



MERIDIAN

Meridian Loudspeakers: The DSP Path

The Meridian Papers – 1



Meridian's top-of-the-line DSP8000 speakers, the essence of high performance

In view of its importance in the overall reproduction of the sound, this first Meridian Paper considers what happens at the end of the line – the amplification system and the loudspeakers themselves – for it is here that Meridian has very much charted its own course among consumer audio manufacturers, coming up with a solution that is both elegant, efficient and capable of extremely high audio quality.

The traditional approach

The traditional method of designing a hi-fi system has been with us for a long time, and has hardly changed over the years. Signal from a source – such as a CD player – is fed into a preamplifier or controller, and from there at line level to a power amplifier.

From this central cluster of equipment, the now high-level signal is fed via extensive cables to the loudspeakers themselves.

If you examine the vast majority of current – and past – hi-fi amplifiers and speakers, you will find the same story: a single channel of amplification handles the full

audible frequency range of the system. A single pair of cables carries this signal to the loudspeaker cabinet, and inside the enclosure the high-level audio is split into multiple bands and fed to appropriate drivers. The circuit that handles this splitting is the *crossover*, and it consists of a number of filters that separate out the different bands to suit the requirements of the different drivers.

The simplest example of this traditional approach is the two-way speaker shown diagrammatically in Fig. 1 (*overleaf*), where the full-bandwidth output from the amplifier is fed into a passive crossover that derives signals to drive the tweeter and woofer.

This, it turns out, is one of the worst things you can do, as processing high-level analogue signals requires components to be chosen primarily for their power-handling capability and not for their audio quality. The filters require inductance, capacitance and resistance, and to operate at high levels and low impedances – in the order of a few ohms – without losing efficiency, these components are often far from perfect. Inductors are iron or ferrite cored and capacitors are non-

About this paper

Meridian Audio has taken an almost unique course in the design of its audio and video systems, and particularly in its loudspeaker design, where the signal remains in the digital domain until the very last moment, and the loudspeakers include digital crossovers and signal processing.

Meridian Audio Limited

Latham Road, Huntingdon
Cambridgeshire PE29 6YE, UK
T +44(0)1480 445678
F +44(0)1480 445686
E info@meridian-audio.com

Meridian America Inc.

8055 Troon Circle, Suite C
Austell, GA 30168-7849, USA
T +1(404) 344 7111
F +1(404) 346 7111

www.meridian-audio.com

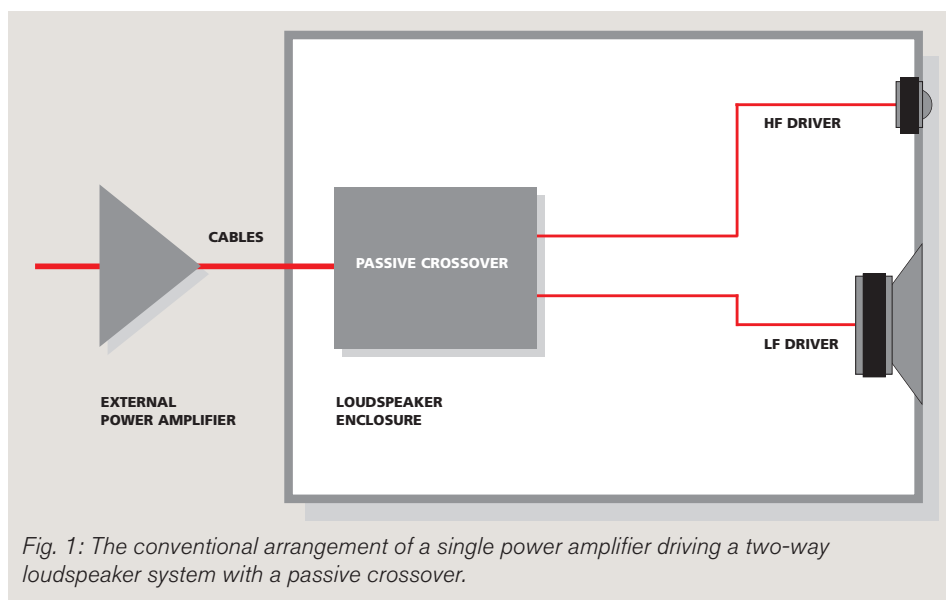


Fig. 1: The conventional arrangement of a single power amplifier driving a two-way loudspeaker system with a passive crossover.

polar electrolytics, introducing distortion. In fact, everything is more difficult to manage at high power levels. Suddenly the cables that connect the amplifier outputs to the loudspeakers can impact the sound of the system, for example – something that benefits only the makers of expensive cables.

Even if it is practical, at great expense, to use air-cored inductors and film capacitors, it is still difficult for the designer to avoid making compromises in the frequency characteristic of the crossover without presenting unpleasant loads to the power amplifier in terms of impedance or phase angle. In addition, the relative efficiencies of the drivers have to be well matched to avoid wasting power and damping – this limits the designer's choices of which units to use.

Look at it another way: In a passive system, the only power available to drive the crossover components is the signal itself.

Hotrod or Hi-Fi?

Consider your car for a moment. Did you buy the engine from one manufacturer, the suspension from another and the transmission from someone else? Probably not. Yet this is the way that high-priced hi-fi systems are often assembled. It is generally not known – and impossible to know – how such a composite system will perform.

Components are chosen independently of one another and out of context with the sound of the system as a whole, often on the basis of irrelevant, anecdotal or simply erroneous information. Hardly surprising,

A solution, long known in the professional field, is to operate the crossover at *line level*, ie before amplification takes place. The amplification then *follows* the crossover instead of preceding it. In modern professional live sound installations, it is extremely common to pass the line-level signal to an active, electronic crossover, then on to the amplification and finally to the actual drivers of the loudspeakers.

However, such an approach – “bi-amping” or “tri-amping” the system – is far too complex and prone to error to be a very practical approach in the consumer field.

The Active Loudspeaker

Back in the mid-1970s, multi-amping was almost unknown. Even more unconventional was Meridian's first product, the M1 Active Speaker, which placed both active crossover and amplification, plus the associated

then, that the elusive Grail of audio – ‘musicality’ – is difficult, if not impossible, to find in the traditional audiophile arena.

At best, hi-fis like this are not integrated systems but hot-rods: they do one thing well. This is why expensive systems often only sound their best playing back one type of music.

Meridian believes in the complete, integrated system, and that a system should be judged on how well the entire package performs in the real world. This is why all our components explicitly speak the same electric and acoustic language. While their performance

power unit, in the same enclosure as the loudspeaker drive units. The principle is illustrated in simple form in Fig. 2 (*overleaf*).

This method delivers a number of important benefits. First, there is a simple line-level connection between the preamplifier and the loudspeakers: a large, heavy box and associated cabling disappears at a stroke.

Second, the crossover is operating at line level, so the considerations as far as components are concerned are the same as with, say, a preamplifier, and the quality delivered by such a crossover should be equivalent. The highest quality components can be employed, such as metal-film resistors and plastic capacitors, for example.

But there are not simply benefits on the component side. The designer of an active crossover can design each element of the crossover – including independent adjustment of phase and amplitude, and filter curves as complex as are required by the acoustic system – without having to be concerned with issues such as matching driver efficiencies or the impedance of the configuration.

In addition, there is another major benefit in that the amplifiers are connected directly to the drivers: there is one power amplifier per crossover band. The directness of the connection means that the amplifier can control the driver over its entire range. DC coupling between amplifier and driver results in a high damping factor.

In simple terms, this means that if the speaker cone makes a movement other than because of an input signal – as a result of a resonance, for example, the electrical energy generated by this movement is fed back to

with other manufacturers' equipment is exemplary, they positively sing when placed in chorus with equipment of their own pedigree.

In almost thirty years of existence, Meridian has learned not only the parameters upon which a superb-quality total system is based: we have also refined our capability to design the individual components that comprise such a system.

Don't forget, a Meridian system can be as simple as a CD player and a pair of DSP speakers. Because the amps and control are in the speakers, that's all you need.

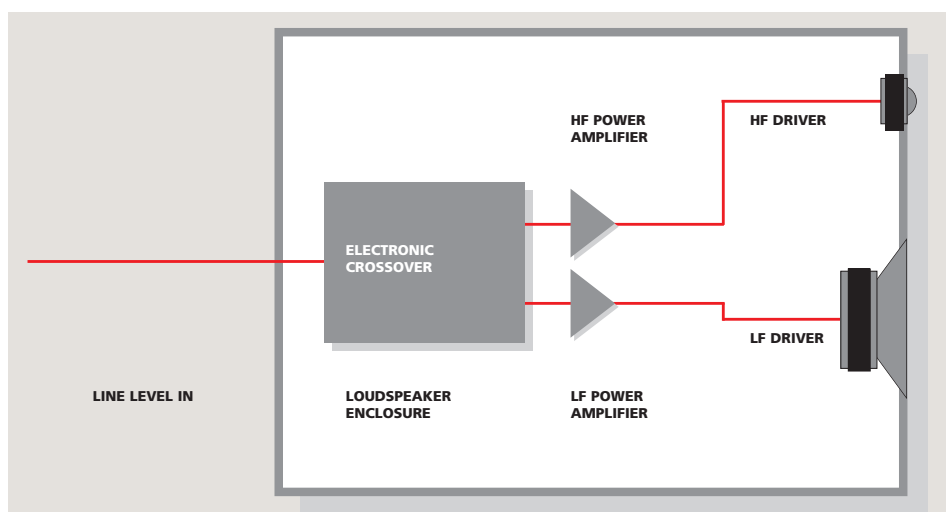


Fig. 2: An alternative arrangement to that shown in Figure 1, in which an electronic, line-level crossover drives a pair of amplifiers feeding woofer and tweeter.

the amplifier and restrains the motion of the cone – allowing the amplifier to control the driver.

This electromagnetic damping reduces resonance, cone effects and spurious responses. Not only that: the direct connection between amplifier and driver means that the amp can control cone movement beyond the range of the crossover band assigned to it – important, because a tweeter's resonant frequency, for example, can often be outside the frequency band supplied to it by the crossover. In an active system, the amplifier can deal with this; in a passive system, it can't.

This tight control also allows a Meridian to sound excellent at any level, from a whisper to a surprisingly loud shout. It's also important to consider the loudspeaker as a complete system. For the designer, this gives a great deal more possibilities than simply multi-amping an existing passive design.

Less power, more sound

On the face of it, there is a downside to this approach: the system requires a power amplifier per crossover band, rather than just one per loudspeaker.

The truth is, however, that the active loudspeaker is much more efficient. When a single amplifier is used in a passive system, apart from the power wasted producing heat in the crossover, there also have to be allowances in the power amplifier for all manner of extraordinary unknowns: strange impedances at certain frequencies, a wide range of loads, and so on. The common

method of dealing with these possibilities is to give a power amplifier four times the current delivery capacity it needs; and give it and its power supply the ability to handle the strange loads likely to be encountered in use and abuse.



DSP5200

Digital Audio: Music to the Ears

Digital audio technology is now widely regarded by industry experts as the best means to hear music in the home. Because music recorded digitally can be transmitted, even over long distances, and played back with no change from the original, like Morse code over a telegraph line.

Why is this important? Traditional analogue systems behave much like the childhood game in which each player repeats a whispered message into the next player's ear, and so on down a chain. Each analogue link – turntable, amplifier, cable, speaker – whispers an analogy of what it hears to the next, but something is always lost or added. What emerges at the end, while charming, may not resemble the original message.

By contrast, digital audio first encodes music as digits – ones and zeros – in patterns describing specific sound waves. This is the binary language of computers, and it's very difficult to mistake a one for a zero. No matter how long the chain, at its end, digital equipment listens only for patterns of those two digits, which it reassembles into music, ignoring all other whispered information as noise.

Hence the crystal clarity of good digital sound: no detail lost, no noise added.

Paramount among audiophile truths is that music's electronic journey to our ears should be as short and unadorned as possible; this preserves the fragile nuances of live performance. This is why, for example, audiophiles have long rejected analogue tone controls, correctly seeing them as electrical mazes where musical subtleties are lost or rearranged.

Yet the typical 'purist hi-fi' is hardly pure. Rather, it's a confusion of components with varying reactive properties, tangled together through a rat's nest of electrically whimsical cables. Each piece lengthens the path and damages delicate harmonic, phase and other relationships that contour music.

The amusing irony is, these boxes and cables are generally assembled for tone control: each piece chosen for how its voice changes the message. Why not simply replace the whole corrupt chain with one transparent digital link, particularly if the music source is digital already?

Continued over...

Digital Audio: Music to the Ears

(Continued)...

At Meridian, that's exactly what we did. In essence, we decided to convert the signal from a source into digital form as early as possible and at the highest level of quality (if it wasn't already), then maintain that signal in digital form as long as possible before converting back to analogue (although the part of our hearing system from middle ear to brain is actually digital, analogue pressure waves carry the sound from a loudspeaker, through the air, to the ear).

So in a complete Meridian system, the signal is only converted from digital to analogue immediately before it enters the amplifier.



Meridian DSP7200 – a recent addition to the range.

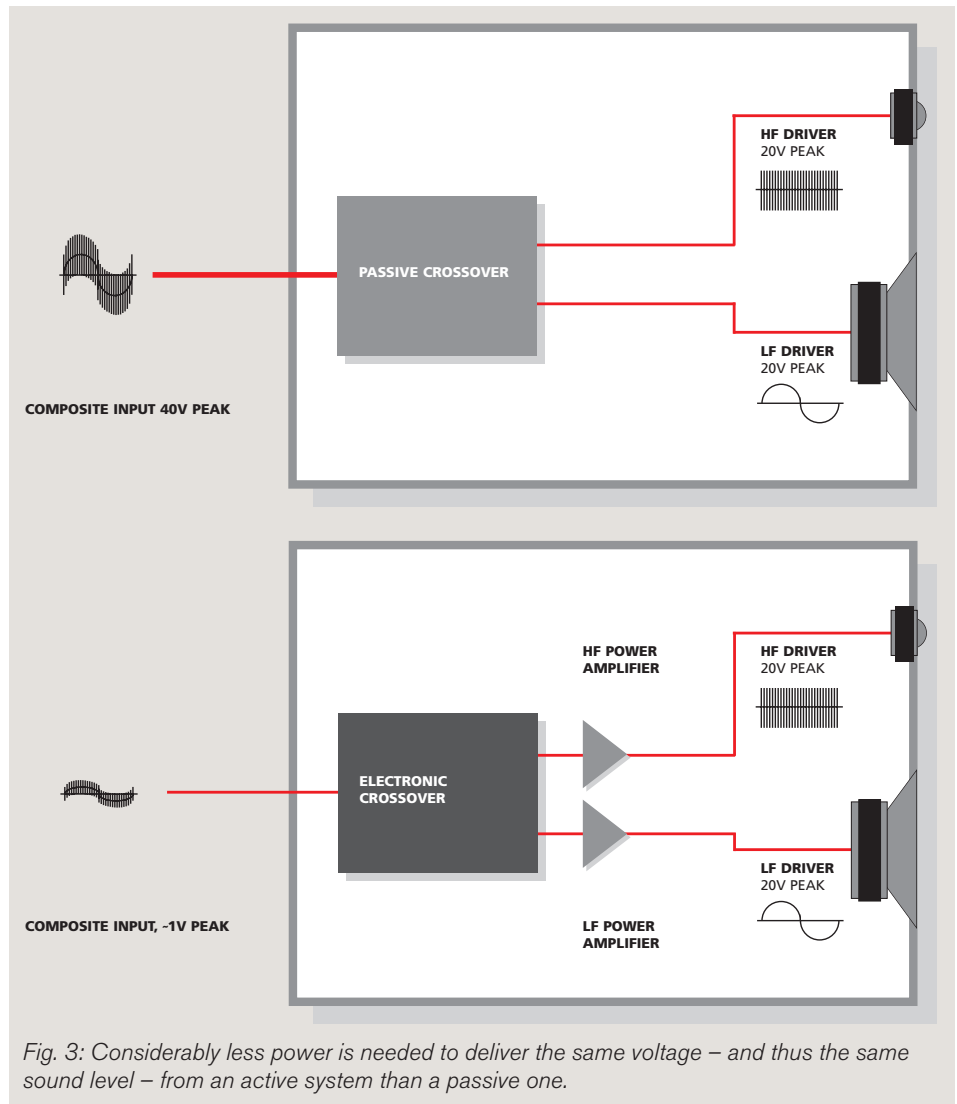


Fig. 3: Considerably less power is needed to deliver the same voltage – and thus the same sound level – from an active system than a passive one.

Engineering for the unknown inevitably means over-engineering. But in a properly integrated active system, however, each part of the system, including the amplifiers and power supply, can be designed specifically to provide the power required – no more, no less – and into a known, carefully defined load. This can obviously improve efficiency and reduce the need for over-engineering. Thus such a design does not have to be more expensive than a conventional passive approach. It can certainly be more efficient, and more effective.

But there's more. Imagine we are listening to a piece of music that includes a bass part and cymbals, and that to replay this accurately at a chosen level on a two-way system we want to see a not unrealistic voltage of 20v peak at the terminals of both the tweeter and the woofer.

To do this with a passive system, even ignoring losses in the crossover, the driving amplifier needs to develop 40v peak. For a 8-ohm system, this requires an average power of 100W (by Ohm's Law, the power is equal to the voltage squared divided by the impedance). In the equivalent active system, with a 1v line level input, a pair of 25W amplifiers will do the same job! (See Fig.3.)

Extend this thinking to a three-way system, and three 25W amplifiers in an active configuration will do the same job as a 250W amplifier driving a passive system. Meridian's first DSP loudspeaker, the DSP6000, for example, included four channels of 70W amplification. This is equivalent to about 1kW driving a conventional passive system.

It is evident from these comparisons that an active system can produce surprisingly high levels from a significantly smaller amplification system.

There are significant improvements in efficiency that can be realised with an active system, even if it is more difficult to design – or rather, we could say that it is possible to implement a more sophisticated design, with many additional features, to deliver these and other benefits.

Bass Extension

There is more to an active loudspeaker than simply improving the efficiency and overall performance of the system. An active approach can deliver benefits that are simply impossible for a passive system to realise. We can't change the laws of physics, but we can use them to our advantage.

There is a known relationship between the low -3dB cutoff frequency (f), the physical volume of the enclosure (V) and the efficiency (e). It is:

$$e = V/f^3 \times K$$

where K is a constant relating to the system's design. In a nutshell, this means that the cost of a smaller cabinet is either less bass or lower efficiency. The ability to consider

an active loudspeaker as a total system – an active crossover with filtering, amplifier, power supply, driver and enclosure – allows the overall response and performance of the system to be modified, essentially altering that constant, K, in the equation above.

For example, the original Meridian "Interactive Bass" system used auxiliary filtering, and the particular alignment provides a sixth-order rolloff plus an additional octave of bass compared to a passive speaker of the same volume and efficiency (see Fig. 4, below).

Putting this more impressively, a passive speaker with equivalent bass response would need to have eight times the volume, or twice the linear dimensions. In addition, this alignment minimises cone movement of the bass driver for a given output – indeed, cone deflection for a ported system such as the DSP7200 or DSP5500 is one third as much as using the same drivers in a passive sealed box with equal broad-band excitation.

Being able to deliver bass from an enclosure an eighth of the size is a useful ability, because it enables us to make loudspeakers that are physically the right size: on a human

scale (see later). That means that they will fit into a room more easily, and take up less space.

But it also means that stereo and surround imaging will be significantly improved, because the nearer to a point source your loudspeakers are, the more they can be made to disappear when recreating a soundfield in your listening room, especially when using Meridian's advanced decoding technologies such as Trifield and Ambisonics.

The Digital Link

Once we began to see the introduction of widespread digital music distribution media, from the Compact Disc (1984) to the Digital Versatile Disk (DVD), DVD-Audio and Blu-Ray Disc, there was another step we could take: we could keep signals in the digital domain for as long as possible: from source to speaker (see sidebar: *Digital Audio: Music to the Ears*).

When it comes to active loudspeakers, a digital design has a great deal to commend it. To begin with, there are no long analogue cables carrying line level signals to the loudspeakers, with the possibility of induced hum and noise. Instead, a slim cable carrying a single channel of digital audio data is all that's required (actually, we add a second cable to carry communications signals between the different parts of the system, but it doesn't carry audio).

Full level is supplied to the loudspeakers, removing potential problems with noise at low signal levels, and the loudspeaker now has a user interface, if only to control and indicate the volume – in fact Meridian loudspeakers have a display that can indicate a number of system parameters... or be turned off.

The DSP Dimension

Now we come to what is – for now – the final step on the path, with the addition of digital signal processing (DSP) to the digital loudspeaker. In Meridian DSP speaker designs, digital signal processing is used to implement the crossover. This means that the digital to analogue converter (DAC) can be placed even later in the chain. In fact a separate DAC is used for each band of the loudspeaker system, maximising the system's dynamic range – a current system can deliver up to 120 dB – giving better intermodulation performance, and offering a level of background noise below 10 dB SPL.

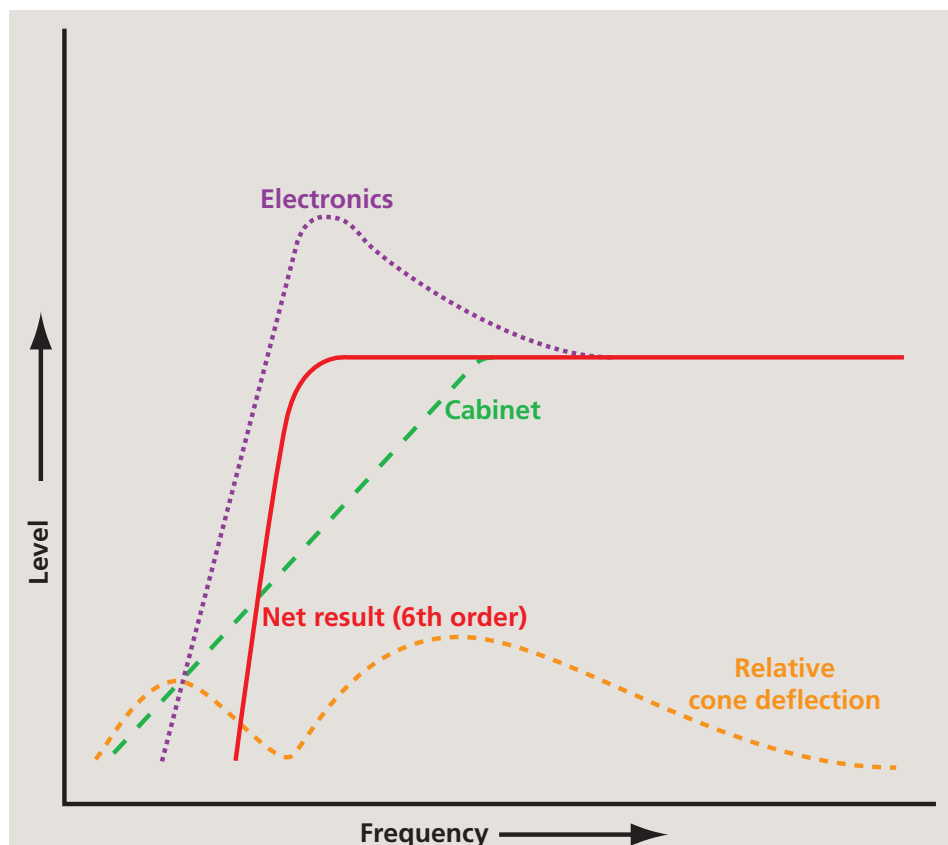


Fig. 4: The overall response of an active speaker can be tailored, the bass improved and the maximum cone excursion limited by careful use of electronic filters.

What is dither? Why do we need it?

In the analogue world, as a signal dies away, it does so smoothly. As the level drops, the signal gets progressively quieter. At some point it reaches the same level as the noise. But importantly, if the signal level continues to drop, you can still hear it, despite the fact that it is below the noise floor.

In the raw digital environment, everything is different. What happens when a bit changes between a one and a zero is essentially inaudible at high levels, because there's so much going on. But if you're dealing with low-level signals, such as reverberation dying away, or the fade at the end of a track, the transition of bits from zero to one and back again becomes increasingly important.

As the level of a signal drops, it is represented by fewer and fewer binary digits, and the changing of these bits becomes increasingly noticeable – it's called "quantization distortion". Ultimately, you simply run out of bits, and when this happens, the signal just stops, and in a 16-bit system such as Compact Disc, this happens at an audible level. This behaviour is another of the several factors that gave early digital recordings a bad name, and led some pundits to claim, erroneously, that digital audio was fundamentally inferior to analogue.

Quite early on in the history of digital audio, it was discovered that a solution to the problem was to add noise to the signal. At low levels, the effective result of this procedure is to turn the last few bits on and off at random, smoothing out the sound and ensuring that everything will not simply disappear as the level falls.

This noise is referred to as "dither noise" or simply "dither". Truly random (white) noise, called "flat dither", contains all frequencies and is clearly audible. More commonly, a noise spectrum where the energy in the highs and lows is modified somewhat ("triangular dither") is used to make the dither noise smoother and more benign.

Dither is not only required when a signal is converted between the analogue and digital domains: it is also needed any time a digital signal processing (DSP) operation is carried out, such as decoding a surround bitstream from a DVD, applying a DSP preset, or passing through a digital tone control.

The more highly optimised the dither signal, the higher the resolution – the further you can hear below the noise, and the more detail you can hear.

In a properly dithered system, the resolution is effectively infinite.

This, however, is only the beginning. With digital signal processing on board, you can do a great deal more. For example, you can design "impossible" crossovers, with linear phase, steep slopes and time delay compensation. And thanks to highly accurate phasing between the drivers, the "beam" of the system can be steered for the best experience at the listening position: there is even an axis control that allows the midrange frequencies to be precisely tailored to suit your height.

Volume control in a Meridian DSP loudspeaker is handled by a precision combination of analogue and digital techniques, combining to give the best of both worlds. In addition, "balance" is not simply a matter of changing the relative levels of the speakers. Instead, the balance control is a "Where am I sitting?" control. If you are listening to a stereo system and move to the left, you hear more level from the left speaker because you are nearer to it; you are further away from the right, from which you hear less. But that's only part of the story.

Because you are nearer to the left speaker, the sound takes less time to travel from the speaker to your ears – and you are further from the right speaker, so the sound takes longer to arrive.

Meridian's approach to "balance", using the power of DSP, automatically adjusts these subtle time delays, so wherever you decide to sit, signals will arrive at the right time, as well as at the right level. In addition, our processors can provide decoding using Trifield and Ambisonic technologies, which literally recreate a solid image of the original environment in your listening room – producing an incredibly lifelike surround-sound experience, and even rotate the soundstage to suit where you are sitting.

Meridian's DSP loudspeakers utilise 48-bit internal fixed-point resolution. This is a long way beyond what anyone can actually hear, but when you perform DSP operations, additional bits are created and it is vital that these are preserved.

Furthermore, whenever digital signals are processed, they have to be dithered correctly.

Dither is a special form of noise that is added to a digital signal whenever operations are performed on it. It smooths out imperfections and significantly improves the sound of a system. In fact, a properly optimised dither signal can make the resolution of a digital system effectively infinite (See sidebar, "What is Dither?").

DSP technology is also used to provide additional features, such as tone controls and, because the loudspeaker knows the sound pressure level it is producing, loudness controls can be implemented more naturally than ever before.

The same principles can provide dynamic bass extension in smaller speakers, where low frequencies are boosted more at low levels. The system computes cone movement, frequency and level, and as a result can provide bass protection, shutting down if there is a risk of parameters being exceeded.



DSP8000 – the inside story The rigid enclosure, laminated from Russian Birch plywood and aluminium alloy, has six coats of hand-finished piano lacquer. The six horizontally-opposed bass drive units neutralise cabinet resonance. The rear-mounted sealed DSP crossover and five power amplifiers are mounted on a precision-machined heat sink.

The voice coil temperature is also calculated, permitting precision thermal protection.

And finally, allowance can be calculated for different locations of the loudspeaker in a room, such as boundary compensation when it is placed near a wall.

Digital signal processing also comes into play when you use a system at different levels. Our ears are less sensitive to bass and treble when we listen quietly: DSP can compensate for this according to carefully-research psychoacoustic principles.

“Human-sized” speakers

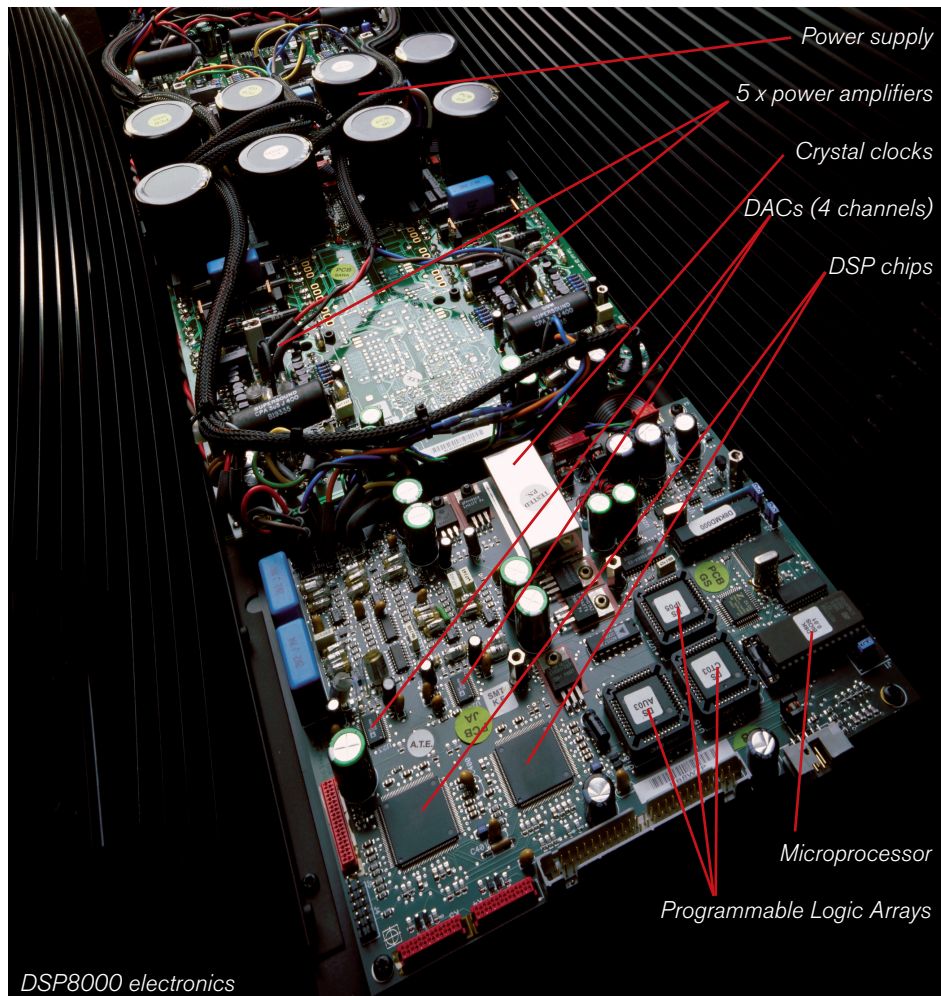
Meridian's speakers look, as well as sound, distinctive, and of course both these factors are related. It has been shown that loudspeakers that are as close to human-like as possible produce the best imaging – mirroring, in a sense, the position of human sense organs. The “head” of a Meridian DSP loudspeaker (such as that of the DSP8000 shown here) produces the vast majority of



sound from 200 Hz up, which is where stereo and surround localization takes place.

If you remove, or disconnect, the “head”, you can hear very little definition. Psychoacoustically we are at our best listening in small spaces, to loudspeakers that have similar physical characteristics to a speaking human being.

Our loudspeakers are essentially “human-sized” because psychoacoustic research indicates that humans are most highly



The Press on Meridian DSP Loudspeakers

Meridian's DSP8000 speakers are a testament to both engineering and aesthetics... You can play extraordinary deep bass tones and put a glass of water on top of the cabinet, and the water won't move.

—*Popular Mechanics*

The effortless sweep of the DSP8000s presentation was aided by the extended and well-defined low frequencies.

—*Stereophile*

This system delivers a performance that's state-of-the-art, especially when it comes to bass extension and control... The Meridian rules supreme when it comes to scale, authority and sheer low-end weight.

—*What Hi-Fi*

[The DSP8000] delivers insane levels of detail. Build quality is unsurpassed... the finest aural experience money can buy.

—*Smartlife International*

[The DSP7200 features] state of the art engineering with multiple on-board amplifiers and serious silicon... the latest addition to Meridian's acclaimed DSP range of high-end floorstanders."

—*Home Cinema Choice*

At first you'd think it would be crazy to control a system through a pair of speakers. But when the loudspeakers in question are Meridian's... it begins to make perfect sense.

—*What Hi-Fi*

Much more than just a speaker, the DSP5000 is designated a 'music system'... This modestly sized speaker is capable of a surprisingly high acoustic volume or sound level... Meridian's ace in the hole here is a dynamic, music-controlled correction for the overall bass alignment which allows clean, remarkably extended bass under normal conditions... The DSP5000 has to be heard. For its size it offers a remarkable combination of bass power and extension, of maximum volume level, of user control and adjustability, and of stereo image performance.

—*Hi-Fi News & Record Review*

Speakers don't get much smarter than this!

—*Sound & Image*



Meridian Loudspeakers – The DSP Path

Meridian White Paper – 1

developed to appreciate this size of sound-producing system, and they will thus sound the most natural.

As much effort goes into cabinet design as into the electronics within, and the keynote here is extremely high integrity. Cabinets are heavy and rigid, allowing no inadvertent movement. Typically, they incorporate multiple layers of wood and metal, bonded together for maximum damping.

The DSP8000, for example, includes side-firing woofers that are horizontally opposed, so that the net movement is zero. Advanced materials ensure that the cabinet is so dead that movement stops at once when excitation ceases, with no ringing.

Meridian DSP loudspeakers are perhaps best thought of as musical instruments. The most difficult sounds to reproduce are those of individual instruments, such as piano or flute, and small ensembles that are on the same kind of scale as the listening room.

If you were to record a live string quartet in your listening environment, the most difficult test of a “high fidelity” system would be to replay that experience in the same room. Meridian DSP loudspeakers rise to that challenge.

