K2.S9900 White Paper
1/12/08
G.T./J.M.

## INTRODUCTION

JBL has had huge success with high performance loudspeakers over its 62-year history. The two most recent of these popular systems are the K2.S9800 (and SE) and the DD66000 (Everest). JBL has taken key elements from both of these loudspeaker systems to create the K2.S9900. The S9900 is a clear update of the S9800. While keeping the traditional "tall-boy" appearance and 15" low frequency drive unit, many elements of the Everest have been incorporated. A curved enclosure, front and rear, integrated horn lips, and a 4" compression driver are a few of the main features carried over from Everest.

The measured performance of the S9900 is extremely good. The frequency response of the system is smooth and extended. Directivity and power response are very uniform, harmonic distortion levels approach that of fine amplifiers and the dynamic linearity of the system is superb. However, we don't listen to measurements; we listen to music and the S9900 effortlessly reproduces the heart and soul of music. It doesn't matter what style of music or what playback level is desired, the S9900 is ready and able to deliver.

## SYSTEM

The basic system configuration is what JBL has historically referred to as an augmented 2-way. In the 1950's and 1960's JBL built primarily 2-way systems with a 12" or 15" woofer crossed over to a large format compression driver/horn combination. Some of the systems would be "augmented" by a UHF device, most usually the 075 ring radiator that would operate above 8 kHz. These systems would have only a single crossover point in the middle of the audio range in an attempt to minimize any sonic degradation caused by the dividing network. The S9900 has a single midrange crossover at 900 Hz blending one 1500AL-1 woofer to the 476Mg compression driver and horn combination. The 045Be-1 UHF driver is brought in at 15 kHz to cover two octaves of ultrasonic frequencies. Above 900 Hz, the HF compression driver and horn combination operates unassisted all the way to 22 kHz. (Fig.1)

Figure 1 – On-Axis response of the K2.S9900 system and that of each of the transducers through its crossover network. (2.83V @ 1m)

The transducers, horns and crossover networks are housed in a visually stunning enclosure that is reminiscent of both the K2.S9800 and Everest systems. The specially curved baffle provides the sidewalls for the main horn. The top and bottom horn flares are accomplished by the attachment of precision molded Sonoglas horn "lips" to the upper enclosure surface. A Sonoglas throat section is mounted inside the enclosure to provide the initial transition from the 38 mm exit of the 476Mg driver to the main horn section. The UHF driver is mounted to a Sonoglas horn which is attached to the back of the die cast aluminum housing. This assembly mounts to the top of the enclosure using a system of metal pins and rubber cups. This methodology provides proper alignment and a measure of mechanical isolation. All of the flat surfaces of the enclosure are 25 mm MDF. The curved panels are made from two different thicknesses of grooved MDF and total 25 mm" combined. A proprietary process is utilized for creating the curved panels. Individual sheets of MDF are grooved to allow flexure and then locked into the proper radius with a backing material. Two different thickness of curved MDF are then combined to form the final thickness panel. These layers are both decoupled and extremely rigid. The voids between the grooves are filled with a foam/glue material after forming. This gives behavior much like double layer glass, which is used to isolate exterior noise in buildings. The enclosure bracing is designed as a shaped form over which the curved panels are applied. The complex bracing is used to precisely hold the outer curved panels in exactly the correct shape allowing exceptional fit and consistency. The woofer baffle module is a shell that is separately assembled and braced. It then slides into place where it's bracing and that of the main enclosure actually interlock to form an extremely rigid and secure final structure. A painted outer baffle is then applied giving the total combined woofer baffle a thickness of 45 mm. The outer baffle is removable should repair or replacement of the painted surface ever be necessary.

The system is ported on the rear with a tuning frequency of 34 Hz. A large 100 mm diameter flared port is combined with the input connections on a massive die cast aluminum structure. The entire enclosure rests on 4 stainless steel foot assemblies. Stainless steel coasters are included to protect wood and tile floors from damage from the spike feet. The grille assembly is constructed of fiberglass reinforced ABS. The grille is held on the enclosure using metal pins and rubber cups.

The 1500AL-1 and 476Mg are both designed to be absolute minimum distortion drive units. Although they are capable of tremendous acoustic output, their design intent is to be completely linear in every way up to a reasonable drive level. Within this operating range there are no appreciable changes in any measured parameter of the system. This enables the system to sound the same regardless of playback level. (Fig.2)

Figure 2 – Second and third harmonic distortion products with the system driven to 96 dB SPL at 1 meter; 0.3% harmonic distortion is equivalent to 50 dB below the on-axis curve.

TRANSDUCERS

1500AL-1 Low Frequency Driver

The 1500AL-1 Low Frequency driver was designed by Jerry Moro, Senior Development Engineer for Harman Consumer Group. It is very similar to the 1500AL used in the S9800 system. The voice coil length has been increased to 25.4 mm (from 20.3 mm) and its milling width has been reduced slightly. This was done to allow greater clearance from the outer diameter of the coil to the laminated top plate and to provide a larger surface area of coil surface for heat dissipation. The coil former perforations have been eliminated to allow greater forced convection cooling from the pumping action of the diaphragm assembly. These coil improvements allow the 1500AL-1 to handle up to 25% more power than the 1500AL. (Fig.3)

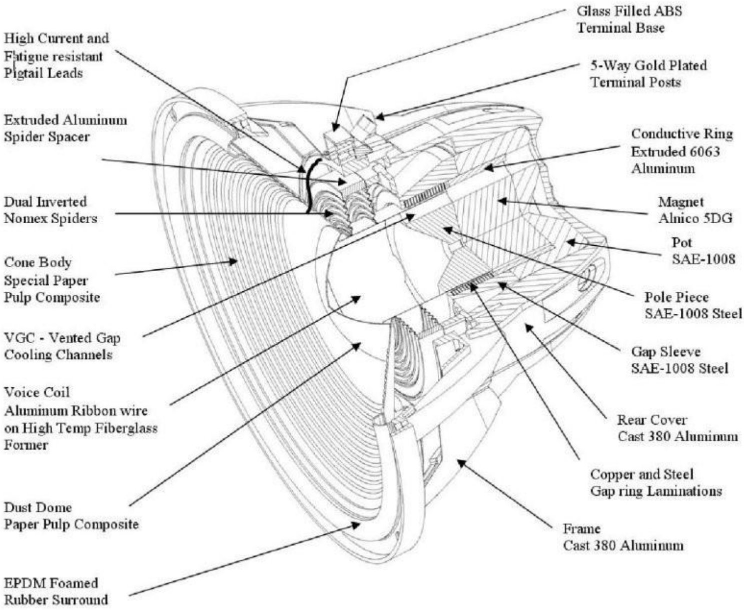


*Figure 1.*

Figure 3 – 1500AL-1 section view (Inserted new Line art – removed coil perfs, better pic quality -JM)

The 1500AL-1 LF driver is a 380 mm diameter device with a 100 mm voice coil completely immersed in a radial field generated by an Alnico 5DG magnet. Alnico was chosen because of its stable operating point. This material is insensitive to temperature changes and back EMF from the coil. JBL has overcome the tendency of Alnico to demagnetize with high drive by utilizing a massive shorting ring at the base of the motor assembly. The top plate is constructed of alternating copper-steel laminations. The presence of the copper rings linearizes the magnetic properties of the gap to all but eliminate eddy current distortion. The total gap is 41 mm long and provides a completely uniform flux field for the voice coil. Another benefit of this construction method is that the voice coil inductance remains essentially constant over the operating range of the driver. This means that the load presented to the crossover network and ultimately to the driving amplifier is uniform with coil position. This eliminates yet another source of dynamic distortion (inductance modulation) that is prevalent in many lesser drivers.

The outer suspension is made of EPDM foamed rubber, which has the longevity and frequency response characteristics of traditional rubber surrounds, but with a low density very close to that of foam surrounds. Low loss EPDM material was chosen so that the transient detail of musical signals could be preserved. Dual inverted Nomex spiders are employed for the cancellation of even-order distortion components. All suspension elements are tailored for maximum mechanical displacement linearity.

The cone is comprised of a special layered paper pulp matrix with proprietary Aquaplas damping which offers more pistonic behavior throughout the woofer's operating bandwidth, and controlled cone breakup beyond it.

A thick wall, cast aluminum frame is used to rigidly support the 16 kg motor structure. It was designed to offer this support yet remain acoustically open to the rear of the cone and spider in order to minimize acoustic compression. Besides cooling, this fully vented frame and motor design also serves to minimize the backpressure under the dome and spider, which helps to reduce harmonic distortion to even lower levels. JBL's Vented Gap Cooling (VGC) is incorporated within the motor structure. Air, pumped by the dome, is forced directly past the coil, and "exhausted" out the 3 pole vents in the rear of the structure. This forced convection cooling helps to lower the operating temperature of the coil during moments of high power operation. The Alnico motor structure is pressed into a special magnetic heat sink/cover designed to increase thermal radiating area, which helps draw heat away to surrounding air. Additional vents around the circumference of the cover, couple to the pumping action of the spiders to offer additional air circulation. (Fig 4 and 5)

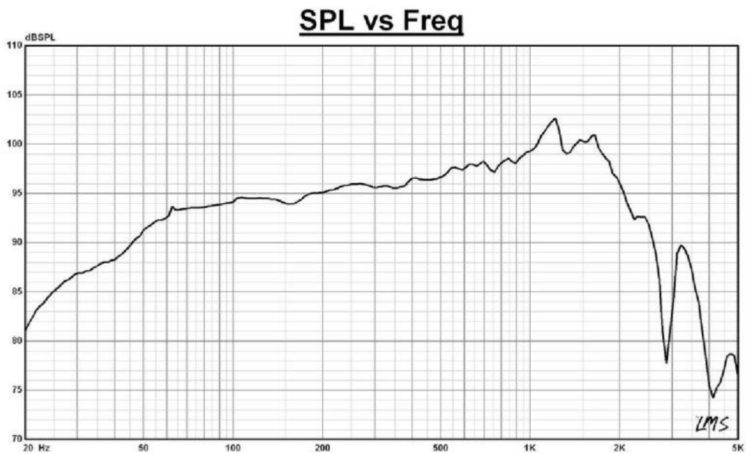


Figure 4 – 1500AL-1 half-space frequency response measured in a 19 cubic foot test enclosure. The measurement was made with 2.83 v @ 1m. (Inserted new Graph – JM)

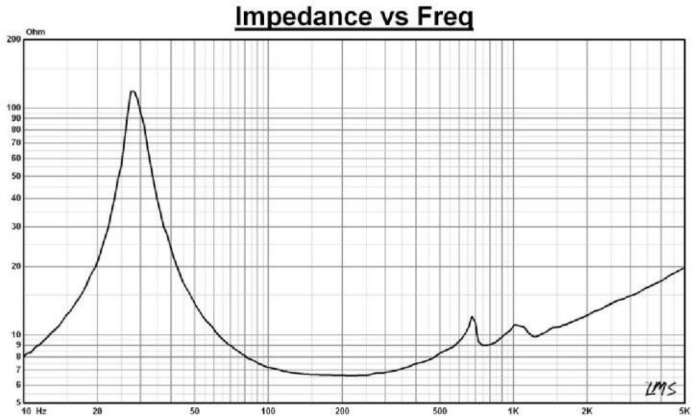


Figure 5 – 1500AL -1 Impedance curve in free air. (Inserted new graph - JM)

Altogether these design factors provide reduced harmonic distortions at very low and high acoustic output, improved power handling, reduced power compression, and more consistent spectral balance with varying input drive level.

Pertinent mechanical, magnetic and acoustical parameters of the 1500AL-1 LF driver are:

Flux density: 0.52 tesla throughout the 40.64 mm long gap
Bl product: 21 T•m
Voice coil resistance: 4.7 ohms
Voice coil winding length: 25.4 mm
Free-air resonance frequency: 30 Hz
Peak-to-peak linear excursion capability: 20.3 mm
Weight of magnetic structure: 13.6 kg (without cover)
Driver sensitivity (2.83v @ 1m): 95 dB SPL

476Mg High Frequency Driver and Horn

The 476Mg High Frequency Compression driver was designed by Jerry Moro, Senior Development Engineer for Harman Consumer Group. It makes use of a 100 mm diameter, Magnesium diaphragm with 99 mm aluminum Edge-wound coil, operating into JBL's existing Rapid Flare type, Coherent Wave phasing plug. The use of an efficient Neodymium rare-earth motor structure with new Copper Sleeved pole piece maintains maximum gap flux and reduced coil inductance at a minimum size and weight. The combination of these features has created a driver that can deliver superior sound quality regardless of acoustic power output with very little distortion and power compression. (Fig.6)

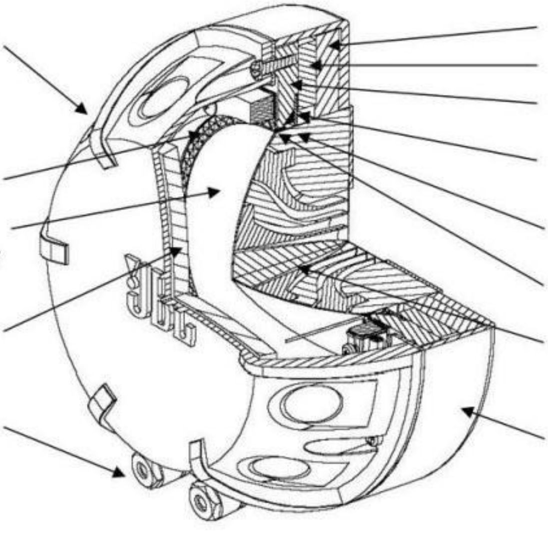


*Figure 1*

Figure 6 – 476Mg section view

The 476Mg motor structure incorporates the following key features:

- A pressed-on, 0.23mm thick, high purity copper sleeved pole piece is used instead of a conventional copper "plated" pole. This technique is used to greatly improve the electrical conductivity of the copper sleeve for lower coil inductance and thus greater high frequency output at 10 kHz and above. To improve high frequency output and sound quality even further, the copper sleeve also greatly minimizes the losses and distortions due to Eddy currents in the pole piece. Another benefit of the copper sleeved pole is the ability of the copper to quickly wick away heat generated by the coil. To further enhance or maximize this efficient heat transfer from the coil to the entire pole piece, the length of the copper sleeve was extended to 13.7mm, for over 4 times the area of the coil. This will mostly benefit reduction of short-term, dynamic power compression.
- Neodymium rare-earth magnet material is used in an "outer ring" configuration formed of 8 individual arc-segments. This configuration creates a very large diameter and magnet area for a moderate cost when compared to a one piece ring design of the same size. To compensate for the higher reluctance gap caused by the use of a copper sleeved pole piece, large magnet area was used in conjunction with special high-grade and high-temperature grade Neodymium. This allowed the motor design to maintain a minimum gap flux density of approximately 18,000 Gauss.
- Special acoustic vents are machined into the top plate, directly under the Diamond surround, to properly control the surround chamber resonances. A filler and acoustic seal are also used in the magnetic gap for similar reasons. Acoustic tuning of these cavity resonances throughout the design, especially in the magnetic gap and under the diaphragm's surround, is necessary to maintain smoothness of the mid-band frequency response.
- The Phasing plug is of JBL's traditional Rapid Flare, Coherent Wave 4-slot design. It is precision Die Cast out of Zinc material, which is used to insure dimensional and structural stability while under high thermal and high acoustic pressure loads. The phase relationship of

the sound emitted from various areas of the large 100mm diaphragm is controlled as it passes through the 4-slots of the phase plug towards the 38mm exit. This Coherent Wave design shapes the wave output producing a truly coincident wave front as the sound enters the horn. When used in conjunction with optimized Bi-Radial horn designs, the Coherent Wave and Rapid Flare phase plug features, offer smooth frequency response and up to 6dB lower 2$^{nd}$ Harmonic distortion, relative to JBL's earlier driver technology.

The major features of the 476Mg diaphragm assembly are as follows:

- The diaphragm is formed of Magnesium Alloy foil and is the first JBL large format 100mm compression driver to use this special material. The Magnesium Alloy is essentially 95 percent pure magnesium with small percentages of aluminum, zinc, and other alloys added to improve characteristics such as diaphragm forming, fatigue strength, corrosive and acoustic properties. A proprietary thermal forming process is used to form the thin sheets of Magnesium Alloy into the 100mm diaphragm shape of exacting dimensions. This new process even enables the integrated JBL Diamond surround to be formed as one piece with the dome. Forming the diaphragms out of sheets of this Magnesium Alloy foil yields greater reliability and resistance against fatigue and corrosive failures than diaphragms formed with 100% pure Magnesium or Aluminum.
- Magnesium has very low density, slightly lower than even that of Beryllium. With such a low density, the thickness of the Magnesium Alloy diaphragm could be greatly increased while still maintaining an equivalent diaphragm mass of approximately 3.4 grams, similar to previous designs using Aluminum and Titanium. Based on this, the new Magnesium Alloy diaphragm was increased to 130 micron, about 1.7 times thicker than JBL's standard 76 micron thick Aluminum diaphragm. When compared to the Titanium diaphragm used in JBL's original K2 S9500 and M9500 systems, this new Magnesium Alloy diaphragm is 2.5 times thicker. This is beneficial because a thicker diaphragm creates a much stiffer diaphragm, which pushes pistonic behavior to higher frequencies than current Aluminum or Titanium diaphragms (given the same moving mass). Better pistonic behavior means less diaphragm modal breakup at the critical mid-band frequencies and so the upper frequency response will be smoother with minimal distortion spikes, (see *Figure 12*). The effects of this will be less distortion and improved and extended frequency response.
- Another benefit of the Magnesium Alloy is the greater Internal Loss, or Damping, when compared to Titanium or even Aluminum. This greater Internal Loss quickly minimizes the amplitude of resonances when the diaphragm is asked to reproduce frequencies beyond its pistonic limit. To further augment this damping, a very light 0.3 gram application of JBL's Aquaplas is also used. Combining the greater internal loss with the stiffer characteristics of the thicker, low density material, this new 100mm Magnesium Alloy dome sonically performs close to the Beryllium diaphragm used in the 476Be High Frequency Everest drive unit, but at a fraction of the cost. In the end, careful optimization of this new Magnesium Alloy diaphragm's characteristics along with the application of Aquaplas damping, has maintained the enhanced detail of musical transients and micro dynamic nuances that JBL listeners have become accustomed to.
- JBL's diamond pattern surround is utilized to maintain proper control and tuning of the second diaphragm resonance (the surround resonance mode). The proper control and placement of this surround resonance is critical for good high frequency shape, extension, and level. Conventional "flat" or "half-roll" type Magnesium surrounds would have placed this surround resonance at too low a frequency to give optimal high frequency roll-off characteristics.

These features, when taken as a whole, create a new large format compression driver that ranks with the best that JBL has ever produced.

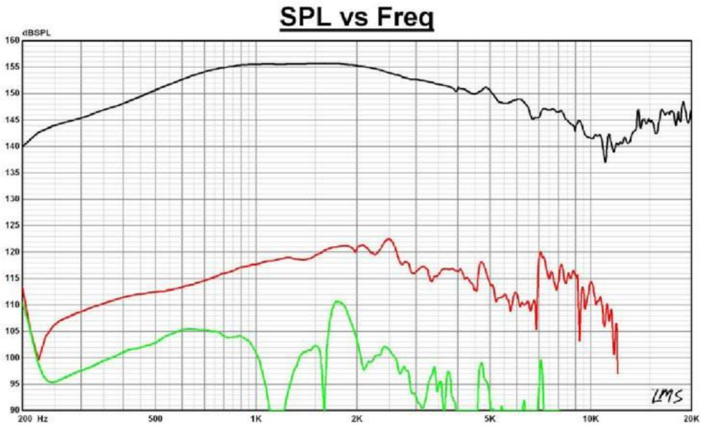


Figure 7 – Terminated tube measurement of 476Mg with distortion products. The measurement was made with 7.5 v applied to the driver. This is equates to about 120 dB @ 1m when mounted in the system.

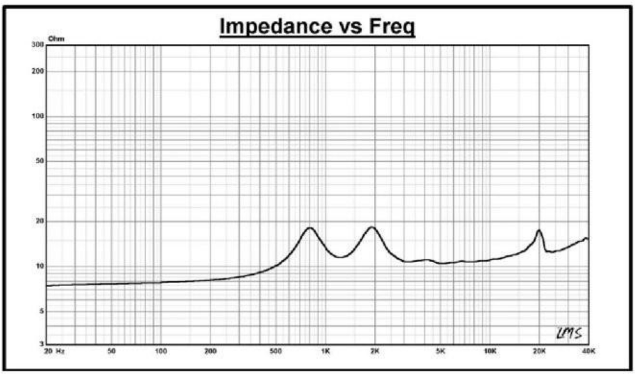


Figure 8 – Impedance curve of 476Mg on a terminated tube.

Pertinent parameters of the 476Mg HF driver are:

Voice coil DCR resistance: 8.0 ohms
Voice coil winding length: 3.25 mm
Mass of moving system: 3.8 g (including 0.3 grams of Aquaplas damping)
Impedance: 12.0 Ohms (Minimum)
Flux density: 1.8 Tesla throughout the 3.17 mm long gap
BL product: 17.0 T•M
Sensitivity (2.83v @ 1 m): 110 dB measured on S9900 horn
Weight: 4.85 kg

045Be-1 Ultra-High Frequency Driver and Horn

Like the 045Be, the 045Be-1 uses a 25-mm beryllium diaphragm and 50-mm neodymium magnetic structure. The pure beryllium diaphragm is less than 0.04 mm thick and has a mass of only 0.1 gram. The single layer aluminum ribbon voice coil is wound without a former and attached directly to the diaphragm. The driver employs the smallest annular slit phasing plug that JBL has ever designed. Each phasing plug assembly is manufactured by modern stereo lithography techniques for absolute dimensional integrity. The 045Be-1 has been redesigned to improve manufacturing yield and consistency. Small changes have been made to the top plate and some significant improvements were made to the surround shape and clamping methodology. As a result, the driver has picked up nearly 5 dB of increased output above 30 kHz. A section view of the 045Be-1 driver is shown in Figure 9. (From S9800 White Paper)

The extremely low mass of the moving system, high magnetic flux density and the high rigidity of beryllium produce response that is very smooth from below 8 kHz to beyond 50 kHz, as seen in Figure 10.

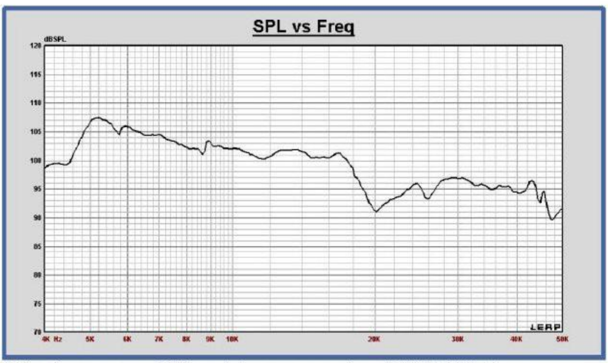


Figure 10 - 045Be-1 response, 2.83 v at 1m measured on S9900 UHF horn.

The response curve has a slight down hill tilt due to the constant directivity nature of the horn used in this system. The horn is properly scaled to maintain a coverage angle of 60 degrees in the horizontal plane and 30 degrees in the vertical plane over the frequency interval from 10 kHz to 50 kHz.

Pertinent magnetic and acoustical details:

Mass of moving system: 0.3 g
Flux density in gap: 20 tesla (20 kg)
Magnetic assembly weight: 0.21 kg

Figure 9 – Section view of 045Be-1

COMPONENT INTEGRATION

It is all well and good to have the finest transducers and enclosures, but without proper integration they are only a group of raw parts. It is the function of the crossover network to divide the frequency spectrum and direct the parts to the appropriate driver. When done properly, the resulting sound quality takes on life as a performance not just a sterile reconstruction of an electronic file.

The circuit topology, combined with the acoustic behavior of the 1500Al-8 and 476Mg provides a 24 dB-per-octave transition at 900 Hz. This is the primary crossover point of the system. Additionally, the 045Be-1 is turned on above 15 kHz to provide extended response to beyond 50 kHz. This technique allows a primary crossover point between just two drivers and permits proper control of the directivity pattern of the system. As a result, the speed and power of the S9900 system is both powerful and delicate from the lowest to the highest frequencies. The crossover network is comprised of 4 individual boards – one for each transducer plus an input control board. They are separated within the enclosure to minimize any potential cross talk. Each crossover board has been optimized for the specific transducer and frequency range with which it is intended to operate. The low frequency board is designed to pass large amounts of current in a linear manner. The high frequency and ultra-high frequency boards have been designed for ultra low distortion and extremely linear behavior. All of the electrical components are of the highest quality and lowest internal loss. The inductors used are air core so as to not introduce nonlinear hysteresis effects. Capacitors are constructed using polypropylene foil, which is known for having minimal distortion caused by dielectric absorption nonlinearities. The low, high and ultra-high frequency networks employ DC bias to operate the capacitors effectively in a Class A mode. Low frequency resistors are of wire-wound construction and are elevated on metal legs to permit significant airflow to minimize value shift during high power operation. Resistors used on the mid, high and ultra-high frequency boards are of metal oxide construction. They have been chosen for their superior sonic characteristics and are used in multiples to minimize value shift during high drive conditions. Every attempt is made to present as smooth a system impedance as possible to the driving amplifier. This design element is often overlooked in many loudspeaker systems. Amplifiers work their best when they are given a smooth, level load impedance in which to deliver current. (Fig.11)

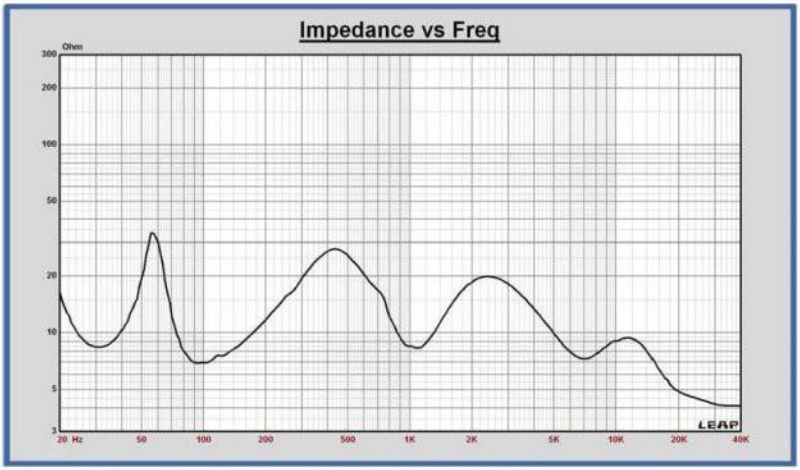


Figure 11 – Magnitude of impedance for the K2.S9900 system.

The aggregate of these attributes allows the K2.S9900 system to translate the electrical signal from source material into an accurate and unencumbered three-dimensional sound field. The system can do this at any desired listening level from whisper quiet to big-band loud while at the same time, maintaining unchanged acoustic characteristics.

CONTROL OPERATION

In addition to the input binding posts and port flare, the rear input plate includes rotary switches that allow for the selection of Bi-Amplification, Presence adjustment and High Frequency level trim. A removable cover provides access to the 9-volt battery used for capacitor bias. Adjustment of the switch positions accomplishes the following adjustments:

Bi-Amp - It is possible to operate the system using an external low level dividing. In this mode, the Low and High Frequency crossovers are totally bypassed. Level adjustment and internal equalization remain on the High Frequency section. Figure 12 shows the low frequency and high frequency voltage drive functions necessary to properly Bi-Amplify a S9900 system using an external dividing network and two amplifiers channels. Neither the low pass nor high pass drive is a standard Butterworth alignment or, for that matter, any standard alignment. The provided drive curves were derived using the internal passive network and resulting acoustic low pass and high pass shapes. Duplicating these shapes will result in the same frequency response and directivity pattern as a passive S9900. The curves shown will be extremely difficult to replicate with standard external crossovers so JBL recommends against bi-amp operation unless the user is very familiar with electronic crossover/EQ equipment.

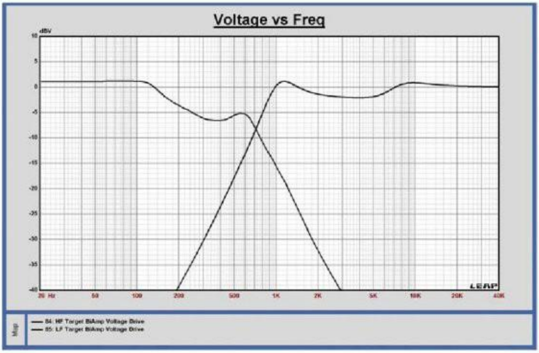


Figure 12 – Low pass and high pass curves for required for the use of an external dividing network to Bi-Amplify the K2.S9900 system.

Presence - There is a trim available for the High Frequency section of the system. The switch raises or lowers the drive to the 476Mg by approximately 0.5dB in the range of 1500 Hz to 3000 Hz. The action is accomplished by trimming the main attenuation resistors. No additional parts are inserted in the signal path.

HF Level - This switch adjusts the attenuation applied to the 476Mg by approximately 0.5 dB over the range of 1000 Hz to about 20000 Hz. The action is accomplished by trimming the main attenuation resistors. No additional parts are inserted in the signal path. It has no affect on the 045Be-1 output level. (Fig.13)

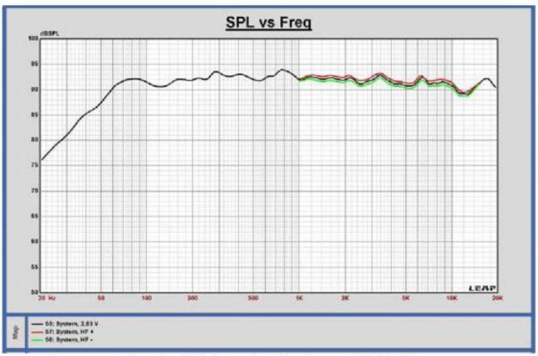


Figure 13 – Response changes due to HF Level adjustment 0.5 dB

The batteries provide a voltage bias to each of the capacitor positions in the various networks. The biasing of the capacitors is done through a large value resistor (2.2 megohm) and thus, draws no appreciable current. The expiration date printed on the battery generally coincides with the need to replace the batteries. Each capacitor position is actually made up of two capacitors connected in series. The battery voltage is applied to the center connection of the two capacitors. This produces a voltage potential between the two plates within the capacitor. When the two parts are taken as a whole, there is no DC voltage that appears across them, but individually they are each biased. The sonic result of the biasing yields an increase in detail, increased smoothness and considerably more natural decay of sounds within the music.

## CONCLUSION

The K2.S9900 system is comprised of many individual parts, each of which is constructed using modern techniques and the best materials available. Every attempt has been made to design and produce a system that measures well, looks great and is built to last. But is this sufficient to make the K2.S9900 the best system it can possibly be? The answer to that question is "No". There are many factors that arise in the design of a complicated system such as this. This is where JBL's longstanding history of outstanding engineering, both sonic and visual, comes into play. Although we are firm believers of the "Science of Sound" we are also practitioners of the "Art of Music". The K2.S9900 will deliver a musical experience that few other loudspeakers can match.

## SYSTEM SPECIFICATIONS

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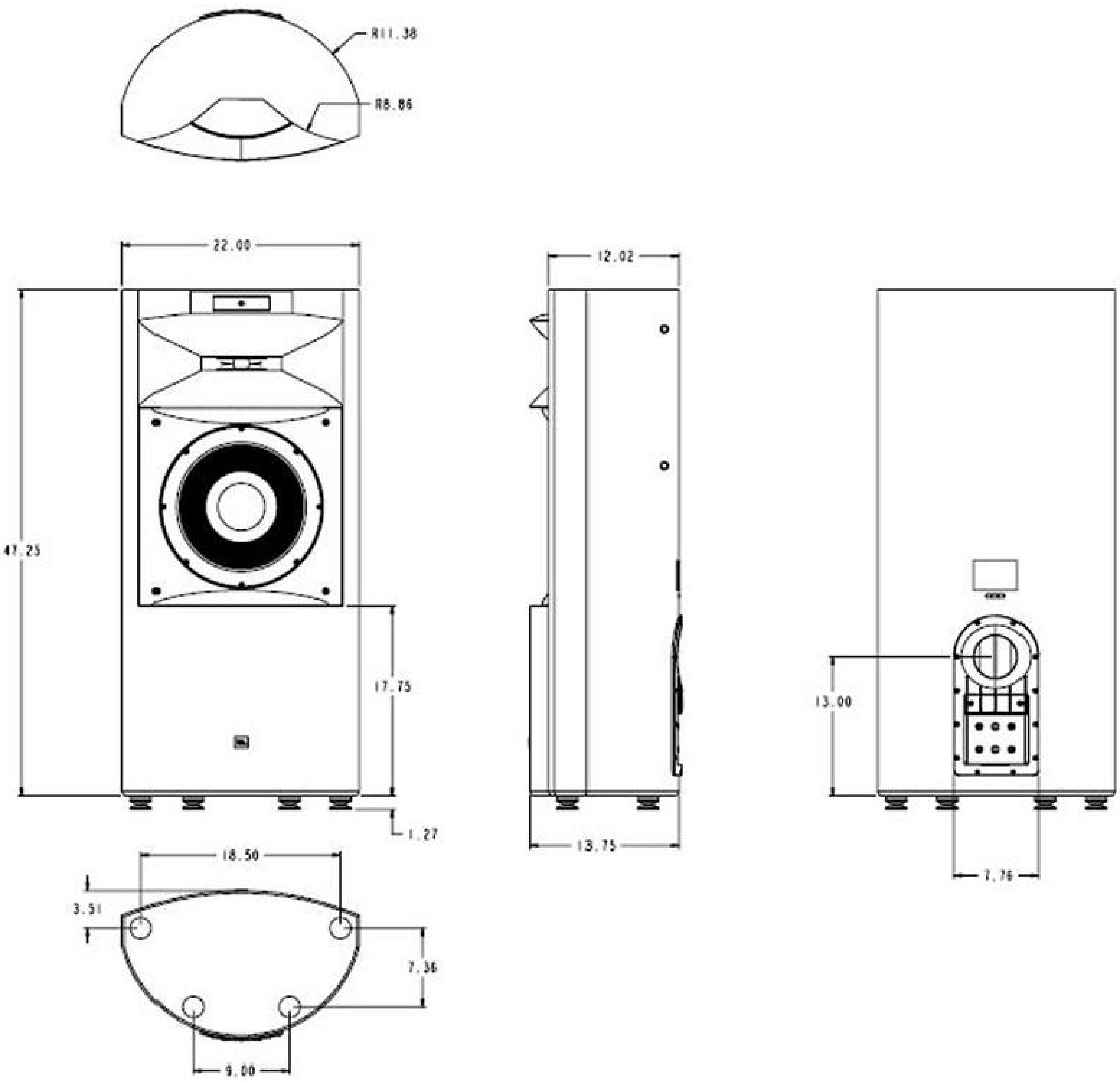
|---|---|
| • Recommended Maximum Amplifier Power: | 500 Watts |
| • Frequency Response (-6 dB, Anechoic): | 48 Hz – 50 kHz |
| • Bass Response (-10 dB, Anechoic): | 33 Hz |
| • Impedance: | 8 ohms nominal, 7.0 ohms minimum at 100 Hz,<br>4.0 ohms minimum at 40 kHz |
| • Sensitivity (2.83 V @ 1m): | 93 dB |
| • Crossover Frequencies: | 900 Hz, 15 kHz |
| • Exterior dimensions (W x H x D) | 560 mm x 1200 mm x 350 mm<br>22" x 47.3" x 13.8", Plus .8"(20mm) for feet |
| • Weight: | 82.7 kg, 182 lb |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R8.86
22.00
12.02
47.25
17.75
13.00
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13.75
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18.50
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9.00