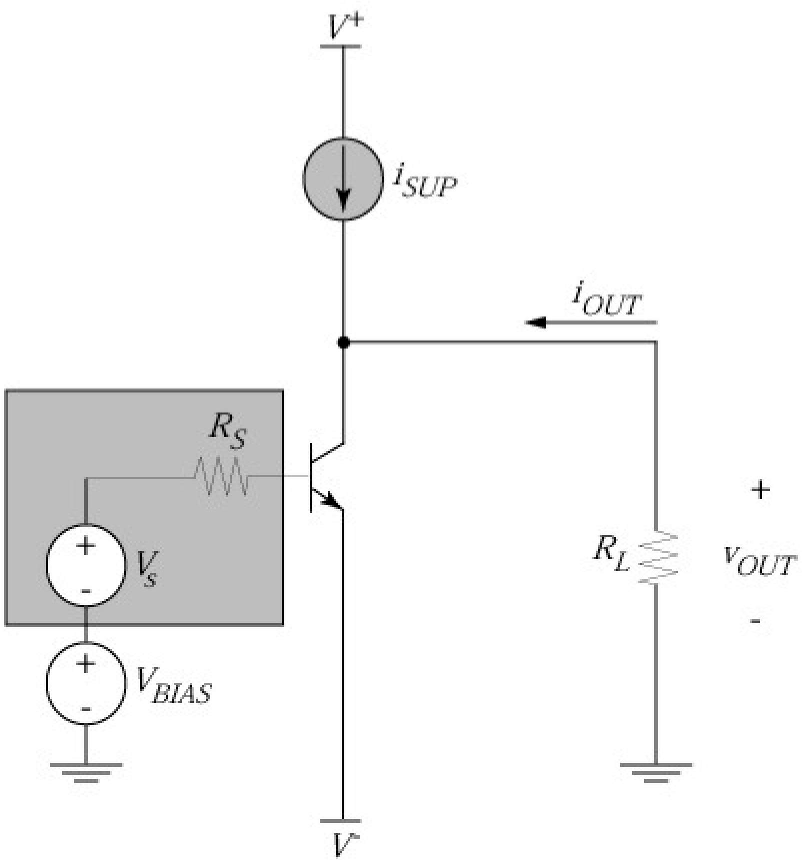
Lecture 31

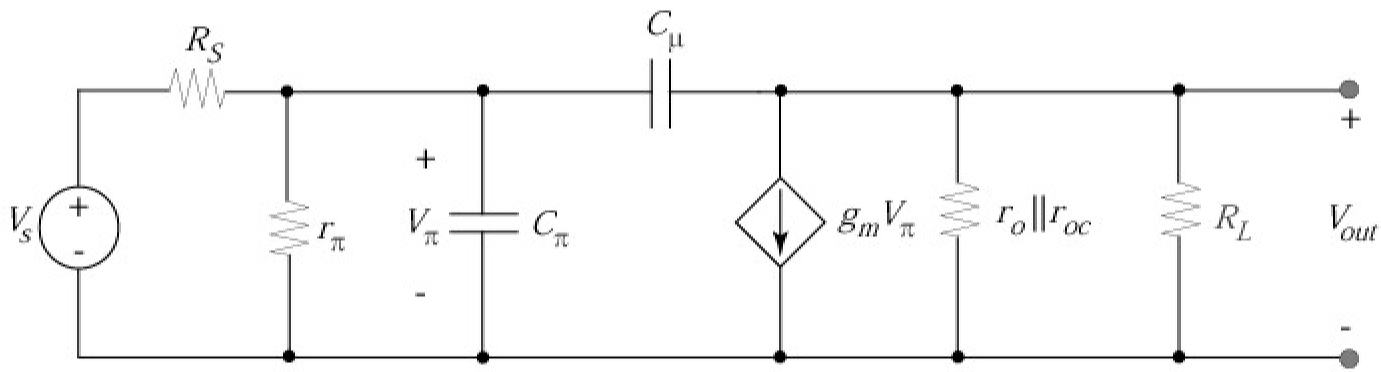
- Last time:
  - Short-circuit current gain of CE and CS amps
  - Unity-gain frequency ω_T
- Today :
  - Frequency response of the CE as voltage amp
  - The Miller approximation

Common-Emitter Voltage Amplifier

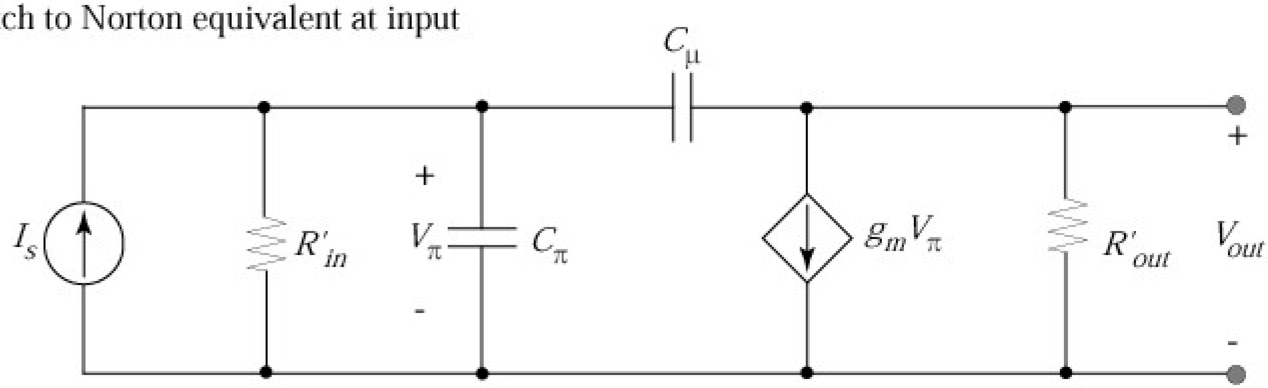


Small-signal model: omit C_{cs} due to avoid complicated analysis

CE Voltage Amp Small-Signal Model



switch to Norton equivalent at input



$R'_{in} = R_S || r_\pi$ $R'_{out} = r_o || r_{oc} || R_L$

Frequency Response

KCL at input and output nodes; analysis is made complicated due to Z_μ branch → see H&S pp. 639-640.

$$\frac{V_{out}}{V_{in}} = \frac{-g_m\left(\frac{r_\pi}{r_\pi + R_S}\right)[r_o \,||\, r_{oc} \,||\, R_L](1 - j\omega/\omega_z)}{(1 + j\omega/\omega_{p1})(1 + j\omega/\omega_{p2})}$$

Low-frequency gain:

Zero: $\omega_z > \omega_T = \frac{g_m}{C_\pi + C_\mu}$

Poles

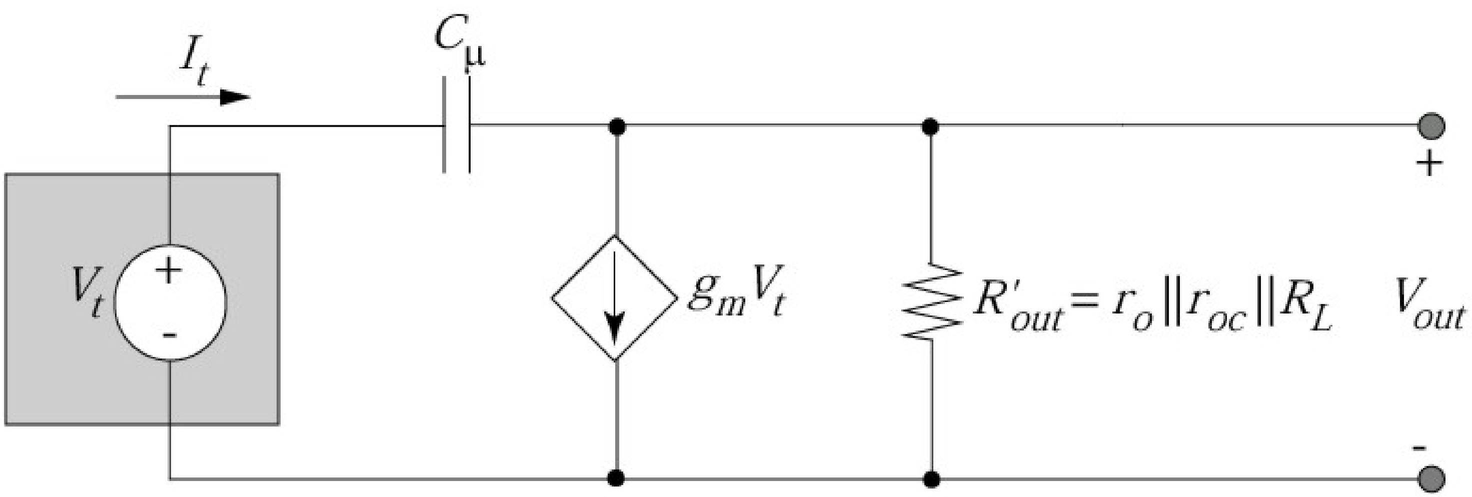
$$\omega_{p1} \approx \frac{1}{\left(R_S \parallel r_\pi\right)\left\{C_\pi + \left(1 + g_m R'_{out}\right)C_\mu\right\} + R'_{out} C_\mu}$$

$$\omega_{p2} \approx \frac{R'_{out} / \left(R_S \parallel r_\pi\right)}{\left(R_S \parallel r_\pi\right)\left\{C_\pi + \left(1 + g_m R'_{out}\right)C_\mu\right\} + R'_{out} C_\mu}$$

Decoupling Input and Output: the Miller Approximation

Results of complete analysis: not exact and little insight

Look at how Z_μ affects the transfer function: find Z_{in}



Input Impedance $Z_{in}(j\omega)$

$$I_t = (V_t - V_{out}) / Z_\mu$$

At output node:

$$V_{out} = (-g_m V_t - I_t) R'_{out} \approx -g_m V_t R'_{out}$$

Why?

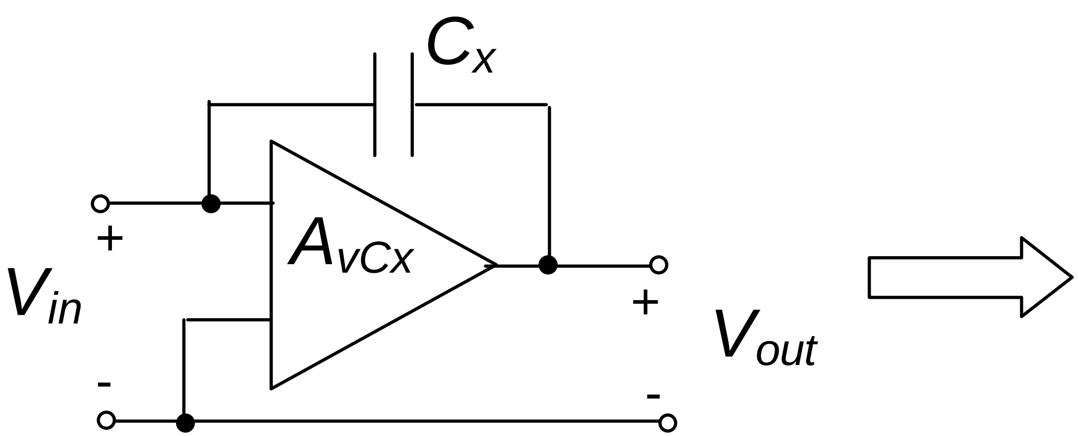
$$I_t = (V_t - A_{vC_\mu} V_t) / Z_\mu$$

$$Z_{in} = V_t / I_t = \frac{Z_\mu}{1 - A_{vC_\mu}}$$

Miller Capacitance C_M

Effective input capacitance:

$$Z_{in} = \frac{1}{j\omega C_M} = \left(\frac{1}{1-A_{vC_\mu}}\right)\left(\frac{1}{j\omega C_\mu}\right) = \frac{1}{j\omega\left[\left(1-A_{vC\mu}\right)C_\mu\right]}$$



What about the role of C_x when viewed from the output port?

Some Examples

Common emitter/source amplifier:

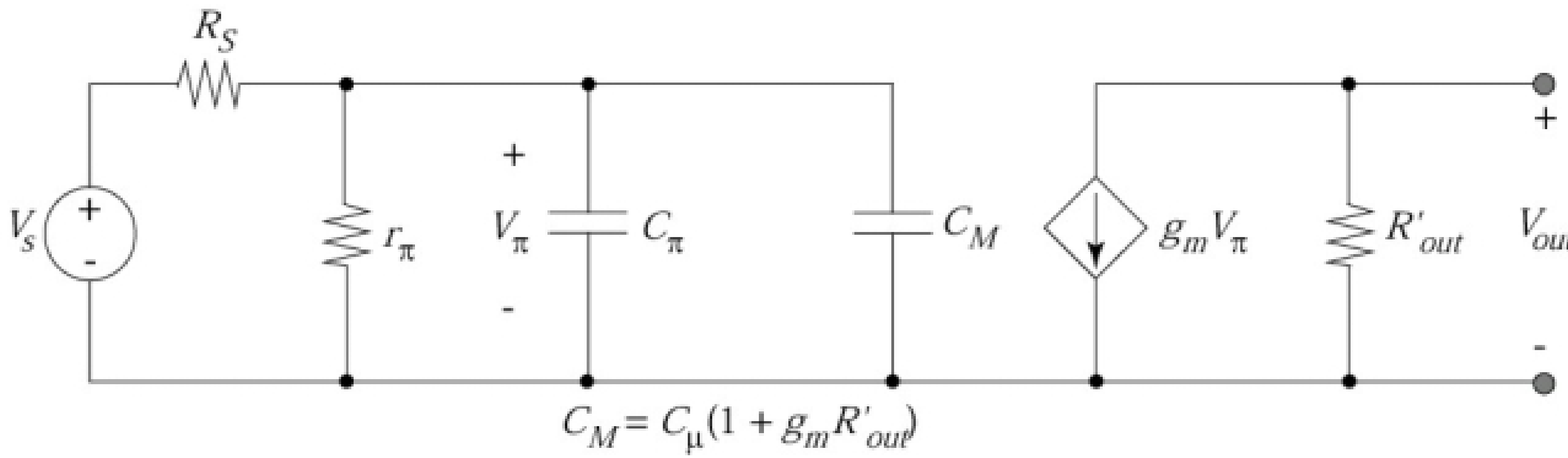
$$A_{vC_\mu} = \text{Negative, large number (-100)}$$

Common collector/drain amplifier:

$$A_{vC_\pi} = \text{Slightly less than 1}$$

CE Amplifier using Miller Approx.

Use Miller to transform C_μ



Analysis is straightforward now … single pole!

Comparison with "Exact Analysis"

Miller result:

$$\omega_{p1}^{-1} =$$

Exact result:

$$\omega_{p1}^{-1} = \left(R_S \parallel r_\pi\right)\left\{C_\pi + \left(1 + g_m R'_{out}\right)C_\mu\right\} + R'_{out} C_\mu$$