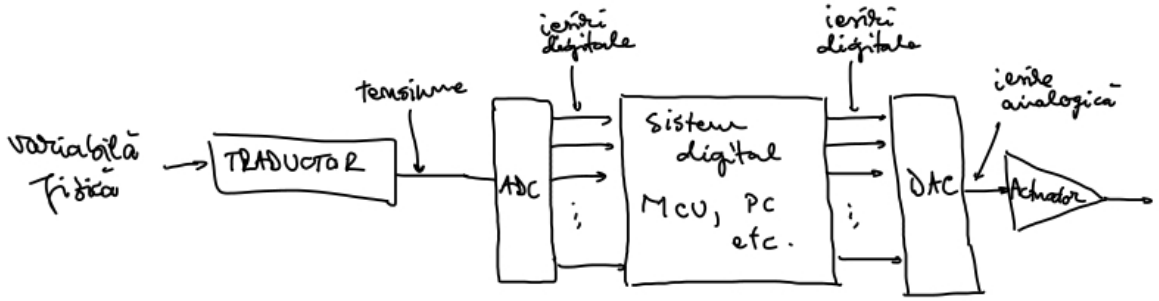
Curs 10 SIS:

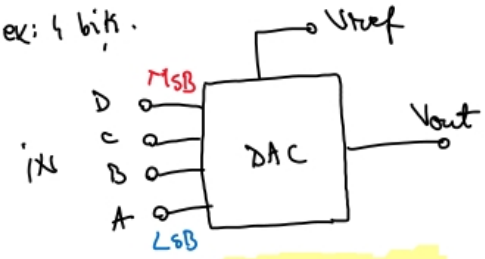
Conversia digital-analogică și analog-digitală:



Conversia digital-analogică:

DAC = „Digital-to-Analog Converter"[4]

ex: 4 biți.



$V_{out} = K \cdot IN_{digital}$

$[K] = V$ sau A

ex: $V_{ref} = 15V \Rightarrow$
$\Rightarrow K = 1V \rightarrow K = f(V_{ref}, I_{ref})$

D C B A	Vout (V)
0 0 0 0	0
0 0 0 1	1
0 0 1 0	2
0 0 1 1	3
0 1 0 0	4
0 1 0 1	5
0 1 1 0	6
0 1 1 1	7
1 0 0 0	8
1 0 0 1	9
1 0 1 0	10
1 0 1 1	11
1 1 0 0	12
1 1 0 1	13
1 1 1 0	14
1 1 1 1	15

•) Full-scale output: A_{fs}

(P1.) DAC pe 5 biți cu output în curent

$I_{out} = 10\ mA$ pt. $IN = 10100$

$I_{out} = ?$ dacă $IN = 11101$

$I_{out} = K \cdot IN$

$10\ mA = K \cdot (1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0)$

$10\ mA = K \cdot (2^4 + 2^2) = K \cdot (16 + 4) = K \cdot 20$

$K = \frac{10\ mA}{20} = 0.5\ mA$

$I_{out} = 0.5\ mA\ (2^4 + 2^3 + 2^2 + 2^0) = 0.5\ mA\ (16 + 8 + 4 + 1) \Rightarrow$

$\Rightarrow I_{out} = 14.5\ mA$ pt. $IN = 11101$

P2. DAC pe 8 biți; $V_{out} = 1V$ pt. $IN = 00110010$

$A_{fs} = ?$

$$V_{out} = k \cdot IN$$

$$1V = k \cdot (2^5 + 2^4 + 2^1) = k(32 + 16 + 2)$$

$$1V = k \cdot 50$$

$$k = \frac{1}{50} = 0.02V = 20\,mV$$

$$A_{fs} = V_{out}^{max} = k \cdot (11111111)$$

$$A_{fs} = 20\,mV\,(2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0) =$$

$$= 20\,mV \cdot 255$$

$$A_{fs} = 5.1\,V$$

Ponderea intrărilor convertorului digital-analogic

ex: DAC pe 4 biți cu $k = 1V$

D C B A	Vout
0 0 0 1	1V
0 0 1 0	2V
0 1 0 0	4V
1 0 0 0	8V

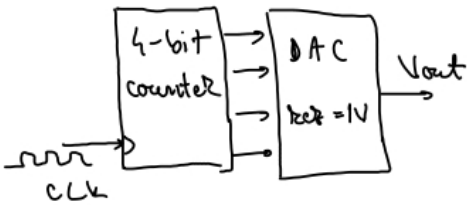
P3. DAC pe 5 biți; $V_{out} = 0.2V$ pt. $IN = 00001$

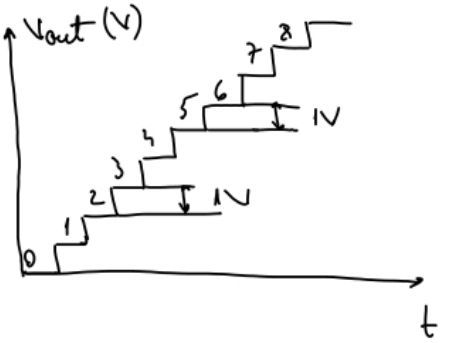
$A_{fs} = ?$

$A_{fs} = V_{out}$ pt. $IN = 11111$

$$A_{fs} = 0.2V + 0.4V + 0.8V + 1.6V + 3.2V = 6.2V$$

Rezoluția (step size):





step size

$$\text{Rezoluția} = k = \frac{A_{fs}}{2^N - 1}$$, N - nr. de biți

$2^N - 1$ → nr. de pași

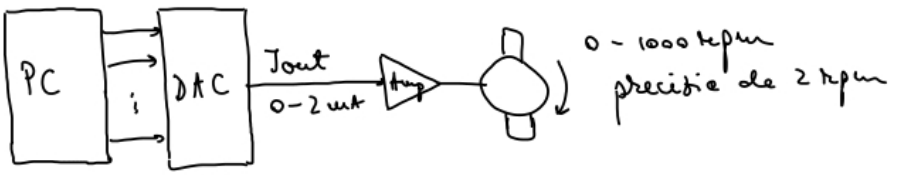
$$\text{Rezoluția (\%)} = \frac{k}{A_{fs}} \cdot 100\% = \frac{1}{2^N - 1} \cdot 100\%$$

ex: $k = 1V$, $A_{fs} = 15V$

$$\text{Rez.}(\%) = \frac{k}{A_{fs}} \cdot 100\% = \frac{1V}{15V} \cdot 100\%$$

$$\text{Rez}(\%) = 6.67\%$$

P4.



$$\text{nr. de pași} = \frac{1000}{2} = 500 \text{ pași}$$

$$2^N - 1 \geq 500 \rightarrow 9 \text{ biți minimum}$$ — 512 pași

$$\text{nr. de pași} = 2^9 - 1 = 511 \text{ pași}$$

$$\text{precizia} = \frac{1000}{511} = 1.96 \text{ rpm}.$$

DAC cu output negativ

ex: DAC pe 8 biți → MSB = bit de semn

1 → +
0 → −

1111 1111	+Vref	128
1000 0000	0 V	0
0000 0000	-Vref	-127

Acuratețea → % FS

- full-scale error

ex: 0.01 % FS. } → 0.01% × 9.375V =>
A_{fs} = 9.375V } => full-scale error - ± 0.9375 mV

- linearity error → % FS

A_{fs} = 9.375V; step size ± 0.9375 mV

P5. DAC pe 8 biți în curent

A_{fs} = 2 mA

full-scale error : 0.5% FS

I_{out} = ? ± ? pt. iN = 1000 0000

$k = \frac{A_{fs}}{2^{N-1}} = \frac{2mA}{255} = 7.84\ \mu A$

$I_{out} = k \cdot 128 \cong 1004\ \mu A$ pt. iN = 1000 0000

eroarea = ± 0.5% × 2 mA = ± 10 μA

I_{out} = 1004 μA ± 10 μA < 994 μA / 1014 μA

Eroarea de offset:

DAC offset error de 2 mV

output ideal 100 mV → real 102 mV

offset error < + / −

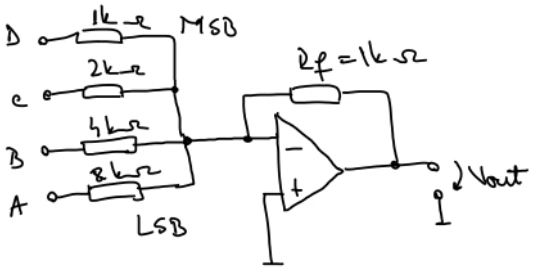
Timp de stabilizare (settling time)

timpul în care I_{out} se stabilizează la V_{out}; $I_{out} \pm \frac{1}{2}k$ (±0.5 LSB)

Monotonicitate:

derivata V_{out}; I_{out} are același semn ca și derivata mărimii de intrare

·) DAC cu AO sumator



$$V_{out} = -\left(\underset{MSB}{V_D} + \frac{1}{2}V_C + \frac{1}{4}V_B + \underset{LSB}{\frac{1}{8}V_A}\right)$$

$$V_{A,B,C,D} = 0;\ 5V$$

$$A_{fs} = -5\left(\frac{8}{1} + \frac{4}{\frac{1}{2}} + \frac{2}{\frac{1}{4}} + \frac{1}{8}\right) = -\frac{75}{8} = -9.375V$$

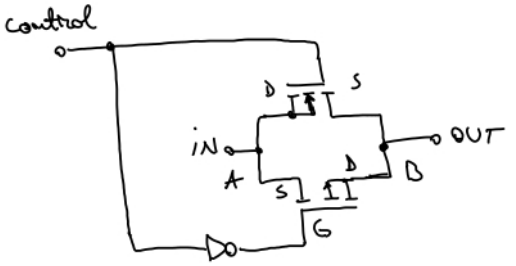
$$Rez = \frac{1}{8}\cdot 5V = 0.625V$$

$$k = -0.625V$$

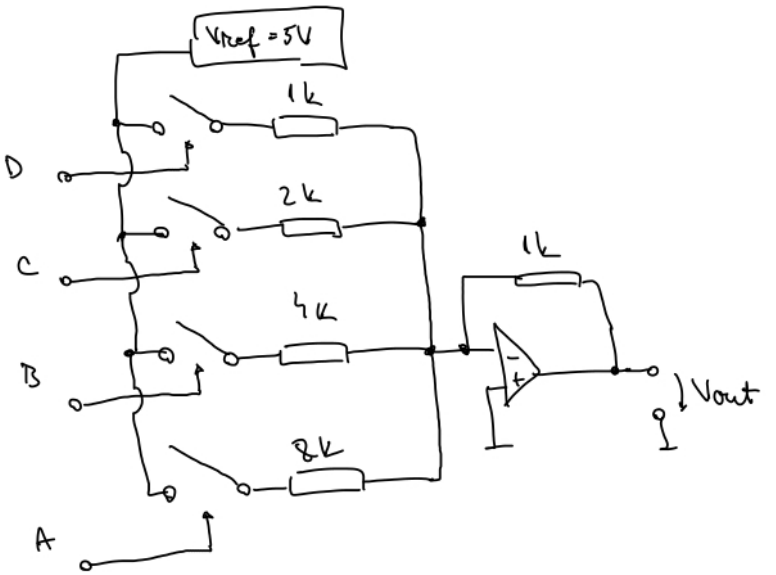
Ponderile intrărilor

D C B A	Vout (V)
0 0 0 1	-0.625
0 0 1 0	-1.25
0 1 0 0	-2.5
1 0 0 0	-5

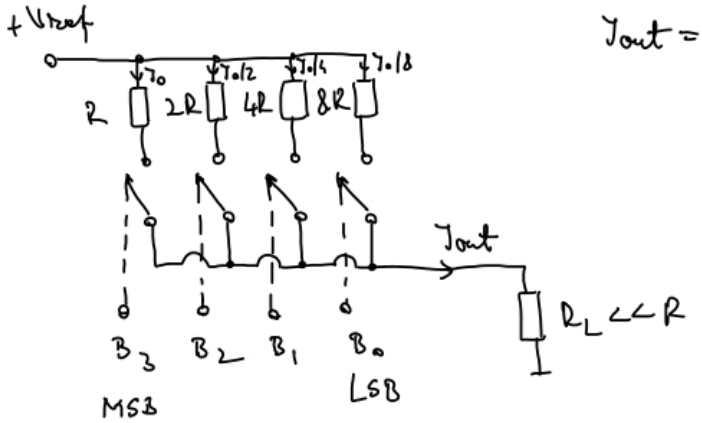
switch electronic → poartă de transmisie CMOS



control	A	B
1	0	0
1	1	1
0	0	High-Z
0	1	High-Z

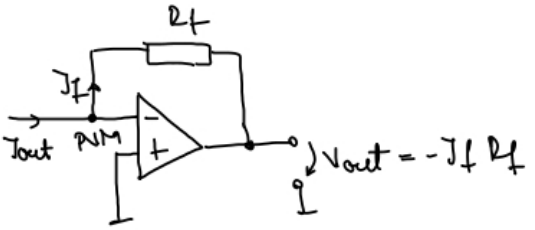


a) DAC cu ieșire în curent



$$I_{out} = B_3 I_0 + B_2 \frac{I_0}{2} + B_1 \cdot \frac{I_0}{4} + B_0 \frac{I_0}{8}$$

$$I_0 = \frac{V_{ref}}{R}$$



P6. $R = 10\,k\Omega$, $V_{ref} = 10V$, $R_L = 0$

DAC pe 4 biți cu output în curent

$R_{eș} = ?$, $A_{fs} = ?$

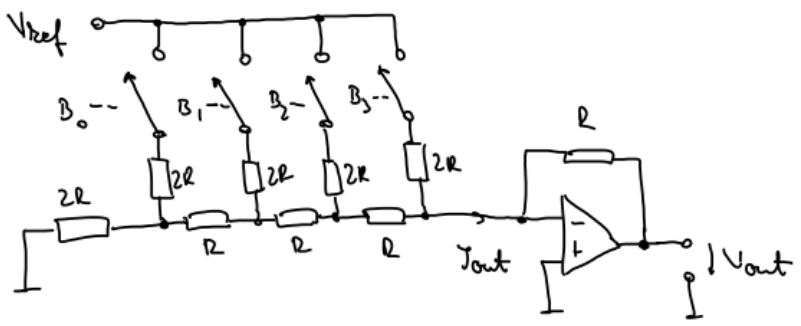
$$I_0 = \frac{V_{ref}}{R} = \frac{10V}{10k\Omega} = 1\ mA$$

$$A_{fs} = I_0 + \frac{I_0}{2} + \frac{I_0}{4} + \frac{I_0}{8} - I_0\left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}\right) =$$

$$= 1.875 \cdot I_0 = 1.875\ mA$$

$R_{eș}$ = ponderea LSB $= \frac{1}{8} \cdot I_0 = \frac{1}{8} \cdot 1mA = 0.125\ mA$

b) DAC cu scară R-2R



Deducere → la seminar

$$V_{out} = -V_{ref}\left(\frac{B_0}{2^4} + \frac{B_1}{2^3} + \frac{B_2}{2^2} + \frac{B_3}{2^1}\right)$$

LSB MSB

P7.)

DAC R-2R pe 4 biți

$V_{ref} = 10V$

$R_{ef} = ?$

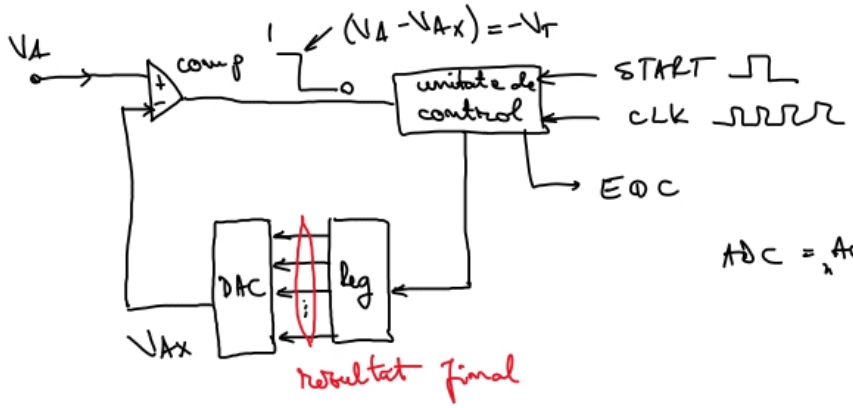
$A_{fs} = ?$

$$R_{ef} = -V_{ref} \cdot \frac{1}{16} = -\frac{10}{16} = -0.625V$$

$$A_{fs} = -V_{ref}\left(\frac{1}{16} + \frac{1}{8} + \frac{1}{4} + \frac{1}{2}\right) =$$

$$= -\frac{15}{16} \cdot 10 = -9.375V$$

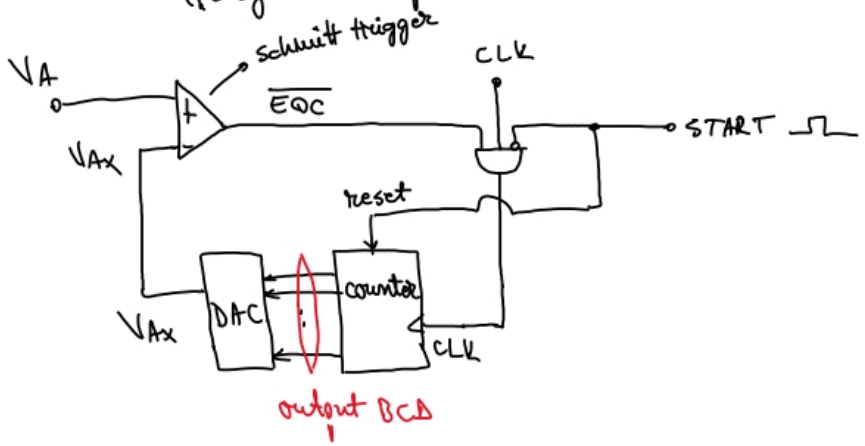
Conversia analog-digitală:

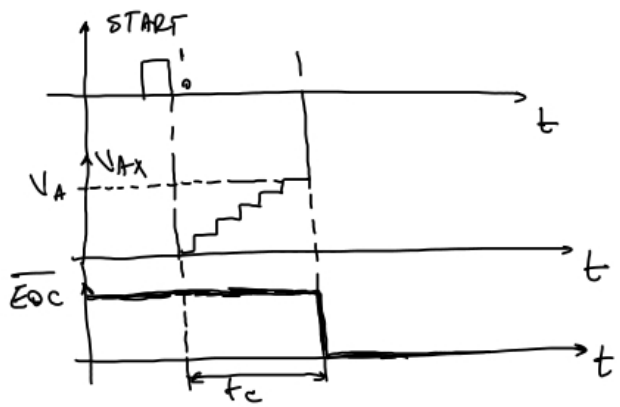


ADC = „Analog-to-Digital Converter"

·) Convertorul analog-digital cu rampă digitală:

(„digital ramp ADC")





P8.

$t_c = ?$ $\quad V_A = 3.728V$

$res = ?$ $\quad f_{CLK} = 1MHz$

$V_T = 0.1 mV$

DAC pe 10 biți $\quad A_{fs} = 10.23V$

Nr. de pași pt. DAC $= 2^{10} - 1 = 1023$

$$k = \frac{A_{fs}}{2^{10}-1} = \frac{10.23}{1023} = 10mV$$

$\Rightarrow$ $res = 10 mV$

$V_A = 3.728V$

Basculare Schmitt trigger:

$$V_{Ax} = V_A + V_T = 3.728V + 0.0001V = 3.7281V$$

$$\text{nr. de pași} = \frac{3.7281}{10mV} = 372.81 \simeq 373 \text{ pași}$$

$$f = 1MHz \Rightarrow T_{CLK} = 1\mu s \Rightarrow t_c = 373 \times 1\mu s = 373\mu s$$

i) Acuratețea ADC $\quad \pm m$ LSB

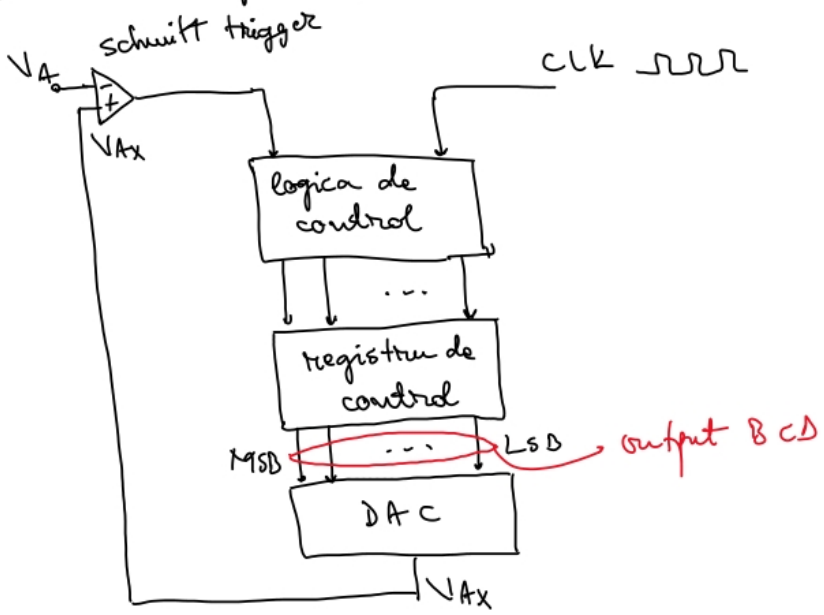
$m < 1$

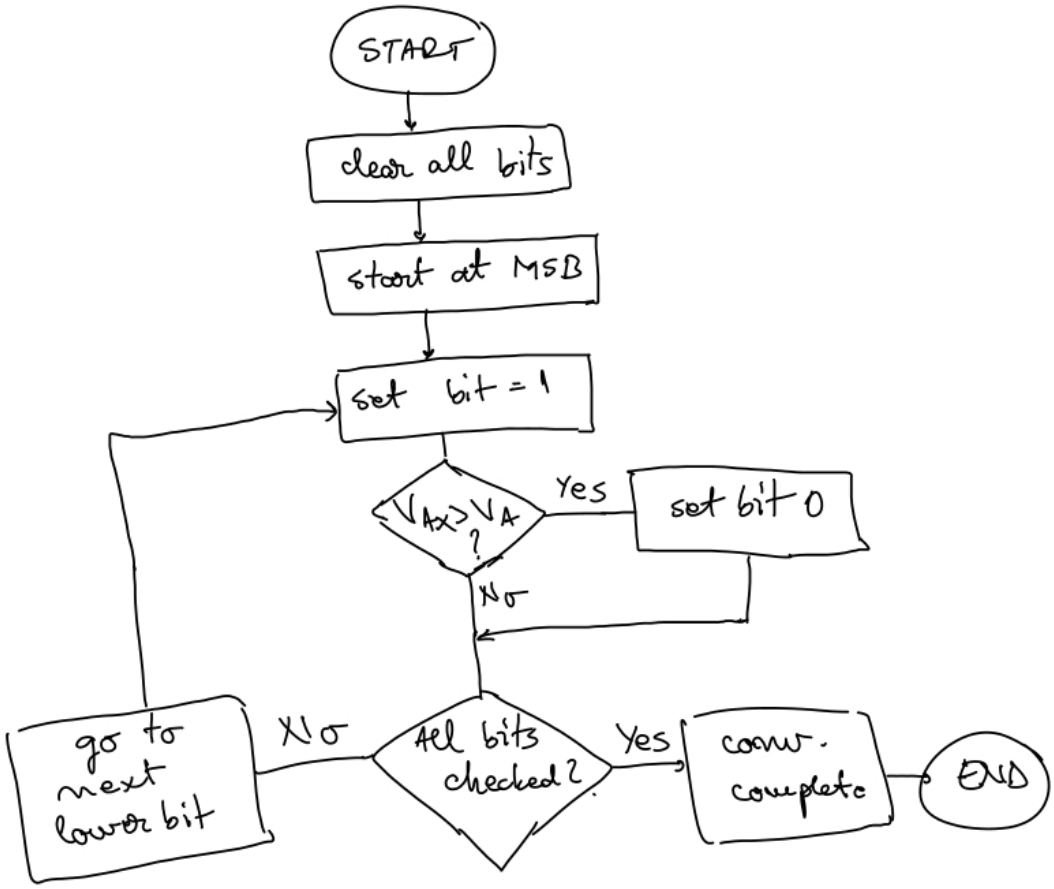
ii) timpul de conversie

$t_c^{max} = (2^N - 1)$ cicluri CLK

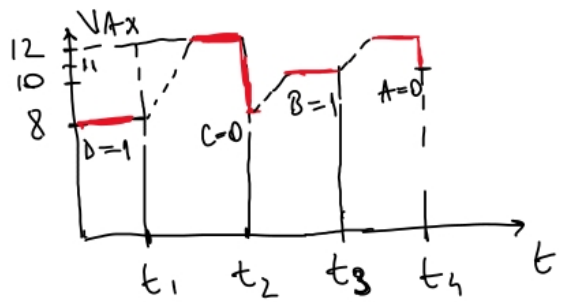
$t_c^{avg} = \frac{t_c^{max}}{2} = 2^{N-1} - 1 \simeq 2^{N-1}$ cicluri CLK

ADC cu aproximații succesive:





Ex.



DAC pe 4 biți $k = 1V$

$V_A = 10.4V$

start

D	C	B	A	
0	0	0	0	
1	0	0	0	t_1
1	0	0	0	t_2
1	0	1	0	t_3
1	0	1	0	t_4

$t_c = N \, t_{CLK}$

$t_c = 4 \times t_{CLK}$.