An excerpt from IAR International Audio Review

Class 2a

Spica TC-50

It's really simple as 1-2-3. One. The Spica TC-50 plays music better than any other mini-speaker, at virtually any price. Two. It also plays music better overall than any other speaker up to twice its $420 price, of virtually any size. Three. Our computer test measurements prove it, and graphically show why the Spica sounds better.

It would be remarkable enough if the Spica musically surpassed other similar size speakers, almost regardless of their price (that would make it the obvious choice for anyone with limited space). ***Or*** if the Spica musically surpassed other speakers up to twice the price, regardless of their size (that would make it the obvious choice for anyone with limited budget). But the Spica does ***both*** (this also makes it an incredible engineering achievement). If you fit into either of those two categories as a consumer, you should consider the Spica TC-50 a virtual must buy. And if you're not interested in technical details, you need read no further; you've got all you need to know.

Key Sonic & Design Factors

What makes the Spica TC-50 so good? We first introduced the TC-50 to you over a year ago, in Hotline 24. There we discussed its revolutionary design by computer, and the essentials of its sonic achievements. You might want to reread that article before proceeding here. The only sonic qualities that have changed since that report are the elimination of the two slight sonic weaknesses we heard in the prototypes: the TC-50 is no longer too thin and lean in the warmth region (quite the converse now), and the upper midrange papery roughness is essentially gone.

To further understand what makes the TC-50 sound so good, for both its size and its price, we should examine what makes other mini-speakers sound not-so-good, or downright bad.

First, most mini-speakers sound small. They sound like ... well, pipsqueaks. A pipsqueak is small, and he sounds like he's small, because his small chest cavity can't give his voice any warmth (the opposite of a basso profundo) — and at the same time the high frequencies of his voice are overemphasized, perhaps by short or taut vocal cords.

Likewise, most mini-speakers sonically give away their size by a pipsqueak sonic character. They sound thin and lean, lacking the warmth and body that can come naturally from larger speakers (e.g. listen to the dramatic warmth contrast between Klipsch's Cornwall and their smaller speakers) — and then they often compound the felony by having a squeaky tweeter that is too bright overall, or has a prominent peak.

In contrast, the Spica TC-50 presents a rich, warm, full and mellow sound, which makes it seem like a much larger system. It is also astonishing how well the TC-50s can fill a very large room with music, thanks to this full sound. Incidentally, we're not talking about loud volume levels here, but rather a sense of richness from the Spicas that almost obviates the desire to keep cranking up the level, as you need to do with other mini-speakers in a vain attempt to give the music some body.

Second, most other mini-speakers, or budget speakers of any size, sound ragged, rough, and colored, usually in the midranges. That's because they're built to a price, and budget drivers tend to have rough frequency responses and worse distortions. The two way design of most mini and budget speakers also makes for rough breakup of the midranges, since the woofer is being stretched beyond its piston response limits, in order to meet the tweeter at the crossover point.

Some speaker systems try to work around this by using high order crossovers, in order to sharply cut off the woofer's roughness at its top end and the tweeter's power limits and high distortion at its bottom end. But these systems throw phase coherence out the window, and thus are far inferior to the Spica in both stereo imaging and in sonic coherence (which gives tactile body and cohesion to the sound of each instrument, by uniting its fundamentals and overtones in the proper waveform structure). The Spica TC-50 is phase coherent. And it is built to a budget price, using something so ancient as a paper cone woofer no less. And yet it is not rough and ragged. In fact, its response (within its frequency range) is among the smoothest of any speaker system, regardless of size or price. How can it do this when other mini and budget speakers can't? Thank the integrated computer design of the TC-50's unique crossover and driver alignment (see Hotline 24 and measurements below).

Third, most mini and budget speakers are too bright and edgy, usually due to a peak in the tweeter's upper response. The problem is similar to that above. To meet a budget, a cheap tweeter is used, and most cheap tweeters have a nasty peak before they prematurely die (presumably this bright peak is supposed to hide from the naive listener the fact that the tweeter's response actually dies at too low a frequency; many tweeters from Philips, Peerless, Morel, and Seas are examples). Also, the increased power requirements of a tweeter in a mini or budget two way system prompt the designer to use a more rugged tweeter, which by nature tends to be more sluggish, hence tends to peak and die off at a lower frequency. The TC-50 uses the Audax dome tweeter, which has a very smooth response with no bright peak, but which is limited in power handling capability. And again, the TC-50's unique crossover design enables the woofer to meet the tweeter at a moderately high frequency, and a safe one for this smooth Audax unit.

Fourth, most mini and budget speakers lack adequate control of diffraction, and this degrades their stereo imaging and sonic coherence (see discussion in Hotline 31). The TC-50 has probably the best anti-diffraction techniques of any speaker having a front panel, with a thick felt blanket covering the entire front of the speaker, allowing only peepholes for the drivers' direct path output to the listener. And the sloping slant of the front panel helps even more, by preventing any unwanted secondary radiations from being concentrated at one point in time (which would make them more detectable and objectionable). The TC-50's excellence in combatting diffraction is due to designer Bau's use of Heyser's TDS technique, which measures unwanted secondary radiations from many possible causes.

Fifth, very few other mini or budget speakers are phase coherent. As we've noted so many times, phase coherence is important for good stereo imaging and for sonic coherence. Why aren't more mini and budget speakers made to be phase coherent? Generally speaking, this raises the system cost and lowers the system's loudness capability. Few other manufacturers want to sacrifice these factors, which appeal to even naive listeners, for better musical coherence and imaging, which appeal only to more sophisticated music lovers and audiophiles. But that's typical of what separates a sophisticated mini, budget speaker like the TC-50 from all the many other crude mini or budget speakers you could buy. Bau has managed to keep the TC-50 affordable by the unique phase coherent crossover design. As to loudness capability, the TC-50 cannot play as loud as some other crude mini speakers; but thanks to its full bodied, rich sound, it seems to be playing louder than it really is.

Complete Synergism vs. Incomplete Equations

The factors discussed in the above five points all work together in a unique and complete synergism, in the Spica TC-50, giving this speaker a big sound and a musical naturalness that is greater than the sum of its parts. Such complete synergism is the result of complete system design, the theme of our Hotline 24 article on the TC-50. There are several examples of this synergism.

The TC-50's low diffraction, phase coherence, and smooth response work together to yield the best stereo imaging to be heard from any commercial speaker at any price. Only a very few larger and more expensive speaker systems come close to the TC-50's overall achievement in imaging. These few might be as good as the Spica in tactile coherence and localization (both width and depth), *within* the curtain of sound between the two speakers. But the TC-50 is unsurpassed in extending that curtain *beyond* the width (and depth) of the actual speaker locations, if the recording (say of large scale music) warrants. The Spica is unsurpassed at having its actual location disappear in your listening room. This presentation of a much larger stage image, with a solid tactile coherence to all musical instruments massed throughout this larger 3D space, gives the Spicas that big sound in stereo — a big sound that belies their mini size, and which can fill up a large room without the need to turn up the volume level. Then, in addition, this larger solid stage image works in synergism with the full warmth and rich lower midrange body of the Spica's tonal balance, to give you a yet bigger sound from such a mini speaker. This full, weighty body of the Spica's tonal balance (except of course for low bass) also helps to make the huge image consistent and believable with large scale symphonic works (a pipsqueak tonal balance would not).

If any one of these synergistic factors were missing, the Spica's sound would not be as big or as musically convincing. And in virtually all other speakers, especially mini or budget ones, at least one element of the synergistic equation is missing. As our first example, the thin, lean, pipsqueak tonal balance of most mini speakers makes a caricature out of a large stereo image presentation. Let's look at some more examples of missing factors in other mini or budget speakers.

Instead of the Spica's smoothness, most budget speakers have sharp response irregularities both in the midrange and their tweeter, which cause ringing after musical transients. This calls attention to the speaker's sound instead of the musical instruments' sound, and to the speaker's location in your listening room — thus degrading the believability of both the music and the stereo image (too much music is concentrated at the speaker location, especially transients that trigger the ringing, including record ticks). These sharp irregularities can also impose unpleasant qualities on the music, like roughness, smearing, sizzle, spittiness, etc.

Instead of the Spica's diffraction control, most budget speakers have secondary radiations that appear at a different time and place from the original direct radiation. This helps your ear/brain localize the speaker box locations in your listening room, and smears the stereo imaging (and musical) information in time. Again, the music and the stereo imaging are degraded, with the stage width restricted to the inter-speaker distance, while the sound may seem small because your ear/brain is drawn to the location of the two mini boxes.

Instead of being phase aligned and phase coherent like the Spica, most mini and budget speakers have their woofer/midrange and tweeter playing at different times and in different phase. This degrades stereo image information, especially depth and width beyond the speakers, both of which depend crucially upon precise time and phase relationships among all information on the recording, such as hall wall reflections. It degrades the tactile coherence of all musical instruments, making them seem like phantoms instead of solid entities, since the fundamentals and overtones are not in the correct time and phase relationships; this loss of tactile solidity defeats any chance of getting a believable big sound out of mini speakers. And it also degrades stereo imaging because the sound from the tweeter appears as a separate spike, isolated from (and usually preceeding) the rest of the music from the woofer/midrange. This leading separate spike, being somewhat unrelated to the rest of the music, tells the ear/brain to localize transients at the speaker locations, while the rest of the music is inconsistently spread out on a stereo stage. The resulting psychoacoustic confusion degrades imaging width and depth, accentuates record ticks, and again makes mini speakers seem small. This leading tweeter spike can also add further sonic emphasis to a bright response peak, giving it perhaps a hard quality, as too much treble attack hits your ear/brain before the remaining body of each musical note.

The Spica TC-50 does all the above things right. And so there's good reason why its stereo imaging is the best, its musicality is excellent, and it produces a big sound. Like a Chesterfield, it satisfies — without the need to crank it up till things start smokin'.

Other mini or budget speakers do at least one of the above things wrong. You can hear the disastrous sonic effects for yourself, for these errors can be simulated by purposely listening to the TC-50 on the wrong axis. If you listen to the TC-50 at the tweeter height, all the carefully worked out synergistic factors of the computerized system design stop working together (see measurements below). Phase alignment, phase coherence, smooth response, warm and consistent tonal balance — all go out the window. And suddenly the TC-50 sounds obviously much, much worse — indeed comparable to other mini speakers instead of being in a class by itself. You can suddenly and dramatically hear firsthand why other minis sound the way they do. With all these factors made wrong, the TC-50 sounds inconsistent and rough in tonal balance, being toppy in the upper midrange. The stereo imaging is degraded on many counts, to being little better than other minis. The hallmark of the TC-50, its marvellous tactile coherence and unity of musical timbre, utterly vanishes, to the point where again the Spica sounds merely comparable to other minis rather than outstanding. There's good reason for all these dramatic sonic changes, as proved by our measurements. Which underscores our point that all these factors discussed above, having been engineered right in the Spica and all working together in synergism, are what truly set it apart from other mini or budget speakers. And which underscores the moral that it is imperative to listen to the TC-50 along the correct axis before one can even remotely hear the unique magic of the Spica.

As is typical of mini-speakers, the TC-50 does not have much bass, with a 3 db down point around 60 hz. The woofer is a sealed system, with a system Q specified around .7 (this gives flatter response, but some soggy sounding overshoot in bass transient response). So the bass is not as extended in quantity nor as tight in quality as some other minis, such as the Qln. Still, the TC-50's bass is not boomy (as is the oppressively colored ringing boom of some vented bass speakers). And the full quality of its .7 Q upper bass, though not as tight as a .5 Q bass which is the most accurate, at least does fit in seamlessly with the overall full warmth of the TC-50's tonal balance. Thus, the TC-50's seamless blending of full warmth with its full upper bass quality is musically consistent. This is preferable to some other pipsqeak minis which, lacking adequate warmth and even lower midrange body, nevertheless try to hide their lack of lower bass by giving you a phony hump of upper bass, which then sticks out like a sore thumb relative to the speaker's tonal balance on either side.

One tradeoff of the TC-50's overall systems design is that you listen to the tweeter off its axis. The Audax tweeter is flat on its axis to 16 or 17 kc, but then dies like a stone (most tweeters except ribbons die like a stone above their cutoff). Listening to it off its axis in the TC-50, its response begins a benign, gentle (about 12 db per octave) slope downward above 12 kc. This gives the TC-50 a top end with a sweet rather than a hot quality. But there's still plenty of upper treble delicacy, air, and detail. In fact, at 20 kc there's just as much energy from the Audax tweeter in the TC-50's off axis listening position as there would be on the tweeter's axis.

If powerful low bass or more loudness are particularly important to you in a budget speaker, and you don't need a mini size, then you might consider getting a full size budget speaker, e.g. a Mirage Model 550, 650, or 750 instead of the Spica.

Room Placement

The Spicas are quite flexible regarding general room placement. As with virtually all mini and bookshelf size speakers, they should be placed off the floor and away from the walls, but the specific distances are not at all critical for the TC-50.

What is critical is that the two speakers be equidistant from the listener, and that they be positioned at the correct vertical angle or height. Your ears (and eyes) should be lined up with the top section of the woofer cone (use a point 1.5 inches below the top lip of the felt blanket's woofer opening; this is about halfway up the height of the speaker enclosure).

But these two precision alignment requirements are virtues of the TC-50, not limitations, and it would be a mistake to attach any cautionary or negative implications to such a virtue. Consider this simple analogy. A Brownie box camera has a fixed focus lens, whose resolution is so low that it seems adequately in focus at all distances. But with a high resolution Nikon or Leica lens, there's a dramatic difference between being in or out of focus. Indeed, the more dramatically you can tell the difference when you're precisely in focus vs. when you're not, the better the lens resolution must be.

Every phase aligned speaker system with more than one driver (vertically arranged, as is common) has only one correct vertical listening axis; it's physically impossible to align two or more drivers along anything but one narrow radiation ray. The more dramatically obvious the sonic differences, between being precisely at the correct vertical listening height or angle vs. being off it, the better is the resolution of the speaker (at least in time and phase parameters).

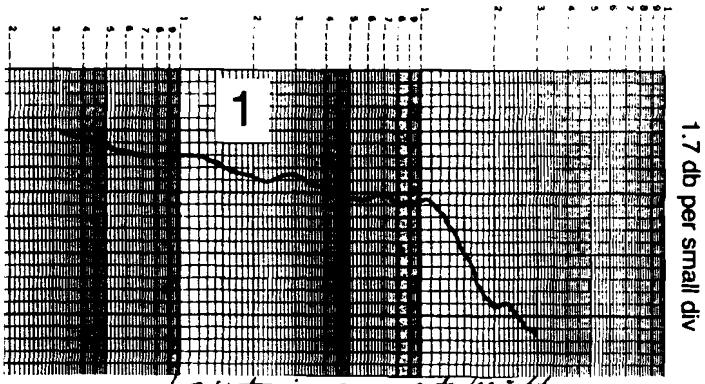
Now, with any phase aligned speaker system, we as trained listeners find it easy to precisely locate the correct listening axis, within about .5 inch of chair height at a normal listening distance, just by listening (a measuring microphone then confirms whether we've picked the correct point by ear). Incidentally, one of the best sounds we've found for doing this is a trumpet playing in the lower part of its range. At the precisely correct listening axis, the lower overtones of the trumpet suddenly and dramatically cohere with the upper overtones (and the trumpet's sound becomes less frazzled, thin, and edgy). It makes sense that a trumpet is a sensitive indicator; its waveform is a series of unidirectional spikes, and slight phase misalignment will cause a more dramatic butchering of this waveform than of any other musically based waveform.

With speakers that are phase coherent as well as phase aligned, the sonic differences are even more dramatic, to the point where any untrained listener should be able to locate the correct phase aligned and coherent vertical axis. The differences sound more dramatic because more parameters are actually changing as the listener moves from the precisely correct axis to slightly off. For example, off axis the tweeter spike will be isolated in phase as well as time from the rest of the music, while on axis it will be in synch in both aspects. And phase coherent systems tend to have a frequency response interference notch at the crossover frequency if measured (or heard) off the correct listening axis; the trumpet's sound would become thin and edgy off axis, as this interference notch takes away the lower overtones.

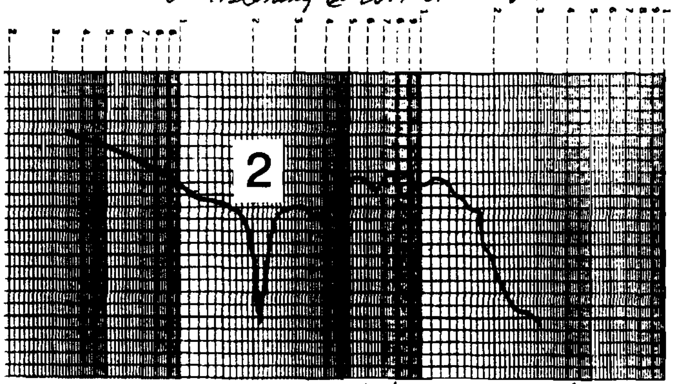
Finally, with the Spica TC-50 the sonic differences between being on and off the correct vertical axis reach stupendous proportions. It is a big mistake for anyone to fail to experiment with vertical listening axis alignment, especially with the Spicas, since their correct axis is so easy for anyone to hear, and since the sonic rewards vs. penalties are so marked.

Why is the TC-50 so rewarding of correct vertical alignment, and why is the sonic contrast so stupendous? First, the TC-50 is a high resolution lens. Both its frequency response and its time domain response are very smooth along the correct vertical axis (see measurements). If other speakers (even ones with good phase coherence and diffraction control) have rougher frequency and time domain curves to begin with, they'll naturally exhibit a less dramatic difference when these curves are further roughened by listening or measuring off axis. Second, the TC-50's unique advanced crossover filter design depends crucially on a precise additional time delay offset, for the proper blending of the two drivers, even in basic frequency response, not to mention more subtle aspects such as phase coherence or lobing. If a listener changes this offset time delay by listening off the correct vertical axis, he has literally messed with the TC-50's crossover network, and he'll totally muck up the system's frequency response.

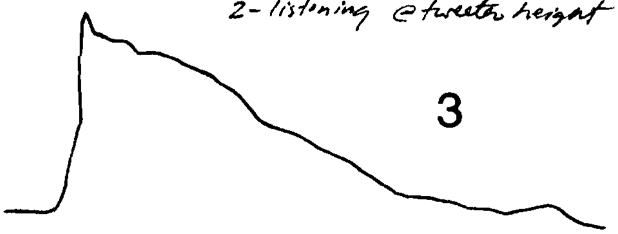
Some listeners naively assume that every speaker system should be auditioned at its tweeter height, so as a demonstration example we'll show you in the measurements how dramatically the Spica's frequency (and time) response gets degraded if one listens at the tweeter height — and thus how grossly unfair it is to the Spica to hear it from such an angle

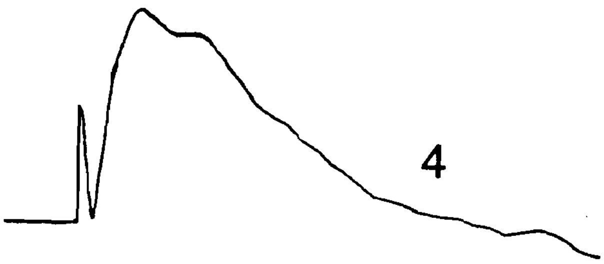


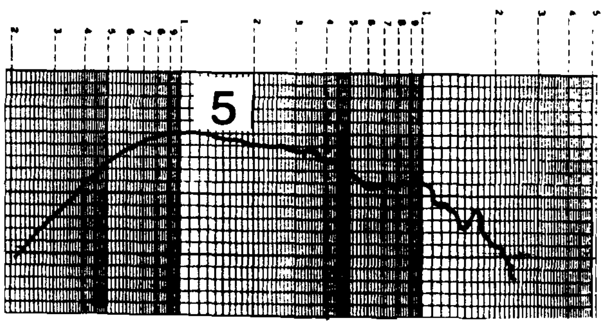
1 - listening @ correct height

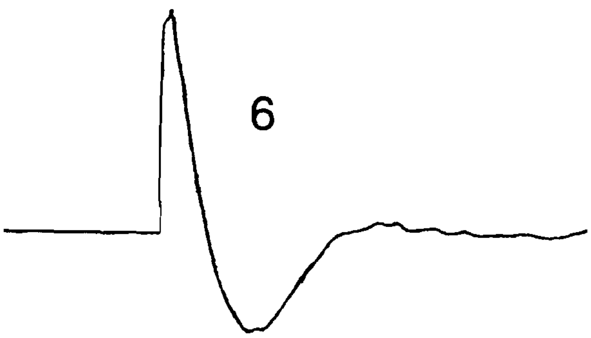


2 - listening @ tweeter height









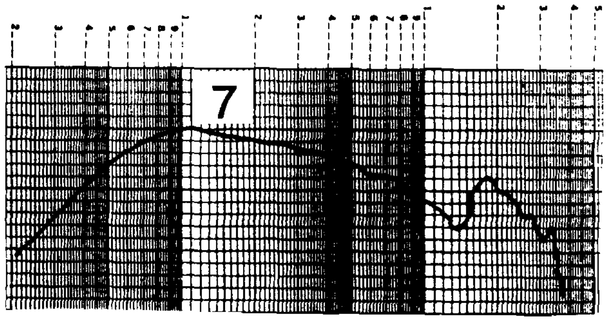
or height. Note that listening to the TC-50 at tweeter height violates Spica's specific instructions, which tell the user to listen at the enclosure's center height. In fact, very few speaker systems sound (or measure) their best at tweeter height, so with all those reviewers who have been in the habit of evaluating speakers at this height, their comments and measurements have been unfair to most of the speakers they've judged in the past.

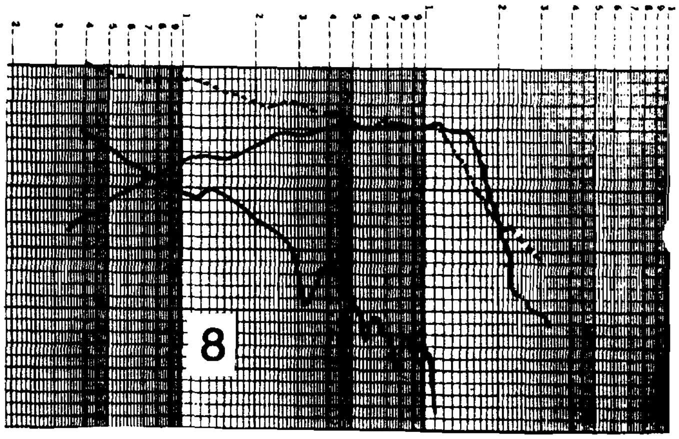
Supporting Measurements & Technical Analysis

Graph 1 shows the far field frequency response of the TC-50 along the correct vertical listening axis, measured at 1 metre distance. Recall that our high frequency computerized measurement graphs start at 500 hz, so as to prevent the room and other reflecting surfaces from contaminating a speaker measurement. Graph 1 shows that the Spica's frequency response is very smooth, with only gentle (not rough or sharp) undulations as irregularities, which vary less than plus or minus 2 db. Note that this smoothness is genuine, not illusory, since this far field frequency response measurement was taken along the phase aligned axis.

Graph 1 also shows why the Spica has a full, warm, and mellow overall tonal balance. The overall slope of this smooth frequency response is not flat, but rather an evenly progressing downward slant, at a modest 1.5 db per octave or so. Such an overall slight downward trend was found by research already back in the 1950s (at AR I think) to be most realistic in reproducing classical music, more so than a flat response. In order for a speaker to do this properly and not sound inconsistently lumpy or colored, it is important that this trend be continued straight and smoothly throughout the reproduced audio band. The Spica does this superbly; see also graph 5 for a continuation of this same smooth trend all the way down to the frequency at which the woofer starts its bass rolloff.

On the correct listening axis, you're hearing the tweeter off axis, so its direct sound slopes off benignly at a moderate 12 db per octave above 12 kc. This explains why the Spica's treble sounds gentle and liquid, not hard or bright. But note that there is still significant energy way out to 30 kc; this helps explain why the Spica still sounds airy and detailed in





reproducing music's upper treble. Another factor to consider is that the TC-50's reverberant power response into your listening room, which affects your perception of a speaker's tonal balance, is brighter than this rolled off curve would suggest. That's because the Spica aims its tweeter's brightest lobe upward, where it contributes to the reverberant sound field. Most other speakers aim their tweeter's brightest lobe directly at the listener, so the speaker sounds duller than the on axis response curve would suggest, since only dull parts of the tweeter's radiation pattern are contributing to the reverberant or power response that affects the tonal balance you hear in your room.

Picture 3 shows the far field time domain step response of the TC-50, along the correct vertical listening axis (duration is 4 msec). Again, the key word is smoothness. This is one of the smoothest and best integrated step responses we've seen on any size speaker at any price, and is truly amazing for a budget mini speaker. Also, the Spica is correctly designed in that the smoothest frequency response and the best time domain response occur on the same axis (many other speakers have different sweet spots for the best frequency response vs. the best time domain response).

The tweeter's spike is well integrated into the overall step waveform, with only a slight overshoot at the leading top corner betraying its presence. There's no negative undershoot before the step waveform begins its climb (as is common with many budget tweeters), nor is there a hint of a notch or gully between the initial tweeter spike and the takeover in the time domain by the woofer/midrange (another common flaw).

Perhaps most extraordinary is the very smooth line marking the step response's descent, with nary a squiggle and no sharp jerks. This extraordinarily smooth and consistent time domain response explains the superb sonic coherence we heard from the Spica, with a seamless reproduction of a musical instrument's timbre, texture, harmonic structure, and tactile solidity. This time domain curve also suggests very smooth phase accuracy, which helps explain the superb sonic 3D imaging, and the solid believability of instruments portrayed within that image. Incidentally, the steadily declining slope of the step response top, without a flat top starting section, merely indicates that the Spica does not have extended low bass.

Now, what happens if someone assumes he should listen to the Spica at the tweeter height, violating the specific instructions? He'll be hearing a drastically different speaker, one that is totally unrepresentative of the Spica heard correctly. It will have far worse sound, perhaps comparable to other budget minis — and we see that this is supported by far worse measurements, perhaps comparable with other, cruder budget minis.

Graph 2 shows the far field frequency response of the TC-50 when erroneously listening at tweeter height. Even when we know in advance that this will mess up the crossover network, by altering the time delay that's a crucial part of the Spica's sophisticated computerized systems design, it's still a shock to see how dramatically different the frequency response has become.

Instead of being beautifully consistent throughout the covered audio range, the sound is now totally disjointed. Graph 2 shows that the warm, mellow consistent downward slope of the woofer/midrange changes over at the 2 kc crossover point (where the notch is) to an upper midrange and treble that not only fails to continue the gentle downward slope, but actually rises with a much too bright and irregularly humped mountain range. In place of the Spica's seamless and consistent portrayal of instrumental timbres, overtones, and transients, we instead have a very inconsistent speaker. A portion of the crucial midrange (from 2 to 3 kc) disappears into a black hole of a notch, while the rest of the midrange, from 1.5 to 4 kc, sits in a depressed gully. The immediately adjacent upper midrange will seem too 'toppy', being much too prominent in proportion to the sucked down midrange notch and gully. The upper midrange and trebles will sound much too bright in quantity, and rough in quality, with a particular raggedness that you can see in the 5 to 9 kc region. And, compared to that depressed midrange, the warmth region will seem excessively prominent, rather than merely consistently rich.

Meanwhile, far field time domain picture 4 shows the corresponding ruination of the Spica's beautiful time and phase response, from listening at the same erroneous tweeter height point. The tweeter is now way ahead of the woofer/midrange, as seen by its separate spike. First come music's trebles, whose excessive amplitude brightness seen in graph 2 will be overemphasized even more by their precedence and separateness from the rest of the music. Transient attacks will seem too prominent and disembodied from the rest of the music, as they hit you over the head first.

Picture 4 shows that a single musical note literally gets torn apart in time, into separate bursts of energy for the treble part and then the midrange/bass part. First comes the spike of treble information from the tweeter. Then, after the treble information from the tweeter, the music falls momentarily silent! And only after this silence does the rest of the musical spectrum follow, even though it's supposed to be part of the same musical note! Thus, the speaker will sound disjointed in time as well as in tonal balance. Also, note that there's some increased roughness in the descending tail part of the time domain step response.

Remember, all this grossness is caused simply by making the mistake of listening to the TC-50 at tweeter height. Obviously, it's a totally different and far inferior speaker to the real TC-50, heard at the proper woofer height. Interestingly, most other mini and budget speakers, at their ***best*** axis, measure about as bad as this gross misview of the Spica, and they also sound comparable to the Spica heard erroneously. But there's no comparison, in sound or the supporting measurements, when you hear or test the Spica correctly.

There are further interesting technical aspects of the Spica's design that we can discover from our measurements. Graph 5, running from 25 hz to about 2 kc, shows the near field bass frequency response of the system, as well as some of the upper frequency response of the woofer cone. The smooth gentle slope of system response seen in graph 1, rising with lower frequency, is seen to extend consistently down to about 100 hz, below which the woofer begins to curve downward in its bass rolloff, reaching its 3 db down point around 60 hz and descending below that at 12 db per octave (the 2nd order response of a sealed system). The bass transient response is seen in picture 6, which shows a 50% negative overshoot (a system with lower Q would have less of this undesirable overshoot), but at least no ringing after the return up to zero (a vented bass system might show a boomy ring here).

Near field probing is also valuable for learning about the strengths and weaknesses of a speaker system's drivers, and about the system design choices and tradeoffs made by the speaker designer.

As smooth as the TC-50's frequency and time domain responses are (on the correct listening axis), there are still slight undulations sprinkled throughout the midrange. Our near field measurements traced all these irregularities to being the fault of the paper cone woofer/midrange driver breaking up in the midranges (irregular breakup mode response is common among paper cone drivers). With a choice of another driver smoother in these regions, the Spica's overall amplitude response could have been even smoother. Why, in an advanced computer designed speaker system, is there something so archaic as a paper cone woofer, when the rest of the speaker world has moved on to bextrene and now polypropylene cones, which have much smoother response? Three possibilities occur to us: to keep the system price affordable to you audiophiles on a budget, to keep system efficiency as high as possible, and perhaps because the computerized system design required a woofer/midrange driver with extended high frequency amplitude and phase response. Bextrene and polypropylene cone woofers are smoother up to their cutoff point, but they cut off at a lower frequency and die steeply; perhaps the computer design dictated that some high frequency response from a woofer (even in breakup rather than piston mode) was preferable to none.

Graph 5 shows that the woofer/midrange driver's paper cone starts breaking up with significant irregularities above 600 hz. And that's the best behaved part of the cone. Graph 7, covering the same frequency region, shows that the stiff paper dust cap of this driver has a smoother response up to 1200 hz, but then has an awful midrange hump from 1200 hz to 3 kc (perhaps this could be tempered by damping the dust cap with a gooey substance).

But the clever crossover design of the TC-50 minimizes these driver irregularities seen in the midranges. The net contribution to the total system response from these irregularities is minimized by cutting off the woofer at a steep 4th order rate (24 db per octave). But how can one design a phase coherent speaker system using a 4th order crossover? Here's where the Spica's advanced computerized design is seen at its best. Designer John Bau, working with his computer and Dean Jensen's optimization programs, discovered that a 4th order Bessel filter could be made phase coherent with a 1st order Butterworth (which is on the tweeter) — if an extra time delay term was introduced. That extra time delay is easy to achieve in a speaker system, by simply physically offsetting the drivers the proper additional amount. This in turn explains why the correct vertical listening axis is so crucial to the TC-50's frequency response curve, as we saw above. The two drivers add in both time and phase to produce the correct total system frequency response, and to be proper, the time and phase addition must include the correct time delay between the two drivers — which means listening and measuring at the correct vertical axis.

You can see the way the Spica's unique crossover works by looking at graph 8. Graph 8 studies the near field frequency response of the two drivers above 500 hz (solid lines), and superimposes them on the final overall system response as seen in graph 1 (dotted line). Note that the overall trend of the woofer/midrange driver response is being brought down at a steep slant by the 4th order filter. If you mentally readjust your view to see this downward slant as a flat reference baseline, you'll note several features: the driver's response has many irregularities, which are sharper and worse in magnitude than those in the overall system response; in spite of these irregularities, the overall trend of this driver is quite flat, as it follows this baseline established by the crossover's 4th order filter; and the driver's response is very extended for a woofer/midrange, reaching to 9 kc before dying off (bextrene and polypropylene cones would only reach to 2 or 3 kc before dying).

The tweeter driver curve shows that it is intrinsically a very smooth and flat driver. You can see the shallow 1st order crossover slope, which begins to take effect below 3 kc. This curve also shows that, on axis, this tweeter has flat response up to 16 kc. Incidentally, it's interesting to contrast the top end of the tweeter's own on-axis response with its off-axis response that you hear along the TC-50's correct vertical listening axis. The listening axis curve rolls off above 12 kc instead of 16 kc, but note that its rolloff slope is much more gentle than the sudden dying plunge on the tweeter axis — which also implies better perceived transient response (sweeter trebles). Indeed, by the time you get to 20 kc, you're hearing as much from the tweeter on the Spica's correct listening axis as you would if you were on the tweeter axis, and above 20 kc you actually get more treble information.

Now, the output from these two drivers acoustically add, in the broad region you see from 500 hz (and even below this) all the way up to 9 kc. The sharp and severe irregularities you see in the woofer's paper cone breakup region from 2.5 kc to 9 kc do contribute to the Spica's final system response. But, as graph 8 shows, this irregular region has been knocked way down in level by the steeply sloping 4th order filter rolloff of the woofer by the crossover network. Because the woofer has been knocked down so low in level, its contribution to the overall system response is very small in this region. You can see in graph 8 that the main contribution in this region comes from the tweeter, which is at a much higher level. And its response is very smooth. So the irregularities of the woofer driver response appear merely in very subdued form in the final system response, with their sharpness and amplitude both quelled (averaged out) by the larger contribution of the smooth tweeter in this region.

By comparing the various graphs and pictures, you can also indirectly get a feeling for the critical importance of the correct time delay (i.e. correct listening axis) in the functioning of the Spica's crossover. If one sets this time delay wrong by listening at the wrong height, such as the tweeter height, picture 4 shows that the woofer/midrange driver's output is entirely separated in time from the tweeter's output (the initial spike). Therefore the tweeter cannot effectively average out or swamp out with its smooth response the woofer/midrange driver's paper cone breakup irregularities in the 2.5 kc to 9 kc region. True, the tweeter is still putting out much greater amplitude than the woofer/midrange driver in this region, but it's doing so at an entirely different time than the woofer/midrange driver. Two signals obviously can't add or affect each other if they occur at different times. Thus, these woofer/midrange driver irregularities from 2.5 kc to 9 kc should become more prominent in the overall system response, if one defeats the crossover's proper functioning by forcing the wrong time delay. Now look at graph 2, taken at the tweeter height axis, and compare it to graph 1 (the correct system response with the correct time delay). Do you see more prominent irregularities in that region from 2.5 kc to 9 kc?

Incidentally, the steep 4th order filter rolling off the woofer's top end has another interesting consequence. The rise time of the woofer/midrange is drastically slowed by this Bessel filter. You can see this as the slow risetime of the major hump (which represents this driver) in picture 4. Now, if you look closely at picture 3, you can see a bit of this same slow risetime slope climbing about halfway up the height of the step's leading edge. Part of the woofer/midrange's time response sticks out like a foot to the left of the tweeter's vertical leading edge. So, for this class of phase coherent speaker systems, the best time domain alignment is apparently achieved not by synchronizing the initial rise of all drivers, as is the case with 1st order phase coherent systems. Rather, the driver that's been slowed down artificially by the steep crossover should be allowed to compensate for this by getting a headstart in time. The TC-50 is the first of this new breed of phase coherent designs, and we'll doubtless all learn more about these matters as more such designs appear.

SPICA

1601 Paseo de Peralta, Santa Fe, NM 87501