

III Chaine de mesure de $T^{\circ}\text{C}$ ($P_T = 100$)

$$R(T) = \sigma \cdot T + R(0)$$

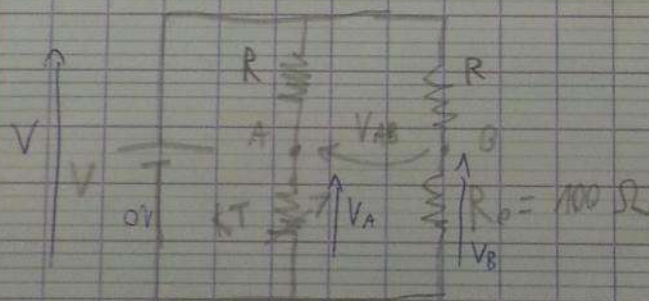
$$R(0) = 100 \Omega$$

$$\text{Graph: } \sigma = \frac{250 - 100}{500 - 0} = \frac{15}{50} = \frac{3}{8} = 0,375 \Omega/^{\circ}\text{C}$$

$$\text{Num: } R(T) = R(0) \cdot (1 + AT + BT^2 - 100CT^3 + CT^4)$$

$$\begin{cases} A = 3,81 \cdot 10^{-3} ^{\circ}\text{C}^{-1} \\ B = -6,02 \cdot 10^{-2} ^{\circ}\text{C}^{-2} \\ C = -6 \cdot 10^{-12} ^{\circ}\text{C}^{-3} \end{cases}$$

$$R(T) = \underbrace{R(0)}_{100 \Omega} + \underbrace{A \cdot R(0)}_{\sigma = 0,381 \Omega/^{\circ}\text{C}} T + \underbrace{B R(0)}_{-6,02 \cdot 10^{-5}} T^2 - \underbrace{100 R(0) C}_{6 \cdot 10^3} T^3 + \underbrace{R(0) C}_{6 \cdot 10^{-9}} T^4$$



On veut $V_{AB} = 0 \text{ V}$ pour $T = 0^{\circ}\text{C} \Rightarrow R_0 = 100 \Omega$

$$V_{AB} = \left(\frac{R_T}{R + R_T} - \frac{R_0}{R + R_0} \right) V \Rightarrow V_A - V_B \Rightarrow \frac{R_T V}{R + R_T} - \frac{R_0 V}{R + R_0}$$

$$V_{AB} = \left(\frac{R_T(R + R_0) - R_0(R + R_T)}{(R + R_T)(R + R_0)} \right) V$$

$$V_{AB} = \frac{R R_T - R R_0}{(R + R_T)(R + R_0)} V$$

$$V_{AB} = \left(\frac{R}{R+R_0} \right) \cdot \left(\frac{R_T - R_0}{R_T + R} \right) V$$

$R_T \ll R$

$$V_{AB} \approx \left(\frac{1}{R+R_0} \right) (R_T - R_0) V$$

$$V_{AB} \approx \left(\frac{1}{R+R_0} \right) (R_T - R_0) V$$

$$V_{AB} \approx \frac{0 \text{ V}_T}{R+R_0} \quad \text{on néglige}$$

Sensibilité :

$$\alpha = \frac{0 \text{ V}}{R+R_0} \text{ V/}^\circ\text{C}$$

A.N : $V = 15 \text{ V}$

$R = 1 \text{ k}\Omega$ ($10 \text{ k}\Omega$)

$$\Rightarrow \alpha \approx \frac{0,38 \cdot 15}{1000} = 0,0057 = 5,7 \text{ mV/}^\circ\text{C}$$

Etape d'amplification

$V_{AB} \rightarrow$

$G?$

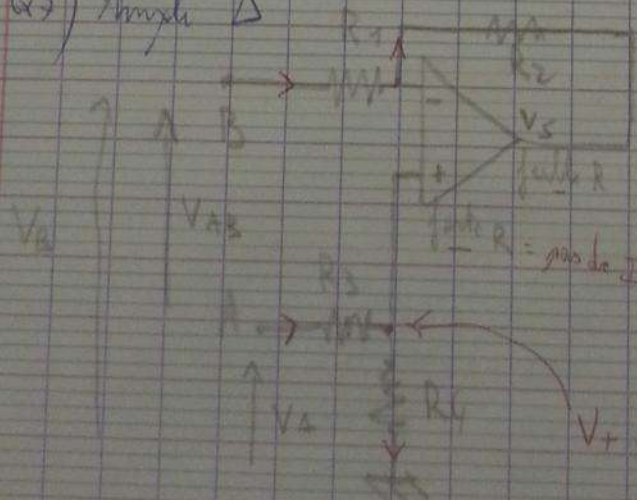
$-15 \text{ V} \leq V_s \leq 15 \text{ V}$

$\downarrow$
 $\pm 15 \text{ V}$

$$\begin{aligned} &\pm 5,7 \cdot 10^{-3} \times 20 \\ &\pm 0,112 \text{ V} \end{aligned}$$

$G = 100$

Q2) Ampli Δ



Relativement aux de -
d'après $U = R \cdot I$ $I = \frac{V}{R}$

$$\frac{V_2 - V_1}{R_1} = V - \frac{-V_s}{R_2}$$

$$\frac{V_s}{R_2} = \frac{V_2}{R_2} + \frac{V_1}{R_1} - \frac{V_s}{R_1}$$

$$V_+ = \frac{R_4}{R_3 + R_4} V_A$$

$$V_+ = V_-$$

$$V_s = G V_{AB}$$

$$\frac{V_s}{R_1} = \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \frac{R_2}{R_2 - R_1} V_2 - \frac{V_2}{R_1}$$

$$V_s = \left[\left(1 + \frac{R_2}{R_1} \right) - \frac{1}{1 - \frac{R_2}{R_1}} \right] V_2 - \frac{R_2}{R_1} V_2$$

On veut factoriser pour avoir V_{AB}
 $V_A - V_B$

$$\text{Soit } \frac{1 + \frac{R_2}{R_1}}{1 - \frac{R_2}{R_1}} = \frac{R_2}{R_1}$$

$$1 + \frac{R_2}{R_1} = \frac{R_2}{R_1} \left(1 + \frac{R_2}{R_1} \right)$$

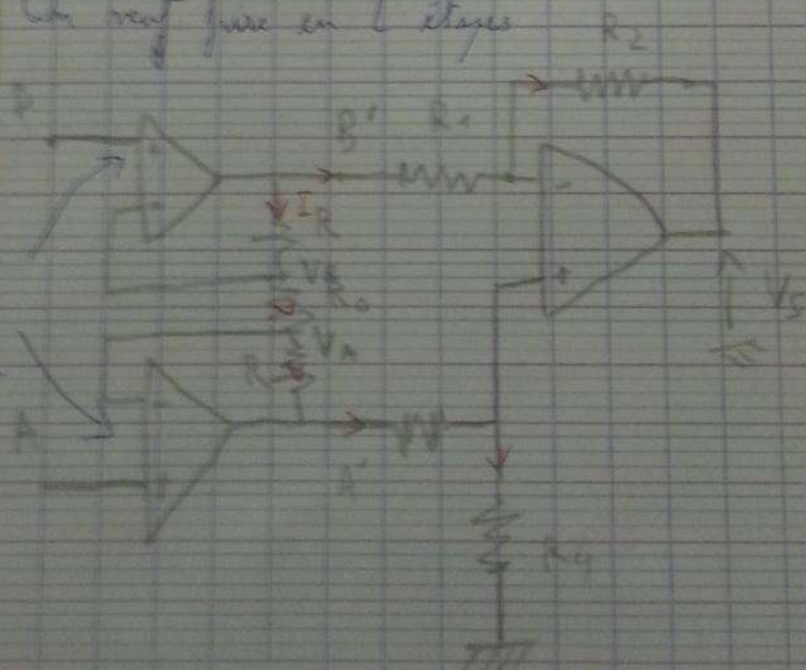
$$1 = \frac{R_2 R_1}{R_2 - R_1}$$

$$\text{Soit } [R_2 R_1 = R_2 - R_1] \Rightarrow V_s = \frac{R_2}{R_1} (V_A - V_B) = \frac{R_2}{R_1} V_{AB}$$

Pour l'appli avec $PT=100 \Rightarrow \frac{R_2}{R_1} = 100$

On veut faire en 2 étages

N° Ampli
pas 1
Isoler le capteur
de l'ampli



$$I = \frac{V_B - V_A}{R_1} = \frac{V_B' - V_A'}{2R_1 + R_2}$$

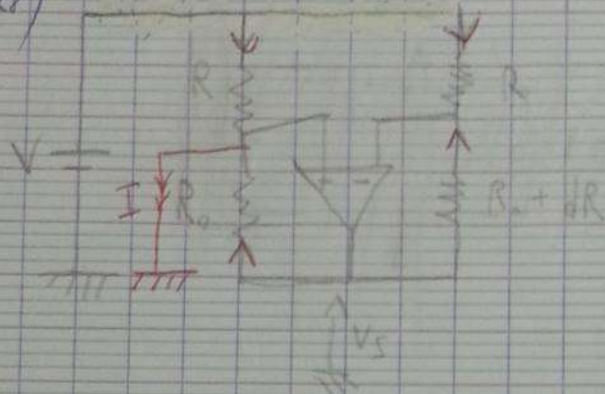
$$V_B' - V_A' = \left(\frac{2R_1 + R_2}{R_1} \right) (V_B - V_A)$$

$$V_{AB}' = \left(1 + \frac{2R_1}{R_2} \right) V_{AB}$$

$$V_s = \frac{R_2}{R_1} V_{AB}'$$

$$V_s = \frac{R_0}{R_1} \left(1 + \frac{2R}{R_0} \right) V_{AB}$$

Q3)



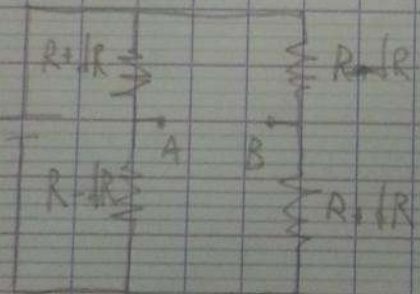
$$I = \frac{V}{R} + \frac{V_s}{R_0}$$

$$\frac{V_s}{R_0 + dR} + \frac{V}{R} = 0 \Rightarrow V_s = -\frac{R_0 dR}{R}$$

$$V_s I = \left[\frac{1}{R} - \frac{1}{R_0 + dR} \right] V = -\frac{dR V}{R R_0}$$

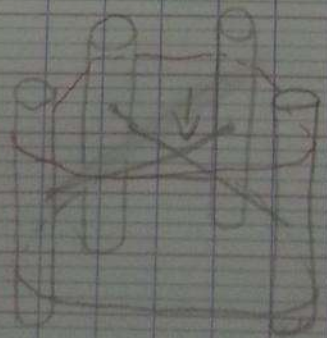
$$I = \frac{-V dR}{R R_0}$$

Q4 Rapp'd \$\rightarrow\$ of course

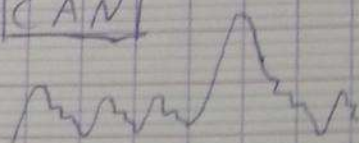


A 100g. \$R = 4 \text{ k}\Omega\$

$$V_{AB} = -\frac{dR}{R} \cdot E$$



CAN



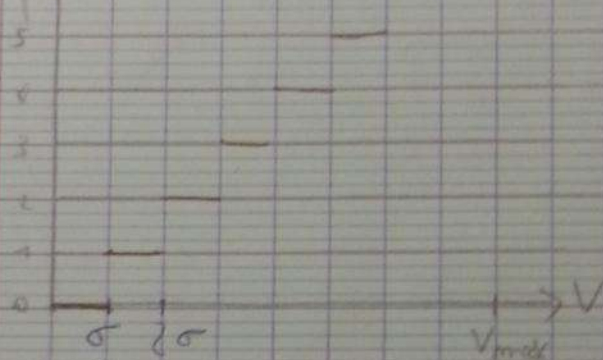
A
N

$$N = \sum_{i=0}^{n-1} b_i 2^i$$

codage sur n bits

1) Quantification

V_q



$$\frac{V_{max}}{\sigma} = N+1$$

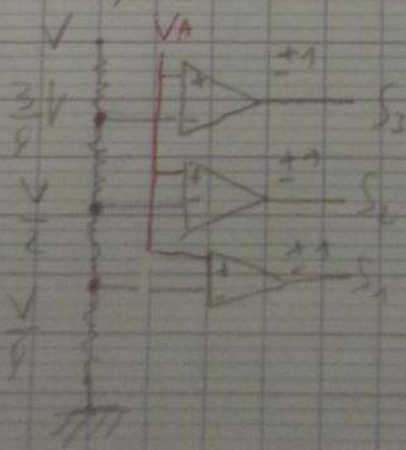
σ : pas de quantification

$N+1$: Nombre de niveaux

Résolution - Pas
généralisé
 $= \frac{\sigma}{V_{max}}$

2) Technique Flash (CAN Flash)

Exemple sur 4 niveaux



	S_3	S_2	S_1
$V_A < 0$	-1	-1	-1
$0 < V_A < 20$	-1	-1	1
$20 < V_A < 30$	-1	1	1
$30 < V_A < 40$	1	1	1

ici $\sigma = \frac{V}{8}$

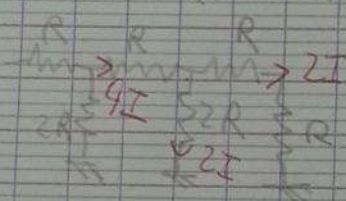
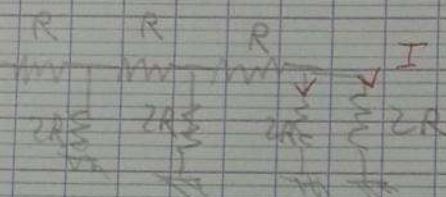
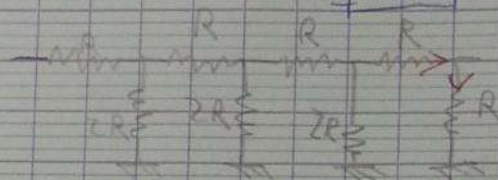
Niveau	bits
0	00
1	01
2	10
3	11

Codage sur n bits

$$N+2^n$$

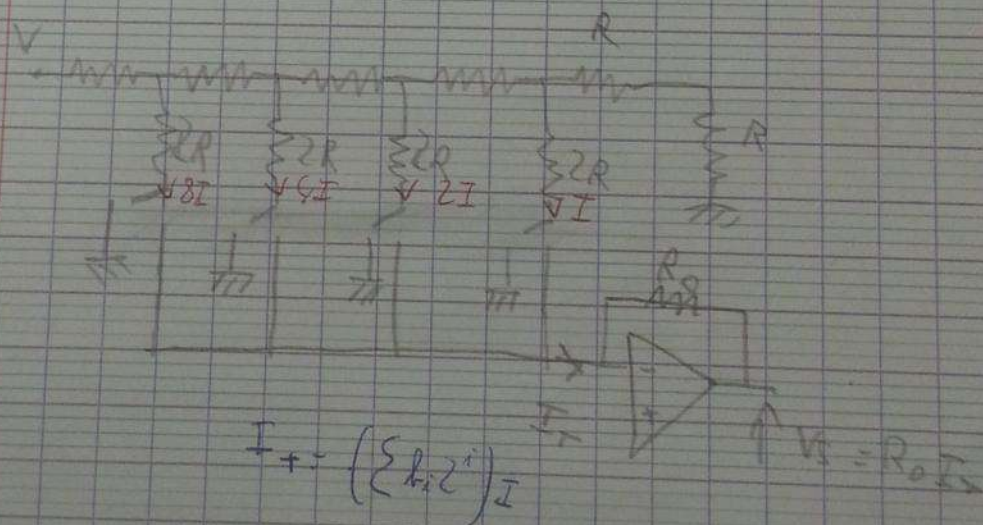
Δ Coût et encombrement

3) CNA
Technique R-2R



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{2R} + \frac{1}{2R} = \frac{1}{R}$$



Ex. Calculer la tension de la PE d'un CNA 4 bits avec 1 pas de Q de 10 mV. Résolution

Niveau 2¹⁰

$$V_{max} = (2^{10} - 1) \sigma = 1023 \times 10 \cdot 10^{-3} = 10V$$

$$\rho = \frac{\sigma}{V_{max}} = 0,1\%$$

$n = 5 \text{ bits}$ $0 \leq V_A \leq 15V$

$\sigma = 1V$

V_A : la sortie du CNA

"Image miroir" de V_A

signe	M	N	i	$V_m (V_{ref})$	$V_N > V_A$
	1100	1000	0	8	F
	0110	1100	1	12	V
	0011	1010	2	10	F
	0001	1011	3	11	V
	0000	1010	4	10	F

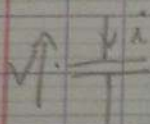
Pour 1 conv sur 8 bits?

$M = 1100 \ 0000$

$N = 1000 \ 0000$

Concours

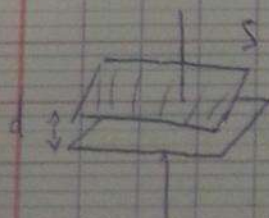
Capteurs CAPACITIFS



$$C = \frac{Q}{V}$$

$$\begin{cases} i = \frac{dQ}{dt} \\ i = C \frac{dV}{dt} \end{cases}$$

Condensateur plan:



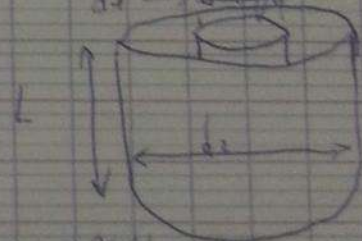
$$C = \epsilon \frac{S}{d}$$

ϵ : permittivité diélectrique de l'isolant

$$\epsilon = \epsilon_r \epsilon_0$$

relative $\Rightarrow$ vide

Condensateur cylindrique:

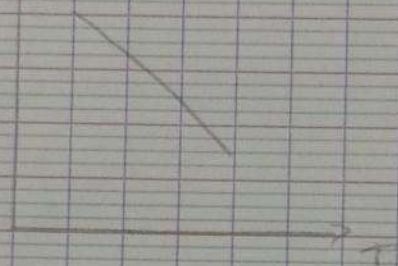


$$C = \frac{2\pi\epsilon L}{\ln(r_2/r_1)}$$

Application: variation de géométrie
 ↳ Déplacement (force, viscosité)
 Variation de ϵ
 ↳ TC, milieu chimique.

1) Mesure de TC

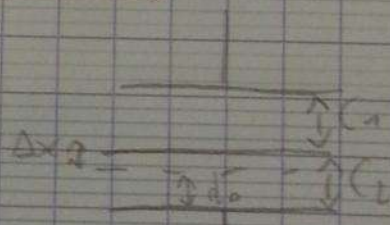
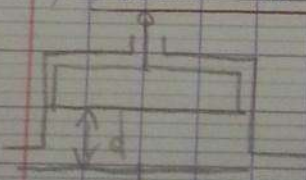
$\Delta \epsilon$



$$\epsilon_a(T) = \epsilon_a(T_0) (1 - A(T - T_0))$$

TC $\approx 1000^\circ\text{C}$: Céramique

2) Mesure de Déplacement



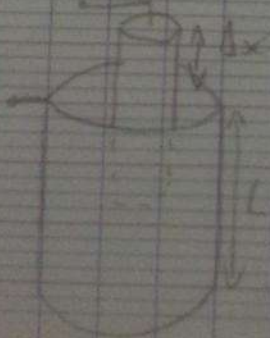
$$C = \epsilon \frac{S}{d}$$

Deux Cops différentielle

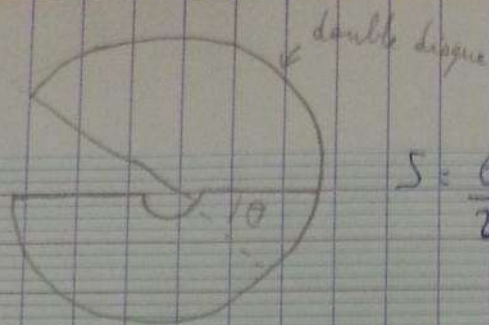
$$C_1 = \epsilon \frac{S}{d_0 + \Delta x}$$

$$C_2 = \epsilon \frac{S}{d_0 - \Delta x}$$

Tres Non linéaire



$$C = \frac{2\pi\epsilon(L - \Delta x)}{\ln\left(\frac{r_2}{r_1}\right)}$$



$$S = \frac{\theta}{2} R^2$$

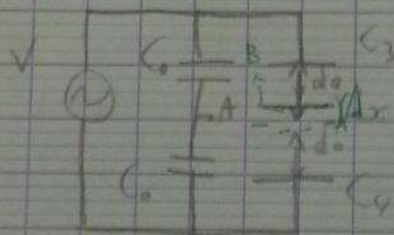
TD n°3

Avec $C_1 = C_2 = C_0$

C_3 et C_4 à que le condensateur différentiel tel que

$$C_1 = \epsilon \frac{S}{d_0 + \Delta x} \quad \text{et} \quad C_4 = \epsilon \frac{S}{d_0 - \Delta x}$$

- 1) A quelle cd sur ce pont est-il équilibré pour $\Delta x = 0$?
- 2) Exprimer la sortie du pont $V_{\Delta x}$
- 3) Terminer le circuit de conditionnement



$$C_3 = \epsilon \frac{S}{d_0 \left(1 + \frac{\Delta x}{d_0}\right)}$$

$$C_4 = \epsilon \frac{S}{d_0 \left(1 - \frac{\Delta x}{d_0}\right)}$$

pour $\Delta x = 0$ $C_3 = C_4 = \epsilon \frac{S}{d_0}$

$\Rightarrow$ Equilibre, alors

$$V_{AB} = 0$$

$$= \frac{1}{2} V - \frac{\frac{1}{C_3}}{\frac{1}{C_3} + \frac{1}{C_4}} V$$

$$= \left(\frac{1}{2} - \frac{\frac{1}{C_3}}{\frac{1}{C_3} + \frac{1}{C_4}} \right) V$$

$$= \left(\frac{1}{2} - \frac{1 - \Delta x / d_0}{\left(1 - \frac{\Delta x}{d_0}\right) + \left(1 + \frac{\Delta x}{d_0}\right)} \right) V$$

$$V_{AB} = \frac{1}{2} \left(1 - \left(1 - \frac{\Delta x}{d_0} \right) \right) V$$

$$V_{AB} = \frac{1}{2} \frac{\Delta x}{d_0} V$$

$$V = V_m \sin(\omega t)$$

$$V_{AB} = \frac{\Delta x}{2d_0} V_m \sin(\omega t)$$

Terminer le circuit de cd $\rightarrow$ Amplitude

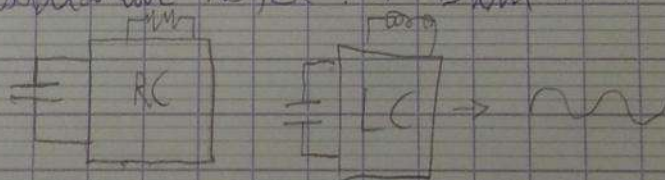
$\rightarrow$ Démodulateur AM

conclusion

g) Electronique associée

* part A + Démodulateur AM

* Oscillateur RC, LC + Dém FM

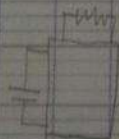


$$\text{Oscill } f_{RC} \approx \frac{1}{RC}$$

$$f_{LC} = \frac{1}{\sqrt{LC}}$$

* Multivibrateurs - Astable

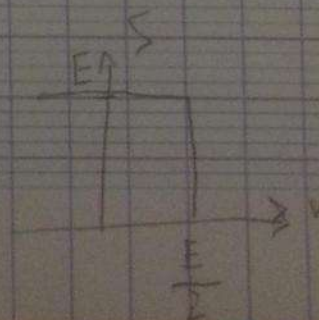
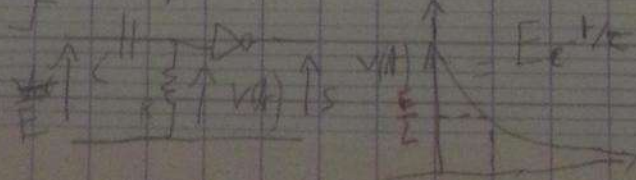
- monostable



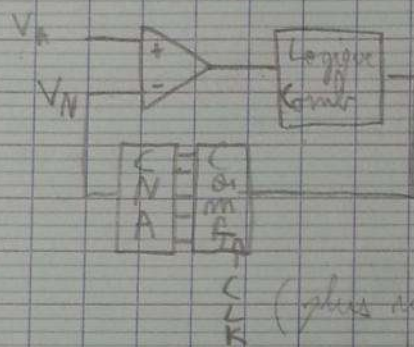
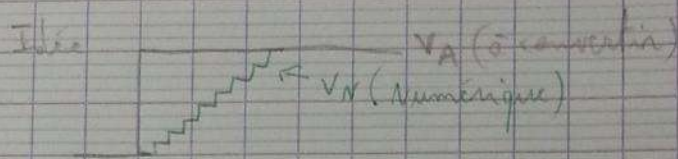
$\tau = RC$

Démo PWM

Ex: basique monostable



Cours : 3) CAN à Range Numérique



(plus rapide que le plein échelle à mesurer)

PB : Durée de conversion dépend de V_A

$$\frac{1}{f_{CLK}} < \text{durée} < \frac{2^n - 1}{f_{CLK}}$$

pour 1 CAN n bits

$$N = 2^n - 1$$

TD : Q1 CAN 10 bits - $f_{CLK} = 1 \text{ MHz}$

$$V_{max} = 10,23 \text{ V}$$

$$\text{Pas de conversion : } \sigma = \frac{V_{max}}{2^{10} - 1} = \frac{10,23}{1023} = 10 \text{ mV}$$

$$\text{Résolution : } p = \frac{\sigma}{V_{max}} = 0,1\%$$

$$V_A = 3,728 \text{ V}$$

$$N = \frac{V_A}{\sigma} = \frac{3,728}{10 \cdot 10^{-3}} = 372,8 \approx 373 \dots (010111010)$$

