L150 CLASSIC

JBL

White Paper & Measurement Data

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L150 CLASSIC



Positioned as the flagship of the JBL Classic series, the JBL L150 Classic combines the unmistakable character and commanding presence of the brand's most iconic designs with advanced developments in loudspeaker design. The L150 Classic is a three-way, bass-reflex floor-stander featuring a 15-inch 2229Nd Differential Drive woofer, a 6.5-inch polymer-coated paper pulp mid-range, and a 28mm titanium dome tweeter.

Among the L150 Classic's most significant innovations is a specially designed constant-directivity waveguide and phase plug, developed through extensive finite element simulation to achieve exceptionally wide and consistent sound dispersion. This is complemented by a comprehensively optimized enclosure, sophisticated passive crossover network, and an innovative approach to user-adjustable frequency and in-room responses.

Departing from traditional mid-range and high-frequency level controls, the L150 Classic introduces independent low-frequency and high-frequency adjustments designed to accommodate different room acoustics, speaker placements, and listening preferences without allowing the degradation of sound power, listening window and estimated in-room responses. The low-frequency control employs a novel implementation of capacitor-assisted bass-reflex alignment, allowing meaningful adjustment of bass extension and tonal balance entirely within the passive crossover network.

Throughout the 1970s and 1980s, JBL was renowned for producing some of the world's finest large-scale domestic loudspeakers. Five decades later, the L150 Classic revisits this heritage, retaining the scale, dynamics, and effortless sound reproduction associated with its predecessors, while introducing a system engineered to modern standards of performance.

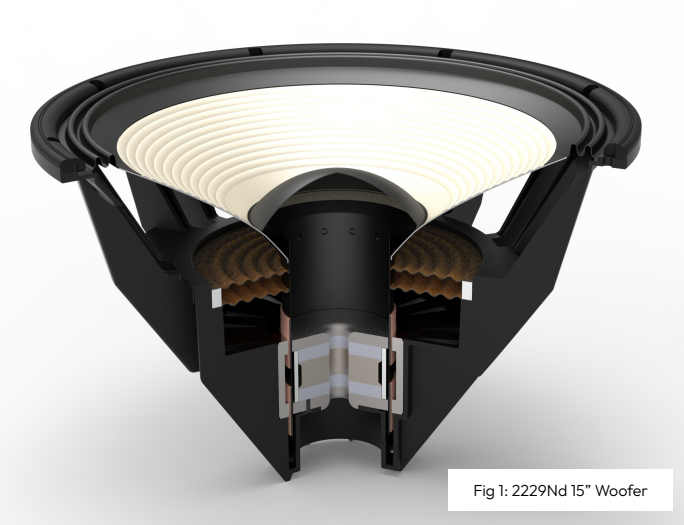


Fig 1: 2229Nd 15" Woofer

Woofer

The 15" woofer implemented in the L150 Classic, designated the 2229Nd, implement's JBL's Differential Drive motor unit technology. This driver, a design specific for the L150 Classic project, is a dual voice coil, dual magnet, dual spider, cast aluminum frame design, with incredible output and power handling capability.

The cone is a pure paper pulp which offers a favorable combination of low mass and excellent intrinsic damping, affording better controlled break-up behavior. First acoustic break-up mode is measured at around 1.1 kHz - well beyond the 300 Hz crossover point implemented in the L150 Classic.

Rather than relying on a single spider to provide the drivers primary restoring and centering force, the dual inverted spider design implements two nomex spiders arranged in opposite orientations. This symmetrizes suspension (Cms) compliance, improves stability and increases maximum excursion capability.

The differential drive motor system consists of two, 3 inch, edge wound, copper clad aluminium voice coils, suspended in two separate magnetic gaps. The two coils are wound in opposite directions, with the two magnetic gaps having opposite polarity due

to the oppositely arranged dual neodymium magnets. By splitting the voice coil across two separate windings, this creates a greater surface area for heat to dissipate than would be achieved for a single winding of equivalent width. As a result, DC resistance rises less during sustained high power operation so sensitivity and output remain much more consistent as the motor heats up. Additionally, by using two smaller magnetic gaps rather than one larger, flux can be more efficiently concentrated and stray flux reduced. The inclusion of an aluminium sleeve around the motor lowers helps to further reduce these stray currents, reducing harmonic distortion and extending high frequency output.

The chassis or frame is a cast aluminum design with vents implemented within the magnetic gap, allowing cool air to be pumped across the coils, increasing power handling. Heat sinks surround the entire chassis which again improves the heat dissipation of the motor.

Mid-Range

The mid-range drive unit is a 6.5" design featuring a polymer coated paper pulp cone. Like the woofer, the natural damping and low mass properties of paper afford well controlled breakup behavior with excellent sensitivity. By then applying a polymer coating, the stiffness of the design is increased, helping to push these well controlled breakup modes higher in frequency, well beyond the crossover point of 1.8 kHz. The motor is a large ferrite design with a vented pole to increase voice coil cooling and reduce power compression. A copper sleeve, or shorting ring, positioned around the top plate has several advantages. Firstly, the ring acts like a shorted secondary winding of a transformer, opposing the alternating magnetic field created by the voice coil. This dramatically reduces its inductance, opposing the impedance rise at higher frequencies meaning sensitivity is retained for much longer. This gives much more flexibility around the crossover point, allowing for the optimisation of directivity control rather than having to worry about sensitivity dropping too low. This opposition to the changing magnetic field also helps stabilize the motor structure, reducing stay flux and effectively suppressing harmonic and intermodulation caused by this flux modulation. Lastly, by positioning such an excellent thermal conductor close to the voice coil, helps wick heat away from the motor structure and by doing so effectively reduces power compression. Additionally, like the 15", an aluminium sleeve is implemented around the inside of the magnet which further reduces stray flux and augments high frequency output. This powerful motor combined with a low moving mass results in a highly sensitive drive unit. Prior to crossover, the raw sensitivity of the mid-range is around 93dB. Consequently, the driver has excellent output capability and dynamic headroom available at very low distortion levels.

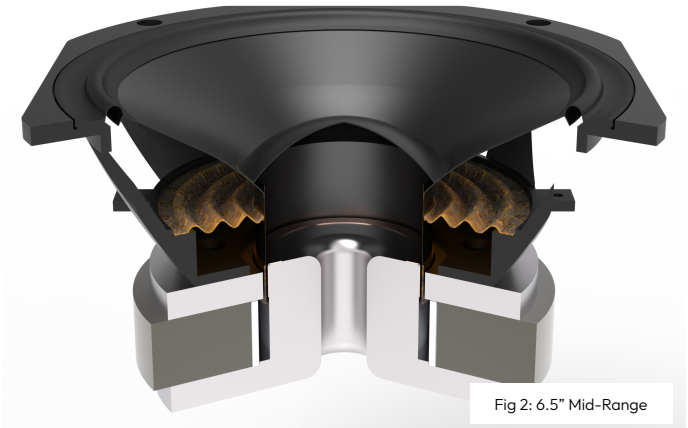


Fig 2: 6.5" Mid-Range

Tweeter

It was a key early engineering constraint that the tweeter designed for the L150 Classic project must achieve higher performance standards than that of the tweeter in the L100 MKII. The higher power handling and sensitivity requirements of the L150 Classic system meant that the tweeter not only needed a larger voice coil diameter in order to handle more current, but it needed to grow in diameter in order to gain efficiency. This would mean it could keep up more effectively with the woofer and mid-range, but also the larger Sd would mean it would couple more effectively to the air at low frequencies, lowering the frequency at which it could be crossed over and thus improving directivity behavior around the crossover point.

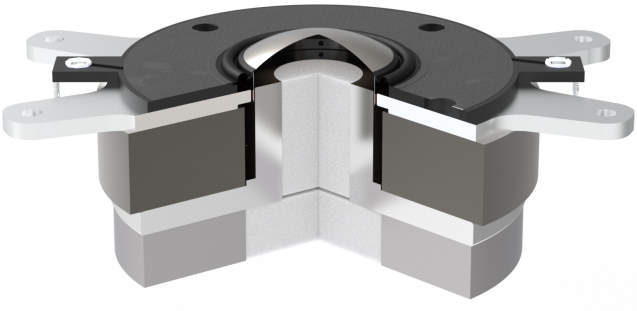


Fig 3: 28mm Titanium Dome Tweeter

As a result, the tweeter diameter was increased from 25mm on the L100 MKII, to 28mm on the L150 Classic. This gave the power handling and lower crossover point flexibility that we wanted, but doing so also meant that the frequency at which beaming or directivity narrowing would occur, began sooner. Although an increase of only 3 mm in diameter doesn't sound significant, all else being equal it would result in the point at which narrowing begins theoretically shifting down by around 1.5 kHz or so.

Therefore, in tandem with the waveguide and phase plug development (see following waveguide section), the shape and profile of the tweeter dome was optimized through FEA simulation in order to further maximize stiffness and push break-up modes as high as possible, while also helping to counteract the narrowing effects of the larger diameter and achieve something approaching a constant-directivity system.

Like the L100 MKII, titanium was selected as the dome material for its exceptional stiffness-to-weight ratio, allowing the larger diaphragm to remain both lightweight and highly rigid. This was particularly important given the increase in dome diameter, where maintaining structural stiffness becomes increasingly challenging. This high specific stiffness helped preserve pistonic behavior across the operating range and push the onset of structural break-up to higher frequencies.

Ferrofluid is positioned within the magnetic gap to improve heat dissipation and reduce power compression, while smoothing the frequency response by diminishing resonant behaviour. An expansive back cup design containing damping material runs from behind the dome through the pole all the way behind the motor structure to completely absorb all backwards radiated energy and prevent any energy reflecting back through the dome.

Constant Directivity Waveguide & Phase Plug

One of the most well-liked and applauded characteristics of the L100 throughout its history and iterations is its wide and expansive soundstage. This provides a consistent listening experience less sensitive to listener position and gives greater flexibility to speaker positioning and less reliance on toe-in: a valuable asset for larger speakers or when space is at a premium. Consequently, it was an early intention to at the very least maintain, and if possible, improve upon this for the L150 Classic project.

Therefore we set about designing a completely ground-up waveguide and phase plug that would counteract the increase in diameter and maintain excellent directivity control throughout the entirety of its bandwidth, while also giving greater output level capability.

The outcome is an innovative constant directivity waveguide & phase plug. The phase plug itself consists of an exponential central cone with a tapered outer ring design as you see pictured (fig 5). It is the result of extensive FEA modelling in COMSOL Multiphysics, running thousands of iterations of geometrical parameters over many days. Simply, the central exponential cone and tapered outer ring are

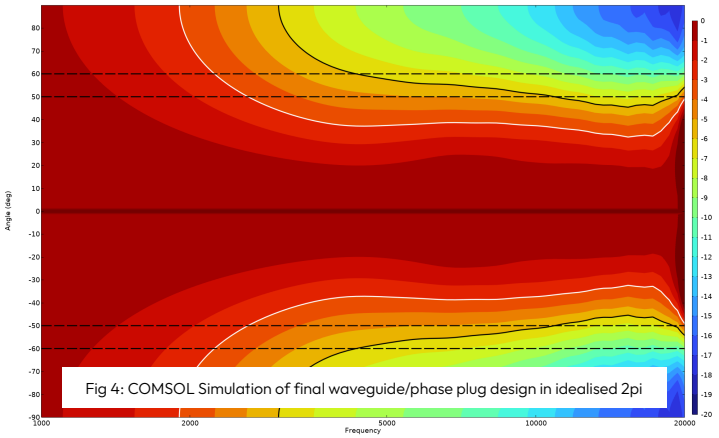
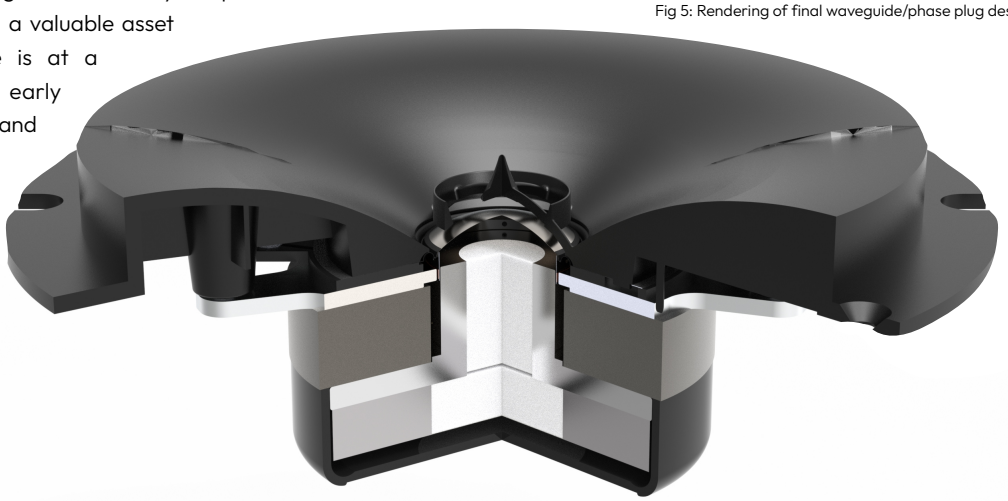
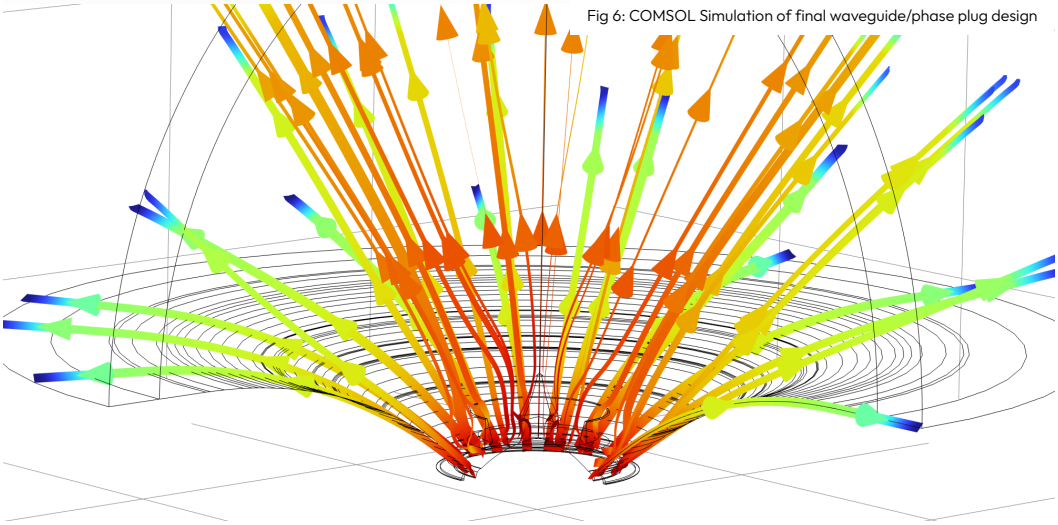


Fig 4: COMSOL Simulation of final waveguide/phase plug design in idealised 2pi

designed to equalize the acoustic path lengths of energy propagating from different sections of the dome, preventing destructive interactions on-axis, and distributing energy more omnidirectionally. This is the same concept applied in compression drivers albeit externally rather than internally (see Altec tangerine). Phase plugs are in of themselves nothing new, what is novel is the application of FEA optimization to every geometric aspect of this type of design and the resulting performance achieved by this approach.

Fig 5: Rendering of final waveguide/phase plug design




Fig 6: COMSOL Simulation of final waveguide/phase plug design

The result is the best performing waveguide and phase plug JBL has designed, with smooth and consistent >110 degree directivity control achieved from its crossover point all the way up to around 12 kHz. Beyond this frequency, directivity is narrowed in order to maintain >90 dB sensitivity out to 20 kHz. For detailed directivity performance, please see the measurement data section, measurements 5 and 6.

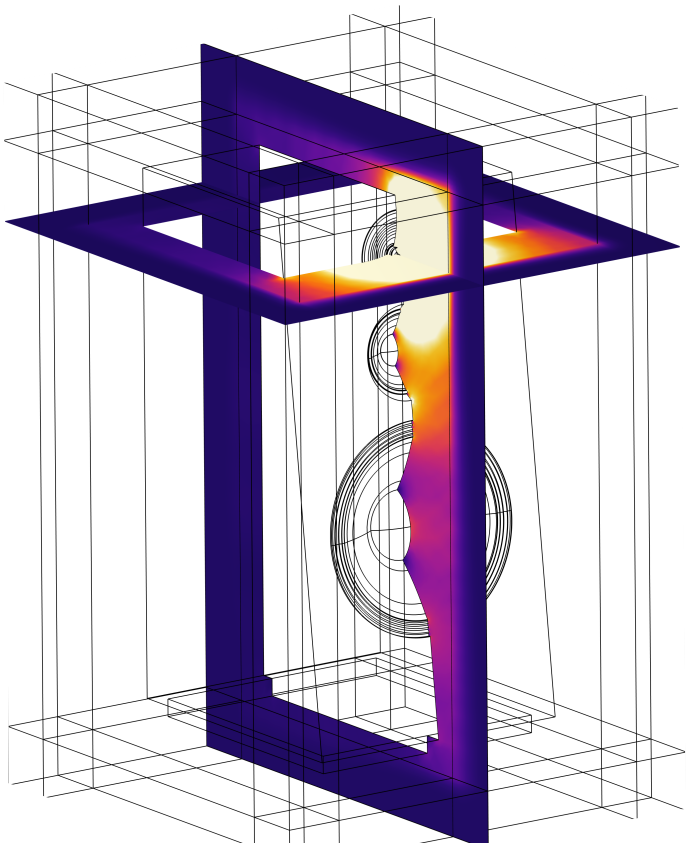


Fig 7:COMSOL Simulation: optimising tweeter waveguide & phase plug in full 3D cabinet

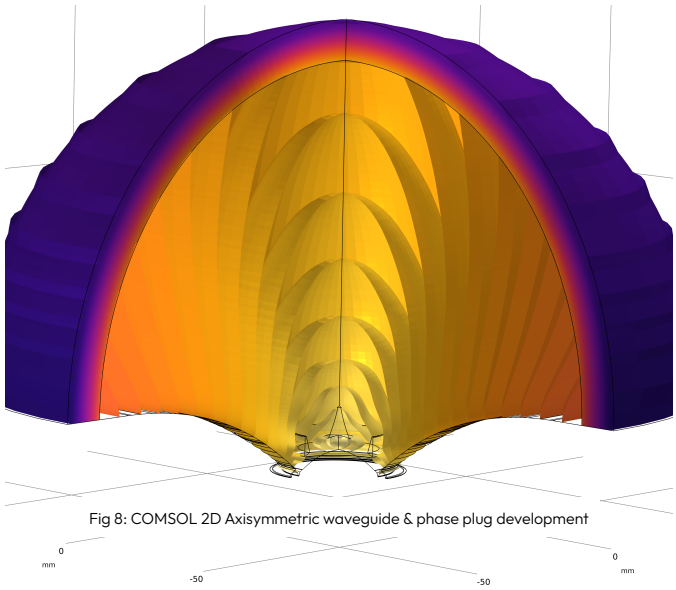


Fig 8: COMSOL 2D Axisymmetric waveguide & phase plug development

Switch Controls

The approach to level or 'tone' control in the L150 Classic is an original implementation that is designed to improve upon the methods used in JBL products of the past. Rather than simply providing a means of altering output level, it was engineered to offer the type of adjustments that are actually useful and worthwhile to listeners across a range of rooms, placements, and preferences, while preventing that adjustment from compromising acoustic performance, such as sound power, listening window and in-room responses. The following section describes the design philosophy and implementation behind these improvements.



Fig 9: Switch control panel

'Tone' or 'Level' controls are nothing new, and have been used on a wide range of JBL and competitor systems over the years. The vast majority of these, including those currently on the market, employ some kind of mid-frequency and high-frequency tone control. In JBL's case, the specific implementation of this MF/HF control has varied over time, particularly as it came to the labelling or naming conventions employed. During the 1960s and 70s the terms 'Presence' and 'Brilliance' were commonly used, referring to, although perhaps not immediately clear to the layperson the amount of mid-range and high-frequency energy sent out respectively. In later years, the more specific language of 'Mid-Frequency' and 'High-Frequency' (and sometimes 'Ultra-high Frequency') became commonplace, sometimes with a +/- dB scale, sometimes with a 0-10 'amount' scale, and sometimes with no numerical scale at all. Some manuals would include a small frequency response chart, showing the differences between switch positions, but these were not common, with the vast majority of systems not providing obvious data to the user as to what these level controls really did. Unless you had an anechoic chamber available to you, users had no real way of finding out what they did either.

It was here at Harman, established by pioneering research by Dr Floyd Toole and Dr Sean Olive, that the on-axis response, the listening window, the predicted in-room, and the sound power, as part of CTA-2034 nicknamed the "Spinorama", are some of the

strongest indicators of listener preference of loudspeakers. If these are smooth and consistent, free from resonances or imbalance, it is an effective signal that a loudspeaker will be perceived as neutral, balanced, and well-liked by the majority of listeners in real-world rooms.

As a result, the “Spinorama” and its derived “Listener Preference Score”, are key metrics that the Luxury Audio Team puts significant engineering effort towards. The mid-range region, from around 300 Hz to 3 kHz, part of which being where human hearing is most sensitive, is a critical area, so maintaining not only consistent frequency response, but also smooth listening windows, power and predicted in-room responses through this region, amongst others, are crucial for maintaining subjective performance. We will discuss next, how being able to vary the mid-range drive unit level with a passive network while maintaining the latter, is not realistically achievable.

In a competently designed passive loudspeaker, the crossover and driver responses are optimized to achieve these smooth and consistent Spinorama performances. If a conventional midrange level control is then implemented by means of an L-pad or similar attenuation network in the way that the vast majority of systems do, it inherently degrades these performances. Attenuating the driver modifies both the slope and smoothness of these Spinorama responses over their affected frequency range, deviating from the intended targets. At the same time, it alters the interaction between drivers at the crossover regions, with the potential to introduce phase and directivity irregularities that compromise the integration originally achieved by the crossover design.

There are two determinations from this: firstly, it is not realistic to design a passive system with a mid-range level control that can have smooth and consistent frequency, power, estimated in-room responses (among others) in all of its switch/level positions. Secondly, it is better to implement level controls that vary levels away from crossover points so that phase alignment and directivity narrowing are not also varying with dB level.

Consequently, with the introduction of the L150 Classic, we have chosen to move away from a mid/high frequency control in favor of a low/high frequency control. By varying the high frequency and low frequency, rather that the mid, we vary the tilt of these Spinorama curves, rather than introducing dips, nulls or errors in them. In this way, the frequency response, sound power, listening window, and predicted in-room responses through the critical mid-range remain smooth and consistent, regardless of the switch position set at either the LF or HF control.



Fig 10: L150 Classic Network

Capacitor Assisted Bass Reflex Alignment: Low-Frequency Control

More often than not, listeners do not have the luxury of positioning speakers where they sound ‘best’, and frequently they instead have to simply go where there’s space - particularly speakers of this size. Therefore, we wanted to achieve the type of low-frequency shaping and control that would be much more useful for listeners living with these in their homes for many years, adjustable and customizable to a range of listening scenarios and environments.

Simply varying the low frequency level drive unit with an L-pad or some resistive-type control would not provide the kind of shaping listeners would find particularly valuable, and it is not practical on a 15” woofer for a number of reasons. Most critically it would sink a huge amount of power into the network as heat, as well as introduce phase inconsistencies at the crossover point at detrimental cost to frequency, listening window, power and in-room responses.

We therefore implemented what is termed a capacitor assisted or passively assisted bass reflex alignment. This utilizes large value capacitors in series with the woofer, which counteracts the woofer’s inductive reactance, temporarily decreasing the impedance, drawing more current and generating more output at low frequencies. When combined with a slightly higher Qts drive unit than might typically be used in a box of this volume, which naturally exhibits a slight bump in its low frequency output, it will flatten and extend its response, providing more bass energy than would be otherwise achieved.

Therefore the woofer was carefully designed so that its parameters, and critically its damping characteristics, provided a moderate amount of additional energy around Fb. This would provide the +2dB switch position profile and would not implement any series capacitors. Then, by designing two separate capacitor assisted network alignments, the 0dB and -2dB profiles were generated. The respective frequency responses of all 3 LF switch positions are shown in the measurement section, measurement 3.

The 0 dB position is the ‘maximally flat’ or neutral position, engaging 1 of the 2 capacitor assisted alignment sections of the network and providing a completely flat response all the way to around 45 Hz, after which it rolls off at a rate of 18dB/octave, achieving a -6dB point of 32 Hz. This position provides the most neutral and balanced anechoic profile, and for speaker positioning scenarios that are away from boundaries and into the room, listeners may find it also provides the most neutral profile in-room.

The -2dB switch position engages the other of the two series capacitor filter sections in the network. The profile of this position has been specifically designed for use cases when the L150 Classic's are positioned in a corner or close to walls when bass gain from boundaries may give rise to too much bass energy, causing boominess and lack of tonal balance. This switch position provides a very gradual downward slope, beginning at around 150 Hz, and resulting in around 2dB less energy than the 0dB switch position by 45 Hz, with the -6dB location raised to 38 Hz.

For listeners that desire additional bass energy, or for those that get twitchy about the idea of capacitor assisted networks, the +2dB position is provided. This position completely bypasses all series capacitors and simply retains its conventional 2nd order low-pass. This switch position provides a ≈ 1.5 dB bump of additional energy at 65 Hz, and lowers the -10dB point from 28 Hz (0dB switch position) to 25 Hz. When listening at low levels, switching the L150 Classic's to this switch position may give rise to a more neutral sounding balance, as human hearing requires additional low and high energy as level decreases for subjective balance to be maintained (see equal loudness contours). Additionally if you have a problem room or modal issue that is sucking energy out of the system in the 50-80 Hz range, this position may help in gaining some of that energy back.

Opponents to this approach most commonly cite an increase in group delay as its primary drawback. There aren't conclusive findings into the precise thresholds of audibility of group delay at frequencies below 100 Hz, but most evidence appears to point towards 1-2 cycles being a likely minimum figure we can perceive. In figure 11 we can see that regardless of switch position, measured group delay stays well below this 1-cycle threshold at all frequencies, and doesn't generate much more delay than the +2dB switch position that bypasses the capacitor-assisted alignments.

Proponents of the design typically quote the 'tight sounding' bass passively-assisted alignments achieve, presumably as the series capacitor effectively blocks sub-sonic frequencies from reaching the bass driver, preventing over-excursion and 'flapping'. It is also possibly effective at reducing doppler distortion - as the cone is no longer trying to reproduce ultra-low frequencies, it modulates the frequency and phase of higher frequency content less. Findings from extensive listening sessions conducted on the L150 Classic's subjectively seem to reinforce these suppositions.

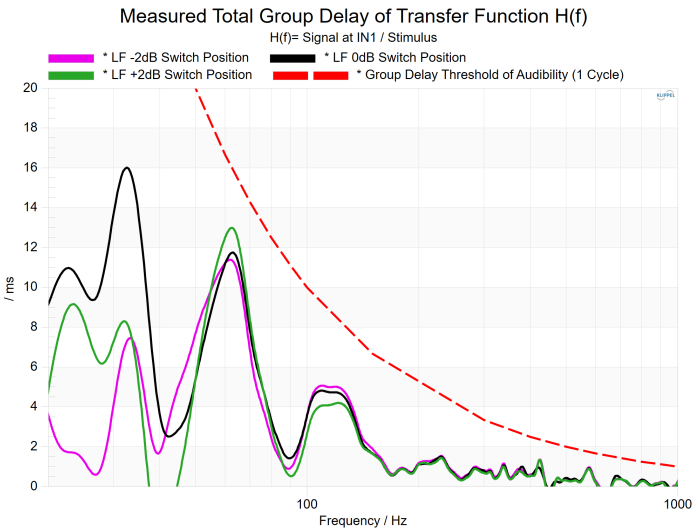


Fig 11: measured group delay at all LF switch positions

A passive low frequency control designed in this way increases the cost and complexity of the network. However it is a worthwhile endeavour in order to achieve a control system that is much more useful and convenient to listeners who want more determination over their speaker's response. You don't need to dig out port bungs if there's a particular evening you don't want to disturb others, or an album you feel has too much bass energy. You don't need to move them closer to a wall if you feel the bass is lacking. With a simple switch, you have easy and on-the-fly control, without the need for DSP-equipped amplification.

High-Frequency Control

As with the low frequency control, the design approach for the high was to provide user control that would be genuinely useful, while not allowing that control to degrade sound power, listening window and predicted in-room responses through the critical mid-range region.

In simple terms, it is a selectable L-pad network, with 5 distinct resistor values resulting in 5 distinct high frequency tilts. This tilt, only just beginning at around 3kHz, comes into full effect by around 6kHz. This is well outside of the crossover point of 1.8 kHz, so regardless of switch position, phase alignment and directivity behavior at the crossover point is not impacted.

This tilt provides not only 5 distinct frequency responses, but also 5 distinct sound power, listening window and in-room response tilts. This gives listeners the ability to tune tilts to their personal preferences.

Additionally, when the grille is in place, implementing the +1dB or +2dB switch will allow the regain of high frequency energy that is lost due to grille absorption and reflections.

As with the low frequency control, the 0 dB is the 'maximally flat' position, maintaining a flat frequency response and providing an approximate sound power tilt of -1 dB/octave , and an estimated in-room tilt of -0.75 dB/octave.

The frequency responses of each switch position can be found in the measurement section, measurement 3, and the estimated in-room tilts of each switch position can be found at measurement 4.

Cabinet Structure

Like any proficient loudspeaker design, the cabinet construction of the L150 Classic is engineered in order to contribute as little extraneous energy to the system as possible. 1 inch (25mm) thick MDF is used throughout in order to mass-load the structure and create an incredibly stiff environment to mount all 3 drivers. The mid-range is isolated in its own sub-enclosure so that no energy generated from either woofer or mid-range may interact, and so the low frequency response of the mid-range is appropriately controlled. Bracing amount and locations were optimized through COMSOL FEA simulation in order to create a maximally stiff and inert structure. A problem region on the back panel, identified through simulation and then validated through accelerometer vibrometry measurement, was rectified through COMSOL structural studies to design the optimal placement and size/shape of bracing required. Figure 12 shows the original cabinet design (left) with its problem region causing a 300 Hz resonance on the back panel. Shown right is the final design, with additional optimized bracing significantly reducing the amplitude of panel resonance of that back panel. Figure 13 shows the accompanying accelerometer measurements conducted on the back panel, measured in the same location as marked in figure 12. The accelerometer measurement of the original cabinet design is shown in black, with the finalised design shown in red. The final design was successful in reducing the amplitude of the 300 Hz resonance by around 15 dB, as well as shifting it up to around 400 Hz, demonstrating the increased stiffness of the structure. As a result of these simulations, studies and extensive measurement taking, an incredibly stiff and inert structure was created. This is demonstrated clearly in the cumulative spectral decay plot in figure 14. It can be shown that it is smooth and free from resonance behaviour that extends in time beyond the rest of the response, indicating that the blurring of transient information does not occur.

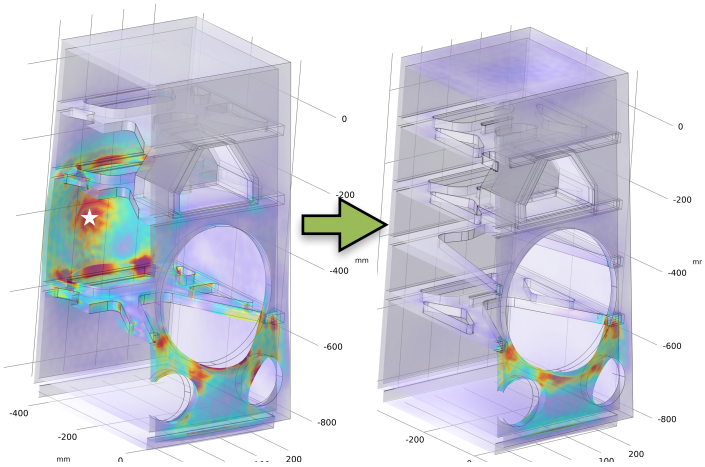


Fig 12: COMSOL simulation identifying problem 300 Hz resonance on rear panel of original design (left). Optimization of bracing design and position to rectify issue (final design - right).

Main area of concern and accelerometer measurement position marked with white star.

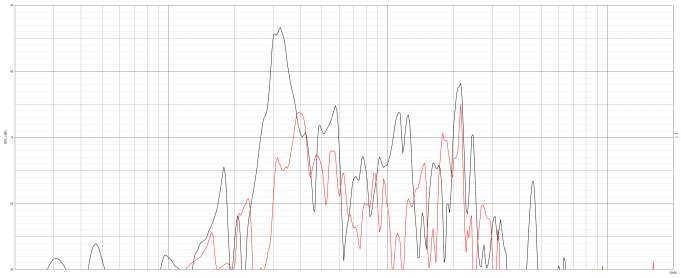


Fig 13: Accelerometer data showing original cabinet design 300 Hz back panel vibration (black), vs optimised final cabinet & bracing design in same measurement location (red)

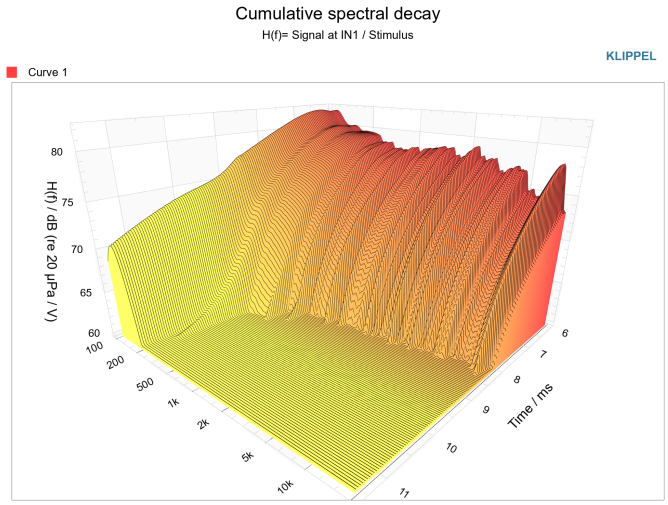


Fig 14: Cumulative spectral decay



Fig 15: Cabinet vibration accelerometer measurement

Internal Acoustics

COMSOL was used extensively to study the internal acoustic behaviour of the cabinet, optimising the shape, size and location of bracing in order to break up internal standing waves as much as possible. Standing waves can contribute unwanted energy by passing back through the cone, escaping through ports, or exciting cabinet walls. They often cause large peaks and dips in the frequency response, and notches in the impedance response are sometimes another give-away. A balance was struck regarding position and amount of open area of each brace had, so that air flow was not impeded, but that standing waves were lessened in their severity.

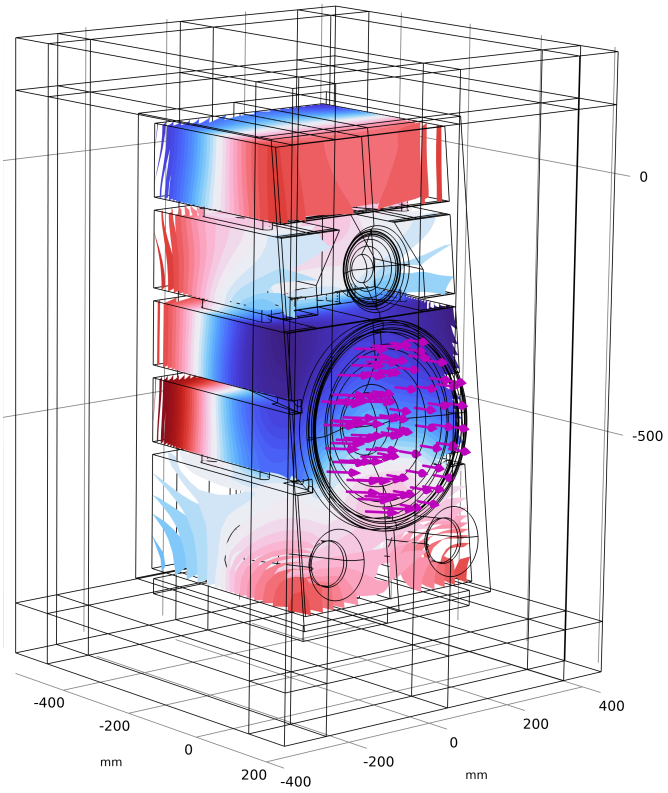


Fig 16: COMSOL Internal pressure / standing wave investigations

Port Design

The bass reflex port on the L150 Classic has been designed in order to contribute as little audible coloration or distortion as possible while effectively augmenting bass output. The port diameter has been maximized as much as baffle real-estate allows to reduce air velocity, with large 32mm radii flares implemented at both ends to promote smooth airflow and minimize flow separation, keeping turbulent airflow-induced noise to a minimum. The geometric profile of the port was studied in COMSOL Multiphysics (figure 19) in order to create a surface that would generate the minimal amount of

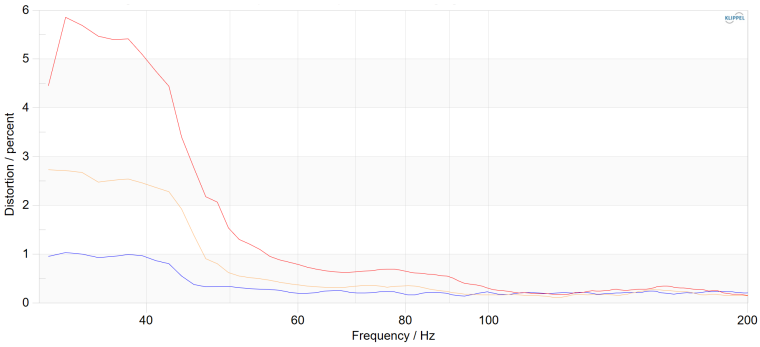


Figure 17: low frequency distortion measurement (0 dB switch position) at output levels: 86dB [BLUE], 96dB [ORANGE], 102dB [RED]

turbulence and air speed for a given input voltage. The attached plots show the simulated measured air flow speed across the port outlet at 86dB, 96dB and 102dB. It demonstrates that even at 102dB, port velocity does not exceed 11 m/s, well below the speed for audible chuffing (figure 18). Distortion measurements conducted at low frequencies support these findings (figure 17). THD for 86dB, 96dB and 102dB does not exceed 1.1%, 2.8% and 6% respectively all the way down to 30 Hz. This demonstrates that regardless of listening level, a consistent and stable amplitude response free from distortion will be experienced.

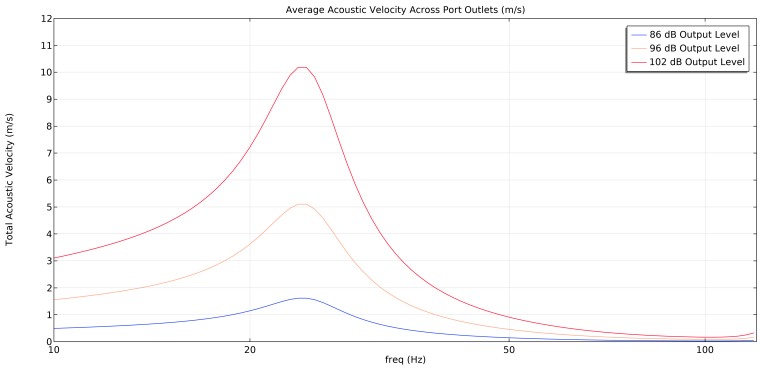


Fig 18: COMSOL simulated port velocities across outlet at 86dB, 96dB, 102dB

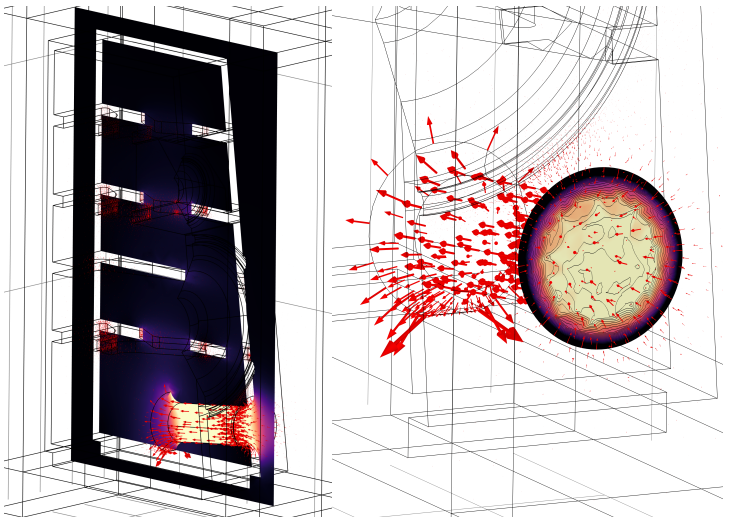


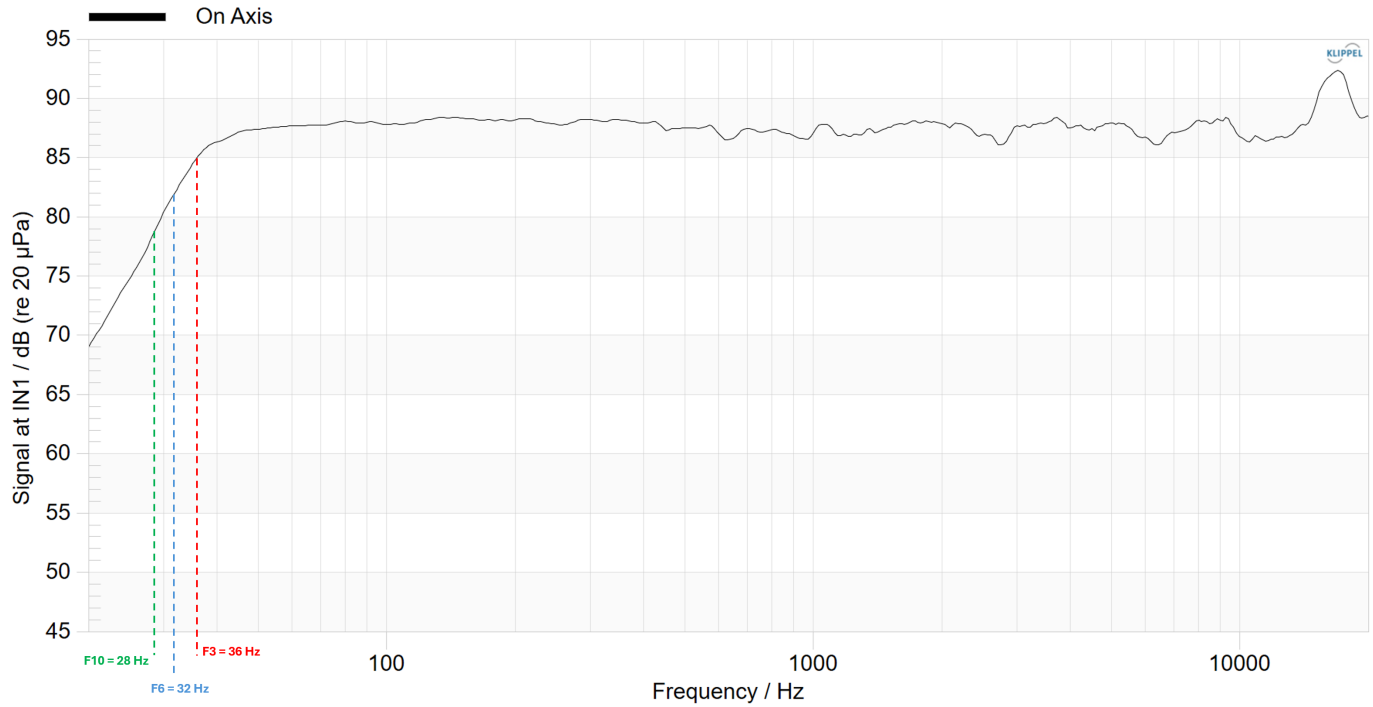
Fig 19: COMSOL port simulations

Measurement Data

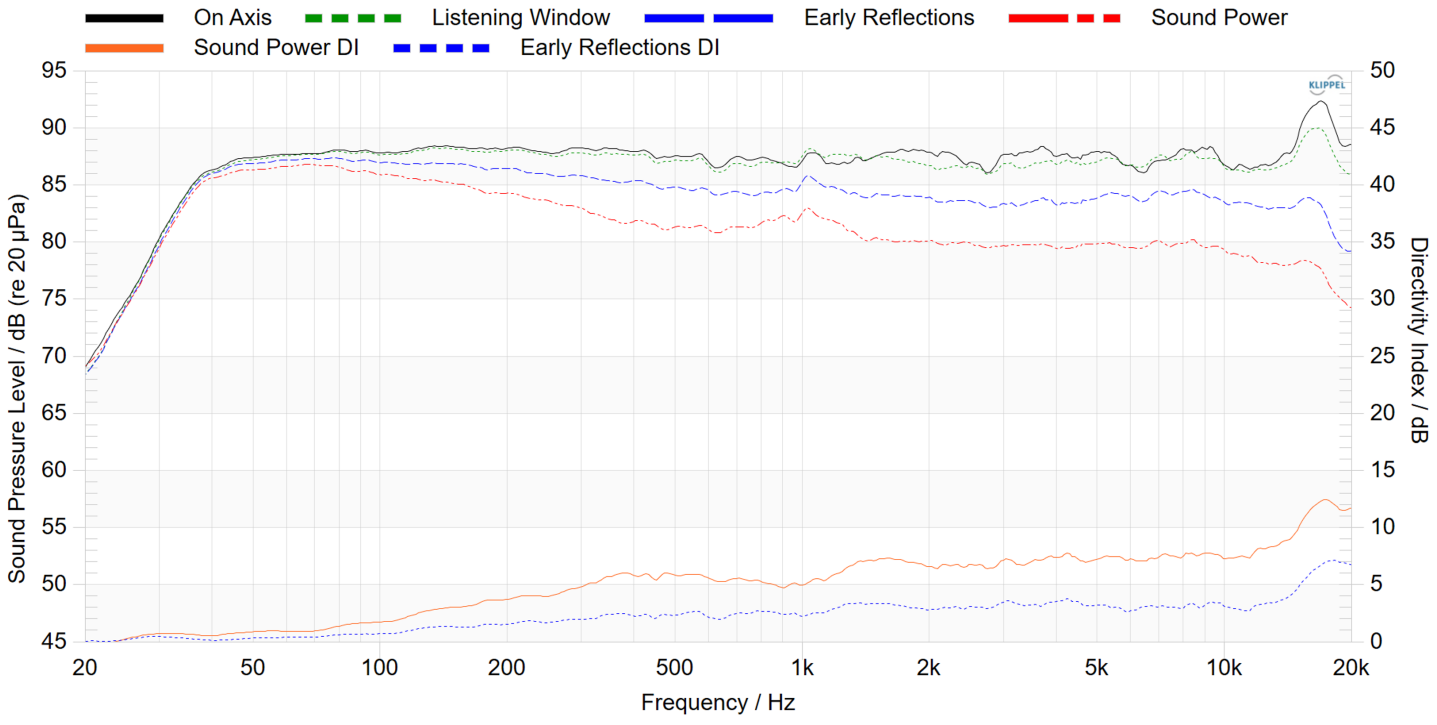
Data was collected in our 4pi (full-space) anechoic chamber. Measurements and the development of the network were conducted at 2m to better match typical listening distances. All levels are corrected to 1m. LF and HF switch in 0dB position unless otherwise stated.

1. Frequency Response

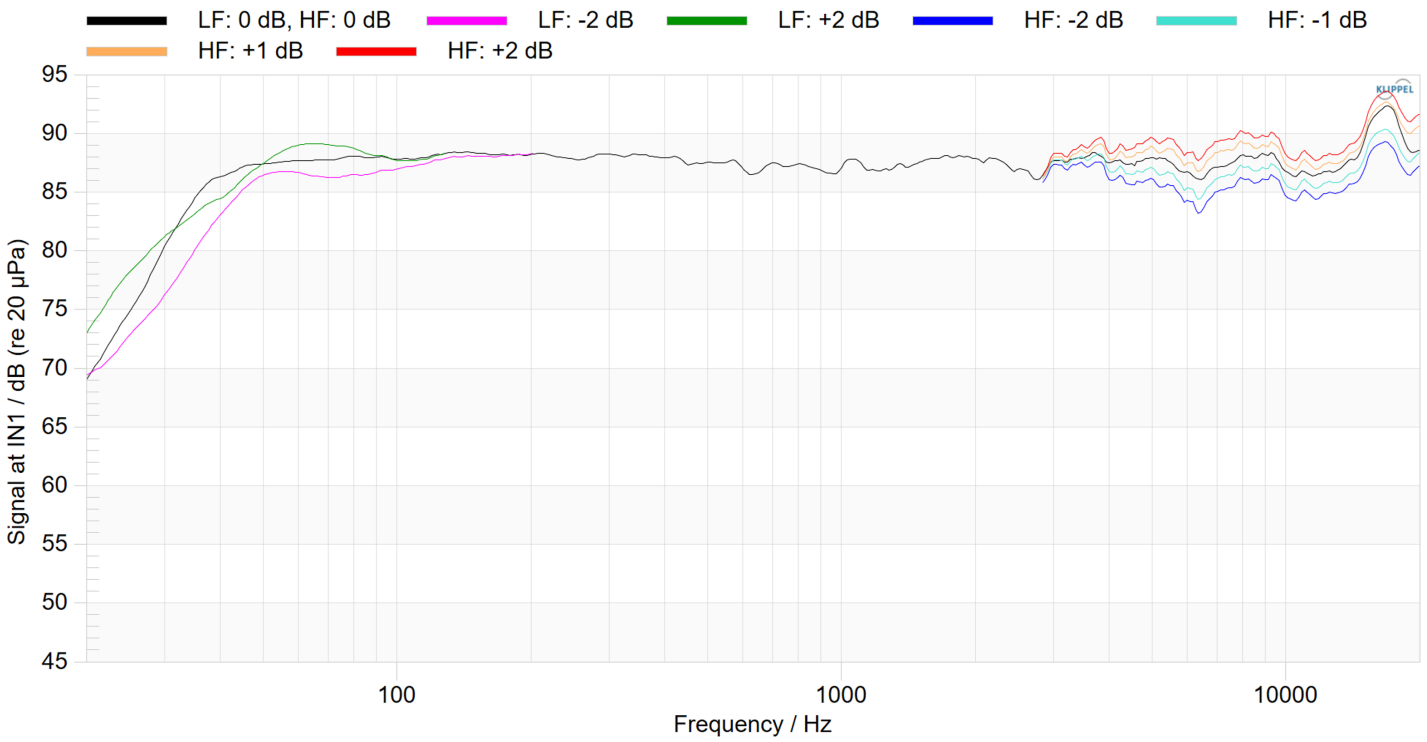
Response linearity is -1.39 dB / +1.07 dB (50 Hz - 14 kHz) from Average Sensitivity Level (300 Hz - 3 kHz), 1/48 oct smoothed.



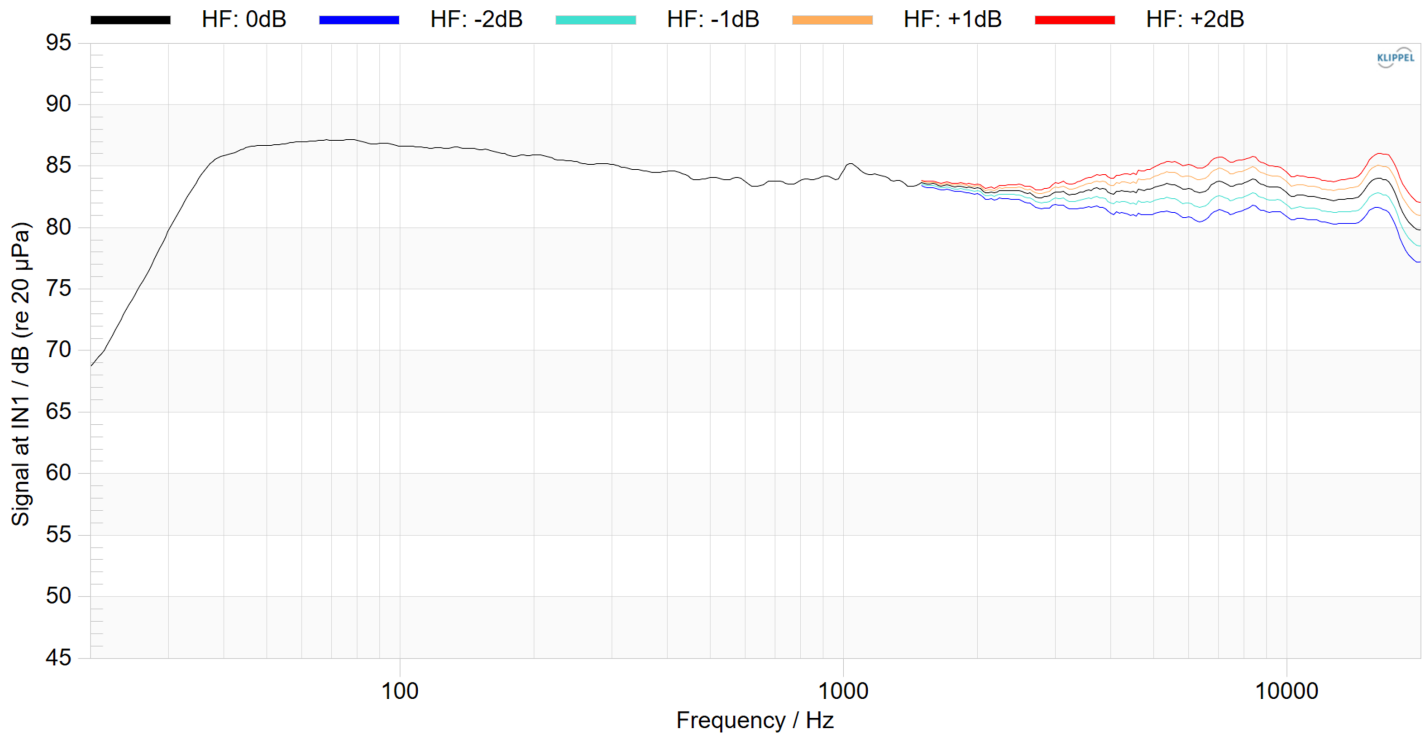
2. CEA2034 'Spinorama'



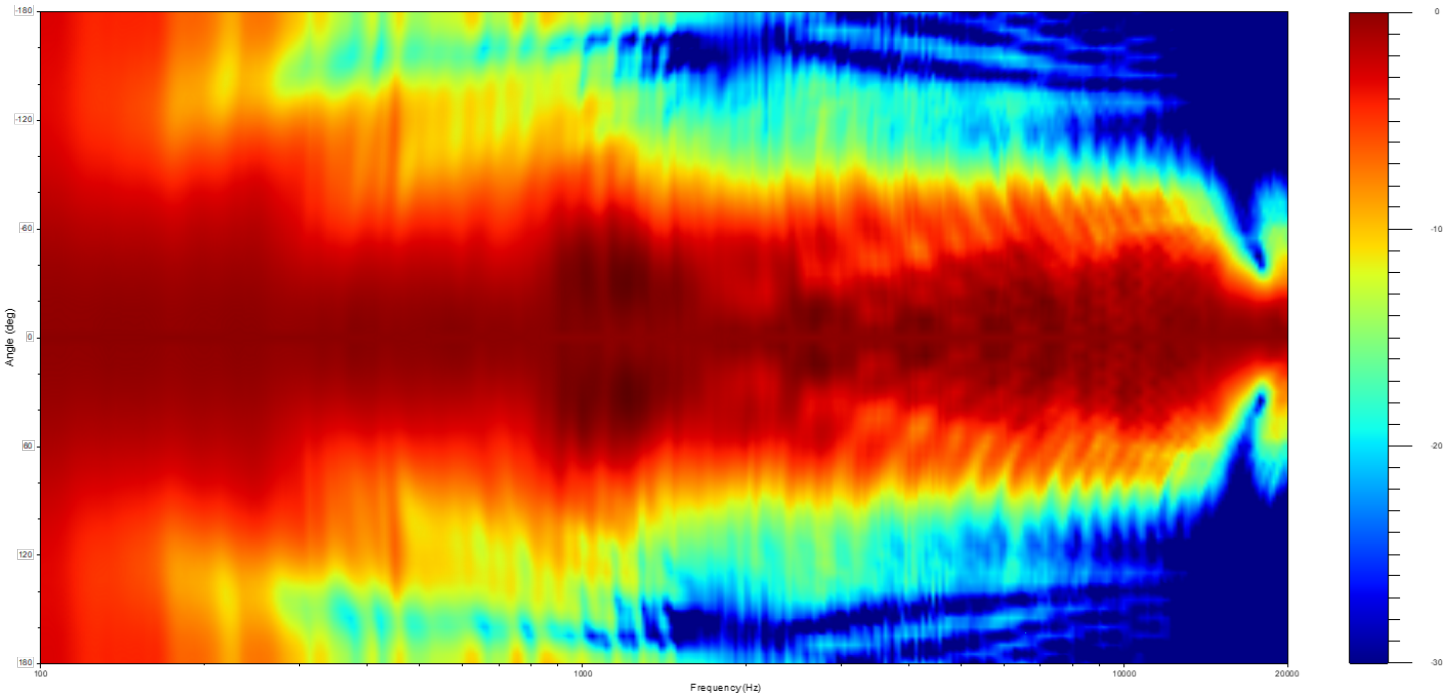
3. Switch Positions: Frequency Responses



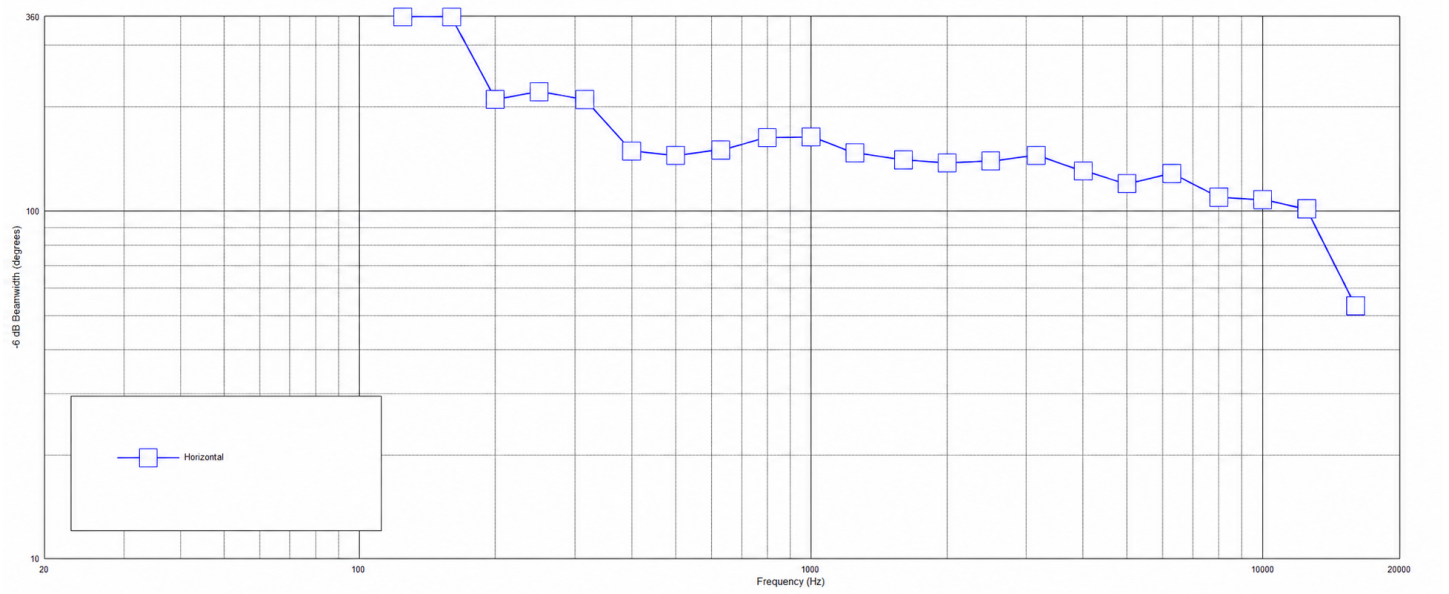
4. Switch Positions: Estimated In-Room Responses



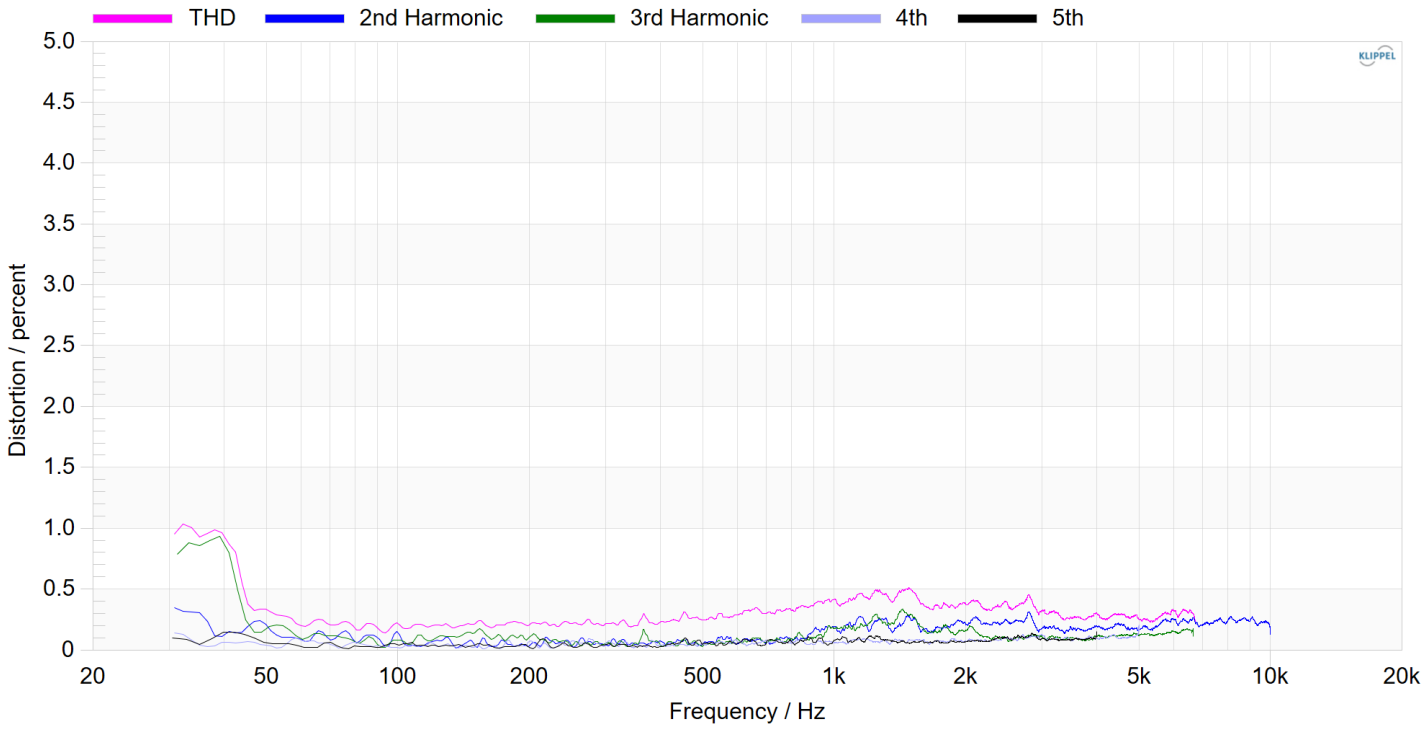
5. Horizontal Contour Plot (Normalized)



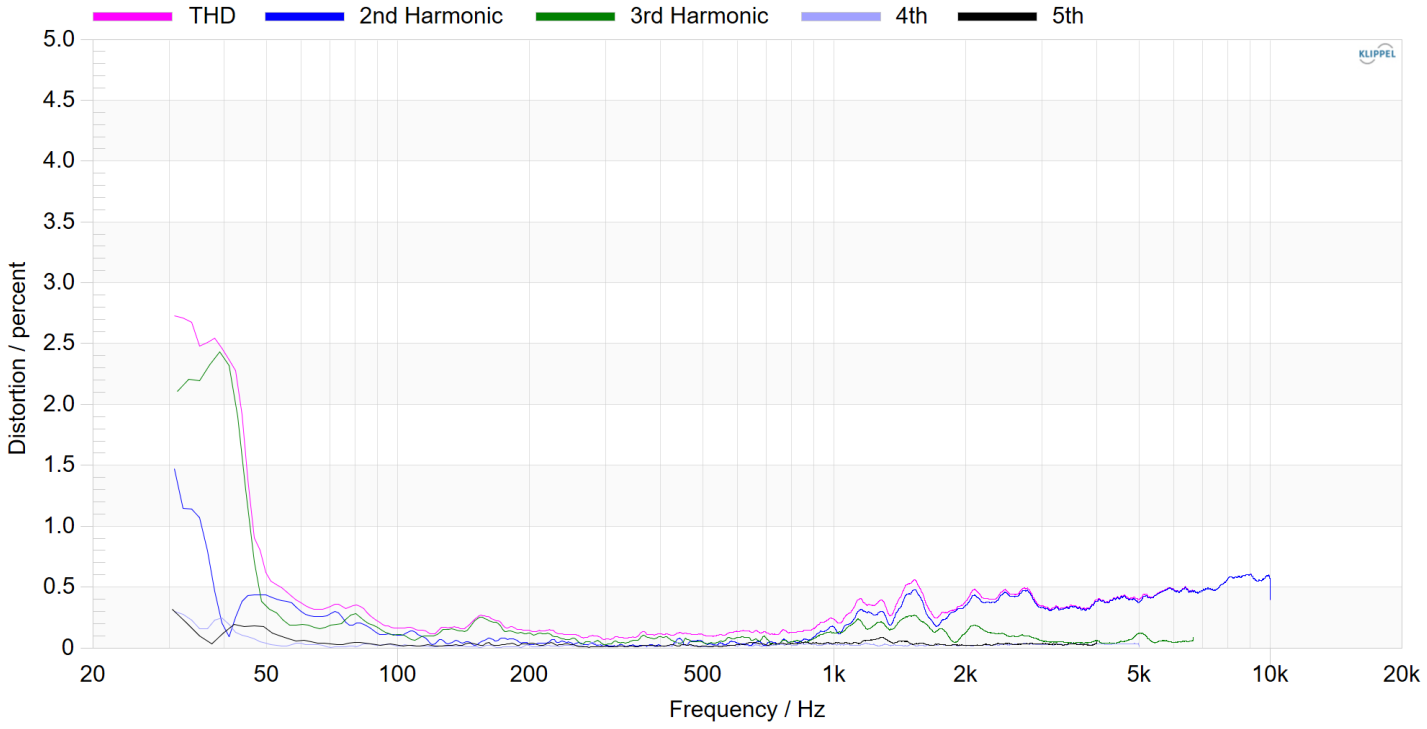
6. Horizontal Beamwidth (-6dB)



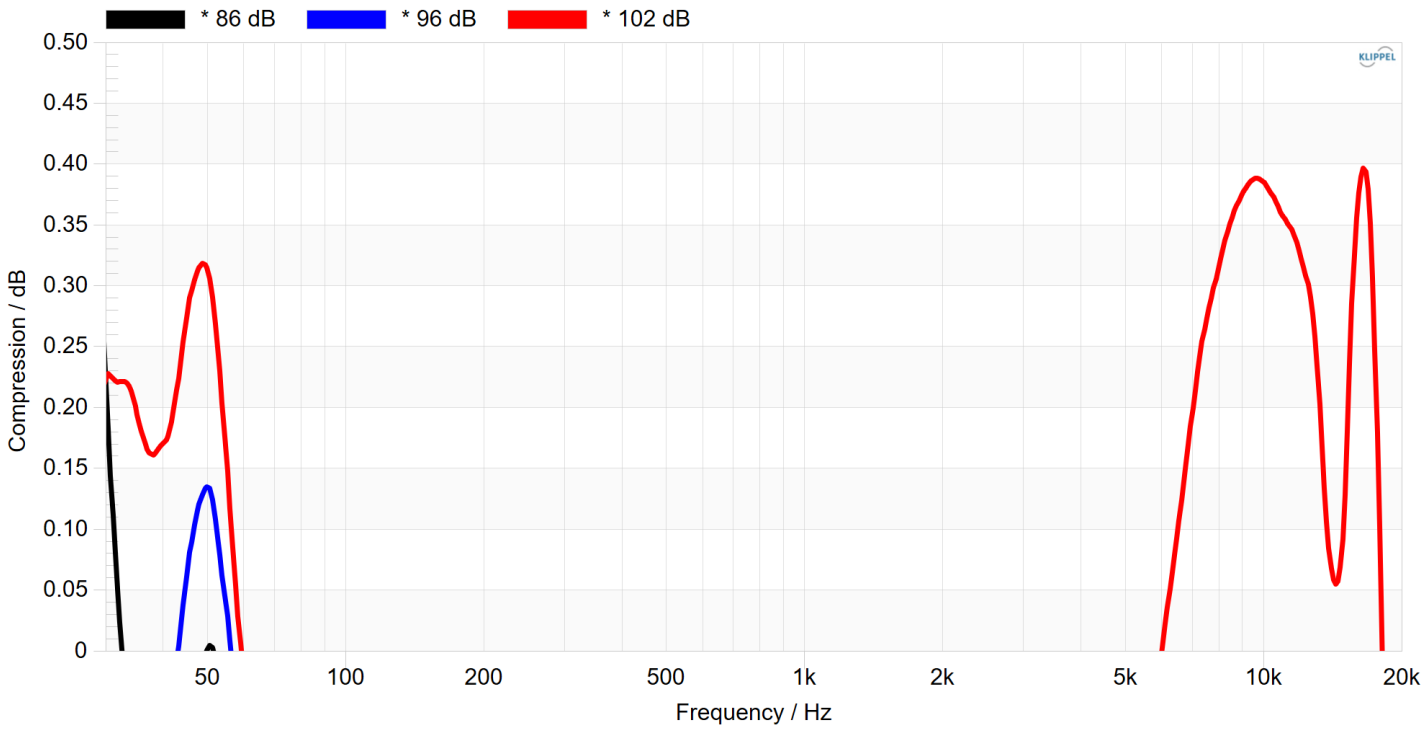
7. Distortion Components (Percentage) at 86 dB Output Level



8. Distortion Components (Percentage) at 96 dB Output Level

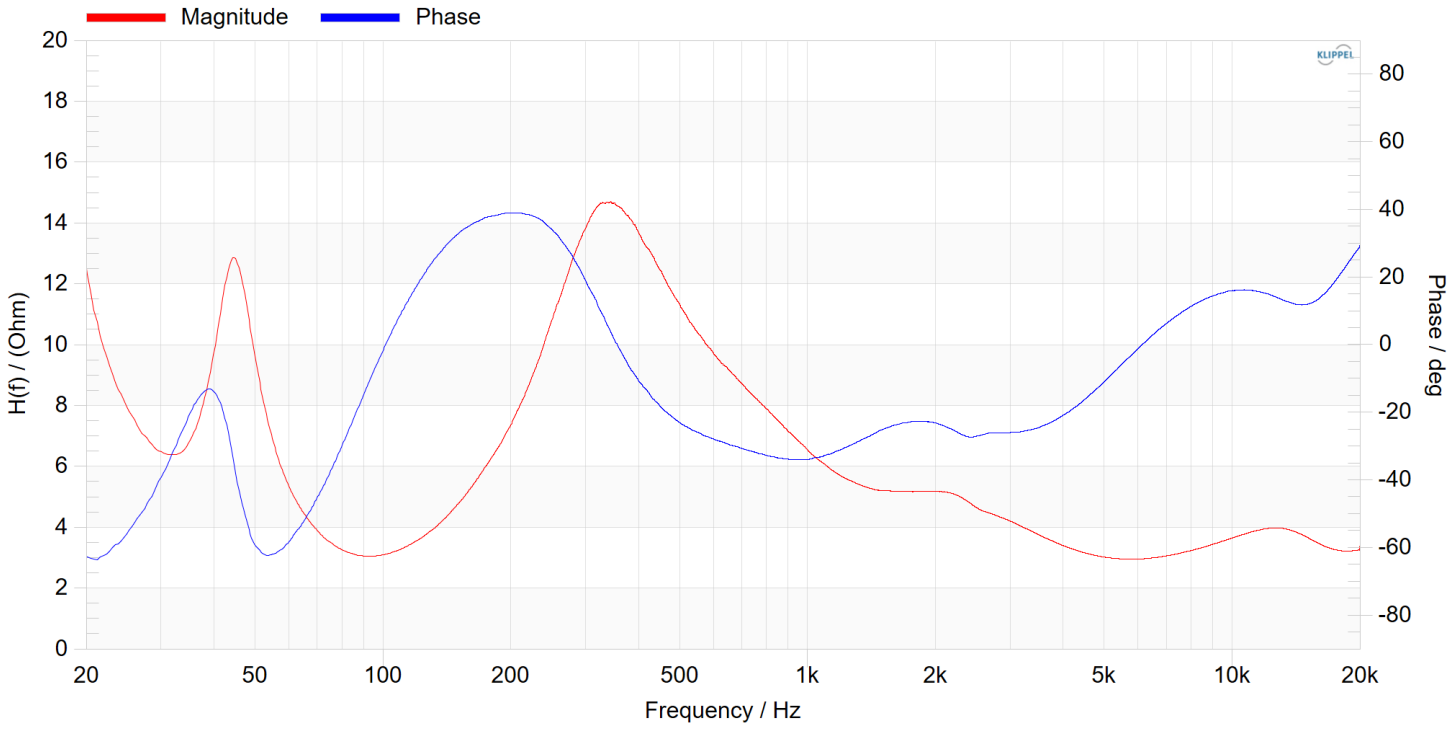


9. Compression at 86 dB, 96 dB, 102 dB Relative to 76 dB Response



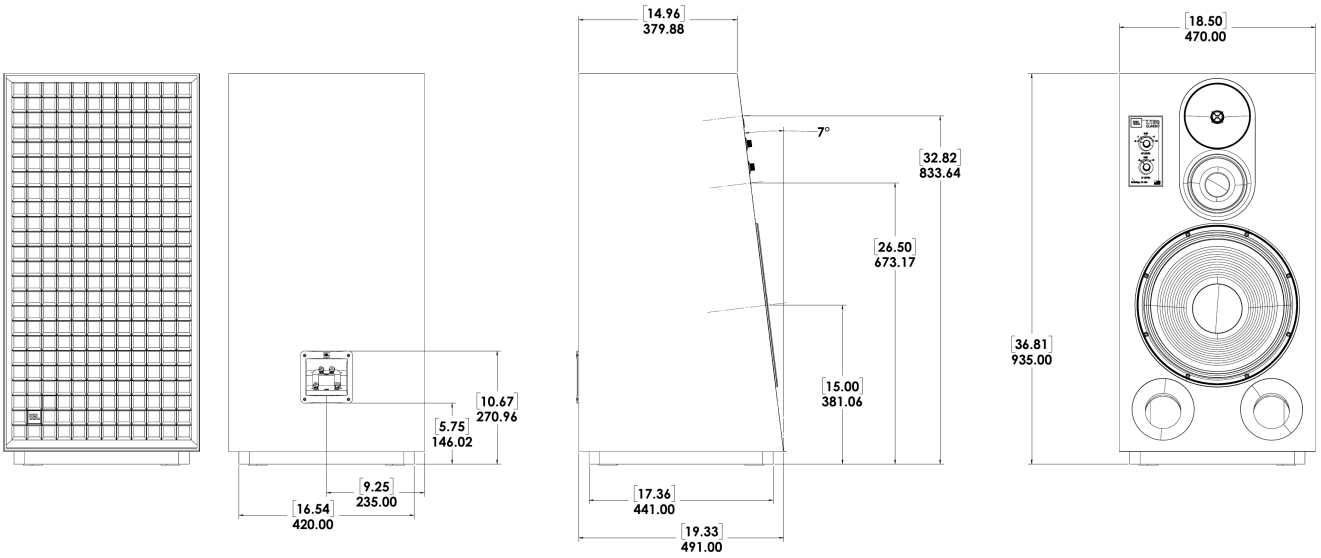
10. System Impedance

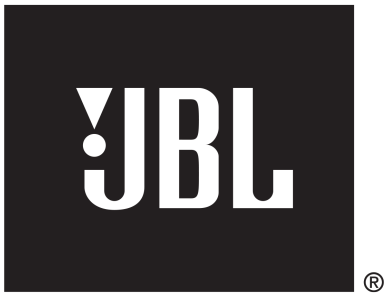
2.95 Ohm minimum at 5.8 kHz



Technical Specifications

Speaker Type		Three-way bass reflex floorstanding		
Drive Units	**LF**	15 inch (380mm) 2229Nd Dual Coil Differential Drive Woofer		
	MF	6.5 inch (165mm) Polymer-coated pure pulp cone mid-range		
	HF	1.1 inch (28 mm) Titanium dome tweeter mated to constant directivity waveguide and phase plug		
Sensitivity (2.83V/1m)		88 dB		
Free Field (Anechoic) Frequency Response (-6dB) **Switch settings:** **LF: 0dB** **HF: 0dB**		32 Hz - 22 kHz		
Free Field (Anechoic) Low Frequency Cutoffs		**LF Switch -2 dB**	**LF Switch 0 dB**	**LF Switch +2 dB**
-6 dB		38 Hz	32 Hz	32 Hz
-10 dB		32 Hz	28 Hz	25 Hz
Horizontal Coverage Angle (-6dB Beamwidth)		>110 Degrees (20Hz - 10kHz)		
Impedance		4 Ω Nominal (min 2.95 Ω)		
Total Harmonic Distortion (THD)		At 86dB, 30 Hz - 50 Hz : <1.1%, 50 Hz - 20 kHz : <0.5% At 96dB, 30 Hz - 50 Hz : <2.8%, 50 Hz - 20 kHz : <0.6%		
Crossover Frequencies		300 Hz, 1.8 kHz		
Maximum recommended Amplifier Power		250 Watts RMS		
Weight		≈ 58.5 kg / 129 lbs		





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