**EE 440/240 A**  
Analog (or Linear) ICs

- more HW, project specs
- coursework enrolled
- background: UCSD, UCSB, UCLA, UCSD, Drex, UCB 11/94
- TA: Nandish Mehta

**HW**  
- 5th project + greater clock. 1st is today => M!
- Labs: 1st 5 weeks bipolar op-amps
- Project
- Tests: M1, M2 4/10-5:30 3/23 F before Spring Break
- F comprehensive
- Books: 1) Razavi 2nd ed.
  2) 240 CHLM 5/4 2nd ed., 5 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
  - microphone, speaker
  - cameras, displays, fingerprint sensors
  - 3D sensors
  - accel, gyro, magnetometers

**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 these above
- feedback & stability
- linearity
- linearization & regions of operation

**A note on HW (and project) and cheating:**

- if it's on the web or in the 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!
tools: pencil & paper

- breadboard
- oscilloscope
- \( \rightarrow \) SPICE
- to surrogade for the real world

Cadence - high end industrial quality tools
- Schematic capture
- SPICE simulation - to match hard analysis
- layout & extraction gets all of the little details right

What's an op-amp?

- Real
- Gain
- BW
- Rin
- Ro
- Power
- CMRR
- Input offset
- Stability

- Ideal
- 0
- oo
- oo
- oo
- oo
- oo
- oo
- oo
- oo
- oo
- Good enough

Not a lot of oo or "0" in real op-amps

How do you know if \( 0 < x < oo \) is ok?

- Hold analysis - mostly what you already know!
  - gain, BW, power
  - Stability
  - PVT variations

Verifed w/ SPICE

Lab 1
jFS in analog & on-chip revenue
IC suppliers: TI, Infineon, Skyworks, ADI, ST,
Maxim, NXP, LTC, ON Semi, Renesas
$1B
2015

IC customers: cell phones Apple, Samsung, Qualcomm,
DoD

easily adapt
$1B

What were we supposed to learn in 16ABD 105?
Device physics -> "large signal" model
(non-linear model)
linearization, regions of operation: gm, fc
(Taylor)
frequency response, Bode plots
simple amplifiers CS/CE, CC/CD, CA/CE

"straight line" Bode approximations

\[
\begin{align*}
\frac{1}{1} & \quad z = \frac{j\omega C}{1} \quad |z| = \frac{1}{\omega C} \\
\frac{1}{m} & \quad z = \frac{j\omega L}{1} \quad |z| = \omega L
\end{align*}
\]