Lecture 23

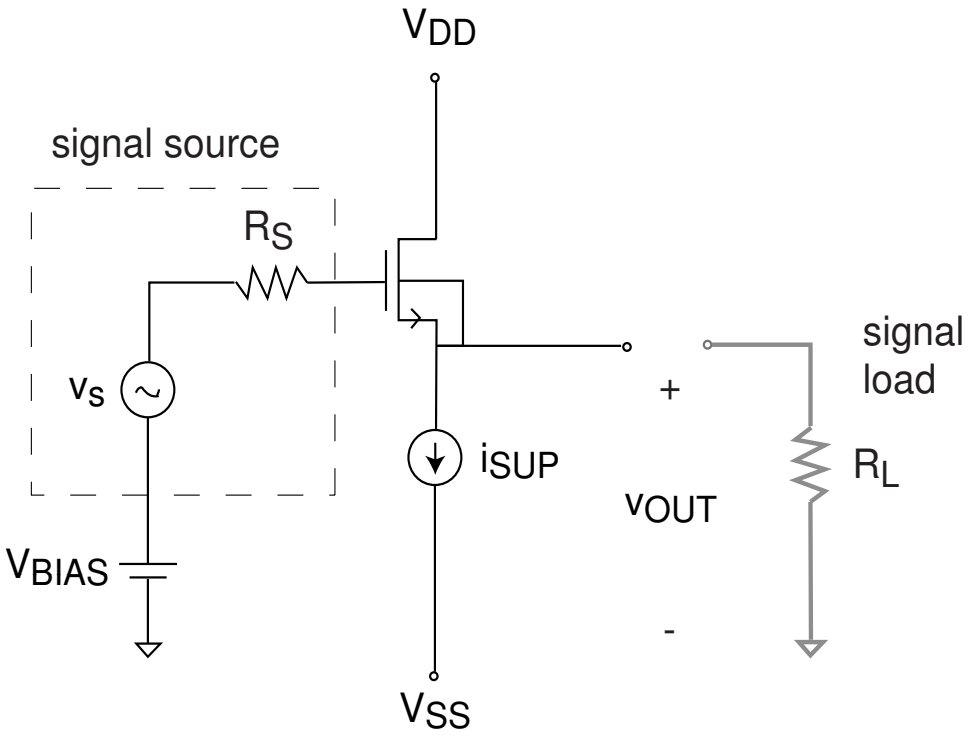
Frequency Response of Amplifiers (III)

OTHER AMPLIFIER STAGES

Outline

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

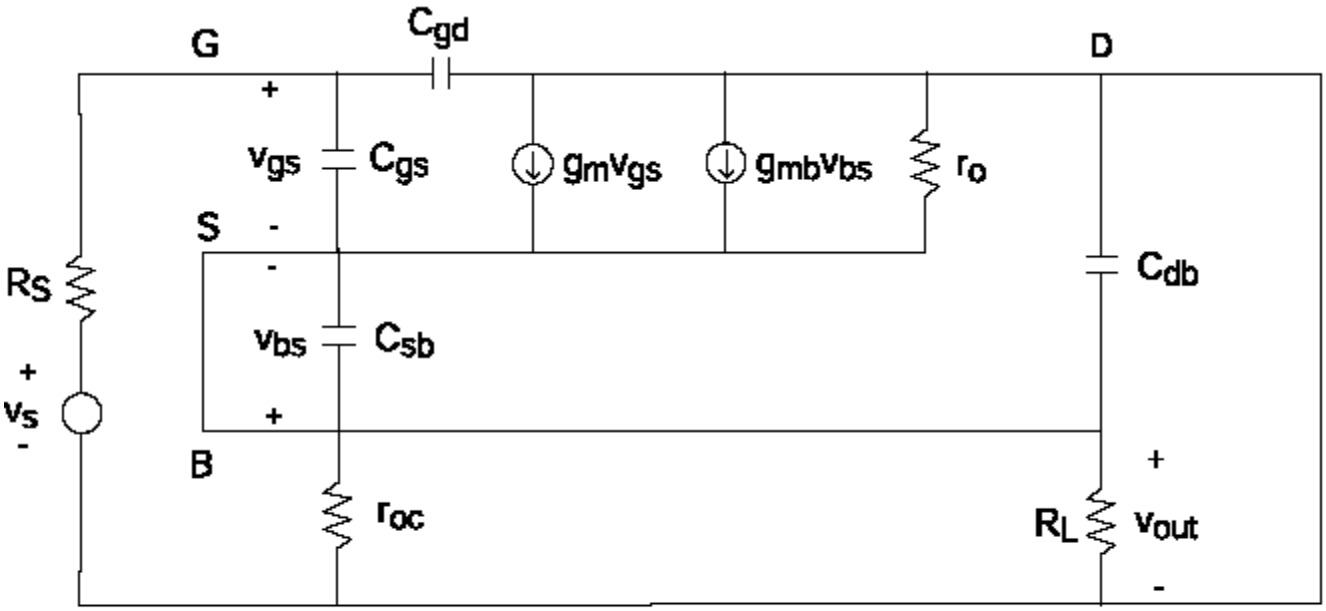
1. Frequency Response of the Common-Drain Amplifier

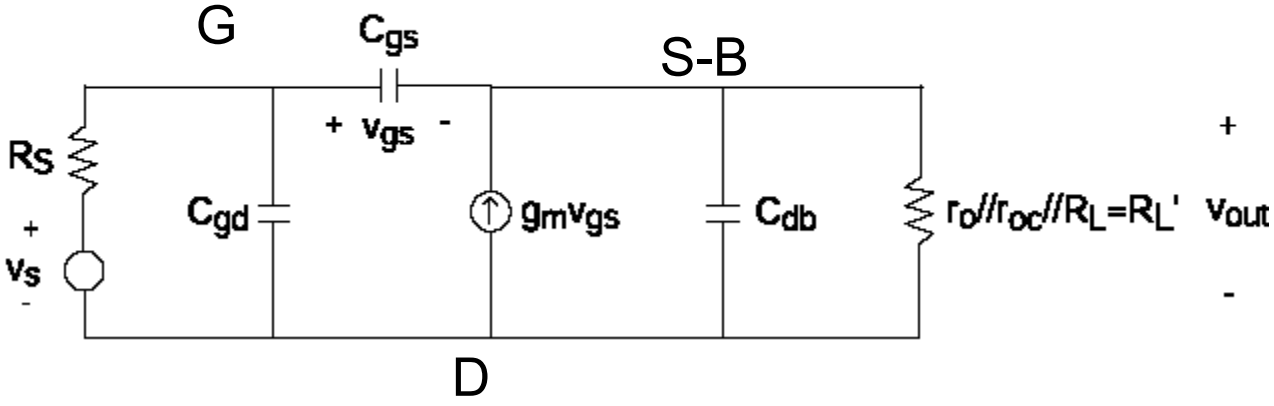


Characteristics of CD Amplifier:

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

High-frequency small-signal model

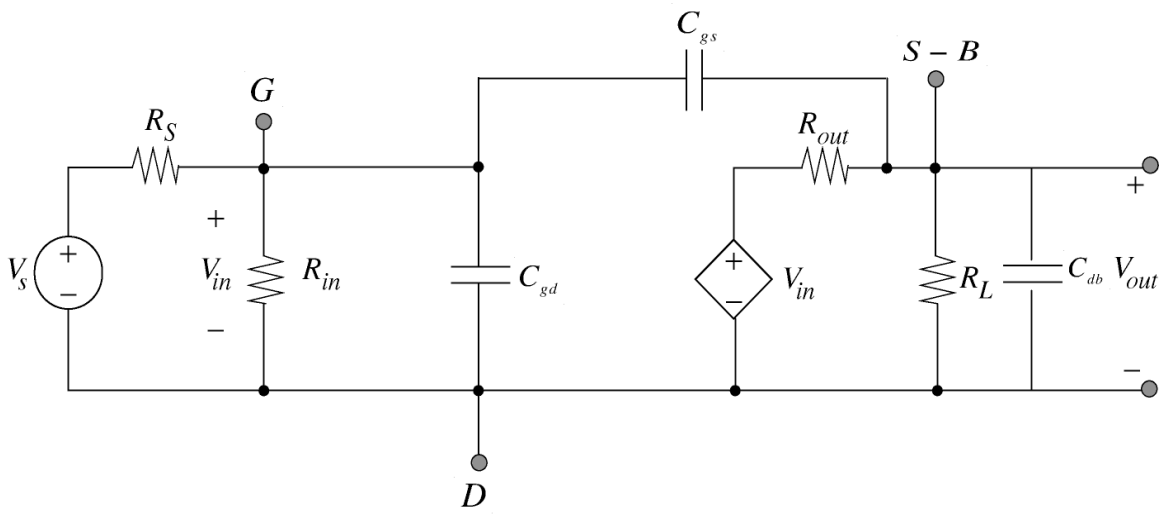




Could use OTC to solve for bandwidth.

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

Low Frequency Analysis Using 2-Port Model



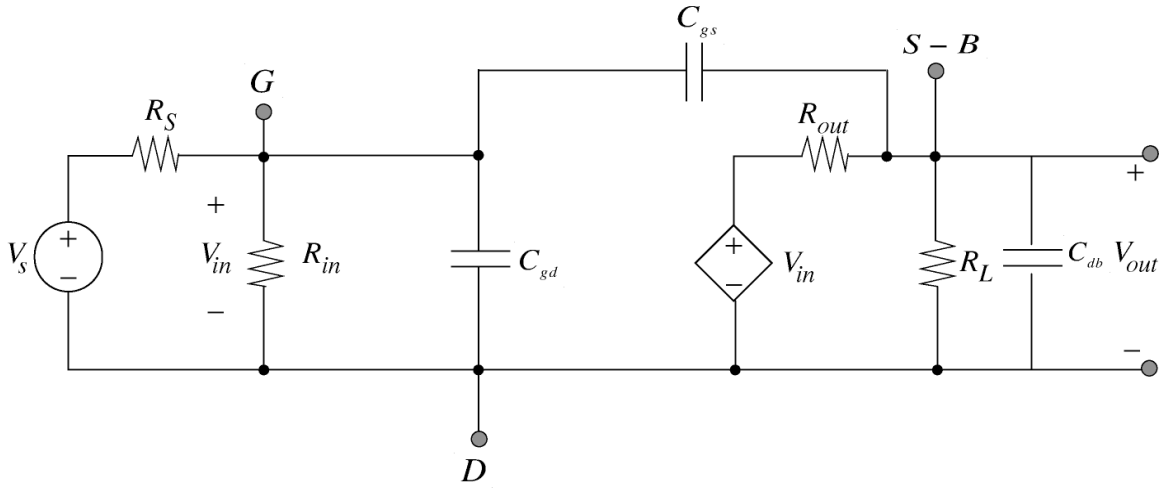
Capacitors -open circuit

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

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

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

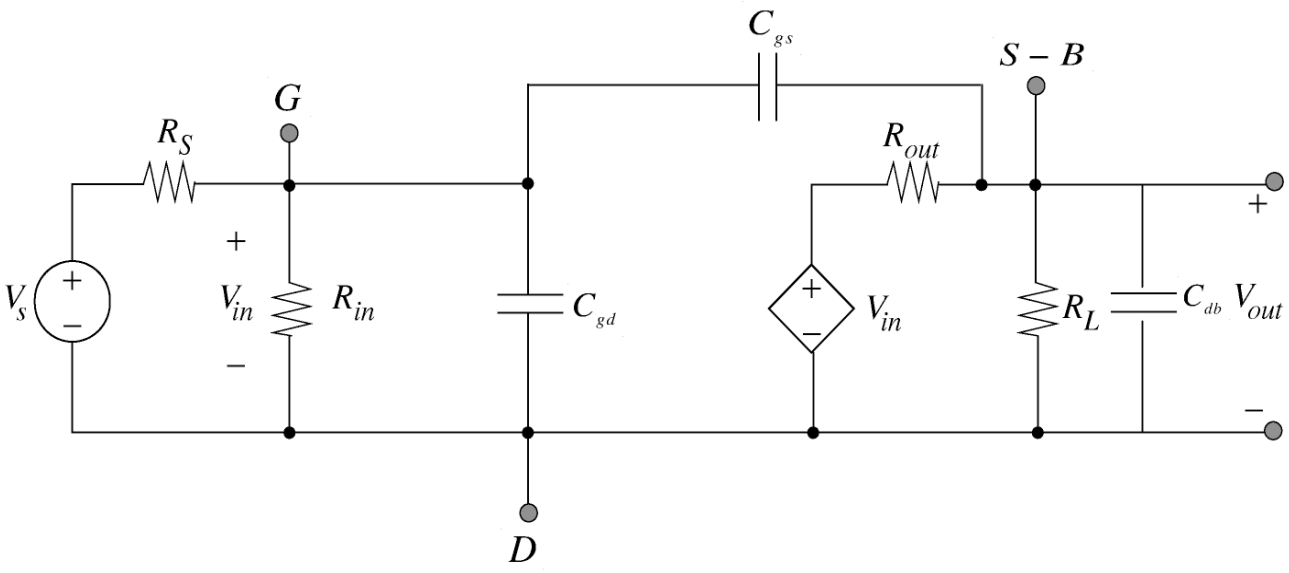
$$C_T = C_{gs}\left(1 - \frac{g_m R_L}{1 + g_m R_L}\right) + C_{gd}$$

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

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

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

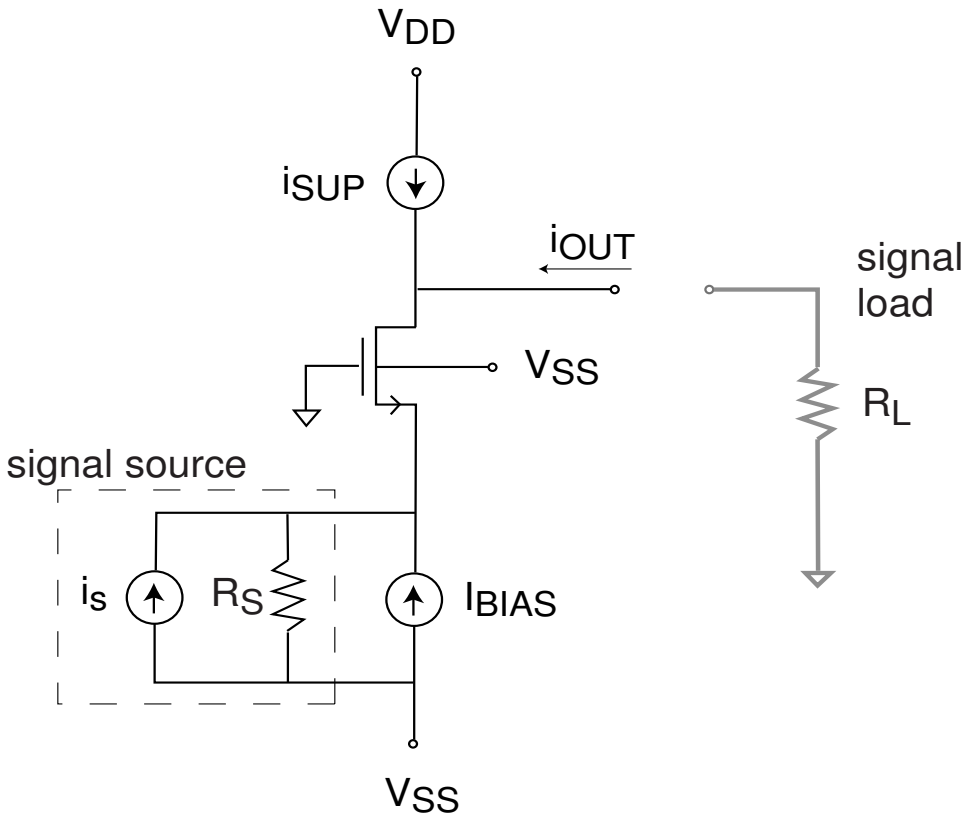
Frequency Response of Common-Drain Amplifier



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

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

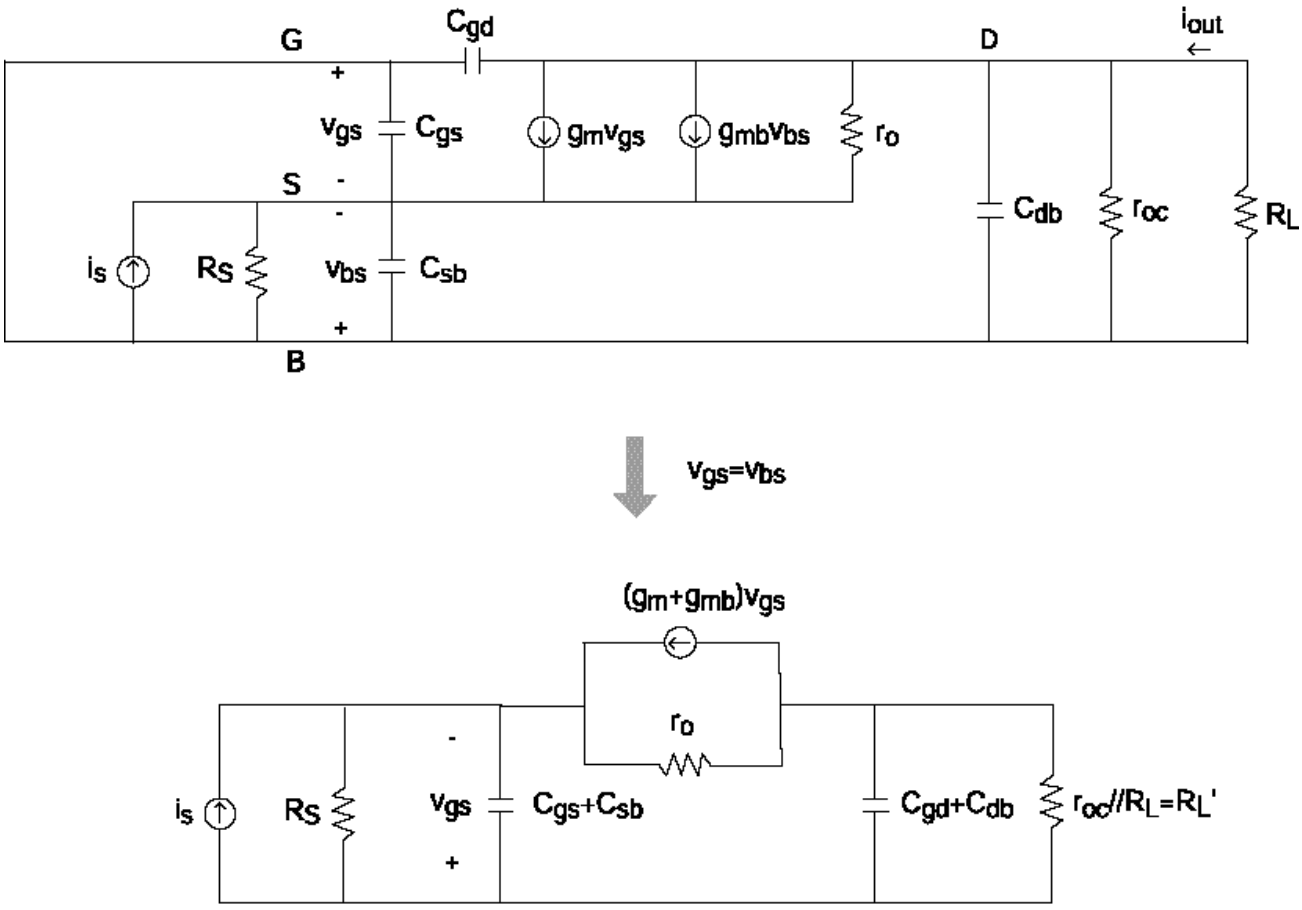
2. Frequency Response of the Common-Gate Amplifier



Characteristics of CG Amplifier:

- Current gain ≈ 1
- Low input resistance
- High output resistance
- ⇒ Good current buffer

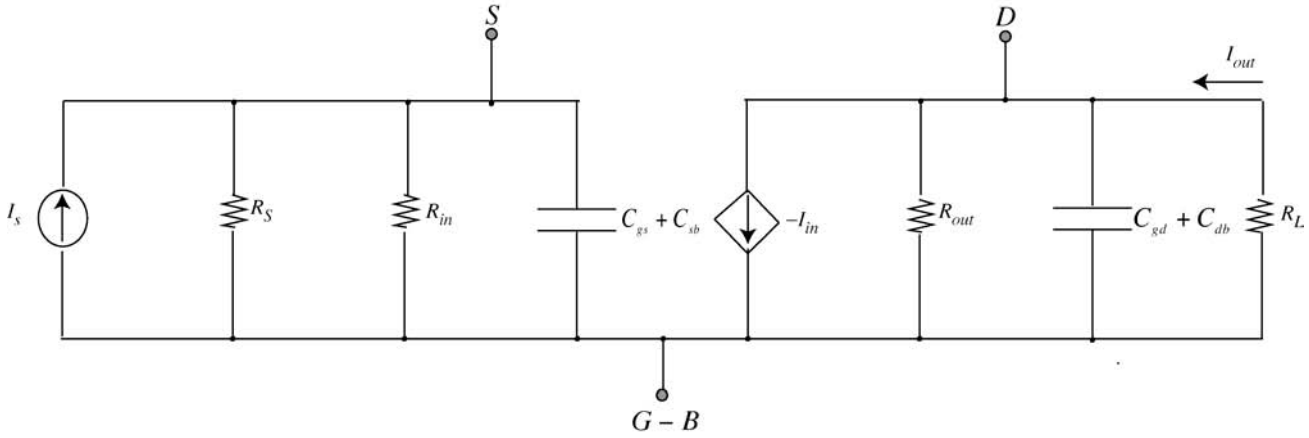
High Frequency Small Signal Model



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}:

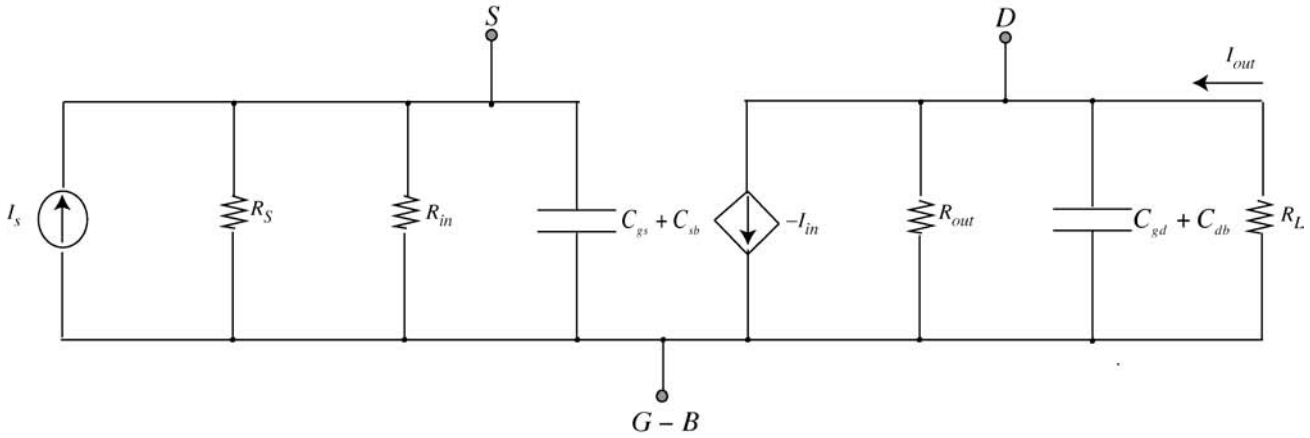
Thevenin resistance across C_{gs} + C_{sb}

$$R_{TC_{gs}} = R_S \,||\, R_{in} = R_S \,||\, \left(1/\left(g_m + g_{mb}\right)\right)$$

Thevenin resistance across C_{gd} + C_{db}

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

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



Open circuit time constants:

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

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

Summing the open circuit time constants:

$$\omega_{3dB} = 1\Big/\left(R_S \,\|\, (1/g_m + g_{mb})\right)(C_{gs} + C_{sb})$$

$$+\left(((r_o + g_m r_o R_S) \,\|\, r_{oc}) \,\|\, R_L\right)\left(C_{gd} + C_{db}\right)\Big]$$

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.

6.012 Microelectronic Devices and Circuits
Spring 2009