• High-Gain Amplifiers
• Current Sources and Mirrors
• Current Source Biasing
High-gain amplifier

$$A_V \approx -8000$$

How can we build the current source?

What is the small-signal model of an actual current source?
Basic Current Sources and Sinks

**Basic Bipolar Current Sinks**

\[ I_X = J_S A E e^{ \frac{V_{XX}}{V_t}} \]

\[ I_X \approx \frac{V_{CC} - 0.6V}{R} \]

**Basic Bipolar Current Sources**

Very practical methods for biasing the BJTs can be used. Current Mirrors often used for generating sourcing and sinking currents.
Basic Current Sources and Sinks

Small-signal Model of BJT Current Sinks and Sources

Small-signal model of all other BJT Sinks and Sources are the same
Basic Current Sources and Sinks

Small-signal Model of BJT Current Sinks and Sources

Small-signal model of all other MOS Sinks and Sources are the same
High-gain amplifier

\[ A_V = \frac{-g_m}{g_0} \]

\[ A_V = \frac{-g_{m1}}{g_{01} + g_{02}} \simeq \frac{-g_{m1}}{2g_{01}} \]
High-gain amplifier

\[ A_V = \frac{-g_m}{g_0} \]

- Nonideal current source decreased the gain by a factor of 2
- But the voltage gain is still quite large

Can the gain be made even larger?
EE 330

• The Cascode Configuration
High-gain amplifier

\[
A_V = \frac{-g_m}{g_0}
\]

- Nonideal current source decreased the gain by a factor of 2
- But the voltage gain is still quite large

Can the gain be made even larger?
High-gain amplifier
Can the gain be made even larger?

The Cascode Configuration

Discuss
The Cascode Amplifier (consider npn BJT version)

• Actually a cascade of a CE stage followed by a CB stage but usually viewed as a “single-stage” structure

• Cascode structure is widely used

• Recall reference was made to the Cascode configuration earlier
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
The Cascode Amplifier (consider npn BJT version)
The Cascode Amplifier (consider npn BJT version)

Instead of just determining the voltage gain, we will obtain the two-port model for the cascode amplifier.
The Cascode Amplifier (consider npn BJT version)

From the two-port model of the cascode, the $A_{VCC}$ in the model is simply the voltage gain of the cascode amplifier and $g_{0CC}$ is the output conductance of the cascode amplifier. Instead of just determining the voltage gain, we will obtain the two-port (Thevenin) model for the cascode amplifier.
The Cascode Amplifier (consider npn BJT version)
Cascode Configuration

Two-port model of cascode amplifier

\[ \begin{align*}
V_1 & = V_{IN} \\
(g_{m1} + g_{m2} - g_{\pi2})V_1 & = V_{IN} + \left( \frac{g_{m1}}{g_{\pi2} + g_{01}} \right) V_{IN} + \left( \frac{g_{02} + g_{m2} + g_{\pi2}}{g_{\pi2} + g_{01}} \right) I_X
\end{align*} \]

Observing \( V_1 = V_{IN} \) and eliminating \( V_2 \) between these two equations, we obtain

\[ V_X = \left( \frac{g_{m1}}{g_{\pi2} + g_{01}} \right) V_{IN} + \left( \frac{g_{02} + g_{m2} + g_{\pi2}}{g_{\pi2} + g_{01}} \right) I_X \]

and

\[ V_{IN} = \frac{1}{g_{\pi1}} I_1 \]
Cascode Configuration

Two-port model of cascode amplifier

\[ V_X = -\left[ \frac{g_{m1}(g_{02}+g_{m2})}{g_{02}(g_{\pi2}+g_{01})} \right] V_1 + \left[ \frac{g_{01}+g_{02}+g_{\pi2}+g_{m2}}{g_{02}(g_{01}+g_{\pi2})} \right] I_X \]

\[ V_{IN} = \frac{1}{g_{\pi1}} I_1 \]

It thus follows for the npn bipolar structure that:

\[ A_{VCC} = -\left[ \frac{g_{m1}(g_{02}+g_{m2})}{g_{02}(g_{\pi2}+g_{01})} \right] \approx -\left[ \frac{g_{m1}g_{m2}}{g_{02}g_{\pi2}} \right] \]

\[ g_{0CC} = \left[ \frac{g_{02}(g_{01}+g_{\pi2})}{g_{01}+g_{02}+g_{\pi2}+g_{m2}} \right] \approx \left[ \frac{g_{02}g_{\pi2}}{g_{m2}} \right] \]

\[ g_{\piCC} = g_{\pi1} \]
Cascode Configuration

- Voltage gain is a factor of $\beta$ larger than that of the CE amplifier with current source load
- Output impedance is a factor of $\beta$ larger than that of the CE amplifier

\[
A_{VCC} \approx - \left[ \frac{g_{m1}g_{m2}}{g_{02}g_{\pi2}} \right]
\]

\[
g_{0CC} \approx \left[ \frac{g_{02}g_{\pi2}}{g_{m2}} \right]
\]

\[
g_{\pi CC} = g_{\pi 1}
\]

\[
A_{VCC} \approx - \left[ \frac{g_{m1}}{g_{02}} \beta \right] \approx - \left[ \frac{g_{m1}}{g_{01}} \right] \beta
\]

\[
g_{0CC} \approx \frac{g_{01}}{\beta}
\]