EE140/240A Analog Integrated Circuits

↳ more HW, project. req.

waitlist, concurrent enrollment

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HW - self grade + spot check. 1st one today!

Labs - 5 weeks bipolar on breadboard then cadence

Project

2 midterms (9/27 and 11/01 wk 5, 10)?

Final - comprehensive

Books: Razavi, GHLM
U.G. Grad.

who am i? SD, B, LA, B, Dust → Linear → Analog, B

Research: μ robots
smart dust → low power circuits

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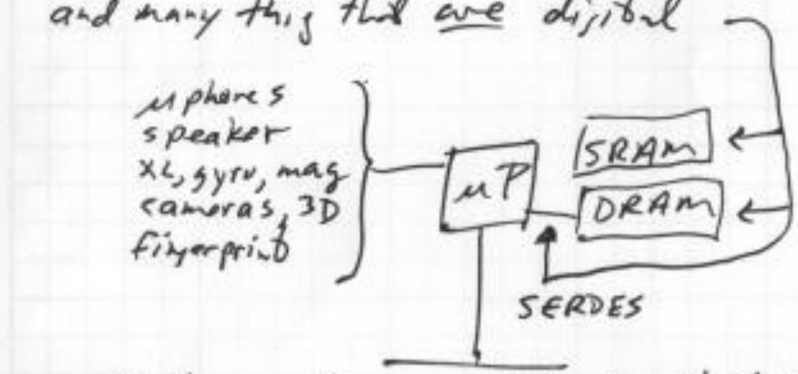
what is analog? Anything not digital ?

(quantized/discrete values in time & I/V)

and many things that are digital

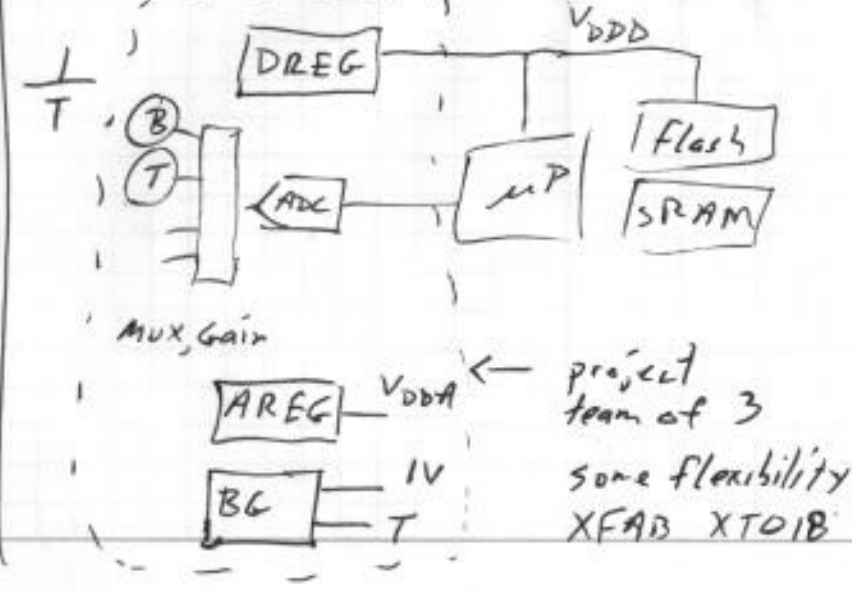


network: optical, ethernet, wifi

power/battery mgmt

power-on reset

typical embedded μ controller



How do you build these?

Mostly op-amps, all w/ different specs

gain, BW

input/output swing, impedance

power constraint (area constraint)

operating over variation in { process V_t, $\mu_n C_{ox}$, ... ; voltage V_{BAT} : 3.2 - 1.6 ; temperature -40 .. +85 C

Use a small number of topologies

diff pair — feedback

cascode

common emitter

current mirror

Design: pick topologies

choose currents, W, L to meet specs

tools: pencil & paper

breadboard, oscilloscope → verify your design, give clues to things that we missed

SPICE — faster than breadboarding

You don't design w/ SPICE

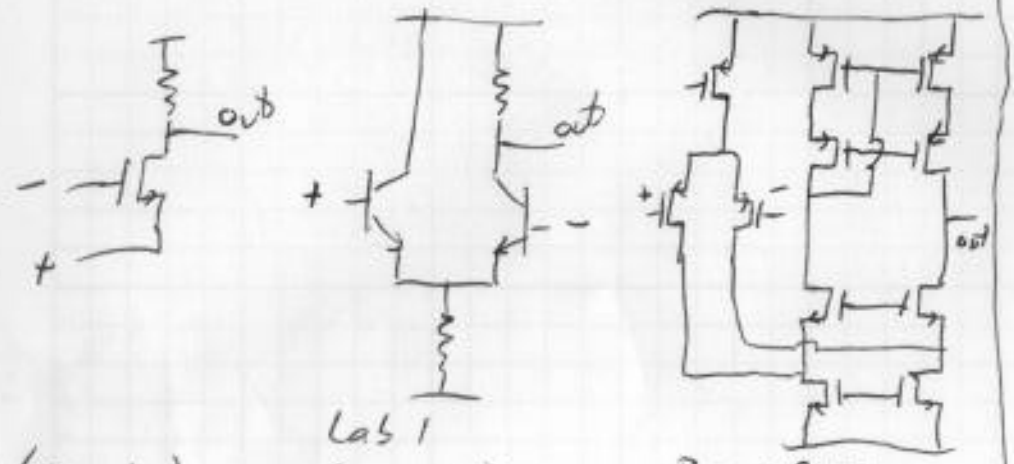
cadence - industrial grade

schematic

layout + extraction / time

	ideal	real
gain	∞	$10 - 10^6$
BW	∞	$10^3 - 10^{11}$ Hz
R_{in}	∞	
R_{out}	0	$<1\Omega$ .. $>10^9\Omega$
V_{cm}	$-\infty .. +\infty$	0.1V .. > Supplies
power	0	$10^{-9} - 1$ W
input offset	0	1 μV - 100 mV
CMRR	∞	0 ... 120 dB
stability	uncond.	as needed

Examples



(IC prelim) Lab 1 (IC prelim) Razavi 9.15 GHLM 6.29

Analog IC industry - Semiconductor companies

	2017 Analog IC revenue, $B
TI	10
ADI	4
Skyworks	4
Infineon	3
ST	3
NXP	2
Maxim	2
ON Semi	2
Microchip	1
Renesas	1

$55B

From anysilicon.com

Analog industry - internal consumers

cell phone companies Apple, Samsung, Qualcomm, Huawei

DoD

µP vendors Intel, AMD, ...

communication systems Cisco, Marvell,

there are a lot of jobs

What should you remember from 105? ICAB

Device physics - "large signal" model

non-linear

regions of operation: off, triode, saturation

linearization: g_m, r_o

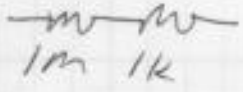
frequency response: Heaviside, Bode

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

Analog designers rarely worry about the 2nd digit of any answer

simplify, solve by inspection

intuition, pattern matching, rules of thumb, ...



$R_{eq} = ?$ $\max(R_1, R_2)$

$R_{eq} = ?$ $\min(R_1, R_2)$

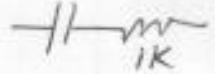
worst case error? $2x, \frac{1}{2}x$

L and C are just frequency dependent resistors

(yes, they have phase
yes, we will take it into account)

but for intuition ...

$Z = \frac{1}{j\omega C}$ $|Z| = \frac{1}{\omega C}$ $1pf @ 1M\frac{rad}{s} = 1M\Omega$



$|Z| = ?$ @ $1M\frac{rad}{s}$

$|Z| = ?$

3 terminal devices

1) I_{CA} depends strongly mostly on V_{BA}

2) I_{CA} depends weakly on V_{CA}

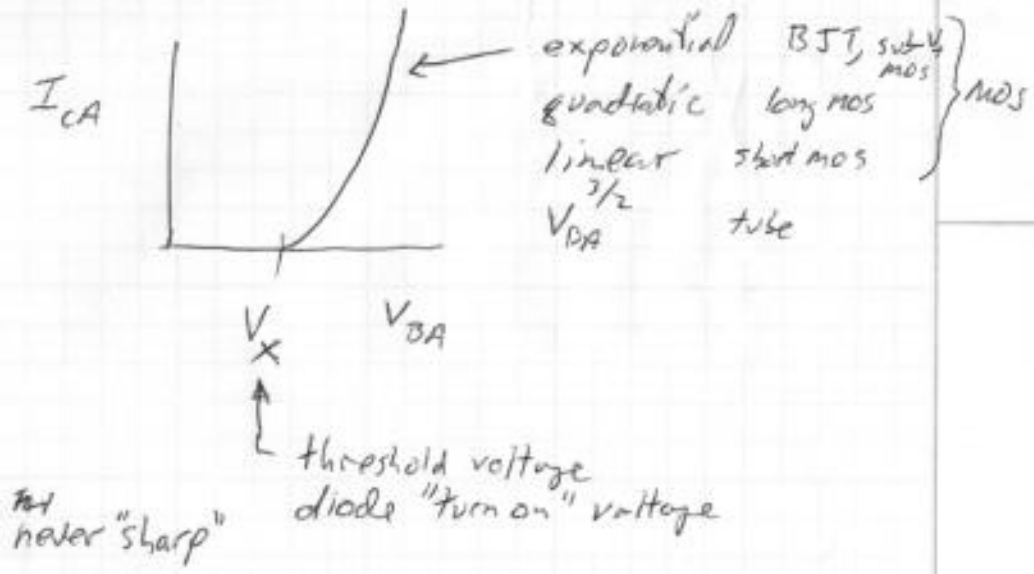
3) I_{BA}, I_{CB} are $<<$ I_{CA}

(tubes (1911), MOSFET (1927), BJTs (1947), JFETs (1950)

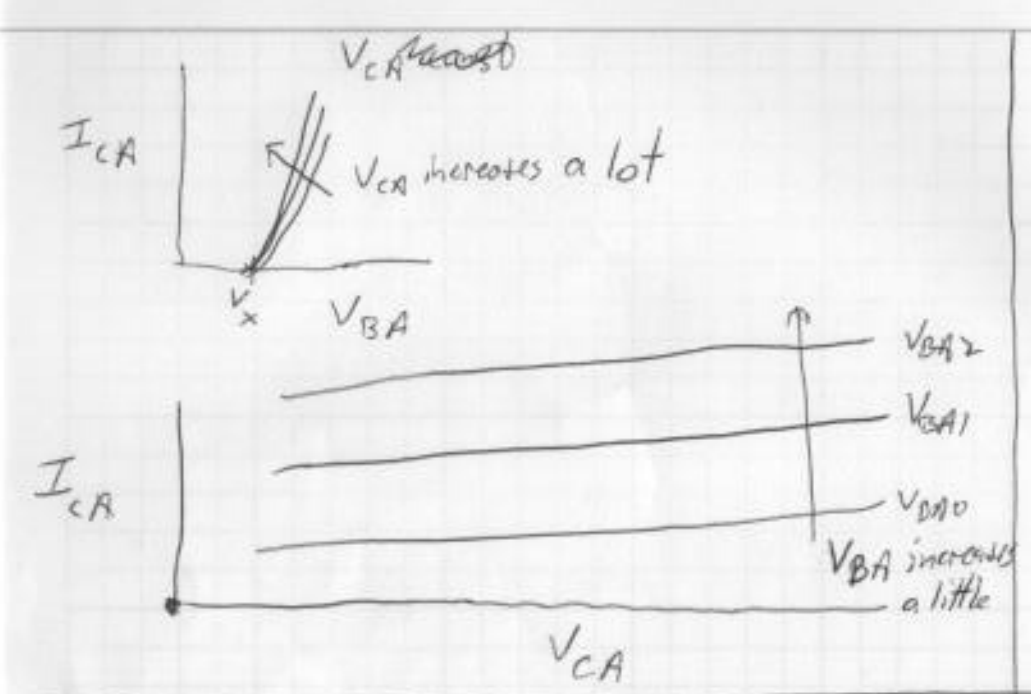
FET, mrelays, nano, ...

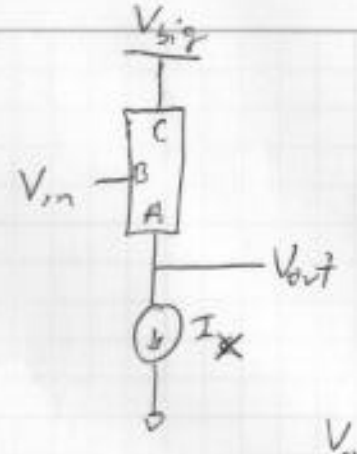
all share these properties

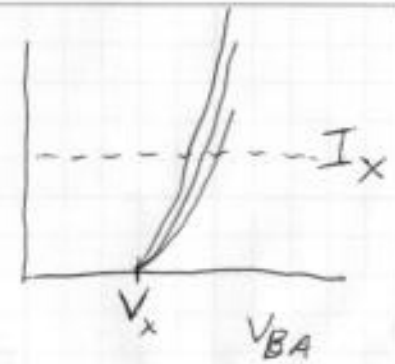
we still use circuit topologies developed 70-100 years ago



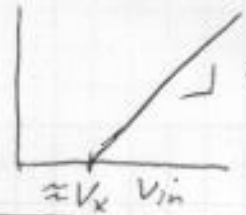
not never "sharp"

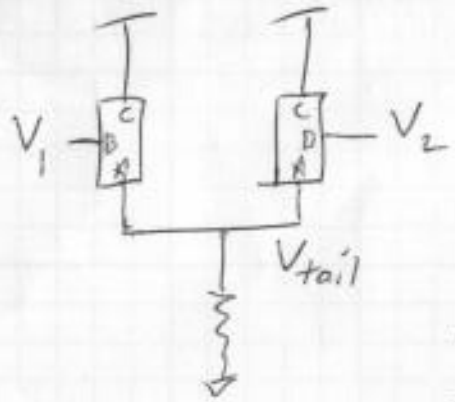






$V_{out} = V_{in} - V_{BA}$





$V_{tail} \approx \max(V_1, V_2) - V_x$

if $|V_1 - V_2|$ is "big" then one device will be off

$V_x = 1V$

$V_1 = 5$	7	3
$V_2 = 5$	5	5
$V_{tail} =$		