Lecture 7, ANIK

Operational amplifiers 2

LiU EXPANDING REALITY

What did we do last time?

Operational amplifiers

- Top-level aspects
- Compensation
- Phase margin, stability, etc.

What will we do today?

Operational amplifiers continued

- Circuit-level aspects
- Implementation details

Operational amplifiers, revisited

Operational transconductance amplifier (OTA)

Drive capacitive load, typically on-chip

Operational amplifiers (OP)

Drive resistive load, typically off-chip

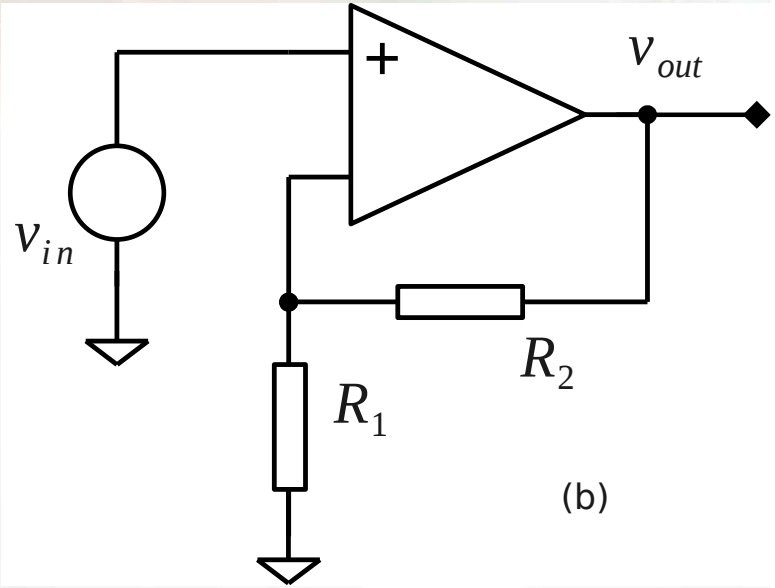
Specifications

Differential input, opt. differential output

Infinite gain

Infinite input impedance

Infinite (OTA) / Zero (OP) output impedance

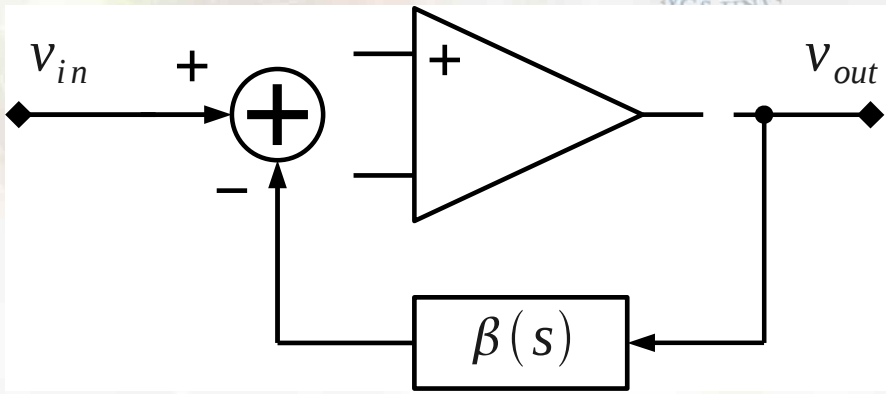


Always used in feedback (otherwise it is a comparator)!

Why do you want controlled feedback?

Gain is now under control!

No variation with gm/gds, instead it is given by passive components



"Unlimited" drive capability

Isolation of input and output

Linearization

Remember, it is a regulation loop. It is designed to track the changes, anything added in the loop will be supressed.

Operational amplifier architectures

Telescopic

Two-stage

Folded-cascode

Current-mirror

Essentially just cascaded stages

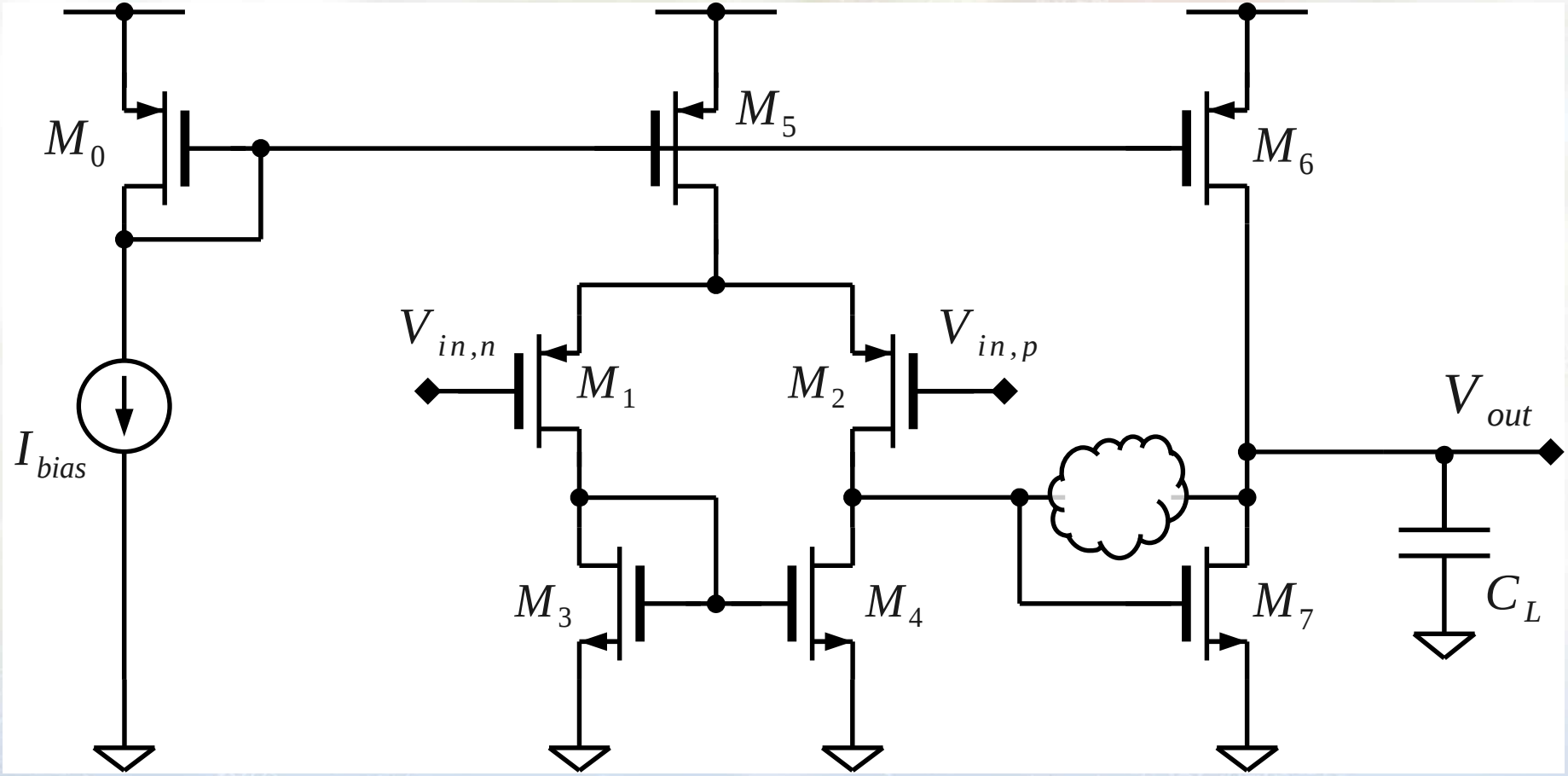
Telescopic OTA

Stack many cascodes on top of each-other and use gain-boosting, etc.

Omitted, since it is not applicable for modern processes.

The swing is eaten up.

Two-stage OP/OTA



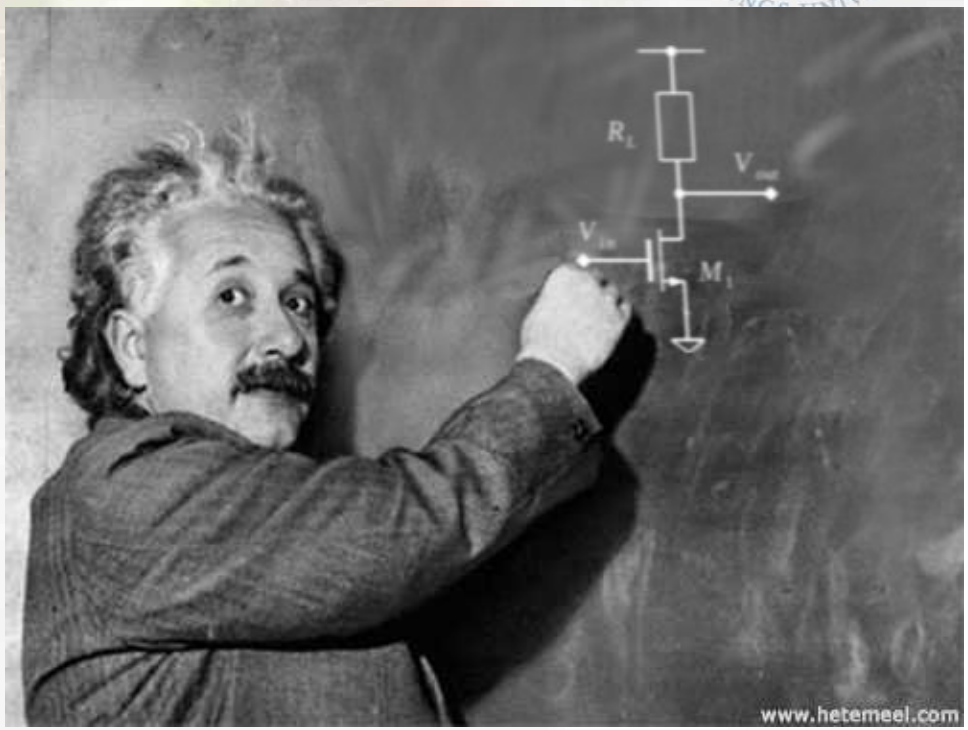
Two-stage OP, how it works

Gain

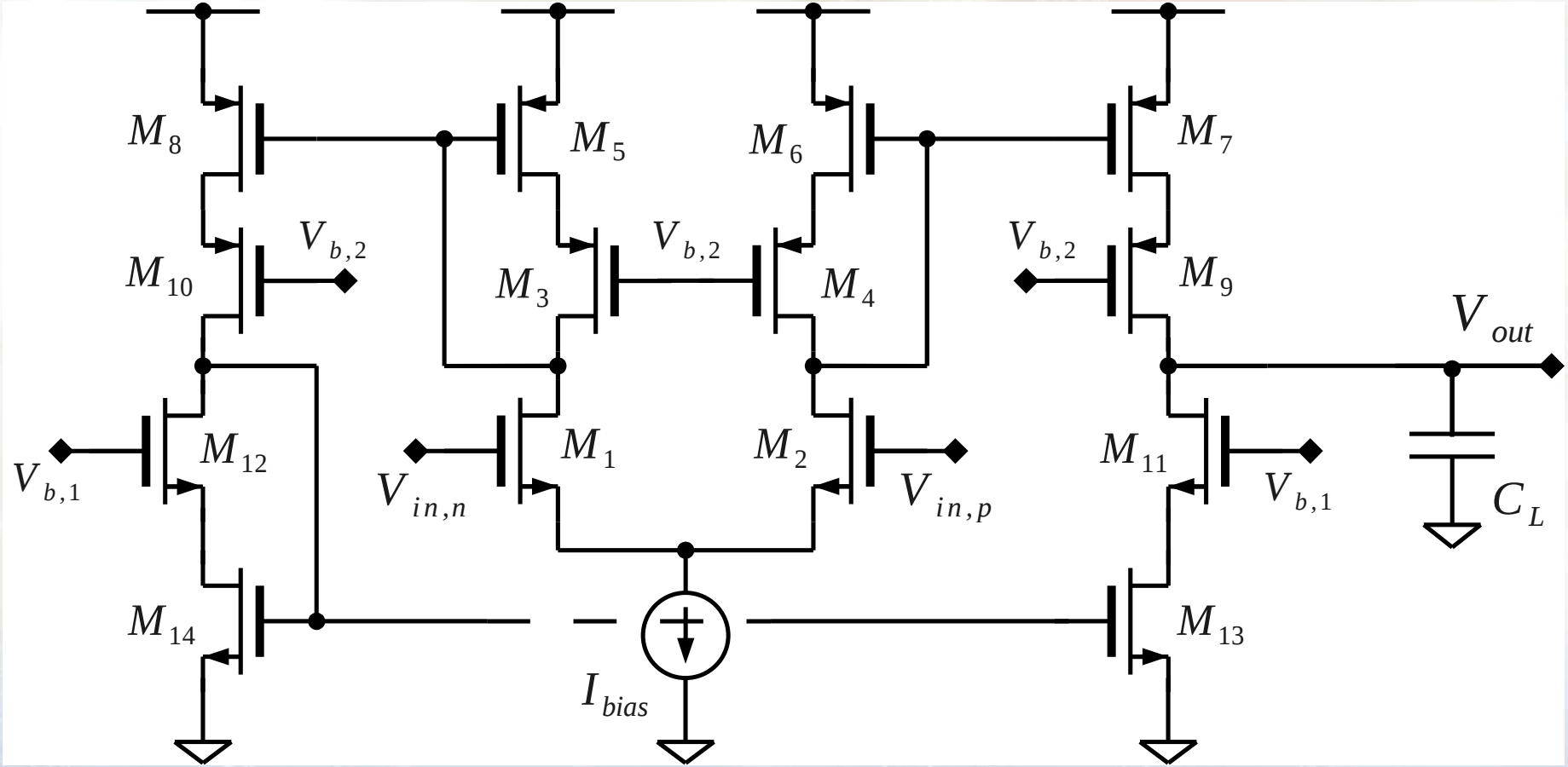
- Transconductance
- Impedances

Swing

- Common-mode range
- Output range
- Input range



Current-mirror OP/OTA



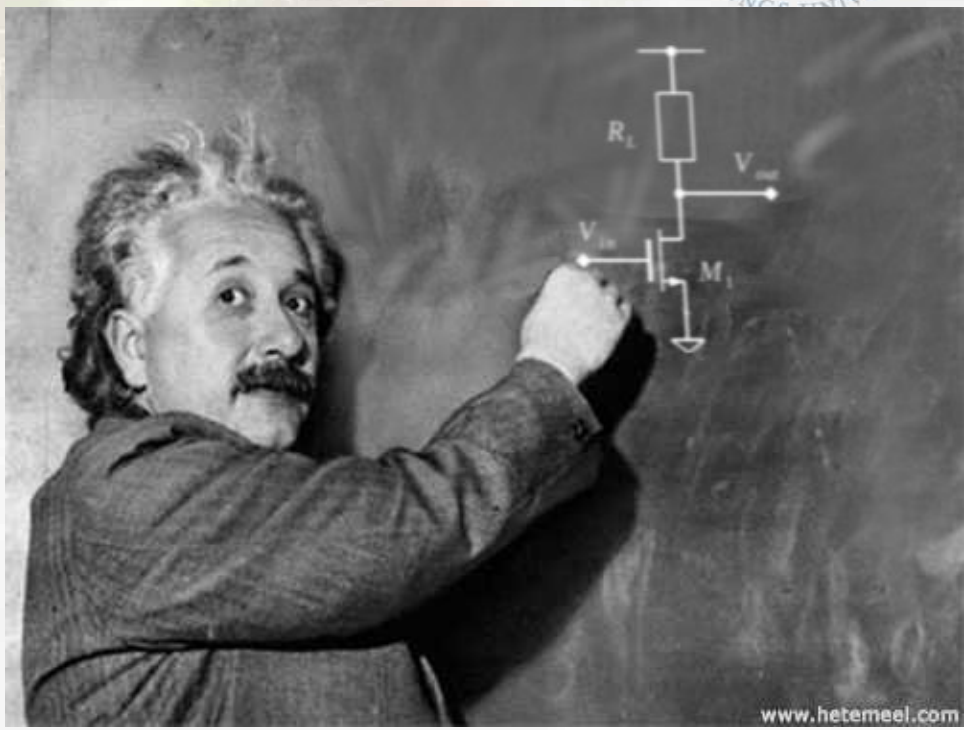
Current-mirror OP/OTA, how it works

Gain

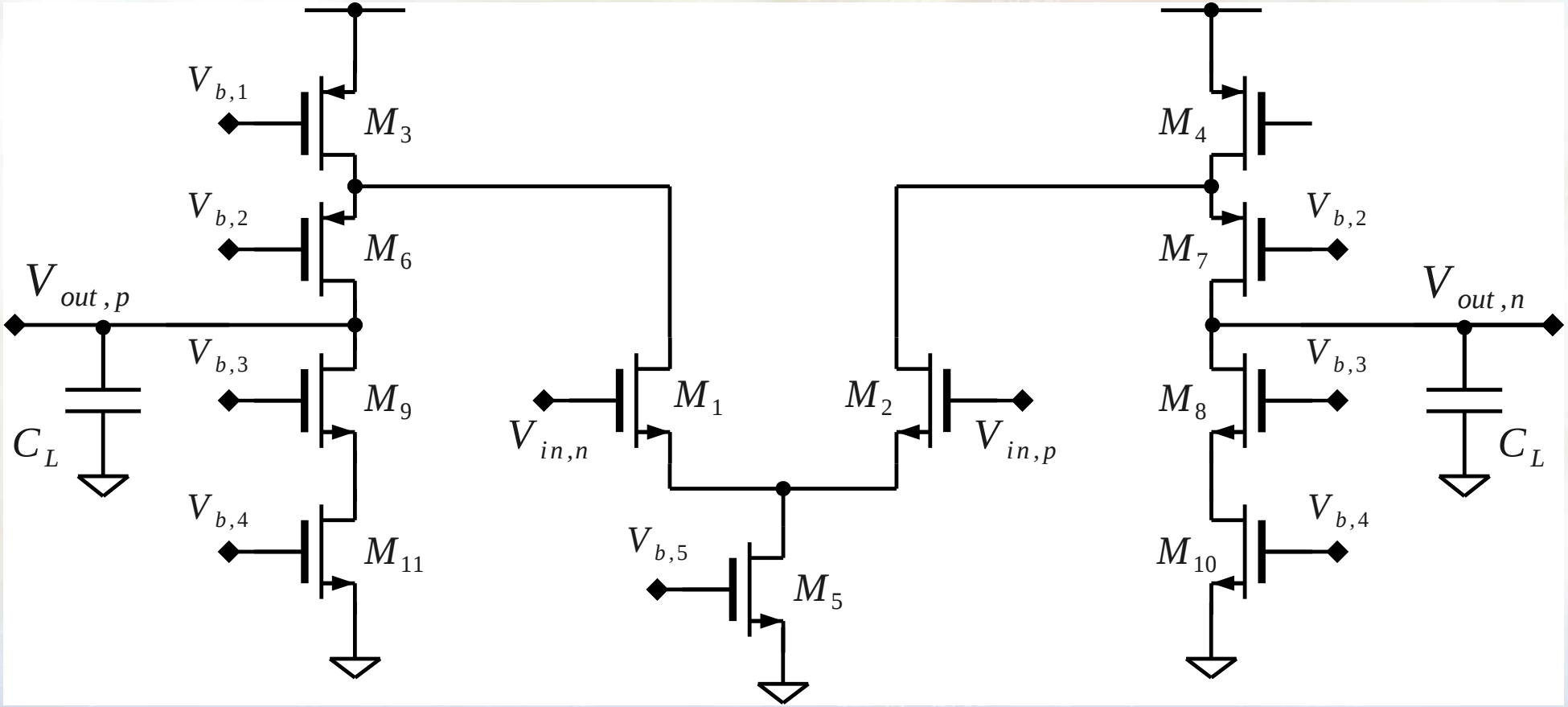
- Transconductance
- Impedances

Swing

- Common-mode range
- Output range
- Input range



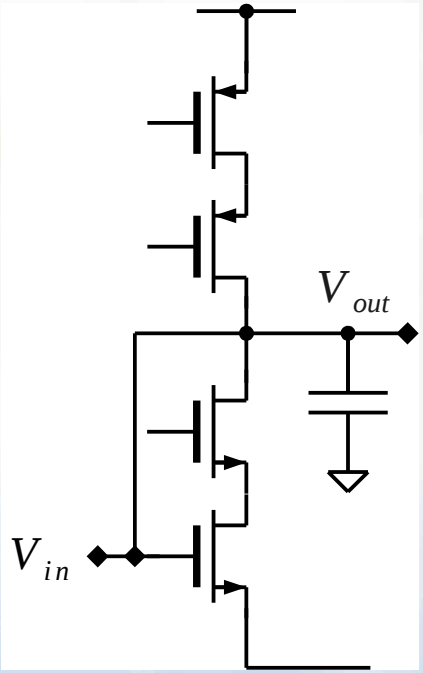
Folded-cascode OP/OTA

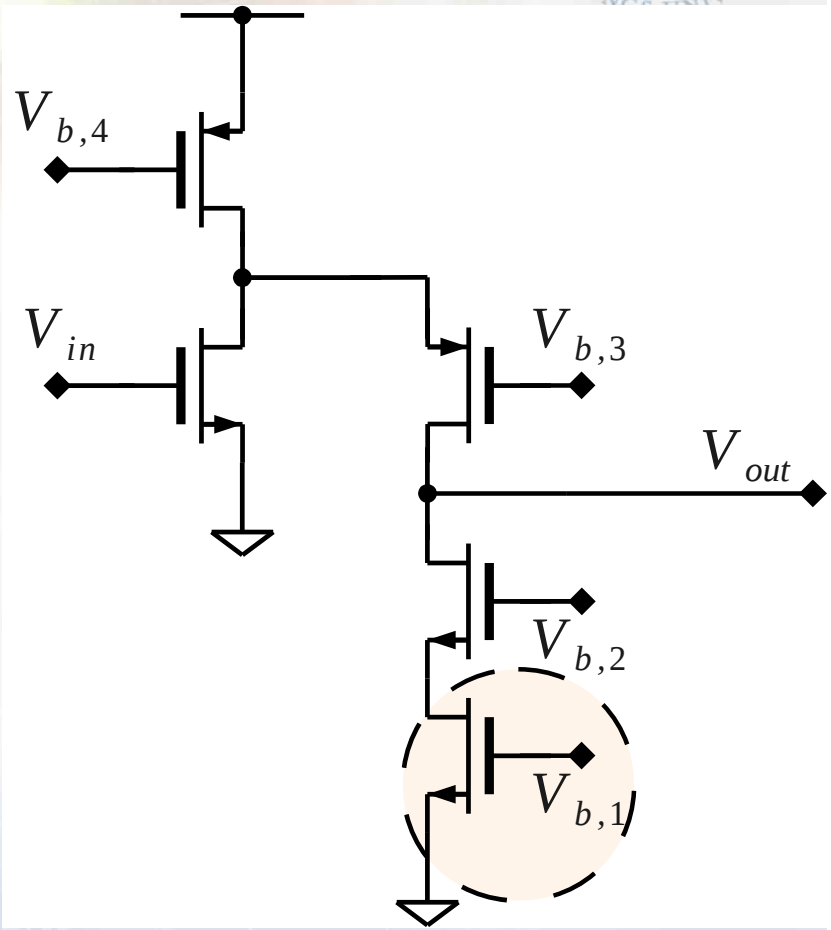


Why folded-cascode?

Consider the CMR in buffer configuration

In telescopic OTA, the swing will be very small since bias transistor "locks" the voltage level





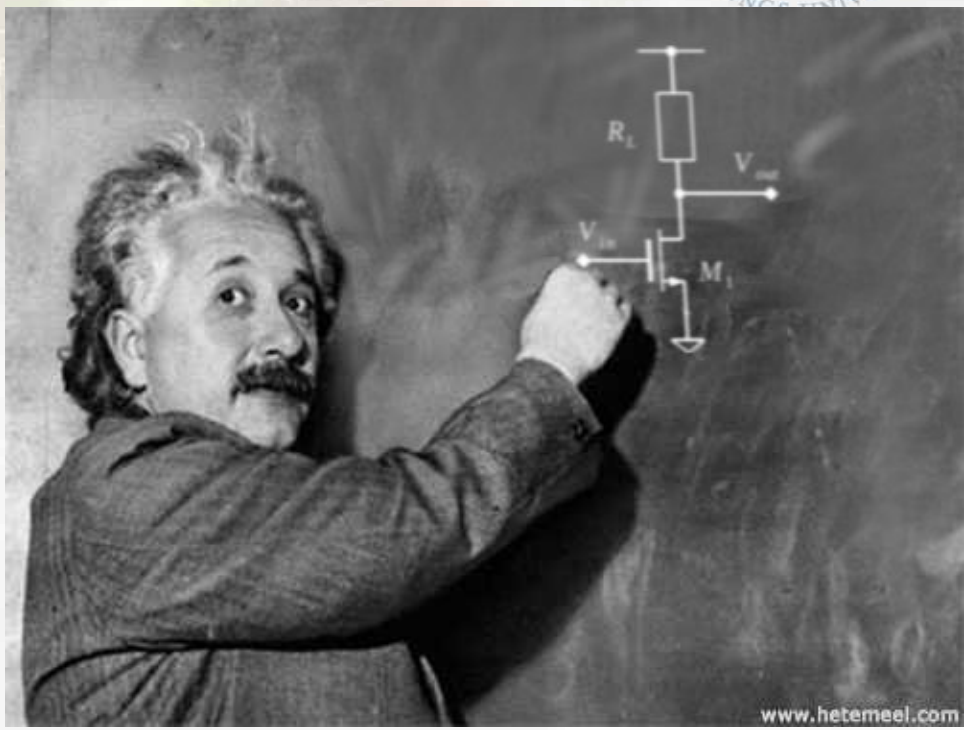
Folded-cascode, how it works

Gain

- Transconductance
- Impedances

Swing

- Common-mode range
- Output range
- Input range



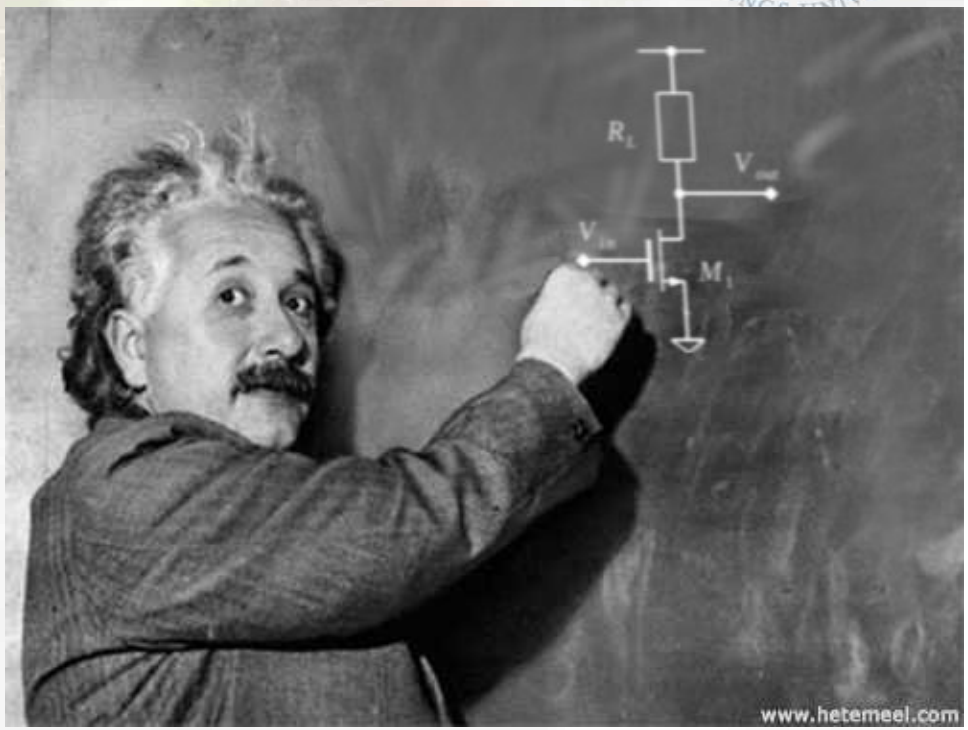
Other practical concerns wrt. current

Feedback with resistors

An OP given with a certain current drive capability.

What is the maximum swing?

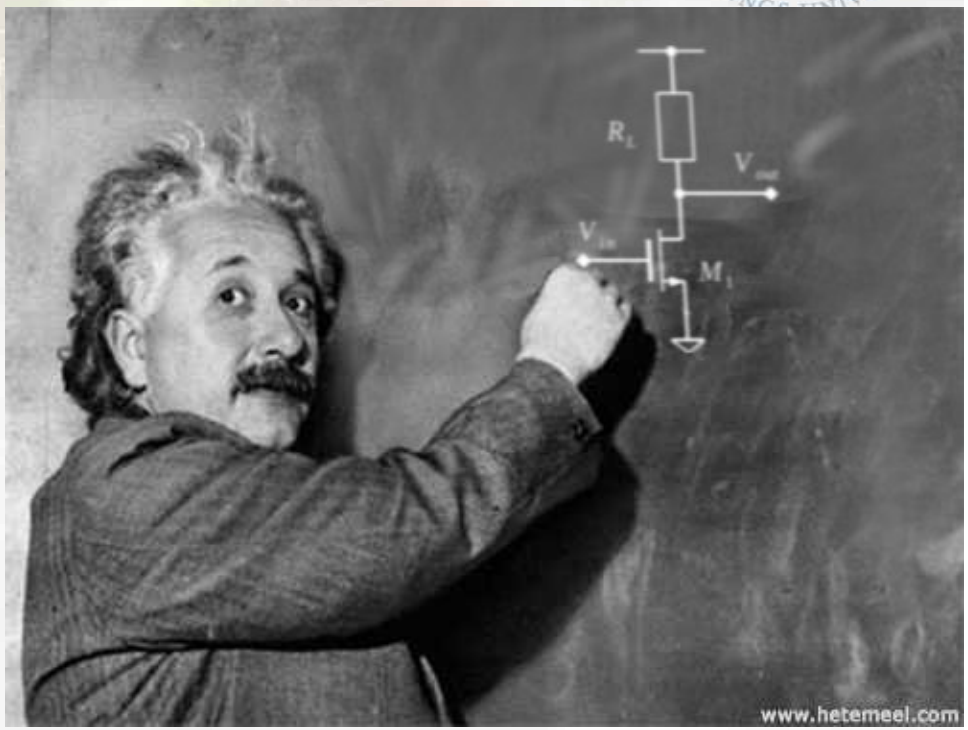
What is the DC level?



Other practical concerns wrt. bandwidth

Various unwanted effects

- Limited gain
- Offset error
- Bandwidth



OP/OTA Compilation

Cookbook recipes

Hand-outs with step-by-step explanation of the design of OP/OTAs

http://www.es.isy.liu.se/courses/ANIK/download/opampRef/ANTIK_0NNN_LN_opampHandsouts_A.pdf

Compensation techniques

http://www.es.isy.liu.se/courses/ANIK/download/opampRef/ANTIK_0NNN_LN_opampCompensationTable_A.pdf

What did we do today?

Operational amplifiers

- Circuit-level aspects
- Simulation aspects
- Some terminology

Some top-level tips-and-tricks

What will we do next time?

Noise

- Circuit noise
- Thermal noise
- Flicker noise

Distortion

- What sets the (non)linearity in our CMOS devices?

Lecture 8, ANIK

Noise and distortion

LiU EXPANDING REALITY