

DALI V-16 F SUBWOOFER

WHITE PAPER



IN ADMIRATION OF MUSIC



1. Introduction

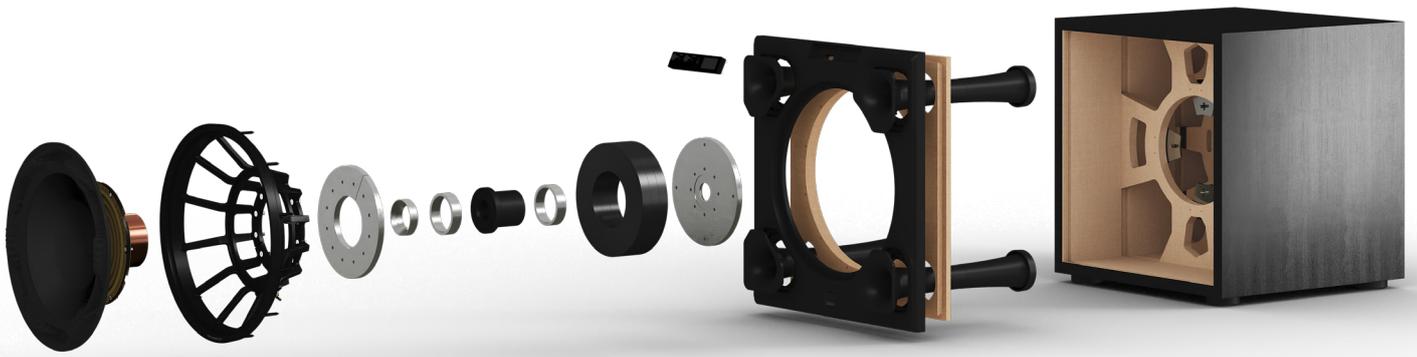
Bass plays the vital role of punctuation in movies: the sub-drop that defines a pivotal plot point, or the explosion that triggers a hero's triumph. And in music, kick drums and bass guitars, or classical timpani and double bass, play the notes and define the rhythms upon which songs and compositions are built. But even as important: The presence of clean, well-integrated deep bass is key to recreating the sense of "being there" in any type of sound reproduction. Despite its vital role however, accurately reproducing deep bass, including both the power and the finesse, isn't easy. It requires tremendous power, and a sharp focus on low-loss, low-distortion audio engineering in order that it doesn't interfere with the crucial midrange of the main speakers. So bass brings some of the greatest challenges to loudspeaker engineering, and the new V-16 F delivers everything we know at DALI about reproducing bass in one signature subwoofer. Bass, for movies and music, done properly, without compromise.

The V-16 F is a unique subwoofer designed for the ultimate reproduction of bass in high-end home theatre and audiophile music systems, and this white paper will describe its technology and performance. Put simply, the V-16 F is the most powerful and least compromised subwoofer we have ever built. It is capable of filling the largest of rooms with audiophile, ceiling-shaking bass, while at the same time possessing all the precision and control needed to work in any audio system context and even in small rooms. It plays lean, deep, detailed bass without any sacrifice of dynamics, pitch, speed, or tonal coloration.

To begin, however, the raw numbers of the V-16 F give a flavour of its extraordinary abilities and potential:

- Class-leading ability to integrate with system acoustics thanks to:
 - Wideband, low-loss design with extremely low harmonic and non-harmonic distortion, optimised both in-, and out of it's primary frequency band.
 - Naturally extended bandwidth from driver and amplifier.
 - Well controlled, non-resonant, low-pass roll-off.
 - Ultra-low signal latency.
- Low frequency in-room bandwidth to -3 dB @ 19 Hz.
- Four continuous flare reflex ports tuned to 18 Hz.
- A single 16 inch (406 mm) driver incorporating the largest ever Constant Surface Surround (CSS rubber surround) and boasting ± 16 mm linear diaphragm travel with 70 mm peak-to-peak excursion.
- 1500 W Class-D power amplification (2500 W peak power).
- Room Mode Attenuation mode.
- Leader/Follower mode.
- Constant Group Delay mode.
- 90 Litre cabinet volume.
- Total weight 53.15 kg / 117.18 lb.

Facts and numbers, however, are sterile, where, in contrast, bass that curls your insides with its visceral impact, or tears your heart with its aching subterranean melody, is anything but. So how does the V-16 F create an emotional response with its remarkable numbers? It begins with a new and extraordinary bass driver.



2. A Subwoofer Driver to Rule Them All

The 16 inch diameter V-16 F low-loss bass driver is the result of a fundamental reappraisal of the needs of a driver designed solely to reproduce low frequencies. Given enough amplifier power, driver excursion and the appropriate cabinet volume, the main enemies of accurate bass reproduction are losses in the form of distortion and compression. Distortion is effectively defined by the presence in the output of anything that isn't present in the input signal. And compression refers to the output not quite reaching the level defined by the input signal. So the V-16 F driver incorporates multiple features designed to minimise the losses that result from both phenomena.

The V-16 F driver's design and engineering story begins with its extravagant die-cast aluminium chassis and motor system of voice coil, magnet and steel parts. The latter comprise a huge 200 mm diameter by 11 mm thick back plate, a similarly dimensioned top plate and a T-shaped vented pole-piece of 86 mm diameter. The T-shape of the pole-piece is designed to ensure symmetrical magnetic flux distribution through the voice coil. Even the vent hole through the pole-piece is specifically designed to ensure laminar airflow, with generous flaring at both ends and, at the diaphragm end, an additional flared aluminium airflow guide is fitted that simultaneously plays the role of a "Faraday" ring to suppress magnetic flux modulation. A second "Faraday" ring to further reduce flux modulation is fitted below the first in the region around the pole-piece T-section.

The V-16 F bass driver's 88 mm diameter and 44 mm long voice coil comprises a 4-layer winding on a vented ultra low-loss glass-fibre former. Using a non-electrically conducting material for the voice coil former prevents the build up of eddy currents and so minimises any breaking effects on the moving voice coil. This in turn reduces odd order (3rd, 5th, 7th, etc.) harmonic distortion and improves dynamics.

The voice coil former is attached to two spider systems for optimum symmetry, strength and zero DC-offset.

The voice coil windings consist of low-mass copper-clad aluminium wire. Combined with the driver's 12 mm thick top plate, the voice coil enables a ± 16 mm linear driver – well over twice the linear excursion of a typical bass driver. And beyond its linear range, the bass driver is capable of an extraordinary ± 35 mm excursion excursion (70 mm peak-peak) without damage.

The final element of the V-16 F bass driver motor system is a stack of three ferrite ring magnets, each one measuring 200 mm in diameter and 20 mm thick. The magnet stack together comprises the largest and most powerful ferrite magnet ever fitted to a DALI driver.

None of this extraordinary bass driver engineering would count for anything if the results weren't spectacular. The V-16 F driver's ability to accelerate huge volumes of air to turn electrical signals into tangible, palpable, room filling bass is absolutely unprecedented. And it's low-loss design ensures that every nuance and tiniest detail of sub-bass is reproduced with extremely low "stiction", which along with the low distortion and impeccable timing, vouches for an agile, accurate bass foundation with perfect dynamics.



2.1 Constant Surface Surround (CSS) Technology

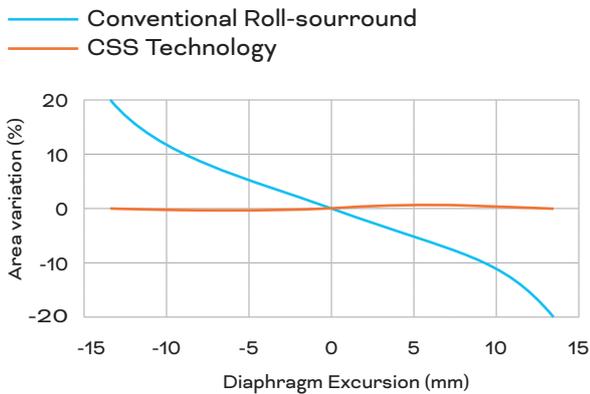
Constant Surface Surround Technology has a physical form entirely unlike that of conventional driver roll-surround components. It comprises alternating positive and negative regions, each of which incorporate curved and stepped sections at differing elevations and angles to the neutral plane.

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.

2.2 CSS Technology Benefits

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 subwoofer drivers that potentially undergo large diaphragm excursion. Due to being geometrically engineered to eliminate the radiating area distortion mechanism, CSS Technology in the V-16 F driver results in a significant reduction in distortion.

Roll-surround Area Variation



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.

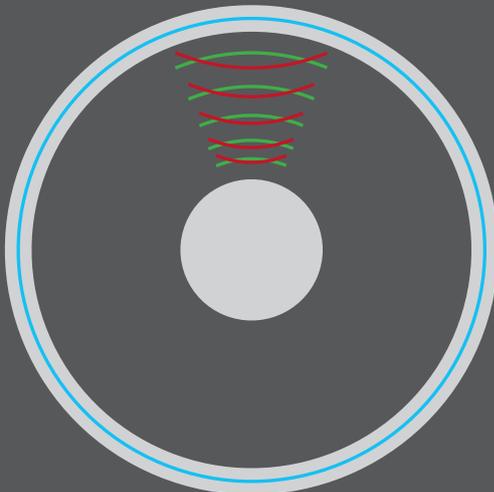
A final benefit of CSS Technology is that its geometry is particularly resistant to deformation due to raised air pressure within a speaker enclosure. This is especially relevant in subwoofers because even with substantial internal cabinet volume the internal air pressure at the reflex port tuning frequency can be extremely high.

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

Conventional vs. CSS Technology Rubber Surround

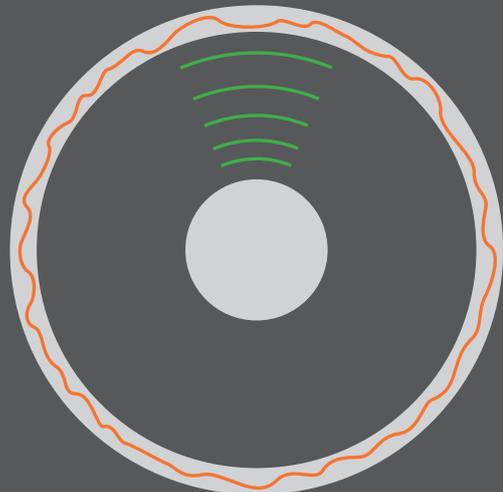
Conventional "Half-Roll" Rubber Surround:

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:

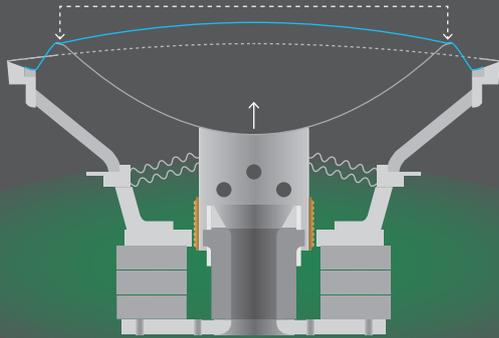
Constant Surface Surround is better at absorbing diaphragm resonances, resulting in less reflections and resonances on the driver surface, and thereby lower distortion overall.



Conventional vs. CSS technology rubber surround

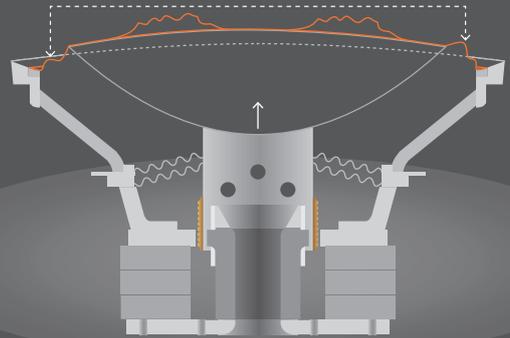
Max forward excursion

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

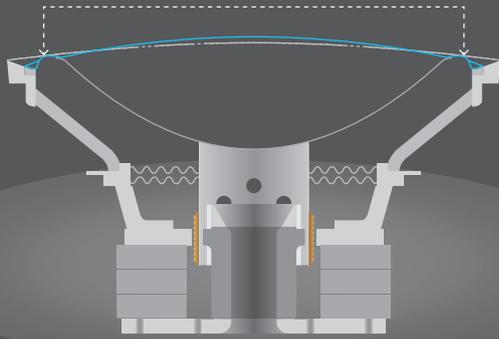
Constant radiating area



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

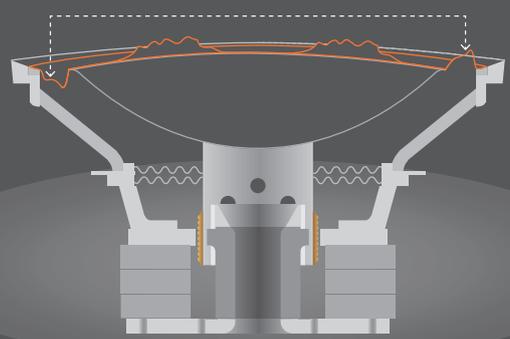
Neutral position

Medium radiating area



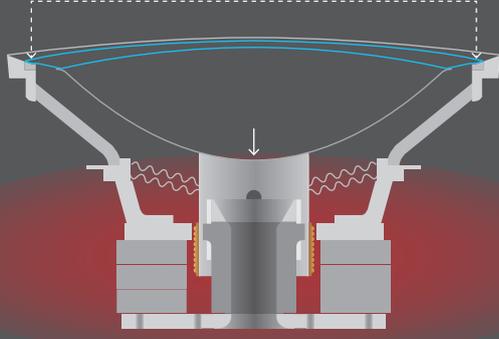
When the cone is in its neutral position, the radiating surface area is medium and the cabinet pressure is medium

Constant radiating area



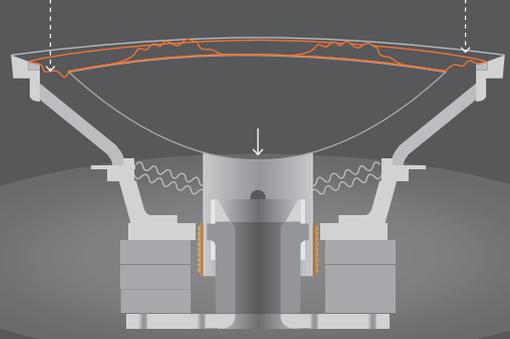
Max inwards excursion

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



2.3 Optimised Low-loss Diaphragm and Extreme High Power Low Distortion Motor

While the most noticeable physical expression of the V-16 F driver's remarkable low-loss design is its Constant Surface Surround, the driver incorporates numerous other features and technologies dedicated to maximising its performance through minimising the losses of distortion and compression.

The driver diaphragm is constructed from aluminium to create an enormously rigid yet light component that retains its profile even under the most extreme excursion. Any bending of a subwoofer diaphragm means signal loss and the V-16 F diaphragm, even despite its large

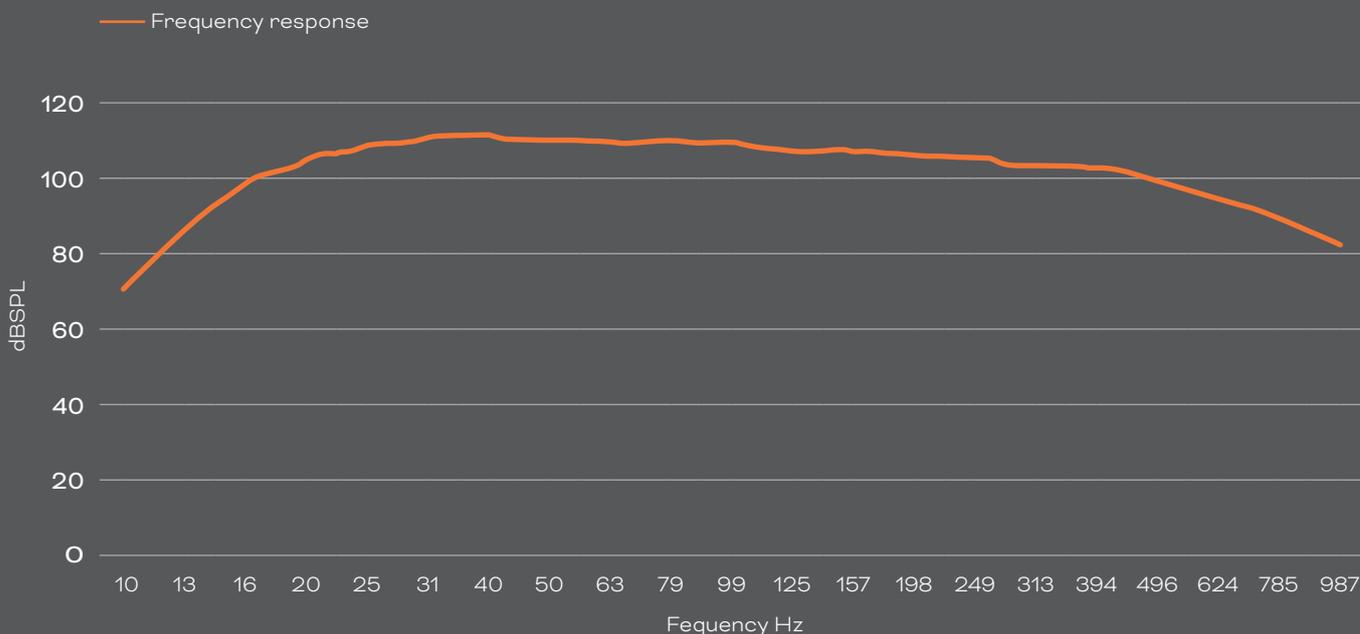


diameter, is the most rigid ever fitted to a DALI driver. The diaphragm is also designed, in combination with the CSS technology surround, to ensure resonance-free performance up to around 1 kHz. This is because even with a low-pass filter set below 200 Hz, a subwoofer's contribution can still be marginally audible an octave, two octaves or even higher. Finally, with its front suspension taken care of by the CSS technology surround, at the rear, the diaphragm is suspended by twin corrugated spiders that enable very high excursion levels without compression.

Frequency Response

The V-16 F driver has a frequency bandwidth reaching beyond 1000 Hz. That is a large bandwidth compared to traditional subwoofer systems.

This highly intentional focus on low losses in the magnet motor as well as in the mechanical parts and the general optimisation of a large bandwidth motor- and cone system ensures a coherent, clean overtone reproduction which, in combination with low-distortion behavior in- and out of the subwoofer's primary frequency band, makes it possible to obtain a completely seamless, natural and non-masking transition in the crucial overlap between the subwoofer and the main speaker system.



2.4 Under the Hood of the Driver

The V-16 F bass driver employs various technologies to ensure low losses and minimal distortion. Technologies, not visible to the eye, like the the glass fibre voice coil former or the inductance linearisation rings surrounding the pole piece, might seem like minor details on paper, but the sum of the improvements they bring results in class-leading performance.

Ventilated Glass Fibre Voice Coil Former:

The voice coil former in the V-16 F is made from electrically non-conductive glass fibre.

If a voice coil former is made from an electrical conductor such as aluminium, that conductivity results in eddy currents flowing in the material. And through interaction with the magnetic flux surrounding the voice coil, the eddy currents create a restraining force that reduces the ability of the voice coil to follow the music signal, and this introduces distortion.

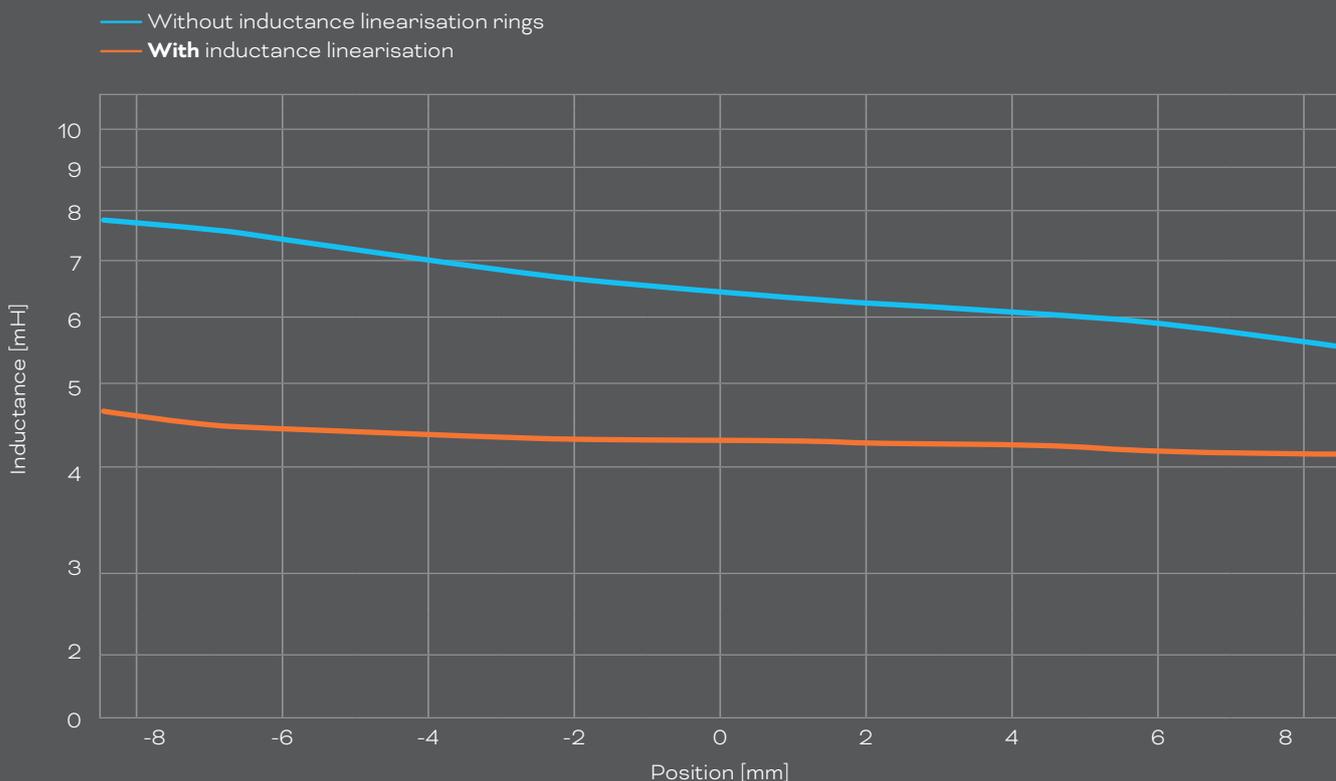
The alternative former material employed in the V-16 F driver is glass-fibre. Glass-fibre is electrically non-conducting and consequently immune to eddy current issues and this significantly reduces distortion. Furthermore, due to the sheer size of

the driver's enormous magnet, the voice coil can be engineered to be large in diameter and to offer huge rigidity that enables large ventilation holes to be placed between the end of its former and the diaphragm. The ventilation holes both increase airflow to help control temperature and minimise thermal compression, and reduce the damping of air trapped beneath the driver dust cap.

Voice Coil Inductance Linearisation:

The output from an audio amplifier is a voltage swing, while the force generated in a driver motor system is a function of current. Thus, the driver impedance seen by the amplifier needs to be stable. However, in many driver motor systems, voice coil inductance and thus impedance depends on diaphragm position. When the diaphragm and voice coil moves towards the magnet system relatively more of the pole piece is 'seen' by the voice coil windings so its inductance increases. The opposite effect occurs when voice coil travel outwards. Consequently the impedance and frequency response of the driver is modulated by voice coil position. In the V-16 F however the voice coil inductance shows minimal variations throughout the entire diaphragm excursion range using two aluminium "Faraday rings" located around the pole piece that linearise inductance variation.

V-16 F Driver Voice Coil Inductance @ 100 Hz





Low Distortion Driver Design

The sum of the numerous in-house developed components and engineering within the V-16 F driver results in the highest performance DALI subwoofer ever. The V-16 F driver shows extraordinarily low distortion, and that translates to a subwoofer that disappears completely in the sound scape, is able to start and stop instantly, and is able to reproduce the most subtle of details. But more importantly, the V-16 F will blend seamlessly with other speaker channels without masking their vitally important midrange clarity. This is the definition of what a true audiophile subwoofer is all about.

Subwoofers are traditionally expected to reproduce only a sub-bass frequencies. But even though they are typically low-pass filtered at 80 Hz, lower performance subwoofers will typically contribute plenty of overtones and destructive harmonic distortion products well beyond 200 Hz. If a subwoofer driver generates distortion, the harmonic

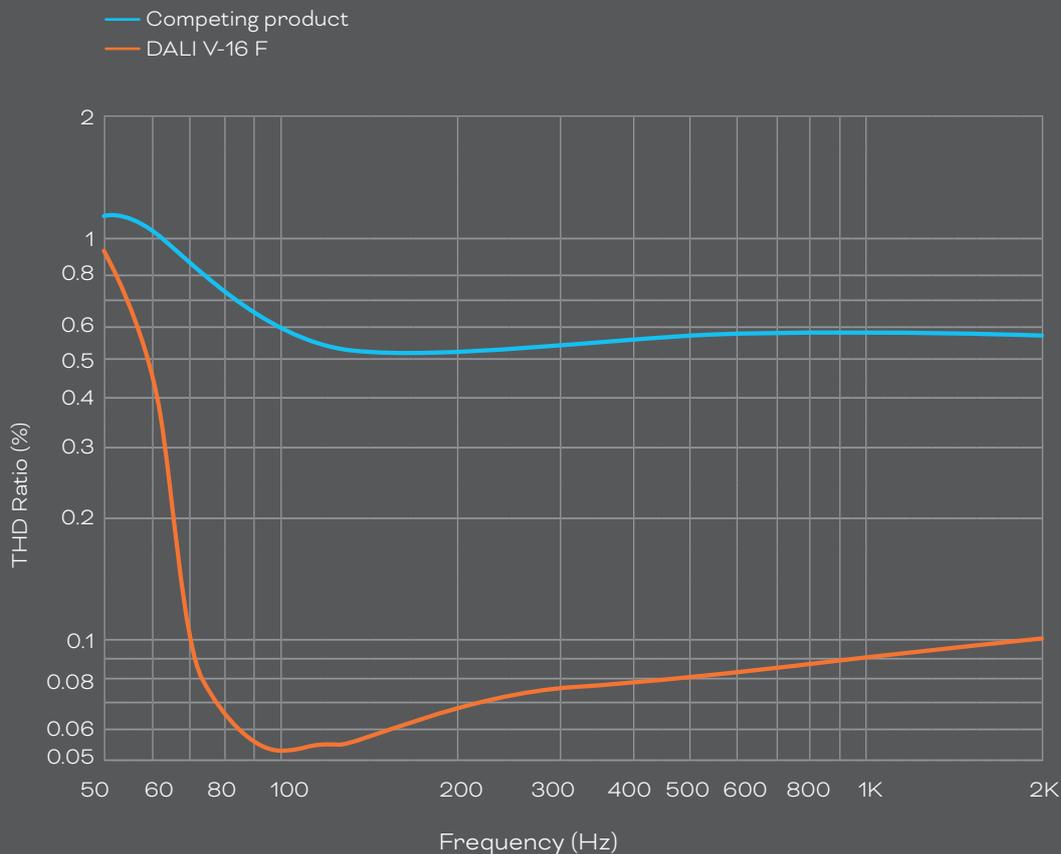
overtones will inevitably degrade the balance and clarity of the multichannel audio system.

These distortion artifacts and electro/acoustic properties are inherent in the driver itself, at all times, and cannot be filtered out by DSP tools. It has to be addressed in the driver design to begin with.

This is why, at DALI, we are obsessed with developing drivers that display a very wide bandwidth with very low-loss and distortion, but perhaps even more importantly, the ability to perform flawlessly way beyond their primary frequency range. This goes for any DALI subwoofer, but the V-16 F driver sets a remarkable new benchmark for our obsession.

Below is an example of the current distortion measured in the V-16 F driver, compared to similar “high-end” drivers in the same product segment.

Current Distortion Measurements



3. Cabinet Engineering

An extraordinary bass driver is nothing without a cabinet to provide the appropriate air-load and that of the V-16 F is unambiguously equal to the task. Its 90 Litre volume is enclosed as space-efficiently as possible through the use of generally cubic proportions. The immensely rigid cabinet structure is constructed from 25 mm thick wood composite panels with multiple, 21 mm thick internal braces. The front panel is double thickness at 50 mm and the internal bracing is strategically arranged to provide internal support for the bass driver and the four 350 mm long Continuous Flare reflex ports.



3.1 DALI Continuous Flare Port Technology

DALI Continuous Flare Port technology, first implemented on the extraordinary DALI EPIKORE 11 ultra high-end loudspeaker, employs variable diameter geometry throughout the port length. The diameter varies from 65 mm (just before the exit flare) to 48 mm halfway through, and then increases again towards the internal port entrance. The constant variation in diameter both discourages the formation of organ-pipe like resonance modes and helps ensure that laminar airflow is retained up to very high sound pressure levels. The reflex ports are tuned to an extremely low 18 Hz and are custom designed to be fully compatible with DALI's low-loss and low-distortion sound design principles.

The V-16 F Continuous Flare Port technology reduces the demand for bass driver excursion at low frequencies, where otherwise diaphragm excursion would be at its greatest, and significantly reduces the effects of the harmonic and modulation distortion mechanisms that typically increase with diaphragm excursion. This is important because distortion generated at bass frequencies becomes evident at multiples of its fundamental. For example, the fifth harmonic of 50 Hz is 250 Hz, a frequency at which the ear is approaching maximum sensitivity and one that can negatively influence the midrange quality of the main speakers.

Furthermore, in minimising excursion, the V-16 F Continuous Flare ports ensures that the driver's motor system spends more time near the rest

position where its compliance, damping and motor force are more linear. This means that low frequency performance remains more accurate and consistent to higher volume levels.

The V-16 F Continuous Flare ports are located internally so that their entry points sit in one of the internal bracing panels. This equalises in-out air-flow and means that flow asymmetry, with its consequent internal pressure build-up is minimised. This helps to stabilise the drivers working point around the resting position and further reduce distortion.

Continuous Flare Bass reflex ports are ultimate low-loss (in fact no-loss) drivers at low levels and very linear and low-distortion drivers at high volume levels, and therefore the perfect choice for the V-16 F with DALI's low-loss and low-distortion sound design principles in mind.

Optional Port Plugs:

In some cases, the acoustic characteristics of a listening room or personal preferences are better suited to subwoofers that employ a closed enclosure, rather than the ported (reflex) design of the V-16 F.

If this appears to be the case for your application, an optional closed-box sound profile and port plugs supplied with the V-16 F can be used to create an optimised closed-box system.

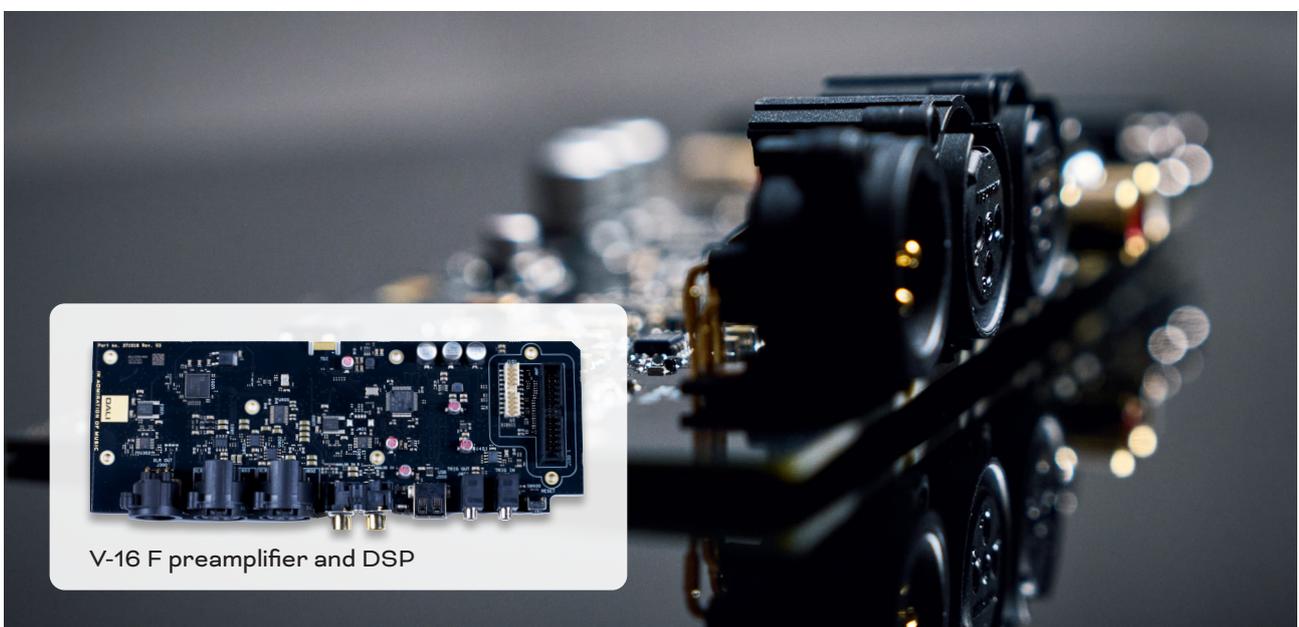
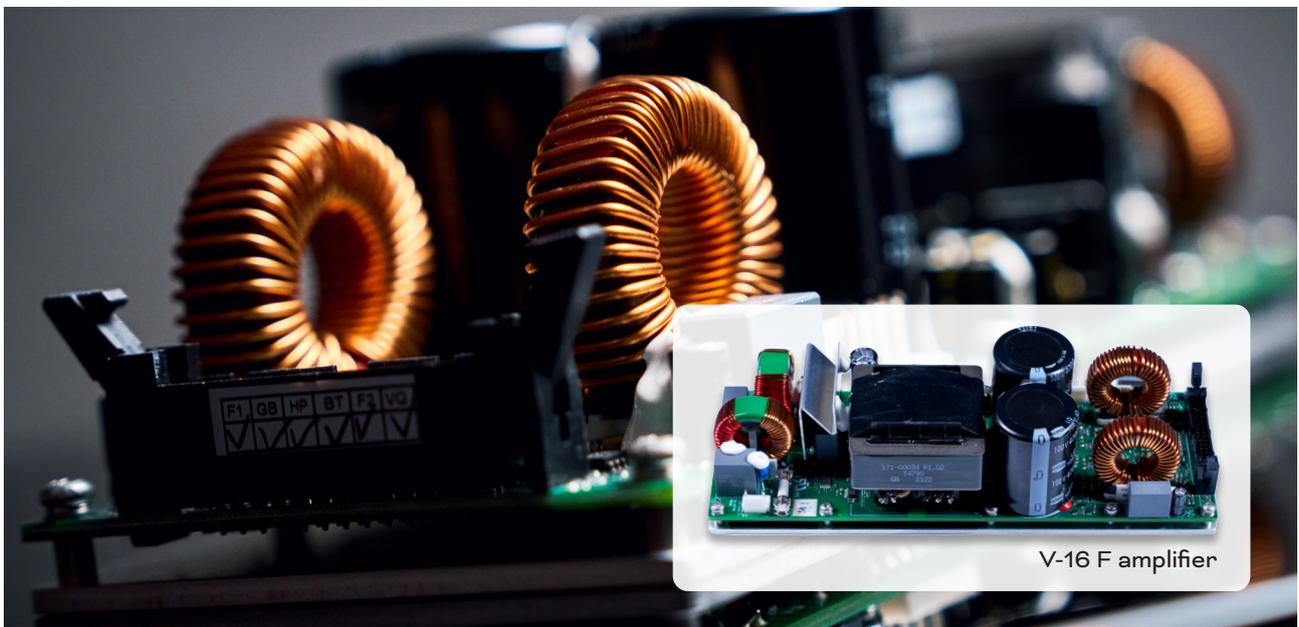
4. Amplification and Configuration

Extraordinary as it is, the driver, cabinet and acoustic system of the V-16 F is only one element of the subwoofer equation. The other, equally significant element, is the V-16 F configuration and amplification electronics.

4.1 Amplification

Following its input and configuration stages, the V-16 F amplification comprises a massively powerful Danish designed 1.500 Watt Class-D amplifier, able to deliver peak power up to 2500 Watts. The amplifier offers ultra-low distortion but also very importantly, a huge voltage swing that ensures vice-like grip of the V-16 F bass driver even at extreme diaphragm excursion levels. The result is powerful and accurate bass dynamics and impeccable timing at any volume level.

The V-16 F amplifier also boasts hugely powerful DSP functionality that enables extremely tight integration with the performance of the V-16 F electro-acoustic system of driver and enclosure. It all adds up to a fully optimised system that excels at both the reproduction of high volume levels and the smallest of low level details over an extended low frequency bandwidth.

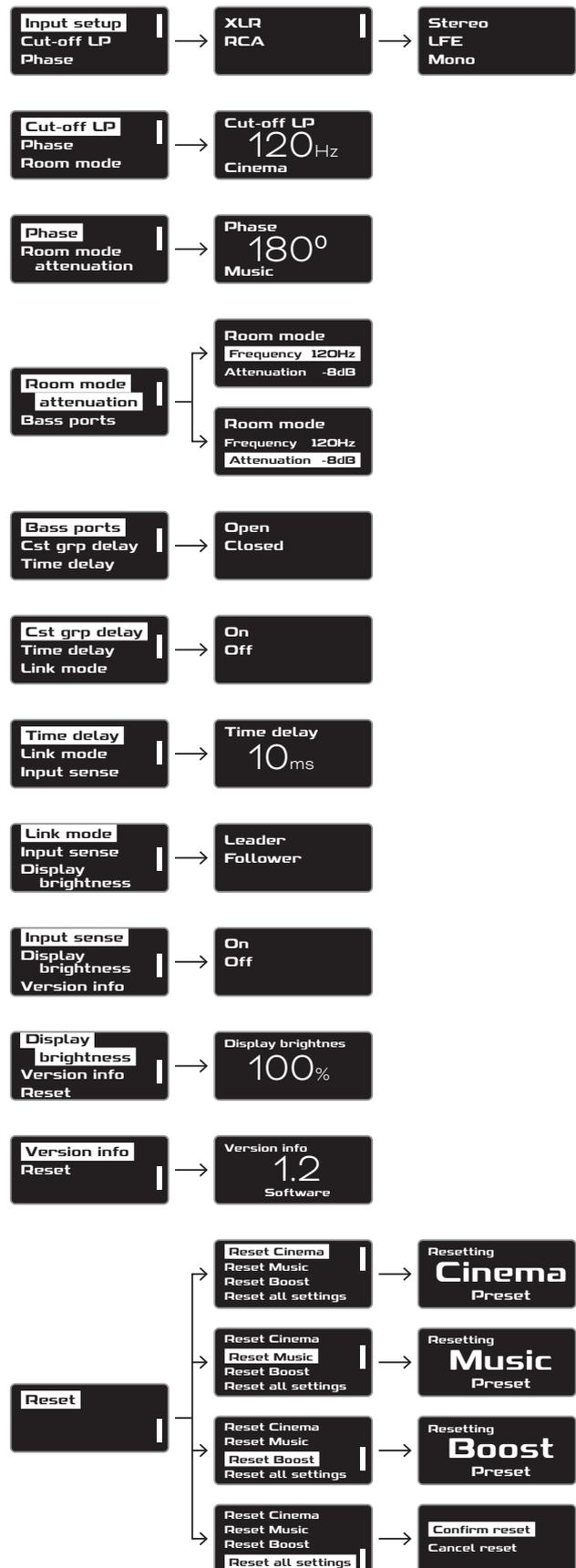


4.2 Configuration

The acoustics of a listening room exert the greatest influence on audio performance, and therefore on movie and music reproduction, at low frequencies. So a subwoofer that offers comprehensive and versatile input and configuration facilities stands the best chance of reaching its subjective potential. The V-16 F undoubtedly falls into the that category with configuration facilities that include the following functions:

- Input setup
- Cut-off LP
- Phase
- Room mode attenuation
- Bass ports
- Constant group delay (Cst grp delay)
- Time delay
- Link mode
- Input sense
- Display brightness
- Version info
- Reset

! All the V-16 F functions are explained in the User Manual.



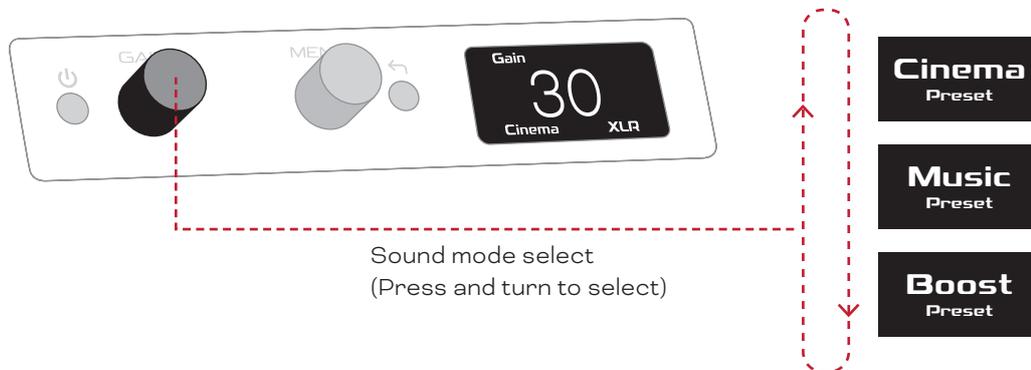
Sound Modes

Stereo multi-channel home theatre systems tend to demand different characteristics from a subwoofer. Music needs detail and dynamic punch, while movie low frequency effects require extremely deep low frequency power.

The V-16 F provides three preset sound modes that can be accessed by pressing the front panel Gain knob. Pressing the front panel Gain knob activates the Sound Mode menu, and turning the Gain knob toggles through the three Sound Modes.

V-16 F sound modes comprise EQ presets designed to offer optimal subwoofer performance for particular types of media content or personal preference in low frequency reproduction.

- **Cinema** sound mode is designed for LFE content in audio-visual and movie content. It emphasises low frequency sound effects and impact.
- **Music** sound mode is designed for optimum extension and a smooth roll-off in the extreme low bass in music. It focuses on dynamics and timing and has the most neutral frequency response of the three sound modes.
- **Boost** sound mode is designed for those occasions on music or movie content when a little extra “party mood” is ideal for the occasion. It emphasises impact and ... fun!



Input setup

The V-16 F provides unbalanced RCA and balanced XLR inputs, configurable for stereo, mono or LFE operation. The RCA and XLR inputs can be used independently which enables a V-16 F potentially to

be used with two audio systems simultaneously: For example, a home theatre system and a stereo music system. Input configuration is managed via the V-16 F Setup Menu.

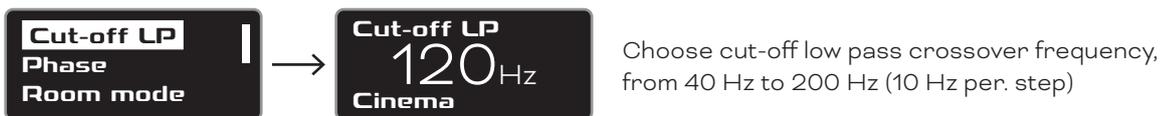


Cut-off LP

The Low-pass crossover function defines the frequency at which the V-16 F integrates with the main channel loudspeakers in either multi-channel home theatre or stereo applications.

The low-pass crossover frequency is variable between 40 Hz and 200 Hz and has a fixed 12 dB/

octave slope. In multi-channel home theatre applications, where the V-16 F is responsible for the LFE (Low Frequency Effects) channel, low pass filtering is likely to be implemented in the connected AV processor so it can be disabled in the subwoofer, by choosing the LFE option.



Phase

In addition to crossover frequency adjustment, optimal subwoofer integration with main channel loudspeakers requires control of acoustic phase so the V-16 F offers phase adjustment from 0° to 270° in 90° steps.

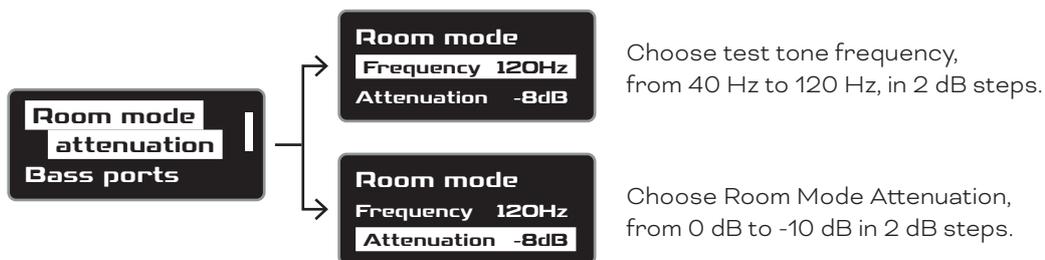
! At the 180° setting, an internal DSP polarity inversion switch eliminates group delay, Consequently, the phase is only delayed 90° at the 270° position (180°+90°).



Room Mode Attenuation

Listening rooms very often display low frequency standing wave resonant modes defined by their major dimensions. Sound with a wavelength that is equal to, or a multiple of, for example, the length of the room, will become noticeably emphasised in the listening position. Room mode attenuation can be used to compensate for the room's general resonant modes, or the resonant modes introduced by the specific placement of the subwoofer in the room.

Such room modes often fall into the frequency band of subwoofers, typically causing problems in the band of 60 - 80 Hz, and can negatively influence or smear the subwoofer's sub bass performance. The V-16 F offers a unique ability to suppress the primary and most damaging room mode through its Room Mode Attenuation feature.



Room Mode Attenuation comprises a high-Q filter ($Q > 4$) that can be adjusted in frequency and attenuation to target and suppress the primary mode frequency of the listening room. Configuring the Room Mode Attenuation feature is carried out using a manual test frequency sweep generated by the V-16 F. When the desired frequency has been found, you can attenuate this simply by using the controls on the front.

Sweeping manually through the subwoofer band, from 40 Hz to 120 Hz, it is quick and easy to identify the frequency at which the room mode peak occurs. The Room Mode Attenuation frequency and attenuation functions can then be set to suppress the mode, with targeted attenuation of up to -10 dB in 2 dB steps.

Room Mode Attenuation is selected through the V-16 F setup menu interface.

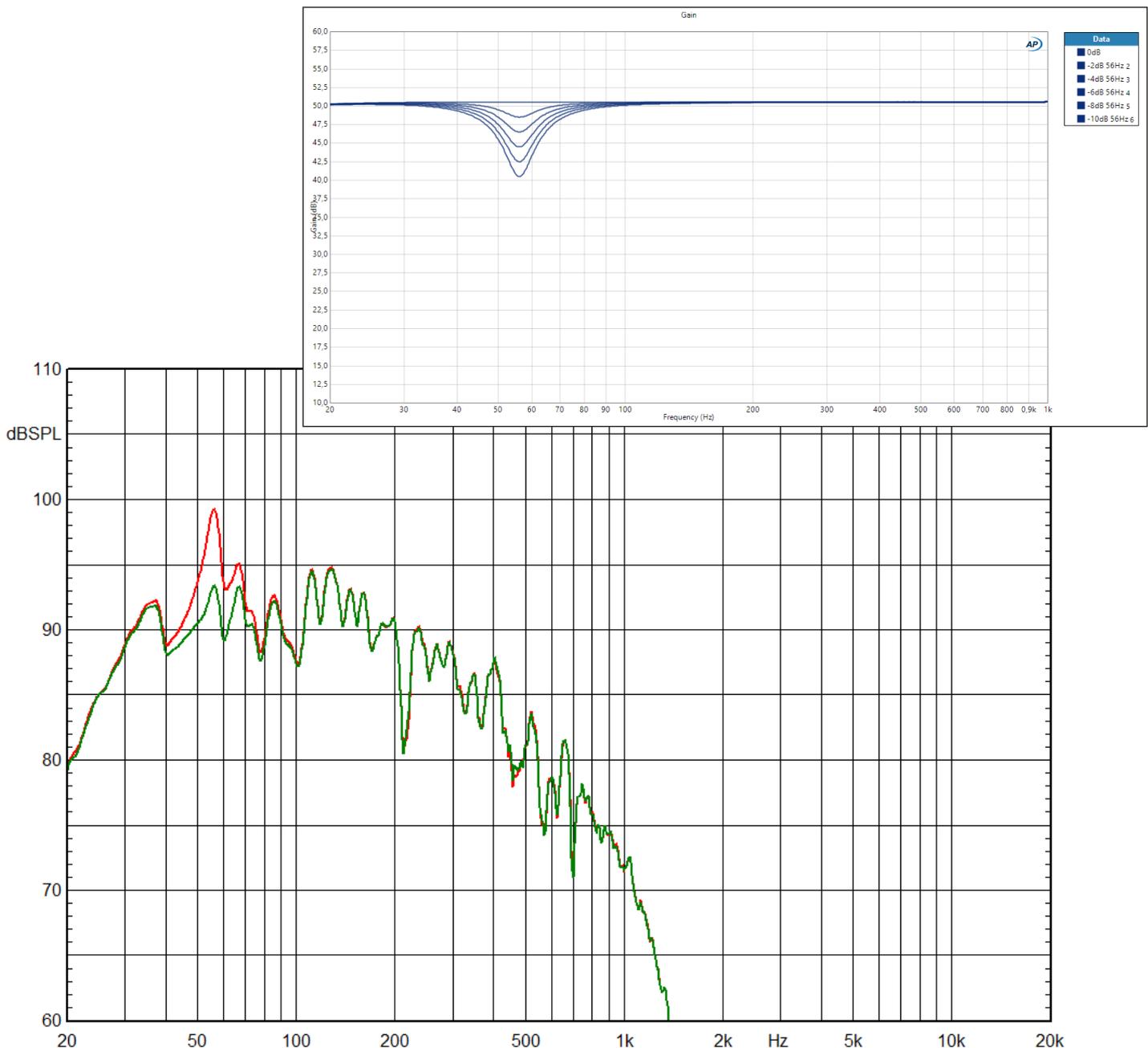
- ! Only one Room Mode Attenuation frequency can be applied at a time - activated by applying attenuation at the selected frequency. If another frequency is selected and attenuated this will reset the first frequency attenuation to 0 dB.
- ! If your V-16 F is moved to a another location, remember to reset and reconfigure Room Mode Attenuation.

Example - Room Mode Attenuation

An example on how Room Mode Attenuation can be used to deal with an unwanted low frequency peak.

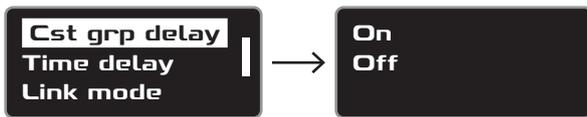
The example below shows an in-room measurement with a significant LF peak (red) at 56 Hz, caused by a standing wave. In-room frequency response below shows a significant LF peak (red) at 56 Hz, caused by a standing wave.

By sweeping the built-in test tone the 56 Hz room mode can be identified and afterwards attenuated from 0 dB to -10 dB, resulting in a more linear and smooth frequency response. (green)



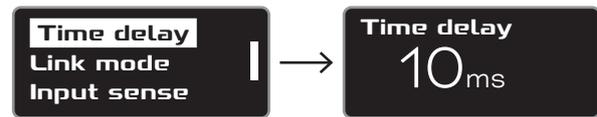
Constant Group Delay

Thanks to its prodigious DSP power, the V-16 F is able to offer time domain compensation to flatten its inherent frequency dependant group delay. The result is linear phase characteristics that some listeners perceive as a subjective increase in dynamic attack and punch. In some instances, it can sound as if the subwoofer both accelerates faster and brakes more urgently. Constant Group Delay is selected through the V-16 F setup menu interface.



Time Delay

The Time Delay menu enables a signal delay between 0 ms and 40 ms and to be implemented within the V-16 F digital signal processing that can provide sync adjustment with video. Select the required delay and confirm the selection by pressing the Menu knob. When used with e.g. A/V processors this setting is best left at 0 ms (default). Total system latency (electrical input to acoustical output in "bypass" mode without Constant Group Delay activated): Under 2 ms.

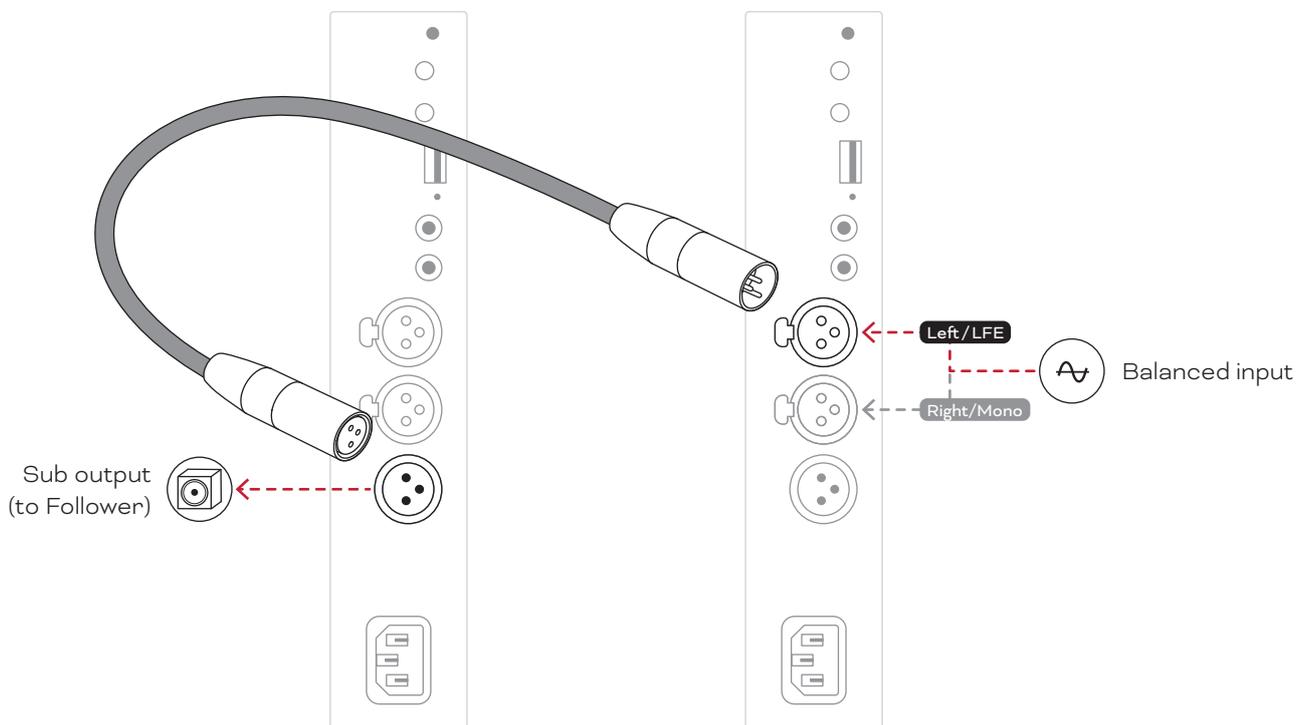
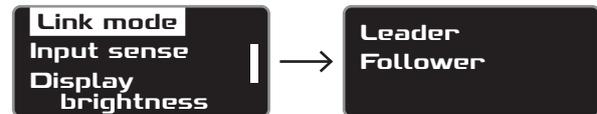


! The Constant Group Delay mode makes sense only when used with an A/V processor capable of compensating for the initial delay. Constant Group Delay introduces approximately 40 ms of initial delay, which can be compensated either by auto-calibrating a room-correction system - or by manually entering a delay of 40 ms on the main speaker system. Equivalent to a 13.7 meter offset between the sub and main speakers.

Always remember to disable Constant Group Delay when the V-16 F is set-up with another system unless you decide to integrate it as described above.

Link Mode

If two V-16 F subwoofers are installed in one system, the Link Mode menu enables one to be defined as the Leader and one to be defined as the Follower. The Follower will inherit all the menu settings of the Leader (except from Open/Closed mode settings). Select the required option and confirm the selection by pressing the Menu knob.



5. Summing up

Reproduction of sub bass is sometimes perceived as a fundamental differentiator between professional audio and hi-fi. And in some respects, it is.

Reproducing bass requires significant amplifier power and drivers, and both are not inexpensive to engineer. But even with generous power and driver diaphragm area it still requires enormous electro-acoustic skill and know-how to design, engineer and manufacture a truly great subwoofer like the V-16 F.

DALI and its R&D team have over 40 years of high performance loudspeaker design experience to draw on, a significant element of which comprises the knowledge of how to engineer extraordinary bass. And every last drop of that knowledge is invested in the V-16 F and as a result the V-16 F is, in our humble opinion, one of the very best and high-end audiophile subwoofers available.

