folded cascode

freq resp, stability

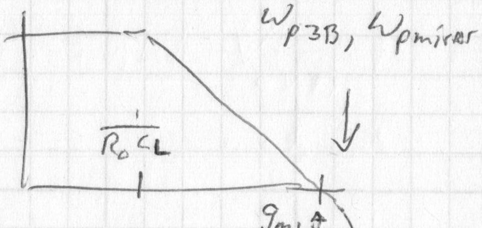
biasing

Project

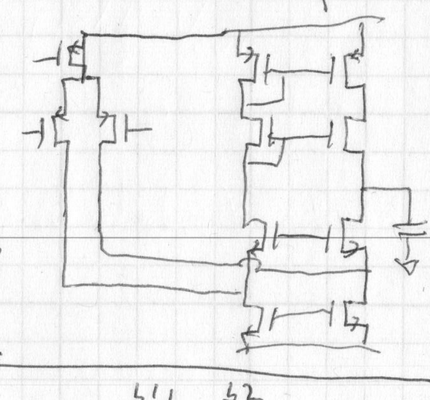
Switched capacitors

folded Cascode

freq resp.



if you don't like the phase margin, add capacitance to C_L



Contrast w/ 2 pole:

$\omega_{uc} = \frac{g_{m1}}{C_c}$
$\omega_{p2c} = \frac{g_{m4}}{C_1 + C_2}$
} less stable w/ more load cap.

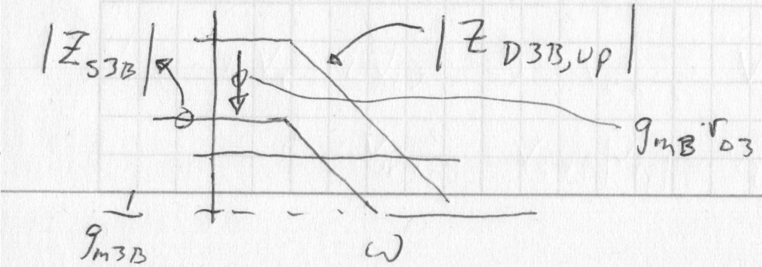
Q: Why is there not a pole at D2B/S3B?

Capacitance is C_{gs3B}

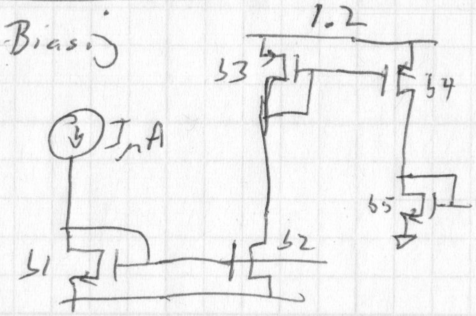
Low freq resistance is $\left(r_{o2B} \parallel \frac{g_{m4} r_{o4}}{g_{m3} r_{o3}} r_{o5}\right) \approx r_{o5}$

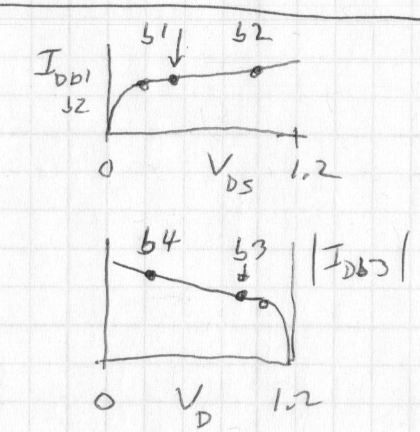
why not a pole at $\frac{1}{r_{o5} C_{gs3B}}$?

A: $Z_{D3B,up} = (g_{m4} r_{o4}) r_{o5} \parallel \frac{1}{\omega C_L}$

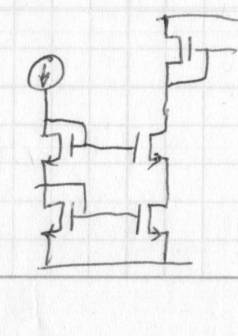


Biasing

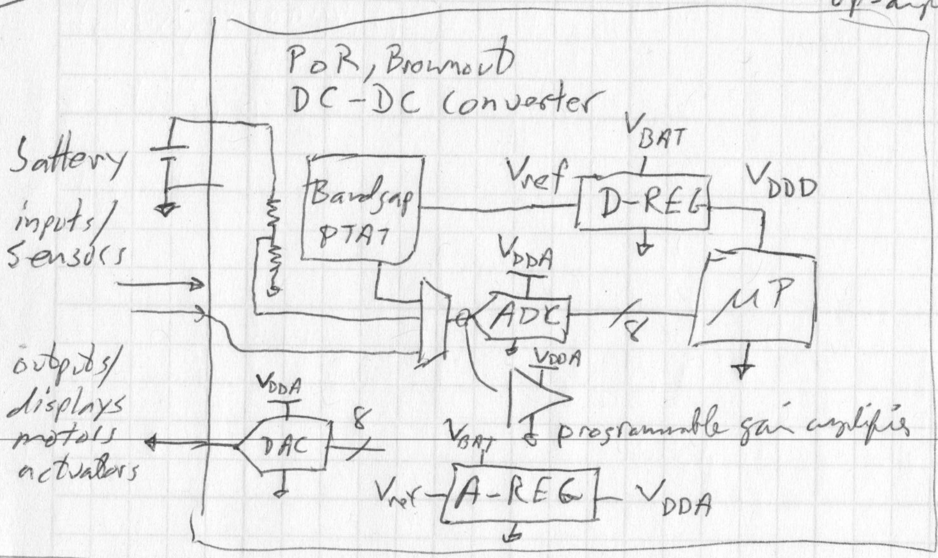




much better:



Project — Analog for Embedded μP or IoT SoC! or why do we care about op-amps?



At least 4 op-amps

- Bandgap
- AREG
- DREG
- PGA

op-amp or comparator

ADC

Lots of real-world examples, e.g. HW9

- ADI regulators
- TI ADCs

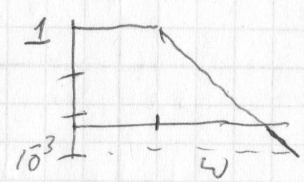
Dust Networks chips

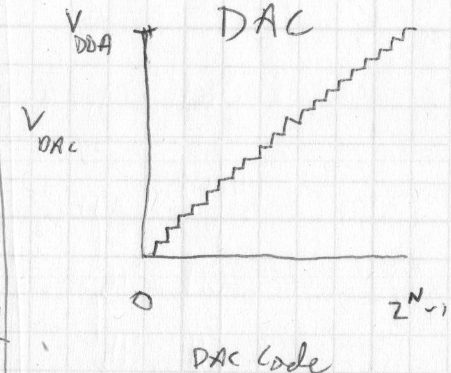
SCμM-2 ...

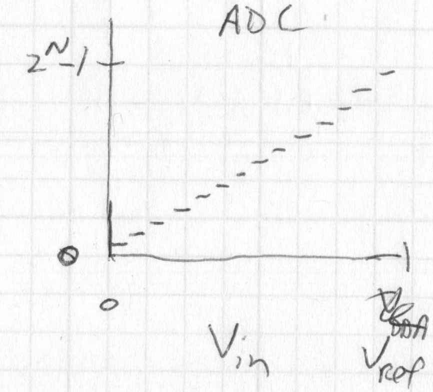
EE194/290C

$\overline{V}_{DAC} = V_{DDA} \frac{t_{on}}{T}$ average

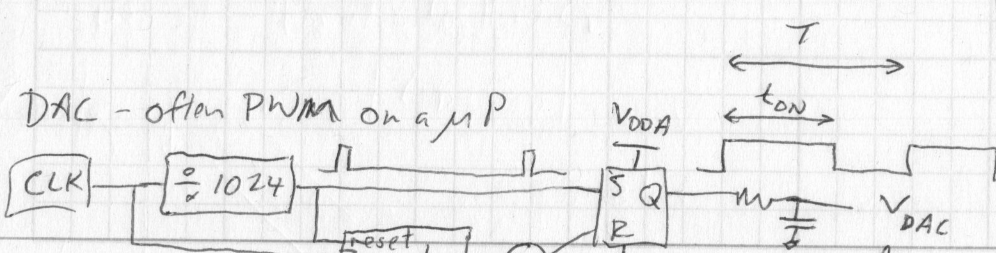
need $T \ll RC$







DAC - often PWM on a μP



$\frac{t_{on}}{T} = \frac{\text{DAC code}}{1024}$

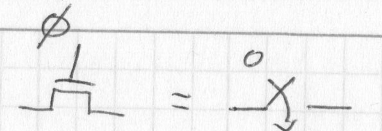
PGA Razavi

Switched capacitors - popularized by Berkeley
Gray et al.

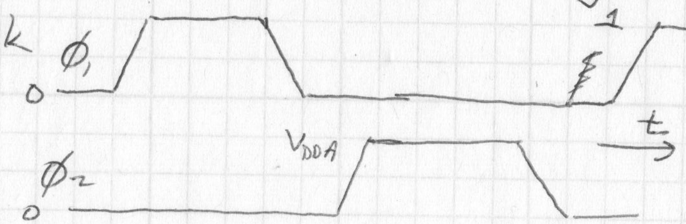
goal: use capacitors instead of resistors to capture benefits of CMOS

→ MOS transistors make good switches

→ MOS op-amps like capacitive loads

transistor is a switch 

ϕ: clock

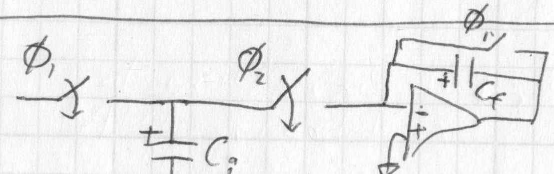


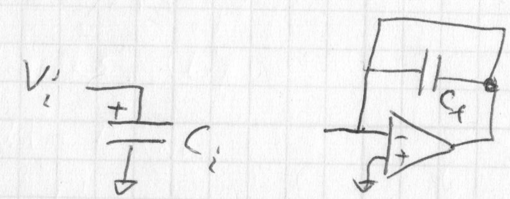
often with 2 or more non-overlapping phases.

→ Lets you change the wiring in your circuit

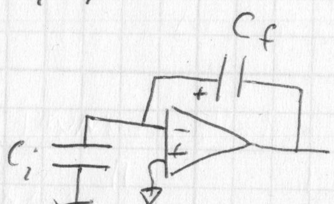
"during ϕ_1 it looks like"

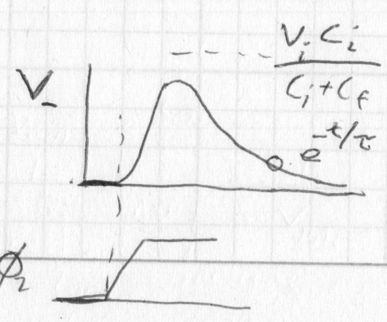
"during ϕ_2 it looks like"

e.g. 

during ϕ_1: 

$Q_{i+} = V_i C_i$

during ϕ_2: 



After things settle ($n\tau$)

must have $V_+ = V_- = 0 \Rightarrow Q_{i+} = 0$

$\Rightarrow Q_{f+} = V_i C_i$ (from ϕ_1)

$\Rightarrow V_{Cf} = \frac{Q_{f+}}{C_f} = V_i \frac{C_i}{C_f}$

$V_{out} = V_- - V_{Cf} = 0 - V_i \frac{C_i}{C_f}$

switched capacitor amplifier w/ gain $= -\frac{C_i}{C_f}$

can choose C_i with switches ⇒ programmable!