What is Q

by Dick Pierce from a posting of his on the newsgroup rec.audio.tech, 14 Nov 1995

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"Q" is one of those dimensionless numbers that causes no small amount of consternation amongst those who don't understand what it means, as well as among those that THINK they do! ☺ However, the principle behind Q, when used in the context of loudspeakers, is VERY simple. It is simply the ratio between energy storing and energy dissipative mechanisms at resonance. In electrical terms, it is the ratio of the reactance to the resistance.

A high Q indicates that for the amount of energy stored in a resonant system, the mechanisms that dissipate that energy are small. So a high-Q system will tend to have a resonance that decays slowly, because the amount of resistance available to dissipate the energy is small compared to the amount of energy stored. A low-Q system will tend to dampen the resonant motion quickly, because the energy is dissipated quickly and removed from the resonant system.

There are primarily 2 energy dissipating mechanisms available in a loudspeaker driver: mechanical and electrical (there is another, acoustical, but it is VERY small when compared to the other mechanisms). The mechanical dissipative mechanisms are primarily the frictional losses in the driver's suspension, and, to a lesser extent, acoustic absorption. There are, essentially, two electrical mechanisms for energy dissipation: the DC resistance to the voice coil and the output resistance of the amplifier. In almost all cases, the DC resistance of the voice coil completely dominates.

These two mechanisms, mechanical and electrical, determine, respectively, the mechanical Q (Q_{ms}) and the electrical Q (Q_{es}) of the loudspeaker driver. Their parallel combination determines the total Q (Q_{ts}) of the loudspeaker driver." Amen.

When we mount a loudspeaker driver onto a baffle system we also have to take into account the Q of the baffle system to arrive at the total system Q. To work out the total Q of the driver and baffle system you simply multiply the baffle system Q with the total Q of the loudspeaker driver. Closed boxes store energy that interacts with the loudspeaker driver in complex ways, especially in vented enclosures. Boxes themselves also have resonances. Normally a high-Q closed box is combined with low-Q loudspeaker driver to give a desirable total system Q. But when we mount a loudspeaker driver on an open baffle this situation is reversed. An open baffle stores no energy and has a low-Q of 0.2 and Carver chose to use a high-Q woofer with a total Q of 3+ to arrive at a desirable total system Q.

Carver's high-Q woofer was also chosen for another good reason to do with mounting a woofer on an open baffle. As we decrease in frequency or increase in wavelength, the system initially behaves as an infinite baffle. When the wavelengths are long enough to be a quarter of the baffle dimensions, the waves begin to cancel each other around the edges of the dipole baffle. The wave travels out to the edge (1/4) and back to the opposite side of the vibrating speaker cone, where it is exactly out of phase and cancels out. Quarter wave cancellation on an open baffle is a first order phenomenon - the roll-off occurs at 6dB per octave. When we reach the free-air resonance point of the high-Q woofer we add to this the second-order sub-resonance fall-off of the high-Q woofer to end up with a third-order or 18db per octave fall-off below the free-air resonance point of the high-Q woofer (this makes a good rumble filter in the Carver case).

In loudspeaker literature we can look at the family of curves for the frequency response of a loudspeaker driver on an infinite baffle as we decrease the frequency. Starting with the rolled-off curve when Q=0.5 (critically damped), then the Butterworth graph with Q=0.71 (maximally flat), then a little ripple at Q=1, then clearly a bumped-up graph at Q=1.4. When the Q is higher than any you can usually find in loudspeaker driver catalogues you start to get boosting above the resonance point of the loudspeaker driver, and a sufficiently high-Q will result in a slope of about 6dB per octave above the free-air resonance point of the loudspeaker driver. This increase of 6dB per octave of the high-Q loudspeaker driver can be used to counteract the 6dB per octave quarter wave cancellation to give a flat frequency response right down to the free-air resonant frequency of the loudspeaker driver. This is a much more elegant solution to the problem of quarter wave cancellation on an open baffle to that used by Celestion, etc of using a conventional low-Q woofer with electronic equalization since it does not involve additional amplifier power and the necessity of electronic equalization equipment. High-Q woofers are relatively easy to design/make. Both ways of overcoming quarter wave cancellation on a baffle entail the use of long throw woofers for the safe operation of the woofer.