ECE 342
Electronic Circuits

Lecture 25
Frequency Response of CG, CB,SF and EF

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Common Gate Amplifier

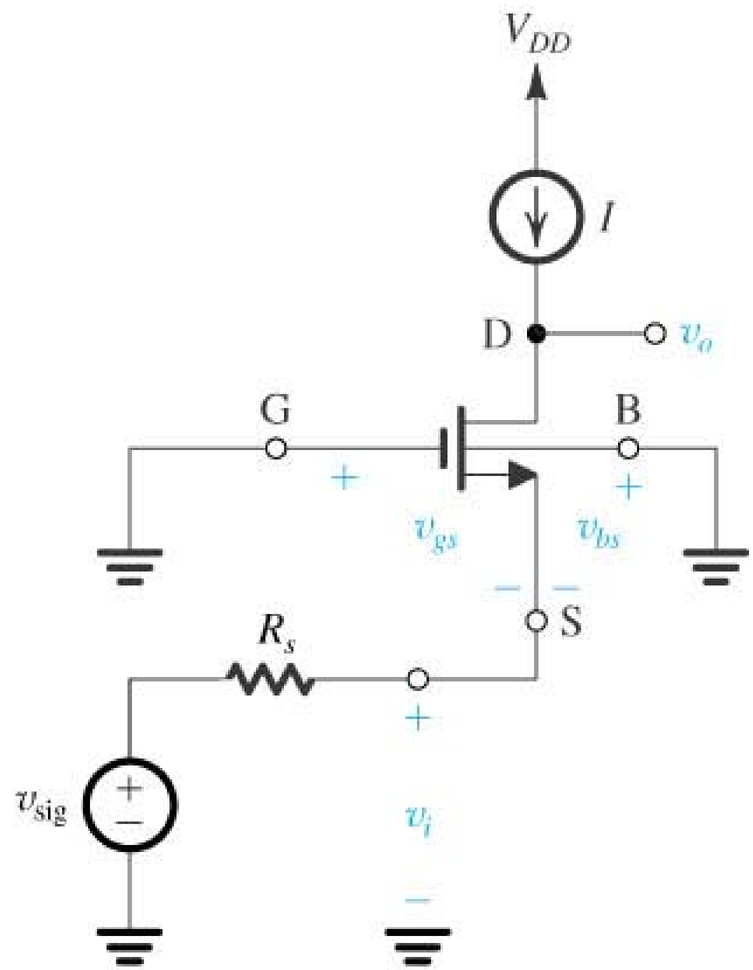
Substrate is not connected to the source➔ must account for body effect

Drain signal current becomes

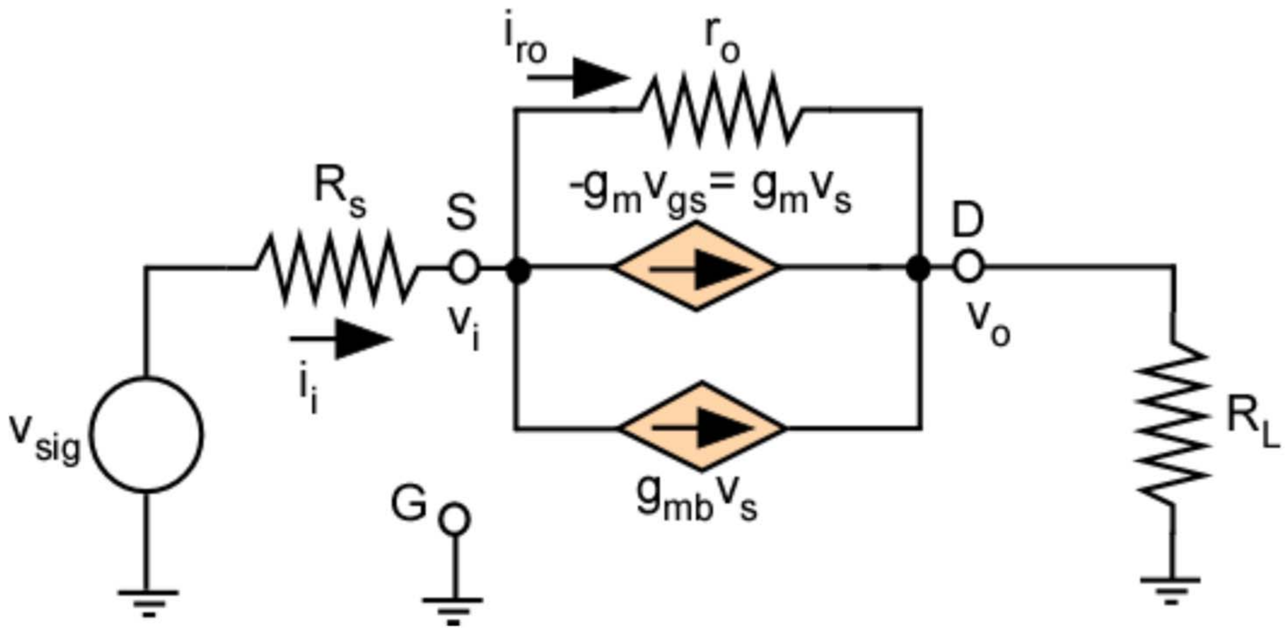
$$i_D = \left(g_m v_{gs} + g_{mb} v_{bs}\right)$$

And since $v_{gs} = v_{bs}$

Body effect is fully accounted for by using $g_m \rightarrow \left(g_m + g_{mb}\right)$



Common Gate Amplifier



$$i_i = \left(g_m + g_{mb}\right) v_i + i_{ro}$$

with $v_i = v_s$

$$i_{ro} = \frac{v_i - v_o}{r_o} = \frac{v_i - i_i R_L}{r_o} \Rightarrow i_i = \frac{\left(g_m + g_{mb} + \dfrac{1}{r_o}\right) v_i}{\left(1 + \dfrac{R_L}{r_o}\right)}$$

IC - Common Gate Amplifier

$$R_{in} \equiv \frac{v_i}{i_i} = \frac{r_o + R_L}{1 + \left(g_m + g_{mb}\right) r_o}$$

$$\text{As } \; r_o \to \infty, \quad R_{in} \to \frac{1}{g_m + g_{mb}}$$

$$\text{If } \; R_L = \infty, \quad R_i \to \infty$$

$$v_o = \left(g_m + g_{mb}\right) r_o v_i + v_i$$

$$A_{vo} = 1 + \left(g_m + g_{mb}\right) r_o$$

IC - Common Gate Amplifier

$$R_{in} = \frac{r_o + R_L}{A_{vo}} \simeq \frac{1}{g_m + g_{mb}} + \frac{R_L}{A_o}, \qquad \text{where} \;\; A_o \cong \left(g_m + g_{mb}\right) r_o$$

Taking r_o into account adds a component (R_L/A_o) to the input resistance.

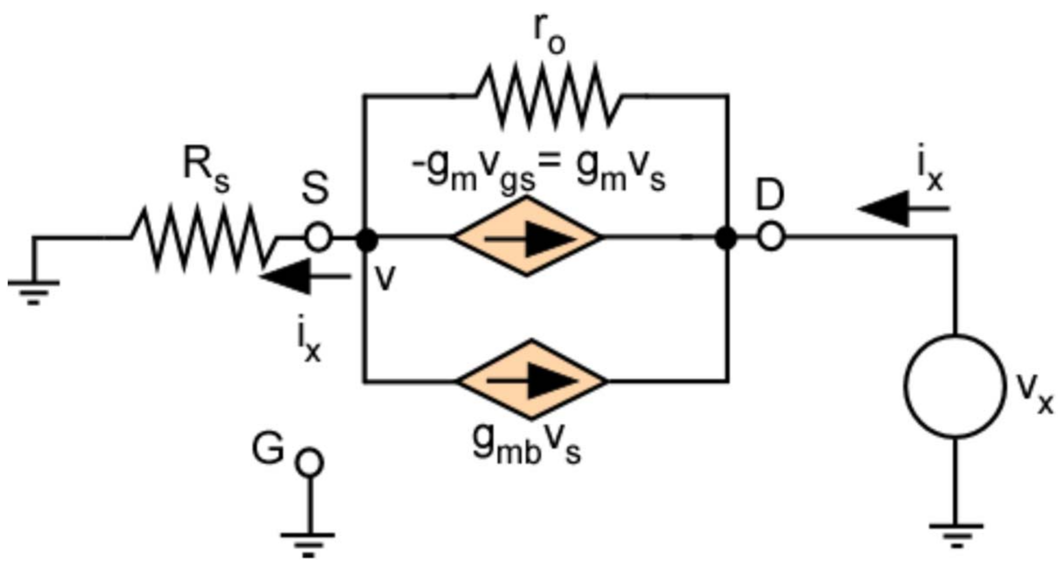
The open-circuit voltage gain is:

$$A_{vo} = 1 + \left(g_m + g_{mb}\right) r_o$$

The voltage gain of the loaded CG amplifier is:

$$G_v = A_{vo} \frac{R_L}{R_L + r_o + A_{vo} R_s}$$

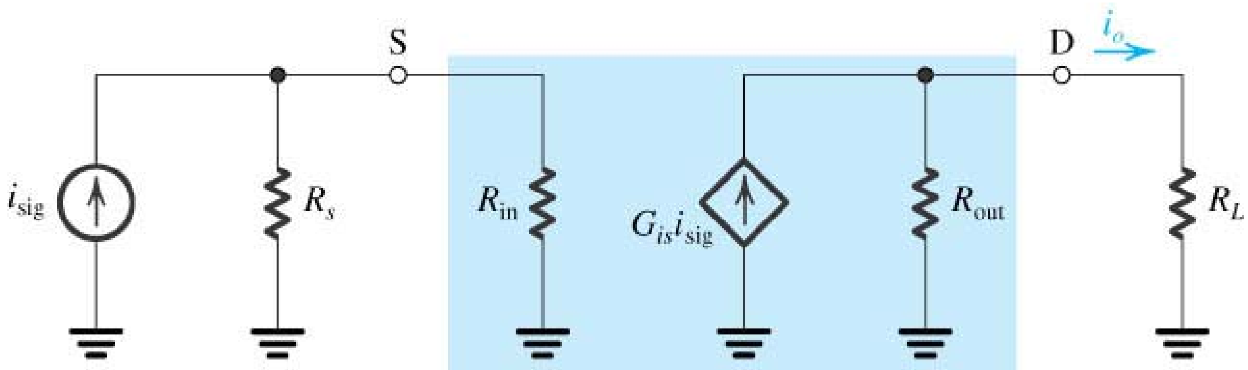
CG Output Resistance



$$v_x = \left[i_x + \left(g_m + g_{mb} \right) v \right] r_o + v \qquad \text{with} \quad v = i_x R_s$$

$$R_{out} = r_o + \left[1 + \left(g_m + g_{mb} \right) r_o \right] R_s \quad \text{or} \quad R_{out} = r_o + A_{vo} R_s$$

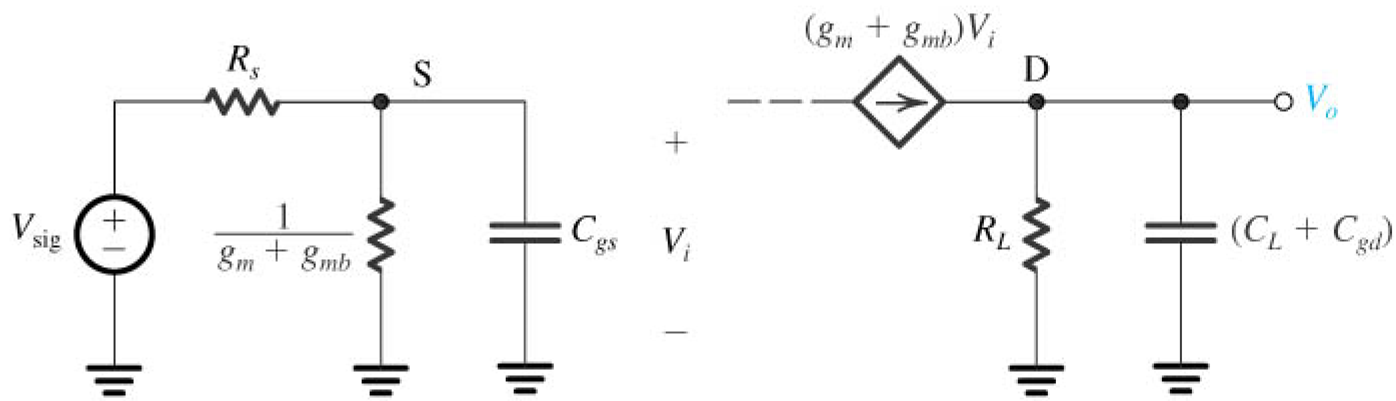
CG Amplifier as Current Buffer



$$G_{is} = G_{vo}\frac{R_s}{R_{out}} \simeq 1$$

G_{is} is the short-circuit current gain

High-Frequency Response of CG



(b)

- Include C_L to represent capacitance of load
- C_{gd} is grounded
- No Miller effect

High-Frequency Response of CG

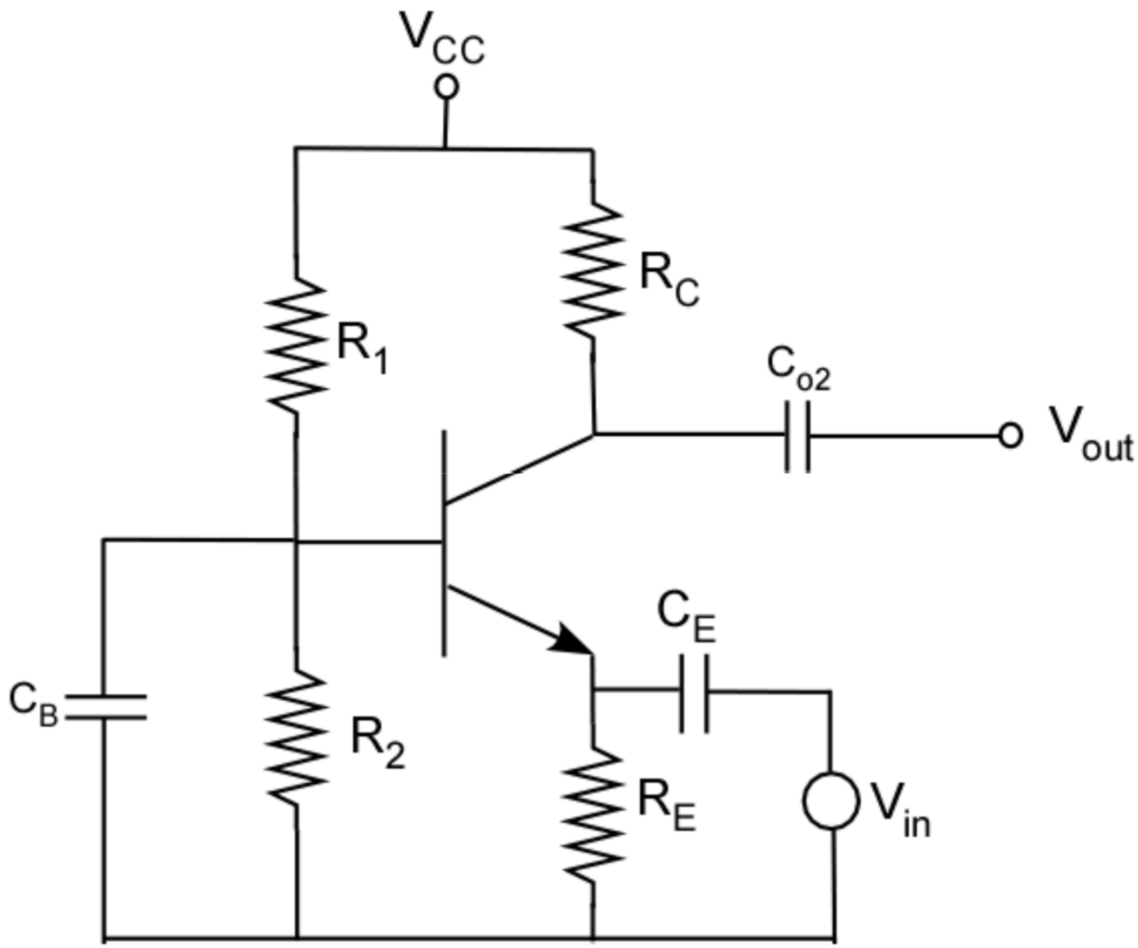
2 poles:

$$f_{P1} = \frac{1}{2\pi C_{gs}\left(R_s // \dfrac{1}{g_m + g_{mb}}\right)}$$

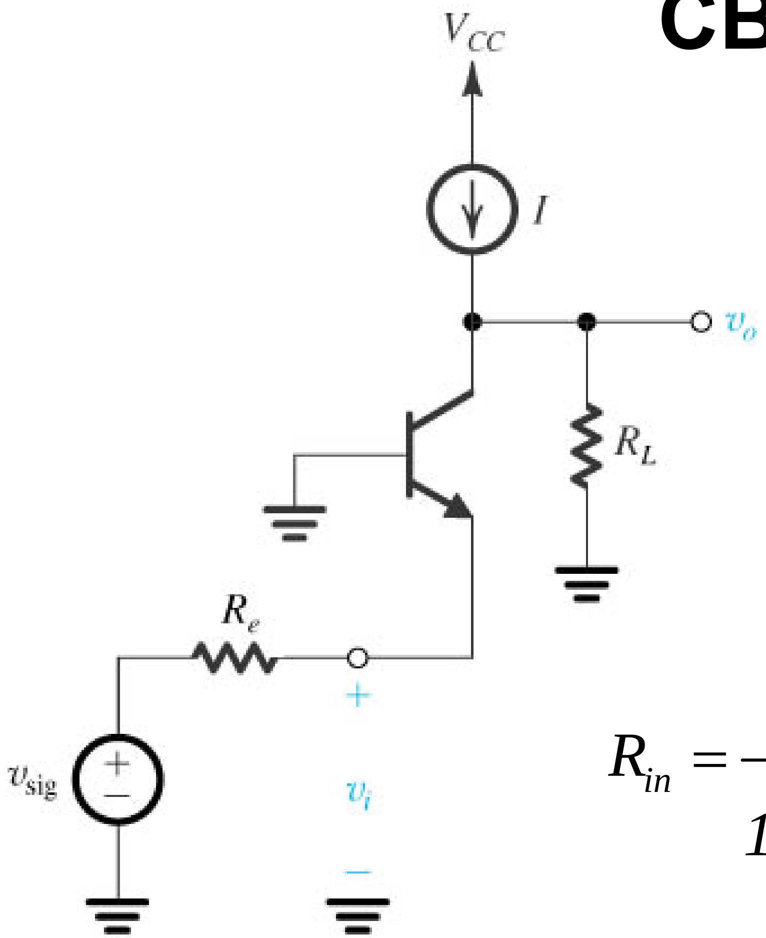
$$f_{P2} = \frac{1}{2\pi\left(C_{gd} + C_L\right)R_L}$$

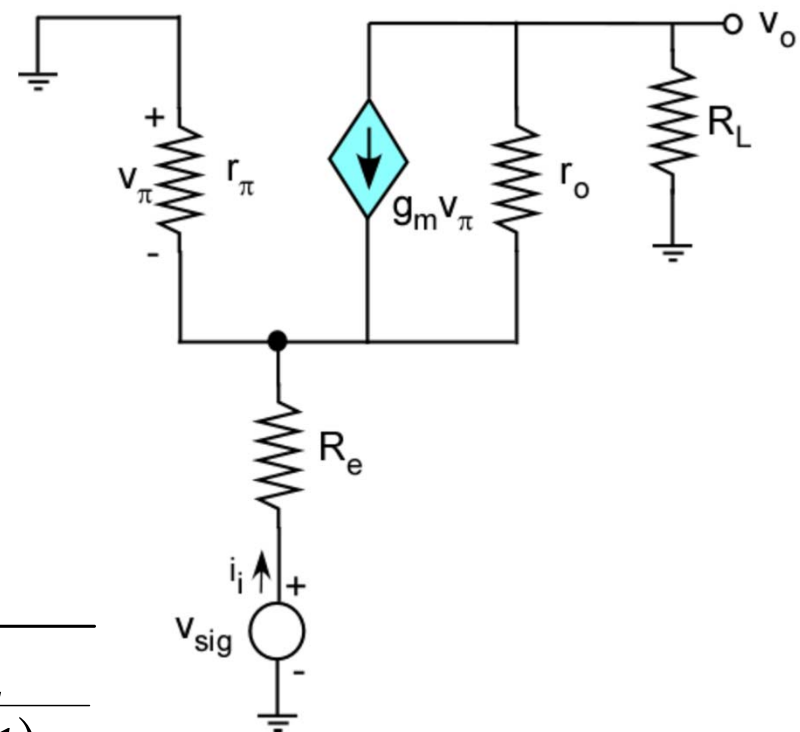
- **f_{P2} is usually lower than f_{p1}**
- **f_{P2} can be dominant**
- **Both f_{P1} and f_{P2} are usually much higher than f_P in CS case**

Common Base (CB) Amplifier



CB Amplifier





$$R_{in} = \frac{r_o + R_L}{1 + \frac{r_o}{r_e} + \frac{R_L}{(\beta+1) r_e}}$$

$$A_{vo} = 1 + g_m r_o$$

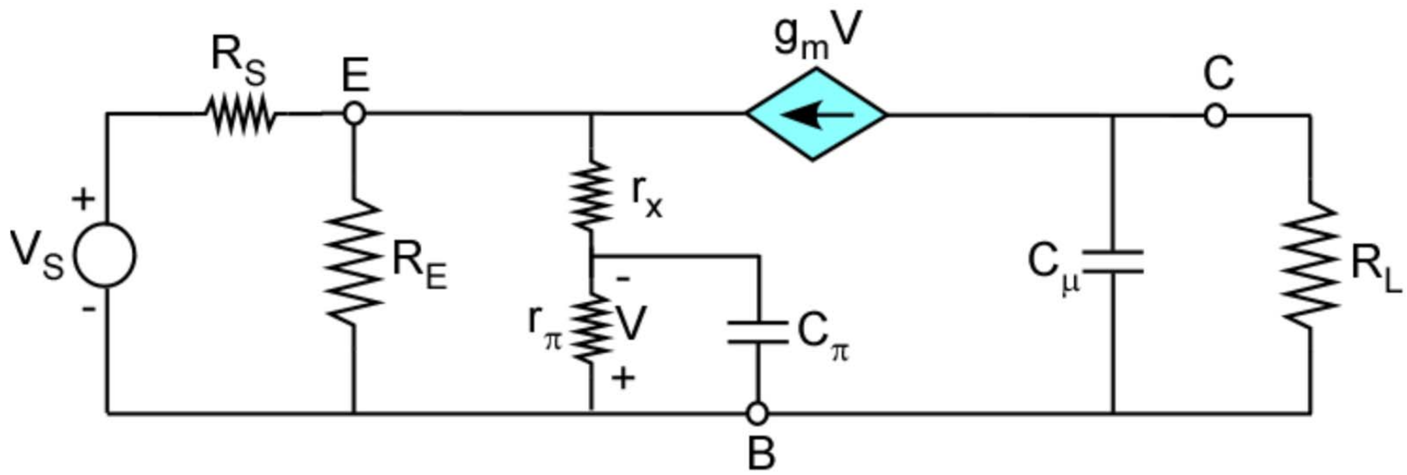
$$r_e = \frac{r_\pi}{\beta + 1}$$

$$R_{out} = r_o + (1 + g_m r_o) R_e'$$

$$R_e' = R_e \,//\, r_\pi$$

High-Frequency Analysis of CB Amplifier

Exact analysis is too tedious ➔ approximate



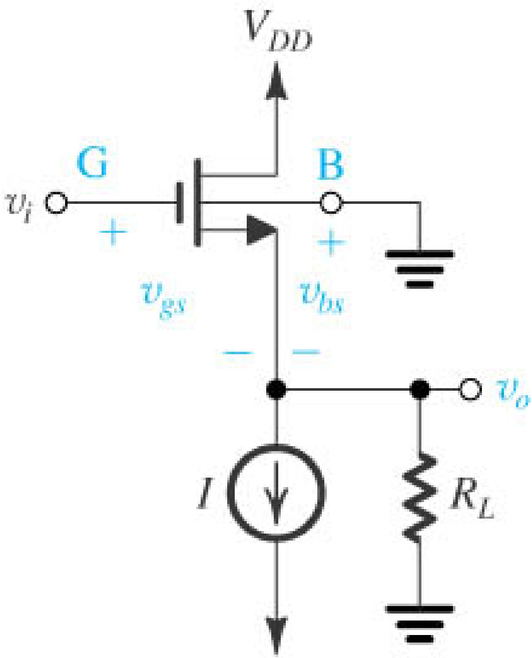
From current gain analysis

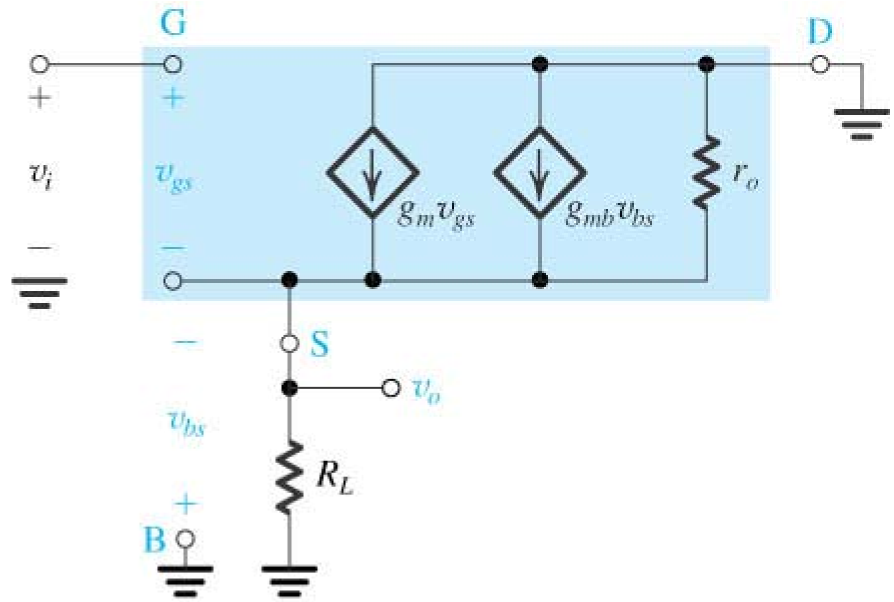
$$\omega_{in-3dB} = \frac{1}{C_\pi \left[R_S \,//\, R_E + \frac{r_x}{1+\beta} \right] // \left[\frac{r_\pi}{1+\beta} \right]}$$

$$\omega_{out-3dB} = \frac{1}{C_\mu R_L}$$

The amplifier's upper cutoff frequency will be the lower of these two poles.

Source Follower



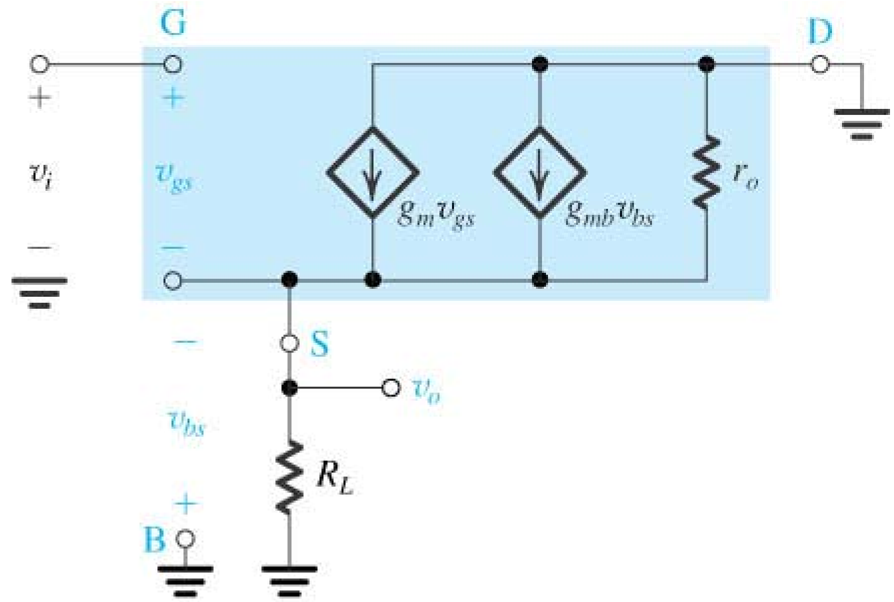


$$R_L^{'} = R_L \,||\, r_o \,||\, \frac{1}{g_{mb}}$$

$$v_o = g_m v_{gs} R_L^{'}$$

Source Follower

$$v_{gs} = v_i - v_o$$

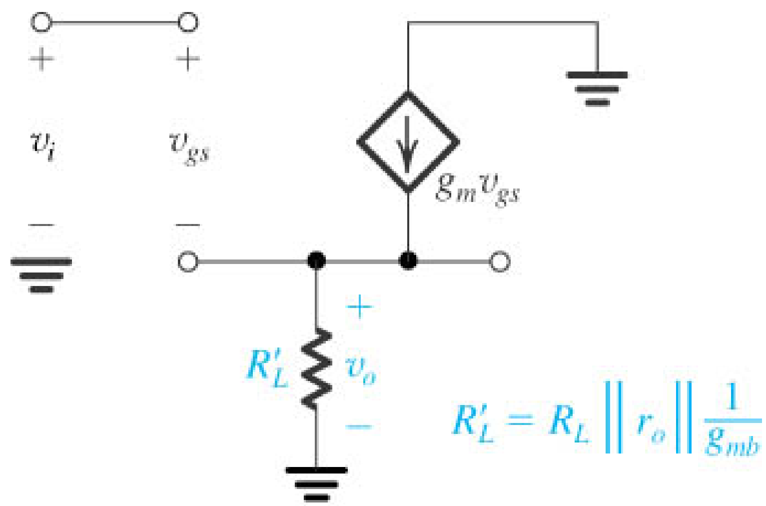


$$A_v \equiv \frac{v_o}{v_i} = \frac{g_m R_L^{'}}{1 + g_m R_L^{'}}$$

$$A_{vo} = \frac{g_m r_o}{1 + \left(g_m + g_{mb}\right) r_o}$$

$$A_{vo} = \frac{g_m}{g_m + g_{mb}} = \frac{1}{1 + \chi}$$

Source Follower – Output Resistance

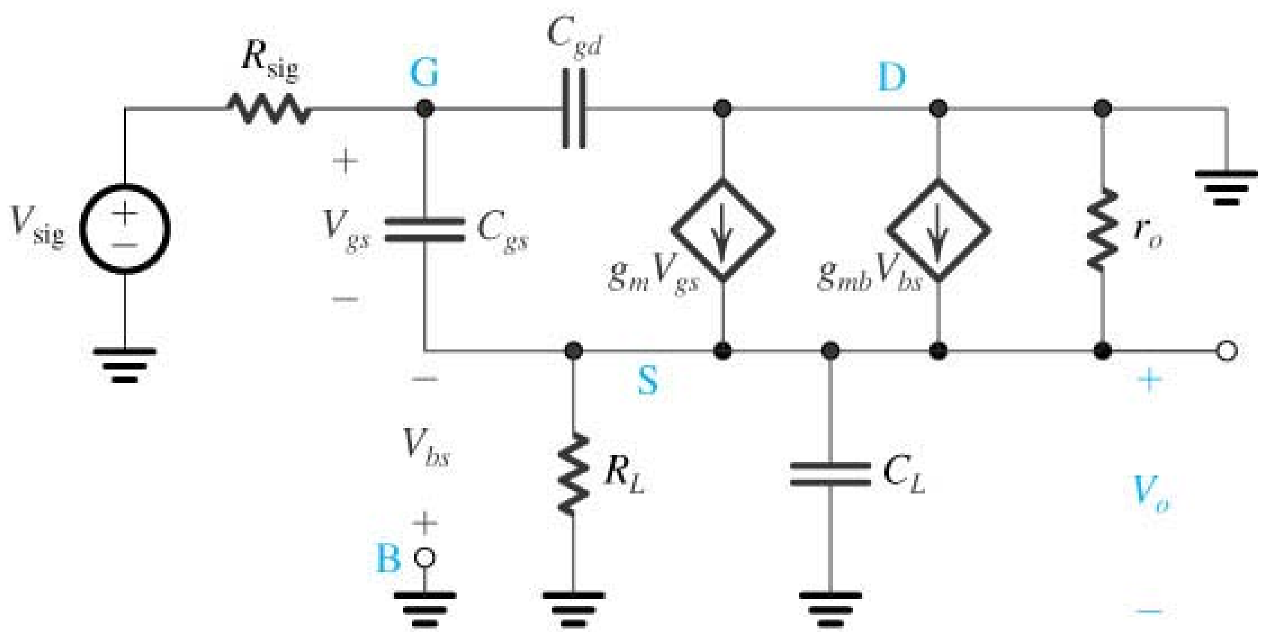


$$R_o = \frac{1}{g_m + g_{mb}} \| r_o$$

$$R_o \cong 1/\left[\left(1+\chi\right) g_m\right]$$

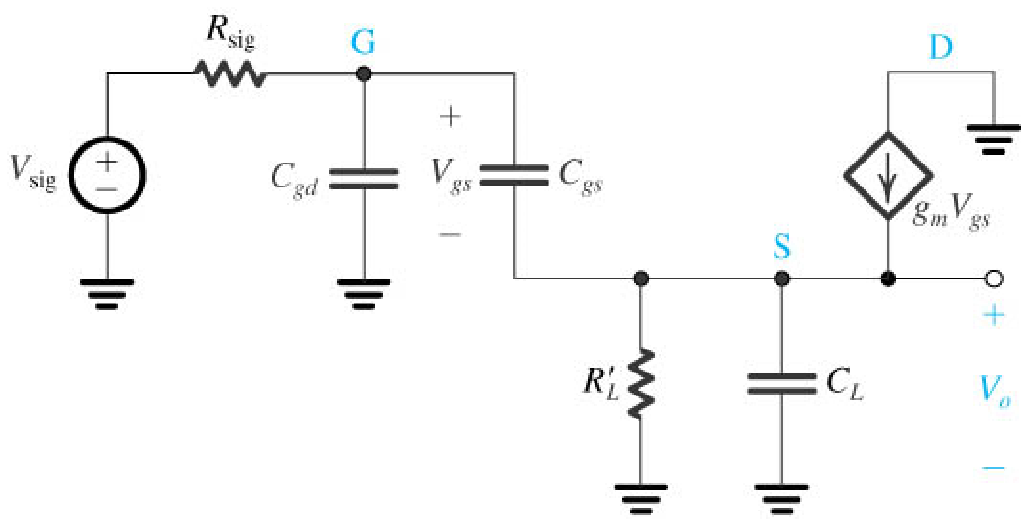
Frequency Response of Source Follower

- Determine location of transmission zeros
- Use method of open-circuit time constants to estimate 3-dB frequency



Determination of Zeros

- Three capacitances form a continuous loop
- Two transmission zeros



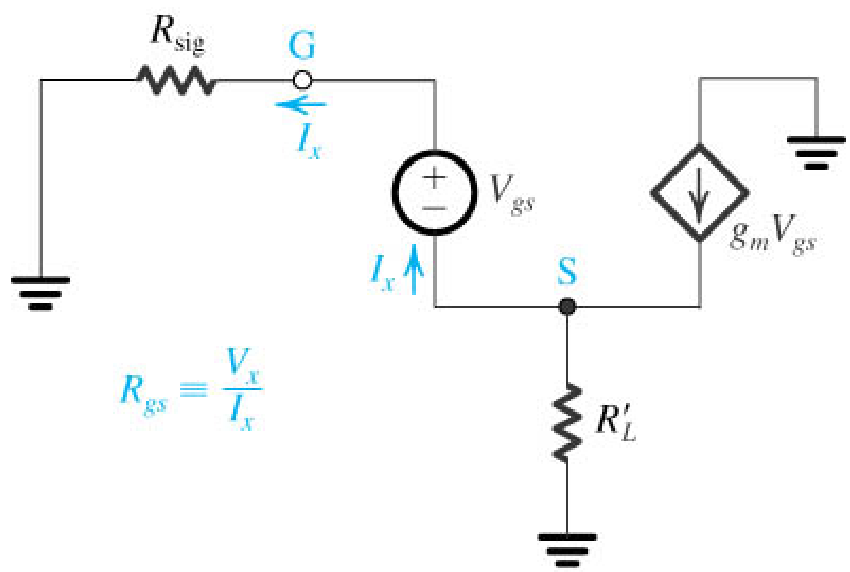
$$\omega_{Z\infty} = \infty \qquad \omega_Z = \frac{g_m}{C_{gs}} \quad \rightarrow \quad f_Z \cong f_T$$

Determination of Poles

$$R_{gs} = R_{sig}$$

$$R_{gd} = \frac{R_{sig} + R_L^{'}}{1 + g_m R_L^{'}}$$

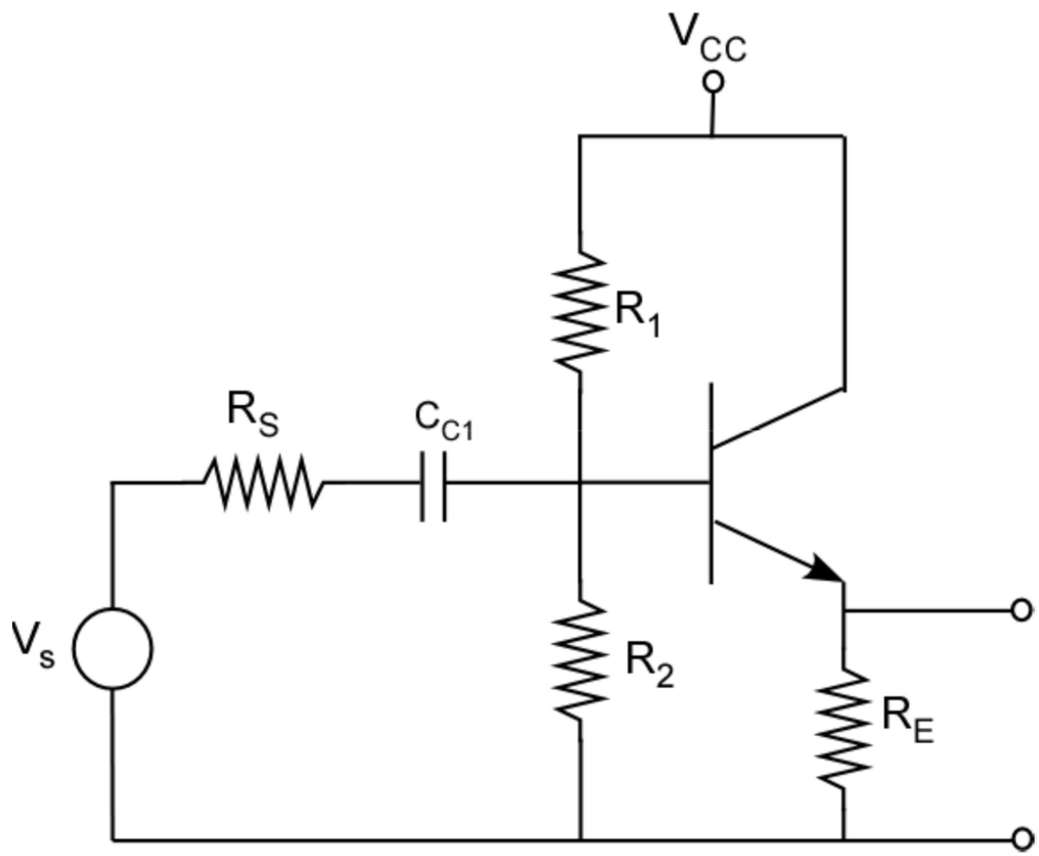
$$R_{C_L} = R_L \,||\, R_o$$



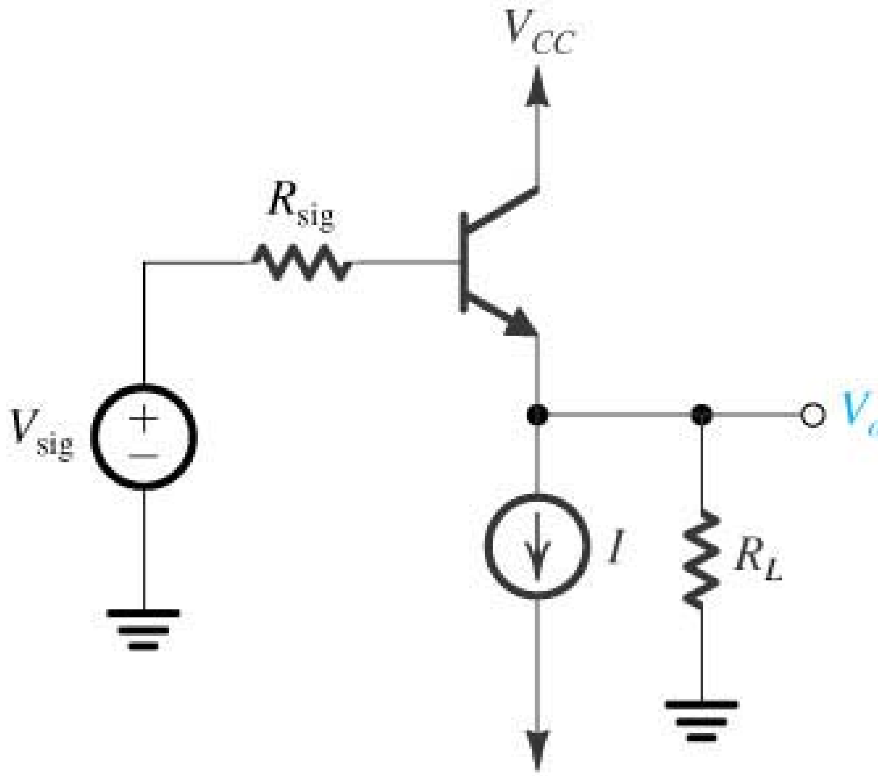
$$f_H = \frac{1}{2\pi\tau_H} = 1/2\pi\left(C_{gd}R_{gd} + C_{gs}R_{gs} + C_L R_{C_L}\right)$$

The source follower has excellent high-frequency response

Emitter Follower

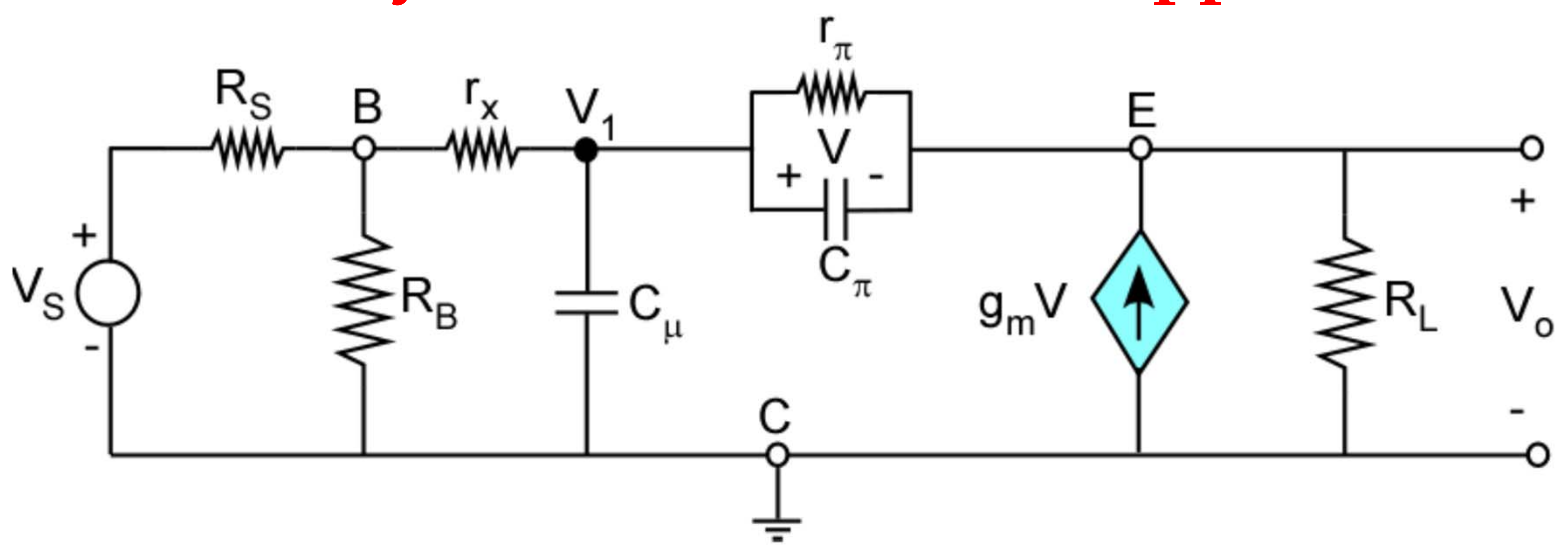


Emitter Follower



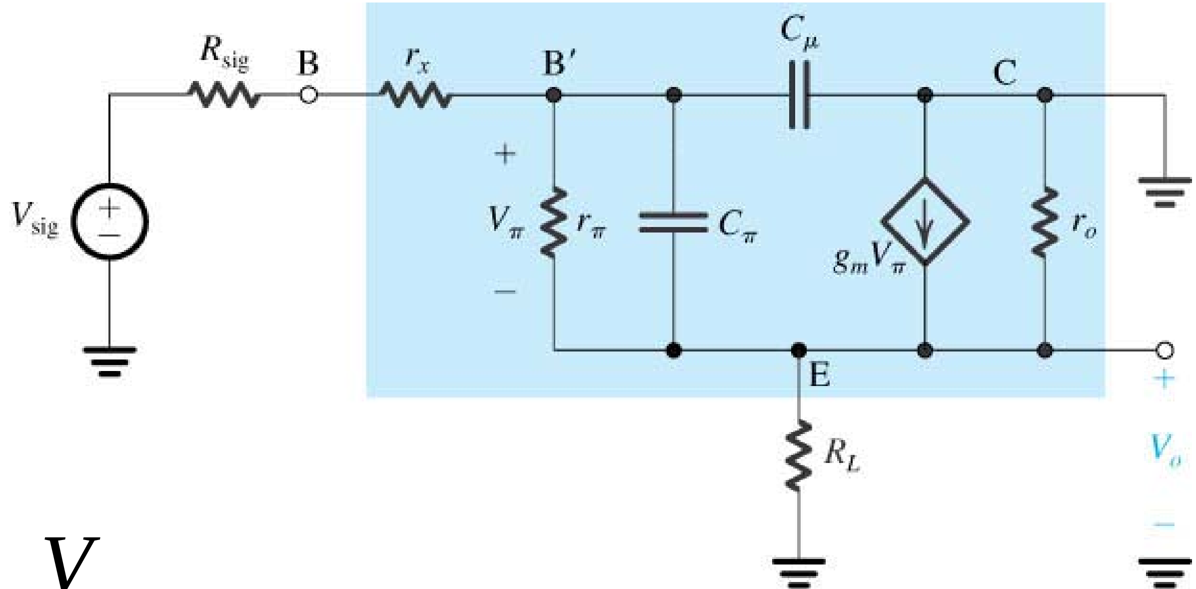
Emitter Follower High-Frequency

Exact analysis is too tedious ➔ approximate



$$A_v'(s) = \frac{g_m R_L}{1+g_m R_L} \frac{1+\dfrac{sC_\pi}{g_m}}{1+\dfrac{sC_\pi R_E}{\left(1+g_m R_E\right)}} \qquad \omega_{3dB} = \frac{1+g_m R_E}{R_E C_\pi} \simeq \frac{g_m}{C_\pi + C_\mu} = \omega_T$$

High-Frequency Analysis of Emitter Follower

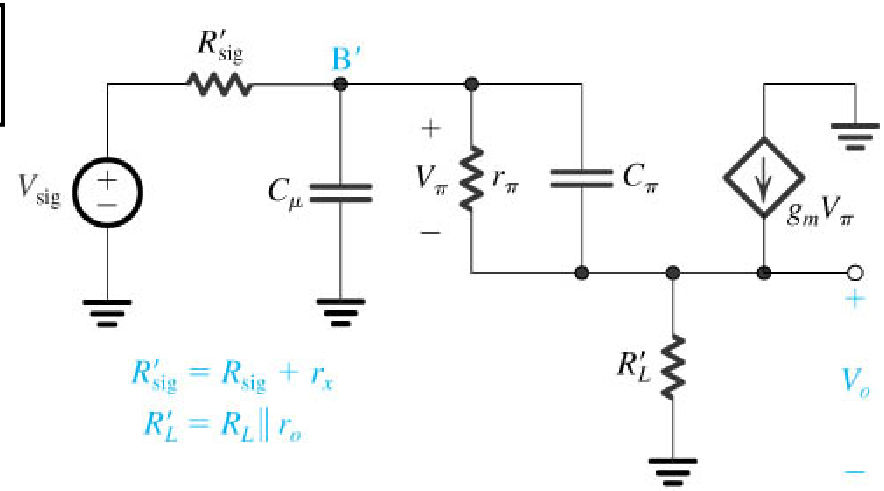


$$g_m V_\pi + \frac{V_\pi}{r_\pi} + s_Z C_\pi = 0$$

leads to: $$\frac{g_m + (1/r_\pi)}{C_\pi} = -\frac{1}{C_\pi r_e} \rightarrow \omega_Z = \frac{1}{C_\pi r_e}$$

High-Frequency Analysis of Emitter Follower

$$R_\mu = R_{sig}^{'} \,||\left[r_\pi + (\beta+1) R_L^{'} \right]$$



$$R_\pi = \frac{R_{sig}^{'} + R_L^{'}}{1 + \dfrac{R_{sig}^{'}}{r_\pi} + \dfrac{R_L^{'}}{r_e}}$$

$$f_H = 1/2\pi\left[C_\mu R_\mu + C_\pi R_\pi \right]$$