EE 330
Lecture 31

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

This gain is very large!

But how can we make a current source?
Current Sources/Mirrors

If the base currents are neglected

$$I_0 \approx \frac{(V_{CC} - 0.6V)}{R}$$

$$I_0 = J_S A_{E_0} e^{V_{BE0} \over V_t}$$

$$I_1 = J_S A_{E_1} e^{V_{BE1} \over V_t}$$

since $V_{BE1} = V_{BE2}$

$$I_1 = \left( \frac{A_{E_1}}{A_{E_0}} \right) I_0$$

Behaves as a current source!

Actually termed a “sink” current since coming out of load
Current Sources/Mirrors

- Multiple Outputs Possible
- Can be built at sourcing or sinking currents
- Also useful as a current amplifier
- MOS counterparts work very well and are not plagued by base current
Current Sources/Mirrors

Multiple-Output Bipolar Current Sink

\[ I_k = \begin{bmatrix} A_{E_k} \\ A_{E_0} \end{bmatrix} I_0 \]
Current Sources/Mirrors

Multiple-Output Bipolar Current Source

\[ I_k = \begin{bmatrix} \frac{A_{E_k}}{A_{E_0}} \end{bmatrix} I_0 \]
Current Sources/Mirrors

Multiple-Output Bipolar Current Source and Sink

\[ I_{nk} = \left[ \frac{A_{Enk}}{A_{E0}} \right] I_0 \]

\[ I_{pk} = \left[ \frac{A_{En1}}{A_{E0}} \right] \left[ \frac{A_{Epk}}{A_{Ep0}} \right] I_0 \]
Current Sources/Mirrors

- Termed a “current mirror”
- Output current linearly dependent on $I_{in}$
- Serves as a current amplifier
- Widely used circuit

$$I_{out} = \left[ \frac{A_{E1}}{A_{E0}} \right] I_{in}$$

npn Current Mirror

\[\begin{array}{c}
E_1 \\
A_{E0} \\
\downarrow \\
\downarrow \\
Q_0 \\
A_{E1} \\
Q_1 \\
\downarrow \\
\downarrow \\
\text{out} \\
\text{in}
\end{array}\]
Current Sources/Mirrors

npn current mirror amplifier

\[ i_{\text{out}} = \frac{A_{E1}}{A_{E0}} i_{\text{in}} \]

Amplifiers both positive and negative currents
Current Sources/Mirrors

If devices are matched, it follows that

\[
\begin{align*}
I_{\text{in}} &= \frac{\mu C_{\text{OX}} W_1}{2L_2} (V_{\text{GS}1} - V_{\text{T}1})^2 \\
I_{\text{out}} &= \frac{\mu C_{\text{OX}} W_2}{2L_2} (V_{\text{GS}2} - V_{\text{T}2})^2
\end{align*}
\]

Current mirror gain can be accurately controlled
Current Sources/Mirrors

n-channel current mirror current amplifier

\[ i_{\text{out}} = \begin{bmatrix} \frac{W_2}{W_1} & \frac{L_1}{L_2} \end{bmatrix} i_{\text{in}} \]

Amplifiers both positive and negative currents
Current Sources/Mirrors

\[ I_k = \begin{bmatrix} W_k & L_0 \\ W_0 & L_k \end{bmatrix} I_0 \]

multiple output n-channel current sink array

multiple output p-channel current source array
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

\[ I_X = J_S A E e^{V_{t}/V_{xx}} \]

Basic Bipolar Current Sources

\[ V_{CC}, V_{YY}, V_{CC}, R \]

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 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

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

\[ A_V = \frac{-g_{m1}}{g_{01} + g_{02}} \approx \frac{-g_{m1}}{2g_{01}} \]
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?