Lec 10C - Diff Amp 4

- Cascoded Current Mirror
  - Need diff amp to make op-amp
  - How? Need to double differential
- Cascoded Current Mirror
- Start by clearing up details from last time

- $\frac{1}{2}$ ckt analysis
- Draw ckt. w/resistor tails
- Define Ado-Aco
- Rules for making $\frac{1}{2}$ circuits

- Common Design Params
  - CMRR
  - PSRR
  - $V_{os}$ Input-output referred
  - was remainder

3.5.11, 2, 3, 3

First ckt

\[
\text{First ckt: } \quad V_{out} = (\beta + 1) V_{o3} + \frac{1}{2} \beta V_{o3}
\]

\[
\beta = \frac{\text{assumed } I_{E3}}{\text{assumed } I_{o3}}
\]

- not undue of simple mirror forces equal
  - snapshot: $V_{out} = \beta V_{o3}$

- for cascoded mirror in notes from last time
- big takeaway is that in bipolar devices it is worse than simple mirror
- for other forces mirrors improve on this

- MOS devices make better mirrors w/o side current, work w/o $V_{os}$
- Finally, mid drew active load badly enough that repeating here

- Lots of other current mirror stuff to say...
- But we're done!

Building blocks unit!
Differential Amplifiers

- We're building an op-amp so they have differential input signals.
- A \((V_+ - V_-)\) — how do we get that?
- Need to make some kind of "differential amplifier" but need to declare differential.

- Any two signals \(V_1 + V_2\) can be decomposed into differential mode and common mode.

\[
V_{DM} = V_1 - V_2 \quad \text{and} \quad V_{CM} = \frac{V_1 + V_2}{2} \quad \text{(average value)}
\]

(Customly signal)

\[V_i = V_{CM} + \frac{V_{DM}}{2} \quad \text{(usually small signal)}\]

You can express \(V_i = V_{CM} + \frac{V_{DM}}{2}\) \((V_i = V_{CM} - \frac{V_{DM}}{2})\)


Example:

\[
\begin{align*}
V_1 &= 10 \cdot \sin(\omega t) \\
V_2 &= 0.5 \cdot \sin(\omega t)
\end{align*}
\]

\[
\begin{align*}
V_{DM} &= 0V \quad \text{average over time} \\
V_{CM} &= 0V \quad \text{average of each individually is 0V}
\end{align*}
\]

\[
V_{CM} = 0.7 \times \sin(\omega t)
\]

\[
V_{DM} = 0.5 \times \sin(\omega t)
\]

You try pseudo-diff signalling — a common digital technique.

- You draw \(V_{CM} + V_{DM}\)
- From this comm link

- Work to build a circuit that is sensitive to \(V_{DM}\) and not \(V_{CM}\).

- Most noise in the word is \(V_{CM}\) e.g.: power supply, pickup, inductive
  parasitics.
The classic diff amp - an emitter coupled pair

- can build w/ Pt+Pt in place of 2R, or Norton
- current steering $V_{i+} > V_{i-}$ means more of Ices goes Ic2
- can swap gain by -1 by switching $V_{o+} = V_{o-}$

- Biasing - don't saturate (R small) or don't cutoff $(V_{i+} - V_{i-}$ high enough)

- Large signal KVL

$$V_{i+} - V_{be1} + V_{be2} - V_{i-} = 0 \quad \Rightarrow \quad V_{be1} < \frac{1}{2} \ln \frac{I_{c1}}{I_s} \quad \text{some } I_s \Rightarrow \text{some } I_c$$

$$V_{i+} - V_{i-} + \phi_T \left( \ln \frac{I_{c2}}{I_s} - \ln \frac{I_{c1}}{I_s} \right) = 0$$

$$\frac{I_{c1}}{I_{c2}} = \frac{V_{dn}}{\phi_T} \quad \text{cool! Dependent current steering}$$

$$I_{c1} + I_{c2} = I_{c10}$$

$$\frac{B_{tr}}{\beta} (I_{c1} + I_{c2}) = I_{c10} \quad \Rightarrow \quad I_{c1} = \frac{B_{tr}}{\beta} I_{c10} \quad I_{c2} = \frac{B_{tr}}{\beta} I_{c10}$$

- Not linear over large range, can add degeneration to help, next time.

- Small signal behavior comes from many places, need to find $A_v$ and $A_{cm}$, an easy way to attack is with $\pi$ circuit analysis

- circuit like a seesaw around 0,1 voltage up or other down

- means diff current sometimes conveniently 0 or can use symmetry

$$A_{cm}, A_{dc}, A_{cm-dc}, A_{dc-cm}\,\text{, Note } \text{CMRR} = \frac{A_{cm}}{A_{dc}}$$
Lec 20 - Bifet Amp 1

- Superposition breaks into cm 2 dm circuits
- Symmetry lets us draw \( \frac{1}{2} \) circuits

\[
\begin{align*}
V_{in} &= A_{cm} V_{cm} + A_{m} V_{m0} \\
V_{cm} &= \frac{V_{in}}{2}
\end{align*}
\]

- \( V_{in} \) is dm ground, no seeing it. small signals.
- dm doesn't result in any flow into R

\[
A_{dm} = g_m \left( \frac{r_{01} R}{1} \right)
\]

- Geneva CMRR : \( A = \frac{1}{2} \frac{g_m R_{tail}}{R_{in}} \) ... want big \( R_{tail} \)
- Can specify differential input resistance or cm input resistance

\[
R_m = \frac{V_{in}}{I_{in}} \quad \text{or} \quad \frac{V_{cm}}{2} = I_{cm} R_{in}
\]

\[
R_m = \frac{g_m}{1}
\]

\[
R_{in} = \frac{R_{cm}}{R_{tail}} = r_{in} (R_{in} + 1) R_{tail}
\]

2 other design specs
- \( V_{os} \) - offset voltage
- \( I_{os} \neq I_{gs} \) different current in each leg
- \( \Delta V \) is output referred offset voltage
- Input-referred: divide by gain - npt of 0U needed. so there's no \( \Delta V \)

\[
A_{cm} = \frac{V_{cm}}{V_{cc}}
\]

\[
PSRR = \frac{A_{cm}}{A_{dm}}
\]