DALI 40 SE

DALI

Danish Audiophile Loudspeaker Industries

"The best ideas live a long time."

DALI 40

Special Edition

This statement certainly applies to the DALI 40 loudspeaker, the original version of which appeared nearly ten years ago. Yet the basic concept underlying its design was so advanced that it has continued to inspire the DALI research and development team right up until the present day with the triumphant introduction of the DALI 40 Special Edition. The DALI 40 SE takes advantage of the most recent developments in driver technology and crossover components to redefine the potential of High End loudspeakers.

The DALI 40 is the result of an unusual genesis. The design team put aside common notions and conventional wisdom about how things should be done and set about asking all the right questions.

The design brief included optimization of the following parameters:

- *Low frequency response flat to 25Hz at full amplitude and with critical damping.*
- *Tightly controlled dispersion characteristics for uniform performance regardless of acoustic environment.*
- *Extremely low distortion.*
- *A stable, wide, deep and tall stereo soundstage.*

THE BEST OF SEALED BOX AND BASS REFLEX

To achieve these goals required an entirely new bass principle, involving four 8" long-throw woofers per speaker, capable of moving the same volume of air as the best 18" driver.

The four drivers operate in pairs, with the back wave from all four drivers reflex-loaded by two ported enclosures. Only the two baffle mounted drivers are forward firing, with the two interior drivers firing into separate sealed air volumes.

Consequently, the system offers the efficiency and bass extension of a reflex cabinet as well as the precise transient response of a sealed system.

OPTIMUM DISPERSION

DALI 40 SE offers tightly controlled dispersion characteristics across a 180_ horizontal angle and across a 30_ vertical angle, making the speaker virtually room-independent and confirming the groundbreaking research of Dr. Floyd E. Toole concerning the relationship between dispersion and subjective musicality.

These exceptional characteristics are achieved by arraying the five forward-firing drivers symmetrically along the vertical axis with the high frequency driver at the center and by matching the electrical charactistics of the crossover network to the specific acoustical characteristics of the drivers. The output of the drivers sums acoustically around the horizontal axis and, as a fortuitous side effect, the twin 8" drivers cancel out the first floor reflection, which would otherwise typically cause a dip in frequency response at 500Hz.

LOW DISTORTION - A QUESTION OF CONTROL

Low loudspeaker distortion can only be achieved by controlling the voice coil/magnetic assembly, driver ventilation, air velocities in the drivers' moving parts and enclosure resonances.

Midrange and bass drivers in the DALI 40 SE are vented via the front of the diaphragm. Pole piece extensions are employed, but without dust caps. The magnetic structures are designed to generate a linear magnetic field and the bass drivers utilize 25mm voice coils. The midrange drivers, which displace much less air than the bass units, employ much shorter voice coils on a Nomex former to reduce mechanical loss.

Substantial effort has gone into selecting the ideal combination of materials for the diaphragm, spider and surround. The midrange driver features a ventilated and decoupled spider, while the high frequency driver is vented through a conical tunnel in the pole piece. The high frequency driver's magnetic system is a unique construction with a pole piece of uniform thickness in spite of the conical opening.

VIBRATION CANCELLATION FOR SHARPER FOCUS

In order to present a superbly stable stereo image, a loudspeaker must be a totally non-resonant sound source, eliminating any risk of phase modulation.

Therefore, the DALI 40 SE bass drivers are mounted in pairs, back to back, so that they cancel each other's vibrations. This, along with the high mass of the DALI 40 SE, causes the speaker to stand firm. Since all the other parameters regarding dispersion are optimized, vibration cancellation makes the final contribution toward a truly convincing and sharply focussed stereo image.

All you have to do is hook up a pair of DALI 40 SE to a DALI Gravity power amplifier or any powerful High End amp in order to experience its supremely musical qualities, from the most delicate low level nuances to the most complex and demanding dynamic passages.

DOCUMENTATION

Back in 1983, DALI engineers were struck with the idea of a new bass principle which would combine the advantages of a sealed enclosure and the bass reflex system. Both systems have well-advertised advantages. It is well-known that the sealed enclosure, by virtue of a smoother rolloff characteristic, is superior to bass reflex designs in terms of transient response. The bass reflex system, on the other hand, is capable of a lower cutoff frequency and lower distortion due to more limited excursion.

Taking these two different design types in mind, DALI decided to engineer an all-new speaker principle in a no compromise loudspeaker system. At the outset, our design goals were:

1. Superior low frequency response characterized by a very low cutoff frequency and excellent transient response.

2. Natural and detailed reproduction throughout the entire operating range of the speaker.

3. Three-dimensional stereo imaging.

4. Smooth and even sound radiation throughout the listening area, with a well-defined soundstage with respect to at relatively fixed listening position.

Closed Versus Bass Reflex

A sealed enclosure constitutes a 2nd order highpass filter which can vary between 1st order rolloff by 2nd order Butterworth to 2nd order Chesbyshev. The type is derived through the Q value of the filter. A B2 system Q value is 0.71, which provides ideal impulse response. Systems with a Q lower than 0.71 exhibit overdamped response, while a system with a higher Q is characterized by a tendency towards overexcursion.

Bass reflex systems constitute 4th order systems. Bass reflex systems have been fundamentaily analyzed by Thiele and Small, and characterized by their analog high pass function from 2nd order sub-Chesbyshev to quasi-Butterworth 3rd and 4th orders and 4th order Chesbyshev.

The best designed bass reflex systems, in terms of transient response, are comparable to sealed box systems with Q between 1.0 and 1.3. The best systems, in terms of low frequency cutoff, are the worst in terms of transient response.

In 1979, Laurie Fincham showed the possibility of obtaining 2nd order response in a bass reflex system by mounting a closed box in front of the woofer cone and utilizing only port radiation. This system, designated Bandpass Bass Reflex, provides excellent transient characteristics due to the minimal woofer and port out of phase cancellations below the tuning frequency.

The drawback to this system is that the port crossover is too low, at 100 Hz, to be effectively used with any conventional midrange driver. This means the system can only be effectively used for subwoofer applications. DALI engineers wanted to incorporate a 2nd order Bass Reflex system, but with response extended to 1000 Hz to facilitate crossing over to standard midrange drivers.

The L Linkage Circuit

After much analysis, we decided to design a system which incorporated multiple drivers. The first driver would be direct-radiating, loaded in a bass reflex enclosure. The second driver would be loaded in the back of the same bass reflex enclosure, and in front of a sealed enclosure. The principle employed in this somewhat complicated design operates as follows: the speaker which is mounted at the front of the bass reflex enclosure is actually in an enclosure which is too large. This allows a rolloff frequency before the resonance and a frequency peak at resonance. The complementary speaker responds in a way which compensates for the frequency dip up to the system Q, and then phases out the peak, while staying in phase until the upper cutoff. This provides a 2nd order Butterworth at cutoff instead of 4th order Butterworth.

This system, in theory, is reasonably complex. Since there are so many parameters to consider we built a simulated system which would allow us to predict limit frequency, rectilinearness, and filter type.

Elimination of Phase Modulation

This proposed system provides yet another important quality. If the two drivers are mounted back-to-back you achieve a cancellation of the vibrations caused by Newton's Third Law: For every action there is an equal and opposite reaction. In other words, for every movement of the cone, there will be an equal attempt to move the driver frame in the opposite direction. This movement, in conventional speaker designs, causes resonances in the cabinet which are transmitted to all other components in the system, causing phase modulation of their response. This is especially true with the high frequency driver. This very measureable type of distortion is one common cause of poor stereo imaging and indistinct localization. To reduce this modulation, speakers can be mounted on rigid spikes which are attached to the floor. Another possible solution is to build an enclosure with very high mass, such as one made out of concrete, where the ratio of cabinet mass to vibrating mass is high. In both cases, vibrational unterference is dramaticaliy reduced.

With the DALI design, counteractive vibrations are negated at the point of connection of the two woofers. The two drivers are solidly connected to each other, cancelling out the vibration at the point of attachment. This prevents transfer to the cabinet and any possible phase modulation. This L linkage is a much more elegant solution than using concrete cabinets, and provides a vibration-free enclosure.

While this worked effectively in theory, the L linkage was difficult to carry out in real loudspeaker systems. To begin with, DALI engineers had to develop a very powerful magnet assembly to drive a four layer voice coil. This created problems with inductance, which became so strong we had to incorporate an inductance-cancelling aluminium ring to isolate the voice coil and absorb eddy currents. We also chose a thin netting to cover the coil area instead of the more typical dust cover. This is because the woofers need a very efficient "breathing" capacity due to the extremely long excursion (over an inch or 2.6 cm) which can be achieved with this system.

Smooth Sound Radiation

With the bass section optimized, we turned our attention to the other factors in the system response. We knew from our own research and from the work of other leading acousticians that radiation patterns are very critical in determining the overall sound quality of any speaker.We knew that we wanted the DALI40 to have very wide and even sound radiation on the horizontal axis and limited but well-defined dispersion throughout the vertical plane.

Radiation on the horizontal level is a product of using speakers with the correct size and using a crossover whose asymmetrical performance correlates to the cone dispersion properties. Radiation on the vertical axis is more complicated. Here side by side drivers show distinct interaction which is dependent on wavelength and crossover design. We, therefore, chose a symmetrical geometric arrangement, with the tweeter positioned between the two midrange/bass drivers. This allows even dispersion, with controlled coverage on the vertical axis. By limiting this vertical radiation, we minimize reflected sound from the ceiling and floor. The much wider response on the horizontal plane allows the system to be as "-room friendly" as possible, without a great deal of variation across a wide listening window. This allows the DALI 40 to be consistent with Floyd E. Toole's findings that the best sounding loudspeakers are always those which have an even radiation pattern, without peaks or dips in the off-axis response.

New Materials in the Midrange System

The midrange response is the most important characteristic of any loudspeaker system. If this section is not well designed, well balanced sound is almost impossible to achieve. In view of this we spent a lot of time designing the midrange system in the DALI 40. This is due, in part, to the tremendous response capability of the woofer section.

Midrange performance starts with the bass drivers. With a crossover frequency of 450 Hz, much of the fundamentals are reproduced by the low frequency units. For that reason we experimented with new materials for the woofer cones. We experimented with paper pulp cones with different surface treatments, and various polypropylene materials, and finally selected a polypropylene material 1 mm thick. This yielded a driver with plane pistonic characteristics to 800Hz and a first breakup mode at about 1000 Hz – approximately one octave above the crossover frequency.

In determining the cone material for midrange drivers themselves, we considered the critical characteristics of stiffness, density, and damping. In the chart below, stiffness is referred to as Young's Modulus, density is given as the material weight per cubic meter, and the damping through the internal loss. The chart below includes the properties of three commonly used cone materials, plus a new material which is called TPX.

Material	Young's Modulus	Mass	Inner loss (1/Q)
Paper	6.5E10⁸	799	0.05
Polypropylene	15.5E10⁸	890	0.09
Titanium	1100E10⁸	0.002	
TPX	32.0E10⁸	830	0.29

As is evident from the above data, TPX is not only lighter than polypropylene, but also much stiffer, and with better damping. The figures for titanium, in contrast, show it to be very stiff, but also very heavy and with poor damping characteristics. This explains why this metal material is used mainly for tweeter diaphragms. Titanium due to poor damping of breakup modes, relies on perfect diaphragm movement, and cannot be considered a good material for midrange cone material. To select the proper midrange cone material, one has to consider the way that this critical element works to produce sound. Energy transfer occurs from electrical impulse which becomes mechanical energy at the cone connection. This energy is transmitted to the air at the surface of the cone, becoming sound waves, much as the wagging of a rope on the ground produces waves throughout its length. Cone oscillations run from the bottom of the cone to its termination at the suspension and findly set air molecules in motion. Ideally, the angular velocity of the cone will match the velocity of the airwave. Only that will allow the propagation of a smooth wavefront.

TPX provides these ideal material characteristics. The sound velocity of this material is approximately 650 m/s, and, contrary to other types of material, has fine frequency independence. This allows very low distortion. And, since TPX is lighter than polypropylene, it has excellent impulse response and greater efficiency than other materials. But, going back to the rope analogy again, at the end of the wave's travel down the rope it produces a small flick of the end. This also occurs in speaker response, causing unwanted radiation from the edge of the cone either back down through the material or into the air. In either case it causes distortion of the primary signals.

This is where a superior suspension material was required for the DALI 40. The midrange in our new system uses an edge suspension made of Norsorex, which is a mixture of rubber and oil. Depending on the mixture proportions, Norsorex can provide extraordinary damping properties. In fact, if you had a ball made of Norsorex and let it fall to a stone floor, it would land completely flat, without any bounce! Norsorex is simply capable of absorbing a lot of energy, which makes it so well suited as an edge suspension material. It also has a sound velocity which is very similar to TPX. Like TPX, the mix is balanced so that sound velocity remains consistent at all frequencies.

The midrange used in the DALI 40 also has an unconventional look. If, instead of a dust cover, the pole piece is extended outward infinitely, in theory, then radiation is perfect. Since this extension is impossible to achieve, we experimented and found the ultimate design which simulates infinite extension. It also optimizes the ability of the cone to breathe properly, without the interference of air trapped under a dust cover.

The Tweeter

The DAL1 40 uses a 1" dome tweeter. It's been our experience that the tweeter is perhaps the most elusive component in the system to design. Often they are built around a theoretical design principle which can't be manufactured to uniform quality.

Tweeter performance is largely determined by the amount of energy of the magnet system, the mass of the moving system, and the radiation pattern. It is usually possible to determine the mass and power of the magnet from calculations, with radiation being a function of the shape of the cone and the type of front plate used. By using a front plate with a short horn, for example, you can create an impedance transformer which helps emphasize radiation at certain frequencies, but with the loss of some directivity. For the DALI 40 we chose a tweeter with a flat front plate, which, due to dome treatment and cone form, is able to produce extremely even sound radiation – one of our key design goals with this system. There is also a lot of experience in the manufacturing of this type of tweeter, which allows consistency. DALI takes great care in the selection and matching of each tweeter used in the DALI 40 system.

The Crossover Network

The crossover design for the DALI 40 is the product of our design goals of wide, even radiation patterns. In addition to even frequency response on-axis, we also wanted an even radiation pattern well off-axis. This was achieved by using asymmetrical crossover slopes which complement the radiation pattern of each driver. This allowed optimum dispersion throughout the entire operating range of the system. It was also achieved with a minimum of crossover devices, since we found that the more devices used, the more the system sound quality changes. By using only the required amount of components to achieve the type of response we wanted the DALI 40 to have, we are also able to closely control the quality of the devices used. The components in the crossover are of very close tolerance performance and are the finest currently being made. We were also able to determine, through extensive listening tests that certain types of components worked well for one thing, and others worked best in other applications. For that reason we use very expensive metalized capacitors for both the midrange and polypropylene tweeter section. The crossover also contains level controls to regulate bass, midrange, and treble.

The Cabinet

Just as all component design areas have received a great deal of attention, so too is the cabinet design well thought-out and innovative. The cabinet is constructed as four separate chambers, which means standing waves are easy to control and minimize. These chambers also prevent intermodulation distortion, and give the entire cabinet great structural integrity. In addition rounded aluminium corners make for a very rugged and durable enclosure, and also help reduce any spurious cabinet resonances. And, of course, the unique combination of anodized aluminium, noble woods, and glass make the DALI almost as impressive to look at as it is to listen to.

SPECIFICATIONS

Cabinet type. . . . . L-linkage VEB2R bassreflex
Drivers:
- Woofer . . . . . 4x 8" very long stroke
- Midrange . . . . . 2x 4 1/2" TPX with floating spider
- Tweeter . . 1" dome with impedance matched rear chamber

Frequency respone ±2dB. . . . . 25 – 20.000 Hz
Harmonic distortion (5W) . . . . . < 0,3%
Listening window ±2dB. . . . . 170° horizontal
15° vertical
Crossover network. . . . . Linear Directivity
Impedance . . . . . 4 ohms
Sensitivity . . . . . 89dB /1W/1m
Recommended amplifier
power ratings. . . . . 50 – 500 W /channel
Dimensions:
- Height . . . . . 49 in (124 cm)
- Depth . . . . . 19 in (48 cm)
- Width . . . . . 15 in (38 cm)
- Weight . . . . . 68 kgs

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