EE 140/240A Analog (or Linear) ICs

↳ more HW, Projects specs

concurrent enrollment

my background: UCSD, UCB, UCLA, UCB, Duke, UCB → 140 → 194

TA: Nandish Mehta

HW - Self graded + grader check. 1st one today → M!

Labs - 1st 5 weeks bipolar op-amps

Project

Tests: M1, M2 4:10-5:30 3/23 F before Sp. Break

F comprehensive

books: 140 Razavi 2nd ed.

240 GHLM 5th ed. } references

Analog

anything not digital

many things that are digital

- SRAM/DRAM sense amps & bits
- ≈ all digital communication wired or wireless

interfaces to the "real world"

e.g. cell phone

uphone, speaker

cameras, displays, fingerprint sensors

3D sensors

accel, gyro, magnetometers

power management

voltage regulators

bandgap reference

temperature sensor

battery management

power-on reset

A note on HW (and project) and cheating:

if it's on the web or in a textbook it's fair game if you cite the source

if you copy without citing a source that's cheating. I will throw the book at you!

How do you deliver necessary gain & BW

with appropriate input/output impedances

at an acceptable power consumption

in the face of supply, temperature, and process variation

and cost constraints

many other topics intertwined with those above

feedback & stability

linearity

linearization & regions of operation

tools: pencil & paper

breadboard, oscilloscope } → SPICE
↳ surrogate for the real world

Cadence - high end industrial quality tools

schematic capture

spice simulation → to match hand analysis

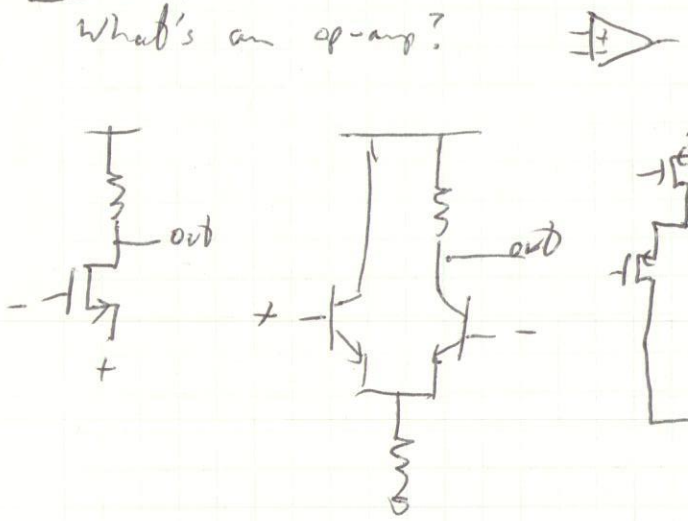
layout & extraction → gets all of the little details right

A good pedagogical (learning) tool: op-amp design

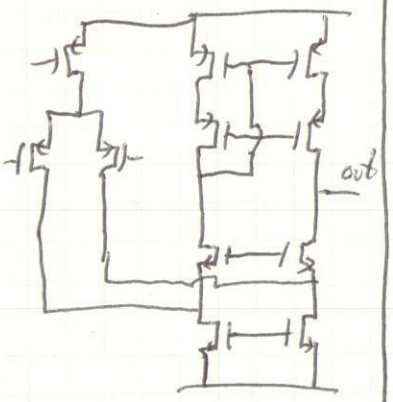
What's an op-amp?

	ideal	Real
Gain	∞	$10 - 10^6$
BW	∞	$10^6 - 10^{11}$ Hz
R_{in}	∞	10ff - ...
R_{out}	0	$<1\Omega - 10^9\ \Omega$
power	0	$<10^{-6} - 10^{-1}$ W
CMRR	∞	$10 - 10^6$
input offset	0	$10^{-6} - 10^{-1}$ V
stability	uncond.	good enough

What's an op-amp?



(IC prelim question)



Razavi 9.15-ish

Not a lot of ∞ or "0" in real op-amps

How do you know if $0 < x < \infty$ is OK?

Hand analysis - mostly what you already know!

gain, BW, power
Stability
PVT variations
} Hand analysis

verified w/ SPICE

jobs in analog & #8B analog revenue

IC suppliers: TI, Infineon, Skyworks, ADI, ST, Maxim, NXP, LTC, ON Semi, Renesas

$8B

≈ #25B in 2015

internal consumers: cell phones Apple, Samsung... Qualcomm,

DoD

easily, motor #25B

µP vendors Intel,...
communication Cisco, Marvell,...

What were we supposed to learn in 16AB & 105?

Device physics → "large signal" model (non-linear model)

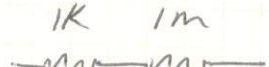
linearization, regions of operation: g_m, r_o (Taylor)

frequency response, Heaviside transform, Bode plots

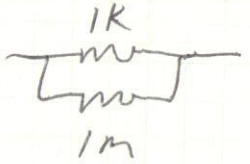
simple amplifiers CS/CE
CG/CB
CD/CC

Analog designers try hard to simplify and solve "by inspection"

Intuition, experience, rules of thumb, pattern matching



$\max(R_1, R_2)$



$\min(R_1, R_2)$

"straight line" Bode approximations

(reactive)
↑ Passives are just frequency-dependent resistors, (with some phase)

$Z = \frac{1}{j\omega C} = \frac{1}{sC}$ $\quad |Z| = \frac{1}{\omega C}$

$Z = sL = j\omega L$ $\quad |Z| = \omega L$