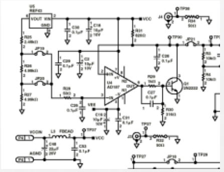
ANF IOT sept 2023

Du capteur à la numérisation

Introduction

Grandeur Physique

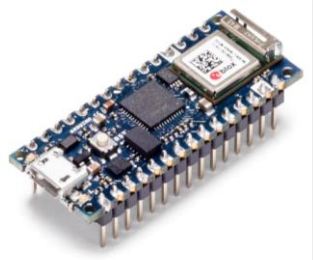


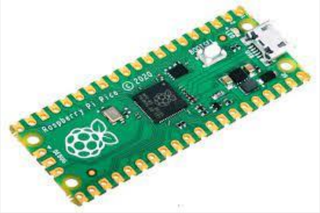
Signal analogique

Data Acquisition

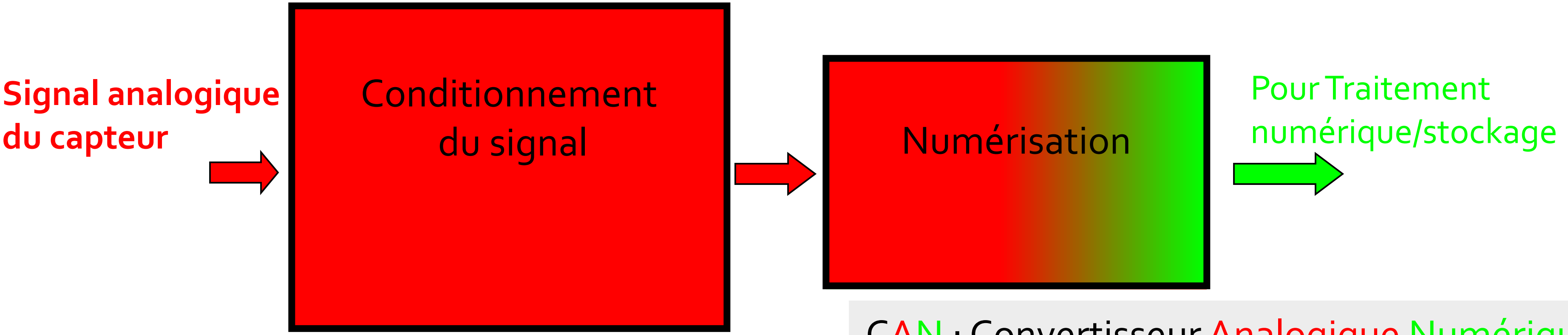
TNS/ stockage

Confitionnement
Niveaux (tension) et Fréquences





De l’analogique au numérique



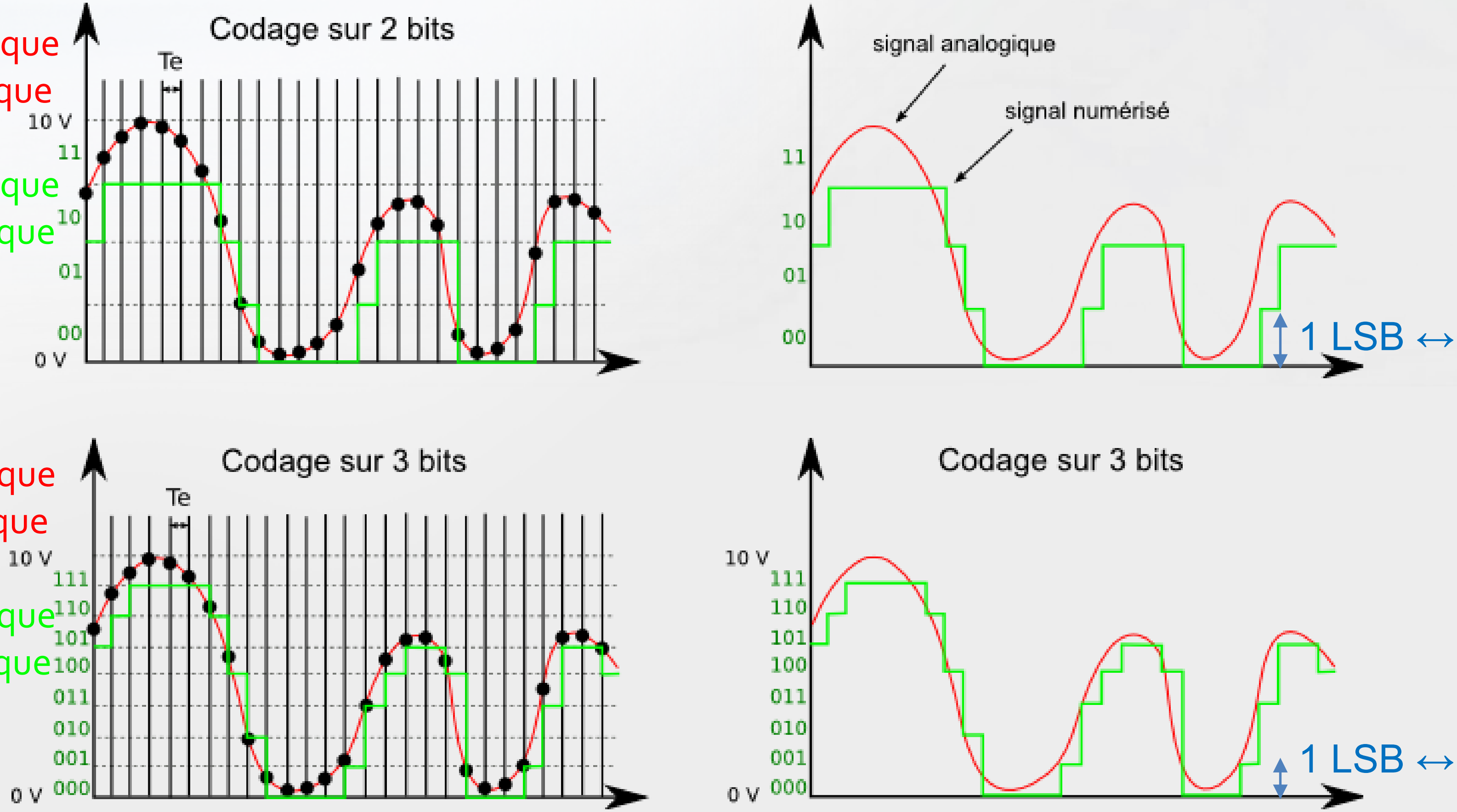
Signal analogique du capteur
Conditionnement du signal
Numérisation
Pour Traitement numérique/stockage

CAN : Convertisseur Analogique Numérique

Caractéristiques principales:

- Résolution en nombre de bits
- Fréquence d’échantillonnage

La numérisation – *(Résolution n bits)*



Dynamique analogique 10V

Dynamique Numérique $2^2 = 4$

1 LSB ↔ 2,5V*

Dynamique analogique 10V

Dynamique Numérique $2^3 = 8$

1 LSB ↔ 1,5V*

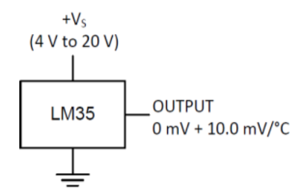
Fig 1

* Cas du codage plein échelle, nécessite un conditionnement du signal avant numérisation

La numérisation – dynamique/résoultion considération pratiques -

Ex: capteur de Température LM35
Sensibilité: 10mV/°C
Plage de mesure de température: 0->100°C

43AC
LM35
DZ



Dynamique grandeur physique : 100°C
Dynamique analogique sortie du capteur : 10mV/°C * 100%C = 1V

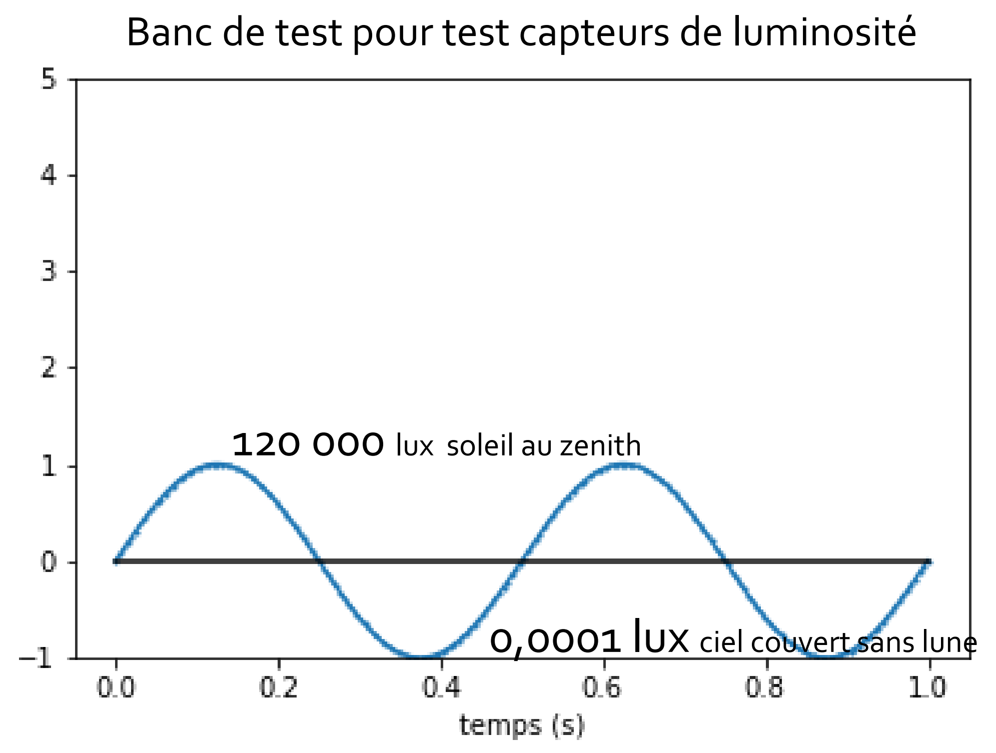
Si lecture (numérisation) capteur avec arduino UNO (exemple)

Arduino UNO (CAN 10bits)
Dynamique analogique : 5V LSB ↔ 5/1024 ≈ 4,9mV
Dynamique numérique: 2^{10}=1024

La lecture « directe » n’est pas adaptée:

- Une variation d’1°C ne correspond qu’à une variation de 2 bits (sur une dynamique de 1024)
- La plage de variation de tension en sortie du capteur ne correespond qu’à 20% du la plage de lecture de l’arduino UNO ➡ Utilisation d’un conditionneur

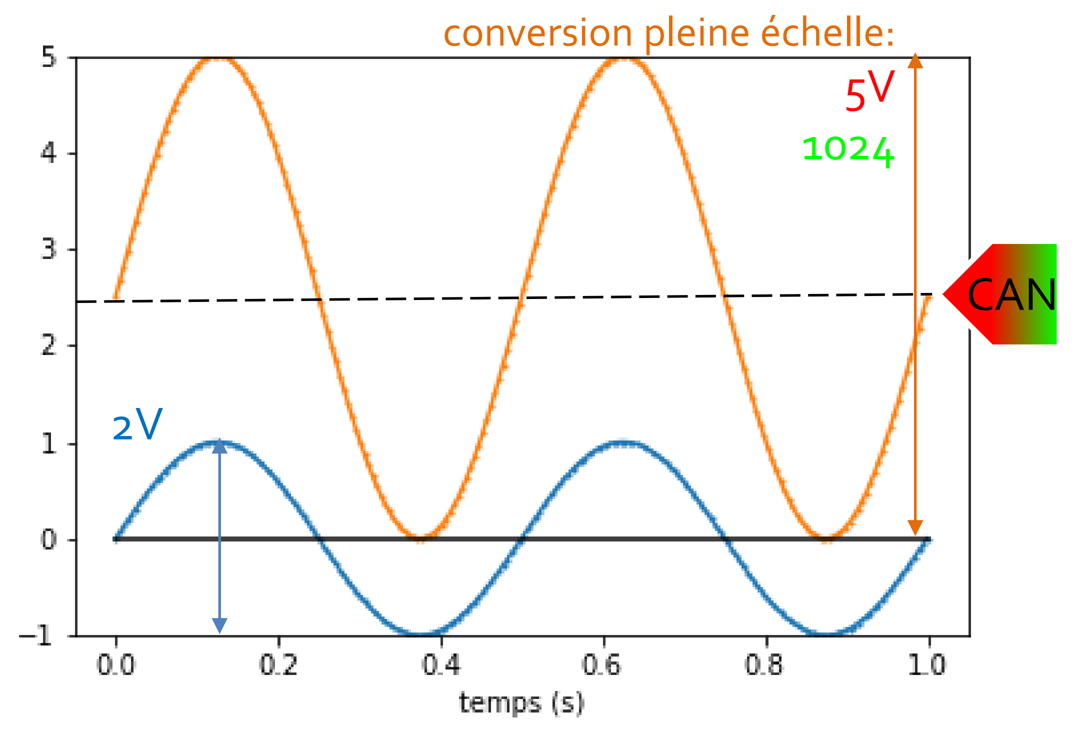
Le conditionneur


Banc de test pour test capteurs de luminosité

120 000 lux soleil au zenith

0,0001 lux ciel couvert sans lune

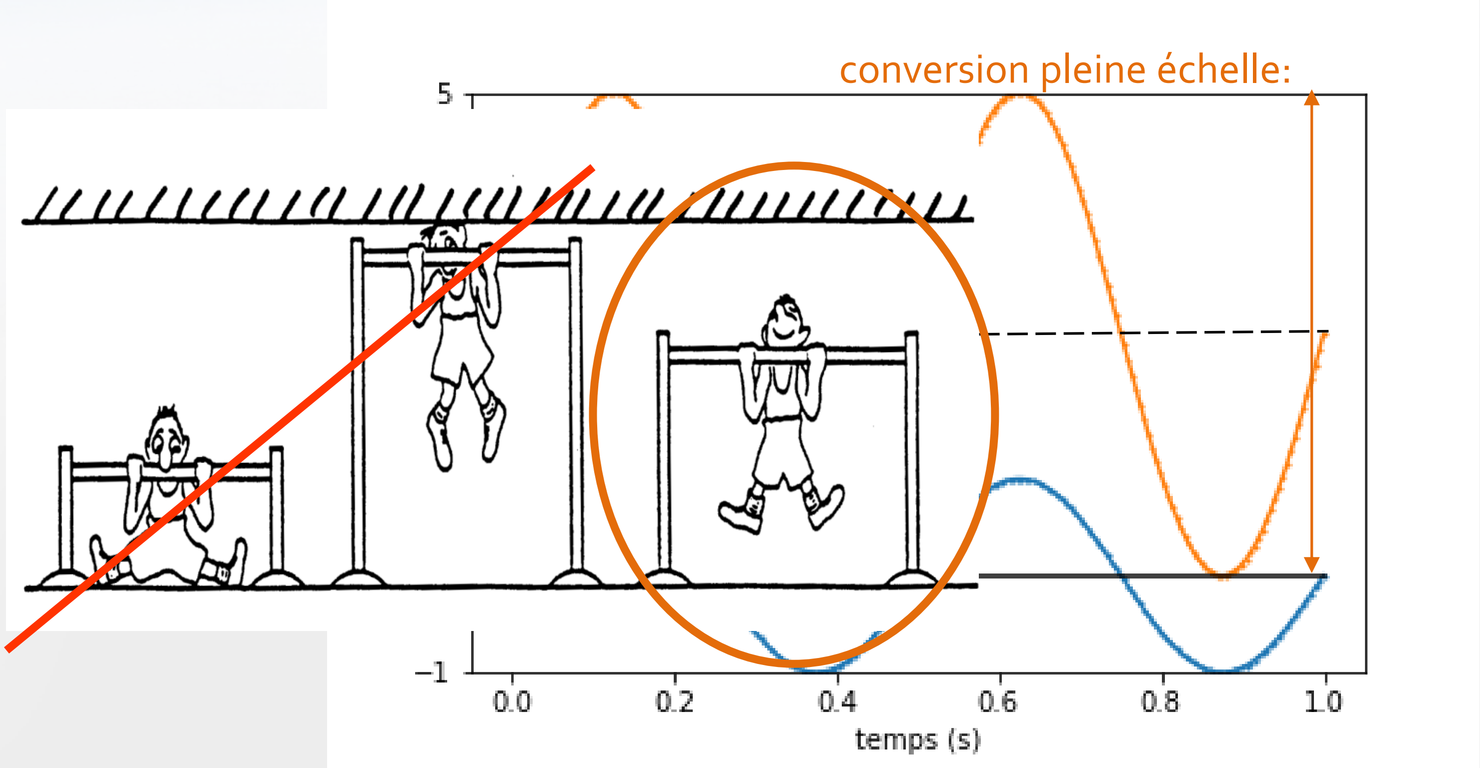
Le conditionneur



Conditionneur : 2 actions

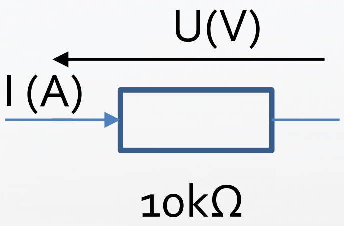
- amplification x2.5
- décalage 2.5V

Le conditionneur – dynamique-

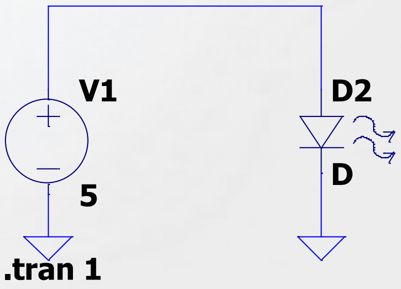


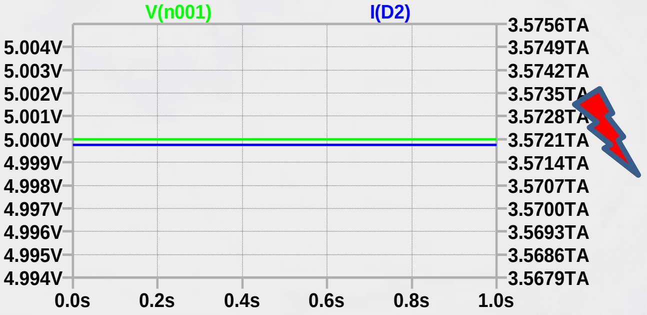
Réalisation d'un conditionneur – composants fréquents

La résistance (ohm)

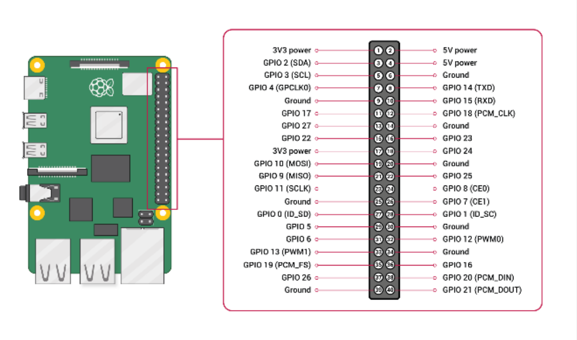


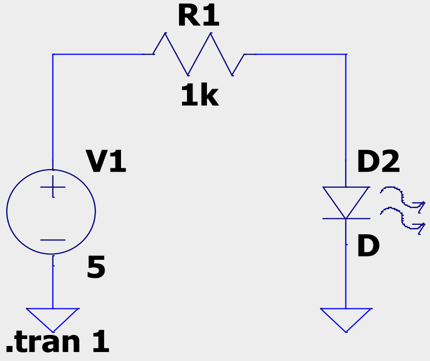
U=Ri

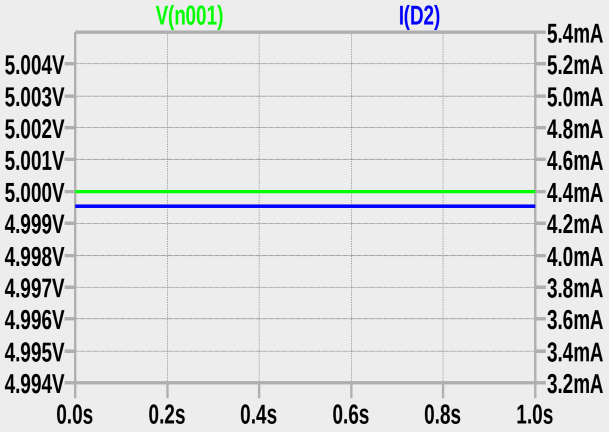

V1
5
D2
D
.tran 1



>>>Permet la limitation de courant <<<

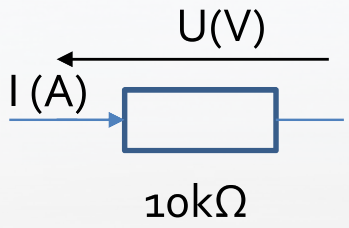

3V3 power
5V power
GPIO 2 (SDA)
5V power
GPIO 3 (SCL)
Ground
GPIO 4 (GPCLK0)
GPIO 14 (TXD)
Ground
GPIO 15 (RXD)
GPIO 17
GPIO 18 (PCM_CLK)
GPIO 27
Ground
GPIO 22
GPIO 23
3V3 power
GPIO 24
GPIO 10 (MOSI)
Ground
GPIO 9 (MISO)
GPIO 25
GPIO 11 (SCLK)
GPIO 8 (CE0)
Ground
GPIO 7 (CE1)
GPIO 0 (ID_SD)
GPIO 1 (ID_SC)
GPIO 5
Ground
GPIO 6
GPIO 12 (PWM0)
GPIO 13 (PWM1)
Ground
GPIO 19 (PCM_FS)
GPIO 16
GPIO 26
GPIO 20 (PCM_DIN)
Ground
GPIO 21 (PCM_DOUT)


R1
1k
V1
5
D2
D
.tran 1



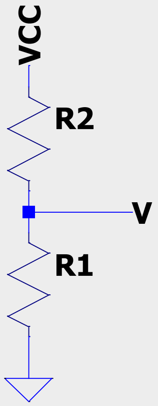
Réalisation d'un conditionneur – composants fréquents: 1 – la résistance

La résistance (ohm)



$U=Ri$

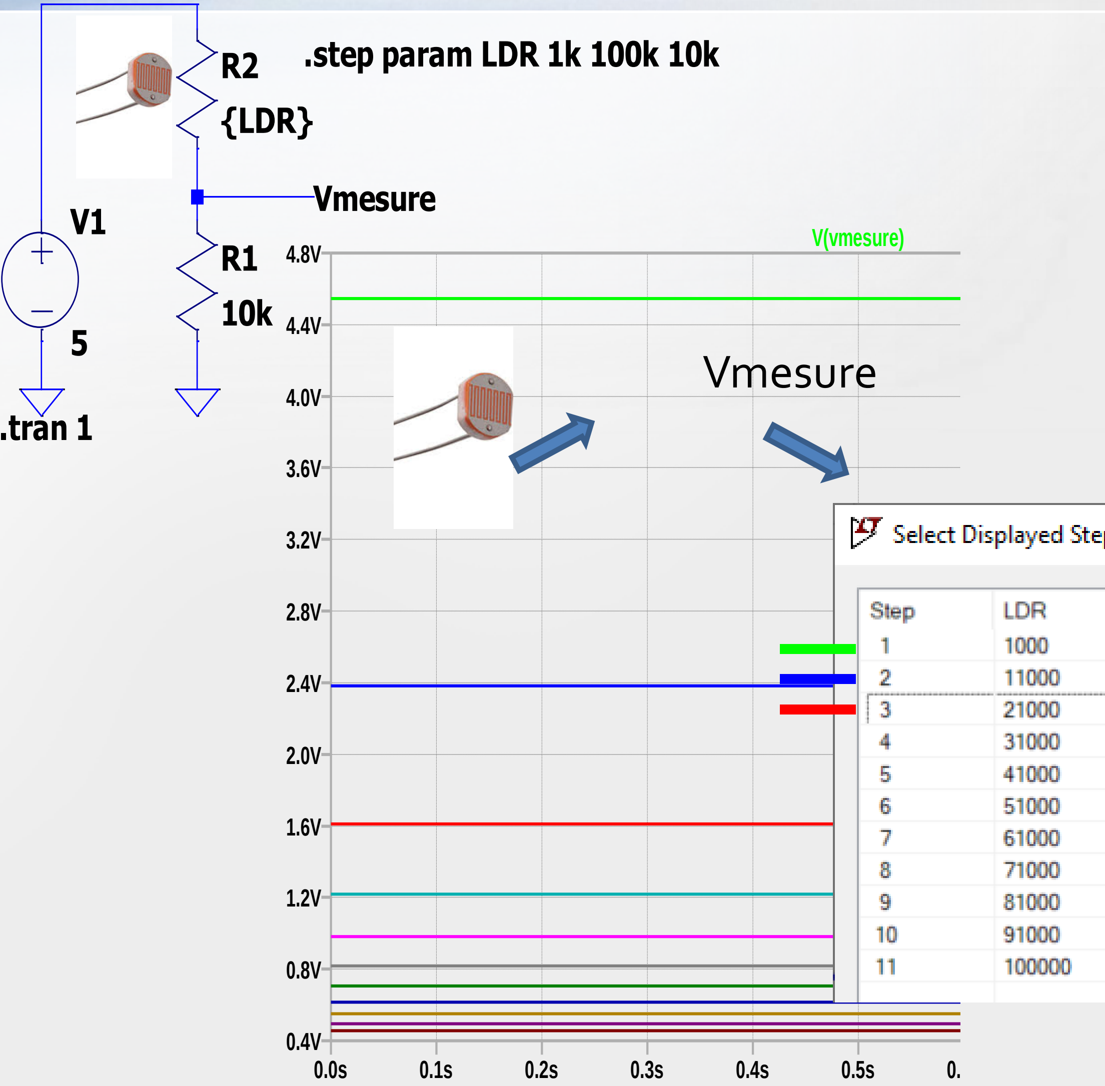
Le pont diviseur de tension



$$V=\frac{R1}{R1+R2}\text{xVcc}$$

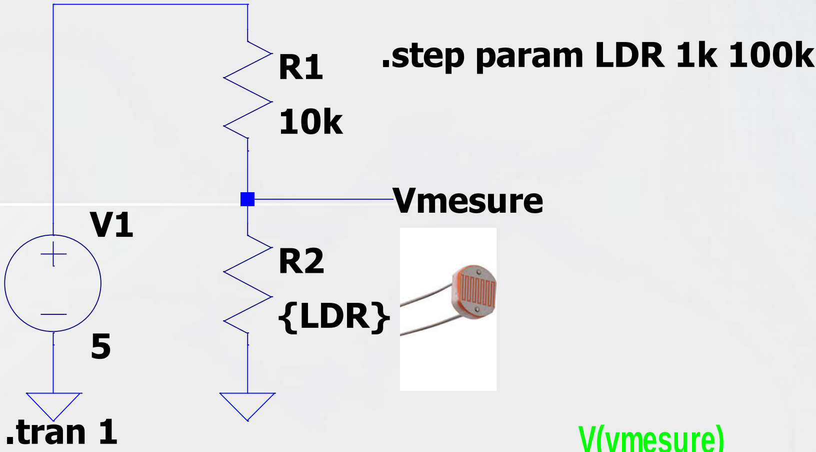
Utilisation directe
En instrumentation

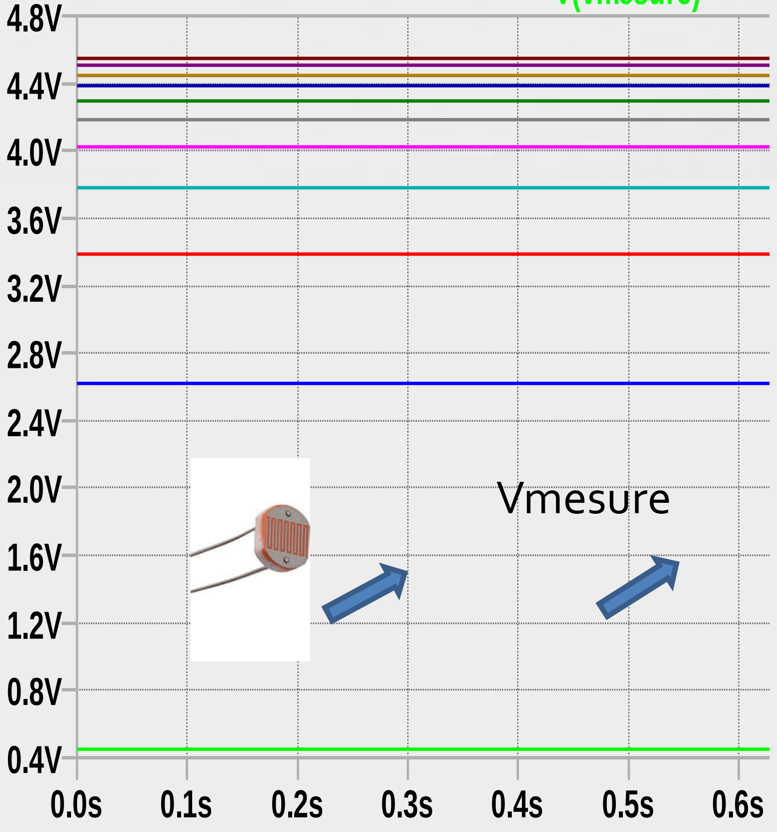
Exemple de lecture d'une LDR (Light Dependant Resistor)



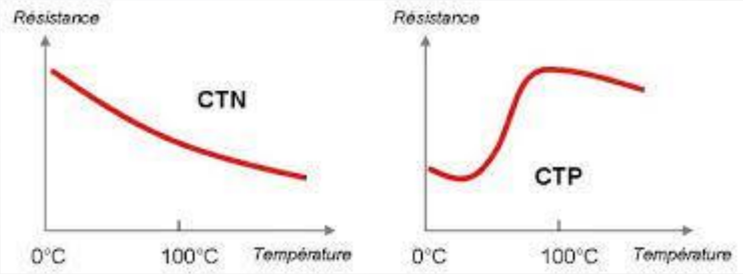
Select Displayed Steps

Step	LDR
1	1000
2	11000
3	21000
4	31000
5	41000
6	51000
7	61000
8	71000
9	81000
10	91000
11	100000

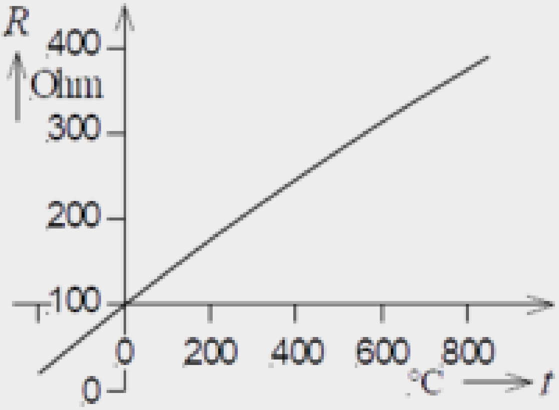

R1
10k
.step param LDR 1k 100k
Vmesure
V1
5
R2
{LDR}
.tran 1



(autres) Composants dont la résistance varie la température



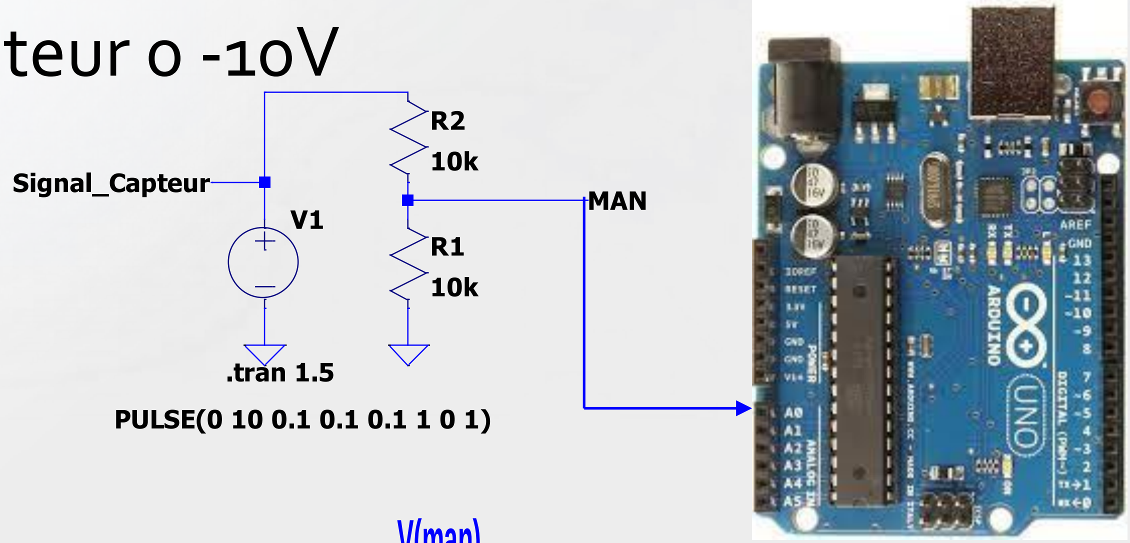
Sonde platine Pt100

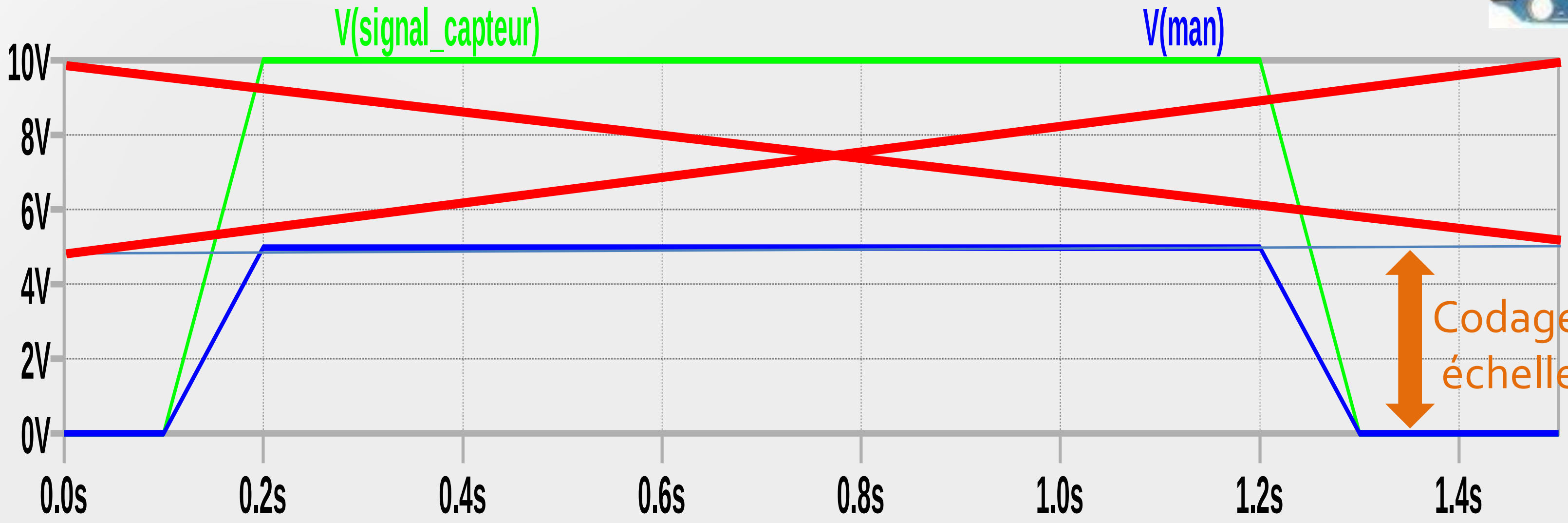


Crédit photo wiki

Utilisation du pont diviseur pour adaptation de niveau

- Utilisation d’un capteur 0 -10V


R2
10k
Signal_Capteur
V1
MAN
R1
10k
.tran 1.5
PULSE(0 10 0.1 0.1 0.1 1 0 1)



Codage pleine échelle 5V <- > 1024

Réalisation d'un conditionneur – composants fréquemment utilisés: 2- le condensateur

Le condensateur:

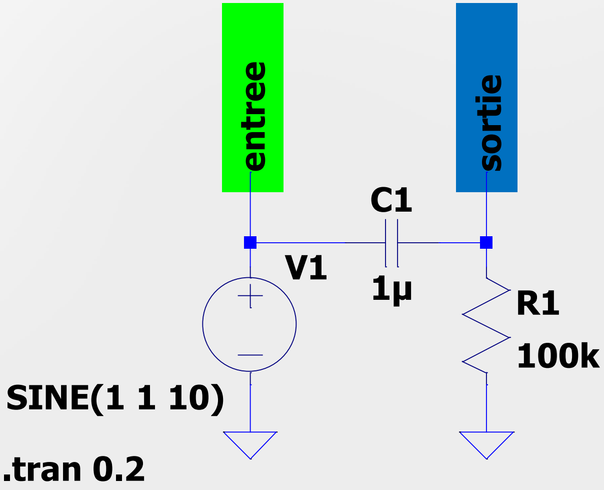
C = 100nF (ex)

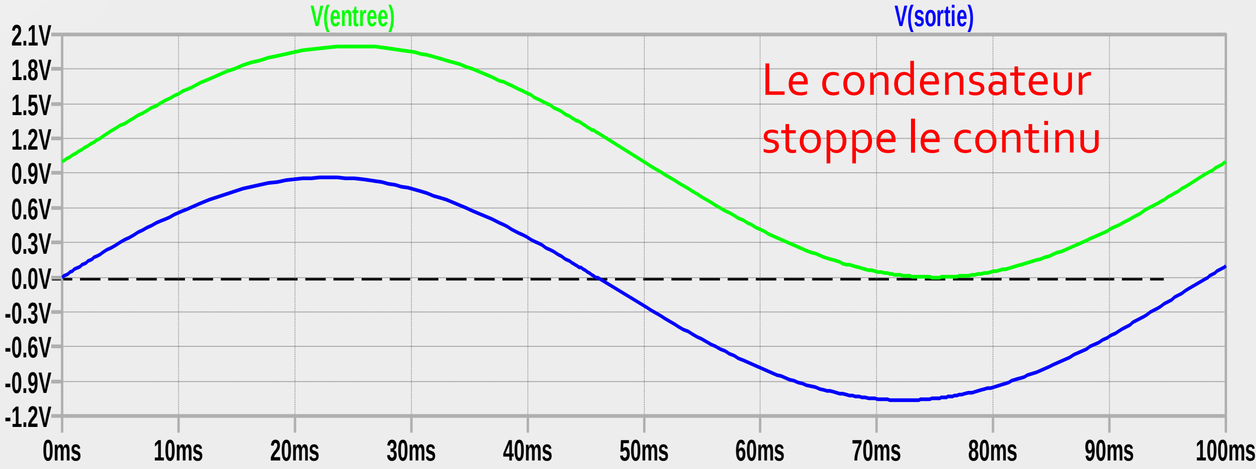
$Z = 1/j(c2*\pi*f)$

L'impédance dépend de la fréquence,

-> ∞ pour le continu (f= 0Hz)

En pratique

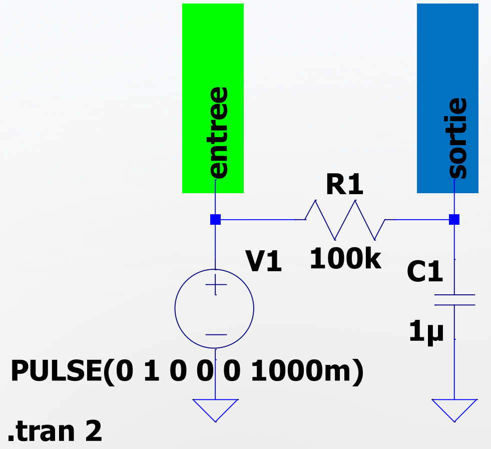

entree
sortie
C1
V1
1µ
R1
100k
SINE(1 1 10)
.tran 0.2

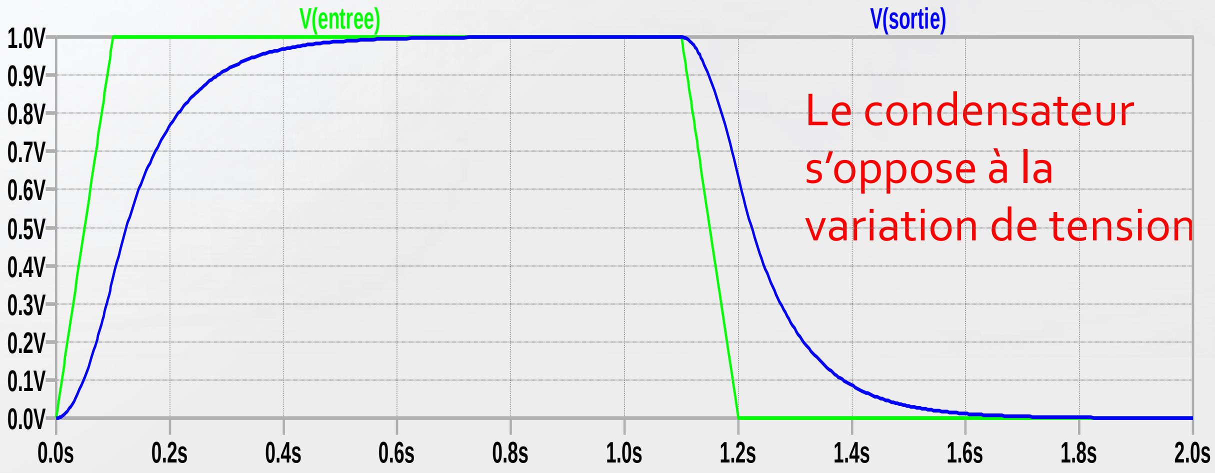


Le condensateur stoppe le continu

Réalisation d’un conditionneur - composants fréquents

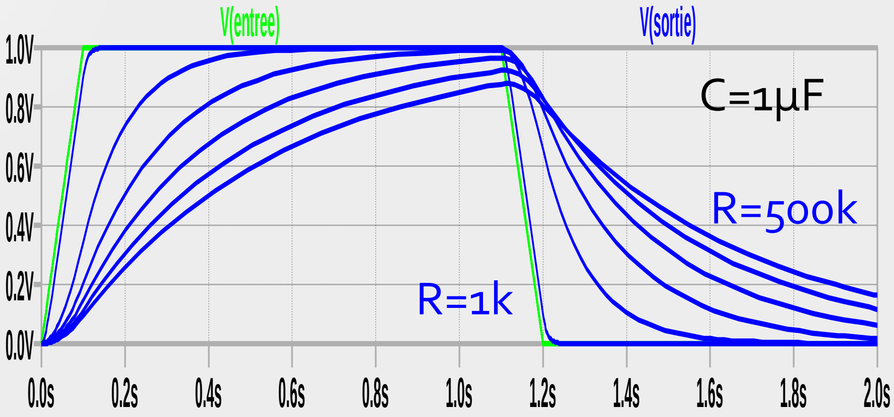
En pratique


entree
sortie
R1
V1
100k
C1
1µ
PULSE(0 1 0 0 0 1000m)
.tran 2



Le condensateur s’oppose à la variation de tension

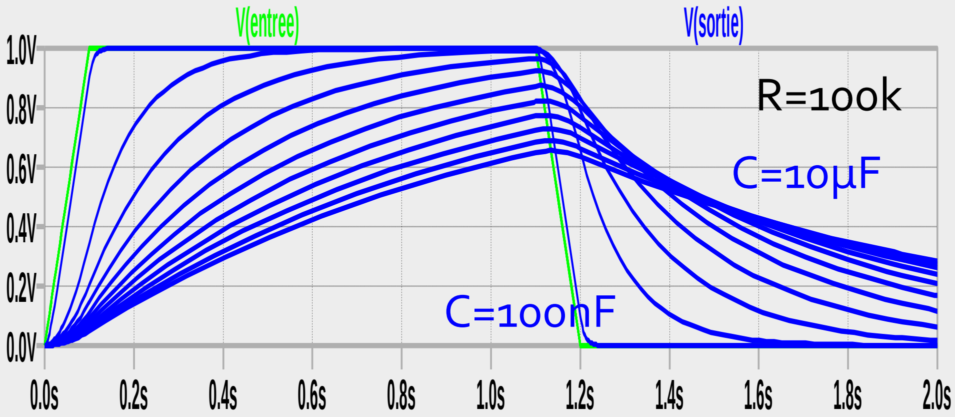
Effet de la constante RC (R.C)



C=1µF

R=500k

R=1k



R=100k

C=10µF

C=100nF

Le rapport Signal à Bruit ou (SNR: Signal to Noise Ratio)

Utilisation des connaissances à priori de la **grandeur physique à mesurer**

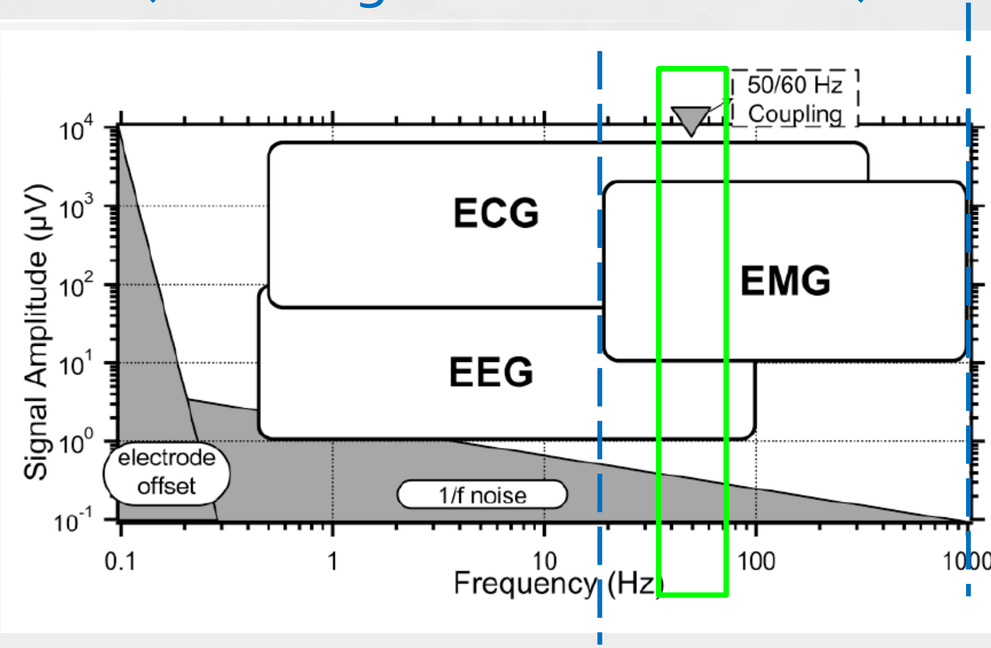


Figure 2. Thermal Time Constant

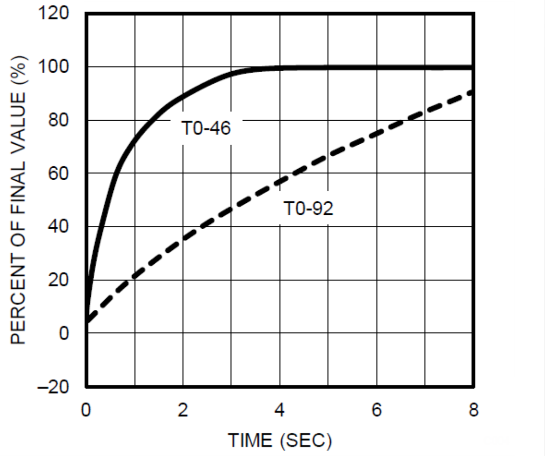


Figure 4. Thermal Response In Stirred Oil Bath

Du capteur utilisé pour la mesure

Bande de fréquences d'intérêt

Du contexte de la mesure, par exemple présence de source **de bruit connues et caractérisées**

Conditionneur – Adaptation (réduction) du spectre du signal par filtrage

- Role of a filter: Limit, cut, Keep part of the spectrum

- Shapes:
  - LOW PASS
  - HIGH PASS
  - BAND PASS
  - NOTCH

- Specifications
  - Cut off frequency(ies)
  - Attenuation order 1st, 2nd.....
  - Ripple

Les différents gabarits de filtres

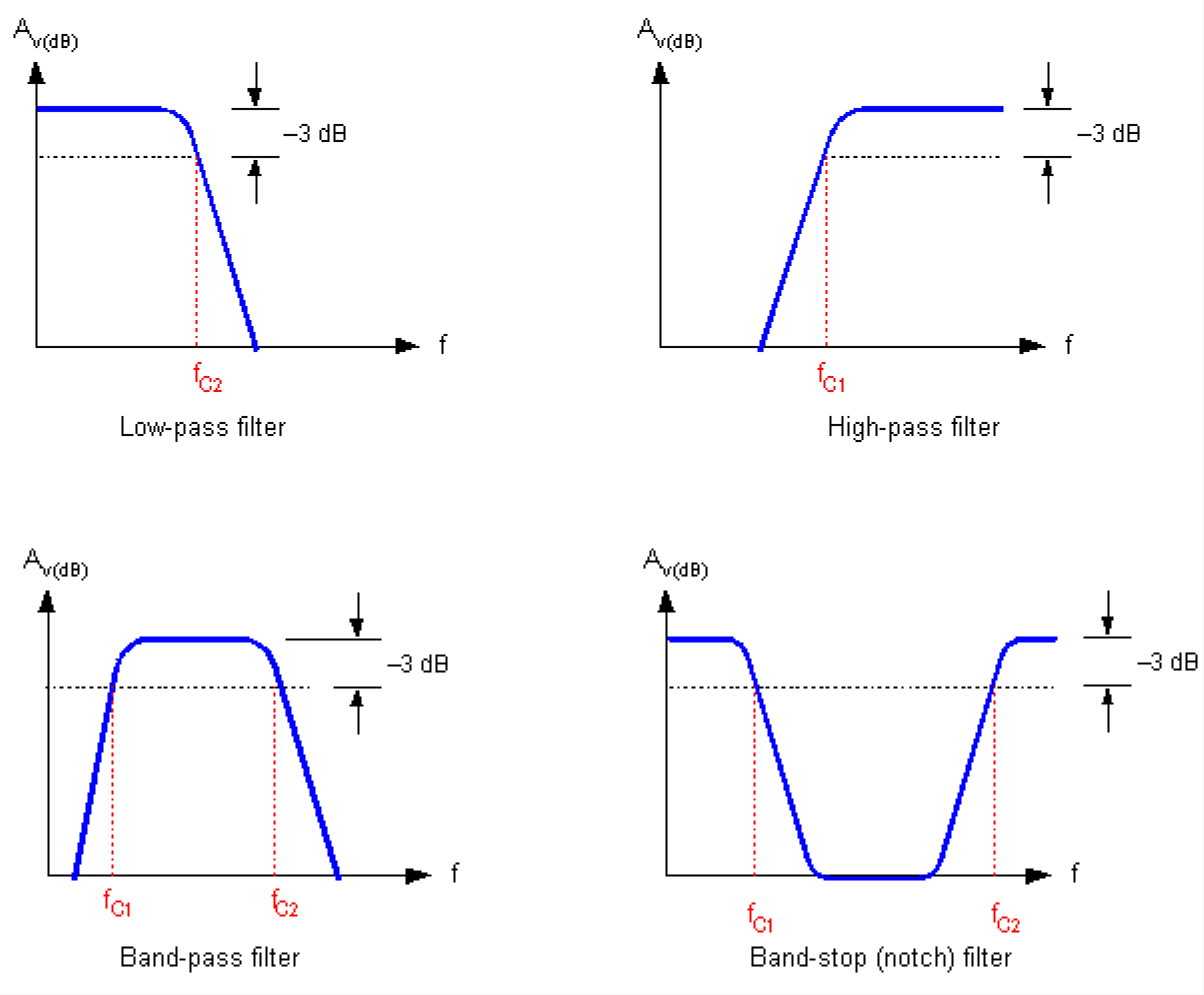
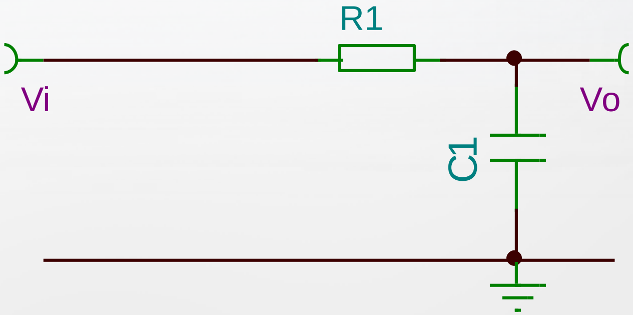

$A_{v(dB)}$
–3 dB
f
f_{C2}
Low-pass filter
$A_{v(dB)}$
–3 dB
f
f_{C1}
High-pass filter
$A_{v(dB)}$
–3 dB
f
f_{C1}
f_{C2}
Band-pass filter
$A_{v(dB)}$
–3 dB
f
f_{C1}
f_{C2}
Band-stop (notch) filter

Figure from:http://wps.prenhall.com/chet_paynter_introduct_6/0,5779,426301-,00.html

Les structures de filtre du 1er ordre

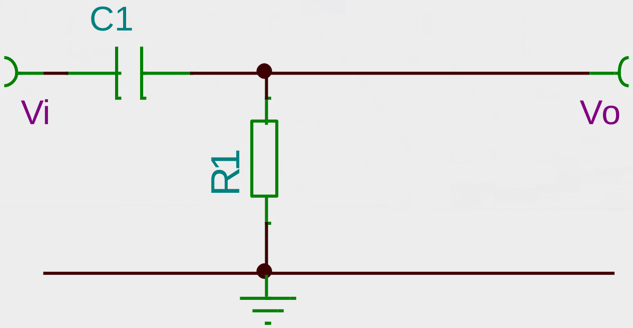
LP

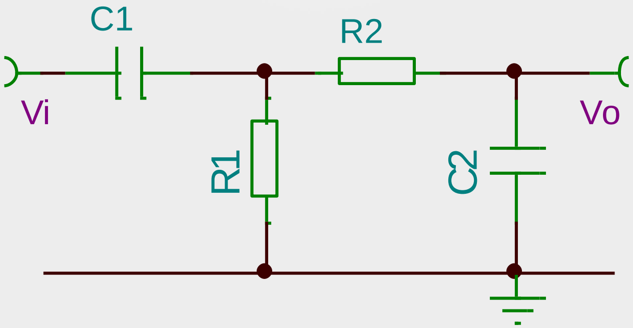
$$H(jw)=\frac{Vo}{Vi}=\frac{1}{1+JR1C1w}$$



HP

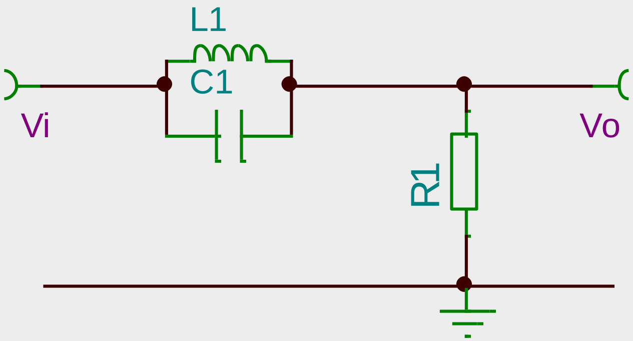
$$H(jw)=\frac{Vo}{Vi}=\frac{jwR1C1}{1+JR1C1w}$$




C1
R2
Vi
Vo
R1
C2

BP

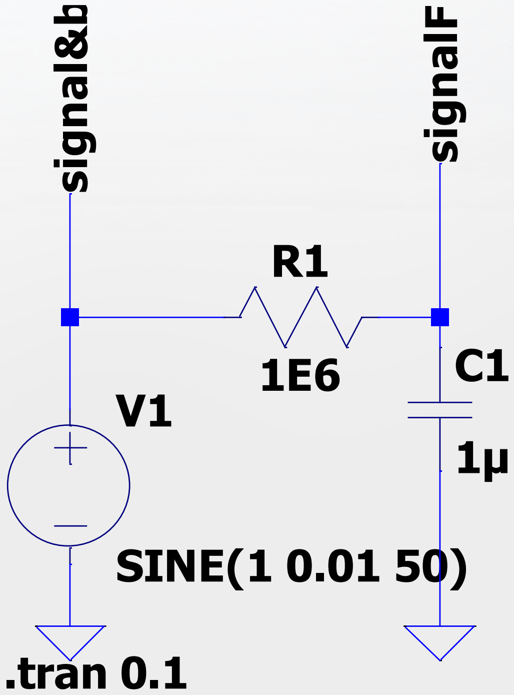
$$H(jw)=\frac{Vo}{Vi}=\frac{jwR1C1}{1+JR1C1w}*\frac{1}{1+JR2C2w}$$

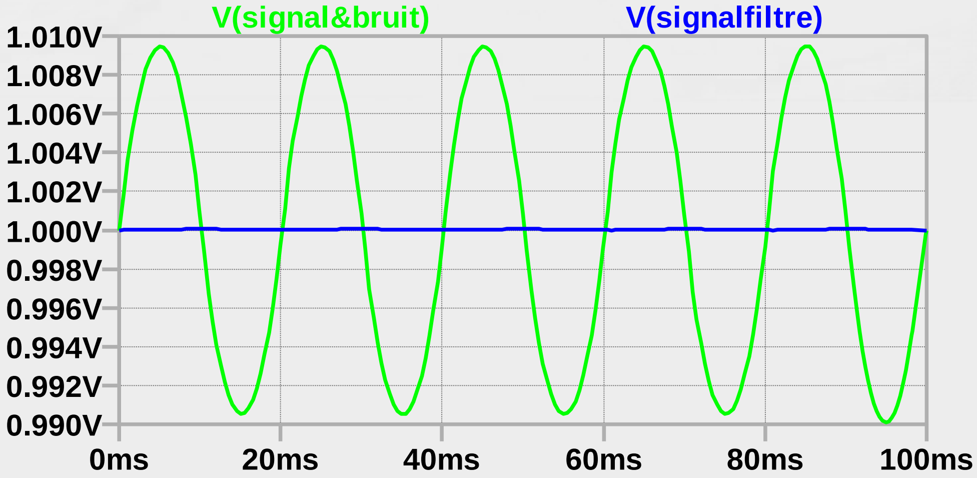

L1
C1
Vi
Vo
R1

NOTCH

$$H(jw)=\frac{Vo}{Vi}=\frac{1-LCw^2}{1+j(Lw/R)-LCw^2}$$

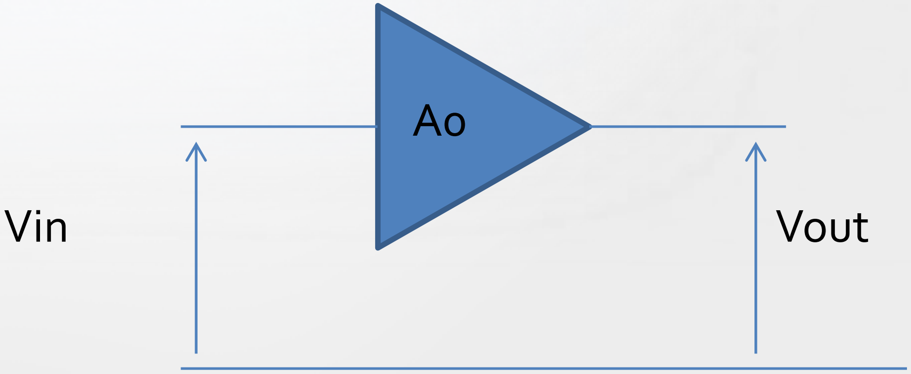
Filtrage cas concret

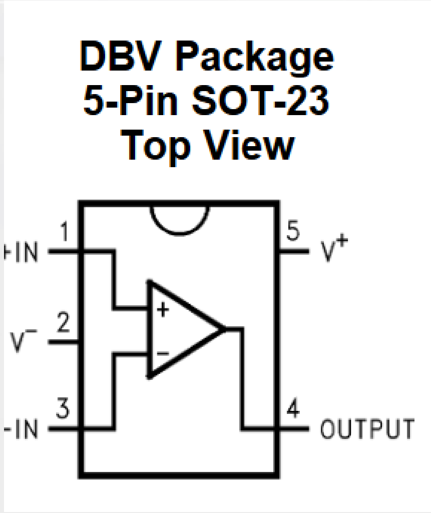

signal&b
signalF
R1
1E6
C1
1µ
V1
SINE(1 0.01 50)
.tran 0.1



Autre composant **très utilisé**: l'Ampli opérationnel

- Infinite open loop gain

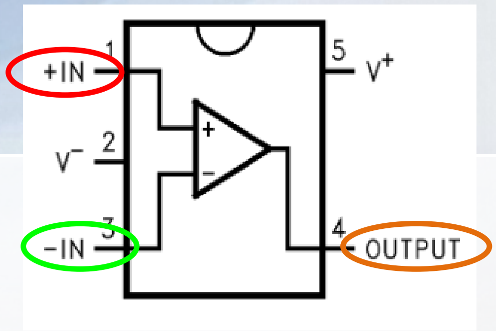


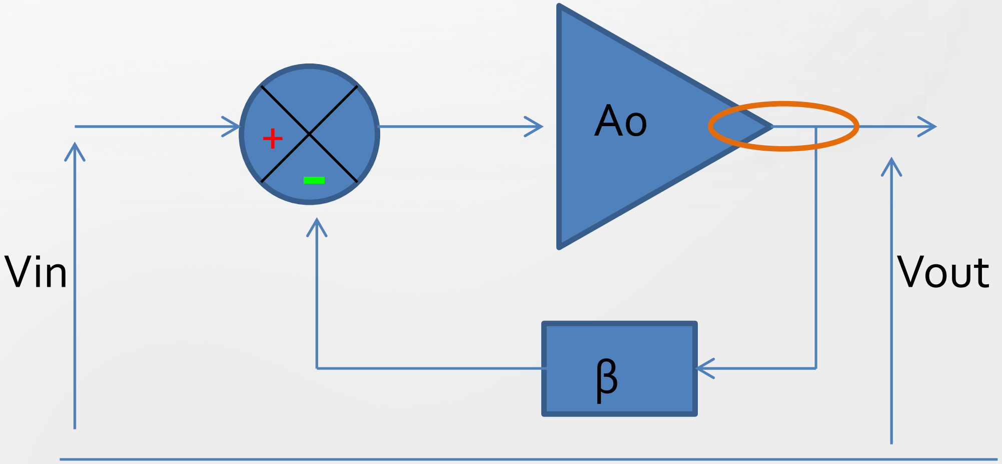

DBV Package
5-Pin SOT-23
Top View
+IN
1
V−
2
−IN
3
5
V+
4
OUTPUT
+
−

LM321

- Ao=Vin/Vout : open loop gain
- ≠ from the function (or application) gain
- No feed back
- The output is not controlled it is just defined by the relationship VOUT=Ao*VIN

l’Ampli opérationnel


1
+IN
2
V⁻
3
−IN
5
V⁺
4
OUTPUT
+
−

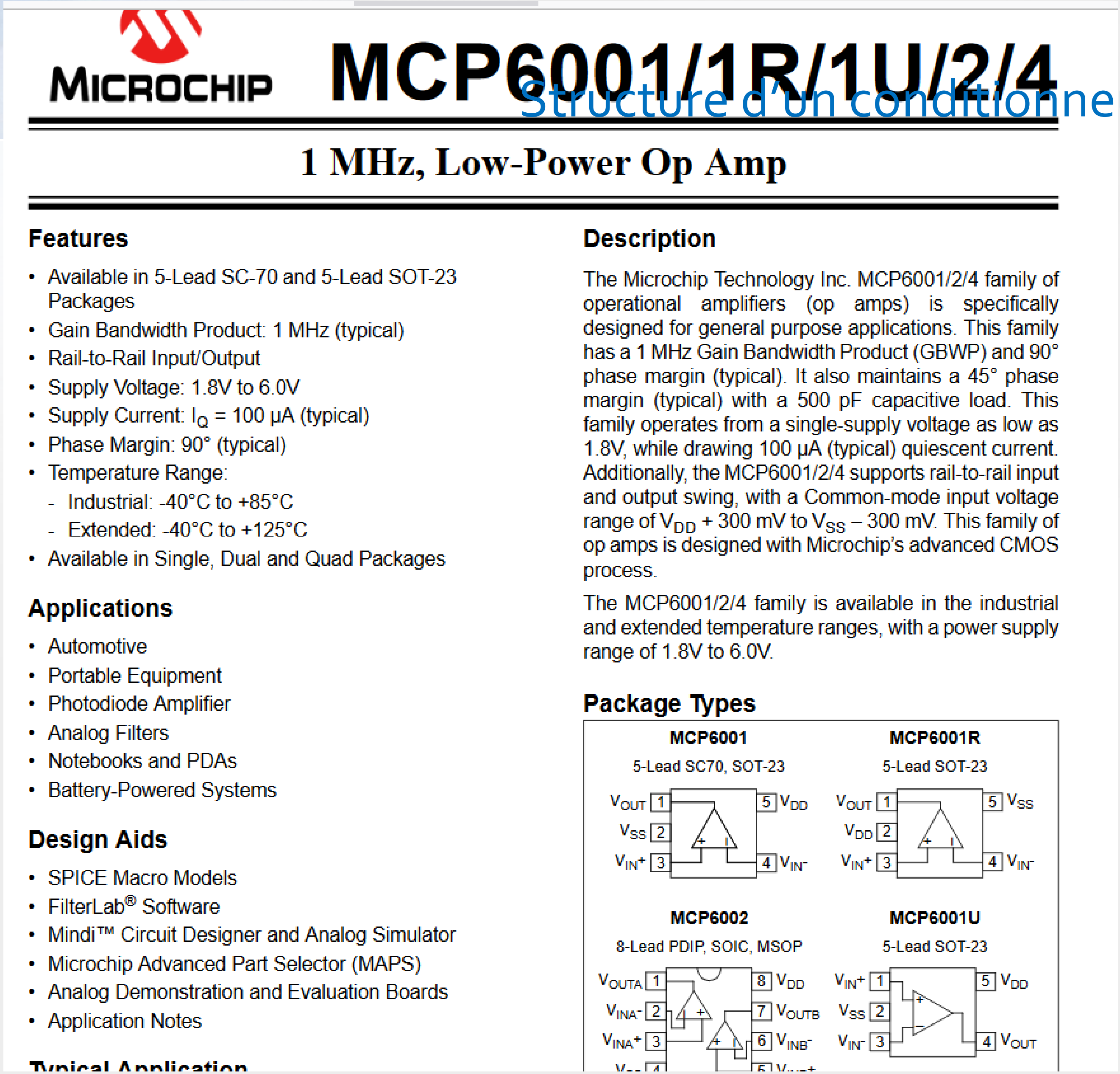

Vin
+
−
Ao
β
Vout

The feed back **provide stability,** the output depends

- on the input value (as in open loop)
- but **also on itself**

Note the that the golbal gain is lower than Ao

Structure d'un conditionneur



MICROCHIP

MCP6001/1R/1U/2/4

1 MHz, Low-Power Op Amp

Features

- Available in 5-Lead SC-70 and 5-Lead SOT-23 Packages
- Gain Bandwidth Product: 1 MHz (typical)
- Rail-to-Rail Input/Output
- Supply Voltage: 1.8V to 6.0V
- Supply Current: I_Q = 100 µA (typical)
- Phase Margin: 90° (typical)
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C
- Available in Single, Dual and Quad Packages

Applications

- Automotive
- Portable Equipment
- Photodiode Amplifier
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

Design Aids

- SPICE Macro Models
- FilterLab® Software
- Mindi™ Circuit Designer and Analog Simulator
- Microchip Advanced Part Selector (MAPS)
- Analog Demonstration and Evaluation Boards
- Application Notes

Typical Application

Description

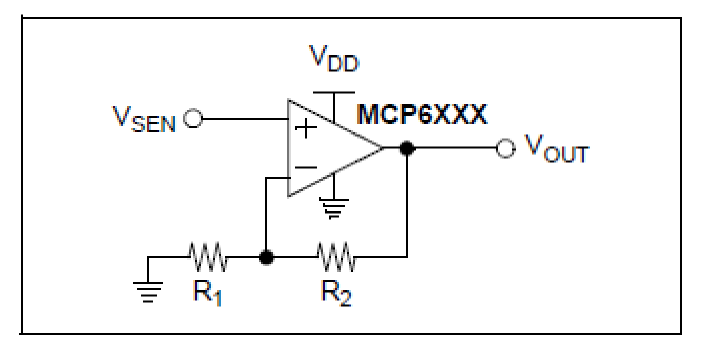
The Microchip Technology Inc. MCP6001/2/4 family of operational amplifiers (op amps) is specifically designed for general purpose applications. This family has a 1 MHz Gain Bandwidth Product (GBWP) and 90° phase margin (typical). It also maintains a 45° phase margin (typical) with a 500 pF capacitive load. This family operates from a single-supply voltage as low as 1.8V, while drawing 100 µA (typical) quiescent current. Additionally, the MCP6001/2/4 supports rail-to-rail input and output swing, with a Common-mode input voltage range of V_{DD} + 300 mV to V_{SS} – 300 mV. This family of op amps is designed with Microchip's advanced CMOS process.

The MCP6001/2/4 family is available in the industrial and extended temperature ranges, with a power supply range of 1.8V to 6.0V.

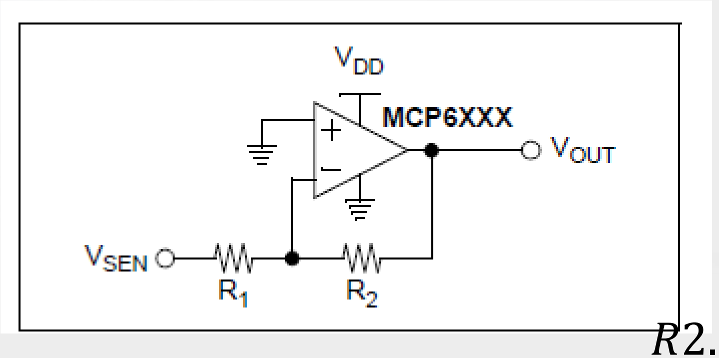
Package Types

MCP6001
5-Lead SC70, SOT-23
VOUT 1
VSS 2
VIN+ 3
5 VDD
4 VIN-
MCP6001R
5-Lead SOT-23
VOUT 1
VDD 2
VIN+ 3
5 VSS
4 VIN-
MCP6002
8-Lead PDIP, SOIC, MSOP
VOUTA 1
VINA- 2
VINA+ 3
8 VDD
7 VOUTB
6 VINB-
MCP6001U
5-Lead SOT-23
VIN+ 1
VSS 2
VIN- 3
5 VDD
4 VOUT

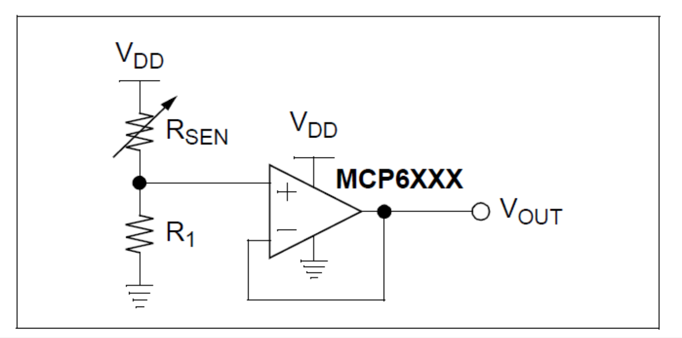
- Application Note : AN990 Signal conditioning circuits – an overview


V_{DD}
V_{SEN}
MCP6XXX
V_{OUT}
R_1
R_2

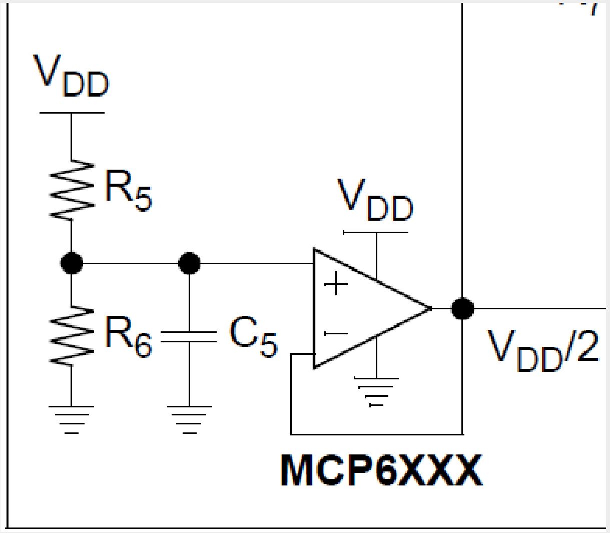
$$VOUT = (1 + \frac{R2}{R1})\text{*VSEN}$$


V_{DD}
MCP6XXX
V_{OUT}
V_{SEN}
R_1
R_2

$$VOUT = -\frac{R2.VSEN}{R1}$$


V_{DD}
R_{SEN}
V_{DD}
MCP6XXX
V_{OUT}
R_1

$$VOUT = -\frac{R1.VDD}{R1 + RSEN}$$

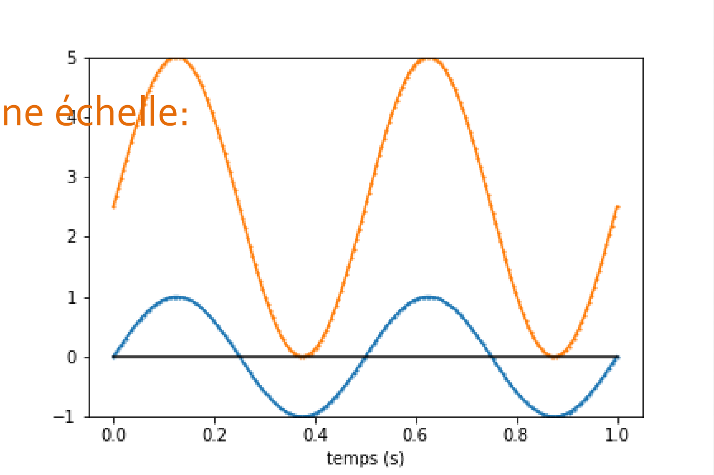

V_{DD}
R_5
V_{DD}
R_6
C_5
$V_{DD}/2$
MCP6XXX

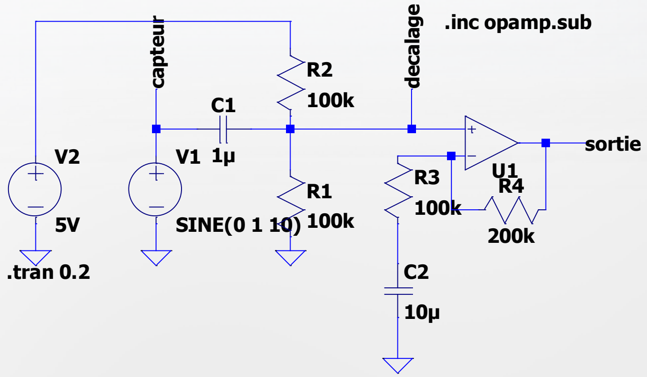
Décalage et amplification

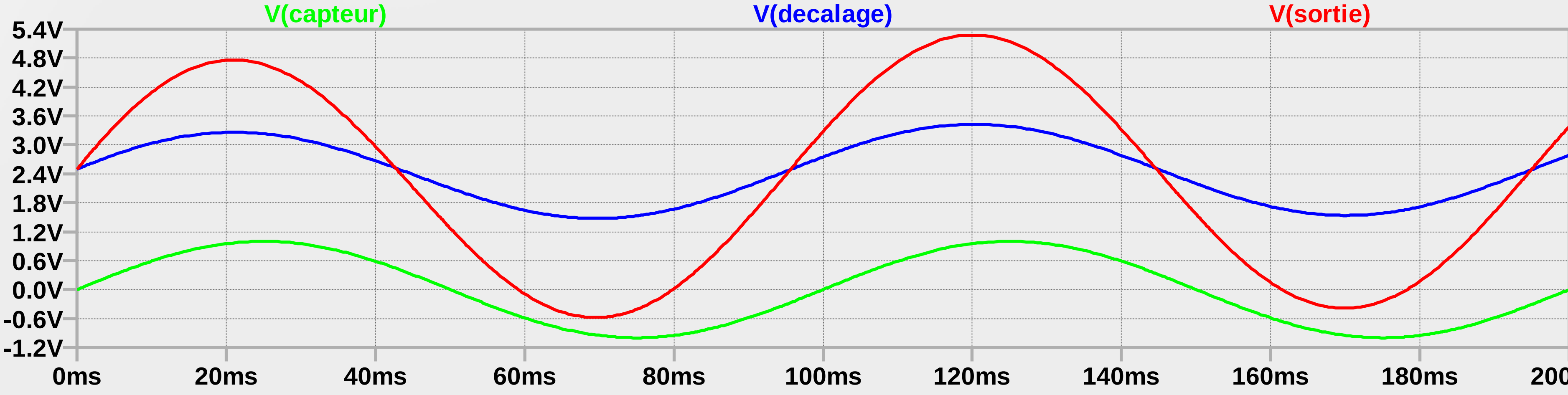
Conditionneur : 2 actions

- amplification x2.5
- décalage 2.5V

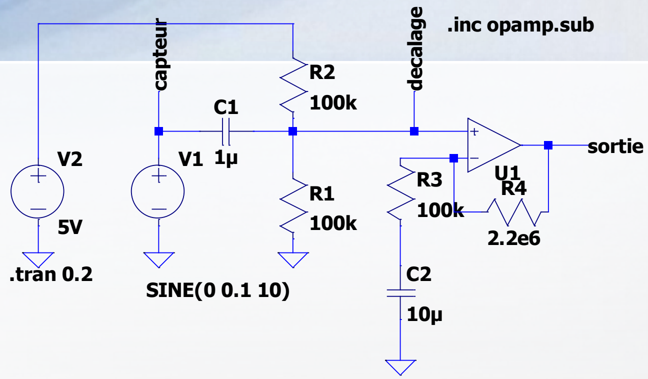
conversion pleine échelle:

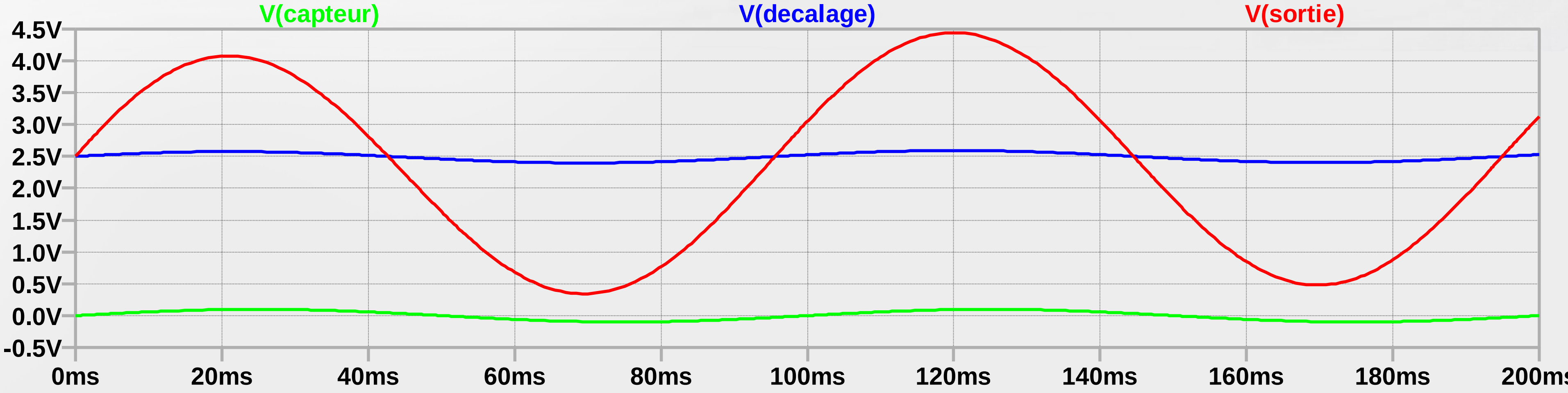


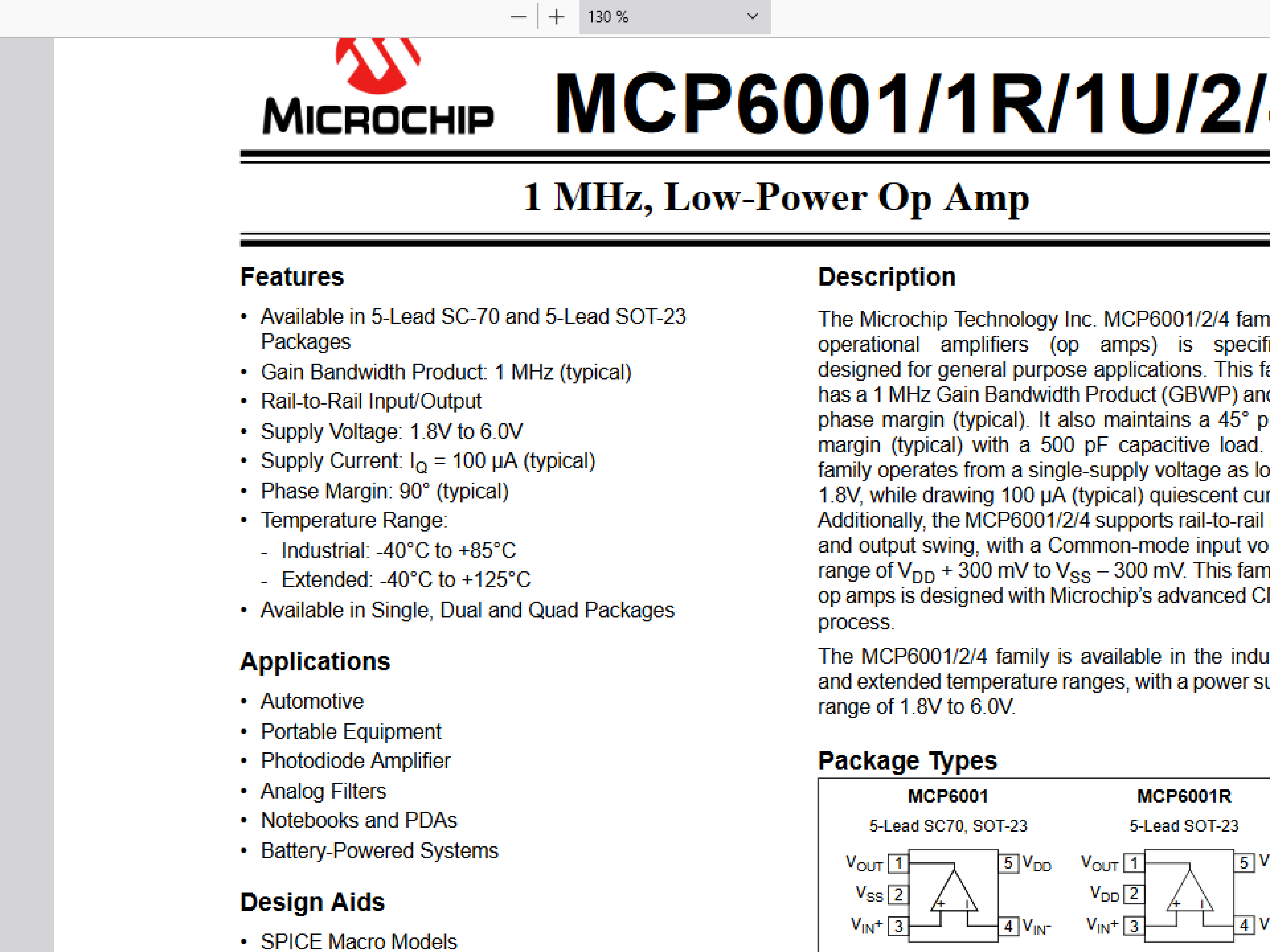

capteur
decalage
.inc opamp.sub
R2
100k
C1
V2
V1 1µ
sortie
R1
R3
U1
R4
100k
5V
SINE(0 1 10)
100k
200k
.tran 0.2
C2
10µ



Décalage et amplification


capteur
decalage
.inc opamp.sub
R2
100k
C1
1µ
V2
V1
5V
R1
100k
sortie
U1
R3
100k
R4
2.2e6
C2
10µ
.tran 0.2
SINE(0 0.1 10)





MICROCHIP

MCP6001/1R/1U/2/

1 MHz, Low-Power Op Amp

Features

- Available in 5-Lead SC-70 and 5-Lead SOT-23 Packages
- Gain Bandwidth Product: 1 MHz (typical)
- Rail-to-Rail Input/Output
- Supply Voltage: 1.8V to 6.0V
- Supply Current: I_Q = 100 µA (typical)
- Phase Margin: 90° (typical)
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C
- Available in Single, Dual and Quad Packages

Applications

- Automotive
- Portable Equipment
- Photodiode Amplifier
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

Design Aids

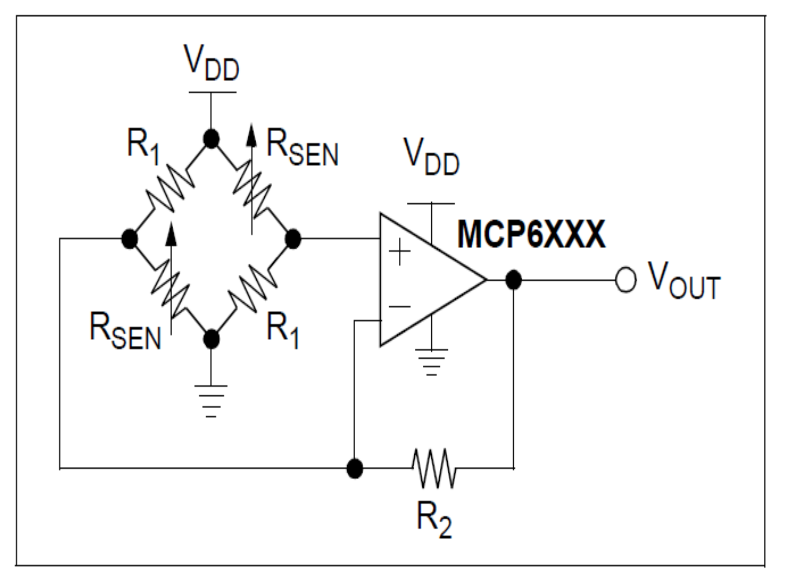
- SPICE Macro Models

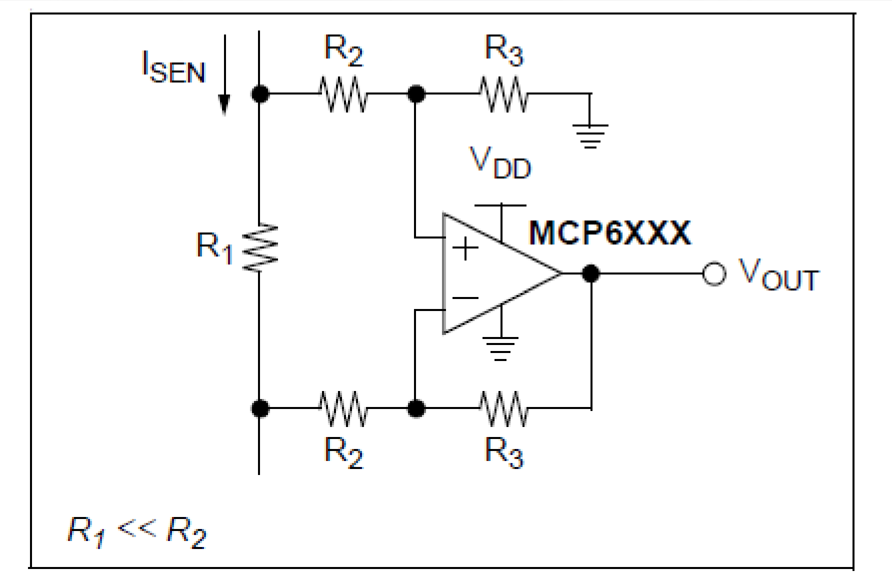
Description

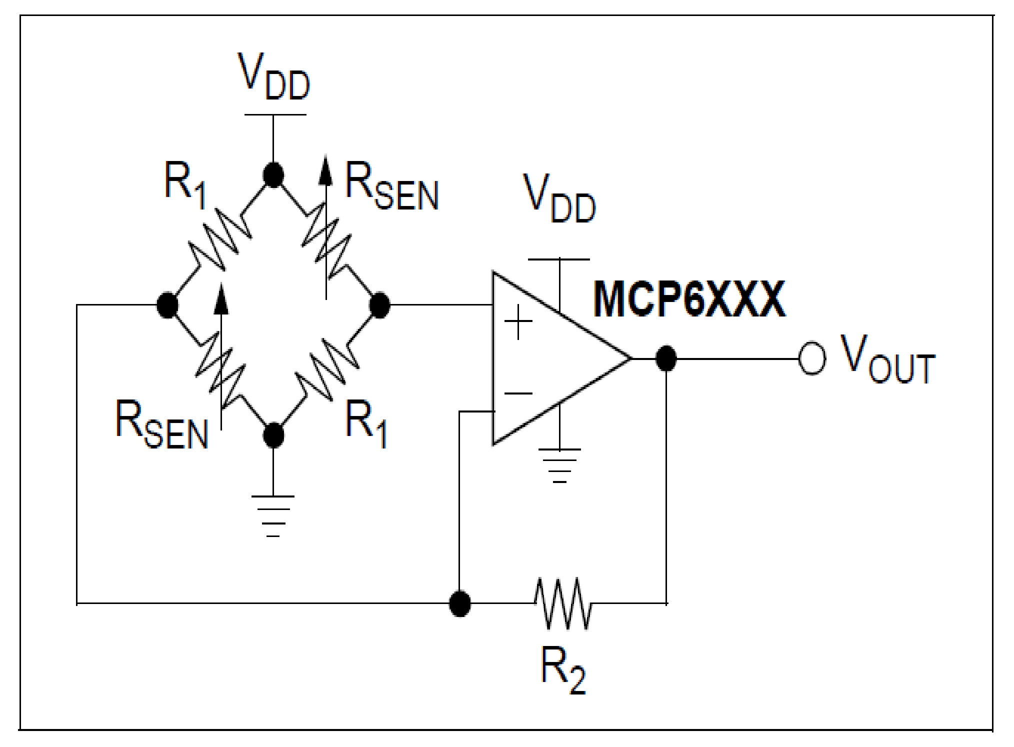
The Microchip Technology Inc. MCP6001/2/4 fam
operational amplifiers (op amps) is specifi
designed for general purpose applications. This fa
has a 1 MHz Gain Bandwidth Product (GBWP) and
phase margin (typical). It also maintains a 45° p
margin (typical) with a 500 pF capacitive load.
family operates from a single-supply voltage as lo
1.8V, while drawing 100 µA (typical) quiescent cur
Additionally, the MCP6001/2/4 supports rail-to-rail
and output swing, with a Common-mode input vo
range of V_{DD} + 300 mV to V_{SS} – 300 mV. This fam
op amps is designed with Microchip's advanced C
process.

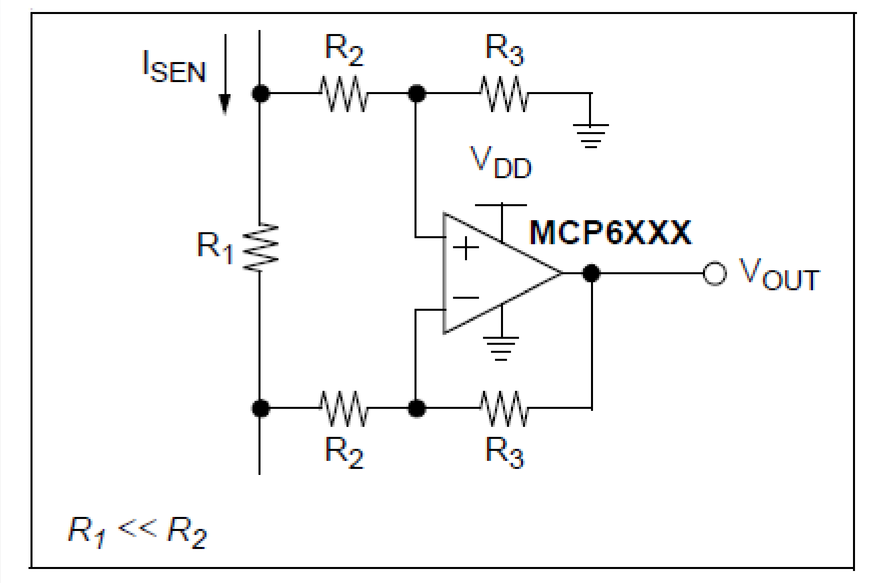
The MCP6001/2/4 family is available in the indu
and extended temperature ranges, with a power su
range of 1.8V to 6.0V.

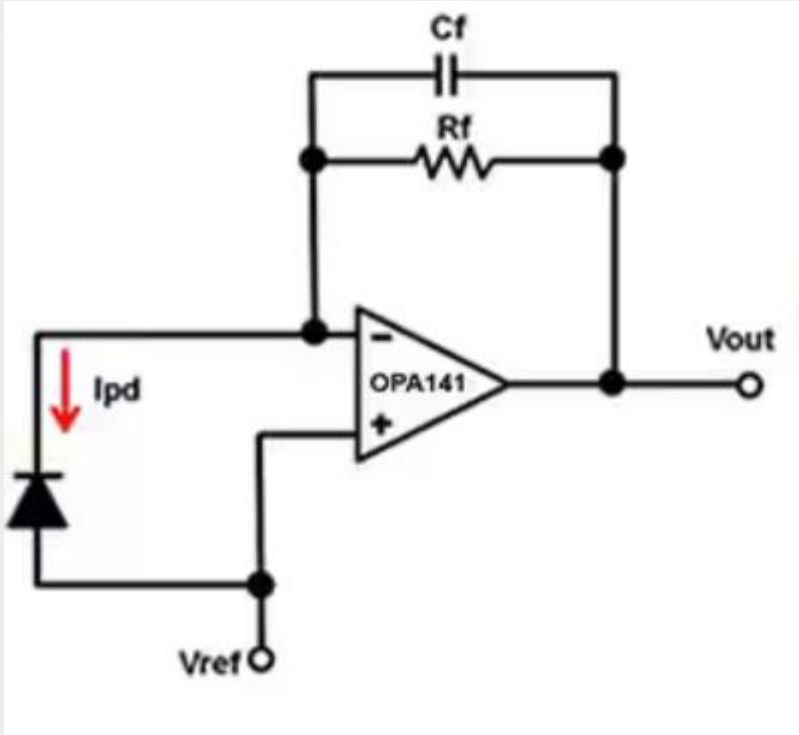
Package Types


V_{DD}
R_1
R_{SEN}
V_{DD}
MCP6XXX
+
−
V_{OUT}
R_{SEN}
R_1
R_2


I_{SEN}
R_2
R_3
V_{DD}
MCP6XXX
+
−
R_1
V_{OUT}
R_2
R_3
$R_1 << R_2$

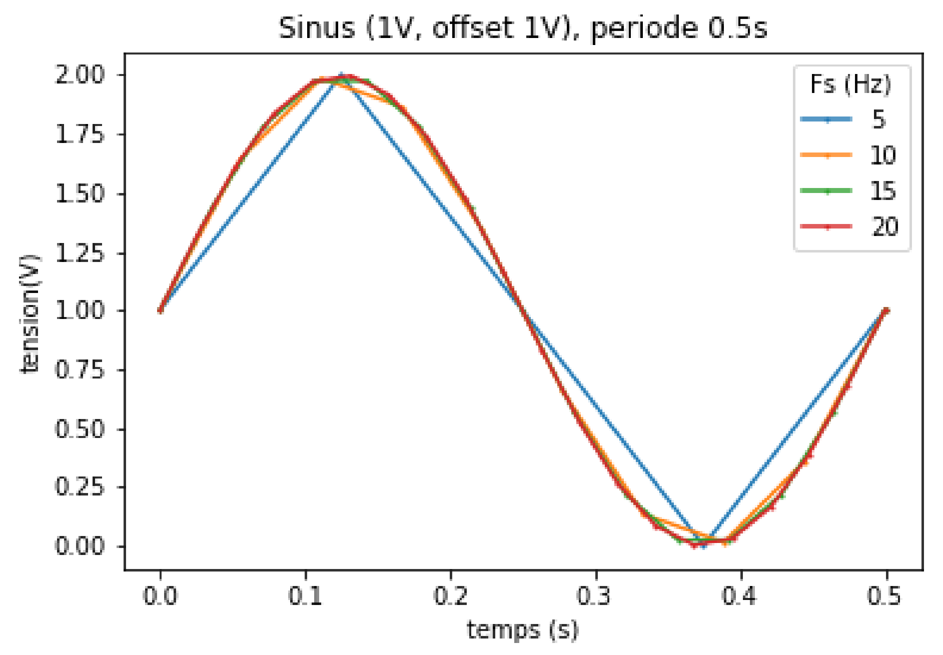

V_{DD}
R_1
R_{SEN}
V_{DD}
MCP6XXX
+
–
V_{OUT}
R_{SEN}
R_1
R_2

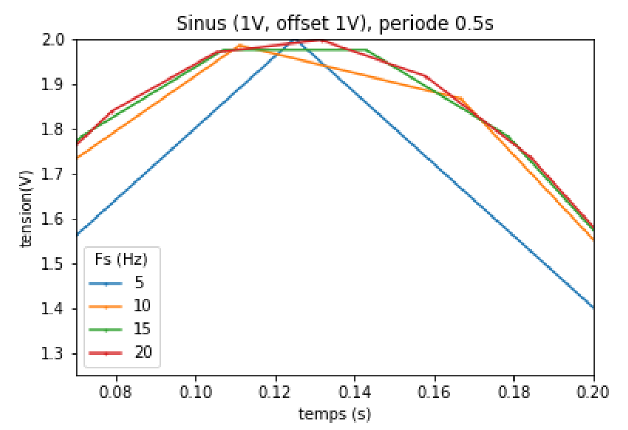

I_{SEN}
R_2
R_3
V_{DD}
MCP6XXX
R_1
V_{OUT}
R_2
R_3
$R_1 << R_2$


Cf
Rf
Ipd
OPA141
−
+
Vout
Vref

$$Vout = Ipd.\frac{Rf}{1 + jwRf * Cf}$$

La numérisation – Fréquence d'échantillonnage -





La fréquence d'échantillonnage (Fs) est déterminée en fonction des caractéristiques fréquentielles du signal à numériser.

Fs > 2*Fréquence maximale du signal

Cas du LM35

Figure 2. Thermal Time Constant

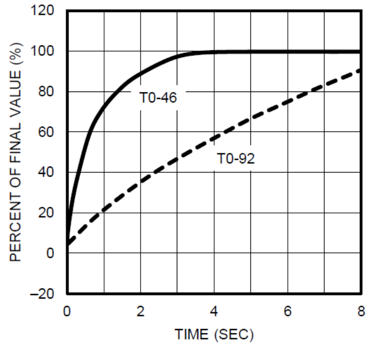
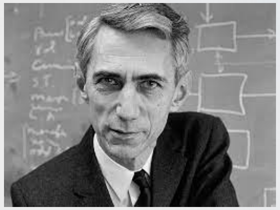
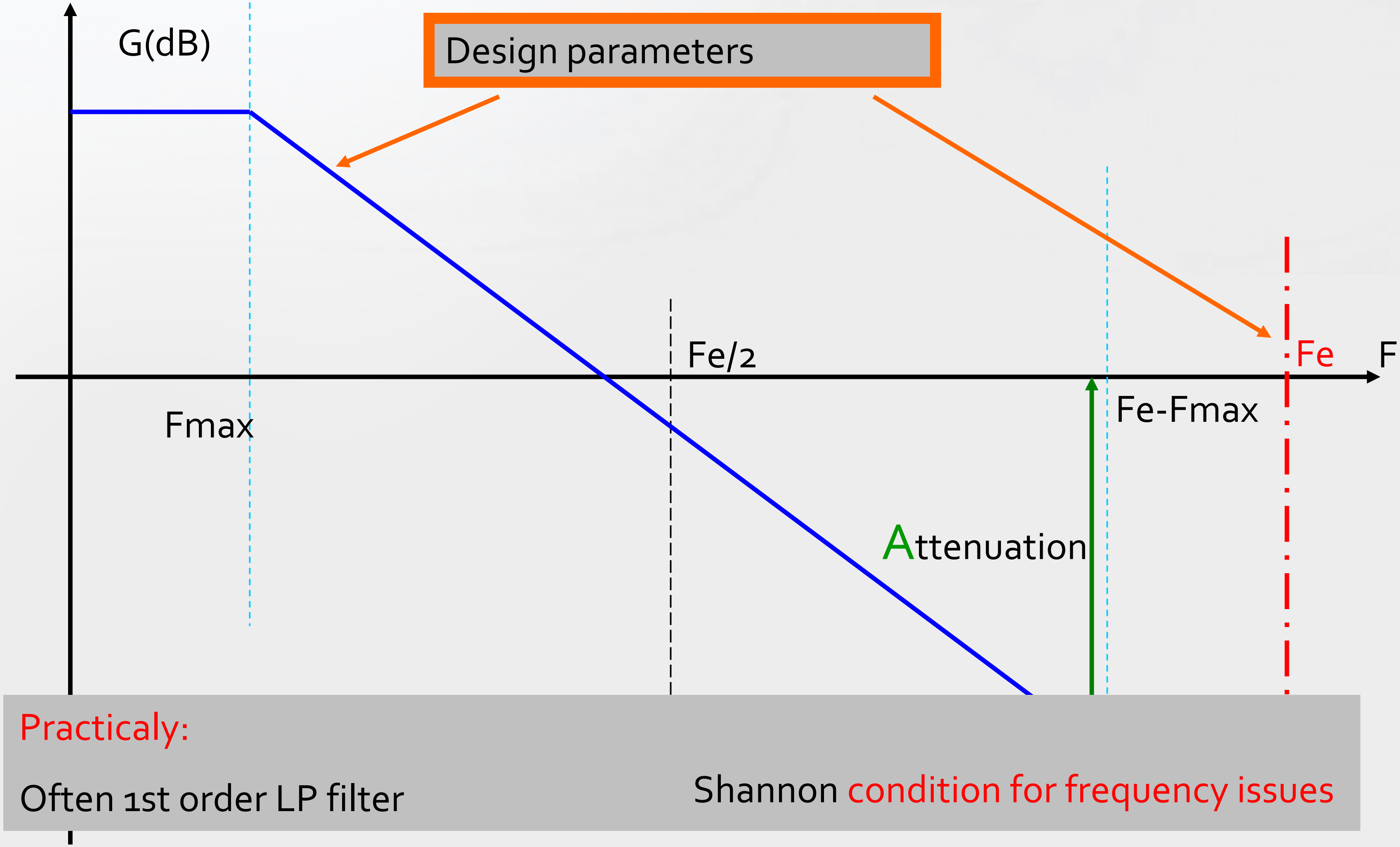


Figure 4. Thermal Response In Stirred Oil Bath



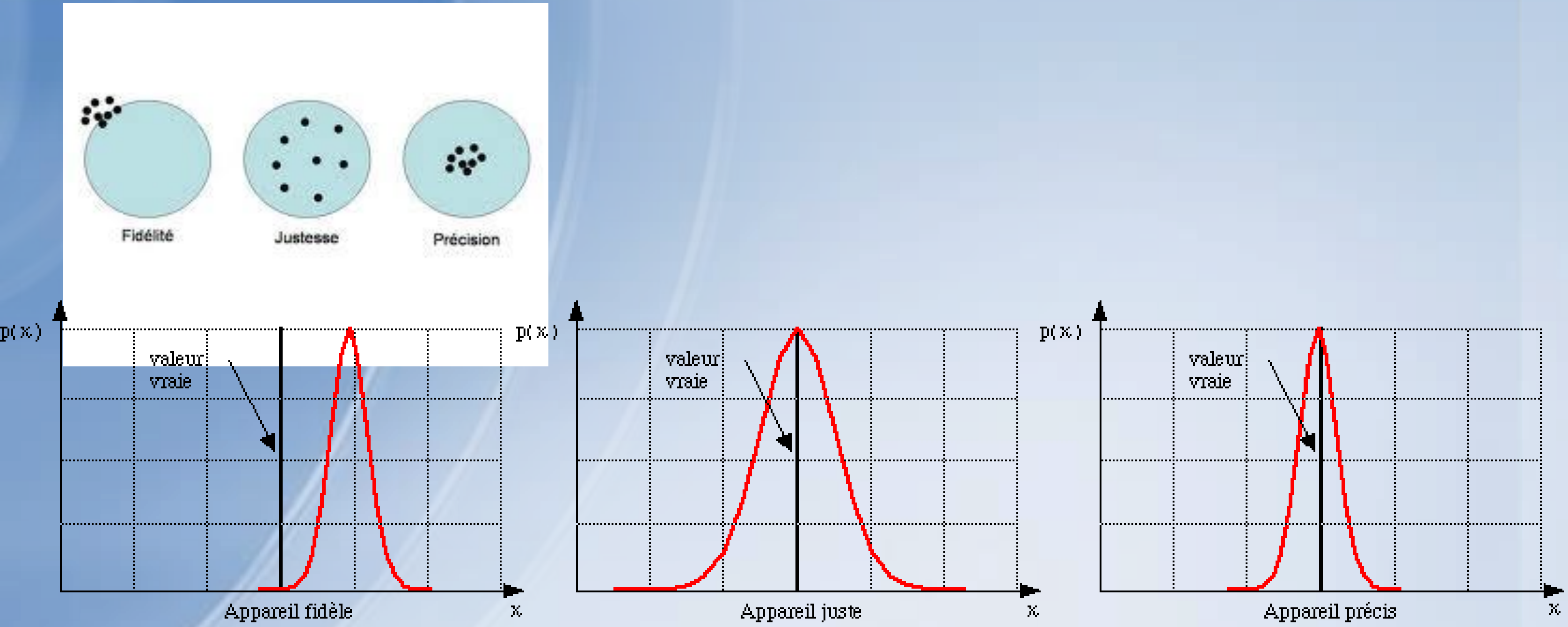
Fréquence d'échantillonnage – Théorème de Shannon


G(dB)
Design parameters
Fe/2
Fe
F
Fmax
Fe-Fmax
Attenuation

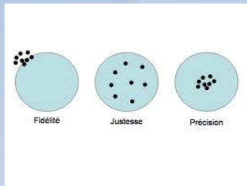
Practicaly:

Often 1st order LP filter

Shannon condition for frequency issues


Fidélité
Justesse
Précision
p(x)
valeur vraie
Appareil fidèle
x
p(x)
valeur vraie
Appareil juste
x
p(x)
valeur vraie
Appareil précis
x

Erreur: c'est une variable aléatoire avec une moyenne (m ou µ) et un écart type σ
Écart de la moyenne à la mesure : c'est l'erreur systématique
Ecart type: fluctuation d'une mesure à l'autre
Intervalle de confiance: c'est l'intervalle où la valeur à n% de chance de se trouver



Incertitude des mesures

Quand on effectue un mesurage… au rang i

Xi=M+Ei
Xi: ième mesure
Ei incertitude de mesure liée à Xi
Ces erreurs sont aléatoires on dit que Xi et Ei sont des variables aléatoires continues

Pour « compenser » E, on fait plusieurs mesurages pour ensuite en général en faire la moyenne

On dispose donc de

- n analyses du même échantillon
- n échantillons