DESIGNING A CLOSED LOUDSPEAKER BOX

There are currently two loudspeaker systems: closed or total (US) box, sometimes unfortunately referred to as infinite baffle, and the reflex box. The latter is typified by a hole in its front panel (other than the drive unit apertures), while the closed box is exactly what its name implies. Of the two, the closed box is

nowadays the preferred system with reputable manufacturers and DIY enthusiasts alike. Because of that, this article will describe briefly what is involved in the design of a closed box as far as bass loading is concerned. Interested readers may note that the design of an excellent cross-over network was featured in the January 1986 issue of *Elektor India*.
It should be noted that the design and construction of a loudspeaker enclosure are well within the competence of most of us and that if the considerations given in this article are observed, the results will approach those of proprietary units.
The net volume of the enclosure should ideally be an optimum for a given drive unit but, unfortunately, this is not always practicable, nor does it necessarily result in a performance that satisfies all personal tastes and preferences. It is, none the less, possible to arrive at an acceptable compromise in virtually every individual case.

The drive unit

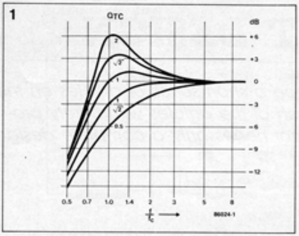
It is important before buying the drive unit to consider the following carefully because this unit will largely determine what sort of enclosure is needed.
Knowing the following three characteristics of the drive unit is essential for the computation of an optimum enclosure: (a) the resonant frequency, f_s, in free air; (b) the Q factor, Q_{TS}, at the resonant frequency; and the suspension compliance, V_{AS}, in litres. All reputable manufacturers publish these characteristics.

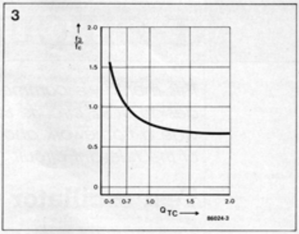
Q factor of the system

The frequency response of a closed-box system is a second-order, i.e. 12 dB per octave, high-pass filter function. The Q value of the loudspeaker system, Q_{TC}, determines the shape of the response characteristic. Fig. 1 gives the characteristics for a number of loudspeaker systems with different Q_{TC} values. It shows that the optimum second-order Butterworth curve is obtained at a Q_{TC} value of $1/\sqrt{2}$, i.e. 0.707. Values between 0.5 and 1.0 are perfectly acceptable, but those above 1.0 result in a distinct peak and lead to poor step response, which is definitely not acceptable in hi-fi systems. Fig. 2 illustrates the differences in step response for varying values of Q_{TC}.

The arithmetic

It is safe to start the computations with a Q_{TC} value of 0.7; when this results in unacceptable values for the resonant frequency, f_c, of the system, or volume of the box, V_B, other values of Q_{TC} may be tried.
The resonant frequency of the loudspeaker system is





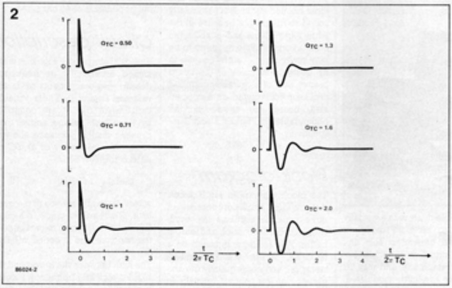


Fig. 1. Effect of the Q_{TC} value on the frequency response of a loudspeaker system. Designers generally consider a value of $1/\sqrt{2} = 0.707$ as ideal.

Fig. 2. Normalized step response of the closed-box system. The higher the Q_{TC}, the poorer the step response: a good reason for not adopting a Q_{TC} value above 1.0.

Fig. 3. The relation between the resonant frequency of the closed box, f_c, and the −3 dB f_3 point depends on the Q_{TC} value. At a Q_{TC} value of 0.7, $f_c = f_3$.

calculated first:

$$f_c = f_s(Q_{TC}/Q_{TS}) \text{ [Hz]} \quad (1)$$

At a Q_{TC} of 0.7, the resonant frequency of the system is also the −3 dB point, f_3, of the box. Other values of Q_{TC} cause a shift as shown in Fig. 3. For instance, at a value of 0.5, f_3 is one and a half times the value of f_c.

If, in formula (1), the values of Q_{TS} and f_s are stated by the manufacturer to be 0.35 and 30 Hz respectively,

$$f_c = 30(0.7/0.35) = 60 \text{ Hz}$$

The volume of the box is calculated from:

$$V_B = V_{AS}/(f_c^2/f_s^2 - 1) \text{ [l]} \quad (2)$$

If, for instance, the manufacturer's stated value of V_{AS} is 0.09 m³, i.e., 90 litres, the net volume of the enclosure is

$$V_B = 90/(60^2/30^2 - 1) = 30 \text{ litres.}$$

Summarizing: if a drive unit with f_s = 30 Hz; Q_{TS} = 0.35; and V_{AS} = 0.09 m³ is built into a 0.03 m³ enclosure, the loudspeaker system will have a resonant frequency of 60 Hz at the ideal Q_{TC} value of 0.7.

If these results are not acceptable, one of the parameters may be changed. It is clear from the foregoing, however, that Q_{TC}, f_c, and V_B are interdependent: change one, and you change all three.

If, for example, the system resonant frequency of 60 Hz is considered too high, insert the desired value, say, 45 Hz, into formula (1) and calculate Q_{TC} from a rehash of the formula:

$$Q_{TC} = Q_{TS} f_c / f_s$$

$$= 0.35 \times 1.5 = 0.525$$

Then, insert the new value of f_c = 45 Hz into formula (2) and calculate V_B:

$$V_B = 90/(45^2/30^2 - 1)$$

$$= 90/1.25 = 72 \text{ litres}$$

If, however, an enclosure volume of 30 litres was considered rather high, Q_{TC} could be taken somewhat higher. It will be found that for the same loudspeaker parameters, and taking Q_{TC} = 1, the system resonant frequency, f_c, will be 86 Hz, and the net volume of the enclosure, V_B, will be 12.5 litres.

As a rule of thumb: the larger the enclosure, the lower the Q and the resonant frequency. A (too) small box will result in a high system Q and a high resonant frequency. JR