Lecture 23
Frequency Response of Amplifiers (III)
OTHER AMPLIFIER STAGES

Outline

1. Frequency Response of the Common-Drain Amplifier
2. Frequency Response of the Common-Gate Amplifier

Reading Assignment:
Howe and Sodini, Chapter 10, Sections 10-5-10.6
1. Frequency Response of the Common-Drain Amplifier

Characteristics of CD Amplifier:

- Voltage gain $\approx 1$
- High input resistance
- Low output resistance
- $\Rightarrow$ Good voltage buffer
High-frequency small-signal model

Could use OTC to solve for bandwidth.

To estimate bandwidth it is easier to use the 2-port models.
Low Frequency Analysis Using 2-Port Model

Capacitors - open circuit

\[ A_{vo} = \left( \frac{R_{in}}{R_S + R_{in}} \right) \left( \frac{R_L}{R_L + R_{out}} \right) \]

\[ \approx \frac{g_m R_L}{1 + g_m R_L} \leq 1 \]

In the calculation of the intrinsic voltage gain we assume that \( r_o || r_{oc} \) was large.
That is why we do not have \( R_L || r_o || r_{oc} \).
High Frequency Analysis Using 2-Port Model - Add capacitors

Use Miller Approximation

$$A_vC_{gs} = \frac{R_L}{R_{out} + R_L} = \frac{g_m R_L}{1 + g_m R_L}$$

$$C_M = C_{gs} \left( 1 - A_vC_{gs} \right) = C_{gs} \left( 1 - \frac{g_m R_L}{1 + g_m R_L} \right) = \frac{C_{gs}}{1 + g_m R_L}$$

Total capacitance at input

$$C_T = C_{gs} \left( 1 - \frac{g_m R_L}{1 + g_m R_L} \right) + C_{gd}$$

$$R_T = R_S || R_{in} = R_S$$

Add time constant due to $C_{db}$ capacitance at output

$$R_{C_{db}} = R_{out} || R_L = \frac{R_{out} R_L}{R_{out} + R_L} = \frac{R_L}{1 + g_m R_L}$$
If $R_S$ is not too high, bandwidth can be rather high and approach $\omega_T$. 

$$\omega_{3dB} \approx \frac{1}{R_S \left(\frac{C_{gs}}{1 + g_m R_L} + C_{gd}\right) + C_{db} \frac{R_L}{1 + g_m R_L}}$$
2. Frequency Response of the Common-Gate Amplifier

Characteristics of CG Amplifier:

- Current gain $\approx 1$
- Low input resistance
- High output resistance
- $\Rightarrow$ Good current buffer
High Frequency Small Signal Model

Could use OTC to solve for bandwidth.
To estimate bandwidth it is easier to use the 2-port models.
High-frequency small-signal 2-port model
Assume backgate is shorted to source

Low frequency transfer function:

\[
A_{io} = \frac{i_{out}}{i_s} = \left(\frac{R_S}{R_{in} + R_S}\right) (1) \left(\frac{R_{out}}{R_L + R_{out}}\right)
\]

Use OTC to find \(\omega_{3dB}\): 

Thevenin resistance across \(C_{gs}\)

\[
R_{TC_{gs}} = R_S \parallel R_{in} = R_S \parallel (1/g_m)
\]

Thevenin resistance across \(C_{gd}\)

\[
R_{TC_{gd}} = R_{out} \parallel R_L = ((r_o + g_m r_o R_S) \parallel r_{oc}) \parallel R_L
\]
Open circuit time constants:

\[ \tau_{C_{gs}} = (R_S \parallel (1/ g_m)) C_{gs} \]

\[ \tau_{C_{gd}} = (((r_o + g_m r_o R_S) \parallel r_{oc}) \parallel R_L) C_{gd} \]

Summing the open circuit time constants:

\[ \omega_{3dB} = \frac{1}{[ (R_S \parallel (1/ g_m)) C_{gs} + (((r_o + g_m r_o R_S) \parallel r_{oc}) \parallel R_L) C_{gd} ]} \]

If \( R_L \) is not too high, bandwidth can be rather high and approach \( \omega_T \).
What did we learn today?

**Summary of Key Concepts**

- **Common-drain amplifier:**
  - Voltage gain \( \approx 1 \), *Miller Effect* nearly completely eliminates the effect of \( C_{gs} \)
  - If \( R_S \) is not too high, CD amplifier has high bandwidth

- **Common-gate amplifier**
  - No Miller Effect because there is no feedback capacitor
  - If \( R_L \) is not too high, CG amplifier has high bandwidth

- \( R_S, R_L \) can affect bandwidth of amplifiers.