Lecture 16: High Gain Op Amps

Announcements:
- Lab#2 extended one week; due week of 3/19
- This is our makeup lecture, occurring Friday, 3/9, 3-4:30 p.m., in 277 Cory

Lecture Topics:
- High Gain Op Amps
- Slew Rate

Last Time: Telecopic Op Amp w/ Single-Ended Output

\[
\begin{align*}
R_o & = \frac{V_o}{I} = \left( \frac{g_m R_o}{g_m} \right) I \left( \frac{g_m R_o}{g_m} \right) \\
& = \left( g_m R_o \right) I \left( g_m R_o \right) \\
& = \left( g_m R_o \right) I \left( g_m R_o \right)
\end{align*}
\]

\[
\begin{align*}
I_o &= g_m V_{in} \frac{V_{in}}{2} + g_m V_{in} \frac{V_{in}}{2} \\
&= g_m \frac{V_{in}}{2}
\end{align*}
\]

Gain: \( A_N = g_m \left[ \left( g_m R_o \right) I \left( g_m R_o \right) \right] \)

\( R_o \) huge 

\( g_m \) will be big!
Problem (2): Difficult to get the input to output!

- Unity gain buffer (very useful!)

**Problem 1:**

$$V_{out}$$

- Need $$V_{out} \geq V_b - V_{out}\text{tr}$$
- Need $$V_{out} \leq V_b - V_{out}\text{tr} + V_{out}\text{re}$$

**Conclusion:**

- $$V_{out} = V_b - V_{out}\text{tr} + V_{out}\text{re}$$
- $$V_{out} = V_b - V_{out}\text{tr}$$

**Problem 2:**

- Need $$V_{out} \geq V_b - V_{out}\text{tr}$$
- Need $$V_{out} \leq V_b - V_{out}\text{tr} + V_{out}\text{re}$$

**Conclusion:**

- $$V_{out} = V_b - V_{out}\text{tr} + V_{out}\text{re}$$
- $$V_{out} = V_b - V_{out}\text{tr}$$

**Notes:**

- Limited output swing:
  - $$V_{max} = V_{bb} - (V_{re} - V_{out}) - (V_{ss} - V_{out}) + V_{out}$$
  - $$V_{min} = V_{out}\text{re} + V_{out}\text{re} + V_{out}\text{re}$$

**Conclusion:**

- $$V_{swing} = V_{max} - V_{min}$$
- Overdrive limit of the tail current source

**Important:**

- $$V_{out}$$ at this node, including from the next stage
High Gain Op Amps

Gain:

1st Stage: \( A_{V1} = \frac{V_{01}}{V_{i1}} = -g_m2 (\frac{R_{o2}}{R_{o1}}) \)

2nd Stage: \( A_{V2} = \frac{V_{02}}{V_{i2}} = -g_m6 (\frac{R_{o6}}{R_{o7}}) \)

\( A_V = A_{V1} A_{V2} = g_m2 (\frac{R_{o2}}{R_{o1}}) g_m6 (\frac{R_{o6}}{R_{o7}}) \)

Freq. Response:

- Open-loop op amp
- 20 dB/dec
- 40 dB/dec
- Gain:

\[ \omega \rightarrow 10^8 \text{ rad/s} \]

Dominant Pole:

\( \omega_p = \frac{1}{\sqrt{R_{o2} R_{o1}} (1 + g_m6 (R_{o6} R_{o7})) C_c} \)

	ext{Hill Effect}

Another solution: 2-stage op amp

Problem:

Low freq. non-dominant pole associated w/ the "mimic" node - will hurt stability in feedback loop!

(we'll cover this later)

Soln: Fully differential, fully balanced

CTN 3/9/12

EE 140: Analog Integrated Circuits
Lecture 16w: High Gain Op Amps

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Output Swing:

$$V_{swing} = V_{bb} - V_{ss} - |V_{ov}6| - V_{ov7}$$

L6: 2-Stage Bipolar OpAmp

Remarks:

1. You analyze this in Lab4.
2. Usually, the resistively-loaded diff. pair is replaced with an active current mirror load for more gain.
3. R6 raises the input R of Q6 (of the 2nd gain stage), plus helps with biasing.
4. Same comment as 3 for the output stage.
5. Output stage needed when driving a resistive load.
   - Often the case for bipolar.
   - Not often the case for MOS, when a capacitive load $C_L$ is often more relevant → MOS op amps often don't need an output stage!