The Unseen Variable

Martin Colloms, April, 1995

Although I still haven't been able to listen to the Cary Audio Design 805 single-ended tube monoblocks that *Stereophile* praised so highly a year ago (Vol.17 No.1, p.104), I've recently auditioned many other tubed single-ended designs. Undeniably, a good SE design has a distinctive quality of harmony and atmosphere in the midrange that reaches well beyond the average attainment of its solid-state brethren.

Provided that very high sound levels and gut-thumping bass are not required, Tim de Paravicini's small SE amplifier, for example, works just fine with the relatively kind and uniform 6 ohm impedance presented by a Wilson WATT V loudspeaker (used without the Puppy woofer), aided by the speaker's 91dB/W/m sensitivity. Yes, the WATT V is slightly altered in character, and wide-band rock music at realistic levels is out of the question. However, with the right kind of music, the result is true high-fidelity, and can often be most beguiling-in several respects reminding me of my first experience with the original Quad electrostatic: the marvellous lack of "box" and mechanical "cone" sounds, the inaudible midrange distortion, the lightning-fast transients, and the low levels of grain.

However, while electrostatics-and, for that matter, good ribbon speakers-do some things exceedingly well, ultimately they cannot always paint a complete audio picture. I wonder whether SE amplifiers are destined to occupy a similar niche in the field of high-quality audio.

In using the term "niche," I am not being derogatory-there will be many who hear the siren call and will be drawn in. For them, the purity and fluidity of the amplifier's midrange will be all that they desire. It's hard to deny that appeal if you have yet to experience a truly great system.

A number of recent products have pointed to the future-in particular, the Wilson X-1/Grand SLAMM loudspeaker system I reviewed for *Stereophile* last December (Vol.17 No.17, p.115). Exposure to the X-1 was a revitalizing experience. It does so many things that I didn't think were possible from reproduced audio that it defines a totality of performance-a standard of excellence and listener satisfaction over the entire audible frequency range, not just the midrange.

While it is SE-compatible in that its 95dB/W/m sensitivity and 6 ohm load are surprisingly amplifier-friendly, the Wilson speaker is also kind to average-quality electronics, in that it gets the best from them. At the same time, however, the X-1 is highly revealing. Once you have heard X-1 bass in full song, you will never forget how that disc you're listening to can sound. You are driven to find amplifiers that are capable of this, but you don't have many choices-try to name the tubed SE that's up to the task!

The X-1's tonal balance remains true over a wide power range, provided that the source amplifier remains tonally stable. The X-1 has low distortion; at powers over a few watts, it produces less distortion than an SE amplifier-and this is audible!

Then there's dynamic range. While the Wilson X-1 can whisper like the thoroughbred it is-crystal-clear at milliwatt input levels-there's no doubt that it thrives on sheer power. And can it take it! Clean, undistorted power elevates the X-1/Grand SLAMM to previously unexpected regions of dynamic range, dynamics, and drama. A few hundred watts coupled with linearity and control allow the X-1 to redefine musical dynamic range in domestic replay. This is a thrilling dimension if you can get it, though it's impossible to achieve with a tubed SE design.

I've used the Wilson X-1 as an example, because its performance is audibly limited by even the finest SE tubed amplifiers-despite its nominally compatible load factor. In my own work (I don't own a pair of X-1s), I continue to find correlations to my X-1 experience. My Quad ESL-63s are sufficiently low in distortion to expose SE amplifiers once the output level rises above a few watts. They also need at least 50W to get acceptably loud. My WATT Vs do play louder than the Quads, but they're also low-distortion designs: single-ended amplifiers played reasonably loud sound increasingly thinner and harder tonally, and the second- and third-harmonic products become increasingly audible.

I have had more success with higher-distortion loudspeakers averaging, say, 0.3-0.5% THD in the midband-particularly if they have smooth impedance characteristics and fairly limited bass extension. With such speakers, the sonic virtues of SE tube amplifiers stand out more clearly, confirming my view of their niche-market application.

The 3.3 ohm amplifier output resistance test

One of the problems for someone auditioning a good SE amplifier for the first time is that all audiophiles have a psychological need to hear a difference. Some audio differences, while important, are quite subtle. Their analysis requires fine equipment, good circumstances, and, in some cases, extended listening. However, when compared with a conventional, solid-state, or push-pull low-impedance tube amplifier, a single-ended tube amplifier will always sound substantially different. This is due to the complex interaction of an SE design with typical loudspeaker loads-as well as their nonlinear behavior at high listening levels. Unfortunately, this provides immediate vindication for the listeners, reassuring them that they are skillful, sensitive, and capable.

There is therefore the attendant danger in such comparisons of confusing the acknowledged positive aspects of SE tube amplifiers with other changes. In fact, there is a distinct danger of making a virtue out of the entire sonic package.

Accordingly, I designed a very simple test to see whether just one of the variables in this subjective problem can be evaluated in isolation. That variable is source impedance.

In the days when "specmanship" was the name of the game, amplifier manufacturers boasted of very high damping factors-even claiming figures of several thousand in some cases. Damping factor is the ratio between the speaker load impedance-typically 8 ohms-and the output impedance of the driving amplifier.

It's a trivial matter for amplifier designers to include a small fraction of the output current in the feedback loop: they can set the theoretical damping factor to infinity, or even make it negative. Even with a zero output impedance, practical damping factors are typically no better than 50 for an 8 ohm speaker (25 for a 4 ohm model), due to speaker-cable and contact resistances. (The load impedance in this discussion is defined as that existing at the loudspeaker terminals. I am treating the loudspeaker as an electro-acoustic "black box" here, not delving into its inner structure, which includes several finite resistances.)

As single-ended tube amplifiers have output resistances in the 2-5 ohm range, I settled on a median value of 3.3 ohms for this investigation. This results in a damping factor (8 ohms) of just 2.4.

One detail required resolution: Should the listening test be conducted with the volume setting unchanged, or should the average midrange loudness be adjusted to take into account the attenuation introduced by the resistor? If the speaker system used could be considered as an 8 ohm design in the region responsible for perceived loudness, then the drop in level would be exactly 3dB.

Clearly the power level should be raised to take into account this loss. But by how much? A simple rise in level is hard to judge, since the loudness gain will be uneven over the frequency range. In practice, as with loudspeaker listening tests, all the assessors can do is to judge loudness by ear (footnote 1).

Two loudspeakers were auditioned for the listening tests: the Wilson WATT V and the Audio Physic Tempo. The former is a nearfield monitor, consequently showing a forward mid-

treble and a shy, well-damped bass. Used in a free-field position, its quality and character are instantly recognizable. By contrast, the Tempo (reviewed in Vol.17 Nos.8 and 11, pp.103 and 169, respectively) has a full, well-developed bass octave and generally good mid-treble balance-but is perhaps a little rich in the low-treble range. Fig.1 shows the Tempo's impedance characteristic, fig.2 its on-axis frequency response when driven by amplifiers with source impedances of 0.1 ohms and 3.3 ohms, respectively.

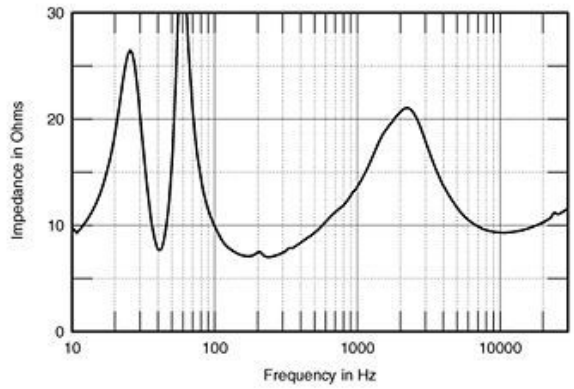

Fig.1 Audio Physic Tempo, electrical impedance magnitude (2 ohms/vertical division).

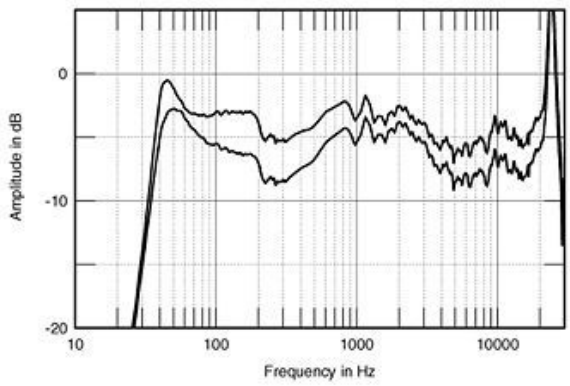

Fig.2 Audio Physic Tempo, on-axis frequency response when driven by an amplifier with an output impedance of 0.1 ohms (top) and 3.3 ohms (bottom). Note overall drop in level and significant change in midrange balance (5dB/vertical division).

Footnote 1: In *Stereophile*'s comparative loudspeaker listening tests, we have found that equalizing the B-weighted spls does give subjectively similar loudnesses.-**JA**

Test 1, WATT V:

The Watt V is nominally a 5-6 ohm loudspeaker. The calibrated loss in loudness due to the simulated source resistance was therefore a substantial 3.6dB. (Note that with an even-lower-impedance speaker, the output impedance of a tube SE amplifier will result in an even greater loss in loudness.) No sense could be made of the comparison, so I raised the volume by 4dB to match the subjective loudnesses.

What a fascinating result! The resistor feed dramatically shifted the tonal balance of the Wilson WATT, with the general view that it now sounded more like a free-field-optimized design. In particular, the bass was louder and better balanced with the series resistor, revealing pretty good power and extension. The midrange sounded open, fast, and articulate, the treble airy and sparkling. The balance was a little brighter than before, but not to the point of upsetting the overall presentation. If anything, stereo perspectives were judged to be superior, with increased spaciousness and a more holographic projection of midrange depth.

Forgive me if I point out at this juncture that some of these characteristics are often promoted by the manufacturers of costly SE tubed amplifiers, and yet here they were achieved by the simple use of a resistor costing just 50 cents!

It must also be noted that, while the above does describe a genuine quality improvement in the case of the WATT V "misused" in a free-field application, there were none of the engineering elements present that could be associated with better sound-such as a better amplifier.

Test 2, Tempo:

While the calculated loss was 3dB, given its nominal 8 ohm load, the subjective loudness of the Tempo was not greatly impaired by the 3.3 ohm series resistor. If anything, certain frequency regions, such as the midbass, were slightly louder. Overall, without any attempt at level matching, the bass loudness was similar but less even, with a loss of extension. Interestingly, the bass did *not* sound significantly boomier or less well-controlled. On a more subtle level, the listeners perceived losses in bass rhythm and impact.

Perceptible shifts in tonality were apparent-there seemed to be more presence and edge definition, yet these were achieved without hardness or glare. The sound appeared to have opened out somewhat. And, again, a feeling of enhanced focus was heard in the midrange, though the impression of depth was now thought to be impaired.

Remember that the complexity of the human hearing process will mean that some of these observed effects result from subtle loudness changes alone. For example, one effect of a slight drop in level is to increase the sense of distance from the perceived soundsources.

For the next set of comparisons, the replay level with the series resistor was increased by 2.5dB to restore the subjective impact and loudness of the program material. Now those previously misleading interpretations of fidelity caused by level reductions in certain frequency regions were blown away. This speaker, with its relatively neutral balance, was recognized as showing clear signs of a warped personality with the series resistor!

The Tempo sounded less neutral with the series resistor. Its vocal balance, for example, was lightened and higher pitched. Cellos were emasculated, sounding more like violas than cellos, while the treble was projected. This can be attractive on some dull-sounding material, but causes undesirable emphasis on others. The Tempo's bass was now unquestionably inferior to that with normal drive. Less even and well-controlled, the low frequencies were less a part of the whole sound. By whatever psychoacoustic association was at work, the bass appeared to lose drive and impact, percussive power and rhythm.

On the plus side, gains were perceived in the midrange focus, depth, and perspective-these are the sorts of changes a speaker designer can introduce by judicious control of frequency response within a specified tolerance (see the sidebar). Often a price has to be paid for such indiscretions, different kinds of music revealing them as false tonal emphases or colorations.

Comment

These anecdotal tests only go to show the remarkable complexity of sound-quality changes that can result from using an amplifier with a significant source impedance. Even experienced critics-sorry, I do place myself in this category-find it very difficult, if not impossible, to separate these physical and acoustic interactions from the overall perception of sound quality. We have to accept that moderate tone-control effects-unfamiliar response changes over limited sections of the overall frequency range, allied to changes in level-can significantly alter perceived sound quality in all its many aspects. And, in my view, it isn't possible with any confidence to separate the sound of an amplifier from the changes it may impart to the frequency response and bass damping of a specific loudspeaker.

A tubed SE amplifier may be of very high intrinsic quality, but its sound will always be hard to pin down, due to this unavoidable load interaction. The one exception will be with loudspeakers that have flat impedance characteristics. However, as such speakers tend to be 4 ohm designs, there will be an undue loss of overall power when they are driven by single-ended tube amplifiers-something that is hard to accept given the limited power delivery available from such amplifiers.

Evaluations of SE amplifiers tend, therefore, to degenerate into a search for that one special speaker-generally an off-the-beaten-track design-that has exactly the right response and impedance characteristics that its sound will be optimized when driven by an SE amp. Thus, the critic is rewarded, his skill in "system matching" vindicated, and the SE amplifier transports him to audio heaven.

A case history

To close, I offer a real-life example of an experienced critic who got the right musical result with an SE amplifier for the wrong reasons, and in the process unknowingly corrected a speaker problem.

My colleague Ken Kessler and I recently co-wrote a review of the Wilson WATT/Puppy V speaker system for the English magazine *Hi-Fi News & Record Review* (*HFN/RR*, January 1995, p.28.). We ran into some trouble in our assessment of the speaker. The test samples had been drawn from early production, which had generally been well-received by customers in the US.

Though the speaker's balance was fine in large listening spaces-especially in US-style timber-frame houses-a moderate flaw in the form of an excess in upper bass centered on 90Hz became apparent, even obvious, in smaller rooms-especially in apartments and houses of concrete or brick construction.

Ken bravely fought the fight for system matching, discovering that he could optimize the sound of the Wilson System V. His intuitive solution was to drive the speakers with single-ended amplifiers: the Cary 805, a Unison Research from Italy, and the Paravicini-designed EAR 954. Using these amplifiers, Ken was amazed to find that, contrary to his expectations, the upper-bass excess of the Wilson speaker had been tamed. "Amazed" because, given the intrinsically good sound quality of these SE amplifiers, we know that the WATT Puppy is a pretty rough load, and that historically it has favored tight, gutsy amplifiers-generally solid-state.

I found the answer to this apparent paradox while performing the test mentioned in this article. It turns out that, while the new WATT is close to a 6 ohm load and is fairly constant over the main frequency range, the new Puppy is a tougher load than the old, falling to around 2.5 ohms in the 90Hz region, and typically averaging 4 ohms. Now Ken's results could be explained! The high SE source impedance acted as an attenuator/damper for the Puppy, depressing its errant upper bass. In addition, the upper range covered by the WATT was now attenuated less overall, changing the balance between the two units.

The figures are instructive: assuming a 3.3 ohm SE source, the WATT is attenuated by 3.8dB. The Puppy, however, is stepped back by an average of 5.2dB, and by 7.2dB at 90Hz. Given tolerances for the exact value of source impedance in the frequency range concerned, you have exactly the -3dB correction this speaker requires (Note Since October 1994, the Puppy V has been fitted with a resistor to the crossover. This damps the Puppy's motional impedance interaction with the crossover, thereby giving 3dB of control at 90Hz-the offending point.0

Ken's story was concluded with Wilson Audio supplying the factory-specified 15 ohm damping resistors for the Puppy woofers. With these connected across the outputs of the woofer crossover feeds-an easy retrofit-the system now sounded bass-light and lacking in slam when driven by the SE amplifiers, mandating Ken returning to a gutsy, solid-state amplifier to complete his evaluation.

It is easy to extrapolate from this tale to other circumstances. Consider, for example, a neutral speaker that is not optimally placed in a room. A high amplifier impedance may, in conjunction with that speaker's characteristic load impedance, deliver a better tonal result. Most of the credit will go to the change in amplifier, not to the unseen variable of source impedance.

Sidebar: Sonic Speaker Tailoring
It's not readily appreciated that a loudspeaker's treble balance exercises a powerful control over perceived clarity, right into the midrange. The perception of a loudspeaker's quality hinges strongly on the balance the designer has achieved between the midrange and treble levels-both in the on-axis frequency response and in the acoustic power delivered to the room.

This is very critical, and if a speaker system lacks sufficient clarity, the designer may be led, intuitively or deliberately, to lift the treble power to improve things. It is amazing what can happen with as little as 0.5-1dB of treble lift, but this is a very dangerous procedure, as too much treble energy will disturb the neutrality and tonal accuracy of the sound. Violins become edgy, flutes breathy, and vocalists have too much toothy or sibilant emphasis. In addition, treble-dominant sounds no longer sit back in the soundstage, where the record producer intended them to be.-**Martin Colloms**