

# PHANTOM

IMPLOSIVE SOUND CENTER

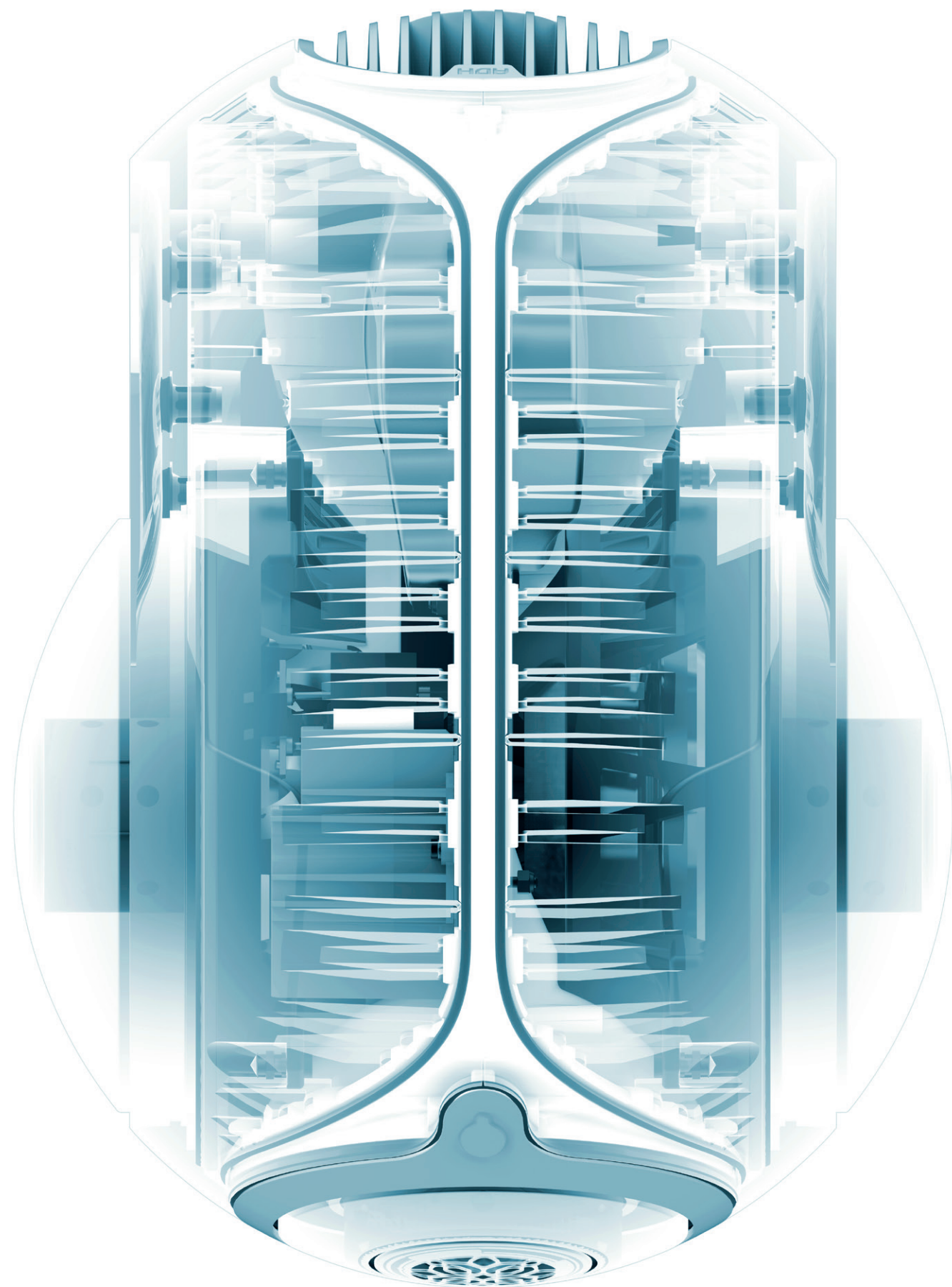
WHITE PAPER

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DEVIALET

INGÉNIERIE ACOUSTIQUE DE FRANCE



## WHAT IS PHANTOM?

PHANTOM is a new category of audio products in itself: it is an Implosive Sound Center. It transforms the way you listen to music, with power and emotion. Anywhere inside your home.

At the heart of PHANTOM beats what made Devialet the most-awarded company in the history of Audio: the ADH Intelligence®. This latter combines the refinement of Analog (or Class A) amplification with the power of Digital (or Class D) amplification. The SAM Processing® technology is then used to control the drive units to perfection, reproducing the exact acoustic pressure recorded by the microphone.

Together, the ADH Intelligence® and SAM Processing® create the only engine in the world capable of driving what makes PHANTOM implosive: the Heart Bass Implosion®. The HBI® consists of two Devialet-exclusive high-excursion bass drivers, moving in perfect symmetry in order to create a sound that has a physical impact and a density never before achieved.

PHANTOM is the fruit of 10 years of Research and Development in the Devialet Laboratories, and embodies close to 100 patents. Although extremely complex on the inside, PHANTOM is the expression of simplicity and elegance on the outside. It is controlled by the revolutionary SPARK application and orchestrated with DIALOG, an intelligent audio router that creates a new experience of multiple sound devices architecture.

There will be a before and an after PHANTOM, and this white paper describes why the audio industry will never be the same again.



## DEVIALET'S ADH®

### What is ADH® amplification?

ADH® (Analog/Digital Hybrid) is the most significant invention in audio amplification in the last 40 years, and is the very reason why Devialet exists.

The idea beyond ADH® is to combine the two opposed technologies of amplification - Analog and Digital, aiming to obtain the best of both worlds: the linearity and musicality of the most acclaimed analog amplifiers (class A) with the power, efficiency and compactness of «digital» amplifiers (class D).

Although simple to explain, this hybridization rapidly proved to be extremely difficult to realize, since it basically meant connecting two amplifiers in parallel. In the end, 3 years of extensive research were needed to obtain a high power prototype with the best performance on the market by a factor 10 to 1000. ADH® actually overdelivered compared to its initial goal.

### How does ADH® work?

ADH® operates through the following enslavement principle:

| *A genuine class A amplifier directly connected to the speaker drives the output voltage: as the master, it sets the sound of the whole ADH® core. That's why what we hear is pure analog sound.*

| *Several class D amplifiers are added in parallel to provide the speaker with the current it requires to sustain the output voltage. They act as slaves to the master class A amplifier, minimizing its workload.*

An illustration of this principle is the power steering of a car: the driver is setting the car direction, assisted by a powerful engine to help turn the wheels, making the driver's job effortless and hence more precise.

A specific class A amplifier is required to fit in the ADH® core: although it is most of the time highly assisted by the class D amplifiers in providing current to set the ideal voltage to the speaker, it must also be able to output a high current over a short period of time, and absorb the ripple current of the digital amplifiers.

This is achieved by a very innovative scheme for the ultra-linear class A of the ADH® core, whose level of performance compares with the best class A amplifiers on the market.

### What are the benefits of ADH®?

Thanks to the assistance of the class D amplifiers, the Class A is freed from the task of delivering much power and is made even more linear. As unexpected as it sounds, the class A is improved by the presence of the class D amplifiers in the ADH® architecture.

Another benefit is that the output impedance of the ADH® core is equal to the class A impedance divided by the current ratio of about 1:1000 between the class A and the class D amplifiers. That's how an output impedance of about 1mΩ is achieved over the whole bandwidth, which is important to maintain high performance while controlling loudspeakers presenting a complex load.

The ADH® technology truly fulfills Devialet's promise of a 'Pure Analog Sound with Smart Digital Power'. It offers the musical qualities of an outstanding class A amplifier, without usual weight, volume and heat generation. The class D amplifiers provide substantial power to the class A without compromising the sound quality; on the contrary the class A amplifier performs even better when assisted by the class Ds.

### Devialet's "Magic Wire"

Just ahead of the ADH® amplification stage, another major technological advance from Devialet is used: the "Magic Wire". The aim of the patented "Magic Wire" typology is to implement the DAC (Digital to Analog Converter) at the core of the class A amplifier, in order to reduce the parasitic, music-impeding phenomena - such as noise and distortion - to an absolute minimum.

In practice, the output current of the highest performance DAC on the market (Texas Instrument PCM179X series) is directly converted into high-voltage without any processing in between: no operational amplifier, no current mirror. Instead, the very elaborate leak-less path of the "Magic Wire" carries the original current of the DAC to an ultra-high linearity resistor (0.01% precision), which operates the current/high-voltage conversion before entering into the class A.

The magic comes from the fact that the guiding elements within the "Magic Wire" do not process the music, whilst providing high-voltage output. Besides, these guiding elements work at a stable power rate, hence constant temperature, which reduces thermal distortion to a non-measurable quantity. In a simplified view, the "Magic Wire" can be considered as the dream of every audiophile: *a straight wire with gain.*



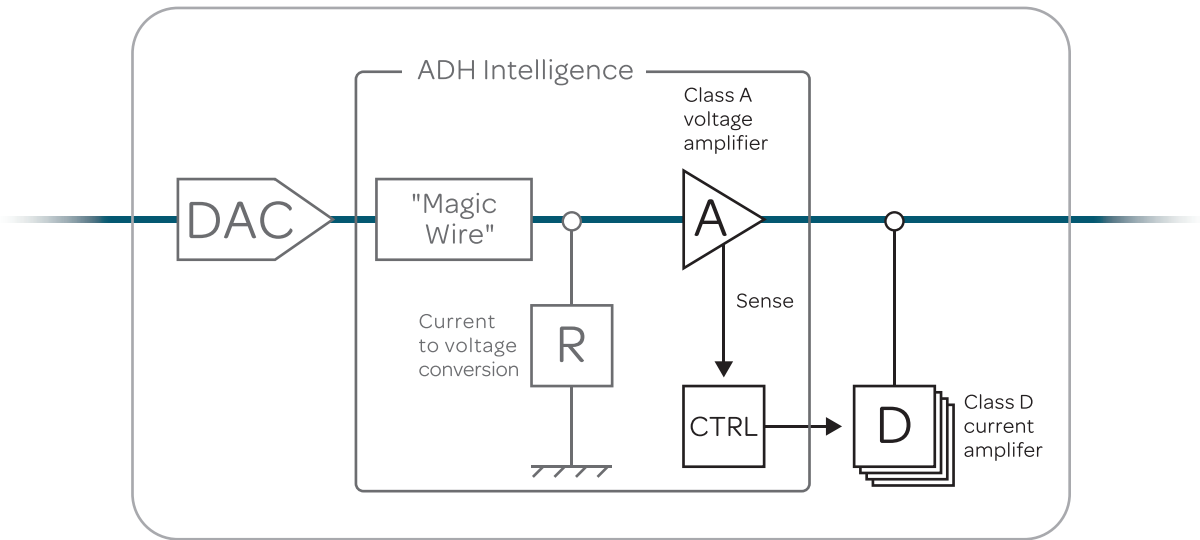
Miniaturization of the ADH® amplification

In order to incorporate the ADH® amplification core inside PHANTOM, an extensive research program has been led in order to reduce dramatically its physical size. The result is the ADH Intelligence® ASIC, grouping both the “Magic Wire” and the Class A circuitries into a single component (see diagram below).

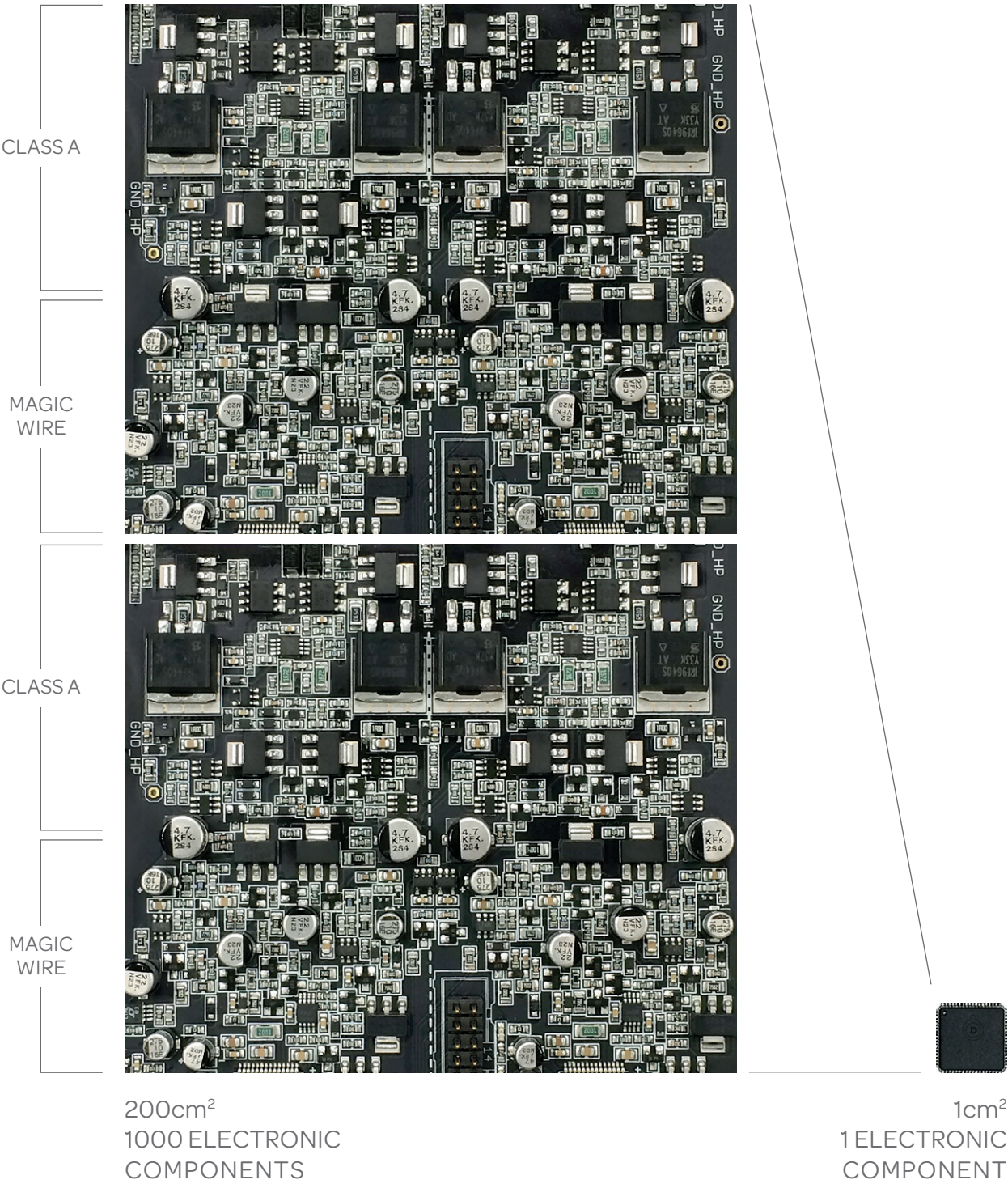
This ASIC (Application Specific Integrated Circuit) is a custom-made silicon chip designed by Devialet which presents the incredible advantage of preserving the extreme level of performance of the ADH® amplification (0.001% Total Harmonic Distorsion), whilst reducing its size by a 200x factor and its electrical consumption by a 10x factor.

Each ADH Intelligence® ASIC contains the equivalent of two differential-mode channels, which is more than 1000 electrical components grouped into a single one. The thickness is also reduced to less than 1mm now. As PHANTOM consists of four drive units, two ADH Intelligence® chips can be found inside it.

ADH Intelligence® diagram



Size reduction of ADH Intelligence® (drawn to scale)





## DEVIALET'S SAM®

### What is SAM®?

After ADH Intelligence®, SAM® (Speaker Active Matching) is Devialet's second technical revolution. SAM® is the signal processing that allows the ADH Intelligence® to adapt its behaviour to the very drive unit it is connected to.

Devialet's SAM® consists in a processing of the audio signal in the digital domain, computed in the Dual Core processor that takes place in PHANTOM ahead of the DAC and power amplifier section. By taking into account the characteristics of the drive unit and its acoustic load, it allows to drive in a very precise and controlled way. Through this is obtained an exact alignment between a recorded music signal, and the pressure wave that reaches the listener's ear.

### How does SAM® work?

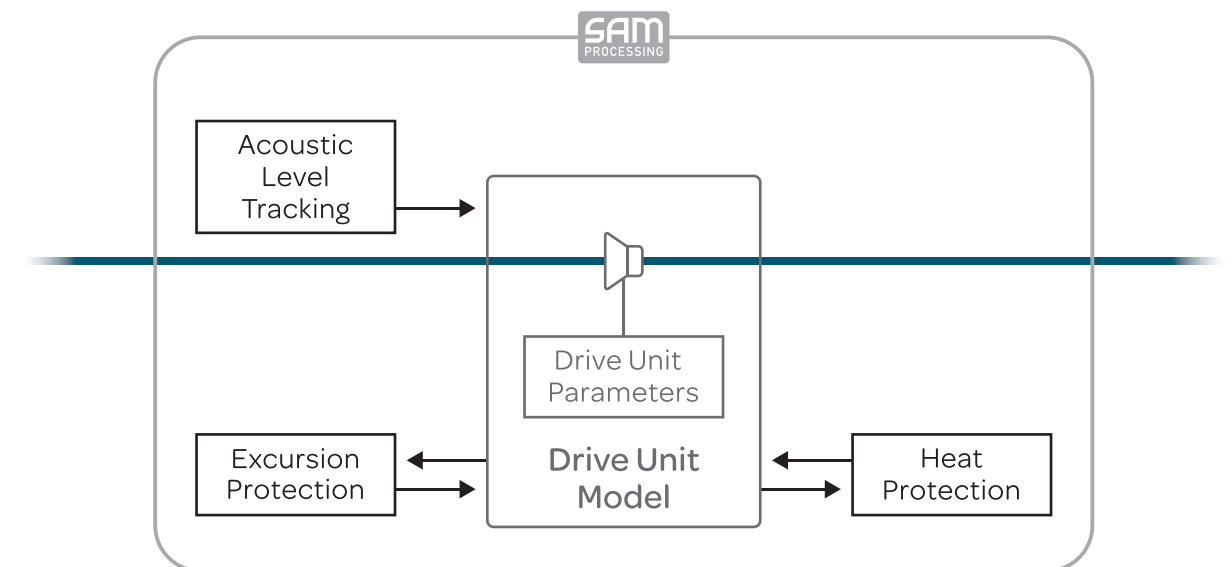
Where ADH® is the engine imposing the signal to the drive unit, SAM® is the processing that allows this engine to adapt the signal by having in-depth understanding of the electroacoustic system's behaviour.

SAM® acts on the driver's motion by means of a novel processing of the audio signal that is performed in the time domain, using a unique proprietary mathematical approach to reach an acoustic performance that is close to perfection. It optimizes in real time the driver's acoustic response, at every moment, on any signal.

A mathematical model of the complete drive unit, accounting for the electrical, mechanical and acoustical behavior is running in real time on PHANTOM's internal processor. It computes for every sample the exact voltage that has to be applied to the drive unit by the power amplifier, so that the acoustic pressure is a one-to-one image of the audio signal.

Other techniques aiming at loudspeaker optimization are commonly simply equalization performed in the frequency domain. They typically involve IIR or FIR filters and cannot reach the same performance, being affected by such phenomena as extra phase rotation or time delay, and in general sub-optimal performance on transients.

### SAM® block diagram



### What are the benefits of SAM®?

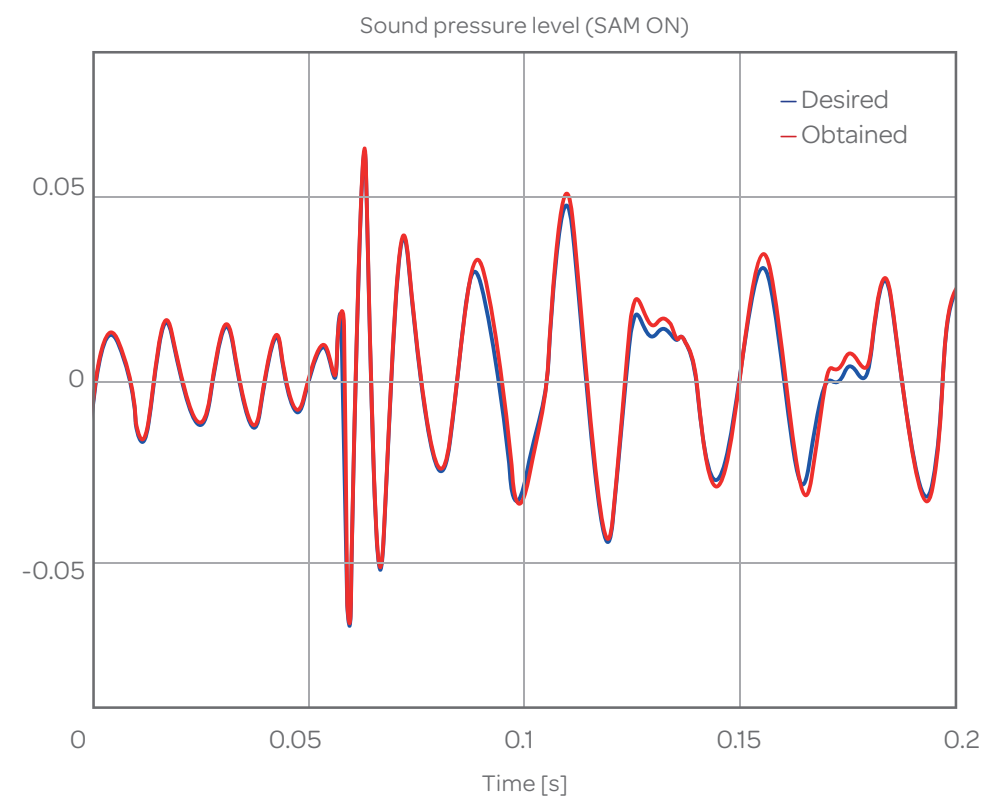
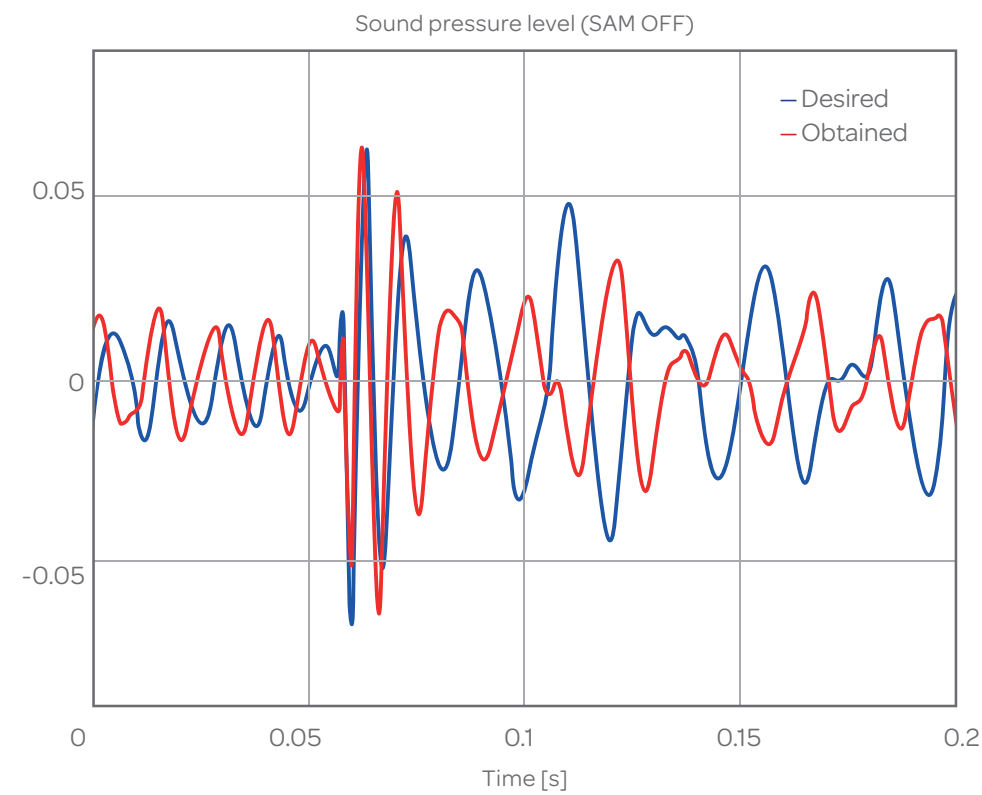
Devialet's Speaker Active Matching® is a truly high-end audio signal processing. SAM® has a qualitative effect, rather than a quantitative one.

By its principle, SAM® ensures that the acoustic response is at every instant an extremely faithful image of the recorded signal ; this is true on transient signals (notes attacks, drums, ...) as well as on continuous signals (notes sustain, organ...). In particular, SAM® prevents any delay between bass and the rest of the spectrum, avoiding the effect of the phase rotation at the vicinity of the natural low-frequency cut-off of the loudspeaker.

Although SAM® is in nature and effect radically different from a bass boost, it actually increases the low-frequency extension of the woofer unit. Since SAM® technology ensures that the music waveform is reproduced exactly as it should in the time domain, even frequencies below the natural loudspeaker cut-off are faithfully represented.

This is of course done within the physical boundaries of what the different drivers can do: maximum excursion of the speaker driver, and maximum continuous power handling. These physical limitations are accounted for in SAM® processing. As a result, SAM® is also an effective protection of the drivers, helping to prevent any damage to occur due to listening at high levels.

Effect of SAM<sup>®</sup> on woofer' response



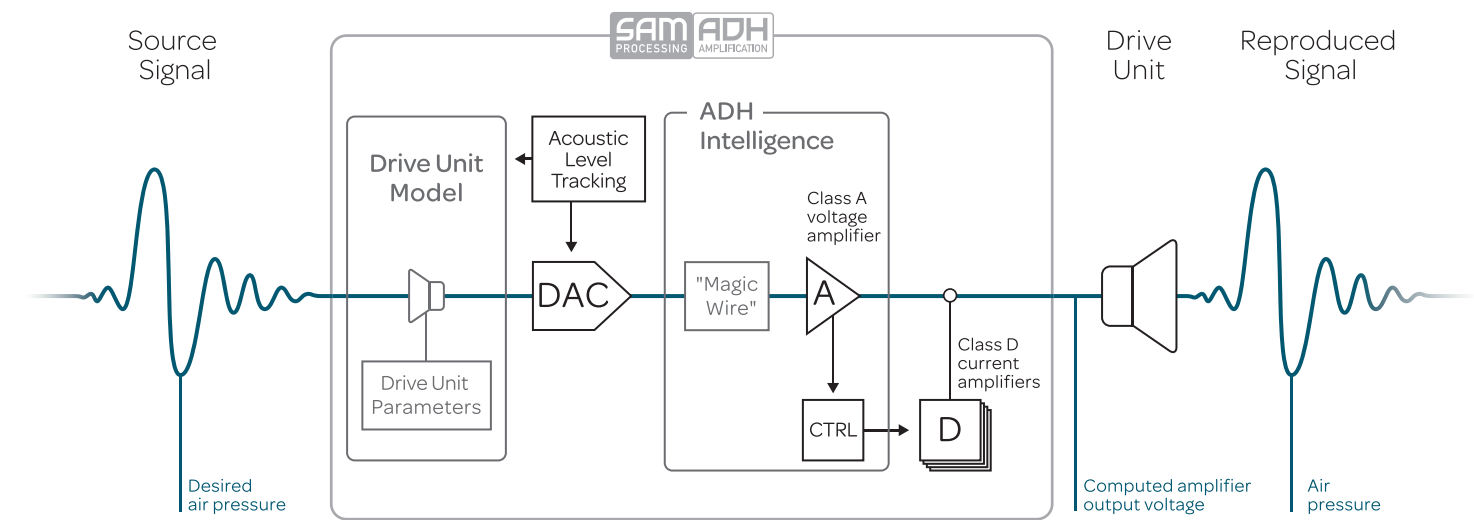
SAM<sup>®</sup> is implemented as a time-domain signal processing using unique patented mathematical techniques, featuring:

- zero latency
- no pre-echo
- no feedback

Here are some of the key subjective, audible, benefits of SAM mentioned by listeners:

- higher impact, particularly on transients / better sense of pace and music tempo
- better sound image
- higher level of detail

ADH Intelligence<sup>®</sup> and SAM Processing<sup>®</sup> complete diagram



The ADH Intelligence<sup>®</sup> and SAM Processing<sup>®</sup> represent the most advanced amplification system in the audio market. Together, they allow the speaker they are connected to to reproduce the exact acoustic pressure desired from the recording.

Devialet's next challenge was then to create the perfect revolutionnary loudspeaker that would glorify these two technologies. And this is when the HBI<sup>®</sup> featured in PHANTOM comes in...





## DEVIALET'S HBI®

### The Technical Challenge: Reproduce the whole audible spectrum

Since the creation of the company in 2007, Devialet's ambition has been to bring high-end audio performance into most homes, with a complete solution that in order to be adopted by most had to produce the best music and movie experience in the world, in the most compact form factor.

The challenge was huge, and not unfamiliar to hi-fi enthusiasts: reproducing the full spectrum of music in order to convey its emotional and physical impact. This required not only the best electronics, but also large loudspeakers.

The reason is simple: in order to reproduce low frequencies one needs to move air. Bass-rich instruments are large: a double bass, an organ, a grand piano. Similarly, loudspeakers capable of reproducing the scale of these instruments traditionally use very large speakers drivers, into very large speaker boxes.

### The State of the Art before PHANTOM: Very large loudspeakers

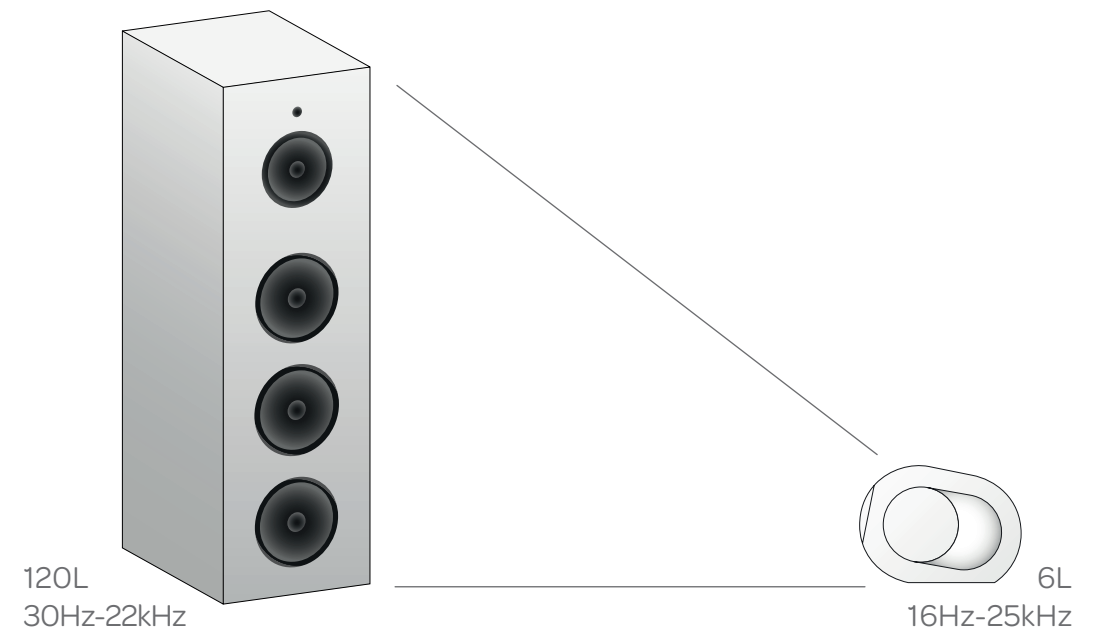
Big sound needs big loudspeakers. This has been true for a hundred years, since the invention of electrodynamic loudspeakers.

The most commonly used speaker acoustic loading principles are bass-reflex (also called vented) designs, and sealed box designs.

Vented designs suffer from energy cancellation at the lowest frequencies, below their resonance frequency - it is called the *acoustic short-circuit*. Except for very large speakers, the scale often lacks scale and impact since the frequencies between 16Hz and 50Hz are not reproduced.

Sealed box design are more desirable when it comes to being able to reproduce very deep bass without losing energy because of the acoustic short-circuit. But again, very large speakers are needed in order to reproduce every music with its entire physical impact.

Typically, the high-end loudspeakers that can reproduce most of the audible spectrum inside a home have a very large internal acoustic volume of 100L to 200L! This is as big as a bath tub. Most people do not want to, or simply are not able to, fit this into their home.



### The Heart Bass Implosion® principle: Electro-acoustics miniaturisation

It is commonly accepted, based on the laws of physics, that great loudspeakers have to be huge. Well the laws of physics cannot be changed, but sometimes there is a lot to gain by pushing them to their very limits. A lot can be done if you don't rely on existing technologies, but are willing and able to develop new ones that serve your specific purpose. It is all a matter of going as far as is physically possible, by looking at a given technical challenge with a new perspective.

We decided on a performance we wanted to achieve, to create the ultimate home audio experience from a compact design, conveying the full music dynamics and physical impact:

- | 16Hz to 25kHz bandwidth,  $\pm 2\text{dB}$
- | 20Hz to 20kHz bandwidth,  $\pm 0.5\text{dB}$
- | 105dB maximum SPL\*

The basic idea behind compact deep bass reproduction was to maximize the efficiency of the electro-acoustic system at every level. The consequences of this logic are simple:

- | use sealed box architecture, for high efficiency at the lowest frequencies
- | design the most efficient compact driver, with very long diaphragm excursion capability
- | use symmetric low-frequency units so as to cancel mechanical vibrations

Working with our designers, we decided to settle on a very challenging acoustic volume of maximum 2x3=6 liters, so as to keep PHANTOM within a very compact form factor. This volume is 20x times smaller than what high-end audio speakers currently use to approach a similar deep bass performance.

This of course created many realisation challenges. To name only one, the maximum air pressure inside the enclosure is 20 times higher than in a conventional speaker box. This pressure is equivalent to 174dB SPL, which is the acoustic pressure level associated with a rocket at launch...

\* SPL stands for Sound Pressure Level ; 105dB SPL is the maximum legal sound level in night clubs and live concerts

This is why we call our technology Heart Bass Implosion®: in order to create lifelike bass from such a compact enclosure, PHANTOM speaker drivers need to be able to create and resist extremely high pressure and vacuum inside the speaker box.

We tried to use in the early prototypes the most robust loudspeakers we could find in the market, and the speaker drivers seemed to ‘implode’: the diaphragm fragmented itself into fractal shapes, sucked in by the excessive force resisting the speaker’s intended displacement.

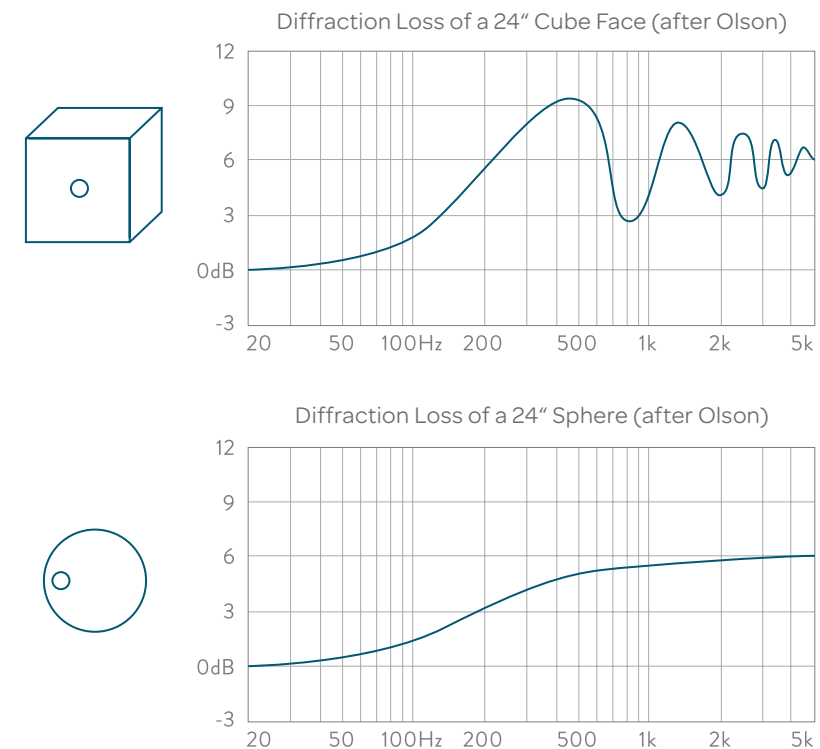
In order to realize this, we hired key engineers with very different and complementary expertise, coming from various industries:

- | experts from the automotive industry, specialized in injection pumps, materials deformation modeling, automated assembly for high pressure devices
- | experts in micromechanics, specialized in designing and manufacturing high-precision metal parts manufacturing for the watch industry
- | experts in high-efficiency professional loudspeakers, specialized in performance repeatability and reliability for live stadium concerts

The result of this unique, blank sheet approach, is Devialet’s first HBI® woofer: a high efficiency, very long stroke (26mm peak-to-peak) yet very compact driver. Four times more powerful than the best woofers on the market of an equivalent diaphragm size, yet 6 times more compact and 6 times lighter. Each woofer can move a mass of more than 30kg.



## PHANTOM’s unique acoustic architecture: approaching the pulsating sphere



We wanted the sound of PHANTOM to be as natural as possible, with a wide dispersion across the listening space, in order to match with modern enjoyment of music – which is rarely for one person only, sitting at a clearly defined listening position.

Sound expands through space as spherical waves; a familiar example is the 2-D visualisation of the shock wave created at the surface of a pond after having thrown in a stone: the wave created at the pond’s surface expands in circles.

A perfect sphere is also the ideal shape when it comes to producing sound and spreading its energy evenly in all directions. Whereas a speaker box is traditionally a parallelepiped (for cost of manufacturing reasons, essentially), the works of Olson have shown as early as the 1940s that the sphere is by far the best shape to avoid diffraction along the box surface.

Just like we need music instruments of different sizes in order to produce sound in specific frequency ranges (a double-bass for the low frequencies, a small violin for the high frequencies), transducers of different sizes are needed, in order to perform optimally in each frequency band: multiway speaker boxes are the norm. In the case of PHANTOM, we wanted two symmetric woofers for low-frequencies, and a midrange and a tweeter to reproduce higher frequencies with perfect piston-like behaviour.

The ideal sound source should though theoretically emit all audible sound from a single point in space, so as to avoid direction-dependent interference to occur between different transducers. This idea of a ‘point source’ is difficult to realize in practice, since the dimensions of the speaker drivers, especially for the low-frequency ones, are far larger than a single point.

It can be approached though by a novel yet very simple design, using coaxial drivers for midrange and tweeter, and diaphragms that are flush with the surface of a perfect sphere. The result: a unique design entirely derived from the laws of acoustics, providing a combination of the best bass reproduction and an optimal directivity pattern.



# SPARK & DIALOG

## HBI® Mechanical Integration

Having defined the key principles of the acoustic architecture was only the first step. Designing a complete product that be mass-produced repeatably and reliably, within the size and cost targets, took two full years.

It could be the object of an entire book to detail the many mechanical challenges that were encountered during the product development. Let us cite only a few key facts that illustrate the level of detail that is needed to make such an integration a success.

| *There is not a single wire in PHANTOM*

| *There are only 10 parts/modules to assemble in order to make a PHANTOM*

| *The gasket that seals off the woofer enclosure has a diameter of 2.620mm, and it is compressed by a force of 1.2 tons to ensure sealing*



Compatible with PHANTOM and the existing range of Devialet amplifiers comes a brand new intelligent audio router called DIALOG.

DIALOG creates a full wireless audio system in high resolution throughout your home, and can control and synchronize up to 24 PHANTOMs. It is connected to your own internet router, DIALOG can also directly access music from the cloud.

Based on an extremely low-latency proprietary protocol realising 1,000,000 calls per second, DIALOG allows multiple users to seamlessly control the music being played and edit a shared playlist in real time. Every user contributes by making their music (stored on their mobile devices, or available from the cloud through the music services they have subscribed to) available to other users hooked up to the same DIALOG network.

Thanks to the SPARK application, your PHANTOMs can be used alone as an independent music system, or grouped in pairs as a classical stereo installation, or in a scalable multichannel system with 3, 4, 5 PHANTOMs or more ...

The SPARK application also allows you to do live grouping, allowing to play different music in each room, or fill the house with the same music for a big party.

DIALOG creates the most robust network on the market today, by combining 3 dual-band Wi-Fi connexions, a 1Gbps Ethernet, and Power Line Communication of the latest generation.

Each PHANTOM has an optical Toslink input and is able to share this input signal with any other PHANTOM on the network. Wired connectivity to the DIALOG network through a 1Gbps Ethernet RJ-45 port is also available.

Based on the EVO® platform, DIALOG will integrate more and more music streaming services natively, multichannel audio decoding, UPnP compatibility to access music from NAS devices, and much more ...



PHANTOM TECHS SPECS

	PHANTOM Implosive Sound Center	SILVER PHANTOM Implosive Sound Center
PERFORMANCE		
Sound Pressure Level	99 dBSPL at 1 meter	105 dBSPL at 1 meter
Amplification power	750 W peak	3000 W peak
Bandwidth	16Hz to 25kHz ± 2dB, 20Hz to 20kHz ± 0,5dB	
Digital Analog Converter	Texas Instruments PCM1798 24bits/192kHz	
Processor	- 800MHz dual-core ARM Cortex-A9 MPCore processor, hard IP, and FPGA in a single Cyclone V System-On-Chip (SoC) - 512 MB DDR3 Memory	
Power Supply	Power supply with IEC 90-240 V~50/60Hz	
Technologies	HBI® ; ADH® ; SAM® ; EVO®	
CHARACTERISTICS		
Size and weight	- Weight: 10.5 kg - Width: 253 mm - Height: 255 mm - Depth : 343 mm	
Materials	- Composite body: - Internal skin: glass fiber filled polycarbonate - External skin: ABS - Aluminum central core - Aluminum dome drivers	
Colors and finish	- White body RAL 9016 - Polished stainless steel side - White dome drivers	- White body RAL 9016 - Sand-blasted stainless steel side - Silver dome drivers
FONCTIONNALITIES		
Synchronization	1 to 24 PHANTOMs	
Connectivity	Dual-band Wi-Fi (a/b/g/n 2.4 GHz & 5 GHz) Ethernet RJ-45 10/100/1000 Mbps (Gigabit) PLC Homeplug AV2 Toslink optical input (TV, blu-ray, video games console, ...)	
Application	SPARK	
Supported OS	Windows 7+, Mac OSX 10.9+ iOS 7+, Android 4.4+	

DIALOG TECHS SPECS

Power	Power adapter	Built-in
Networking	Guest network  PHANTOM network  Ethernet PLC	Wi-Fi x Dual-band Wi-Fi ( a/b/g/n 2.4 GHz & 5GHz ) Wi-Fi x Dual-band Wi-Fi ( a/b/g/n 2.4 GHz & 5GHz ) 10/100/1000 ( Gigabit ) Homeplug AV2
Compatibility	Requires smartphone/ tablet/desktop software  Supported OSs	Yes  iOS 7+, Windows 7+, Android 4.4+, OS X 10.9+
Processing unit	Processor Memory Synchronisation	Quad-core processor 1 GHz 1GB ( RAM ) / 2GB ( Flash ) Devialet synchronisation module ( for more than one Phantom )
Peripherals	Optical: USB:	Input (Toslink) Asynchronous audio output for Expert product line

