Simplest Single-Ended OTA

\[ a_{in} = \frac{dV_{out}}{dV_{in}} \]

\[ A_{in} = \frac{V_{out} - V_{out_{dc}}}{V_{in} - V_{in_{dc}}} \]

Frequency Response

DC Input/Output, Gain

\[ V_{in} = 4kTg \left( \frac{1}{R_{in}} + \frac{1}{R_{out}} \right) \]

\[ = 4kTg \left( \frac{1}{R_{in}} + 1 \right) \]

\[ = 4kTg \left( \frac{1}{R_{in}} + \frac{1}{R_{out}} \right) \]

Noise
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
  - $V_{\text{id}} = V_{\text{i}+} - V_{\text{i}-}$
  - $V_{\text{ic}} = \frac{(V_{\text{i}+} + V_{\text{i}-})}{2}$
  - $V_{\text{id}} = V_{\text{o}+} - V_{\text{o}-}$
  - $V_{\text{oc}} = \frac{(V_{\text{o}+} + V_{\text{o}-})}{2}$
- Still need to be careful with common mode

PSRR, CMRR, ...

- 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

Differential Input Stage Options

Fully Differential Amplifier Gains

- $A_{\text{id}} = \frac{V_{\text{id}}}{V_{\text{i}+}} \rightarrow \infty$
- $A_{\text{id}} = \frac{V_{\text{id}}}{V_{\text{i}-}} \rightarrow 0$
- $A_{\text{ddm}} = \frac{V_{\text{o}+}}{V_{\text{o}}} \rightarrow \infty$
- $A_{\text{ddm}} = \frac{V_{\text{o}-}}{V_{\text{o}+}} \rightarrow 0$
- $A_{\text{psrr}} = \frac{A_{\text{ddm}}}{A_{\text{id}}} \rightarrow \infty$

CMRR Example