Lecture 32

• Last time:
  – Frequency response of the CE as voltage amp
  – The Miller approximation

• Today:
  – Frequency response of voltage and current buffers
  – Start multi-stage amplifiers: Chapter 9
Common-Collector Amplifier

Procedure:

1. Small-signal two-port model
2. Add device (and other) capacitors
Two-Port CC Model with Capacitors

Find Miller capacitor for $C_\pi$ -- note that the base-emitter capacitor is Between the input and output
Voltage Gain $A_{vC\pi}$ Across $C_\pi$

$$A_{vC\pi} =$$

Note: this voltage gain is neither the two-port gain nor the “loaded” voltage gain

$$C_{in} = C_\mu + C_M = C_\mu + (1 - A_{vC\pi})C_\pi$$
Bandwidth of CC Amplifier

Input low-pass filter’s –3 dB frequency:

$$\omega_p^{-1} = \left( R_S \parallel R_{in} \right) \left( C_\mu + \frac{C_\pi}{1 + g_m R_L} \right)$$

Substitute favorable values of $R_S$, $R_L$:

$$R_S \approx 1/ g_m \quad R_L >> 1/ g_m$$

$$\omega_p^{-1} \approx \left( 1/ g_m \right) \left( C_\mu + \frac{C_\pi}{1 + BIG} \right) \approx C_\mu / g_m$$
Bandwidth of the Common-Base Current Buffer

Same procedure: start with two-port model and capacitors
Two-Port CB Model with Capacitors

No Miller-transformed capacitor!

Unity-gain frequency is on the order of $\omega_T$ for small $R_L$
Summary of Single-Stage Amplifier Frequency Response

• CE, CS: suffer from Miller-magnified capacitor for high-gain case
• CC, CD: Miller transformation $\rightarrow$ nulled capacitor $\rightarrow$ “wideband stage”
• CB, CG: no Millerized capacitor $\rightarrow$ wideband stage (for low load resistance)
Multi-Stage Amplifiers: Chap. 9

• First topic: voltage and current sources (9.4)
• Generating a voltage: use a current source to set $V_{GS}$ (or $V_{BE}$)
Modeling the Voltage Source

Find \( i_{OUT} \) versus \( v_{OUT} \)  

MOSFET is off or saturated: why?

\[
i_{OUT} = i_{D,SAT} - I_{REF} = \mu_n C_{ox} \left( \frac{W}{2L} \right)(v_{GS} - V_{Tn})^2 (1 + \lambda_n v_{DS}) - I_{REF}
\]

Typical operating point:

\( i_{OUT} = 0 \text{ A} \)
Small-Signal Source Resistance

\[ R_S = \left( \frac{di_{OUT}}{dv_{OUT}} \bigg|_{I_{OUT}=0} \right)^{-1} = \frac{v_t}{i_t} \]

Equivalent Circuit:

\[ R_S + i_{OUT} \]

\[ V_S + v_{OUT} \]
Using a Voltage Source to Make a Current Source

Diagram:

- Voltage Source $V_{DD}$
- Current Source $I_{REF}$
- Transistor $M_1$
- Voltage $V_{REF}$
- Transistor $M_2$
- Output Voltage $v_{OUT}$
- Output Current $i_{OUT}$

Rest of Circuit