Lecture 33

- Last time:
  - Frequency response of voltage and current buffers
  - Voltage/Current sources using MOS transistors
- Today :
  - Improved current sources
  - Current mirrors

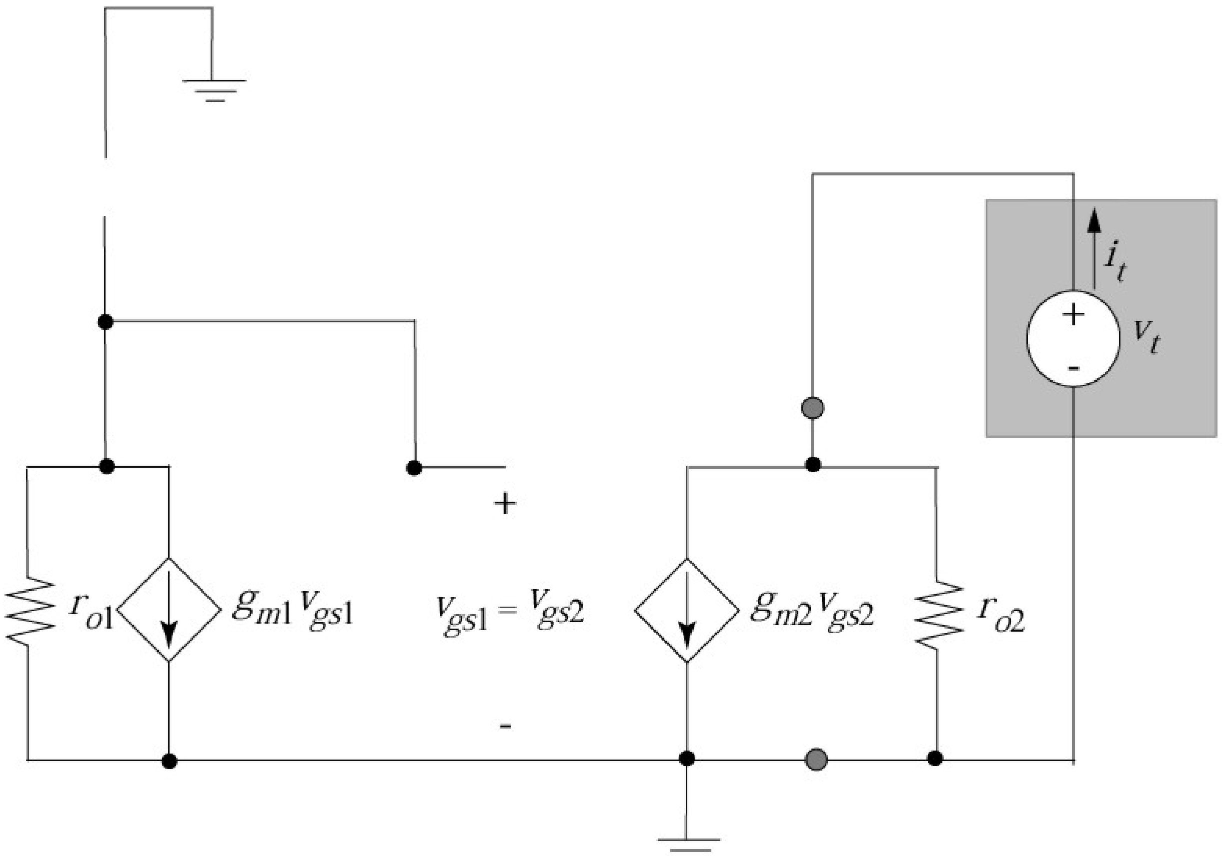
Equivalent Circuit for *I*-Source

Find the DC current for "gray circle" equivalent circuit

$$I_{OUT} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_2 \left(V_{REF} - V_{Tn}\right)^2$$

Substitute for V_{REF}

Small-Signal Resistance of *I*-Source

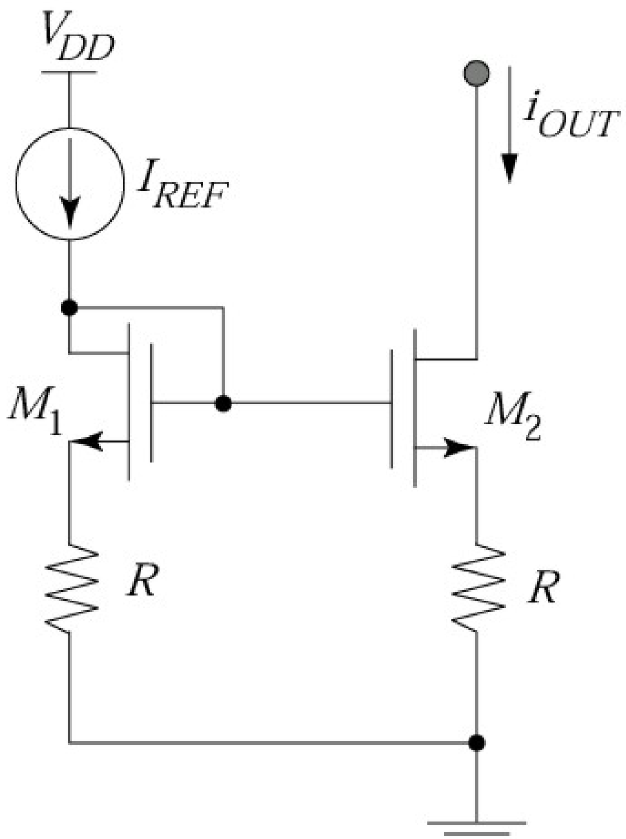


Improved Current Sources

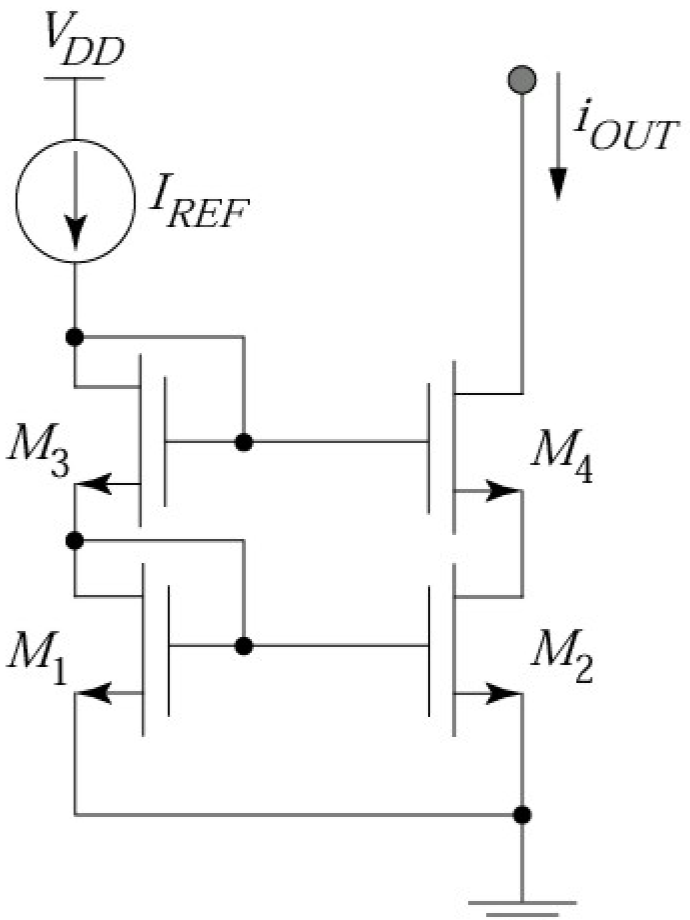
Goal: increase r_{oc}

Approach: look at *amplifier* (?) output resistance results

… to see topologies that boost resistance



Cascode (or Stacked) Current Source



Insight: V_{GS2} = constant AND
V_{DS2} = constant

Small-Signal Resistance r_{oc}:

Drawback of Cascode *I*-Source

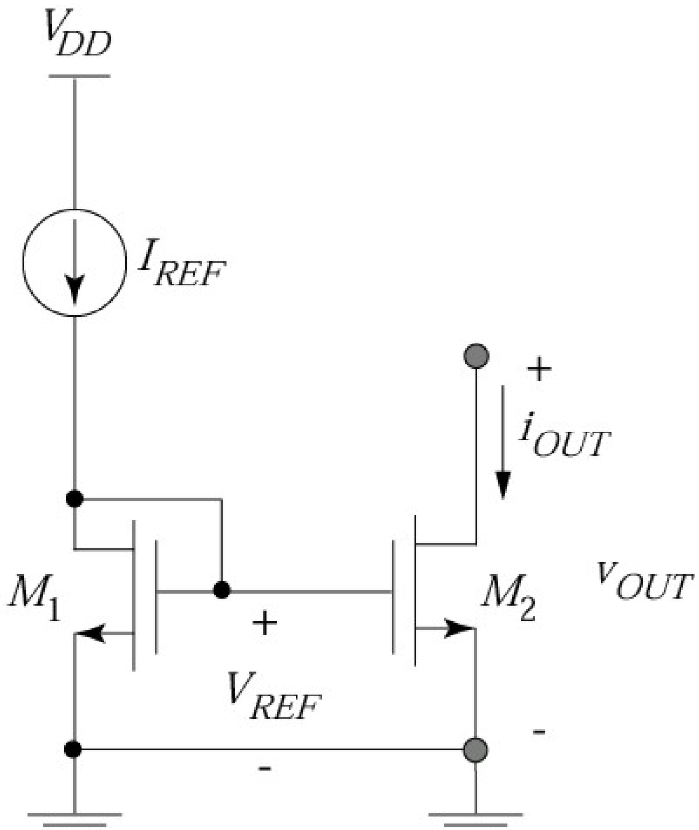
Minimum output voltage for all transistors saturated:

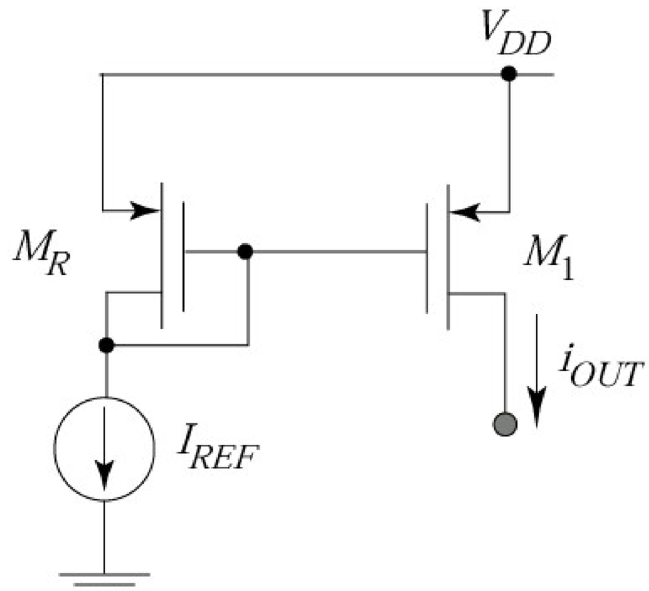
$$V_{OUT,MIN} = V_{DS4,SAT} + V_{S4} = V_{DS4,SAT} + V_{GS2}$$

Current Sinks and Sources

Sink: output current goes to ground

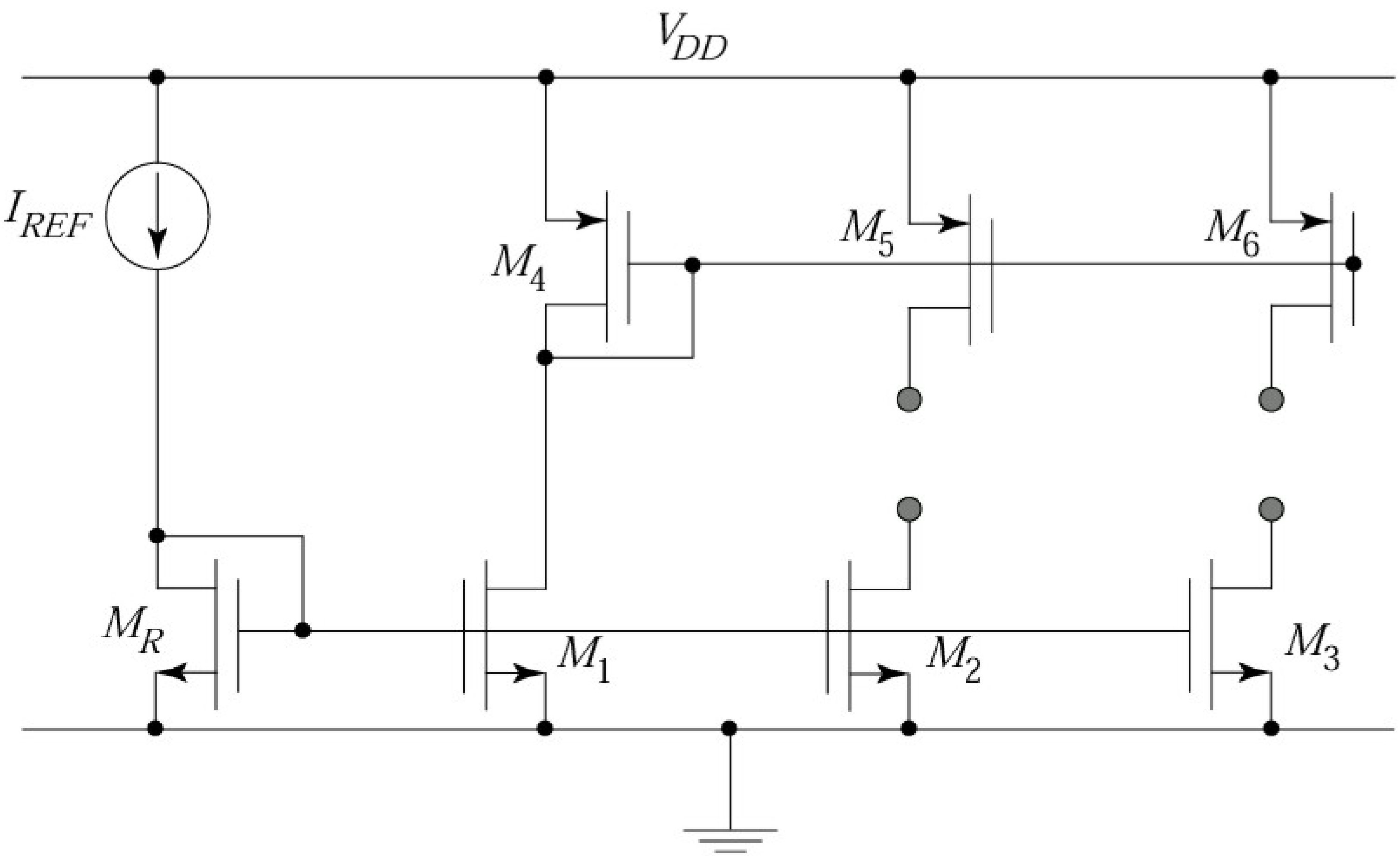
Source: output current comes from voltage supply





Current Mirrors

Idea: we only need one reference current to set up all the current sources and sinks needed for a multistage amplifier.



Multistage Amplifiers

Necessary to meet typical specifications for any of the 4 types

We have 2 flavors (NMOS, PMOS) of CS, CG, and CD and the npn versions of CE, CB, and CC (for a BiCMOS process)

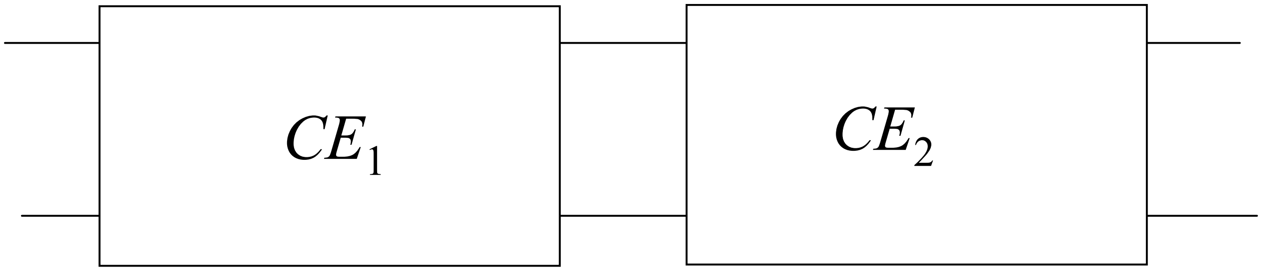
What are the constraints?

1. Input/output resistance matching

2. DC coupling (no passive elements to block the signal)

Start: Two-Stage Voltage Amplifier

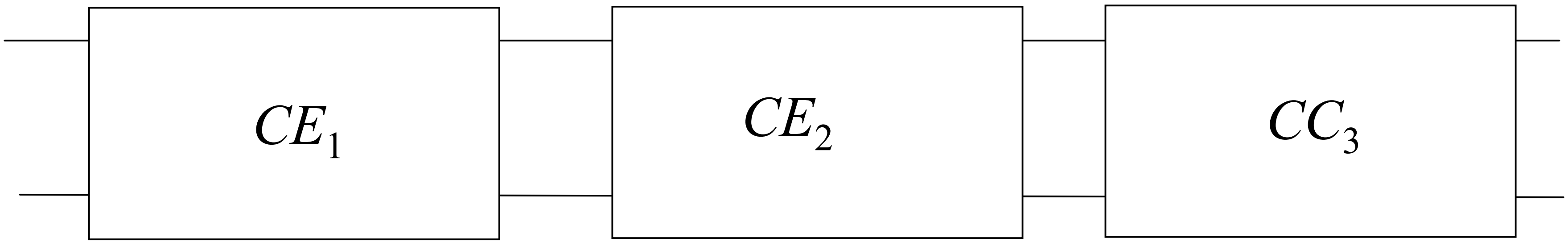
- Use two-port models to explore whether the combination "works"



Results: $R_{in} = R_{in1}, R_{out} = R_{out2}, A_v =$

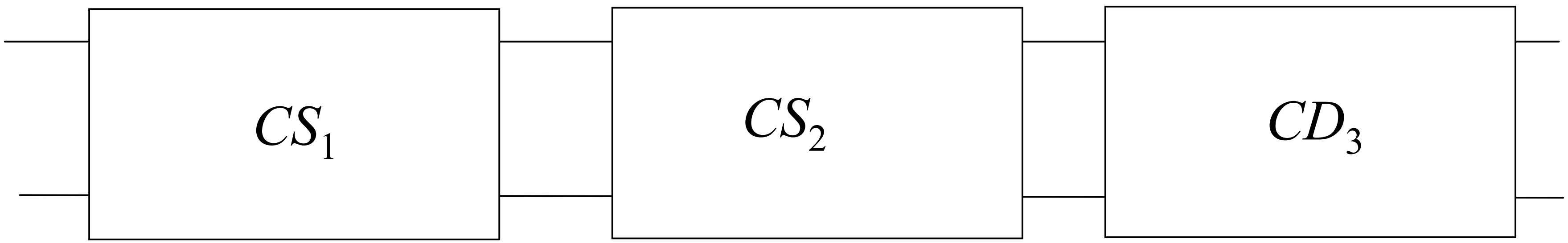
Add a Third Stage: CC

Goal: reduce the output resistance
(important spec. for a voltage amp)



Output resistance:

Using CMOS Stages



Input resistance:

Voltage gain (2-port parameter):

Output resistance: