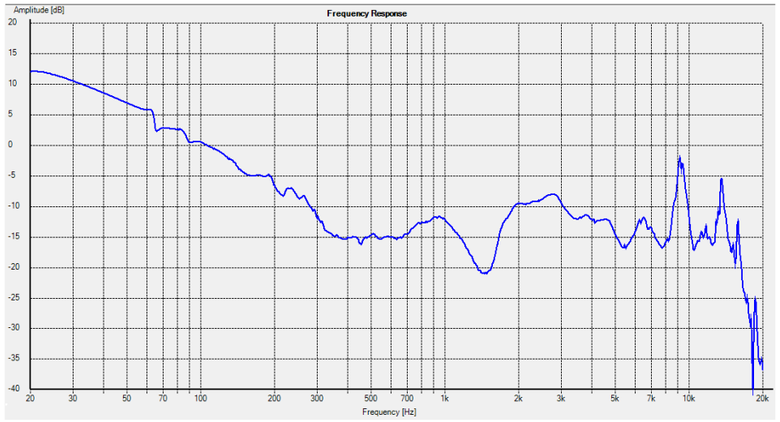
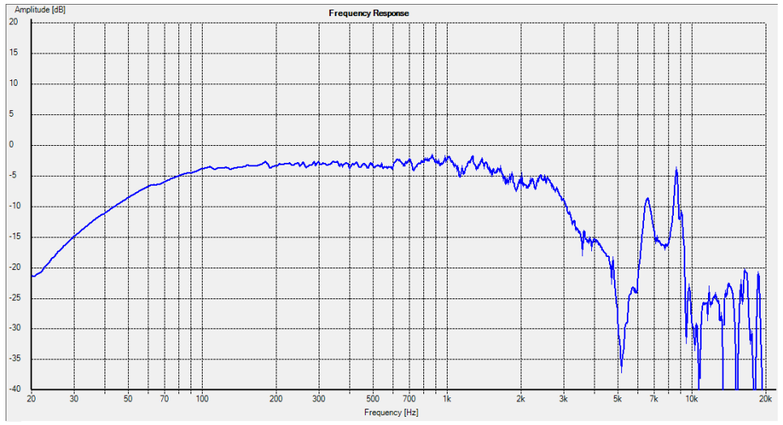
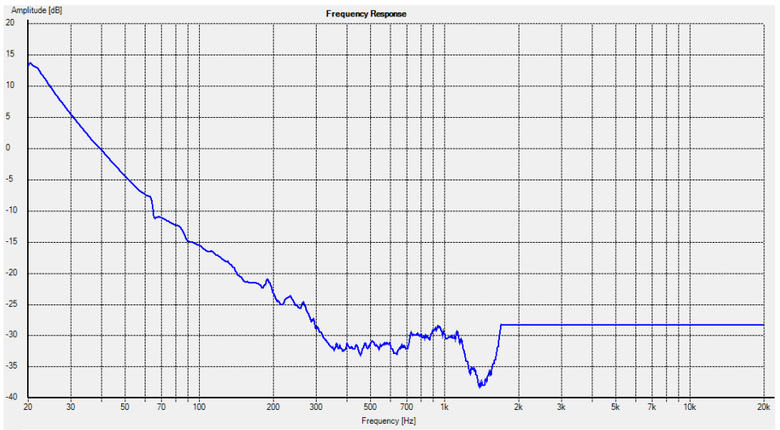


A SEAS H1207 loudspeaker measured internally in a TTC 750



The same SEAS H1207 Loudspeaker measured externally at the rear in the very near field in a TTC750



From these we calculate the chamber correction curve. The final result of this SEAS H1207 Loudspeaker in a TTC750 test chamber is shown on the front cover

Tetrahedral Test Chambers

Consistently stable and accurate loudspeaker measurements throughout the world

For further Information please see our website

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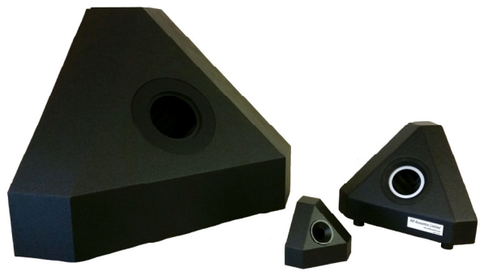
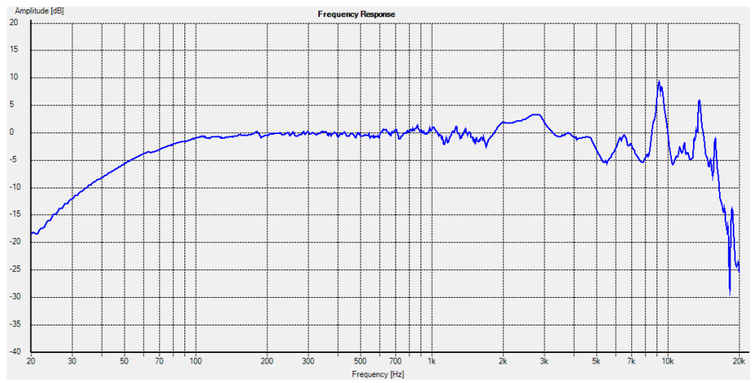


TTC750, TTC170 and TTC350 Tetrahedral Test Chambers showing relative size

We look forward to helping you solve your loudspeaker measurement problems.

Tetrahedral Test Chambers

- **Consistently stable & accurate measurements**
- **Are a small fraction of the cost and size and inconvenience of an anechoic chamber**
- **Eliminate many common setup problems**
- **Ensure consistently reliable measurements in challenging environments**
- **Use inter-changeable sub baffles for rapid & accurate configuration**
- **Are your design, production and quality control measurements this good?**



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Designing & Supplying Loudspeaker Test Chambers used throughout the World.

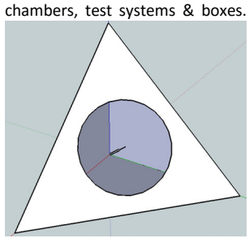
Tetrahedral Test Chambers call Geoff on +44(0)7967 024518 or e-mail geoff@hillacoustics.com

Tetrahedral Test Chambers provide an ideal measurement environment for loudspeaker drive unit characterization. Perfectly suited for use in R&D and also production/QC they provide a consistent, repeatable measurement bridge between these often conflicting and geographically separate departments.

A Tetrahedral Test Chamber (TTC) is a way of dramatically improving the quality of loudspeaker measurements. It removes most, if not all of the causes of variation and replaces these with a known structure which can be accurately and reliably calibrated to ensure accuracy and consistency across many locations.

How does a TTC work?

A TTC works by making SPL measurements within a known and controlled environment with a fixed and controlled geometry. An environment which inherently minimizes internal reflections; known as "Standing Waves" these plague most measurement chambers, test systems & boxes.



At the core is a microphone facing outward from a corner toward a triangular baffle which retains and supports the loudspeaker being measured.

However this Box is NOT a Box!

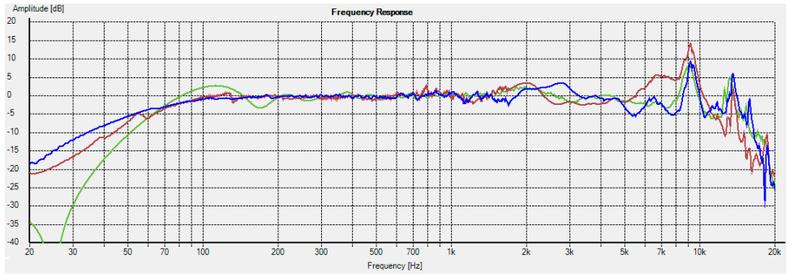
1. Why does this matter? Well what do you want or need a test box for? - The chances are pretty high you need to check or measure some loudspeaker drivers yes? Well now boxes "Sound" and typically measure "Boxy" and that means that the response you are trying to measure is mixed in with the test boxes own response... So it can be difficult to separate out the response you are measuring from that of the test box itself.
2. But all we need is a relative measurement! Oh do you? - If the test boxes response varies at or near the same frequency as a variation that you are trying to measure, you then have to fit limits around fast changing Test Box modes. And you risk ending up with false negatives.
3. What are "False negatives?" These are false rejects. Good loudspeakers that you should be selling to your customers at a profit, which instead are "Quarantined" as if they were some sort of infectious disease. In a way they are: Why? Well…
4. Let us look at what happens to them later: The boss under pressure to increase production and profits does a surprise inspection and finds the crate of "Quarantined" drivers gathering dust and with last weeks/months date stamp on them.

The boss demands to know what's wrong with them and is greeted with a tale of confusion as to whether they pass inspection or not - taking one he passes it to the line inspection lady who sweeps it and pronounces it good to go.

5. Where upon the QC manager is heard to complain that it does not pass the "Tests" but no one from here can find out what is wrong with all of these and engineering being on another continent are 8 hours ahead or behind of production so getting them to help is out of the question...
6. Result not only are you rejecting perfectly good product but also you are weakening your quality standards either way: If you open limits up you will pass genuine rejects. But if you don't you are faced with unacceptable and unjustified reject levels. Are relative measurements still acceptable? – Were they ever?
7. Another advantage of using the tetrahedral test chambers is that if you were in the situation (4) you can directly e-mail the results to your design/R&D knowing you can get an immediate yes/no as your measurements are now directly comparable with the Original design measurements...
8. The Tetrahedral Test Chambers provide a quick, straightforward and accurate system that does not require specialised knowledge and expertise but does give a level of precision and accuracy otherwise unmatched - by all but the finest facilities.
9. The Tetrahedral Test Chambers do this without requiring to 'Window' the data. Now windowing is a powerful technique but it swaps accuracy at higher frequencies for practically all of the low frequency information. It is difficult to do well and the results can be ambiguous not exactly an ideal recipe for high pressure production environment.
10. The Tetrahedral Test Chambers can use high quality reference standard microphones through to ICP or suitable 48v phantom powered microphones and we specify / certify performance from 10Hz or 20Hz (try doing that with a conventional anechoic Chamber) to 20 kHz, 50 kHz or 100 kHz depending upon the supporting equipment and software.
11. "I have never heard of the Tetrahedral Test Chamber before - Why and why now?" Developed in 2013 they are now in use throughout the loudspeaker industry, Geoff Hill the inventor and designer has nearly 40 years experience designing and measuring loudspeakers, together with many years building and implementing anechoic chambers and acoustic test facilities. These facilities are in use measuring PA, Hi-Fi, Mobile and Automotive Loudspeakers.
12. The design concepts are backed up by fundamental theory by Richard Small and Don Keele, verified by boundary element modelling and finite element analysis of the tetrahedral structure. They were designed by Geoff Hill, to directly eliminate as many of the loudspeaker measurement problems so that they never trouble us again.
13. "If this is so good surely it must have been published or standardised?" - Yes indeed it has been published as an Engineering Brief at the Audio Engineering Society (AES) conventions also at ISEAT and ALMA. An AES Information document is also in progress
14. What equipment have they been used with? And to whom have they been demonstrated?

The Chambers themselves have been demonstrated to hundreds of people. Using a wide range of transducers and measurement equipment including: -

15. ARTA, Audio Precision, B&K, CLIO, HOLMImpulse, Klippel, ListenINC, Loudsoft, MLSSA and NTi. Basically any equipment that can accept a calibration or equalisation curve is suitable.
16. You can also post process the amplitude data the measurement results are accurate.
17. "All of this sounds great almost too good to be true - surely there must be some problems?" Well you do need to use a Tetrahedral Test Chamber appropriate for the measurement That you are producing; essentially if you are making a free field measurement then you need to ensure that the Test Chamber itself does not change the resonance frequency by more than +/-5%. Just select the correct chamber that it is large enough…
18. Also depending upon the size of the chamber being used the SPL may be higher internally than externally and it certainly will be at low frequencies as we are measuring in a pressure region where the wavelengths are much longer than the size of the chamber, for small drivers at low frequencies this is usually a major advantage as the signal to noise Ratio is boosted significantly and clean reliable measurements are now available.
19. Yes there is a significant boost at low frequencies often 40dB or more: However most loudspeaker drivers do not have: Extended bass performance, small size and high sensitivity all at the same time we can still handle the sound pressure levels using conventional high SPL microphones.



SEAS H1207 Loudspeaker in a TTC 350 (Brown), TTC 900 (Blue) and Ground Plane (Green)

20. Where is the best use for these chambers? Ideally we would see these chambers at every stage of the design, production and quality control stages on through to the final customer
21. "The Tetrahedral shape seems very simple and obvious - but why and why now?" Geoff Hill came up with the design as a result of writing a book "How to Design High Quality Loudspeakers" he realised that it is all very well to design something in Theory: Ultimately you need to verify or measure the performance to confirm that it is working as designed. Usually we use conventional Loudspeaker measurements:
22. Free Field conditions which can be difficult if the weather is poor or if you are in a noisy environment.
23. Open Baffle in a normal room using "Windowing" trades low frequency accuracy by removing time domain reflections. The "Windows" themselves can and do significantly affect the results.
24. The use of an anechoic chamber: Fine in a university research department, or a branch of the military. They are big and expensive requiring massive investment in concrete, steel, timber and loads of acoustic absorption, to prevent reflections interfering with measurements.
25. Making measurements in an extremely large and quiet room; so you get as much time before reflections is possible but even in a very big room there are typically strong echo's easily heard and measured though with care they can be "Windowed" out.
25. All of these options still leave many set-up variables as unknowns which will affect the quality of the measurements undertaken. Geoff thought "What would I do if I had none of the above available and was doing this from the start today using our current technology"? Throwing the out the "Rule Book", Geoff designed anew making consistency of measurements the absolutely top goal and working onward from there.
26. A question is an anechoic measurement really the Gold Standard? Well yes and no...

With a perfectly set-up anechoic chamber you can reduce many of the problems; however anechoic chambers are really designed to be a quiet non reflecting environment. Anechoic chambers are designed to have this behaviour over a large portion of the chambers volume. They are a general purpose acoustical tool, better suited to old style 1/3rd octave analysis rather than modern FFT based analysis

27. Anechoic Chambers are NOT generally designed to have high geometric and dimensional control of a measurement. Also they are not terribly good at low frequencies. Their behaviour is typically only controlled to +/-3dB over their working range and pretty well none of them is better +/-4dB below say 80Hz.
28. Why well let us look to the Physics for a moment: The speed of sound in air is about 340m/S (depending upon ambient air pressure, height and so on) so half a wavelength at 80Hz is just over 2m which is about the maximum wedge length in practice.
29. If we wanted to absorb 20 Hz we would need a wedge 8.5 metre long! Unfortunately this is totally impractical. So practically speaking an anechoic chamber is a compromise between size, volume and the cut-off frequency.
30. Then unfortunately many Anechoic Chambers have a floppy mesh floor making microphone and loudspeaker placement difficult or unstable.
31. Other times they have a stable mechanical platform of steel bars and grids that can and do reflect considerable sound back into a measurement… An Anechoic Chamber is often placed where there is sufficient space and that is not always where it is needed.

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32. What about the IEC baffle or JIS test box don't they help? – In theory yes – In practice they add another layer of complexity and possibility to an already difficult situation. Where the microphone should be positioned, on what axis and so forth? Are just some of the questions that are left as unknowns?
33. "Okay I can see an anechoic chamber can have problems at low frequencies, but why is the tetrahedral chamber better?" The tetrahedral test chambers take a different approach to the measurement of low frequencies in particular; we do not attempt to absorb them at all as we know that the wavelengths are so long that is impossible anyway.
33. Instead we define the geometry and a structure which is much smaller than the wavelengths at low frequencies and is an enclosed volume.
34. This then gives us a stable and predictable low frequency pressure field. In this we define both the microphone and measurement positions rigidly - This in itself is a major departure from the anything goes typical anechoic environment.
35. We also have a stable acoustical absorption at higher frequencies so that the response from 1 or 2 kHz upward is effectively anechoic.
36. "But the shape - why that shape?" Geoff has been designing then measuring and designing for years and remembered that some of the most repeatable 'Best' measurements or the most consistent measurements had been made in the corner of a room or of an anechoic chamber.
37. These measurements were always stable and he found that stability in measurement is probably the most important thing. If you have stability you can improve the absolute accuracy through calibration and correction, without stability you can do little.
38. We all know the best solutions are often the simple ones. What is simpler than four triangles!

One of the platonic solids is the tetrahedron composed of four equilateral triangles. We use three right angle triangles in a corner this is known as a tri-rectangular tetrahedron and a single equilateral triangle as the baffle mounting of the loudspeaker being measured.

39. "What is the aim of the Tetrahedral Test Chambers?"

The aim is to improve loudspeaker measurements by providing a consistently stable, mechanically and acoustical environment; resolving many of the existing problems of conventional loudspeaker measurement techniques. The core design can be produced by using an equilateral triangular shaped baffle in a corner.

40. "Look we will be blunt here - we already have a system for measuring loudspeakers, why should we change?" - Let us ask you something though... Are your measurement results from all stages of design, manufacture, and quality control through to customer acceptance directly comparable?
41. Could you in fact take or look at data at any point through this chain and see what is happening? No: Well how could we? The results and requirements are totally different.
42. Take Design: they use Multi-physics modelling together with an anechoic chamber and precision instrumentation regularly calibrated to the highest international standards.
43. While production is frankly more concerned with ensuring each and every unit produced meets its target specifications so a relative measurement is fine against the production golden sample.
44. That's it, of course design and development, research or, production then quality through to the customer all seem to have different requirements and measurements that they need to ensure compliance to their own requirements...
45. I say seem as up until now there really has not been an acceptable solution bridging these differing requirements:
46. Accurate enough for R&D, stable enough for QC, able to operate on the line under noisy high volume conditions but still cost effective enough for production and independently verifiable so as to reassure the final customer.
47. Now there are the Tetrahedral Test Chambers, the missing link providing a bridge between design, production and quality ; on through to your customer by ensuring stable, accurate & consistent measurements.
48. You say you have published this? Yes a second paper 'Further measurements using a Tetrahedral Test Chamber was presented to the AES 136th Convention of the Audio Engineering Society in Berlin in April 2014 it is available for download from the AES e-library.
49. Also you are working with the AES Standards Committee's? Yes the concept of a triangular baffle which retains sub baffles and a fixed microphone was accepted as part of project X-223 and will thus form part of a forthcoming AES Information Document.
50. This allows anyone to stick a triangular baffle into a corner and get a measurement in some respects better than in most anechoic environments.
51. Okay back to the Tetrahedral Test Chambers you produce, what sizes are available?

Our smallest chamber is the TTC170 this can measure loudspeaker drive units up to 2".

Then there is the TTC350 this can measure loudspeaker drive units up to 4" diameter.

Next one is the TTC 750 this can measure loudspeakers up to 8" diameter.

Then we have our larger Chambers currently we have the TTC 900 this can measure up to 12" Loudspeakers.

Then the next planned version is the TTC 1500 which will measure up to 24" Loudspeakers.

52. The Tetrahedral Test Chambers are accurate enough for R&D, stable enough for QC, able to operate on the line under noisy high volume conditions but still cost effective enough for production and independently verifiable so as to reassure the final customer.
53. So if you already get comparable results all through your supply chain; then no you don't need the Tetrahedral Test Chambers. In truth though that's very unlikely so the Tetrahedral Test Chambers can bring you all of these advantages...
54. So let me assume that if you are still reading this admitted long piece you have a problem with consistently stable loudspeaker measurements - if so I invite you to contact me direct and I'll do my best to help resolve your measurement problems.

To purchase Tetrahedral Test Chambers please e-mail: - sales@hillacoustics.com

For further information see www.hillacoustics.com