Course Material Outline

- Except for a couple of items we’ll look at later, now basically done with “core” amplifier functionality

- In many cases though, amplifier design driven not just by core functionality, but by robustness to external interference
  - Cover some of the sources of interference and how to mitigate them today/next lecture
Interference

Typical Interferers

- Power supplies
- Clocks
- Digital signals

- Electrical interferers can couple into your circuit:
  - Directly by capacitive coupling (most common on IC)
  - Directly by inductive coupling (more common on PCB)
  - Indirectly due to finite supply impedance (common everywhere)
Fully Differential Circuits

- Fully differential circuits:
  - $V_{id} = V_{i+} - V_{i-}$
  - $V_{ic} = (V_{i+} + V_{i-})/2$

- Try to make all interfering signals affect only common mode
  - And “reject” common mode as much as possible

Example

**Single Ended**

- Signal
- Interference

**Differential**

- Signal+
- Signal-
- Interference
Fully Differential Amplifier Gains

\[
\begin{align*}
A_{dm} &= \frac{V_{od}}{V_{id}} \to \infty \\
A_{cm} &= \frac{V_{oc}}{V_{ic}} \to 0 \\
A_{cdm} &= \frac{V_{od}}{V_{ic}} \to 0 \\
A_{DD} &= \frac{V_{od}}{V_{DD}} \to 0 \\
A_{SS} &= \frac{V_{od}}{V_{SS}} \to 0
\end{align*}
\]

CMRR, PSRR, ...

\[
\begin{align*}
CMRR_{direct} &= \frac{A_{dm}}{A_{cm}} \to \infty & PSRR_{DD} &= \left| \frac{A_{dm}}{A_{DD}} \right| \to \infty \\
CMRR_{cross} &= \left| \frac{A_{dm}}{A_{cdm}} \right| \to \infty & PSRR_{SS} &= \left| \frac{A_{dm}}{A_{SS}} \right| \to \infty
\end{align*}
\]
PSRR Example

Differential Input Stage Options

\[ V_i \rightarrow V_r \]
Differential Input Stage Options

Vi+ ————> ————> Vi-

Side Note
Design Methodology Implications

- Can “add” a CMRR_{direct} spec to any of our methodologies
  - Since I_{ss} is fixed by g_m, only degrees of freedom are \( V_{\text{tail}}^* \) and \( L_{\text{tail}} \)

- How would you pick \( V_{\text{tail}}^* \) and \( L_{\text{tail}} \)?

Design Methodology Implications

- In practice, need to specify CMRR_{direct}(f) requirement
  - Could be pairs of \( f \) and CMRR, worst-case across range of \( f \), etc.

- High-\( f \) CMRR may limit allowable \( V_{\text{tail}}^* \) and \( L_{\text{tail}} \)
  - Sometimes cascode tail for this reason, although can still be hard to maintain high-\( f \) CMRR
  - Is there anything else we can do?