EE112 - Fall 2016
Analog Integrated Circuits I

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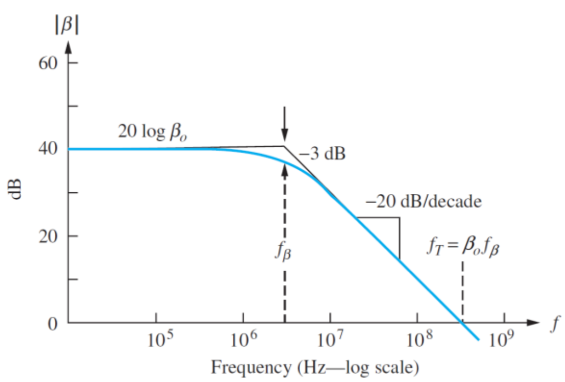
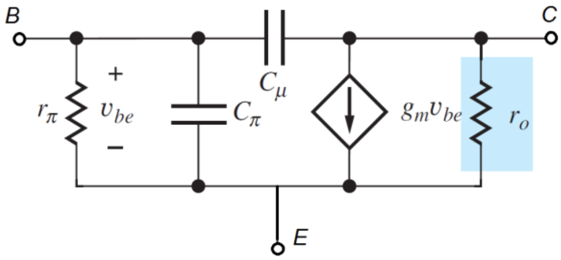
5210 Research Bldg.

BJT Unity-Gain and Beta-Cutoff Frequencies

- The current gain of the transistor decreases as the frequency increases and can be modeled by a single-pole transfer function.



Frequency-Dependent Transistor Models
Hybrid-Pi Model for the BJT



- C_μ is the capacitance of the reverse-biased collector-base diode:

- The frequency dependence of the BJT in forward-active region can be modeled by adding capacitors C_μ and C_π to the hybrid-pi model.
- C_π models the change in base minority carrier charge as the base-emitter voltage of the transistor changes:

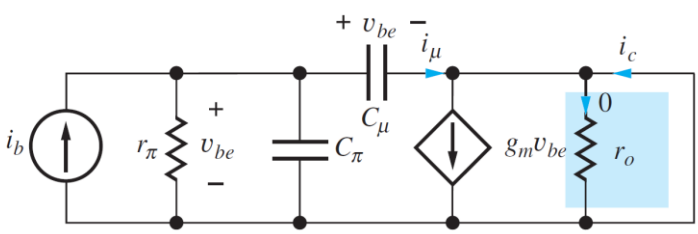
$$C_\pi = g_m \tau_F$$

where, τ_F is the forward base transit-time of the transistor, the time a carrier takes to cross the base region. For BJT,

$$\tau_F = Q/i_T = W_B^2/(2D_n)$$

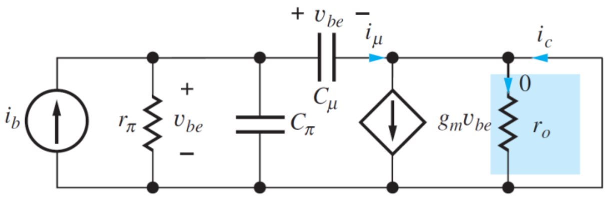
where, W_B is the base width, D_n is the diffusion coefficient.

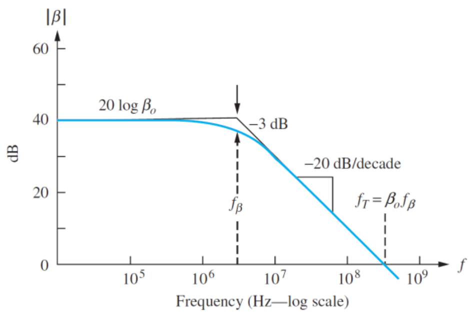
Beta-cutoff Frequency (ω_β) of BJT



- We calculate the cutoff frequency for the short-circuit current gain using the circuit model given here.
- The right-half plane transmission zero $\omega_Z = +g_m/C_\mu$ occurring at high frequency (above ωT) can be neglected.

Unity-gain Frequency (ω_T) of BJT

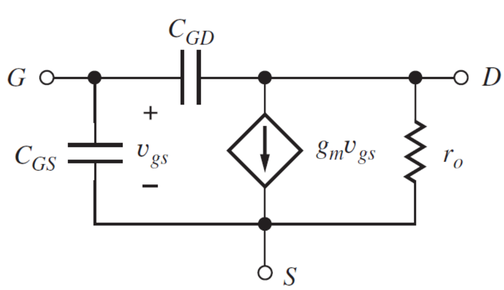


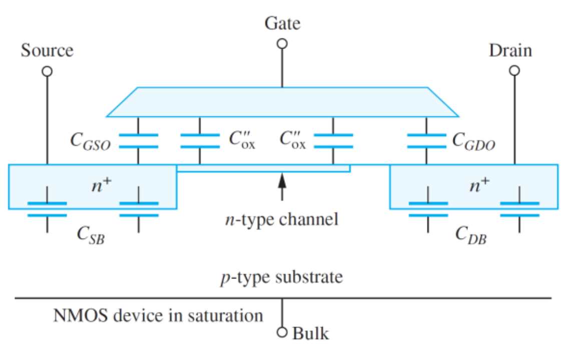


- We can rearrange the current gain expression to expose the unity-gain frequency ω_T of the transistor.

High-frequency Model for the MOSFET

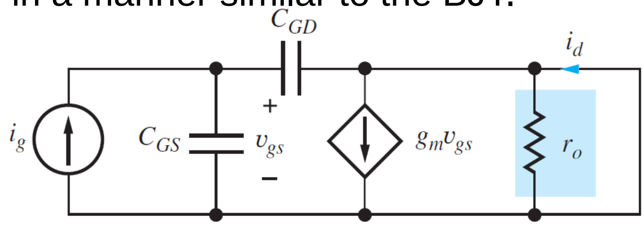
- At frequencies above dc, the input resistance and current gain of the MOSFET is no longer infinite. The pi-model for the MOSFET includes the gate-source and gate-drain capacitors C_{GS} and C_{GD}.





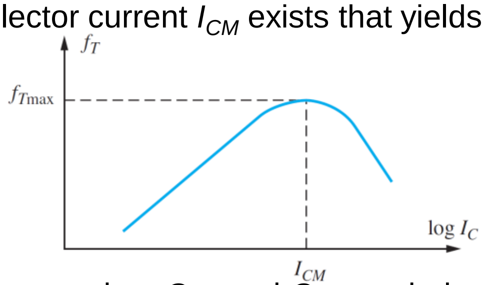
Unity-gain Frequency for the MOSFET

- The short-circuit current gain and unity-gain frequency of the MOSFET are calculated in a manner similar to the BJT.



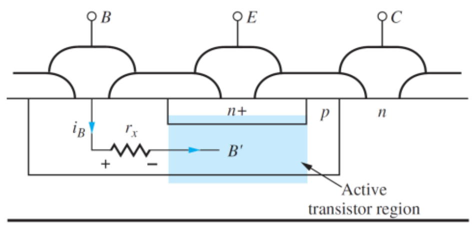
Limitations of High-frequency Models

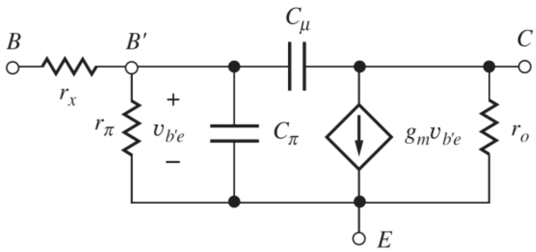
- Above $0.3f_T$, behavior of simple pi-models begins to deviate significantly from the actual device.
- Also, ω_T depends on operating current as shown below and is not constant as assumed in the earlier slides.
- For given BJT, a collector current I_{CM} exists that yields f_{Tmax}.



- For the MOSFET in saturation, C_{GS} and C_{GD} are independent of Q-point current,

Bipolar Transistor Model
Base Resistance r_x





- Base current enters the BJT through the external base contact and traverses a high resistance region before entering active area.
- Resistor r_x models the voltage drop between the base contact and the active area of the BJT.