THE BOOK OF HORNS

History – Theory – Technology

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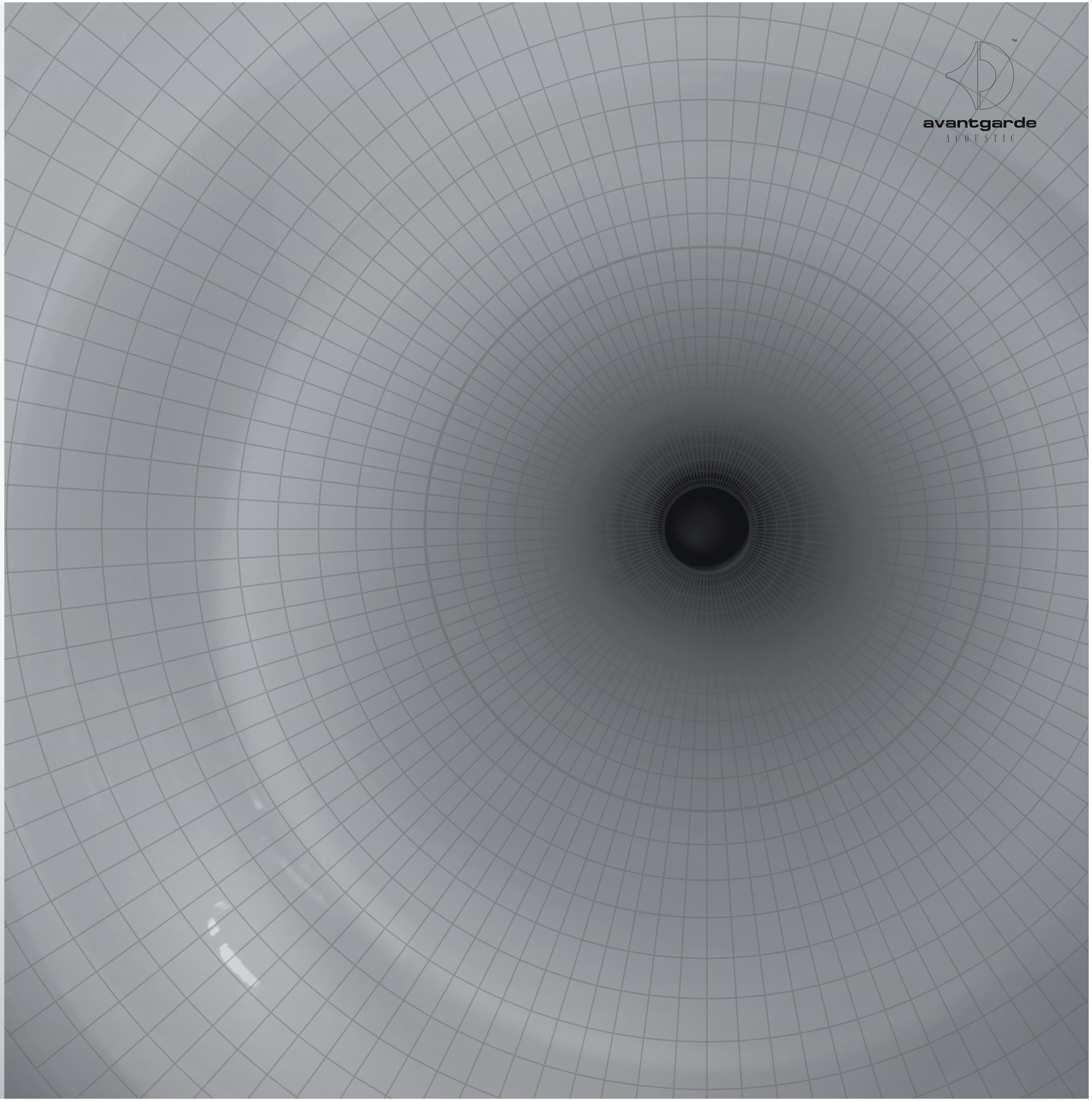
THE STORY OF THE HORN

Horn loudspeakers are the most natural physical concept for sound reproduction. Its characteristics offer incredible advantages compared to other loudspeaker concepts.

In order to give you a closer insight into this fascinating technology, Avantgarde Acoustic™ has compiled for you on the following pages, a short history as well as the most important principles of a horn.



THE VERY BEGINNING

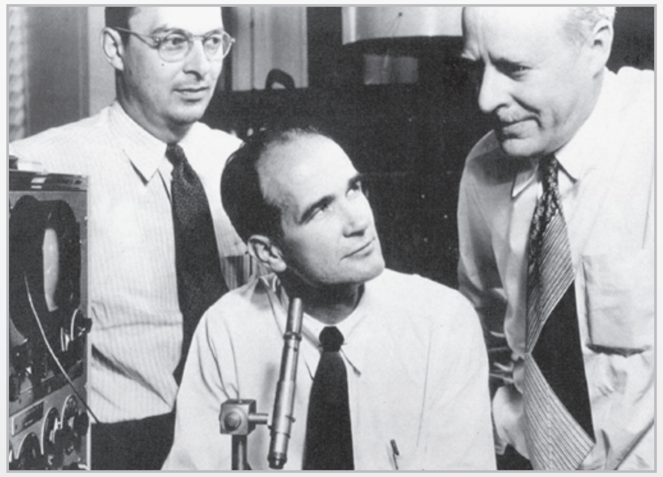
It happened more than 100 years ago, when, for the first time, Emil Berliner presented his gramophone to the public. The horn of the gramophone amplified the mechanical oscillations of a pin running along a groove in a disc producing a sound that could be heard by the human ear.

This technological feat was followed by the search for the optimal shape of the horn. This revealed to be a bold and complex venture as already hinted at by Harry F. Olson: “The design of a horn loudspeaker is usually a long and tedious task”. Similarly, horn pioneers as Gustavus, Webster, Klipsch and Voigt required decades in order to explore the laws of the horn technology. In 1926 Paul Voigt submitted his first tractrix horn to the British Patent Office.

The hey-day of the horn loudspeaker followed. At that time tube amplifiers had only very low power capabilities and required very efficient and powerful loudspeaker systems. The horn loudspeaker was the only existing loudspeaker concept which was able to transfer low electrical power into high sound levels.

Famous classics amongst these designs were “The Voice of the Theatre” designed by Altec Lansing, the “Klipschorn” by Paul Klipsch, the “Imperial Hyphex Horns” by Jensen Manufacturing Company, the “Voigt Domestic Corner Horn” by Paul Voigt of Voigt Patents Ltd and other horn designs, e.g. “Acousta” and “Audiovector” from the British company Lowther.

HISTORY



THE EMERGENCE OF THE TRANSISTOR

In 1925, along with the invention of the horn, Kellog and Rice submitted their patent for the dynamic loudspeaker. In those days it was called the loudspeaker "without a horn" since, in contrast to the gramophone, this device was able to reproduce sound without a horn. An abundant number of technical innovations were to follow. In 1947 Bardeen, Brattain and Shockley from the Bell Telephone Laboratories made a historic discovery in this area when placing a metal tip on a piece of germanium (see picture). The small control current which entered over the tip into the semi-conductor, increased the current flowing within the germanium. The principle of the transistor was discovered.

A transistor can increase electrical currents and voltages just as tubes do. Furthermore transistors are relatively small and easy to manufacture. Hence, this was the end of the tube and the elaborate horn loudspeaker. The main advantage of the horn loudspeaker, namely its high efficiency, was no longer a prerequisite for sound reproduction. It was substituted by the high power capacity of transistor amplifiers which were capable of producing sufficient sound volume via inefficient loudspeakers.

Consequently, everybody was able to listen to music anywhere and at any time. However, the fact that the well-designed horn loudspeaker, still remained the most efficient physical concept of sound reproduction, fell somewhat into oblivion. How does the horn principle work? Please find below an explanation of its technology.

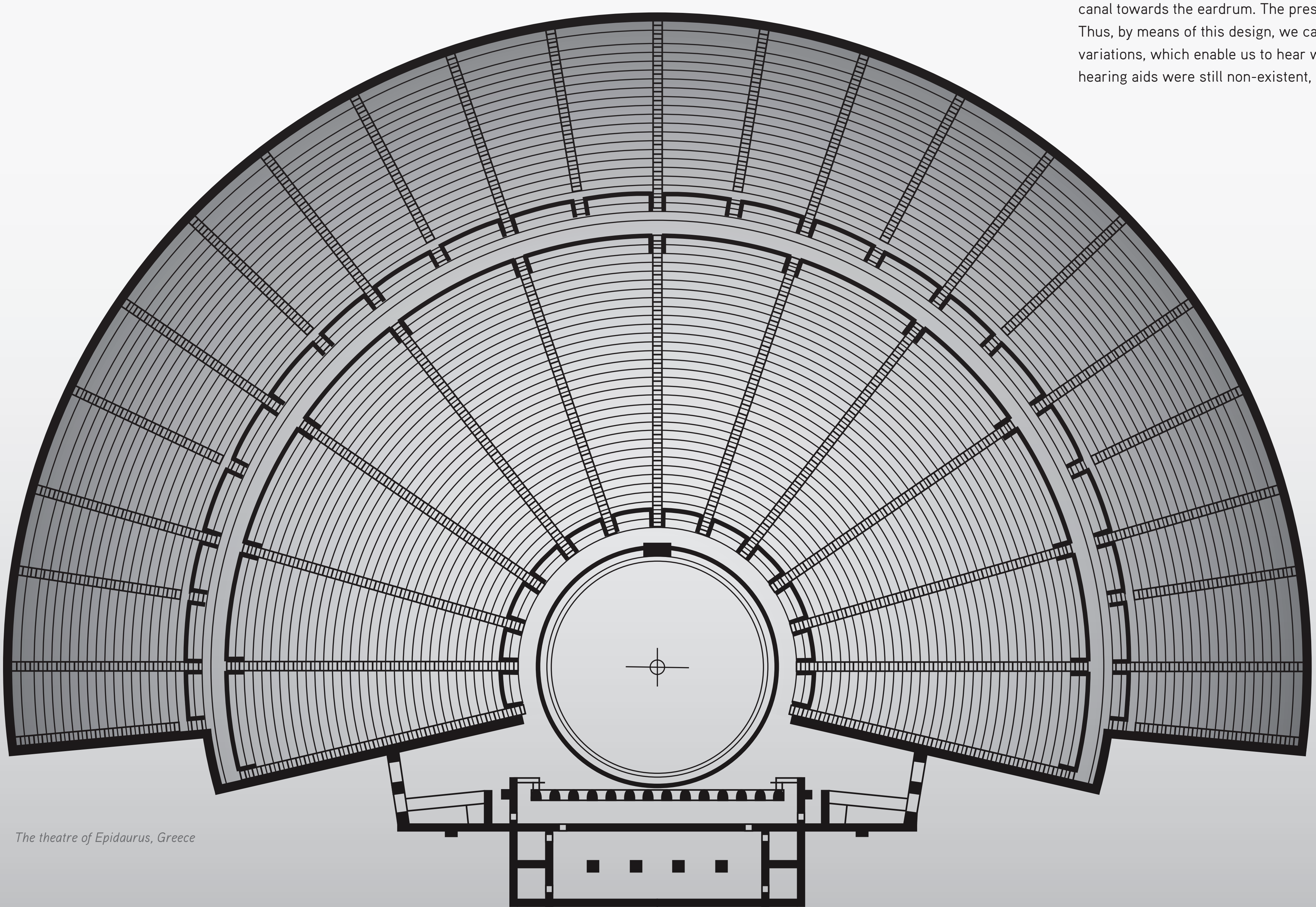
Germanium christal

THE HORN PRINCIPLE

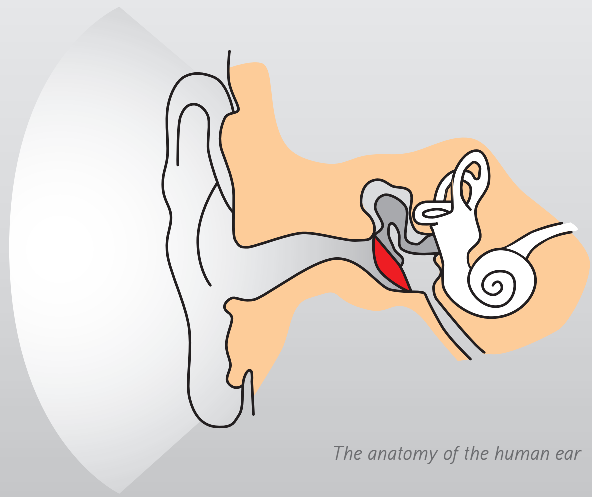
Horns are transforming pressure by using a sound source, which means a driver. Thus they work in principle the opposite to a human ear. The ear consists of the outer, the middle, and the inner ear. The outer ear gradually decreases in diameter via the auditory canal towards the eardrum. The pressure increases accordingly. Thus, by means of this design, we can perceive infinite pressure variations, which enable us to hear well. In former times, when hearing aids were still non-existent, simple horns were used as such devices. Try for yourself, by increasing the size of your ear with the palm of your hand, and you will achieve the same result.

Loudspeakers, however, are supposed to work the other way round. They should improve the emission of sound waves. For this purpose, a sound emitting membrane is placed at the beginning of the horn, which means the horn throat. Compared with the human ear, the horn is used from the other side. You will experience this by cupping your hands around your mouth. Your voice will be louder, however, it will sound slightly different. This can easily be explained. Your hands form a horn of approx. 1,000 Hz. The sound of your voice is thus being increased within this frequency range, which is responsible for the unusual tonality. So to speak, this physical effect of the horn was already known to the Neandertal Man, even though unconsciously.

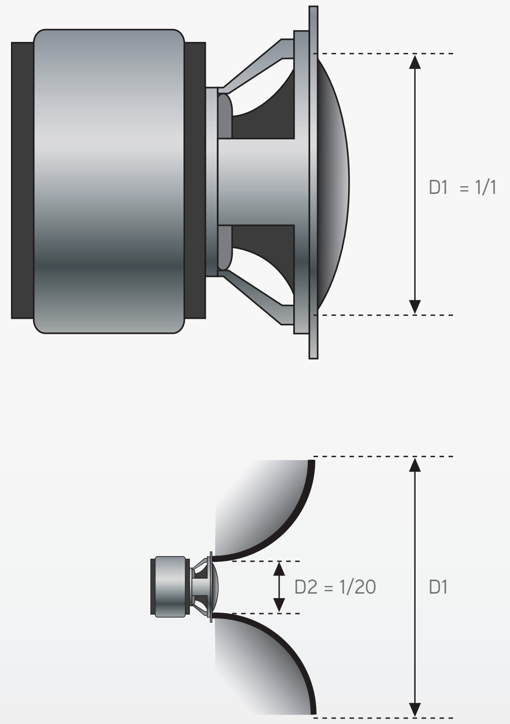
Already in the ancient world of the Greeks and Romans it was entirely different. They knew very well how to make use of the amplification of sound by means of the horn. Amplifiers did not exist in those days, therefore circular or semi-circular arenas which opened up to the top like a funnel, were built for performances. Simply imagine the famous Greek theatre in Epidaurus on the Peleponnes (4. century b.c.) to be a 113 m (370 ft) horn where the spectator would sit on the upper rim. The stage can be considered as the horn throat and the artist as the sounding membrane. Even if the artists were whispering on stage the voices could be clearly heard on the uppermost seats.



The theatre of Epidaurus, Greece



The anatomy of the human ear



At a given SPL output a horn loaded driver can be designed significantly smaller than a driver without a horn. This results in a reduction of the moving mass of up to 1/20!

THE PRINCIPLES OF PHYSICS

Horn loudspeakers are provided with a sound reproducing membrane on the horn mouth. The operational membrane has to oppose an increased pressure induced by the horn shape. If you compare the excursion of a membrane built into a loudspeaker enclosure with one installed behind a horn and actuated with the same level of power, this will result in a reduced membrane excursion depending, of course, on the shape and size of the horn. Hence, the following principle applies: the more the membrane excursion is reduced, the higher the sound intensity will be.

„Increased sound intensity in spite of decreased membrane excursion?“ This seems to be somewhat of a contradiction, which apparently led to the widespread misunderstanding that the vibration of the horn itself is the major cause for sound emission. But this is not the case, by no means!

The explanation of this phenomenon is easier than you might expect. The physical principle of energy conservation runs as follows: „the sum of the absorbed energy equals the sum of the emitted energy.“ If this principle is applied to the loudspeaker model, „the added electrical energy in W/s equals the emitted sound waves plus the electrical and mechanical energy waste due to friction which causes the loudspeaker to heat up.“

If using a horn reduces the membrane excursion of a loudspeaker, the waste of energy due to friction on the moving elements (voice coil, suspension, fixtures on the rim), as well as due to friction of the flow of air around the voice coil will be reduced at the same time.

It is as easy as that: the energy used in order to allow the significantly stronger movement of the operational elements of the loudspeaker, is transferred by the horn with its increased mechanical resistance into increased acoustic output.

High mechanical resistances are always a prerequisite for efficient energy transmission. This statement seems difficult to understand and contradictory, but the contradiction can be explained by means of a simple example. Imagine a sprinter running on parquet with pantoufles, or let us think of him sprinting with spikes on a racetrack.

The actual gain is not the maximum sound intensity, which can be achieved. When reproducing sound at the same sound level on the same loudspeaker, once on an ordinary loudspeaker built into an acoustic baffle, and the other equipped with a more efficient horn, the membrane excursion in the latter can be reduced by factor 10.

The reduced membrane excursion causes a membrane velocity increased by the factor 10. If you wish to obtain this velocity within the same time, which means a velocity increased by the factor 10, the distance as well as the acceleration would have to be increased again by the same factor. This implies that an amount of energy by factor 100 would be required. What an incredible waste!!

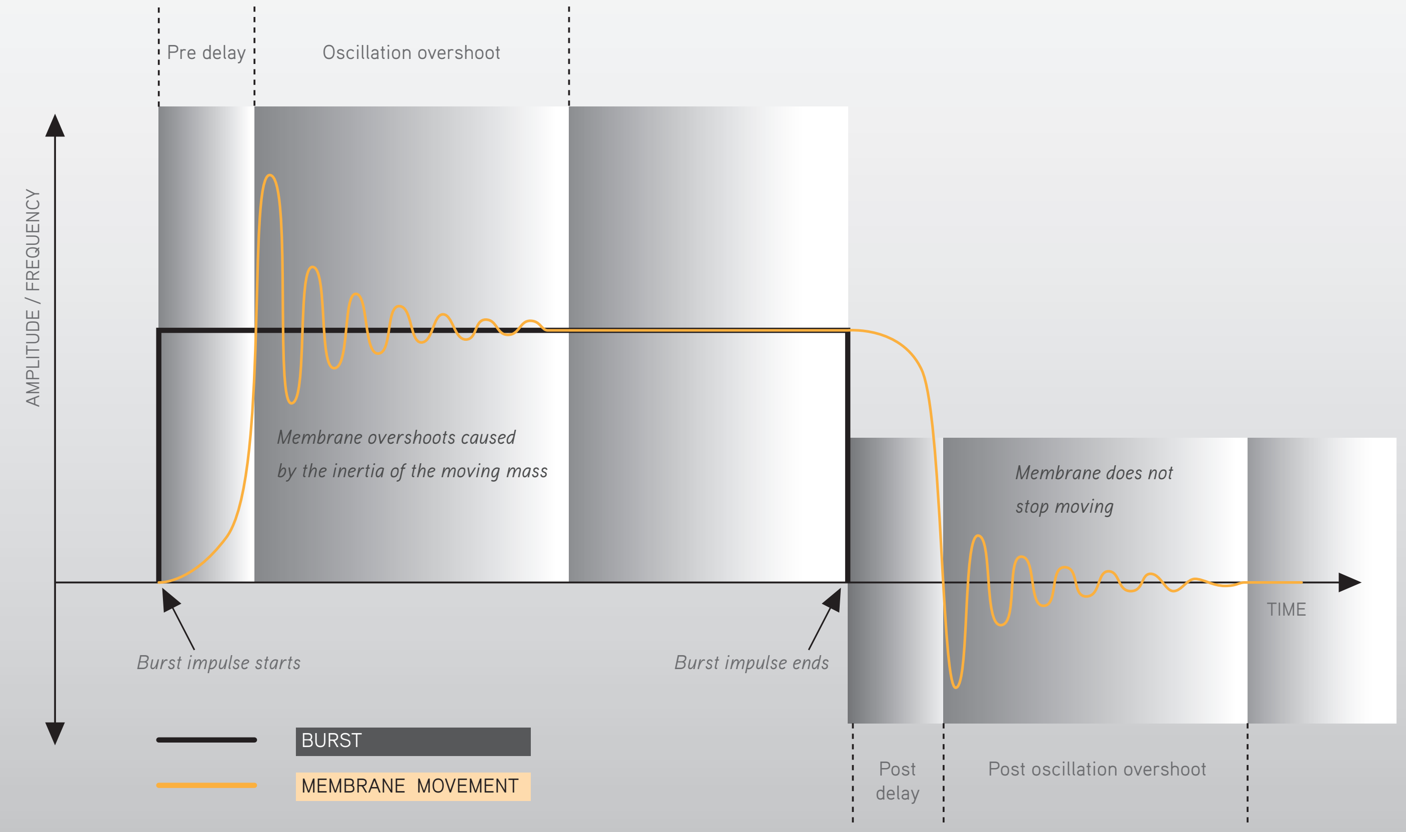
By using a horn, the acceleration of the membrane and as well the air happens nearly without inertia, allowing a speed of sound, which would not be feasible without a horn.

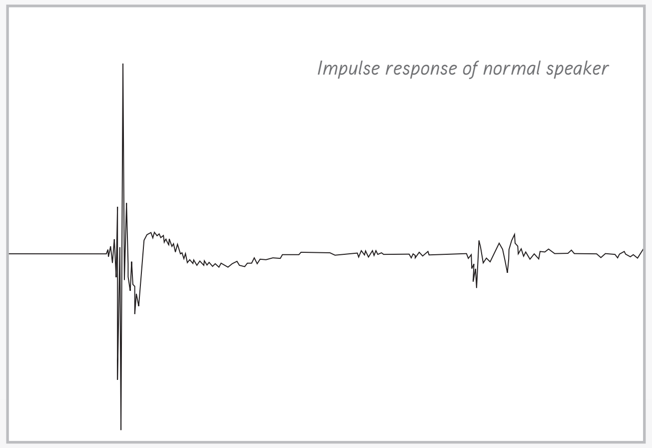
Dynamic pressure amplitudes are reproduced extremely fast and the membrane very quickly reaches back its neutral position. That is to say, the critical post oscillations of the membrane are efficiently suppressed. Due to this fact, the quick suppression of post oscillations in horn loudspeakers results in an exceptionally audible resolution of infinite details.

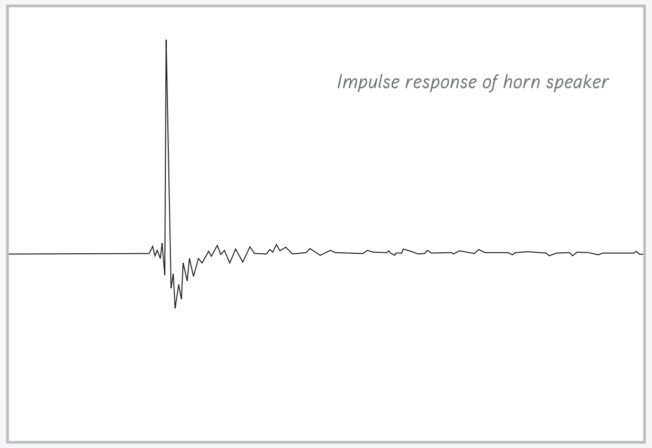
What kind of impact does this velocity of a horn have to the quality of sound? Music consists of constantly changing intensities, which means sound levels can vary in their intensity depending on the music. A loudspeaker has to follow these impulses accordingly, and should reproduce them as precisely as possible.

The following example is going to depict the related factors: Just imagine the narrow bends of the Monte Carlo F1 racing circuit in Monaco. No problem for a racing car, but for an „ordinary“ car the narrow bends poses an insurmountable problem. It can easily reach the required speed, however, acceleration and deceleration distances are completely insufficient.

The very same applies to an ordinary loudspeaker. The power and the maximum volume are absolutely irrelevant!! Since already with an „ordinary“ speaker enclosure you are able to achieve high sound pressure levels. Much more important is its acceleration potential since every loudspeaker can only process information which is slower than the loudspeakers potential. That is the reason why, with our horn systems, you will hear all music details, even those you have never heard before!







MEASURING TECHNOLOGY

The behaviour of a loudspeaker along the time axis (acceleration/ deceleration), which has just been described, cannot be clearly discerned via standard sound pressure frequency graphs.

Sound pressure frequency plots show whether a loudspeaker is balanced over its entire frequency range. This implies that you obtain the value of the amplitude of the membrane excursion and in turn, the induced sound pressure. But from frequency plots we cannot see what time the loudspeaker requires in order to reach this level and the time needed to come back into its initial position. The latter can be made visible graphically by means of a so-called waterfall diagram by using a MLSSA measuring system.

However, one has to be especially cautious with regard to the evaluation and comparison of the graphs of other loudspeakers, since most of the time the measurements are based on a given initial power input. And the higher the restoring forces on the actuating elements (spider, crimp; crease, fixtures on the rim) the quicker the loudspeaker comes back to its initial position. This means that a good decay spectrum at a given power input normally correlates with a slow and inert driver design; allowing us to use the following slogan: The more inert the better.

Please consider the following example: Comparing the (ground) noise within the interior of two cars, the noise in car B is higher than that in car A. Thus car A´s performance is deemed better than that of car B. However, the fact that car A runs at 50 km/h and car B at 150 km/h means that this performance test is meaningless.

It would be more appropriate to proceed as follows: First, the decay spectrum should not be measured at a given initial power but at a pre-defined sound pressure level. The graphs would then depict true evidence and would make them comparable with others. Secondly, our interest should actually focus rather on the initial oscillation than on the post oscillation behaviour. Why should we concentrate on the second defect if the first has not even been brought to light? This implies that the elapsing time is measured between the initial power input on the loudspeaker terminals and on reaching a pre-defined sound intensity. Since the more inert a loudspeaker is, the longer its raise time. Furthermore, please note that the loudspeaker can only process signals which are slower than its own capacity. The bulk of the remaining information will be inevitably lost!

A horn will significantly increase the accelaration and at the same time reduce the amplitudes of the post oscillations of any driver. Critical vibrations of the membrane are effectively surpressed. Distortions are significantly reduced and dynamic compression does not occur.

TECHNOLOGY

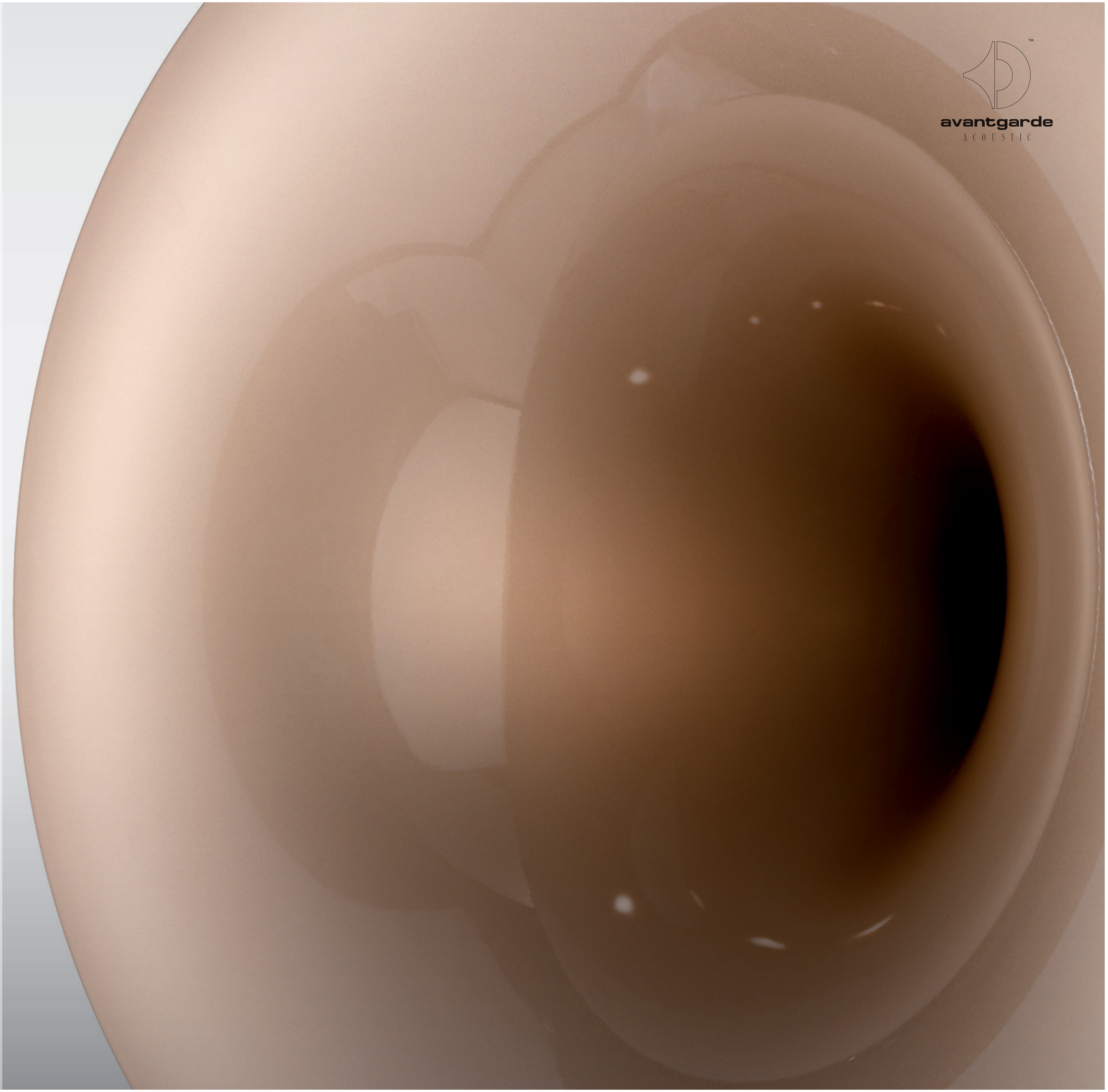
HORNS DO NOT COMPARE

The theoretical advantages of horn loudspeakers are common knowledge to specialists in this field. Nevertheless, this construction principle is only rarely put into practice. One reason may be the considerable efforts and the ensuing costs. But the major obstacle is to put theory into operational practice.

The horn loudspeaker does not only emphasize the positive aspects of musical enjoyment, but also impurities which were not perceivable before. Simply imagine the horn loudspeaker to be an acoustical magnifying glass with which everything can be seen much more clearly - its beauty as well as its impurities. Thus, the most infinite errors occurring during developing of a loudspeaker will be indiscriminately brought to light.

A horn loudspeaker is like a mimosa; it is extremely sensitive, blatantly showing every single mistake. Therefore, the Avantgarde Acoustic™ horn loudspeakers are not just beautiful horns mounted to an attractive frame, but an expression of affectionate dedication to detail and meticulous and careful manufacturing. The Avantgarde Acoustic™ philosophy is to set superior standards, which means creating top quality from the very first stage of research and development to manufacturing. This inevitably involves turning to new horizons and also to carefully consider issues which at first glance seem to be rather less important.

With its spherical horn systems Avantgarde Acoustic™ proves the true potential of the horn technology. Therefore, we would like to acquaint you, on the following pages, with the technical subtleties, which distinguish our loudspeakers from simple horn concepts.



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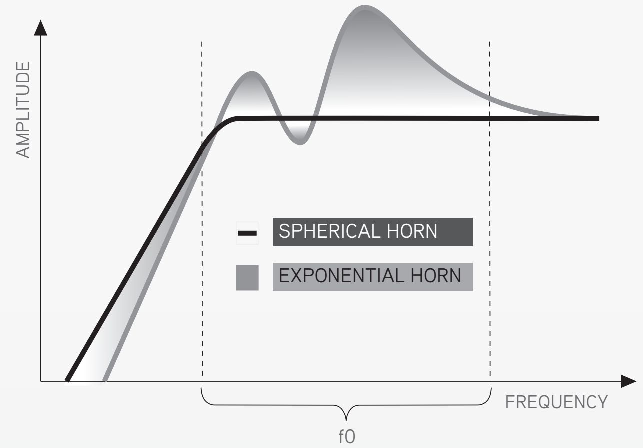
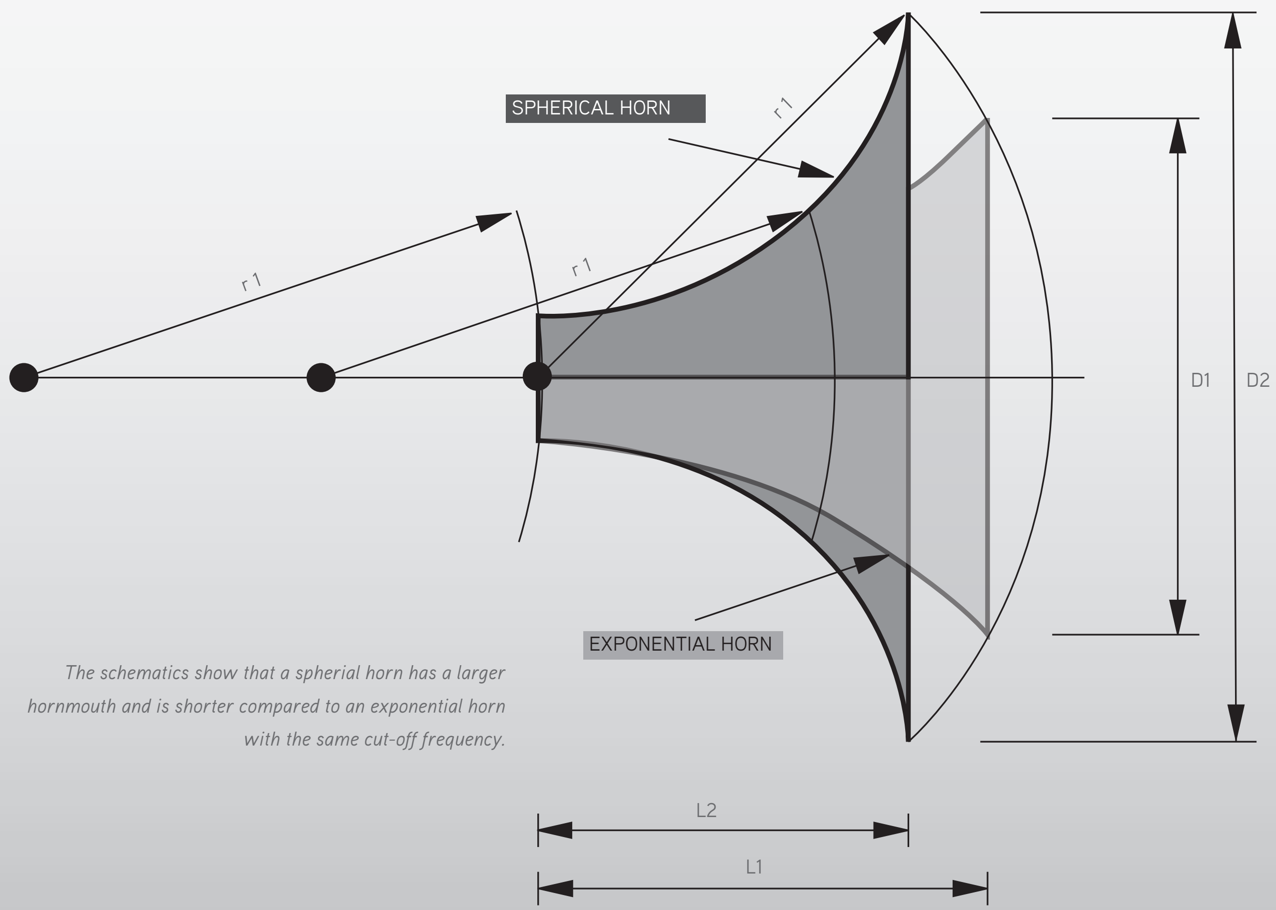


The graphic shows the response of the frequency range in the „fo“ area (horn cut-off frequency). The comparison of exponential and spherical horns show that a spherical horn is linear at the cut-off frequency of the horn. Non-linearities caused by reflections within the horn do not occur.



The schematics show that a spherial horn has a larger hornmouth and is shorter compared to an exponential horn with the same cut-off frequency.

THE HORN FUNCTION

The shape of our horn curvature does not follow the whim of our designer, but is precisely calculated by means of complex mathematical procedures. This is aiming at a controlled increase of the soundwave front within defined limits from the beginning of the horn all along the end. The slightest imprecision of the horn shape will be mirrored by the sound waves. These will take on a slightly “crooked” shape instead of their original form. Just imagine, for example, a trumpet. By means of its design, which means the length and the curvature of the horn, a particular sound - namely the typical sound of a trumpet, is intentionally achieved. Horn loudspeakers follow an entirely different aim since the sound must be reproduced unbiased and undistorted!

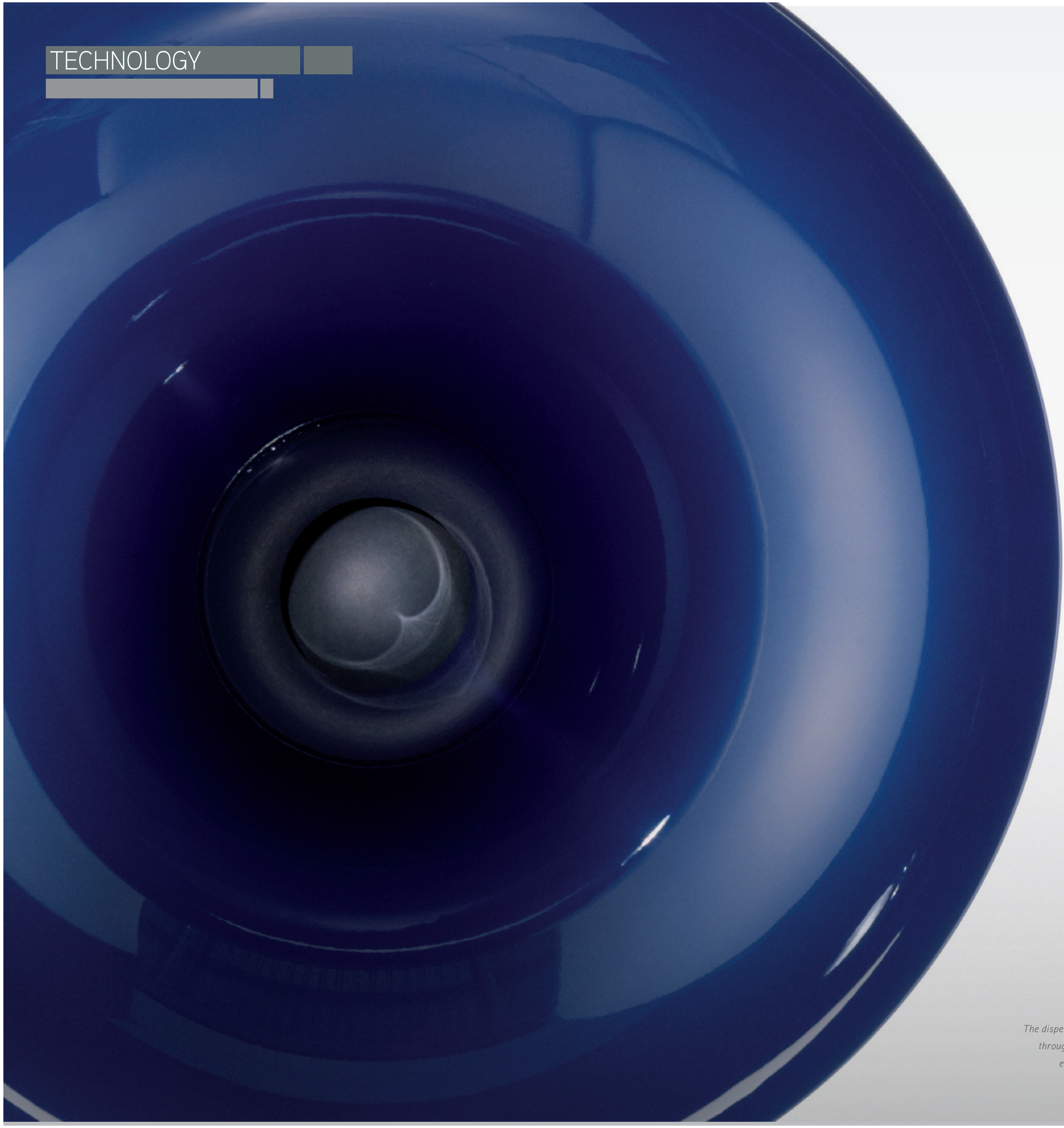
Basically, there are various algorithms for calculating the horn shape:

Exponential horns which emerged in the 1920´s, are based on the conception that an even sound wave is emitted at the beginning of the horn. As one part of the sound waves namely that along the central horn axis has to travel a shorter distance than those parts who follow the horn curvature, this theory turned out to be wrong. The wave front within an exponential horn is slightly bent and causes so called colorations, which means changes of tonality during reproduction.

A substantial improvement of sound emission can be achieved by using spherical horns. Instead of the 90-degree horn opening of an exponential horn, the spherical horn allows an even transition due to its broad opening of 180 degree. This algorithm is based on the knowledge that the wave surface at the horn throat is not a plane, but is dome shaped. In an exponential horn, part of the sound waves located along the axis inevitably have to cover, indeed, a longer distance than those on the rim of the horn. If this influence is taken into account as well as the fact that the surface of the dome (not the even diameter) should rise according to the exponential principle, one obtains an altered shape of the spherical horn.

Altogether, this results in a linear and constant sound wave emission along the entire frequency range of a spherical horn. Since emission already comes from an spherically shaped surface at the horn throat, a wide and well-controlled directivity over the entire frequency spectrum is achieved.

Another difference of the spherical horn regarding the lower frequency range should be noted. The spherical horn shows a linear decline at its lower cut-off frequency point. The typical bumpy response of exponential horns does not occur.

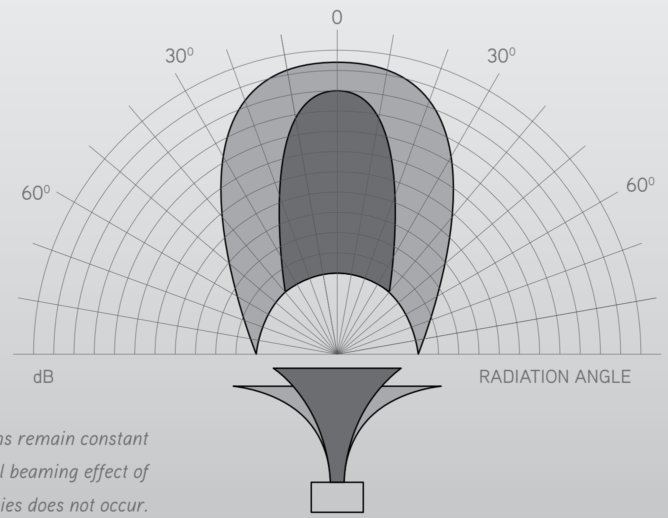


THE HORN SHAPE

The calculated values along the horn's axis are adaptable to whatever shape one wishes to obtain, be it square or rectangular, etc. Simply imagine a spotlight reflector. You will find round and rectangular lamps and, depending on the design, you will obtain a beam of light serving as a spot light or as a light illuminating the surrounding area.

The same applies to a horn loudspeaker. Depending on the design of the horn the sound waves can be shaped in order to accurately distribute the sound waves, which means the music. This procedure used mostly in professional sound reinforcement has one crucial disadvantage: It transforms the shape of the original sound wave. You will obtain the same volume everywhere, however, you will not hear the same music anymore. In terms of the spot light, you will obtain the same light intensity everywhere in the room, but overall it will have become darker.

Since Avantgarde Acoustic™ prefer it to be lighter, they manufacture their spherical horns simply according to the image of nature, which means in circular, spherical shape. It can be assured that as long as the physical principles of the world remain unchanged, and the sound waves spread as they do now, the Avantgarde Acoustic™ spherical horns are just as right as they are. And this will be the way forever.



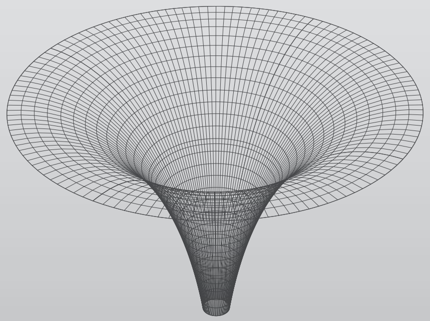
The dispersion characteristics of spherical horns remain constant throughout the frequency range. The typical beaming effect of exponential horns in the high frequencies does not occur.

TECHNOLOGY

THE MANUFACTURING PROCESS

Let us turn from theory to practice. How does Avantgarde Acoustic™ manage to transform the right horn principle into an excellent product?

There are various procedures available. The easiest way would be to manufacture the horn on a lathe, using wood as the basic material. However, wood tends to alter and change its shape. Depending on humidity, temperature and air pressure, wood expands or shrinks which would consequently alter the horn's curvature. A much better material is glass fibre reinforced plastic (GFP). This technique implies that the negative mold is covered with a mixture of epoxy resin and glass fibre. The surface structure, however, is of inferior quality. This is the reason why GFP horns have to be reworked manually. Herewith, the same problem arises as with wooden horns. The more the horn surface has to be manually smoothed, the less precise the horn shape curvature will be. Uncompromising product quality cannot be realized that way.



That is the reason why Avantgarde Acoustic™ took a new approach. As the very first manufacturer in the world, Avantgarde Acoustic™ produces its spherical horns by using the elaborate injection moulding technology. Under a pressure of 2,500 tons (5 million lb) the molten resin is injected into a steel mold. These steel molds are manufactured with a tolerance of ± 0.05 mm (± 0,002 in), and a weight of more than 8,000 kg (17,600 lb) for the 950 mm (37.4 in) low-midrange horn SH9504. This ensures a precision in horn manufacturing, which had been impossible to date and results in an unmatched long term stability and accuracy of our horns.

On the one hand, this guarantees a very precise emission of the sound waves within the horn, which is achieved by the exact design of the horn shape curvature. On the other hand, it is possible to offer extremely high quality and product continuity in the Avantgarde Acoustic™ series production process. Thus, one horn resembles the other, left and right channel are always 100% identical, which is absolutely indispensable for an exact stereo sound reproduction and imaging.

THE HORN MATERIAL

Avantgarde Acoustic™ uses purest ABS (Acrylnitril-Butadien-Styrol) material for the production of its spherical horns. The merits of this high-quality polymer are its neutral resonance behaviour as well as its extreme durability and resistance to wear and tear. Already the plain spherical ABS horns without the final high quality color coatings have a perfectly polished and smooth finish on the front and the backside of the horns.

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THE DRIVER HORN COMPRESSION RATIO

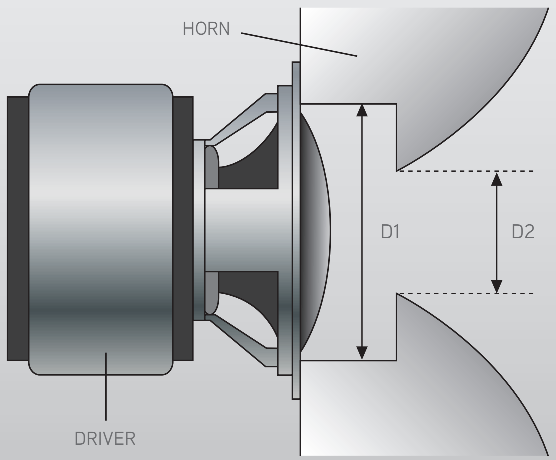
Imagine a hose through which water is running with a constant pressure. A nozzle installed on the mouth of the hose will reduce its diameter. Thus, the pressure of the water now increases and consequently the water will flow through the narrow opening with an increased speed. The same applies to a horn.

By reducing the opening diameter of the horn, the prerequisites for a speed transformation are achieved. This pressure chamber which consists of the ratio of the effective membrane surface „D1" to the horn throat opening „D2", is a very efficient means to significantly increase the membrane performance and simultaneously the efficiency of sound emission. However, should the horn's throat diameter be too small, the resulting very high velocity of the sound waves leads to a non-linear behaviour, which means distortions to the sound wave will take place.

Until now, horn and driver constructions were primarily developed for professional sound reinforcement. For this purpose, the loudspeakers are tuned to reach a maximum acoustical output. The non-linear distortion factor only plays a minor role.

In order to avoid these distortions, the Avantgarde Acoustic™ midrange designs are operating without any compression ratio. The low-frequency horns do operate with a well-balanced low compression ratio.

The Avantgarde Acoustic™ driver systems reach their sound pressure via a highly linear excursion of the membrane. Therefore, Avantgarde Acoustic™ could eliminate large compression ratios (D1: D2) as shown in the graphic and operate its systems in the optimal 1:1 mode.

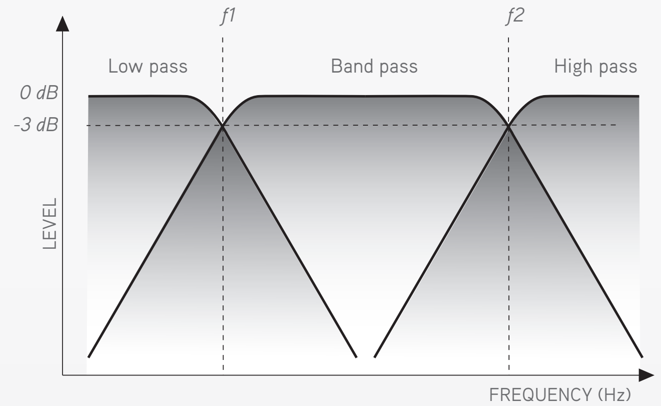


THE PASSIVE FREQUENCY CROSSOVER

With multi-way loudspeakers, frequency ranges are subdivided into several ranges, which are reproduced by drivers that are specifically designed for a particular frequency range. A typical three-way loudspeaker will cover the following frequency ranges: bass drivers cover 30 to 800 Hz, the mid-range cover 800 to 6,000 Hz and the high-range is covered above 6 kHz. A „specialist" driver covers each frequency range. The only obstacles are the overlapping frequencies between the various drivers, since they do not only operate in a strictly defined range but also have a slow roll-off above and below that area. In other words, two drivers emit specific frequencies simultaneously. This leads to alterations of single frequencies, phase shifts, etc. That is the reason why multi-way loudspeakers are equipped with passive crossover networks.

THE TYPES OF FILTER

It is extremely difficult to „calculate" a passive frequency crossover, since its application always leads to considerable deviations from the theoretical ideal. That is why, after having developed our systems and having established the theoretical ideal values, every single system undergoes meticulous fine-tuning and accurate, empirical investigation. This is a very time consuming and complicated procedure, however the results make it worthwhile.



By using different kind of filters in a passive crossover each driver is working in a defined frequency range. A low pass filter lets pass through low frequencies and a high pass high frequencies. A bandpass filter is used for the midrange. Frequencies above and below a defined frequency range are filtered.

What kind of frequency crossover is used depends on the driver system. Therefore, the filter rate, the frequency of the loudspeaker as well as its phase has to be considered at the same time. Furthermore, the resistance of the loudspeaker, depending on the frequency, has a detrimental effect on the operation of the frequency crossover.

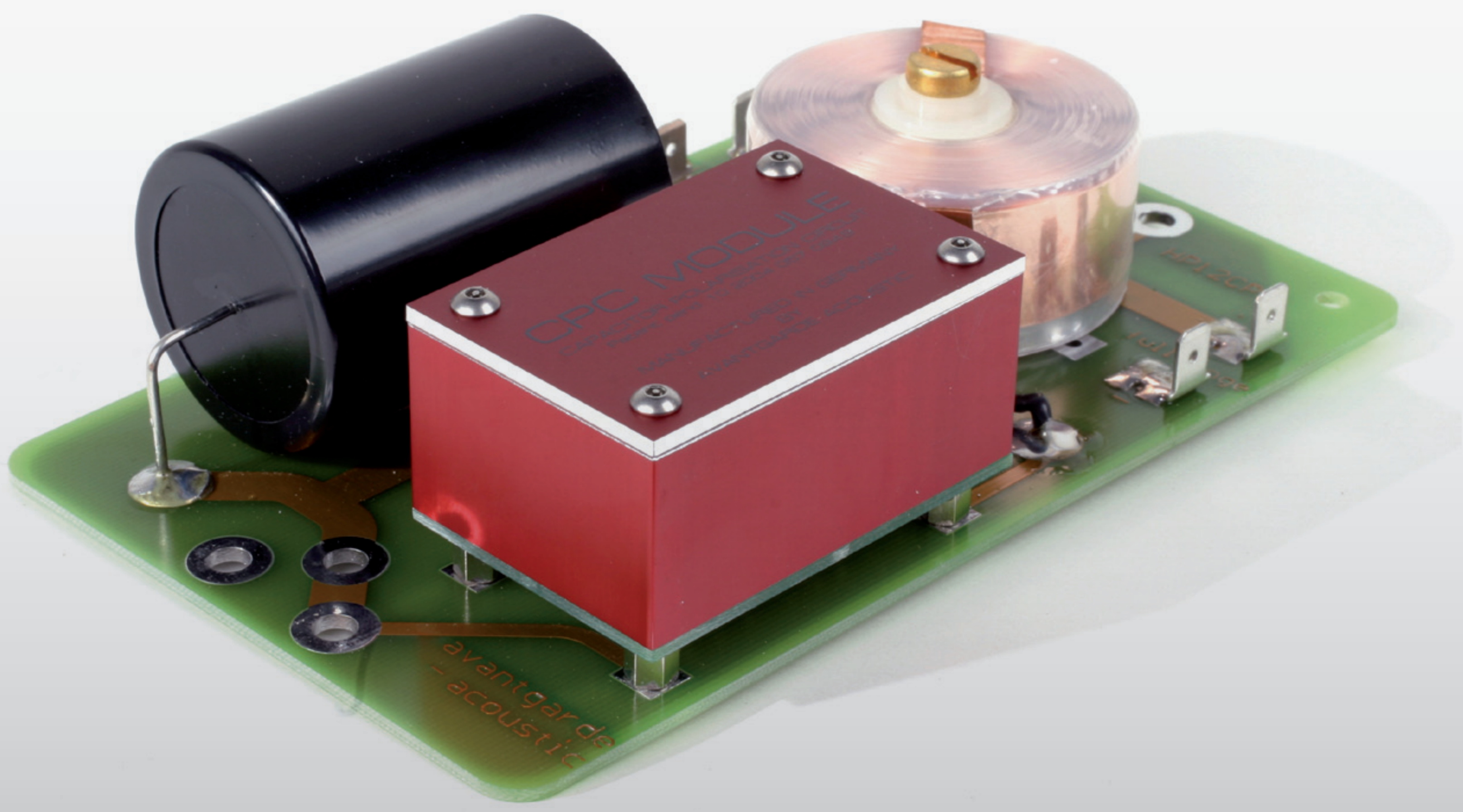
The mechanical and electrical performance of the loudspeaker requires a specific filter design. Basically, there are various types of filters available with differing roll-off rates. The roll-off rates are measured in dB/octave and indicate the reduction of voltage at the loudspeaker with a specific type of filter.

The most commonly used filters are: the Chebyshev filter was developed to show the highest filter effect, however, its impulse behaviour is poor. The Bessel filter shows the best impulse and phase behaviour. But the filter effect in the cut-off frequency area is very low. The Butterworth filter is a compromise; it achieves a good filter effect and acceptable impulse behaviour.

Depending on the roll-off rate (order of filter) and the type of filter, distinctive overlapping occurs which means that loudspeakers have to operate linearly even outside their application range. This leads to considerable problems around the frequency crossover.

Butterworth filter or Chebyshev filter of higher order bring about considerable advantages for the systems because they offer an increased roll-off rate. Thus the drivers are not „misused" having to work in a non-designated frequency range. However, this has a detrimental effect on the impulse behaviour. That is why frequency crossovers of that kind are always a compromise.

The attempt of optimising the impulse behaviour therefore automatically leads to the use of filters of the first order. Usually, these filters lead to large overlapping. In this case, the high-range loudspeaker has to cover additional two octaves below the cut-off frequency. In order to apply a first order crossover, the high-range loudspeaker has to bear considerable amounts of mechanical wear and the mid-range loudspeaker has to show excellent impulse behaviour.



THE CDC-SYSTEM

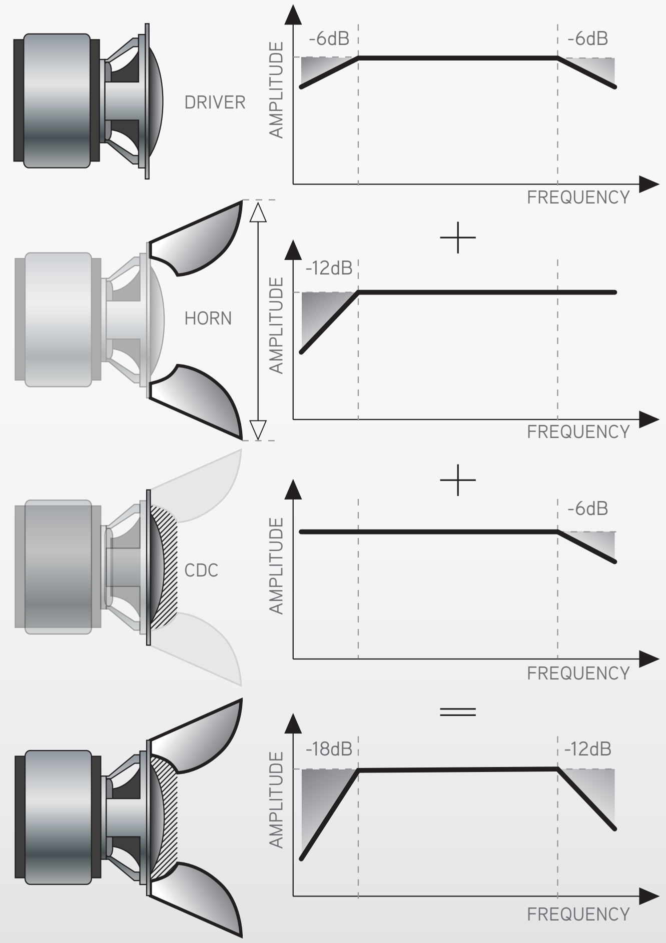
In general, there are only few loudspeaker systems on the market, which can be operated with 1st order frequency crossovers. By virtue of the proprietary CDC-system Avantgarde Acoustic™ is able to eliminate this problem. CDC stands for „Controlled Dispersion Characteristic“ and induces the driver to work only in a precisely pre-defined frequency range.

This is how CDC works: the lower cut-off frequency of a horn loudspeaker is determined by the size of the horn. The larger the horn, the lower the response. Below the cut-off frequency of the horn, the response falls off steeply at 18 dB/octave. Avantgarde Acoustic™ speakers thus operate only down to their cut-off frequency limit and require no high pass filters.

The upper frequency response is determined by the driver. However, it can as well be influenced acoustically by the horn. For this purpose, Avantgarde Acoustic™ places a small chamber between the driver's membrane and the horn throat. The driver does not emit directly but via a small air chamber into the horn throat opening. This air volume operates as a low-pass filter and automatically filters frequencies above the resonance volume of the chamber (at 6 dB/oct.).

Within the design process of the horn driver, Avantgarde Acoustic™ carefully matches the -6dB roll-off point of the unit to exactly the same frequency of the CDC air chamber. Thus Avantgarde Acoustic™ obtains an acoustic attenuation of the frequency response of 12 dB without any passive frequency crossover. No further low pass filters are necessary! The CDC system thus causes the midrange to only operate within their operational band and steeply fall off at the transition points.

If you take a look at the Avantgarde Acoustic™ frequency crossovers, do not be surprised to find only few electronic components. This does not imply exaggerated economy measures. On the contrary, it shows the balanced design of the system as a whole. At this point, the saying: „Less is more!“ is appropriate.



Thank you for giving us the opportunity to share our passion for music with you. In this book of horns we have talked a lot about the past, the theory and about the unique horn technology from Avantgarde Acoustic™.

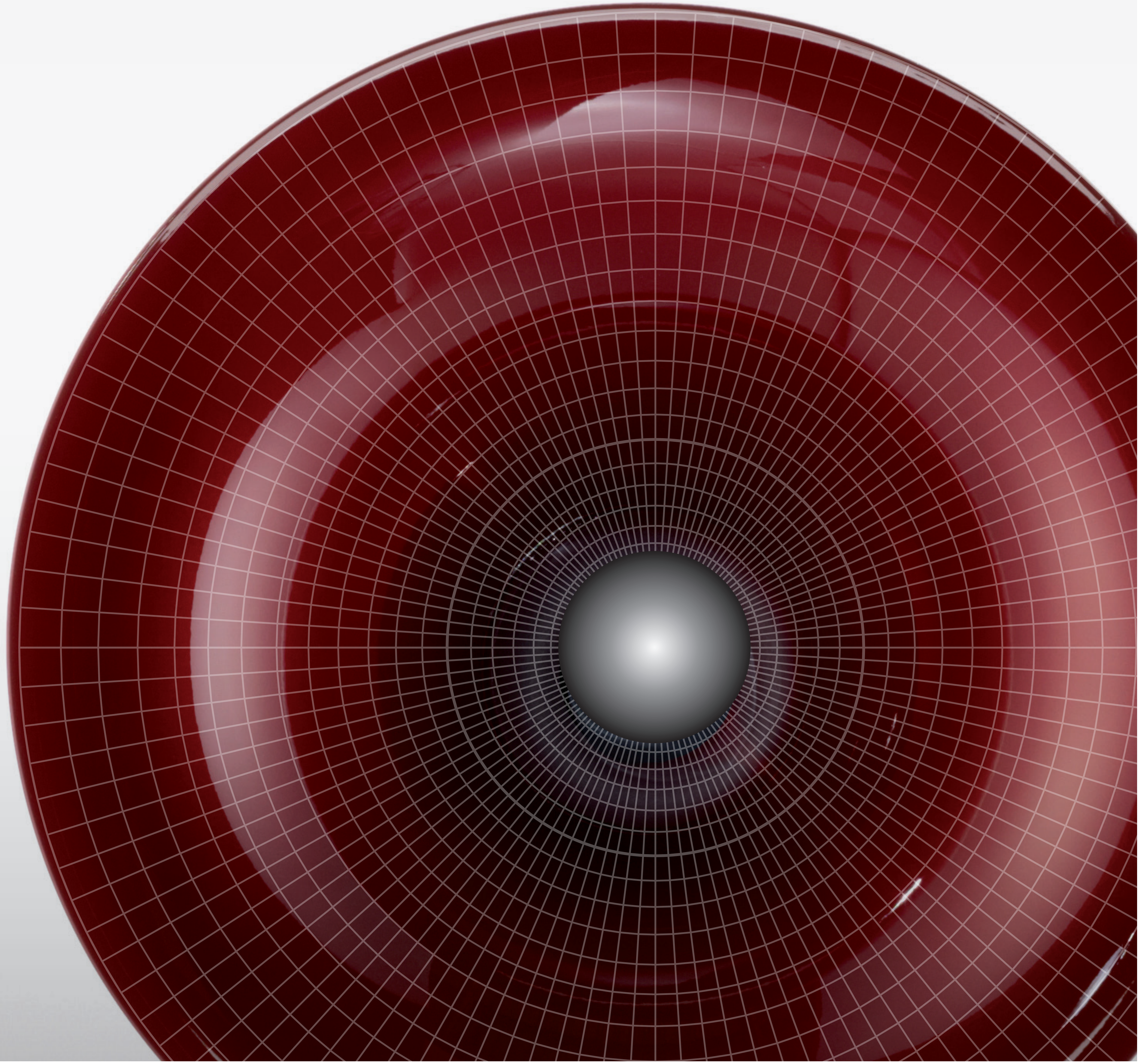
But finally we should not forget what music is all about. It is not about frequencies, tones, bass response, resolution, dynamics, and so forth. Music is about passion, feelings, rememberance, emotions and dreams. Music makes us enjoy and celebrate the moment. To feel music is unique and precious. It makes us laugh, cry and remember. Music creates a universal understanding. Who takes the chance of letting the emotional feelings pass through, will be touched and deeply moved – by the true power and intensity of the voice of horns.

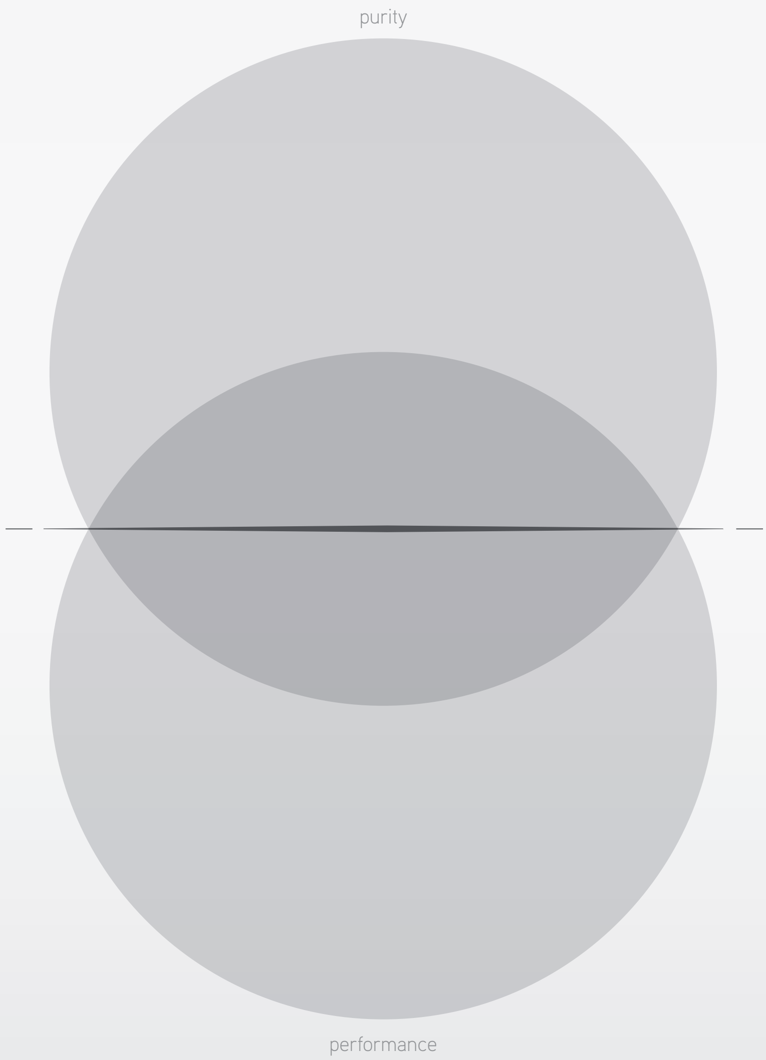
For this reason we deeply love what we are doing, we are proud of our collegues and we are thankful to our clients. Thank you for being part of our community.

This book of horns has fulfilled its purpose if it has been able to answer some of your questions. But hopefully you want to know even more. For this reason we would be very happy if you pick up the phone or contact us through our website. Here you can obtain up to date information and we would be very happy to assist you in any matters.

Yours faithfully from the Odenwald,
your Avantgarde Acoustic™ team

Contact us:
Telephone +49.6254.306100
info@avantgarde-acoustic.de





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