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Speakers

PART 2

Introduction

Audio Perfectionist Journals #6 and #7 *have been combined for improved continuity. It took several months to gather this data and write the more than 20,000 words contained herein. Rather than split this information into two consecutive* ***Journals****, I decided to present everything together in a double issue.*

We'll continue the discussion of loudspeaker accuracy and I'll restate some of my views on the importance of accurately replicating the information on the recording. We'll talk about what high quality loudspeakers should cost and about the cost-versus-performance crisis in the industry. A guest writer will share some of his personal experiences with ***Journal*** *readers.*

Previously, we examined some speaker systems which are demonstrably inaccurate and we discussed the reasons why many speakers fail to accurately reproduce the input signal. In this **Journal** we'll examine some speaker systems which are demonstrably accurate, according to all the accepted objective standards.

These speakers have flat frequency response within narrow limits so they don't emphasize some frequencies while de-emphasizing others. These speakers are time- and phase-correct so they won't reproduce some harmonic overtones out-of-phase with the fundamental tones, smearing transient sounds over time.

These speakers don't sing along after the song has ended because they are carefully designed and constructed to minimize electrical and mechanical energy storage and delayed reflections.

These speakers sound better than conventional *"let's put some drivers-in-a-box"* designs yet they cost no more. These speakers can provide more long-term satisfaction than exotic "like nothing you've ever heard before" designs and often cost far less.

Are these speakers perfect? Hardly. Don't all speakers with accurate response sound the same? No, and it would certainly be a dull world if they did.

Each of the speaker brands represented here has a sonic signature that is shared by all models in that manufacturer's line, but the sonic characteristics of each brand are slightly different.

These speakers have the capability of accurately reproducing the input signal, as demonstrated by the objective measurements, but no model described here is completely free of coloration or compromise.

We have discussed how speakers can go wrong but measurements can't tell us everything about speaker sound. Objective measurements can only tell us which products are capable of accurate response and which ones can't possibly reproduce music correctly.

Measurements can clearly show when the design process has failed.

Measurements can clearly show when the design process has failed by demonstrating that a given speaker has gross deviations from flat frequency response or is incoherent in the time domain. While poor measurements can guarantee that a product will

be unsatisfying in the long term, good measurements can only guarantee the *potential* for good sound.

Our ears can still hear a lot more than our instruments can measure and, while much of speaker design is based in science, there is still some art involved.

Each of the three designers profiled in this issue has applied different engineering techniques while attempting to solve the speaker design problems delineated in **Journal #5**. These problems cause speakers to deviate from accurate reproduction of the input signal. All speaker designers must confront these same issues but some have been far more successful in overcoming these challenges. In the articles that follow I'll profile three of the designers who have been the most successful, in my opinion, and describe their individual approaches to the science and art of loudspeaker design. In this double issue we'll discuss design philosophies and in the next **Journal** we'll talk more about the sound of these products.

Before we begin, let's revisit the subject of accuracy and the philosophical arguments for its importance. While I believe that accurate reproduction of the recorded signal is the ultimate goal of a high fidelity audio system, this is an arbitrary position that is not universally accepted.

In The Beginning

In the premier issue I made some statements about the philosophy I would follow in writing the **Audio Perfectionist Journal** and I presented an article titled *Accuracy* that included arguments supporting my position on that subject.

I believe that a high fidelity audio system should attempt to reproduce the recorded signal as faithfully and accurately as possible. Others disagree—even though they might not admit that fact aloud or in print. Many believe that the experience of listening is of primary importance, and how that experience is produced is of little significance. This, too, is a valid position. Here is an analogy.

Viewing a photograph of a beautiful sunset will seldom produce the emotional response of seeing the real thing. While many photographers try to capture the actual scene as faithfully as possible, others strive primarily to create an emotional effect on the viewer. Some feel that the impact of the photograph can be increased by making the colors in the photo a little more "colorful." Others consider the act of viewing a photograph to be an entirely different experience from the act of viewing a sunset. They feel that there should be no limitations at all on how far the photo can deviate from a realistic presentation so long as it produces the desired emotional response. Similar arguments occur in audio.

Some feel that the job of an audio system is to accurately reproduce the recorded information. Those of us who feel this way think that the artists who make the recording should decide how that recording will sound, not the playback system. We assume that the artists and engineers who make the recording are attempting to bring the live performance into our homes so that we can experience at home what they experienced during the actual event.

Some feel that the job of an audio system is to accurately reproduce the recorded information.

Those of us who accept this philosophy believe that the audio system should resolve as much information from the recording as possible and should not impose its characteristics on the sound we hear during playback. We think that recordings should be presented "as is" with no embellishment. There is another point of view.

Listening to music at home and attending a live performance are two very different experiences, in the opinion of some. This viewpoint holds that the two activities have little in common and should be considered separately. After all, the musicians aren't really there in your living room helping to get the audience involved in the music.

Some think that a home audio system needs to present sound that is a little more spectacular than what you'd hear at the live event in order to provide the listener with similar emotional gratification. These folks feel that "goosing up" the response of a home audio system is a perfectly acceptable thing to do. The arrival of home theater has increased the numbers in this camp.

Movie sound doesn't even try to mimic real sound. Everything is exaggerated for effect. That's why most movie sounds are called "effects." Real people don't make that much noise when they walk or when they eat. Romantic moments in real life are seldom accompanied by theme music. Real fists seldom make that much noise when they strike real flesh. There is no "real" standard for sound effects, which were artificially created to start with. THX has added to the confusion about the goal of a home audio system. Should the system accurately reproduce the recorded sound track or should the system alter the recorded information in an attempt to make the living room sound like a movie theater?

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I have found that honesty is the best policy, in audio as in life. I think that an audio system should accurately reproduce the recorded information, whatever that may be. I think that this philosophy provides the best path to long-term satisfaction. This is an arbitrary choice based on my personal experience and others can effectively argue for other points of view.

In The Last Issue

In **Journal #5** we discussed some of the problems that designers face when trying to create an accurate loudspeaker system. The fact that many designers don't even make an attempt at accurate reproduction was mentioned and the reasons why this is true were presented.

In this issue we'll see that some manufacturers do strive for the most accurate reproduction possible and some designers have been very successful in overcoming the inherent problems of accurate electromechanical transduction—changing an electrical signal to an acoustical signal while preserving the amplitude and phase characteristics of that signal.

Journal #5 presented measurement graphs of speakers which are demonstrably inaccurate. This issue will present graphs from speakers which are demonstrably accurate. In **Journal #8** I'll show how some measurements can actually be misleading and we'll discuss the subjective aspects of speaker sound.

There is probably not a more controversial subject than the argument about whether the time and phase characteristics of a loudspeaker are audible. Many "authorities" with PhDs after their names claim to have proven that average listeners cannot hear the effects of phase shift in loudspeakers. While there is no doubt in my mind that these characteristics are audible and important this is still the subject of intense debate. **Journal #5** presented some of my views on the subject. **Journals #6/7 & #8** will present some more. I advise you to read all you can about the subject and then go and listen to make your own determination.

In This Issue

The article titled *Crisis in the Industry* introduces this issue and states some of my motives for writing it and launching the **Audio Perfectionist Journal** in the first place. Many so-called "high-end" speakers cost too much and perform poorly. This article presents some of the reasons for this situation.

The article titled *Time and Phase, Not Just a Craze* presents my views on the importance of time-domain performance in loudspeaker design. This is a very controversial subject and it is not the primary thrust of this **Journal**. If you don't feel that this aspect of performance is audible, please don't abandon the entire issue. There is plenty of other valuable information presented here.

There are three major manufacturers making time- and phase-accurate speakers and there may be many smaller ones of which I am not aware. In this **Journal** I'm going to write about each of the three with which I am familiar, in alphabetical order. I'll discuss the approach that each designer has taken to overcome the speaker design problems delineated in **Journal #5**.

This is not meant to be a sales pitch for these brands. My goal is to enlighten the reader about the technology that is available and about what it costs. In my opinion, most people are paying far too much for speakers and getting far less for their money than they should in terms of performance.

This issue contains the first article contributed by someone other than me. Shane Buettner is Equipment Review Editor of *Widescreen Review* magazine. He has had the opportunity to listen to virtually all the major and many of the minor speaker brands at trade shows, in *WSR's* laboratories, and at home during equipment reviews. He has also spent much time in my home listening to my personal systems. Shane has contributed the article titled *Journey to Enlightenment* that appears in this **Journal**. It's a story of personal discovery that describes one man's path toward musical—and home theater—nirvana.

Coming Up

In **Journal #5** we discussed some objective measurements of loudspeaker performance. Measurement graphs from speakers which are demonstrably inaccurate were presented along with suggestions about how to interpret these graphs. **Journal #5** provided a list of problems which all speaker designers must face. In **Journal #6/7** various solutions to these problems are discussed and the unique approaches taken by three of the industry's top engineers are described. Measurement graphs from speakers designed by these engineers are presented.

In **Journal #8** we'll continue to examine the subjective qualities of loudspeakers. We'll talk about how good measurements can sometimes be achieved at the expense of sound quality.

While good measurements can reliably predict which products will provide unsatisfying performance in the long term, measurements can actually lead you astray in some circumstances. I'll write more about the sound of the speakers discussed in this issue and I'll review some specific models of loudspeakers and comment on their use for stereo and home theater applications.

The information in **Journals #5 & #6/7** is specifically about stereo speakers but the same basic data is applicable to speakers used in a home theater system, although some additional factors must be considered when speakers are used for center channel and surround channel applications. We'll discuss these special surround sound applications in **Journal #8** and beyond.

APJ

The Crisis in the Industry

by Richard Hardesty

*The ongoing crisis in the high-end audio industry was one of my original motivations to launch the **Audio Perfectionist Journal**. It appeared to me that charlatans and snake oil salesmen had overrun the seekers of the sonic truth, converting a once legitimate and vital high-end audio community into an industry promoting poorly engineered and often ridiculously overpriced components. I wanted to speak out about this situation and to offer a voice of reason to those who simply want good sound along with good value for their money.*

I believe that knowledge can be a powerful tool in the hands of consumers. The more you know about how things are made, and about how they work, the less likely you are to be confused by a product review in a magazine; if you understand the products that are being discussed and how these products should be used you are less likely to be swayed by a skillful salesman's polished pitch.

My goal is to provide you with objective, useful information and thoughtful opinions about home audio components and systems. It is impossible to do this from any perspective but my own. *My* ears are attached to *my* head, after all.

While I certainly don't know everything, I have learned a lot about our subject of interest over the years. My opinions are based on my experiences and I can share those with you. I can write about the things that I have experienced and the opinions I've formed, and mention opposing viewpoints that you can research elsewhere. You may come to different conclusions in your own search for sonic satisfaction and that's part of the fun.

In that spirit, I present this issue of the **Audio Perfectionist Journal**. I hope that you will find it interesting and that it will provoke you to read other viewpoints and to go out and listen.

The Early Years

In the beginning, discerning music lovers could buy audio products with acceptable performance at the local chain store, or they could seek out specialty audio retailers where they could often get better sound for the same money. State-of-the-art products were offered to those willing to spend more. "High-end" stores were run, for the most part, by audiophiles

dedicated to helping music lovers achieve greater satisfaction from their home audio systems. They sold products made by specialty manufacturing firms with the same motives.

Better sound for the money was the rallying cry. Of course very expensive products, by the standards of the day, were available there as well but nobody bought them on faith. If it cost more, the dealer usually had to prove that it sounded better. Things are different now.

Today, it is assumed that a high price tag guarantees high performance, and the higher the price the better the product is presumed to be. Dealers often feature just a single product at a given price point and comparisons are seldom allowed and almost never encouraged. A high price is equated with high performance but the facts tell a different story.

Today, it is assumed that a high price tag guarantees high performance.

Price tags are often completely unrelated to the cost of manufacturing the product. Many high-end audio products seem to be made primarily to fleece the wealthy and cheat the uninformed, and this drives away music lovers who might otherwise enter the high-end market. What started with a group of sincere audiophiles trying to make legitimate advances in the audio art has begun to look like a big con game.

The Mass-Market and High-End Audio

Over the years, the sound from mass-market electronic products has been steadily improving and the prices for these products have actually decreased when adjusted for inflation. At the same time, the price tags on high-end audio components have continued to soar ever upward. Many components claiming high-end status offer questionable performance benefits when compared to well-engineered offerings selling for far less. It wasn't always that way.

I was there at the genesis of high-end audio. My former partner, Curtis Havens, and I opened one of the first stores catering to discerning music lovers who were seeking better performance from their home audio systems. We sold Yamaha, Technics and Advent, but we also sold all the top electrostatic speakers including Dayton-Wright, Sound Lab, Quad, Acoustat, Beverage and Martin-Logan. We sold all the top planar-magnetic speakers including Magneplanar, Eminent Technology and Audire, as well as some true ribbons like Sequerra. We sold all the top dynamic speakers like Vandersteen, Thiel, Dahlquist, B&W, KEF, Rogers, Snell, Braun, M&K, Linn and many others.

We sold all the top vacuum tube electronic lines like Audio Research, Berning, Audible Illusions, CAL, Theta (Moffat), and Luxman. We sold all the top solid-state electronic lines like Mark Levinson, Threshold, GAS, Naim, Linn, Audire, CAL, Theta (Sinclair), Proceed, Nakamichi, NAD, Rotel, PSE, PS Audio, Tandberg, Accuphase, and many, many more.

Our goal was to provide the best sound for the money at all price points. That was a common goal throughout the industry in the early days. Value was always a consideration.

Many of the things we sold were expensive but the retail price was always directly related to the cost of manufacturing the product and we could explain why expensive components cost so much. We would disassemble Mark Levinson amplifiers and preamplifiers in front of customers to show a potential buyer why these components cost more. We could demonstrate that our more costly products delivered audibly superior sound by direct comparison. This is almost unheard of today. Value and common sense are rare commodities in our modern world.

Common sense suggests that $10,000 speaker cables cannot be justified on any basis related to manufacturing cost, but Transparent Marketing just introduced a cable that sells for $23,500 for an 8-foot pair (as reported in *Stereophile*)! That report said that it takes two men, two 8-hour work days to make a set of these cables. Imagine that. Well, two highly skilled men worked for a week-and-a-half remodeling my bathroom and I can assure you that it didn't cost $23,500 to complete that job! Who do they think they're kidding?

Speaker cables aren't the only components with exorbitant profit margins. While the prices (in real dollars) of most mass-market audio components have actually decreased in recent years, the prices for high-end audio components have reached levels that would have been unimaginable a decade ago. Whether these incredibly expensive new components actually

perform better than those from the previous decade is a matter for debate. Some probably do, but many certainly do not.

Electronic component parts are better today and cost less. Engineers have learned a few things over the years and a thousand dollars will buy a much better amplifier today than what the same money would have purchased a decade ago. While it will definitely cost several thousands of dollars to purchase a really good solid-state power amplifier, spending $20,000 may or may not buy audibly superior performance. (See my review of the Theta Dreadnaught in **Journal #4** for an example.) Spending big money generally will, however, buy an amplifier made from more and/or better parts. Speakers are different.

Many of today's most expensive speaker models use the same off-the-shelf drivers, and other components, as products that cost far less. Rather than providing superior performance, many of the highest-priced speakers available today are demonstrably inaccurate.

Loudspeaker drive elements are a lot better than they used to be—some technological advancements are real. While the performance capability of speaker component parts has improved and the cost of these components has risen only modestly, the price tags on some models of complete loudspeakers are simply absurd.

You won't get better performance by paying these high prices. In fact, you'll most likely get demonstrably inferior performance compared to better-engineered, lower-cost alternatives. The magazine reviewers, who present themselves as your advocates laud these poorly conceived products and never mention that better sound can be had for less. Often far less.

This issue of the **Audio Perfectionist Journa**l is all about loudspeakers and we're going to concentrate on accurate, high-value speakers here. As usual, I'm going to start right off with some bold and controversial statements.

Real Value versus Perceived Value

If you believe that today's best high-end speakers must cost $20,000 a pair or more, you may be pleasantly surprised to discover that you are mistaken. Anyone who spends that much is paying for something other than performance.

Prestige and "pride of ownership" are perfectly valid reasons for buying things, of course, but the **Audio Perfectionist Journal** is about sound quality and how to get it. The fact is that you can get better sound quality for much less. Notice that I didn't say equivalent sound quality—I said better sound quality. [See Vandersteen 5a review in **Journal #12**.]

No dynamic loudspeaker with a couple hundred dollar's worth of component parts inside should cost $20,000, even if it is properly engineered and meticulously built. Electrostatic and planar-magnetic speakers often have substantially lower manufacturing costs than dynamic systems and should sell for less, in most cases.

Most exotic speakers are neither properly engineered nor meticulously built, as their measurements prove, yet they frequently cost far more than products which are technologically superior and sound better. Making an enclosure from machined *unobtainium* can't compensate for a lack of engineering skill or the performance limitations of off-the-shelf drive elements.

No loudspeaker with a couple hundred dollar's worth of component parts inside should cost $20,000.

The truth is that some of the world's best loudspeakers can be purchased for far less than $20,000. For about one third that price, $6,000 to $8,000, you can buy an outstanding stereo speaker system that will provide demonstrably more accurate performance and better sound than the exotic systems you read about in *Stereophil*e which cost as much as a luxury automobile! Let me give you some examples.

The world's best electrostatic speaker, the Quad 988, sells for about $6,000 a pair in the USA. The same money, about $6,000, will buy a pair of Vandersteen 3A Signature speakers along with a pair of Vandersteen 2WQ powered subwoofers—the stereo speaker system I'm listening to now.

Thiel CS6s and Dunlavy SCIV/As cost about $8,000 a pair. Pay $10,000 to $15,000 and you'll get a little better performance from models in the Dunlavy, Thiel and Vandersteen lines. (It costs a disproportionate amount to squeeze that last five percent of performance from a loudspeaker.) The top models from these manufacturers are dramatically better speakers than the prestige products costing $20,000 to $30,000 and more that get so much press these days.

A speaker system that can deliver a satisfying musical experience for all but the most critical listeners, the Vandersteen 2Ce Signature, can be purchased for about $1,500 a pair. The 2Ce is a time- and phase-accurate, floor-standing, four-way, "baffleless" design that has broader bandwidth and flatter frequency response than the two models of $10,000 a pair speakers that *Stereophile* reviewed in the same issue, along with the 2Ce Signature. (See **Watch Dog #6**.) How can that be?

Are the manufacturers of the overpriced but poorly performing products at the top of the speaker price heap really trying to rip us off? Are the magazines aiding and abetting them? Read on and judge for yourself.

The High-End Myth

Most "high-end" speaker manufacturers don't actually make anything, and many "genius" designers don't actually design the "breakthrough" products they tout. Anybody with a computer can buy software which will automatically design a standard "textbook" crossover network to integrate the output from readily available speaker drive elements. These crossovers can be manufactured by electronic assembly houses that specialize in "stuffing boards." Purchase some off-the-shelf drivers and put them in rectangular fiberboard boxes, along with these simple crossovers, and you're a speaker manufacturer.

You don't even have to make the boxes because you can buy them from large woodworking firms that do nothing but manufacture speaker enclosures.

Get enough press from the influential magazines, which can be easily obtained with a big advertising budget, and you're a design "genius." Charge an exorbitant price and your product may be perceived as a technological breakthrough, especially if you add some advertising hyperbole and have a charismatic company leader with a toothy smile and a good line of BS. A stratospheric price tag will guarantee that your product will be perceived as a high quality offering even if it really isn't.

Think about this folks. Respectable companies like Polk and Paradigm can offer well-engineered, high quality speaker systems for a couple hundred bucks while some high-end speaker "manufacturers" ask $10,000, $12,000, even $20,000 for speakers with no more technology and only slightly higher (in the best cases) component quality.

This **Journal** is an attempt to alert consumers to this egregious situation. My goal is not to sell you Dunlavy, Thiel or Vandersteen speakers. I want to demonstrate that truly accurate, well-engineered and genuinely well-made speaker systems can be had for prices that are fully justified by the manufacturing costs involved.

If you are looking for the most accurate speakers available and want to spend the least amount possible to own them, you will likely choose one of these brands because these three manufacturers are the only major companies making time- and phase-accurate speakers today. But you may find another brand with products that please you more. I won't mind.

You shouldn't spend bundles of money simply because you believe that a greater expenditure will guarantee better performance. Examine what goes into these speakers. Then listen and compare them to other products before you write that big check. Ask a dealer to insert a pair of Vandersteen 3A Signature speakers, or a pair of Thiel CS2.3s, into his highest-priced audio system in place of the more expensive speakers he is probably demonstrating. You may be surprised to find that the sound actually improves as the price goes down.

The following articles present information about three loudspeaker brands in alphabetical order. Each company is well established—Dunlavy for nearly ten years; Thiel and Vandersteen for nearly twenty-five years. Each company is headed by a real engineer who understands the laws of physics and knows the immutable rules of electronics.

Each product line is unique and each line offers a different approach to solving the problems that cause most speakers to deviate from accurate response. All the products from these three manufacturers have some things in common: they sound good, they're demonstrably accurate, and they are reasonably priced. Products from these three manufacturers offer one thing that you won't get from most other speakers: waveform integrity.

The acoustical waveform that comes out of these speakers will look very much like the electrical waveform that goes in when viewed on an oscilloscope screen. You'd expect that from any amplifier. Why not demand the same performance from a speaker system? APJ

Time and Phase, Not Just a Craze

by Richard Hardesty

Is loudspeaker time domain performance audible? Do time- and phase-accurate speakers provide better sound than conventional time-incoherent speakers? Harmon International's Dr. Floyd Toole says no and I say yes, absolutely. Who can you believe?

Toole and others have performed listening experiments which "prove" that average listeners cannot hear the effects of phase shift and time smear. I have personally demonstrated, to a far larger number of people, that time- and phase-accurate speakers can be easily distinguished from speakers with steep filter slopes, even when both types have comparable amplitude response linearity.

This conflict in opinions can be confusing to readers who may not have had the opportunity to experience a properly conducted presentation.

The fact is that nobody can conclusively prove what someone else can or cannot hear under all conditions. Whether others can perceive a given phenomenon, and the relative importance of their perceptions, is irrelevant to us anyway. What matters to each individual is whether certain things are audible to that individual and whether those things make a significant difference to that individual.

You'll have to decide if time- and phase-accuracy is important to you. I can give you some clues about what to listen for and then you can decide if what you hear is worthy of your concern.

This article is filled with rhetoric about why I think that time domain accuracy is an important aspect of loudspeaker performance. I believe that it is. I'll present some logical arguments for my position and tell you what to listen for in your own experiments. In this **Journal** we'll look at graphs of sine waves and resultant combinations of sine waves. In the next issue we'll examine graphs of the output waveforms of various loudspeakers and talk about sound.

History Lesson

More than five hundred years before Christ, Pythagoras wrote the law of consonance for strings. He discovered that there was a physiological reason for the numerical ratios between consonant intervals produced by musical instruments. He described the musical scale and the importance of partials (sometimes called overtones) in determining the characteristic sound of instruments. Nearly twenty-five hundred years before the oscilloscope was invented, Pythagoras knew that musical tones were made up of complex combinations of frequencies.

About one hundred fifty years ago, Hermann Helmholtz listed the three factors which distinguish musical tones. These factors are force, pitch, and quality. Force describes the amplitude of the vibrations which define the loudness of the tone. Pitch describes the frequency of the vibrations or oscillations. Quality describes the type of vibrations or the shape of the waveform they create. The factor of quality allows us to distinguish between a violin, a clarinet, a flute or a human voice, even though all four may sound the same note (pitch) at the same level (force).

Today, many assume that our ears can detect only volume (force) and frequency (pitch). This is clearly not the case. How is it possible for us to hear individual instruments in a large orchestra and to hear the differences in tonal character between one violin and another if our ears can only detect frequency and amplitude? I believe that the answer is obvious.

Our ear/brain mechanism can detect the shape of the waveform that moves our ear drums. Waveform shape is created by the relative amplitude of the frequencies that make up the waveform and by the timing relationships between these frequencies.

It is clear that we can sense how far our ear drums move, which allows us to detect the force (amplitude) of a tone. We can sense the frequency of the vibrations of our ear drums to determine the pitch of the tone. Just how we detect the quality of a tone is not fully understood but the fact that we can is clearly evident.

Helmholtz, in his groundbreaking work *On the Sensations of Tone*, compared the perceptions of the ear to those of the human eye. These sensory organs have very different capabilities. While the eyes can perceive an overview of simultaneously occurring events, the ears are limited to the perception of the result of these events.

Eyes

When a stone is dropped into a pond, concentric ripples (a waveform) emanate from the point where the stone entered the water. When several stones are dropped into a pond, each one creates a unique set of ripples in concentric circles around the point of entry (waveforms).

The expanding circles of ripples from different stones can intersect, and the amplitude of the ripples can add or subtract at the point of intersection. Each waveform can pass through and beyond the others while maintaining its individuality. The eye can perceive all the individual waveforms simultaneously and watch as they cross and continue on.

I have observed this while sitting on a cliff above the ocean and when paddling my kayak in various bodies of water. Waves traveling in one direction pass through boat wakes traveling in another and both continue on as before.

If the crest of a boat wake meets the crest of a wave the level of the water becomes momentarily higher than either (addition). If the trough of one meets the crest of the other, the height of the larger is diminished momentarily by the level of the smaller (partial cancellation). The eye can observe these interactions individually and simultaneously but the ear works differently. The ear, like the kayak, is only impacted by the result.

Ears

Sound waves in the air are like ripples in a pond. The ripples in a pond are made up of crests where the water level is slightly higher than the average level, and troughs where the water level is slightly lower. Sound waves are made up of crests where the air pressure is slightly higher than the ambient pressure, and troughs where the air pressure is slightly lower.

When a crest (higher pressure) strikes your ear drum it moves inward. When a trough (region of lower pressure) arrives, your ear drum moves outward in response to the higher ambient pressure inside your head. The ear drum cannot perceive sound waves propagating across the room like the eye can perceive water waves propagating across the sea. The ear can only detect the pressure fluctuations impinging on the ear drum while the brain records when they occur.

When two sound waves intersect, the pressures combine algebraically just like the ripples on the water. When two or more sound waves impinge on the ear simultaneously, the ear drum moves in response to the resultant air pressure, which is the algebraic sum of the two (or more) pressure waves. How then do we perceive the “quality” of a tone?

Periodic Waves

The ear drum responds only to air pressure. Sounds are pressure waves in the air. Musical tones are complex sounds. Musical instruments produce tones made up of many frequencies.

These many frequencies add up algebraically to produce a sum which can be represented as a resultant periodic wave, as demonstrated by Helmholtz. Virtually everyone accepts the fact that the ear perceives the amplitude and frequency of the air pressure fluctuations created by this resultant periodic wave.

I believe that the perception of quality is based on the shape of the waveform. What else is there that would allow us to distinguish between a Steinway and a Yamaha?

The shape of a resultant waveform is determined by the amplitude and phase of the individual waves that combine to make a resultant wave. To help visualize this, let’s look at some simple sine waves as they appear on an oscilloscope. (Figures 1 through 4 are “screen shots” taken directly from my digital oscilloscope. The sine waves were created by signal generators and the math was performed in the ‘scope. These are actual signal traces, not drawings.)

Figure 1 shows a 100Hz sine wave and a 200Hz sine wave with the higher frequency wave at half the amplitude of the lower frequency wave. This could represent the sound of an

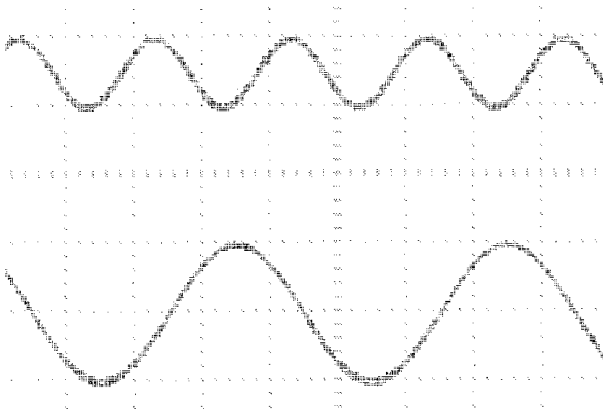


Figure 1

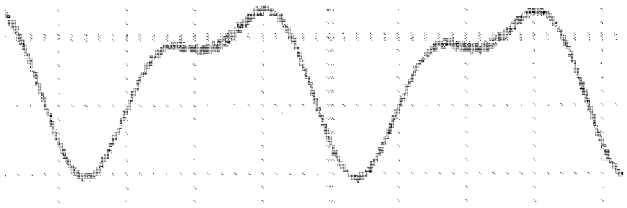


Figure 2

instrumental tone where the harmonic is half as loud as the fundamental with the phase relationship shown (arbitrary).

Figure 2 shows the resultant waveform that would be recorded when the 100Hz fundamental and the 200Hz harmonic are combined algebraically, as they would be by a microphone or the ear. If the phase relationship between the two waves is altered the resultant wave will look (and sound) very different.

Figure 3 shows sine waves at 100Hz and 400Hz with the same 2:1 ratio of amplitude. Figure 4 shows the resultant wave when these frequencies are added algebraically in the phase relationship shown.

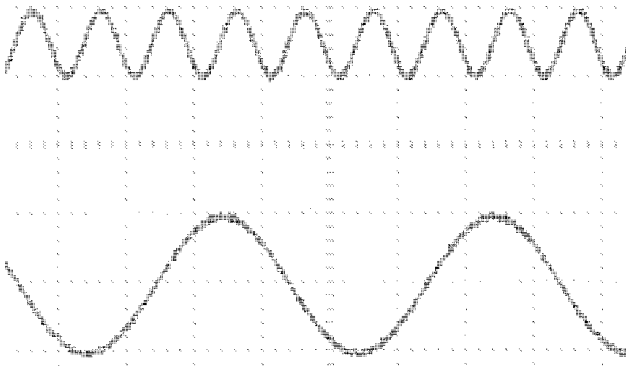


Figure 3

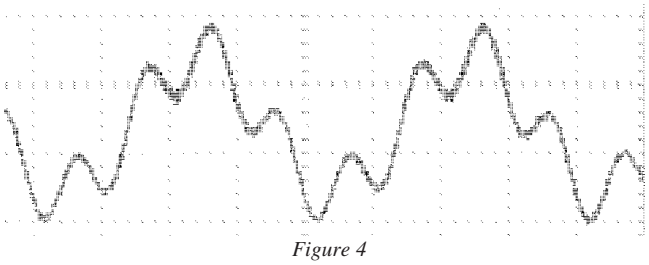


Figure 4

Waveform Integrity

Accurately maintaining the original shape of the waveform is critical if you want to accurately reproduce the original sound. Waveform shape makes a difference in imaging, too. In the next **Journal** we'll discuss these things and I'll show you the signals that come out of some speakers which do maintain waveform integrity and the signals that emanate from some that don't. APJ

Dunlavy

by Richard Hardesty

Dunlavy Audio Labs was founded in 1992, making it the youngest of the three manufacturers we'll examine in this issue. However, speaker designer and company founder John Dunlavy has been around quite a bit longer. He has headed two previous loudspeaker companies—both named Duntech.

The first Duntech was headquartered in Texas and produced a time- and phase-correct three-way speaker system, the DL-15, in the 1970s. The more recent and better-known Duntech speaker company was an Australian firm that made highly-regarded speakers in the 1980s and early 1990s. The Australian Duntechs were similar in design to the current Dunlavy products, which are produced in Colorado Springs, Colorado.

Before entering the speaker business, John Dunlavy designed antenna systems. He is considered an authority on certain antenna types and holds several patents on his inventions in that field.

I have known John Dunlavy casually for many years and I am familiar with his designs going right back to the first one, which I auditioned in my retail store in (I'm guessing) 1978. I was never a Dunlavy or Duntech dealer, but I have visited the Dunlavy factory in Colorado Springs and interviewed John for *Widescreen Review* magazine. I have watched as speakers were built and tested at the Dunlavy facility and I was impressed by what I saw. In this article I'll try to describe Dunlavy's approach to building what he feels are the most accurate speakers possible, and I'll give you my opinions about the strengths and weaknesses of the Dunlavy designs.

Dunlavy Audio Labs makes sixteen loudspeaker models ranging in price from $1,500 a pair to $23,995 a pair (as of June, 2001). We'll concentrate on the six-model Reference Series in this article but other models, like the Cantata and Aletha, are similar in principle and I'll mention how these differ.

The Basics

Dunlavy speakers are "phased array" designs. All models have a single, centrally-located 1-inch soft-dome tweeter and matched pairs of midrange drivers arranged one above and one

below the tweeter. Larger models add additional drivers, which, in most cases, are symmetrically arranged above and below the midrange drivers. Dunlavy speakers are individually measured and adjusted to deliver flat frequency response within narrow limits.

All Dunlavy speakers are time- and phase-correct with first-order acoustic slope transitions between driver elements and stepped front baffles which mechanically align the individual drive units.

All models use sealed enclosure, low-Q bass loading for extended, well damped bass. John Dunlavy chooses soft materials with high internal damping for all driver diaphragms. Edge diffraction is minimized by the use of a thick blanket of felt which surrounds the tweeter in all models and also the mid-range drivers in the larger speakers.

All Dunlavy speaker models share the same basic design and the same tweeter. Each step up from one model to the next provides extended bass response and greater dynamic range.

The $1,500 a pair SC-1/AVs are 2-way speakers with three drivers: one 1-inch tweeter and two 5.5-inch midrange units.

The 2-way, $2,495 a pair SCIIs offer extended bass response and slightly greater dynamic range, when compared to the SC-1/AVs, by employing slightly larger 6.5-inch woofers and floor standing cabinets with greater internal volume.

SCIIIs and SCIV/As are 3-way speakers with dual 5-inch mid-range drivers and 1-inch tweeters. The SCIII uses two 6.5-inch woofers arrayed one above and one below the midrange drivers. SCIIIs sell for $3,995 a pair. The SCIV/A model has two 10-inch woofers arrayed one above and one below the mid-range drivers and sells for $7,995 a pair.

The SCV and SCVI are 4-way designs with symmetrical driver arrays. The $14,995 a pair SCVs have two 12-inch woofers, two 6.5-inch midbass drivers, two 3-inch midrange drivers and a single 1-inch dome tweeter in each speaker. The $23,995 a pair SCVIs utilize two 15-inch woofers, two 8-inch midbass drivers, two 5-inch midrange drivers, and a single 1-inch dome tweeter in each speaker.

The Cantata and Aletha models feature symmetrical arrays of tweeters and midrange drivers with a single, downfiring woofer driver placed near the floor. These models perform in a similar manner to comparable models in the Reference Series except that they have one larger woofer instead of two smaller drivers. The downward-firing woofer allows a front baffle with less width. The Cantata and Aletha models have slightly less dynamic range and deliver sound that is slightly more open than what you hear from their Reference Series counterparts, in my opinion.

Phased Arrays

The “phased array” design has many advantages and some disadvantages, too. Advantages include controlled vertical dispersion, increased sensitivity and added cone area for higher output, especially at low frequencies.

Vertical dispersion is narrowed, minimizing the effects of floor and ceiling reflections. While I consider “floor bounce” to be a measurement phenomenon with little or no negative impact on sound, the multiple-woofer design helps to ameliorate this “problem.”

All Dunlavy speaker models share the same basic design and the same tweeter.

The woofers load the room from different locations, one near the floor and one several feet above the floor, for smoother in-room bass response. Doubling up on drivers increases sensitivity by as much as 6dB because of mutual coupling between driver pairs at certain frequencies. Increased sensitivity allows driver nonlinearities to be corrected, by tailoring crossover components, while keeping the overall sensitivity of the speaker system quite high.

Higher sensitivity, combined with the greater diaphragm surface area provided by pairs of drivers covering the same frequency range, allows the speakers to play louder for increased dynamic range and reduced power requirements. Double woofers move more air at low frequencies allowing the use of sealed enclosures for superior bass performance.

Disadvantages include the large enclosures required to implement the phased array designs and the fact that perfect driver matching is a practical impossibility. The vertical height of listeners' ears becomes extremely critical with dual midrange drivers, too.

Even with close inspection and matching there will be substantial variations in the response of two different drivers, especially those using paper cones. Two midrange drivers with slightly different response curves will have a smoothing effect on the measured frequency response of the speaker. While a perfectly positioned measuring microphone "hears" only the combined output of both drivers in a pair, the ear may detect subtle differences. Even with perfectly matched drivers, the listeners' ears must be exactly equidistant from each of the midrange units, or time smear and some comb filtering will occur.

The enclosures required for the sealed box, phased array designs are larger than what would be necessary for conventional multiway speakers using single drivers for each frequency range. Larger enclosures contribute more unwanted energy to the sound due to larger box panels and larger baffles around drivers.

Larger panels store more energy and resonate at lower frequencies. Larger baffles reflect mid and high frequencies. Both factors cause time smear and tend to make speakers sound slightly more "closed in" and "boxy."

Dunlavy uses felt around the tweeters to minimize baffle reflections and diffraction, and the speaker cabinets are heavily braced with thick panels to control resonance. These attempts to minimize the problems of large enclosures are not entirely successful, in my opinion. The smaller Dunlavy models sound more open, spacious and detailed than the larger ones, to me.

Drivers

The drivers used in the Dunlavy speaker systems are sourced from Vifa/Scanspeak. These are among the highest quality drivers available today, despite what you might hear elsewhere.

All drive elements feature cast alloy frames and ceramic magnets. Every driver used in a Dunlavy speaker is individually tested and each one must meet strict performance standards. Drivers are closely matched and the individual performance data is recorded for future reference, in case a replacement is required.

Cone drivers in Dunlavy speakers use pulp paper-based diaphragm materials loaded with stiffening agents like carbon fiber. The tweeters have soft fabric domes. Dunlavy chooses these diaphragm materials based primarily on impulse response testing.

The choice of diaphragm materials is a matter of intense debate among speaker manufacturers. Advocates of softer, highly damped materials, like those used by Dunlavy, point out that diaphragms with increased rigidity often have large resonant peaks and exhibit ringing. Advocates of stiffer, more rigid diaphragm materials claim that softer diaphragms produce higher distortion because these diaphragms fail to perform as perfect pistons and "break up" at relatively low frequencies. Here are both sides of the story.

Diaphragm Materials

Softer diaphragm materials, like fabric and reinforced paper pulp, have high internal damping and may exhibit few resonant peaks within the usable bandwidth and to frequencies well above the normal operating range of the driver. Resonant peaks which do exist will usually be low-Q and well damped. Impulse response tests on drivers with softer diaphragms will not exhibit the overshoot and ringing that can often be seen when testing drivers using stiffer diaphragm materials.

However, laser interferometry shows that softer diaphragms tend to break up at lower frequencies. Some soft-dome tweeters, for instance, start to break up (perform like imperfect pistons) at frequencies below 10kHz.

When a radiating diaphragm begins to perform less like a perfect piston due to "break up," distortion rises and resolution is diminished. Soft materials absorb some energy that might otherwise become sound, compressing dynamic contrasts and obscuring subtle details in the signal.

Stiffer diaphragms, made from materials like polyamides (Kevlar), metal alloys, and ceramic (actually anodized aluminum), may act more like perfect pistons throughout the normal operating range of frequencies and well above. But at some fre-

quency, even a stiff diaphragm will break up and fail to perform as a perfect piston. When a stiff diaphragm reaches its first resonance or break-up frequency, a sharp resonant peak with a high-Q is often observed.

Within their useful bandwidth, stiff diaphragm materials may exhibit lower distortion and less coloration allowing higher resolution of minute details in the signal. When stiffer diaphragm materials do "go off" there is a tendency for the high-Q resonance to ring over a period of time due to a lack of internal damping.

Which diaphragm material is better, a highly damped substance which breaks up in the pass band or a stiffer material that produces a ringing resonance out of the pass band?

Actually both faults, cone break-up and ringing, cause time smear due to the storage and delayed release of energy. Strong arguments can be made for each of these choices. Dunlavy uses soft materials exclusively, Thiel uses aluminum (almost) exclusively, and Vandersteen uses several different materials for different frequency ranges. You'll have to go and listen to discover which you prefer.

Enclosures

Dunlavy enclosures are rectangular boxes (with the exception of the Alethas, which are hexagonal as viewed from the top). All models have steps in the front baffles to temporally align the drivers. (I can't say "time align" because E. M. Long has trademarked those particular words and effectively taken them out of the English language.)

In all Dunlavy speakers, the tweeter is mounted on a baffle, which is stepped back from the mounting baffles on which the midrange drivers are mounted. Midrange driver baffles are stepped back from the surface on which the woofers are mounted, on models which utilize separate woofer drivers.

Enclosure walls are made from MDF and are internally braced. The larger models have 1-inch thick panels and are very heavy. Dunlavy cabinets are nicely finished with furniture grade veneers and are available in a variety of woods. They look quite traditional—wood veneered, rectangular boxes with grille cloths covering the drivers—and most models are quite large.

Crossover Networks

The crossover networks in all Dunlavy speakers are engineered to provide frequency and phase compensation for the drive elements and to provide first-order acoustic transitions between drivers. All crossover components, internal wiring and circuit boards are of high quality.

The high sensitivity provided by pairing midrange and woofer drivers allows the crossover networks to provide lots of frequency response and phase response tailoring, while maintaining high overall speaker sensitivity. Response tailoring is accomplished by adjusting component values on the crossover boards during design and testing. Individual crossovers are partially assembled and tested, and then matched with a speaker for final tweaking.

Each speaker is placed in an anechoic chamber and measured using this basic crossover. Crossover component values are individually adjusted by a technician until the desired performance objectives for the complete speaker are met.

Quality Control

All speaker components are quality selected and inspected at every phase of construction. Individual drive units are tested, selected, matched in pairs for each speaker and matched in fours for each speaker pair. Individual crossover components are selected and crossover assemblies are tested before final adjustments are performed during anechoic testing. Enclosures are inspected for mechanical integrity and fit & finish.

Every completed Dunlavy speaker is placed in an anechoic chamber and measured.

Every completed Dunlavy speaker is placed in an anechoic chamber and measured. Crossover components are individually adjusted to produce the desired response characteristics. Each speaker and crossover assembly must equal or exceed the frequency response and phase response specifications that

are guaranteed for that particular model. Speakers are built and tested in pairs, and each pair is matched within narrow limits.

Performance graphs are generated for all Dunlavy speakers. These graphs demonstrate that the speakers you receive meet or exceed the advertised performance specifications.

Strong Points

Model for model, the Dunlavy speakers generally have higher sensitivity and greater dynamic range than time- and phase-accurate speakers using fewer drivers. They will play somewhat louder and require somewhat less amplifier power to perform at maximum capability.

All Dunlavy models feature low-Q sealed enclosures. Sealed enclosures provide tighter bass control along with superior bass definition, deeper extension to well below the nominal cut-off frequency, and greater phase linearity with less group delay at low frequencies, when compared to most vented designs. Dunlavys have flatter phase response at low frequencies than time- and phase-accurate speakers which use vented bass systems.

Negative Considerations

The large rectangular enclosures of the Dunlavy speakers, particularly the bigger ones, contribute some sound of their own. Big boxes sound like big boxes, to me.

Dunlavy speakers do not image as well as Thiels and Vandersteens.

The effects of wide baffles can be heard when comparing the smaller models to the larger ones within the Dunlavy line. The sonic price you pay for the extended bass response and increased dynamic range of the larger models is a slightly less open and spacious sound.

Dunlavy speakers do not image as well as Thiels and Vandersteens, in my opinion. Paired midrange drivers tend to blur image focus and response differences between these driver pairs may produce some vertical image wander.

The smaller Dunlavy models have compromised bass output compared to similarly priced products using vented enclosures. Vents allow smaller speakers to deliver higher bass output levels at some frequencies.

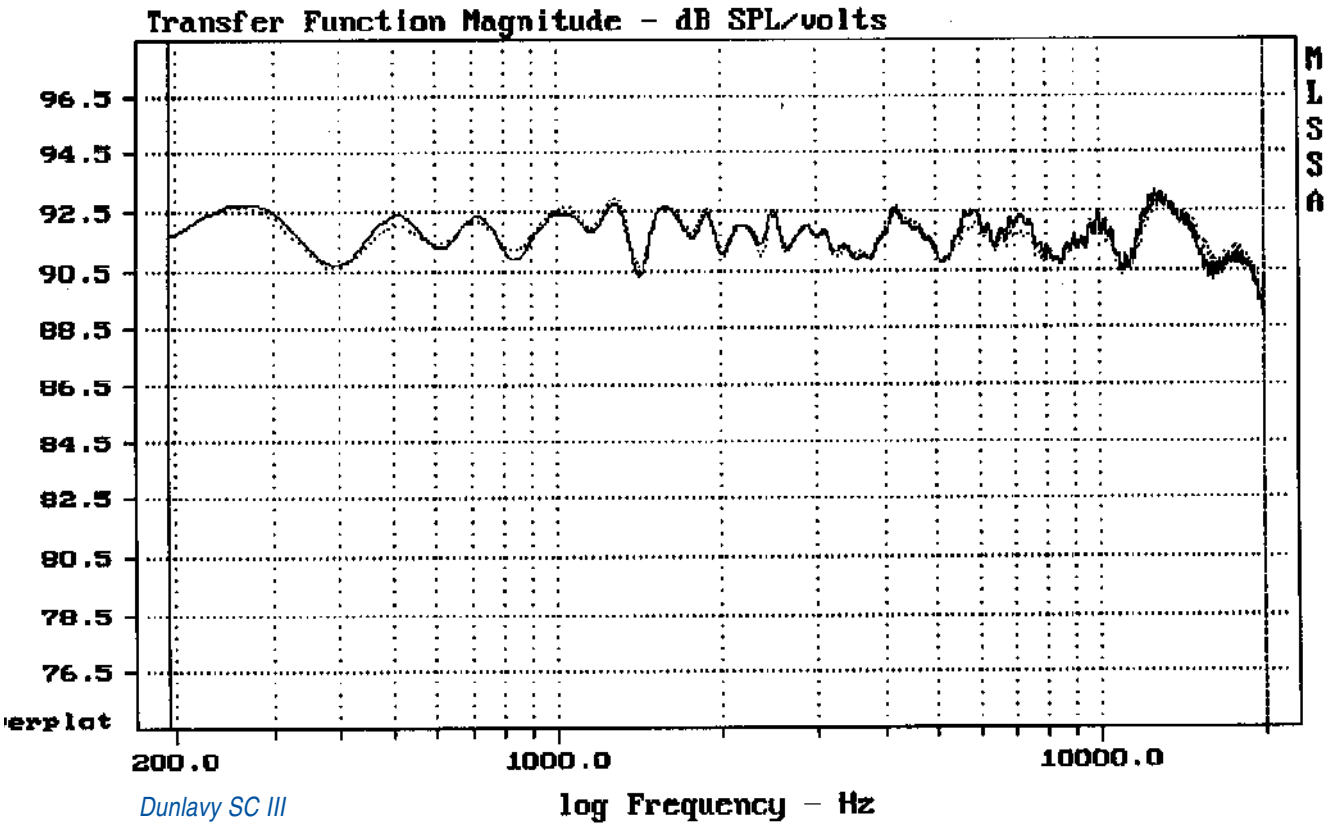
Dunlavy uses soft dome tweeters and comparatively large midrange drivers (in most models), which deliver consistently smooth and musical sound, but some critical listeners may long for higher definition and more midrange detail along with a more extended and airy top end.

Measurements

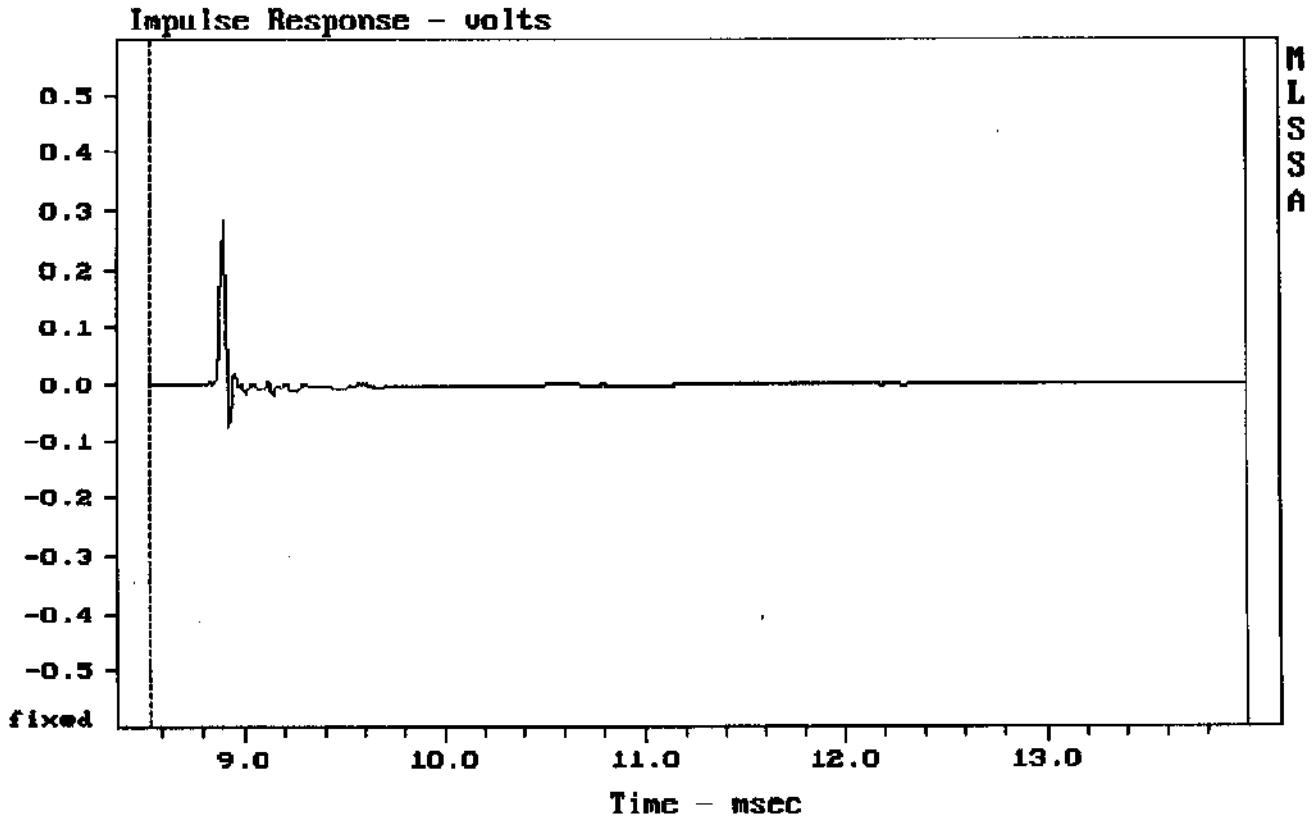
Impulse response is the Holy Grail to John Dunlavy so it's not surprising that his speaker designs perform well when tested with the MLSSA system. And perform well they do.

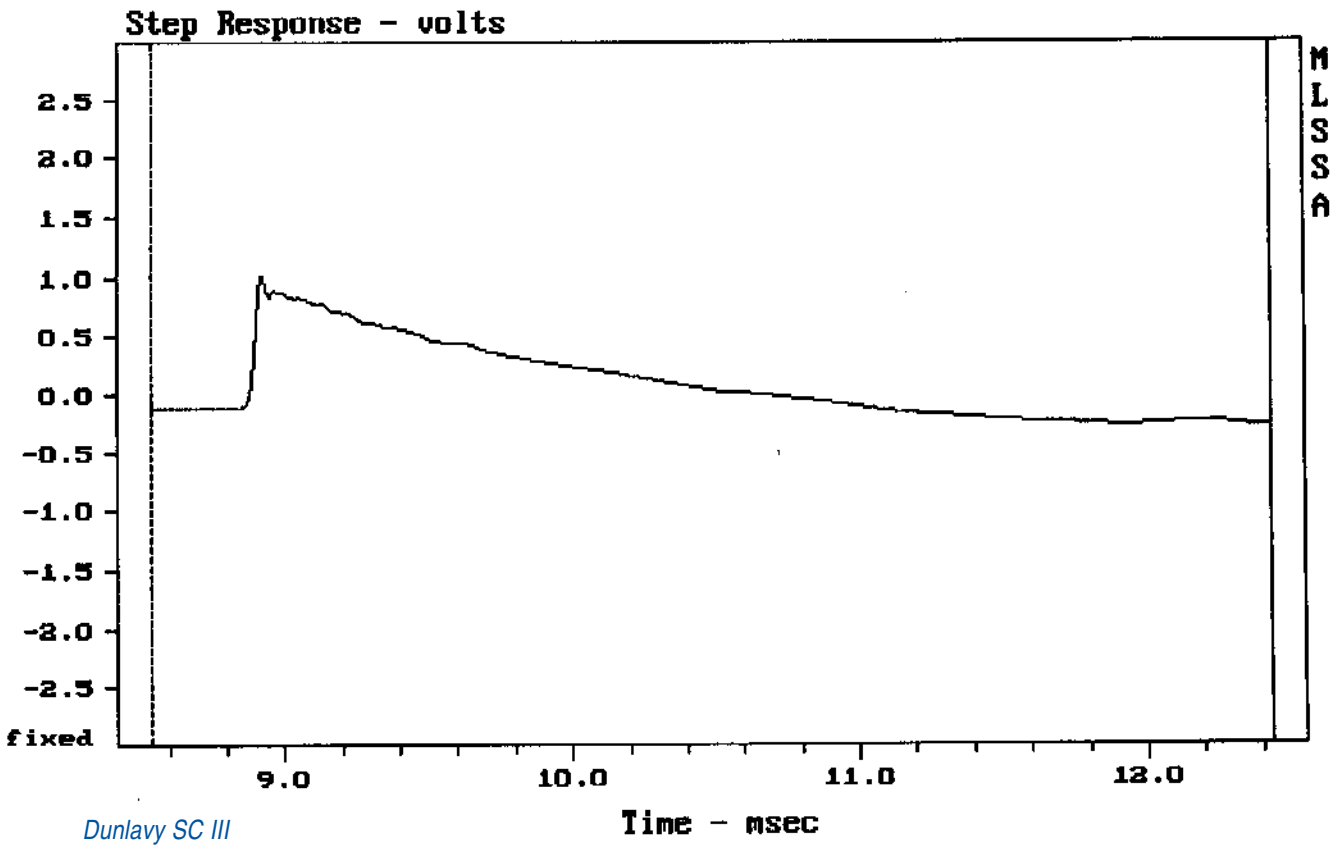
Dunlavy speakers deliver impeccable measured performance on all tests except cumulative spectral decay. Frequency response of the smaller models is guaranteed to be flat within ±1.5dB. The larger models are guaranteed to be flat within ±1dB. Impulse and step response graphs look like textbook examples of ideal time domain performance. Compare these measurements to those of the speakers discussed in **Journal #5**.

Remember, perfect measurements do not guarantee perfect performance. In fact, sonic compromises may be required to produce flawless graphs. In **Audio Perfectionist Journal #8** we'll discuss the things that measurements don't show and I'll tell you how, in certain circumstances, measurements can actually be misleading. APJ

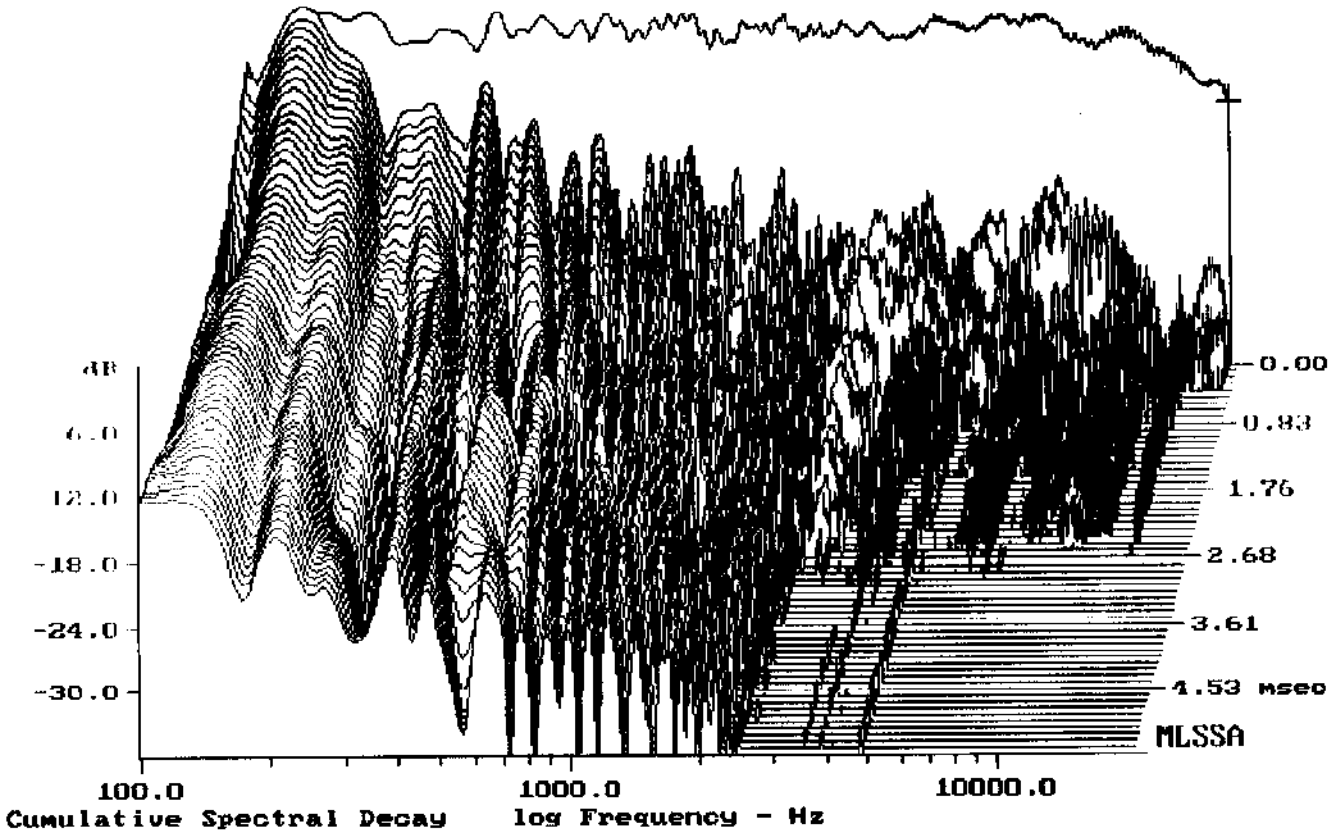


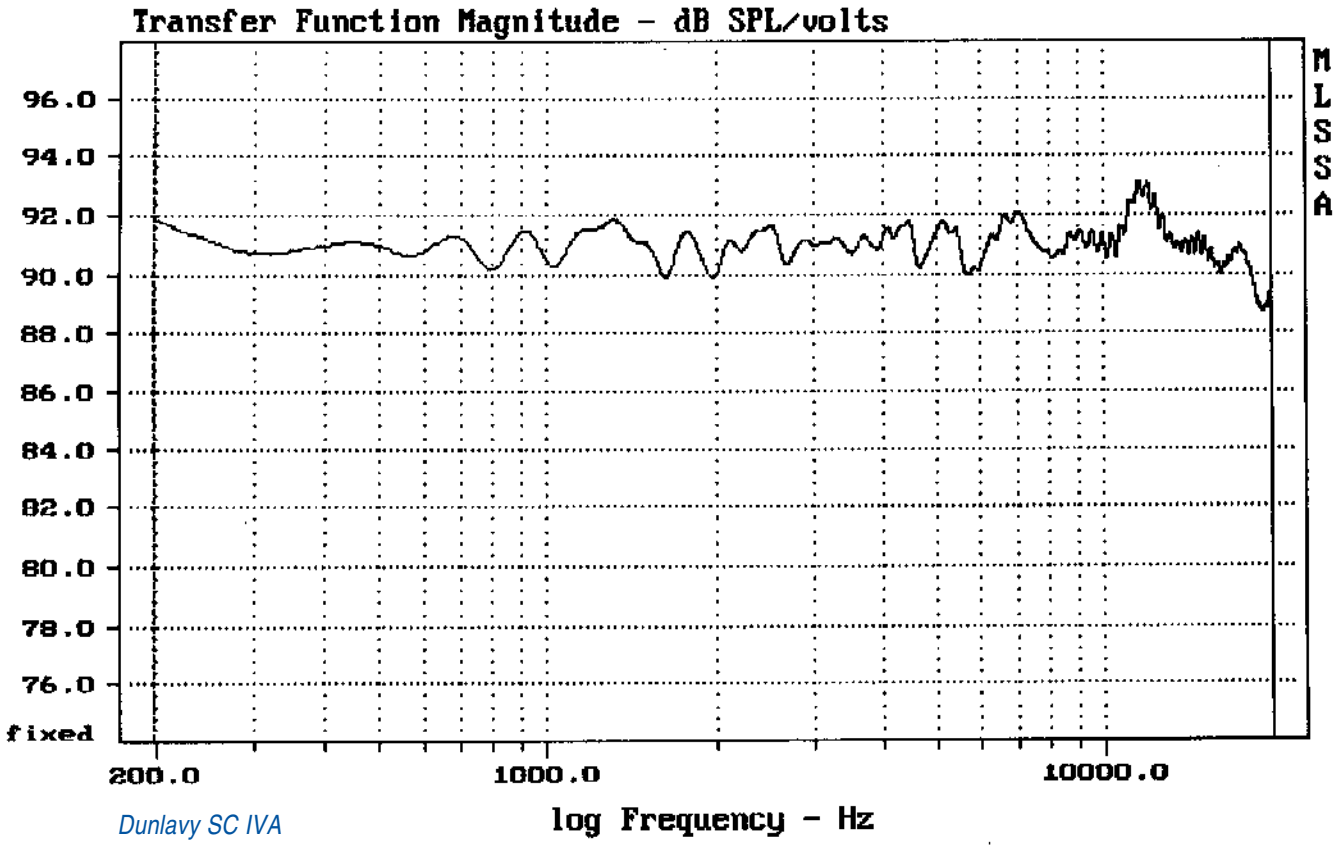
Dunlavy SC III



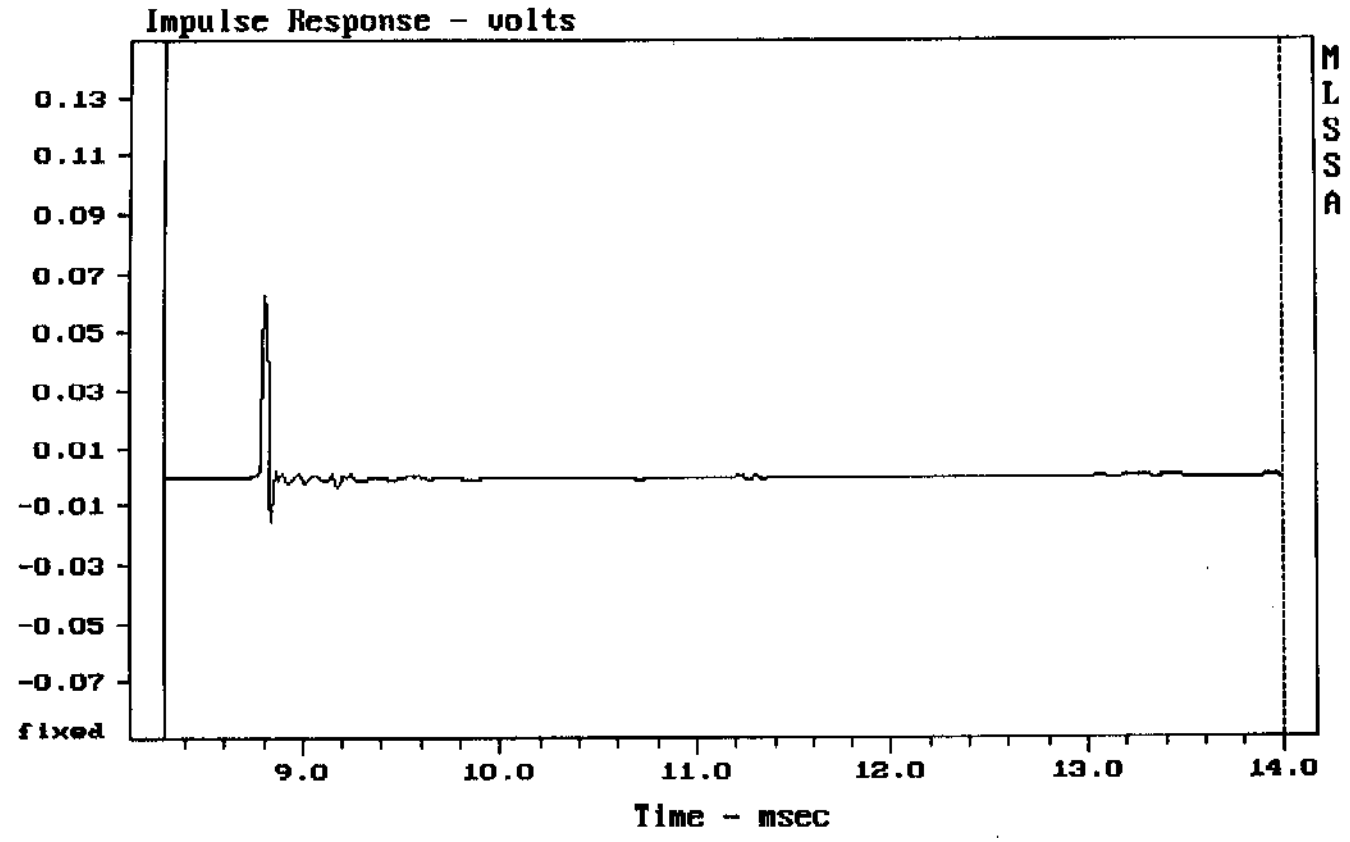


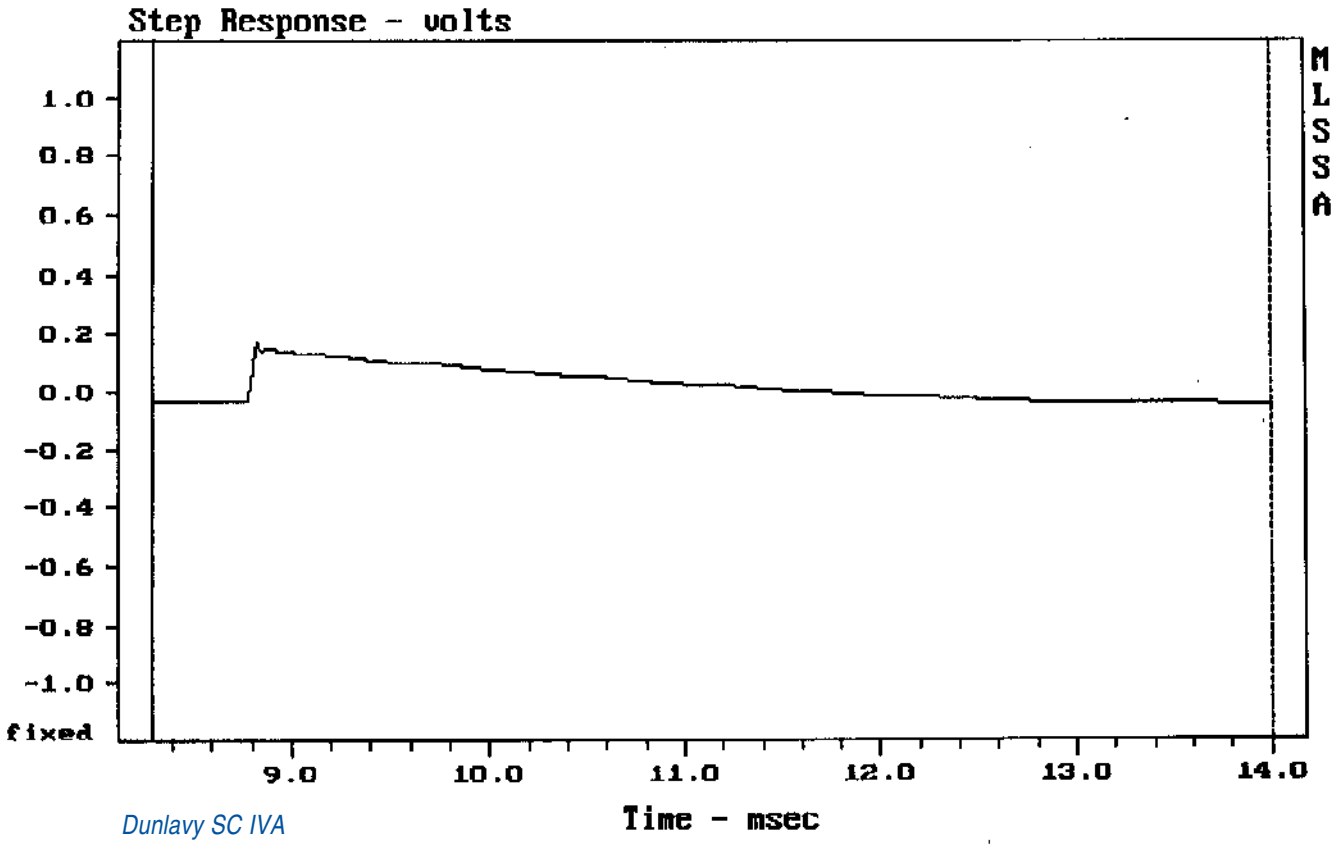
Dunlavy SC III



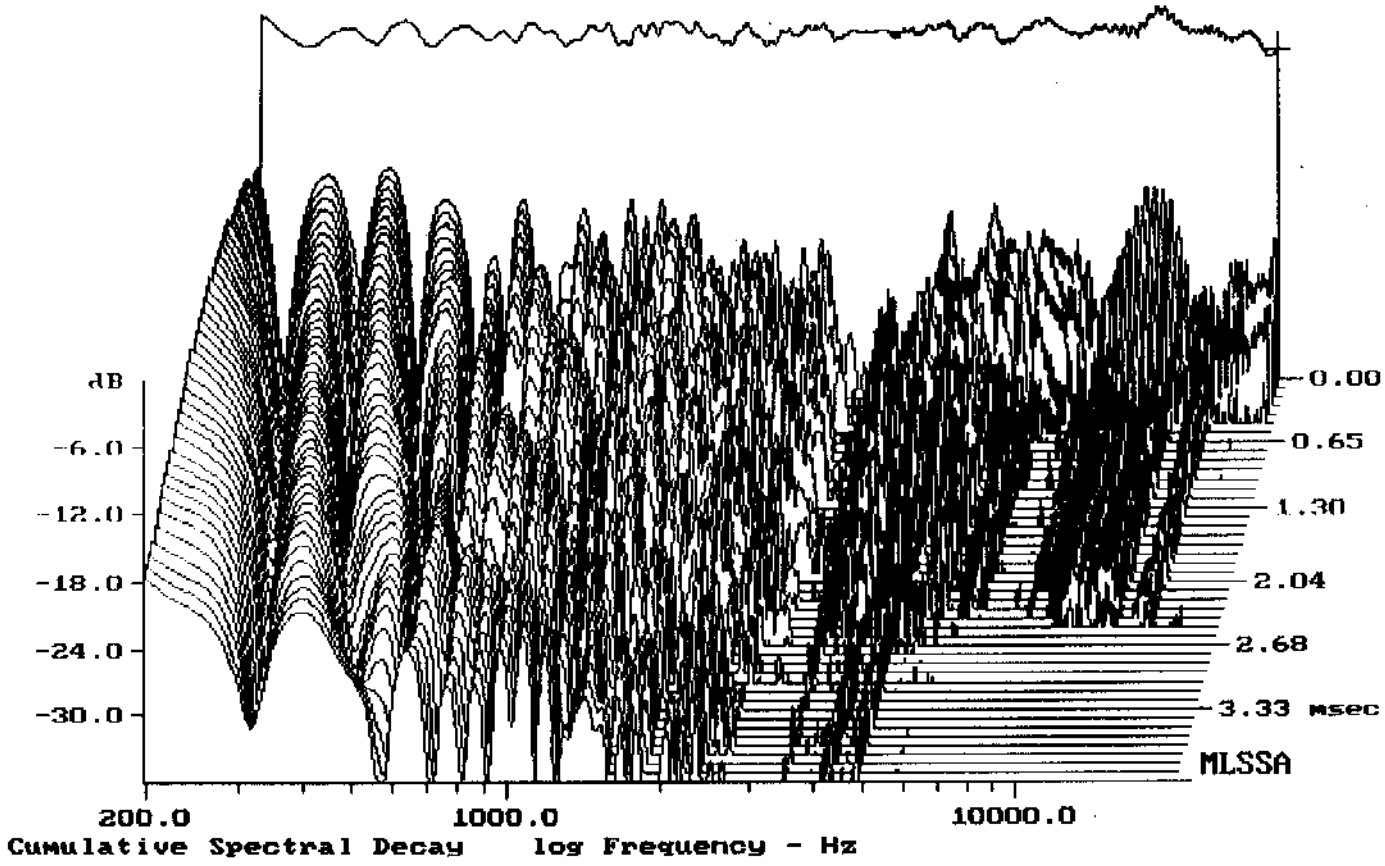


Dunlavy SC IVA





Dunlavy SC IVA



Thiel

by Richard Hardesty

Thiel Audio Products began shipping the Model 01, Jim Thiel's first commercial speaker design, in 1977. Shortly thereafter, in 1978 or so, I became a Thiel dealer and began selling their bookshelf Model 02 and the first time- and phase-accurate Thiel speakers, the 03 and 04. I have closely followed the development of the Thiel Audio loudspeaker line since the beginning, and maintained an ongoing friendship with designer Jim Thiel and company president Kathy Gornik for more than twenty years.

I sold, installed and repaired Thiel speakers in the 1970s and 1980s and I have had much experience with later models in the '90s through the present. (What do we call this decade? The 00s?) I reviewed the CS7 for *Widescreen Review* and used that speaker system to evaluate more than fifty amplifiers for my series on multichannel amplifiers, which ran in *WSR* over a period of several years.

Widescreen Review has a complete Thiel home theater speaker system based on four Model CS6s. I've spent many hours listening to this system and I'll be reviewing it later this year. I personally installed the latest drivers in the CS6s at *WSR* so I've had hands-on experience inside some of the newest models in the Thiel line.

In preparation for this article, my wife Paula and I visited the Thiel facility in Lexington, Kentucky, and spent a couple of days with Jim and Kathy. I wanted to see their new factory and to interview Jim so that I could accurately convey his design philosophies in print. That interview will be published in *WSR* later this year and I'll try to communicate what I learned about the Thiel designs in this article.

Jim Thiel is one of the most innovative and technically astute engineers that I have ever met. I've learned a lot from him over the years and the recent visit to Kentucky was highly informative. When I ask Thiel a question I get a thoughtful answer, not marketing rhetoric. When I ask about a competitor's designs, Jim calmly expresses his opinions and tells me why he has chosen to do things differently.

The Lexington factory is an impressive facility. Thiel Audio Products is one of the largest manufacturers of loudspeakers in the high-end segment of the market. Thirty-five employees work in a modern 40,000 square foot factory, making twelve loudspeaker models ranging in price from $1,450 a pair to $13,500 a pair (as of June, 2001).

We'll concentrate on the six-model floor-standing CS Series in this article but other models, which are aimed more at home theater use, will be discussed in future **Journals**.

The Basics

Thiel speakers are "Coherent Source" designs with sloping front baffles, which temporally align the individual drive elements. Thiel uses unique dynamic drivers with "underhung" voice coils and metal diaphragms. Most Thiel drivers are designed and manufactured in the Thiel factory including all the drivers in the models CS2.3, CS6 and CS7.

Thiel speakers are "Coherent Source" designs with sloping front baffles.

Thiel speakers deliver flat frequency response within narrow limits. All Thiel speakers are time- and phase-correct with first-order acoustic slope transitions between drive elements. The sloped and contoured front baffles, which mechanically align the individual drive elements relative to the listener, also minimize edge diffraction and baffle reflections.

All CS Series models have vented bass loading utilizing either a port or a passive radiator. Jim Thiel chooses aluminum alloy for nearly all driver diaphragms.

Each Thiel model is uniquely designed to provide the highest definition and the broadest bandwidth possible at its price point. Each step up in price buys an increase in dynamic range, slightly higher resolution and slightly smoother response. Low bass capability is improved with each model step.

The Thiel CS Series

The small, floor-standing CS.5 is a 2-way vented (ported) design with a 6.5-inch paper-composite woofer and a 1-inch

metal dome tweeter. The CS.5s sell for $1,450 a pair (slightly more on the west coast). The step up model CS1.5 has a similar driver complement but uses a much more costly woofer featuring an aluminum cone. The CS1.5s employ a passive radiator in place of the ducted port seen on the CS.5 model. CS1.5s sell for about $2,200 a pair.

The models CS2.3, CS3.6 and CS6 are 3-way speakers. The $3,600 a pair CS2.3 has a unique 3.5-inch aluminum cone midrange and a coaxially mounted 1-inch aluminum dome tweeter, along with an 8-inch aluminum cone woofer and a passive radiator.

The CS3.6, which costs about $4,300 a pair, uses a 1-inch aluminum dome tweeter, a 4.5-inch double cone midrange, a 10-inch aluminum cone woofer and a passive radiator. The $7,900 a pair CS6 has a 1-inch aluminum dome tweeter coaxially mounted in a 4-inch aluminum/polystyrene/aluminum sandwich cone midrange, with a 10-inch aluminum cone woofer and a passive radiator.

The flagship CS7.2 is a 4-way design utilizing a coaxial midrange/tweeter unit with a 3-inch aluminum sandwich cone midrange diaphragm and a 1-inch aluminum dome tweeter. A 6.5-inch lower midrange/upper-bass driver with an aluminum cone and double magnet motor system covers the range between the midrange element and the 12-inch aluminum cone woofer, which is complemented by a passive radiator. CS7.2s cost $13,500 a pair.

Drivers

The drivers used in most Thiel speaker systems are designed and manufactured in-house by Thiel. Some drivers used in the smaller models are currently sourced from Vifa/Scanspeak. All drive elements feature cast alloy frames. The woofers and midrange drive units utilize huge ceramic magnets to concentrate flux in the extended magnetic gaps, and some of the coaxially-mounted tweeters use more compact and powerful rare earth magnets.

First-order speakers require exceptional performance from drive units which must exhibit outstanding frequency response and phase performance over a much wider bandwidth than the drivers used in conventional speakers with steep-slope filters.

When even the best off-the-shelf drivers failed to meet all of his demanding requirements, Jim Thiel decided to design and manufacture his own drive elements. All the drivers used in the CS2.3, CS6 and CS7.2 models are custom units, engineered for their specific purpose and manufactured by Thiel.

Thiel Audio staff members have designed and fabricated custom tooling and specialized automated machinery to make the drive units. This speeds development time and allows the designer to test new ideas almost immediately. Jim Thiel can dream up a new cone profile and have a prototype driver, utilizing the new diaphragm shape, ready for testing that same day.

A special tool can be produced by the staff CAD/CAM specialist and a cone can be fluid-pressure formed using this tool in the Thiel Audio prototype shop. The new cone can then be assembled into a complete driver in the factory and hand carried to the laboratory for testing.

Some Thiel driver units are remarkably unique. The coaxial midrange/tweeter unit in the CS2.3 features two concentric metal diaphragms driven by a single voice coil with a mechanical crossover which decouples the larger diaphragm at higher frequencies.

The coaxial midrange/tweeter drivers in the CS6 and CS7.2 have sandwich cones.

The coaxial midrange/tweeter drivers in the CS6 and CS7.2 have sandwich midrange cones made from two outer skins of aluminum with a layer of polystyrene in between to provide the shallow depth required for an ideal tweeter environment (the midrange cone surrounds the tweeter in a coaxial driver) along with the steeper cone angle required for rigidity.

The tweeters in these drivers have unique neodymium magnet structures. Small, powerful magnetic systems are required to provide high flux density in the extended gaps, and coaxially mounted tweeters must have compact overall dimensions.

Jim Thiel prefers to use stiffer, aluminum material for virtually all driver diaphragms. He favors the use of motor systems utiliz-

ing a short voice coil in a long magnetic gap for reduced distortion. He likes coaxially mounted drivers for the upper frequency ranges to minimize lobes in the dispersion pattern and to make vertical listening height less critical. All of these preferences are controversial and I'll try to present the basic arguments for both sides of each issue.

Metal Diaphragms

The controversy regarding softer versus stiffer diaphragm materials was discussed in the article about Dunlavy speakers in this issue. Stiffer diaphragm materials, like aluminum, generally perform as near-perfect pistons over a wide range of frequencies and then exhibit a sharp resonant peak in response. Ringing may occur due to a lack of internal damping.

Jim Thiel feels that his aluminum diaphragm drivers deliver lower distortion, less dynamic compression and higher resolution than comparable drivers with diaphragms made from paper or plastic materials, over the range of frequencies which they are called upon to produce in his speaker designs.

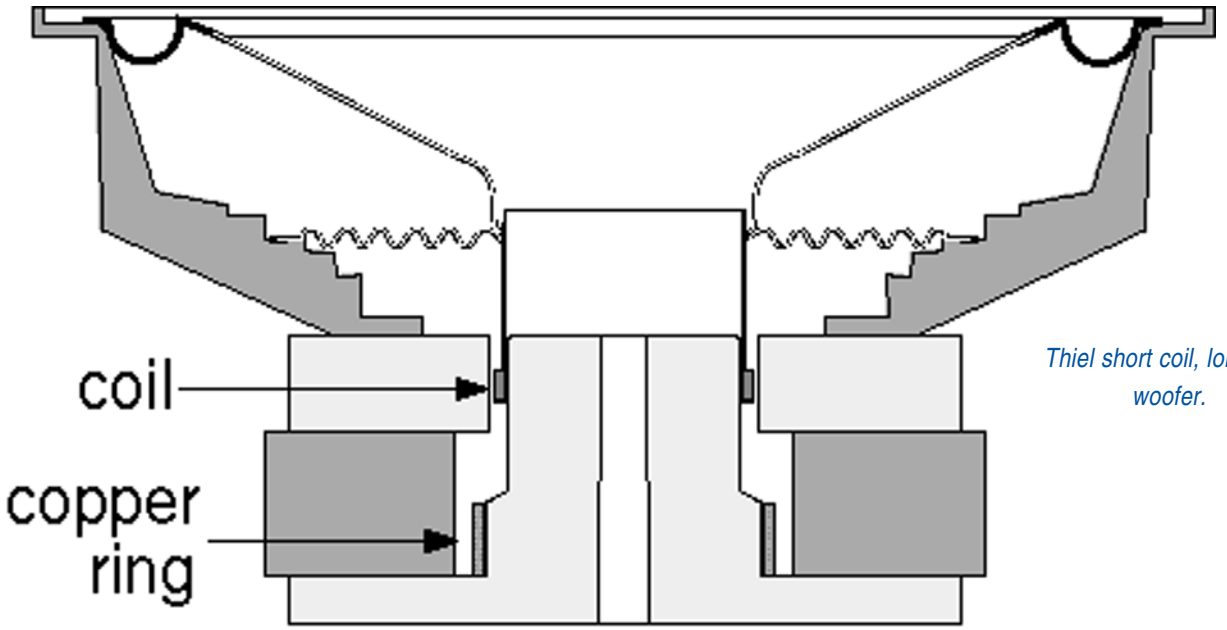
He can design the diaphragms so that the first resonant peak occurs at frequencies well above the range of use and Thiel feels that these out-of-band resonances can be compensated for in the crossover design. The sandwich midrange cones used in the CS6 and CS7.2 models have a layer of polystyrene bonded to the aluminum diaphragms, which helps to damp the metal layers.

Those who favor softer diaphragm materials with more internal damping point to the ringing which can be observed on impulse response tests of metal diaphragm drivers, and speaker systems based on these drivers. They contend that the sharp resonant peaks exhibited by metal diaphragms produce undesirable audible effects even when they are "notched out" by electrical filters. They point out that resonant behavior can be excited by harmonically related frequencies well below the frequency of resonance.

Underhung Voice Coils

The voice coil is the moving element in the motor system of a loudspeaker driver. The voice coil becomes an electromagnet when energized by the signal current from the amplifier.

The alternating electromagnetic field in the voice coil reacts to the fixed magnetic field created by the permanent magnet, front and back plates and the pole piece which make up the non-moving parts of the driver motor system. This magnetic reaction causes diaphragm movement because the voice coil is coupled directly to the diaphragm.



Thiel short coil, long gap woofer.

The diaphragm is free to move because it is attached to the driver frame by two springs—the spider near the voice coil and the surround at the perimeter of the diaphragm.

The voice coil has inductance and inductive reactance varies with voice coil position because the amount of iron in and around the voice coil varies as the coil moves back and forth—toward and away from the permanent magnetic structure. The asymmetrical variation in coil inductance can distort the output waveform.

Placing a short voice coil in a long magnetic gap eliminates much of this distortion by making inductive reactance more linear. Copper sleeves over the pole piece and copper shorting rings around the base of the pole piece help to linearize the magnetic field and eliminate eddy currents which develop in the iron structure of the motor system. These copper parts bring about an additional reduction in distortion. Thiel uses all these distortion-reducing techniques in his custom drive elements.

Huge magnets are required to create an intense magnetic field in the extended gap, and the added cost of the enormous magnet structure is the only drawback to the short coil/long gap designs, according to Thiel.

Thiel uses all these distortion-reducing techniques in his custom drive elements.

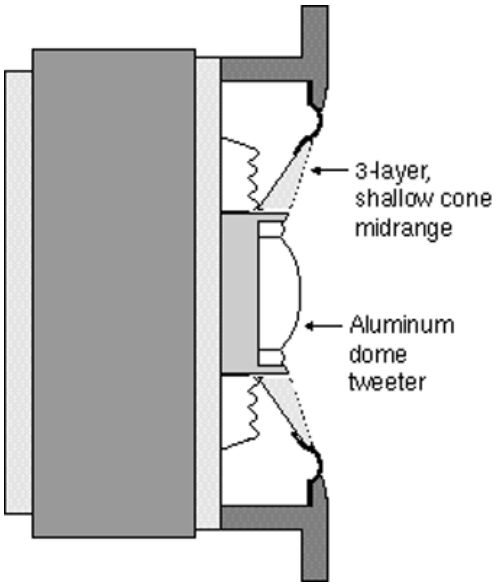
Those with opposing views argue that the short voice coil length concentrates heat in a smaller area which affects reliability and dynamic range, and that shaped pole pieces can effectively reduce distortion to levels that are nearly as low as those achieved with short coil/long gap designs.

Jim Thiel counters these arguments by pointing out that the increased mass of iron surrounding the coil effectively deals with heat build-up and that his measurements demonstrate distortion figures that are much lower than the levels attainable with shaped pole pieces alone.

Coaxial Drivers

The best way to simulate a point source radiator is to make the individual radiating elements truly coincident. Coaxial midrange/tweeter drivers are particularly advantageous in first-order speakers where the large overlap between driver operating ranges shrinks the vertical dispersion window and makes the relationship between speaker tilt back and listener ear height very critical. There are, however, many problems with coaxial drivers.

Mounting a dome tweeter in the center of a midrange driver has deleterious effects on the performance of the midrange unit, and a moving midrange cone is a poor environment for a tweeter. A conventional midrange cone can horn-load a coaxially-mounted tweeter and a deep midrange cone will create a



Thiel CS 6 coaxial midrange/tweeter drive unit.

cavity around the tweeter and add a cavity resonance which may affect response. A moving midrange cone surrounding a tweeter may modulate the output of that tweeter and vice versa.

Conventional coaxial drivers don't perform very well in objective tests or subjective listening experiments. (To hear examples of this, go listen to KEF speaker models using their UniQ coax drivers, or to Tannoy models using their Dual-Concentric drivers.) Thiel has attempted to overcome these problems with unique coaxial driver designs. (To which you should also listen for comparison.)

Thiel's midrange cones are extremely shallow on the surface surrounding the tweeter. In fact, the forward-facing contour of these cones approximates the contour of the mounting flange surrounding the popular Vifa dome tweeter used in some Thiel models.

This shallow cone shape is not very rigid and that's where the sandwich construction comes in. Thiel's midrange cones are actually constructed from two aluminum skins separated by a layer of polystyrene. This three-layer laminate has a shallow contour facing forward and a steeper contour facing rearward to increase rigidity. The styrene helps to damp the aluminum, too.

The Thiel cabinets are much more than structurally inert; they are among the most beautiful in the industry.

The advantage of this construction technique is that the front of the midrange cone becomes a nearly ideal shape to surround the tweeter. However, the midrange cone is still moving and that movement may modulate the output from the tweeter somewhat.

Enclosures

You could duplicate the enclosures of many "high-end" speakers using only a table saw and a router, but you couldn't build Thiel speaker enclosures in your garage, regardless of your woodworking skills.

Even a master craftsman couldn't create the close-tolerance, compound angles and elaborate shapes required without the use of specialized multiaxis, computer-controlled woodworking machinery. Thiel has several such machines which are programmed in-house. These same computer-controlled machines are used to create the tooling that aids the manufacturing and assembly processes for the enclosures and the tooling that is used to form the driver diaphragms.

Thiel speaker enclosures are made from heavily braced 1-inch thick MDF material. All Thiel cabinets are unusually solid and acoustically inert. The contoured front baffles on the smaller models are made from machined MDF material that is up to 3-inches in thickness. Baffles on the CS6 and CS7.2 models are made from a cast mineral/polymer material which has a much higher compression strength than MDF.

Thicker baffles make better sound but increasing the MDF baffles beyond 3-inches in thickness failed to produce beneficial results. The limiting factor proved to be the compression strength of the material itself.

To overcome this limitation, Thiel developed a unique mineral/polymer material that is similar to the cast granite materials used for kitchen counter tops. This material is cast and machined in-house but the high cost prohibits its use on all but the top models in the Thiel line (CS6, CS7.2).

The Thiel cabinets are much more than structurally inert; they are among the most beautiful in the industry. The graceful, sloping design and the flawless wood finish make each speaker an elegant esthetic statement. Thiel speakers are constructed like fine furniture by master craftsmen.

Thiel buys entire flitches of hardwood veneers. A batch of veneer obtained from a single tree will be selected and matched for grain and color so that each speaker in a pair (or more) will be esthetically complementary. MDF enclosure panels are veneered inside and outside prior to machining. All the parts for a pair of speaker enclosures proceed through the factory together and are assembled into finished pieces of fine furniture as a matching set. The craftsmen who build these cabinets are rightfully proud of their work.

Thiel will build speakers with virtually any wood veneer and with just about any finish and they will match cabinets to a customer's specifications. Unusual materials and finishes can cost a lot more but the result is a truly custom product.

Crossover Networks

The crossover networks in all Thiel speakers are engineered to provide frequency, impedance and phase compensation for the drive elements and to provide first-order acoustic transitions between drivers. The crossovers also compensate for the out-of-band resonant peaks inherent in metal diaphragm drivers.

Thiel crossovers are unusual in that they are hard-wired rather than built on circuit boards. Component parts are of exceptional quality. Custom polypropylene and polystyrene capacitors are utilized along with air-core inductors wound with low-oxygen copper wire. Solid-conductor copper wire with Teflon insulation is used throughout the crossovers and between the crossovers and drivers. Silver solder is used exclusively.

Quality Control

Cabinets are inspected at every stage of construction and that attention to detail will be evident to anyone who visits a Thiel dealer and views these elegant speakers. Thiel speakers can be esthetically compared to the finest furniture pieces. Speaker pairs match perfectly.

Crossover components are individually inspected and selected. Completed crossover networks are tested and matched. Each crossover must pass a computerized QC test before it is assembled into a speaker system.

Drivers are inspected at each stage of construction and then individually tested and matched. Thiel magnetizes the woofer magnets after the drivers are assembled because these huge magnets would be otherwise unmanageable. Individual drivers are performance tested before being incorporated into speaker systems.

Each completed Thiel loudspeaker is sweep tested to reveal any buzzes or other mechanical flaws. Then each speaker is placed in an automated anechoic chamber and computer tested for frequency response and phase response. Each speaker must match the performance of a reference standard for that model, within narrow limits.

Strong Points

Thiel builds some of the most elegant and thoroughly engineered loudspeakers available at any price. Thiel makes everything (in the top models) and is not hindered by the performance limitations of off-the-shelf drivers. Thiel speakers have extremely low distortion and high resolving power. They are demonstrably accurate in both frequency and time domains.

Negative Considerations

Thiel speakers cannot be biwired or biamped because they have only a single set of inputs. Beautiful cabinets cost money and Thiels are relatively expensive. (If you visit the factory, as I have, you'll see that the prices are more than reasonable for the quality offered.) Vented bass systems cannot equal the performance of sealed boxes, in my opinion, but subwoofers can change all that.

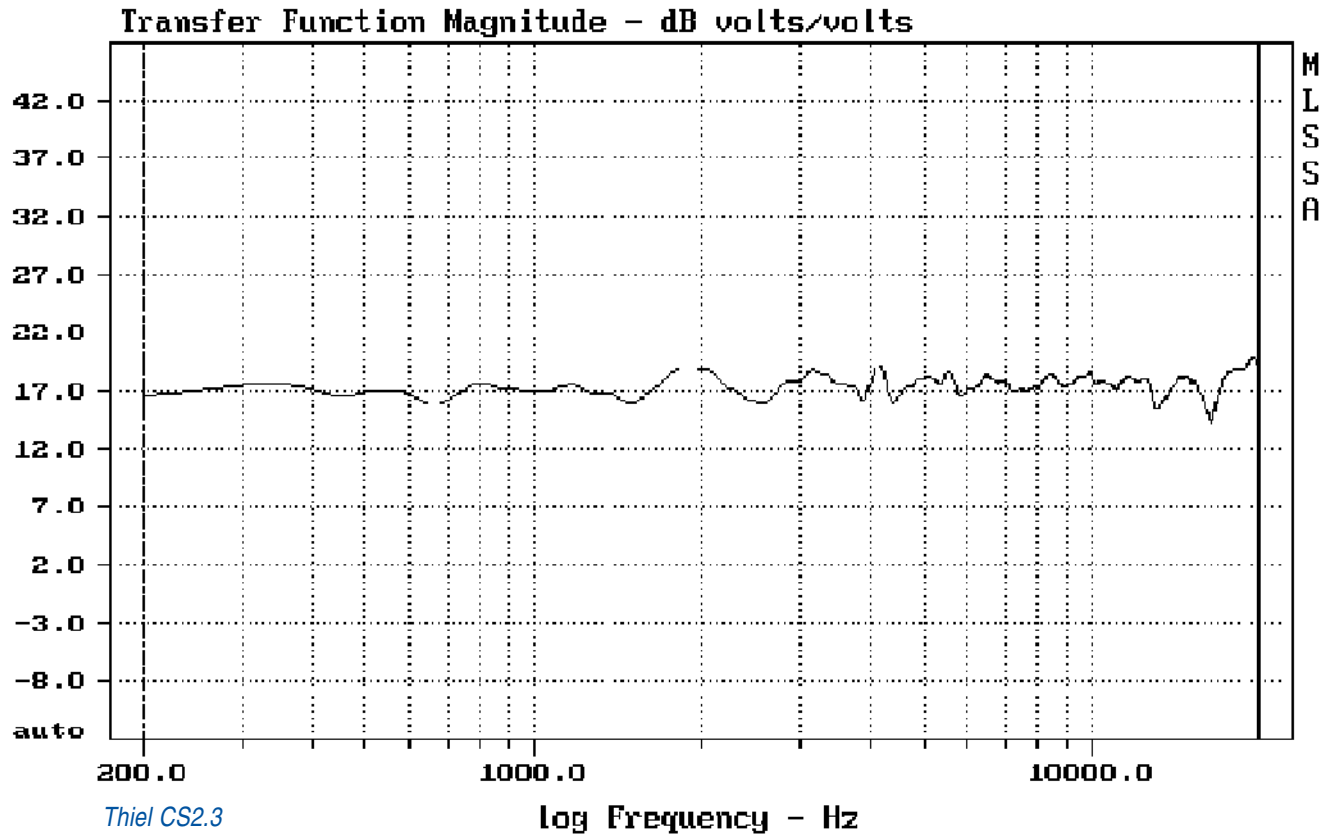
The CS series Thiels have low nominal impedance (dipping to well below 4 in some cases) and are only moderately sensitive. They will require powerful, stable amplifiers for best performance. They won't play as loud as speakers with higher sensitivity and/or crossovers with sharper transitions between drive elements (steeper-slope crossovers).

The most controversial aspects of the Thiel designs are, in my opinion, the metal diaphragms and the coaxial midrange/tweeter drivers. Thiels and Dunlavys certainly sound different. You'll have to listen to determine which is more pleasing to you.

Measurements

The Thiel response graphs demonstrate outstanding performance in all areas. Frequency response is quite linear. (Note that the Thiel graphs have 5dB increments between lines.) The Step and Impulse Response tests show time- and phase-coherence. Some minor ringing is apparent and this is probably due to the metal diaphragm materials used.

Ringing is an energy storage phenomenon that causes time smear. The debate is about whether this minor ringing is a reasonable trade-off for the increased resolution provided by stiffer diaphragm materials. There will be more about this in the next issue. APJ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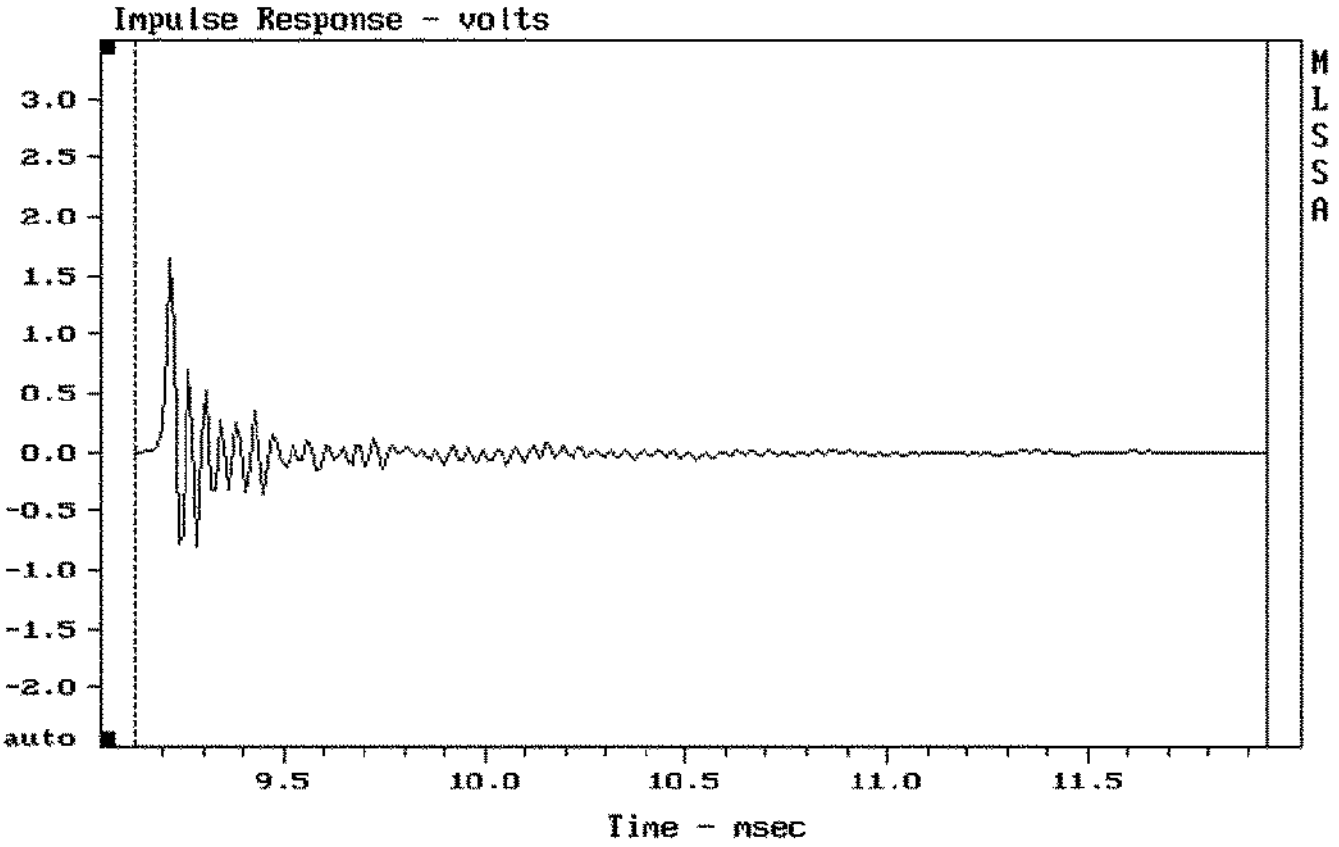
log Frequency - Hz
M
L
S
S
A

Thiel CS2.3


Impulse Response - volts
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0.0
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-1.0
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Time - msec
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L
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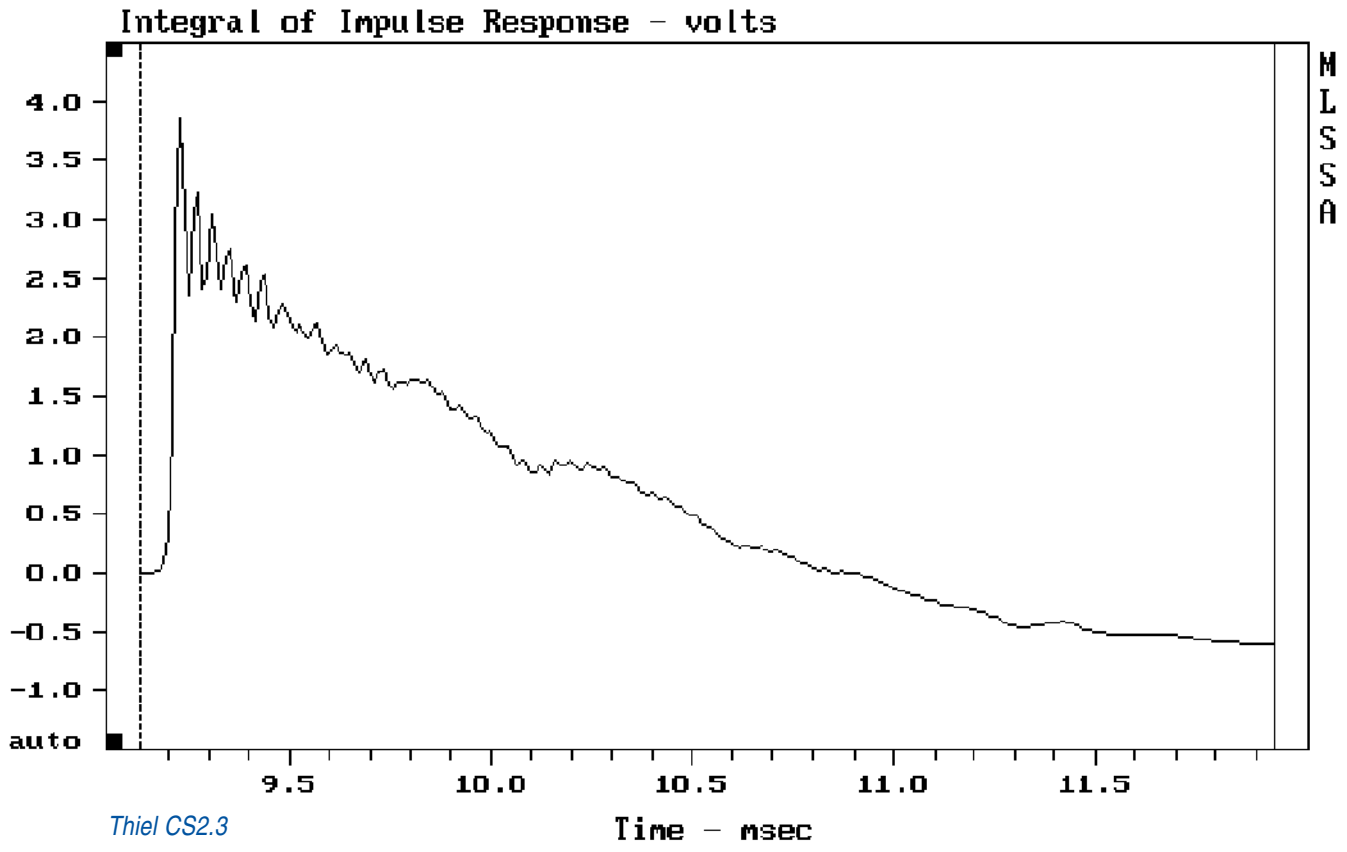
S
A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3.0
2.5
2.0
1.5
1.0
0.5
0.0
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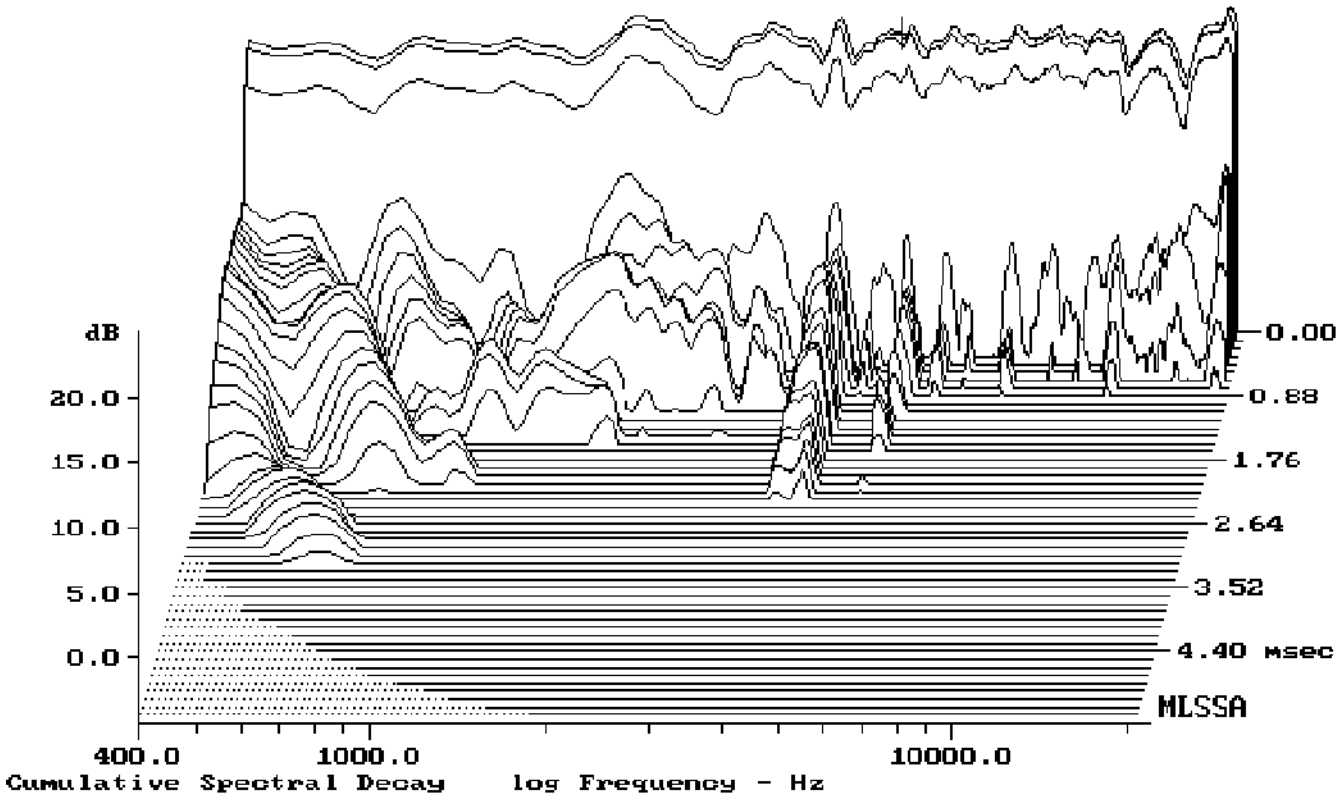
11.5
Time - msec
MLSSA

Thiel CS2.3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10.0
5.0
0.0
0.00
0.88
1.76
2.64
3.52
4.40 msec
MLSSA
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1000.0
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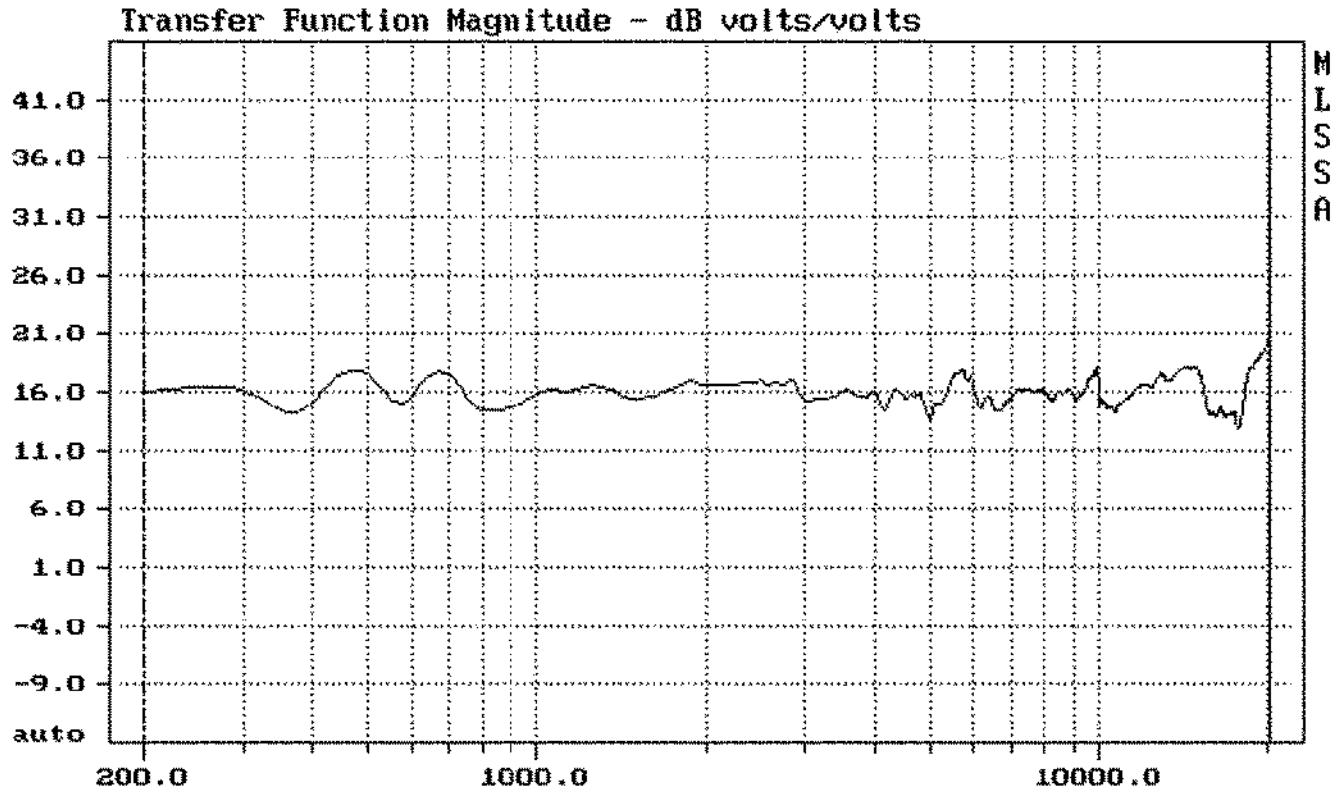
Cumulative Spectral Decay
log Frequency - Hz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-9.0
auto
200.0
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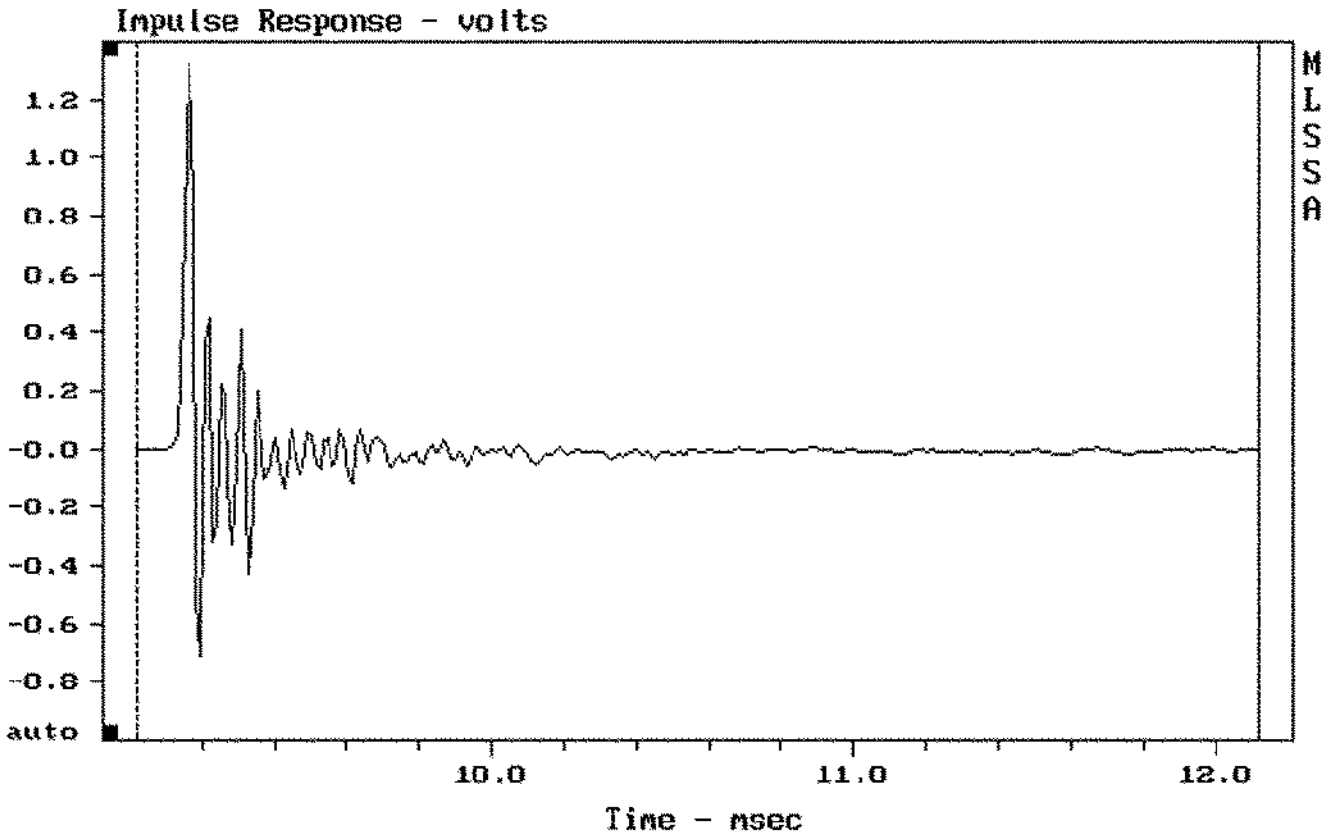
log Frequency - Hz
MLSSA

Thiel CS6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0.2
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-0.4
-0.6
-0.8
auto
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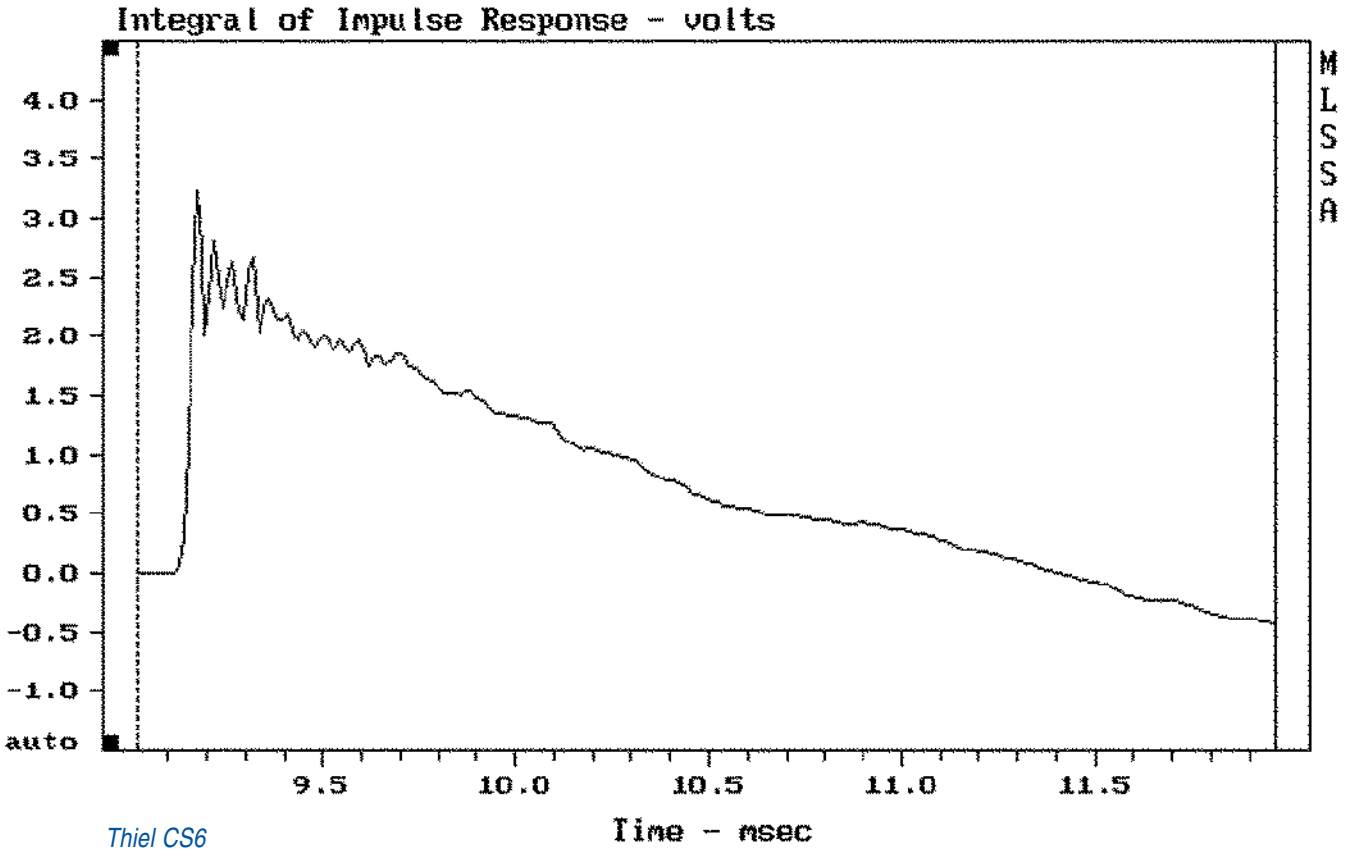
11.0
12.0
Time - msec
MLSSA


Integral of Impulse Response - volts
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2.5
2.0
1.5
1.0
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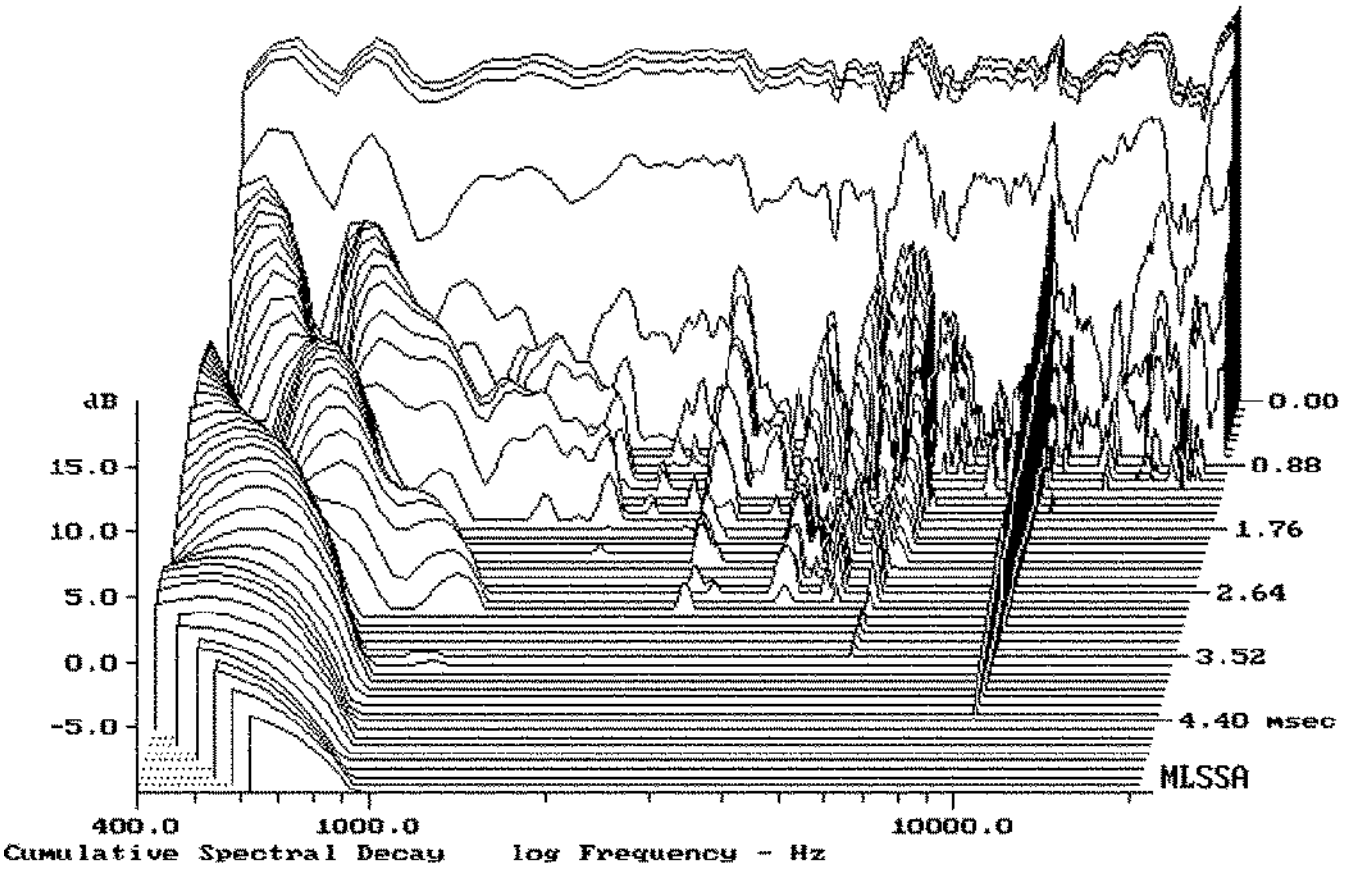
-1.0
auto
9.5
10.0
10.5
11.0
11.5
Time - msec
MLSSA

Thiel CS6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10.0
5.0
0.0
-5.0
400.0
1000.0
10000.0
Cumulative Spectral Decay
log Frequency - Hz
0.00
0.88
1.76
2.64
3.52
4.40 msec
MLSSA

Vandersteen

by Richard Hardesty

In the late 1950s, the original Quad ESL electrostatic loudspeaker was available for purchase only in the UK. It took nearly a decade for Quads to appear at retail locations in the United States. Stores selling Quads were few and far between and the speakers were available only in limited quantities.

Serious audiophiles managed to find them. I bought a pair from Jonas Miller Sound in Beverly Hills, California, in the early 1970s. Many speaker designers of the day were listening to Quads, too. They were trying to figure out how to make a practical loudspeaker that could sound as open and natural as the Quad ESL.

The Quad ESL (sometimes called the Quad '57) was a 2-way, three element electrostatic design with temporally aligned panels. (The electrostatic tweeter panel was centered between two electrostatic woofer panels and set back from the plane of the woofers.) It was the first time- and phase-correct multiway speaker, so far as I know. The Quad could pass a pretty good semblance of a square wave and offered midrange fidelity that was simply unrivaled in this era.

The Quads were far from perfect, however. They focused an image in a spot just big enough for a single head. They could play just loud enough to produce chamber music at realistic sound pressure levels for a listener seated no more than six or seven feet away.

Quads had limited bandwidth with very little output capability in the low bass or high treble regions. They were fragile—I sold mine when my stock of tweeter panels was depleted—and they presented a difficult load for the amplifiers of the day. The reward, for the few enthusiasts who could tolerate these impracticalities, was glorious sound and an immensely satisfying musical experience. After parting with my Quads, I struggled for many years before I was able to fully duplicate this level of musical satisfaction.

High Standards

The Quad ESL speakers set a high standard for the audiophile speaker designers of the day. Many labored to create practical loudspeakers with the open, natural sound of Quads. Two talented designers, Jon Dahlquist and Richard Vandersteen, suspected that the open sound of the Quads might be attributable to the fact that they had no reflective baffle surrounding the drive elements. They were partially correct.

Dahlquist was the first major speaker manufacturer to produce dynamic loudspeakers with small baffles (one eighth wavelength, I believe) around all drivers except the woofer. The original DQ-10 was introduced in the mid-1970s and it was a revolutionary design.

With the grilles in place, the Dahlquist DQ-10 looked almost exactly like a Quad ESL. Under the Quad-styled grilles, the DQ-10 had a 10-inch Advent woofer in a rather conventional sealed enclosure that made up the lower two thirds of the speaker. The other three drivers in this four-way system were each surrounded by small baffle boards, made from Masonite, which were attached by brackets to the top of the woofer enclosure.

Upper range drivers included a 5-inch Philips midrange, a 1-inch dome tweeter and a Motorola piezo super tweeter. These drivers were staggered so that the voice coil terminations were lined up, in an early attempt at time—oops, I mean temporal—alignment.

…beneath his modest facade is one of the sharpest minds that I've ever encountered…

The drivers were not arranged in a vertical array. Due to its steep-slope crossover filters and primitive attempts at driver alignment—there were no FFT analyzers then—the DQ-10 was not a time- and phase-accurate speaker system. But it was a major advance in dynamic speaker design.

Vandersteen went a step farther to eliminate what he refers to as "baffle distortion." The original Vandersteen Model 2 speakers had virtually no baffle at all. The first Model 2 had an 8-inch woofer mounted in a trapezoidal (as viewed from the top) enclosure with no baffle extending beyond the sides of the bass driver. A 10-inch rearward facing passive radiator shared this same enclosure.

The dome midrange and dome tweeter drivers were mounted in free air, supported by a backbone structure attached to the woofer enclosure. This was the first "baffleless" Aligned Dynamic loudspeaker and Vandersteen has been building speakers based on the same basic principle ever since.

Although current Vandersteen baffleless speakers are also time- and phase-correct, the original Model 2 was not completely phase coherent.

Minimizing baffle reflections proved to be only a partial solution. While both Dahlquist and Vandersteen had successfully managed to reduce the negative audible effects produced by reflective baffles surrounding the drive elements, their early speakers were not time- and phase-correct.

The Dahlquist DQ-10s and the original Vandersteen Model 2 speakers sounded more open and natural than conventional box loudspeakers but neither could match the transient speed and transparency of the time- and phase-accurate Quad ESL.

Because his speakers cost less than other high-end brands, Vandersteen sells lots more of them.

Vandersteen made a giant leap toward closing the gap with the introduction of the Model 2A—the first time- and phase-correct Vandersteen speaker—at the end of 1977.

Today, Vandersteen Audio makes fifteen time- and phase-accurate loudspeaker and subwoofer models including many designed primarily for home theater use. In this article we'll concentrate on the four floor-standing, full-range models numbered 1, 2, 3 and 5. (There used to a Model 4 but, alas, it is no more. There will be a Reference Monitor, priced between the 3 and 5, but it's not available yet.)

Because his speakers cost less than other high-end brands, Vandersteen sells lots more of them. The lower price tags are achieved by minimizing the costs of expensive, furniture-grade enclosures on all but the flagship Model 5.

While a big percentage of the price of competing speaker systems is invested in the enclosures, most of the price of Vandersteen speakers is devoted to the components inside. These components, even in the lowest-priced models, are among the finest available regardless of price.

Vandersteen likes to refer to the $3,500 a pair Model 3 Signature as "a $6,000 speaker system in a plain wrapper." I'd go farther and say that the Model 3 Signatures can be favorably compared to any speaker system selling for $8,000 a pair or more. There are negative aspects to this "bargain" pricing (but only for the manufacturer not the consumer).

Because Vandersteen speakers are so inexpensive, they have failed to get much attention from the influential magazines or from audiophiles who believe that high cost is synonymous with high quality. I'm going to provide slightly more detail when describing Vandersteen products in an attempt to dispel this false notion.

These relatively inexpensive speakers are built to quality standards that equal or exceed any in the industry, and Vandersteen speakers contain many innovative design features which can't be obtained anywhere else at any price.

Shane Buettner and I visited the Vandersteen factory in early July in preparation for this article and a review that I had planned for *Widescreen Review* magazine. (It appears at the time of this writing that Shane, rather than I, will be doing that review.)

Vandersteen Audio employs twenty-two people in the small central California town of Hanford. The factory is located on the outskirts of the central business district in a 50,000 square foot, free-standing building built and owned by Richard Vandersteen.

The facility is as low-key as the owner. There is no sign on the building other than the address. There are no plush listening or meeting rooms where visitors can be entertained and there are no fancy offices for the sales and management staff. In fact there is no sales and management staff. This is a family business run by the patriarch and manned by a hand-picked crew, which includes two sons and a daughter.

Richard Vandersteen likes to describe himself as "just a truck driver from Hanford, California," but beneath his modest facade is one of the sharpest minds that I've ever encountered. He and

I have been good friends for nearly twenty-five years and I was one of the very first Vandersteen dealers, so I am admittedly biased. The man's engineering talent is quite extraordinary and his ingenuity has led to some breakthrough technology. He studied advanced Fast Fourier Transform measurement techniques with the late Richard Heyser at Cal Tech, but Vandersteen had already pioneered the use of FFT analysis in speaker design some years before. Vandersteen Audio was the first speaker company to employ FFT analysis, using an early Gen Rad 2512 instrument for research and development.

Today, Vandersteen also employs the TEF and MLSSA instruments along with his keen ears. I've shared listening sessions with many key figures in the audio industry (including the three designers profiled in this issue of the **Journal**) and Richard Vandersteen is among the most aurally perceptive. (I'm prejudiced here too, because he and I share similar tastes in music and equipment.)

Vandersteen has developed many unique technologies which are offered in various speaker models. The patented reflection-free midrange driver used in the Model 3 and Model 5 speaker systems, the true push-pull subwoofer driver used in the Model 5, the baffleless enclosure designs used throughout the line, and the multilayer constrained-layer construction of the Model 5 head module are examples.

Vandersteen Audio, in the early 1980s, was the first company to build subwoofers that operate primarily below system resonance. These subwoofers are essentially aperiodic in the pass band.

Vandersteen Class B subwoofer amplifiers have a number of circuit innovations. Battery-biased crossover networks are still unique in the industry. Forerunners of the current Vandersteen "open frame" midrange and push-pull subwoofer drivers date back to the early 1980s. Aligned Dynamic baffleless designs date back to the late 1970s.

The Basics

Vandersteen speakers are Aligned Dynamic "baffleless" designs. That means that there are virtually no baffles extending to the sides of the drive elements. Each driver is mounted in an individual subenclosure with a front face that is just large enough to contain the mounting flange of that driver.

The faces of these subenclosures are staggered to temporally align the drive units. Adjacent structures are rounded and covered with felt to eliminate any reflective surfaces or diffractive edges around the drivers. Woofer enclosures are trapezoidal in shape (as viewed from above) so that no reflective surfaces extend to the sides of the low frequency drivers. Grille cloths are wrapped around dowels placed well away from the enclosure assembly for complete sonic transparency.

The driver outputs are blended with first-order acoustic slope, impedance compensated crossover networks with battery-biased capacitors in the flagship models.

Vandersteen uses a variety of diaphragm materials depending on the application. Various metal alloys are utilized for subbass drivers and tweeters. Upper bass, and midrange frequencies are reproduced by mica-filled polymer cones with proprietary profiles. The upper bass/lower midrange driver in the Model 5 has a Kevlar-reinforced cone with a mica-filled polymer skin on one side.

The patented reflection-free midrange driver and the true push-pull subwoofer driver are unique Vandersteen designs.

Bass loading varies from model to model. The Model 1 has a bass transmission line. The Models 2 and 3 have dual active drive units (8-inch and 10-inch) that share a common sealed enclosure but operate over different frequency ranges. This unique bass loading system performs like a theoretically perfect QB3 vented system over much of its range.

The Model 5 has a built-in powered subwoofer with a remarkable driver that features a true, symmetrical push-pull motor system. The bass enclosure of the Model 5 is sealed. Midrange and tweeter drivers are transmission line loaded in all Vandersteen models.

Each Vandersteen model is a full-range speaker system. Stepping up in the model range buys higher resolution, primar-

ily, along with smoother response and some bass extension. Adding Vandersteen subwoofers improves the midrange definition of all models except the Model 5, which has an integral powered subwoofer.

Vandersteen Full-Range Speakers

The Vandersteen Model 1C is a 2-way, floor-standing, truly full-range (38Hz-22.5kHz ±3dB), baffleless, time- and phase-accurate speaker system with an 8-inch cast frame, curvilinear polycone woofer and a 1-inch alloy dome tweeter. Model 1Cs sell for $785 per pair! That is not a misprint. Vandersteen 1Cs cost seven hundred eighty-five dollars a pair.

The Model 2Ce Signature is a baffleless, time- and phase-accurate 4-way (Vandersteen calls it a 3-way) speaker system with a 10-inch active bass coupler (low-woofer), an 8-inch cast frame polymer cone woofer, a 4.5-inch linear surround midrange (same cone assembly as the Model 3 but mounted in a conventional die-cast frame with ceramic magnet), and a 1-inch alloy dome tweeter.

Each Model 2Ce Signature is hand-tweaked in an anechoic chamber to produce response from 32Hz-21kHz within ±1.5dB. Pairs are matched to .1dB (one tenth dB) and sell for $1,549.

The Model 3A Signature is a baffleless, time- and phase-accurate 4-way (Vandersteen calls it a 3-way) speaker system with a 10-inch cast frame aluminum cone active bass coupler with dual spider suspension, an 8-inch cast frame polymer cone woofer, a 4.5-inch patented “open-frame” midrange and a 1-inch dual-chamber alloy dome tweeter (using Model 5 technology).

Each Model 3A Signature is hand-tweaked in an anechoic chamber to produce response from 30Hz-22kHz within ±1.5dB (-3dB@26Hz). Pairs are matched to .1dB and sell for $3,495 including Sound Anchor rear braces.

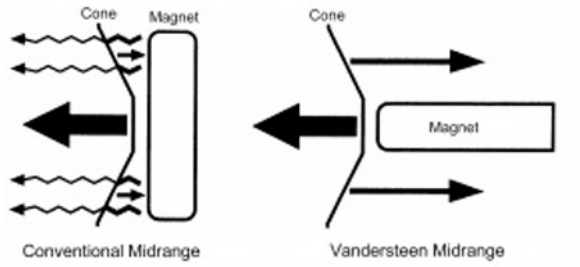
The Model 5 is the Vandersteen flagship. It has a built-in powered subwoofer based on a unique 12-inch dual aluminum cone driver with an enormous symmetrical push-pull motor system.

This subwoofer is blended with the upper frequency drivers utilizing a passive high-pass filter system, which is placed in front of the main amplifier, which drives the speaker above about 100Hz. This subwoofer interface is similar to the method used with the Vandersteen 2WQ subwoofer (see **Audio Perfectionist Journal #2**). The Model 5 subwoofer system utilizes a 400-watt internal amplifier (in each speaker) and offers multiband parametric equalization and adjustable “Q.”

Midbass in the Model 5 is handled by a transmission-line-loaded 7-inch driver featuring a kevlar-reinforced cone with a mica-filled polymer skin. The 4.5-inch transmission-line-loaded midrange driver is the patented Vandersteen open frame unit that has no reflective magnet structure behind the cone. High frequencies are reproduced by a 1-inch ceramic coated alloy dome, dual chamber tweeter. There is a rear facing .75-inch alloy dome auxiliary tweeter and a switch to turn it off. Vandersteen Model 5s cost $10,900 a pair.

Drivers

The drivers used in the Vandersteen speaker systems range from near-catalog units, sourced from Vifa/Scanspeak and SEAS, to unique Vandersteen designs protected by patents. All drivers have Vandersteen part numbers and are made to proprietary specifications.



All drivers are assembled overseas from parts obtained from sources around the world. Vandersteen owns the tooling for all proprietary components, some of which are manufactured in Hanford.

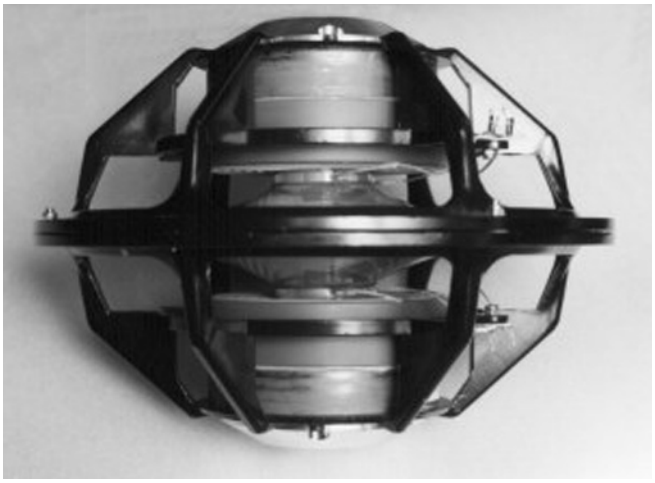
Vandersteen tweeters are modified in the Hanford factory and the level of modification varies with speaker model. The tweeters used in the Models 3 and 5 are quite different from those used in the Models 1 and 2 although they all look similar from the front.

All drive elements have die-cast alloy frames (except the active bass coupler in the Model 2) and large ceramic magnets are

utilized in all drivers except for the open frame midrange unit, which has an Alnico magnet that is made in England.

Vandersteen woofers have linear magnetic systems with extended and shaped pole pieces and copper rings. The 10-inch active bass coupler used in the Model 3 has a filled aluminum cone and a dual spider suspension for extremely long linear travel. The chassis for the symmetrical push-pull subwoofer driver used in the Model 5 is die-cast in Hanford.

The "open frame" midrange driver used in the Models 3 and 5 (patent number 5073948) has a curvilinear mica-filled polymer



Vandersteen symmetrical push-pull subwoofer driver

cone and a flat, linear surround. The die-cast chassis for this driver is manufactured in Hanford, the magnet assembly comes from England, the cone is made in Germany and the driver is assembled in Scandinavia. This very special midrange is partly responsible for the extremely open, spacious sound of the Vandersteen Model 3 and Model 5 speakers. Here's why.

Conventional midrange drivers have large magnet assemblies directly behind the radiating diaphragm (cone or dome). Sound coming from the back of the diaphragm is reflected off the magnet and frame of the driver and is reradiated through the diaphragm with a slight delay. Planar speakers don't suffer from this problem and that's one reason that planar speakers tend to sound more open than conventional dynamic speakers.

The Vandersteen open frame midrange driver eliminates these reflections as a source of time smear. Removing this reflective time smear improves transient response and makes the speakers sound more open and less "boxy." The aerodynamic frame and small diameter Alnico magnet used in this driver provide an open path from the rear surface of the diaphragm to the transmission line of the enclosure, where the rear wave is terminated without harmful reflections.

Vandersteen uses metal alloys for subbass driver diaphragms, which, in his designs, do not radiate directly toward the listener. He prefers metal alloys for tweeters, too. The metal domes in Vandersteen tweeters are mechanically damped to minimize the inevitable resonant peak that occurs at ultrasonic frequencies.

Vandersteen has chosen a mica-filled polymer material for the diaphragms of his midrange drivers. For this critical range of frequencies, he believes that this material provides the best compromise between softer compounds like paper and stiffer alternatives like metal alloy. We have already discussed, at length, the arguments about diaphragm materials in the articles profiling Dunlavy and Thiel. Vandersteen offers another balance of compromise for you to evaluate by listening.

Dunlavy uses soft diaphragm materials exclusively. Thiel uses primarily aluminum alloys. Vandersteen uses aluminum for subbass, metal alloys for high frequencies and high-tech polymers for midrange diaphragms.

Enclosures

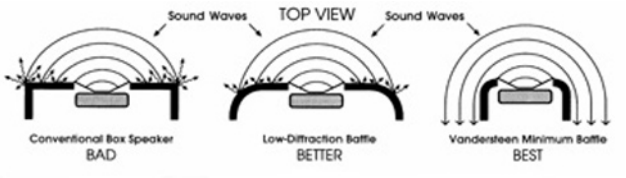
Vandersteen uses individual subenclosures to create smaller baffles around each driver than those found in other speakers. These structures are complex and commensurately difficult to make. Computer controlled woodworking machinery is required to manufacture the elaborate shapes of the various parts used to create the Vandersteen enclosures.

Vandersteen has designed and made specialized machinery to automate the manufacturing process but much work must still be completed by hand. For example, there are 32 pieces of MDF material, in different sizes and shapes, used to make each Model 2 speaker. These parts are created by computer controlled saws and multiaxis routers and assembled using custom-built pneumatic jigs and fixtures.

Models 1, 2, and 3 have enclosures made from heavily braced

MDF material. Panels in the Model 3 are 1-inch to 1.5-inches thick. The trapezoidal shape of the bass enclosures adds stiffness to the structure and helps to break up internal standing waves.

Cabinet resonances have been specifically engineered to be dispersive rather than additive by shaping and arranging the many small parts used to form the enclosures. The mechanical design of the Vandersteen cabinets was accomplished with the aid of FFT analysis. An accelerometer was placed on all cabinet surfaces and the output analyzed with a computerized instrument during the design process.



Vandersteen minimum baffle enclosure design

The subwoofer enclosure for the Model 5 is shaped like a truncated pyramid and made from constrained-layer damped, 2-inch thick laminated MDF sitting on a base made from 1-inch thick machined epoxy laminate material. This bass enclosure has a series of unique braces throughout its interior (see pictures on next page and in **Audio Perfectionist Journal** #12). The head module for the Model 5 is made from 22 laminated layers of .75-inch MDF. The front plate of the head module, on which the drivers are mounted, is made from a 1-inch thick machined epoxy laminate material.

The Models 1, 2, & 3 have hardwood-veneered end caps, available in a variety of finishes, at the top and bottom of cloth-wrapped enclosures.

The Model 5 has a furniture-grade wood finish on the lower portion of the cabinet with a cloth-covered bonnet crowning the upper portion. Model 5s are available in a variety of standard and custom wood finishes.

Crossover Networks

The crossover networks in all Vandersteen speakers are engineered to provide frequency and phase compensation for the drive elements and to provide first-order acoustic transitions between drivers. All components are of exceptionally high quality, including the unique barrier strip input connectors which facilitate biwiring.

All glass-epoxy circuit boards are double-sided and through-plated. Premium resistors, premium film capacitors and air-core inductors wound with 6n copper wire are used throughout.

Critical components are encapsulated in potting resin to make them immune to vibration. The crossover networks in the Model 5 use battery-biased film capacitors as do the external high-pass filters used with the Model 5 speaker system.
Models 1, 2, & 3 have unique thermal protection circuits which prevent damage to the midrange and tweeter drivers in the event of a severe overload. This makes these models ideal for home theater use.

Quality Control

All speaker components are individually performance tested. Drivers are selected, matched and coded for response characteristics. Driver response characteristics are recorded to aid in speaker matching and to facilitate future replacement. Crossover components are tested and selected before assembly. Completed crossover networks are individually tested and matched to .1dB tolerances.

All speakers are high-power sweep tested and performance verified by computer instruments. All “Signature” models, and the Model 5, are individually tested in an anechoic chamber where crossover components are hand tweaked to achieve the advertised performance specifications. Speaker pairs are matched to .1dB (one tenth dB).

Model 5 cabinets are hand finished and inspected at all stages of assembly.

Strong Points

Vandersteens offer a unique combination of smooth, musical sound and high resolution. When driven by the best electronic components, Vandersteen speakers produce a more focused and three-dimensional image than most other speakers, regardless of type or cost. You hear more of the signal and less of the speaker, in my opinion.

They cost far less than speakers with fancier cabinets and comparable component quality. Each model in the Vandersteen line provides performance that can be favorably compared to speakers costing twice as much or more.
Models 2 and above can be biwired or passively biamped. Vandersteen subwoofers blend seamlessly with all models except the 5, which has a built-in powered subwoofer.
Even the lower-priced models in the line provide full-range response with bass extension that is unrivaled by competitors costing far more.

Interior of Vandersteen Model 5 subwoofer enclosure

Negative Considerations

Vandersteen speakers do not present a difficult load to the amplifier but they do have low nominal impedance and they are relatively low in sensitivity. They will require more amplifier power than higher sensitivity designs and they will not play as loud as speakers with higher sensitivity or steep-slope crossover filters.

While inexpensive amplifiers will drive Vandersteens, the shortcomings of less than state-of-the-art electronic components will be mercilessly presented to the listener by these high resolution speakers.

The unique bass loading system of the Vandersteen Models 2 and 3 allows these products to produce lots of bass energy down to very low frequencies. Some listeners may prefer a tighter, leaner low end with more definition. Vandersteen subwoofers provide the solution here.

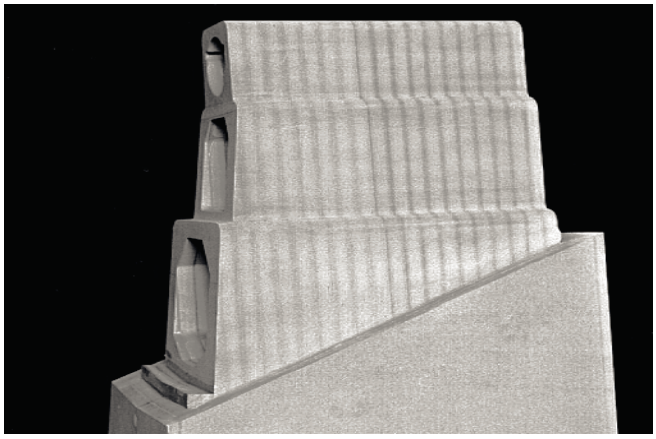
Vandersteen speakers, with the exception of the Model 5, may seem to be dynamically compressed to some listeners. I believe that this is due to a reduction in distortion, particularly baffle distortion, to which many listeners have become accustomed. Subwoofers can increase the perceived and actual dynamic range potential of most Vandersteen models.

The low price tags on Vandersteen speakers may be confusing to the novice buyer. These are high resolution loudspeakers that should be used with associated equipment of the highest quality. They are seldom demonstrated or reviewed that way. Consumers and reviewers who have been told that they should spend two-thirds of their audio budget on speakers will need to be reeducated.

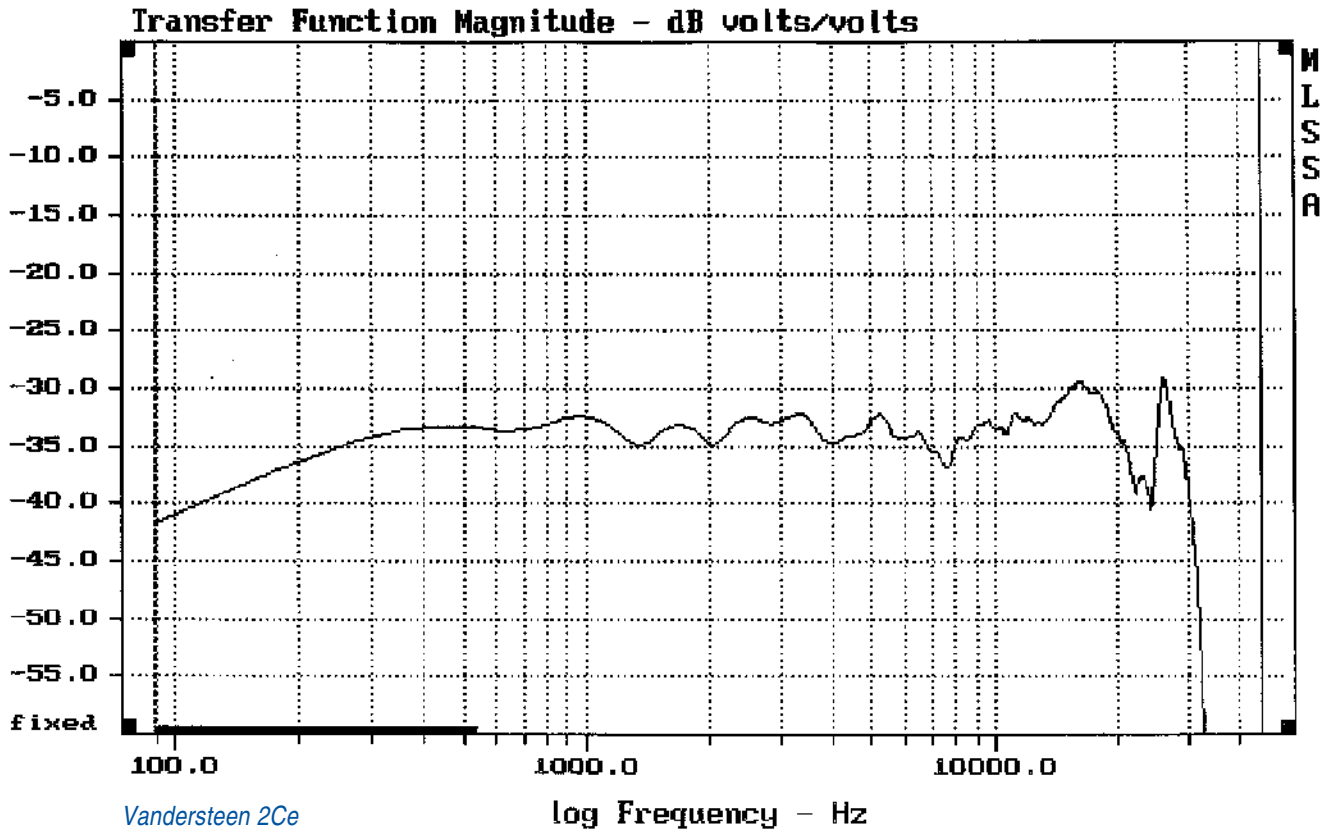
Measurements

Vandersteen speakers deliver impeccable measured performance. They are demonstrably accurate in both frequency and time domains. The alloy dome tweeters produce some minor ringing on the impulse and step response graphs. This is due to energy storage at ultrasonic frequencies. Is this a reasonable trade-off for higher resolution? We'll discuss this question in the next **Audio Perfectionist Journa**l.

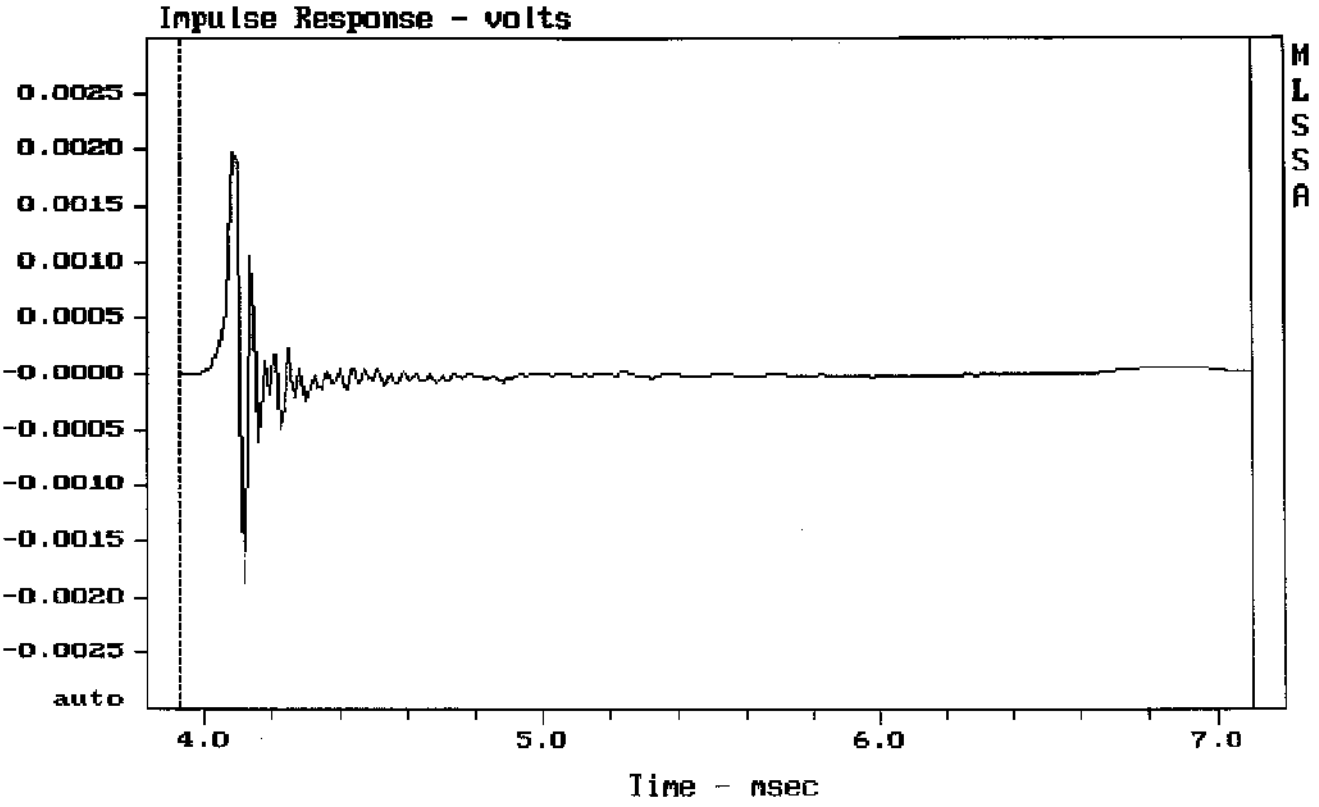
The Vandersteen measurements show a wider range of frequencies, 100Hz to 40kHz, and have 5dB increments per division. These graphs are not accurate below 300Hz. Ignore the lower portion of the range between 100 and 300Hz. Note that the tweeter resonance is well above the audible range and that high frequency bandwidth extends far above the range of soft dome tweeters to -6dB at 30kHz. APJ

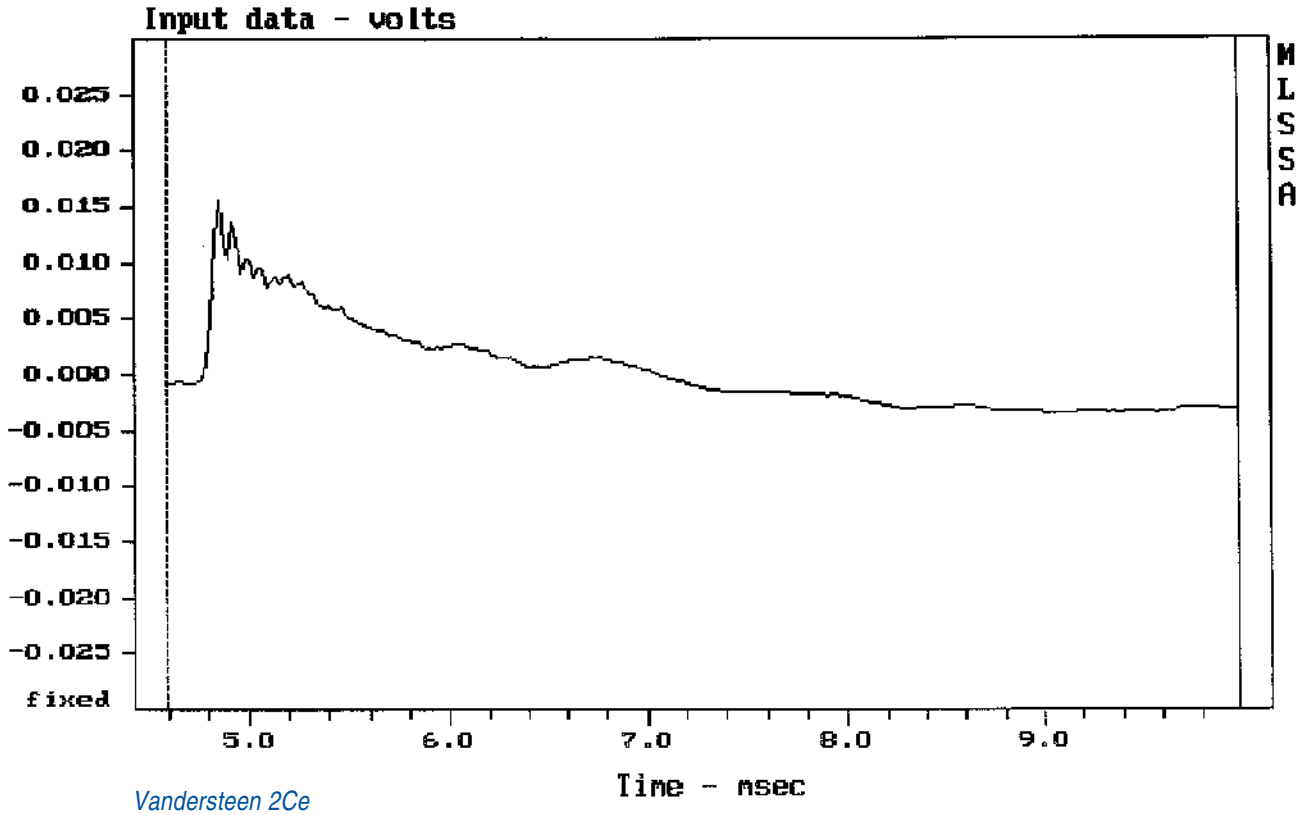


Vandersteen Model 5 head module

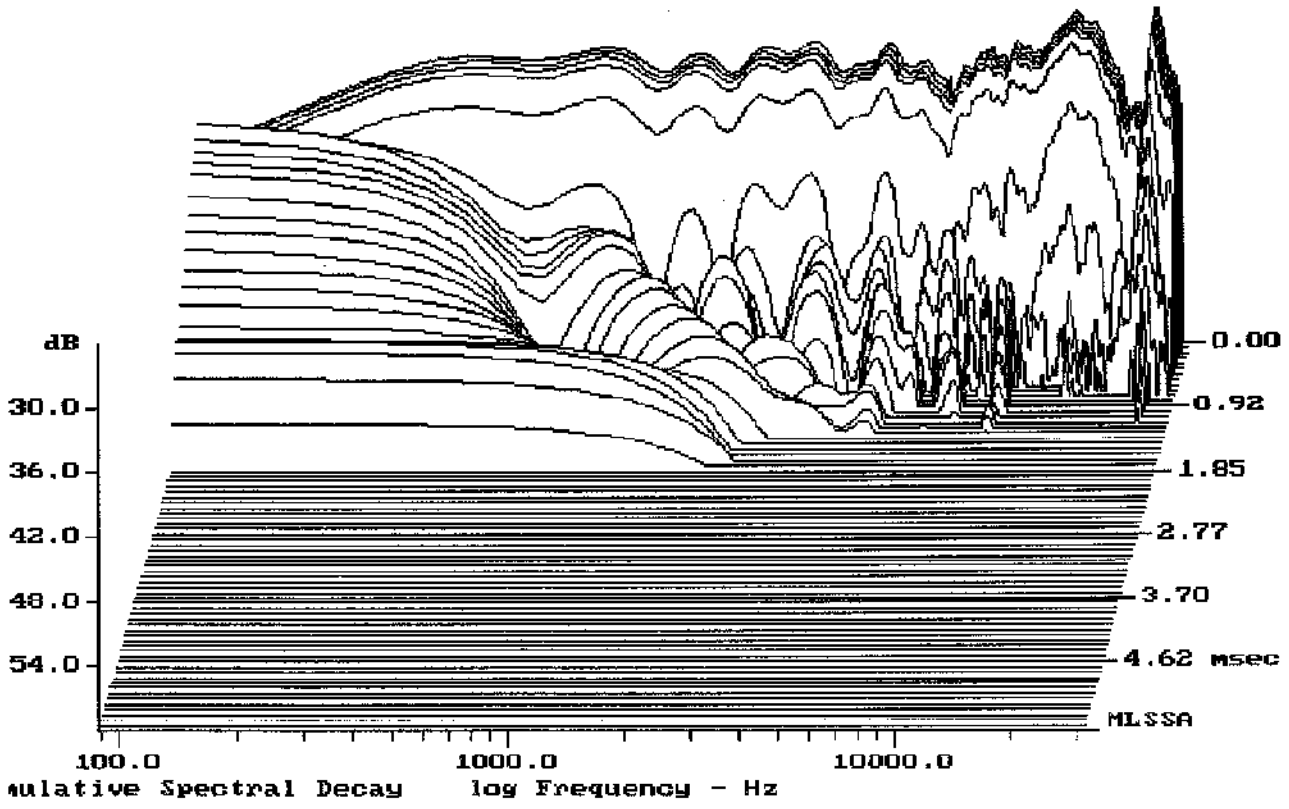


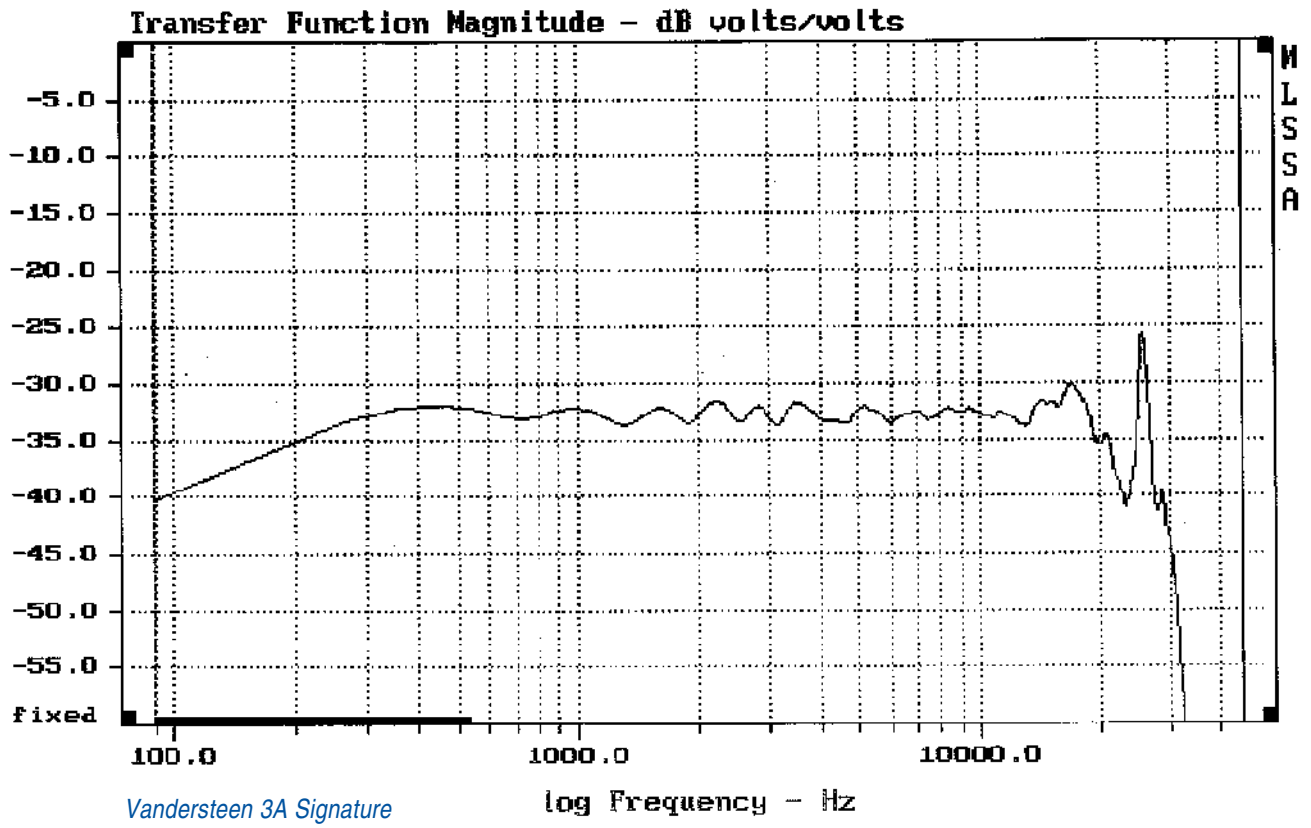
Vandersteen 2Ce



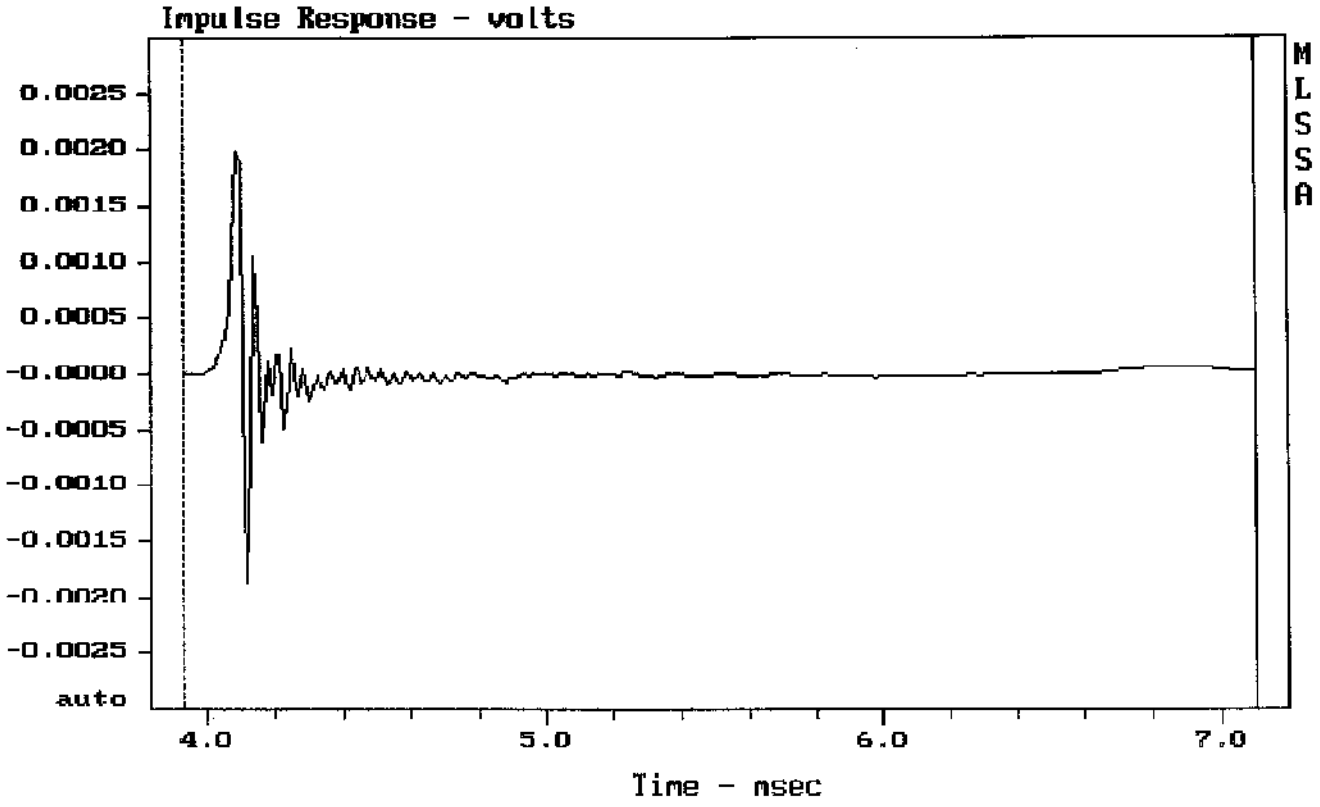


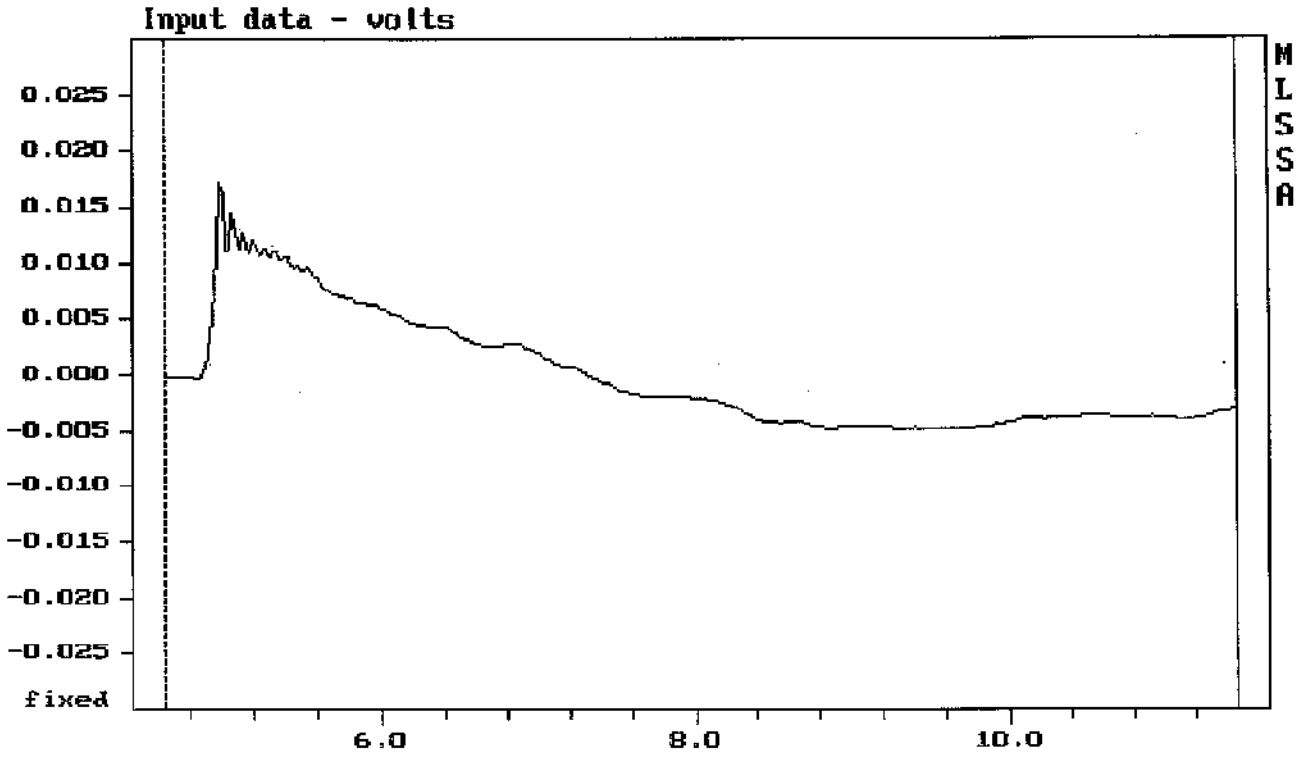
Vandersteen 2Ce



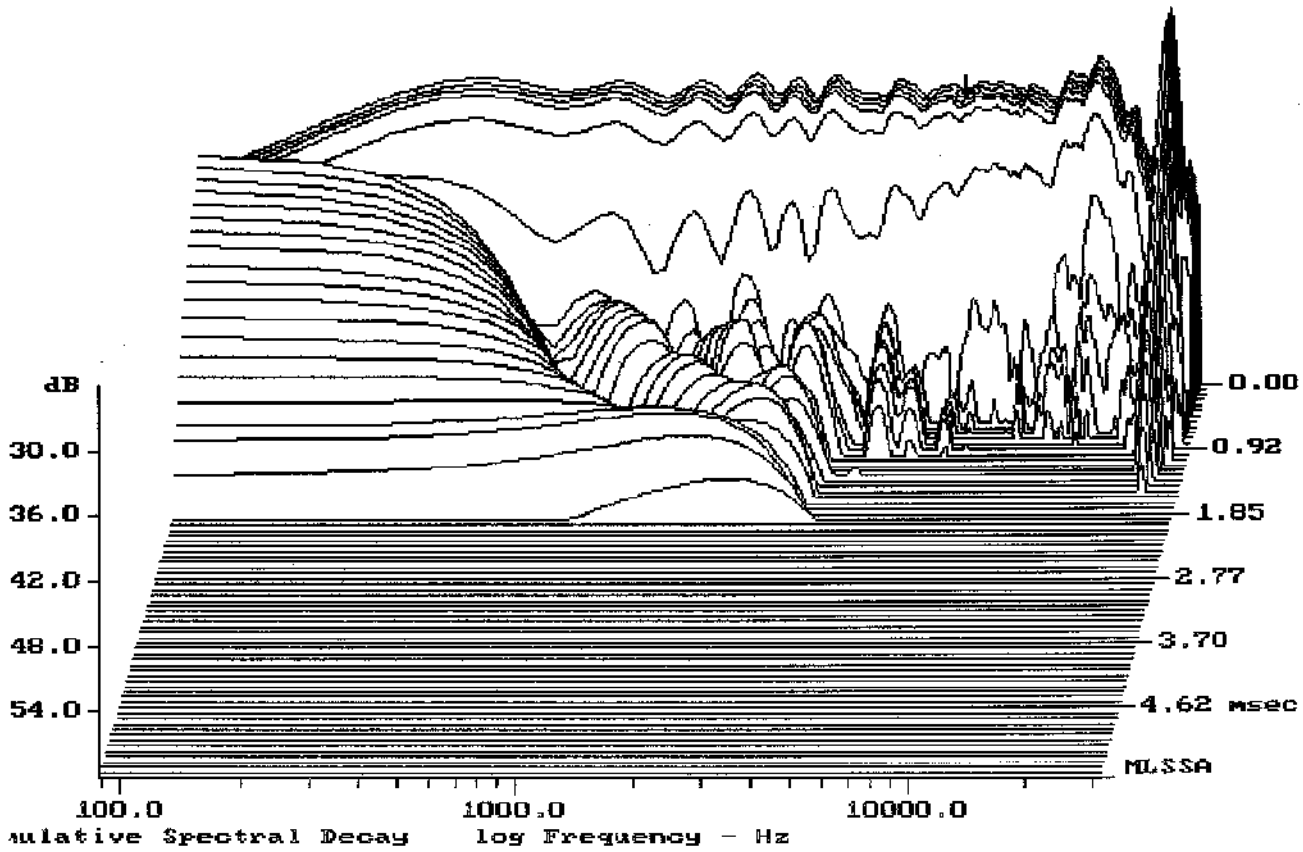


Vandersteen 3A Signature





Vandersteen 3A Signature



Journey to Enlightenment

by Shane Buettner

From bipolar speakers to time- and phase-accuracy: a description of my personal journey into high-end audio.

As a complement to Dick Hardesty's work on time- and phase-accurate speakers, Dick thought it would be interesting for you to read a testimonial regarding my own experiences in the last year. This time period started with me using Definitive Technology bipolar loudspeakers and, after experiencing several high-end speaker systems, culminated with me buying a reference system of Vandersteen loudspeakers (just as Dick predicted I would after gaining more experience).

For me, this journey is very much about being exposed to a higher standard and set of perspectives on audio than the current home theater gurus promulgate. The attitude that products out there are "good enough for home theater" is keeping people from being exposed to truly high-end audio products in many cases. This is pervasive in the industry, from what you'll read in the magazines that support the industry, to what you'll likely be shown on a showroom floor by dealers of home theater products. But trust me, there is a higher fidelity, truer experience to be had if you're willing. I wrote a song about it, and now I'm gonna' play it for ya'....

My Roots

I'm 31 years old. As long as I can remember I've been emotionally involved with books, music and movies, and not necessarily in that order at any given time. I was an avid vinyl collector in my later years of high school, and throughout college.

A college roommate and I collected records and shared a system to play them on. (At one point we even had a huge pair of Acoustat electrostatic speakers that we used to cram into the tiny apartments we lived in!) When we went our separate ways the turntable went with him and, with the CD boom in full force, I started collecting CDs from that point on. It was the most convenient thing to do.

CD collecting was coincident with an increased involvement with film and movies on home video. I bought a laserdisc player to experience films in their original aspect ratios and remained very focused on movie watching. I still listened to a lot of music but I wasn't nearly as involved with it emotionally. At the time I thought this was simply because I was watching more movies and reading more books. But, as I found out, it was something more.

Six or seven years back, I swapped out the Harman Kardon integrated amp that I had used through college for a Pro Logic surround sound A/V receiver. I had a big screen TV and a laserdisc player, and I enjoyed watching movies on this system very much. But I found I was listening to music more often in my car than at home. Then one day I upgraded my laserdisc player from a lower end Pioneer player to a Pioneer Elite CLD-79. This not only improved the video end of the movie experience, I accidentally rediscovered music as an emotional experience through the CLD-79, which was a decent CD player.

It's good enough for home theater...

All of a sudden, instead of a congealed tangle of sounds creating each song, I could hear the instruments that made up the band when the music played. All of a sudden digital didn't sound as bad, and I began to focus much more on music and became emotionally involved with it once again.

From that point on music playback began to enter into my purchasing decisions again, but getting access to reliable information on which products fit that particular bill became another obstacle. As much as I'd like to debunk some of the myths regarding front-end electronics and their suitability for music as well as home theater, I need to stick to speakers, so, now that you have some background on me, let me refocus.

The Home Theater Years

Over the last several years I've used two brands of loudspeakers for the most part: NHT and Definitive Technology. I bought an NHT system several years ago based on their home theater model VT-2. NHT builds a good and honest loudspeaker that's well engineered, and provides a hell of a lot of performance for the money compared to many conventional loudspeaker manufacturers. I used the VT-2 system for two to three years before swapping it out for another NHT system, this one based on the 2.5i model, which I found to be more satisfying musically.

Over a year ago I swapped out the NHT 2.5i-based speaker system for a Definitive Technology system based on a pair of their "powered tower" bipolar loudspeakers with built-in powered subwoofers, which I had reviewed for *Widescreen Review*.

The Definitives are also a relatively good buy for the money, particularly for home theater. They're very dynamic, to say the least, with the home theater slam and impact that many people enjoy. The resolution overall is pretty good, about as good as the NHTs, but more laid back compared to the rather forward and matter-of-fact sound of the NHTs.

Of course, the signature of the Definitives is the bipolar radiation pattern created by having driver arrays mirrored on the front and back of the speakers, firing in phase with one another. The seductive thing about them is that, in a room like mine, which is a very typical tract home living room doubling as a home theater/listening room, they add a sense of spaciousness without the other colorations and dynamic limitations that electrostatic (or hybrid electrostatic) designs offer.

The soundstage of the Definitives sounds relatively focused compared to other conventional designs, but is artificially expanded by the reflected radiation coming off the front wall. What I didn't notice until living with the Definitives for several months, followed by living with a superior monopole speaker system by Aerial Acoustics (that I also reviewed for *Widescreen Review*), is that this artificial spaciousness is entirely detrimental to image focus and was not allowing me to truly hear what was happening in the soundstage of music and to the spatial characteristics of multichannel music and movies.

When the Aerial Acoustics speaker system came in, the improvements were immediate and dramatic. The midrange, in particular, came to life, imparting a dramatic sense of increased resolution. Spatially, sonic images became very sharply focused; it was like going to the eye doctor and getting a new prescription.

With some of the multichannel music material that I had previously appreciated, the increased focus revealed spatial and spectral clues that I simply hadn't heard before. On the DTS CD of Lyle Lovett's *Joshua Judges Ruth* I was able to hear that the mixes on several of the songs put Lovett's voice into all five channels creating a vocal image right inside my head. This effect had actually been mitigated by the poor image focus of the bipoles I had been listening to. But hearing this effect as it actually is on the disc was maddening.

Instead of Lovett being a palpable vocal presence in the front of the room, which is a reasonable impression of Lyle being in the room on the regular CD, the multichannel mix on the DTS disc created a big, fat, lifeless image emanating from everywhere but nowhere in particular. And that's to say nothing of the rest of the mix. You can argue about whether you want to hear how ludicrous some of these mixes are, which accurate speakers will certainly show you.

It was like going to the eye doctor and getting a new prescription.

Up at the front of the soundstage, with two-channel material, the differences between the Definitive and Aerial systems were just as obvious. Instead of an artificially large soundstage up front, the Aerials offered a sharp perspective with space and air around vocals and instruments, and sound that was not at all confined to the physical boundaries of the speakers. But the Aerial's spaciousness did not come at the expense of detail and resolution, which was inevitably the case with the bipoles, whose soundstage was undoubtedly blurred as a result of all the reflected energy bouncing off the front wall from the rear-firing driver arrays.

The Aerials also did a better job of sounding less like big speakers with big cabinets. The Aerials are built to a higher standard, with superior damping and extensive cross-bracing. This results in the Aerials doing a much better job of keeping the cabinet from singing along with the music. The midrange and tweeter of the Aerials are isolated in separate subenclosures, with the midrange surrounded by asphalt and wool to prevent coloration in that critical frequency range. This construction quality allowed the Aerials to "disappear" in the room to an extent that the Definitives really couldn't approach.

The experience I've gained in the year since I wrote that review has been invaluable, and the things I look for in a loudspeaker don't allow for the colorations I hear now in bipolar loudspeakers. I like and respect the people I know at Definitive and I

hope this isn't taken to sound as critical as it might. I do believe that Definitive offers products superior to many things out there at the same price and even higher. But today my standard is elevated, and let me tell you why.

Exposure to Time- and Phase-Accurate Speakers

During the months that I had the Aerial Acoustics speaker system in my home, I also spent a lot of time listening to music and movies on Dick's Vandersteen system. There were several things I noticed immediately about the Vandersteen system that I would not hear from anything else I listened to.

The first thing that struck me was how open and transparent the sound from the Vandersteens was in general, and the midrange in particular. Relaxed, liquid, musical detail and low level resolution that just poured out of… well, nothing.

The "baffleless" design of the Vandersteens means that there is no baffle around the midrange and tweeter module at all. I think the main thing that people are seduced by with electrostats is that you don't hear a box around them; they just seem to disappear in the room. The Vandersteen baffleless design imparts much of that same sense of openness and lack of cabinet coloration. Smooth, grain-free sound with lots of air and extension is what I heard from the Vandersteens.

This sensation of the Vandersteen's open sound, uncolored by large cabinet structures, is interesting to contrast with Dunlavy's speakers, another time/phase-accurate, well-engineered design. While there were many things I admired listening to Dunlavy speakers, I was always aware of those speakers being just what they are: very big speakers with enormous cabinets.

At the CES show in January 2001 Dunlavy's room was set up with several of his speaker pairs lined up next to one another. It was always easy to discern exactly which speaker pairs were playing at any given time. The Dunlavy's are certainly more efficient and will play louder and perhaps more dynamically than the Vandersteens, which will be a strong recommendation for many people. But I just didn't get the same sense of open transparency that the Vandersteens offer in spades, and in the end I found I couldn't live without that.

The other thing that knocked me out with the Vandersteens was the precise and defined soundstage and unparalleled imaging. At Dick's place, when he played a reference quality LP like *Mel Torme and Friends Live at Marty's*, it was spooky in its "you are there" feeling that particular recording imparts. The sound of the crowd, the musicians on stage, the dual vocalists coming from different sides of the stage—it was all there so clearly that I could practically see it. That's imaging!

And I could certainly feel it; the connection to the music was physical, just like being there. Needless to say, this experience also renewed my interest in vinyl, but that's a different story for a different day!

This sensation of the Vandersteen's open sound… is interesting to contrast with Dunlavy's speakers.

Moving on, Dick also played some cuts off of the Q-Sound recording of Roger Waters' *Amused to Death*, and some multichannel music such as Columbia's DVD of the *Best of Sessions at West 54th Volume 1*. With the Roger Waters disc, which uses a bunch of phase-related shenanigans to create some very interesting spatial effects, the Vandersteens placed sounds so far out to the sidewalls that, if I closed my eyes, it sounded like I was in a much larger room, an absolutely enormous space. Sounds also imaged directly above my head at the listening position, an amazing sensation I'd not experienced with any other loudspeaker. Although we were listening in stereo, to the uninitiated I think it might have seemed that the Vandersteen VSM surround speakers on the walls were active (they weren't), so expansive was the imaging.

The *Session*s DVD features a Dolby Digital 5.1-channel track of a mix that's not nearly as offensive as many of its multichannel brethren. It's an interesting sonic perspective that moves with the camera around the musicians, but it's subtly and tastefully done. The performances are tremendous.

This disc illustrates how precise the Vandersteens are spatially, especially on the Rickie Lee Jones cut, which has sound moving along the sidewalls and in between the front and surround

speakers in a fairly aggressive but still natural fashion. Suzanne Vega's *Caramel* and Annie DiFranco's *32 Flavors* are other examples, with everything from backing vocals and drums to accordions wrapping gently around the soundstage and into the surrounds as the camera pans. Neat stuff, and the Vandersteens make it feel natural, real and emotionally involving.

Emotional involvement is a key issue here. As you'll read in the **Journal**, Dick's belief is that time- and phase-accuracy are of such paramount importance that experienced high-end enthusiasts should only consider loudspeakers that are accurate in that respect—which means Thiel, Dunlavy, and Vandersteen would be your only choices out there in the wide world of speakers.

After listening to the Aerial Acoustics speakers for a long time—which are some of the best (if not the best) conventional speakers I've heard—I must agree with Dick that the time- and phase-accurate designs are in another performance category altogether. Thiel, Dunlavy and Vandersteen all offer superb loudspeakers but, for the reasons outlined above, I connected emotionally to what I heard from the Vandersteens. You may feel differently and connect emotionally to one of the other two brands, which are indeed outstanding loudspeakers, too.

Reviewers can help point you in the right direction by accurately describing the performance attributes of a component, and hopefully, in some cases, ferreting out the genuine products from the snake oil. Some people want us to do all the work, as we're constantly bombarded with people who say "I've read all the reviews you've done, but is product X better than product Y?" Do yourself a favor, use the reviews as a guide, and go out and listen. Find out which of these recommended products you respond to emotionally and I think you'll be happiest with your purchases.

At Home with the Vandersteens

The Vandersteens had a few more tricks up their proverbial sleeves that I discovered upon having them in my own home. I knew from listening at Dick's that I was getting tremendous two-channel performance with the Vandersteen system I purchased. But I wasn't prepared for just how stellar they'd be with movie soundtracks.

My system is identical to Dick's with 3A Signatures in the front, a VCC-5 center speaker, wall-mount VSM surrounds, and four 2WQ subwoofers for the right and left front and right and left surround speakers, respectively. While this system isn't going to produce action movie explosions louder than they'd be in real life, the Vandersteens, with the 2WQ woofers at the four primary channel positions, have enough transient snap and oomph that I've not missed any of the previous speakers I've had in my room when I watch movies.

The imaging in between all speaker positions that made the *Sessions* DVD so involving is also revelatory with movie material. This system presents the most precise 360-degree imaging I've heard yet in my room. And what's more, the time- and phase-accurate VSM surrounds do a better job of providing diffuse ambience (when called for) than any type of diffuse-radiating speaker I've heard.

…time- and phase-accurate designs are in another performance category altogether…

This improvement is an order of magnitude above the performance you'd get from dipole surround speakers or DSP-based decorrelation from a digital controller. Further, this speaker system is evidence of the absurdity of the extended surround sound "features," such as Surround EX and DTS-ES, now being peddled by the manufacturers of digital controllers and A/V receivers.

The spatial precision of the Vandersteen system is such that I get dead-center phantom images between the surround channels that are much more natural and "real" sounding than any hard center channel could be in the back of my room. And I know of what I speak.

During the time that I had the Definitive Technology speakers in my room, I had enough of them that I tried several configurations of extended surround: two speakers at the side of the listening position with one or two speakers along the back wall, as well as two speakers on the back wall and a single center speaker in between.

With the Definitives this brute-force approach yielded some increased performance with movie soundtracks encoded in extended surround (which should have been a clue regarding the imaging capability of the Definitive bipolars). But in my room, which measures about 13 feet across and about 18 feet long, the Aerials first, and then the Vandersteens especially, sounded much better with any and all soundtracks in a straight-up 5.1-channel configuration due to the fact that these speakers image in a much more accurate fashion.

In all but the largest rooms I don't believe that any more than 5.1-channels of accurate, time- and phase-correct speakers are necessary for realistic, high resolution surround sound.

These are some of the most advanced and best performing speakers available.

Of course, all of this is contrary to what some people in the industry are saying. There are some people saying that the alleged success of Surround EX and DTS-ES proves that people want more channels. Some even cite decades-old studies that "prove" the more channels you have the better and more "realistic" the sound is.

Tomlinson Holman himself trumps up a demo of a 10.2-channel system at every trade show, touting that system as the height of realism. All I can say in response is that I seriously wonder if any of these people have ever heard a properly set-up system of time- and phase-accurate speakers. If they had, I doubt they'd be pushing systems of inferior products that require so many channels to create sound that is still grossly inferior to that attained by my Vandersteen 5.1-channel system. Of course, I think this is a moot point anyway.

Surround EX and DTS-ES may have helped some manufacturers sell some A/V receivers, but on the content side DVD producers haven't even bothered to indicate on DVD packaging when a soundtrack is presented in one of these formats. And my guess is that they haven't been flooded by complaints from consumers who care.

This is to say nothing of the fact that most people have a hard time cramming 5.1-channels of speakers into their living rooms, let alone 6.1, 7.1, or, God forbid, 10.2 channels!

And Did I Mention the Price?

On top of the fact that I found the Vandersteens I purchased offer superior performance to anything else I listened to, they cost little more than the Definitives and far less than other high-end competitors' products.

The cost of my entire Vandersteen system is $11,619. This is certainly not chump change, but look at everything that's in this system: a pair of 3A Signatures ($3,495/pr, stands included), a VCC-5 center speaker ($1,995), a pair of VSM surrounds ($949/pr), and four 2WQ subwoofers ($1,295 each.) That's a hell of a deal for nine loudspeakers, four of which have on-board power amplifiers, and all of which contain proprietary components and technology.

The Aerial Acoustics speakers I reviewed, for example, had a system cost of $25,800 with just two of their subwoofers, and $15,000 with no subwoofers.

The cost of a pair of Vandersteen 3A Signatures and two woofers is $6,085. This combination offers time- and phase-accurate performance that is accurate in the frequency domain to tolerances of ±3dB from 18Hz to 22kHz. Name another speaker, time- and phase-accurate or otherwise, that offers the kind of performance and accuracy that the Vandersteen package does at anywhere near this price.

These are some of the most advanced and best performing speakers available, and yet they're also among the most reasonably priced. What else is there to say?

That's All Folks

For more information about the speaker manufacturers profiled in this issue visit their web sites.

Dunlavy Audio Labs: http://www.dunlavyaudio.com

Thiel Audio: http://www.thielaudio.com

Vandersteen Audio: http://www.vandersteen.com

APJ

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Rick Johnson, Art Director

Conclusion

by Richard Hardesty

*This **Journal** included only brief comments about the sound quality of the products described. We'll discuss the sound of Dunlavy, Thiel and Vandersteen speakers in greater detail in the **Journal #8**. We'll talk more about time- and phase-accuracy and its importance in stereo systems and how it affects the performance of home theater systems, too.*

I'll tell you the truth about center channel speakers and describe why most of them perform so poorly and we'll talk about the surround channels in a multichannel system, and I'll describe some special requirements for accurate reproduction from speakers positioned at the sides or back of the room. APJ

Flash Forward to 2008

*Since this **Journal** was written in 2001 there have been several significant changes. While the industry continually changes concepts and objective measurements remain the same. Dunlavy Audio is no longer in business. Thiel and Vandersteen have improved their products and introduced new models. Meadowlark Audio assumed the position of the third major manufacturer to offer a complete line of time- and phase-accurate loudspeakers and subsequently went out of business.*

Shane Buettner became a reviewer for *The Absolute Sound* magazine and Video Technical Editor for *The Perfect Vision* magazine, and Equpment Review editor for the **Audio Perfectionist Journal**. He then became editor of *Ultimate AV* on the web and now is the editor of *Home Theater* magazine.

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