Conception Electronique pour le Traitement de l'Information

Capter des photons

TD7 - Photodétection

Julien VILLEMEJANE

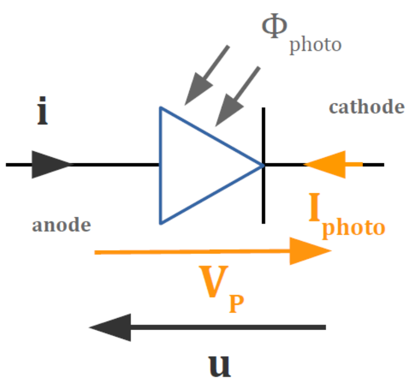

Paris-Saclay


Saint-Étienne


Bordeaux

- ## Qu'est-ce qu'une photodiode ?

PHOTODIODE = CAPTEUR



V_p : tension de polarisation

I_{PhD}: courant proportionnel au flux lumineux

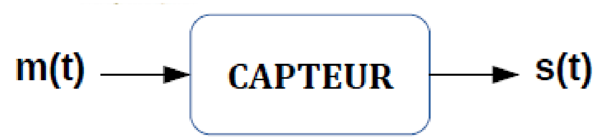
A A/W W

$$I_{photo} = S_\lambda \cdot \eta \cdot \Phi_{photo}$$

Sensibilité spectrale

Rendement quantique

Flux lumineux



Transforme une grandeur physique observée (mesurande) **vers une autre grandeur physique utilisable** (électrique)

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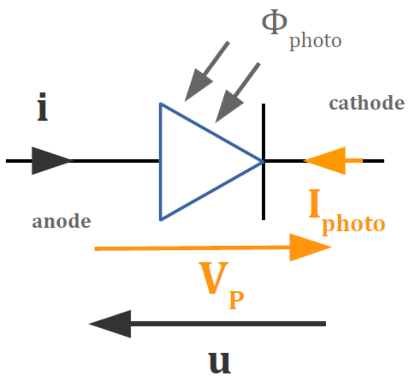


V_P : tension de polarisation

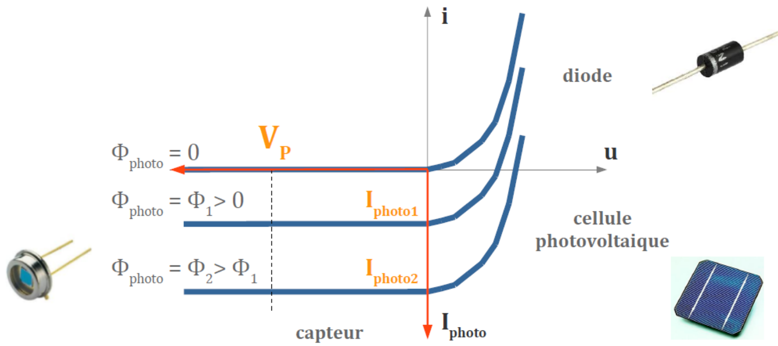
I_{PhD} : courant proportionnel au flux lumineux

A — A/W — W

$$I_{photo} = S_\lambda \cdot \eta \cdot \Phi_{photo}$$

- S_λ : Sensibilité spectrale
- η : Rendement quantique
- Φ_{photo} : Flux lumineux

CARACTÉRISTIQUES ÉLECTRIQUES



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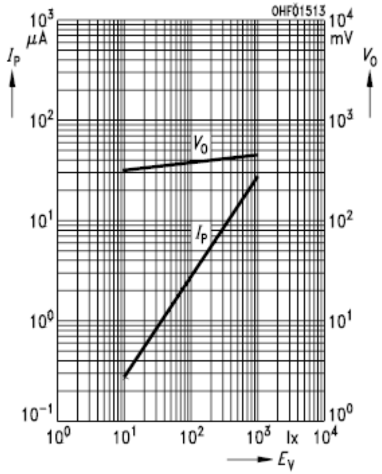
CéTI / Capter des photons

• Caractéristiques d'une photodiode

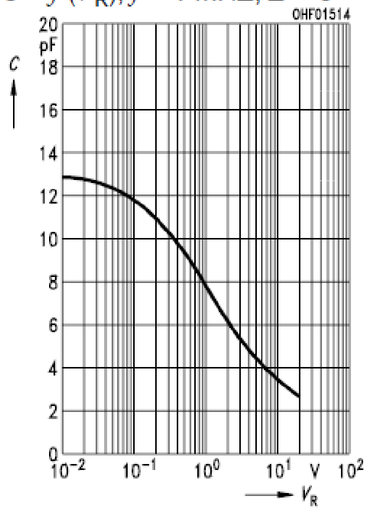
Maximum Ratings

Bezeichnung Parameter	Symbol Symbol	Wert Value	Einheit Unit
Betriebs- und Lagertemperatur Operating and storage temperature range	T_{op}; T_{stg}	– 40 … + 100	°C
Sperrspannung Reverse voltage	V_R	20	V
Verlustleistung Total power dissipation	P_{tot}	150	mW

Photocurrent $I_P = f(E_v)$, V_R = 5 V
Open-Circuit Voltage $V_O = f(E_v)$
SFH 229



Capacitance
$C = f(V_R)$, f = 1 MHZ, E = 0



Characteristics

Bezeichnung Parameter	Symbol Symbol	Wert Value		Einheit Unit
		SFH 229	SFH 229 FA	
Fotostrom Photocurrent V_R = 5 V, Normlicht/standard light A, T = 2856 K, E_V = 1000 lx V_R = 5 V, λ = 950 nm, E_e = 1 mW/cm^2	I_P I_P	28 (≥ 18) –	– 20 (≥ 10.8)	μA μA
Wellenlänge der max. Fotoempfindlichkeit Wavelength of max. sensitivity	$\lambda_{S\ max}$	860	900	nm
Spektraler Bereich der Fotoempfindlichkeit S = 10% von S_{max} Spectral range of sensitivity S = 10% of S_{max}	λ	380 … 1100	730 … 1100	nm
Bestrahlungsempfindliche Fläche Radiant sensitive area	A	0.3	0.3	mm^2
Abmessung der bestrahlungsempfindlichen Fläche Dimensions of radiant sensitive area	$L \times B$ $L \times W$	0.56 × 0.56	0.56 × 0.56	mm × mm
Halbwinkel Half angle	φ	± 17	± 17	Grad deg.

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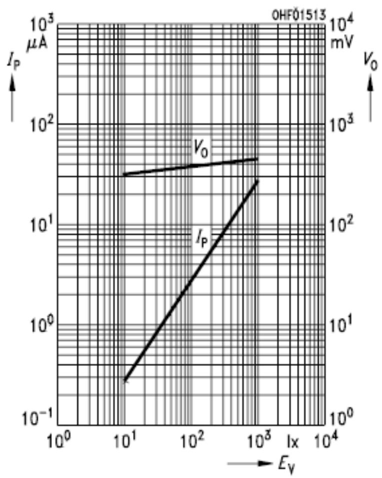

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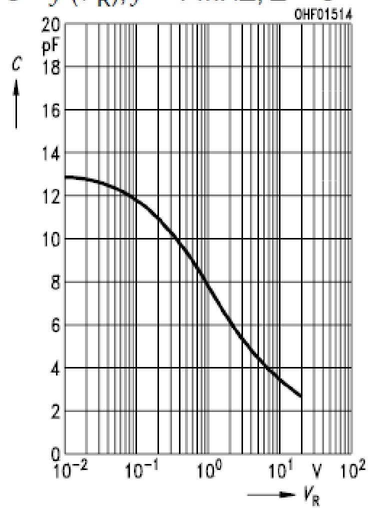
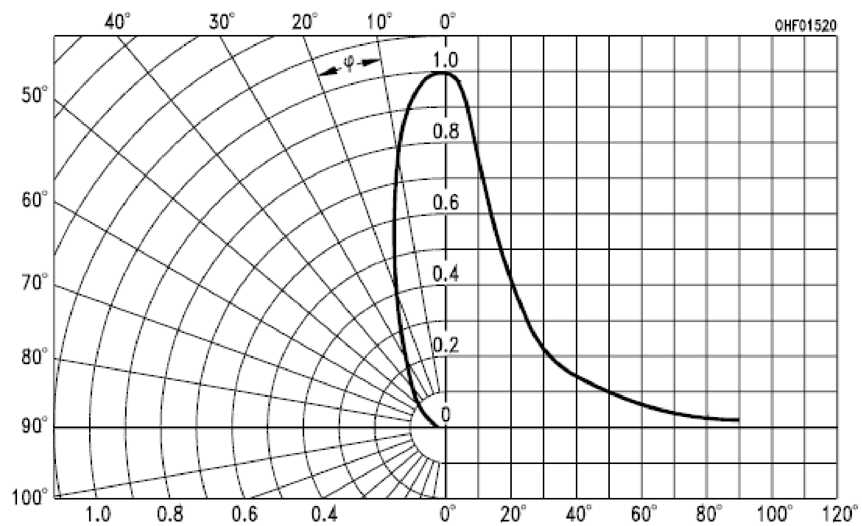


Directional Characteristics
$S_{rel} = f(\varphi)$



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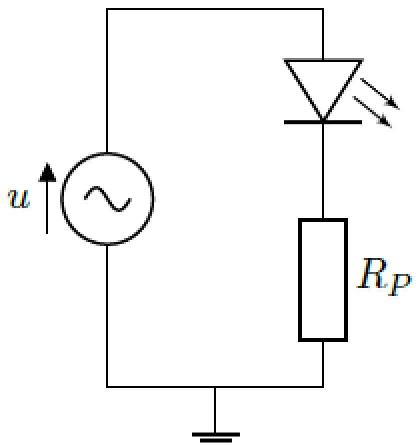
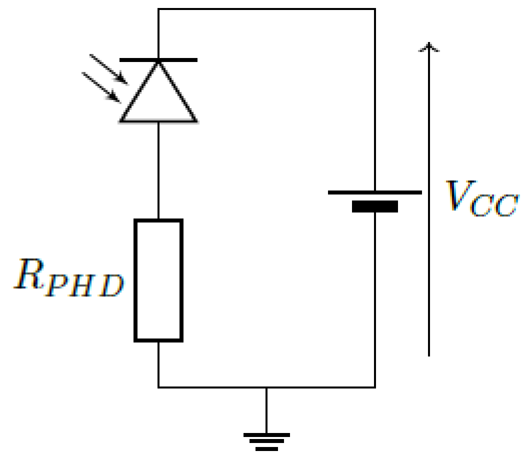
- **Transmission par la lumière**



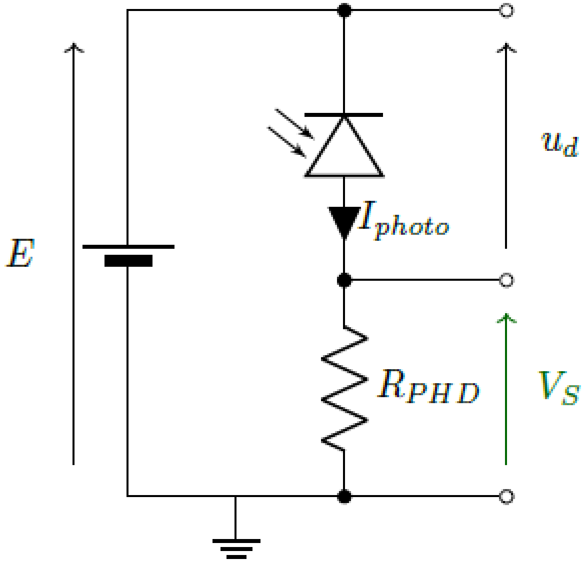
(a) Emetteur



(b) Récepteur simple

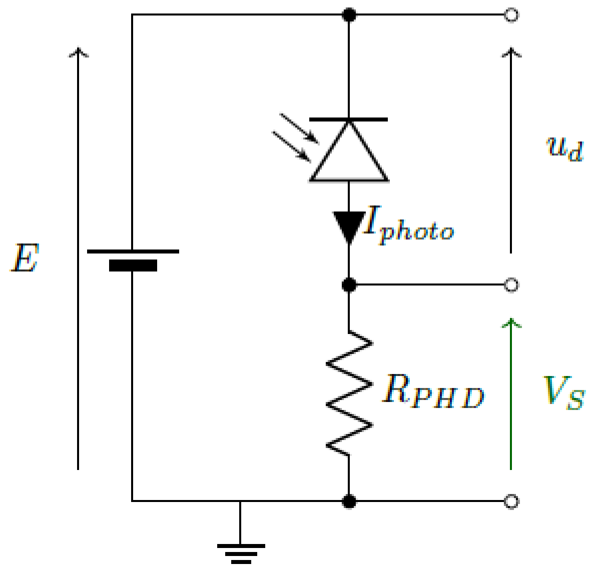
• Montage simple / Fonction de transfert

$$V_S = R_{PhD} \cdot I_{photo}$$

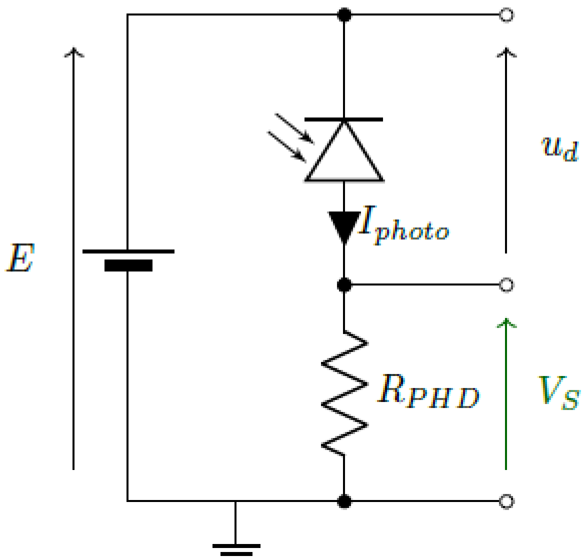


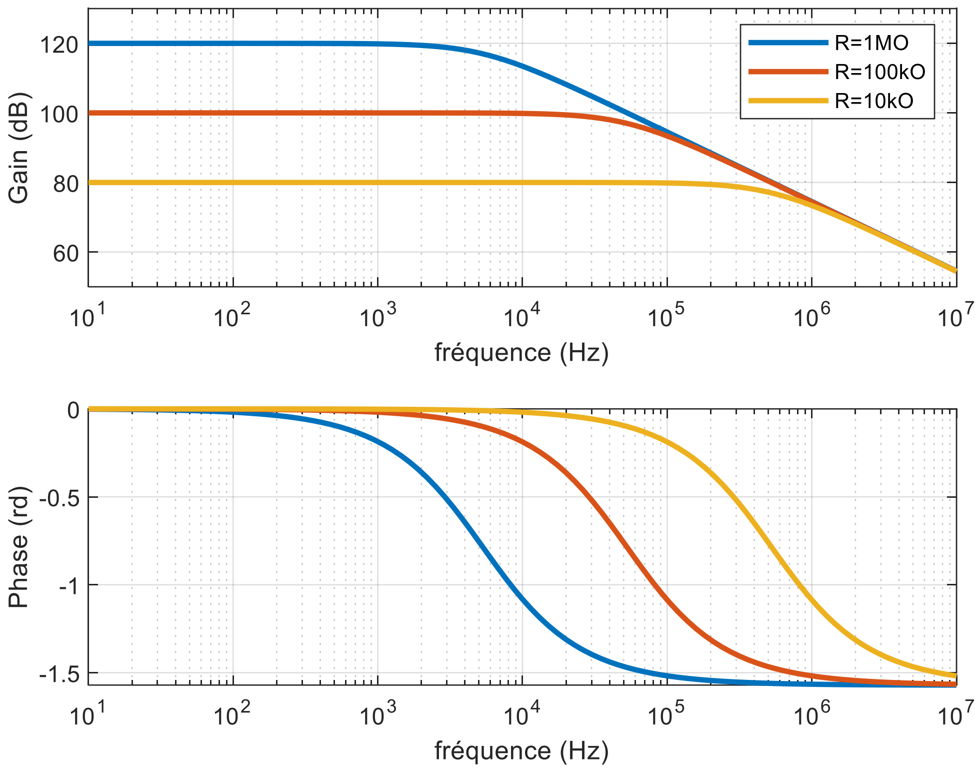
- **Montage simple / Réponse en fréquence « théorique »**

$$V_S = R_{PhD} \cdot I_{photo}$$

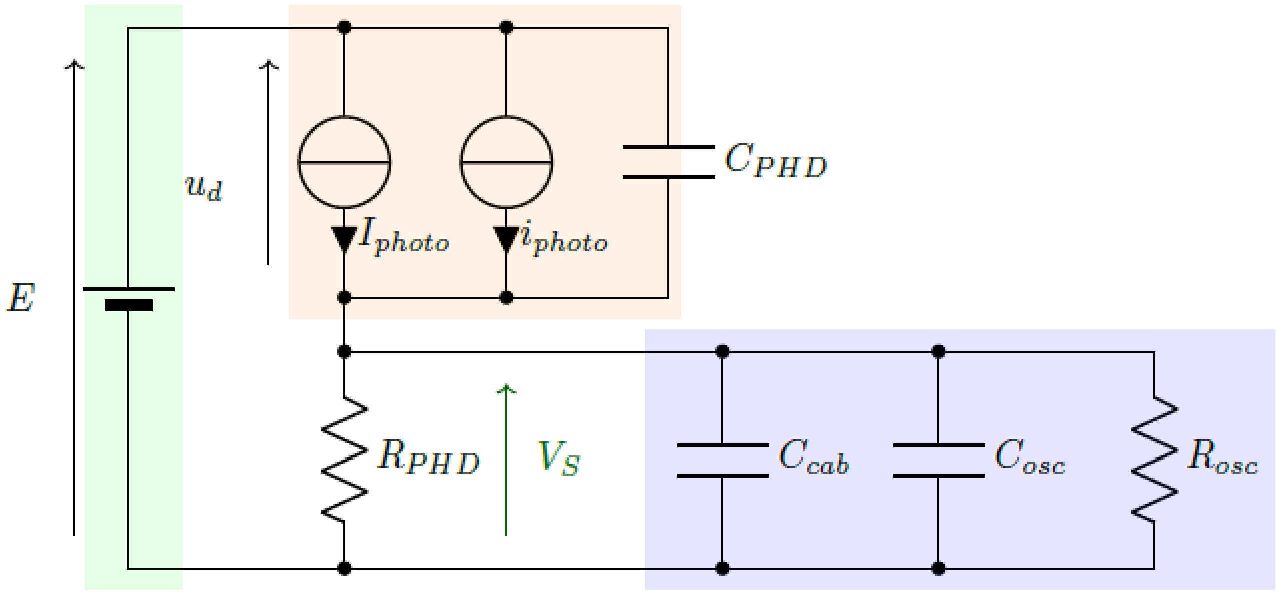


- **Montage simple / Réponse en fréquence « expérimentale »**





- **Montage simple / Modèle**



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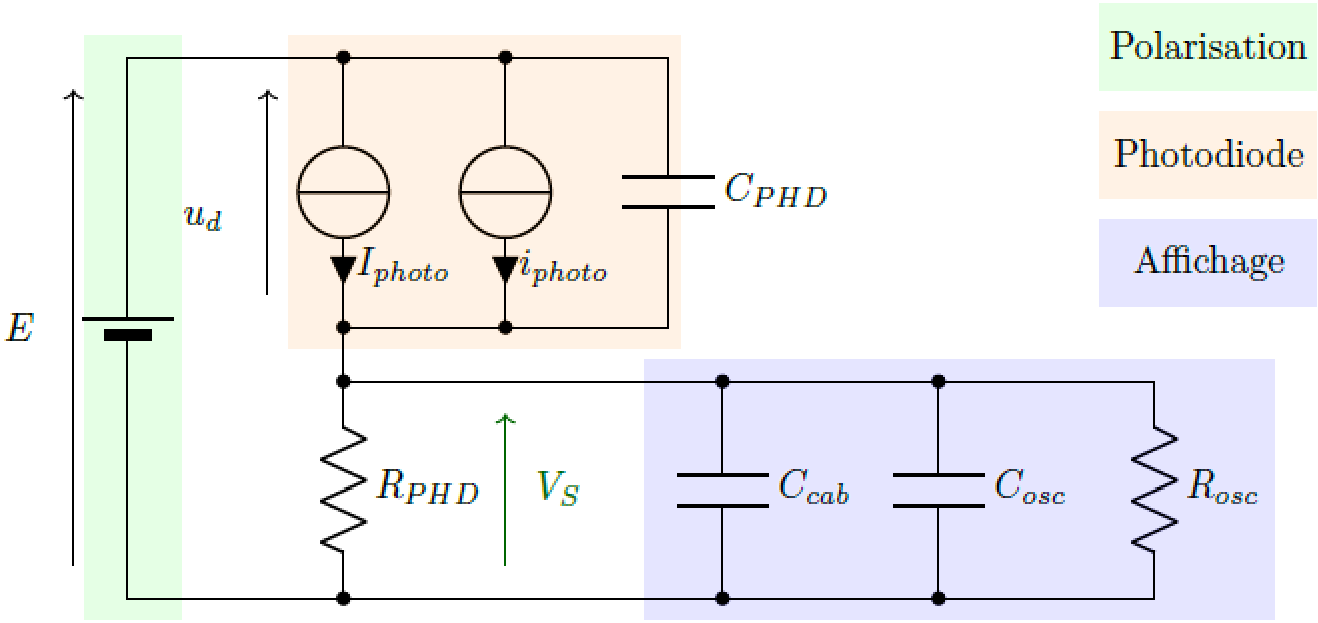
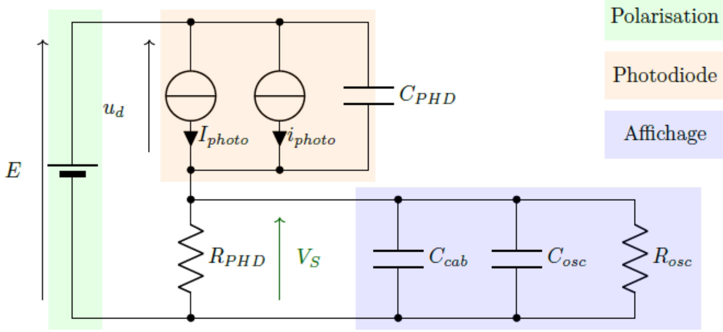
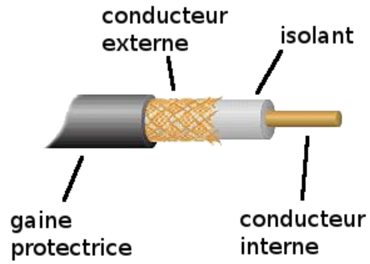
- **Montage simple / Modèle**

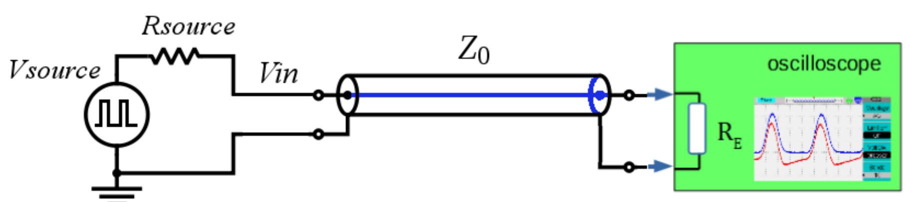


CéTI / Capter des photons

• Montage simple / Modèle







Capacité linéique

C_{cab} ≈ 100 pF / m

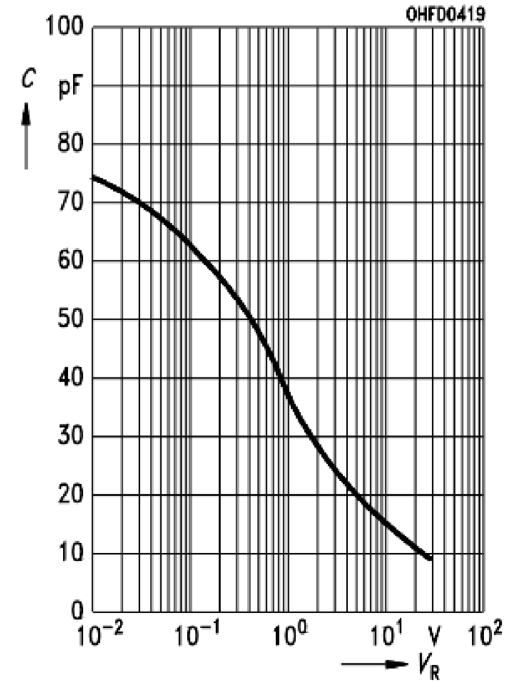
R_{osc} ≈ 1 MΩ

C_{osc} ≈ 10 pF

SFH206

Capacitance

$C = f(V_R)$, f = 1 MHz, E = 0



Pour V_R = 5 V

C_{PHD} = 20 pF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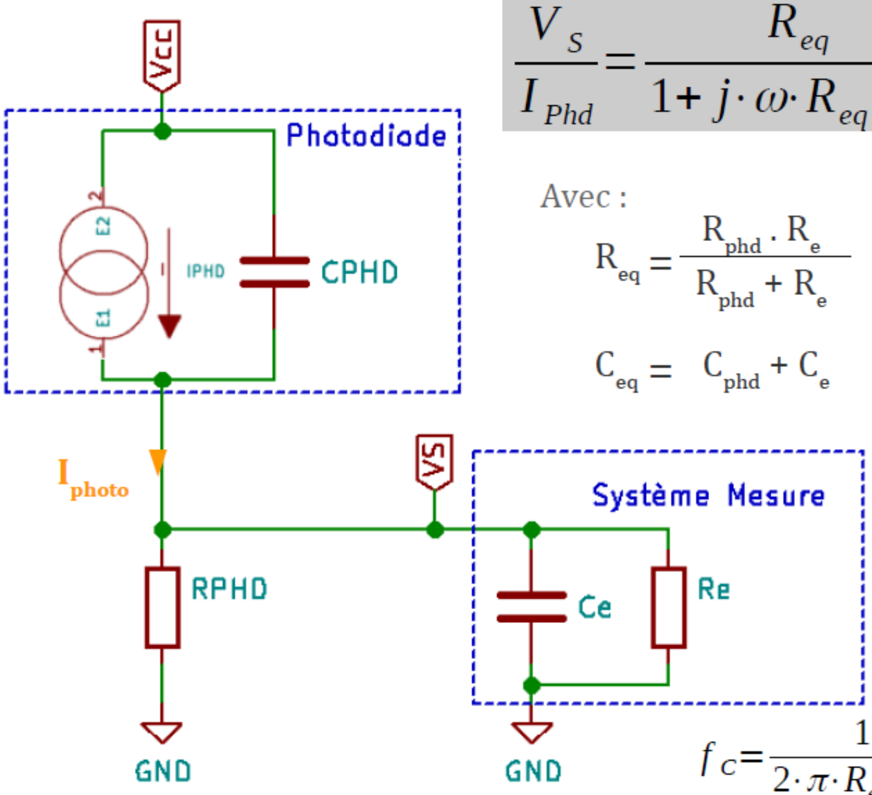
- **Montage simple / pour résumer**



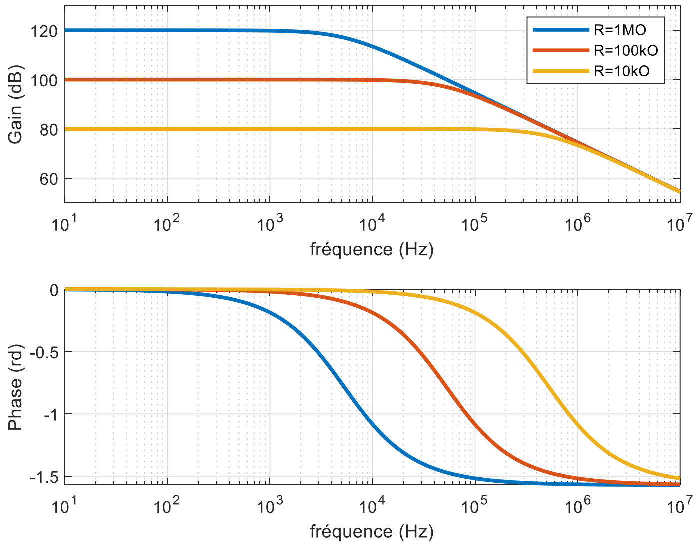
$$\frac{V_S}{I_{Phd}} = \frac{R_{eq}}{1 + j \cdot \omega \cdot R_{eq} \cdot C_{eq}}$$

Avec :

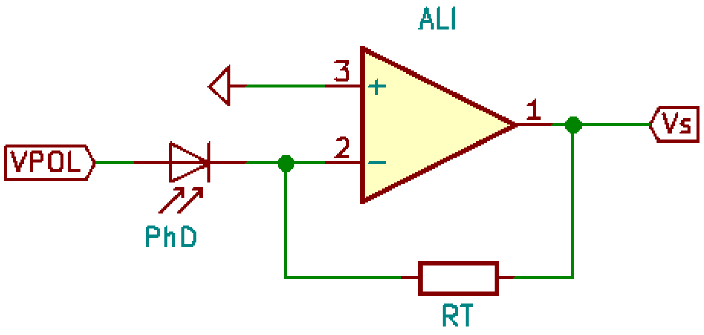
$$R_{eq} = \frac{R_{phd} \cdot R_e}{R_{phd} + R_e}$$

$$C_{eq} = C_{phd} + C_e$$

$$f_C = \frac{1}{2 \cdot \pi \cdot R_{eq} \cdot C_{eq}}$$



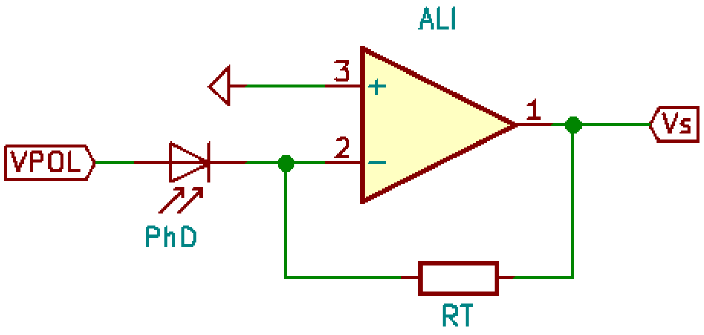
- **Montage transimpédance / Fonction de transfert**



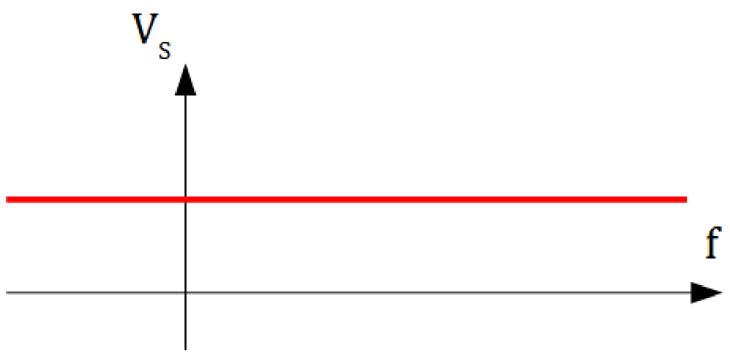
$$V_S = R_T \cdot I_{photo}$$

CéTI / Capter des photons

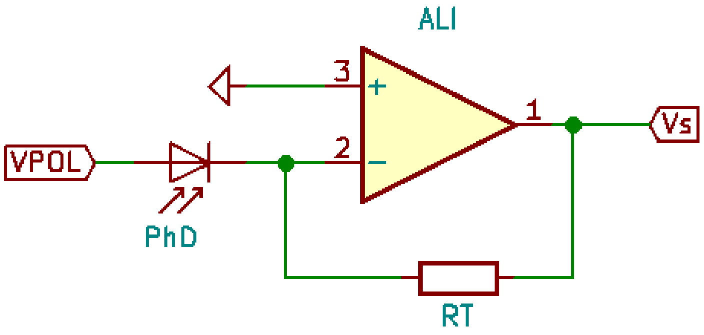
- **Montage transimpédance / Rép. fréquence « théorique »**

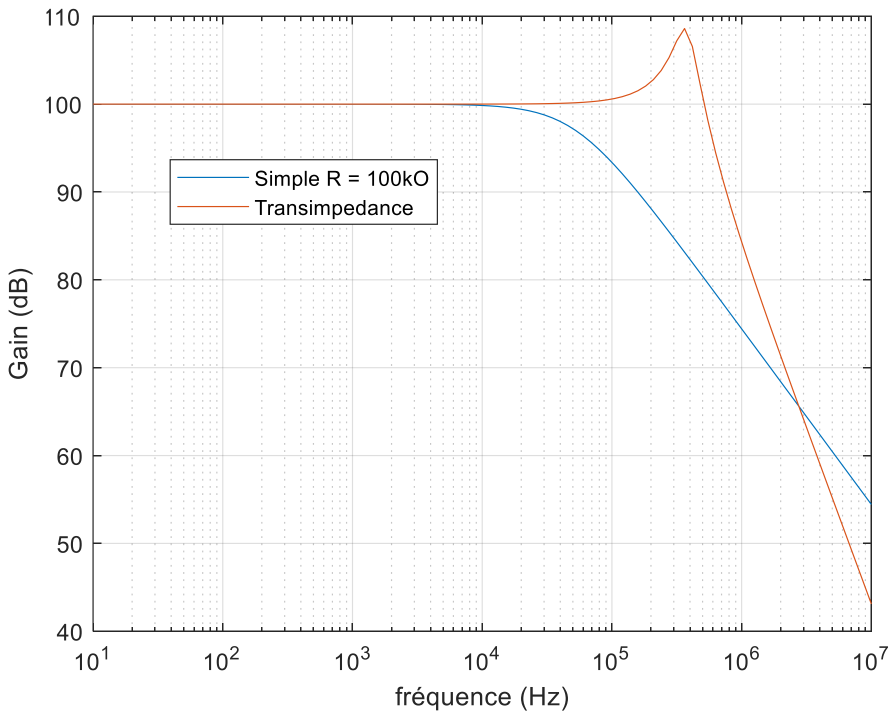


$$V_S = R_T \,.\, I_{photo}$$

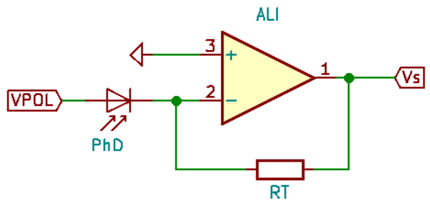


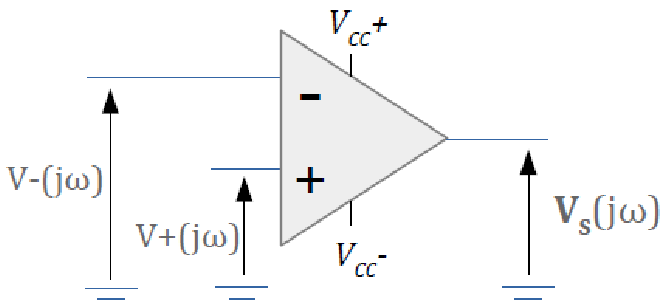
- **Montage transimpédance / Rép. fréquence « expérimentale »**





- **Montage transimpédance / Modèle de l'ALI**



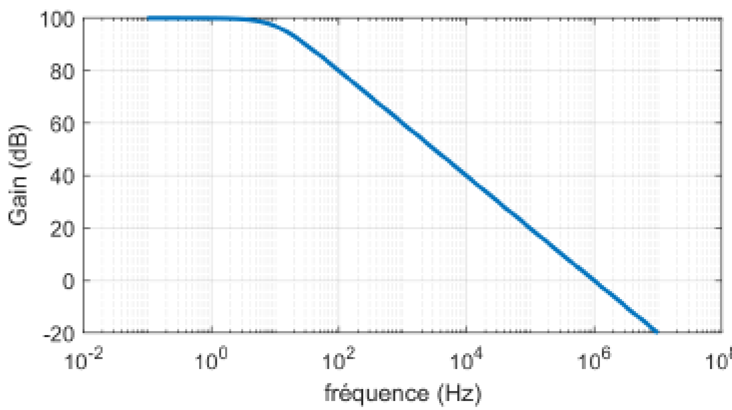


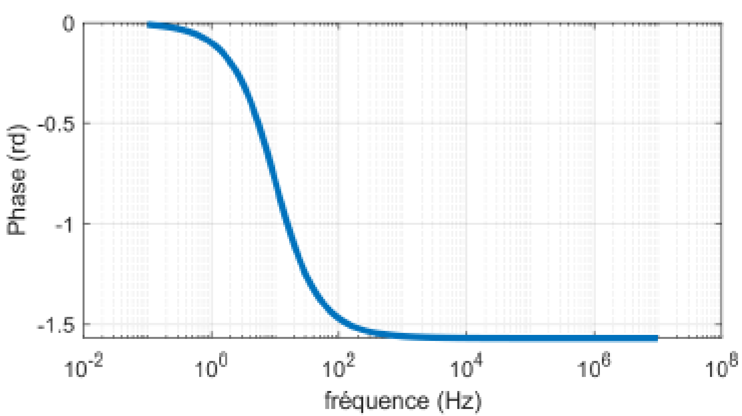
$$V_s(j\omega) = A(j\omega)\,.\,[V+(j\omega)\ -\ V-(j\omega)]$$

Où $\underline{A}(j\omega) = \dfrac{Av}{1 + j\dfrac{\omega}{\omega_c}}$

Av : amplification différentielle

$\omega_c = GBW / Av$





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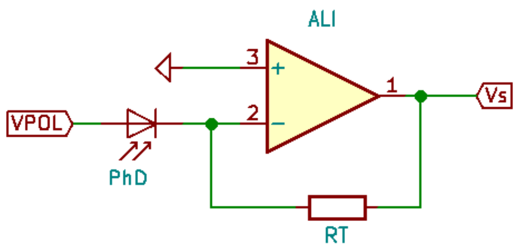
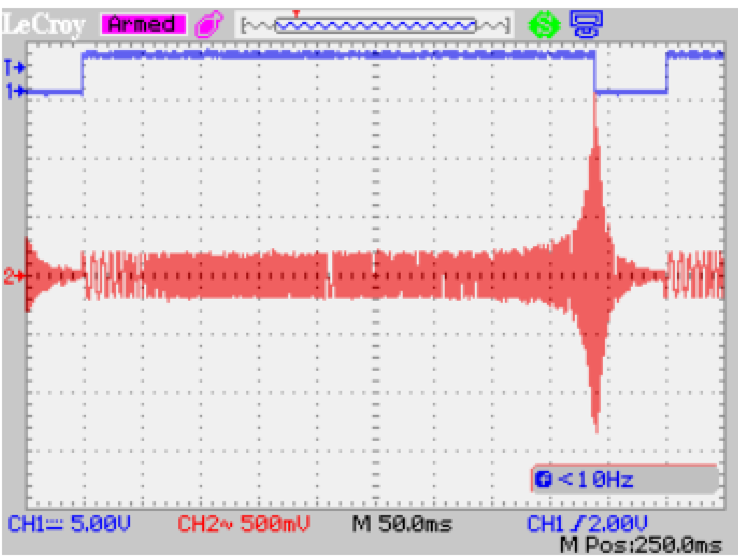
- **Montage transimpédance / Rép. fréquence « expérimentale »**

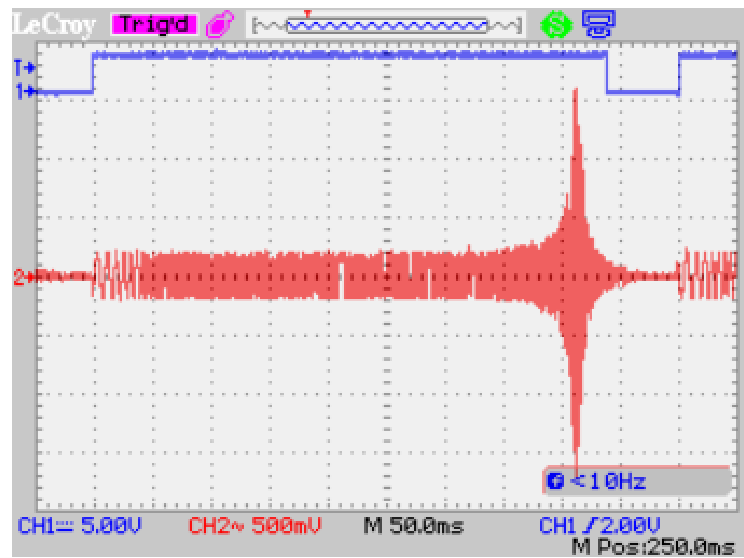


Gain Peaking

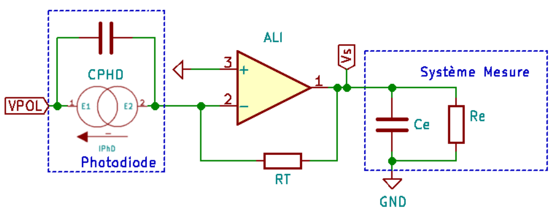
- Polarisation 15 V / Peak @ 330 kHz

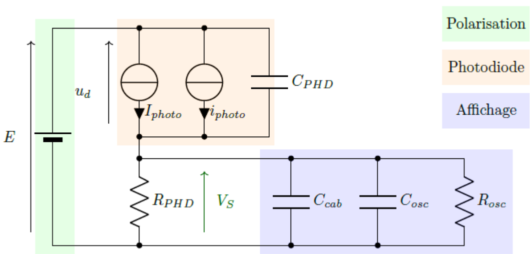


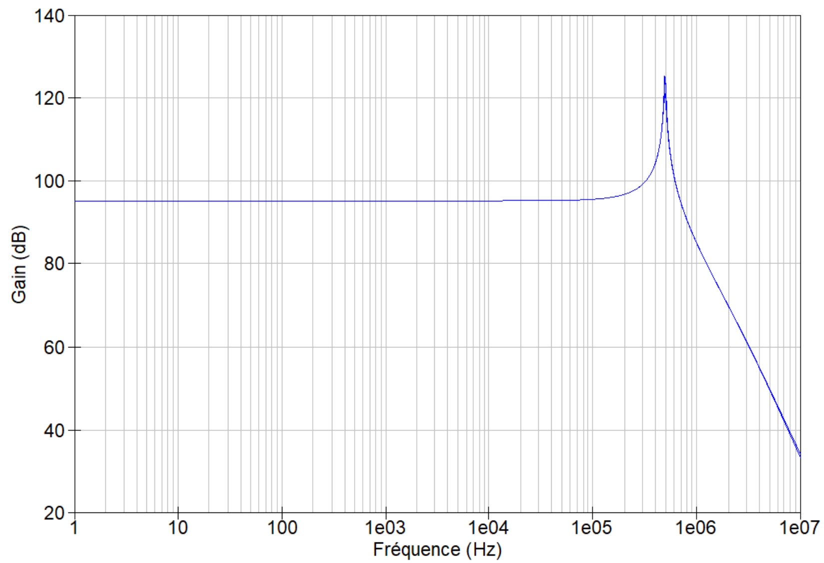
- Polarisation 0V / Peak @ 210 kHz

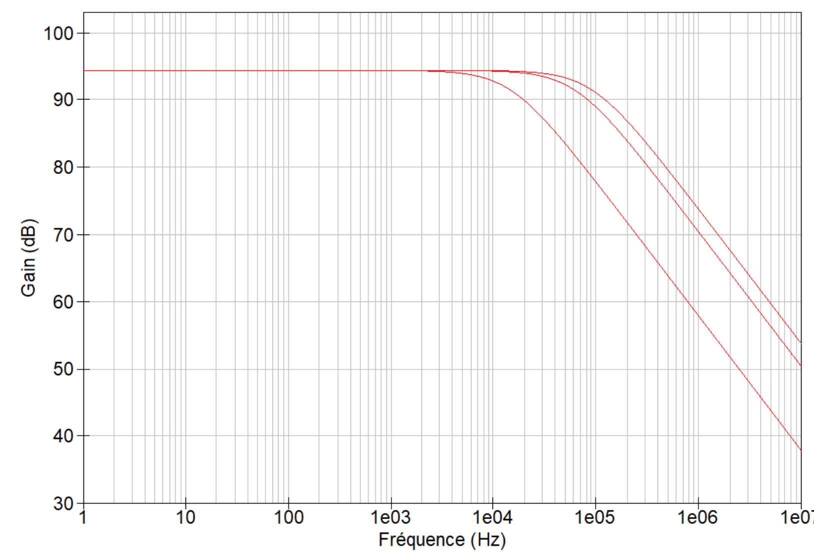


• Montage transimpédance vs simple









Pour Cosc+Ccab = 1pF, 10pF et 100pF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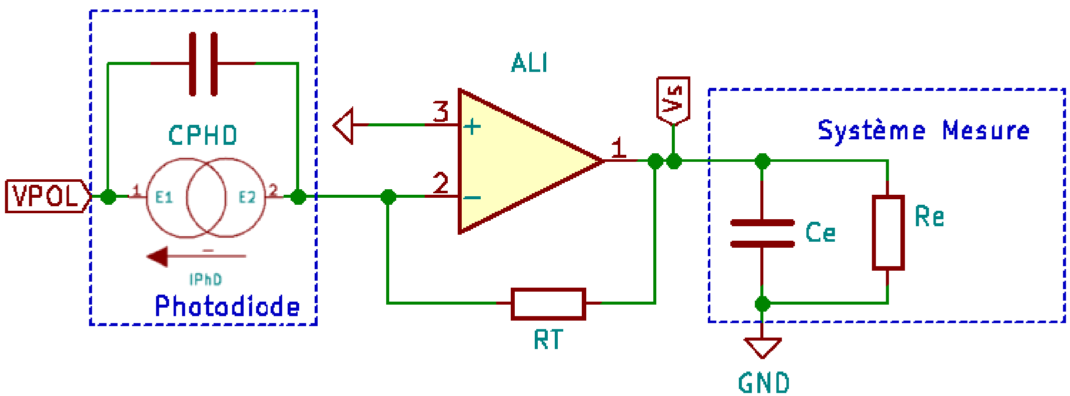
• Montage transimpédance / pour résumer



simple

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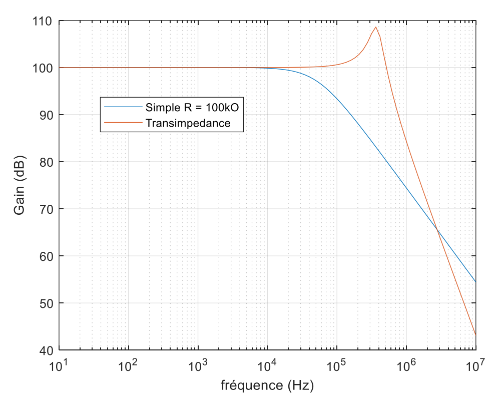
$$C_{eq} = C_{phd} + C_e$$

$$f_C = \frac{1}{2 \cdot \pi \cdot R_{eq} \cdot C_{eq}}$$

$$\frac{V_S}{I_{Phd}} = \frac{R_T \cdot A_0}{\left(1+\frac{j\cdot\omega}{\omega_0}\right)\cdot\left(1+\frac{j\cdot\omega}{\omega_c}\right)+A_0}$$

En utilisant le modèle du premier ordre pour l'amplificateur intégré (A_0, w_0)

Gain-peaking : $f_T = \sqrt{f_C \cdot GBP}$ avec $f_C = \frac{1}{2 \cdot \pi \cdot R_{PhD} \cdot C_{PhD}}$

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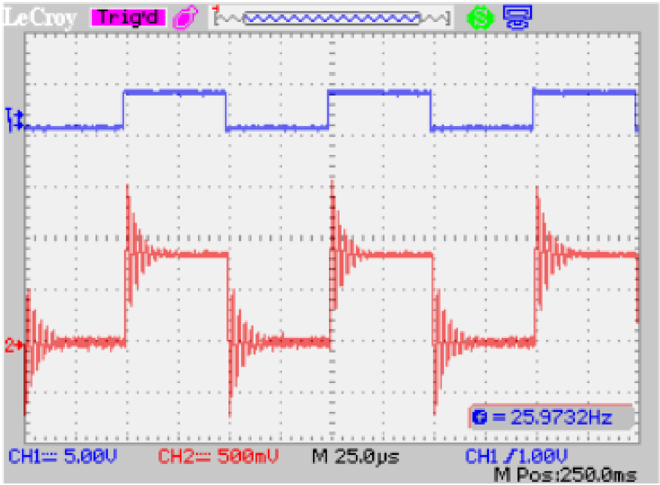
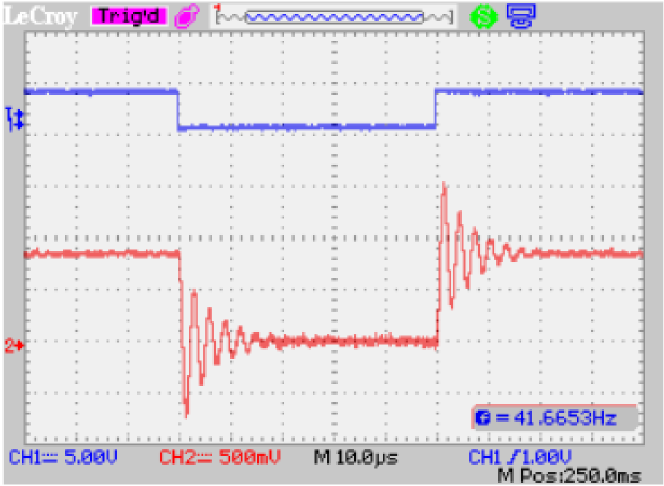
• Montage transimpédance / Gain peaking

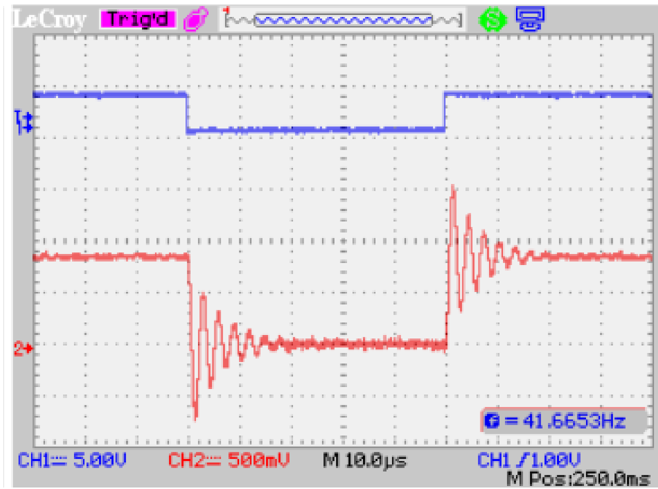
Signal carré à 10kHz / GBF : offset +4.8V / Amp = 3.3V





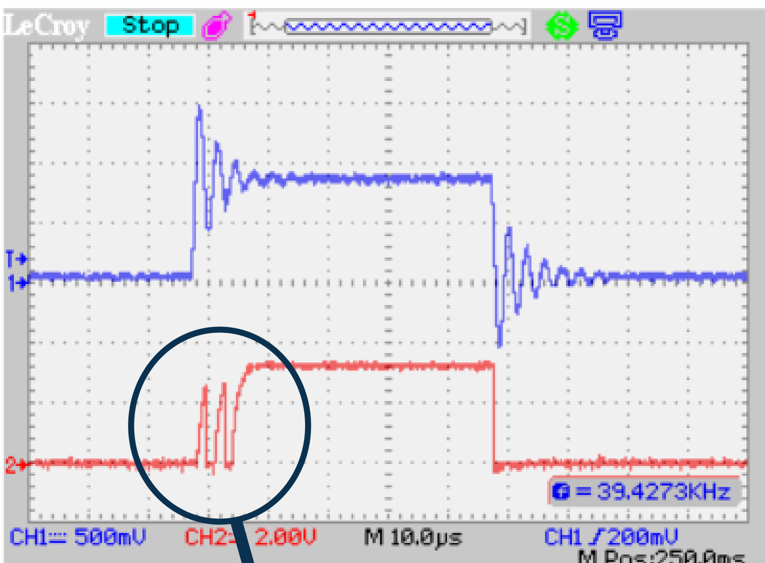
- ## Montage transimpédance / Gain peaking

Signal carré à 10kHz / GBF : offset +4.8V / Amp = 3.3V



Signal numérique comparé (LM311)

Signal carré à 10kHz / GBF : offset +4.8V / Amp = 3.3V



Erreurs !!