EE 147/247A Linear/Analog ICs

- → extra homework problems
- → more project requirements

Admin

What is analog?

What will we study/learn?

Who am I?

Grading

HW + Labs	25
Midterms	20
Project	25
Final	30

Labs a few bipolar labs in the first 6 weeks

HW Due Monday. Late Tues 9AM.

Self graded. ~~Regrade~~ Resubmission/regrade OK within 1 week

Lecture MWF 1-2 } 293 this week

Dis F 10-11, 2-3

Lab M 5-8p } 125 Cory next week

Th 2-5p

W 8-11 X

OH M 9:30-10:30

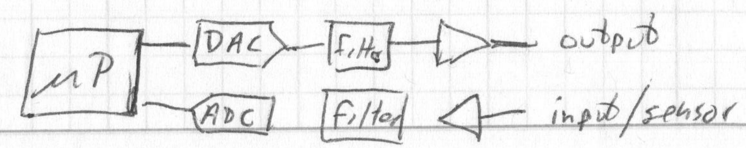
W 2-3

TA David Burnett

What is analog?

- anything not digital
- lots of what gets called digital
  SRAM, DRAM, flash

  digital communication - anything high performance
  - ethernet, HDMI, USB, RF
- interfaces to the real world, e.g. cell phone
  inputs: µphones, accel, gyro, magnetometer
  cameras, fingerprint sensors
  outputs: speaker, buzzer, LEDs, displays, flash, backlight



And all of the stuff that you need to make that work: battery management (charging, shutdown)

supply regulations

voltage reference

temp sensor

power-on reset

final project will design many of these components in a real process

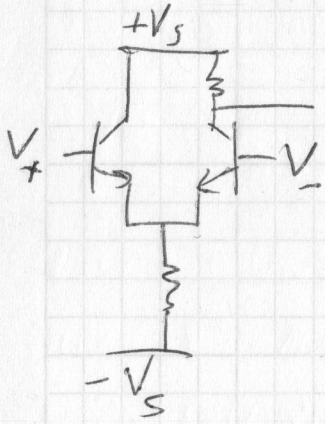
Most of these rely on op-amps 

Ideal op-amp

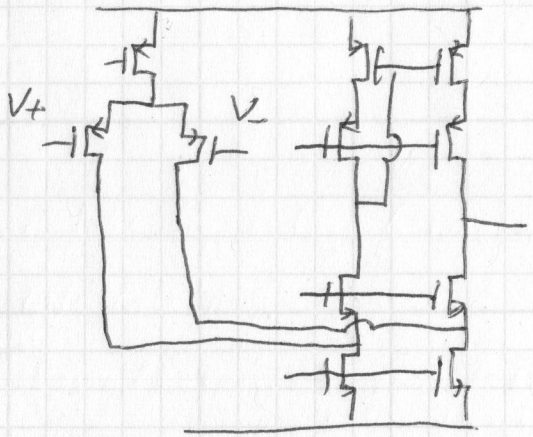
gain	∞
BW	∞
in/out impedance	∞/0
CMRR	∞
PSRR	∞
input offset	0
stability	uncond.

Real op-amps

bare minimum



better



Are these "Ideal"? No way!

Are they good enough? How do you know?

→ Hand analysis

gain, BW, power

frequency response, feedback, stability

process, voltage, temp (PVT) variation response

→ SPICE simulation

- gets the details right

We will use Cadence for schematic design & SPICE + layout/extraction

Same software used in industry

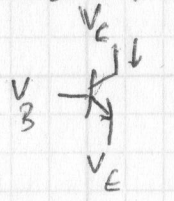
Who ~~uses~~ designs analog circuits?

- every cell phone company Apple, Samsung, ...
- every μprocessor company Intel,
- every communications company Cisco, Marvell
  Broadcom, Qualcomm, ...
- ADI, TI, Freescale, NXP, Linear Tech, ST, ...

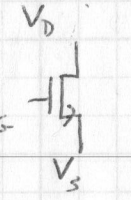
~ $50B industry

What did we learn in ee105? Regions of Operation

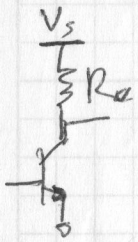
Large signal behavior of BJT, MOS devices



$$I_C = \begin{cases} I_S\left(e^{V_{BE}/V_T} - 1\right)\left(1 + \frac{V_{CE}}{V_{BA}}\right) & \text{(1.55)} \end{cases}$$



$$I_D = \begin{cases} 0 & V_{GS} < V_{TH} \\ \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS}) & \\ \cdots & \end{cases} \quad \text{(1.165)}$$



How to solve?

$$V_{out} = V_s - I_C R$$

approximate $e^{V_{BE}/V_T} - 1 \approx e^{V_{BE}/V_T}$

$$1 + \frac{V_{CE}}{V_A} \approx 1$$

$$V_{out} = V_s - I_s e^{V_{BE}/V_T} \quad \text{transcendental}$$