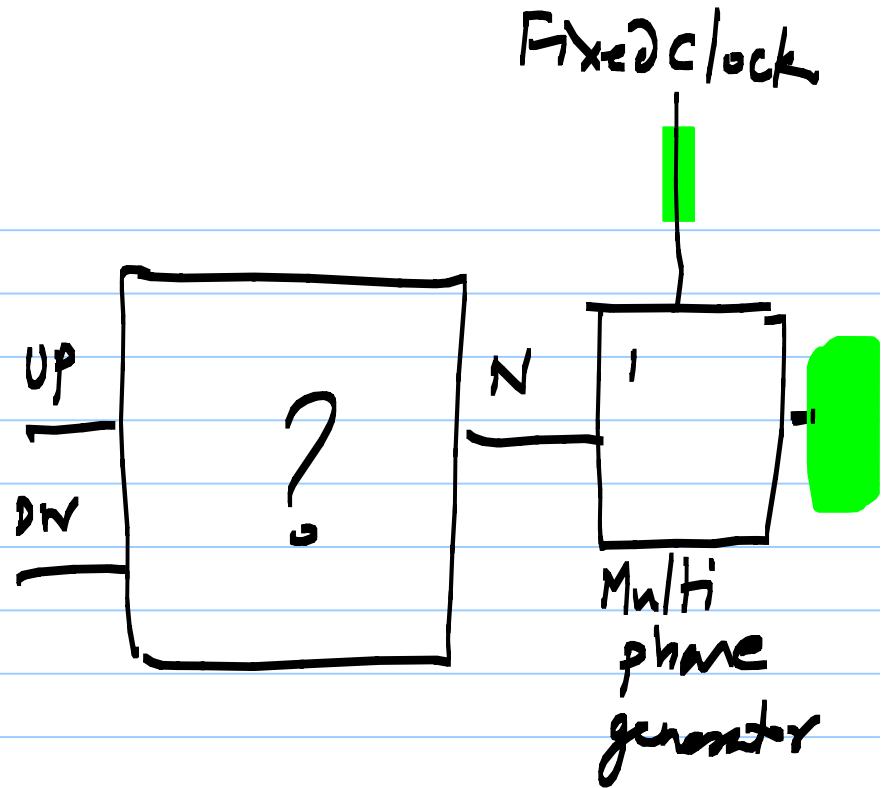
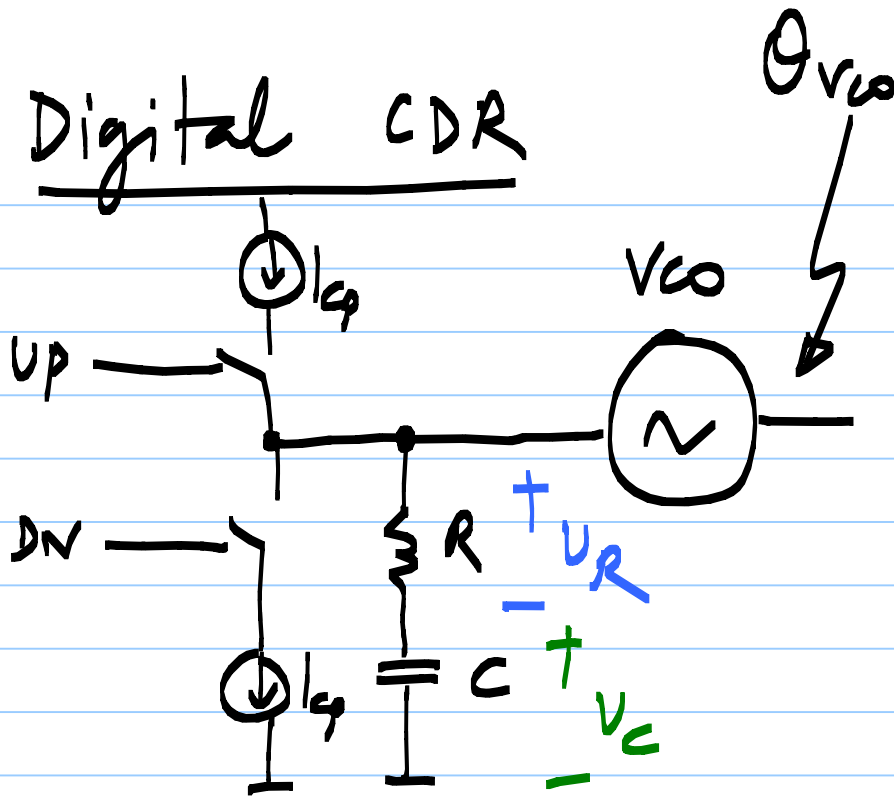
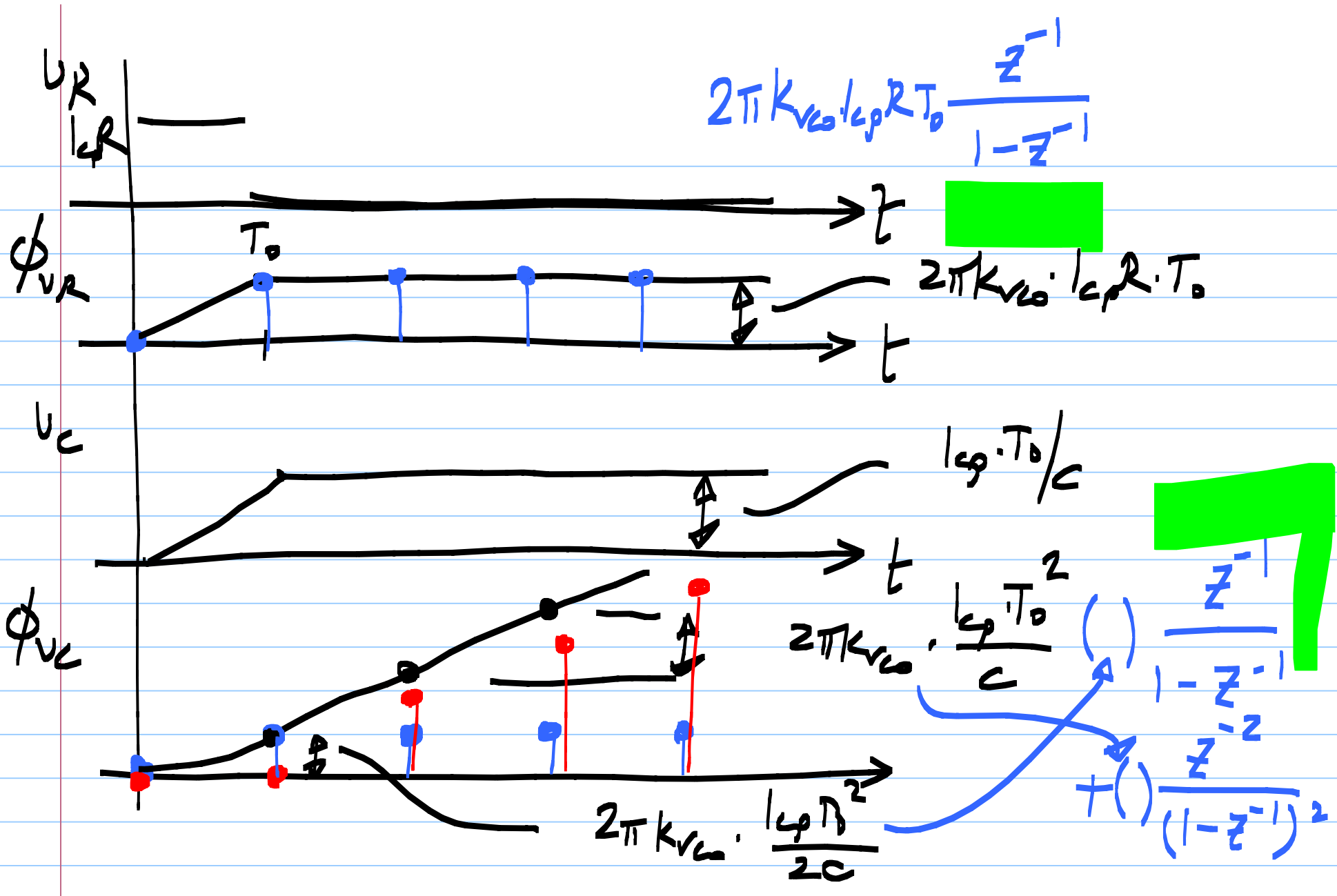


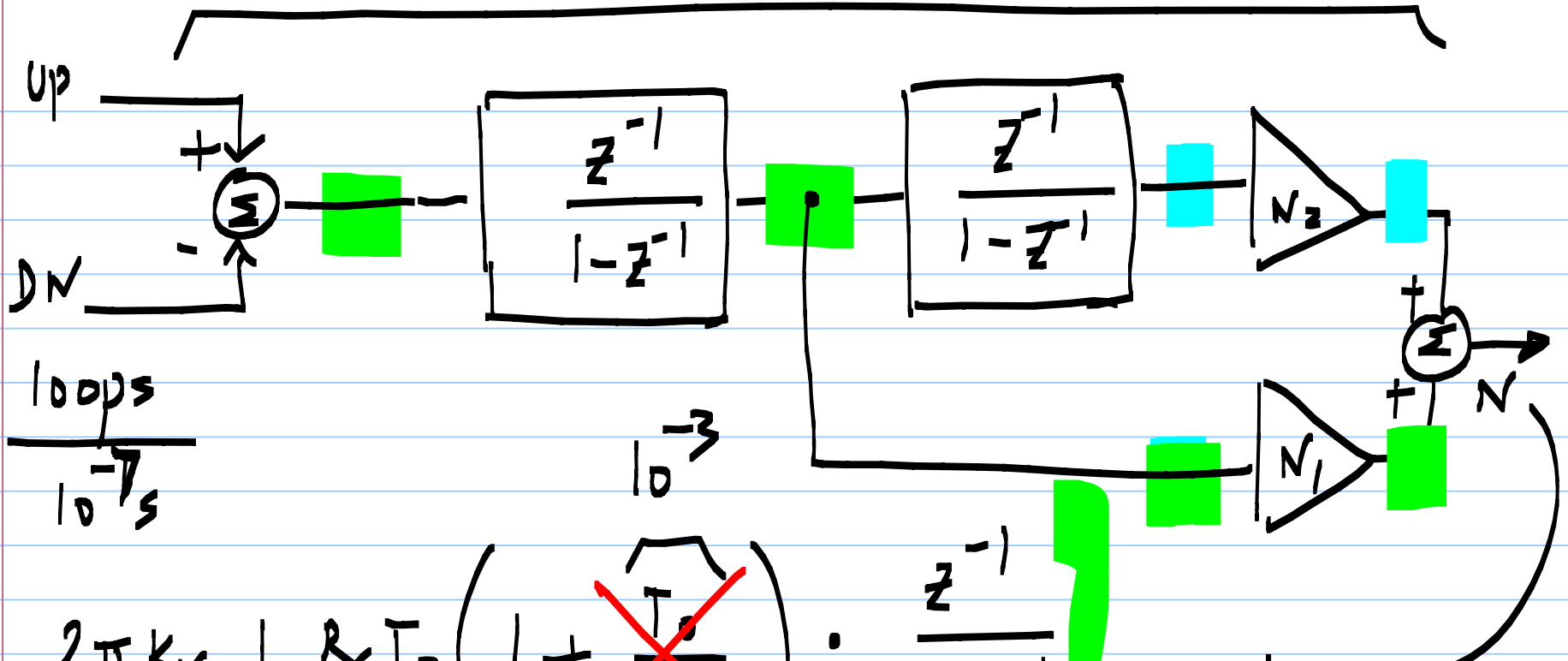
Digital CDR



Digital input selects one of the phases
Phases span the cycle



@ data rate f_0



loops
 $\frac{100ps}{10^{-7}s}$

10^{-3}

$$2\pi K_{VCO} I_{CP} R T_0 \left(1 + \frac{T_0}{2RC} \right) \cdot \frac{z^{-1}}{1 - z^{-1}}$$

$$+ 2\pi K_{VCO} I_{CP} T_0^2 \cdot \left[\frac{z^{-2}}{1 - z^{-2}} \right]$$

phase selection
 word

$$N \cdot \phi_{LSB} : \text{phase}$$

$$N_1 \cdot \phi_{LSB} = 2\pi K_{VCO} \cdot \ln R \cdot T_0$$

$$\frac{z^{-1}}{1 - z^{-1}}$$

$$+ \frac{2\pi K_{VCO} \cdot \ln T_0^2}{C}$$

$$\frac{z^{-2}}{1 - z^{-2}}$$

$$N_2 \cdot \phi_{LSB}$$

Resolution of the phase inter

$$\phi_{LSB} \sim \frac{2\pi}{2^7}$$

< 8 bits

Cannot realize LSB as small as this

10^{-2}

$\phi_{LSB} = 10^{-2}$

$$\phi_{LSB} = 2\pi K_{VCO} \cdot \frac{\ln T_0^2}{C}; \quad N_2 = 1$$

$$N_1 = \frac{RC}{T_0} \sim$$



Digital CDR w/ forwarded clock

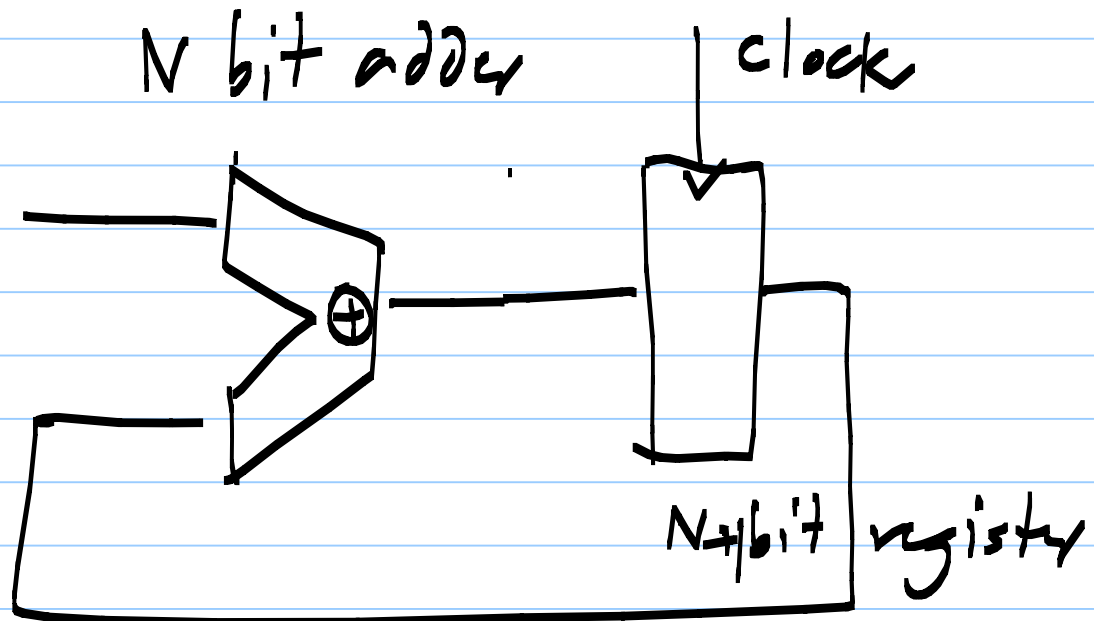
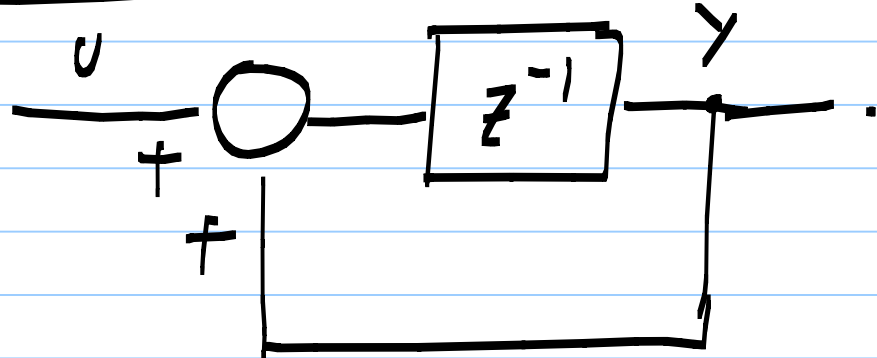
- * Two accumulators form the digital loop filter
- * Loop filter o/p: weighted sum of accumulator outputs.
- * Phase interpolator has a limited resolution
 - Quantization error
 - Bang-bang jitter could be determined by ϕ_{LSB}

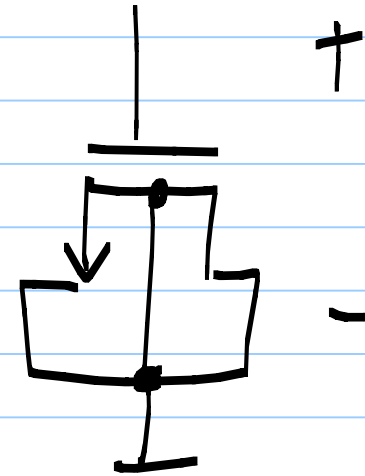
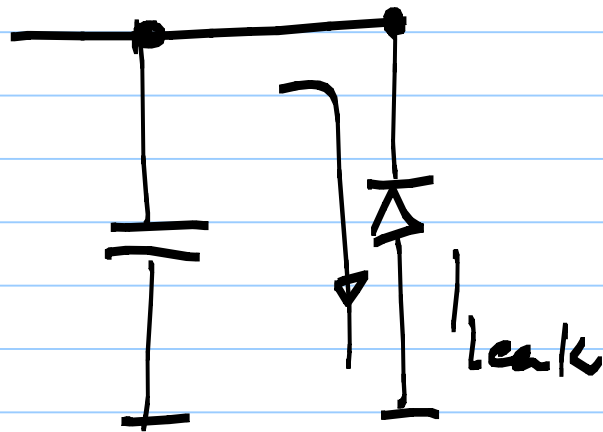
Advantages of digital CDR

- * Loop filter capacitor in an analog CDR tends to be large: Digital accumulator area scales with process.
- * No leakage in a digital accumulator.
- * CK source w/ low phase noise; Single high quality VCO for multiple lanes

Digital accumulator:

$$\frac{Y}{U} = \frac{z^{-1}}{1 - z^{-1}}$$



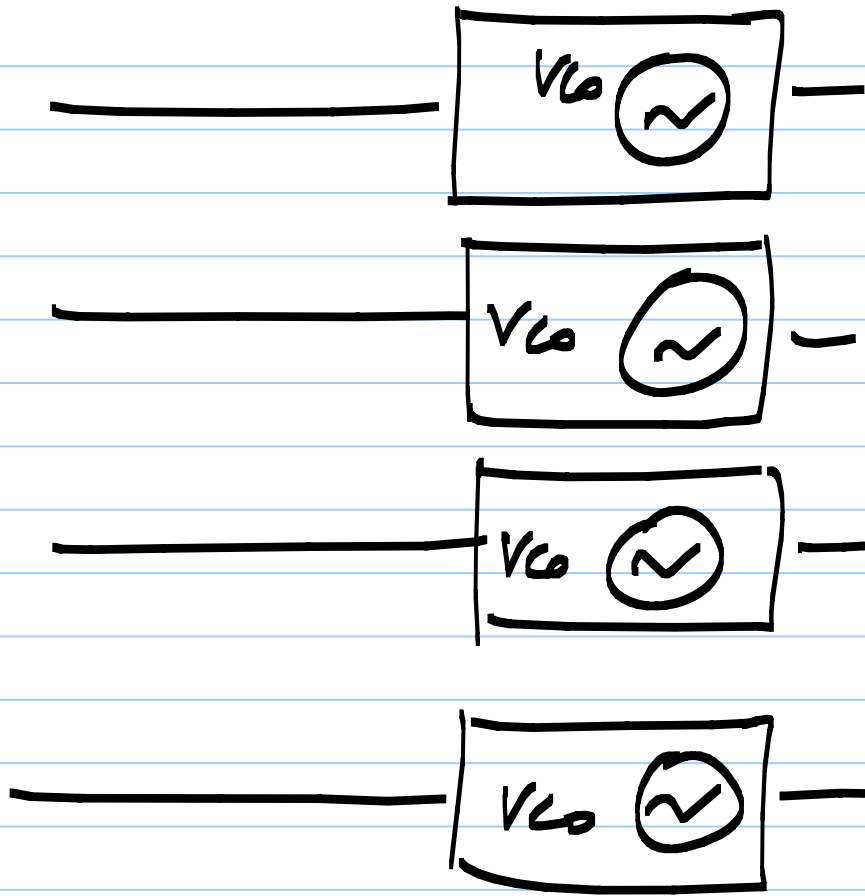


Metal-metal capacitor: no leakage

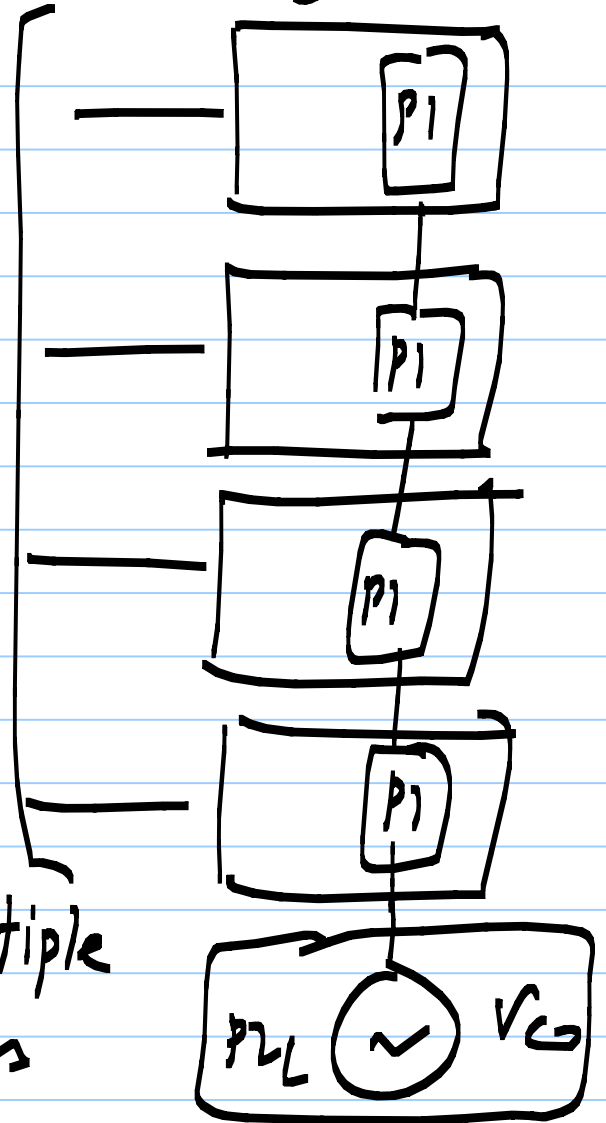
MOS capacitor: Gate leakage
(smaller area)

Multi
lane
input

Analogs cor

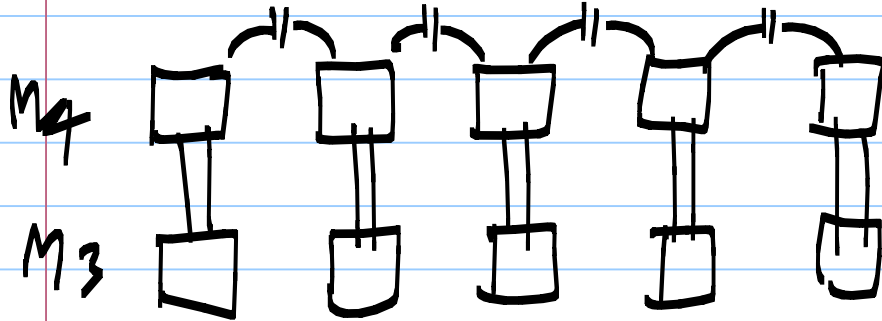
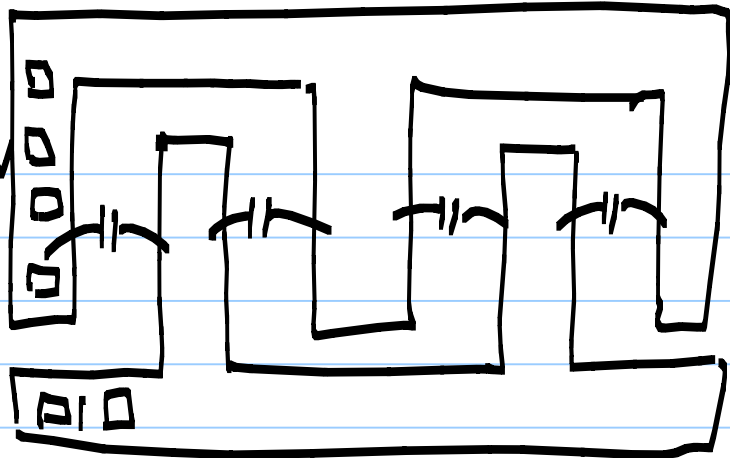


Dig. cor



Multiple
lanes

Top view

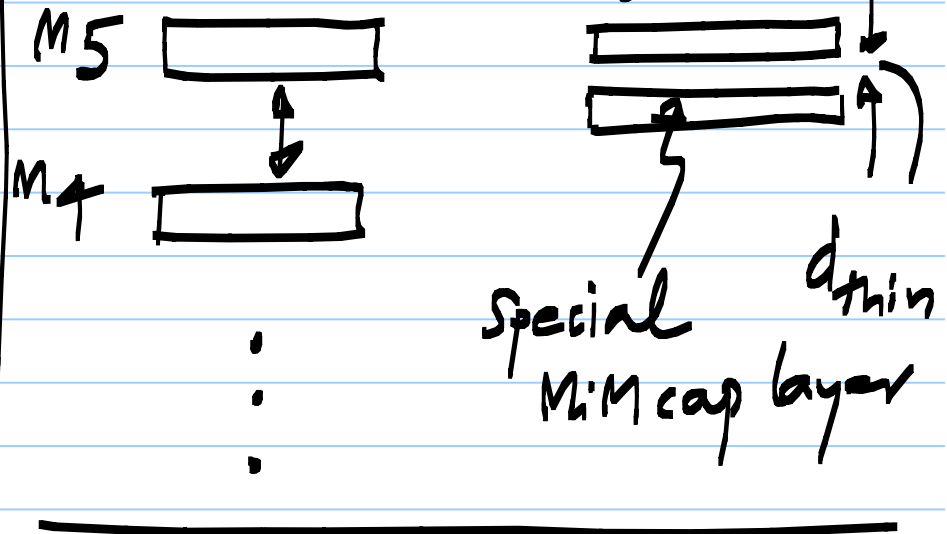


Interdigitated structure

$4F/\mu m^2$

MiM (Metal-insulator-metal)

special layer l_{thin}



substrate

- * Higher capacitance/area
- * special processing steps

Disadvantages of a digital CDR

- * Limited phase resolution of the phase interpolator \rightarrow Bang-bang jitter
- * Power consumption in the implementation of the loop filter
- * Digital CDR operates from demultiplexed data \rightarrow Larger latency \rightarrow Higher BB jitter or lower bandwidth