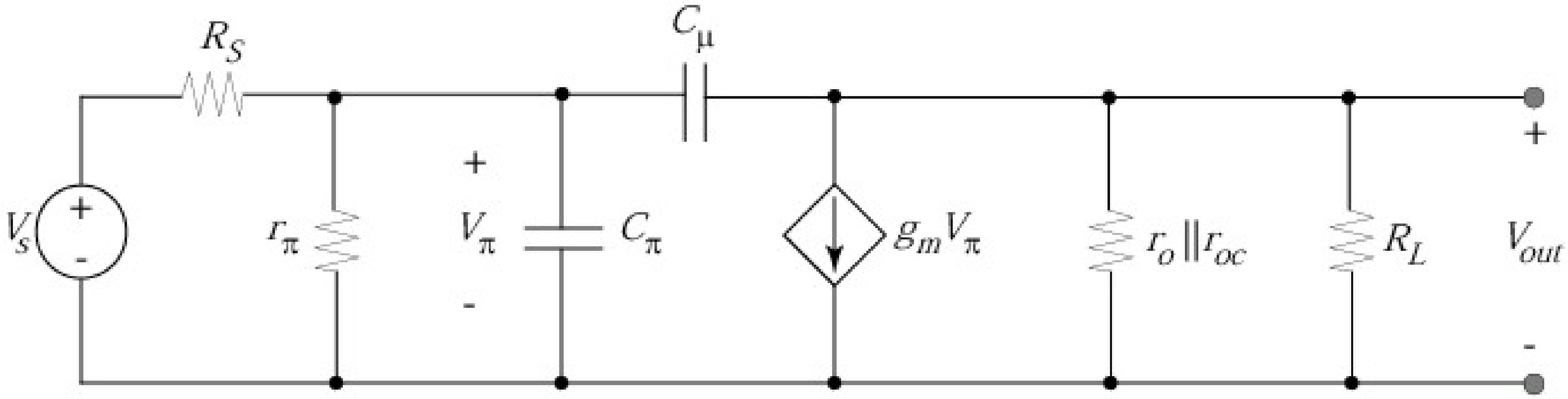
Lecture 40

- Last time:
  - Bias and output swing for BiCMOS voltage amp
  - Start open-circuit time constant analysis (back to Chapter 10)
- Today :
  - Applications of open-circuit time constant analysis: CE amplifier and cascode amplifier

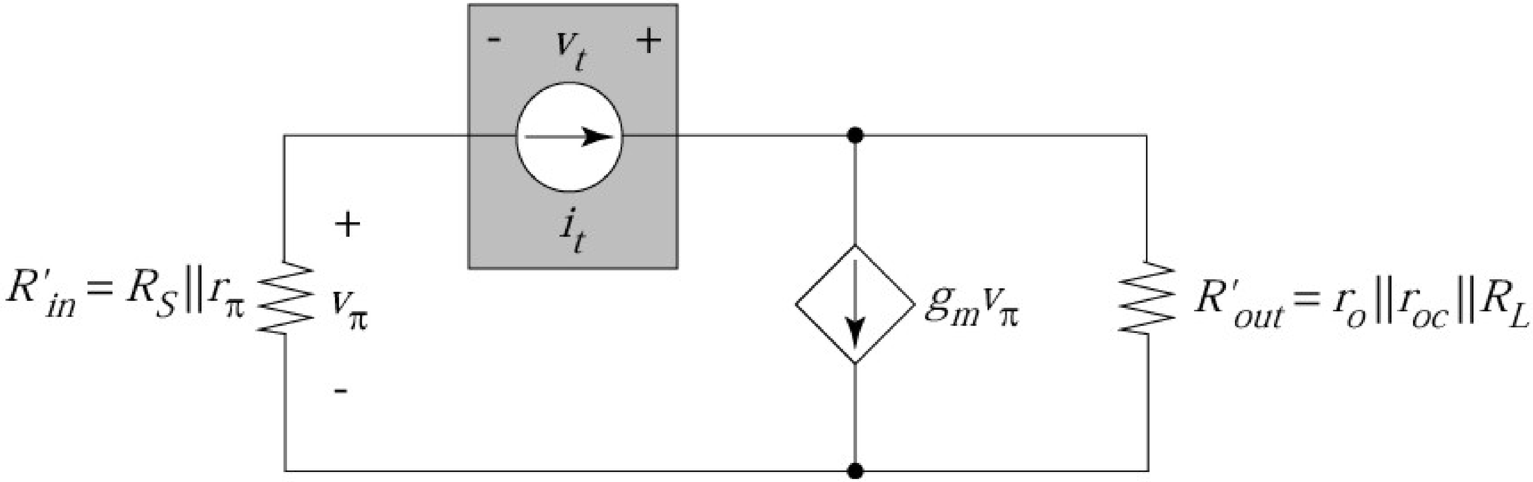
Common-Emitter Voltage Amplifier



Time constant for base-emitter capacitance C_π:

Base-Collector Time Constant

Must apply a test source (can’t see $R_{T\mu}$ by inspection):



Solving for $R_{T\mu}$

Find v_π: $v_\pi = -i_t\left(R_S \| r_\pi\right) = -i_t R'_{in}$

Find v_o: $v_o = -i_o R'_{out} = \left(i_t - g_m v_\pi\right) R'_{out} = i_t\left(1 + g_m R'_{in}\right) R'_{out}$

Find v_t: $v_t = v_o - v_\pi = i_t\left(1 + g_m R'_{in}\right) R'_{out} - \left(-i_t R_{in}\right)$

Solve for Thèvenin resistance:

Dominant Pole of CE Amplifier

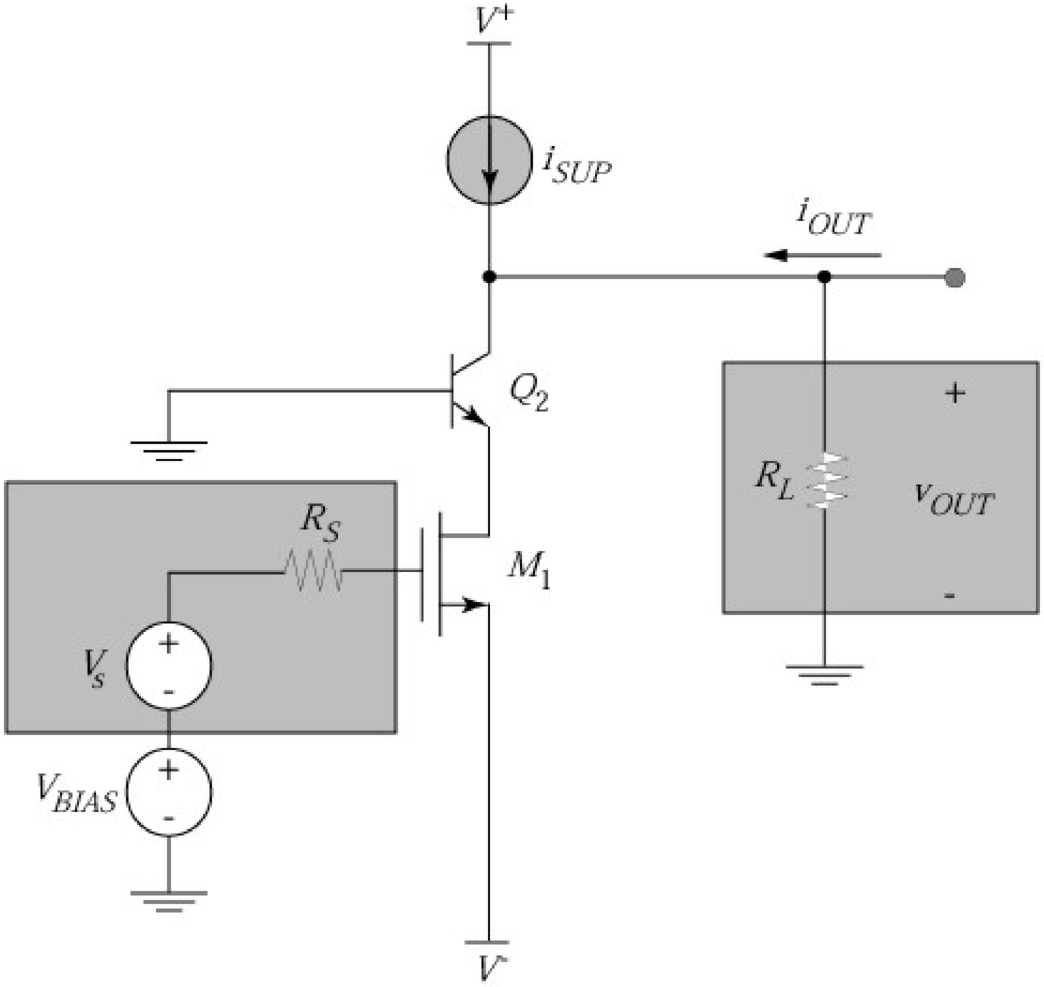
Estimate dominant pole as inverse of sum of OCTCs:

$$\omega_1 \approx \frac{1}{\tau_{C_\pi} + \tau_{C_\mu}} = \left(R'_{in} C_\pi + [R'_{in} + R'_{out} + g_m R'_{in} R'_{out}] C_\mu \right)^{-1}$$

Identical to the "exact" analysis in Chapter 10

Why bother with the OCTC technique … add effect of C_{cs}

Multistage Amplifier Frequency Response



CS*-CB cascode

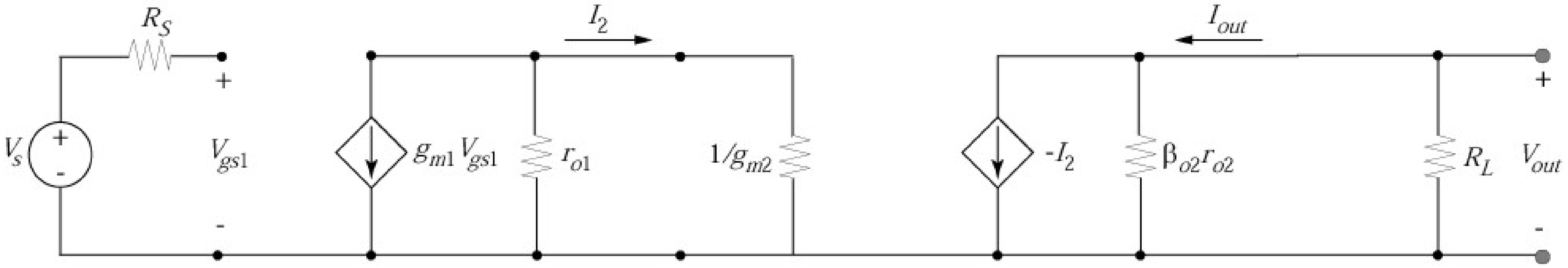
Systematic Approach

1. Construct *two-port* small-signal models for each stage

2. Add the capacitors for each device across the appropriate nodes in the two-port models. Make sure how the gate, drain, and source (or base, collector, and emitter) terminals of each device fit onto the two-port models!

3. (Optional) Use Miller's Theorem to transform capacitors across amplifiers into effective capacitances to ground (note that we ignore the "output Miller" in this course)

Cascode Two-Port Model



Add capacitors: C_{gs1}, C_{gd1}, $C_{\pi 2}$, $C_{\mu 2}$ …
what about C_{db1}, C_{cs2}?

Finding the Thèvenin Resistances

C_{gs1}: $R_{TC_{gs1}} = R_S$

C_{gd1}: $R_{TC_{gd1}} = R'_{in} + R'_{out} + g_{m1} R'_{in} R'_{out} =$

$C_{\pi 2}$: $R_{TC_{\pi 2}} =$

$C_{\mu 2}$: $R_{TC_{\mu 2}} =$

Dominant Pole

Applying the theorem:

$$\omega_1^{-1} \approx R_S C_{gs1} + R_S\left(1 + g_{m1}/g_{m2}\right)C_{gd1} + (1/g_{m2})C_{\pi 2} + R_L C_{\mu 2}$$

Find approximate voltage transfer function:

$$A_{vo} = \left.\frac{v_{out}}{v_s}\right|_{R_S, R_L} = -g_{m1}\left(\frac{r_{o1}}{r_{o1} + 1/g_{m2}}\right)\left(\beta_o r_{o2} \parallel r_{oc2} \parallel R_L\right)$$

Gain-Bandwidth Product

Metric for amplifier performance: note that

$$\left|A_v\left(j\omega^*\right)\right| = 1 \quad \text{when} \quad \omega^* = \left|A_{vo}\right|\omega_1$$

$$\left|A_{vo}\right|\omega_1 = \frac{g_{m1}R_L}{R_S C_{gs1} + R_S\left(1 + g_{m1}/g_{m2}\right)C_{gd1} + C_{\pi 2}/g_{m2} + R_L C_{\mu 2}}$$

Special case: small R_S

$$\left|A_{vo}\right|\omega_1 \approx \frac{g_{m1}R_L}{C_{\pi 2}/g_{m2} + R_L C_{\mu 2}}$$