DALI PHANTOM IW SUB S-100

TECHNICAL PAPER

MAY 2023

DALI

IN ADMIRATION OF MUSIC

Introduction

Designing and engineering a subwoofer that provides the enormous installation versatility of the DALI PHANTOM IW SUB S-100, while still achieving class leading electro-acoustic performance, was no trivial undertaking. DALI however is blessed with an extraordinary team of designers, acousticians and engineers, and an enviable library of both new ideas and past achievements to draw on. Over the next few pages we'll describe the technology of the PHANTOM IW SUB S-100 subwoofer and how it achieves performance that even just a few years ago would have been considered unlikely.

Accepted wisdom holds that the reproduction of very low frequencies requires generous speaker enclosure volume and bass driver diaphragm area, and that is fundamentally true. However, there are two further factors that can change the rules: bass driver diaphragm excursion and amplifier power. If a bass driver is designed such that its diaphragm is able to move significantly further than usual, and significant power amplifier is available, the usual low frequency constraints defined by enclosure volume and diaphragm area can be overcome. And that is what the PHANTOM IW SUB S-100, with its partnering DALI PHANTOM CI AMP-2500 DSP amplifier, achieves. (From here: SUB S-100 and AMP-2500 DSP).

PHANTOM IW SUB S-100
Electro-acoustics

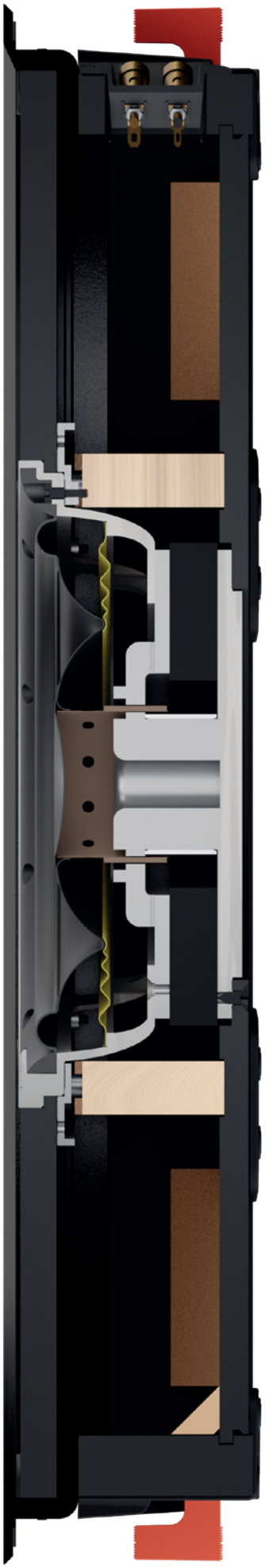
The SUB S-100 enclosure is designed to fit between conventionally spaced drywall joists and be shallow enough that typical drywall free depth would enable its flush-to-wall installation. Consequently, if the SUB S-100 was not to be unfeasibly tall, these two constraints its internal volume to around 9 litres and its frontal area such that a driver no larger than 250 mm (10 inches) diameter could be used. Neither are characteristics normally associated with a subwoofer.

In electro-acoustic terms, the primary result of mounting the relatively large diameter SUB S-100 driver in a small enclosure is that, due to the high stiffness of the air in the enclosure, the fundamental low frequency resonance of the system is raised to a relatively high 60Hz. Normally, the low frequency resonance of a speaker system broadly defines the limit of its low frequency bandwidth, below which its acoustic output falls; at 12dB/octave for a closed box like the SUB S-100, and 24dB/octave for a reflex loaded enclosure. However, in the case of the SUB S-100, the low frequency resonance does not define its bandwidth, and that is the result of low frequency equalisation applied by its partnering AMP-2500 DSP amplifier. The 12dB/octave roll-off of the system is compensated by an equivalent targeted EQ boost from the amplifier. As a result, the SUB S-100 system actually does most of its subwoofer work at frequencies below its low frequency resonance. Its low frequency -3dB cut-off, rather than being close to its low frequency resonance, is over an octave lower at 26Hz.

We mentioned reflex loading in the previous paragraph and perhaps it's worth explaining why that configuration is not employed in the SUB S-100, because the conventional wisdom of speaker design is that reflex loading offers extended low frequency bandwidth. There are two reasons why the SUB S-100 is not reflex loaded:

- Firstly, the shallower frequency response roll-off below resonance of the closed box configuration compared to reflex loading means that the degree of equalisation gain required from the amplifier to recover the response is less. Closed box loading also helps minimise low frequency latency (group delay) and resonant overhang.

- Secondly, the subwoofer role of the SUB S-100 implies that any reflex port would need to be tuned to a relatively low frequency (around 30Hz or less), and the lower the tuning frequency, the longer is the port tube required. However, the restricted internal dimensions of the SUB S-100 would simply not provide space for a long reflex port tube of adequate diameter to be able to handle the necessary airflow volume.



PHANTOM IW SUB S-100
Driver Technology

A consequence of the SUB S-100 bandwidth reaching down to 26Hz with an enclosure volume of only 9 litres is that it demands some unusual engineering features and performance characteristics from its driver. And if that wasn't challenging enough, the SUB S-100 driver is also required to fit in an enclosure that offers a mounting depth of only 102 mm.

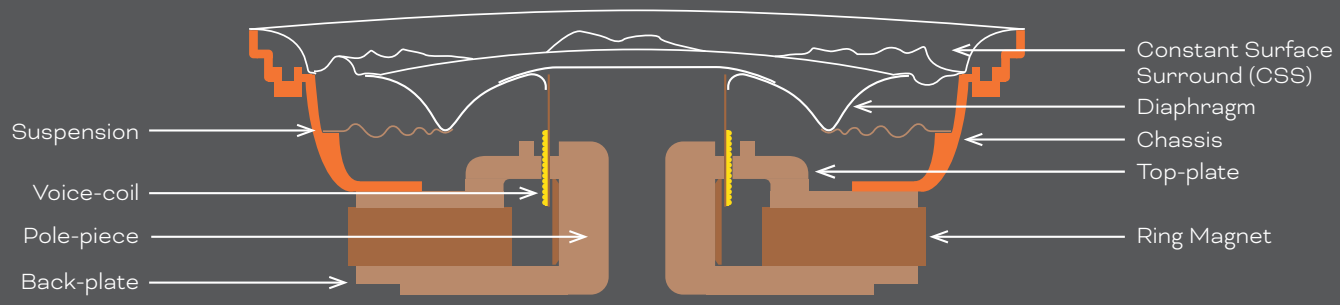
The SUB S-100 driver was designed and engineered to incorporate both an innovative low-profile architecture developed by DALI's in-house team, and a radical new Constant Surface Surround Technology (CSS) conceived and developed by Danish high-end driver manufacturer Purifi Audio. As we'll describe later, Constant Surface Surround Technology is particularly well suited to compact subwoofer applications and now, through a collaboration between DALI and Purifi Audio it has been integrated in the SUB S-100 driver.

SUB S-100 Driver Architecture

In contrast to a conventional driver, the architecture of SUB S-100 driver incorporates three primary modifications that together enable both generous diaphragm excursion capability and a significant reduction in physical depth.

- Firstly, rather than taking a conventional conical form, the curved outer region of the pressed aluminium diaphragm joins a large convex central domed region. By combining the curved outer section and domed central region the diaphragm exhibits the very high structural rigidity necessary for a subwoofer driver. However the diaphragm shape also offers much reduced overall depth and, by keeping the diaphragm apex clear of the magnet system components, maximises excursion potential.
- Secondly, rather than attaching the driver suspension conventionally to the voice-coil former, it attaches to the diaphragm at the point where its profile changes from curved to dome. This change of suspension mounting location enables the motor system to be brought much closer to the underside of the diaphragm to reduce the depth of the assembly while not impacting on excursion capability.
- Lastly, rather than being attached to the bottom of a curved conical diaphragm, the voice-coil former attaches to the underside of the diaphragm dome. This again brings the motor system closer to the diaphragm.

SUB S-100 driver architecture



SUB S-100 Constant Surface Surround (CSS) Technology

The SUB S-100 driver employs Constant Surface Surround Technology, co-developed with Purifi Audio, and is the world's first in-house developed driver to do so.

Constant Surface Surround Technology has a physical form entirely unlike that of conventional driver roll-surround components. It comprises alternating positive and negative regions, each of which incorporate curved and stepped sections at differing elevations and angles to the neutral plane. The immensely complex form of the Constant Surface Surround is the result of an intensive development programme by Purifi Audio, driven by a fundamental reappraisal of the function of the roll-surround and its contribution to driver performance.

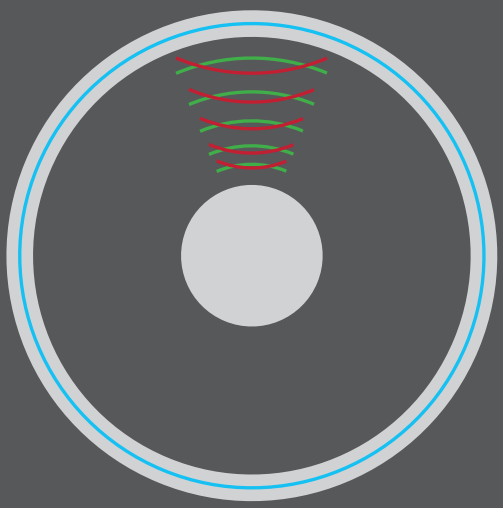
The roll-surround of any bass or bass/mid driver has three fundamental functions. Firstly, in parallel with the voice-coil suspension, it ensures that the driver diaphragm remains centred and free to move only backwards and forwards.

Secondly, while constraining the diaphragm axially, the roll-surround must offer minimal resistance to diaphragm movement at low frequencies so that bass transients aren't slowed and attenuated.

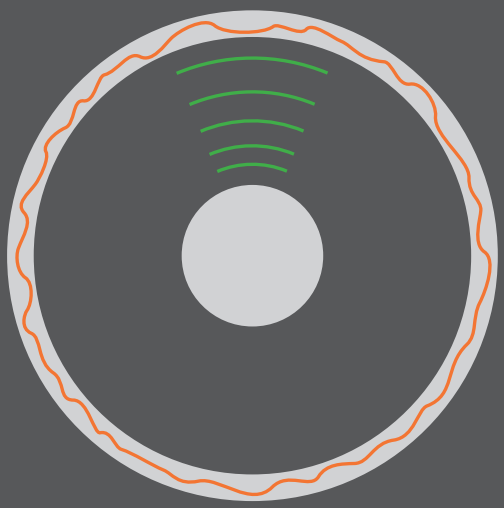
Thirdly, simultaneously with contributing minimal dynamic resistance at low frequencies, the roll-surround must dissipate the higher frequency vibrational energy that travels outward through the driver diaphragm from the voice-coil. Any vibrational energy reflected back from the roll-surround will potentially set-up a standing-wave diaphragm resonance.

Conventional vs. CSS technology rubber surround

Conventional "half-roll" rubber surround:
Resonances on the diaphragm travels outwards and gets reflected back by the rubber surround and causes further unwanted resonances and distortion on the driver surface.



CSS Technology:
The Constant Surface Surround is better at absorbing the the diaphragm resonances so that they don't reflect back on the driver surface and cause additional distortion.



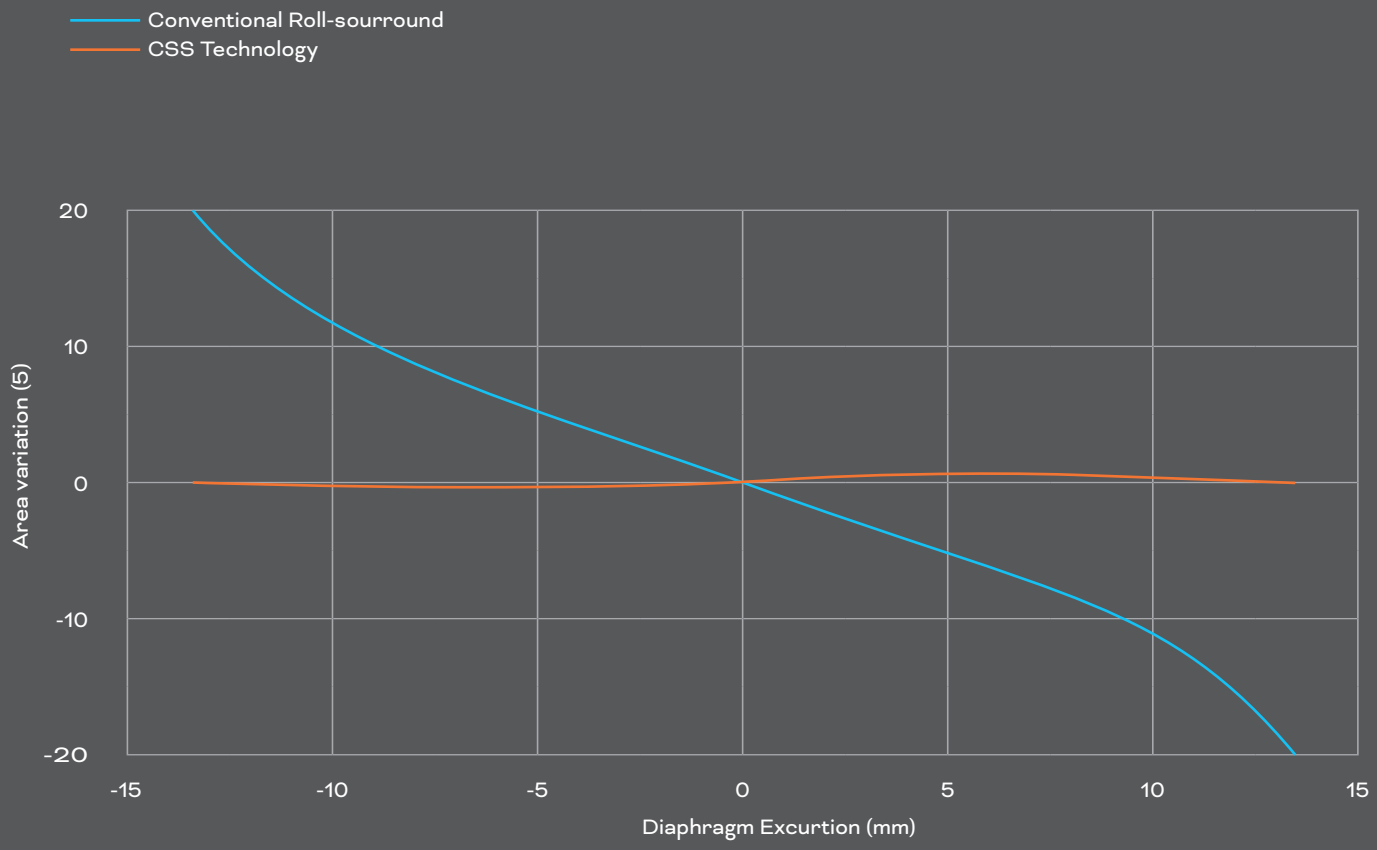
While the traditional roll-surrounds of all DALI speakers are of course engineered to function excellently, the fresh analysis undertaken by Purfi Audio revealed some valuable insights into roll-surround characteristics that are of particular value in compact subwoofer drivers. Firstly, due to the nature of its geometry, a traditional roll-surround varies in effective surface area as it moves through positive and negative excursion. And as a roll-surround can contribute a significant portion of a driver's radiating area, this effect modulates the acoustic output, resulting in distortion. It's a distortion mechanism that is particularly relevant to compact subwoofer drivers that demand large diaphragm excursion, and due to being geometrically engineered to eliminate the mechanism, CSS Technology in the SUB S-100 driver results in a significant reduction in distortion.

A further benefit of CSS Technology is that its geometry enables the simultaneous combination of minimal dynamic restraint at low frequencies with more effective vibrational energy dissipation at higher frequencies. This is because, while the simple geometry of conventional roll-surrounds is potentially prone to resonance, the far more complex geometry of CSS Technology tends to randomise the mechanical impedance at the outer edge of the diaphragm. This has the effect of suppressing any tendency for reflective standing waves to arise. The result is cleaner audio with less distortion and resonance.

A final benefit of CSS Technology is that its geometry is particularly resistant to deformation due to raised air pressure within a speaker enclosure. This is especially relevant to the SUB S-100 because its extreme enclosure volume to driver diameter ratio results in unusually high internal air pressure. Again, a reduction in distortion, especially at high volume levels results from the use of CSS Technology.

CSS Technology marks a significant advance in driver design and performance that we at DALI are excited and proud to be the first to introduce to an in-house manufactured subwoofer driver.

Roll-sourround Area Variation



Conventional vs. CSS Technology: Surround Radiation Distortion and cabinet pressure.

Conventional "half-roll" rubber surround:
A conventional "half-roll" rubber surround will change its parameters depending on the position of the cone. When the cone is in its maximum forward excursion the effective radiating surface area of the cone and surround decrease, and conversely, when in its maximum inwards excursion, the radiating surface area increase. This position-dependent effective area deviation can often be as much as 20% of a drivers radiating surface area and is therefore a direct contributor to distortion.

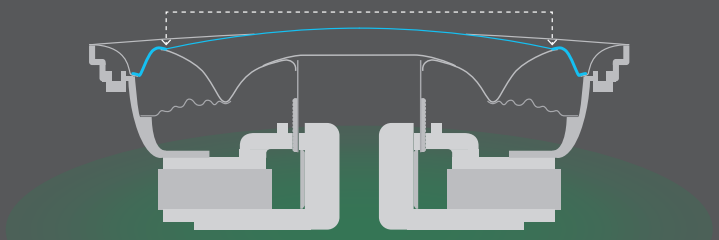
Furthermore, because of this variation, the pressure inside the cabinet will also vary depending on the position of the cone. Also a contributor of distortion.

CSS technology:
The Constant Surface Surround (CSS) technology uses a special surround geometry that is optimized mathematically, keeping modulation to a minimum, effectively eliminating SRD and significantly reducing distortion. No matter the position of the cone and surround, the effective radiating area remains linear.

Also, the cabinet pressure behind the driver remains constant.

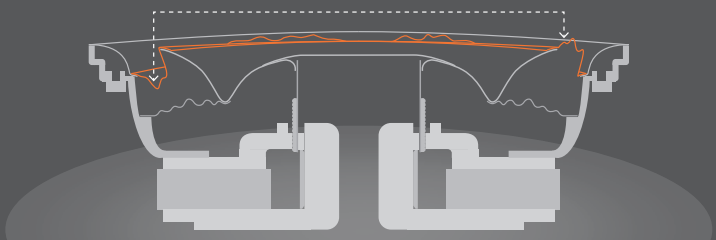
Max forward excursion

Smaller radiating area



When the cone is in its maximum forward excursion position, the radiating surface area is smaller and the cabinet pressure is low

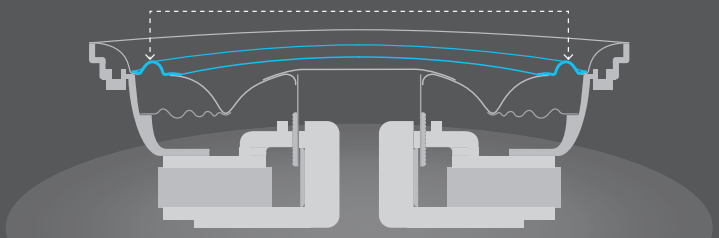
Constant radiating area



With CSS Technology, no matter the position of the cone, the total radiating surface area stays constant as does the cabinet pressure.

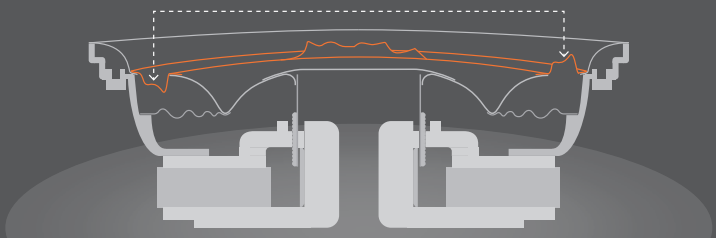
Neutral position

Medium radiating area



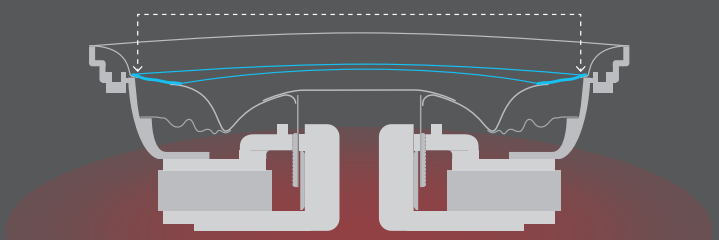
When the cone is in its neutral position, the radiating surface area is medium and the cabinet pressure is medium

Constant radiating area



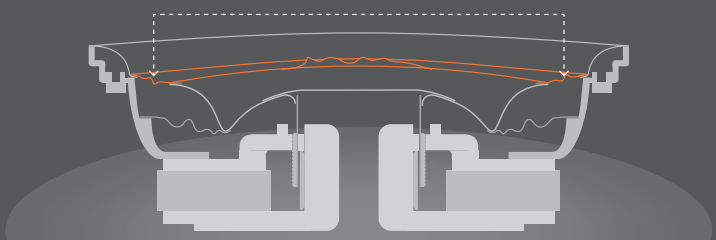
Max inwards excursion

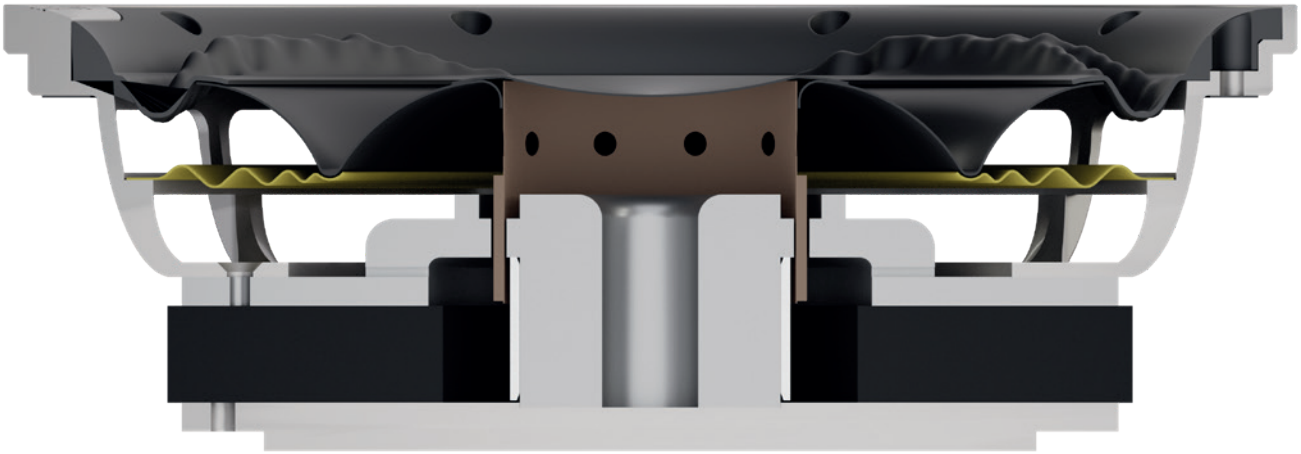
Larger radiating area



When the cone is in its maximum inner excursion position, the radiating surface area is large and the cabinet pressure is high.

Constant radiating area





SUB S-100 Driver Motor System

Notable design features of the SUB S-100 driver don't end with its innovative architecture and Constant Surface Surround Technology however. Its motor system, comprising a generous 200 mm diameter magnet, an 8 mm top plate, and 26 mm long by 63 mm, 4-layer voice-coil, was FEA modelled and engineered to optimise flux linearity. An aluminium shorting ring fitted around the pole piece is additionally employed to minimise and stabilise voice-coil inductance. The voice-coil itself is designed to be able to handle very significant power with minimal thermal compression and faultless reliability.

The overall result of the new architecture is a 250 mm subwoofer driver with a depth dimension less than half that of a conventionally engineered unit yet able to offer ±9 mm linear and ±18 mm maximum excursion. Furthermore, in terms of low frequency parameters, power handling, distortion and compression the SUB S-100 is also more than competitive with conventionally engineered units. The new driver architecture makes it possible for the SUB S-100 to be extraordinarily slim, yet offer all the bandwidth, impact and scale of the best conventional subwoofers.

PHANTOM IW SUB S-100 Amplification

The SUB S-100 is designed to be used with its partnering PHANTOM CI AMP-2500 DSP amplifier and will not perform as intended if used with alternative amplification.

The AMP-2500 DSP is a two output, high performance Class-D technology amplifier rated at 500 Watts per channel into 4Ω. The amplifier's high power rating enables it to accommodate the extra gain demands that results from the low frequency equalisation described earlier in this document. The amplifier can be rack mounted or free-standing and is cooled through temperature controlled intelligent fan ventilation that switches on only when the amplifier is continuously delivering very high power. The fan is very unlikely to switch on under any circumstances of normal subwoofer use.

The AMP-2500 DSP incorporates fully configurable DSP output functions that enable custom speaker equalisation profiles to be created and installed. The low frequency equalisation required for the correct performance of the SUB S-100 is created through these DSP functions and installed by default. Configuration of the AMP-2500 DSP is achieved via a wired or wireless network connection to its web page based DALI PHANTOM CI AMP CONFIGURATOR

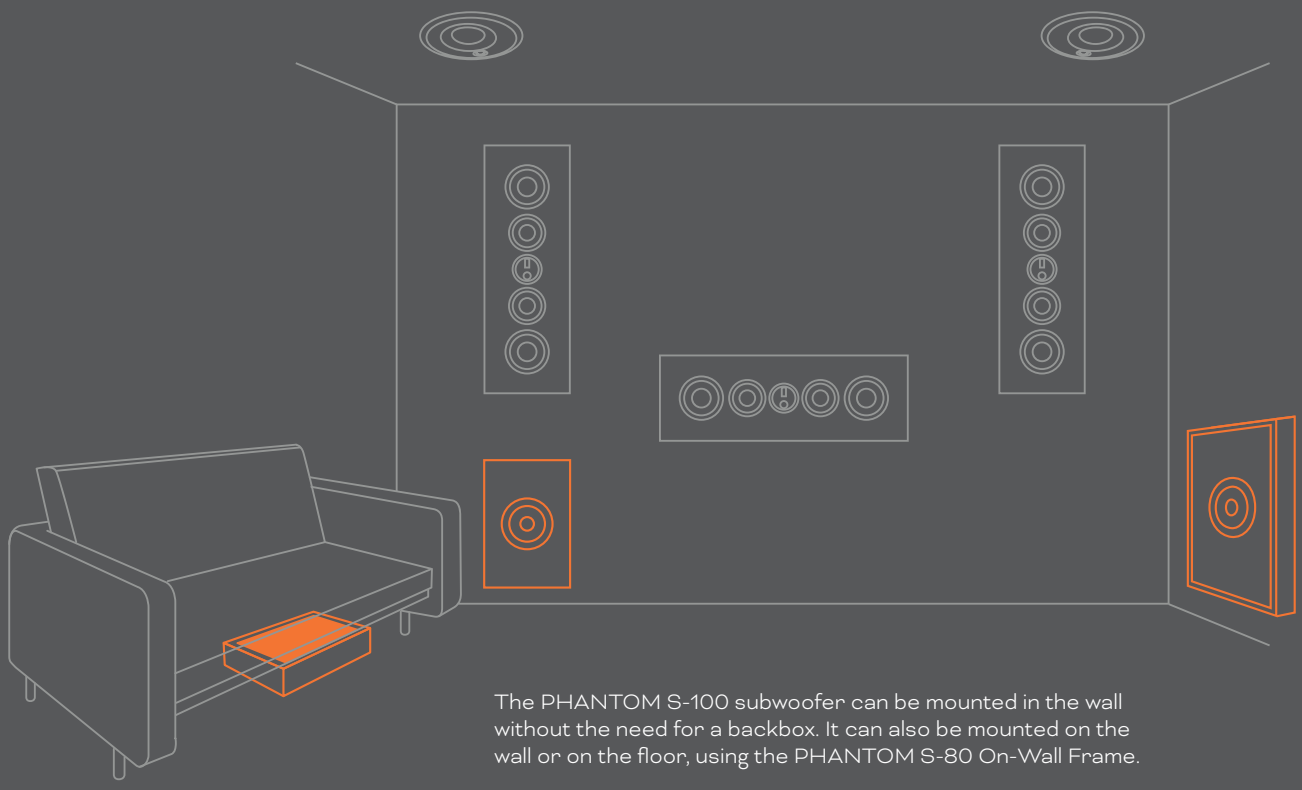
PHANTOM IW SUB S-100
Enclosure Design and Engineering

The versatility of the SUB S-100 extends further than simply its in-wall installation. And the versatility all results from the subwoofer's enclosure design.

The engineering and construction of the IW SUB S-100 enclosure combines 25 mm and 15 mm MDF panels with aluminium extrusions and injection moulded structural plastic components. The result is inherently an extremely rigid construction, however rigidity is further increased by the use of the SUB S-100 driver chassis and magnet components as a brace between the front and rear enclosure panels. It helps ensure that even when working hard, the SUB S-100 enclosure remains completely inert.

Due to the requirement for the air volume behind the driver to be fixed, the SUB S-100 effectively incorporates its own back box. This significantly simplifies in-wall installation but also means that, in combination with a DALI PHANTOM S-80 ON-WALL FRAME, SUB S-100 subwoofers can also be mounted on-wall (rather than in-wall) or even used unmounted; lying on their back beneath items of furniture, for example. The PHANTOM IW SUB S-100 is undoubtedly among the most versatile custom install subwoofers available.

In-Wall, On-Wall and Unmounted (Floor) installation



The PHANTOM S-100 subwoofer can be mounted in the wall without the need for a backbox. It can also be mounted on the wall or on the floor, using the PHANTOM S-80 On-Wall Frame.

Technical specifications

DALI PHANTOM S	SUB S-100*
Frequency range	26 - 250 Hz, ±3 dB
Sensitivity	84 dB @ 1 m for 2.83 V
Nominal impedance	6 ohm
Recommended amplifier power	200 - 500 W RMS
Recommended amplifier	DALI PHANTOM AMP-2500 DSP
Maximum SPL	110 dB @ 1 m
Low frequency driver	1 x 10 inch long throw, low profile
Low frequency diaphragm	Anodised aluminium
Connection input	Single wire
Enclosure type	Closed box / Infinite baffle
Installation location	In-wall / On-wall / Floor
Outer dimensions incl. grille (H x W x D)	657 x 412 x 107 mm / 25.87 x 16.22 x 4.22 inches
Outer dimensions excl. grille (H x W x D)	647 x 402 x 106 mm / 25.5 x 15.9 x 4.21 inches
Cut-out dimensions (H x W)	615 x 370 mm / 24.2 x 14.5 inches
Mounting depth	102 mm / 4.02 inches
Wall thickness (total dog-leg span)	10 - 70 mm / 0.4 - 2.8 inches
Weight incl. grille	17.25 kg / 38.03 lb
Shipping weight	21 kg / 46.3 lb
Finish	Black
Accessories	Cut-out template Front grille Rubber pads
Optional Accessories	PHANTOM PHANTOM OW Frame S-80 DALI CONNECT SC F222C (speaker cable) DALI CONNECT SC F215C (speaker cable)

* All SUB S-100 specifications are measured driven by the PHANTOM CI AMP-2500 DSP amplifier