# Tweeter Setback

By Dick Crawford

Have you noticed that on some loudspeakers the tweeter is mounted on the front panel, while on others the tweeter is set back, so that the front of the tweeter is behind the front of the woofer? Why is that? What is the optimum setback for the tweeter? How can the amateur speaker builder find the optimum setback? This article explores these questions.

## CAUSES OF TWEETER SETBACK

Tweeter setback is intended to reduce what Dennis Colin calls delay distortion[1]. In his article "Frequency Delay Dispersion" (*audioXpress* 11/07), Colin says, "In my article "Waveform Phase Distortion" (*SB* 1/97), I described how most speaker crossovers (COs) generated delay dispersion, where lower frequencies are delayed more than higher frequencies." Colin goes on to say that he could barely hear (with test signals and good headphones) about 300µs of delay dispersion. He also notes that Joe D'Appolito advises a maximum delay dispersion of 200µs for loudspeakers. In this article I show you how to achieve about 100µs of delay dispersion.

I must emphasize that delay dispersion is due to the lower frequencies (mid-bass) arriving at the listener after the higher frequencies (tweeter).

The delays due to crossovers can be found in electronic handbooks[2], but I will give typical values or approximate formulae to give you an idea of the delays. For comparison, remember that it takes about 73µs for sound to travel 1″.

1. Crossovers: Tweeter crossovers usually have no delay. Mid-bass crossovers have a significant delay. An approximation for the mid-bass crossover delay is:

   Low-pass crossover delay = (0.5)/(low-pass crossover frequency in Hz).

   A 24dB/octave Linkwitz-Riley (L-R) low pass of 3.5kHz would have a delay of 143µs using this approximation; whereas, a more accurate calculation gives a delay of 164µs.

   Drivers also have delays, due to several causes (the numbers given are for a mid-bass driver and a dome tweeter mounted to the same front panel).

2. Frequency response.

2.1. Tweeters have small delays, usually less than 20µs.

2.2. The delay of the mid-bass can be calculated from the equation in #1, which applies to the low-pass characteristics of a driver as well as a crossover. For a mid-bass with a 5kHz rolloff, this approximation is 100µs.

3. Inductance of the driver. This forms a delay of (L/R) in seconds (where R is the resistance of the driver). This is usually small for the tweeter, but might be 50µs or more for a mid-bass.

4. Center of sound radiation. Most dome and planar tweeters radiate sound from near their front surface, but mid-bass drivers radiate sound from the centroid of the cone. This results in a delay of from 20µs to as much as 70µs.

5. Driver spacing delay. If the loudspeaker is measured on the tweeter axis, then the distance from the tweeter to the mid-bass will result in a mid-bass delay. For a tweeter to mid-bass distance of 6″ (center-to-center), then at 39″ (1m) measuring distance the mid-bass delay is about 32µs.

From these delays you can see that the delay dispersion could be as much as 300µs for mid-bass drivers. This isn't bad, but it might be audible.

## OPTIMIZING TWEETER SETBACK

The easiest way to determine the delay dispersion of a loudspeaker is to measure it. I measured the delay dispersion of my current design, which used 5.25″ mid-bass (Dynavox LW5004 PMR available from Parts Express) and 1.1″ domes (Hi-VI TN28, also from Parts Express) with L-R crossovers of 24dB per octave at 3.5kHz, in a mid-bass/tweeter/tweeter/mid-bass (MTTM) configuration (more on this later). I measured 210µs with the woofers and tweeters mounted to the front panel.

210µs is a low delay dispersion, which might partly explain why some English monitors, which use similar drivers and crossovers, have a good reputation. A way to improve the delay dispersion is to set back the tweeter. To calculate the setback in inches, remember that it takes 73µs for sound to travel 1″.

It might seem that if you move the tweeter back 210µs = 2.88″, that you would remove the delay dispersion. I call this a complete setback (pun intended). Indeed, 2.88″ of tweeter setback will align the leading edge of the tweeter step response to the leading edge of the mid-bass step response, but at a price, which is sound cancellation.

There is a problem with the waveforms of the mid-bass and tweeter step response[3]. The tweeter step response looks rather like a single cycle waveform, with the second half of the cycle sometimes being larger than the first half. So if you align the leading edges, this second half causes partial cancellation of the mid-bass waveform.

The result is a poor waveform. This translates into an uneven frequency response. Furthermore, this cancellation will

change as you go off-axis, giving a lumpy off-axis response. So the dilemma is that with no tweeter setback, there is too much delay dispersion, and with complete setback, a poor frequency response.

An answer is to use a tweeter setback of 100µs less than complete, or, in this case, 110µs (1.5″) of tweeter setback. This gives the tweeter step response time to settle (mostly) before the woofer step response gets going (mostly), yielding a step response and frequency response that are mostly unmarred[4]. Specifically, for the drivers chosen I measured less than 1dB in frequency response changes because the delay dispersion was reduced to 100µs by moving the tweeter back 1.5″. Granted, results will vary with different drivers, and lower crossover frequencies will need a larger tweeter setback.

Tweeter setback works for any crossover, improving delay dispersion. A popular choice is 0.75″, but it is usually not optimum.

The 24dB per octave L-R crossover is not the best choice for low delay dispersion. Lower order filters would have less mid-bass delay. A Bessel filter would result in a more uniform delay. But I prefer the results with the 24dB per octave L-R crossovers, because their faster rolloff gives less acoustic interaction between the mid-bass and tweeter. By using tweeter setback, I can get steep slope crossovers and a desirable delay dispersion.

To measure delay dispersion I feed a step waveform, or a 2Hz square wave, to a loudspeaker. I use a step generator (of my own design) to generate the step, but a Sound Strobe, or even a function generator generating a square wave at 2Hz, will do as well. Any measurement mike (including those in the Radio Shack sound level meter) will do. The oscilloscope you use to measure delay dispersion should have a delayed sweep and good brightness.

For frequency response tests I use a pink noise generator and Real Time Analyzer (RTA) and the same measurement mike. I usually put the mike just in back of the chair I sit in, which is 72″ from the loudspeaker under test. I don't put much faith in the measurements below about 500Hz, because the room response will cause peaks and valleys in the RTA.

You can use passive crossovers with tweeter setback, but I prefer active crossovers because of their ease of experimentation. I like the Behringer DCX2496, which is digital, very flexible, low noise (both mechanical and electrical), and small. I try to use digital processors sparingly, because I have had problems with digital processors when I ask them to do too much. For example, I could generate the tweeter setback with the DCX2496, but I prefer to mechanically move the tweeters back the 1.5″. I appreciate the digital world, and I am glad I helped it to come along in my lifetime, but as they say, it takes a digital device to really screw up your signal.

Why not use setback for subwoofer/mid-bass? The answer is that the subwoofer/mid-bass crossover is about 100Hz, and the driver imperfections have much smaller consequences at 100Hz than at 3.5kHz. An imperfection (such as the center of sound radiation) might cause 1″ setback at 3.5kHz, which is a significant 92° of phase shift at 3.5kHz. The same 1″ setback will cause an insignificant 2.6° of phase shift at 100Hz.

## A Step Forward

By Dennis Colin

There's something about live percussive sounds that grabs your attention even if the source has been reflected or diffracted around obstacles. For example, a spoon dropped in another room, a fire engine bell heard from inside your car, or a neighbor playing drums—despite the long path colorations, you *know* it's a real, physical object.

That's because the ear is extremely well acclimated to (therefore, can "tune out") the effects of reflections and diffractions. We still hear the initial attack transient, which if reasonably coherent in time, says, "I'm a *real* spoon, bell, or drum!"

Dick Crawford's combination of time coherence (via tweeter setback) and spatial coherence (via the symmetrical MTTM configuration) should, with well-recorded music, convey a superior sense of realistic immediacy.

Regarding transient response, I would say that Mr. Crawford's "setback" is a "step forward." ■

### CABINET FOR TWEETER SETBACK

I designed a cabinet to accommodate tweeter setback. It is 24″ high × 11.25″ wide × 12.25″ deep. The front panel has two mid-bass and two tweeters in an MTTM sequence[5]. The dual tweeters have the same advantages as dual mid-bass, namely, increased power handling, increased efficiency, lower distortion at the same sound level, and increased vertical directivity. However, MTTM crossovers can become complicated.

The two tweeters are in a cavity (or recess) of 6″ H × 6″ W × 8″ D (internal dimensions). I have built front panels with larger cavities to accommodate larger tweeters, such as planar tweeters.

Of course, you can use this cavity for a single tweeter in an MTM arrangement, and still achieve tweeter setback. This cavity is in the center of the front panel. The mid-bass drivers are mounted at each end of the front panel. There is usually enough room for up to 7″ mid-bass drivers, but you must measure carefully.

I attach the tweeters to a separate bracket (made of wood 1 × 4s), and then I slide this bracket (with the tweeters) in and out of the cavity to achieve the desired tweeter setback. Then you can fasten the bracket in place in the cavity. I then put sound-absorbing foam around the tweeters, which thus have low reflections from the cabinet. You can attach a grille cloth to the front panel.

I use the same size cabinet for a 10″ subwoofer. For the subwoofer, the driver is mounted near one end of a flat front panel (24″ H × 11.25″ W). I then place the subwoofer vertically with the 10″ driver near the floor, and stack the MTTM cabinet on top, giving a 48″ high tower. I put foam rubber between cabinets to reduce vibration. The cabinets should be tied together at the back to reduce the chance of the top cabinet sliding off, crinkling your toes.

**Figures 1** and **2** show a sketch of the MTTM cabinet, along with the wood dimensions. All of the wood widths and thicknesses are standard and available at lumberyards or DIY stores. The front panels are available cut to length at Lowes. The sides are 1″ thick stair treads, cut in half. Stair treads can be in oak,

which is heavy, inert, and attractive.

I have a stereo pair of these loudspeakers, with the following features:

1. They are tower loudspeakers with a small footprint.
2. They are three-way designs with each loudspeaker having a subwoofer, mid-bass, and tweeters.
3. The mid-bass and tweeters are in pairs (MTTM), aligned vertically, which gives me improved power handling, improved efficiency, and some vertical directivity[5].
4. The tweeters can be moved to achieve 100µs delay dispersion.
5. The tweeters are near ear height when seated.
6. The cabinet designs are easy to build and modify.
7. They can play loud.
8. They measure well and sound better.

I like the results so far, but I suspect the MTTM configuration contributes as much as the tweeter setback. *aX*

## REFERENCES


1. Dennis Colin, "Waveform Phase Distortion," *SB* 1/97.
2. Williams and Taylor, *Electronic Filter Design Handbook*, ISBN 0-07-070434—1, Chapter 2.
3. John Atkinson, "Vandersteen Quattro Wood: Measurements," *Stereophile* 12/07.
4. John Atkinson, "Dynaudio Confidence C1: Measurements," *Stereophile* 11/07.
5. John Atkinson, "Dynaudio Confidence C4: Measurements," *Stereophile* 3/07.


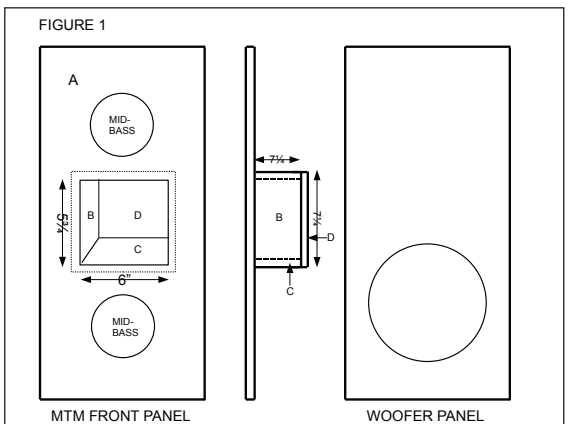


**FIGURE 1: Cabinet shell.**

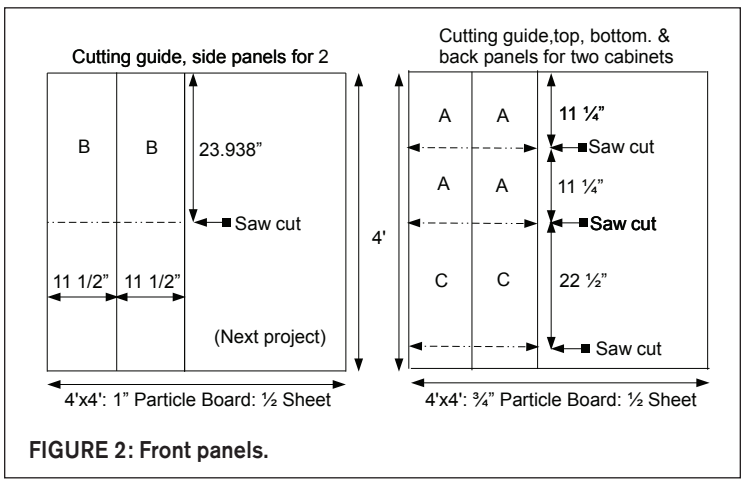


**FIGURE 2: Front panels.**