EE 330
Lecture 30

Basic amplifier architectures
Consider Common Emitter/Common Source Two-port Models

Review from Last Time

Will focus on Bipolar Circuit since MOS counterpart is a special case obtained by setting $g_{\pi}=0$
**Common Source/Common Emitter Configuration**

**Review from Last Time**

- **Input impedance is mid-range (infinite for MOS)**
- **Voltage Gain is Large and Inverting**
- **Output impedance is mid-range**
- **Widely used as a voltage amplifier**

\[
R_{\text{out}} = \frac{1}{g_0 + g_c} \approx R_C
\]

\[
A_v \approx -g_m R_C
\]

\[
R_{\text{in}} = \frac{1}{g_0 + g_D} \approx R_D
\]

\[
A_v \approx -g_m R_D
\]

\[
R_{\text{in}} = \infty
\]

\[
R_{\text{out}} = \frac{1}{g_0 + g_D} \approx R_D
\]

\[
A_v \approx -\frac{2I_{DQ}R_D}{V_{EBQ}}
\]

\[
R_{\text{in}} = \infty
\]

\[
R_{\text{out}} = \frac{1}{g_0 + g_D} \approx R_D
\]

\[
R_{\text{in}} = \frac{\beta V_t}{I_{CQ}}
\]
Consider Common Collector/Common Drain Two-port Models

Review from Last Time

Will focus on Bipolar Circuit since MOS counterpart is a special case obtained by setting $g_{m}=0$.
Common Collector/Common Drain Configurations

For these CC/CS applications:

\[ A_V = \frac{g_m + g_{\pi}}{g_m + g_E + g_0 + g_{\pi}} \quad \text{if } g_n >> g_x \]

\[ R_{in} = r_{\pi} + \beta R_E \]

\[ R_0 \approx \frac{R_E}{1 + g_m R_E} \approx \frac{1}{g_m} \]

In terms of operating point and model parameters:

\[ A_V = \frac{I_{CQ} R_E}{I_{CQ} R_E + V_t} \quad I_{CQ} R_s >> V_t \]

\[ R_{in} \approx \beta R_E \]

\[ R_0 \approx \frac{V_{EBQ} R_S}{V_{EBQ} + 2 I_{DQ} R_S} \]

\[ \frac{V_{EBQ}}{2 I_{DQ}} \]

- Output impedance is low
- \( A_{V0} \) is positive and near 1
- Input impedance is very large

\[ A_V = \frac{g_m}{g_m + g_S + g_0} \approx 1 \]

\[ R_{in} = \infty \]

\[ R_0 \approx \frac{R_S}{1 + g_m R_S} \approx \frac{1}{g_m} \]

\[ A_V = \frac{2 I_{DQ} R_S}{2 I_{DQ} R_S + V_{EBQ}} \quad \text{if } 2 I_{DQ} R_s >> V_{EBQ} \]

\[ R_0 \approx \frac{V_{EBQ} R_S}{V_{EBQ} + 2 I_{DQ} R_S} \]

\[ \frac{V_{EBQ}}{2 I_{DQ}} \]

- Widely used as a buffer
- Not completely unilateral but output-input transconductance is small
Consider Common Base/Common Gate Two-port Models

Will focus on Bipolar Circuit since MOS counterpart is a special case obtained by setting $g_{\pi}=0$.
Common Base/Common Gate Application

\[ A_V \approx g_m R_C \quad R_{in} \approx \frac{1}{g_m} \quad R_{out} \approx \frac{R_c}{R_C} \]

In terms of operating point and model parameters:

\[ A_V \approx \frac{I_{CQ} R_C}{V_t} \quad R_{in} \approx \frac{V_t}{I_{CQ}} \quad R_{out} \approx \frac{I_{cQ} R_C}{V_{AF}} \]

- Output impedance is mid-range
- \( A_{V0} \) is large and positive (equal in mag to that to CE)
- Input impedance is very low
- Not completely unilateral but output-input transconductance is small
Basic Amplifier Structures

1. Common Emitter/Common Source
2. Common Collector/Common Drain
3. Common Base/Common Gate
4. Common Emitter with $R_E$/ Common Source with $R_S$
5. Cascode (actually CE:CB or CS:CD cascade)
6. Darlington (special CE:CE or CS:CS cascade)

The first 4 are most popular
Common Emitter with Emitter Resistor Configuration

\[ A_V \approx -\frac{R_C}{R_E} \]

\[ R_{\text{in}} \approx r_{\text{in}} + \beta R_E \]

\[ R_{\text{out}} \approx R_C \]

(this is not a two-port model)

- Analysis would simplify if \( g_0 \) were set to 0 in model
- Gain can be accurately controlled with resistor ratios
- Useful for reasonably accurate low gains
- Input impedance is high
# Basic Amplifier Gain Table

<table>
<thead>
<tr>
<th>MOS</th>
<th>BJT</th>
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<th>BJT</th>
<th>MOS</th>
<th>BJT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_V$</td>
<td>$-g_mR_C$</td>
<td>$\frac{g_m}{g_m+g_E}$</td>
<td>$g_mR_C$</td>
<td>$-\frac{R_C}{R_E}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{in}$</td>
<td>$\infty$</td>
<td>$\frac{r_T}{I_{CQ}}$</td>
<td>$\infty$</td>
<td>$\frac{r_T+\beta R_E}{I_{CQ}}$</td>
<td>$r_T+\beta R_E$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{out}$</td>
<td>$R_C$</td>
<td>$\frac{1}{g_m}$</td>
<td>$R_C$</td>
<td>$R_C$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Can use these equations only when circuit is EXACTLY like that shown above!!
Why are we focusing on these basic circuits?

1. So that we can develop analytical skills
2. So that we can design a circuit
3. So that we can get the insight needed to design a circuit

Which is the most important?
Why are we focusing on these basic circuits?

1. So that we can develop analytical skills
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Which is the most important?

1. So that we can get the insight needed to design a circuit
2. So that we can design a circuit
3. So that we can develop analytical skills
Properties/Use of Basic Amplifiers

CE and CS

- More practical biasing circuits usually used
- $R_C$ or $R_D$ may (or may not) be load
Properties/Use of Basic Amplifiers

CE and CS

- Large inverting gain
- Moderate input impedance for BJT (high for MOS)
- Moderate output impedance
- Most widely used amplifier structure
Properties/Use of Basic Amplifiers

CC and CD
(emitter follower or source follower)

- More practical biasing circuits usually used
- $R_E$ or $R_S$ may (or may not) be load
Properties/Use of Basic Amplifiers

CC and CD
(emitter follower or source follower)

- Gain very close to +1 (little less)
- High input impedance for BJT (high for MOS)
- Low output impedance
- Widely used as a buffer
Properties/Use of Basic Amplifiers

CB and CG

- More practical biasing circuits usually used
- $R_C$ or $R_D$ may (or may not) be load
Properties/Use of Basic Amplifiers

CB and CG

- Large noninverting gain
- Low input impedance
- Moderate (or high) output impedance
- Used more as current amplifier or, in conjunction with CD/CS to form two-stage cascode
Properties/Use of Basic Amplifiers

CEwRE or CSwRS

- More practical biasing circuits usually used
- $R_C$ or $R_D$ may (or may not) be load
Properties/Use of Basic Amplifiers

CEwRE or CSwRS

- Reasonably accurate but somewhat small gain (resistor ratio)
- High input impedance
- Moderate output impedance
- Used when more accurate gain is required
### Basic Amplifier Characteristics Summary

#### CE/CS
- Large noninverting gain
- Low input impedance
- Moderate (or high) output impedance
- Used more as current amplifier or, in conjunction with CD/CS to form two-stage cascode

#### CC/CD
- Gain very close to +1 (little less)
- High input impedance for BJT (high for MOS)
- Low output impedance
- Widely used as a buffer

#### CB/CG
- Large noninverting gain
- Low input impedance
- Moderate (or high) output impedance
- Used more as current amplifier or, in conjunction with CD/CS to form two-stage cascode

#### CEwRE/CSwRS
- Reasonably accurate but somewhat small gain (resistor ratio)
- High input impedance
- Moderate output impedance
- Used when more accurate gain is required