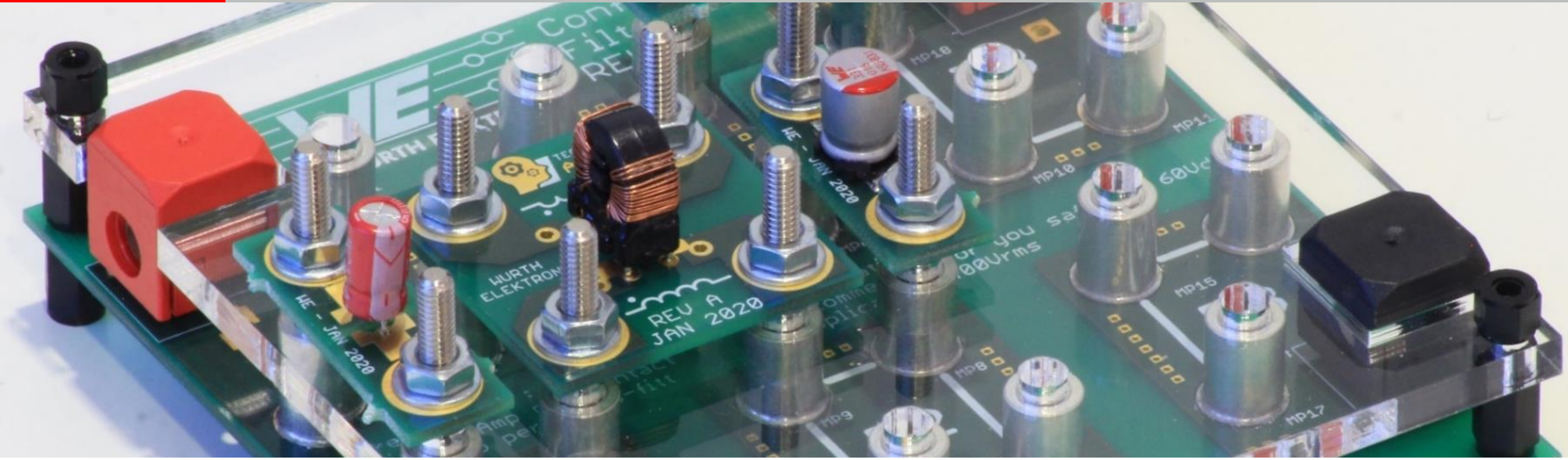
TECHNICAL ACADEMY

WÜRTH ELEKTRONIK

Filtrage : Dimensionnement et Topologies

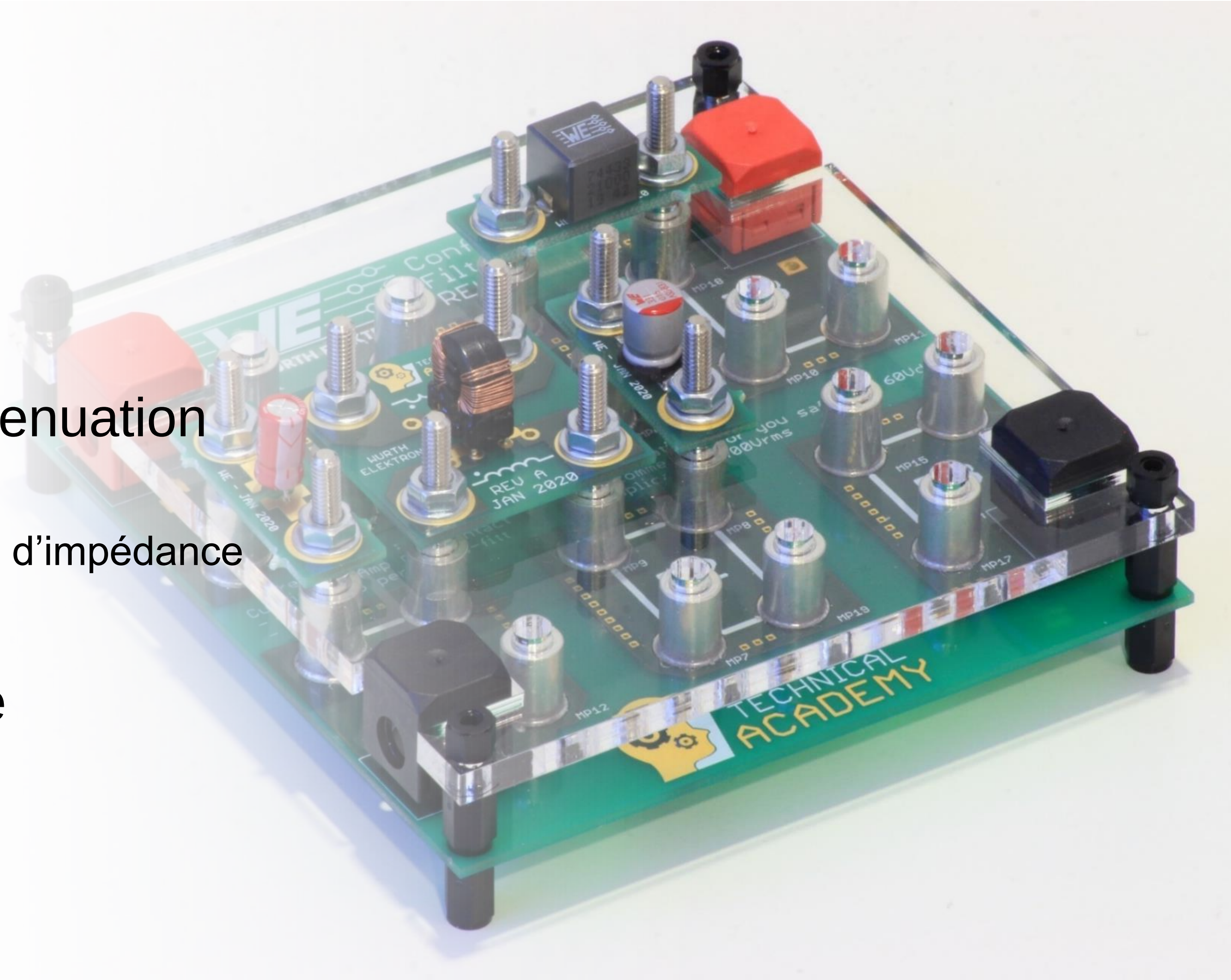


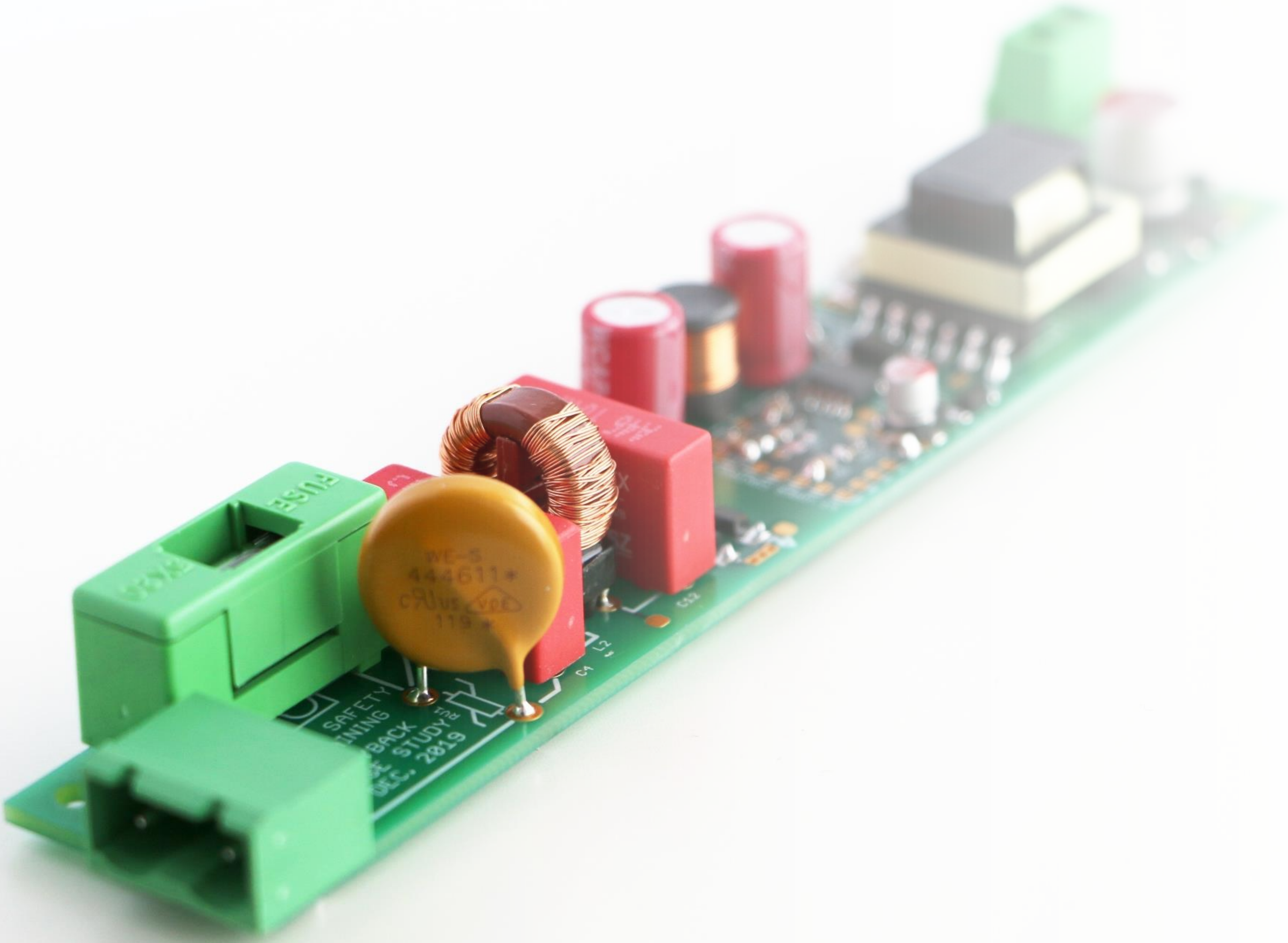
Sylvain LE BRAS

Wurth Elektronik eiSos

Filtrage : Dimensionnement et Topologies

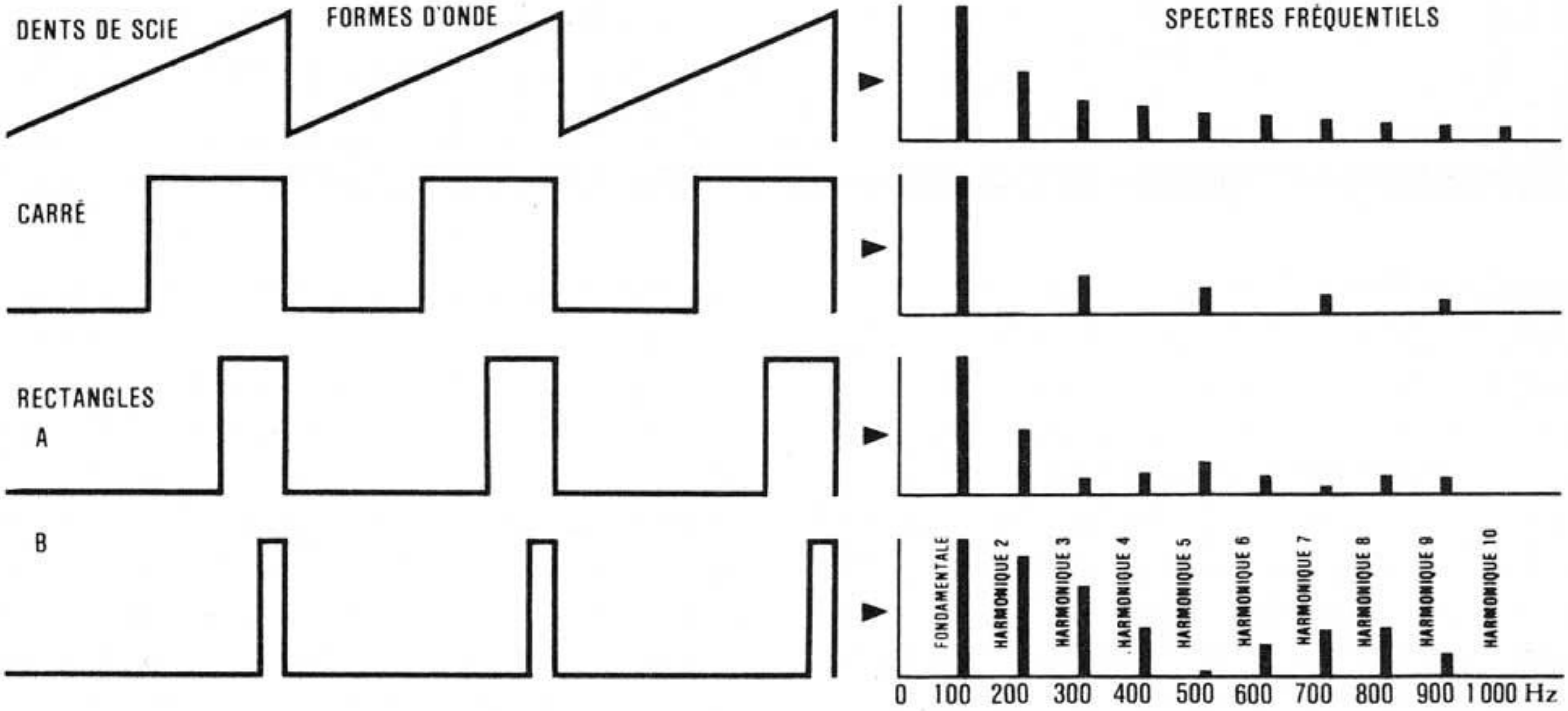
- Filtrer ?
- Dimensionnement de votre filtre
  - Courant
  - Tension
  - Atténuation
- Passer d’une impédance à une attenuation
  - Le système d’impédance et son impact
  - Topologie à choisir en fonction du système d’impédance
- Rappels sur le filtrage
- Obstacles entre théorie et pratique
  - Facteur de qualité
  - Fréquences de self-résonance
  - Couplages parasites





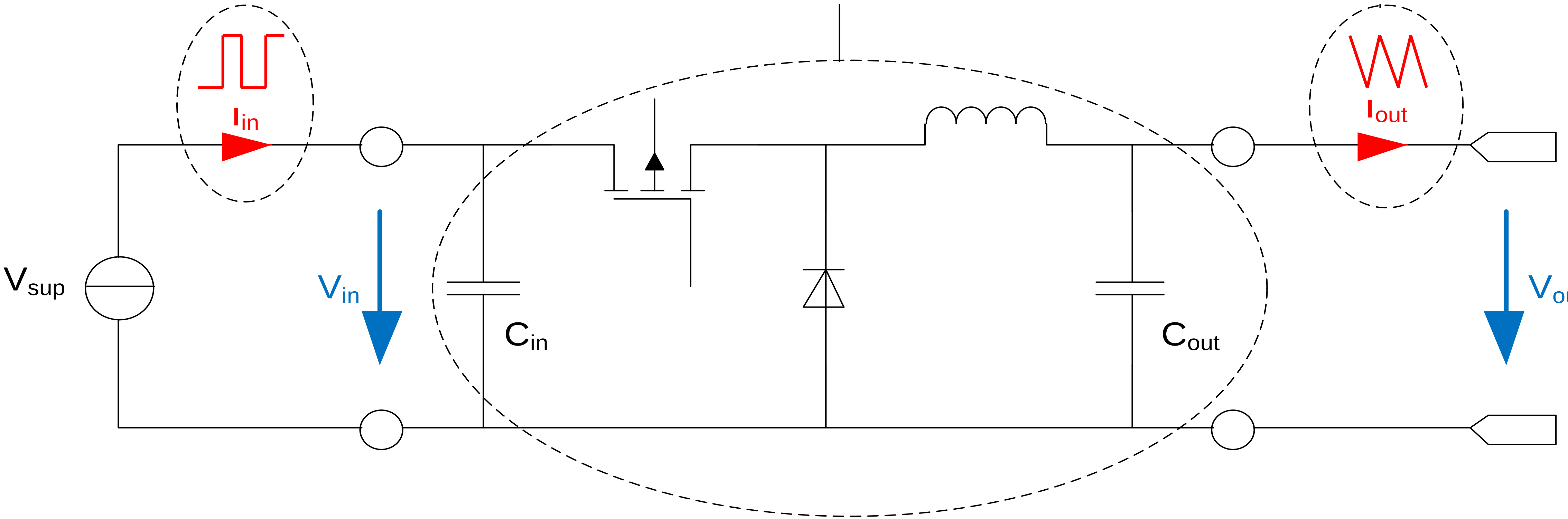
FILTRER ?

Filtrer quoi ?

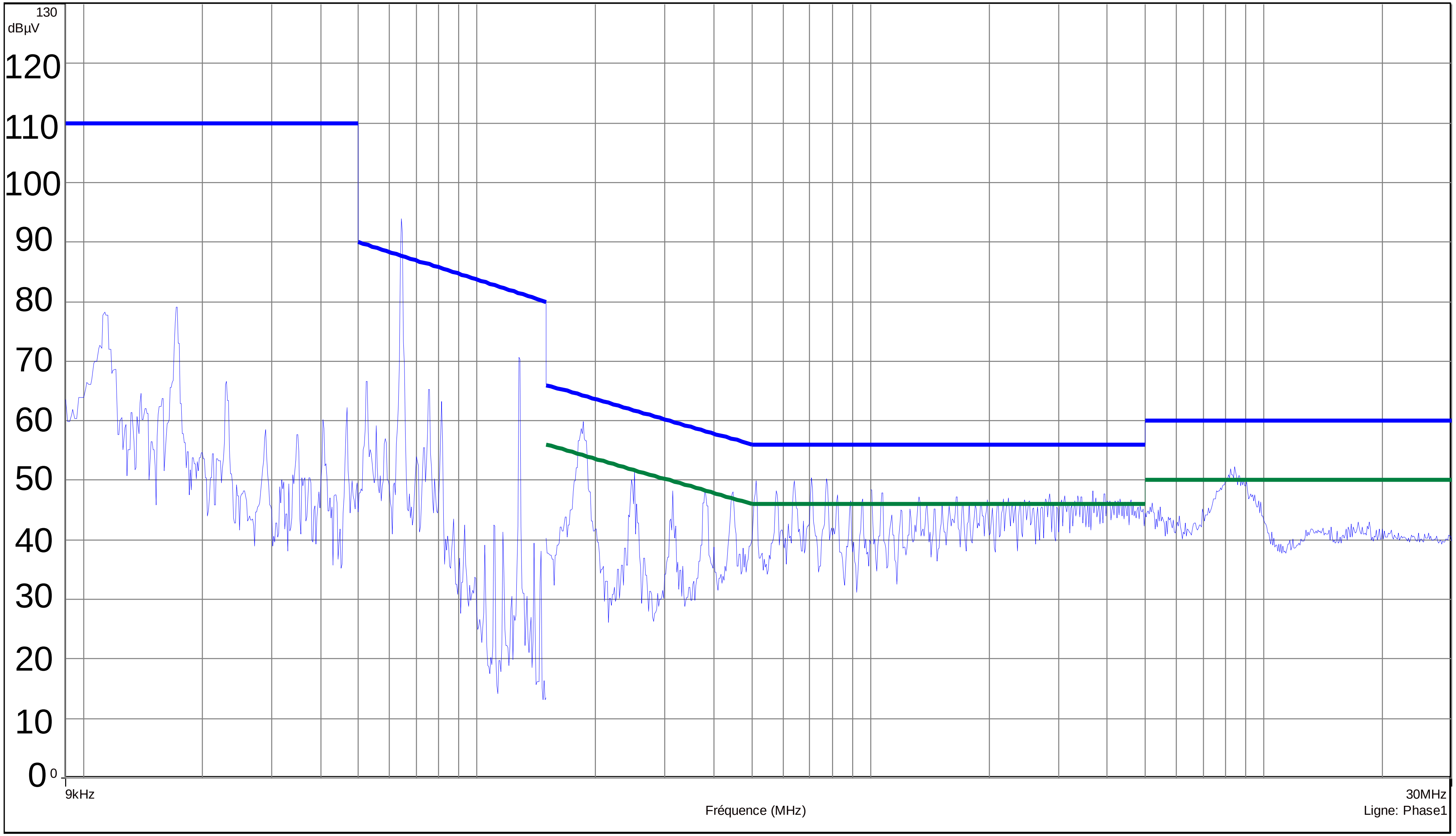


Source : Pianoweb-fr

Filtrer quoi ?



Filtrer dans quel but ?



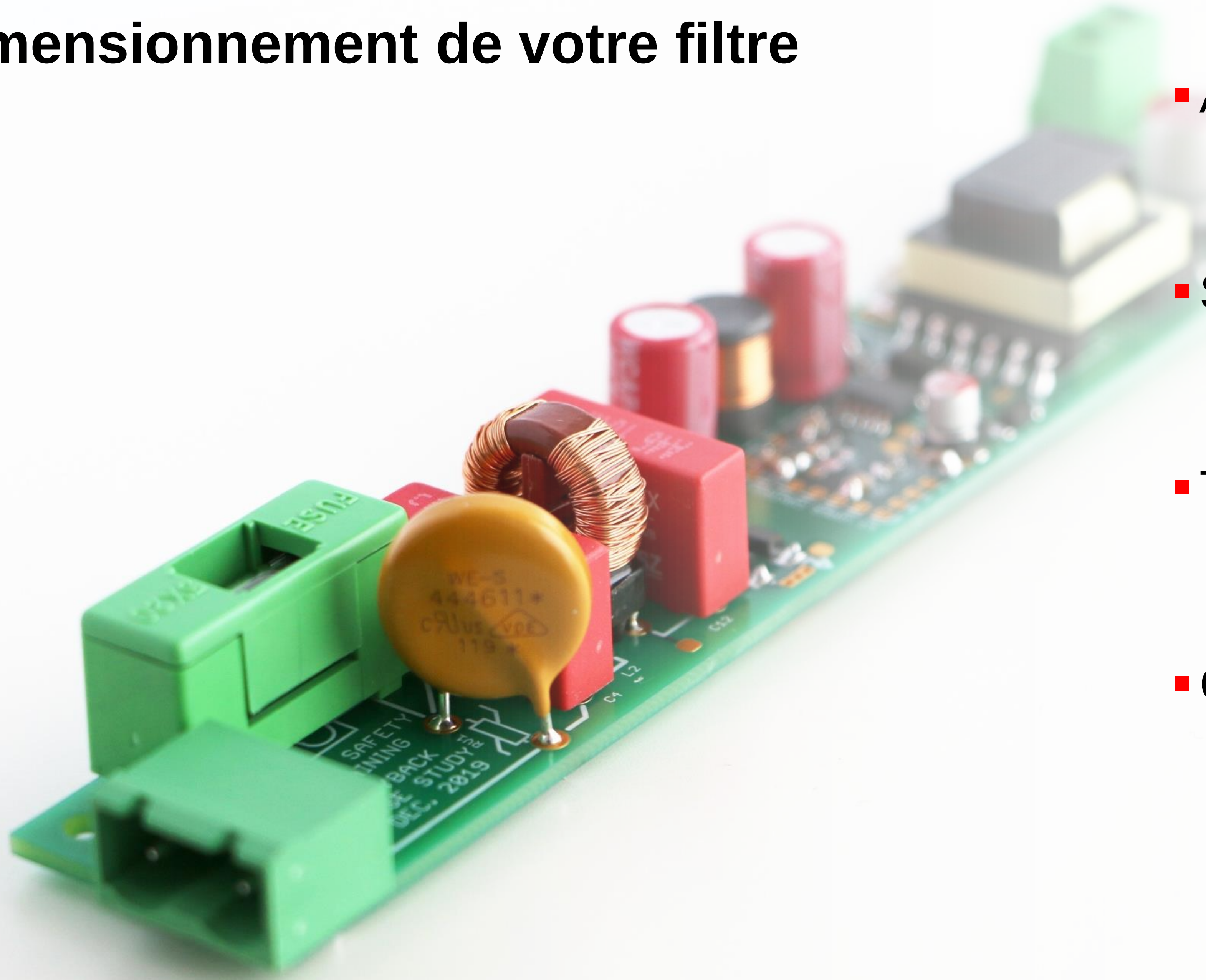
Filtrer dans quel but ?

Table 3. Electrical characteristics measured at V_{CC+} = +3 V, V_{CC-} = 0 V, V_{icm} = $V_{CC}/2$, T_{amb} = 25° C, and R_L connected to $V_{CC}/2$ (unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage				500	µV
		$T_{min} \le T_{amb} \le T_{max}$			900	
$\Delta V_{io}/\Delta T$	Input offset voltage drift			2		µV/°C
I_{io}	Input offset current	$V_{out} = V_{CC}/2$, $T_{min} \le T_{amb} \le T_{max}$		1	30	nA
I_{ib}	Input bias current	$V_{out} = V_{CC}/2$ $T_{min} \le T_{amb} \le T_{max}$		15	55 90	nA
CMR	Common mode rejection ratio	V_{icm} from 0 to 3 V $T_{min} \le T_{amb} \le T_{max}$	65 60	85		dB
SVR	Supply voltage rejection ratio	V_{CC} = 2.7 to 3.3 V $T_{min} \le T_{amb} \le T_{max}$	75 70	90		dB

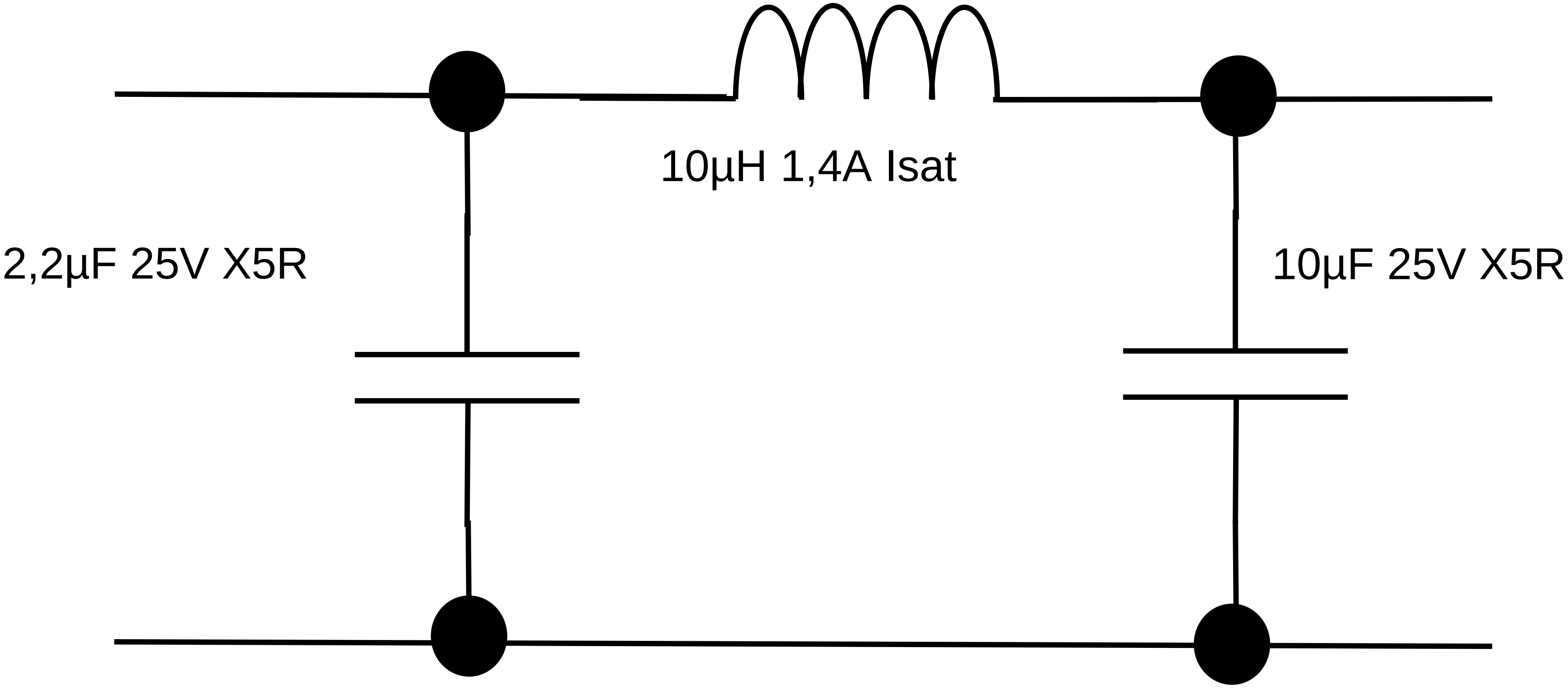
Source : datasheet ST - TS9222

Dimensionnement de votre filtre

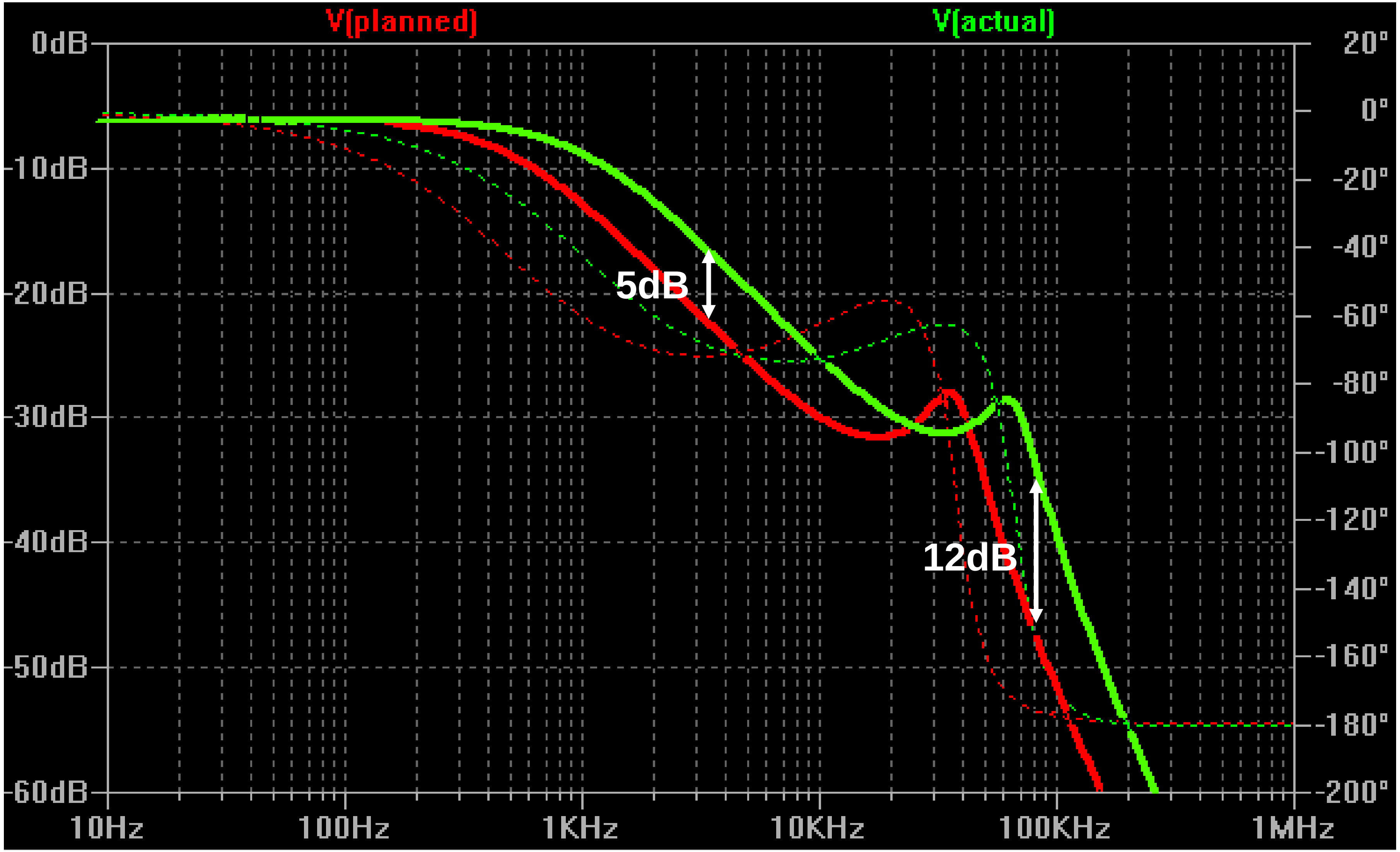


- Attenuation
  - Mode commun
  - Mode différentiel
- Système d’impédance
  - Source
  - Charge
- Tension
  - AC / DC
  - Tenue aux surtensions
- Courant
  - Nominal
  - Rms / Crête
  - En défaut
  - De fuite ?

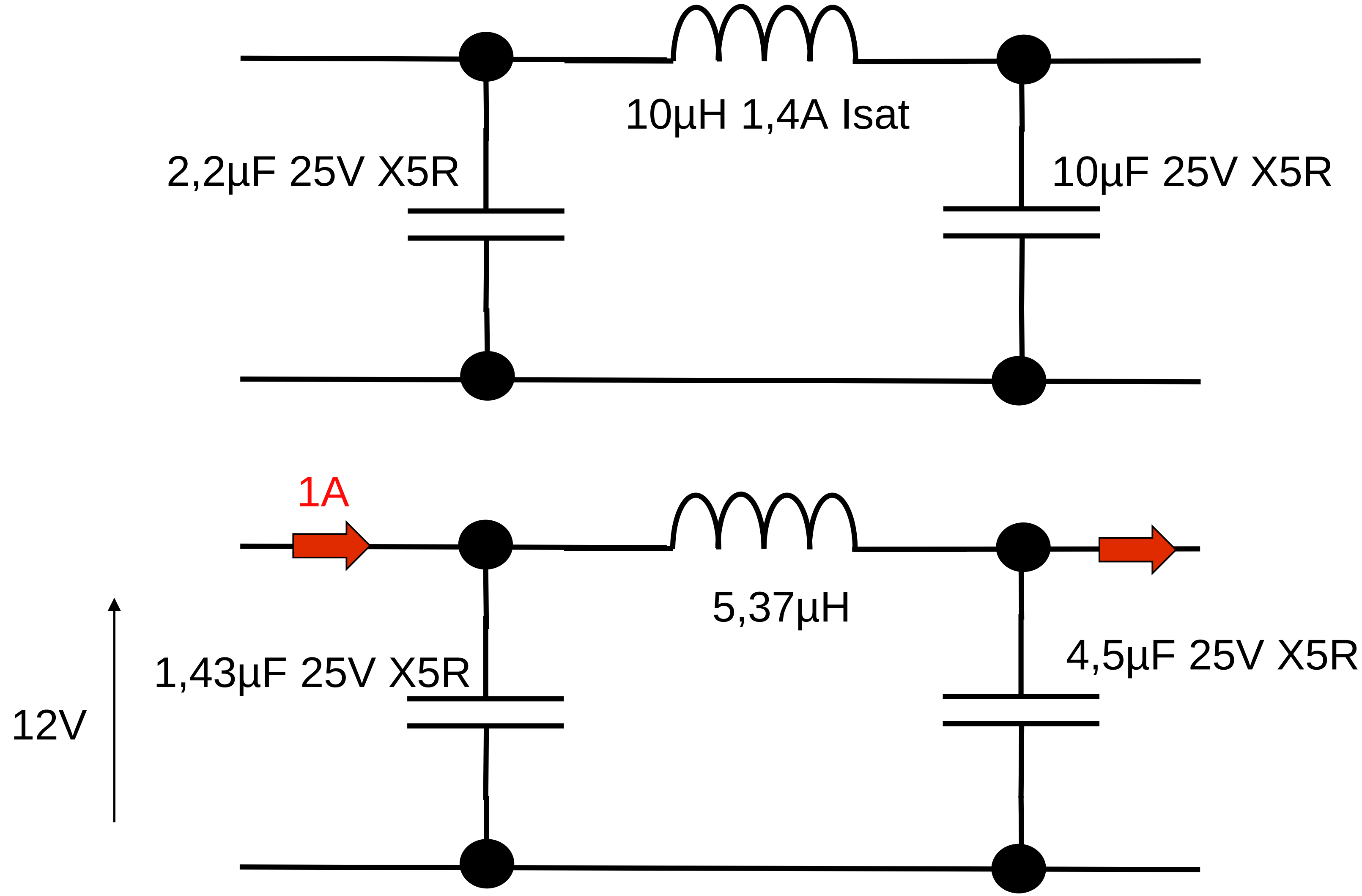
Dimensionner son filtre en courant et en tension ?



Dimensionner son filtre en courant et en tension ?

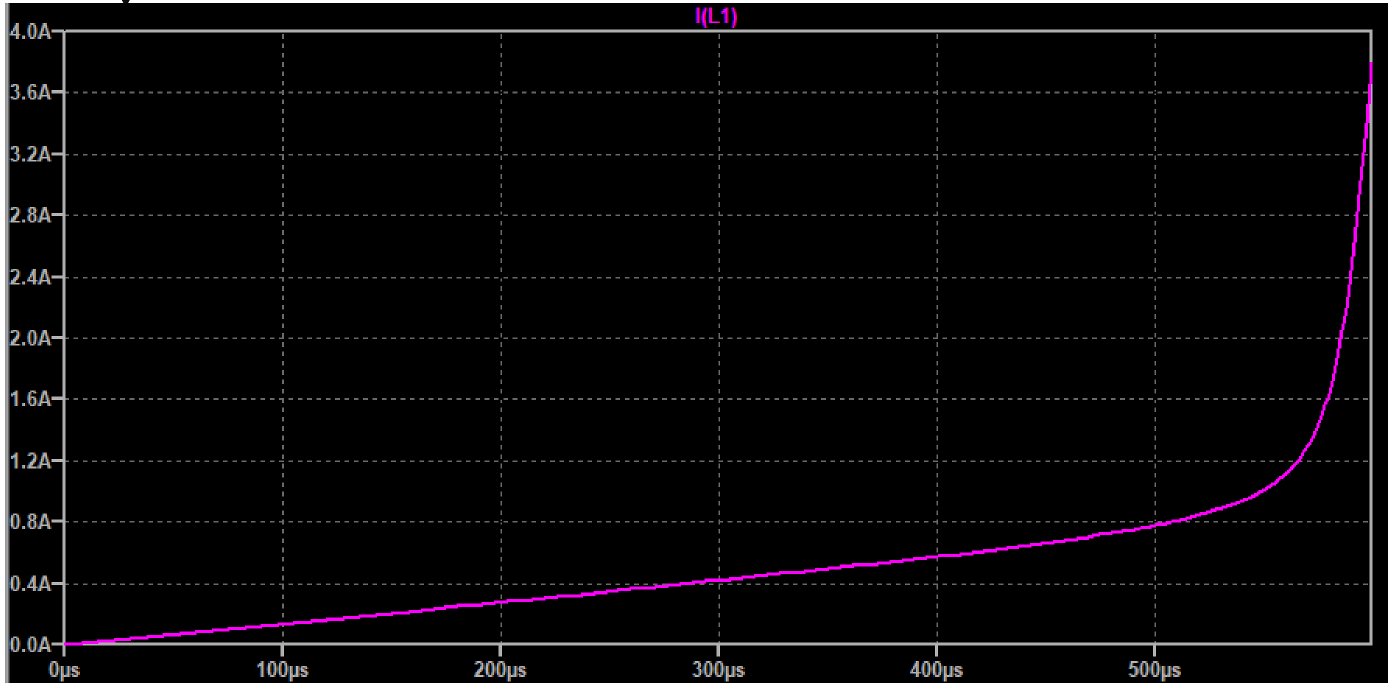


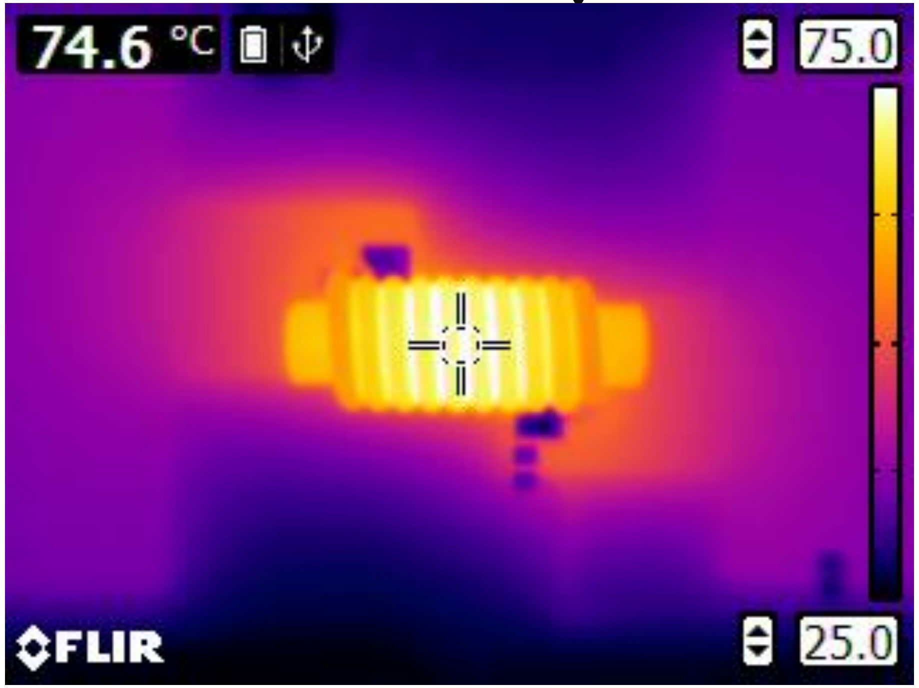
Dimensionner son filtre en courant et en tension ?



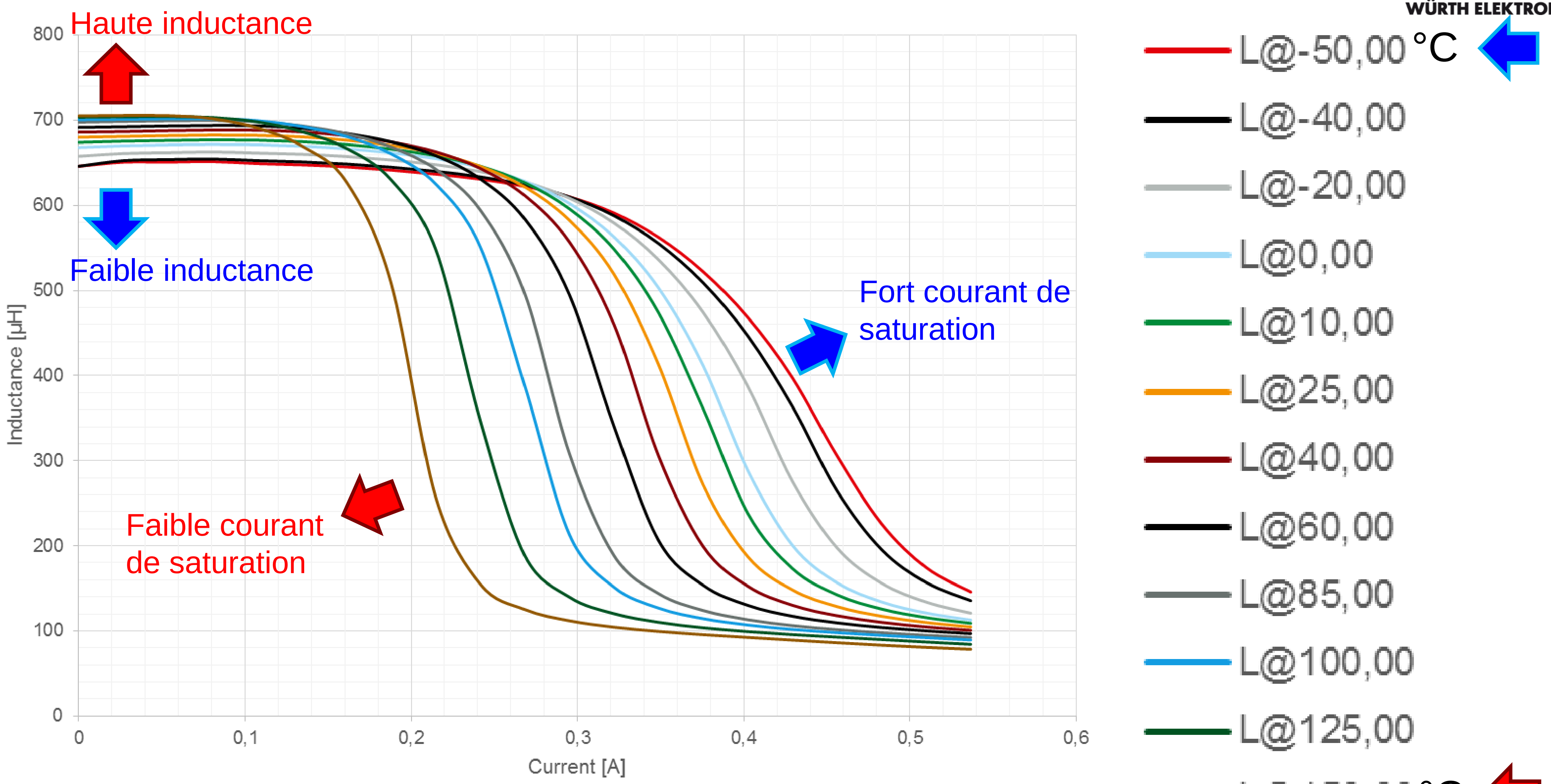
Influence du courant

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 1 V	1000	µH	±20%
Rated Current	I_R	$\Delta T = 40$ K	0.48	A	max.
Saturation Current	I_{SAT}	$\lvert\Delta L/L\rvert < 30$ %	0.65	A	typ.
DC Resistance	R_{DC}	@ 20 °C	2350	mΩ	±20%
Self Resonant Frequency	f_{res}		1.39	MHz	typ.

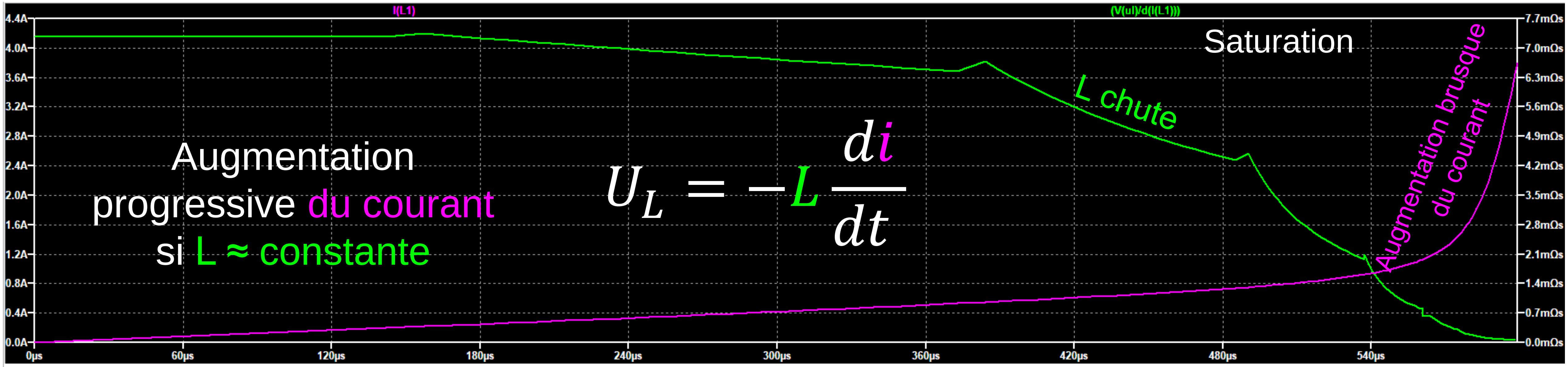


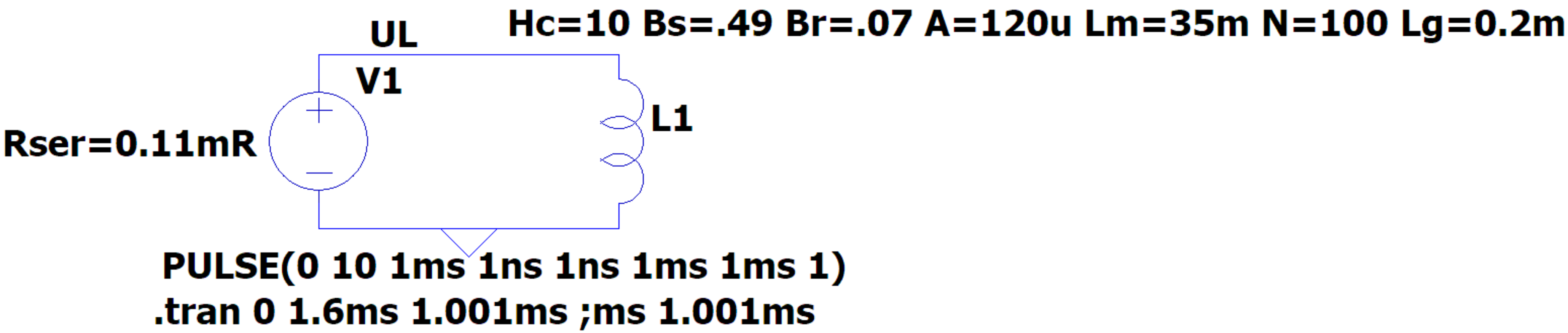


Comportement en température et en fonction du courant

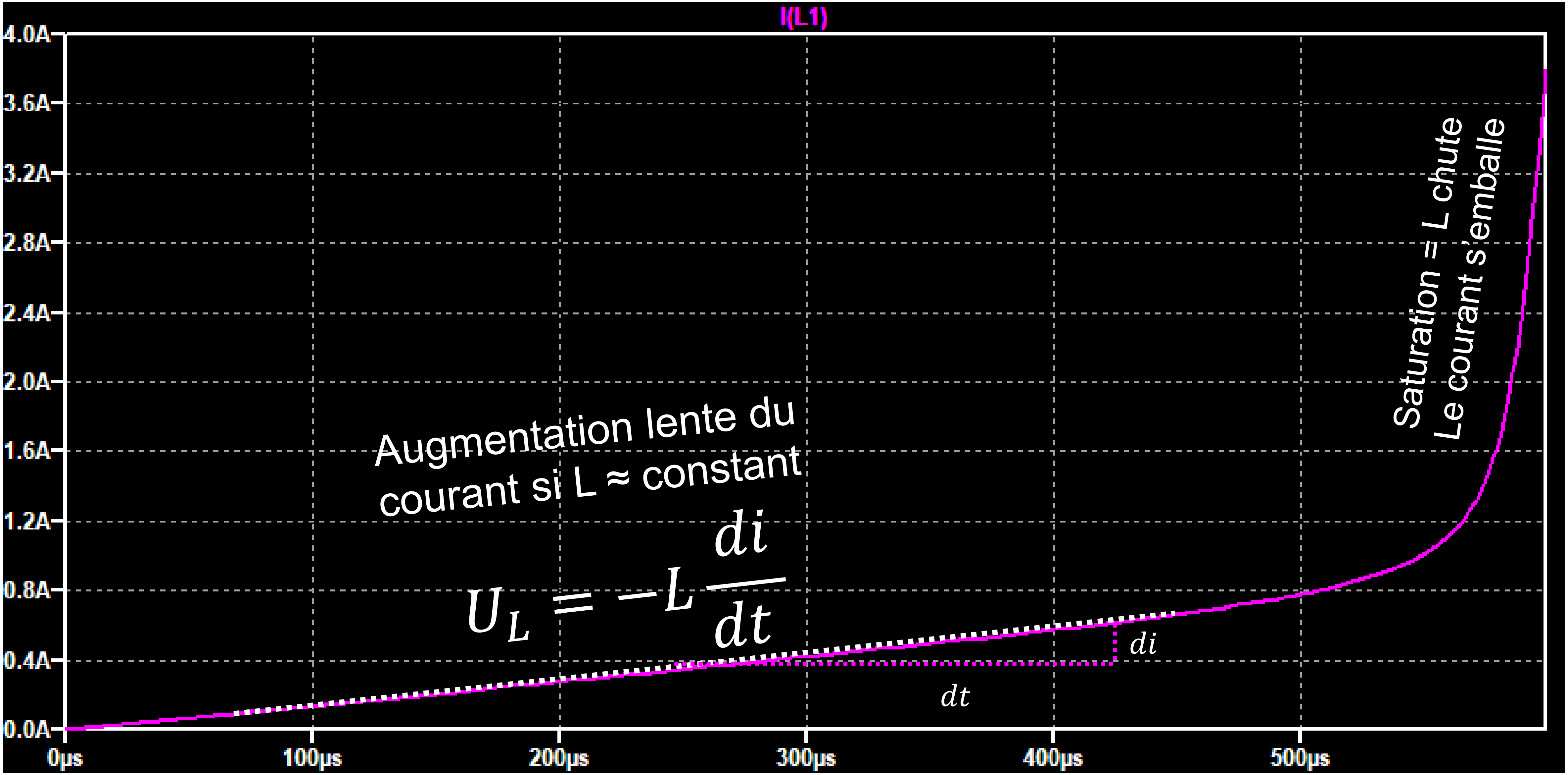


Impact mathématique de la saturation (et simulation)

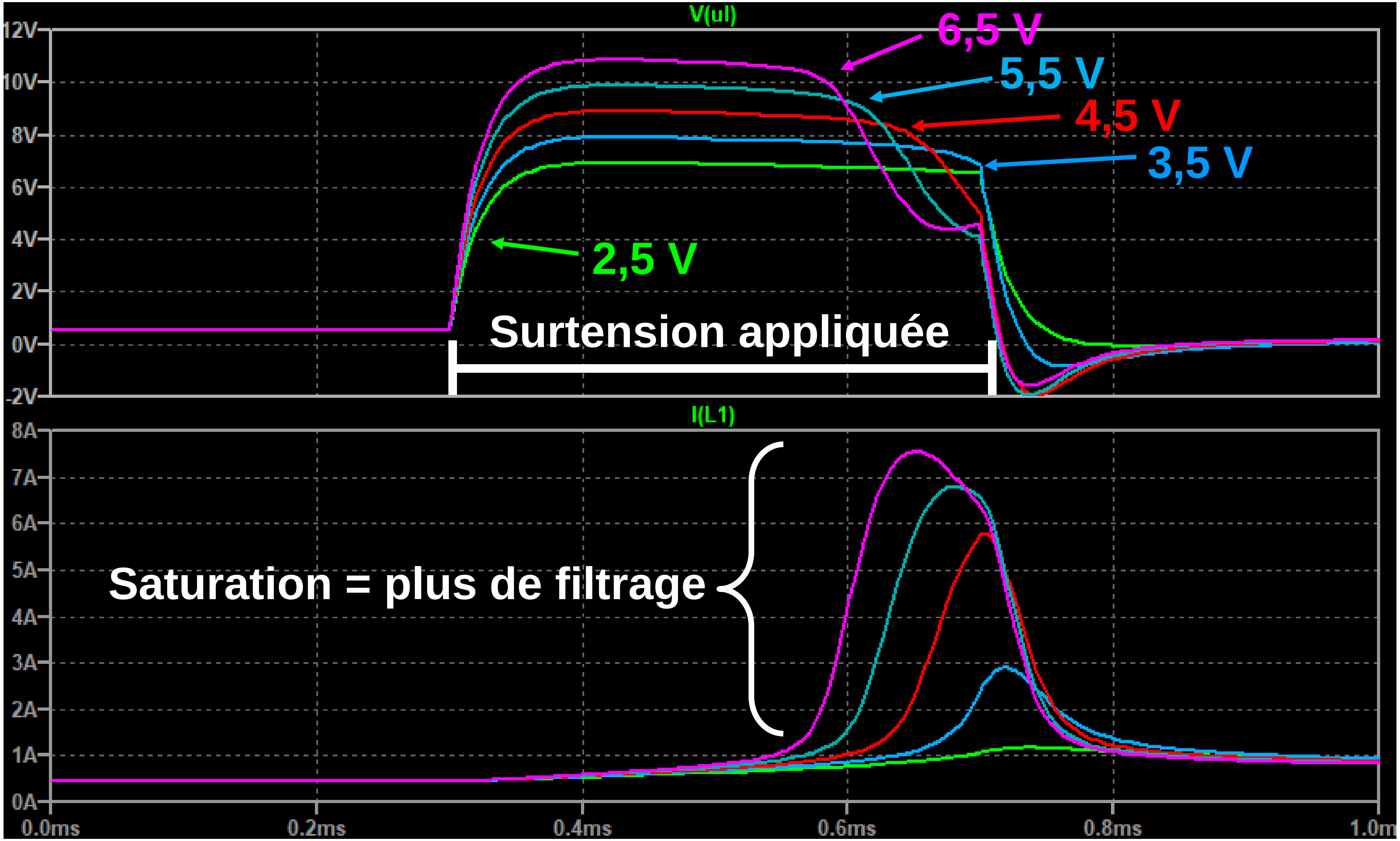




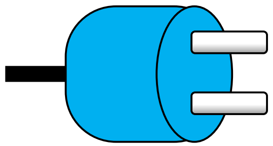
Les effets de la saturation dans les filtres

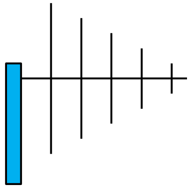


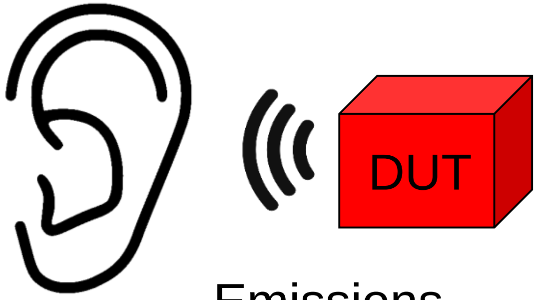
Exemple de saturation



Impact typique de la saturation

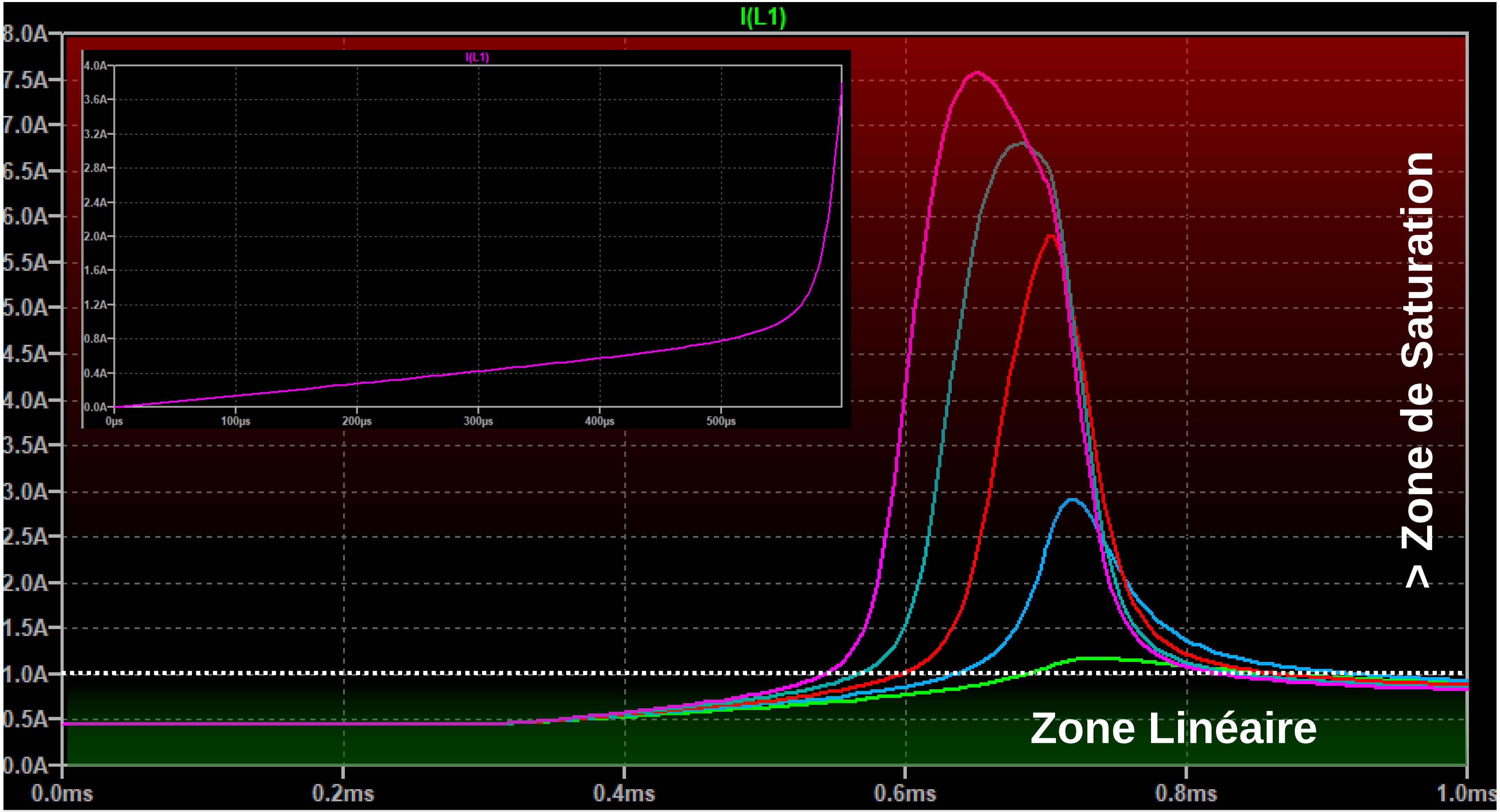






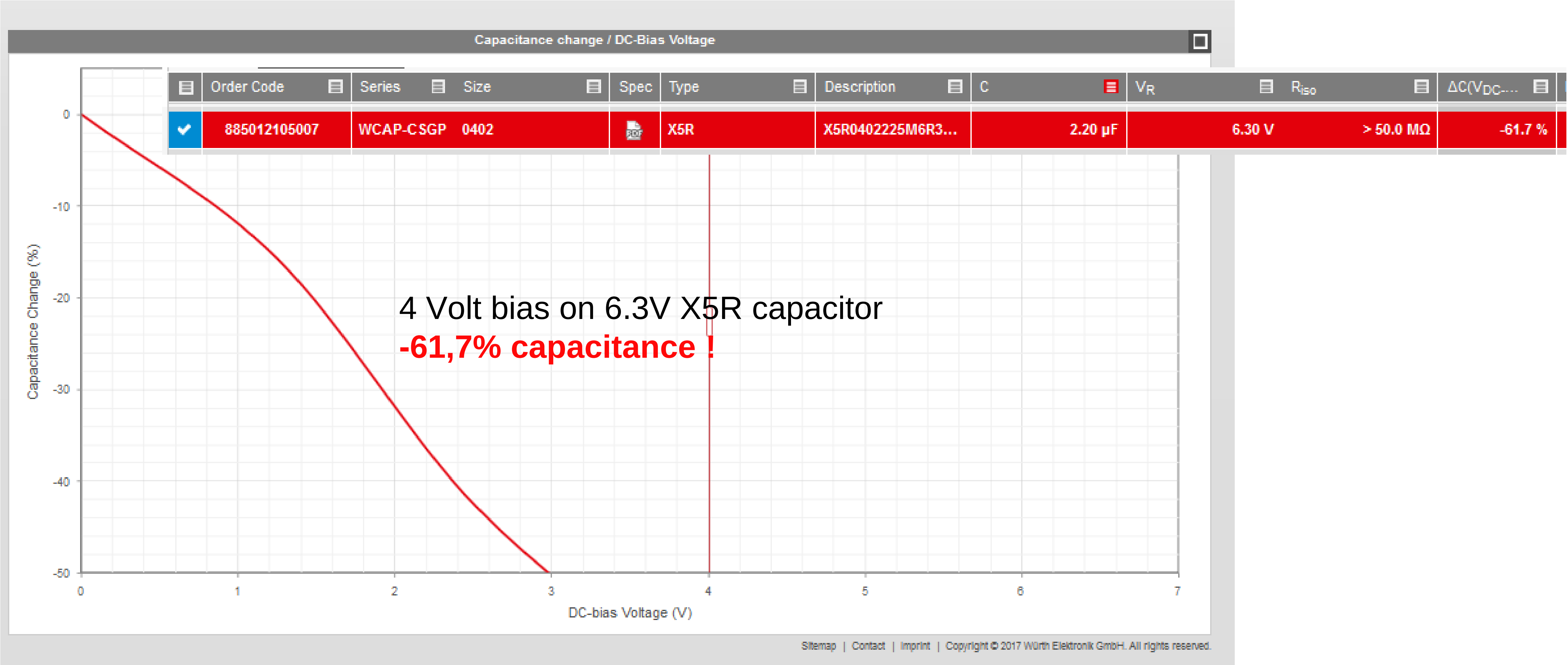
	Conducted	Radiated
Emissions	Frequency + Level	Frequency + Level + Orientation
Immunity	**Frequency / shape + Level + Coupling + Stability criteria**	**Frequency + Level + Orientation + Stability criteria**

Les effets de la saturation dans les filtres

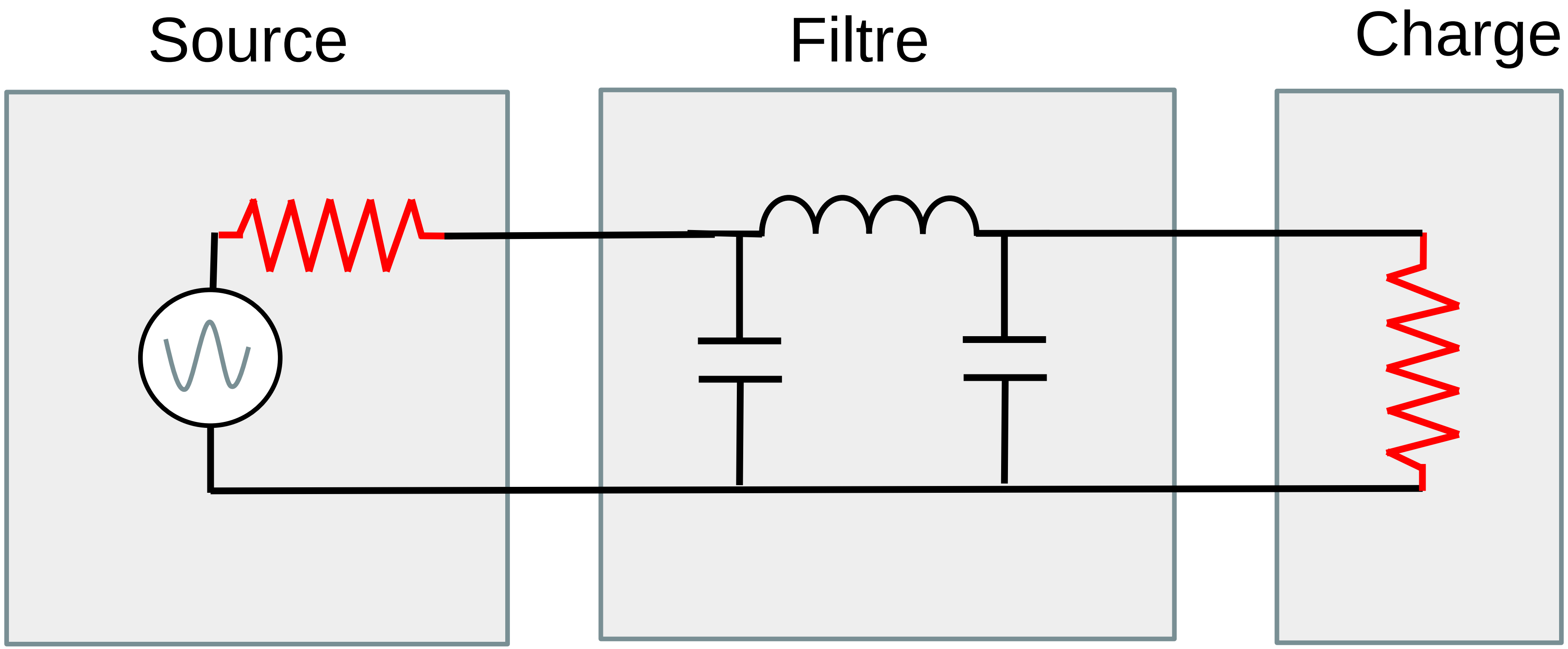


Effet du biais en tension dans les condensateurs

- **La valeur d'un condensateur est donnée à 0Vdc et 25°C**

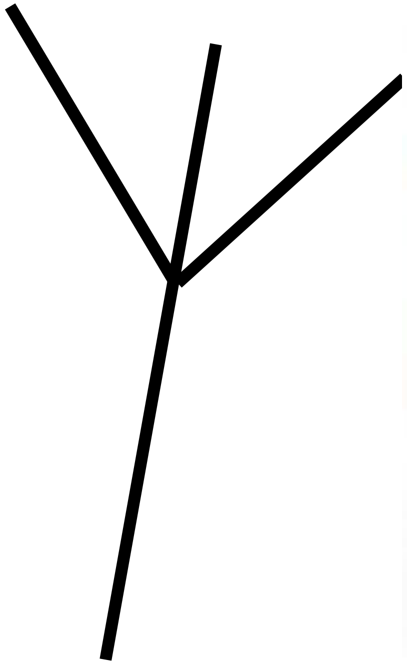


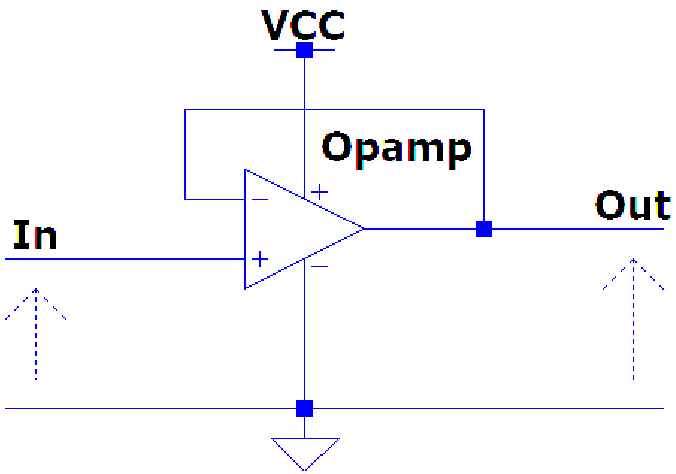
Système d’impédance ?



Votre système d’impedance ?

- System impedance ?

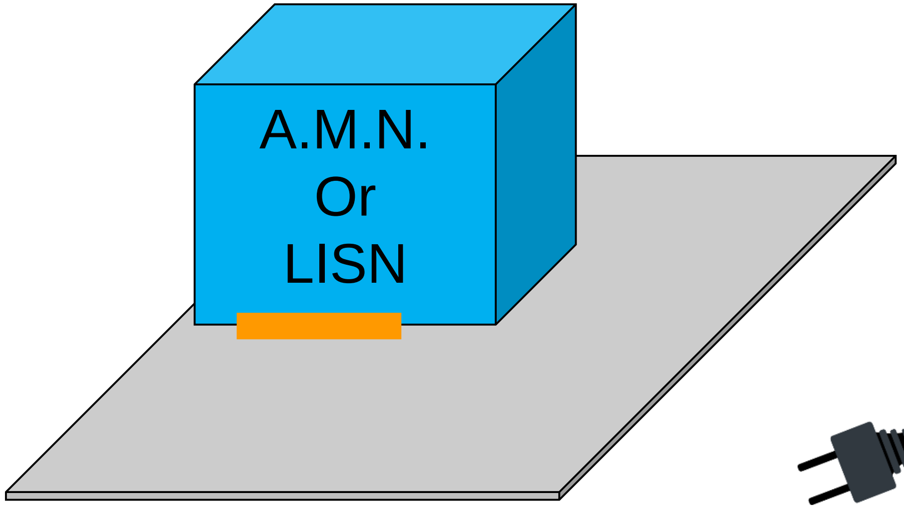




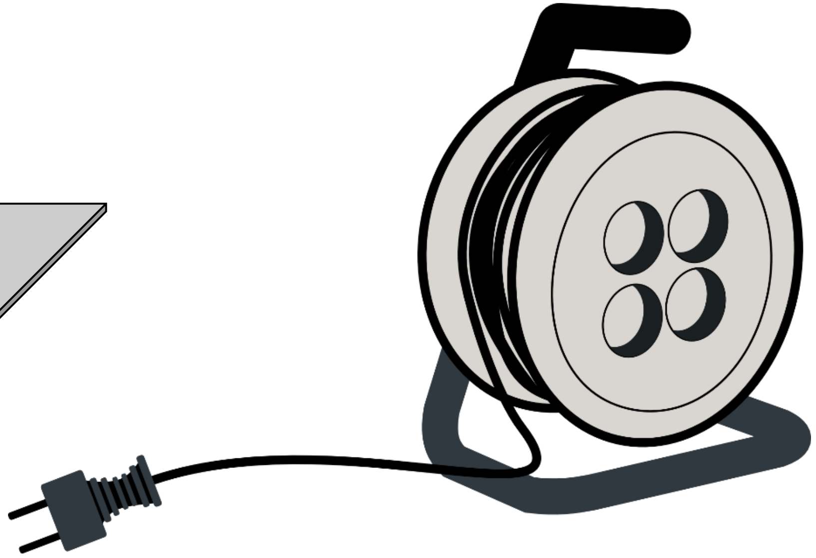
Low High Low High Low

Votre système d’impedance ?

- System impedance ?



High and Low

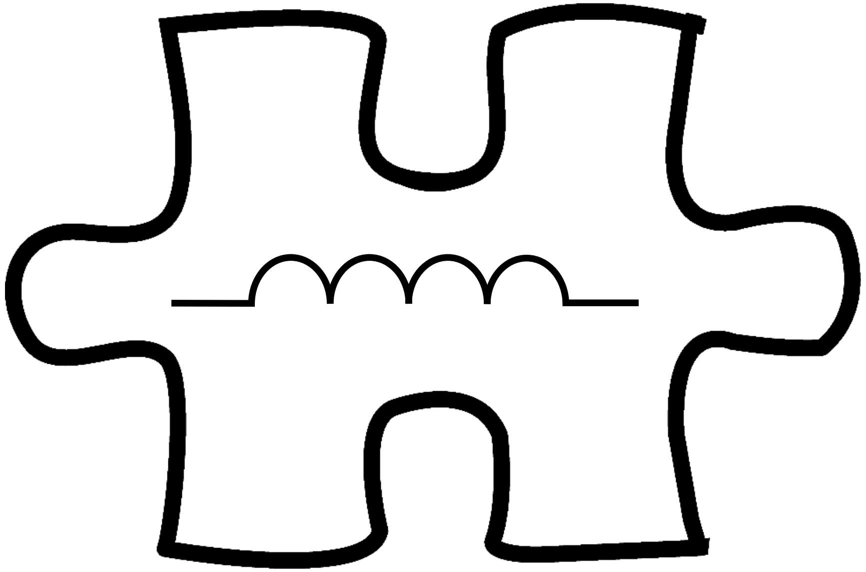


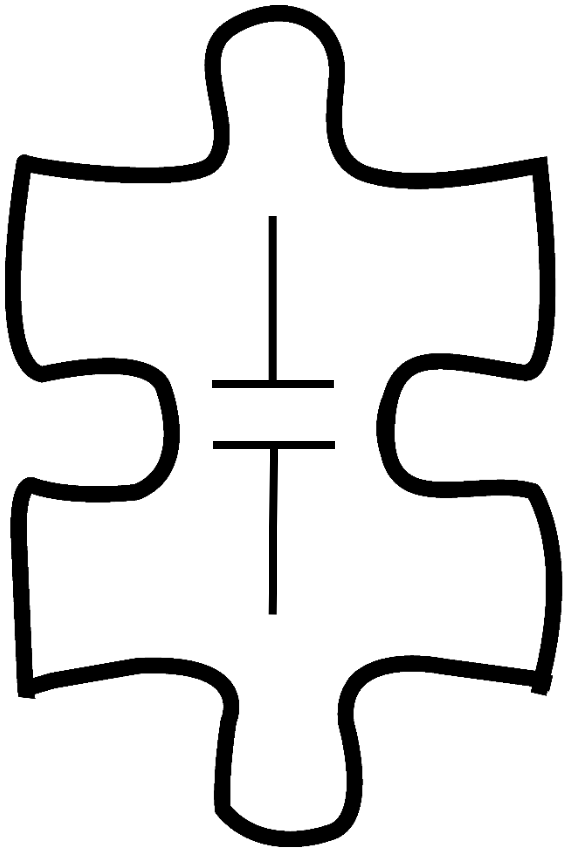
Low to High

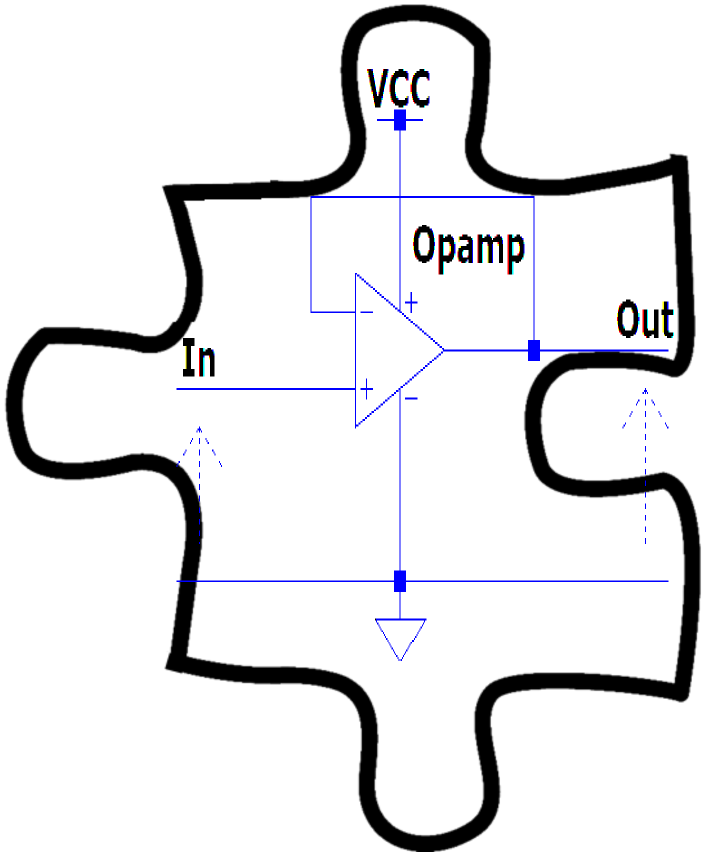
High

Votre système d’impedance ?

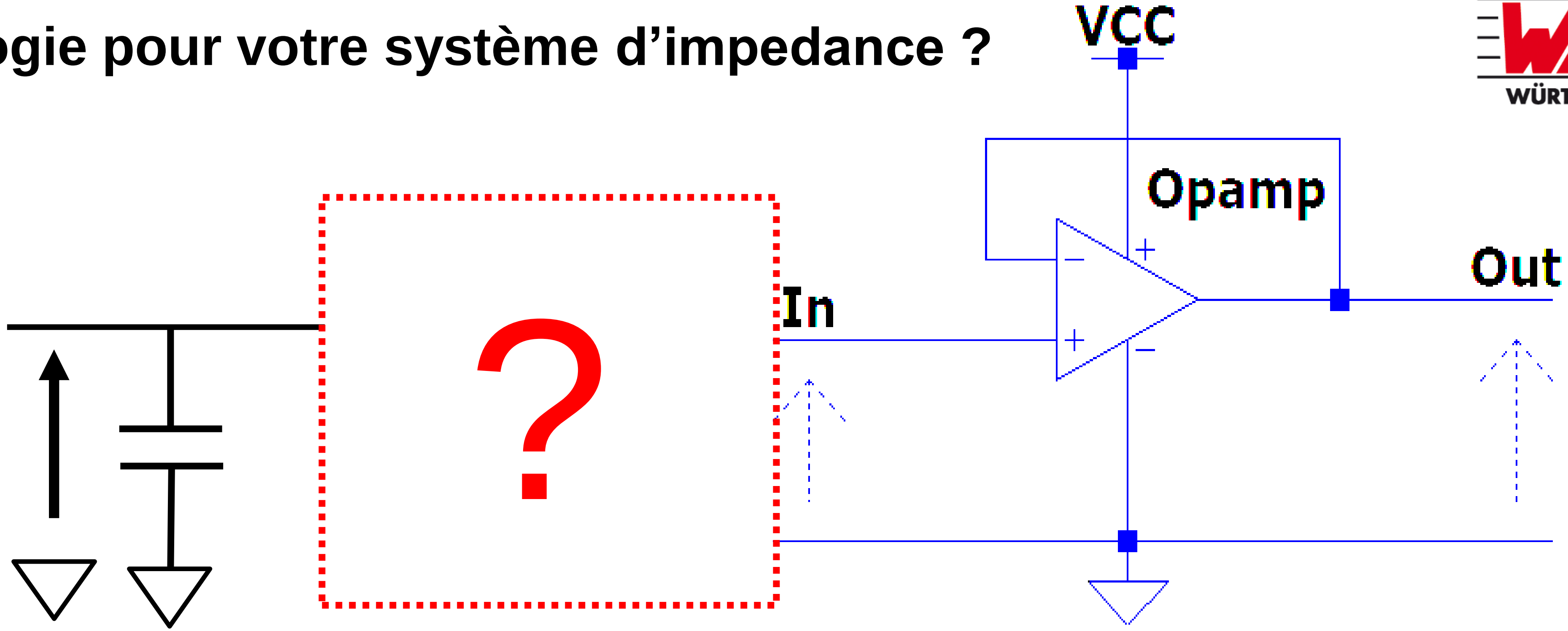
- Restons sur des choses simple

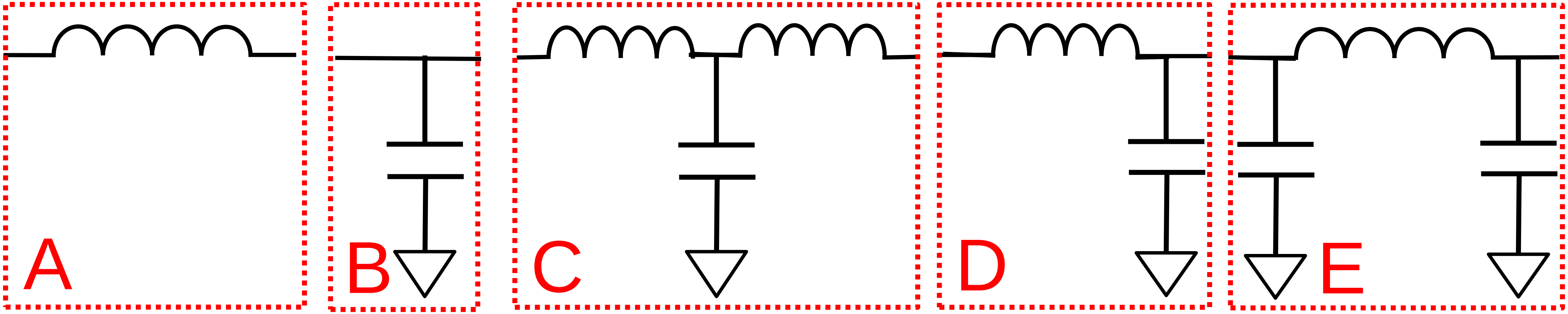




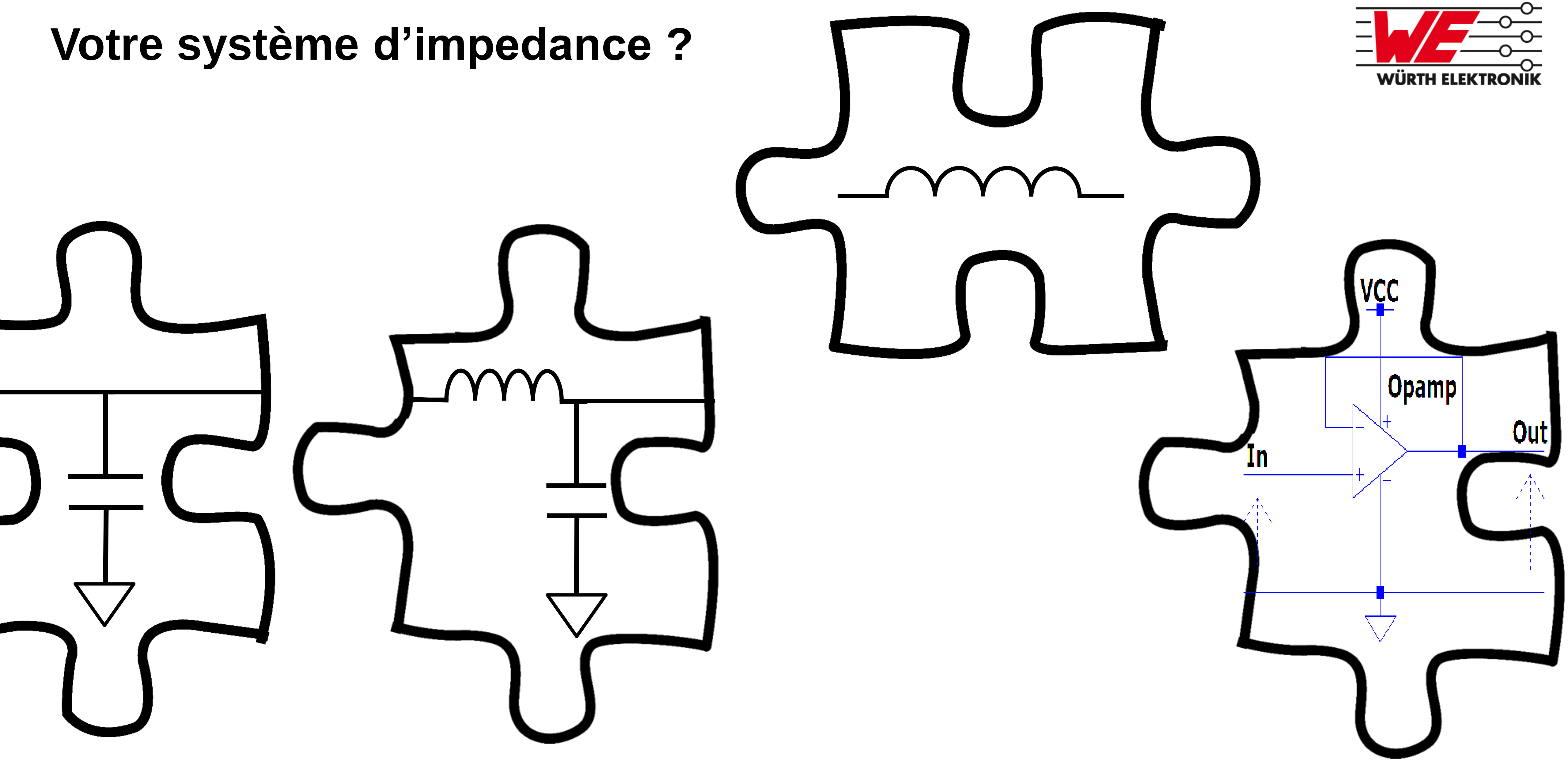


Quelle topologie pour votre système d'impedance ?





Votre système d’impedance ?



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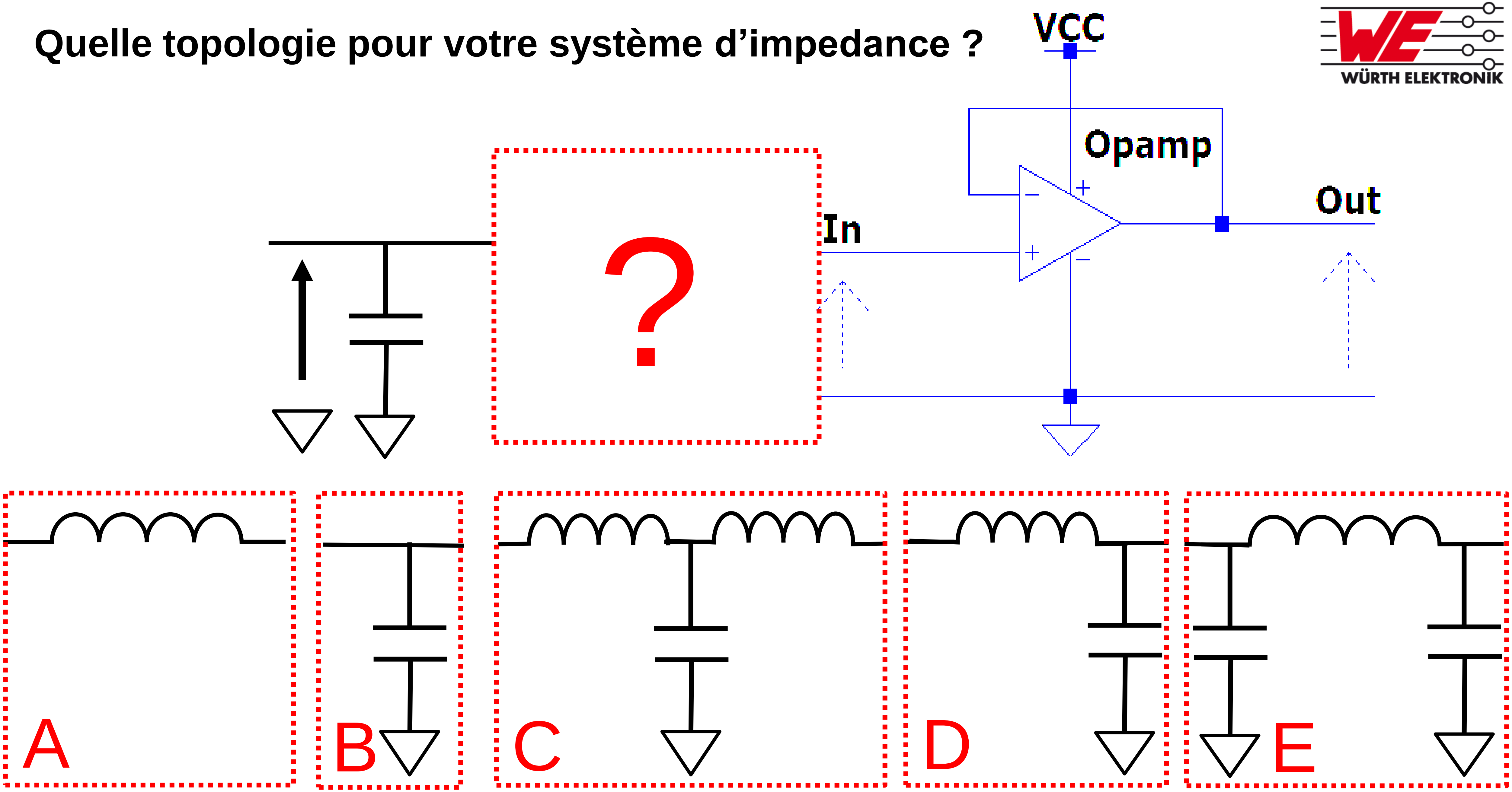
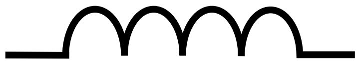
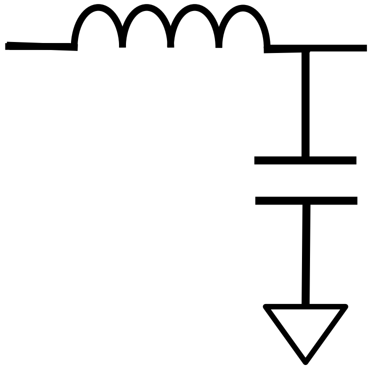
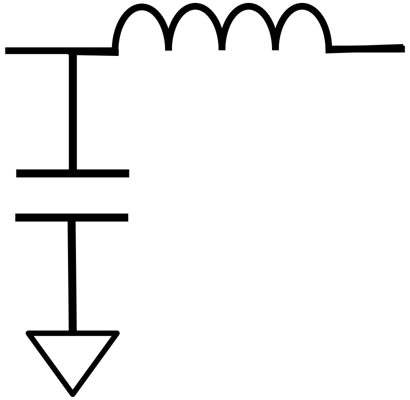
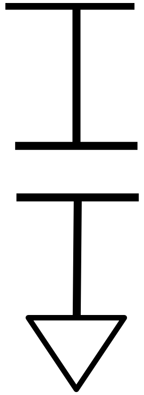
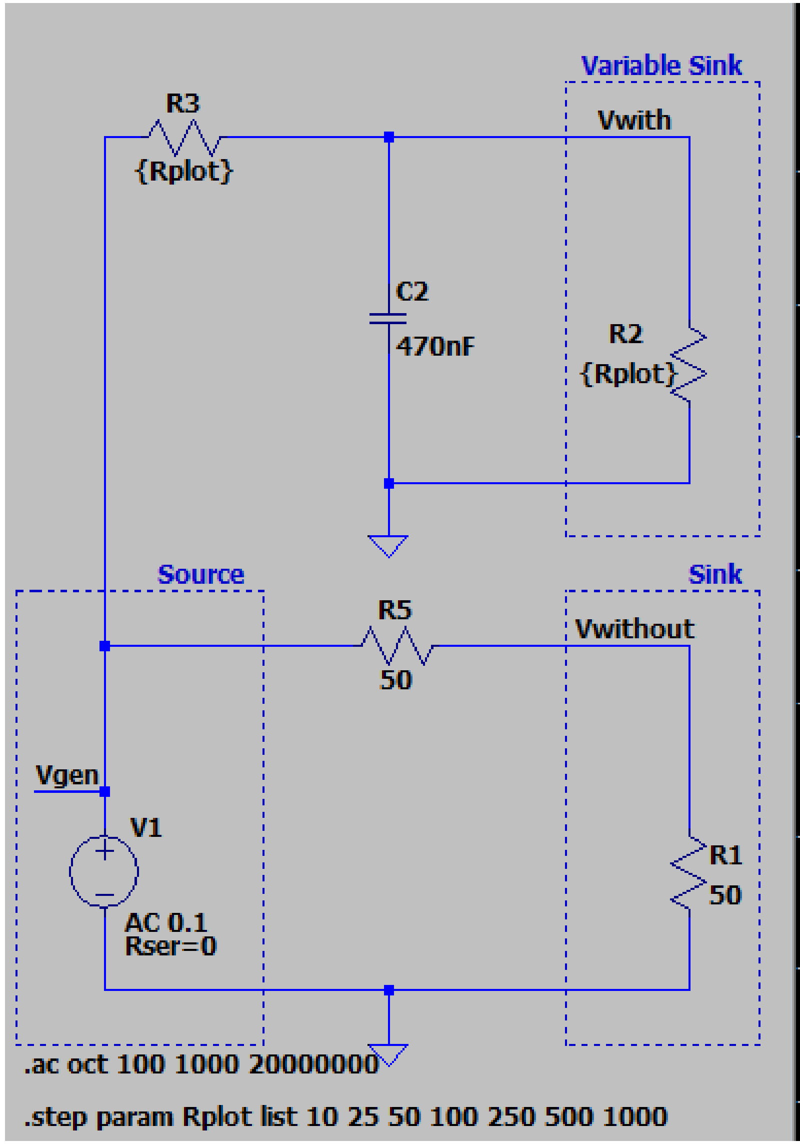
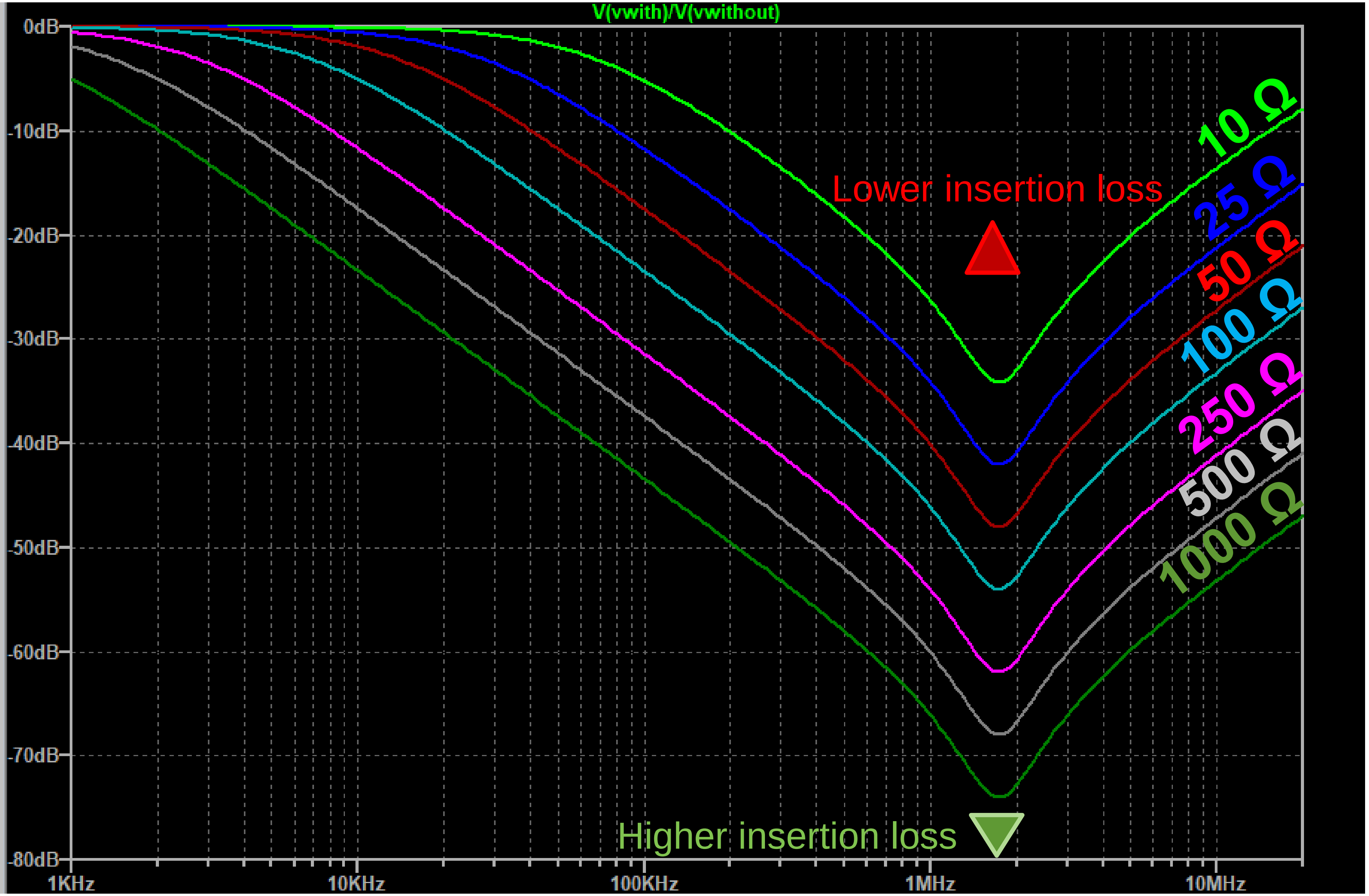


Quelle topologie pour votre système d'impedance ?

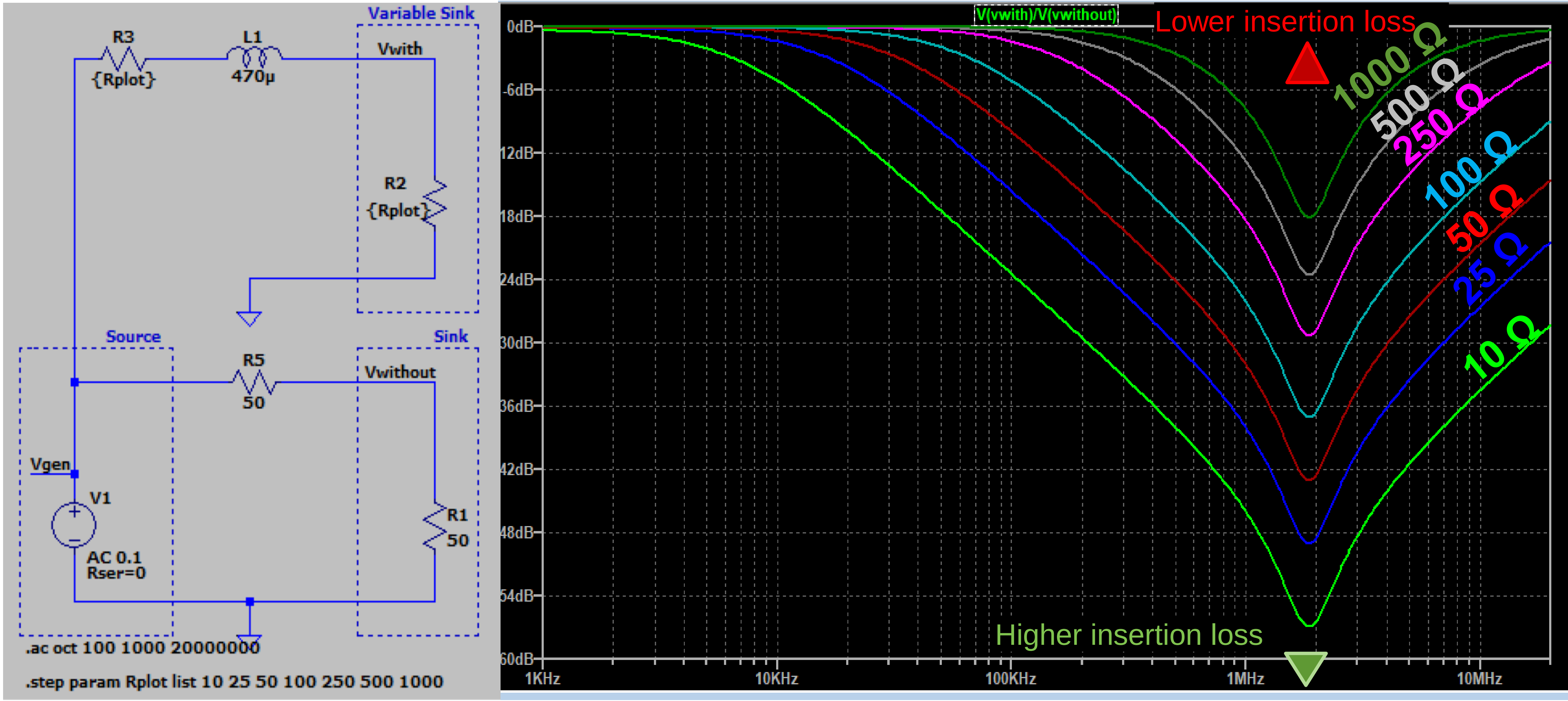
Load |Z| / Source |Z|	Low	High
Low		
High		

Impact du système d'impedance ?

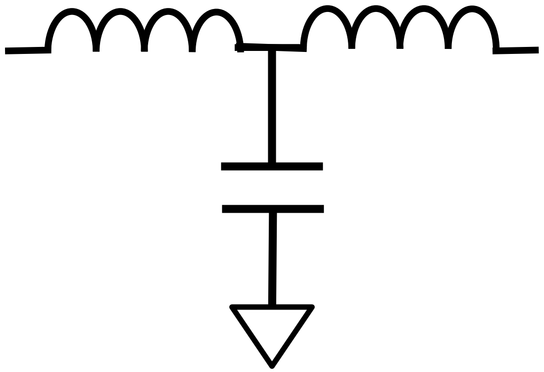
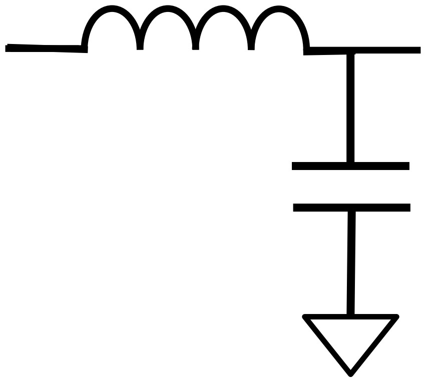
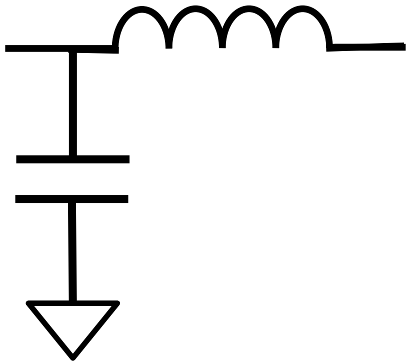
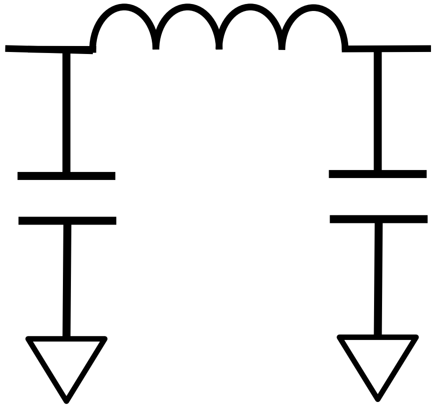




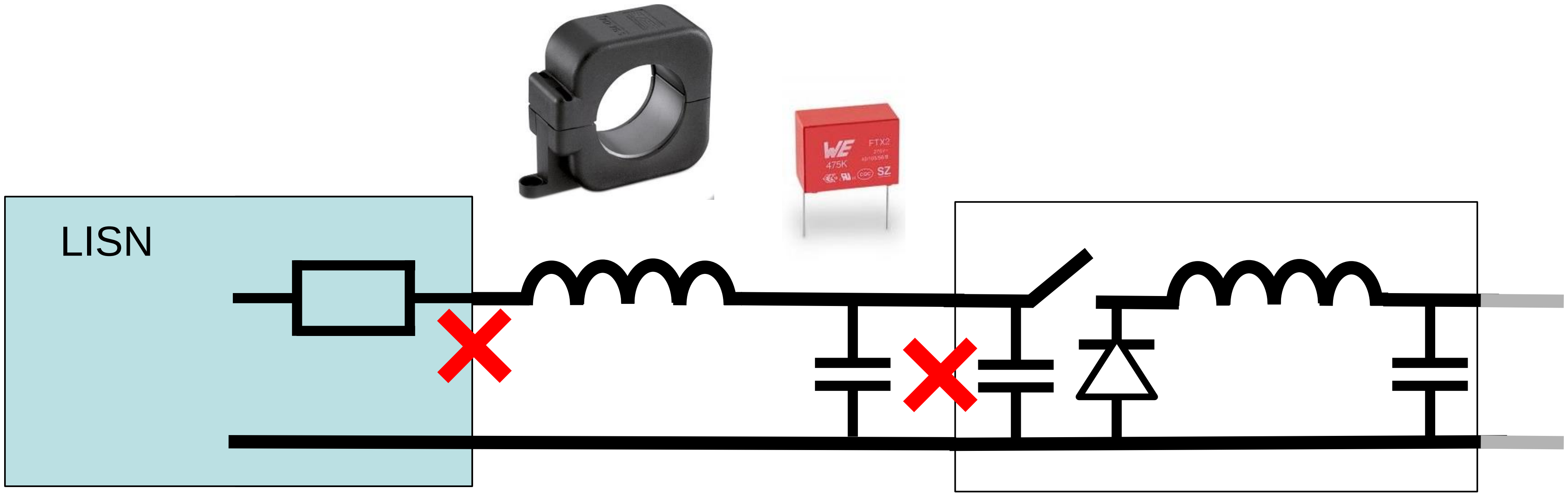
Impact du système d'impedance ?



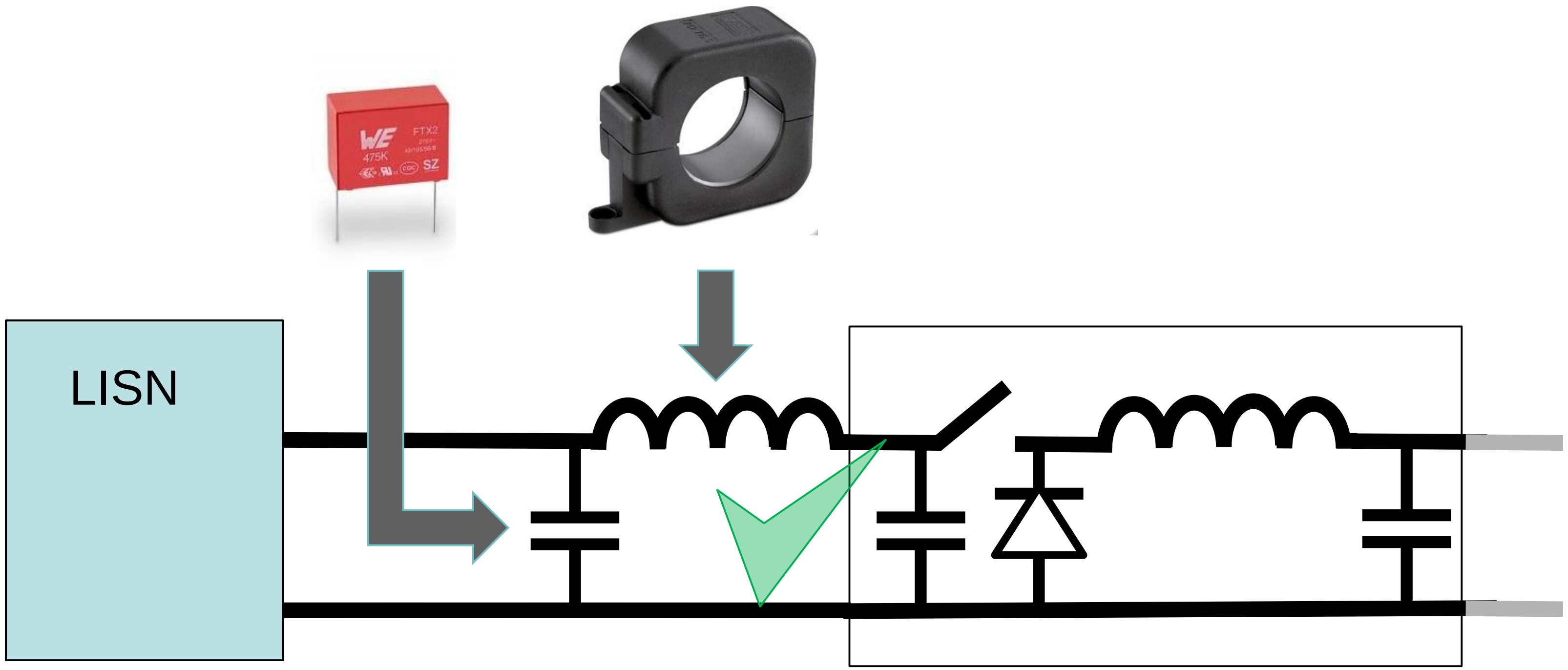
High Order Filter topologies for your Impedance system

Load |Z| / Source |Z|	Low	High
Low		
High		

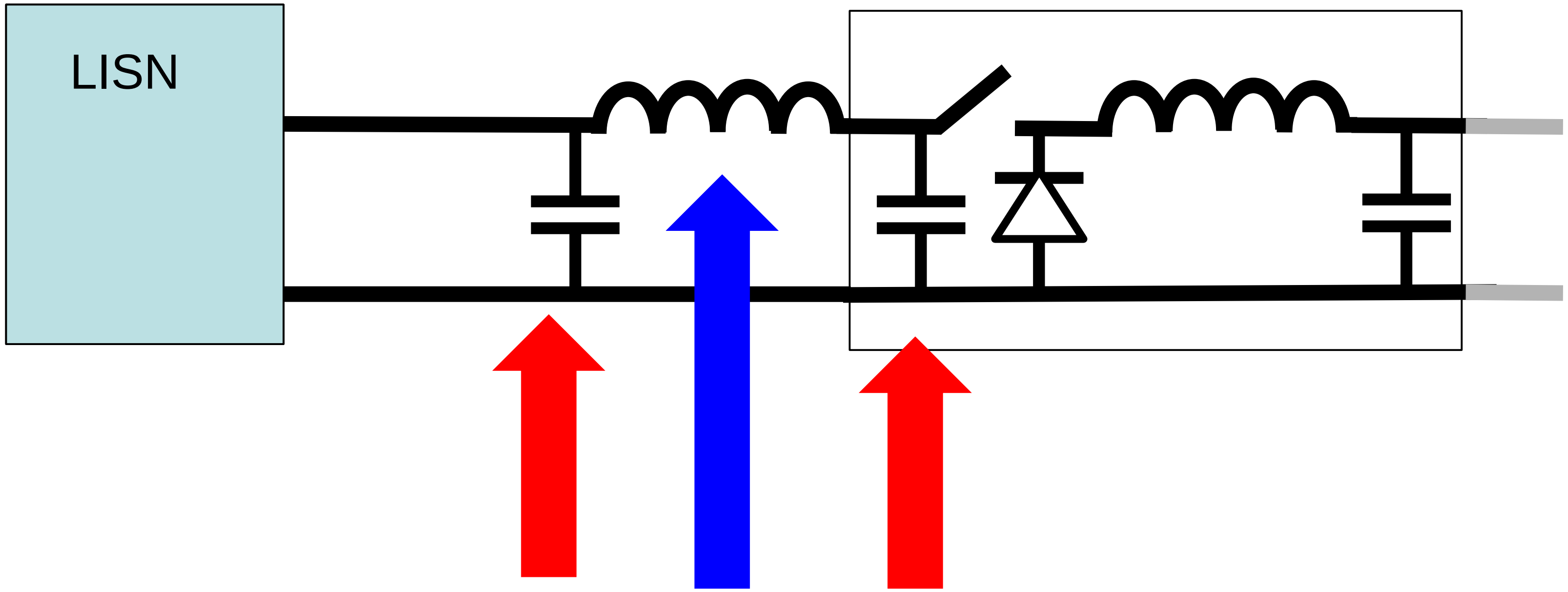
La mauvaise méthode pour les bons composants



La bonne méthode pour les bons composants



Mnémotechnique du “block and bypass”

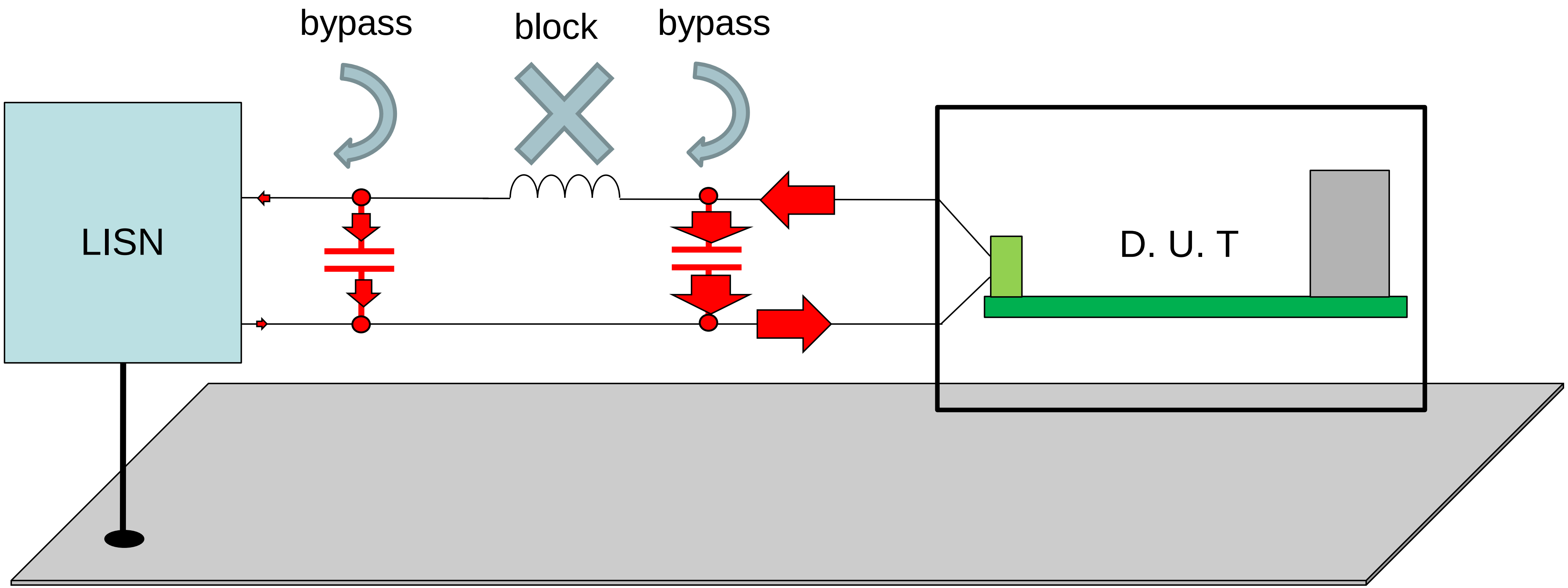


Solution CEM = Inductive + Capacitive

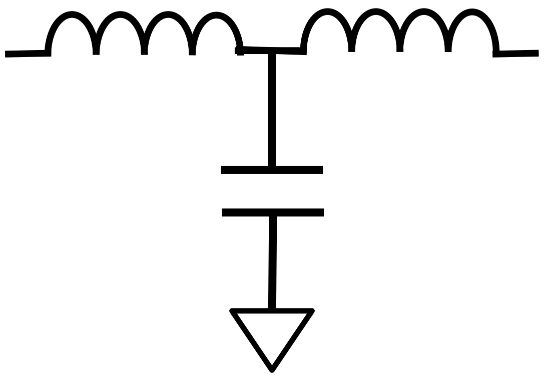
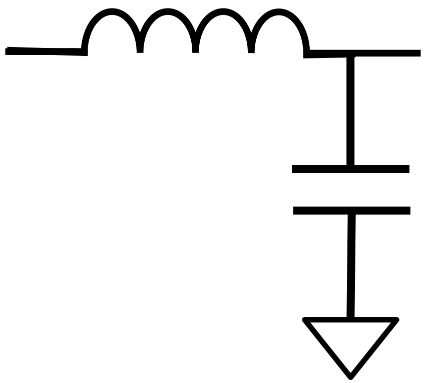
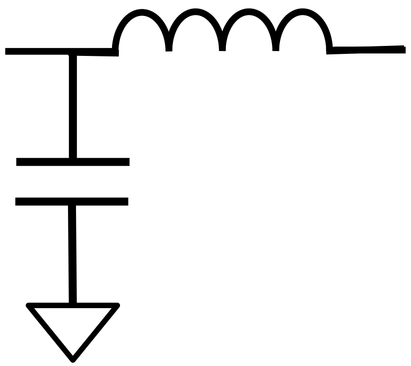
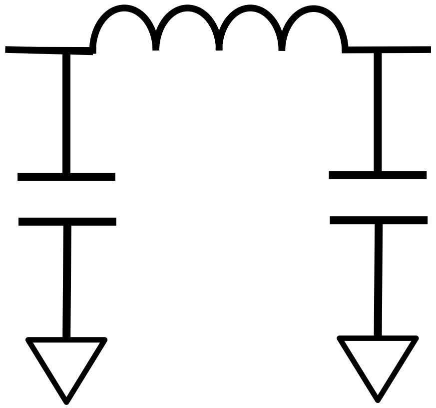
En série

En parallèle

“Block and Bypass”

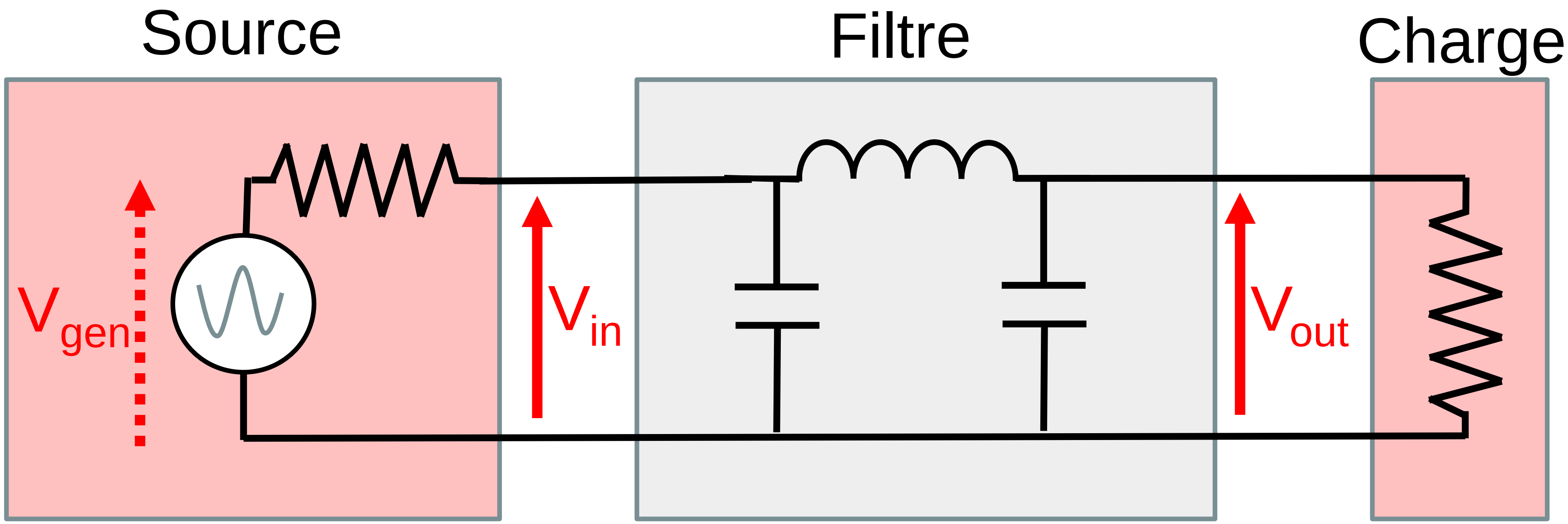


Les filtres d'ordre supérieur

Load |Z| / Source |Z|	Low	High
Low		
High		

Définition des pertes d'insertion

Apportées par un filtre dans un système 50/50 Ohm



A $20 \text{ Log}_{10} (V_{out}/V_{in})$

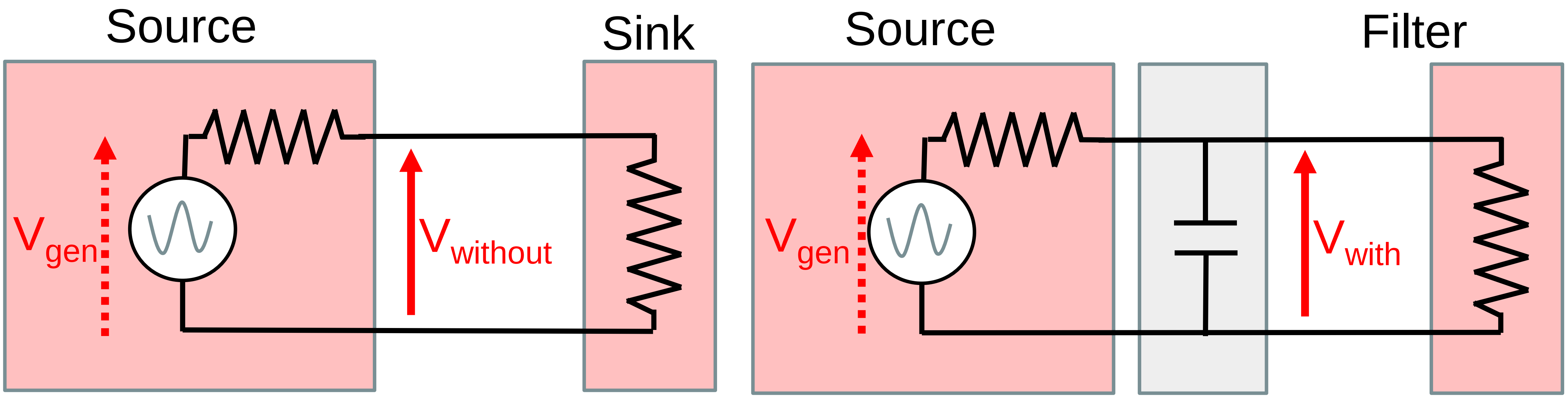
C $10 \text{ Log}_{10} (V_{out}/V_{in})$

B $20 \text{ Log}_{10} (V_{in}/V_{Out})$

D $20 \text{ Log}_{10} ((V_{gen}/2)/V_{out})$

Définition des pertes d'insertion

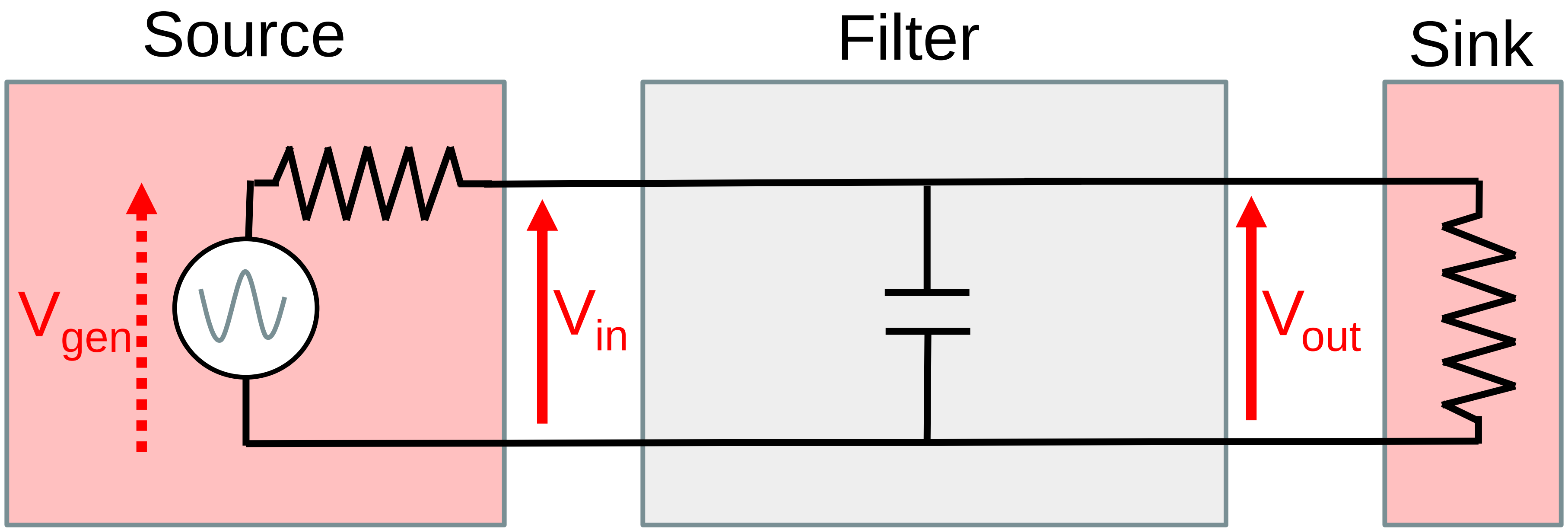
Apportées par un filtre dans un système 50/50 Ohm



$$20\ \mathrm{Log}_{10}\ ((V_{without})/V_{with}) \Rightarrow 20\ \mathrm{Log}_{10}\ ((V_{gen}/2)/V_{out})$$

Définition des pertes d’insertion

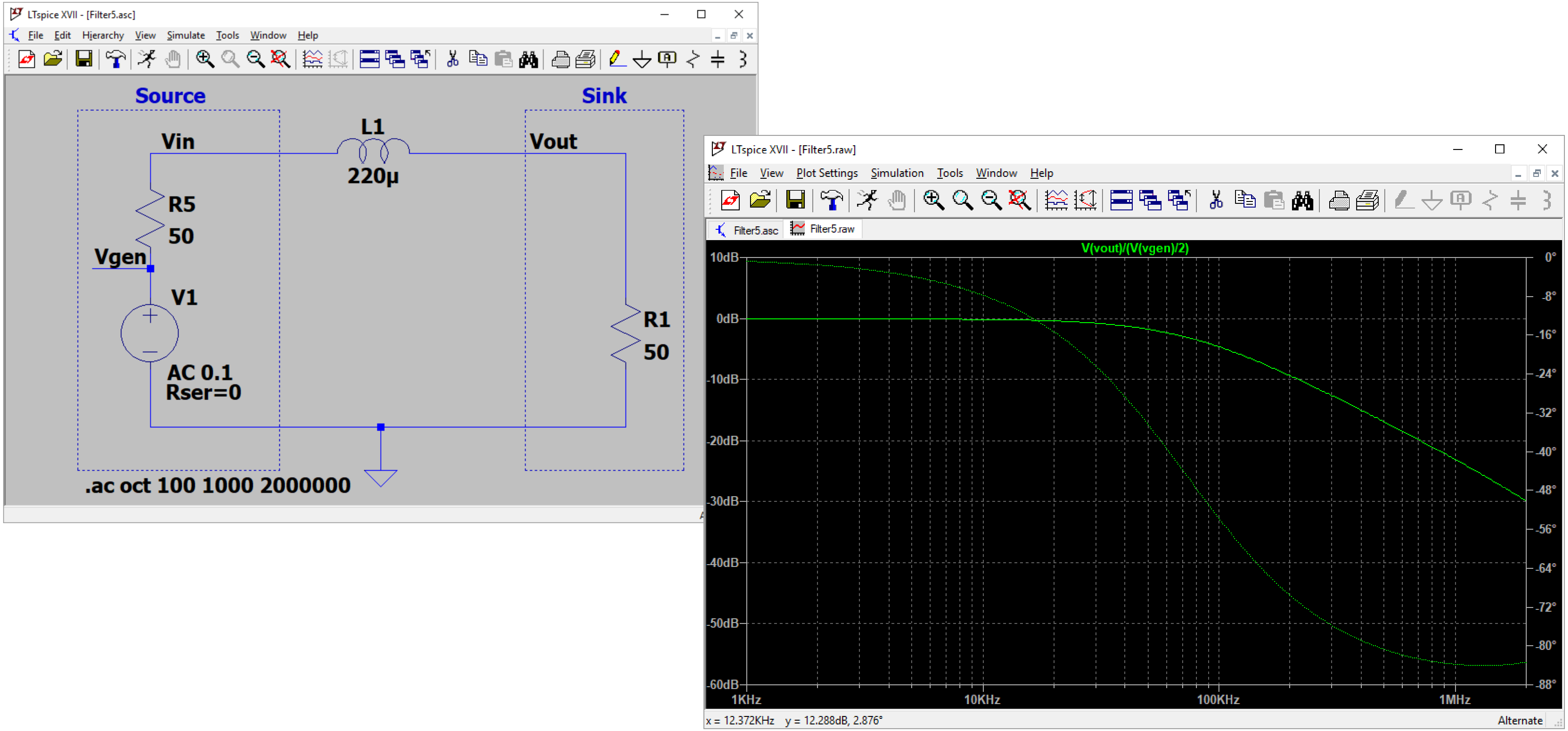
Apportées par un filtre dans un système 50/50 Ohm



A $\cancel{20 \log_{10} (V_{out}/V_{in})}$

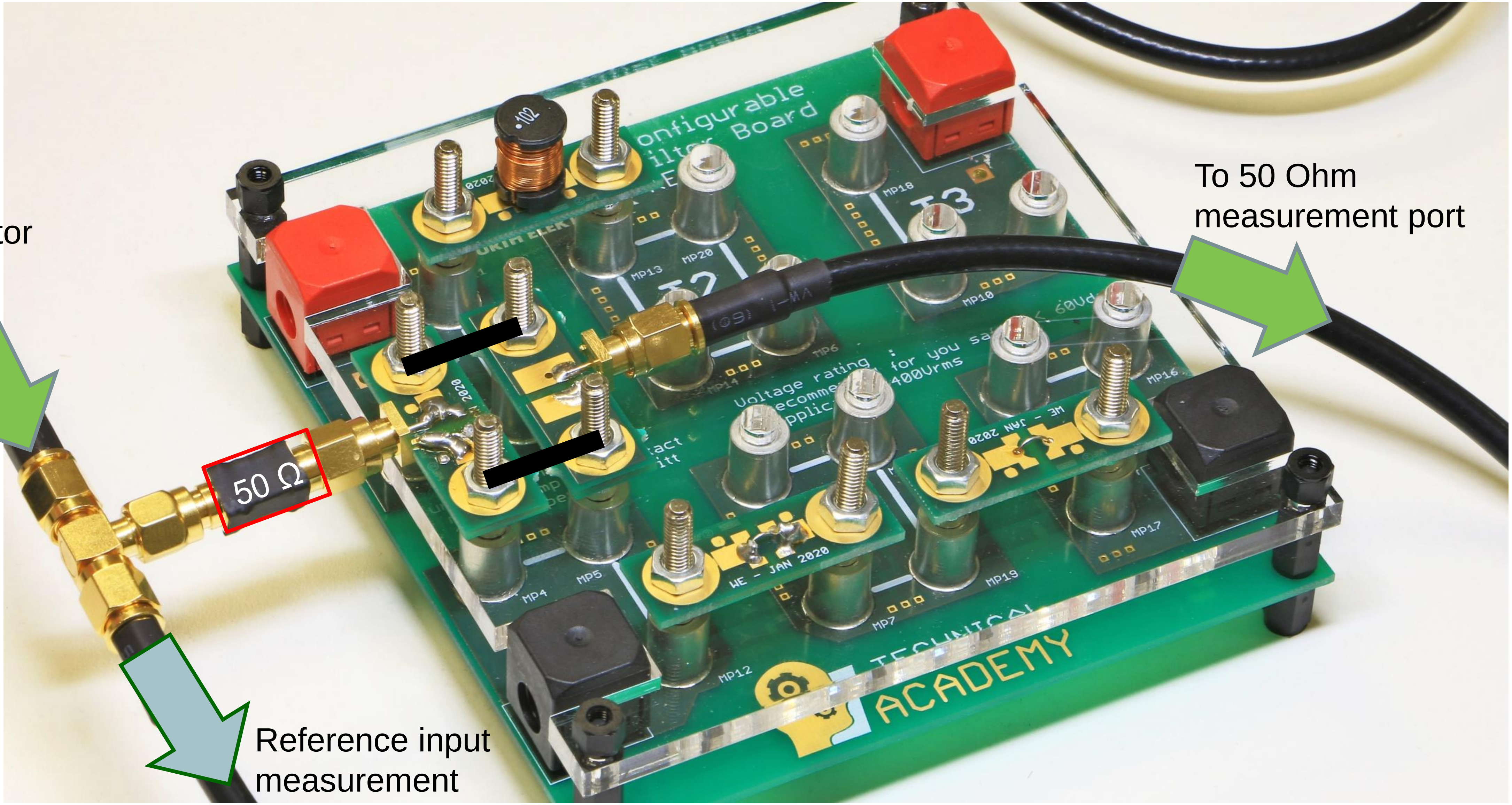
B $\cancel{20 \log_{10} (V_{in}/V_{out})}$

Simuler un filtre



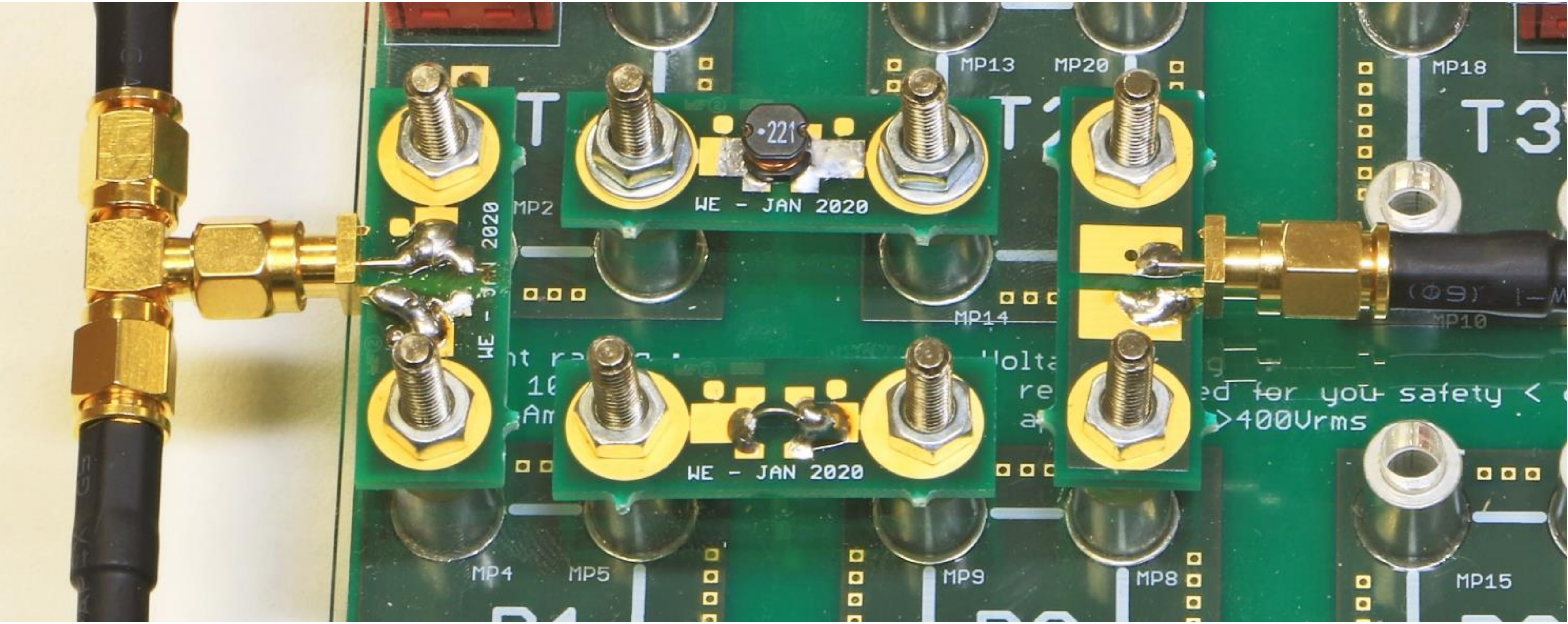
Measure a filter

Calibrate reference level Without filter

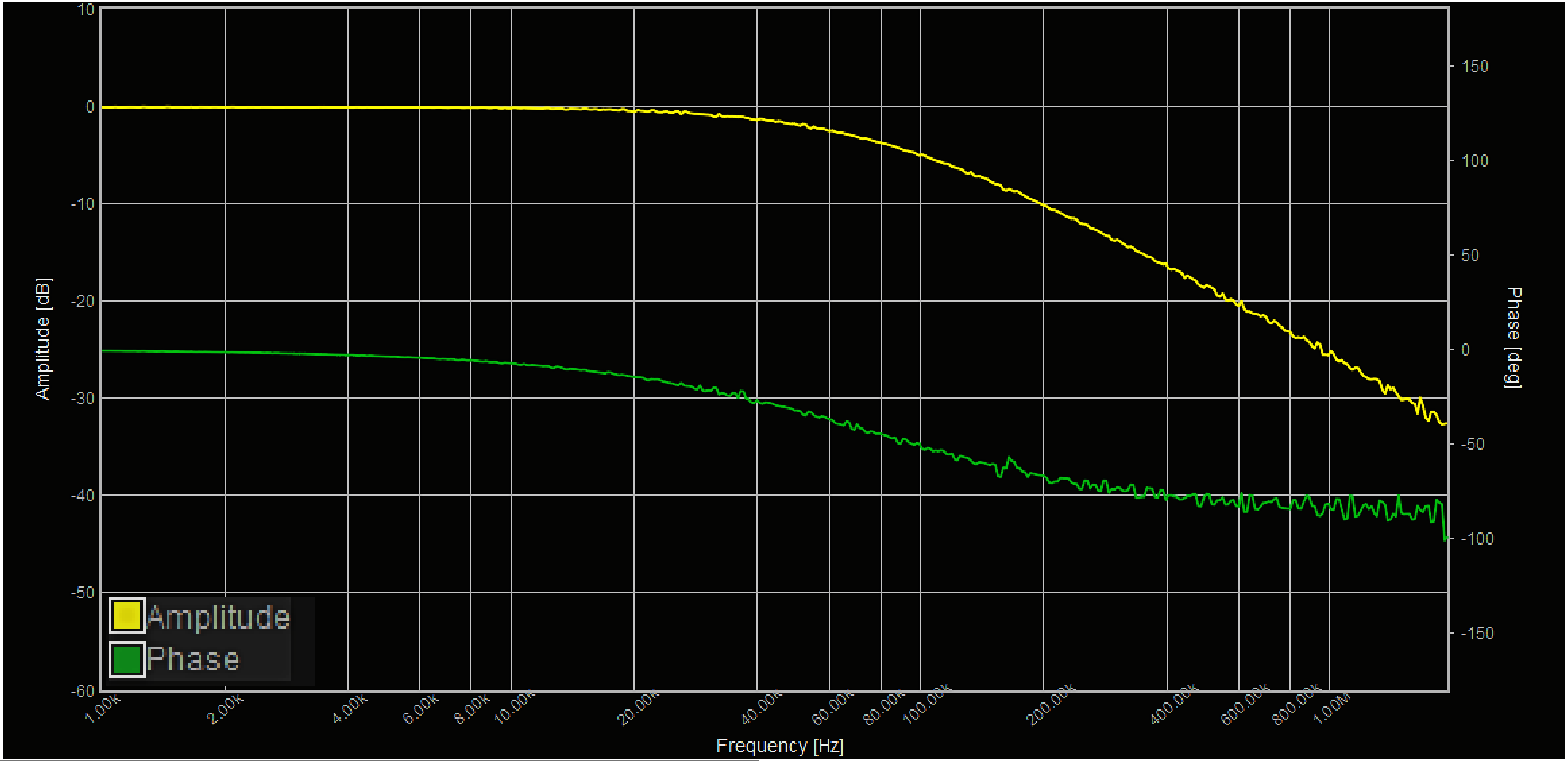


Measure a filter

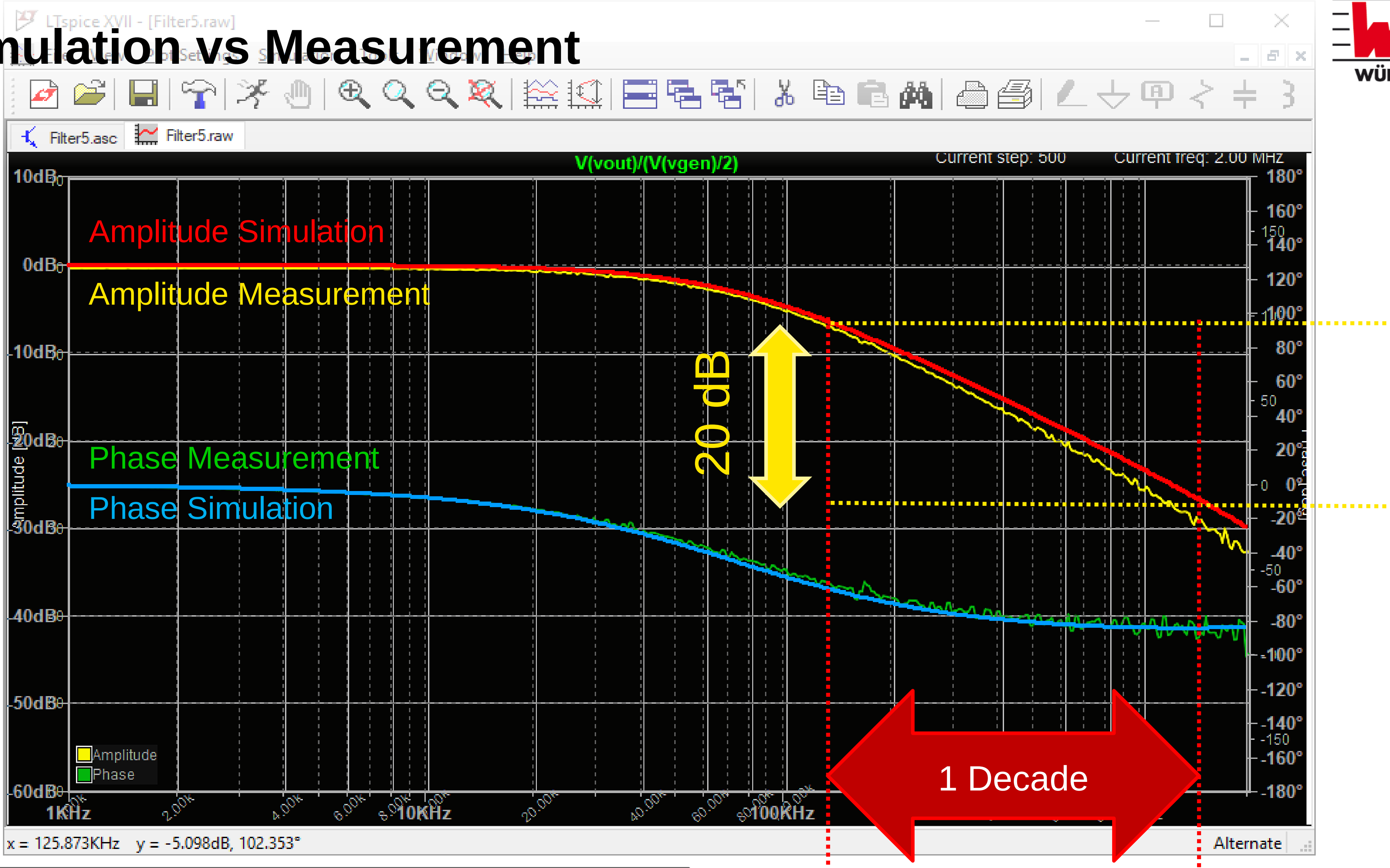
Insert filter



Measure a filter
Insert filter

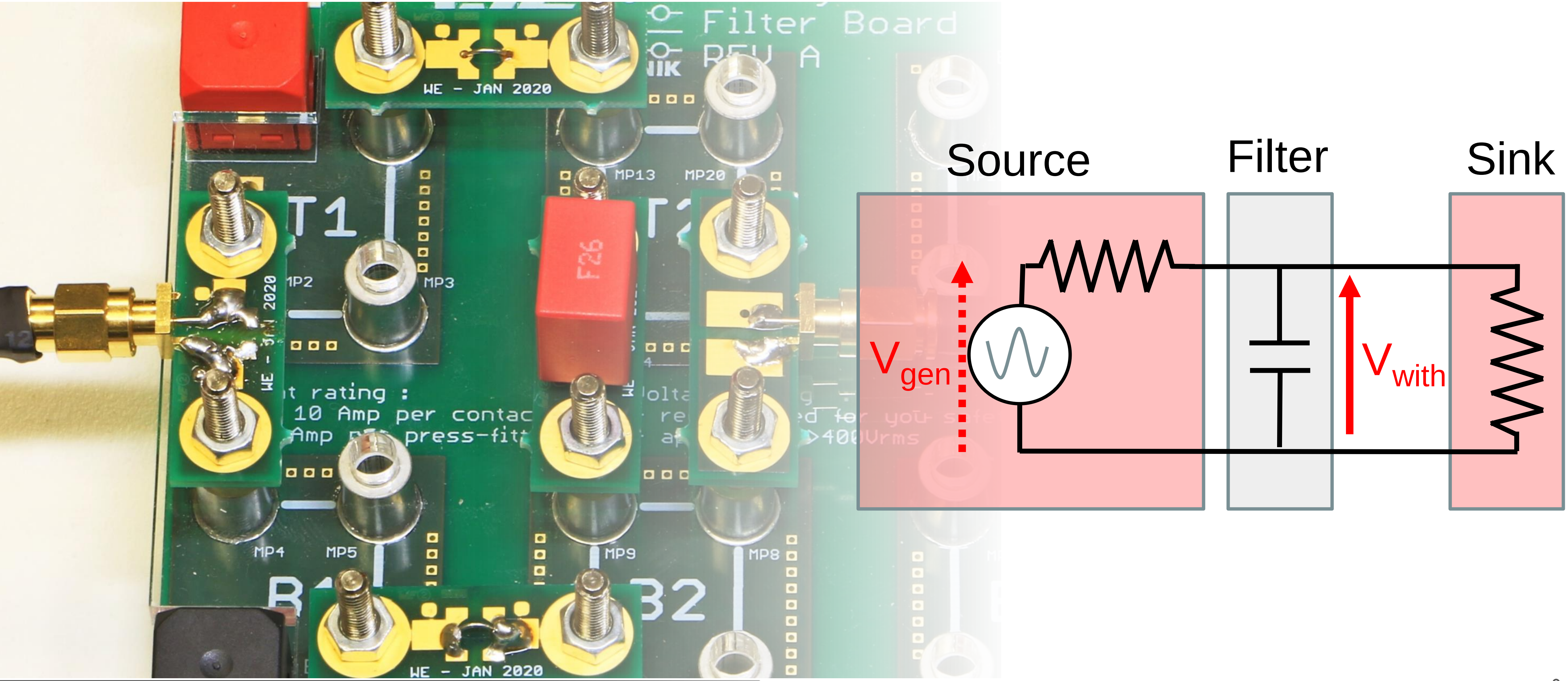


Simulation vs Measurement

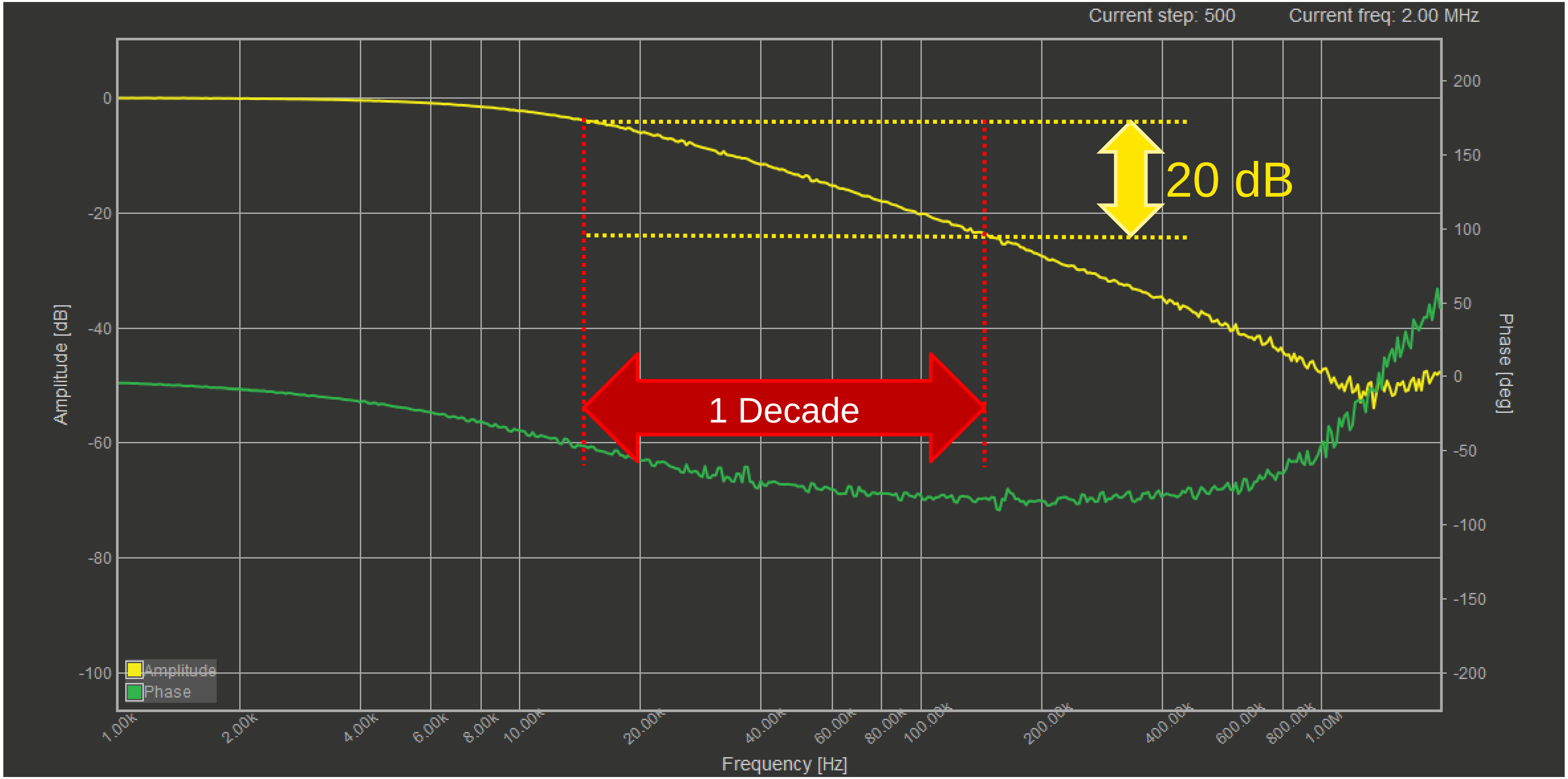


Usual filters and their frequency responses

Order 1 filters – Capacitor



20dB per Decade ?



1^{st} Order filter

-20dB per Decade ?

$$10^{\left(\frac{-20}{20}\right)} = 10$$

Amplitude / 10

Frequency * 10

-6dB per Octave

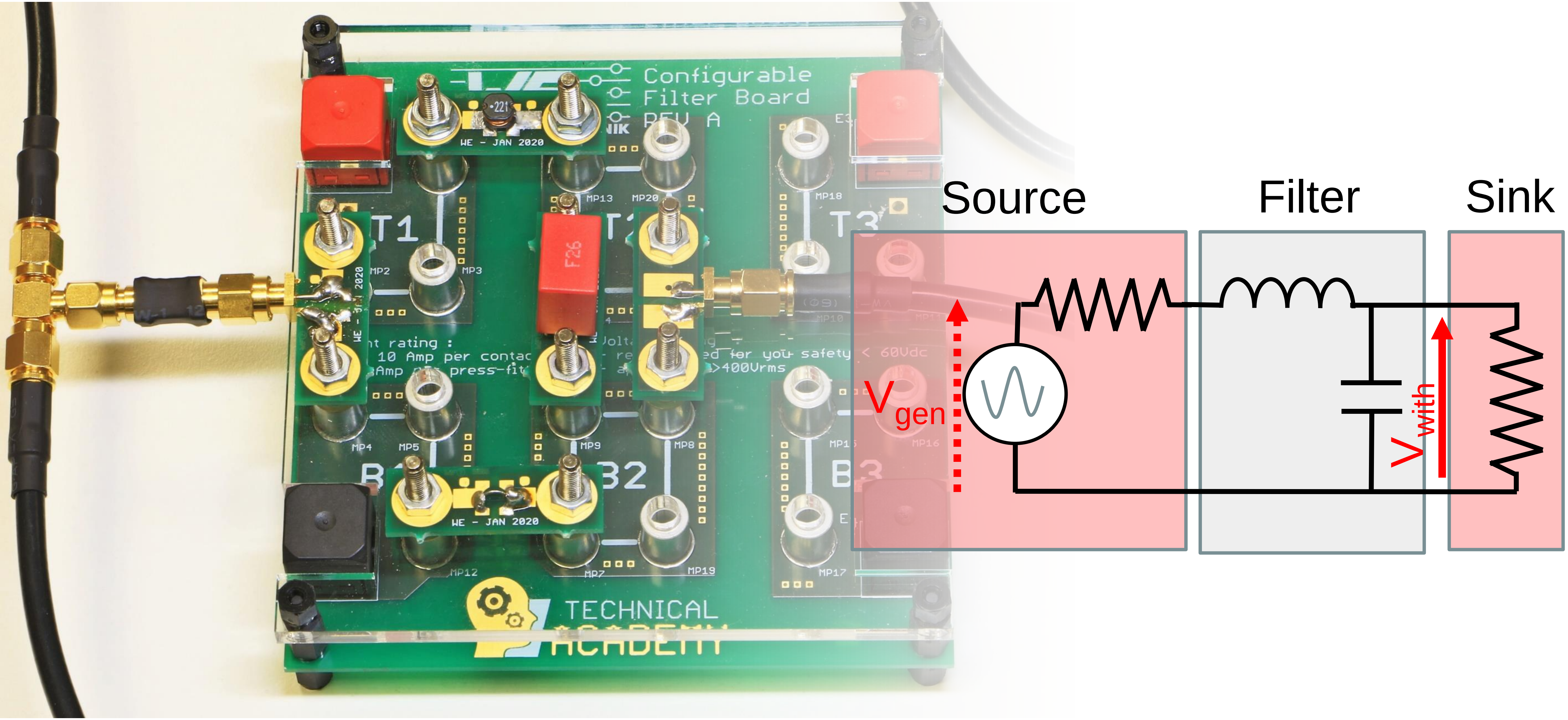
$$10^{\left(\frac{-6}{20}\right)} \approx 0{,}5 \approx 1 / 2$$

Amplitude / 2

Frequency * 2

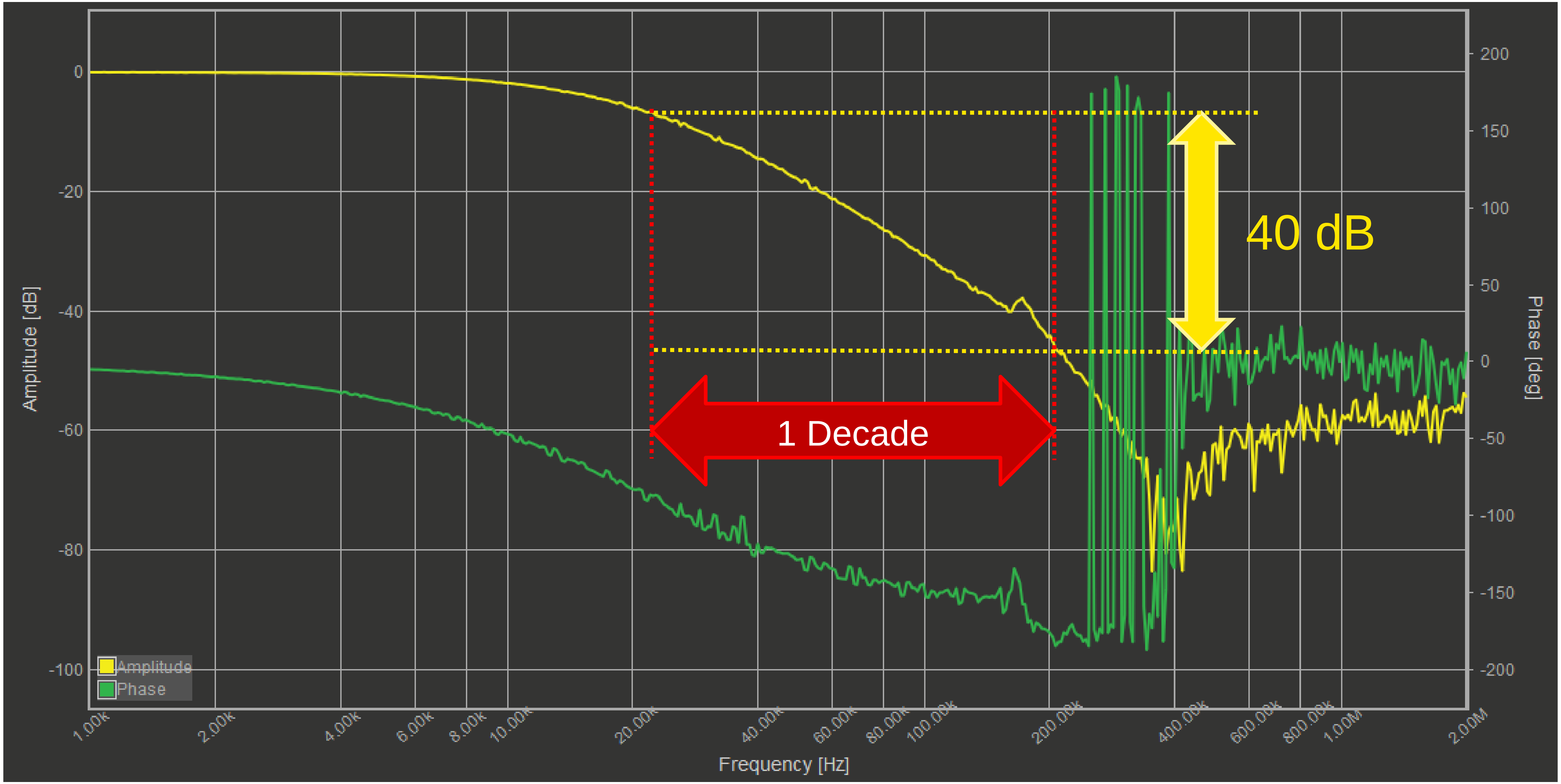
Usual filters and their frequency responses

2nd Order filters – Inductor / Capacitor



Usual filters and their frequency responses

2nd Order filters – Inductor / Capacitor



2^{nd} order filter

-40dB per Decade

$$10^{\left(\frac{-40}{20}\right)} = 10^{-2} = 1/100$$

Frequency * 10

Amplitude / 100

-12dB per Octave

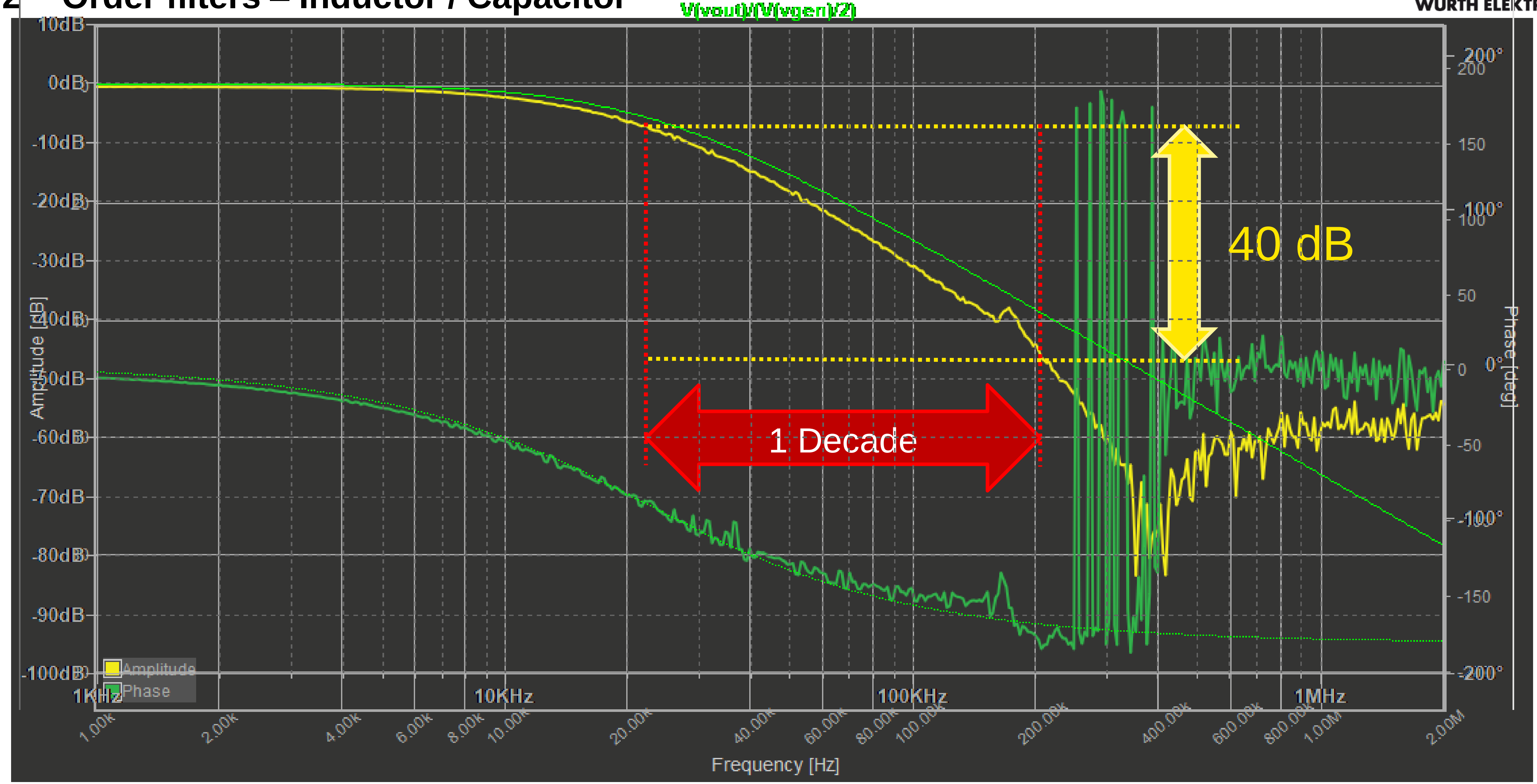
$$10^{\left(\frac{-12}{20}\right)} \approx 0{,}25 \approx 1/4$$

Frequency * 2

Amplitude / 4

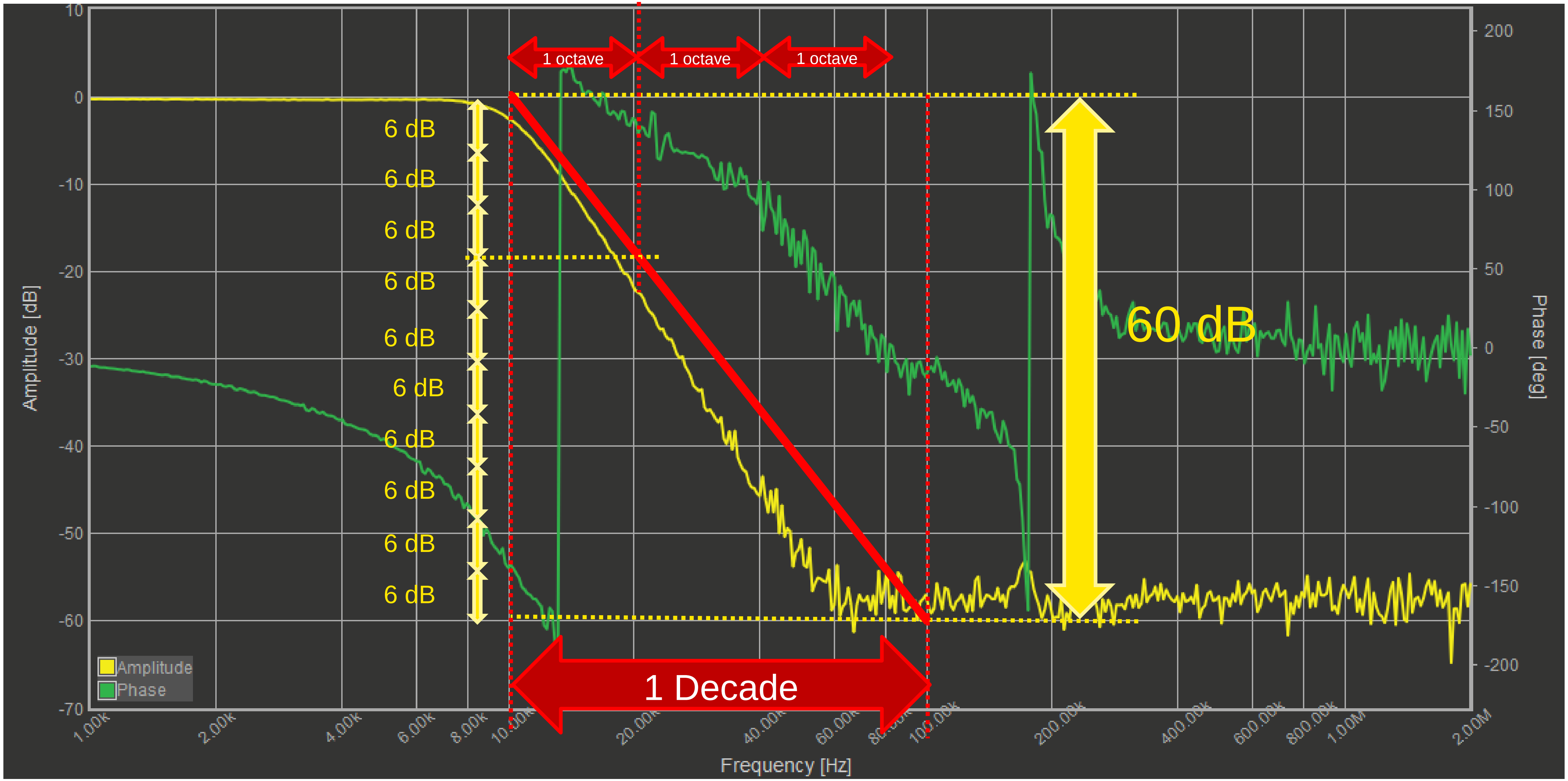
Usual filters and their frequency responses

2nd Order filters – Inductor / Capacitor



Usual filters and their frequency responses

3rd Order filters – Inductor / Capacitor / Inductor



3^{rd} order filters

-60dB per Decade

$$10^{\left(\frac{-60}{20}\right)} = 10^{-3} = 1/1000$$

Amplitude / 1000

Frequency * 10

-18dB per Octave

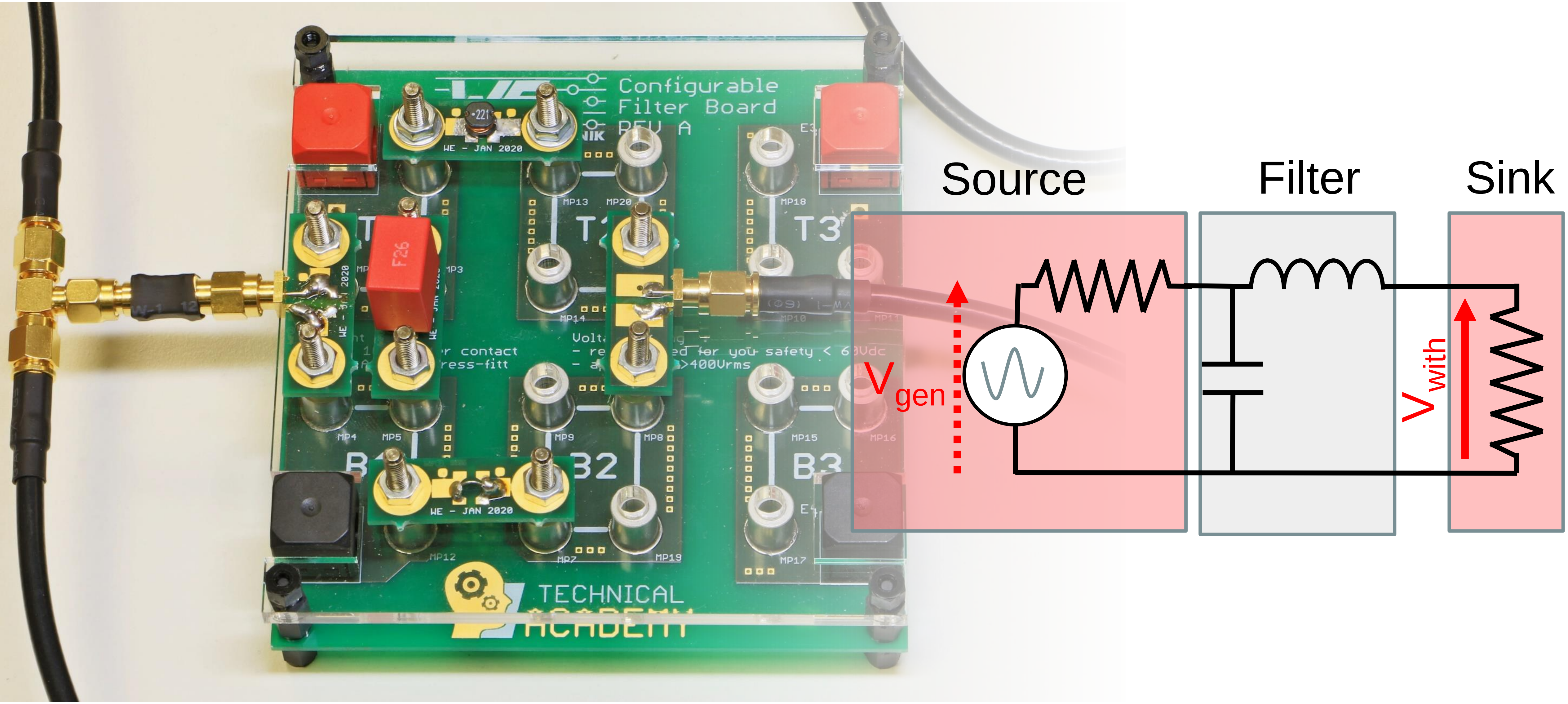
$$10^{\left(\frac{-18}{20}\right)} \approx 0{,}125 \approx 1/8$$

Amplitude / 8

Frequency * 2

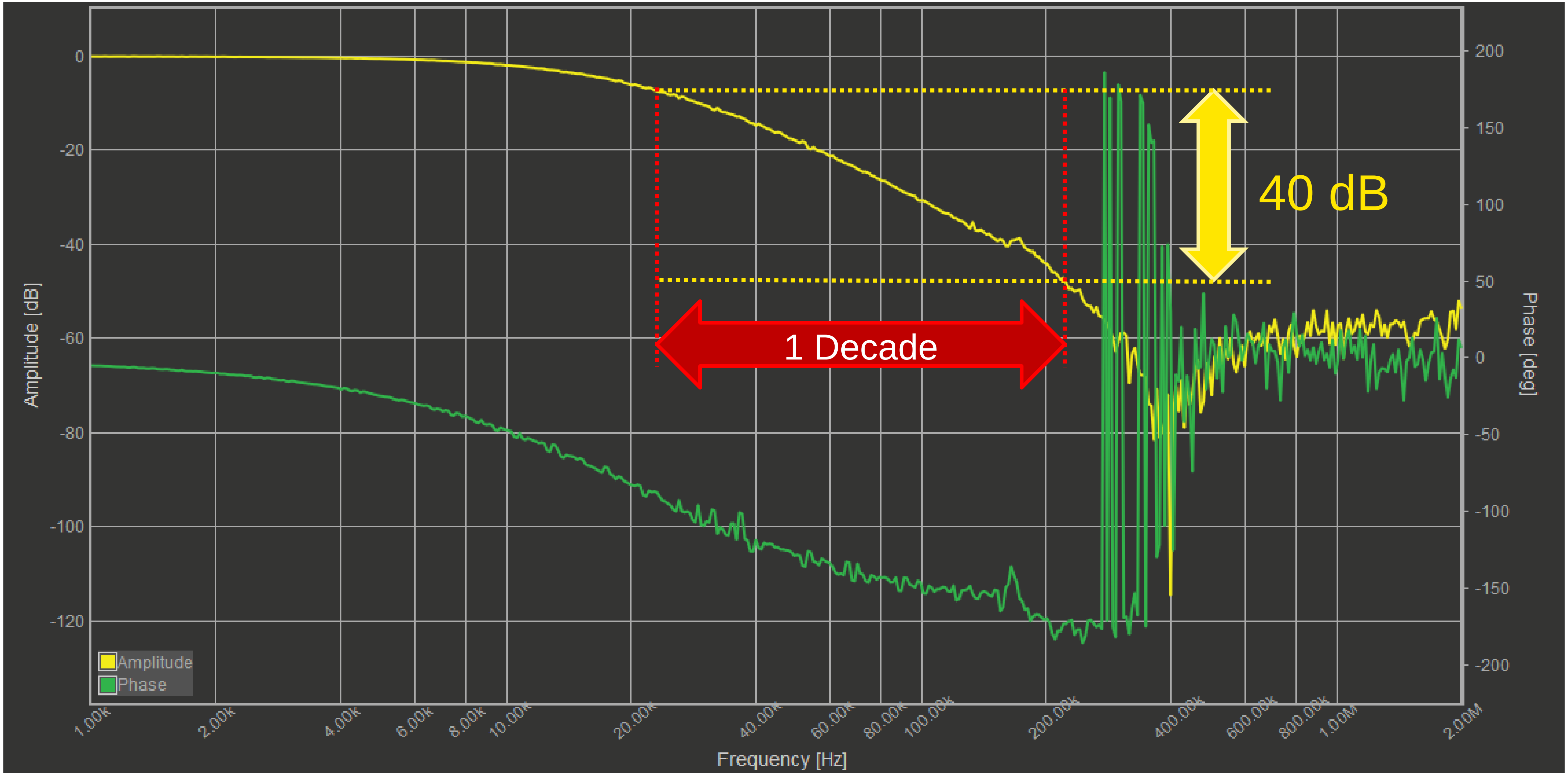
Usual filters and their frequency responses

2nd Order filters – Capacitor / Inductor



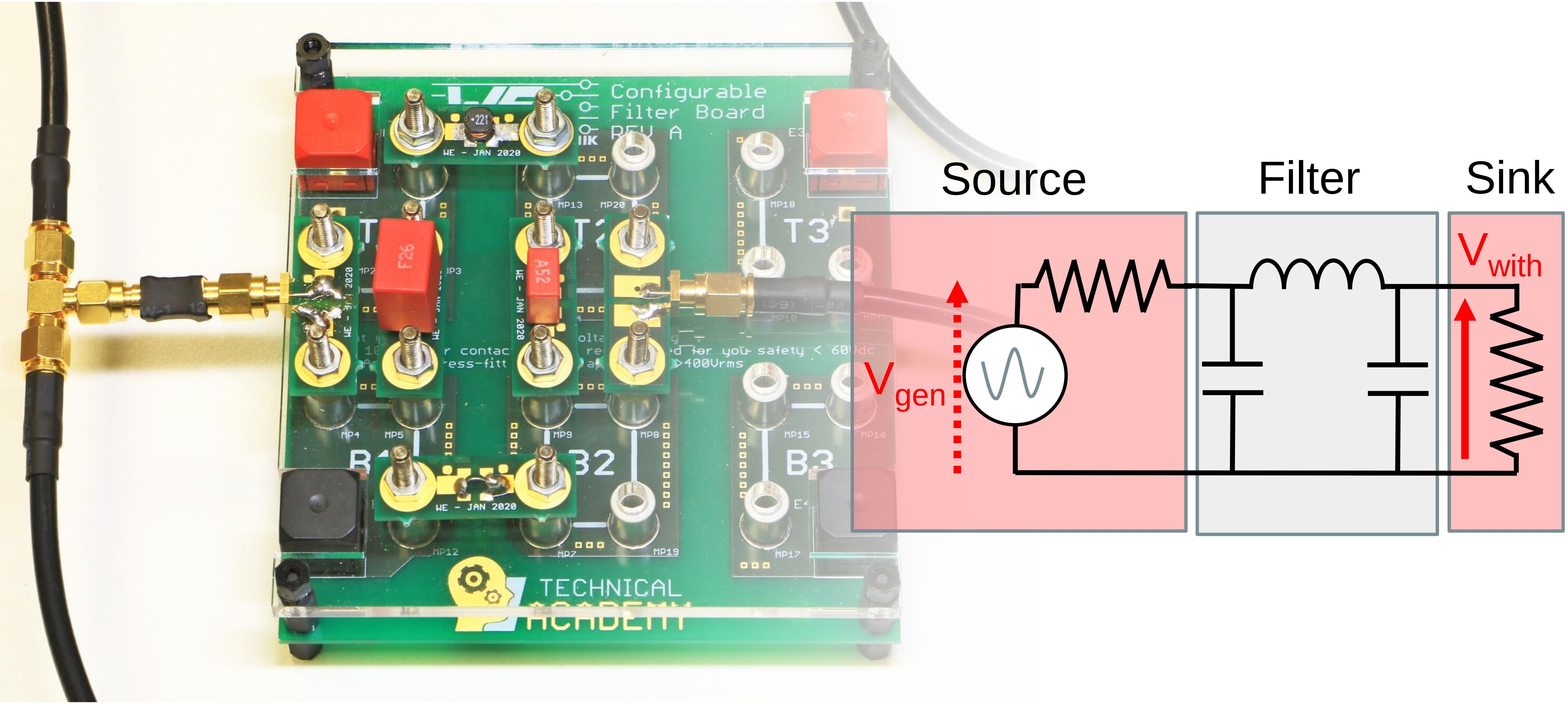
Usual filters and their frequency responses

2nd Order filters – Capacitor / Inductor



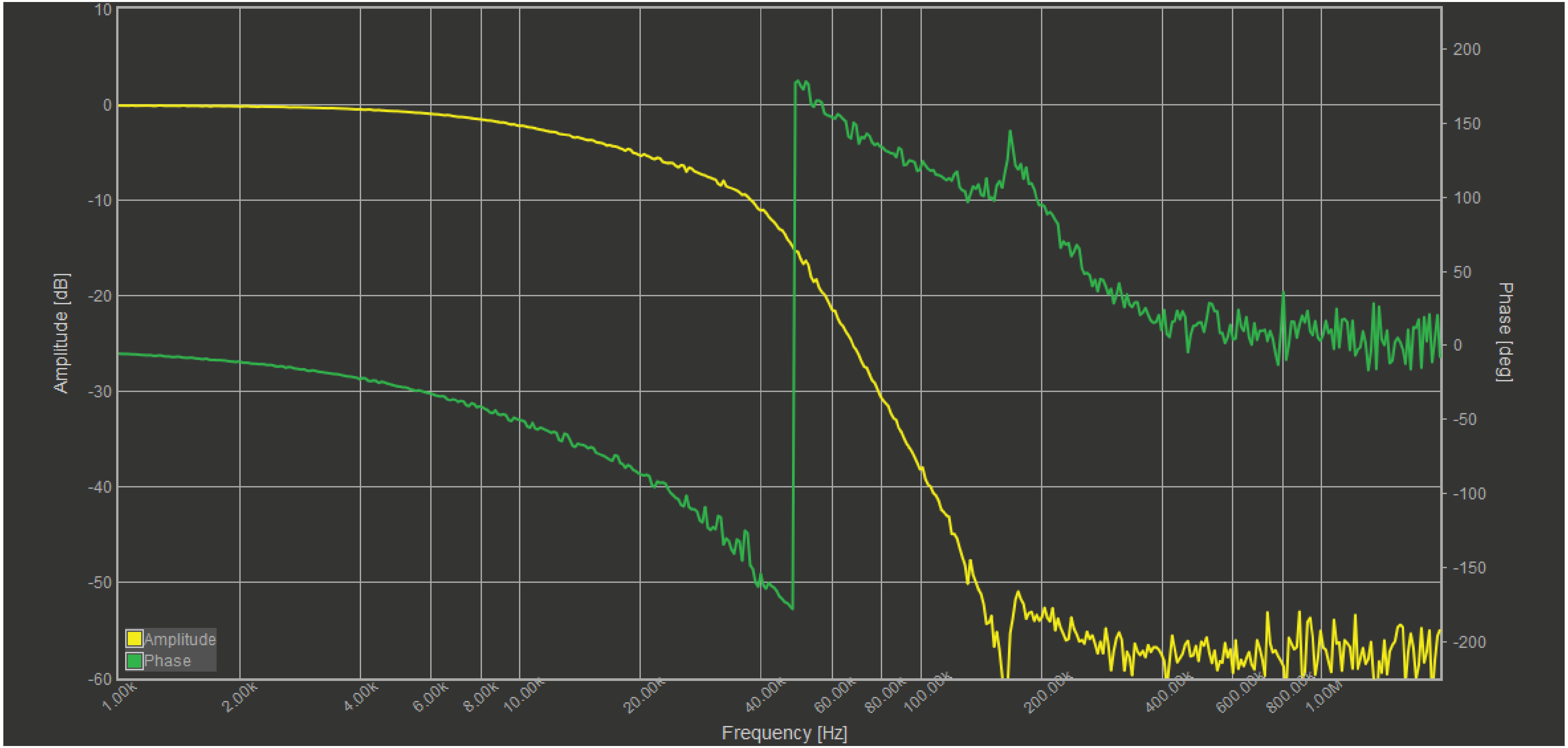
Usual filters and their frequency responses

3rd Order filters – Capacitor / Inductor / Capacitor



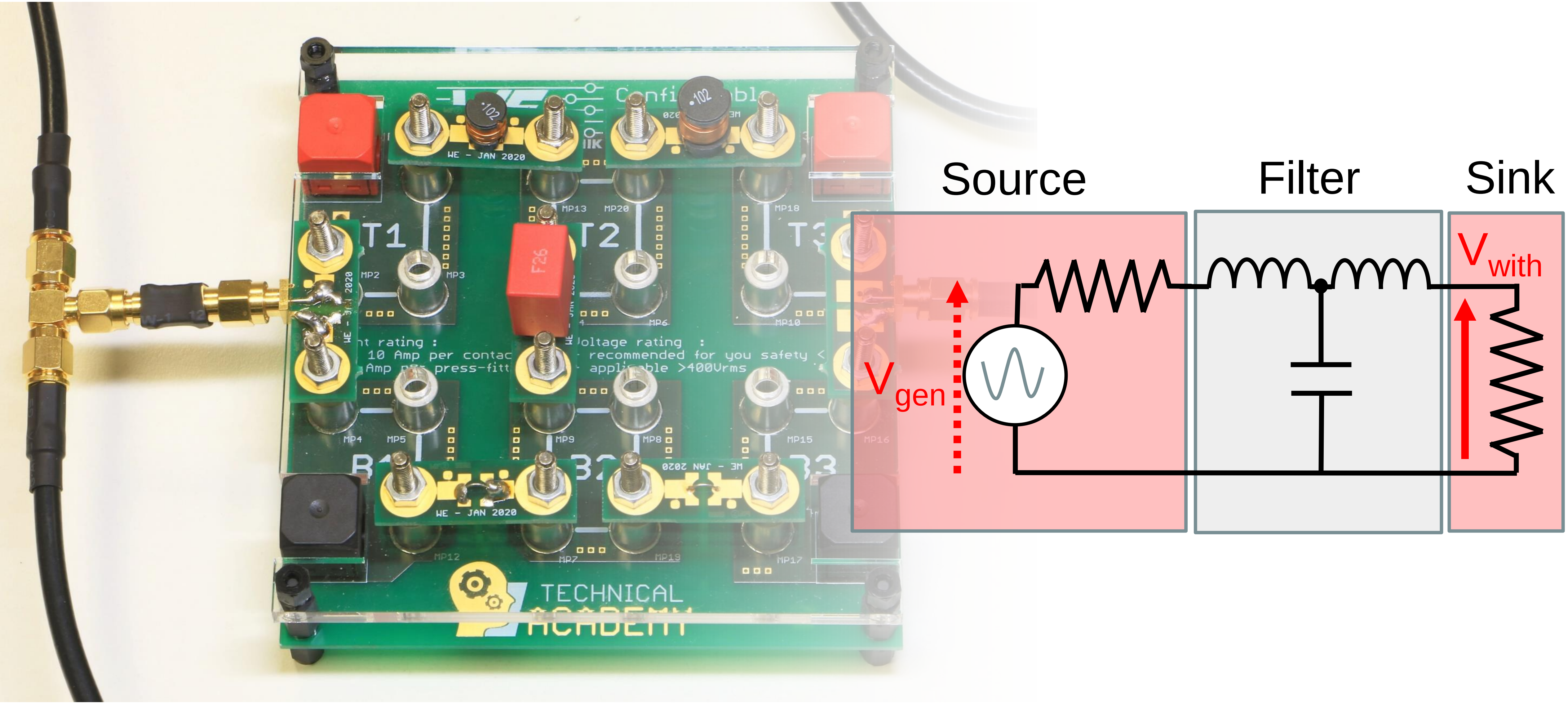
Usual filters and their frequency responses

3rd Order filters – Capacitor / Inductor / Capacitor



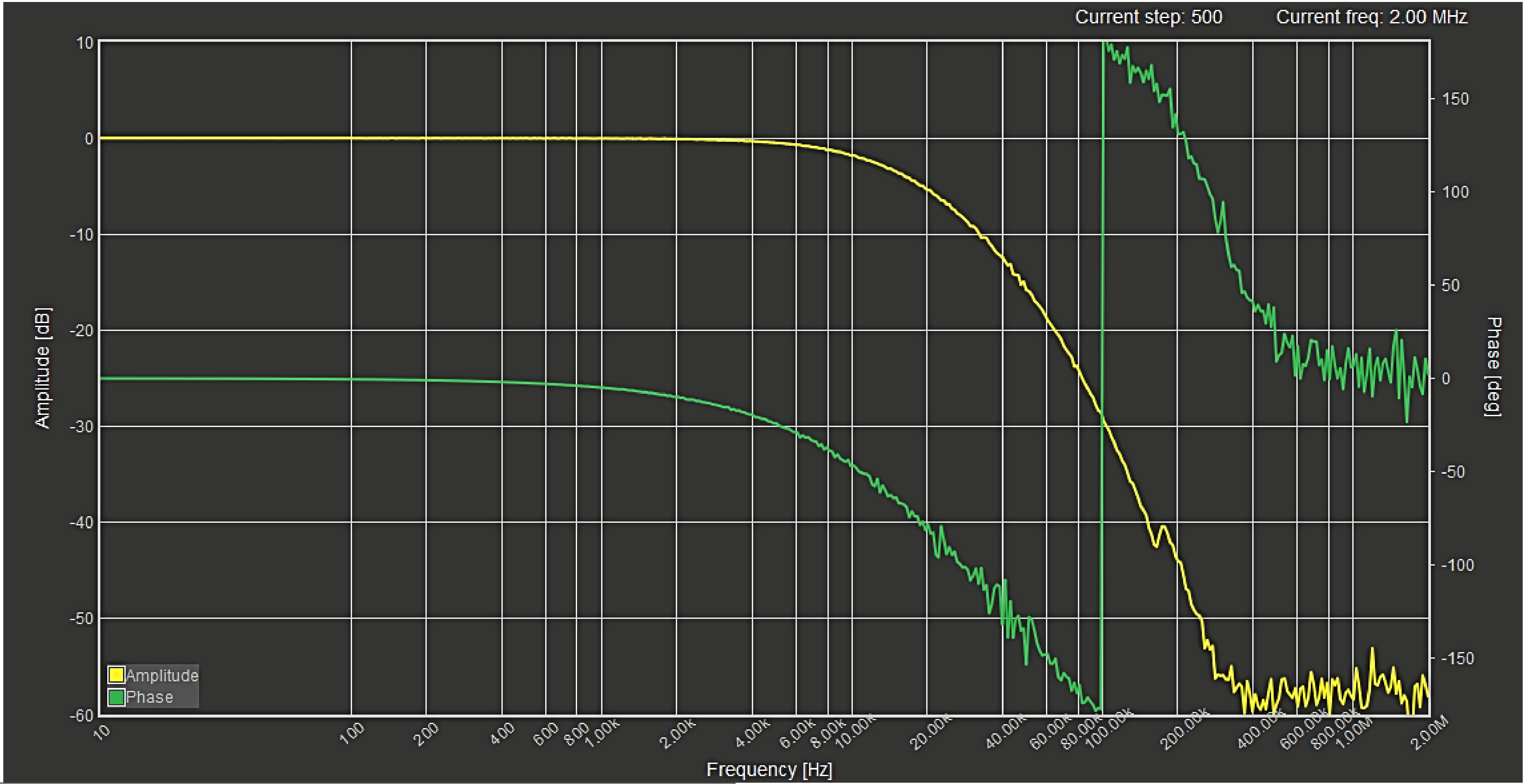
Usual filters and their frequency responses

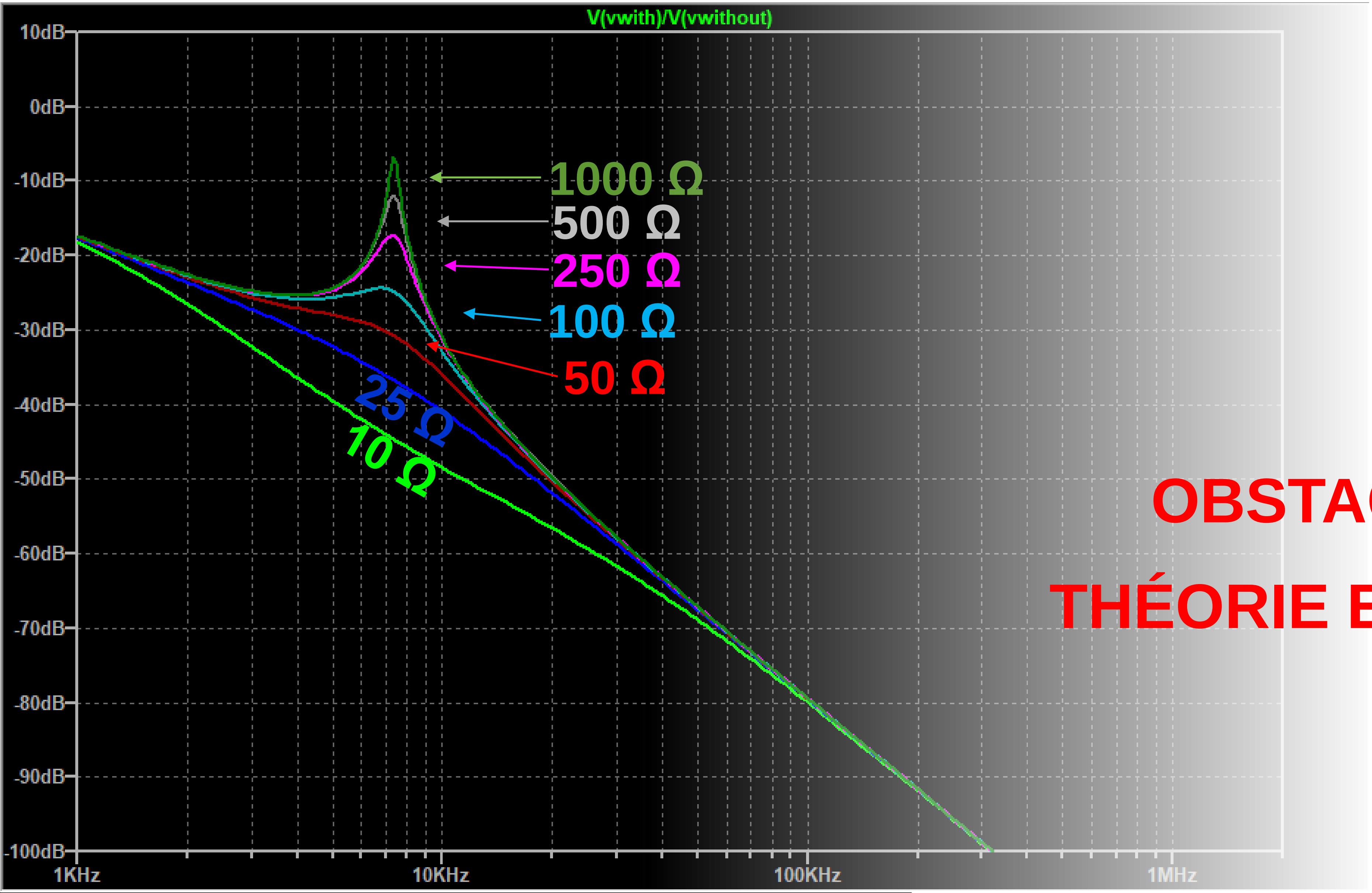
3rd Order filters – Inductor / Capacitor / Inductor



Usual filters and their frequency responses

3rd Order filters – Inductor / Capacitor / Inductor

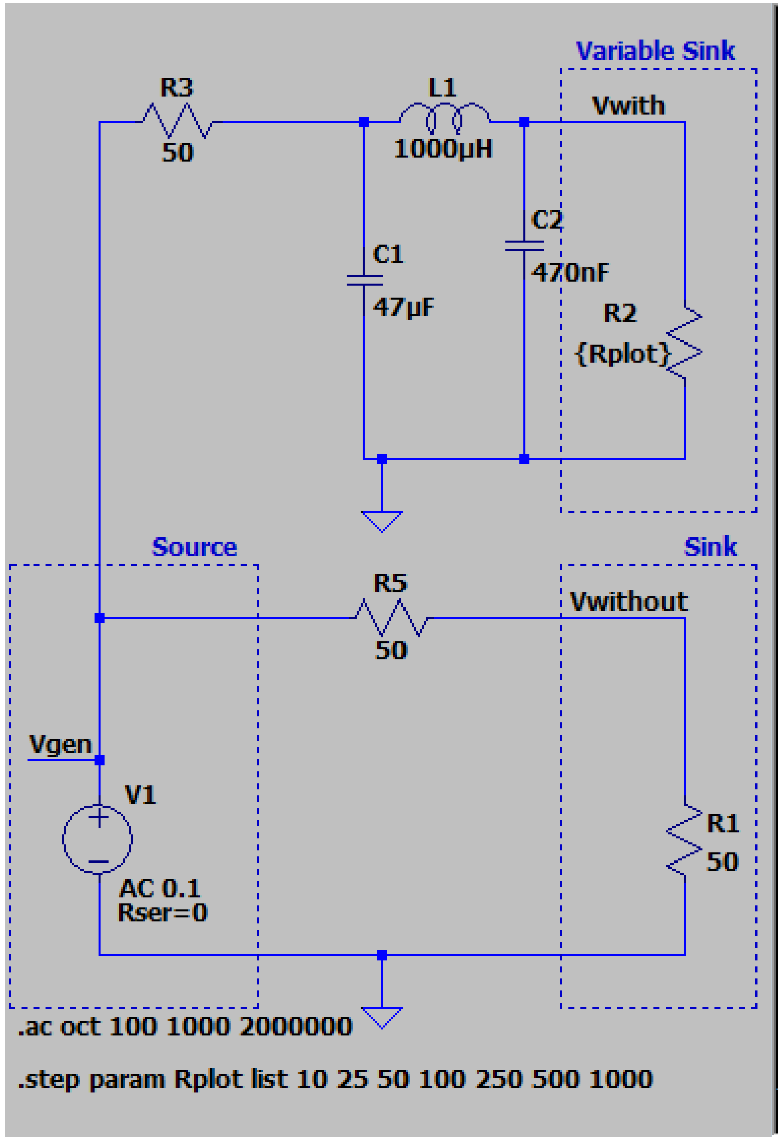


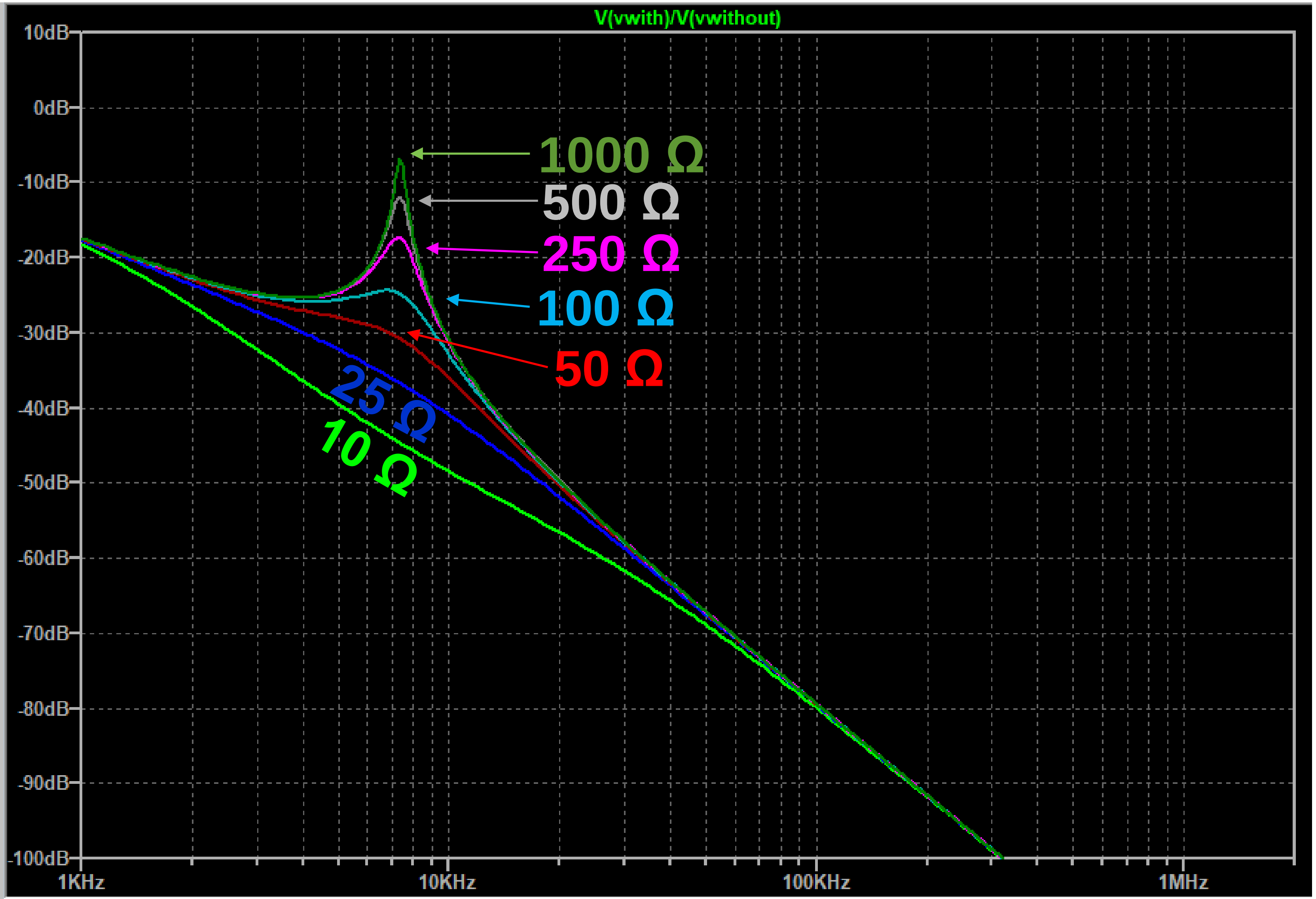


OBSTACLES ENTRE THÉORIE ET PRATIQUE

Impact de “l’impédance de charge” sur filtre “CLC”

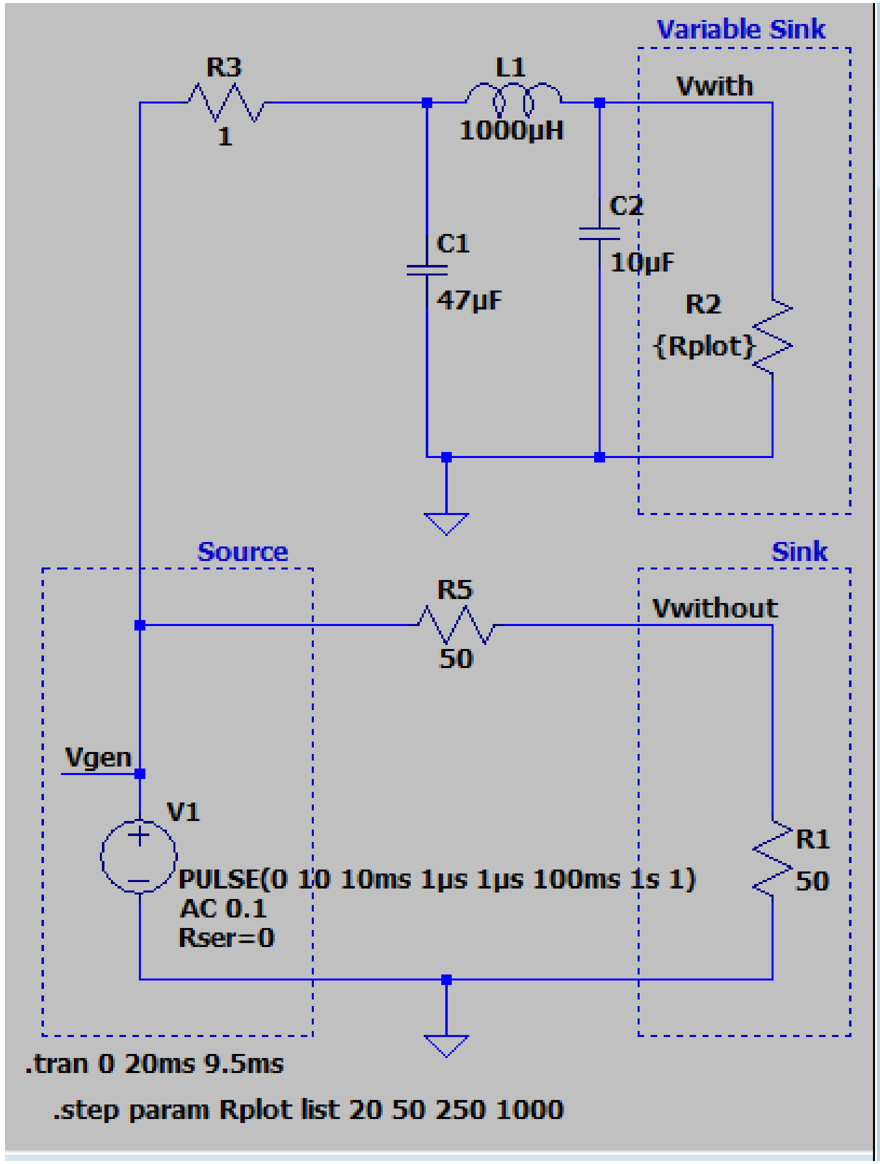
Amortissement des filtres

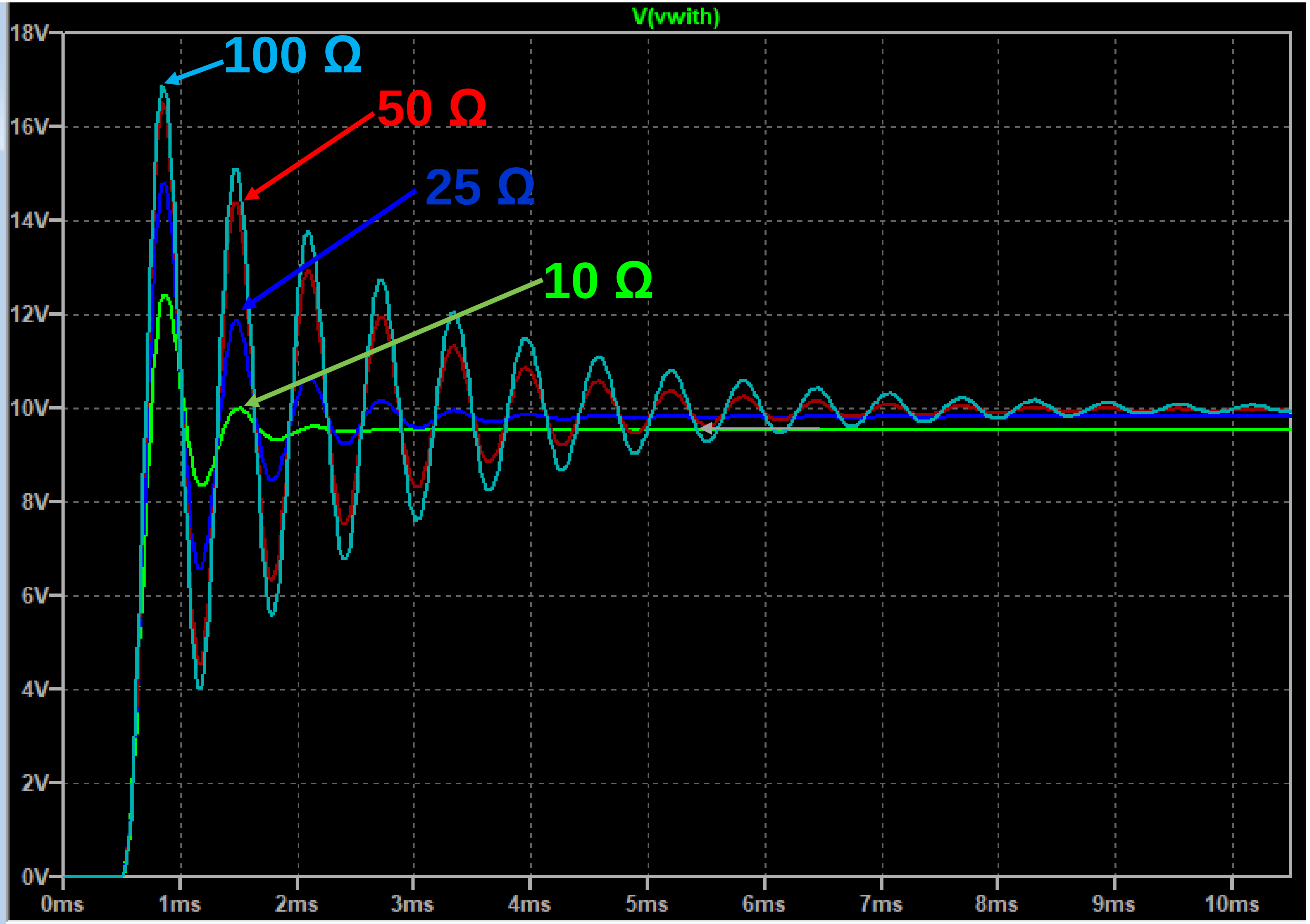




Impact de “l’impédance de charge” sur filtre “CLC”

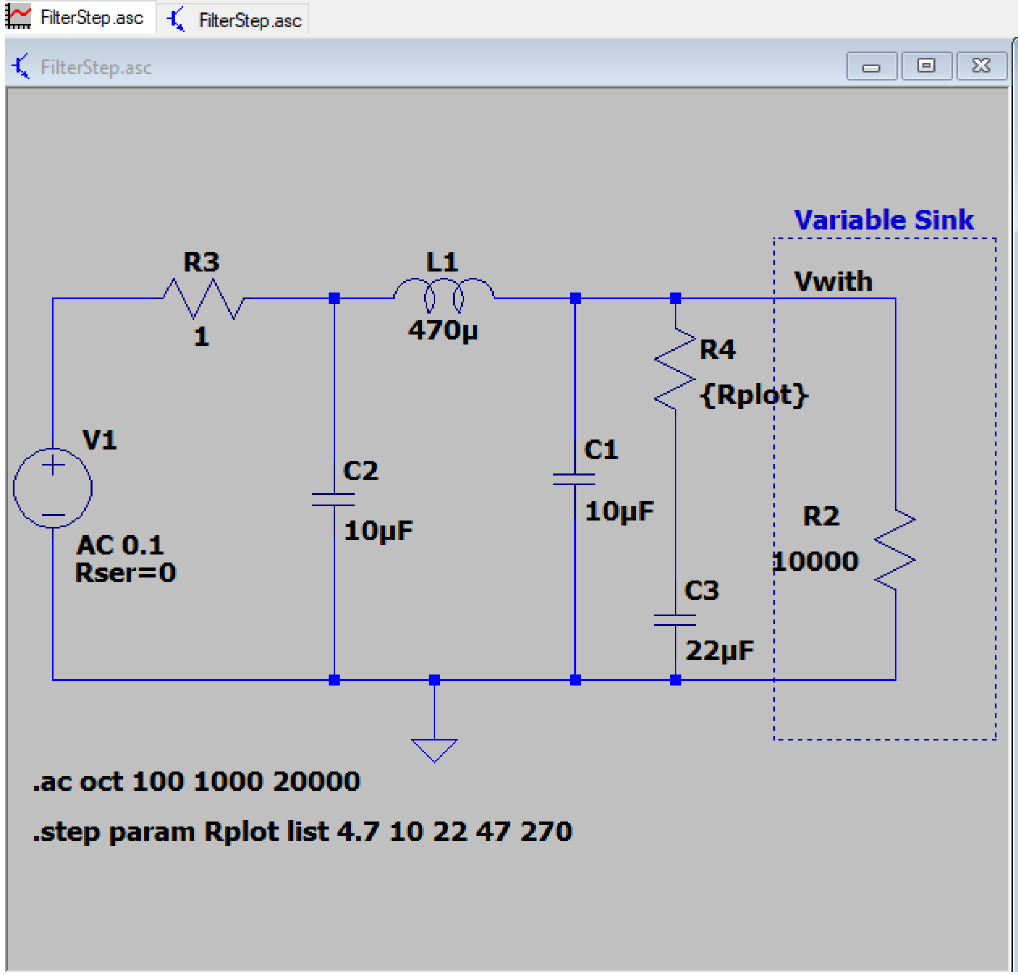
Amortissement des filtres

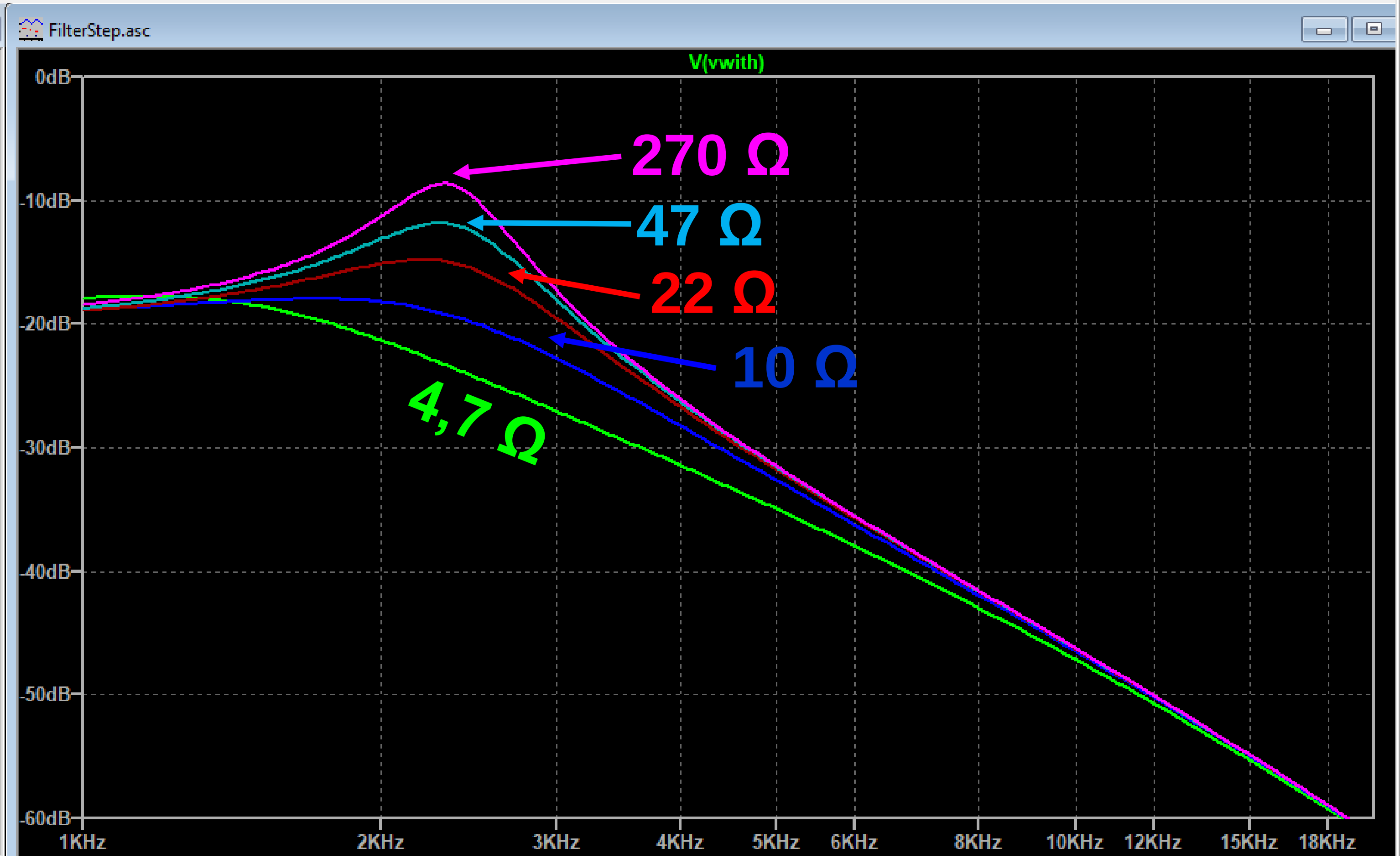




Amortissement des filtres

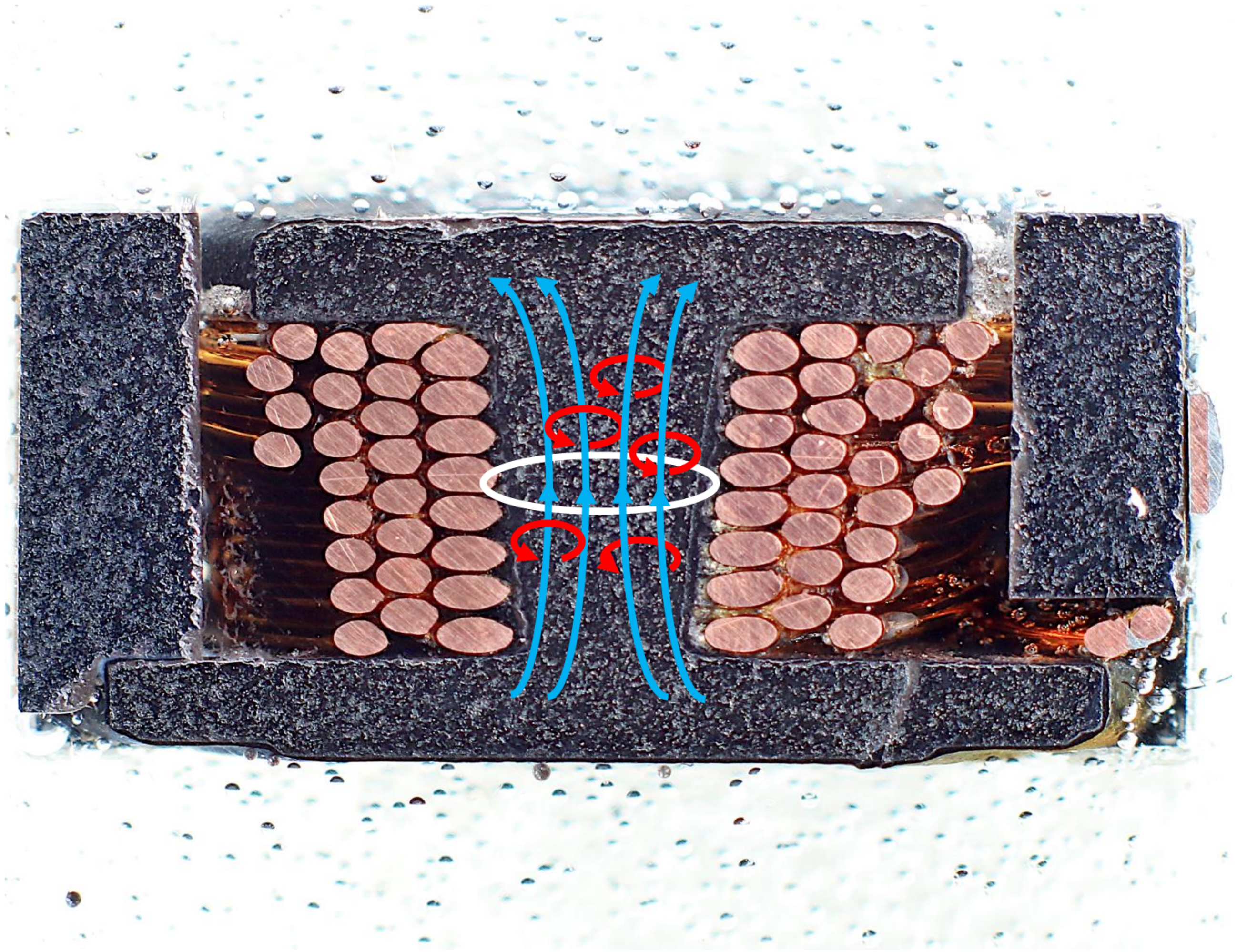
Avec capa + résistance

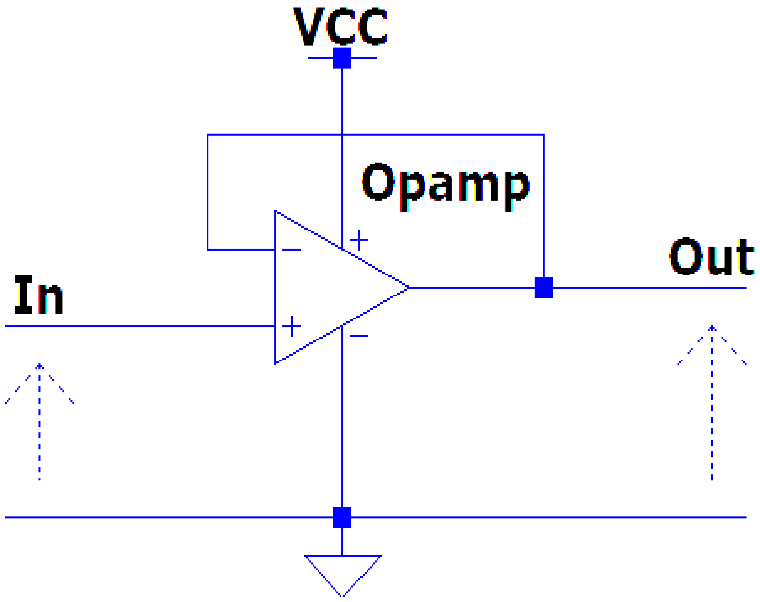




Amortissement des filtres

Basé sur le facteur de qualité / les pertes par courant de Foucault

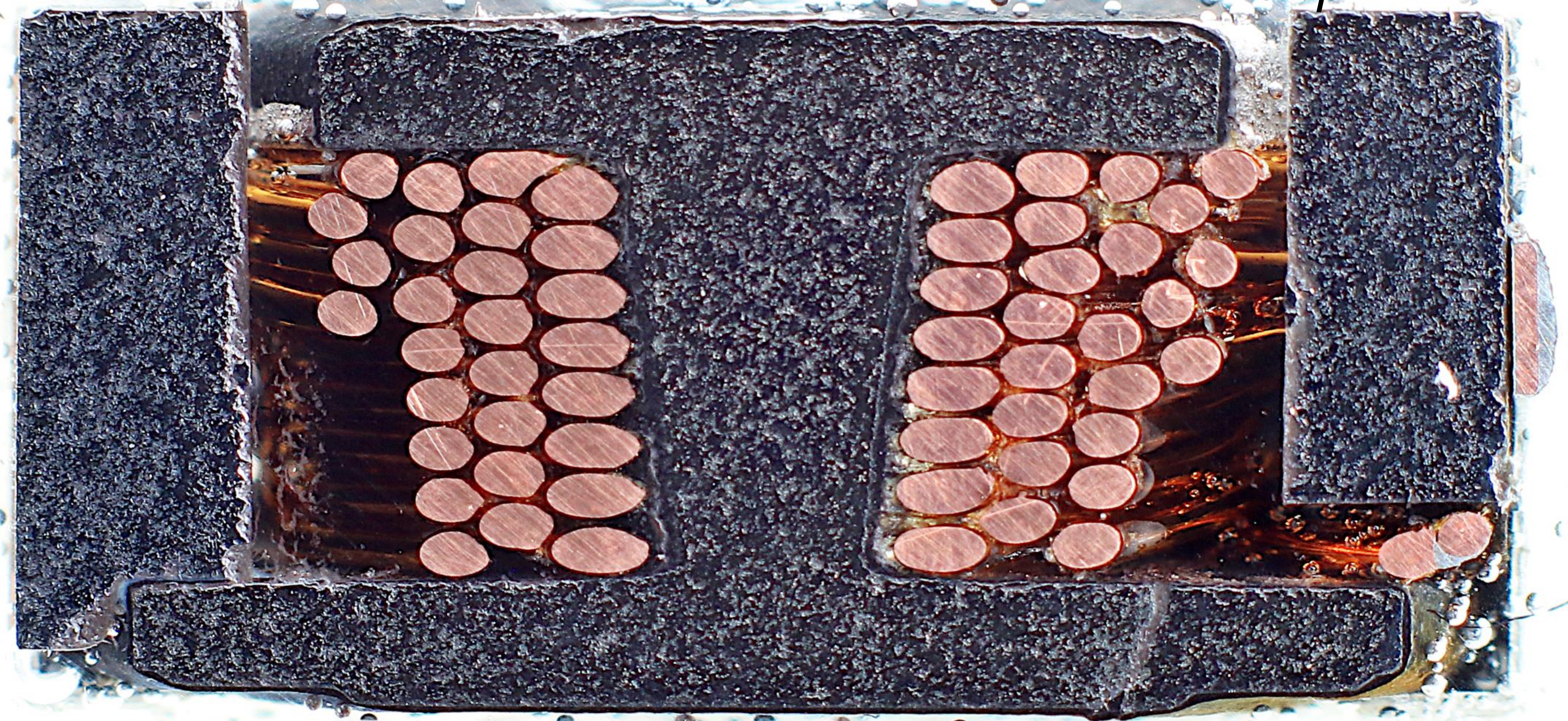




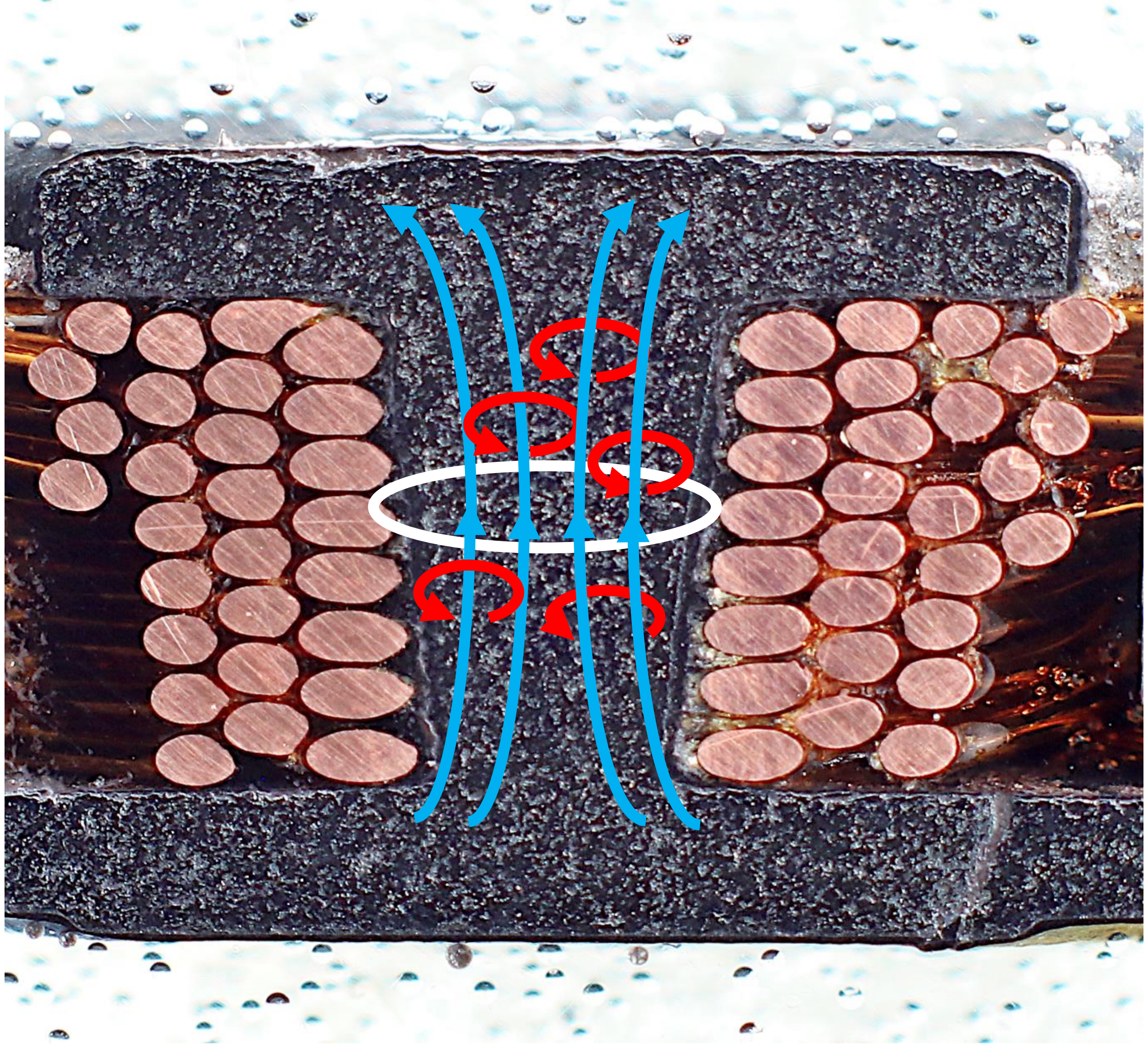
Amortissement des filtres

Basé sur le facteur de qualité / les pertes par courant de Foucault

$$P_{Eddy} = \frac{\pi^2 {B_p}^2 d^2 f^2}{6k\rho D}$$



Amortissement des filtres
Basé sur le facteur de qualité / les pertes par courant de Foucault



Peak Magnetic field
(Current dependent)

Frequency²

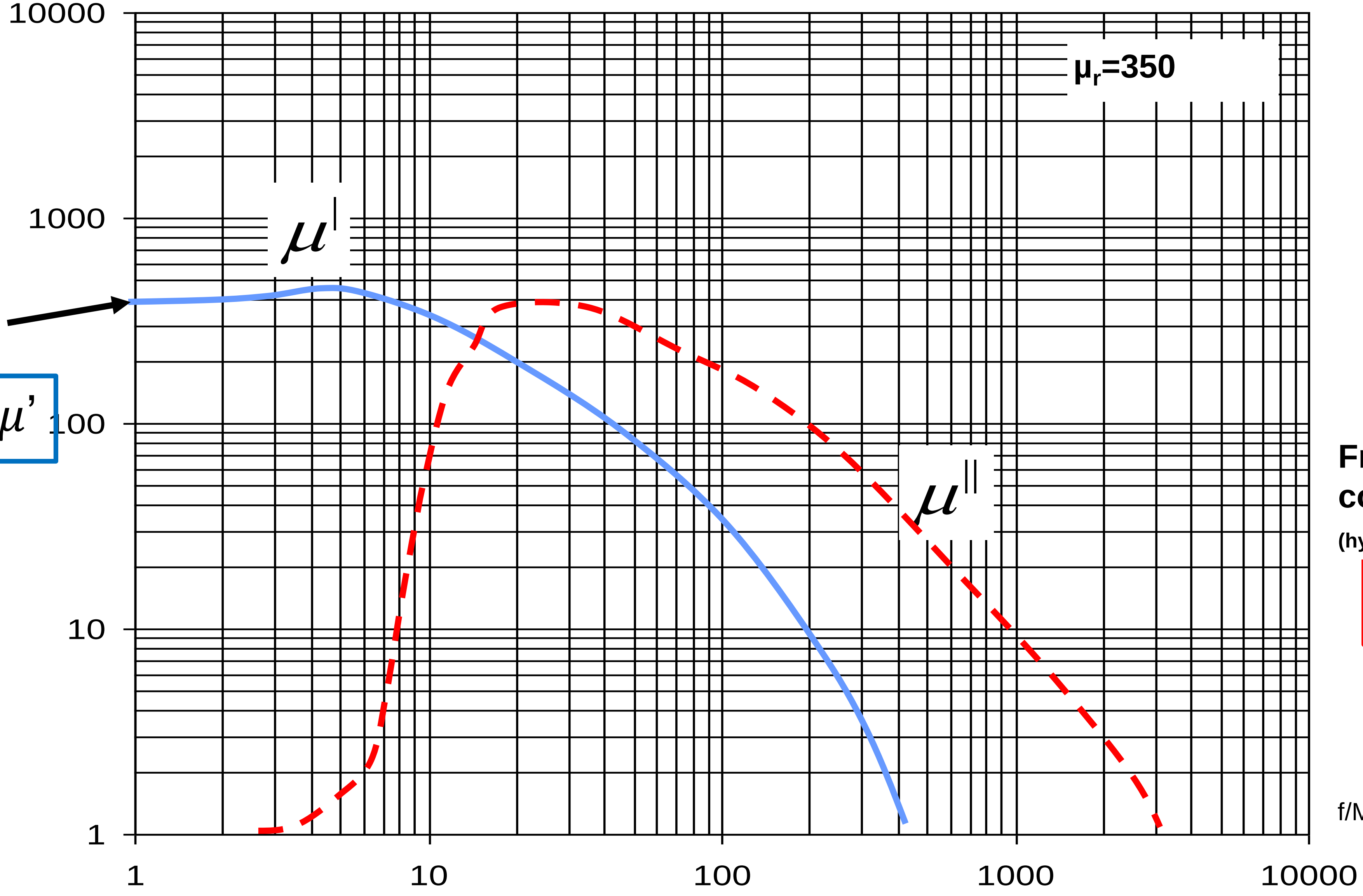
$$P_{Eddy} = \frac{\pi^2 B_p{}^2 d^2 f^2}{6k\rho D}$$

Amortissement des filtres
Basé sur le facteur de qualité / les pertes par courant de Foucault

reactance

(Magnetize ability)

$$X_{LS} = \omega L_0 \mu'$$



Frequency dependent core losses

(hysteresis loss)

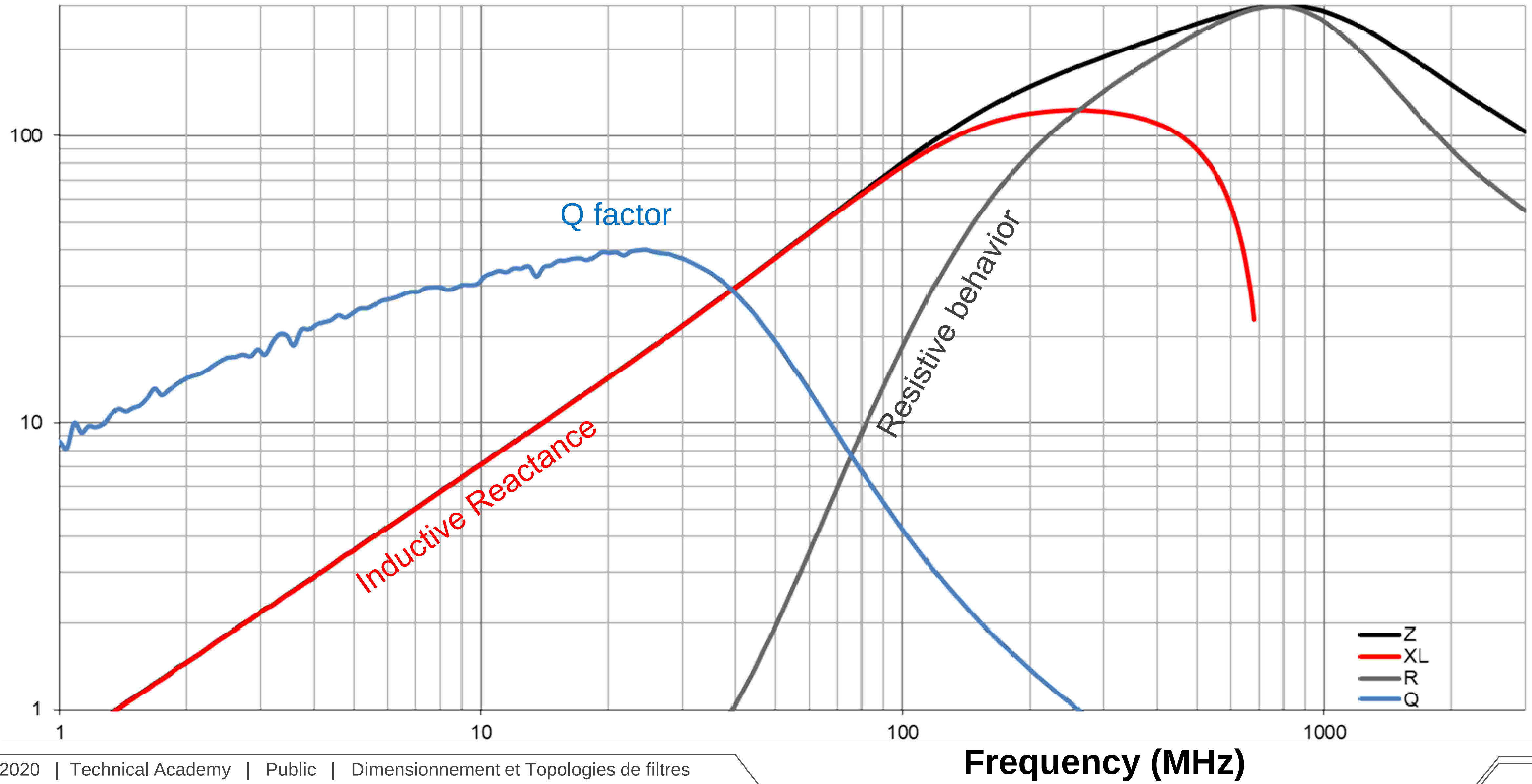
$$R_S = \omega L_0 \mu''$$

f/MHz

Amortissement des filtres

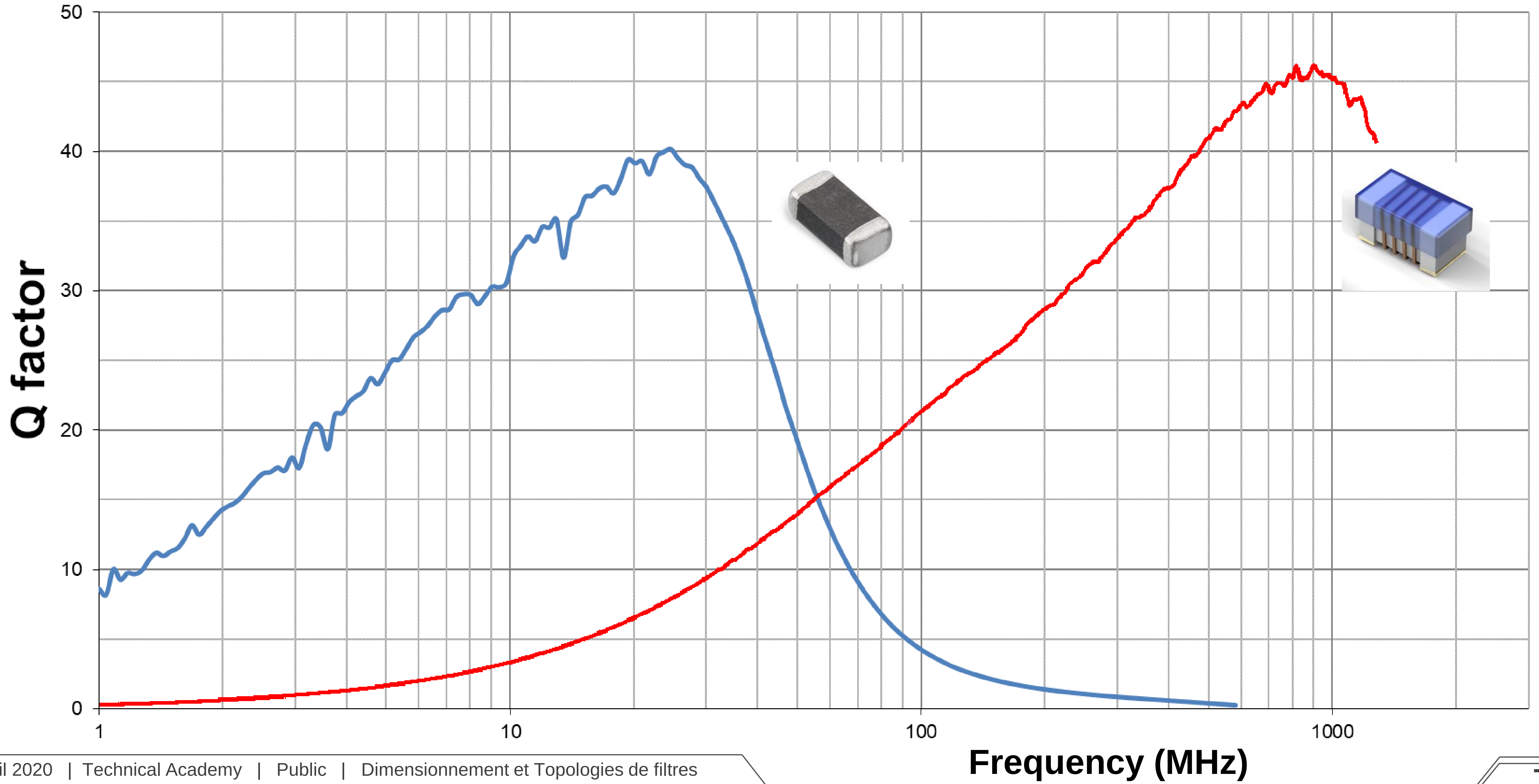
Basé sur le facteur de qualité / les pertes par courant de Foucault

$$Z = \sqrt{{X_L}^2 + R^2}$$

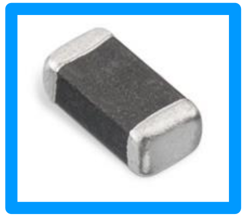


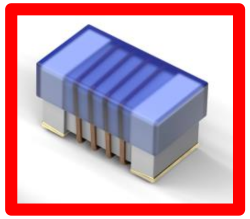
Amortissement des filtres
Basé sur le facteur de qualité / courants de Foucault

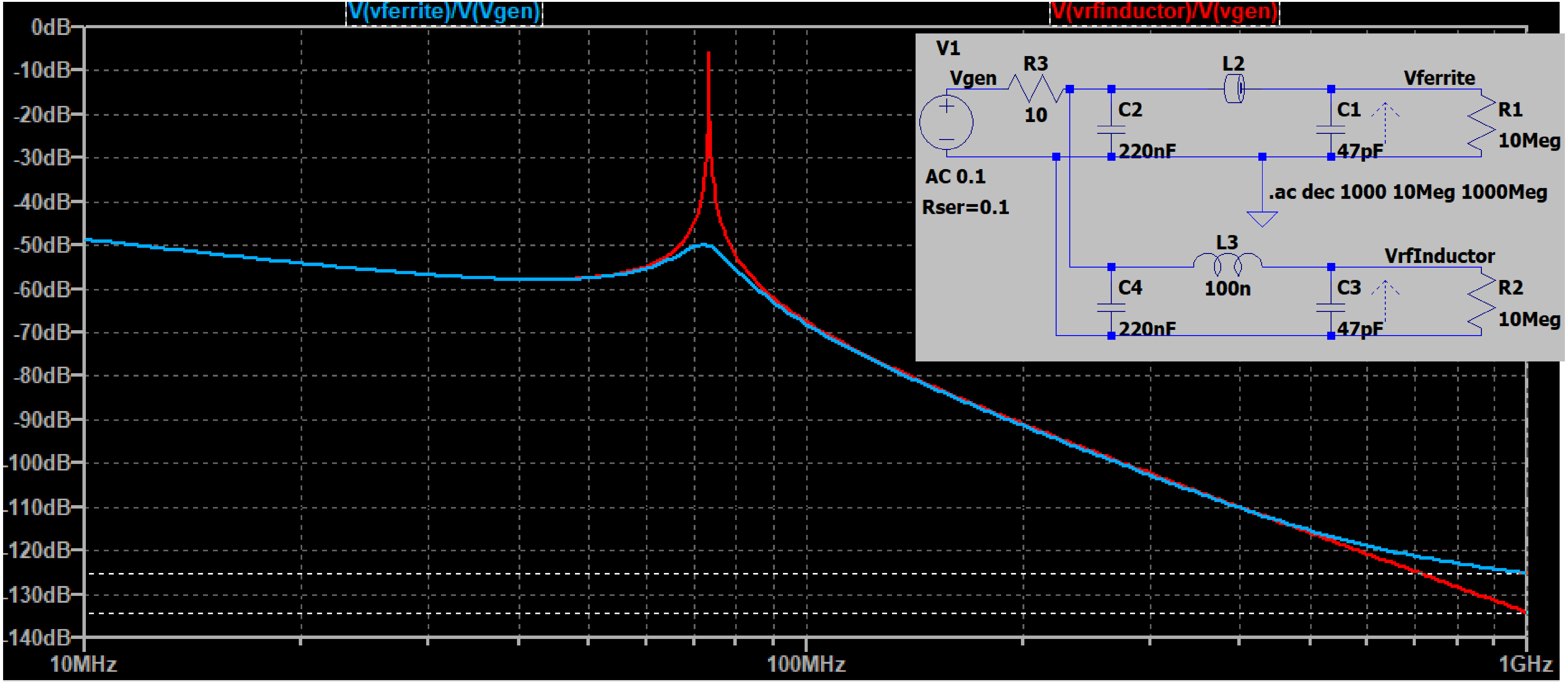
$$Q = \frac{X_L}{R}$$



Amortissement des filtres
Basé sur le facteur de qualité / courants de Foucault

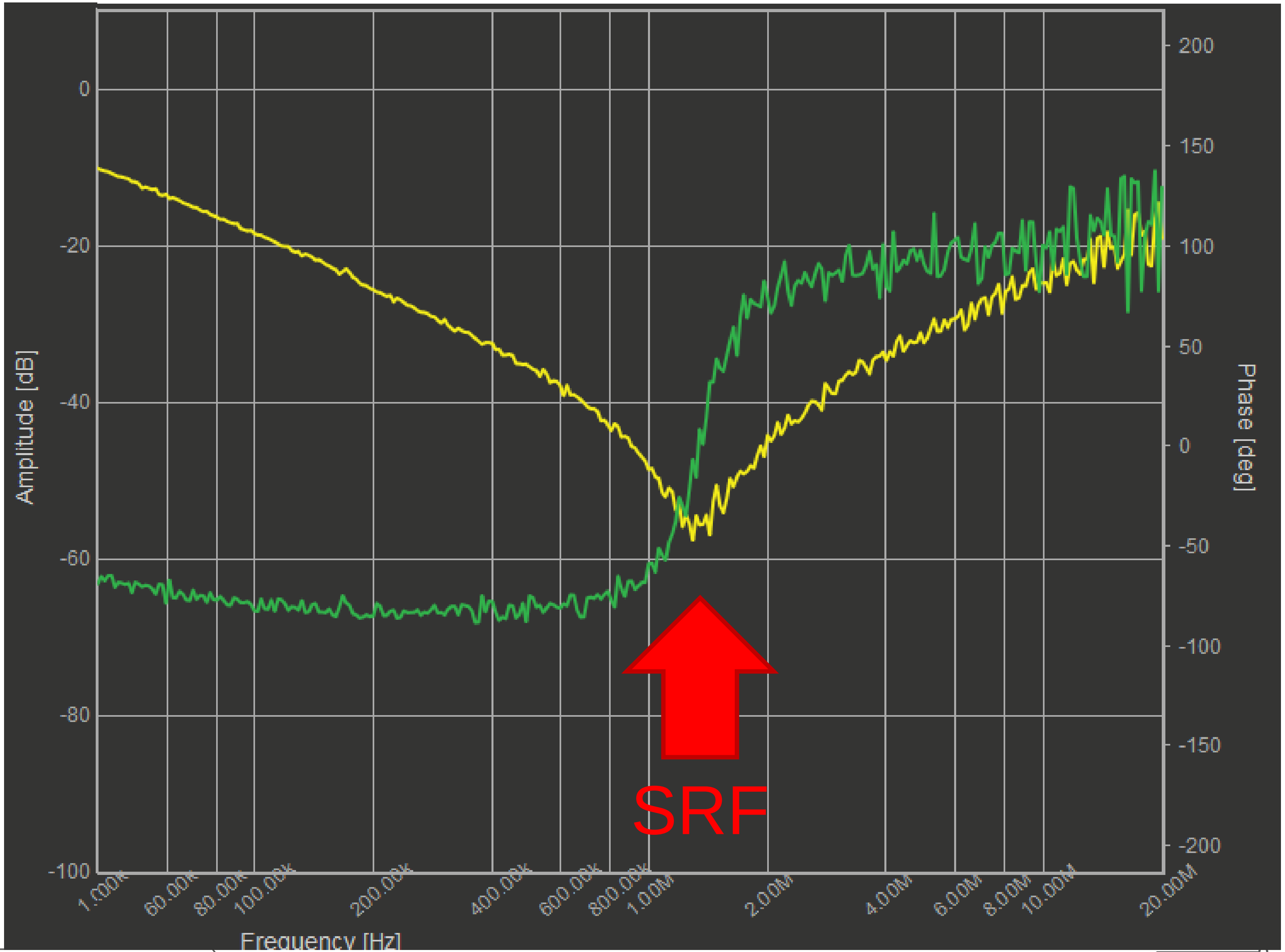






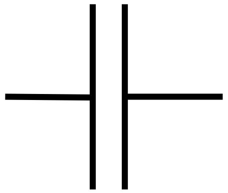
La fréquence de résonance propre (SRF) et ses impacts

- Au delà de la SRF
  - Décroissance de l’impedance des inducances
  - Augmentation de l’impedance des condensateurs



Self Resonance Frequency of capacitors

- Impedance of perfect capacitor

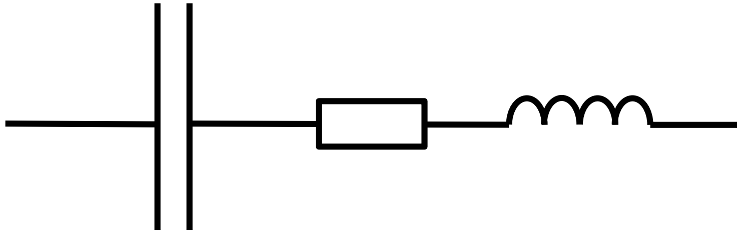


$$\omega = 2\pi f$$

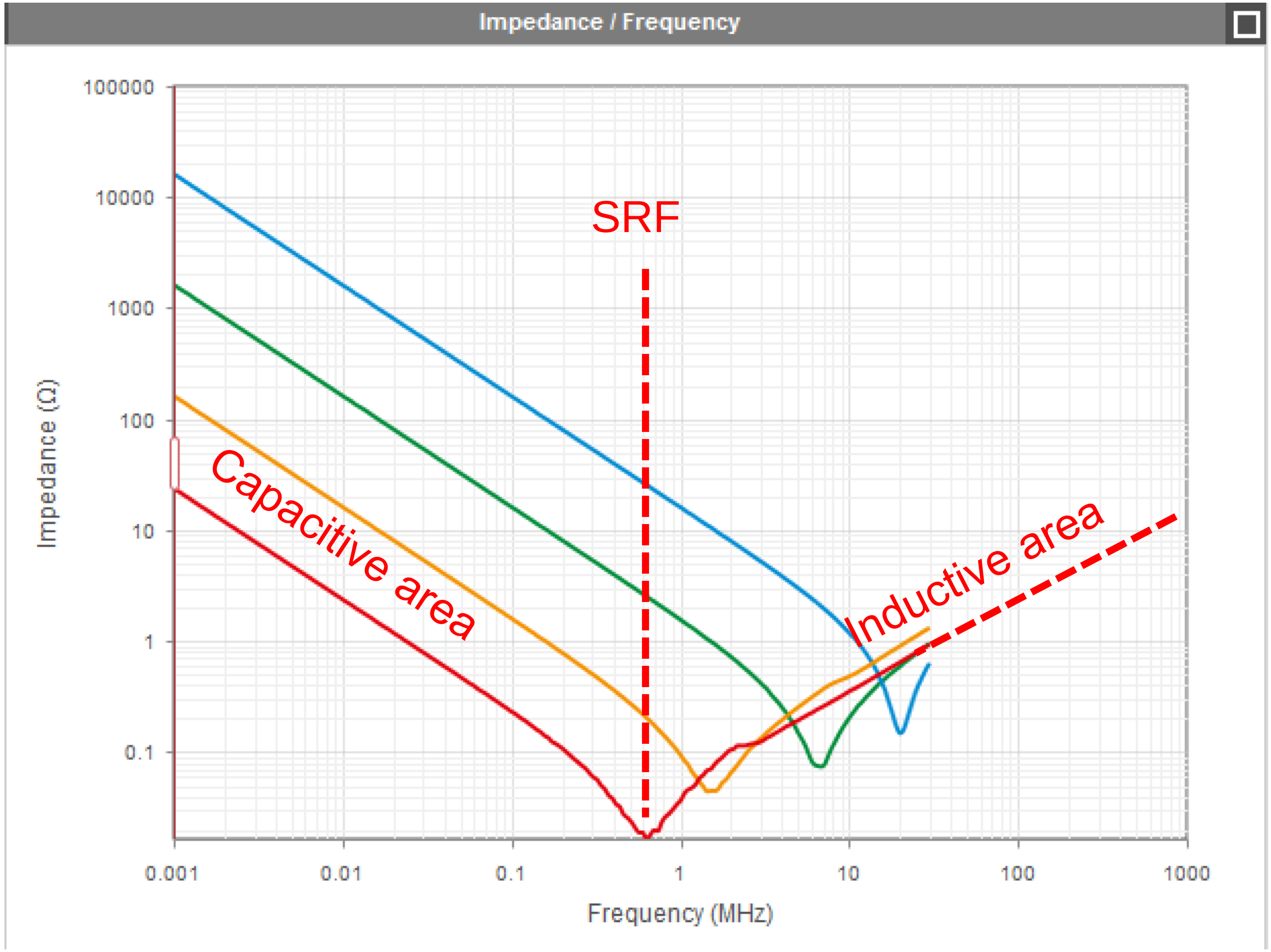
C = capacitance

$$\boxed{|Z| = \frac{1}{|jC\omega|}} \quad in\ (\Omega)$$

- Impedance of real* capacitor



$$\boxed{|Z| = \frac{1}{|jC\omega|} + ESR + |jL_{ESL}\omega|}$$



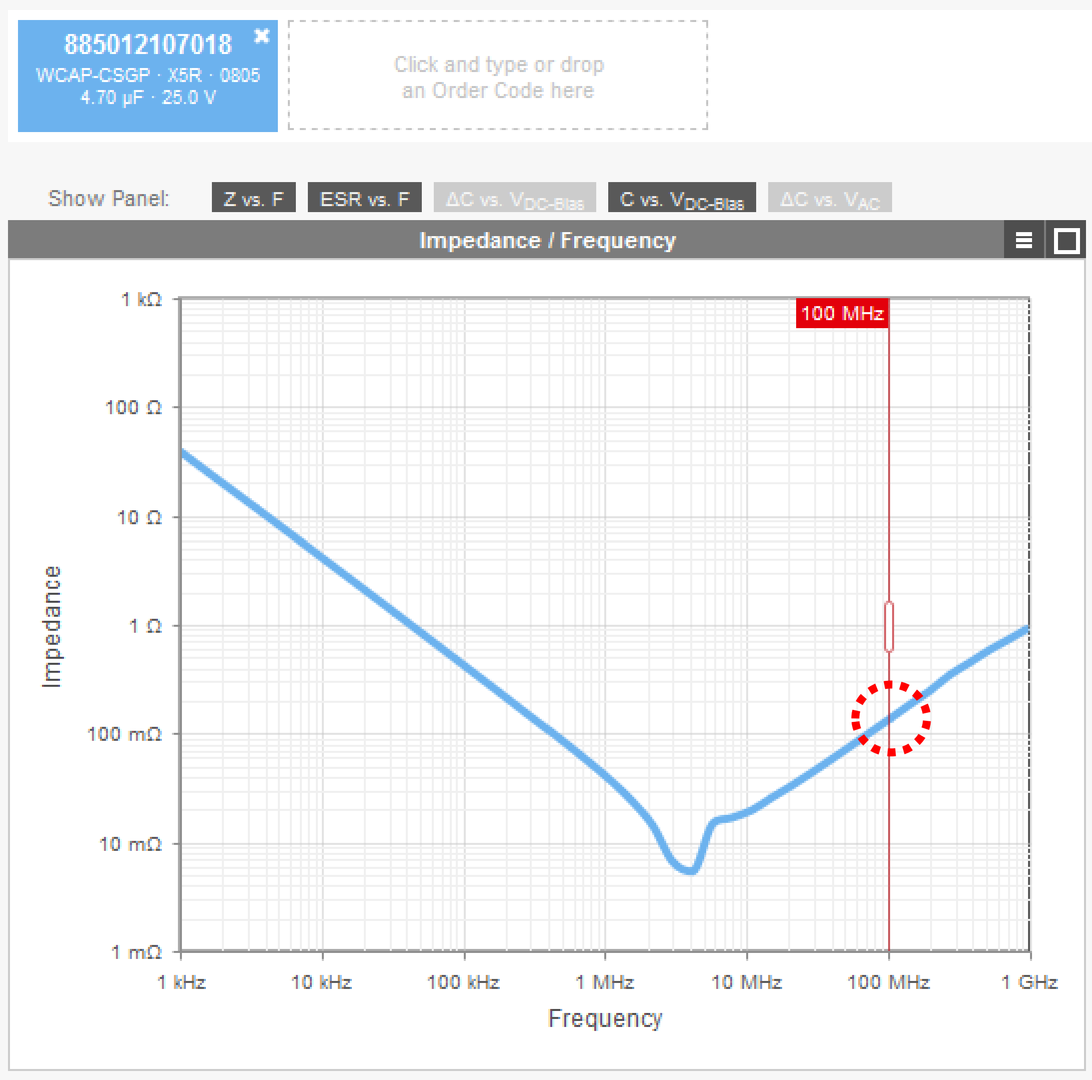
ESL identification from Datasheet or REDExpert

$$|Z_L| = L\omega$$

$$\frac{Z_L}{\omega} = L$$

$$L = \frac{|Z_L|}{2\pi F} = \frac{5}{100 \times 10^6 \times 2\pi} \cong 8\,nH$$

ESL identification from Datasheet or REDExpert

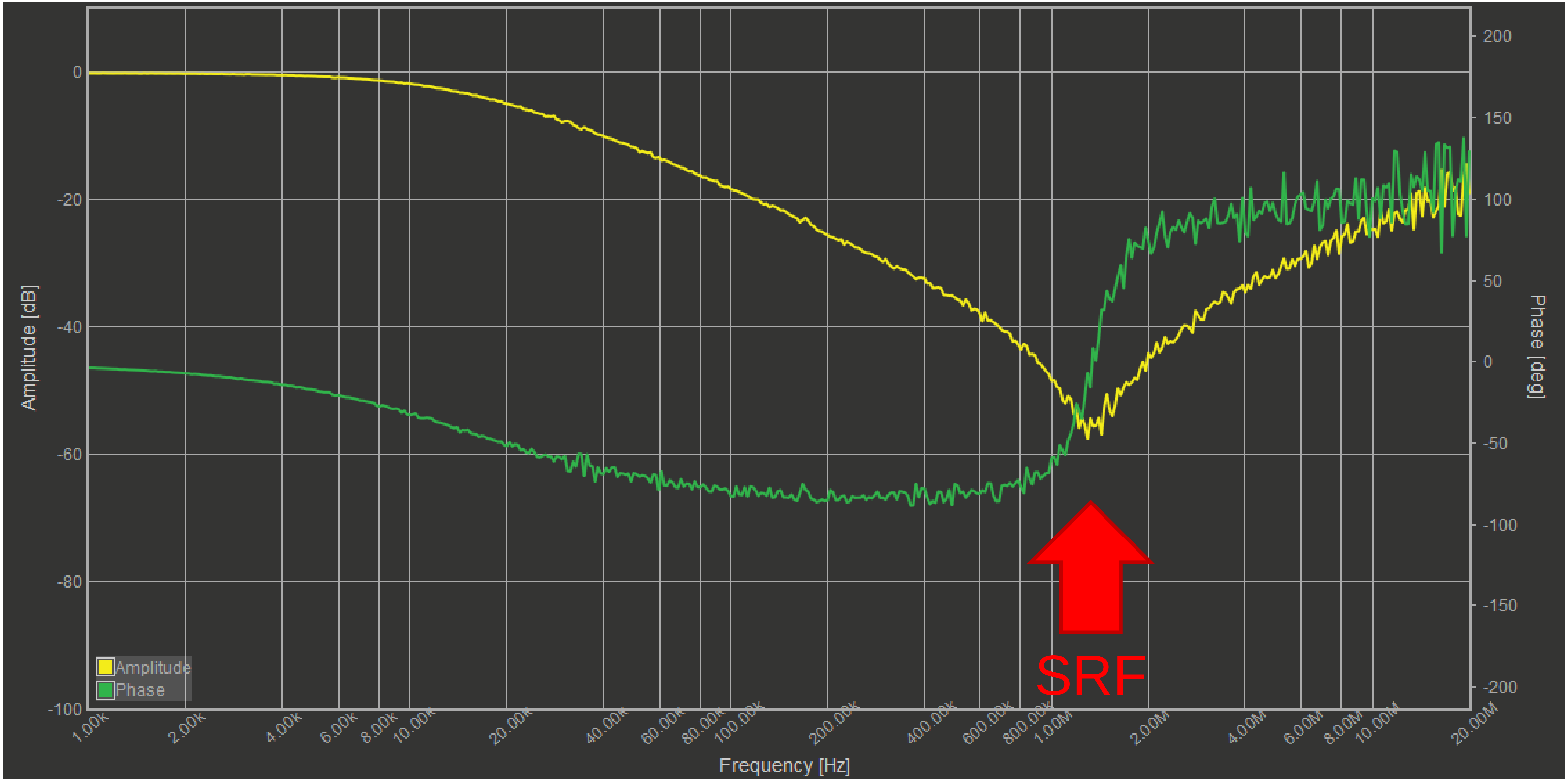


$$|Z_L| = L\omega$$

$$\frac{Z_L}{\omega} = L$$

$$L = \frac{|Z_L|}{2\pi F} = \frac{0{,}132}{100 \times 10^6 \times 2\pi} \cong 0.2\,nH$$

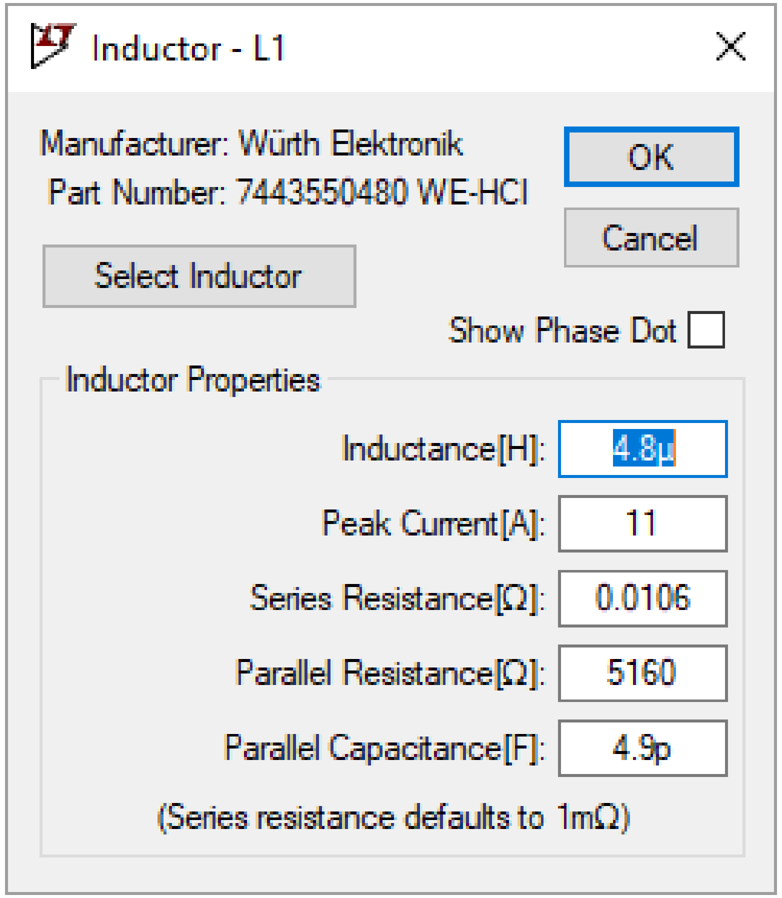
Self Resonance Frequency of Inductors

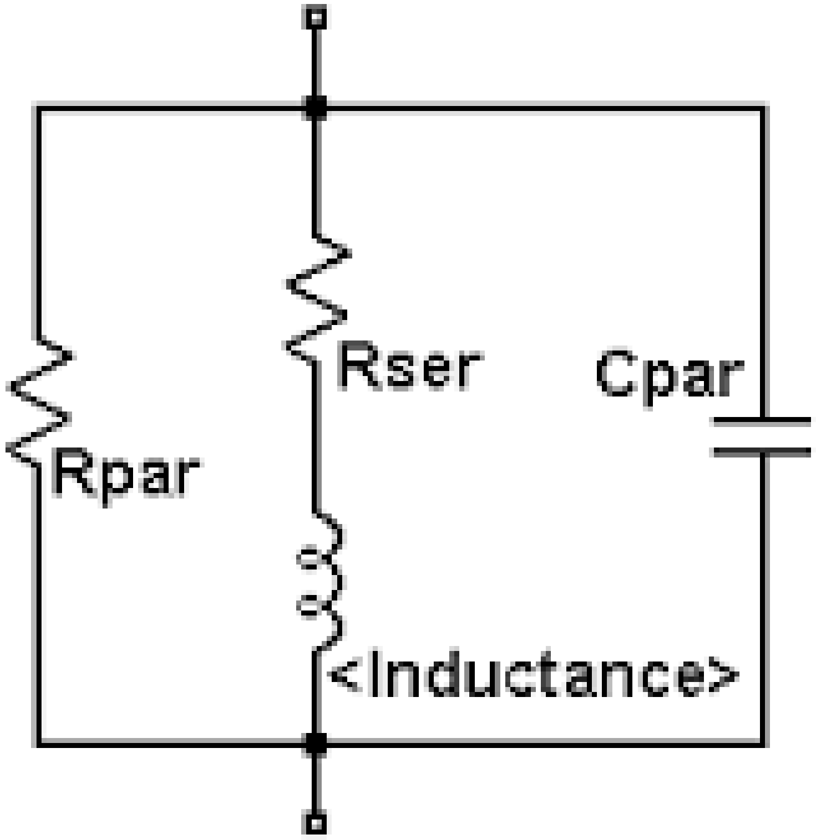


Technologies to improve SRF

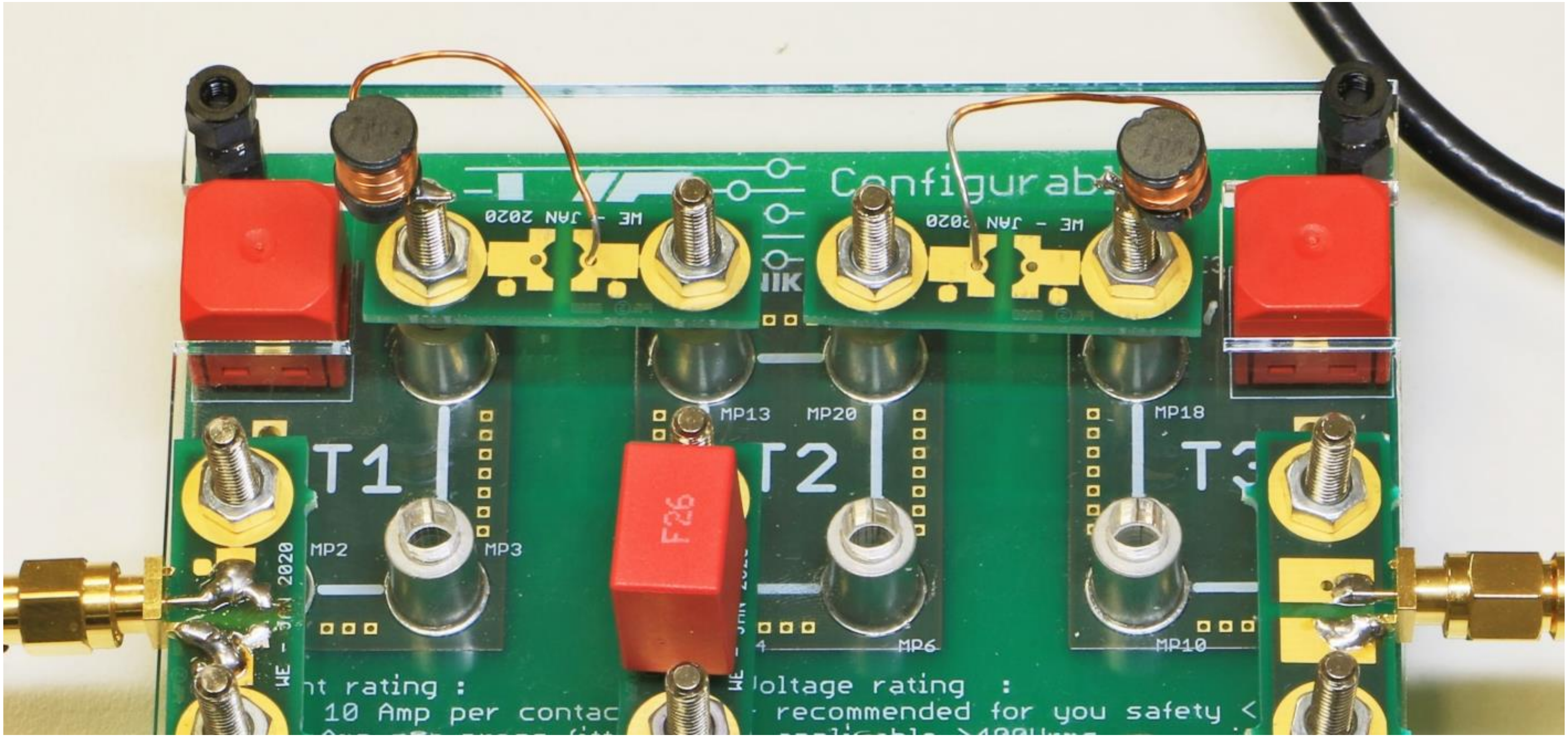
- Core material
- Winding Chambers
- Winding Style

Technologies to improve SRF

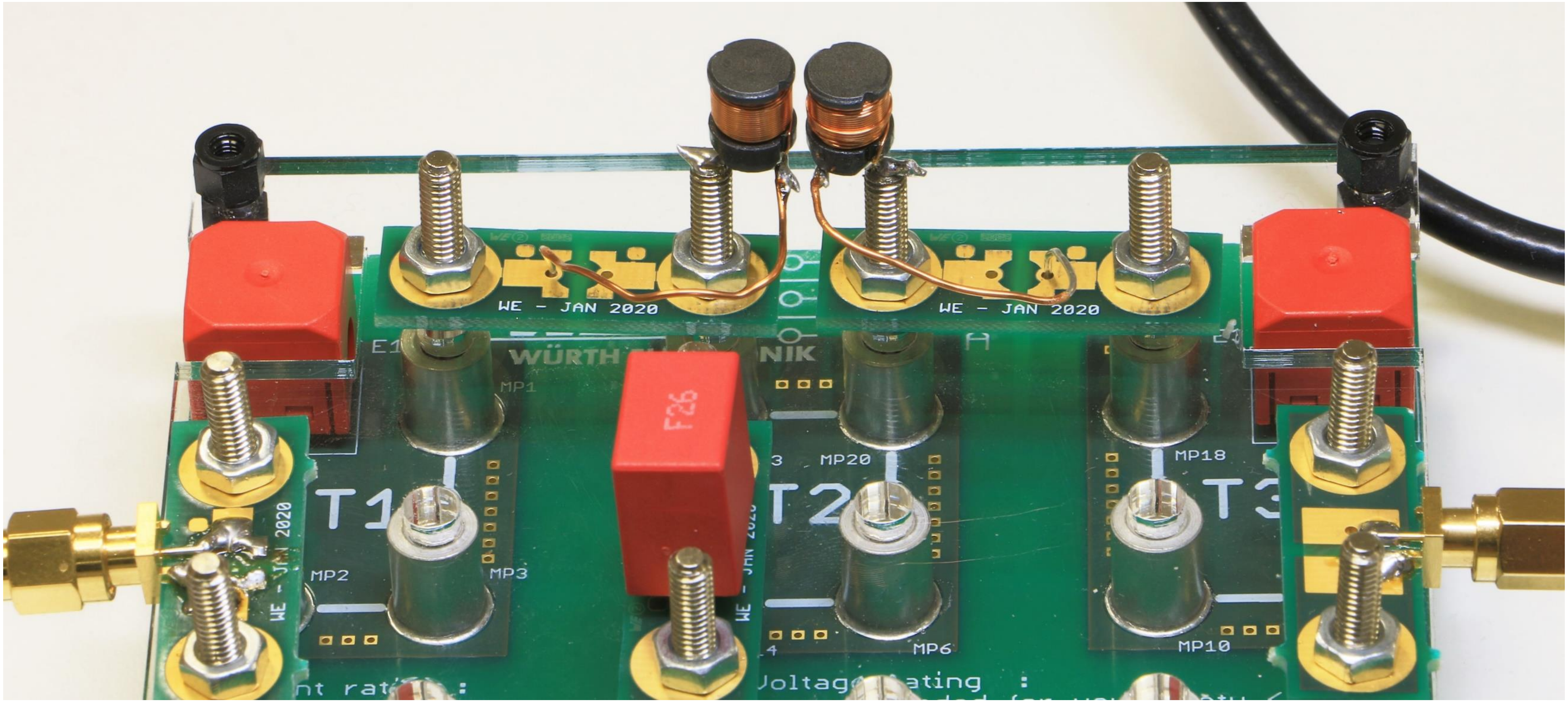




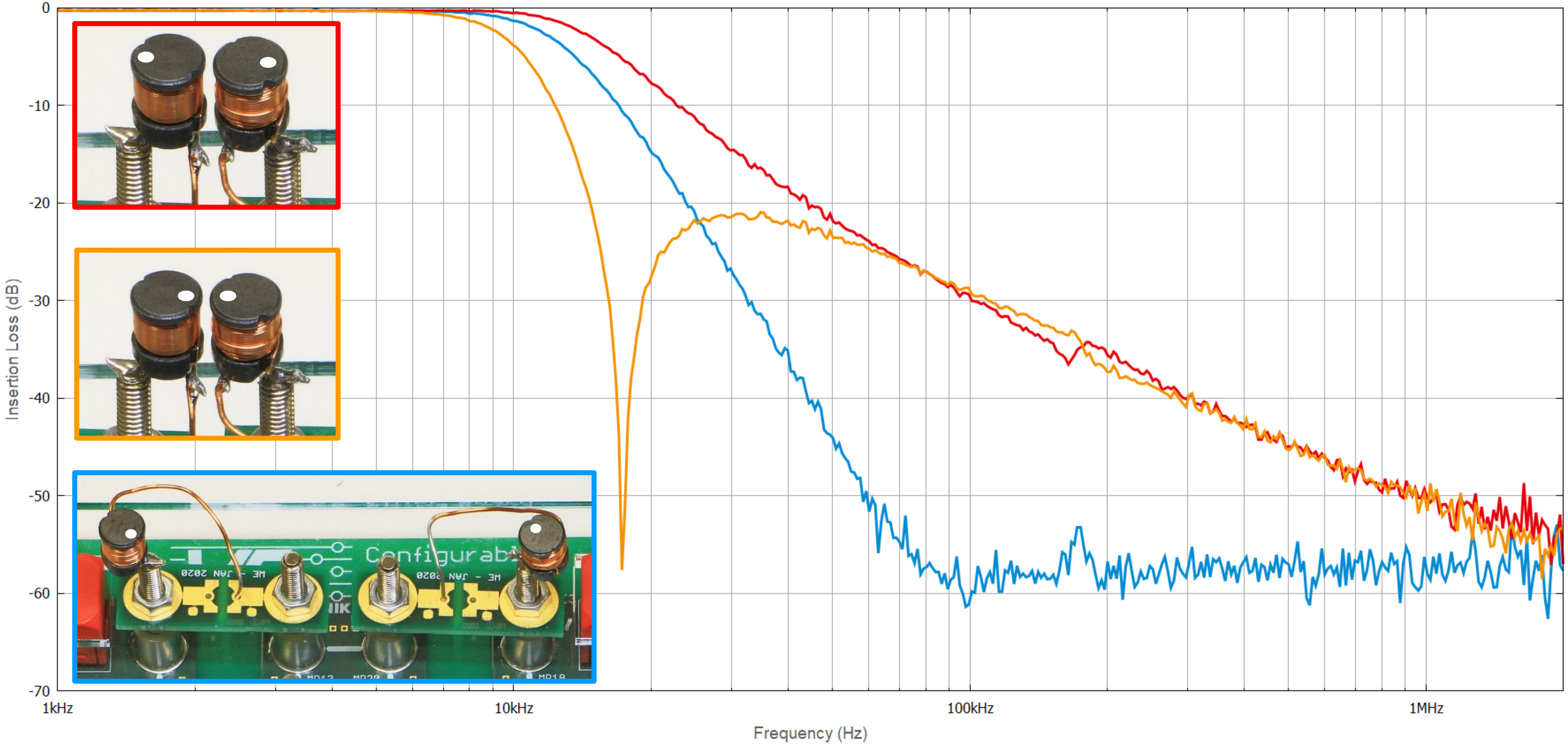
Parasitic E and H field coupling



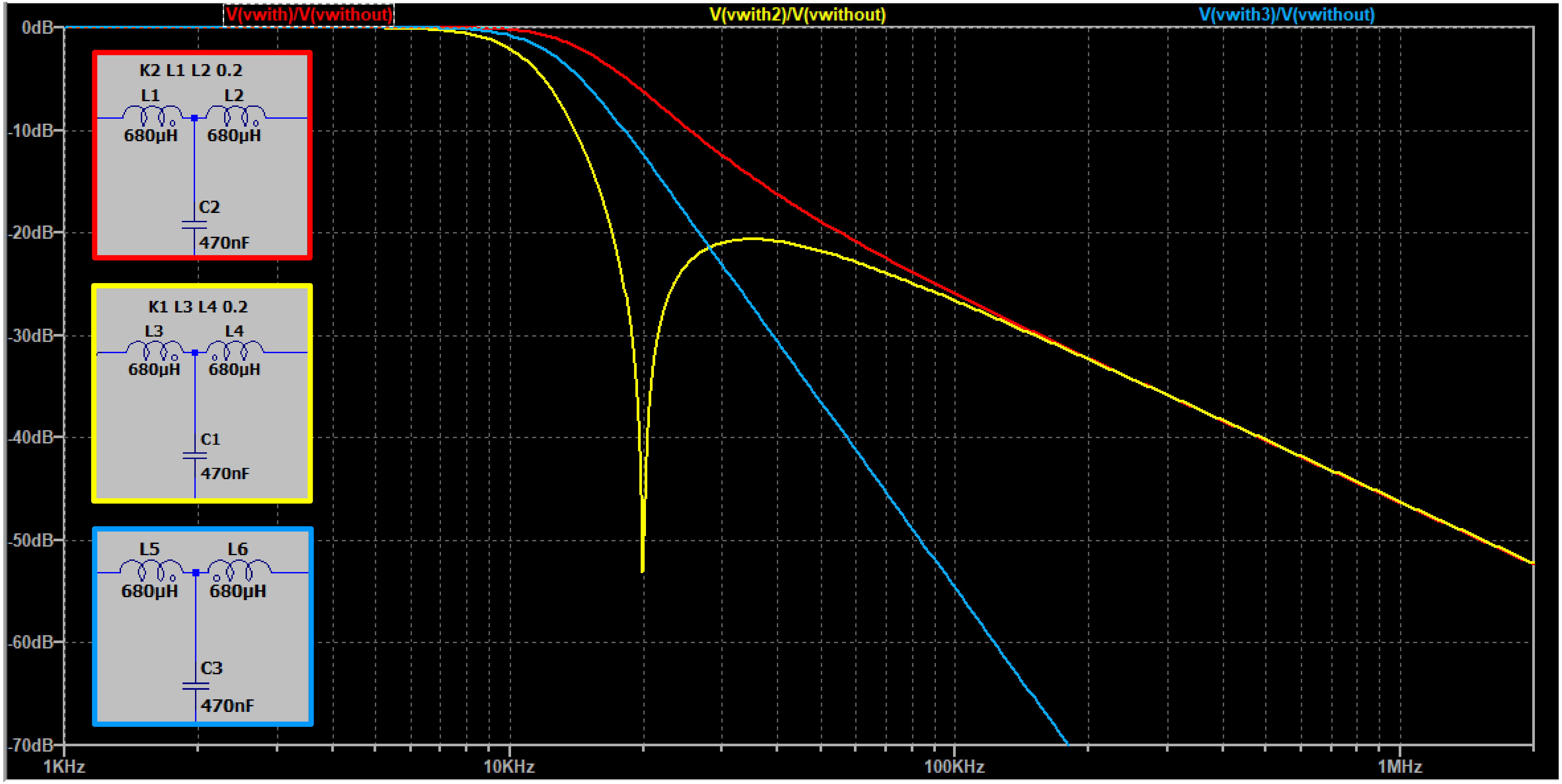
Parasitic E and H field coupling



Parasitic E and H field coupling (measurement)



Parasitic E and H field coupling (measurement)




Thank You!