EECS240 – Spring 2010

Lecture 10: Single-Ended and Differential OTAs

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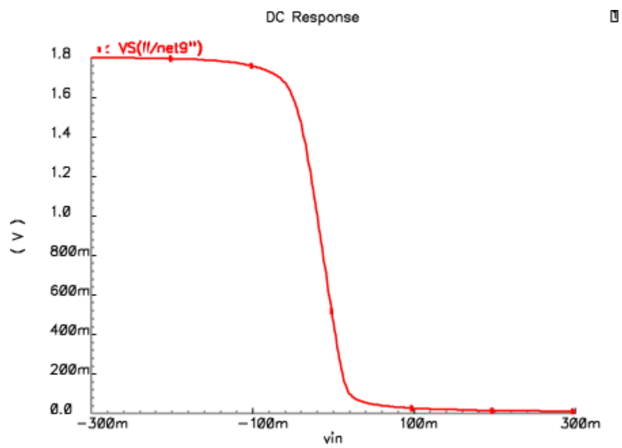
Simplest Single-Ended OTA

DC Input/Output, Gain



Gain, Output Range

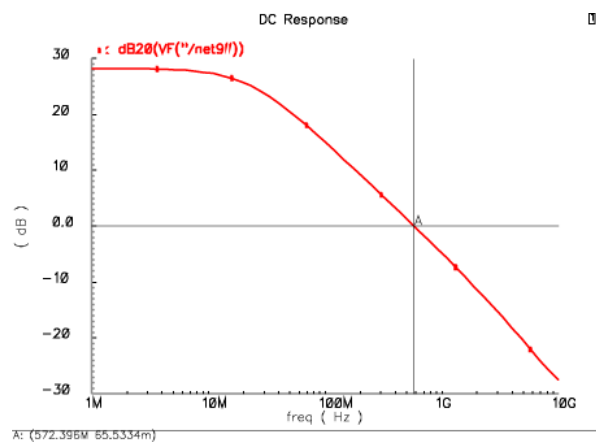
- **Small Signal:**

$$a_{vo} = \frac{dV_{out}}{dV_{in}}$$

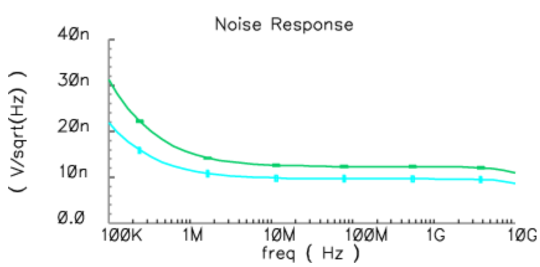
- **Large Signal:**

$$A_{vo} = \frac{V_{out} - V_{out\_o}}{V_{in} - V_{in\_o}}$$

Frequency Response



Noise

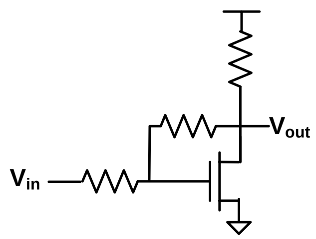


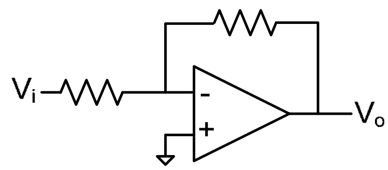
$$\frac{\overline{v_{ieq}^2}}{\Delta f} = 4k_B T\gamma \frac{1}{g_{m1}^2}(g_{m1}+g_{m2})$$

$$= 4k_B T\gamma \frac{1}{g_{m1}}\left(1+\frac{g_{m2}}{g_{m1}}\right)$$

$$= 4k_B T\gamma \frac{1}{g_{m1}}\underbrace{\left(1+\frac{V_1^*}{V_2^*}\right)}_{n_f}$$

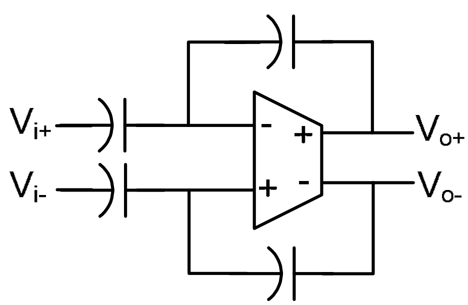
Differential Input?





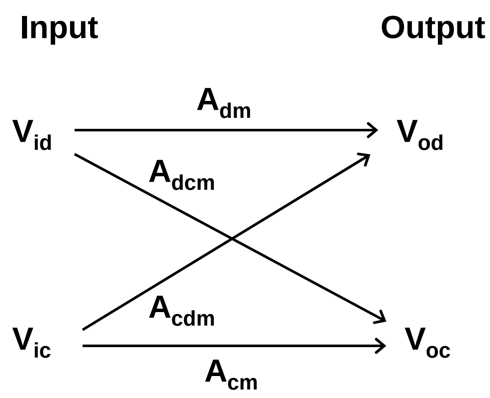
- **Why use a differential input?**
  - **Diff. version has extra device(s) – more power, noise, etc.**
- **Real reason is systematic offset**
  - **All voltages are relative**
- **Inherent asymmetry to get single-ended V_{out}**
  - **"common-mode" sensitivity**

Fully Differential Circuits



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

Fully Differential Amplifier Gains



PSRR, CMRR, …

$$A_{dm} = \frac{v_{od}}{v_{id}} \rightarrow \infty \qquad A_{VDD} = \frac{v_{od}}{v_{DD}} \rightarrow 0 \qquad CMRR = \left|\frac{A_{dm}}{A_{cdm}}\right| \rightarrow \infty$$

$$A_{cm} = \frac{v_{oc}}{v_{ic}} \rightarrow 0 \qquad A_{VSS} = \frac{v_{od}}{v_{SS}} \rightarrow 0 \qquad PSRR_{VDD} = \left|\frac{A_{dm}}{A_{VDD}}\right| \rightarrow \infty$$

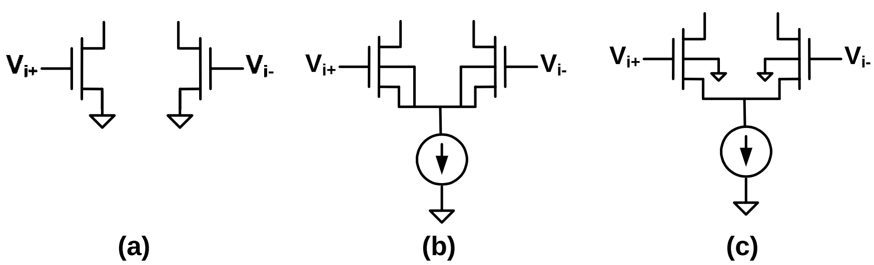
$$A_{cdm} = \frac{v_{od}}{v_{ic}} \rightarrow 0 \qquad PSRR_{VSS} = \left|\frac{A_{dm}}{A_{VSS}}\right| \rightarrow \infty$$

- **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



PSRR Example

Baluns