

Errata for Acoustics: Sound Fields and Transducers by Leo Beranek & Tim Mellow, Jan 2017 to August 2017.

Updated October 2, 2018

P. 39, 2nd column of Table 2.1: Replace $\begin{matrix} 0 & 0 \\ -1 & -1 \\ 2 & 0 \end{matrix}$ with $\begin{matrix} 0 & \infty \\ -1 & -1 \\ 2 & 0 \end{matrix}$.

P. 52, Eq. (2.109): Replace “s” or “rayls” with “rayls”.

P. 55, 6th line after Eq. (2.115): Replace “three equations for each ordinate as follows” with “three equations, one for each ordinate as follows”

P. 57, 1st line: Replace “ $W_n(w)\Phi(\phi)Z(z)$ ” with “ $W_n(w)\Phi_n(\phi)Z(z)$ ”.

P. 62, Eqs. (2.163) and (2.164): Exchange “ $h_n^{(1)}$ ” and “ $h_n^{(2)}$ ”.

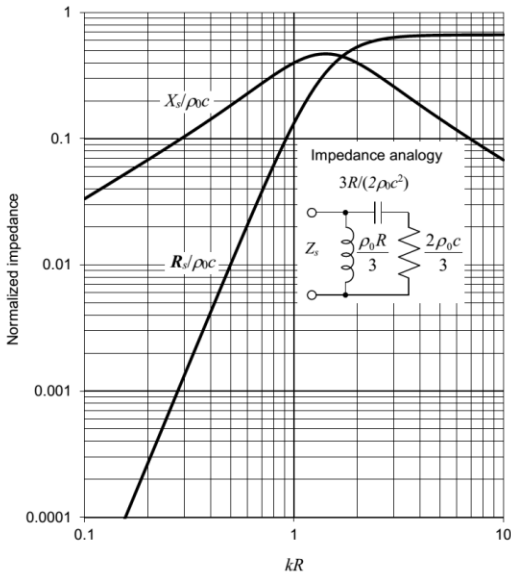
P. 161: Replace Eq. (4.136) with

$$\begin{aligned} \tilde{F} &= 2R^2 \int_0^{2\pi} \int_0^{\pi/2} \tilde{p}(R, \theta) \cos \theta \sin \theta d\theta d\phi \\ &= \rho_0 c \tilde{U}_0 \frac{2}{3} \frac{jkR(1 + jkR)}{2 - k^2 R^2 + 2jkR} e^{-jkR}. \end{aligned}$$

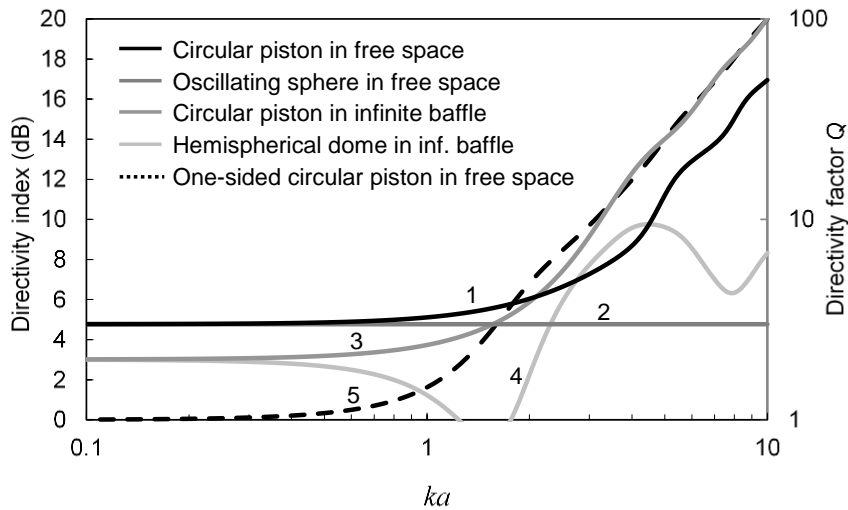
P. 161: Replace equation Eq. (4.137) with

$$\begin{aligned} Z_s = R_s + jX_s &= \frac{\tilde{F}}{\tilde{U}_0 e^{-jkR}} \\ &= \frac{2}{3} \cdot \frac{jkR(1 + jkR)}{2 - k^2 R^2 + 2jkR} \rho_0 c \\ &= \frac{2}{3} \cdot \frac{k^4 R^4 + j(k^3 R^3 + 2kR)}{k^4 R^4 + 4} \rho_0 c. \end{aligned}$$

P. 162, Replace Fig. 4.27 with

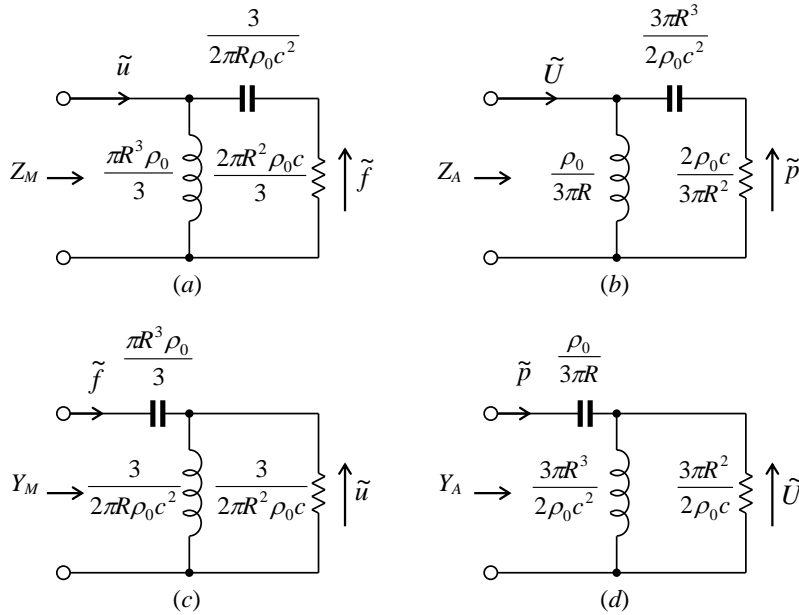


P. 166, Replace Fig. 4.30 with



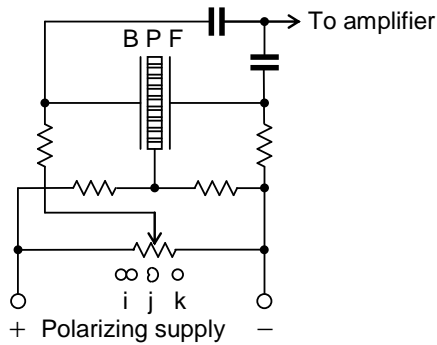
P. 166, Add to caption of Fig. 4.30 “These are plotted using Eq. (4.143), which is divided by 2 in the case of the piston and oscillating sphere in free space because they radiate from both sides and hence radiate twice the power.

P. 170, Replace Fig. 4.34 with



P. 175, 3rd line after heading 4.20: Replace “Eqs. (12.249), (12.250), and (12.251)” with “Eqs. (13.248), (13.249), and (13.250)”.

P. 231: Replace Fig 5.31 with



P. 239, Table 5.2, 2nd column: Replace “ D ” with “ d ”.

P. 269: Replace Eq. (6.90) with

$$E_{ff} \approx 100 \frac{2B^2 S_D^2 \rho_0}{\pi^2 \kappa \rho_w^2 V_g c}, \quad 2f_0 < f < \frac{c}{4\pi a}, \quad M'_{MS} \approx M_{MC}$$

P. 305, last sentence before Eq. (7.9): Replace “total volume the absorbent” with “total volume of the absorbent”.

P. 306: Delete “ α is the real part of the propagation coefficient”.

P. 306: Delete “ β is the imaginary part of the propagation coefficient”.

P. 314, Replace Eq. (7.38) with

$$D(0) = \frac{1 - 2(ka/\sqrt{5})^2 + j2(ka/\sqrt{5})}{1 - (ka/\sqrt{5})^2 + j(ka/\sqrt{5})}$$

P. 314, Replace Eq. (7.39) with

$$|p(r)| = \frac{f\rho_0|U_c|}{2r} \sqrt{\frac{(5-2k^2a^2)^2 + 20k^2a^2}{(5-k^2a^2)^2 + 5k^2a^2}}$$

P. 356: Replace Eq. (7.119) with

$$\begin{aligned} \tilde{u}_z(x, y, l_z) &= \frac{2}{k} \tilde{u}_0 \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} k_{mn} A_{mn} \frac{k\rho_0 c \cos k_{mn} l_z + jk_{mn} Z_s \sin k_{mn} l_z}{k\rho_0 c - k_{mn} Z_s} \\ &\quad \times \int_0^{l_x} \cos(m\pi x/l_x) \cos(p\pi x/l_x) dx \int_0^{l_y} \cos(n\pi y/l_y) \cos(q\pi y/l_y) dy \\ &= \tilde{u}_0 \int_{(l_x-a_1)/2}^{(l_x+a_1)/2} \cos(p\pi x/l_x) dx \int_{y_1-b_1/2}^{y_1+b_1/2} \cos(q\pi y/l_y) dy \end{aligned}$$

P. 399, final paragraph: Replace “The circuit for an electret microphone shown in Fig. 8.7 is much simpler than that for an externally polarized microphone, shown in Fig. 5.18, because the electret provides both the polarization for the capsule and the bias for the FET.” with “The circuit for an electret microphone shown in Fig. 8.7 is simpler than that for an externally polarized microphone, shown in Fig. 5.18, because the electret provides the polarization for the capsule, although the bias for the FET usually settles to zero due to leakage.”

P. 446: Replace equation for S_T with

$$\begin{aligned} S_T &= 4R_T^2 \left\{ \arctan \left(\frac{\tan \frac{\pi}{12} \tan \frac{\pi}{6}}{\sec^2 \frac{\pi}{12} + \sqrt{\sec^2 \frac{\pi}{12} + \tan^2 \frac{\pi}{6}}} \right) + \arctan \left(\frac{\tan \frac{\pi}{12} \tan \frac{\pi}{6}}{\sec^2 \frac{\pi}{6} + \sqrt{\sec^2 \frac{\pi}{6} + \tan^2 \frac{\pi}{12}}} \right) \right\} \\ &= 4 \times 0.022^2 \times 0.13 = 2.52 \text{ cm}^2 \end{aligned}$$

P. 491, 3rd line after Eq. (12.17): Replace “ $\cos \theta = Z/\sqrt{w^2 + Z^2}$ ” with “ $\cos \theta = z/\sqrt{w^2 + z^2}$ ”.

P. 497, 1st line after Eq. (12.35): Replace “ $D(r, \theta)$ ” with “ $D(\theta)$ ”.

P. 498, Fig. 12.10: Exchange “ $D(\pi)$ ” and “ $D(0)$ ”.

P. 499, Fig. 12.11: Exchange “ $D(\pi)$ ” and “ $D(0)$ ”.

P. 501, Eq. (12.45): Replace “ e^{jkr} ” with “ e^{-jkr} ”.

P. 504, after Eq. (12.51): Insert “of Eq. (2.4a)” between “condition” and “gives”.

P. 505, Eq. (12.57), Replace “ ρ ” with “ ρ_0 ”.

P. 506, Eq. (12.60), Replace first instance of “ $(2n + 1)$ ” with “ $(2n + 2)$ ”.

P. 507, Replace Eq. (12.62) with

$$\tilde{F} = R^2 \int_0^{2\pi} \int_0^\pi \tilde{p}(R, \theta) \cos \theta \sin \theta d\theta d\phi$$

P. 508, Replace Eq. (12.63) with

$$Z_s = \frac{\tilde{F}}{\tilde{U}_0} = j\rho_0 c \left(\frac{\sin^2 \alpha h_0^{(2)}(kR)}{4h_1^{(2)}(kR)} - \frac{(1 - \cos^3 \alpha)^2 h_1^{(2)}(kR)}{\sin^2 \alpha (h_0^{(2)}(kR) - 2h_2^{(2)}(kR))} \right. \\ \left. - \sum_{n=2}^{\infty} \frac{(2n+1)^2 (\sin \alpha P_n(\cos \alpha) + \cos \alpha P_n^1(\cos \alpha))^2 h_n^{(2)}(kR)}{(n-1)^2 (n+2)^2 (nh_{n-1}^{(2)}(kR) - (n+1)h_{n+1}^{(2)}(kR))} \right)$$

P. 508, Replace “When $\alpha = \frac{1}{2}\pi$, the second term simplifies to that for an oscillating sphere, as described in Par. 4.15, and the expansion vanishes so that Eq. (12.63) simplifies to” with “When $\alpha = \frac{1}{2}\pi$, the odd terms of the expansion vanish, except for the second term, which simplifies to that for an oscillating sphere, as described in Sec. 4.15. Hence, Eq. (12.63) simplifies to”

P. 508: Replace Eq. (12.64) with

$$Z_s \Big|_{\alpha=\frac{\pi}{2}} = \rho_0 c \left(\frac{k^4 R^4 + j(k^3 R^3 + 2kR)}{3(k^4 R^4 + 4)} - j \sum_{n=0}^{\infty} \frac{(4n+1)^2 (P_{2n}(0))^2 h_{2n}^{(2)}(kR)}{(2n-1)^2 (2n+2)^2 (2nh_{2n-1}^{(2)}(kR) - (2n+1)h_{2n+1}^{(2)}(kR))} \right)$$

P. 516: Replace Eq. (12.92) with $\tilde{u}_r(R, \theta) = \frac{1}{-jk\rho_0 c} \cdot \frac{\partial}{\partial r} \tilde{p}(r, \theta) \Big|_{r=R} = 0, \quad \alpha < \theta \leq \pi, \quad r = R$

P. 521, Eq. (12.118), Replace “ $p(r, \theta)$ ” with “ $\tilde{p}(r, \theta)$ ”.

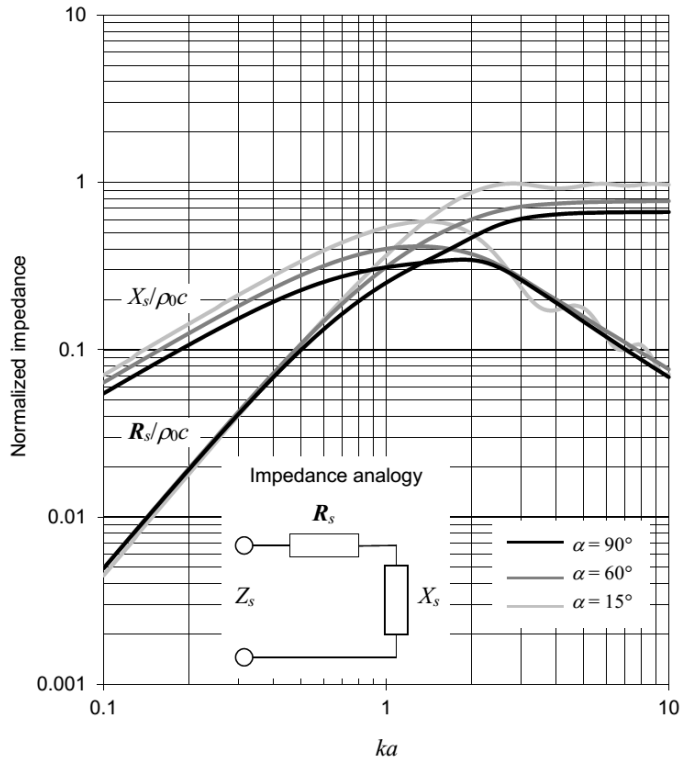
P. 523, Eq. (12.130), Replace “ $P_m^1(\alpha)$ ” with “ $P_m^1(\cos \alpha)$ ”.

P. 523, Eq. (12.133), Delete “ j ” from the denominator.

P. 525, Replace Eq. (12.140) with $\tilde{F} = R^2 \int_0^{2\pi} \int_0^\alpha \tilde{p}(R, \theta) \cos \theta \sin \theta d\theta d\phi$.

P. 525, Replace Eq. (12.141) with $Z_s = \frac{\tilde{F}}{\tilde{U}_0} = \frac{2\rho_0 c}{\sin^2 \alpha} \sum_{n=0}^N A_n h_n^{(2)}(kR) K_n$.

P. 526, Replace Fig. 12.29 with



P. 527, Eq. (12.144), Replace “ $p(r, \theta)$ ” with “ $\tilde{p}(r, \theta)$ ”.

P. 527, Eq. (12.145), Replace “ \tilde{p}_l ” with “ \tilde{p}_l ”.

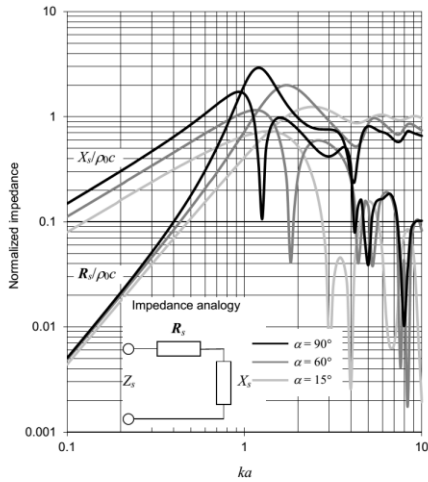
P. 529, Eq. (12.161): Replace “ $P_n(\cos\alpha)P_m(\cos\alpha) - P_m(\cos\alpha)P_n(\cos\alpha)$ ” with “ $P_m(\cos\alpha)P'_n(\cos\alpha) - P_n(\cos\alpha)P'_m(\cos\alpha)$ ”.

P. 532, Replace Eq. (12.169) with $\tilde{F} = R^2 \int_0^{2\pi} \int_0^\alpha \tilde{p}(R, \theta) \cos\theta \sin\theta d\theta d\phi$.

P. 532, 1st line after Eq. (12.169): Replace “Eq. (69)” with “Eq. (68)”.

P. 532, Replace Eq. (12.170) with $Z_s = \frac{\tilde{F}}{\tilde{U}_0} = \frac{2\rho_0 c}{\sin^2 \alpha} \sum_{n=0}^N y_n j_n(kR) L_n$.

P. 532, Replace Fig. 12.33 with



P. 542, 4th line from top: Replace “waves are converging” with “waves converge towards them”.

P. 542, 14th line after Eq. (13.34): Replace “Sec. 13.20” with “Sec. 13.19”.

P. 542, 4th line from bottom: Replace “non-integral” with “Euclidean”.

P. 542, 3rd line from bottom: Replace both instances of “integral” with “Fourier”.

P. 543, 1st line after Eq. (13.40): Replace “integral” with “Fourier”.

P. 545, 2nd line after Eq. (13.49): Replace “non-integral” with “Euclidean”.

P. 545, 2nd line after Eq. (13.52): Replace “integral” with “Fourier”.

P. 545, 3rd line after Eq. (13.52): Replace “ $k_y = k_w \cos \varphi$ ” with “ $k_y = k_w \sin \varphi$ ”.

P. 546, last line: Replace “non-integral” with “Euclidean”.

P. 556, In caption to Fig. 13.5: Replace “ ω ” with “ $2\pi fa$ ”.

P. 557, Eq. (13.106): Replace “ $\frac{k^2 a^2}{4}$ ” with “ $-\frac{k^2 a^2}{4}$ ”.

P. 564, In caption to Fig. 13.9: Replace “ ω ” with “ $2\pi fa$ ”.

P. 565, In Eq. (13.131): Delete “2”.

P. 577, In caption to Fig. 13.16: Replace “ ω ” with “ $2\pi fa$ ”.

P. 578, Eq. (13.184): Replace “ $\frac{k^2 a^2}{4}$ ” with “ $-\frac{k^2 a^2}{4}$ ”.

P. 580, Eq. (13.192): Insert “=” just before “ $G_s + jB_s$ ”.

P. 581, Eq. (13.196): Replace “ $-j \frac{G_s}{G_s^2 + B_s^2}$ ” with “ $-j \frac{B_s}{G_s^2 + B_s^2}$ ”.

P. 586, Eqs. (13.219) and (13.221): Replace “+” with “-”.

P. 587, Eq. (13.232): Replace “-j” with “+j”.

P. 590, In caption to Fig. 13.23: Replace “ ω ” with “ $2\pi fa$ ”.

P. 591, In captions to Fig. 13.24: Replace “ ω ” with “ $2\pi fa$ ”.

P. 599, In caption to Figs. 13.31 & 13.32: Replace “ ω ” with “ $2\pi fa$ ”.

P. 621, Eqs. (13.328) and (13.329): Replace “ $g_{m,n}(q)$ ” with “ $g_{m,n}$ ”.

P. 627, 3rd line before Eq. (13.342): Replace “integral” with “Fourier”.

P. 652, 2nd line after heading 14.10: Replace “current sources” with “a current source”.

P. 667, Eq. (14.164): Replace “ \tilde{i}_{T1P} ”, “ \tilde{i}_{T1S} ”, “ \tilde{i}_{G1P} ”, and “ \tilde{i}_{G1S} ” with “ \tilde{i}_{VV1S} ”, “ \tilde{i}_{CC1S} ”, “ \tilde{i}_{VC1S} ”, and “ \tilde{i}_{VC2S} ” respectively.

P. 680, In Eq. (70), replace “ $P_n(\cos \alpha)P'_m(\cos \alpha) - P_m(\cos \alpha)P'_n(\cos \alpha)$ ” with “ $P_m(\cos \alpha)P'_n(\cos \alpha) - P_n(\cos \alpha)P'_m(\cos \alpha)$ ”.

P. 684, Eq. (101): Replace “ $\alpha_{km} n \alpha_{kn}$ ” with “ $\alpha_{km} \neq \alpha_{kn}$ ”.

P. 688, Eq. (152): Replace “x” with “z”.

P. 384, Replace Eq. (7.179) with

$$f_0 = \sqrt{5}c/(2\pi a)$$

After “=” insert “-” in Eqs. (4.116), (4.134), (4.135), (12.30), (12.33), (12.34), (12.46), (13.13), (13.105), (13.160), (13.177), and (13.181).

After “=” delete “-” in Eqs. (4.64), (4.65), (4.67), (4.71), (4.72), (4.75), (4.110), (4.112), (4.114), (4.117), (4.118), (4.125), (4.126), (4.127), (4.129), (4.130), (4.132), (4.133), (6.31), (6.32), (6.36), (12.24), (12.25), (12.45), (13.2), (13.11), (13.12), (13.87), (13.89), (13.91), (13.92), (13.178), (13.184), (13.204), (13.206), (13.215), (13.222), (13.227), (13.230), (13.231), (13.232), (13.247), and (13.269).

P. 385-386: Replace Example 7.4 with the following simpler corrected version:

Example 7.4. Crossover for woofer of Example 7.2. In this example we shall implement a 3rd-order Butterworth high-pass filter using a series capacitor for the 1st-order section and the native response of the tweeter for the 2nd-order section. Because the tweeter will be mounted in a sphere, we shall design a crossover to compensate for the 6 dB lift associated with a point source in a sphere (see Fig. 7.14) so that it provides part of the 1st-order section. The low-pass section will be designed to give an all-pass overall

response with zero phase shift, as discussed in the previous section. Hence the low-pass section will use just a series inductor together with the 6 dB lift due to the baffle effect, using a closed-back piston as a model (see Fig. 7.15). Since the woofer occupies almost the full width of the box, we will take a as 9.4 cm which, using Eq. (7.179), gives us a crossover frequency of

$$f_0 = 2.24 \times 344.8 / (2 \times 3.14 \times 0.094) = 1305 \text{ Hz}$$

Hence the value of the series inductance needed is

$$L_1 = \frac{R_E}{2\pi f_0} = \frac{6.27}{2 \times 3.14 \times 1305} = 0.766 \text{ mH}$$

However, the coil inductance is 0.71 mH, so to make up the difference we will use an inductor with a value of $0.766 - 0.71 = 56 \mu\text{H}$. Next we need to choose a tweeter suitable for a crossover frequency of 1305 Hz. The SEAS model 27TFF (H0831) has a resonance frequency of $f_C = 1200$ Hz, which is close enough. The effective area of the dome is $S_D = 7.5 \text{ cm}^2$. The maximum sound pressure of the woofer has already been specified as 99.6 dB SPL at a distance of $r = 1$ m. At the crossover frequency f_0 , the sound pressure produced by the tweeter is 3 dB less than this, that is 96.6 dB SPL, and decreases at a rate of 18 dB/octave below f_0 . The peak displacement at f_0 is obtained from Eq. (6.35) to give

$$\eta_{\text{peak}} = \frac{\sqrt{2}r \times 10^{\frac{\text{SPL}}{20}-5}}{\pi f^2 \rho_0 S_D} = \frac{1.414 \times 1 \times 10^{\frac{96.6}{20}-5}}{3.14 \times 1305^2 \times 1.18 \times 7.5 \times 10^{-4}} = 0.2 \text{ mm}$$

which is within the linear excursion limit of 0.5 mm and at frequencies above and below f_0 the displacement is reduced. Using the method described in Sec. 6.10 for measuring the Thiele-Small parameters, we estimate the Q factors from the impedance curve to be

$$Q_{EC} = \omega_S M_{MD} R_{ES} / (Bl)^2 = 2\pi \times 1200 \times 0.0003 \times 4.8 / 3.5^2 = 0.89$$

$$Q_{MC} = \omega_S M_{MD} R_E / (Bl)^2 = 2\pi \times 1200 \times 0.0003 \times 10.2 / 3.5^2 = 1.88$$

Also, the quoted sensitivity is 92 dB SPL in a baffle at 1 m with an input voltage of 2.83 Vrms (or 86 dB SPL in free space). However, the woofer has a sensitivity of 79.6 dB SPL in free space, so the tweeter needs a series resistor to match its sensitivity to that of the woofer. If $R_E = 4.8 \Omega$, then the series resistor value is

$$\begin{aligned} R_1 &= R_E (10^{(\text{TweeterSensitivity} - \text{WooferSensitivity})/20} - 1) \\ &= 4.8 \times (10^{(92-79.6)/20} - 1) = 15.2 \Omega \approx 15 \Omega \end{aligned}$$

This will modify the values of Q_{EC} and Q_{TC} as follows

$$Q'_{EC} = \left(1 + \frac{R_1}{R_E}\right) Q_{EC} = \left(1 + \frac{15}{4.8}\right) \times 0.89 = 3.67$$

$$Q'_{TC} = Q'_{EC}Q_{MC} / (Q'_{EC} + Q_{MC}) = 1.24$$

which is close enough to unity for a 3rd-order Butterworth response. We need to correct for the 6 dB lift in the response of the tweeter due to the baffle effect. We will simplify this by mounting the tweeter on a wooden sphere so that we can model it as a point source on a sphere of radius R . Then the transfer function of the point source on a sphere from Eq. (7.36) (producing a 6 dB lift) provides the shelf filter response

$$\frac{s + c/R}{s + 2c/R} = \frac{s + \omega_E}{s + \omega_0}$$

where the radius of the sphere is given by

$$R = 2c/\omega_0 = 344.8/(3.14 \times 1305) = 84.1 \text{ mm}$$

Thus the 6 dB transition takes place between $f_E = f_0/2 = 1305/2 = 653 \text{ Hz}$ and $f_0 = 1305 \text{ Hz}$ with a 1st-order slope. Hence we need the series capacitor to continue the 1st-order slope from f_E downwards and its value is determined by

$$C_1 = \frac{1}{2\pi f_E (R_E + R_1)} = \frac{1}{2 \times 3.14 \times 653 \times (4.8 + 15)} = 12.3 \mu\text{F} \approx 12 \mu\text{F}$$

The network is shown in Fig. 7.51.

P. 386: Replace Figure 7.51 with:

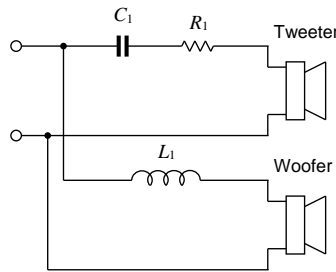


Fig. 7.51. Crossover network of Example 7.4 with a crossover frequency of $f_0 = 1305 \text{ Hz}$. The values of the crossover circuit elements are $R_1 = 15 \Omega$ (25 W), $L_1 = 56 \mu\text{H}$, and $C_1 = 12 \mu\text{F}$. The woofer is a Bandor type 100DW/8A mounted in a closed-box baffle as described in Example 7.2 and shown Fig. 7.18. The tweeter is a SEAS type 27TFF (H0831) mounted in a 16 cm diameter sphere.