switched capacitors

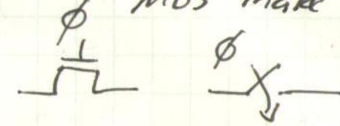
Switched Capacitors

Bipolar amps tend to use resistive feedback

MOS amps in the early days couldn't drive as much current

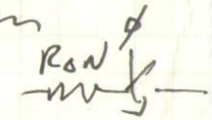
Berkeley led the charge on capacitors in FB

MOS make great <u>switches</u>

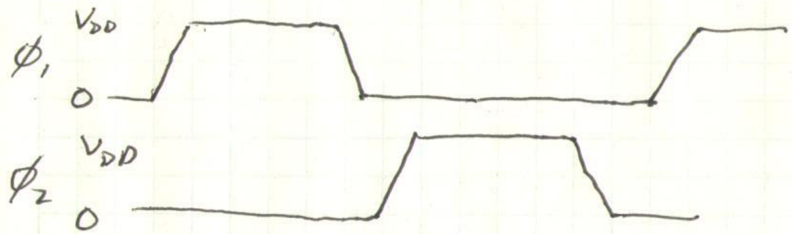


simplest model: short or open

next: resistor or open



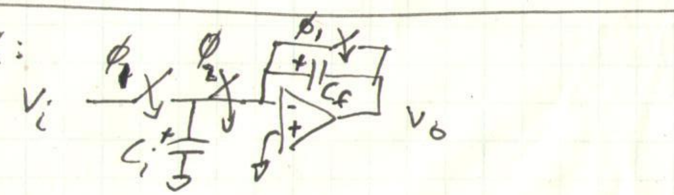
SC circuits have 1 or more <u>clock</u> <u>signals</u>, often w/ non-overlapping <u>phases</u>



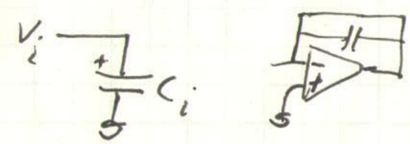
clock phases open and close switches (FETs) which rewire the circuit.

"During ϕ_1" "During ϕ_2"

EX:



During ϕ_1



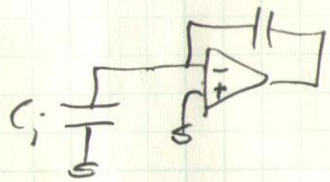
$Q_{Ci} = V_i C_i$ $\quad Q_{Cf} = 0$

~~During ϕ_2~~

Between ϕ_1 and ϕ_2

$Q_{Ci} = V_i C_i$ $\quad Q_{Cf} = 0$

Durig ϕ_2:



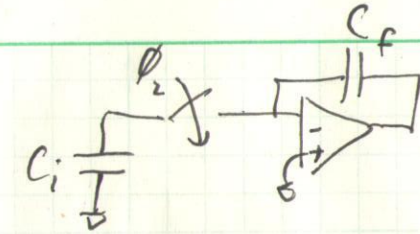
op-amp drives $V_- = 0$ so $Q_{Ci} = 0$

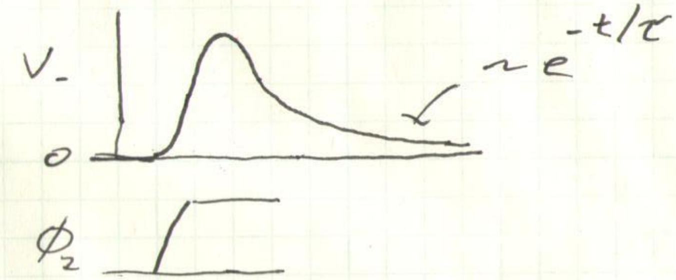
where does it go? To C_f

$$Q_{Cf2} = Q_{Ci1} = V_i C_i$$

$$V_{Cf2} = \frac{Q_{Cf2}}{C_f} = V_i \frac{C_i}{C_f}$$

$$V_o = V_- - V_{Cf2} = 0 - V_i \frac{C_i}{C_f}$$

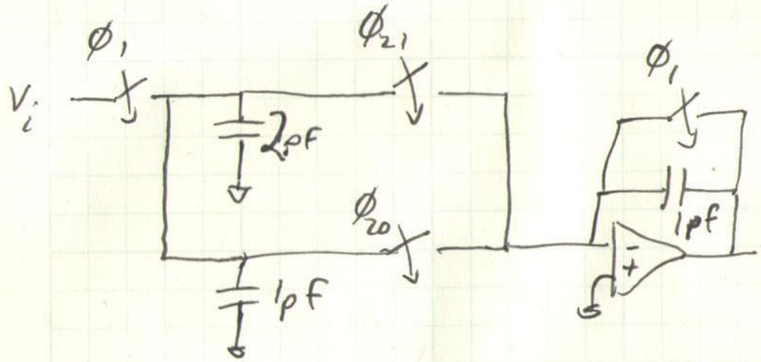


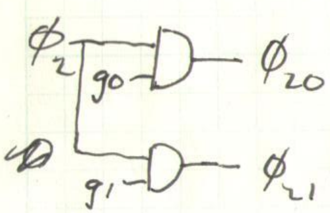


What's τ? $\frac{1}{\omega_{pCL}}$

$\omega_{pCL} = f\,\omega_u$

$f = \frac{C_f}{C_i + C_f}$





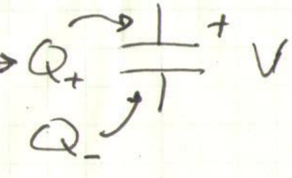
programmable gain

digital input $[g_1 g_0]$

determines gain 0, -1, -2, -3

A note on caps $\quad Q = CV$

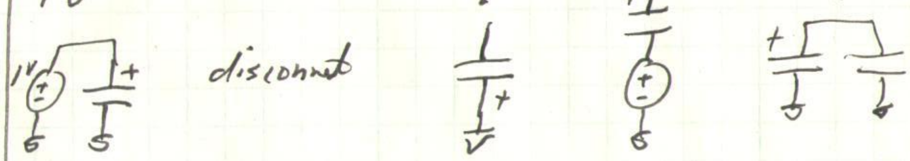
label the "+" side!

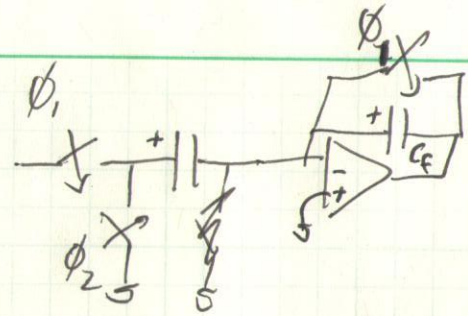


$$Q_- = Q_+$$

Real caps have parasitics - we will mostly ignore (240B)

Charge a cap to 1V

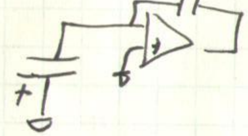




ϕ_1:

same

ϕ_2



same? NO!

$A_v = +\frac{C_i}{C_f}$

~~optimistic~~ pessimistic $\frac{1}{R_{on}} = \frac{I_{DSAT}}{V_{DSAT}} = \frac{\frac{\mu_n C_{ox}}{2}\frac{W}{L}V_{OV}^2}{V_{OV}}$

$R_{on} = \frac{2}{\mu_n C_{ox}\frac{W}{L}V_{OV}}$

optimistic ~~pessimistic~~

$\frac{1}{R_{on}} = \left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{DS}=0}$

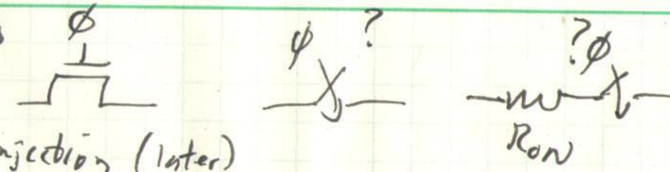
$I_D = \mu_n C_{ox}\frac{W}{L}\left(V_{GS} - V_t - \frac{1}{2}V_{DS}\right)V_{DS}$

$\left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{DS}=0} = \mu_n C_{ox}\frac{W}{L}V_{OV}$

$R_{on} = \frac{1}{\mu_n C_{ox}\frac{W}{L}V_{OV}}$

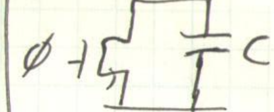
2× diff,

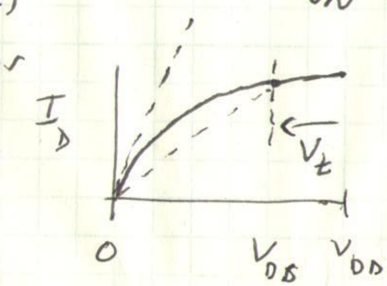
Switches



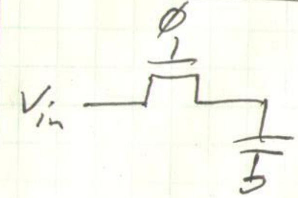
Charge injection (later)

Non-linear resistor



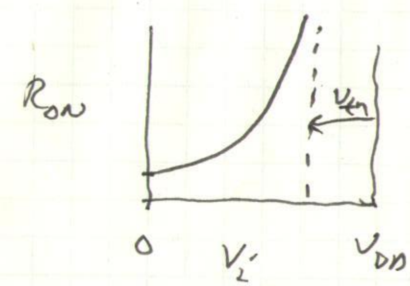


What value to use for R_{on}?



$I_D = \mu_n C_{ox}\frac{W}{L}(V_{DD} - V_{in} - V_{tn})V_{DS}$

$R_{on} = \frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{DD} - V_{in} - V_{tn})}$



NMOS can't pull high (above $V_{DD} - V_{tn}$)

PMOS can't pull low (below $|V_{tp}|$)

body effect makes this worse $|V_{tp}|$ bigger