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Why Must an Accurate Speaker System be Time- and Phase-Correct?

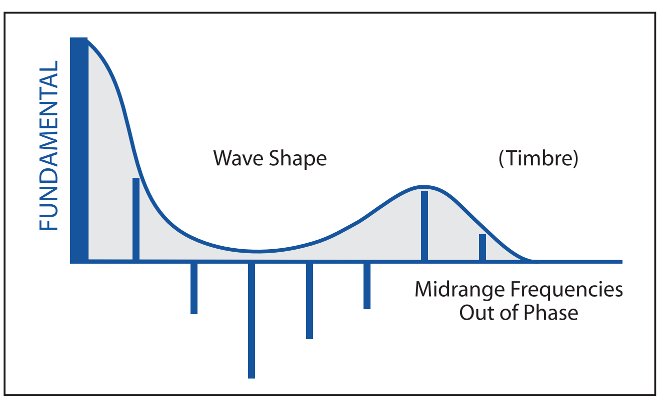
by Richard Hardesty

As described in the articles about frequency response, correct timbre cannot be reproduced by a speaker system that alters the amplitude of any harmonic overtone because that will surely alter the shape of the resulting waveform. The same is true of phase. Reversing the phase of portions of the frequency spectrum changes the shape of the waveform. No audio component—except the loudspeaker—does this.

Stereo imaging is of great importance to some (like me) and couldn't matter less to others. This effect has a more subtle influence on musical realism than the accurate reproduction of timbre but is significantly impacted by the time domain performance of the speakers.

Timbre

The harmonics of real instruments or voices add to or subtract from the fundamental frequency which creates pitch. This results in unique tone called timbre that allows us to identify the instrument or voice. A piano doesn't sound like a violin and Sheryl Crow doesn't sound like Ray Charles even when they each play or sing the same note. The pitch is identical but the timbre—and the waveform—is different.



Arguing about whether an alteration to the shape of the resulting waveform is audible is like arguing about whether a frog is waterproof. Observation provides irrefutable evidence. You can observe frogs in a pond and you can observe waveforms on an oscilloscope. A frog emerges from water completely unscathed and musical instruments produce different waveforms on an oscilloscope. Changing the phase of any wave component alters the shape of that waveform. Period.

Of course we can distinguish between waveform shapes with our ears. How else could we hear timbre and distinguish between various voices and instruments? Helmholtz demonstrated this fact 150 years ago and modern day musicians are well aware of it even if they can't necessarily provide an explanation. Piano tone can be altered by changing the point where the hammer strikes the string because this alters the relationship between the harmonics that string produces. If the piano is in tune the fundamental frequency will not change, regardless of where the hammer strikes the string. If the piano is not in tune it can be adjusted with an electronic tuning device that displays the fundamental frequency (pitch) of each string. The same tuning device can be used with other instruments even though they have unique timbre.

Guitar players can alter the tone they produce by changing the place where the string is plucked or altering the way in which

the string is set in motion (nail, pick or flesh). If the guitar is in tune the pitch stays the same. The switch at the bottom of a Fender Stratocaster changes the electrical phase relationship of the three pickups positioned beneath the strings. This 5-position switch alters the tone of the instrument, not the pitch, which is established by the fundamental frequency of the vibrating string.

Phase does matter and those who suggest that it doesn't probably make speakers which are not time coherent.

Imaging

The effect of phase on stereo imaging is more subtle but can be observed with experience. Time- and phase-accurate speakers produce a stage that is rectangular (as viewed from above) with depth that is apparent well to the sides of that stage and not only at the center. Stage width can extend well beyond the loudspeakers.

Typical speakers produce a stage that is triangular (as viewed from above) with an illusion of depth only at the center and a reduced sense of depth toward the speakers (sides of the stage). Time incoherent speakers will usually define the outer edges of the soundstage. APJ

How Can You Tell if a Speaker System is Time- and Phase-Accurate? *by Richard Hardesty*

Speaker manufacturers and reviewers have presented loads of meaningless misinformation about the importance of phase and you've probably seen dealers or manufacturers meticulously adjusting the position of drivers or speaker tilt-back, as if this has an effect on phase coherence. It doesn't.

Phase shift is primarily the result of crossover filters which divide the spectrum into ranges of frequencies which are directed to appropriate drive elements. Phase shift varies with frequency and can't be corrected by changing the physical position of the drivers.

Driver position can affect the time relationship between drivers because each has a slightly different rise-time and driver position may have a minor effect on cancellation in the overlap region where two drivers are reproducing part of the same signal which has been phase-shifted by the crossover filters.

Speakers with steep filter slopes can't be made time- and phase-correct. Speakers with first-order acoustic slopes will also require that drivers be carefully positioned to compensate for differing rise-times. Read this paragraph again because it's very important.

A time- and phase-accurate speaker will have gentle filter slopes and physically aligned drive elements. One without the other won't do and all talk to the contrary is simply rhetorical. Time and phase do matter and there is a sure way to tell when these timing relationships are correct.

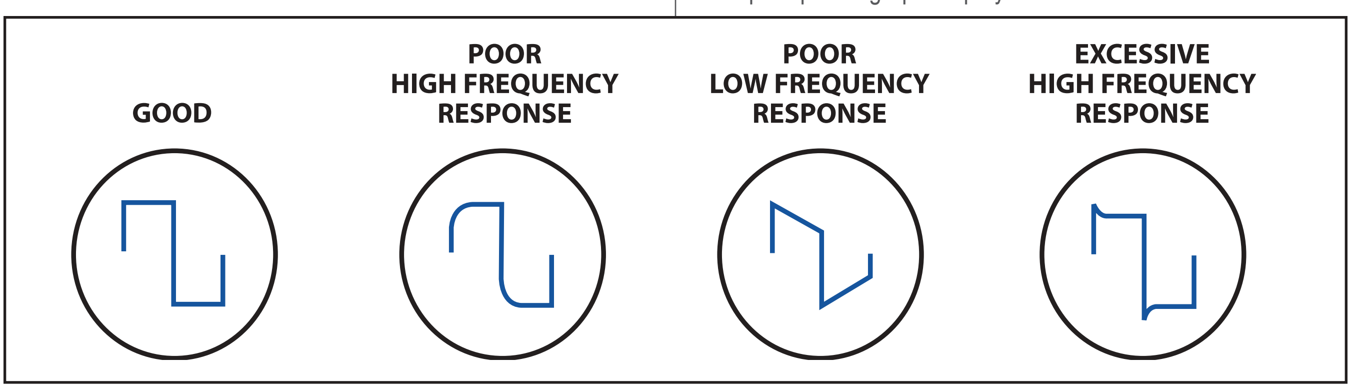
When the Green Flag Drops the Bullshit Stops

The step response graph tells whether a speaker system is time- and phase-accurate, clearly and without ambiguity. If some drivers pull while others push, the speaker is not phase coherent and this will be revealed by the speaker's step response.

A speaker that is not phase coherent cannot accurately reproduce timbre or image correctly. The shape of the step response graph tells all. Here's why.

The Step Response Graph

A step response graph displays time on the horizontal scale



across the bottom, sometimes called the “X” scale, and amplitude on the vertical scale at the left side of the graph, sometimes called the “Y” scale. You can use this graph to determine if the speaker under test is time coherent or if some drivers push while other pull.

The factor important to us is the shape of the output signal, not the increments which may be significant to designers but not to listeners. The step stimulus is like the top half of a square wave or an impulse with extended duration. I’ll try to explain that in the simplest terms possible.

The Square Wave

I’ve heard it said that we don’t listen to square waves but the lowly square wave is the test signal that most resembles music. A square wave, like a musical wave form, is composed of many sign waves—in fact an analog square wave generator creates a square wave by generating a sine wave at the fundamental frequency and adding sine waves for all the odd harmonics. The resulting square wave is a combination of many sine waves with precise amplitude and phase relationships, just like music. If everything is right the result looks square. Deformation indicates deviation—showing that some part of the signal has been altered.

You can learn almost everything about amplifier performance by observing the square wave response. Most speakers can’t even come close to reproducing a square wave because some drivers push while others pull and there can be no output when a drive element is stationary. To gauge the time domain performance of loudspeakers we use the step response instead.

The Test Signal for the Step Response

The step response is actually derived from an impulse correlated from an MLS stimulus but for understanding think of it like an impulse with extended duration or the top half of a square wave. The signal starts at zero, rises quickly to a level that is maintained for a time at a positive DC potential and then returns to zero. The signal never goes negative, which is important to remember. This signal tells you which drivers move in which direction and when, but the speaker can’t produce a step that exactly matches the input signal because there is no sound when the drivers reach maximum excursion in response to a constant current (DC).

Sound occurs as a drive element moves and stops when the drive element stops, even if it stops at the end of a long excursion. Why? Because a stationary driver diaphragm can’t move air and create sound.

If you apply direct current (DC) to a loudspeaker the woofer will be displaced in direct proportion to the amplitude of the current—and stay there until the current is removed. The capacitors that act as high-pass filters for the other drivers will block DC allowing only the upper harmonics to pass. The stimulus exercises the entire speaker just like music, but only momentarily. With computerized test instruments that’s all we need to determine which drivers move to create positive displacement (outward) and which ones are out-of-phase (move inward). These facts are important to know if we want the output waveform to mimic the input signal, which is absolutely necessary for accurate reproduction of the recording.

Step Response

The step response graph shows only the output of the speaker under test. Think of the stimulus like the top half of a square wave. The output from a time- and phase-accurate speaker should look like a triangle above the reference line with a sharp rise and a slow decay. The beginning rise will slope slightly because the step stimulus rises almost instantly (straight up) but the speaker has limited bandwidth and takes some time to rise. (Bandwidth and rise-time are corollaries.)

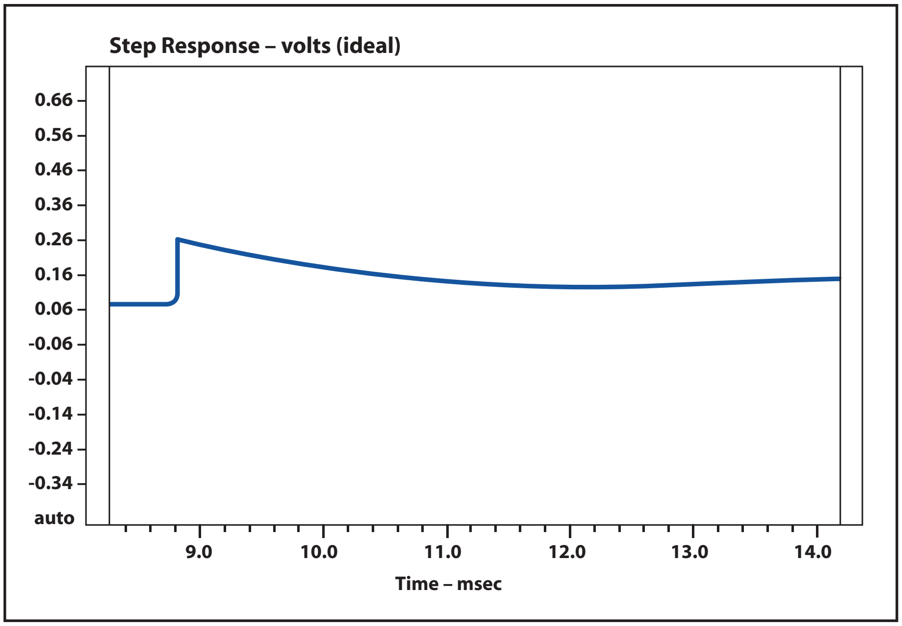
The speaker makes sound as the drivers respond to the stimulus and then output ceases so the signal on the graph decays back to zero, and maybe a little beyond due to inertia (rebound), over a period of a few milliseconds.

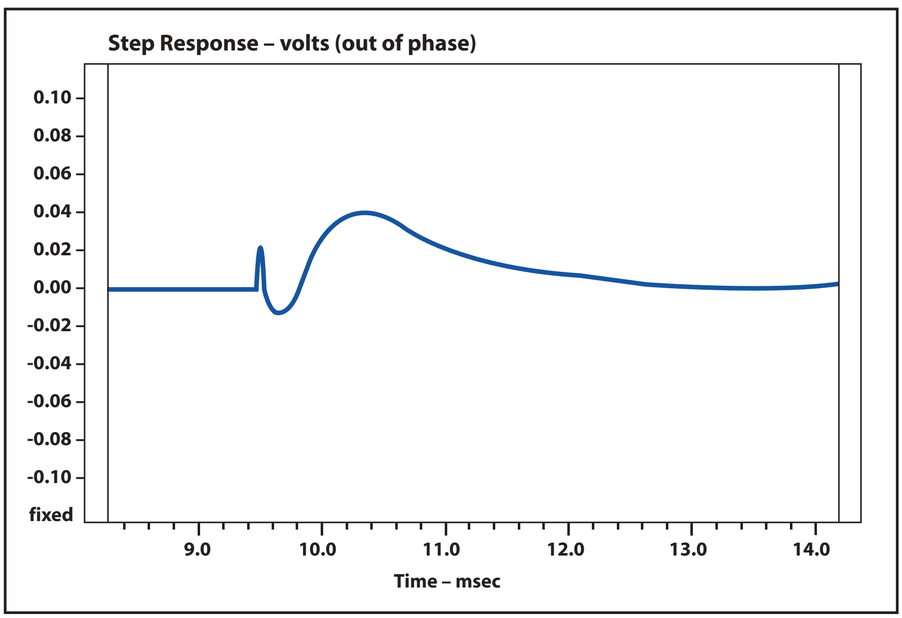
The test signal never goes negative so any significant output that extends in a negative direction (below zero) is out-of-phase. You can’t tell for sure which part of the frequency spectrum is out-of-phase but the output from the tweeter usually arrives first followed by the output from the midrange (if there is one) and then the woofer.

A speaker with a third-order crossover will typically have the midrange driver wired out-of-phase. A speaker with a fourth-order crossover will typically have the drivers wired in phase but their output will be smeared over time and a portion may still go negative due to crossover phase shift.

Examples

The following examples show an ideal step response and the step response from a typical speaker. A step response graph that is not a positive (upward) triangle indicates a speaker that is not time- and phase-accurate. Trying to extract additional





data from the graph is not within the scope of this article or the experience of most readers.

Don't be fooled by the appearance of a speaker or rhetoric from the manufacturer. The step response graph shows which speakers are time- and phase-correct and which ones aren't. Most of them aren't. APJ