Simplest Single-Ended OTA
DC Input/Output, Gain

Gain, Output Range

- Small Signal:
  \[ a_{vo} = \frac{dV_{out}}{dV_{in}} \]

- Large Signal:
  \[ A_{vo} = \frac{V_{out} - V_{out_{o}}}{V_{in} - V_{in_{o}}} \]
Frequency Response

\[ V_{eq}^2 / \Delta f = 4kT \gamma \frac{1}{g_{m1}} (g_{m1} + g_{m2}) \]

\[ = 4kT \gamma \frac{1}{g_{m1}} \left( 1 + \frac{g_{m2}}{g_{m1}} \right) \]

\[ = 4kT \gamma \frac{1}{g_{m1}} \left( 1 + \frac{V^2}{V_2^2} \right) \]
Differential Input?

- Why use a differential input?
  - Diff. version has extra device(s) – more power, noise, etc.
- Real reason is systematic offset
  - All voltages are relative
  - Inherent asymmetry to get single-ended $V_{\text{out}}$
    - “common-mode” sensitivity

Fully Differential Circuits

- Fully differential circuits: complete symmetry
  - $V_{\text{id}} = V_{i+} - V_{i-}$
  - $V_{ic} = (V_{i+} + V_{i-})/2$
  - $V_{od} = V_{o+} - V_{o-}$
  - $V_{oc} = (V_{o+} + V_{o-})/2$
- Still need to be careful with common mode
**Fully Differential Amplifier Gains**

![Diagram of Fully Differential Amplifier Gains]

**PSRR, CMRR, ...**

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

- **CMRR**
  \[
  CMRR = \frac{A_{dm}}{A_{cdm}} \rightarrow \infty
  \]

- **PSRR**
  \[
  PSRR_{VDD} = \frac{A_{dm}}{A_{VDD}} \rightarrow \infty
  \]
  \[
  PSRR_{VSS} = \frac{A_{dm}}{A_{VSS}} \rightarrow \infty
  \]

- **All “terminals” are inputs**
  - May not be a node in the circuit – could be e.g. temperature

- **Typical metrics: CMRR, PSRR**
  - Careful with how you use these
CMRR Example

Differential Input Stage Options

(a) \( V_H \rightarrow V_L \)  
(b) \( V_{i+} \rightarrow V_i \)  
(c) \( V_{i+} \rightarrow V_i \)
PSRR Example

Baluns