JBL White Paper
The New K2.S9800 Loudspeaker System

By JBL Technical Staff

TIMOTHY PRENTA
Director, JBL Consumer Engineering
JBL Consumer Products

GREG TIMBERS
Chief System Engineer
JBL Consumer Products

JERRY MORO
Senior Transducer engineer
JBL Consumer

DOUGLAS BUTTON
Vice President, Research & Development
JBL Professional

Editor

John M. Eargle
Advisor
JBL Consumer & Professional

harman international

JBL White Paper: The New K2.S9800 Loudspeaker System

By JBL Technical Staff

A. Introduction -- The Design Brief:

The advent of high-density recorded media for the consumer has challenged manufacturers of loudspeakers and microphones to push the frequency response envelope of transducers and systems up to 50 kHz in order take advantage of the program signals that can now be recorded in the DVD-Audio and Sony-Philips SACD software formats. The issue is not so much whether listeners can hear this uppermost octave as such, but rather that the bandwidth extension ensures smoother and less aberrated frequency response in the upper portion of the normal audio bandwidth than we have known before.

Another major consideration is uniformity of acoustical power radiation from the loudspeaker into the listening space. There are two aspects here: smooth on-axis response and controlled vertical and lateral radiation angles. Studies carried out by various technical groups within the Harman organization have shown a universal preference on the part of professionals and critical consumers for loudspeakers that exhibit such response uniformity.

At the same time, there is an ever stronger demand from critical listeners for lower distortion in loudspeaker systems, effectively matching the low distortion normally found in the best microphones, recording systems and playback electronics.

In addition to the foregoing requirements, critical listeners demand realistic playback levels with minimal compression of dynamics. While there may be several approaches to achieving bandwidth extension and uniform power response, there remains only one way to ensure high playback levels with high dynamic linearity -- and that is through the use of over-designed transducers that are capable of output levels many times greater than will normally be required of them.

In critical loudspeaker auditioning sessions, listeners become very aware of subtle timbral aspects which are often difficult to measure. Such matters as cone materials, high frequency diaphragm materials and dividing network component integrity become important design considerations in defining a modern state of the art loudspeaker system.

Finally, the appearance and shape of a fine loudspeaker system must reflect natural and pleasing proportions, show use of the finest materials, and be acoustically correct insofar as physical boundary conditions for transducer performance is concerned.

In this White Paper we will examine transducer, horn and system designs in detail, discussing all aspects of their engineering and development. We will then move on to the evolution of the system concept and the integration of the elements into the whole. We will conclude with a discussion of system setup and optimization in typical listening spaces.

B. The Transducers:

Low-Frequency Driver:

The Model 1500AL LF driver was designed by Jerry Moro, Senior Development Engineer for JBL Consumer Products. It is a 380 mm diameter device with a 100 mm voice coil completely immersed in a radial field generated by an Alnico 5DG magnet. A section view of the driver is shown in *Figure 1*. Its salient features are:

1. Large outer suspension, made of EPDM foam rubber material, which offers low mass, low losses and much improved longevity.

2. Double Nomex inner suspensions, inverted with respect to each other for cancellation of even-order distortion components. All suspension elements are tailored for maximum mechanical displacement linearity.

3. A very large aluminum shorting ring positioned below the gap to reduce global flux modulation of the static field. This eliminates the demagnetization problems that have plagued Alnico motor designs in the past.

4. Use of alternating copper-steel laminations in the top plate. The presence of the copper rings provides the familiar JBL shorting ring adjacent to the voice coil to reduce its inductance and to further stabilize the local magnetic field throughout the steel in the long gap length. The presence of the steel laminations produces an effectively narrow magnetic gap through the "sharing" of space with the copper.

5. The use of Alnico 5DG magnet material provides a stable magnetic operating point under high drive conditions, further reducing distortion due to flux modulation. The magnetic circuit has been optimized for flux consistency throughout the normal range of voice coil movement, and the moving system has a linear operating range of ±12.7 millimeters.

6. Choice of cone material. A traditional felted material of thick cross-section was chosen for its combination of high internal damping, mass, mechanical stiffness and freedom from acoustical coloration.

7. A fully vented frame and motor structure is used for minimizing acoustic losses and for cooling of internal parts through optimum transfer of air into and out of the magnetic structure.

Altogether, these factors provide: lower losses at high frequencies, reduced harmonic distortion, and improved power handling.

Pertinent mechanical, magnetic and acoustical parameters of the 1500 Al LF driver are:

Flux density: 0.52 tesla throughout the 40.64 mm long gap
Bl product: 21 T•m
Voice coil resistance: 5.3 ohms
Voice coil winding length: 20.32 mm
Free-air resonance frequency: 26 Hz
Peak-to-peak linear excursion capability: 25.4 mm
Weight of magnetic structure: 13.6 kg (without cover)
Driver sensitivity (1 watt at one meter): 94 dB SPL

[Insert Figure 1 about here.]

Mid-Frequency Compression Driver and Horn:

The model 435 Be compression midrange driver was designed by Douglas Button, Vice President of Engineering for JBL Professional. It makes use of a 75 mm diameter diaphragm operating into a traditional Western Electric type annular slit phasing plug. The use of neodymium magnetic material keeps the size of the driver to a minimum. *Figure 2* shows a section view of the midrange compression driver.

Its salient features are:

1. As an intermediate size between JBL's large and small format compression drivers, derivatives of the 435 have found great use in JBL's recent professional line arrays, where the small size of the driver and its magnetic structure allow them to be used in multiples for driving high frequency line arrays without the design and fit problems that would be unavoidable with large format drivers.

2. The phasing plug and initial flare development are both of the newer rapid flare type, which reduces second harmonic distortion by up to 6 dB, relative to JBL's earlier driver technology.

3. With efficiency in the range of 25 - 30%, the driver can deliver high amounts of acoustical power with relatively little electrical input. The diaphragm is made of beryllium, whose pistonic behavior is maintained to well beyond 15 kHz. The diaphragm is coated with a fine layer of Aquaplas for damping of spurious resonances.

[Insert Figure 4 about here.]

4. Pertinent magnetic and acoustical details:

Mass of moving system: 1.25 g
Flux density in gap: 20 tesla (20 kGs)
Magnetic assembly weight: 1 kg

Figure 5 shows a plane wave tube response curve of the 435 Be driver.

[Insert Figure 2 about here.]

The 435 Be driver is attached to a Bi-Radial™ horn designed by Greg Timbers, Chief Engineer of JBL Consumer. It is executed in a high impact plastic that has high dimensional stability. Horn section views are shown in *Figure 3.* The -6 dB beamwidth plots and directivity data are shown in *Figure 4*. Note that the pattern control is uniform (±10°) from 1 kHz to 10 kHz. The DI is within ±1 dB over the same frequency range.

[Insert Figures 3 and 4 about here.]

<u>Ultra-High-Frequency (UHF) Compression Driver and Horn:</u>

The 045 Be UHF compression driver was designed by Tim Prenta, Director of Engineering for JBL Consumer products. With its 25-mm beryllium diaphragm and 50-mm neodymium magnetic structure, this is the smallest compression driver that JBL has ever designed. 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. A section view of the 045 BE driver is shown in Figure 5.

The extremely low mass of the moving system, high magnetic flux density and the high rigidity of beryllium produce response that is essentially flat from 10 kHz to 48 kHz, as seen in *Figure 6*.

[Insert Figures 5 and 6 about here.]

The UHF horn was designed by Greg Timbers. It 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 kGs)
> Magnetic assembly weight: 0.21 kg

Figure 7 shows various views of the UHF horn. *Figure 8* shows pattern control and directivity for the horn.

[Insert Figures 7 and 8 about here.]

C. System design and component integration:

Figure 9 shows front, top, side and perspective line drawings of the systems, illustrating the various curved transitions that define the smooth acoustical boundary conditions for the LF driver and the MF and UHF horns.

The dividing network topology combined with the acoustic behavior of the individual transducers provides 24-dB-per-octave transitions between adjacent system elements. The response of each element is -6 dB at the transition frequency. These rapid transitions provide more uniform system response over a larger vertical listening angle than that provided by lower-order slopes, and this translates into an increased solid listening angle for the system. The contribution of each element, along with the overall on-axis response of the system is shown in *Figure 10.*

Another important factor in the design of the dividing network is the use of DC biasing of the capacitors in this system. The biasing ensures that normal zero-crossings of the audio waveform from plus to minus are displaced from actual zero potential and thus do not force the capacitors to undergo a zero charge condition, even momentarily. This is analogous to "Class A" behavior in amplifiers.

[Insert Figures 9 and 10 about here.]

Details of the system's directional response are shown in *Figure 11*. This family of curves is defined as follows:

Curve 1. On-axis response.
Curve 2. Average of response over 30° horizontal and 15° vertical angles.
Curve 3. First reflected sound power sum.
Curve 4. Total reflected sound power sum.
Curve 5. On-axis overall directivity index (dB).
Curve 6. On-axis directivity index for first reflections (dB).

[Insert Figure 11 about here.]

The overall trend is for the system to be fairly nondirectional at low frequencies, reaching a plateau of uniformity at about 1 kHz, where the midrange Bi-Radial horn comes into play, and extending beyond 20 kHz as the UHF takes over.

Under these conditions the system will integrate well with a wide variety of acoustical conditions. In a room where the boundary absorption is uniform over the midrange, the system will provide ideal spectral coverage over a broad listening angle.

The impulse response of the system is shown in *Figure 12*. The response shows system time alignment within an interval of about 350 microseconds, along with highly damped low frequency response

[Insert Figure 12 about here.]

From an electronic point of view, we want to ensure that the system does not present a troublesome electrical load to any amplifier that is chosen to drive the system. *Figure 13* shows the modulus of impedance as not dropping below 6 ohms at any point over the range below 10 kHz. The drop to about 3 ohms at 50 kHz is considered negligible.

[Insert Figure 13 about here.]

Overall system distortion at reference level of 102 dB at a measuring distance of one meter is shown in Figure 14. Because the fundamental response is so uniform we can add at the right edge of the graph an approximate scale indicating distortion percentage from the range of about 60 Hz to 20 kHz. The second and third harmonic distortion components at this extremely high playback level are amazingly low. Only in the range above about 5 kHz does the value of second harmonic (dashed curve) rise slightly above one percent.

[Insert Figure 14 about here]

D. System Integration into the Listening Room:

The target consumer for the K2.S9800 system will probably already know enough about loudspeaker positioning in the home listening environment to ensure good results with a pair of these new loudspeakers in normal stereo configuration. It is for the listener who wants to use these loudspeakers in a surround sound configuration that we offer the following recommendations.

The ITU (International Telecommunications Union) standard for surround loudspeaker placement is shown in *Figure 15.* When possible, the circular outline of loudspeaker location should be maintained. If it is necessary to place the three frontal loudspeakers against a wall, then the center loudspeaker should be time-delayed so that its effective distance from the primary listening position will be equal to that of the left and right front channels. In calibrating the system levels at the primary listening position, any differences in distance to the primary listening position should be taken into account so that both level and relative timing from all five channels will be the same at the center listening position.

Since the ITU recommendation is basically a broad guideline, individual users may modify it in minor ways to fit the requirements of a given listening space. Specifically, the placement of rear channels may be changed slightly to allow for difficulties in room setup. Some listeners may prefer the rear channels to be slightly greater than the ±110° limit shown here. In any event, both rear channels should be at the same off-axis angle, relative to the center channel, to maintain system left-right balance.

Figure captions:

1. Section view of 1500AL low frequency transducer.
2. Section view of 435 Be mid-frequency compression driver.

3. Vertical and horizontal profiles of the mid-frequency Bi-Radial™ horn.
4. -6-dB beamwidth and directivity data for the mid-frequency horn over its nominal operating range.
5. Section view of the 045 Be UHF compression driver.
6. Unequalized on-axis response of the UHF system.
7. Vertical and horizontal profiles and views of the UHF horn.
8. -6-dB beamwidth and directivity data form the UHF horn over its nominal operting range.
9. Front, side, top and perspective line drawings of the complete system.
10. On-axis contributions of LF, MF and UHF sections of the system.
11. Overall system directional and room response.
12. System impulse response.
13. System modulus of impedance.
14. Second and third harmonic distortion at 102 dB SPL at a measuring distance of one meter.
15. Target loudspeaker locations for surround sound playback.