Lecture 16

• Last time:
  – Finish methods for finding two-port model parameters
  – Common-source amplifiers (NMOS, PMOS)

• Today:
  – Common-gate amplifier
Common Gate Amplifier

DC bias:
CG as a Current Amplifier: Find $A_i$

\[ i_{out} = i_d = -i_g - i_s = -i_t \]
CG Input Resistance

At input: \[ i_t = -g_m v_{gs} + g_{mb} v_t + \left( \frac{v_t - v_{out}}{r_o} \right) \]

Output voltage: \[ -i_{out} \left( r_{oc} \parallel R_L \right) = -(-i_t)(r_{oc} \parallel R_L) \]
CG Output Resistance

* Kirchhoff's current law at the source resistor node: sum currents leaving node

\[ \frac{v_s}{R_S} - g_m v_{gs} - (-g_{mb} v_s) + \frac{v_s - v_t}{r_O} = 0 \]

\[ v_s \left( \frac{1}{R_S} + g_m + g_{mb} + \frac{1}{r_O} \right) = \frac{v_t}{r_O} \]
Common-Gate Output Resistance

Substituting $v_s = i_t R_S$

$$i_t R_S \left( \frac{1}{R_S} + g_m + g_{mb} + \frac{1}{r_o} \right) = \frac{v_t}{r_o}$$

The output resistance is $(v_t / i_t) \| r_{oc}$

$$R_{out} = r_{oc} \| \left( R_S \left( \frac{r_o}{R_S} + g_m r_o + g_{mb} r_o + 1 \right) \right)$$
Approximating the CG $R_{\text{out}}$

$$R_{\text{out}} = r_{oc} \parallel [r_o + g_m r_o R_S + g_{mb} r_o R_S + R_S]$$

The exact result is complicated, so let’s try to make it simpler:

$$g_m \approx 500 \mu S \quad g_{mb} \approx 50 \mu S \quad r_o \approx 200k\Omega$$

$$R_{\text{out}} \cong r_{oc} \parallel [r_o + g_m r_o R_S + R_S]$$

Assuming the source resistance is less than $r_o$,

$$R_{\text{out}} \approx r_{oc} \parallel [r_o + g_m r_o R_S] = r_{oc} \parallel [r_o (1 + g_m R_S)]$$
Common-Gate Two-Port Model

Function: a current buffer
Common-Drain Amplifier
CD Voltage Gain

Note \( v_{gs} = v_t - v_{out} \)
CD Voltage Gain (Cont.)

KCL at source node:

Voltage gain (for $v_{SB}$ not zero):
CD Output Resistance

Sum currents at output (source) node:
CD Output Resistance (Cont.)

\[ r_o \parallel r_{oc} \text{ is much larger than the inverses of the transconductances} \rightarrow \text{ignore} \]

\[ R_{out} = \]

\[ \frac{1}{g_m + g_{mb}} \left[ \frac{g_m}{g_m + g_{mb}} \right] v_{in} \]

\[ v_{out} \]
## Transistor Type

<table>
<thead>
<tr>
<th>NMOS</th>
<th>PMOS</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="NMOS Circuit Diagram" /></td>
<td><img src="image2.png" alt="PMOS Circuit Diagram" /></td>
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### Common Source/Common Emitter (CS/CE)

- **NMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)
- **PMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)

### Common Gate/Common Base (CG/CB)

- **NMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)
- **PMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)

### Common Drain/Common Collector (CD/CC)

- **NMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)
- **PMOS**
  - Input: IN
  - Output: OUT
  - Current: \( i_{SUP} \)