EE 240B – Fall 2019

Advanced Analog Integrated Circuits

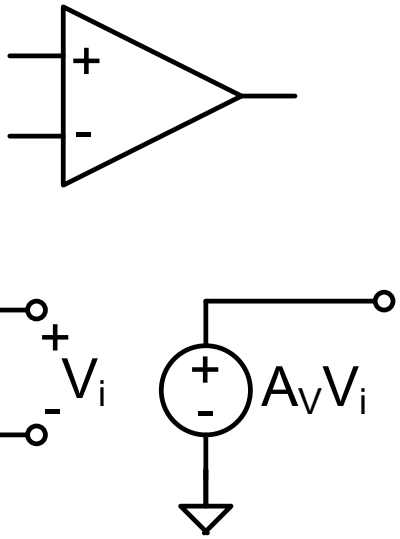
Lecture 8: Operational Transconductance Amplifiers (I)

Ali M. Niknejad

Dept. of EECS

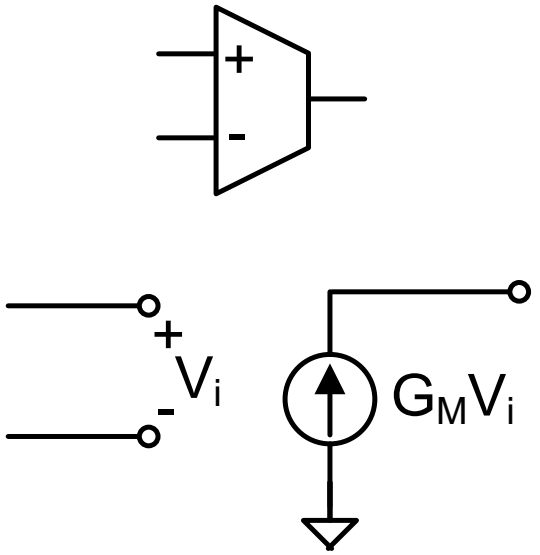
OpAmps and OTAs

OpAmp



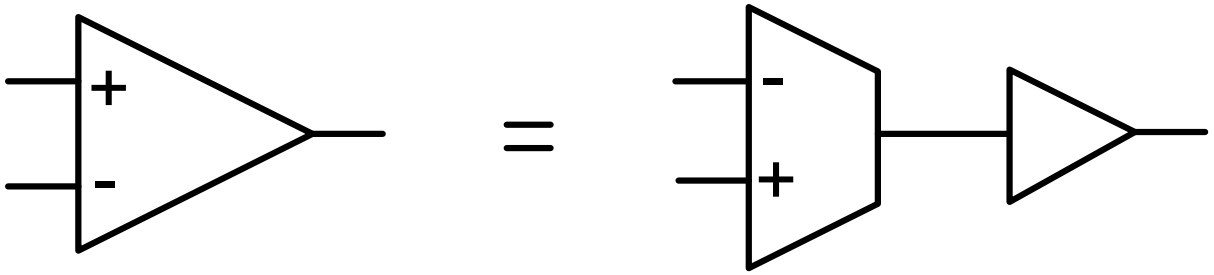
- **High voltage gain, high input impedance**
- **Voltage source output (low impedance)**

OTA



- **High "voltage" gain, high input impedance**
- **Current source output (high impedance)**

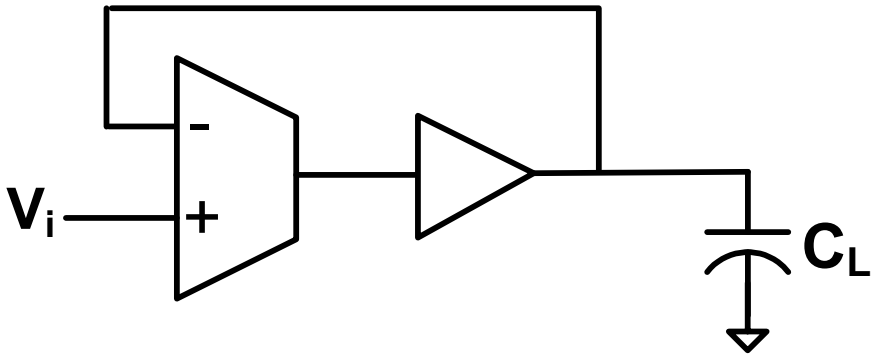
Opamp & OTA in CMOS

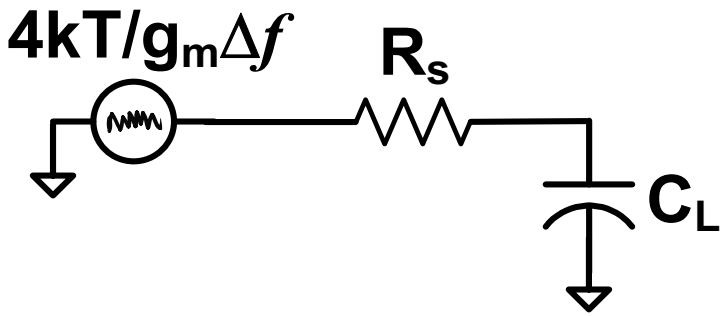


OpAmp **OTA (CS amp)** **Buffer (SF)**

Opamp vs. OTA Noise

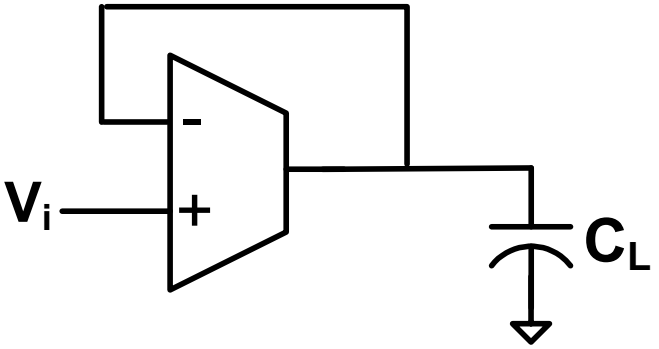
OpAmp

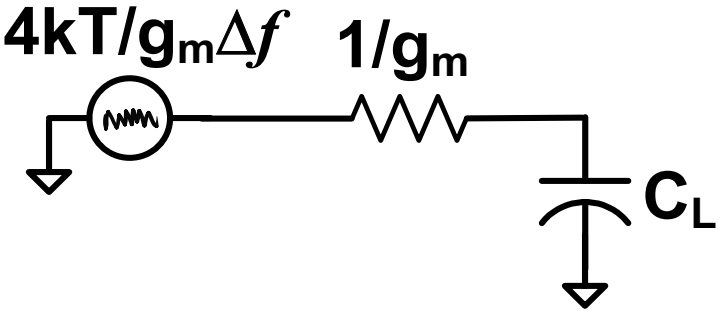




$$v_{o,n}^{\,2} = \frac{4k_BT}{g_m}\frac{1}{4R_sC_L} = \frac{k_BT}{C_L}\frac{R_n}{R_s}$$

OTA

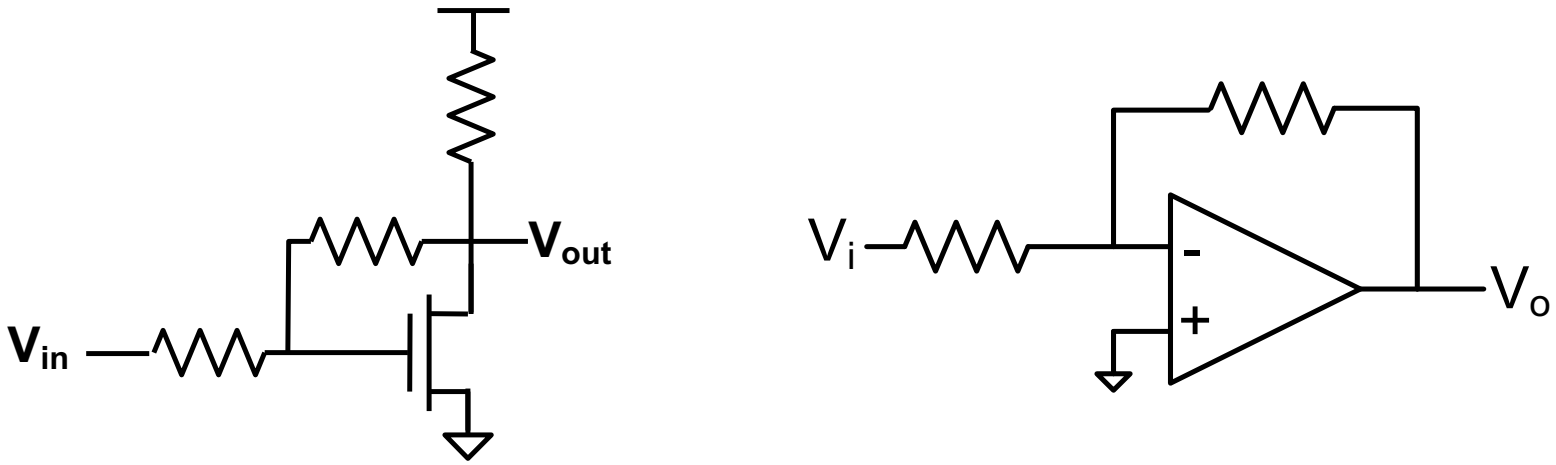




$$v_{o,n}^{\,2} = \frac{k_BT}{C_L}$$

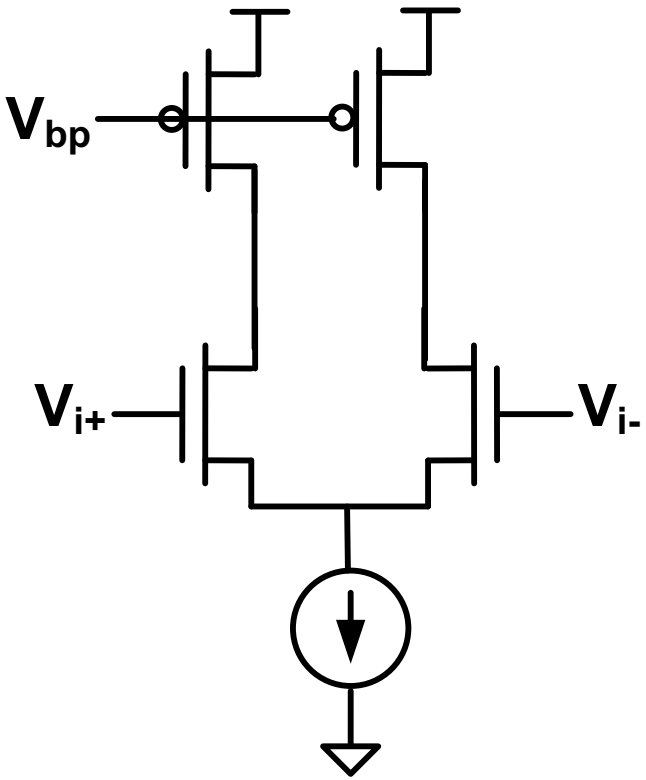
Simplest Single-Ended OTA

Differential Input?

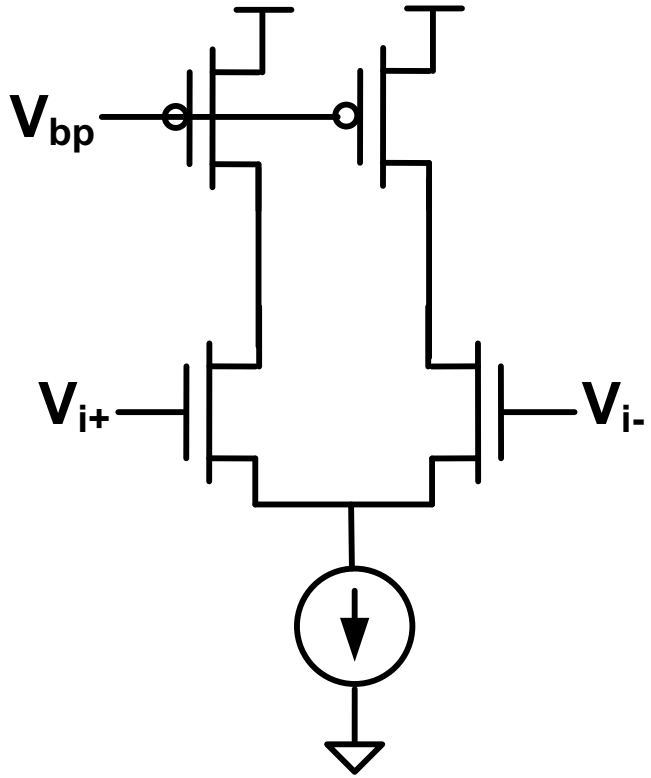


- **Why use a differential input?**
  - **Diff. version has extra device(s) – more power, noise, etc.**
- **Real reason is systematic offset**
  - **All voltages are relative**
- **If used a differential input, often might as well use differential output too…**

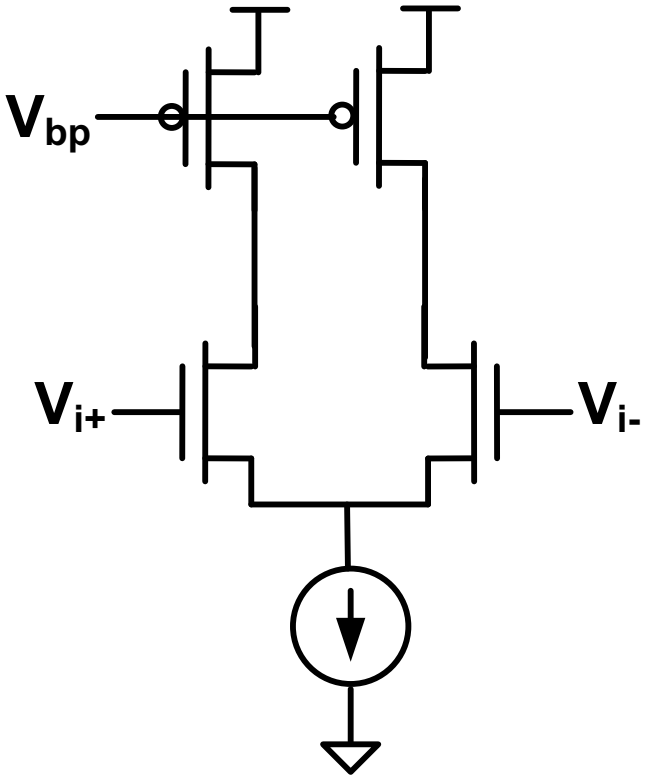
Simple Diff. Input OTA



Simple Diff. Input OTA: Noise (1)



Simple Diff. Input OTA: Noise (2)



Simple Diff. Input OTA: Noise (2)

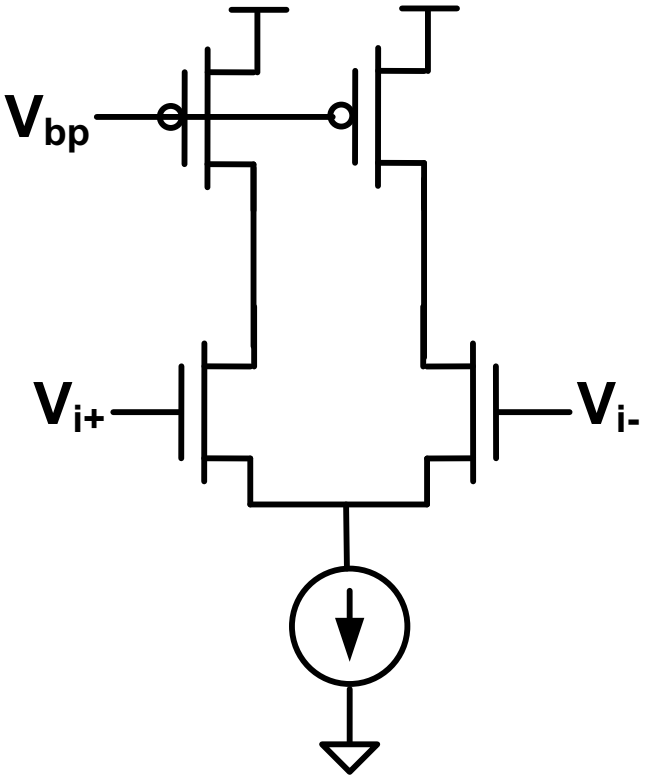
More Careful Look at Noise…

More Careful Look at Noise…

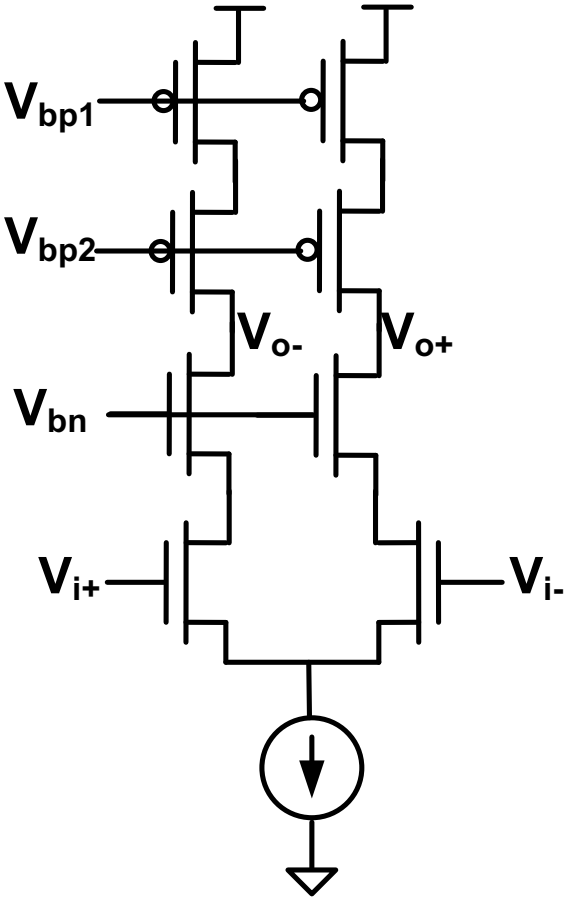
Real R vs. Current Source (1)

Real R vs. Current Source (2)

Limitations of Simple OTA

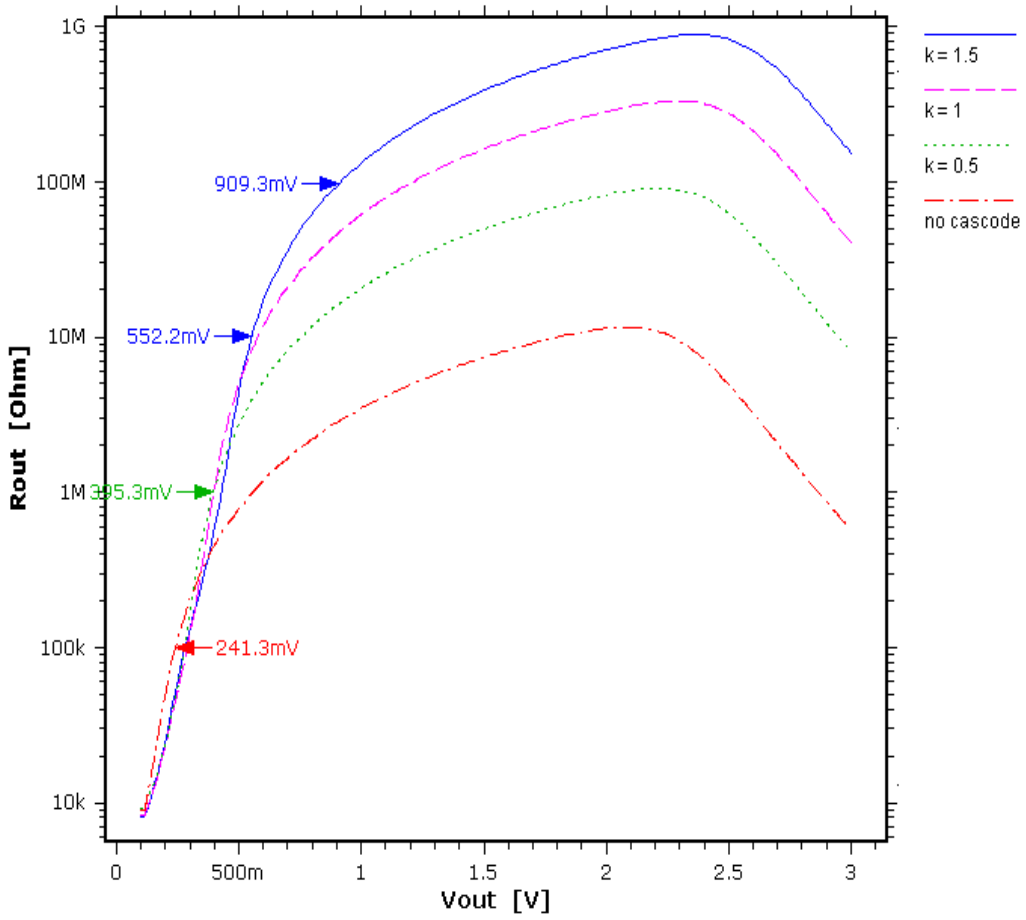


Telescopic Cascoded OTA



Why Cascoding Helps

Cascode Sizing for r_o



Cascode Noise?

Cascode Noise?

More Complete Analysis

More Complete Analysis

Cascode Sizing