520.492 Mixed-Signal VLSI Systems

Week 4

Data Conversion

References

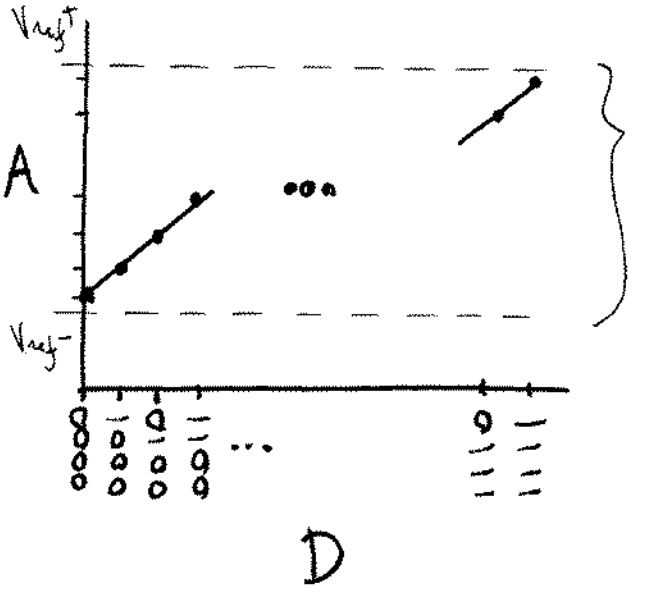
1. Geiger, Allen and Strader: pp. 612-672.
2. Franca and Tsividis, Chapter 9.

DATA CONVERSION

ref # { • GEIGER, ALLEN & STRADER, pp 612-672
• FRANCA & TSIVIDIS, CHAPTER 9

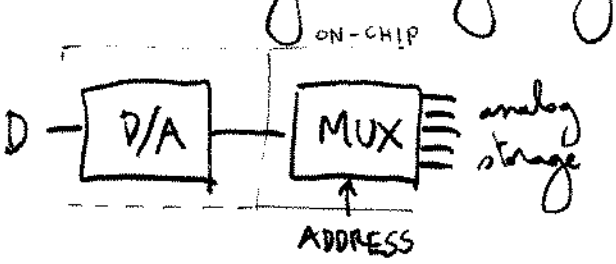
- D/A conversion: $\{D_i\} \rightarrow A$
- A/D conversion: $A \rightarrow \{D_i\}$

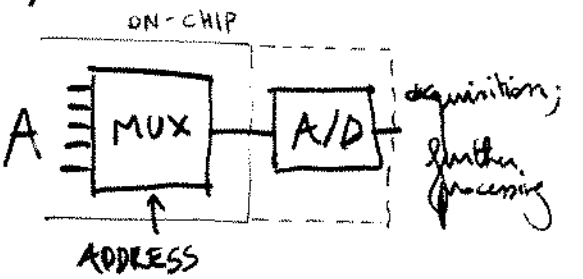
$D = D_{n-1} D_{n-2} \cdots D_3 D_2 D_1 D_0$
$i = 0$: LSB
$i = m-1$: MSB
n = # bits

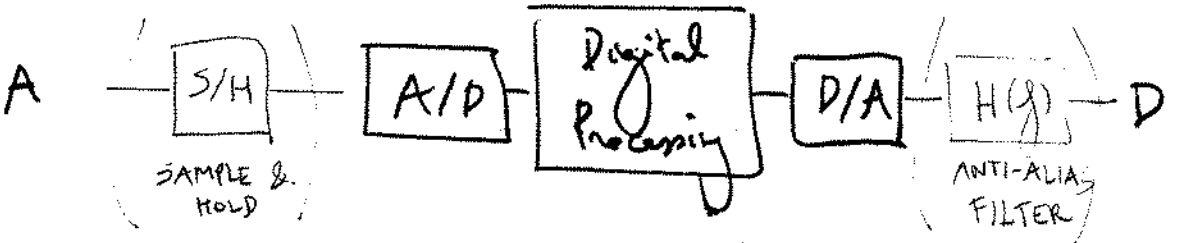


$$A = \left(\sum_{i=0}^{n-1} 2^{i-n} D_i + 2^{-1-n} \right) \left(V_{ref}^{+} - V_{ref}^{-} \right) + V_{ref}^{-}$$

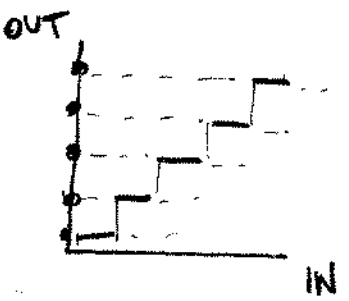
Applications (just a few of them ...)







A/D/A quantizer



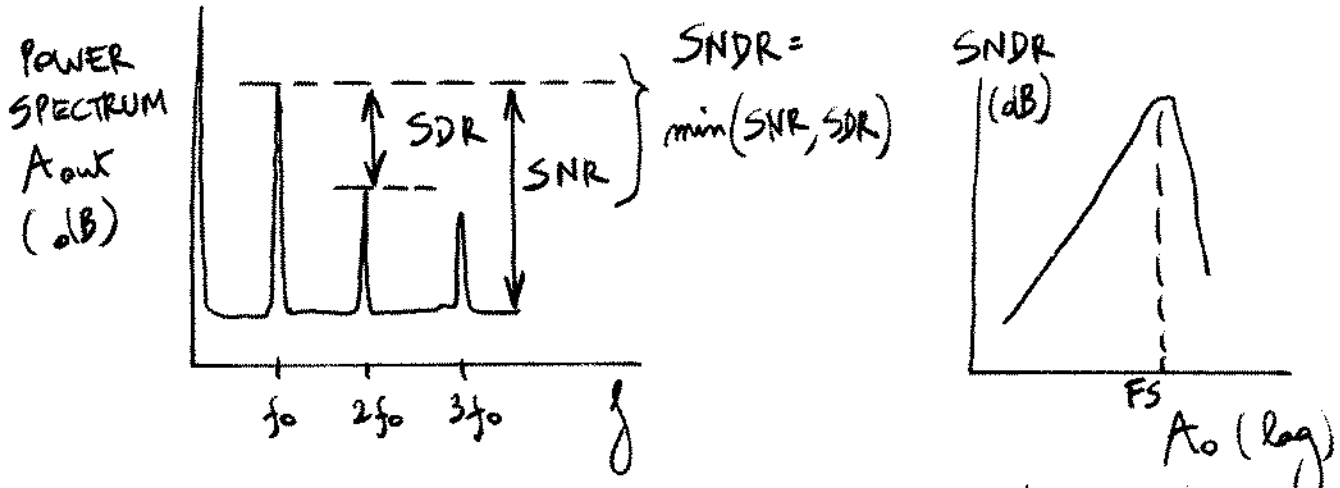
Resolution, Noise, and Distortion in Data Conversion

- Resolution: $1\ LSB = 2^{-n} \times FS$ (full scale)

  $\Rightarrow$ dynamic range (dB) $= 20 \log\left(\frac{FS}{1\ LSB}\right) = 20n \log_{10} 2 \approx \underline{\underline{6n}}$

- Noise and Nonlinear Distortion: $D_{in}(t) = A_0 \cos(2\pi f_0 t)$

  (Noise → SNR; Distortion → SDR; A_0 → AMPLITUDE)



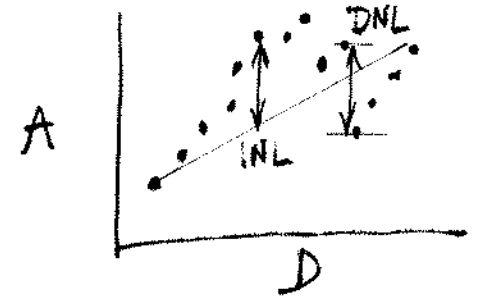
$\Rightarrow$ # effective bits $= \frac{1}{6} \max_{A_0}(SNDR)$

- Nonlinearity characterization (static): $A \leftrightarrow A_{ideal} = \alpha \sum 2^i D_i + \beta$

  (α → SCALE; β → OFFSET)

INTEGRAL NONLINEARITY: $INL\ (\#\ LSB's) = \dfrac{\max_D |A(D) - A_{ideal}(D)|}{1\ LSB}$

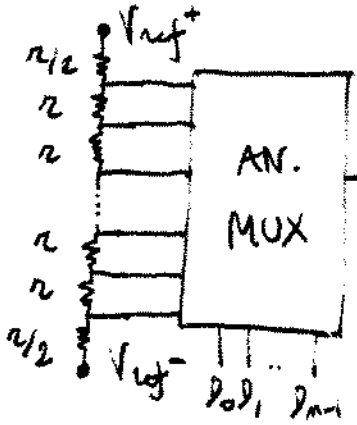
DIFFERENTIAL NONLINEARITY: $DNL\ (\#\ LSB's) = \dfrac{\max_D |A(D) - A(D-1) - 1LSB|}{1\ LSB}$



D/A CONVERTERS

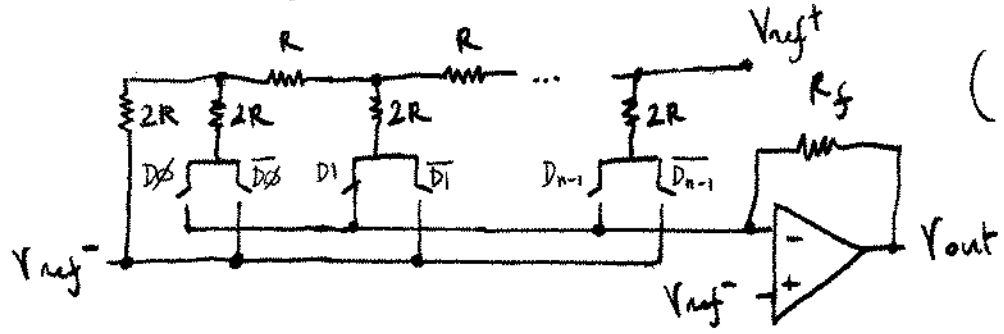
1) PARALLEL :

- voltage mode:



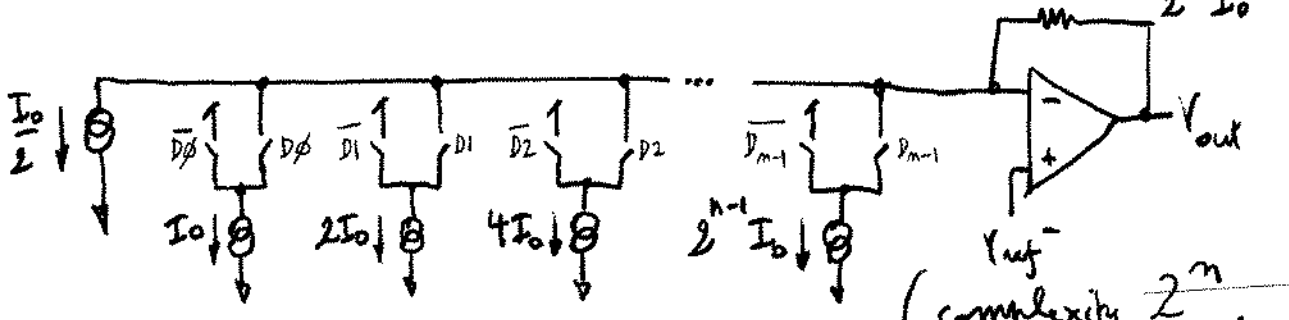
(complexity 2^n)

- current mode:



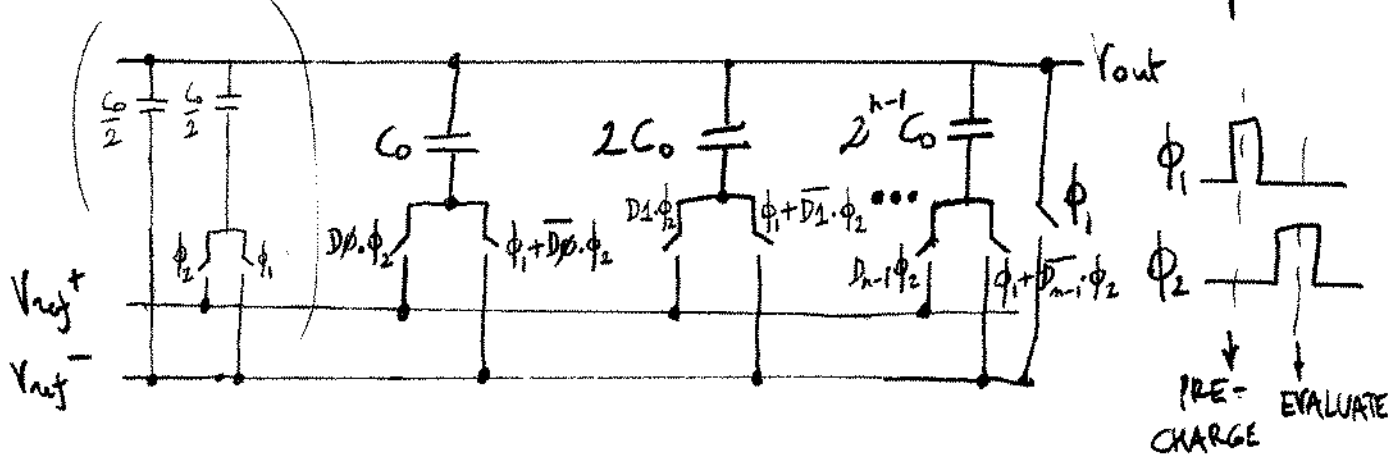
(complexity n)

$$R_F = \frac{V_{ref}^+ - V_{ref}^-}{2^n I_0}$$

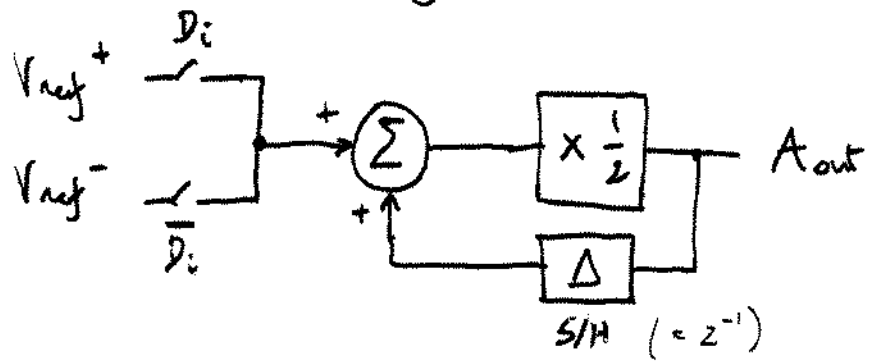


(complexity 2^n, unless pre-scaled)

- charge mode (sampled):



2) BIT-SERIAL "algorithmic" D/A converter: D_i — D/A — A (sampled)



$\begin{cases} V_{ref}^- = \text{"0"} \\ V_{ref}^+ = \text{"1"} \end{cases}$:

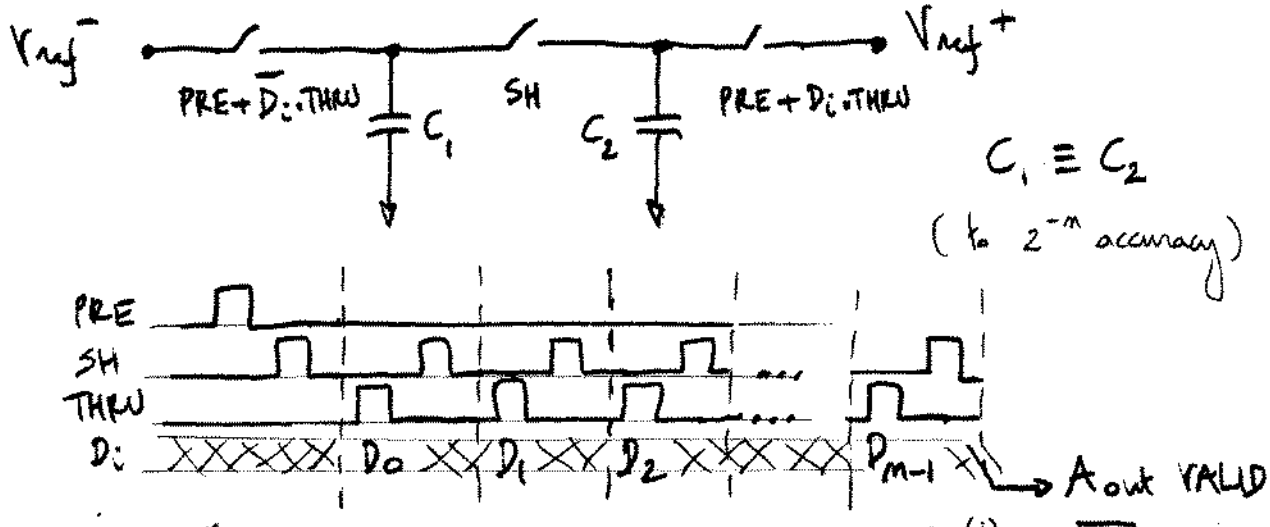
$$A_{out}(0) = \frac{1}{2}$$

$$A_{out}(1) = \frac{1}{2}\left(\frac{1}{2} + D_0\right) = \frac{1}{4} + \frac{1}{2}D_0$$

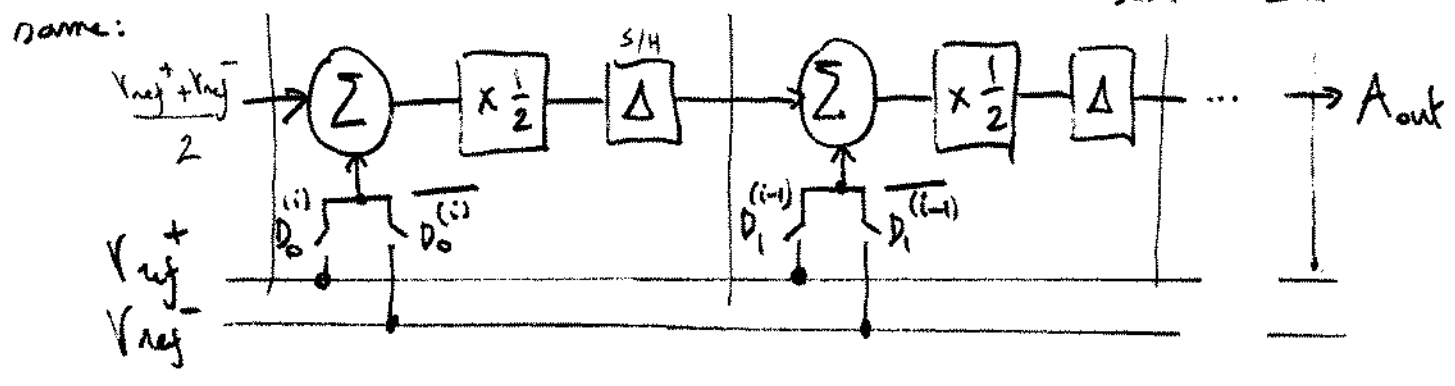
$$A_{out}(2) = \frac{1}{2}\left(\left(\frac{1}{4} + \frac{1}{2}D_0\right) + D_1\right) = \frac{1}{8} + \frac{1}{4}D_0 + \frac{1}{2}D_1$$

$$\vdots$$

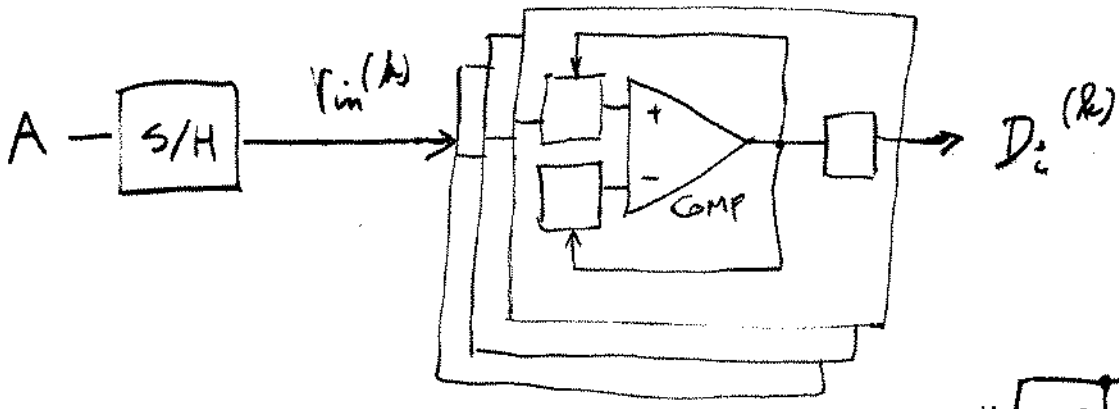
$$A_{out}(m) = \frac{1}{2}\left(\left(\frac{1}{2^n} + \frac{1}{2^{n-1}}D_0 + \frac{1}{2^{n-2}}D_1 + \dots\right) + D_{m-1}\right) = \frac{1}{2^{n+1}} + \sum_{i=0}^{n-1} 2^{i-n} D_i$$



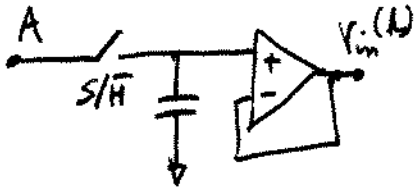
3) PIPELINED "algorithmic" D/A Converter: $D_0^{(i)}$, $D_1^{(i-1)}$, …, $D_{m-1}^{(i-m+1)}$ — D/A — A



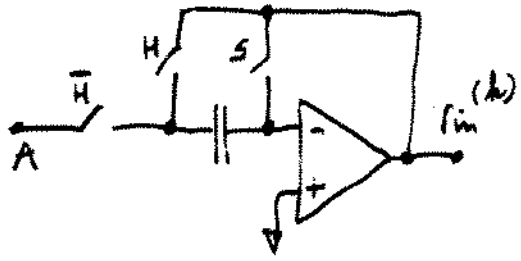
A/D CONVERSION



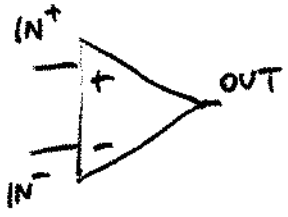
S/H :



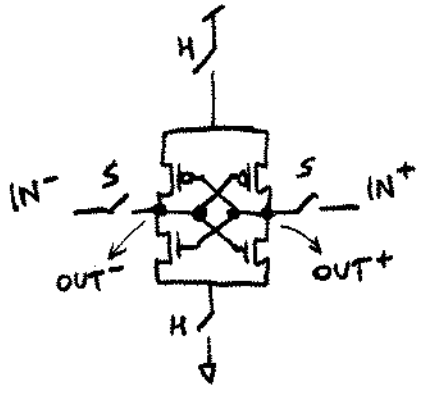
or



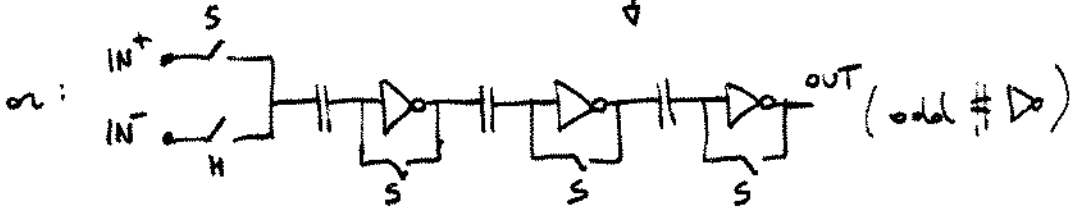
COMP :



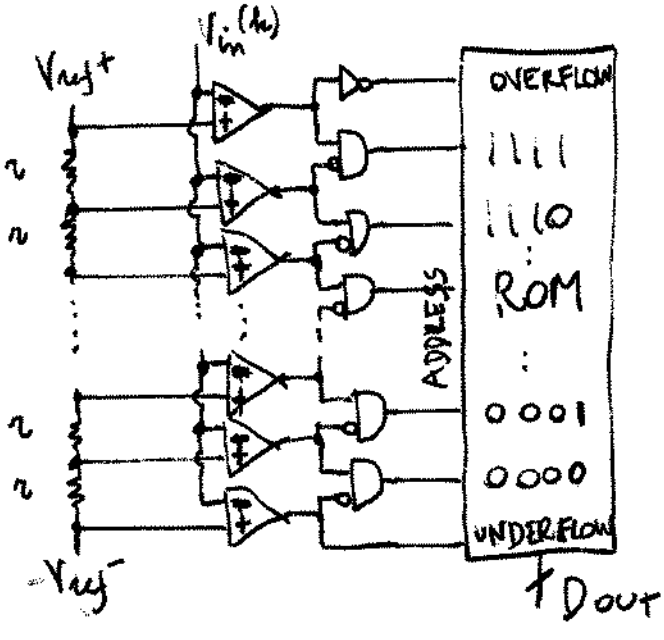
:



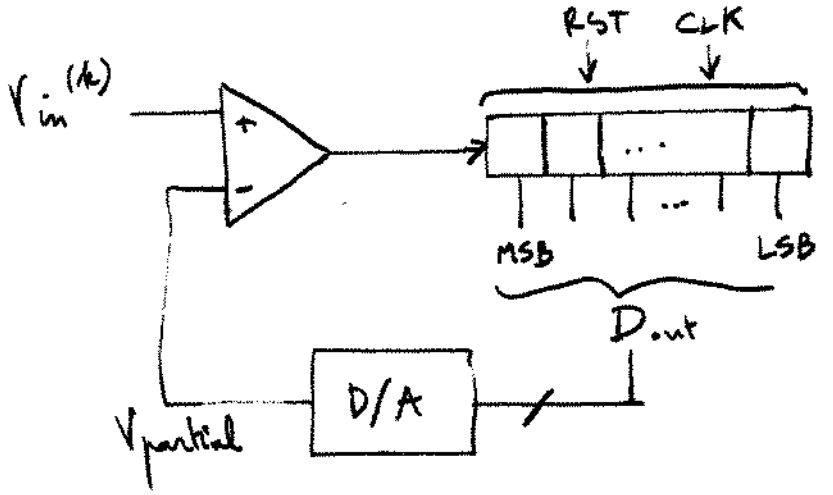
or :



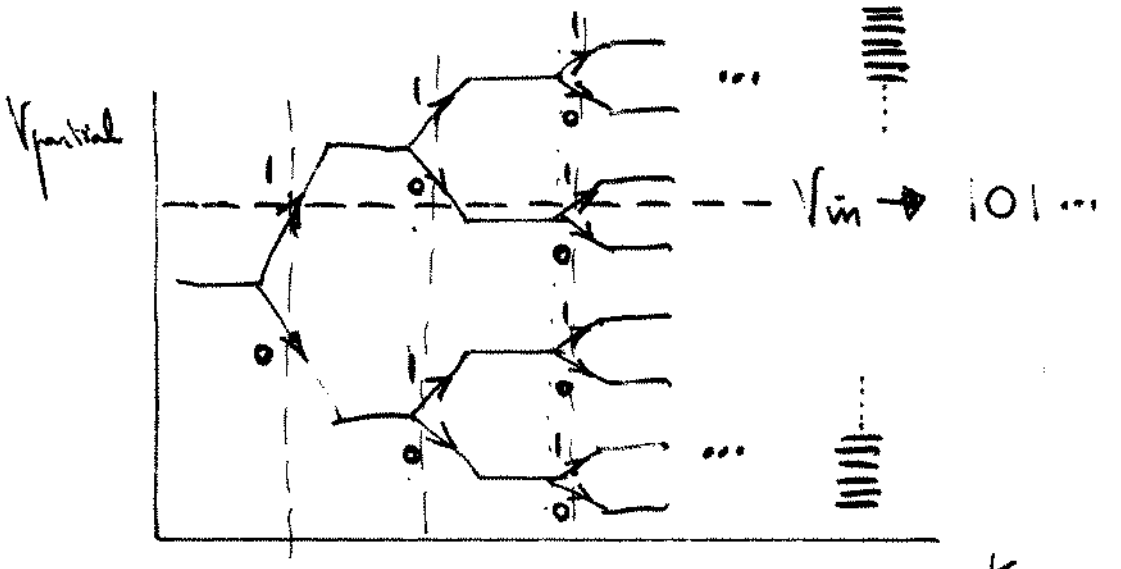
1) FLASH :



2) SUCCESSIVE APPROXIMATION



SAR
(successive approximation register)



D_{n-1} D_{n-2} D_{n-3} ... D_0

$\frac{1}{2}$

$\frac{1}{2}D_{n-1} + \frac{1}{4}$

$\frac{1}{2}D_{n-1} + \frac{1}{4}D_{n-2} + \frac{1}{8}$

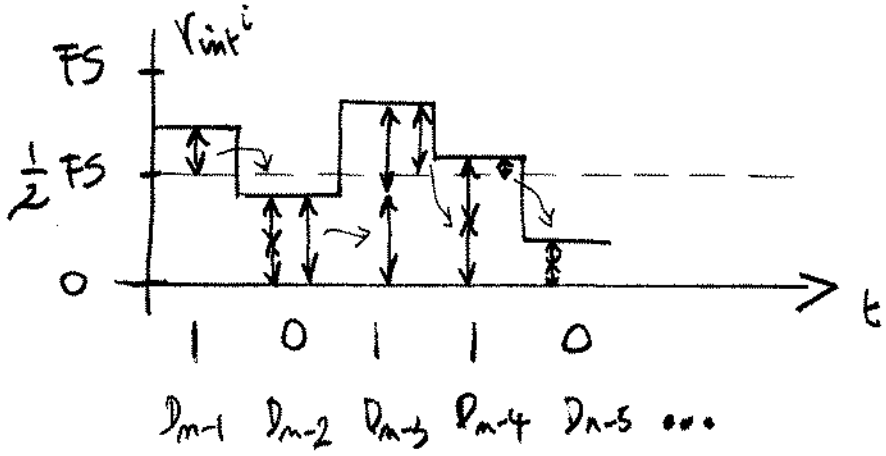
$\frac{1}{2}D_{n-1} + \frac{1}{4}D_{n-2} + \frac{1}{8}D_{n-3} + \frac{1}{16}$

$\sum_{i=0}^{n-1} 2^{i-n} D_i + \frac{1}{2^{nn}}$

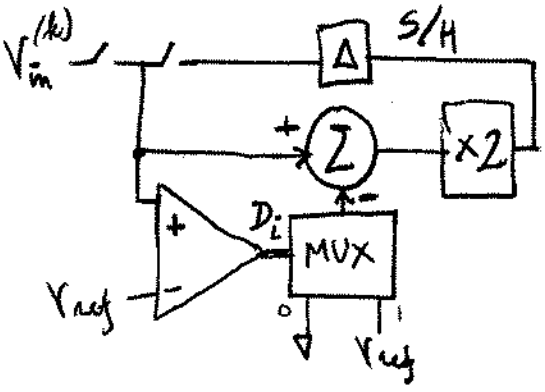
3) ALGORITHMIC A/D CONVERTERS

$$D_i := \left(V_i^{int} > V_{ref}\right)$$

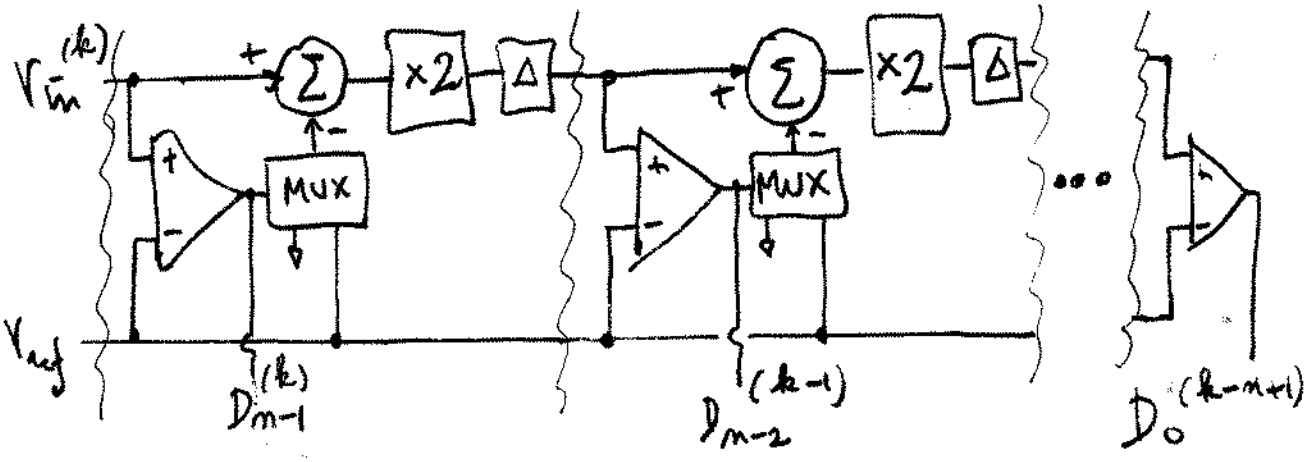
$$\text{with} \begin{cases} V_0^{int} := V_{in} \\ V_{i+1}^{int} := 2\left(V_i^{int} - D_i \cdot V_{ref}\right) \end{cases} \qquad \left(V_{ref} = \frac{FS}{2}\right)$$



BIT-SERIAL:

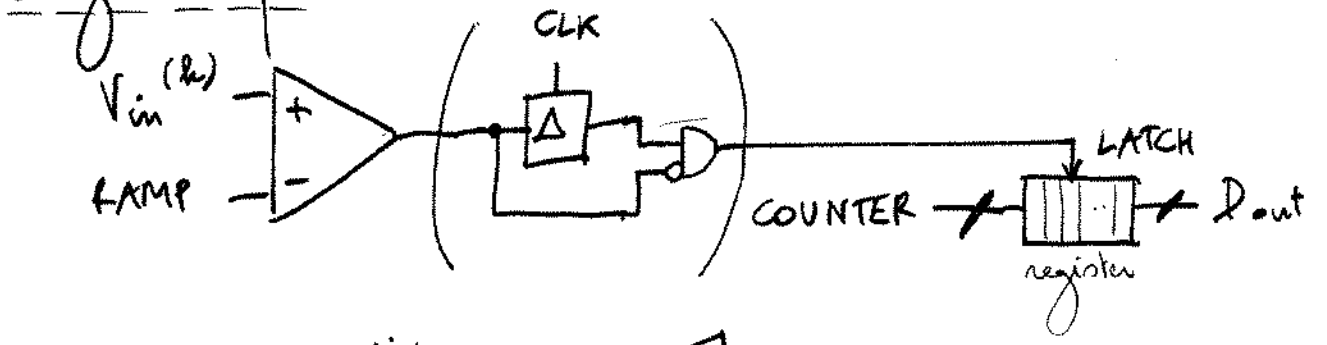


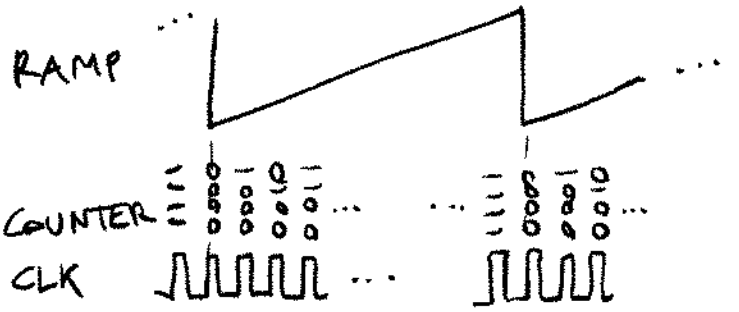
PIPELINED:



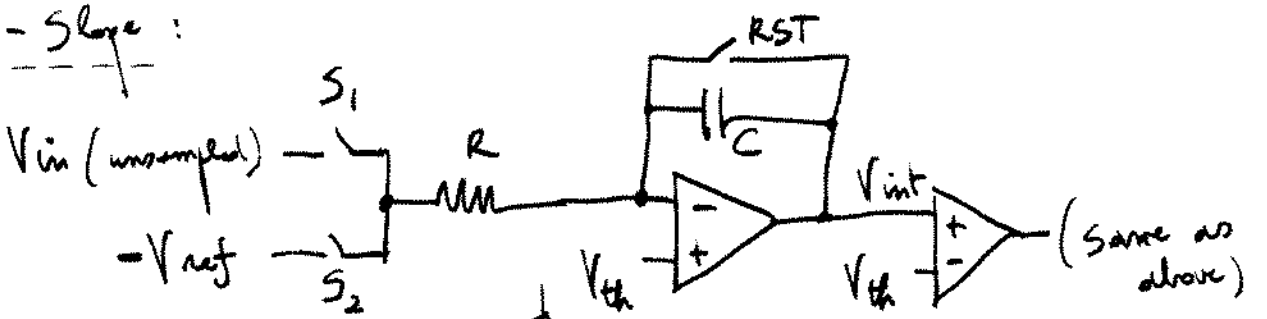
4) INTEGRATING

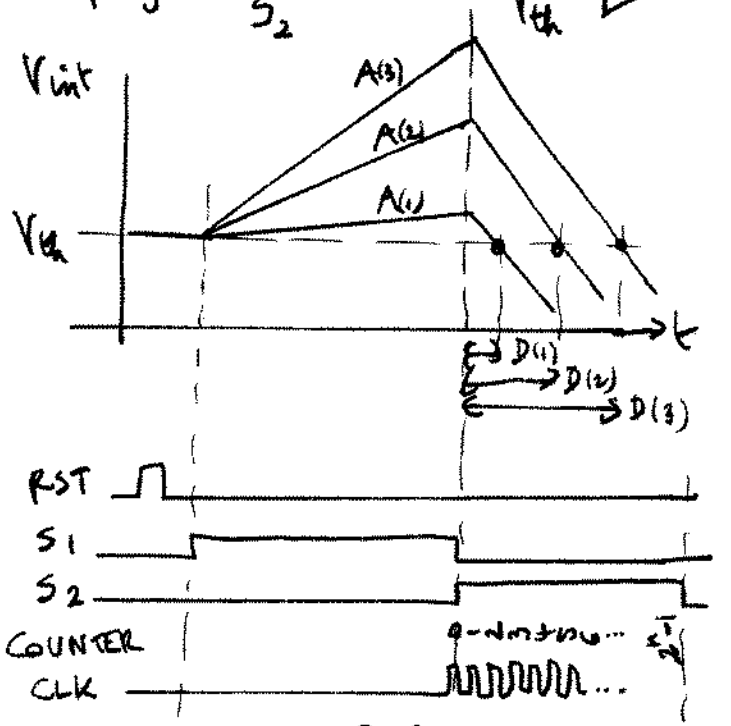
Single-Slope:





Dual-Slope:





5) OVERSAMPLED (Sigma-Delta) → NEXT