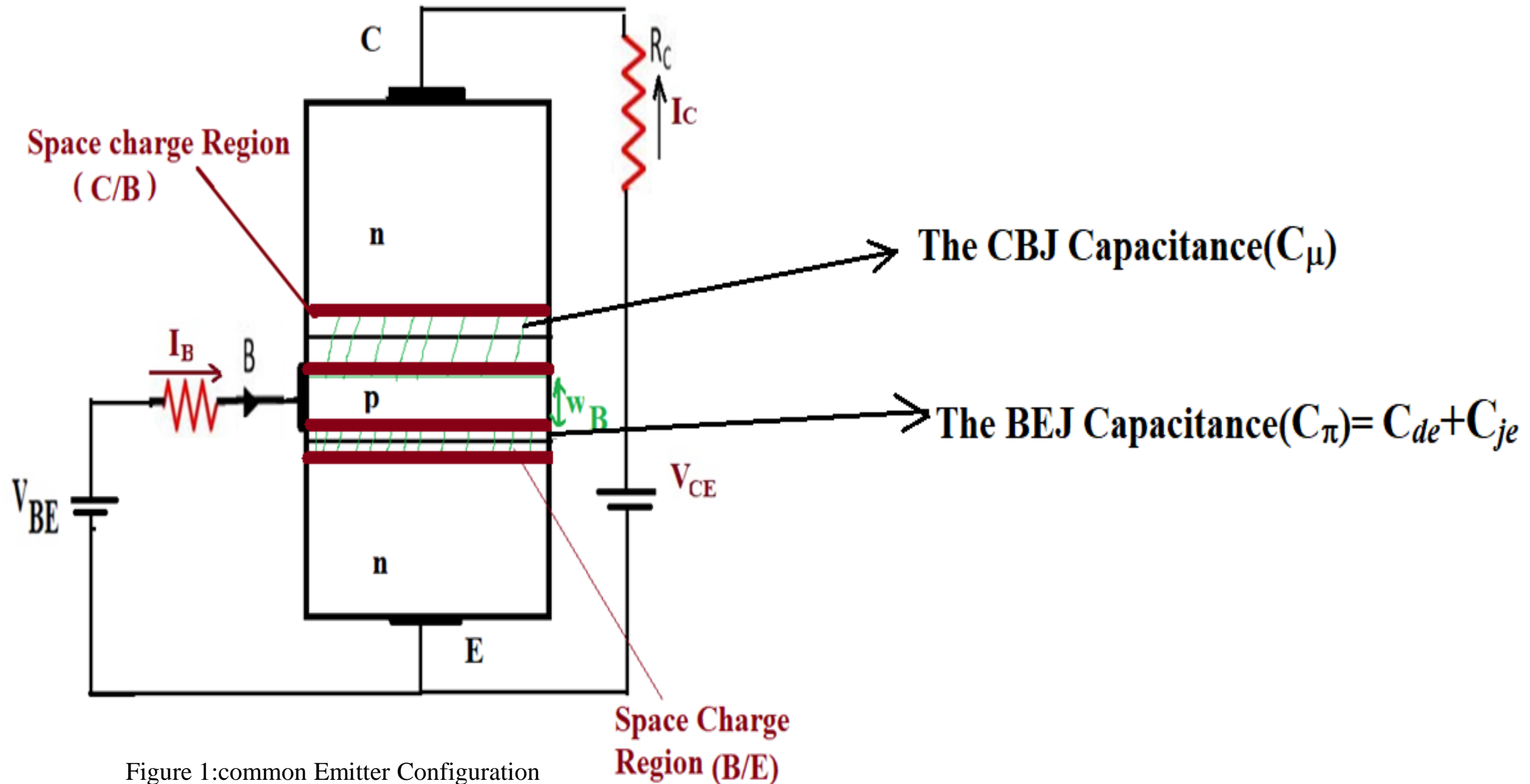


Figure 1: common Emitter Configuration

The BJT internal Capacitances

(1) *BEJ Capacitances* (C_{π}) = $C_{de} + C_{je}$ (1)

Small signal diffusion capacitance, $C_{de} = \frac{dQ_n}{dv_{BE}}$ (2),

where $Q_n = \frac{W^2 i_c}{2D_n} = \tau_f i_c$, $\tau_f = \frac{W^2}{2D_n}$

$C_{de} = \frac{dQ_n}{dv_{BE}} = \tau_f \frac{di_c}{dv_{BE}}$ (3),

where $g_m = \frac{di_c}{dv_{BE}} = \frac{I_C}{V_T}$

$C_{de} = \tau_f \frac{I_C}{V_T}$ (4)

Depletion layer capacitance, $C_{je} = \frac{C_{je0}}{(1 - \frac{V_{BE}}{V_{0E}})^m}$ (5)

(2) *CBJ Capacitances* (C_{μ}):

$C_{\mu} = \frac{C_{\mu0}}{(1 - \frac{V_{CB}}{V_{0C}})^m}$ (6)

The high frequency hybrid Model

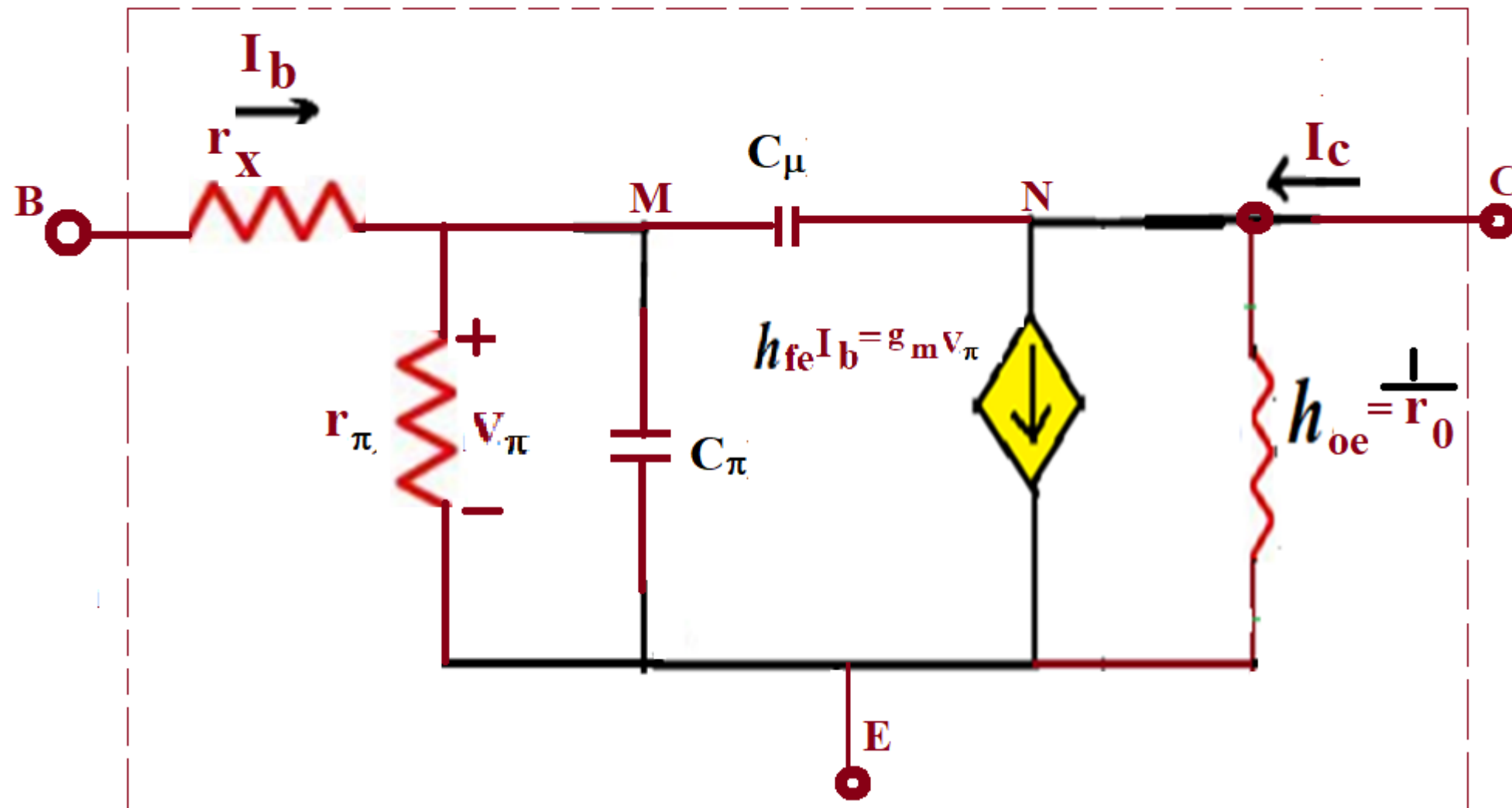


Figure 2 : The high frequency hybrid π model.

Impedance of C = $1/sC$, where $s = j\omega$

The high frequency operation of BJT

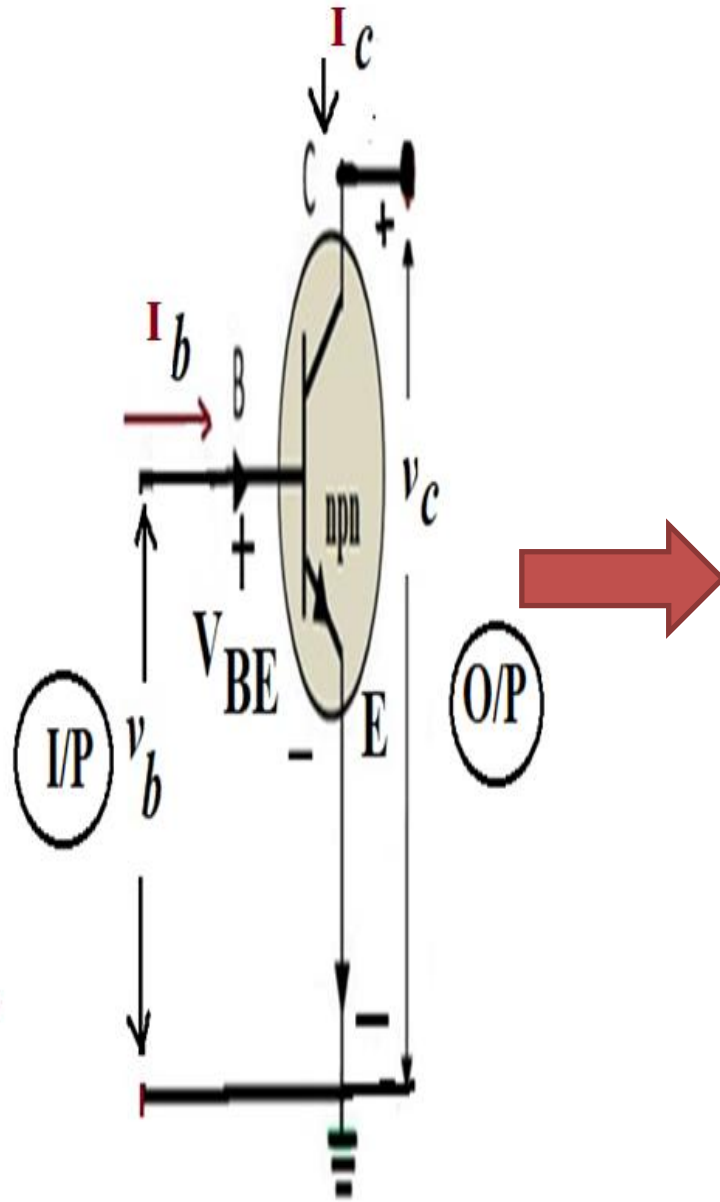


Figure 3: npn transistor.

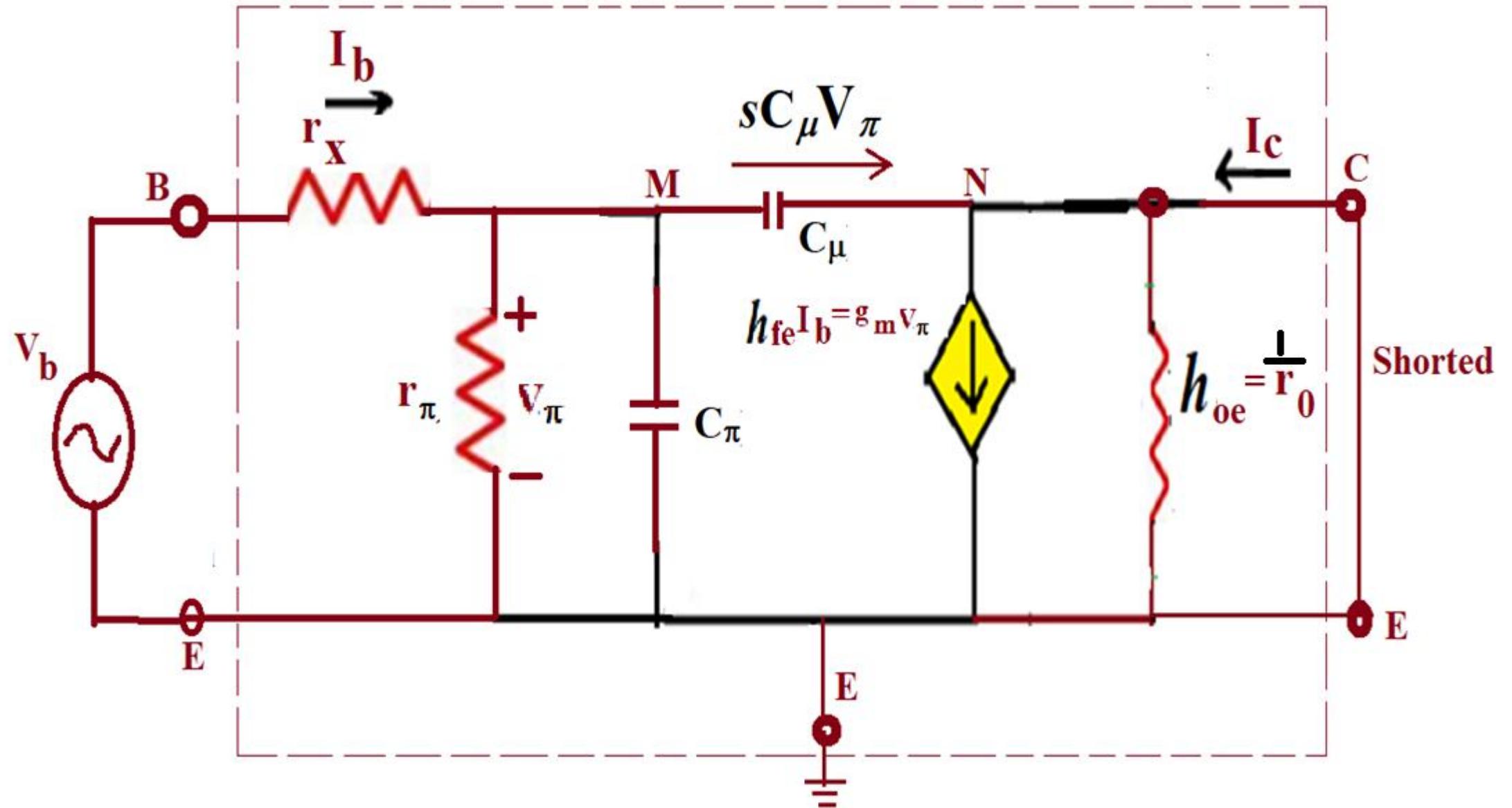


Figure 4: The high frequency hybrid π model based circuit.

The current gain (h_{fe})

$$\text{Current across } C_{\mu}(I_{C\mu}) = \frac{V_M - V_N}{1/sC_{\mu}} \dots\dots\dots(7),$$

where $V_N=V_{ce}=0$ & $V_M=V_{\pi}$

$$I_{C\mu} = \frac{V_{\pi}}{1/sC_{\mu}} = sC_{\mu}V_{\pi} \dots\dots\dots(8)$$

Apply *k.c.l.* to collector end

$$I_c + sC_{\mu}V_{\pi} = g_m V_{\pi} \dots\dots\dots(9)$$

$$I_c = g_m V_{\pi} - sC_{\mu}V_{\pi} \dots\dots\dots(10)$$

$$V_{\pi} = I_b(r_{\pi} \parallel C_{\mu} \parallel C_{\pi}) \dots\dots\dots(11)$$

$$V_{\pi} = \frac{I_b}{\frac{1}{r_{\pi}} + sC_{\mu} + sC_{\pi}} \dots\dots\dots(12)$$

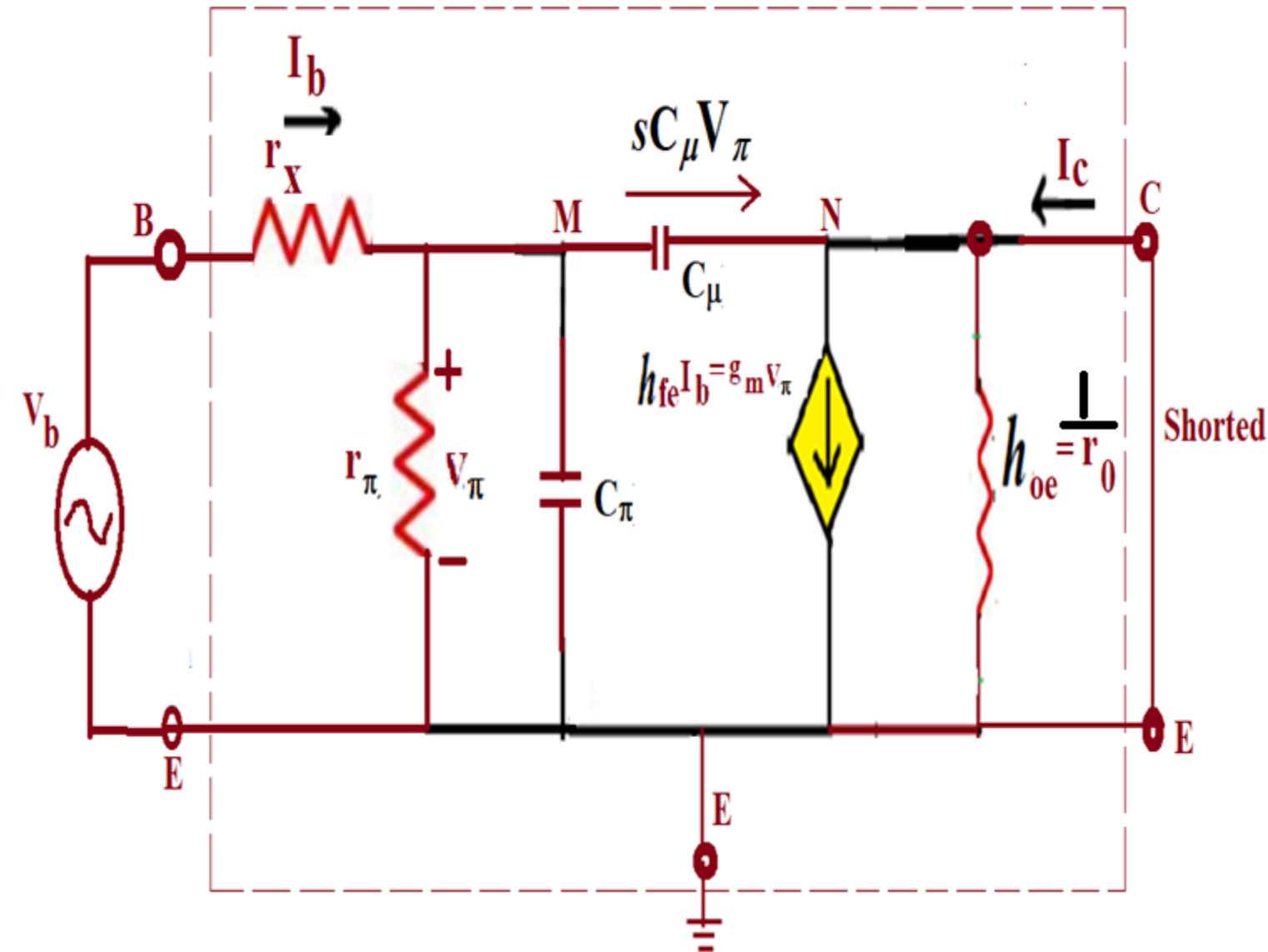


Figure 4: The high frequency hybrid π model based circuit.

$$h_{fe} = \frac{I_c}{I_b} = \frac{g_m - sC_\mu}{\frac{1}{r_\pi} + s(C_\mu + C_\pi)} \dots\dots\dots(13)$$

$$h_{fe} = \frac{g_m r_\pi}{1 + s(C_\mu + C_\pi)r_\pi} = \frac{\beta_o}{1 + s(C_\mu + C_\pi)r_\pi} \dots\dots(14)$$

$$\text{Transfer function} = \frac{K}{1 + s/\omega_o}$$

h_{fe} has single pole response with a 3-dB frequency at $\omega_o = \omega_\beta$

$$\omega_\beta = \frac{1}{(C_\mu + C_\pi)r_\pi} \dots\dots\dots(15)$$

From the Fig.5 , the frequency at which h_{fe} drops to unity is called “*unity gain bandwidth(ω_T)*”.

$$\omega_T = \beta_o \omega_\beta \dots\dots\dots(16)$$

$$\omega_T = \frac{g_m}{(C_\mu + C_\pi)} \dots\dots\dots(17)$$

$$f_T = \frac{g_m}{2\pi(C_\mu + C_\pi)} \dots\dots\dots(18)$$

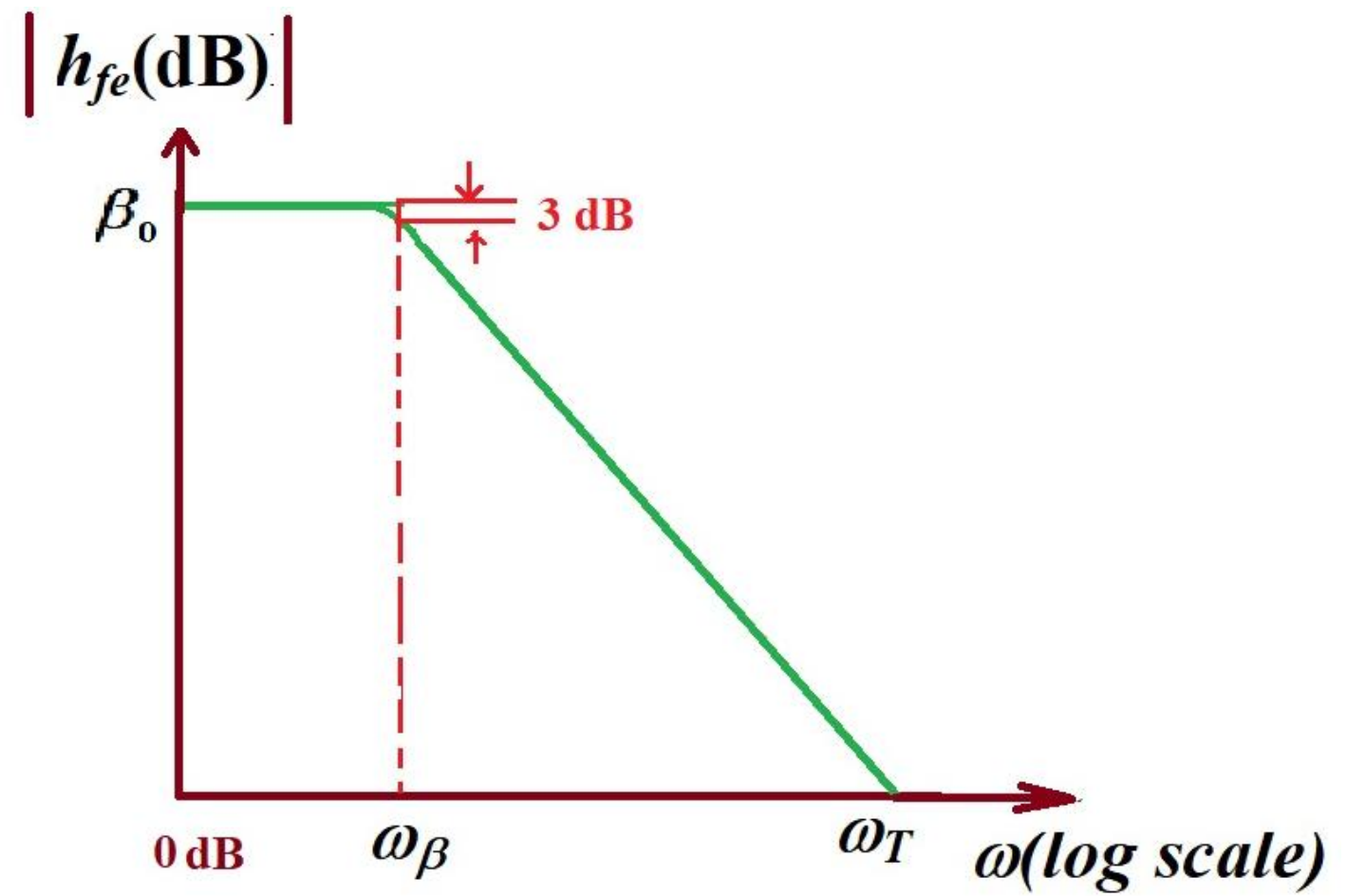
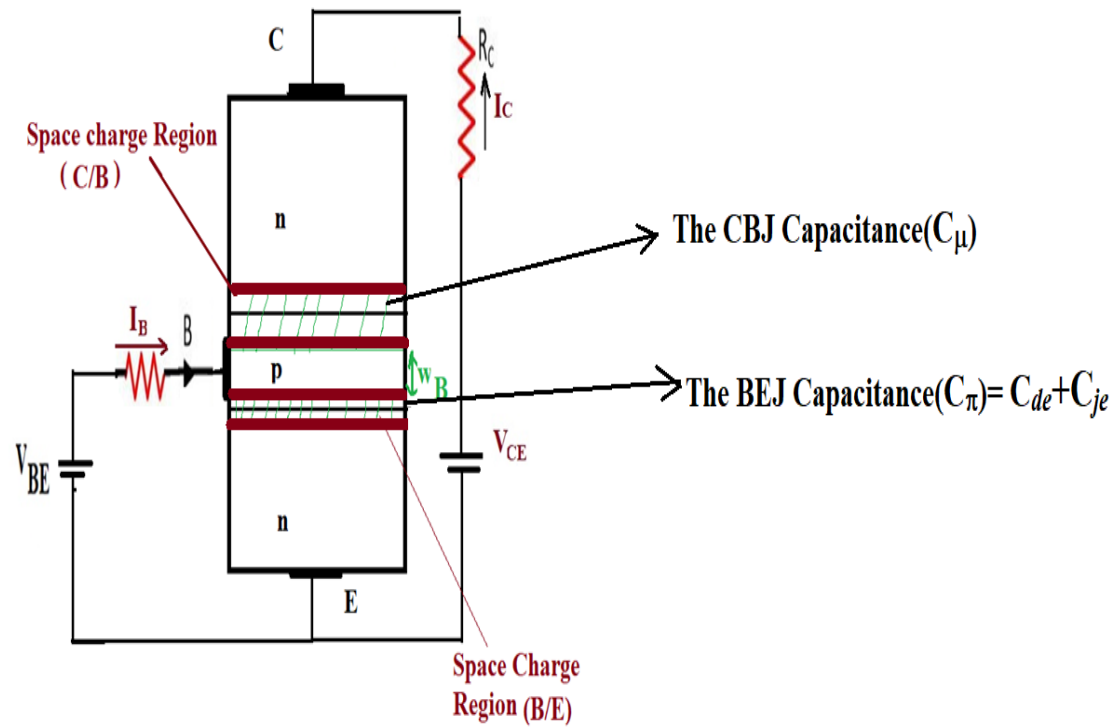


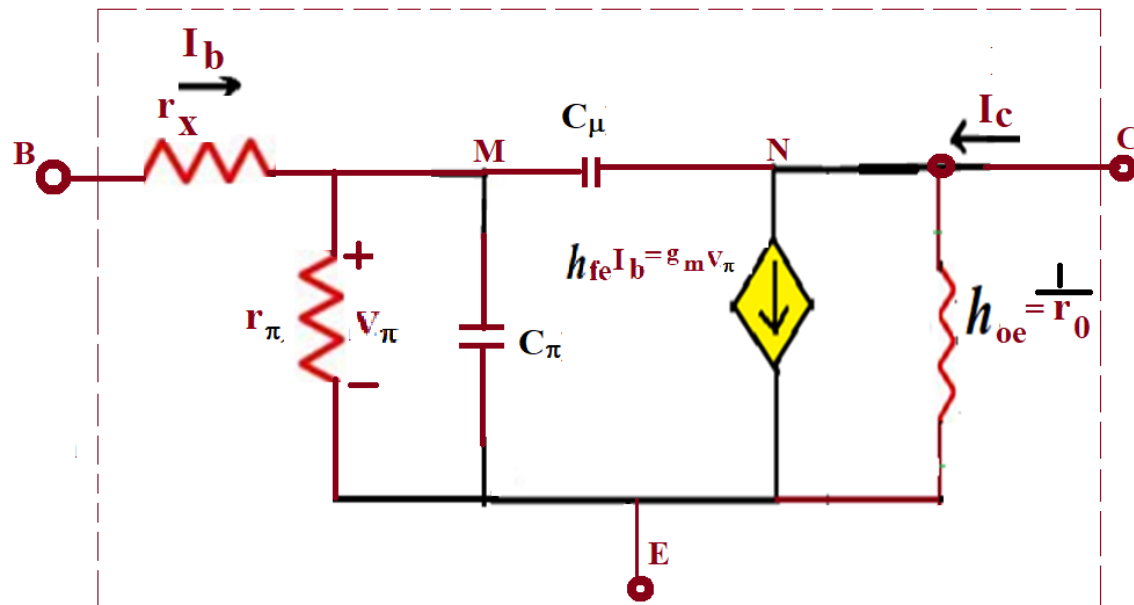
Figure 5: Frequency response.

Summary

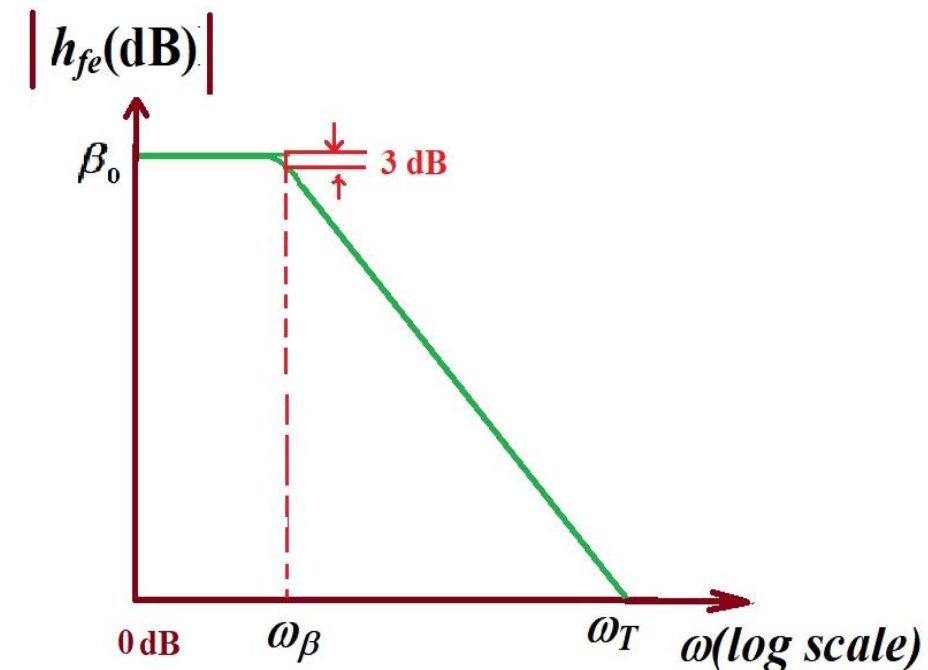
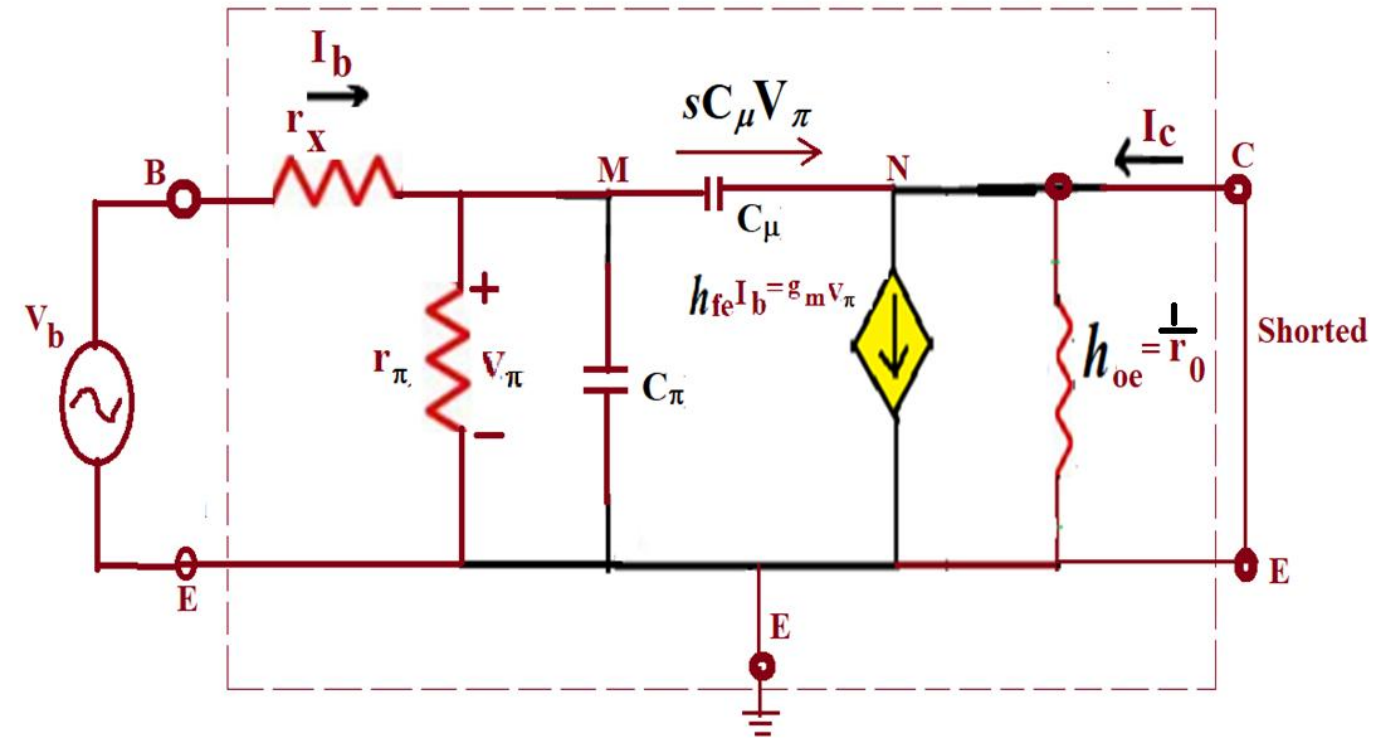
✓ The BJT capacitances



✓ The high frequency hybrid Model



✓ The high frequency hybrid Model based circuit



Thank You

