Testing the Parts Express Dayton Euro Loudspeaker Kit

By Joe D'Appolito

I ran a series of impedance, frequency response, polar response, and distortion tests on the Parts Express Dayton Euro loudspeaker kit built by the Ketlers.

IMPEDANCE

It is my habit in testing these kits to arbitrarily pick one unit of a pair for all tests and then check the second unit simply to match against the first. **Figure 1** is a plot of system impedance magnitude (A) and phase (B). At low frequencies the plot displays the double peaked curve typical of vented systems.

The impedance minimum between the peaks at 40Hz indicates the vented-box tuning frequency (F_b). There is an absolute impedance minimum of 5.4Ω at 375Hz. Over most of the frequency range impedance phase angles range between ±36°. A rather large negative angle of –60° occurs at 85Hz, but the impedance magnitude at this point is 17Ω. I would rate this an 8Ω speaker.

FREQUENCY RESPONSE

Figure 2 shows the full-range frequency response of one of the pair of Dayton Euro speakers. This response is obtained as a combination of the far-field quasi-anechoic response in the free standing position and a set of appropriately combined near-field woofer and port measurements[1]. I placed the microphone along the tweeter axis at a distance of 1.06m to produce the far-field free-standing response. Near-field and far-field responses were then spliced together at 200Hz to produce the full range response[1].

The response data is 1/6 octave smoothed. In the two octaves between 500Hz and 2kHz, sensitivity averages 85.3dB SPL/2.83V/1m. Response varies by ±3dB over the range of 100Hz to 20kHz. The response would be flatter except for the "S" shaped peak-dip of 6dB between 1.5kHz and 2.5kHz. (As you will later see, the second speaker has a much flatter response.) The low-frequency –3dB point is at 58Hz.

The Dayton Euro is not configured for bi-wiring so I could not determine responses for the individual drivers, but the assembly instructions state the crossover frequency is 2kHz.[2]

WOOFER/ TWEETER TIMING

The Dayton Euro step response is plotted in **Fig. 3**, which shows two separate arrivals of acoustic energy. The initial sharper positive spike is the tweeter arrival. It is followed by the woofer arrival—also positive—beginning about 160µs later. The woofer peak is delayed relative to the tweeter peak by approximately 300µs. This is a rough estimate of the tweeter/woofer delay.

Although both drivers are connected with positive polarity, the system is not time-coherent. Notice the "wiggles" in the step response both at the negative-going peak and the woofer peak. This suggests that there is some oscillatory behavior in the speaker response.

CUMULATIVE SPECTRAL DECAY

This is confirmed by the cumulative spectral decay (CSD) response in **Fig. 4**. This waterfall plot shows the frequency content of the system response following a sharp impulsive input at time zero. Frequency increases from left to right and time moves forward from the rear.

FIGURE 1: Dayton Euro impedance magnitude (A) and phase (B).

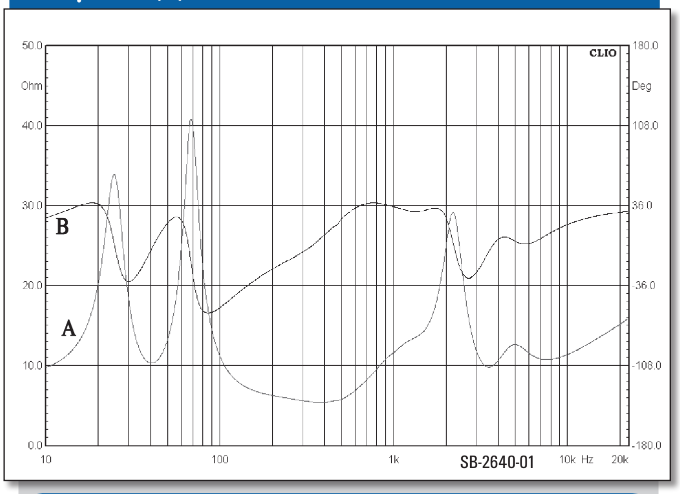
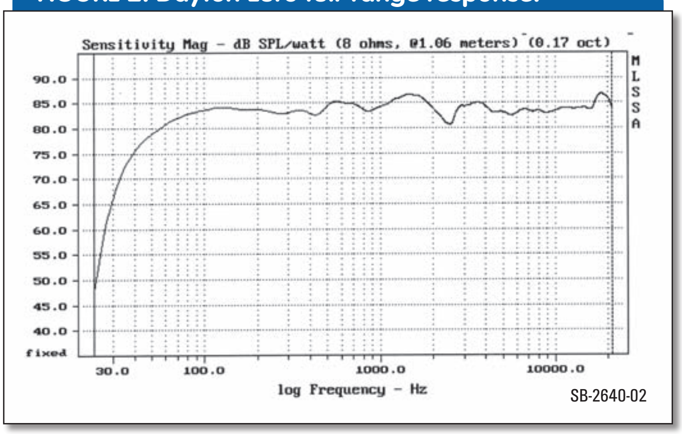


FIGURE 2: Dayton Euro full-range response.



Each slice represents a 0.2ms increment of time. The total vertical scale covers a 30dB dynamic range.

Ideally, the response should decay to zero instantaneously. Real speakers, however, involve inertia and stored energy that take a finite amount of time to die away. A prominent ridge parallel to the time axis indicates the presence of a strong system resonance.

The first time slice in **Fig. 4** (0.00ms) represents the system frequency response. There are major response ridges between 1kHz and 9kHz decaying slowly and extending out to 5ms. Considering the frequency range of this decay, it appears to be coming from both the woofer and tweeter. Compared to other loudspeakers I have tested for *audioXpress*, this is rather poor decay performance.

HORIZONTAL POLAR RESPONSE

Horizontal polar response is examined in **Figs. 5** and **6**. **Figure 5** is a waterfall plot of horizontal polar response in 10° increments from 60° right (+60°) to 60° left (-60°) when facing the speaker. All off-axis plots are referenced to the on-axis response, which appears as a straight line at 0.00°. For this reason, the plotted curves show the change in response as you move off-axis. For good stereo imaging the off-axis curves should be smooth, evenly spaced replicas of the on-axis response, with the possible exception of some tweeter rolloff at higher frequencies and larger off-axis angles.

Within ±30° off-axis the curves are indeed fairly smooth replicas of the on-axis response. The –3dB coverage at 15kHz is ±25°. At 10kHz the -3dB coverage extends to ±35°. This is typical of 25mm dome tweeters. The 60° curve shows the response transition from the woofer to the tweeter starting at about 2kHz.

Within the woofer's active range the worst-case –3dB coverage occurs at 1400Hz and ±35°. This is due to the woofer directivity at that frequency. At ±60° off-axis 1426Hz response is down 7.2dB. By 3kHz the system output has fully transitioned from the woofer to the tweeter. At 3kHz and ±60° response is down only 3.1dB. The response at large off-axis angles is typical of two-way systems.

The average response over a 60° horizontal window (±30°) in the forward direction is a good approximation of the way a speaker will sound in a typical listening environment. This response is plotted in **Fig. 6** (solid line) and compared with the on-axis response (dotted line). The average horizontal response is within 1.1dB of the on-axis response out to 10kHz and is only 2dB down at 15kHz. This is excellent horizontal performance and suggests good direct field coverage in the primary listening area. There will be little change in spectral balance with changing position. Image stability should be very good.

VERTICAL POLAR RESPONSE

Figure 7 is the waterfall plot of vertical polar response. Responses are shown in 5° increments from 20° below (-20°) the tweeter axis to 20° above it. Moving below the tweeter (negative angles), the response changes little from the on-axis curve out to –15°. Recall that the woofer is behind the tweeter acoustically, so as you drop below the tweeter axis you move closer to the woofer, bringing the drivers closer into phase. The opposite happens as you move above the tweeter axis. As shown in **Fig. 7** a deep notch develops just above the crossover frequency, reaching -13.5dB at +20°. Clearly you should be listening at or below the tweeter axis for best response.

INTERMODULATION DISTORTION

In past reports I have listed results for both harmonic and intermodulation distortion (IMD) tests. However, I believe that IMD tests are more revealing of loudspeaker performance. So in this and future reports, I will list only IMD results, which do not directly predict how

FIGURE 3: Dayton Euro step response.

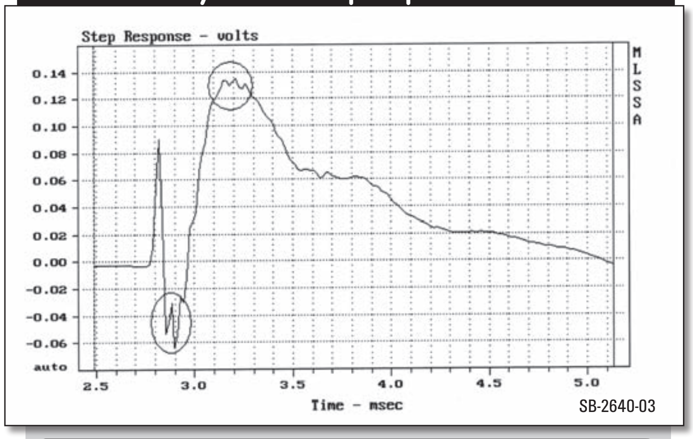


FIGURE 4: Dayton Euro cumulative spectral decay.

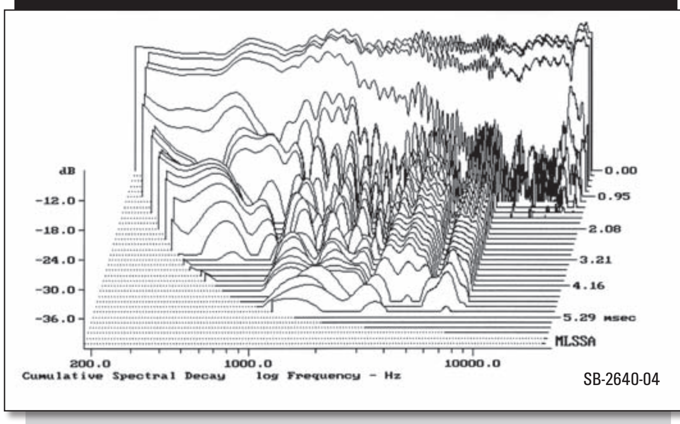
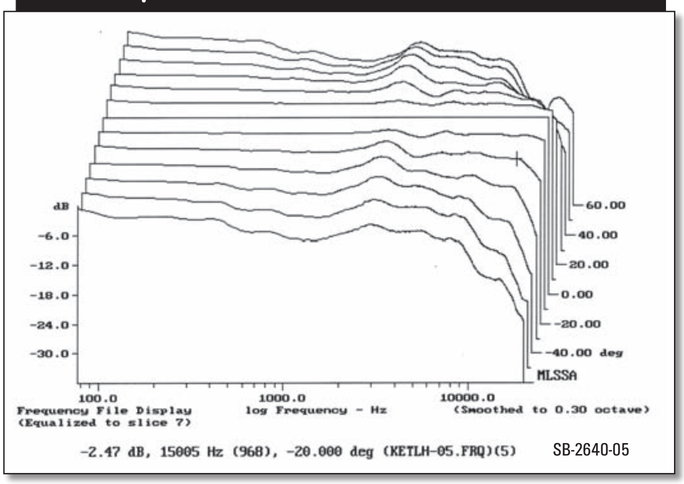


FIGURE 5: Dayton Euro horizontal polar response waterfall plot.



a speaker will sound, but help us judge driver linearity and by implication driver quality. In the next section I'll introduce a new criterion for judging driver quality.

In IMD tests two frequencies are input to the speaker. IMD produces output frequencies that are not harmonically related to the input. These frequencies are much more audible and annoying than harmonic distortion. Let the symbols f_1 and f_2 represent the two frequencies used in the test. Then a 2nd-order nonlinearity will produce intermods at frequencies of $f_1 \pm f_2$. A 3rd-order nonlinearity generates intermods at $2f_1 \pm f_2$ and $f_1 \pm 2f_2$.

First, I examined woofer intermods by inputting 400Hz and 550Hz signals at equal levels. These frequencies should appear predominantly in the woofer output. Total SPL with the two signals was adjusted to 90dB at 1m. **Figure 8** is a plot of the resulting output spectrum. The principal output frequencies of 400 and 550Hz are highlighted on the graph.

In addition to these frequencies you will see many additional vertical lines representing both IMD products and harmonics of the 400 and 550Hz signals. Counting only the IMD products, there are significant lines at 700, 950, and 1500Hz. However, the overall level is only 0.06%. This is an excellent result.

Next, I measured tweeter intermods with a 9kHz and 10kHz input pair adjusted to produce a 90dB SPL at 1m. Results are plotted in **Fig. 9**. The major IM products occurred at 8, 11, and 12kHz. Total IM distortion was 0.068%, a result in line with many other tweeters I have tested.

The last IMD test examines cross-intermodulation distortion between the woofer and tweeter using frequencies of 550Hz and 10kHz, again at a 90dB level. Ideally, the crossover should prevent

FIGURE 6: Dayton Euro horizontal response averaged over ±30°.

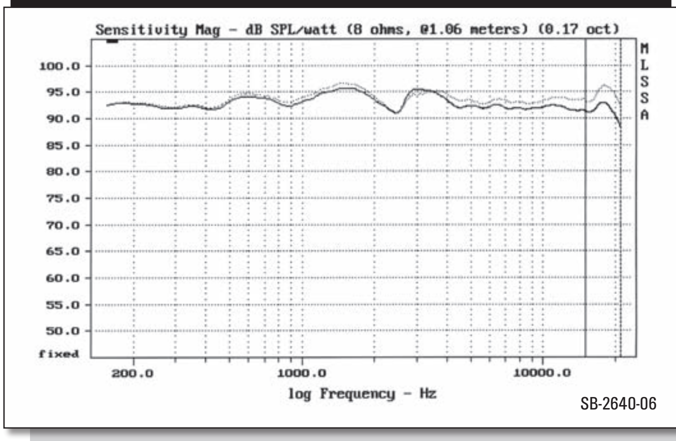


FIGURE 7: Dayton Euro vertical polar response waterfall plot.

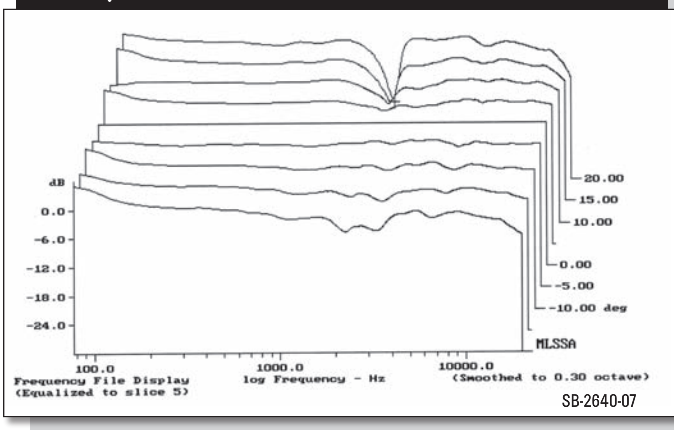


FIGURE 8: Dayton Euro woofer IMD.

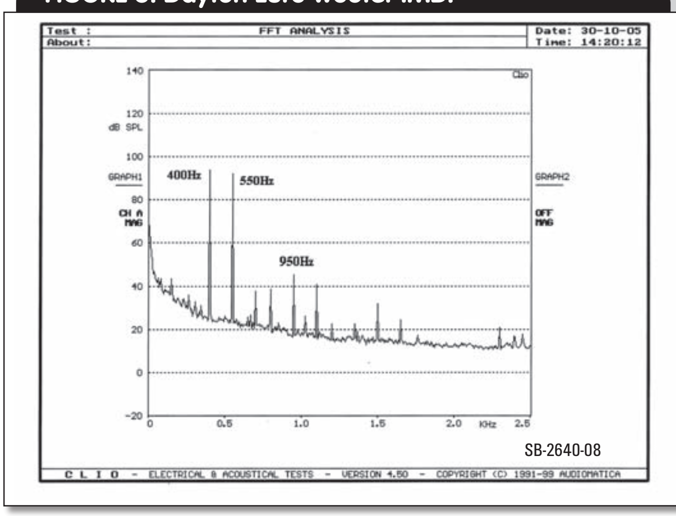


FIGURE 9: Dayton Euro tweeter IMD.

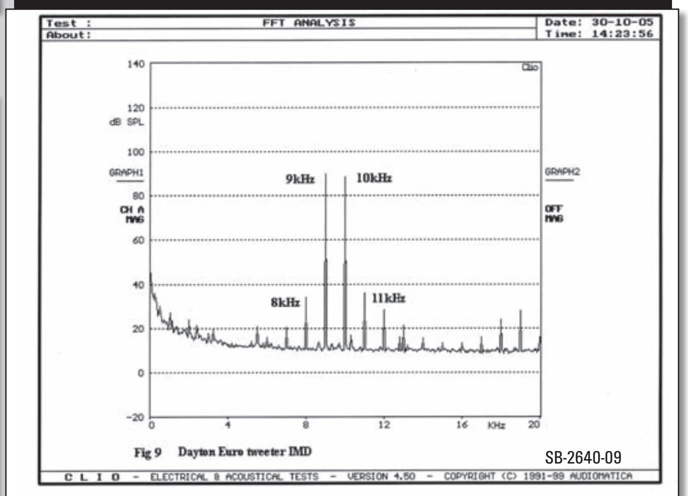
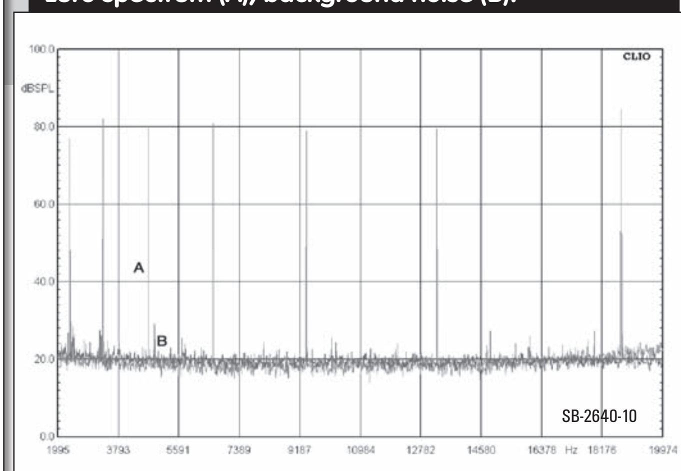


FIGURE 10: Dayton Euro spectral contamination—Euro spectrum (A), background noise (B).



high-frequency energy from entering the woofer and low-frequency energy from entering the tweeter. Tweeter sidebands appeared at 9450 and 10,550Hz at an overall level of 0.056%. This is a very good result and indicates good inter-driver isolation by the crossover.

SPECTRAL CONTAMINATION

This is a new and interesting test of driver performance. When excited by a broad range of frequencies in program material, drivers may produce responses unrelated to the program material. The causes of these spurious responses may be turbulent air velocity in the gap, cavity resonances in the back volume, and mechanical hysteresis, among others. This response is called spectral contamination. You can test for it by exciting the loudspeaker with a spectrum of widely spaced sine waves. Then, analyzing the output spectrum, you look *between* the sine waves to see whether there is any significant acoustic output.

I drove the Dayton Euro with a multi-tone signal consisting of 17 sine waves between 50Hz and 18kHz spaced one-half octave apart. The resulting output spectrum is marked A in **Fig. 10**. The scale has been expanded to show the spectrum between 2kHz and 20kHz. The output sine waves are seen as a series of narrow vertical lines averaging 80dB SPL each. Between the sine waves you see a low-level noise-like spectrum averaging 20dB SPL. Is this noise-like spectrum coming from the drivers, or is it simply the background noise level in my lab?

To answer this question I show the measured background level on **Fig. 10** marked B. Now it is clear that most of the acoustic energy between the sine waves is background noise, and thus spectral contamination is at least 60dB below the program material. This is a good result. Defective or poorly designed drivers often show spectral contamination levels 40dB or less below the sine waves.

FIGURE 11: Matching between two samples of the Dayton Euro.

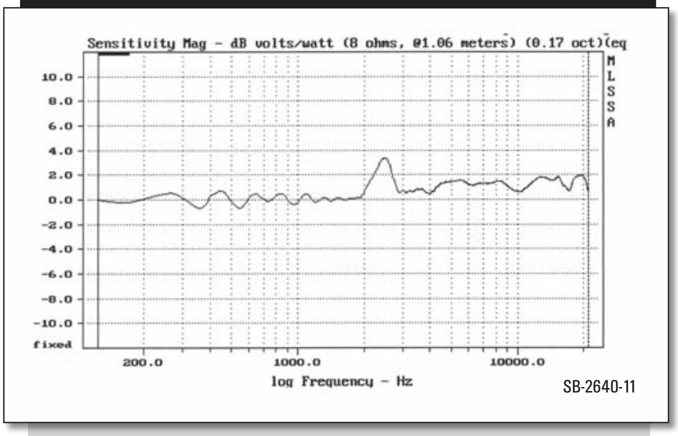


FIGURE 12: Comparing responses of Samples 1 & 2.

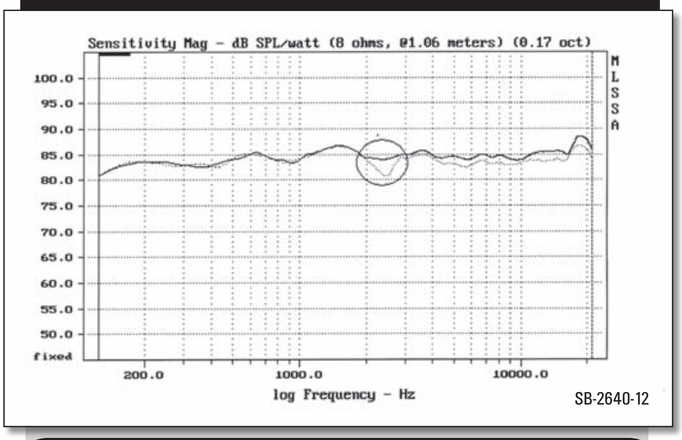
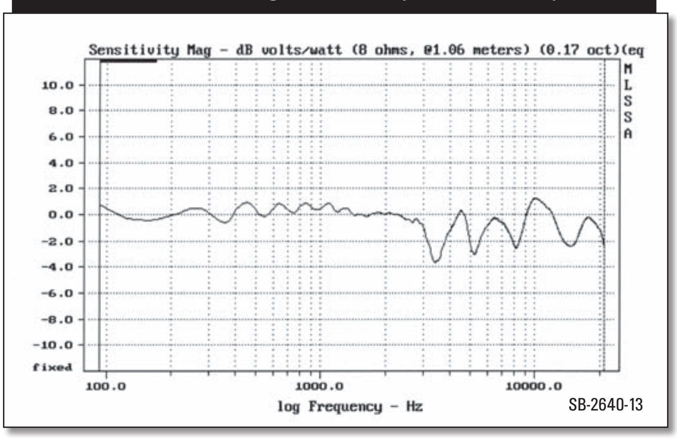


FIGURE 13: Effect of grille on Dayton Euro response.



SPEAKER MATCHING

All of the test results reported so far were obtained from a single sample. Now look at how well the two speakers match in frequency response.

A frequency response plot of the *difference* between the two samples is shown in **Fig. 11**. The two Dayton Euro samples match quite well below 2kHz. Above 4kHz the second system slowly departs from the first reaching a +2dB mismatch at 20kHz. Between 2 and 3kHz you see the mismatch peaking at 3.6dB. Looking at the circled area in **Fig. 12**, you see that the second system is actually flatter than the first. Ignoring the area between 2 and 3kHz, matching is fairly good, especially for a kit.

GRILLE EFFECTS

I conducted all of these tests with the grille off. **Figure 13** shows the Dayton Euro response with the grille on, but referenced to the response with the grille off. That is, it plots the *change* in response under the two conditions. The grille has a fairly substantial effect on response at all frequencies above 3kHz. Overall response variations of +1.6dB to –3.8dB are seen. As usual, the grille is there only for cosmetic effect and to protect the drivers from prying fingers. ***aX***

REFERENCES

1. J. D'Appolito, *Testing Loudspeakers*, Audio Amateur Inc., Peterborough, NH, 1998.

2. Loudspeaker Kit Assembly Instructions: Dayton Euro Series Monitor Kit, Parts Express document.

A note on testing: The Dayton Euro was tested in the laboratories of Audio and Acoustics, Ltd. using the MLSSA and CLIO PC-based acoustic data acquisition and analysis systems. Acoustic data was measured with an ACO 7016 ¼" laboratory grade condenser microphone and a custom designed wideband, low-noise preamp. Polar response tests were performed with a computer controlled OUTLINE turntable on loan from the Old Colony Division of Audio Amateur Inc.