EE 140 / 240A Analog/Linear ICs

→ more HW
→ more project specs

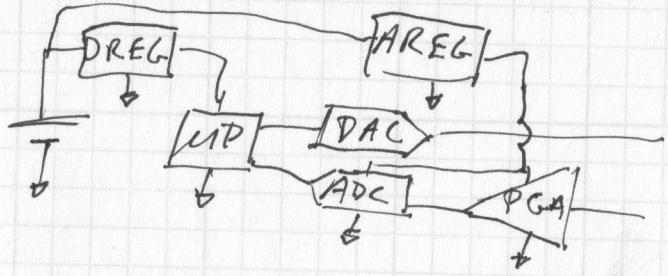
Who am I? UCSD, UCB, UCLA, UCB, Rust, UCB

TAs: Brad Wheeler
David Burnett

HW: generally due late Friday (9AM sat)
this week: Monday
self-graded

Labs: Bipolar op-amps, ~~[illegible]~~ = 5 weeks?
any lab OK

Most
Projects: ~~All~~ of the analog from an embedded µP



ee194 tapeout!

What is 1V? How do you know?

Bandgap reference (and temp sensor)

All of these contain an opamp.
All use feedback

What is analog?

- anything not digital
- many things that are digital: DRAM, SRAM, flash

  digital communication - anything high speed
  ethernet, HDMI, USB, RF
- interfaces to the real world. E.g. cell phone

  inputs/sensors: XL, gyro, magnetometer, µphones
  camera, fingerprint sensor

  outputs: speakers, displays, buzzer, backlight, flash
  LEDs, humidity, barometric pressure
  ↑ sensors

battery charger

DC-DC converters

power-on reset

Who designs this stuff?

~~ADI Apple Broadcom~~

Apple, Samsung, Qualcomm, ...

Marvell, Intel, ...

>> $25B

	Mkt 2015
TI	$8B
Infineon	
Skyworks	
ADI	
ST	
Maxim	
NXP	
LT	
ON	$1.3B
	$25B

140/240A
1/7 50
WLL

Key concepts

Gain, BW, power

noise, power

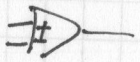
feedback, stability

Process, voltage, temp variation

Tools - hand analysis
cadence, SPICE, layout + extraction

Same software as used in industry

What's an op-amp?



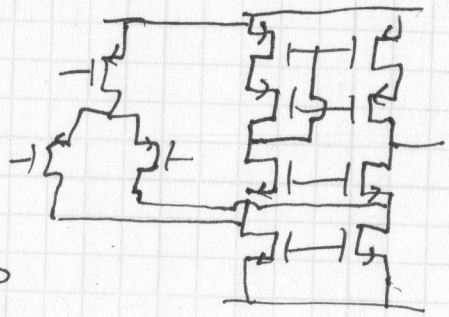
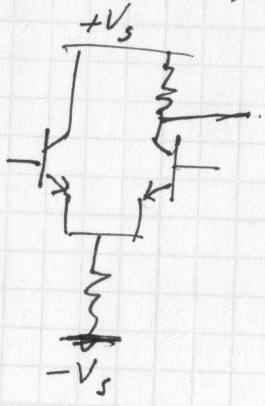


Fig 9.15

Gain	∞	100
BW	∞	1GHz
R_{in}	∞	10ff
R_{out}	0	1MΩ
CMRR	∞	60dB
input offset	0	10mV
Stability	uncond	OK?

Crappy op-amps, real op-amps



Are they good enough?

How do we know?

Hand analysis of all "concepts"

SPICE simulation
- verify hand analysis

What were you supposed to learn in 16AB, 105?

frequency response, Bode plots

device physics → large signal model

linearization: small signal model

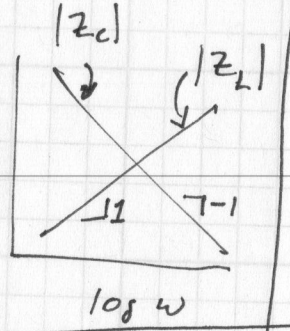
simple transistor amplifiers: CS/CE
CG/CB
CD/CC

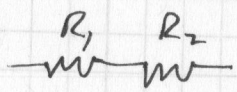
diff pair?

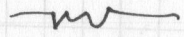
inductors & capacitors are just freq.-dependent resistors

$z = \frac{1}{j\omega C}$ $|z| = \frac{1}{\omega C}$

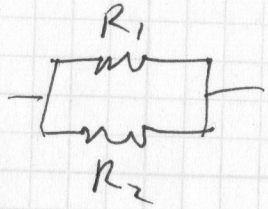
$z = j\omega L$ $|z| = \omega L$

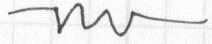






max (R_1, R_2)

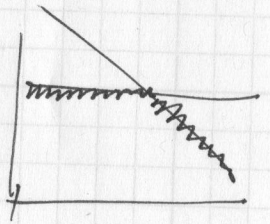


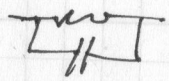


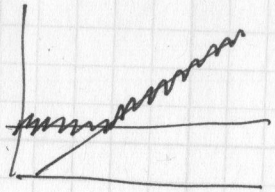
min (R_1, R_2)

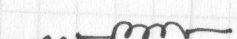
worst case error: $2^{\pm 1}$

with R,C or R,L : $2^{\pm\frac{1}{2}}$, $\pm 45°$

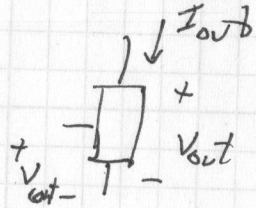








Device physics



Vaccuum tubes