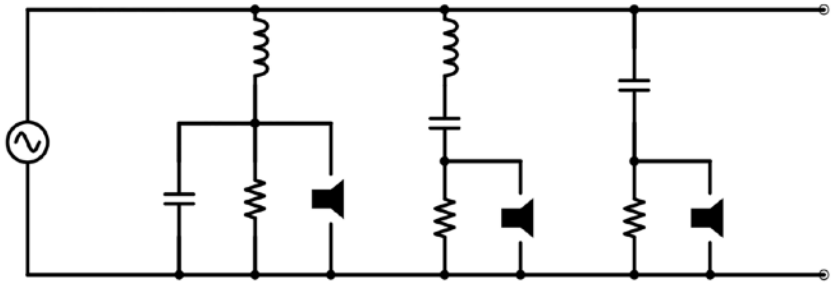
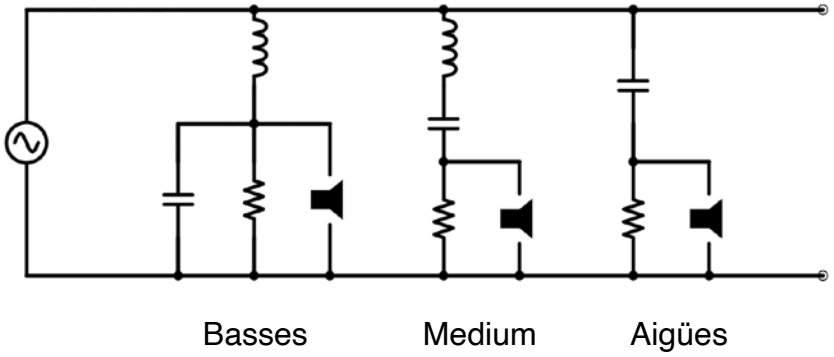
Expérimentation sur les circuits - II
Dipôles et quadripôles

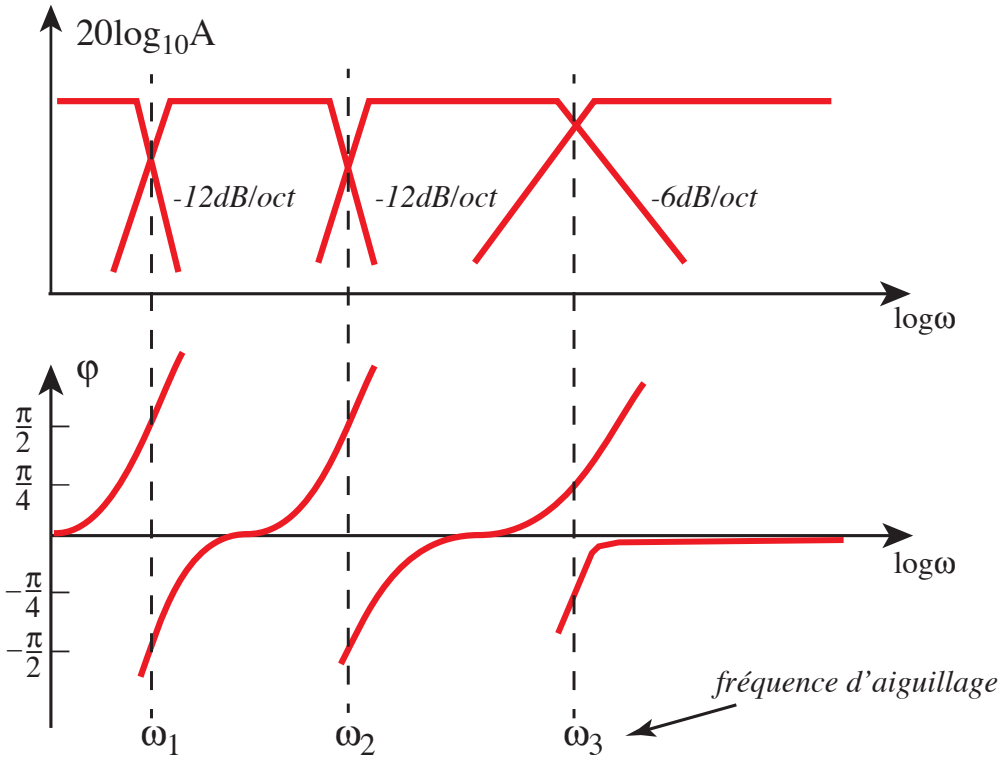
D. Mari



Les colonnes sonores

Exemple de filtres d'aiguillage





Pour aiguiller le son sur chaque haut-parleur (basse, médium, aigu) de la colonne, on utilise des **filtres passifs d'aiguillage** composés de résistances, inductances et condensateurs

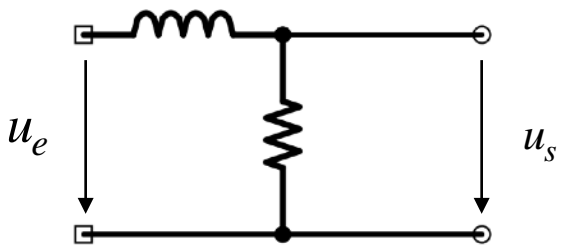
Les filtres passifs

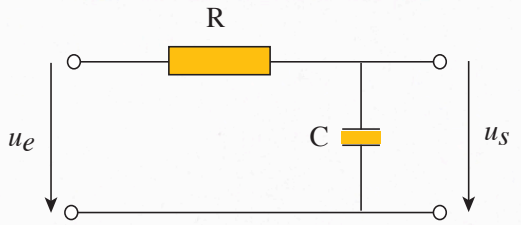
Note: 6 dB/octave=20dB/décade
Ou dB/décade=3.32dB/octave

$\text{Log}_2(10)$

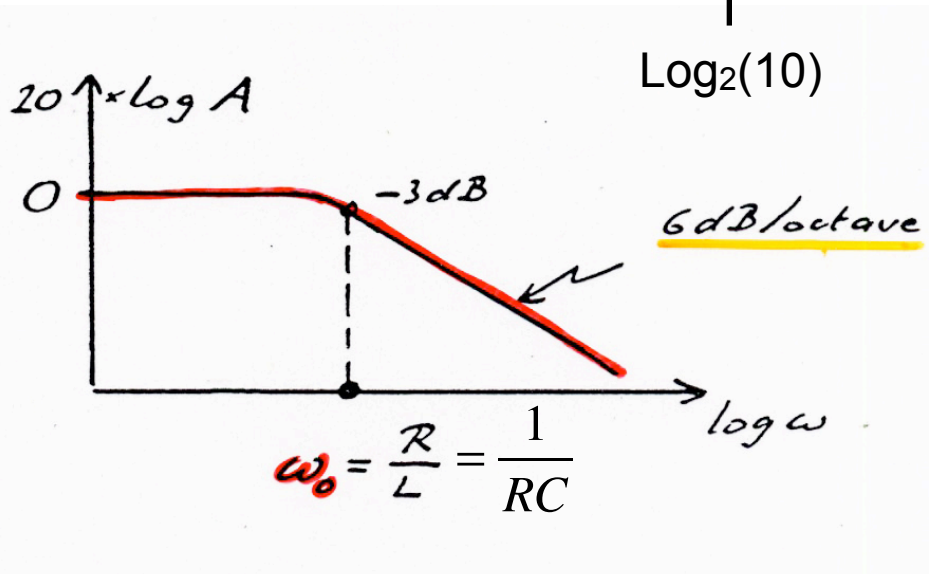
Filtres passe-bas

1er ordre





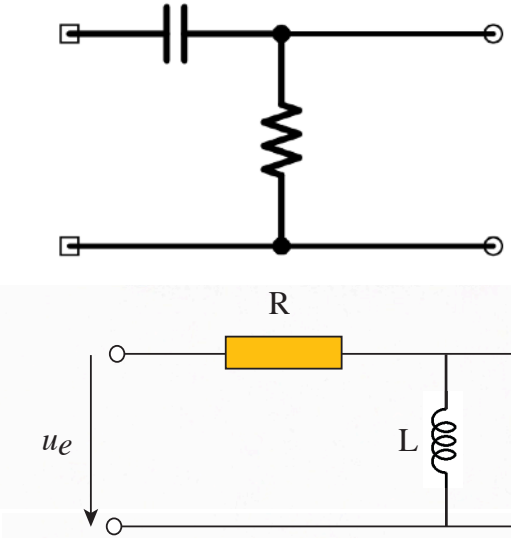
2eme ordre

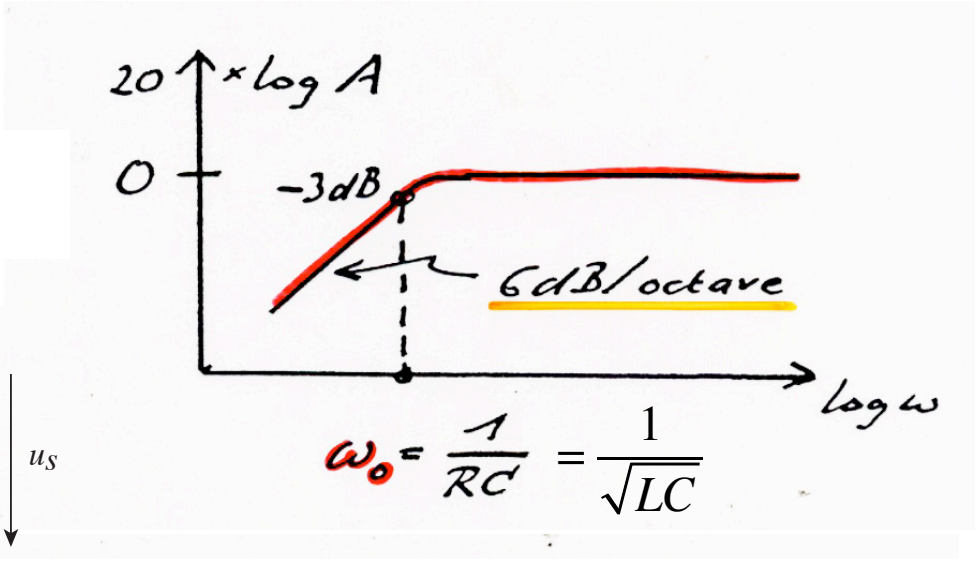


Les filtres passifs

Filtres passe-haut

1er ordre





$$\omega_0 = \frac{1}{RC} = \frac{1}{\sqrt{LC}}$$

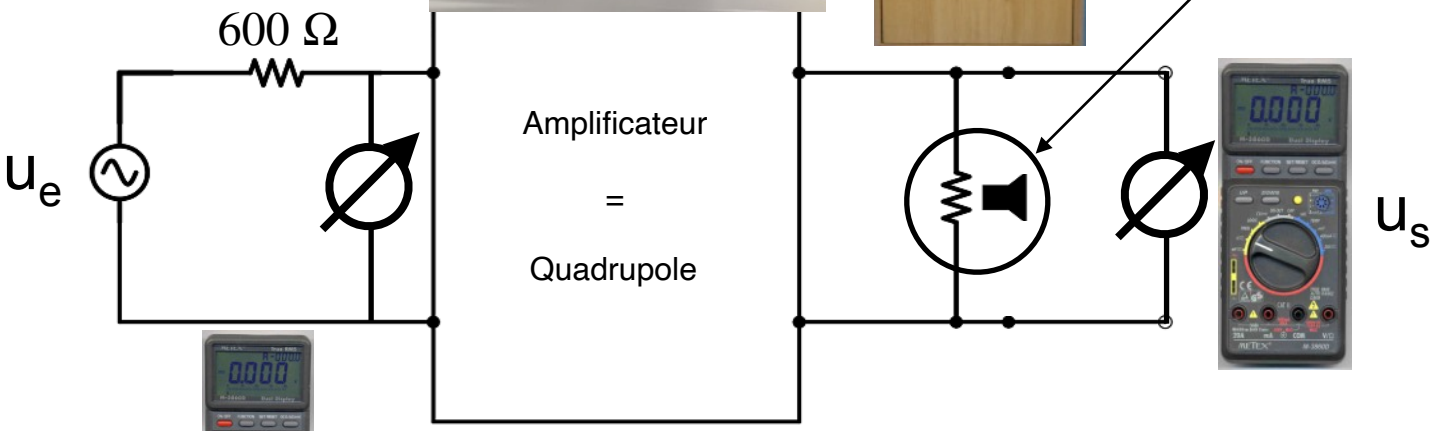
1) Réponse d'un quadripôle actif: l'ampli HI-FI

Effectuez le montage suivant (sortie du générateur de fonctions sur ***600Ω* et *-20 dB***). Réglez la sortie du générateur de fonctions tel que, à 1 kHz : $u_e(RMS) \cong 100$ mV

Réglez le volume de l'ampli tel que la sortie soit à 1 kHz:

$u_s(RMS) \cong 20$ mV

Haut-parleur



Sortie 1 canal (R/L) et A ou B

Entrée 1 canal (R/L)

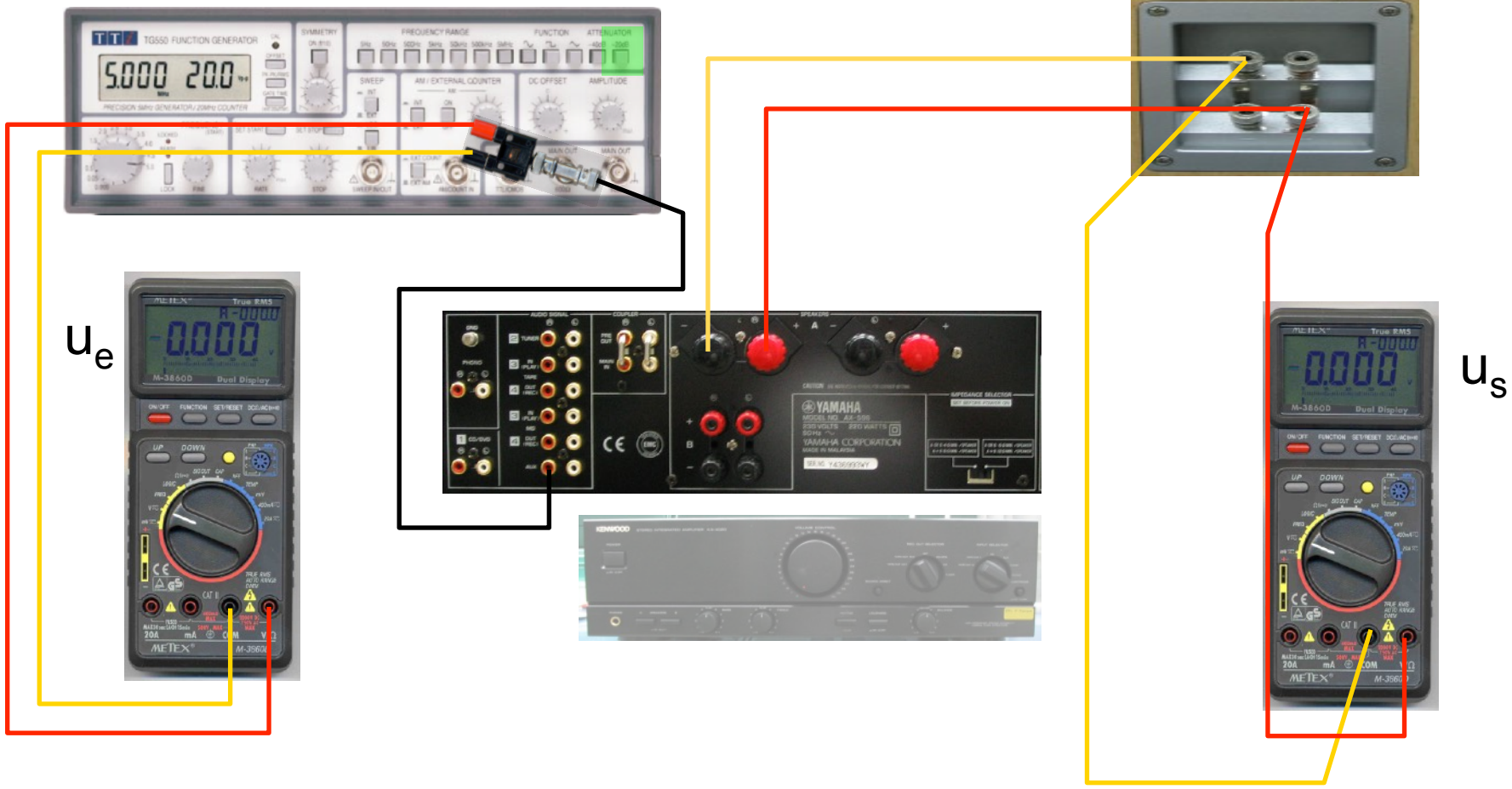
1) Réponse d'un quadripôle actif: l'ampli HI-FI

Effectuez le montage suivant (sortie du générateur de fonction sur ***600Ω*** **et** ***-20 dB***). Réglez la sortie du générateur de fonctions tel que, à 1 kHz :

$$u_e(\text{RMS}) \cong 100 \text{ mV}$$

Réglez le volume de l'ampli tel que la sortie soit à 1 kHz:

$$u_s(\text{RMS}) \cong 20 \text{ mV}$$



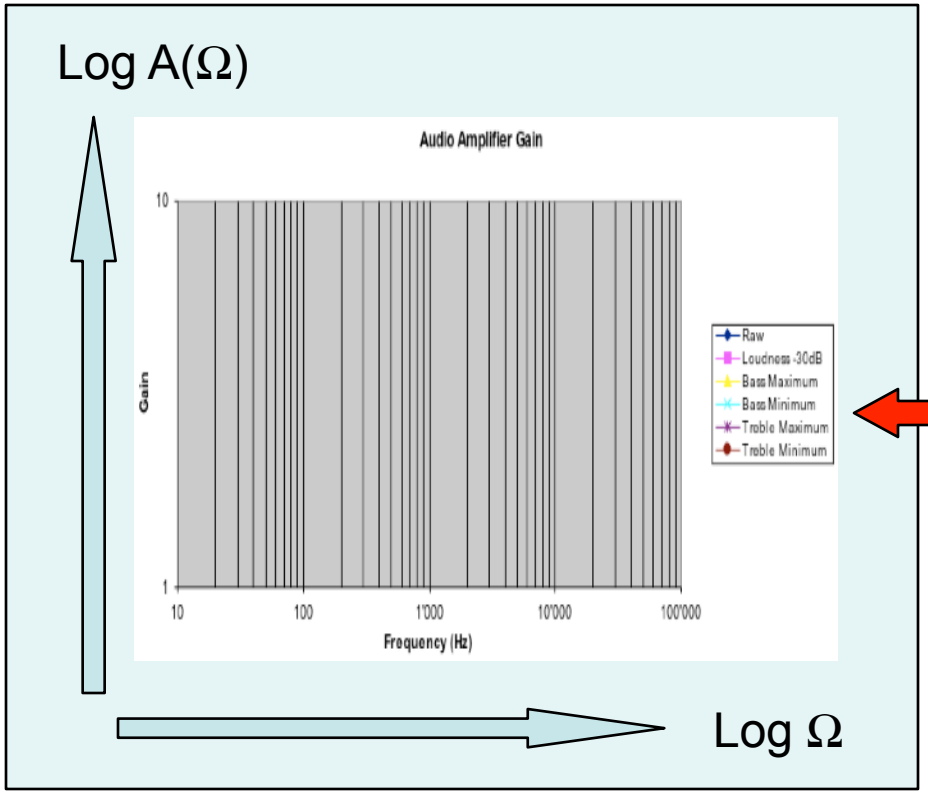
Réponse d'un quadripôle actif: l'ampli HI-FI

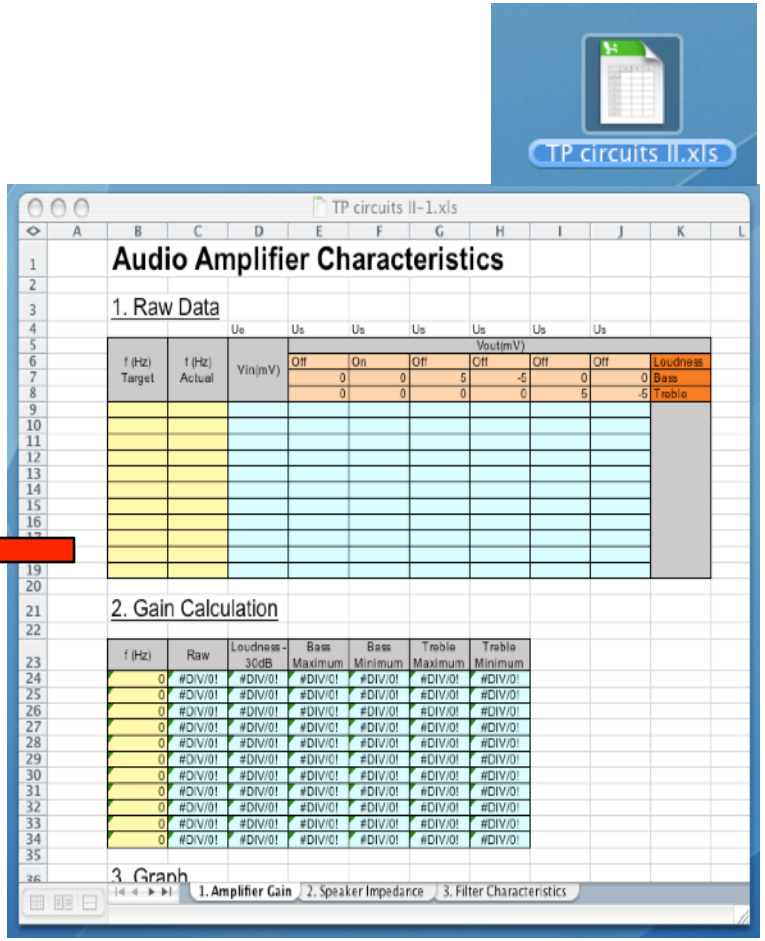
Reportez dans un diagramme log-log (diagramme de Bode) ***le gain*** de l'ampli en fonction de la fréquence de l'entrée (signal sinusoïdal, **20 Hz à 20 kHz**), pour les correcteurs physiologiques (basse, aigue ou loudness) placés:

- au minimum
- au centre
- au maximum

$$u_e(RMS) \cong 100\ mV$$

$$|A| = \frac{u_s(RMS)}{u_e(RMS)}$$

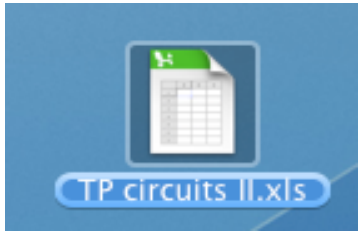


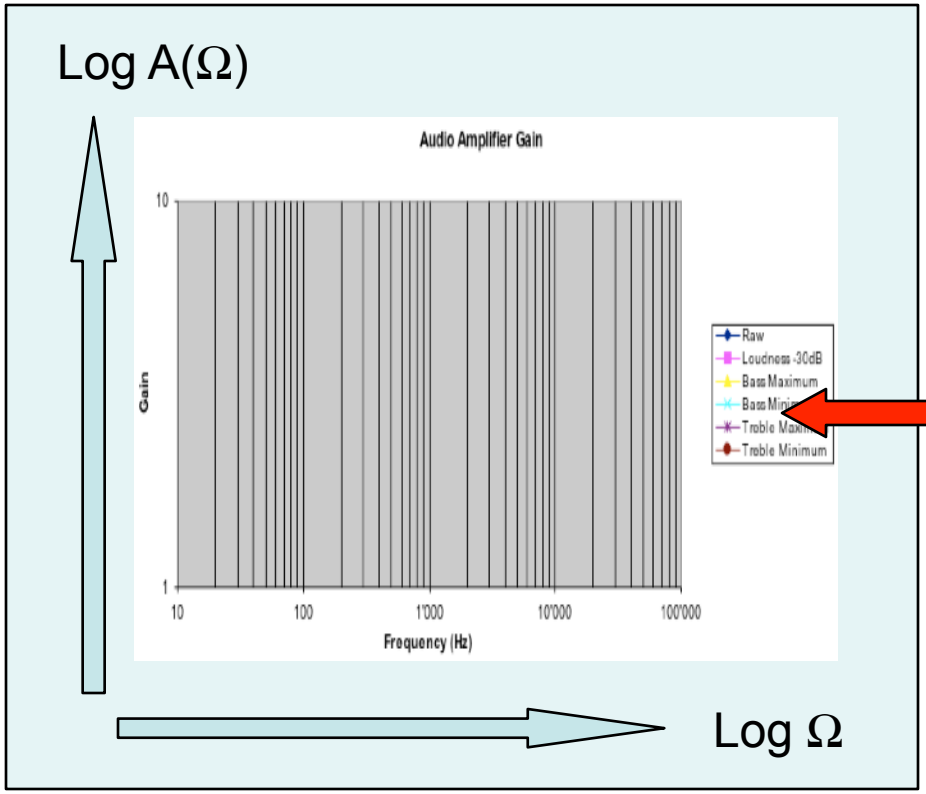


Réponse d'un quadripôle actif: l'ampli HI-FI

$$u_e(RMS) \cong 100\ mV$$

$$|A| = \frac{u_s(RMS)}{u_e(RMS)}$$





Audio Amplifier Characteristics

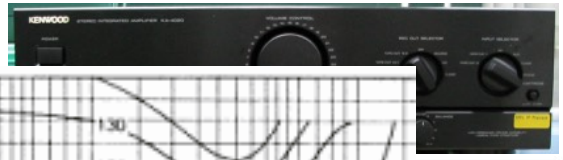
1. Raw Data

f (Hz) Target	f (Hz) Actual	Vin(mV)	Ue	Us	Us	Us	Us	Us	Us	
			Vout(mV)							
			Off	maxi	Off	Off	Off	Off		Loudness
			0	0	maxi	mini	0	0		Bass
			0	0	0	0	maxi	mini		Treble
20	20	98.5	19.2	50.6	20.4	18.2	19.2	19.2		
100	100	99.3	19.5	45.9	46.3	7.9	19.6	19.5		
500	499	99.5	20.0	25.1	22.2	18.3	23.0	19.9		
1'000	1'002	99.6	19.9	20.8	21.0	19.0	21.0	19.1		
2'000	2'002	99.6	19.7	21.5	20.7	19.0	23.9	16.4		
4'000	3'993	99.6	19.7	27.7	20.5	18.9	31.9	11.6		
7'000	7'014	99.5	19.5	35.8	20.4	18.7	44.3	8.1		
10'000	9'992	99.5	19.3	40.8	20.2	18.5	54.0	5.9		
14'000	14'010	99.5	18.9	45.6	20.3	18.6	64.1	4.6		
18'000	18'007	99.5	19.0	47.0	19.9	18.3	69.5	3.6		
20'000	19'984	99.5	18.8	47.3	19.7	18.0	71.3	3.0		

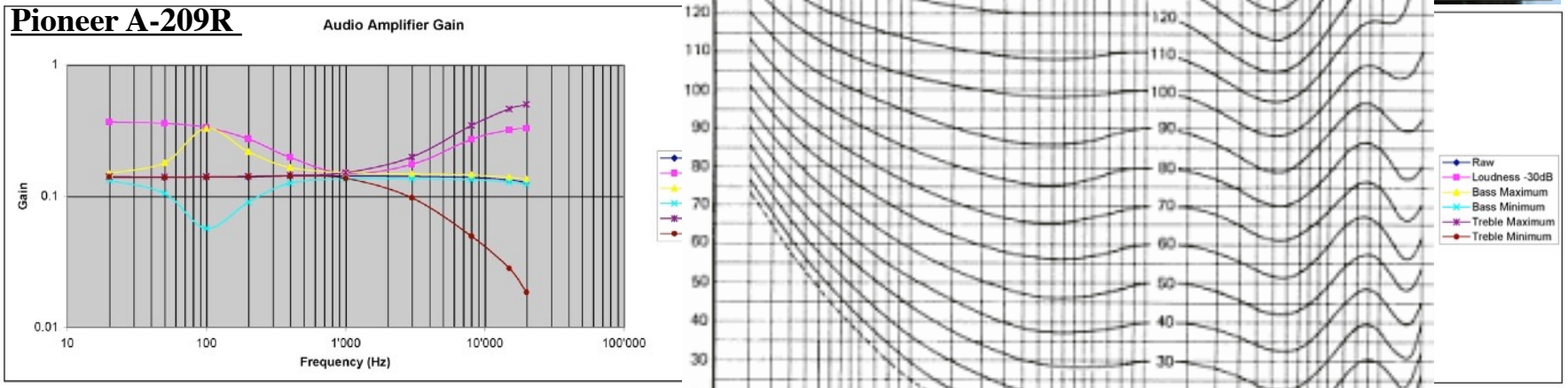
2. Gain Calculation

f (Hz)	Raw	Loudness -30dB	Bass Maximum	Bass Minimum	Treble Maximum	Treble Minimum
20	0.194924	0.513706	0.207107	0.184772	0.194924	0.194924
100	0.196375	0.462236	0.466264	0.079557	0.197382	0.196375
499	0.201005	0.252261	0.223116	0.18392	0.231156	0.2
1'002	0.199799	0.208835	0.210843	0.190763	0.210843	0.191767
2'002	0.197791	0.215863	0.207831	0.190763	0.23996	0.164659
3'993	0.197791	0.278112	0.205823	0.189759	0.320281	0.116466
7'014	0.19598	0.359799	0.205025	0.18794	0.445226	0.081407
9'992	0.19397	0.41005	0.203015	0.18593	0.542714	0.059296
14'010	0.18995	0.458291	0.20402	0.186935	0.644221	0.046231
18'007	0.190955	0.472362	0.2	0.18392	0.698492	0.036181
19'984	0.188945	0.475377	0.19799	0.180905	0.716583	0.030151

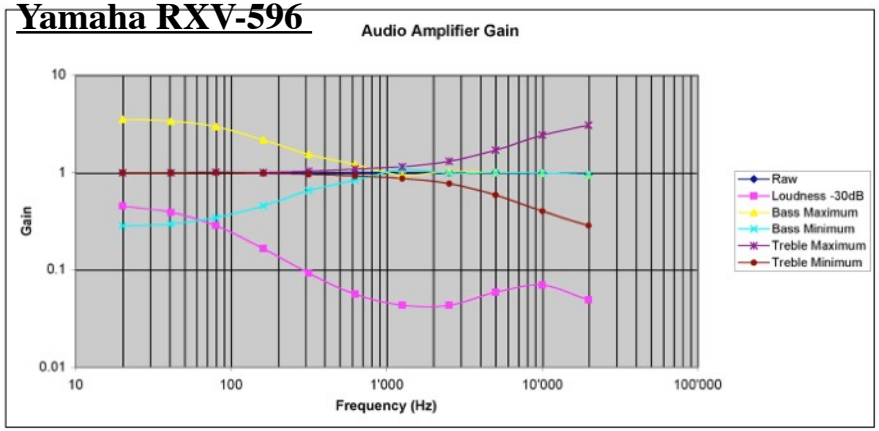
Réponse d'un quadripôle actif: l'ampli HI-FI



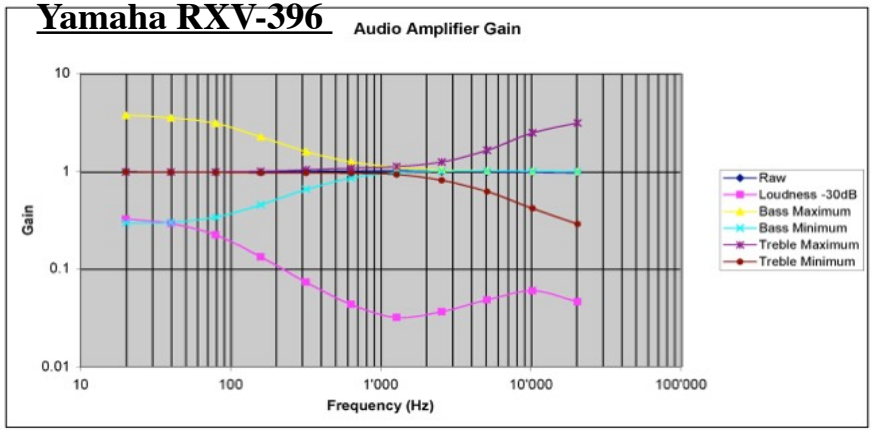
Pioneer A-209R



Yamaha RXV-596

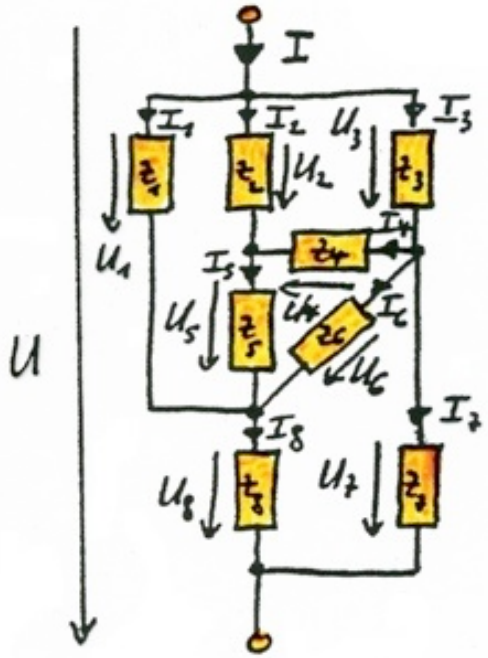


Yamaha RXV-396



Les dipôles

On appelle **dipôle** un ensemble d'éléments à deux bornes



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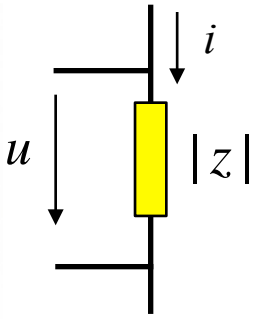


Si tous les éléments sont linéaires :

$$\begin{cases} u = u_0 \sin(\omega t) \\ \Downarrow \\ i = i_0 \sin(\omega t - \varphi) \end{cases}$$

$$\begin{cases} \text{Impédance :} & |Z| = \dfrac{u_0}{i_0} = \dfrac{u_{RMS}}{i_{RMS}} = |z|(\omega) \\ \text{Phase :} & \varphi = \varphi(\omega) \end{cases}$$

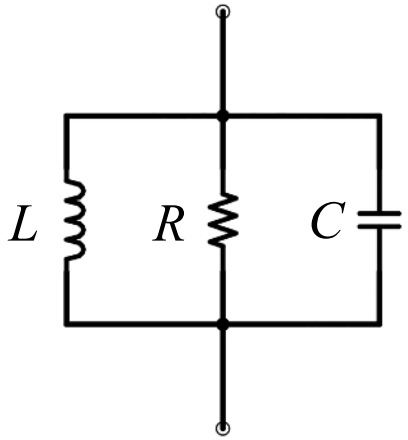
En règle générale, le calcul d'un dipôle fait appel au calcul complexe

Les dipôles

$$U = ZI$$ Loi d'Ohm

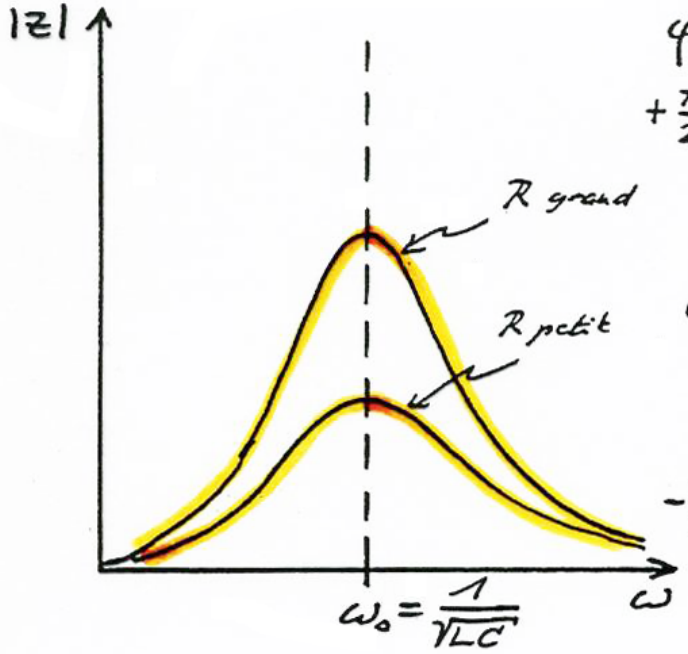
Exemple: circuit résonnant parallèle

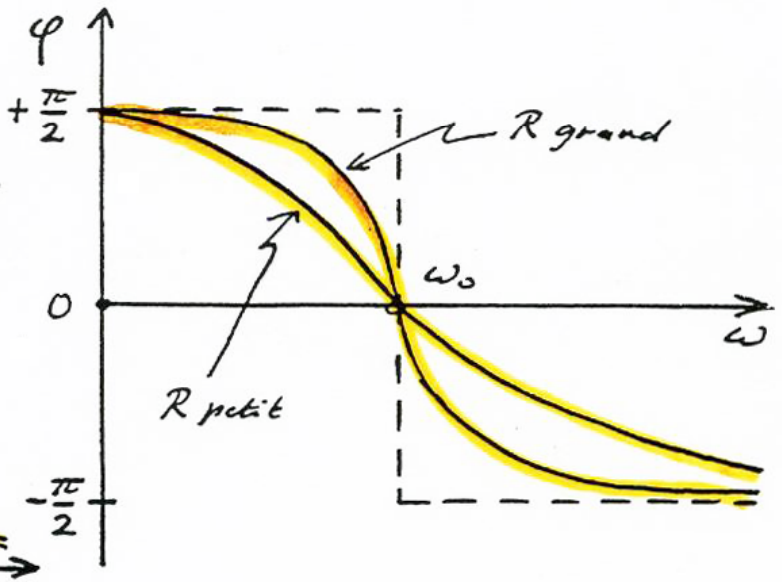
$$Z = |Z| e^{i\varphi} \qquad \frac{1}{Z} = \frac{1}{R} + i\omega C + \frac{1}{i\omega L}$$



$$|z| = \frac{1}{\sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2}}$$

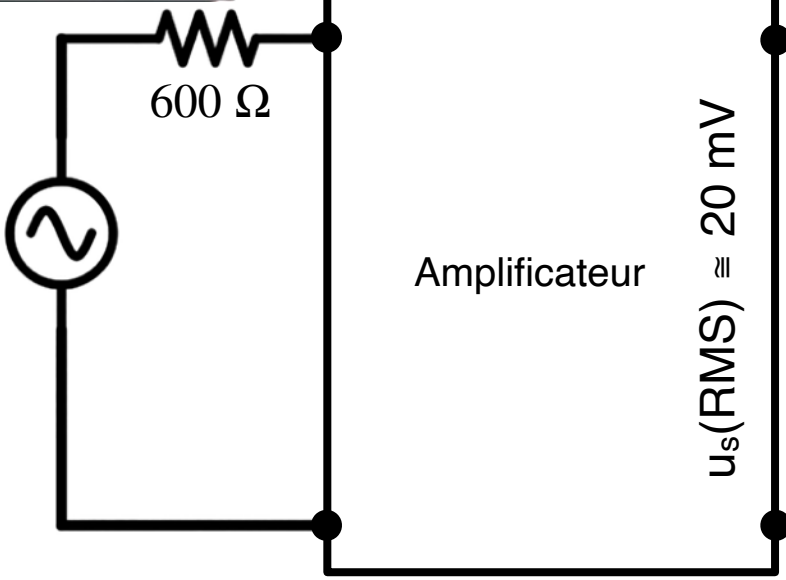
$$\tan\varphi = R\left(\frac{1}{\omega L} - \omega C\right)$$





2) Réponse d'un dipôle: impédance d'une colonne sonore

Effectuez le montage suivant pour la mesure de ***l'impédance d'entrée*** de la colonne en fonction de la fréquence. Réglez le volume de l'ampli tel que la sortie soit à 1 kHz: u_s(RMS) ≅ 20 mV



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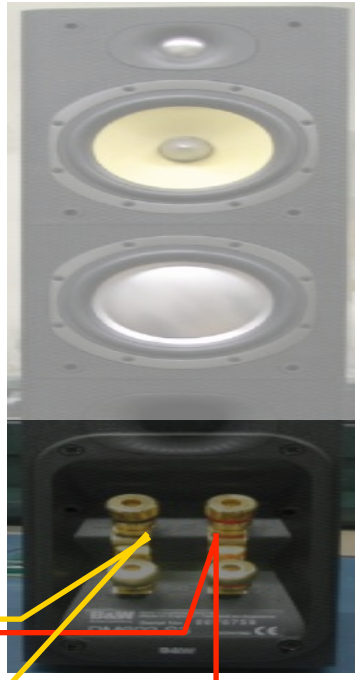
i_{RMS}

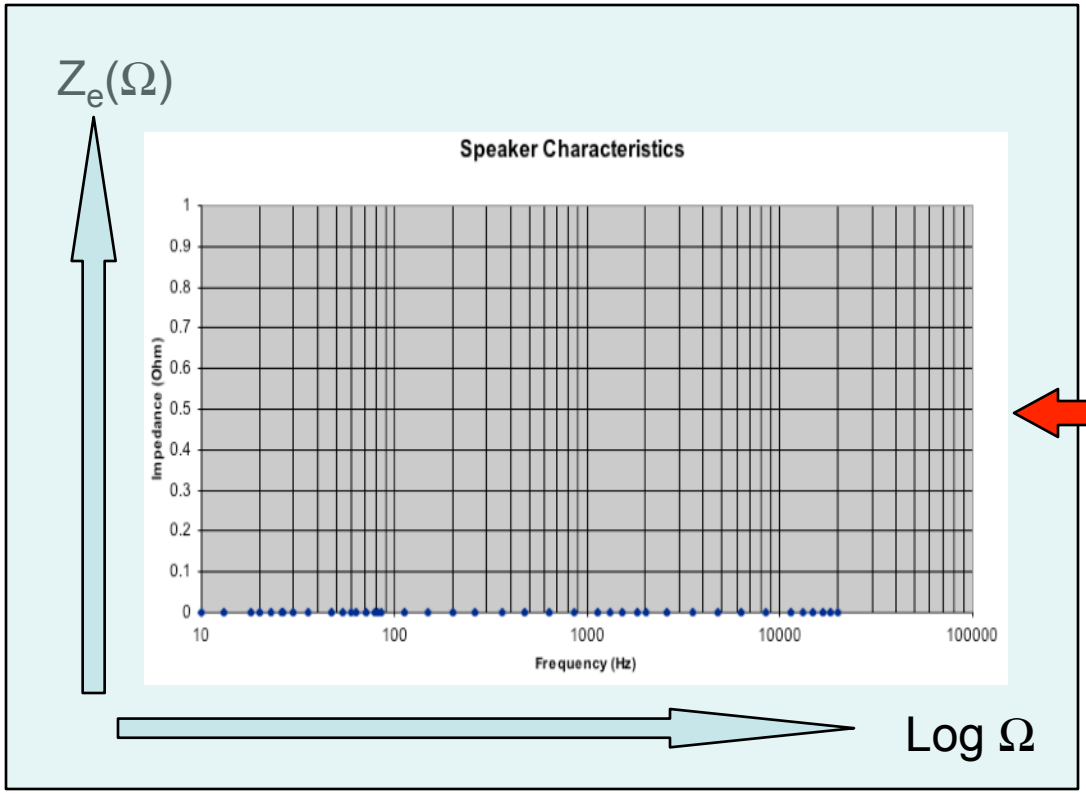


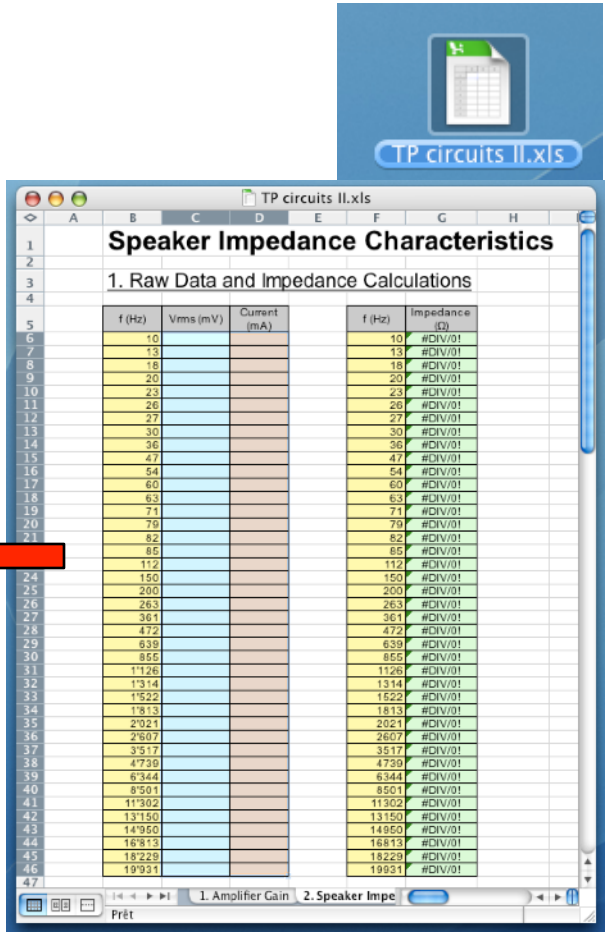
u_{RMS}

Réponse d'un dipôle: impédance d'une colonne sonore

Reportez dans un diagramme lin-log ***l'impédance d'entrée*** de la colonne en fonction de la fréquence (**20 Hz à 20 kHz**)

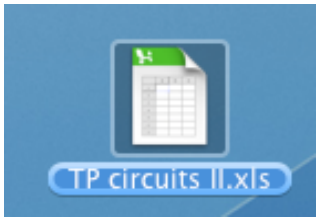
$$|Z_e| = \frac{u(RMS)}{i(RMS)}$$

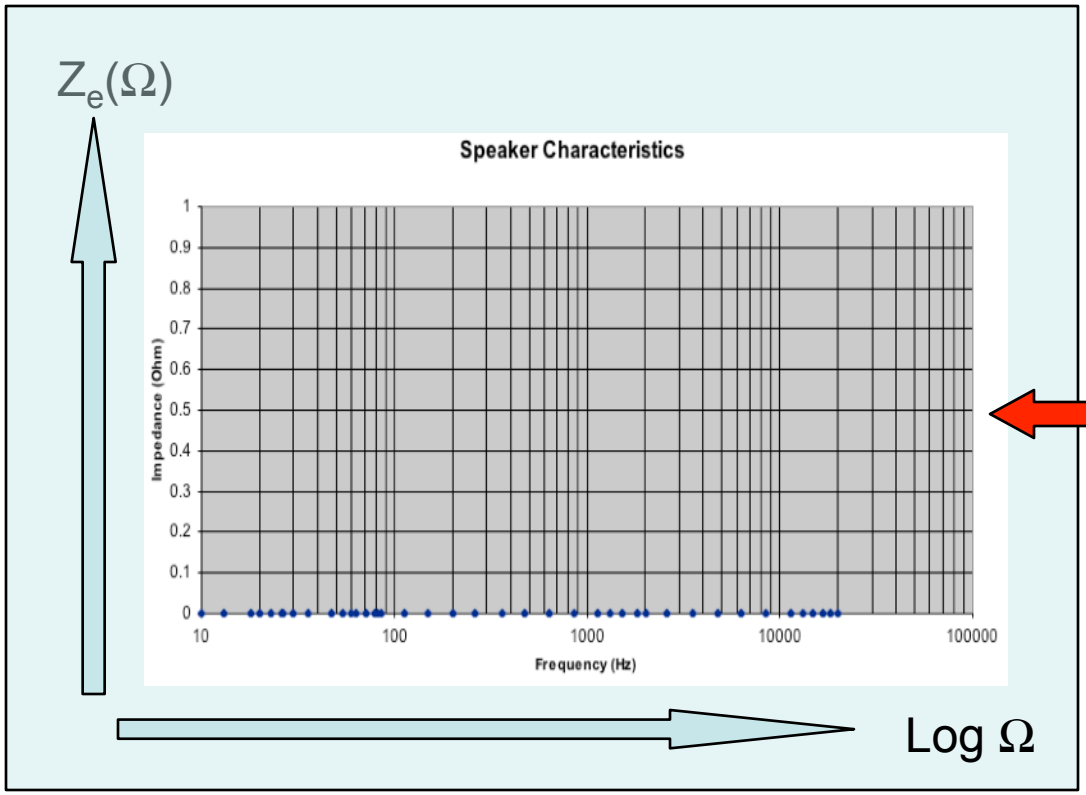




Réponse d'un dipôle: impédance d'une colonne sonore

$$|Z_e| = \frac{u(RMS)}{i(RMS)}$$





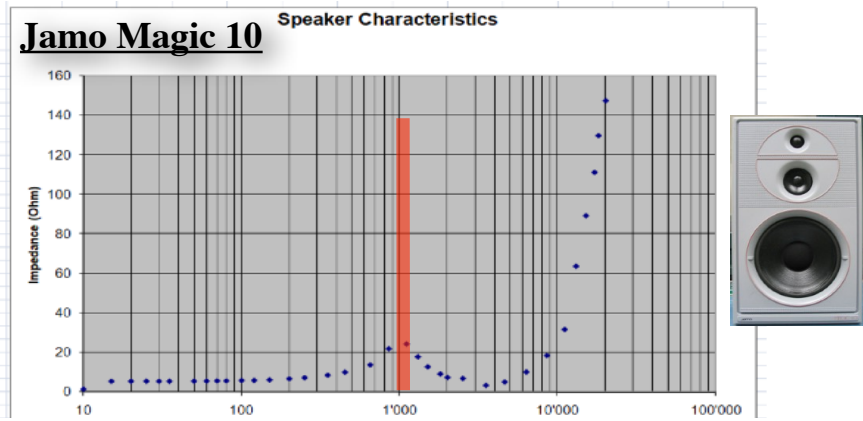
Speaker Impedance Characteristics

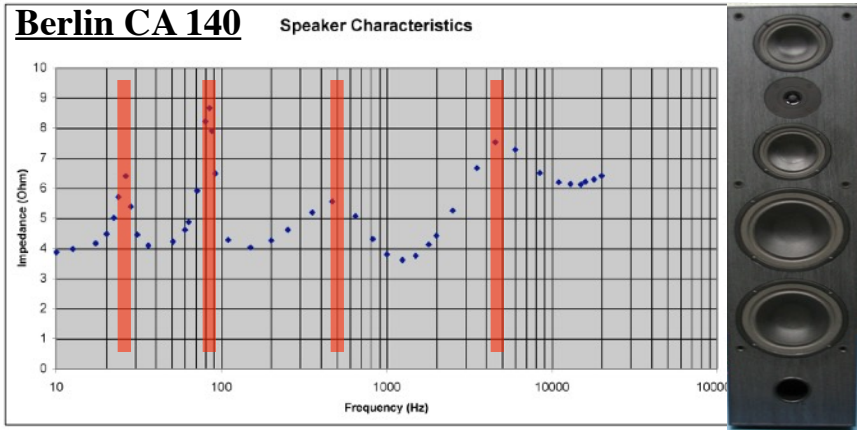
1. Raw Data and Impedance Calculations

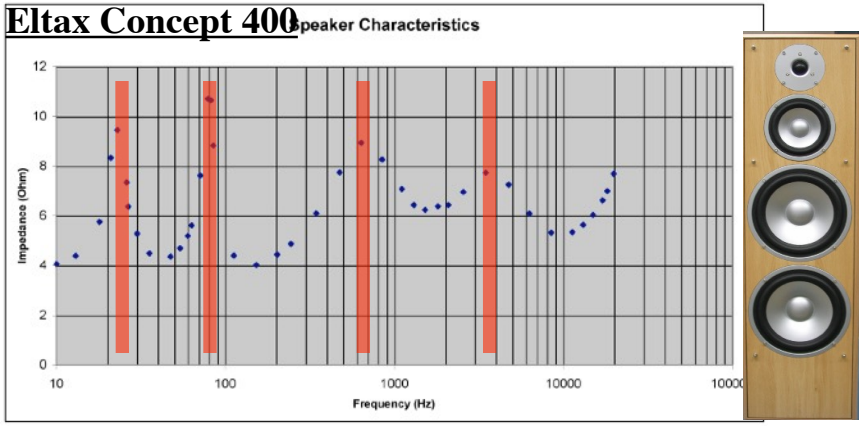
f (Hz)	Vrms (mV)	Current (mA)	f (Hz)	Impedance (Ω)
10	12.2	3.23	10	3.7770898
13	12.7	3.32	13	3.8253012
18	13.1	3.28	18	3.9939024
20	13.3	3.22	20	4.1304348
23	14.1	2.96	23	4.7635135
26	15.1	2.49	26	6.064257
27	15.0	2.48	27	6.0483871
30	14.2	2.97	30	4.7811448
36	13.2	3.29	36	4.0121581
47	13.2	3.28	47	4.0243902
54	13.4	3.20	54	4.1875
60	13.7	3.09	60	4.433657
63	13.9	3.02	63	4.602649
71	14.7	2.72	71	5.4044118
79	15.7	2.20	79	7.1363636
82	16.0	2.06	82	7.7669903
85	16.1	1.98	85	8.1313131
112	13.4	3.22	112	4.1614907
150	13.0	3.33	150	3.9039039
200	13.4	3.23	200	4.1486068
263	13.9	3.08	263	4.512987
361	14.4	2.90	361	4.9655172
472	15.1	2.64	472	5.719697
639	14.5	2.95	639	4.9152542
855	13.5	3.35	855	4.0298507
1'126	12.8	3.62	1126	3.5359116
1'314	12.8	3.62	1314	3.5359116
1'522	13.0	3.55	1522	3.6619718
1'813	13.6	3.32	1813	4.0963855
2'021	14.1	3.13	2021	4.5047923
2'607	14.9	2.75	2607	5.4181818
3'517	15.6	2.27	3517	6.8722467
4'739	15.9	1.90	4739	8.3684211
6'344	15.6	1.82	6344	8.5714286
8'501	15.1	1.72	8501	8.7790698
11'302	14.8	1.46	11302	10.136986
13'150	14.8	1.23	13150	12.03252
14'950	14.7	1.02	14950	14.411765
16'813	14.7	0.84	16813	17.5
18'229	14.6	0.69	18229	21.15942
19'931	14.6	0.58	19931	25.172414

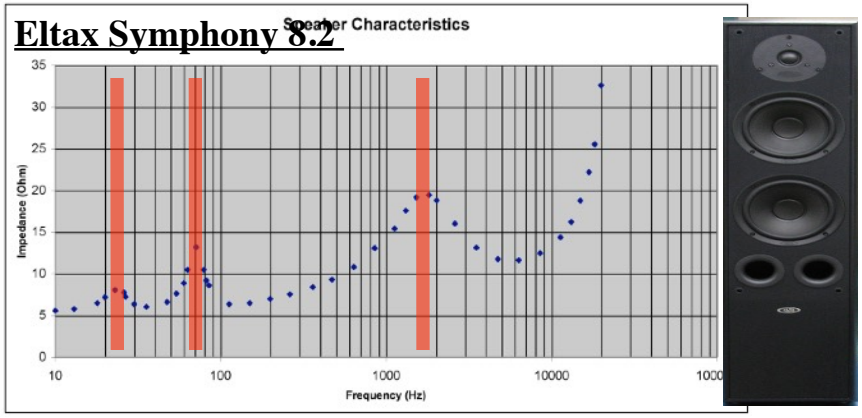
Réponse d'un dipôle: impédance d'une colonne sonore

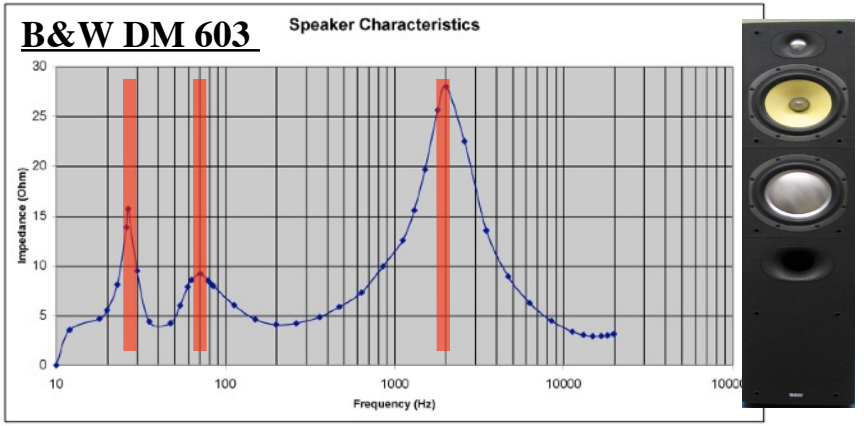
Le diagramme de ***l'impédance d'entrée*** de la colonne en fonction de la fréquence (**20 Hz à 20 kHz**)







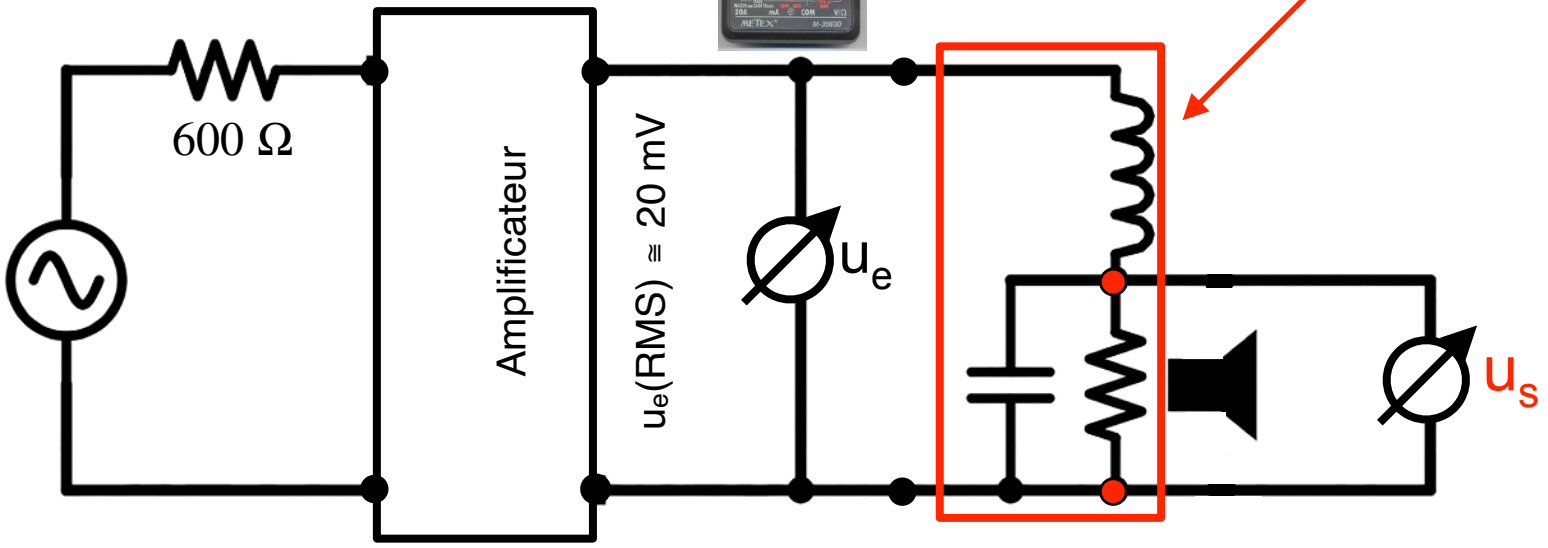




3) Réponse de quadripôles passifs: les filtres d'aiguille des hauts-parleurs

Effectuez le montage suivant pour la mesure des fonctions de transfert des filtres d'aiguille des hauts-parleurs. Réglez le volume de l'ampli tel que le l'entrée vers le haut-parleur soit à 1 kHz : u_e(RMS) ≅ 20 mV

Un des filtres internes du haut-parleur



Quadrupole

3) Réponse de quadripôles passifs: les filtres d'aiguille des hauts-parleurs

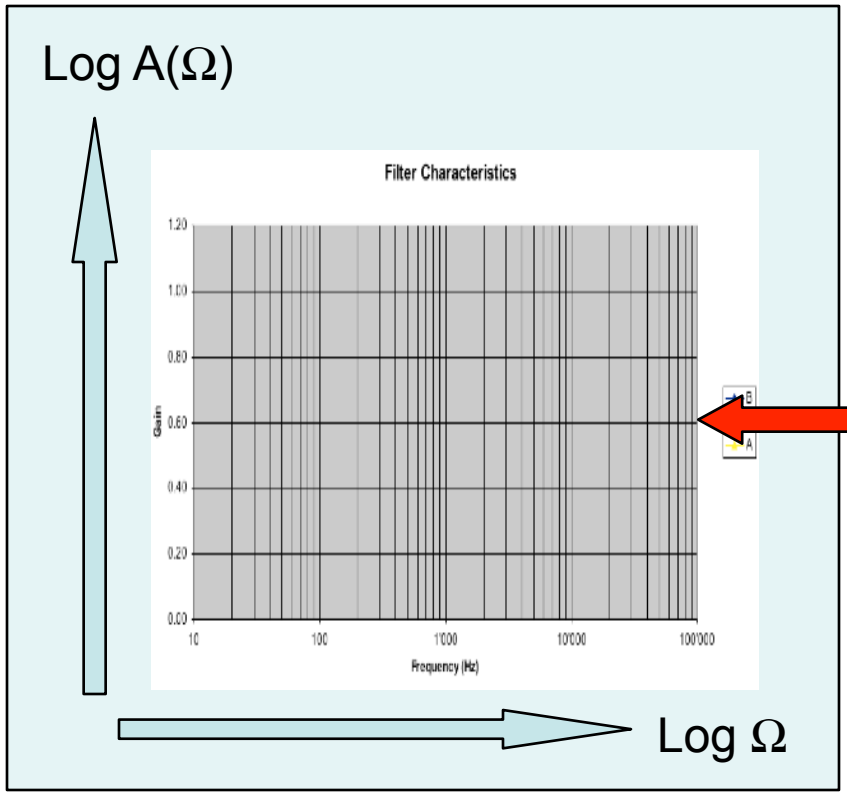
Effectuez le montage suivant pour la mesure des fonctions de transfert des filtres d'aiguille des hauts-parleurs. Réglez le volume de l'ampli tel que le la sortie soit à 1 kHz : u_s(RMS) ≅ 20 mV

u_s

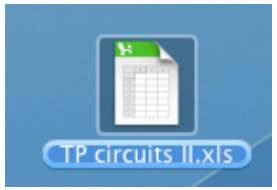
u_e

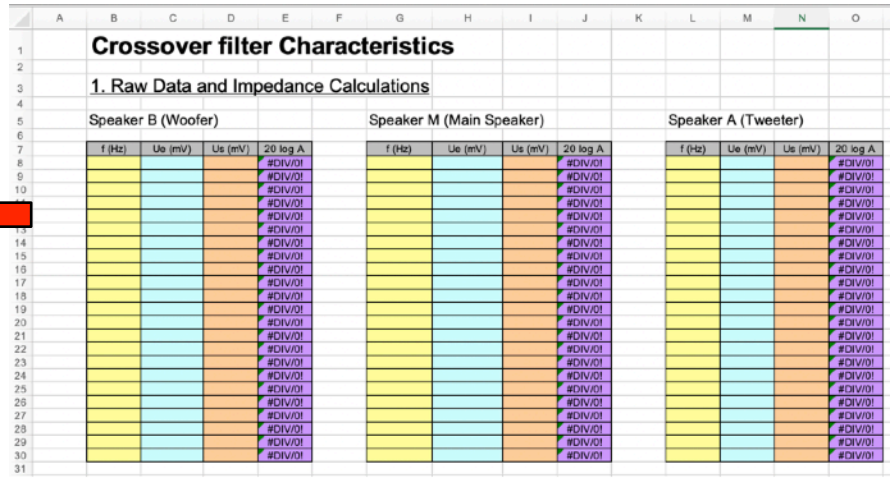
Réponse de quadripôles passifs: les filtres d'aiguille des hauts-parleurs

Reportez dans un diagramme log-log de Bode ***les 3 fonctions de transfert*** des filtres d'aiguille pour les haut-parleurs basse, médium et aigu, en fonction de la fréquence (**20 Hz à 20 kHz**):



$$|A| = \frac{u_s(RMS)}{u_e(RMS)}$$





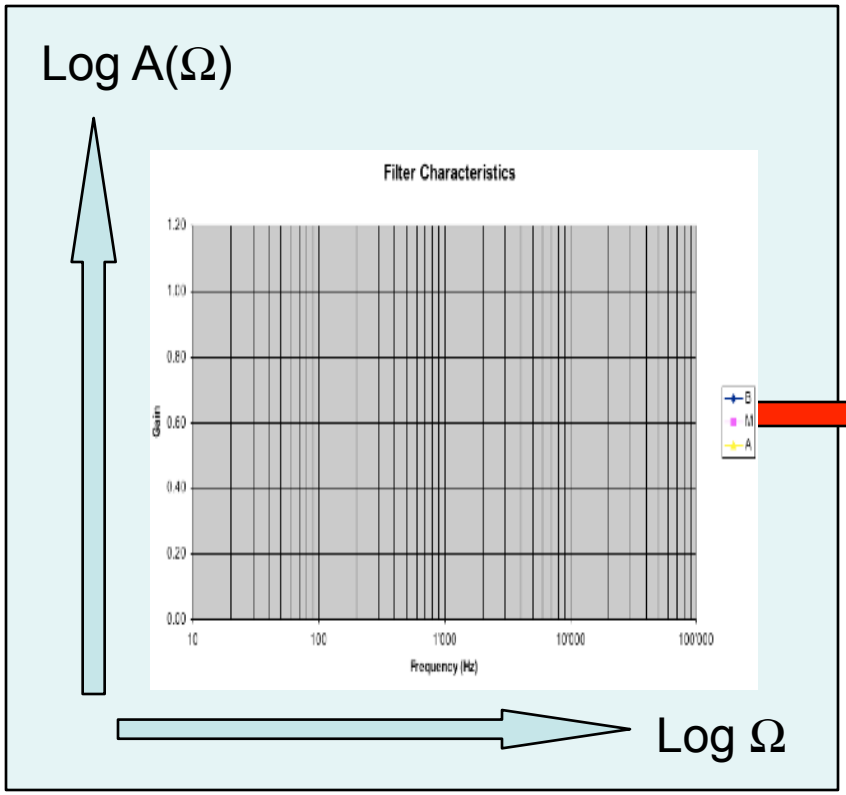
Crossover filter Characteristics

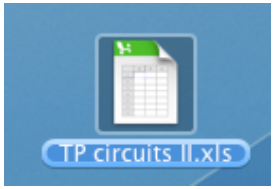
1. Raw Data and Impedance Calculations

Speaker B (Woofer)				Speaker M (Main Speaker)				Speaker A (Tweeter)			
f (Hz)	Ue (mV)	Us (mV)	20 log A	f (Hz)	Ue (mV)	Us (mV)	20 log A	f (Hz)	Ue (mV)	Us (mV)	20 log A
			#DIV/0!				#DIV/0!				#DIV/0!

Réponse de quadripôles passifs: les filtres d'aiguillage des hauts-parleurs

$$|A| = \frac{u_s(RMS)}{u_e(RMS)}$$





Crossover filter Characteristics

1. Raw Data and Calculations

Speaker B (Woofer)

f (Hz)	Ue (mV)	Us (mV)	20 log A
20	20.4	16.30	-1.95
50	20.3	16.00	-2.07
80	20.5	17.60	-1.32
90	20.5	18.70	-0.80
120	20.3	17.30	-1.39
150	20.4	16.10	-2.06
300	20.7	13.20	-3.91
500	20.8	10.30	-6.10
1'000	20.7	6.50	-10.06
1'500	20.6	5.00	-12.30
2'000	20.6	4.10	-14.02
2'500	20.5	3.60	-15.11
3'500	20.5	2.90	-16.99
4'500	20.5	2.50	-18.28
6'000	20.4	2.00	-20.17
8'000	20.2	1.50	-22.59
10'000	20.1	1.00	-26.06
12'500	19.9	0.60	-30.41
15'000	19.7	0.30	-36.35
17'500	19.4	0.30	-36.21
20'000	19.2	0.20	-39.65

Speaker M (Main Speaker)

f (Hz)	Ue (mV)	Us (mV)	20 log A
20	20.4	0.50	-32.21
50	20.4	1.00	-26.19
80	20.5	1.60	-22.15
90	20.5	1.70	-21.63
120	20.4	2.30	-18.96
150	20.4	2.90	-16.94
300	20.7	6.30	-10.33
500	20.8	9.70	-6.63
1'000	20.7	16.40	-2.02
1'500	20.6	17.20	-1.57
2'000	20.6	15.70	-2.36
2'500	20.5	14.10	-3.25
3'500	20.5	11.90	-4.72
4'500	20.5	10.50	-5.81
6'000	20.4	9.20	-6.92
8'000	20.2	8.10	-7.94
10'000	20.1	7.30	-8.80
12'500	19.9	6.30	-9.99
15'000	19.6	5.60	-10.88
17'500	19.4	5.00	-11.78
20'000	19.2	4.40	-12.80

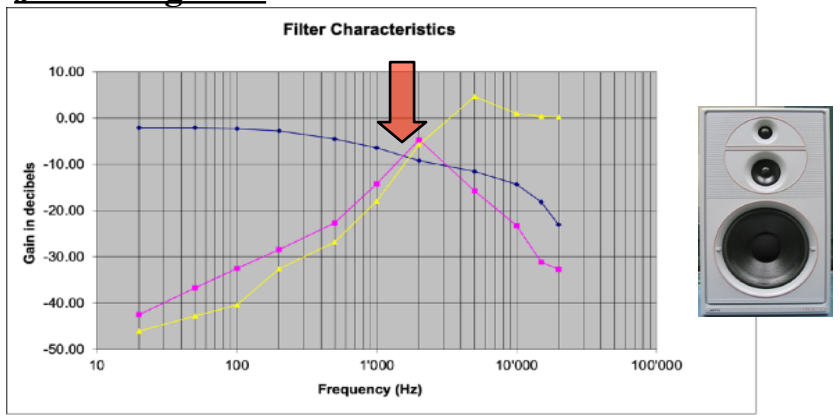
Speaker A (Tweeter)

f (Hz)	Ue (mV)	Us (mV)	20
20	20.4	0.30	
50	20.3	0.20	
80	20.5	0.40	
90	20.5	0.30	
120	20.4	0.50	
150	20.4	0.50	
300	20.7	1.10	
500	20.8	1.80	
1'000	20.7	3.60	
1'500	20.6	5.30	
2'000	20.6	7.20	
2'500	20.5	9.10	
3'500	20.5	12.00	
4'500	20.5	13.00	
6'000	20.4	15.40	
8'000	20.2	17.50	
10'000	20.1	18.60	
12'500	19.9	19.20	
15'000	19.6	19.20	
17'500	19.4	19.20	
20'000	19.2	19.00	

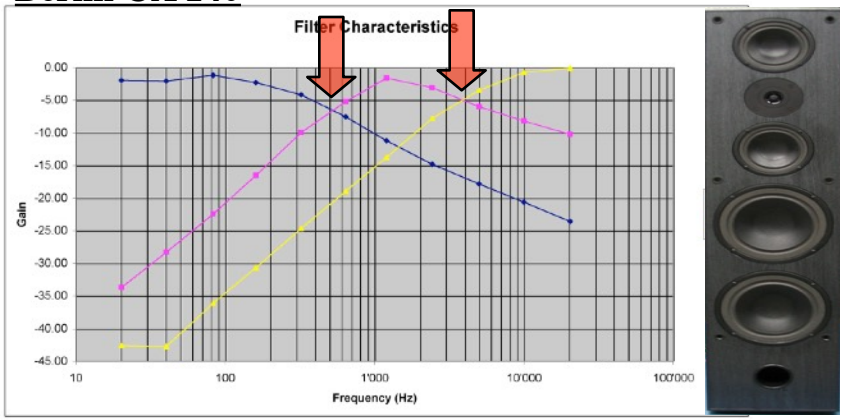
Réponse de quadripôles passifs: les filtres d'aiguille des hauts-parleurs

Le diagramme de Bode des ***3 fonctions de transfert*** des filtres d'aiguille pour les haut-parleurs basse, médium et aigu, en fonction de la fréquence (**20 Hz à 20 kHz**).

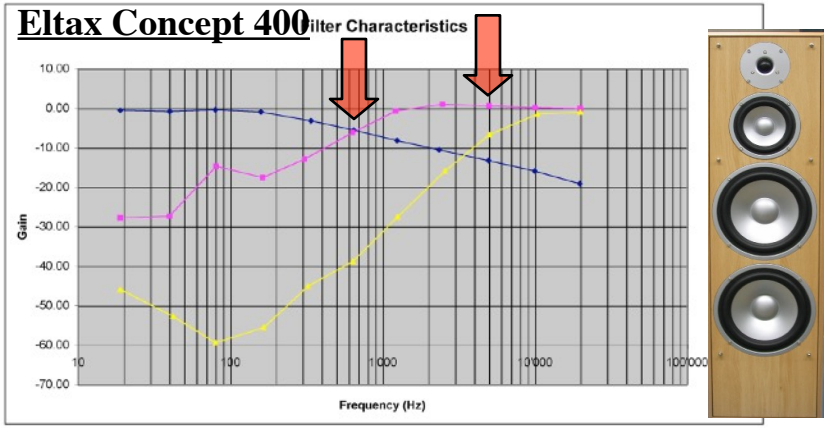
Jamo Magic 10



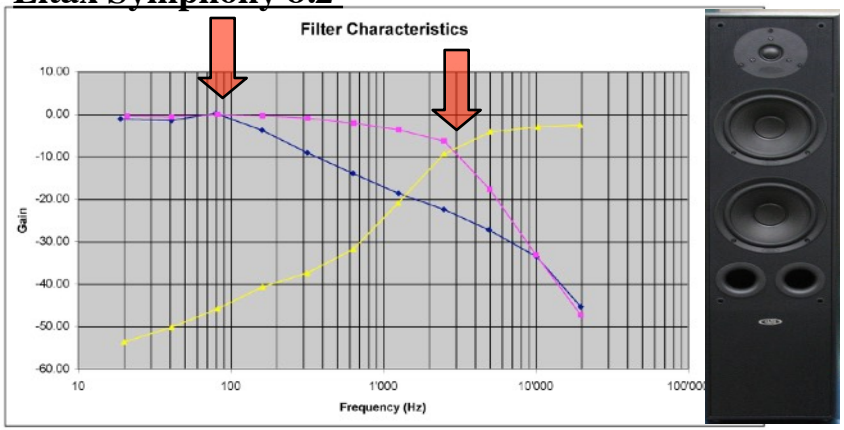
Berlin CA 140



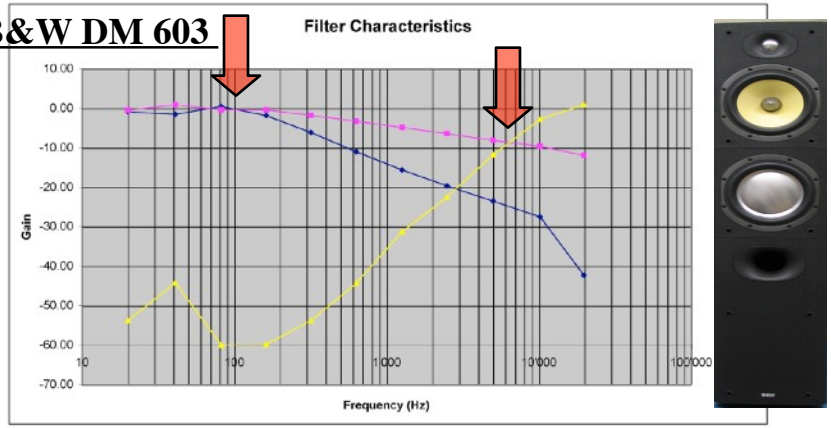
Eltax Concept 400



Eltax Symphony 8.2



B&W DM 603



Discussion

a) Essayer de commenter en les corrélant ***la courbe d'impédance de la colonne*** et ***les fonctions de transfert des filtres d'aiguillage*** de la colonne.

b) A l'aide de la courbe d'impédance de la colonne et des fonctions de transfert des filtres d'aiguille, pouvez-vous retrouver ***quel est le filtre de votre colonne*** parmi les filtres suivants ? Justifiez votre choix !

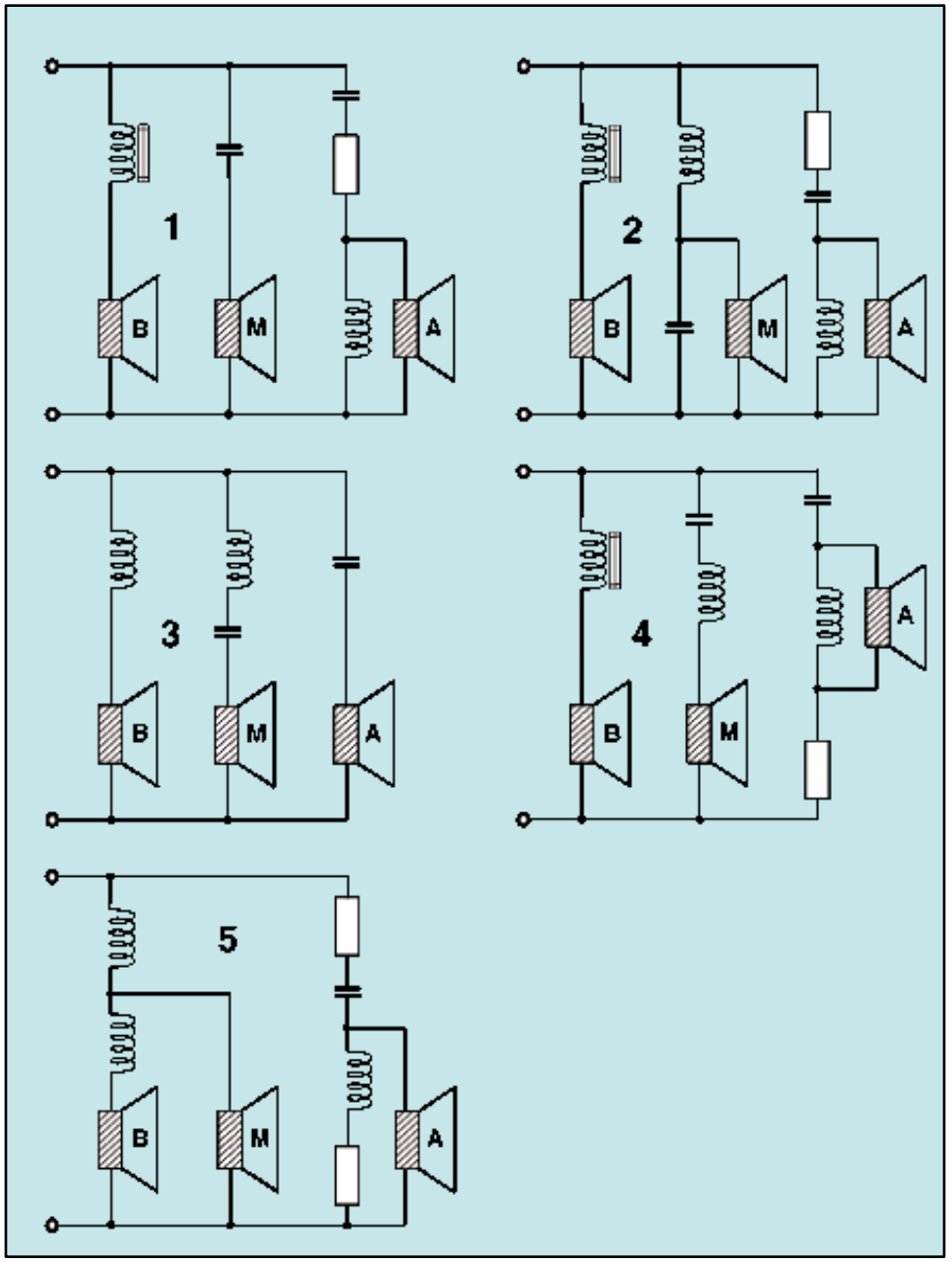
Eltax Symphony 8.2

B&W DM 603 S3

Eltax Concept 400

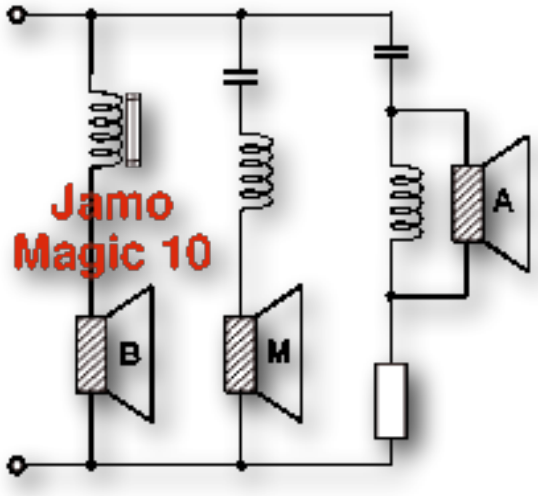
Jamo Magic 10

Berlin CA 140

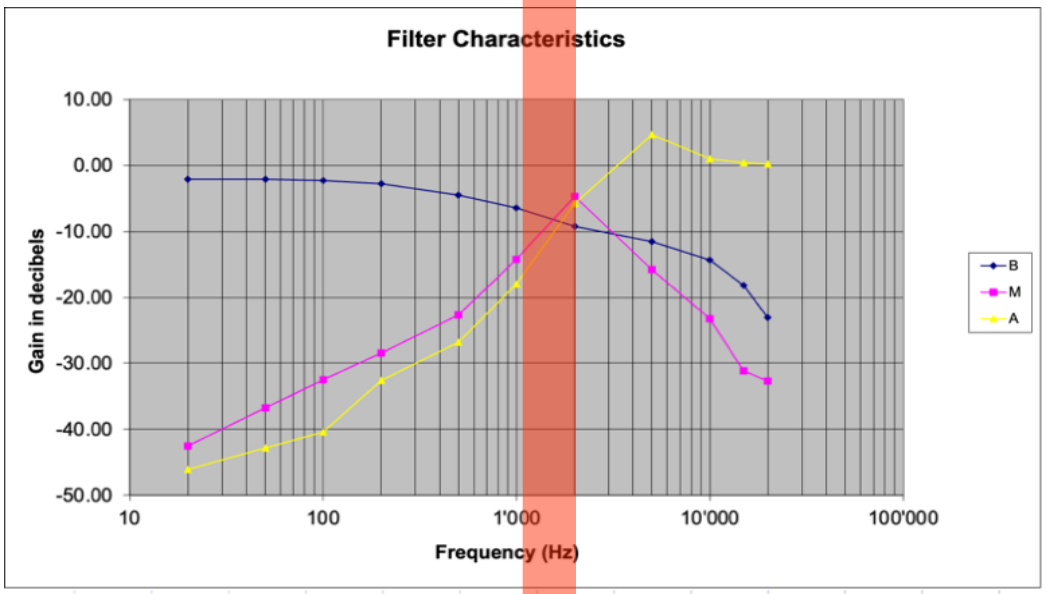


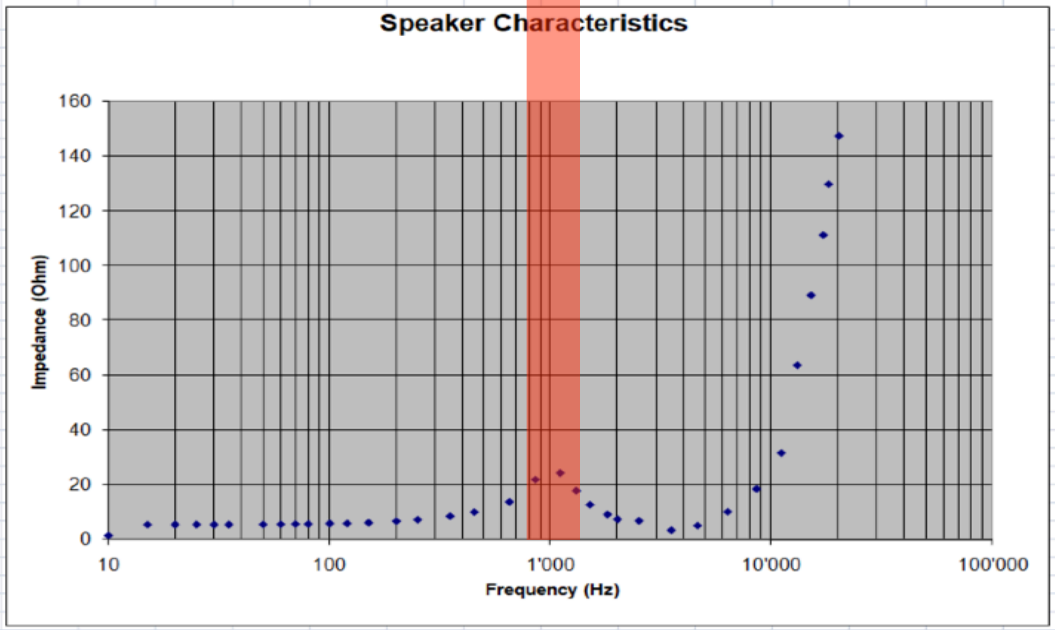
Jamo Magic 10

4



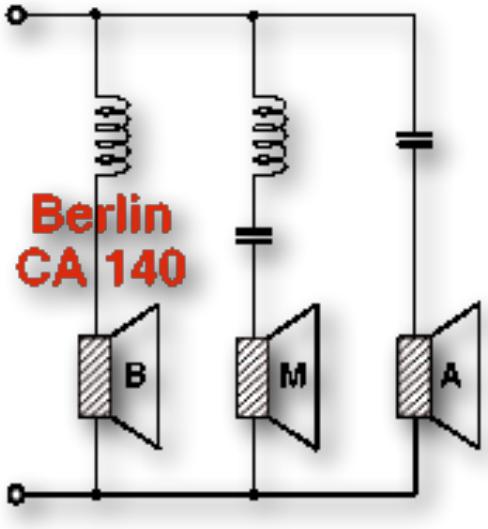
Fréquences d'aiguilles
basse-médium & médium-aigus





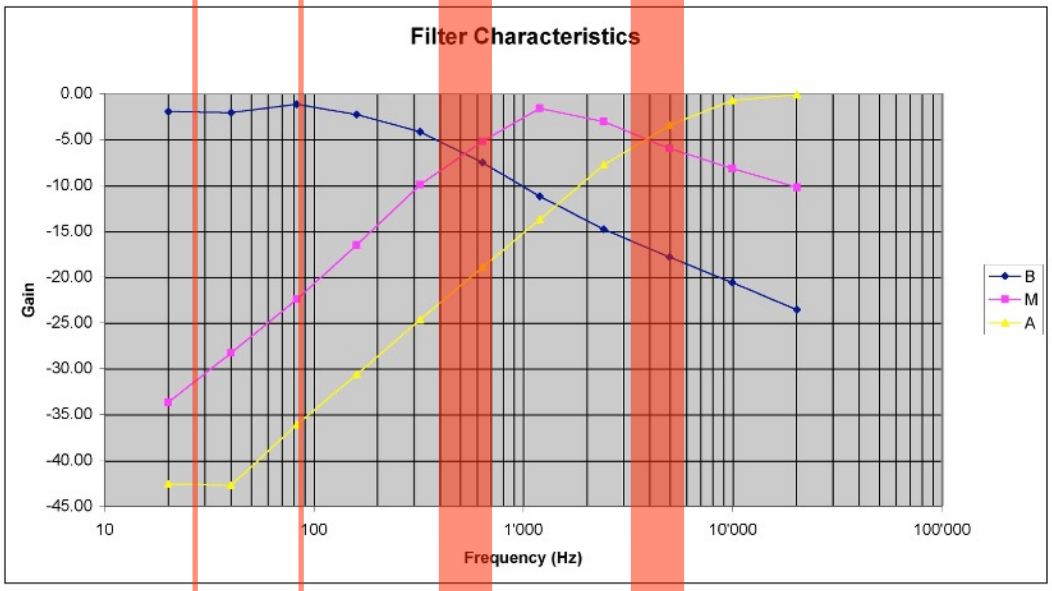
Berlin CA 140

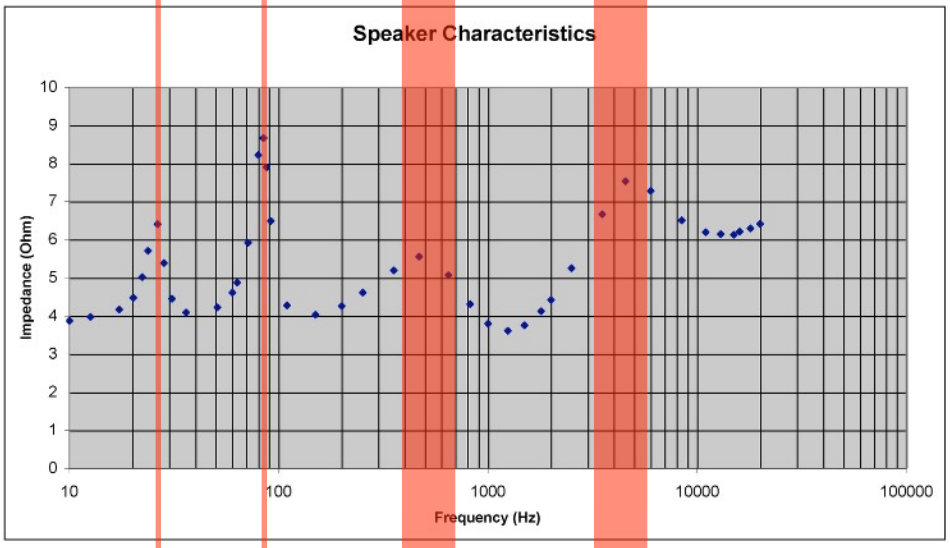
3



Résonance mécanique HP grave et médium

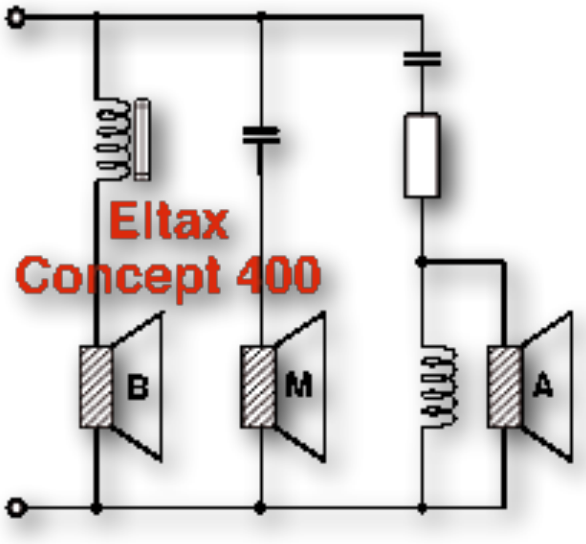
Fréquences d'aiguilles basse-médium & basse-aigus





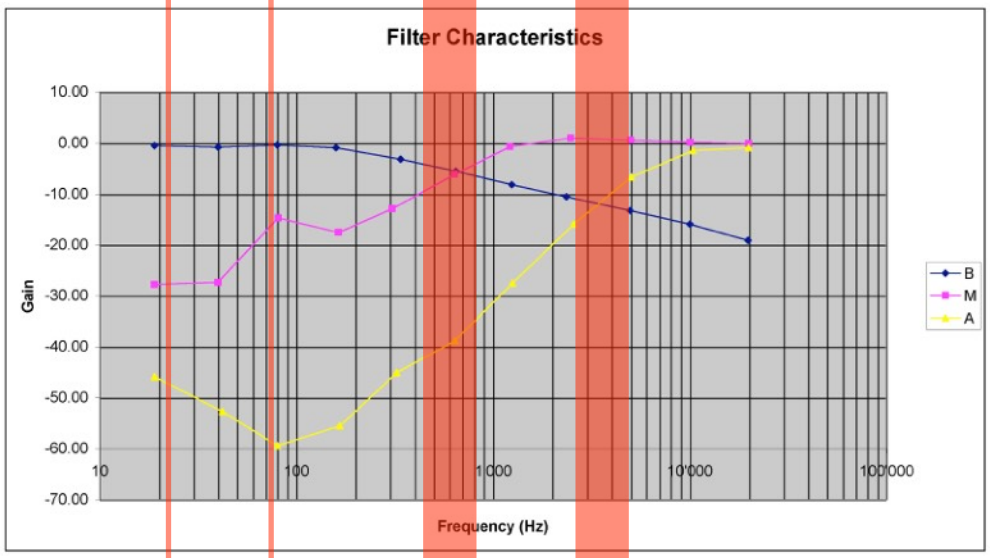
Eltax Concept 400

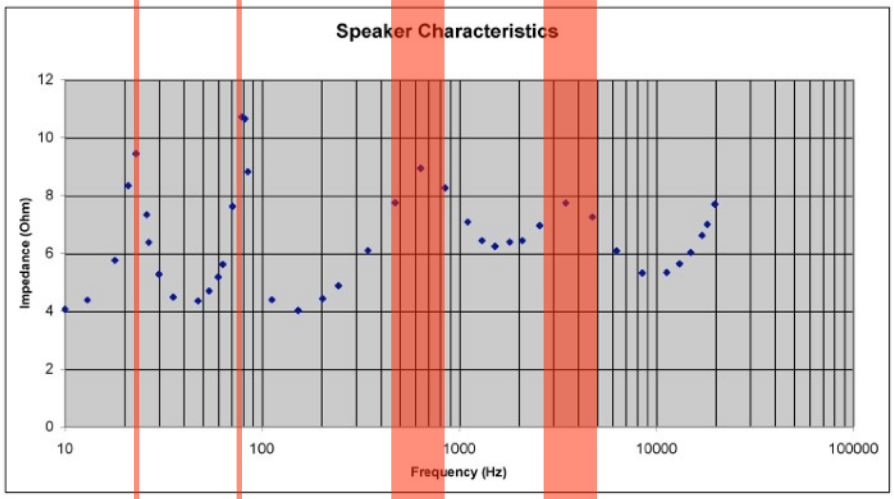
1



Résonance mécanique HP grave et médium

Fréquences d'aiguilles basse-médium & basse-aigus





Eltax Symphony 8.2

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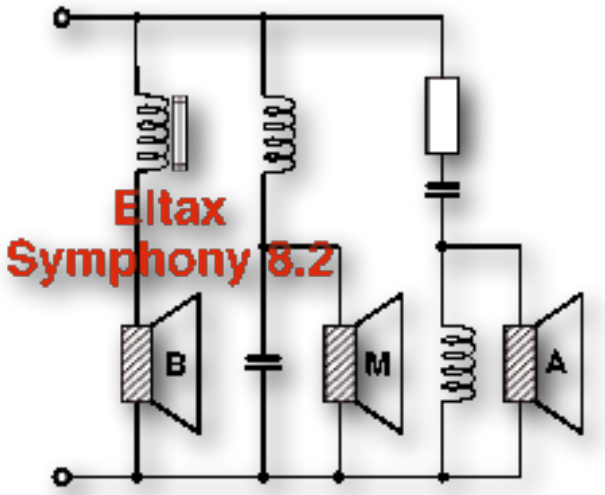
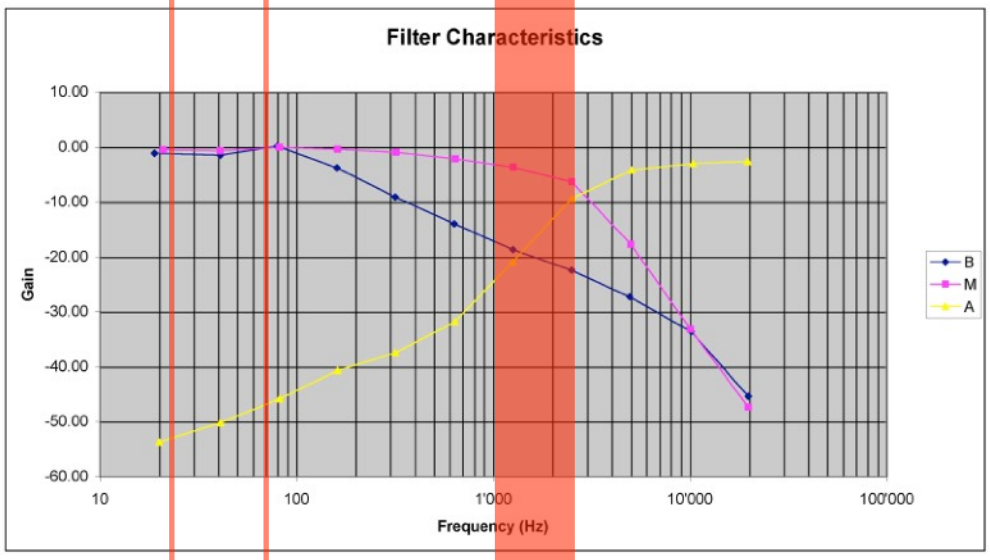
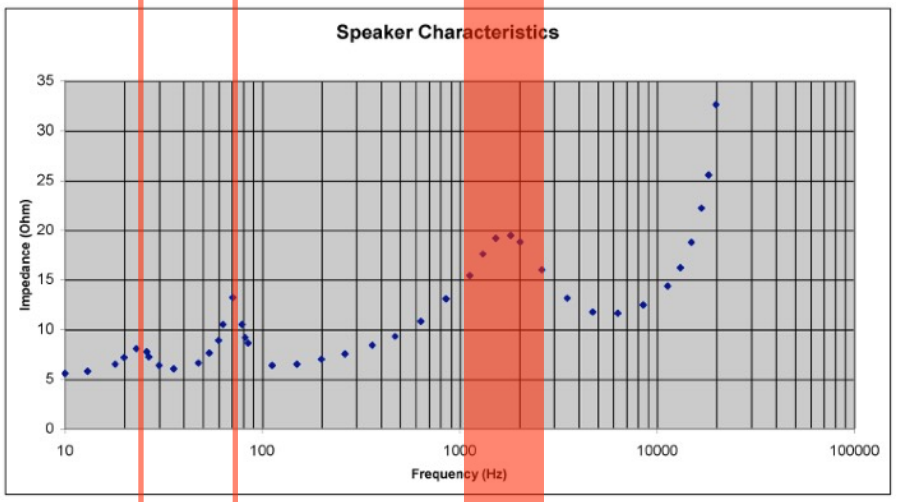


Résonance mécanique HP grave et médium

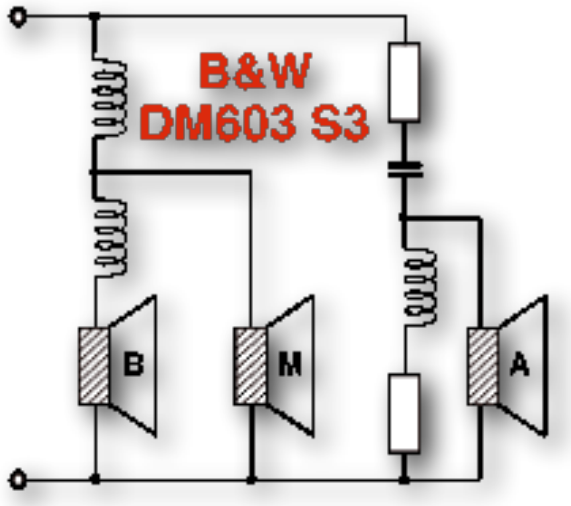
Fréquences d'aiguilles basse/médium-aigus





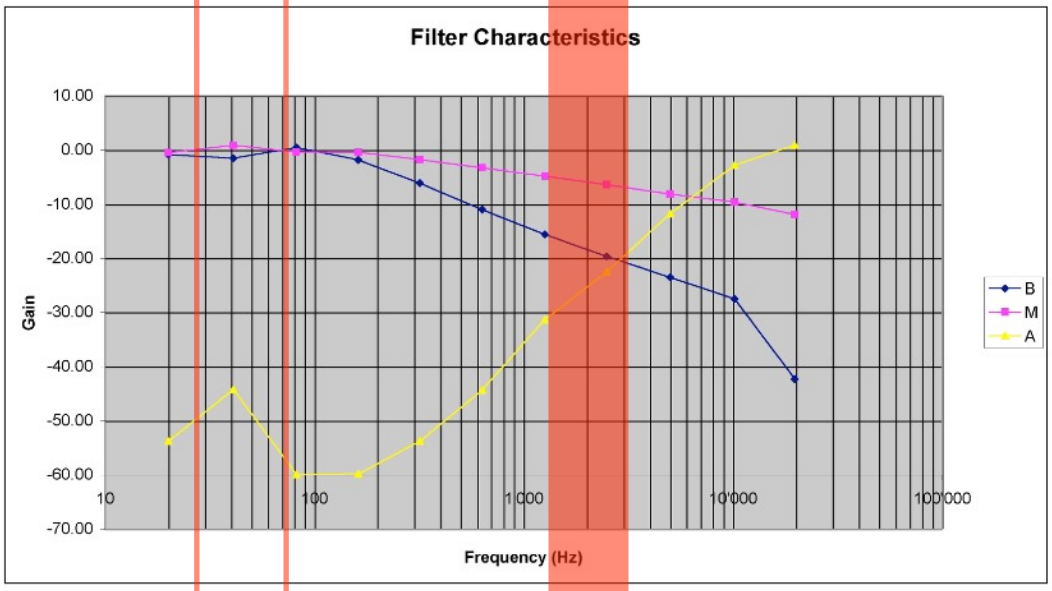
B&W DM 603 S3

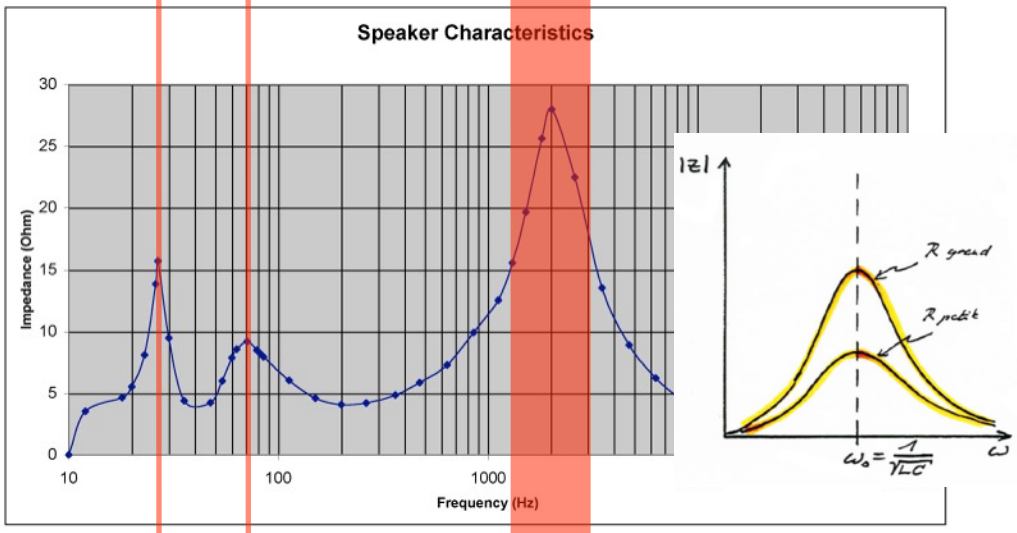
5



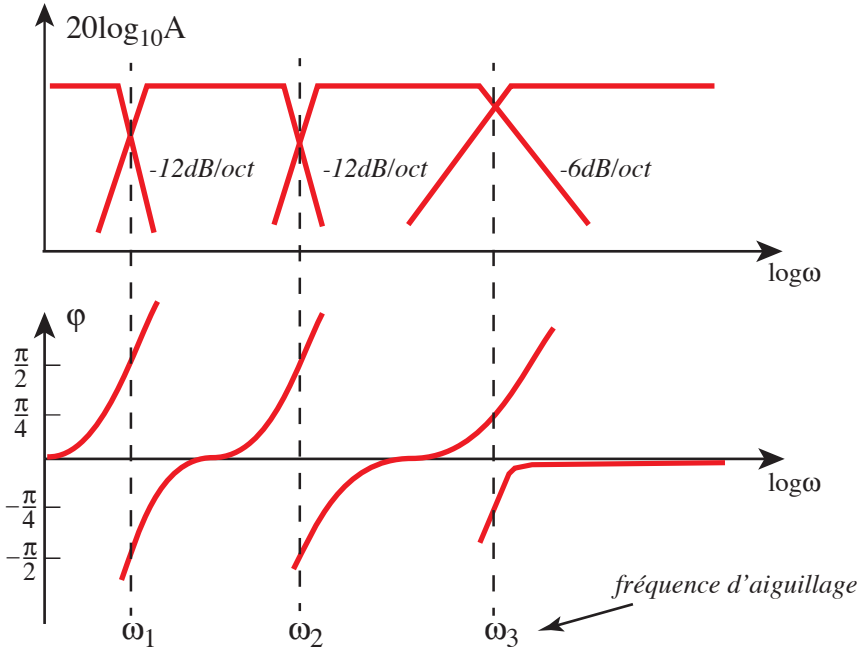
Résonance mécanique HP grave et médium

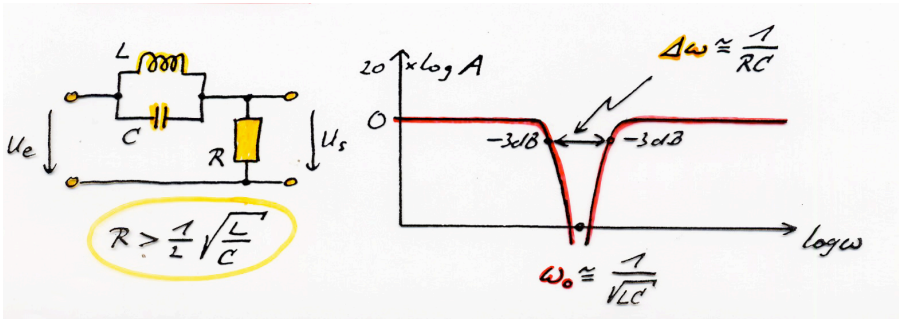
Fréquence d'aiguilles basse/médium-aigus



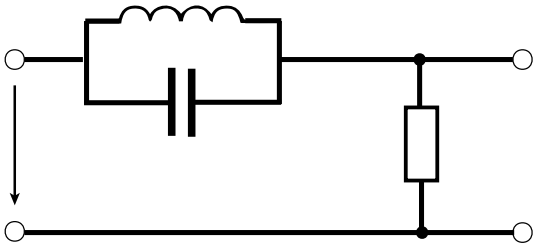


Pourquoi maximum d'impédance au crossover des filtres ?

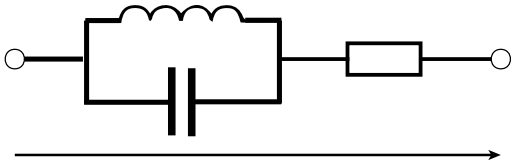




equivalent à un filtre bouchon



Quadrupole

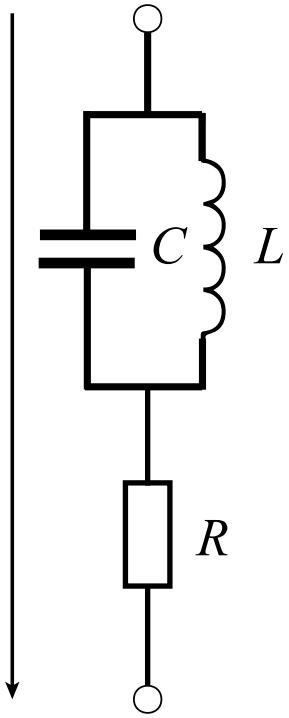


Dipole équivalent

Les dipôles

$$U = ZI$$ Loi d'Ohm

Exemple: circuit résonnant parallèle



$$Z = |Z| e^{i\varphi}$$

$$Z = R + \frac{1}{i\omega C - \frac{i}{\omega L}} = R - \frac{i\omega L}{\omega^2 LC - 1}$$

$$|z| = \sqrt{R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}} \qquad \tan\varphi = \frac{1 - \omega^2 LC}{\omega LR}$$