motional feedback

Many people are quite satisfied with the musical pleasure they can obtain from a well-designed reproducer. For the others, the pleasure is heightened by the intellectual satisfaction of knowing how the thing works and why it sounds the way it does. A brief outline of the theory of motional feedback is therefore in order.

A good starting point is to take a look at the arrangement chosen for the 22RH532 'Electronic': a loudspeaker driver fitted with an accelerometer, mounted in a stiff airtight enclosure.

This arrangement is shown in the block diagram of figure 1. The acceleration of the cone is measured, the derived voltage being applied as negative feedback. A short calculation will show that this is the best approach. The radiated acoustic power (P_a) is given by:

$$P_a = u^2 \cdot R_a$$

where u is the 'particle velocity' (equal to the cone velocity) and R_a is the 'radiation resistance' (real part of the air-load on the moving cone). For frequencies below about 500 Hz the value of R_a increases with the square of the frequency (figure 2).

The application of acceleration-dependent negative feedback will tend to keep the acceleration of the cone (a) linearly dependent on the input voltage (v_i) and independent of frequency.

The relation between acceleration (a) and velocity (u) of the cone is:

$$u = a \cdot t \text{ so that } u \sim \frac{a}{\omega} \sim \frac{v_i}{\omega}$$

Since a is independent of ω in this case, the velocity will be inversely proportional to frequency (figure 3).

This leads to:

$$P_a = u^2 \cdot R_a = C \cdot \frac{1}{\omega^2} \cdot \omega^2 \cdot v_i^2$$

where C is a constant. (If we ignore box dimension- and room position-effects!) The relationship between radiated sound power and input voltage is therefore independent of frequency (figure 4). In other words, the amplitude-frequency response characteristic is flat.

Summary

The amplitude-frequency response characteristic (the 'frequency response') is determined by two terms: the radiation resistance and the cone velocity (squared). The radiation resistance rises quadratically with frequency (up to about 500 Hz, figure 2). The velocity decreases in inverse proportion to the rising frequency (assuming constant acceleration, figure 3). The final result is obtained by combining figure 2 with twice figure 3 (velocity squared!) — which yields figure 4. ■

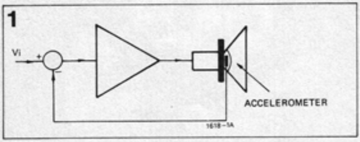

Figure 1. Block diagram of a motional feedback system making use of an accelerometer.

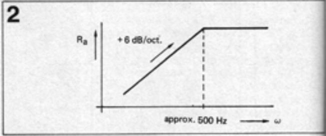

Figure 2. The radiation resistance (R_a) of the air-load on a typical moving-coil loudspeaker in box increases (up to about 500 Hz) with ω^2. Since it is the radiated power that is proportional to R_a, the output at constant cone velocity would rise at 6dB/octave.

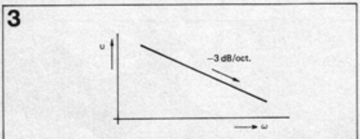

Figure 3. Constant acceleration means a cone velocity that is inversely proportional to ω. This velocity is proportional to the square root of the radiated power. So u can be plotted as a −3dB/octave slope.

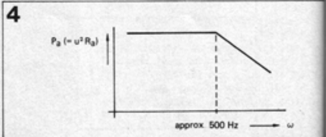

Figure 4. The radiated acoustical power is proportional to the product of radiation resistance and velocity squared. Combination of figure 2 with twice figure 3 yields a total slope of 0dB/octave below 500 Hz i.e. flat frequency response!