Lecture 23

Frequency Response of Amplifiers (III)

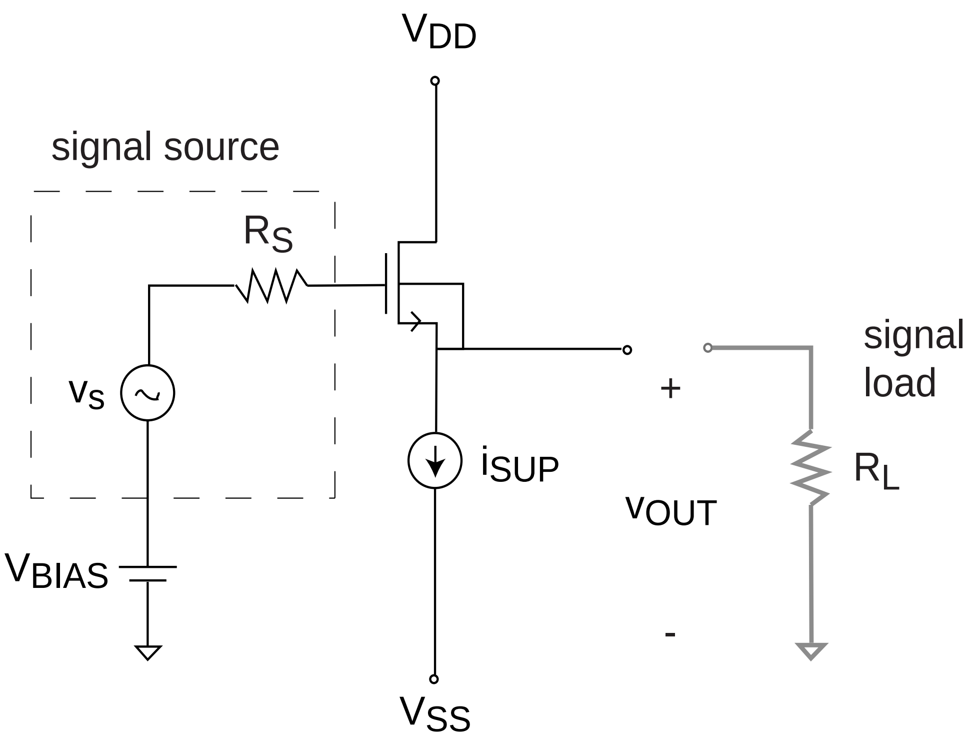
OTHER AMPLIFIER STAGES

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

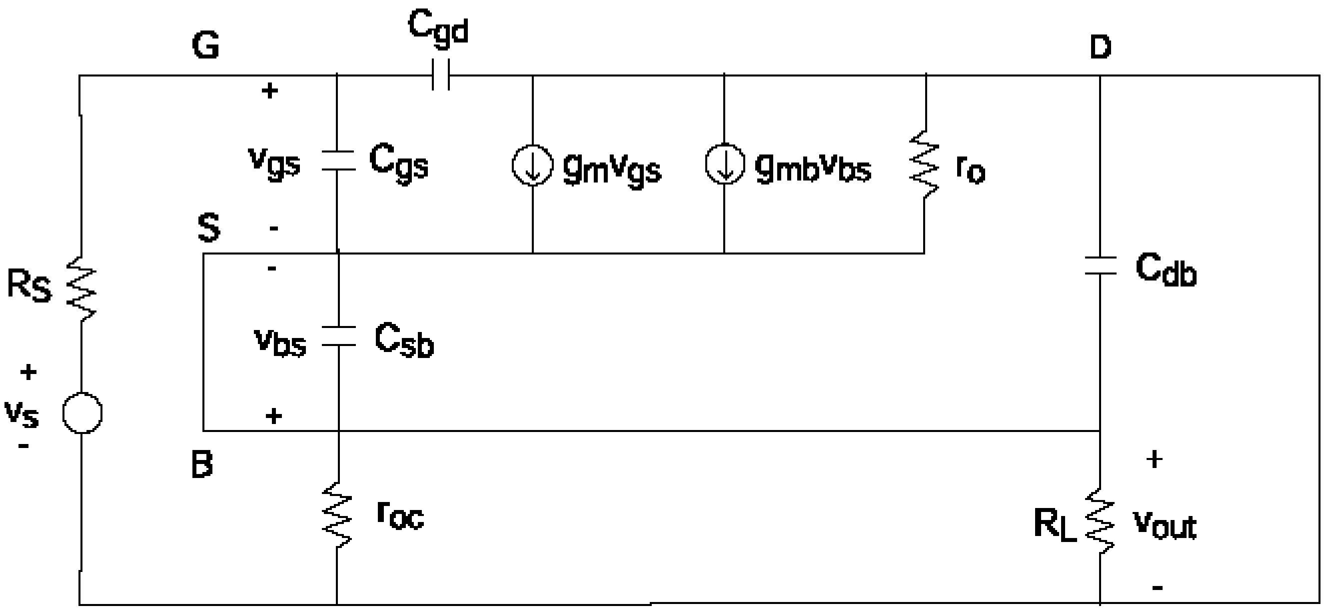
1. Frequency Response of the Common-Drain Amplifier

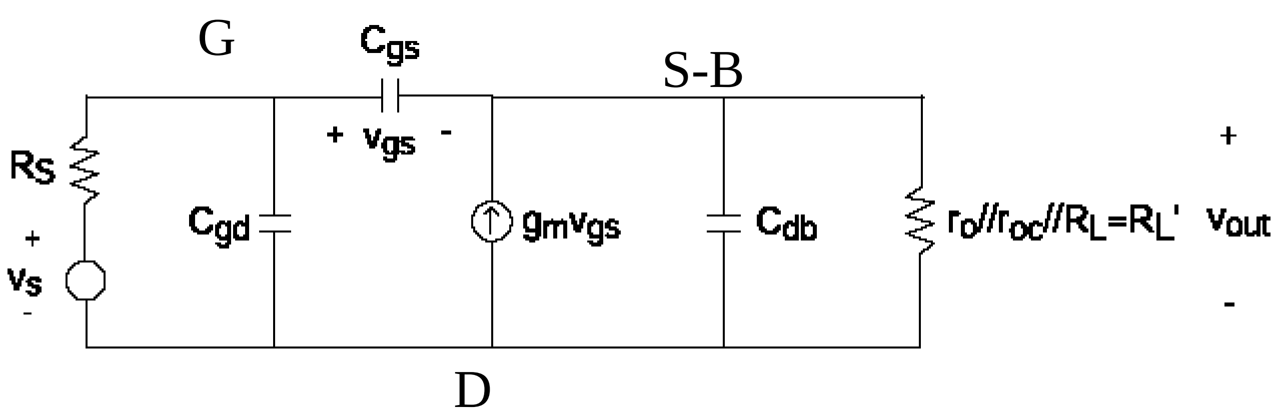


Characteristics of CD Amplifier:

- Voltage gain ≈ 1
- High input resistance
- Low output resistance
- ⇒ Good voltage buffer

High-frequency small-signal model

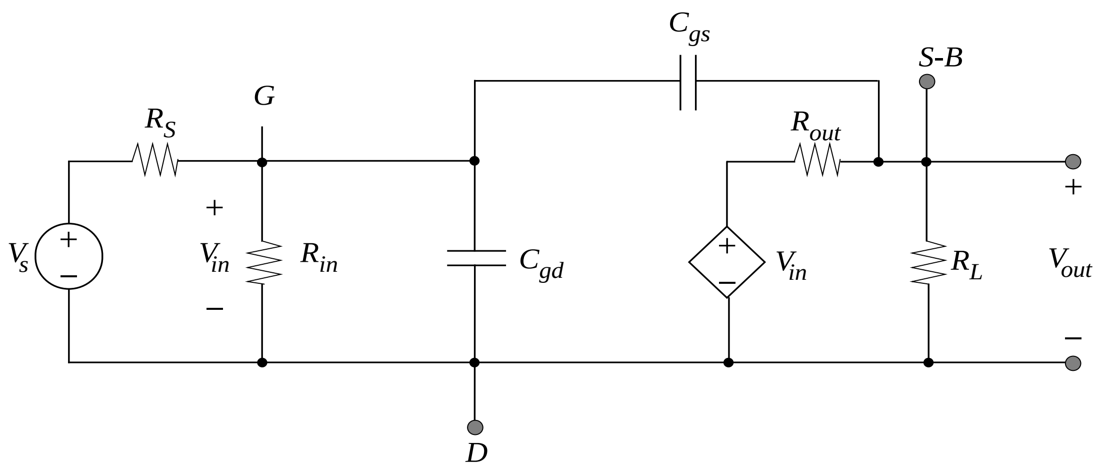




Could use OTC to solve for bandwidth.

To estimate bandwidth it is easier to use the 2-port models.

Low Frequency Analysis Using 2-Port Model



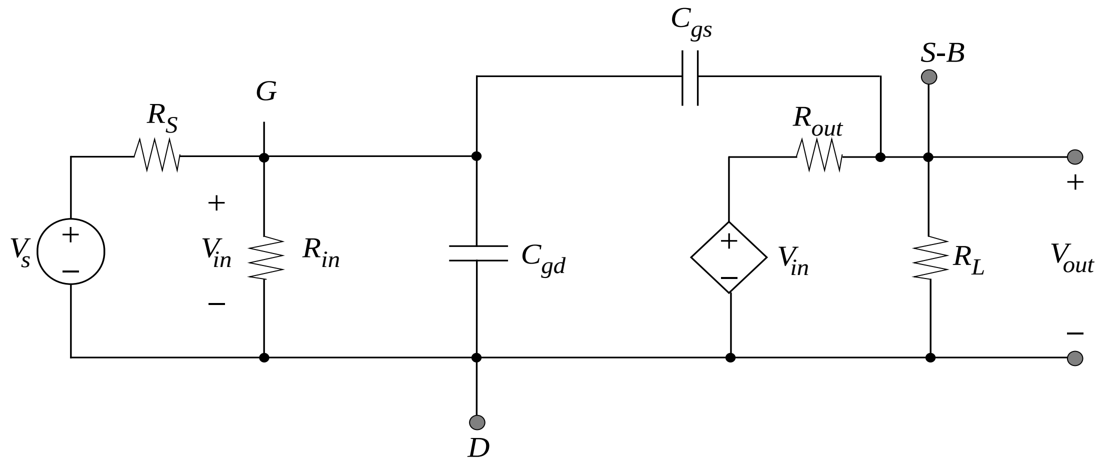
Capacitors -open circuit

$$A_{vo} = \left(\frac{R_{in}}{R_S + R_{in}} \right) (1) \left(\frac{R_L}{R_L + R_{out}} \right)$$

$$\approx \frac{g_m R_L}{1 + g_m R_L} \leq 1$$

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

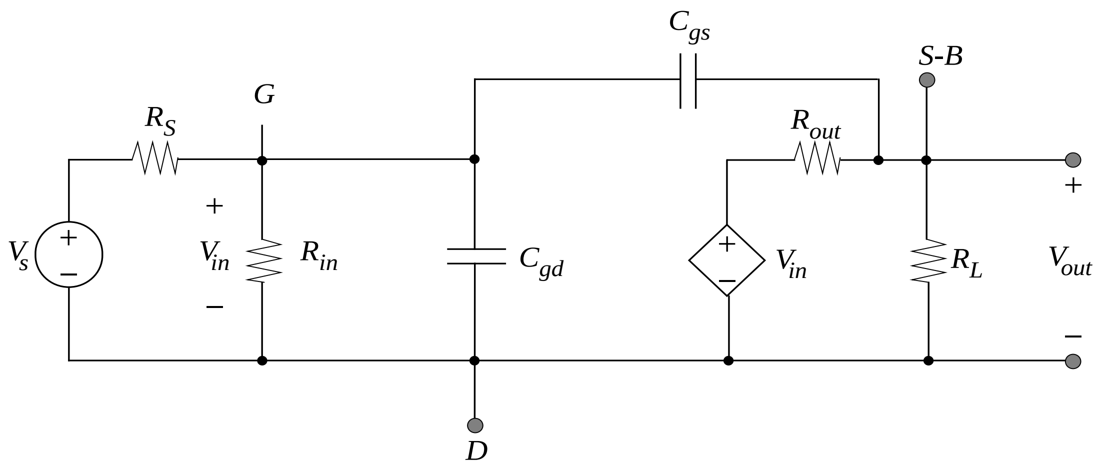
$$C_T = C_{gs}\left(1 - \frac{g_m R_L}{1 + g_m R_L}\right) + C_{gd}$$

$$R_T = R_S \parallel R_{in} = R_S$$

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

$$R_{C_{db}} = R_{out} \| R_L = \frac{R_{out} R_L}{R_{out} + R_L} = \frac{R_L}{1 + g_m R_L}$$

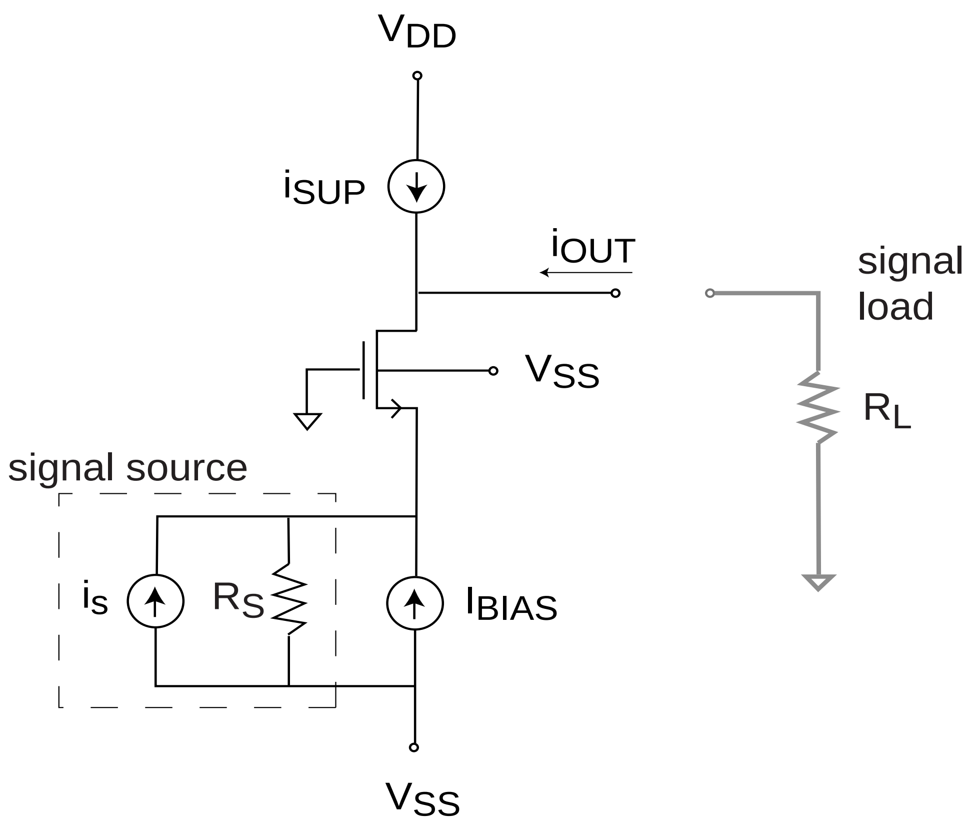
Frequency Response of Common-Drain Amplifier



$$\omega_{3dB} \approx \frac{1}{R_S\left(\frac{C_{gs}}{1+g_m R_L}+C_{gd}\right)+C_{db}\frac{R_L}{1+g_m R_L}}$$

If R_S is not too high, bandwidth can be rather high and approach ω_T.

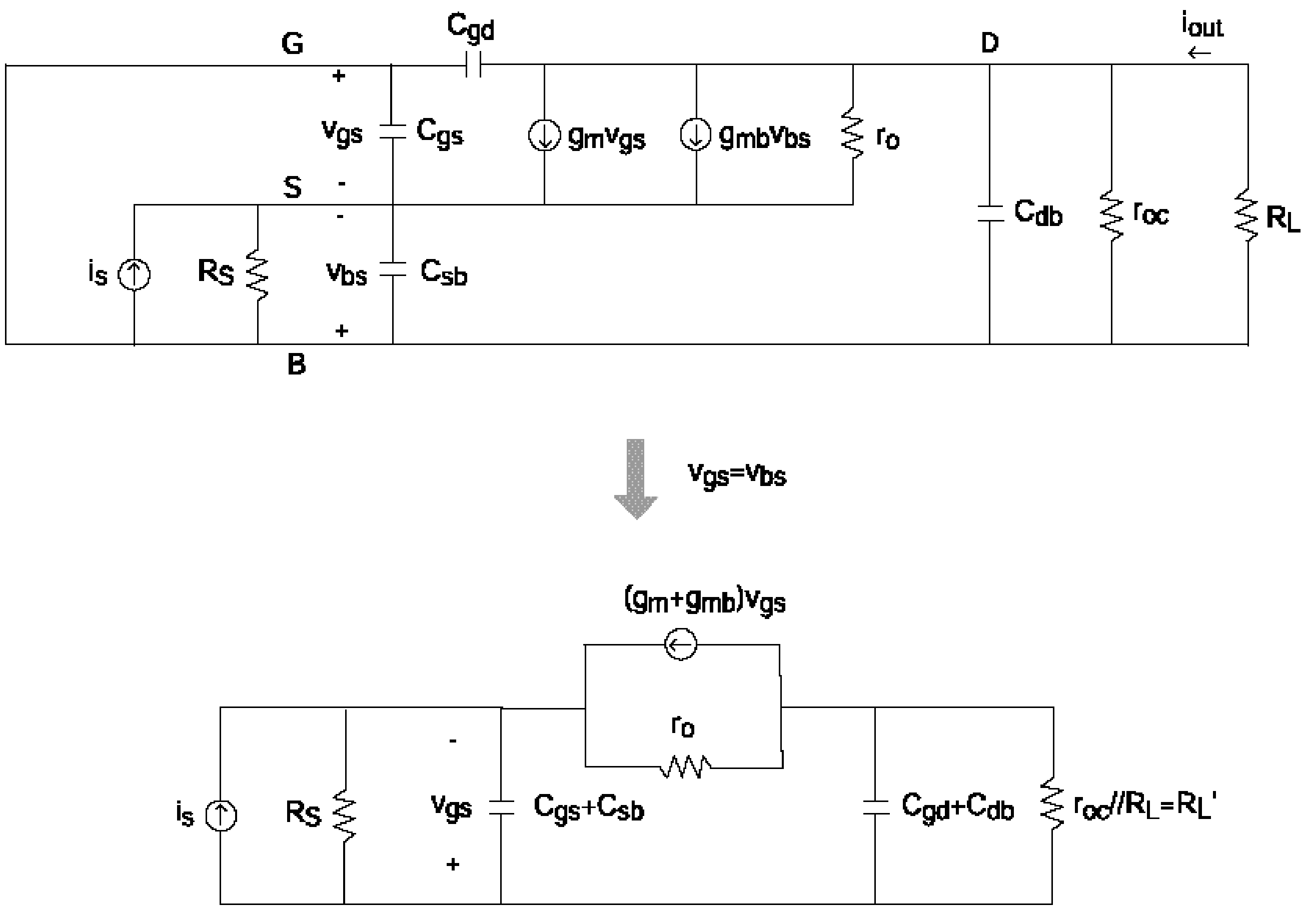
2. Frequency Response of the Common-Gate Amplifier



Characteristics of CG Amplifier:

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

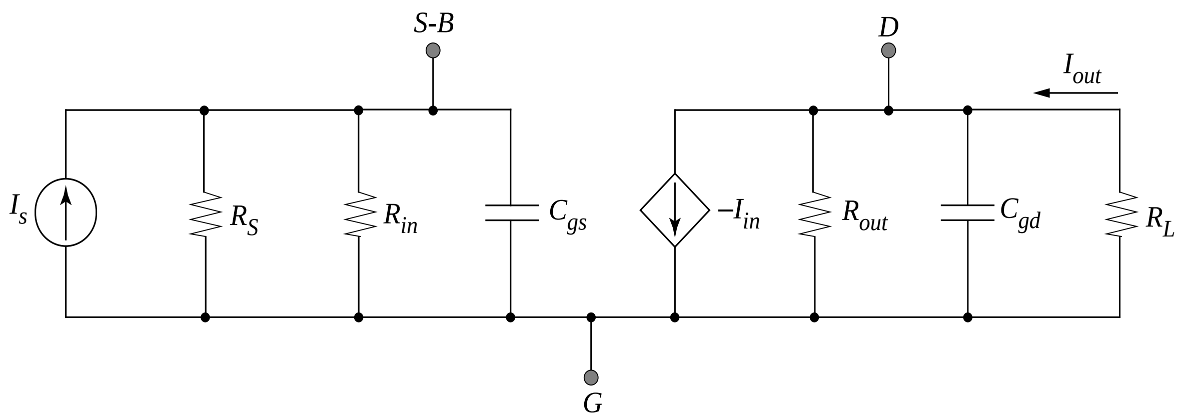
High Frequency Small Signal Model



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 ω_{3dB}:

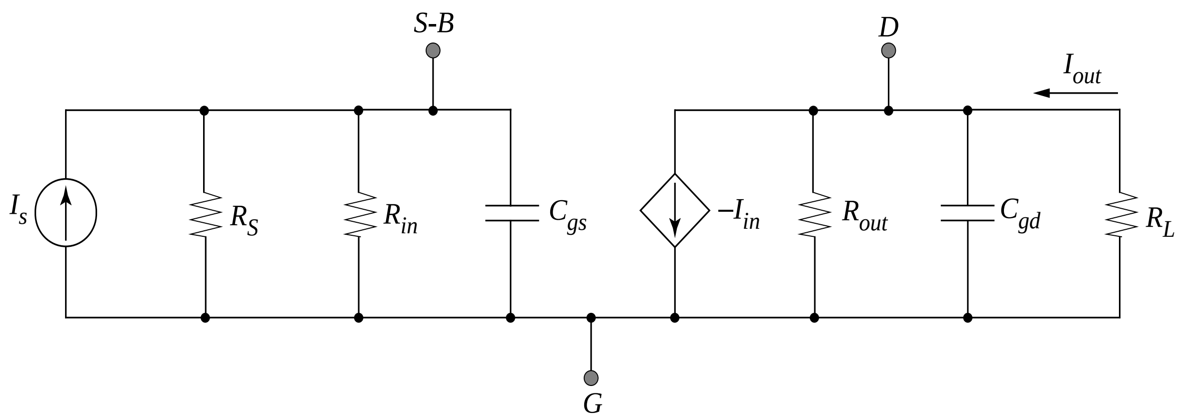
Thevenin resistance across C_{gs}

$$R_{TC_{gs}} = R_S \,||\, R_{in} = R_S \,||\, (1/g_m)$$

Thevenin resistance across C_{gd}

$$R_{TC_{gd}} = R_{out} \,||\, R_L = ((r_o + g_m r_o R_S) \,||\, r_{oc}) \,||\, R_L$$

High-frequency small-signal 2-port model con't



Open circuit time constants:

$$\tau_{C_{gs}} = \left(R_S \,\|\, (1/g_m)\right)C_{gs}$$

$$\tau_{C_{gd}} = \left(((r_o + g_m r_o R_S) \,\|\, r_{oc})) \,\|\, R_L\right)C_{gd}$$

Summing the open circuit time constants:

$$\omega_{3dB} = 1\Big/\Big[\left(R_S \,\|\, (1/g_m)\right)C_{gs} + \left(((r_o + g_m r_o R_S) \,\|\, r_{oc}) \,\|\, R_L\right)C_{gd}\Big]$$

> If R_L is not too high, bandwidth can be rather high and approach ω_T.

What did we learn today?

Summary of Key Concepts

- Common-drain amplifier:
  - Voltage gain ≈ 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.