Unidad III: Altavoz en Caja Bass Reflex
Parte 1
Alineamientos

Recinto para Altavoces

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1.- Bass Reflex

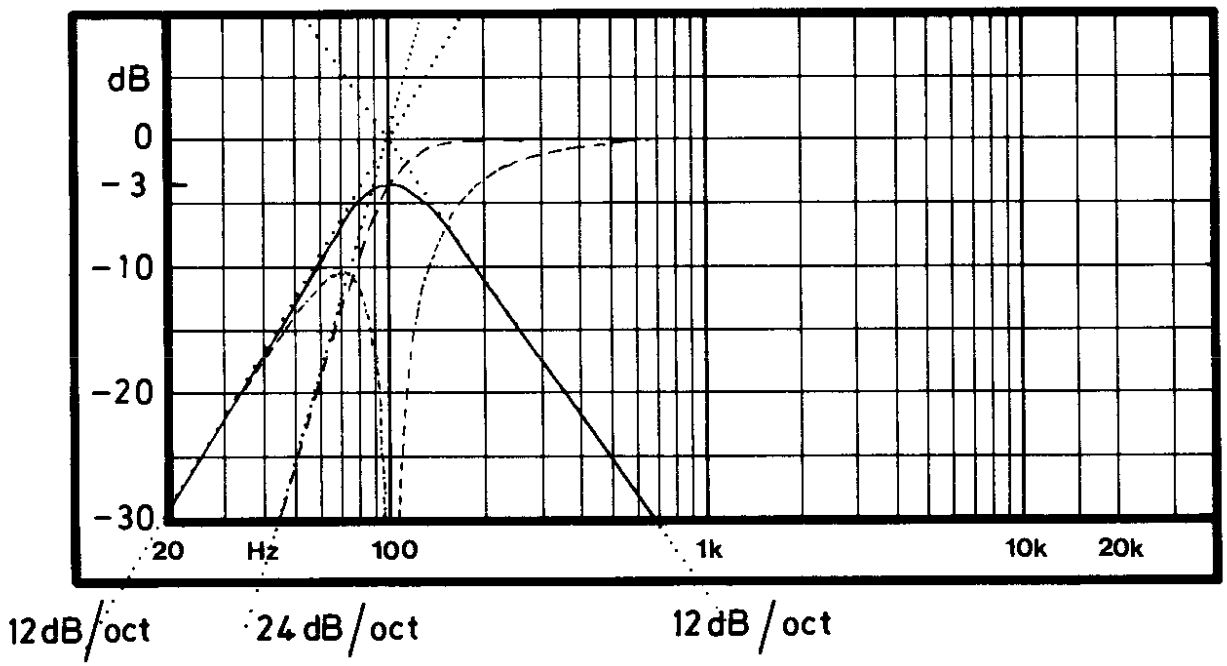
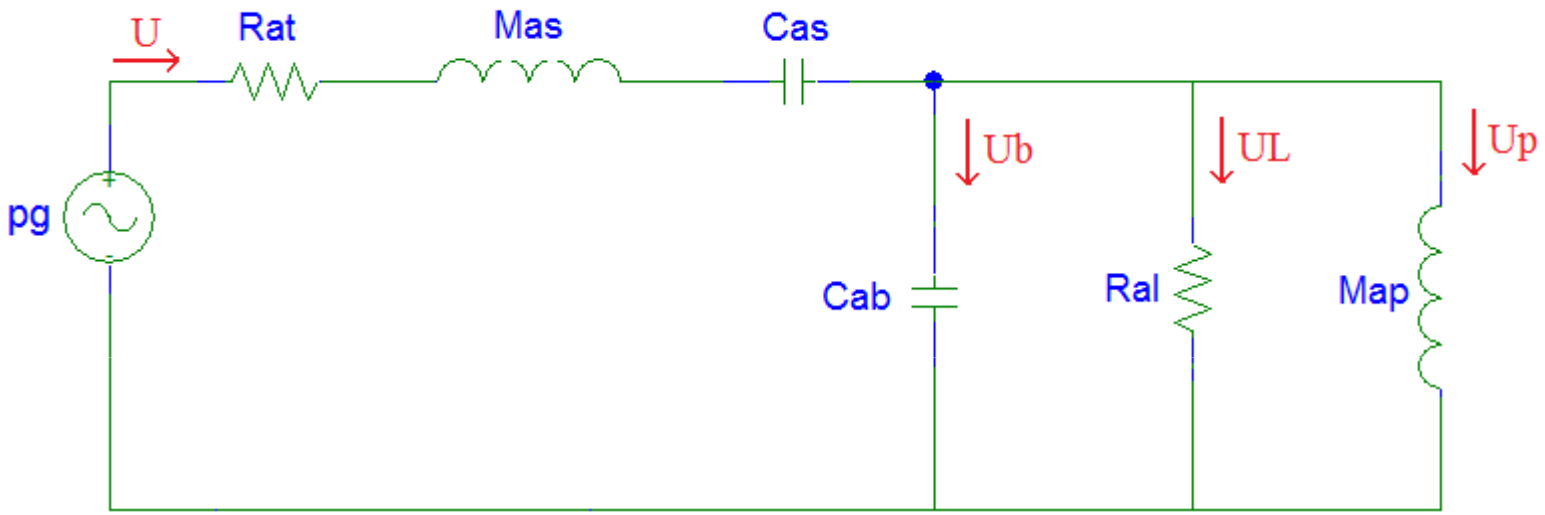


Figure 4.16 (b) *Theoretical responses for a QB4, 4th order maximally flat response for a bass reflex system showing response asymptotes and scaled to a vent resonance at 100 Hz. The port output reaches a maximum of −3 dB relative to the reference level. The driver output goes through a null as the port reaches to maximum, presenting the maximum value of acoustic impedance load to the rear force of the driver cone. The combined level of driver and port extends to 100 Hz, −3 dB, the roll-off slope at 24 dB/oct. the sum of the 12 dB slopes of the port output and the driver. (Key: —— port, - - - - driver, – – – summation, ····· asymptotes)*

3.- Circuito Acústico Aproximado



$$p_g = \frac{eg \cdot Bl}{(Rg + \mathrm{Re})Sd}$$

$$Rat = Ras + \frac{(Bl)^2}{(Rg + \mathrm{Re})Sd^2}$$

4.- Parámetros Thiele-Small del Sistema Bass Reflex

4.1.- Altavoz

Frecuencia de resonancia

$$f_S = \frac{1}{2\pi\sqrt{MasCas}}$$

Factor de Pérdidas Total

$$Qts = \frac{QmsQes}{Qms + Qes}$$

4.- Parámetros Thiele-Small del Sistema Bass Reflex

4.2.- Ducto/Caja

Frecuencia de resonancia del sistema caja/ducto

$$f_B = \frac{1}{2\pi\sqrt{MapCab}}$$

Factor de Pérdidas del ducto

$$Qb = \frac{1}{\frac{1}{Q_A} + \frac{1}{Q_P} + \frac{1}{Q_L}} \approx Q_L$$

Absorción

Roce en el ducto

Fugas por el cono

4.- Parámetros Thiele-Small del Sistema Bass Reflex

4.3.- Relaciones Altavoz/Caja

Razón de Compliancias

$$\alpha = \frac{Cas}{Cab} = \frac{Vas}{Vb}$$

Razón de Sintonía

$$h = \frac{f_B}{f_S}$$

5.- Función de Respuesta

FILTRO PASA ALTOS 4º ORDEN

$$G(s) = \frac{s^4 T_B^2 T_S^2}{s^4 T_B^2 T_S^2 + s^3\left(\frac{T_B^2 T_S}{Q_T} + \frac{T_B T_S^2}{Q_L}\right) + s^2\left[(\alpha+1)T_B^2 + \frac{T_B T_S}{Q_L Q_T} + T_S^2\right] + s\left(\frac{T_B}{Q_L} + \frac{T_S}{Q_T}\right) + 1}$$

$$T_B = \frac{1}{\omega_B}$$

$$T_S = \frac{1}{\omega_S}$$

$$Q_T = Q_{TS}$$

6.- Función de Respuesta

Alineando con un filtro normalizado 4º orden, e igualando coeficientes, se obtiene:

$$G(s) = \frac{s^4 T_0^4}{s^4 T_0'^4 + a_1 s^3 T_0'^3 + a_2 s^2 T_0'^2 + a_3 s T_0' + 1} \qquad con \qquad T_0 = \frac{1}{\omega_0}$$

$$|G(j\omega)|^2 = \frac{\omega^8 T_0^8}{\omega^8 T_0^8 + A_1 \omega^6 T_0^6 + A_2 \omega^4 T_0^4 + A_3 \omega^2 T_0^2 + 1}$$

Sistema de 4 Ecuaciones con 5 variables (h, Q_L, Qts, fs, α)

$$T_0 = \sqrt{T_B T_S} = \frac{T_S}{h^{1/2}}$$

$$a_1 = \frac{Q_L + hQ_T}{h^{1/2} Q_L Q_T}$$

$$a_2 = \frac{h + (\alpha + 1 + h^2) Q_L Q_T}{h Q_L Q_T}$$

$$a_3 = \frac{hQ_L + Q_T}{h^{1/2} Q_L Q_T}$$

7.- Alineamientos “Clásicos”

BUTTERWORTH 4º ORDEN (B4)

$$a_1 = (4 + 2\sqrt{2})^{1/2} = 2.6131$$

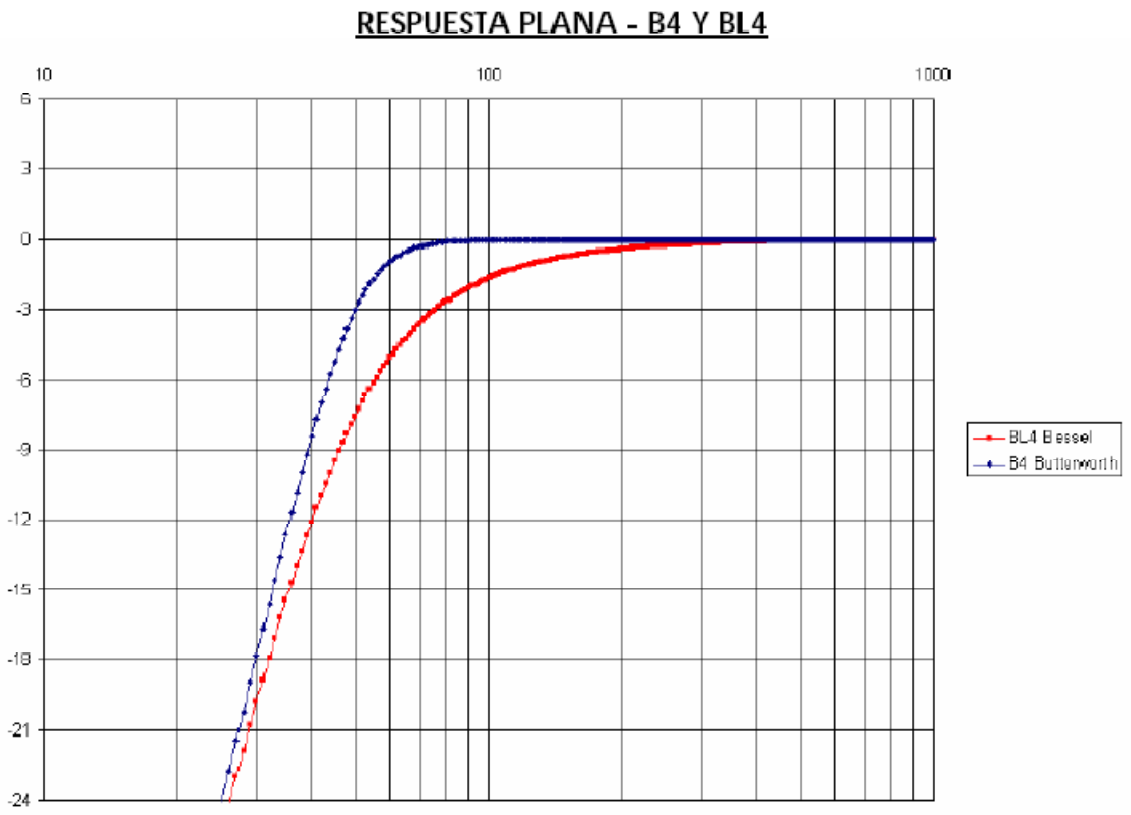
$$a_2 = 2 + \sqrt{2} = 3.1412$$

$$a_3 = a_1 = 2.6131$$

$$A_1 = A_2 = A_3 = 0$$

$$f_3 / f_0 = 1.0000$$

7.- Alineamientos “Clásicos”



7.- Alineamientos "Clásicos"

CHEBYSHEV "EQUAL-RIPPLE" (C4) Y "SUB-CHEBYSHEV" (SC4)

Si k < 1 → Chebyshev C4
Si k > 1 → Sub-Chebyshev SC4

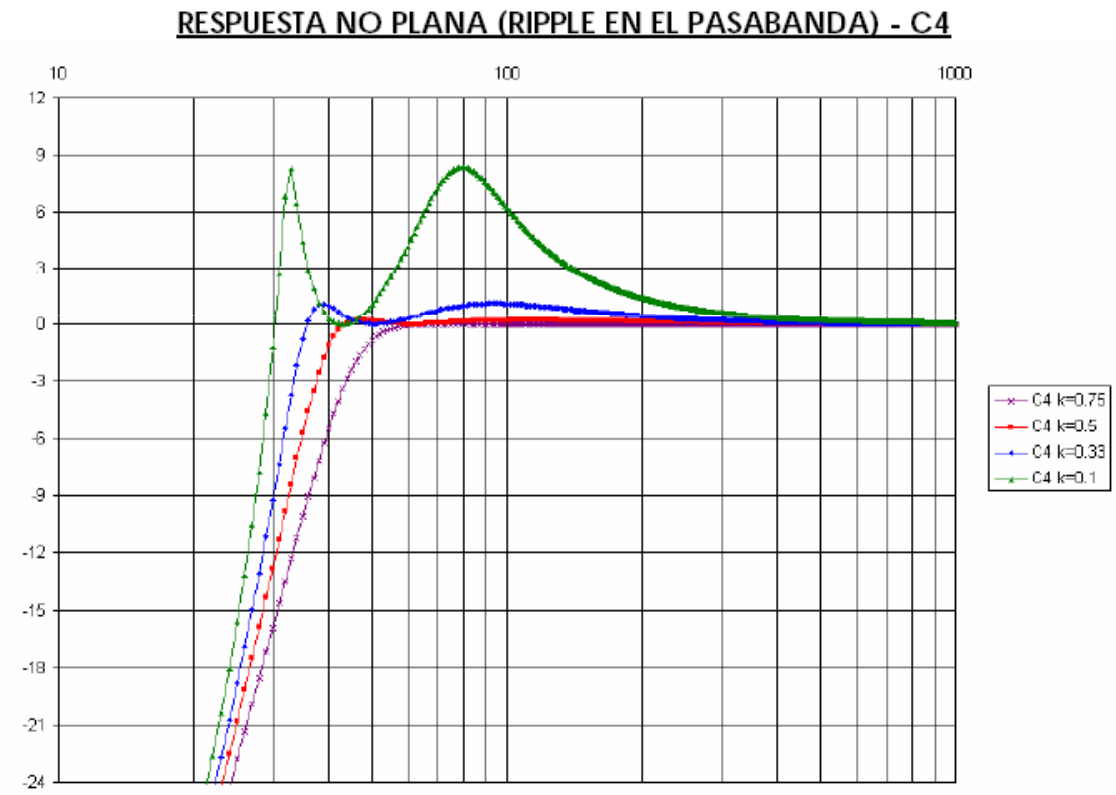
$$a_3 = \frac{k\left(4+2\sqrt{2}\right)^{1/2}}{D^{1/4}}$$

$$a_2 = \frac{1+k^2(1+\sqrt{2})}{D^{1/2}}$$

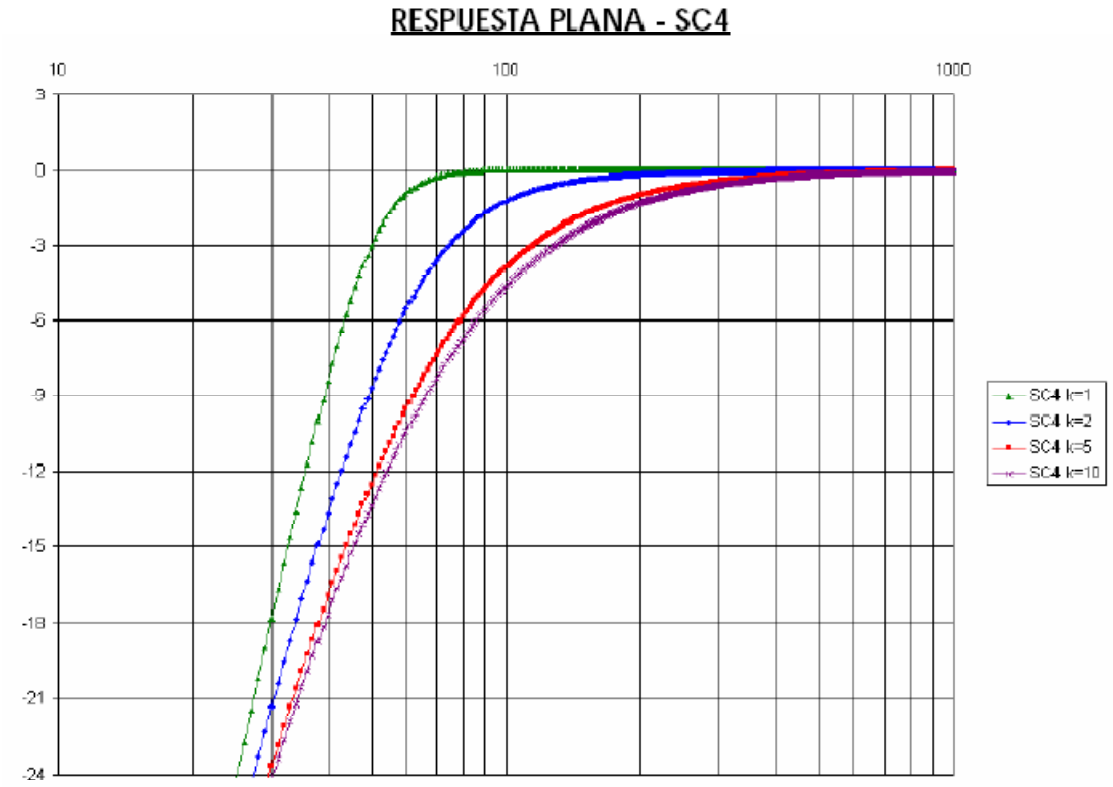
$$a_1 = \frac{a_3}{D^{1/2}}\left[1-\frac{1-k^2}{2\sqrt{2}}\right]$$

$$\text{donde} \quad D = \frac{k^4+6k^2+1}{8}$$

7.- Alineamientos “Clásicos”



7.- Alineamientos “Clásicos”



7.- Alineamientos "Clásicos"

QUASI-THIRD-ORDER BUTTERWORTH (QB3)

La respuesta QB3 varía en función del parámetro B

$$B = A_3^{1/2}$$

Los otros coeficientes están dados por:

$$A_1 = A_2 = 0$$

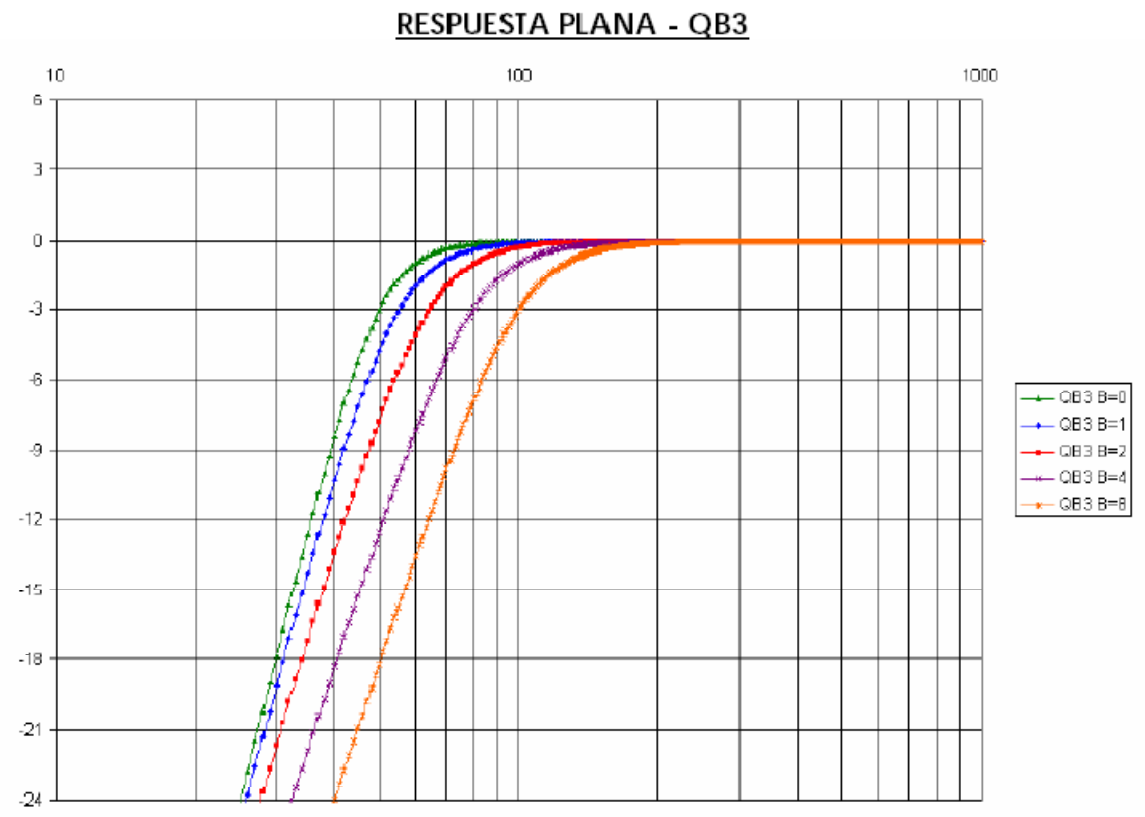
$$a_2 > 2 + \sqrt{2}$$

$$a_1 = (2a_2)^{1/2}$$

$$a_3 = \frac{a_2^2 + 2}{2a_1}$$

Si B = 0 → Butterworth B4

7.- Alineamientos “Clásicos”



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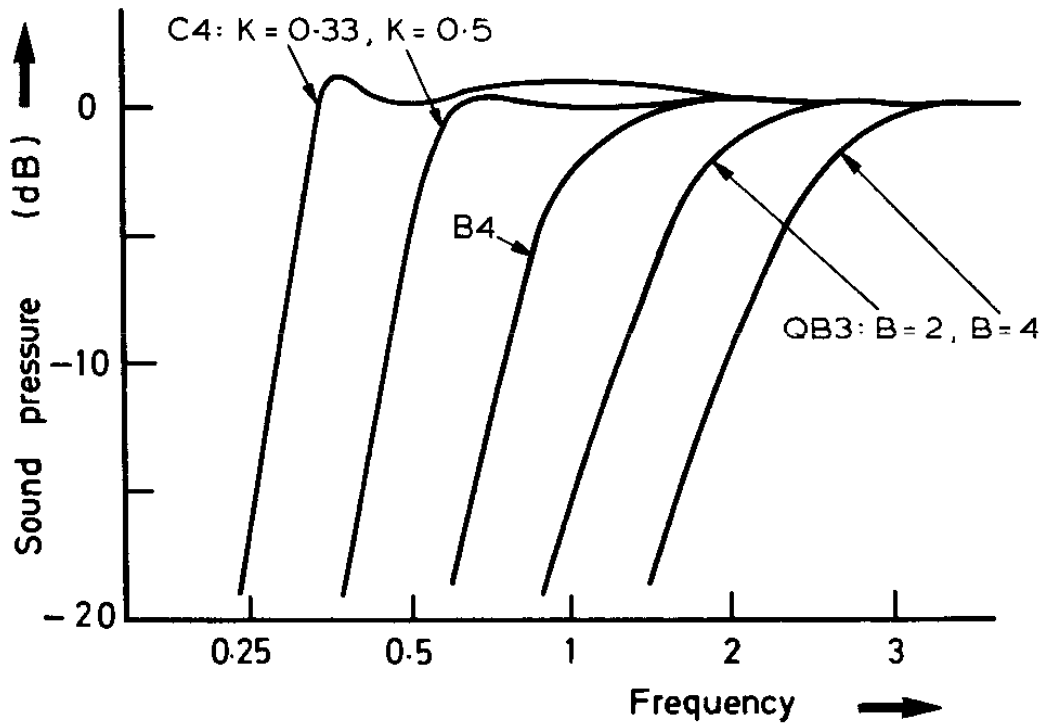

Figure 4.18 Normalised response curves for B4 and selected C4 and QB3 alignments of vented-box loudspeaker system (after Small)[8]. (B4 maximally flat Butterworth.)

8.- Gráficos de Alineamiento (R.Small)

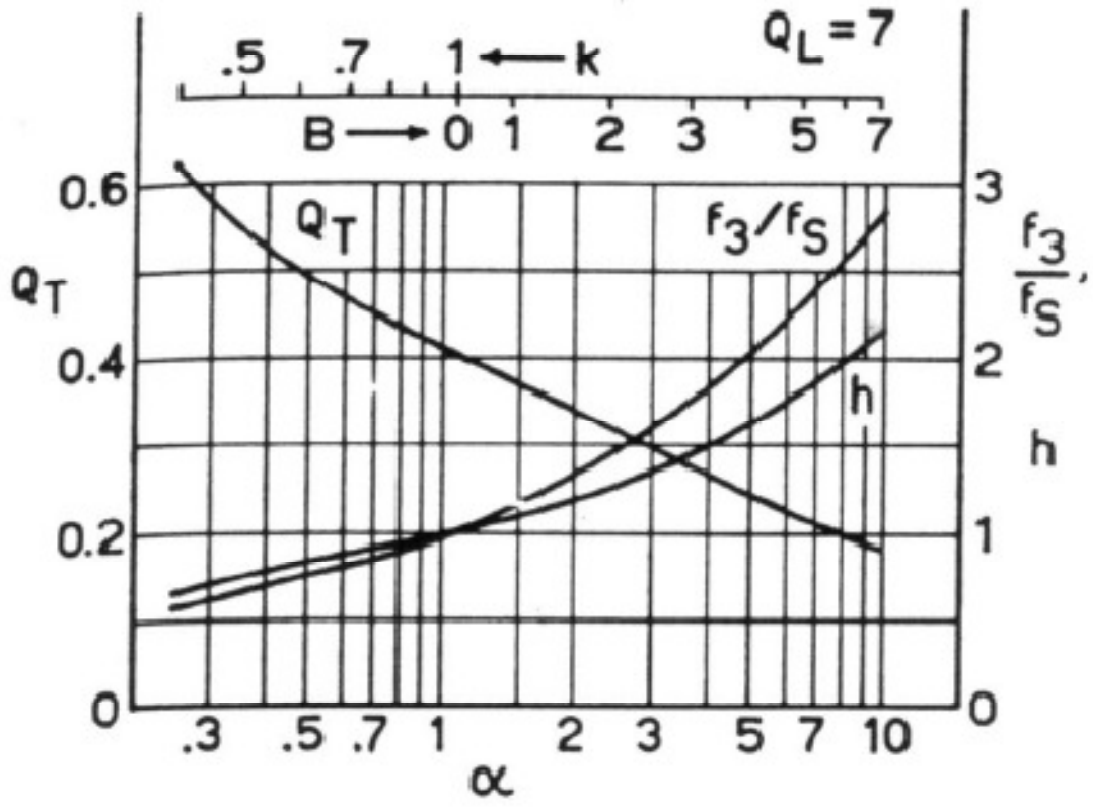

Fig. 11. Alignment chart for vented-box systems with $Q_B = Q_L = 7$.

8.- Gráficos de Alineamiento (R.Small)

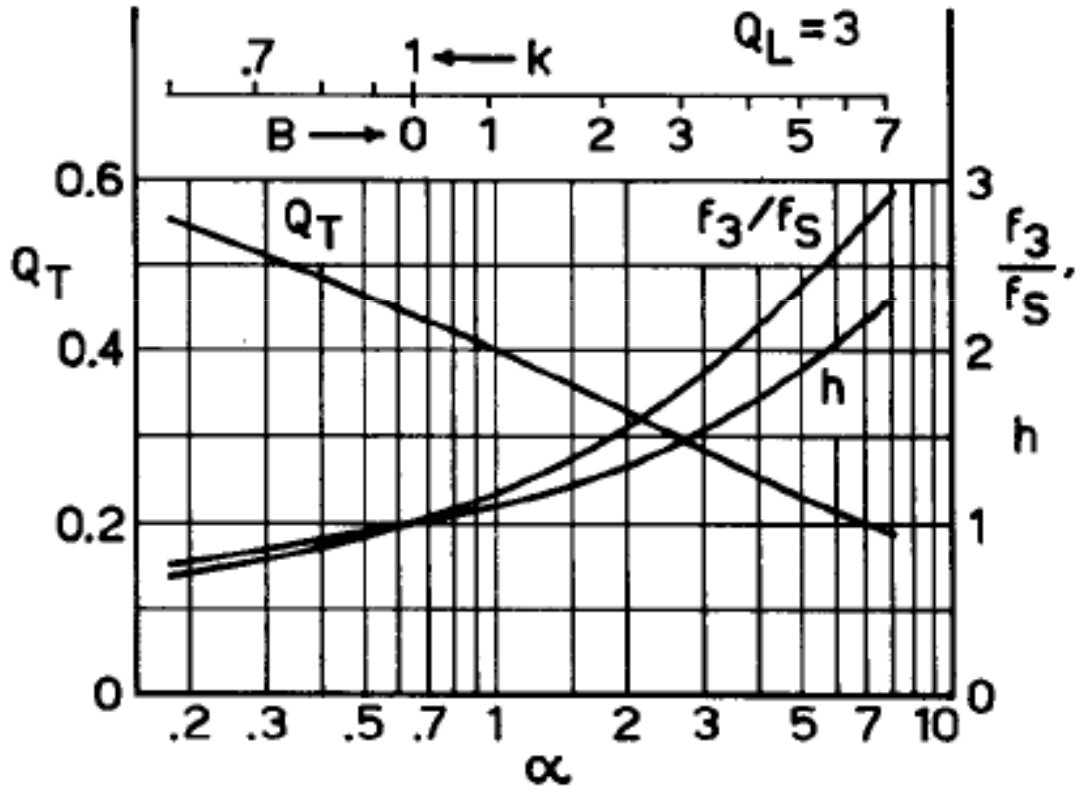

Fig. 13. Alignment chart for vented-box systems with $Q_B = Q_L = 3$.

8.- Gráficos de Alineamiento (R.Small)

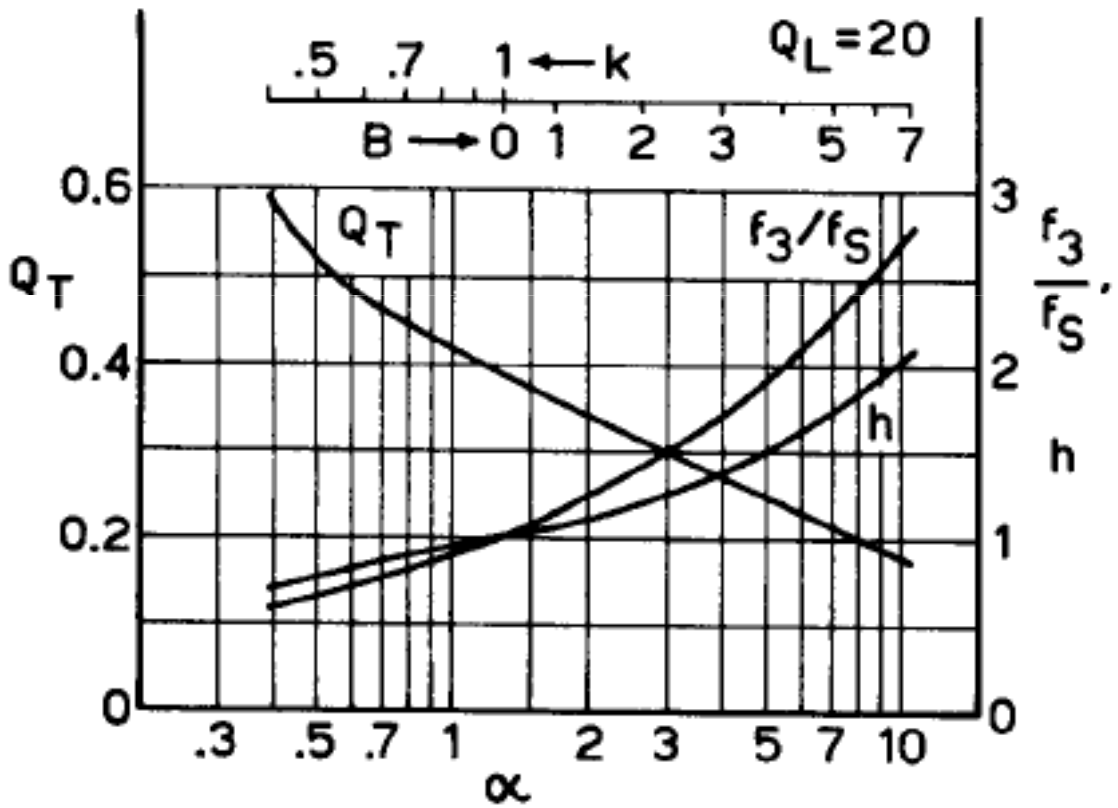

Fig. 9. Alignment chart for vented-box systems with $Q_B = Q_L = 20$.

Ejemplo

Determinar el alineamiento (C4, B4 ó QB3), volumen de la caja (Vb), frecuencia de corte de la caja (f_3) y frecuencia de resonancia del ducto (f_B) para el siguiente altavoz:

Fs = 27 [Hz]

Qts = 0.45

Vas = 156 [L]

9.- Tablas de Alineamiento (Dickason, 2009)

Alineamiento	Familia	Sigla	Características
Plano	Super Fourth-Order Boom Box	SBB4	Caja grande, buena transiente, de baja afinación.
Plano	Fourth-Order Sub Chebychev	SC4	Similar al SBB4 pero de diferente afinación.
Plano	Quasi Third-Order	QB3	Alineamiento muy usado, baja frecuencia de corte, caja pequeña.
No Plano	Chebychev	C4	De Ripple pequeños (menor a 1 dB).
No Plano	Fourth-Order Boom Box	BB4	De característica similares a la alineación de alto QTC en sistema caja cerrada.
No Plano	Super Third-Order Quasi Butterworth	SQB3	Similar al QB3 pero para valores altos de Q_{TS}

TABLE 2.10

Discrete Alignments

Q_L	Q_{ts}	H	α	f_3/f_s
		Butterworth		
3	0.4386	1.0000	0.6543	1.0000
7	0.4048	1.0000	1.0613	1.0000
15	0.3937	1.0000	1.2444	1.0000
		Bessel		
3	0.3535	0.9696	1.4036	1.4911
7	0.3312	0.9735	1.9076	1.4941
15	0.3230	0.9749	2.1296	1.4951
		Butterworth Inter-Order		
3	0.3835	1.1397	1.1722	1.2432
7	0.3572	1.1184	1.6802	1.2315
15	0.3477	1.1117	1.9030	1.2278

ALINEAMIENTOS DISCRETOS

TABLE 2.4

$Q_L = 3$
QB_3 and SQB_3

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.1000	4.3303	31.2904	5.6709	0
0.1100	3.9371	25.6824	5.1456	0
0.1200	3.6096	21.4169	4.7069	0
0.1300	3.3325	18.0974	4.3348	0
0.1400	3.0950	15.4635	4.0150	0
0.1500	2.8892	13.3386	3.7371	0
0.1600	2.0792	11.5994	3.4932	0
0.1700	2.5504	10.1581	3.2772	0
0.1800	2.4092	08.9502	3.0844	0
0.1900	2.2830	07.9280	2.9113	0
0.2000	2.1694	07.0552	2.7548	0
0.2100	2.0666	06.3041	2.6125	0
0.2200	1.9733	05.6531	2.4824	0
0.2300	1.8881	05.0851	2.3630	0
0.2400	1.8100	04.5866	2.2528	0
0.2500	1.7381	04.1467	2.1508	0
0.2600	1.6719	03.7566	2.0559	0
0.2700	1.6105	03.4090	1.9674	0
0.2800	1.5536	03.0980	1.8845	0
0.2900	1.5006	02.8186	1.8065	0
0.3000	1.4512	02.5666	1.7331	0
0.3100	1.4050	02.3386	1.6636	0
0.3200	1.3617	02.1317	1.5978	0
0.3300	1.3210	01.9432	1.5351	0
0.3400	1.2828	01.7712	1.4754	0
0.3500	1.2467	01.6136	1.4183	0
0.3600	1.2127	01.4690	1.3636	0
0.3700	1.1806	01.3360	1.3110	0
0.3800	1.1501	01.2133	1.2605	0
0.3900	1.1213	01.0999	1.2118	0
0.4000	1.0939	0.9949	1.1649	0
0.4100	1.0679	0.8974	1.1198	0
0.4200	1.0431	0.8069	1.0763	0
0.4300	1.0195	0.7225	1.0346	0
0.4400	0.9970	0.6439	0.9947	0
0.4500	0.9755	0.5704	0.9568	0
0.4600	0.9550	0.5016	0.9210	0.02
0.4700	0.9354	0.4672	0.8875	0.06
0.4800	0.9166	0.3767	0.8563	0.14
0.4900	0.8986	0.3199	0.8276	0.27
0.5000	0.8813	0.2665	0.8014	0.45
0.5100	0.8647	0.2161	0.7775	0.70
0.5200	0.8488	0.1686	0.7558	1.00
0.5300	0.8336	0.1238	0.7363	1.36
0.5400	0.8189	0.0814	0.7186	1.77
0.5500	0.8047	0.0413	0.7027	2.25
0.5600	0.7911	0.0033	0.6883	2.78

TABLE 2.5

$Q_L = 7$
QB_3 and SQB_3

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.1000	3.8416	34.3925	5.2233	0
0.1100	3.4947	28.2341	4.7386	0
0.1200	3.2058	23.5499	4.3337	0
0.1300	2.9615	19.9046	3.9902	0
0.1400	2.7525	17.0150	3.6949	0
0.1500	2.5712	14.6784	3.4381	0
0.1600	2.4129	12.7685	3.2126	0
0.1700	2.2743	11.1855	3.0128	0
0.1800	2.1495	9.8589	2.8345	0
0.1900	2.0388	8.7361	2.6741	0
0.2000	1.9393	7.7775	2.5289	0
0.2100	1.8494	6.9524	2.3968	0
0.2200	1.7678	6.2372	2.2759	0
0.2300	1.6935	5.6132	2.1647	0
0.2400	1.6254	5.0655	2.0620	0
0.2500	1.5629	4.5822	1.9667	0
0.2600	1.5054	4.1535	1.8778	0
0.2700	1.4522	3.7714	1.7946	0
0.2800	1.4029	3.4295	1.7165	0
0.2900	1.3571	3.1223	1.6429	0
0.3000	1.3145	2.8421	1.5732	0
0.3100	1.2748	2.5944	1.5070	0
0.3200	1.2376	2.3667	1.4439	0
0.3300	1.2028	2.1594	1.3836	0
0.3400	1.1702	1.9699	1.3258	0
0.3500	1.1395	1.7964	1.2702	0
0.3600	1.1106	1.6371	1.2167	0
0.3700	1.0834	1.4905	1.1651	0
0.3800	1.0578	1.3552	1.1153	0
0.3900	1.0335	1.2300	1.0674	0
0.4000	1.0106	1.1141	1.0214	0
0.4100	0.9889	1.0065	0.9776	0
0.4200	0.9683	0.9064	0.9362	0.01
0.4300	0.9488	0.8131	0.8975	0.05
0.4400	0.9303	0.7260	0.8618	0.14
0.4500	0.9128	0.6445	0.8294	0.31
0.4600	0.8961	0.5682	0.8001	0.56
0.4700	0.8802	0.4966	0.7741	0.90
0.4800	0.8651	0.4294	0.7510	1.32
0.4900	0.8507	0.3661	0.7307	1.85
0.5000	0.8370	0.3065	0.7129	2.46
0.5100	0.8240	0.2503	0.6972	3.18
0.5200	0.8116	0.1971	0.6835	4.01
0.5300	0.7998	0.1468	0.6715	4.97
0.5400	0.7886	0.0992	0.6610	6.08
0.5500	0.7779	0.0540	0.6518	7.36
0.5600	0.7677	0.0111	0.6438	8.87

TABLE 2.6

$Q_L = 15$
QB_3 and SQB_3

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.1000	3.6841	35.4793	5.0715	0
0.1100	3.3494	29.1286	4.6004	0
0.1200	3.0732	24.2984	4.2069	0
0.1300	2.8398	20.5392	3.8730	0
0.1400	2.6400	17.5563	3.5859	0
0.1500	2.4670	15.1498	3.3362	0
0.1600	2.3158	13.1802	3.1169	0
0.1700	2.1826	11.5478	2.9225	0
0.1800	2.0644	10.1797	2.7488	0
0.1900	1.9589	9.0218	2.5926	0
0.2000	1.8640	8.0331	2.4512	0
0.2100	1.7784	7.1822	2.3225	0
0.2200	1.7007	6.4446	2.2045	0
0.2300	1.6299	5.8010	2.0960	0
0.2400	1.5652	5.2361	1.9956	0
0.2500	1.5058	4.7375	1.9023	0
0.2600	1.4512	4.2952	1.8153	0
0.2700	1.4007	3.9011	1.7338	0
0.2800	1.3540	3.5484	1.6571	0
0.2900	1.3106	3.2314	1.5846	0
0.3000	1.2703	2.9455	1.5159	0
0.3100	1.2327	2.6867	1.4504	0
0.3200	1.1976	2.4517	1.3880	0
0.3300	1.1648	2.2376	1.3281	0
0.3400	1.1341	2.0420	1.2705	0
0.3500	1.1052	1.8629	1.1251	0
0.3600	1.0781	1.6983	1.1615	0
0.3700	1.0526	1.5468	1.1099	0
0.3800	1.0286	1.4070	1.0602	0
0.3900	1.0059	1.2777	1.0125	0
0.4000	0.9845	1.1579	0.9672	0
0.4100	0.9643	1.0466	0.9245	0.02
0.4200	0.9452	0.9430	0.8849	0.08
0.4300	0.9272	0.8464	0.8488	0.21
0.4400	0.9101	0.7562	0.8162	0.43
0.4500	0.8939	0.6719	0.7872	0.76
0.4600	0.8786	0.5928	0.7618	1.18
0.4700	0.8641	0.5185	0.7395	1.72
0.4800	0.8503	0.4488	0.7202	2.36
0.4900	0.8373	0.3830	0.7034	3.13
0.5000	0.8249	0.3211	0.6889	4.04
0.5100	0.8132	0.2625	0.6764	5.09
0.5200	0.8021	0.2072	0.6656	6.33
0.5300	0.7916	0.1547	0.6563	7.79
0.5400	0.7817	0.1050	0.6483	9.56
0.5500	0.7723	0.0577	0.6416	11.80
0.5600	0.7635	0.0128	0.6359	14.70

TABLE 2.7

$Q_L = 3$
SC_4 and C_4

Q_{ts}	H	α	f_3/f_s	Ripple–dB
0.2500	1.0093	3.4080	2.6083	0
0.2600	1.0322	3.2301	2.4391	0
0.2700	1.0529	3.0516	2.2860	0
0.2800	1.0703	2.8731	2.1473	0
0.2900	1.0871	2.6952	2.0217	0
0.3000	1.1004	2.5188	1.9078	0
0.3100	1.1109	2.3447	1.8042	0
0.3200	1.1187	2.1738	1.7097	0
0.3300	1.1236	2.0069	1.6232	0
0.3400	1.1255	1.8448	1.5437	0
0.3500	1.1244	1.6885	1.4703	0
0.3600	1.1203	1.5387	1.4023	0
0.3700	1.1133	1.3961	1.3390	0
0.3800	1.1034	1.2616	1.2798	0
0.3900	1.0909	1.1356	1.2244	0
0.4000	1.0758	1.0187	1.1723	0
0.4100	1.0586	0.9110	1.1236	0
0.4200	1.0394	0.8128	1.0778	0
0.4300	1.0188	0.7238	1.0348	0
0.4400	0.9770	0.6439	0.9947	0
0.4500	0.9744	0.5726	0.9572	0
0.4600	0.9515	0.5093	0.9222	0
0.4700	0.9286	0.4533	0.8898	0
0.4800	0.9059	0.4040	0.8597	0
0.4900	0.8837	0.3605	0.8318	0
0.5000	0.8621	0.3223	0.8060	0.01
0.5100	0.8412	0.2885	0.7822	0.02
0.5200	0.8212	0.2586	0.7601	0.02
0.5300	0.8021	0.2321	0.7397	0.03
0.5400	0.7838	0.2084	0.7208	0.05
0.5500	0.7664	0.1872	0.7033	0.06
0.5600	0.7499	0.1681	0.6871	0.08
0.5700	0.7341	0.1508	0.6720	0.10
0.5800	0.7192	0.1350	0.6579	0.12
0.5900	0.7049	0.1205	0.6447	0.14
0.6000	0.6913	0.1072	0.6324	0.17
0.6100	0.6784	0.0984	0.6209	0.20
0.6200	0.6661	0.0832	0.6101	0.23
0.6300	0.6543	0.0723	0.5999	0.26
0.6400	0.6430	0.0630	0.5906	0.29
0.6500	0.6322	0.0524	0.5812	0.32
0.6600	0.6218	0.0431	0.5726	0.35
0.6700	0.6118	0.0343	0.5644	0.39
0.6800	0.6022	0.0258	0.5567	0.42
0.6900	0.5929	0.0175	0.5493	0.46
0.7000	0.5840	0.0096	0.5423	0.50

TABLE 2.8

$Q_L = 7$
SC_4 and C_4

Q_{ts}	H	α	f_3/f_s	Ripple–dB
0.2500	1.0338	3.8961	2.3949	0
0.2600	1.0534	3.6755	2.2282	0
0.2700	1.0703	3.4551	2.0784	0
0.2800	1.0842	3.2360	1.9439	0
0.2900	1.0951	3.0193	1.8229	0
0.3000	1.1028	2.8062	1.7137	0
0.3100	1.1073	2.5977	1.6149	0
0.3200	1.1086	2.3952	1.5251	0
0.3300	1.1065	2.1997	1.4431	0
0.3400	1.1012	2.0125	1.3679	0
0.3500	1.0926	1.8347	1.2986	0
0.3600	1.0810	1.6672	1.2345	0
0.3700	1.0667	1.5109	1.1751	0
0.3800	1.0498	1.3665	1.1200	0
0.3900	1.0309	1.2343	1.0689	0
0.4000	1.0103	1.1146	1.0215	0
0.4100	0.9886	1.0070	0.9777	0
0.4200	0.9662	0.9113	0.9373	0
0.4300	0.9436	0.8266	0.9001	0
0.4400	0.9212	0.7521	0.8660	0
0.4500	0.8992	0.6868	0.8348	0.01
0.4600	0.8780	0.6297	0.8064	0.01
0.4700	0.8578	0.5798	0.7804	0.02
0.4800	0.8385	0.5361	0.7567	0.03
0.4900	0.8203	0.4978	0.7351	0.05
0.5000	0.8031	0.4642	0.7155	0.07
0.5100	0.7870	0.4345	0.6975	0.09
0.5200	0.7719	0.4083	0.6810	0.12
0.5300	0.7578	0.3849	0.6659	0.15
0.5400	0.7445	0.3640	0.6520	0.19
0.5500	0.7321	0.3453	0.6393	0.23
0.5600	0.7205	0.3284	0.6275	0.27
0.5700	0.7096	0.3131	0.6166	0.31
0.5800	0.6993	0.2992	0.6065	0.36
0.5900	0.6896	0.2865	0.5971	0.41
0.6000	0.6805	0.2749	0.5883	0.46
0.6100	0.6719	0.2641	0.5802	0.51
0.6200	0.6638	0.2542	0.5726	0.57
0.6300	0.6561	0.2449	0.5654	0.63
0.6400	0.6488	0.2363	0.5587	0.68
0.6500	0.6418	0.2283	0.5524	0.74
0.6600	0.6353	0.2208	0.5465	0.80
0.6700	0.6289	0.2136	0.5409	0.89
0.6800	0.6229	0.2069	0.5355	0.92
0.6900	0.6171	0.2006	0.5305	0.98
0.7000	0.6116	0.1946	0.5258	1.05

TABLE 2.9

$Q_L = 15$
SC_4 and C_4

Q_{ts}	H	α	f_3/f_s	Ripple–dB
0.2500	1.0420	4.0890	2.3097	0
0.2600	1.0601	3.8500	2.1477	0
0.2700	1.0751	3.6119	1.9970	0
0.2800	1.0871	3.3757	1.8647	0
0.2900	1.0958	3.1429	1.7460	0
0.3000	1.1011	2.9147	1.6391	0
0.3100	1.1031	2.6924	1.5426	0
0.3200	1.1016	2.4774	1.4549	0
0.3300	1.0966	2.2711	1.3749	0
0.3400	1.0884	2.0748	1.3016	0
0.3500	1.0769	1.8896	1.2342	0
0.3600	1.0626	1.7166	1.1720	0
0.3700	1.0456	1.5567	1.1146	0
0.3800	1.0265	1.4101	1.0615	0
0.3900	1.0058	1.2779	1.0125	0
0.4000	0.9840	1.1591	0.9675	0
0.4100	0.9615	1.0535	0.9262	0
0.4200	0.9390	0.9604	0.8884	0
0.4300	0.9167	0.8787	0.8539	0
0.4400	0.8951	0.8074	0.8226	0.01
0.4500	0.8744	0.7453	0.7942	0.02
0.4600	0.8547	0.6911	0.7684	0.03
0.4700	0.8361	0.6439	0.7451	0.05
0.4800	0.8187	0.6027	0.7239	0.07
0.4900	0.8025	0.5666	0.7047	0.09
0.5000	0.7873	0.5348	0.6873	0.12
0.5100	0.7732	0.5068	0.6714	0.16
0.5200	0.7601	0.4820	0.6569	0.20
0.5300	0.7479	0.4599	0.6437	0.24
0.5400	0.7366	0.4402	0.6315	0.29
0.5500	0.7260	0.4225	0.6204	0.34
0.5600	0.7162	0.4065	0.6101	0.39
0.5700	0.7070	0.3921	0.6006	0.45
0.5800	0.6984	0.3789	0.5919	0.51
0.5900	0.6903	0.3670	0.5838	0.57
0.6000	0.6828	0.3560	0.5762	0.63
0.6100	0.6757	0.3459	0.5692	0.70
0.6200	0.6690	0.3366	0.5626	0.77
0.6300	0.6627	0.3281	0.5565	0.83
0.6400	0.6567	0.3201	0.5508	0.90
0.6500	0.6511	0.3127	0.5454	0.97
0.6600	0.6458	0.3058	0.5403	1.00
0.6700	0.6408	0.2994	0.5355	1.12
0.6800	0.6360	0.2933	0.5311	1.19
0.6900	0.6314	0.2876	0.5268	1.26
0.7000	0.6271	0.2823	0.5228	1.33

TABLE 2.1

$Q_L = 3$
SBB_4 and BB_4

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.2000	1.0000	5.4444	3.5401	0
0.2100	1.0000	4.9031	3.3255	0
0.2200	1.0000	4.4355	3.1280	0
0.2300	1.0000	4.0290	2.9454	0
0.2400	1.0000	3.6736	2.7761	0
0.2500	1.0000	3.3611	2.6186	0
0.2600	1.0000	3.0850	2.4718	0
0.2700	1.0000	2.8399	2.3347	0
0.2800	1.0000	2.6213	2.2068	0
0.2900	1.0000	2.4257	2.0873	0
0.3000	1.0000	2.2500	1.9759	0
0.3100	1.0000	2.0916	1.8724	0
0.3200	1.0000	1.9484	1.7763	0
0.3300	1.0000	1.8114	1.6876	0
0.3400	1.0000	1.7002	1.6060	0
0.3500	1.0000	1.5924	1.5313	0
0.3600	1.0000	1.4938	1.4632	0
0.3700	1.0000	1.4035	1.4014	0
0.3800	1.0000	1.3205	1.3456	0
0.3900	1.0000	1.2441	1.2952	0
0.4000	1.0000	1.1736	1.2499	0
0.4100	1.0000	1.1085	1.2091	0.01
0.4200	1.0000	1.0482	1.1724	0.05
0.4300	1.0000	0.9923	1.1394	0.12
0.4400	1.0000	0.9403	1.1096	0.20
0.4500	1.0000	0.8920	1.0828	0.30
0.4600	1.0000	0.8469	1.0585	0.41
0.4700	1.0000	0.8049	1.0365	0.53
0.4800	1.0000	0.7656	1.0165	0.66
0.4900	1.0000	0.7289	0.9983	0.79
0.5000	1.0000	0.6944	0.9815	0.93
0.5100	1.0000	0.6621	0.9663	1.08
0.5200	1.0000	0.6318	0.9523	1.23
0.5300	1.0000	0.6033	0.9394	1.38
0.5400	1.0000	0.5765	0.9275	1.54
0.5500	1.0000	0.5512	0.9165	1.70
0.5600	1.0000	0.5274	0.9063	1.86
0.5700	1.0000	0.5048	0.8968	2.02
0.5800	1.0000	0.4836	0.8880	2.18
0.5900	1.0000	0.4635	0.8797	2.34
0.6000	1.0000	0.4444	0.8720	2.50
0.6100	1.0000	0.4264	0.8649	2.66
0.6200	1.0000	0.4093	0.8581	2.82
0.6300	1.0000	0.3931	0.8518	2.98
0.6400	1.0000	0.3777	0.8458	3.14
0.6500	1.0000	0.3631	0.8402	3.30
0.6600	1.0000	0.3492	0.8349	3.46
0.6700	1.0000	0.3359	0.8299	3.61
0.6800	1.0000	0.3233	0.8252	3.77
0.6900	1.0000	0.3113	0.8207	3.92
0.7000	1.0000	0.2999	0.8165	4.08

TABLE 2.2

$Q_L = 7$
SBB_4 and BB_4

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.2000	1.0000	5.8980	3.3686	0
0.2100	1.0000	5.3339	3.1518	0
0.2200	1.0000	4.8457	2.9521	0
0.2300	1.0000	4.4204	2.7674	0
0.2400	1.0000	4.0478	2.5960	0
0.2500	1.0000	3.7114	2.4366	0
0.2600	1.0000	3.4286	2.2883	0
0.2700	1.0000	3.1699	2.1503	0
0.2800	1.0000	2.9388	2.0220	0
0.2900	1.0000	2.7315	1.9031	0
0.3000	1.0000	2.5448	1.7932	0
0.3100	1.0000	2.3761	1.6922	0
0.3200	1.0000	2.2233	1.6000	0
0.3300	1.0000	2.0843	1.5162	0
0.3400	1.0000	1.9576	1.4406	0
0.3500	1.0000	1.8419	1.3728	0
0.3600	1.0000	1.7357	1.3122	0
0.3700	1.0000	1.6392	1.2583	0
0.3800	1.0000	1.5484	1.2104	0.01
0.3900	1.0000	1.4656	1.1679	0.06
0.4000	1.0000	1.3890	1.1302	0.14
0.4100	1.0000	1.3181	1.0966	0.24
0.4200	1.0000	1.2523	1.0667	0.37
0.4300	1.0000	1.1911	1.0399	0.51
0.4400	1.0000	1.1341	1.0160	0.66
0.4500	1.0000	1.0809	0.9944	0.82
0.4600	1.0000	1.0313	0.9750	1.00
0.4700	1.0000	0.9849	0.9574	1.17
0.4800	1.0000	0.9414	0.9415	1.36
0.4900	1.0000	0.9006	0.9270	1.55
0.5000	1.0000	0.8622	0.9137	1.74
0.5100	1.0000	0.8262	0.9015	1.93
0.5200	1.0000	0.7923	0.8904	2.13
0.5300	1.0000	0.7603	0.8801	2.33
0.5400	1.0000	0.7302	0.8706	2.53
0.5500	1.0000	0.7017	0.8619	2.73
0.5600	1.0000	0.6747	0.8537	2.93
0.5700	1.0000	0.6493	0.8462	3.13
0.5800	1.0000	0.6251	0.8391	3.33
0.5900	1.0000	0.6022	0.8325	3.53
0.6000	1.0000	0.5805	0.8264	3.73
0.6100	1.0000	0.5599	0.8206	3.93
0.6200	1.0000	0.5403	0.8152	4.12
0.6300	1.0000	0.5216	0.8102	4.32
0.6400	1.0000	0.5038	0.8054	4.51
0.6500	1.0000	0.4869	0.8009	4.70
0.6600	1.0000	0.4708	0.7967	4.90
0.6700	1.0000	0.4554	0.7926	5.09
0.6800	1.0000	0.4407	0.7889	5.27
0.6900	1.0000	0.4267	0.7853	5.46
0.7000	1.0000	0.4133	0.7819	5.65

TABLE 2.3

$Q_L = 15$
SBB_4 and BB_4

Q_{ts}	H	α	f_3/f_s	Peak–dB
0.2000	1.0000	6.0844	3.2996	0
0.2100	1.0000	5.5113	3.0818	0
0.2200	1.0000	5.0149	2.8811	0
0.2300	1.0000	4.5821	2.6955	0
0.2400	1.0000	4.2025	2.5233	0
0.2500	1.0000	3.8678	2.3633	0
0.2600	1.0000	3.5711	2.2146	0
0.2700	1.0000	3.3070	2.0764	0
0.2800	1.0000	3.0708	1.9483	0
0.2900	1.0000	2.8588	1.8301	0
0.3000	1.0000	2.6678	1.7214	0
0.3100	1.0000	2.4650	1.6222	0
0.3200	1.0000	2.3384	1.5323	0
0.3300	1.0000	2.1958	1.4514	0
0.3400	1.0000	2.0357	1.3790	0
0.3500	1.0000	1.9467	1.3146	0
0.3600	1.0000	1.8375	1.2576	0
0.3700	1.0000	1.7372	1.2071	0.01
0.3800	1.0000	1.6447	1.1626	0.07
0.3900	1.0000	1.5593	1.1233	0.16
0.4000	1.0000	1.4803	1.0886	0.27
0.4100	1.0000	1.4070	1.0577	0.41
0.4200	1.0000	1.3390	1.0303	0.57
0.4300	1.0000	1.2757	1.0059	0.73
0.4400	1.0000	1.2167	0.9840	0.91
0.4500	1.0000	1.1616	0.9643	1.10
0.4600	1.0000	1.1101	0.9466	1.30
0.4700	1.0000	1.0619	0.9305	1.50
0.4800	1.0000	1.0167	0.9160	1.71
0.4900	1.0000	0.9743	0.9027	1.91
0.5000	1.0000	0.9344	0.8906	2.13
0.5100	1.0000	0.8969	0.8795	2.34
0.5200	1.0000	0.8616	0.8696	2.56
0.5300	1.0000	0.8282	0.8599	2.78
0.5400	1.0000	0.7967	0.8513	2.99
0.5500	1.0000	0.7670	0.8432	3.21
0.5600	1.0000	0.7388	0.8358	3.43
0.5700	1.0000	0.7121	0.8289	3.65
0.5800	1.0000	0.6868	0.8224	3.86
0.5900	1.0000	0.6628	0.8164	4.08
0.6000	1.0000	0.6400	0.8108	4.29
0.6100	1.0000	0.6183	0.8055	4.51
0.6200	1.0000	0.5977	0.8006	4.72
0.6300	1.0000	0.5781	0.7959	4.93
0.6400	1.0000	0.5594	0.7916	5.14
0.6500	1.0000	0.5415	0.7874	5.35
0.6600	1.0000	0.5245	0.7836	5.55
0.6700	1.0000	0.5083	0.7799	5.76
0.6800	1.0000	0.4927	0.7764	5.96
0.6900	1.0000	0.4779	0.7731	6.16
0.7000	1.0000	0.4637	0.7700	6.36

Unidad III: Altavoz en Caja Bass Reflex
Parte 1
Alineamientos

Recinto para Altavoces

Prof. Ing. Andrés Barrera A.