MRS™

Maximum Radiating Surface™ Flat-Panel Transducer

Infinity®

Technology • Performance • Design

The Challenge

The requirements for designing and building loudspeakers are dramatically different from what they were even a decade ago and present several new challenges, both technical and aesthetic. The days of monolithic loudspeakers requiring a large percentage of a room's floor space are gone. Today's customers are demanding architecturally friendly designs that will blend with and even disappear into their homes. However, at the same time, the loudspeakers are being asked to do more and more. Today, a speaker system is not only expected to play music from a CD, but also is typically used for movies, TV and video games. Customers also want to connect their portable music devices such as the iPod® to play through their home loudspeakers. This produces an interesting conundrum in the marketplace. Consumers are demanding that their loudspeakers do more – and often appreciate improved performance – but, on the other hand, want them to only minimally intrude into their living spaces.

The challenge for Infinity is to introduce attractive loudspeakers that easily blend into a wide range of home décors while not compromising Infinity's hallmark sonic performance in any way. The Infinity Cascade™ series is the first, beautiful result of this unique challenge. Each Cascade model is designed to be slim and elegant, while delivering superlative sonic performance.

The Technology

Typically, new technical developments have influenced the final visual design of a loudspeaker. For example, if a newly developed driver was 6" in depth, the enclosure was designed around the driver's requirements. We employed a slightly different approach. Knowing that any future designs would require the thinnest possible drivers to work with slimmer and more compact enclosures, our engineering team began development of a radical new transducer design that would be far thinner than previous designs and would also offer improved performance. The key requirements of this driver were…

- Very thin form factor
- Flat broadband frequency response
- Uniform dispersion, both on- and off-axis
- Delivery of high output levels with a minimum of breakup and power compression

Developing the Maximum Radiating Surface™ (MRS™) Flat-Panel Transducer

CONVENTIONAL-CONE TRANSDUCERS

We began by examining the advantages as well as the disadvantages of conventional-cone transducers. Conventional-cone drivers use the force from a tubular voice coil immersed in a static radial magnetic field to energize a cone-shaped diaphragm. The static magnetic field is maintained by a magnetic loop driven by permanent magnets. As current from the amplifier flows through the voice coil wire, a magnetic field that interacts with the static magnetic field is generated, causing a mechanical force along the axis of the voice coil. The direction of current flow through the coil determines the direction of the mechanical force.

Conventional-cone transducers have been around for a long time and there's a good reason for this. The design and manufacture of conventional-cone-type drivers is a fairly well-established process, allowing loudspeaker designers to achieve specified performance goals in a reasonable amount of time and at a reasonable cost. Conventional-cone transducers can certainly meet the high performance standards required. However, the height of the cone diaphragm and surround, as well as the stacking of the motor components, causes this type of device to fall short of the depth requirements.

ELECTROMAGNETIC INDUCTION TRANSDUCERS

Next, we revisited Infinity's vintage electromagnetic induction (EMI) transducers. This driver design utilized a thin, rectangular sheet of plastic with a flat, aluminum coil etched on its surface, suspended between sets of powerful samarium cobalt magnets. As electrical current flows through the coil, the induced magnetic field interacts with the stationary magnetic field created by the magnets. This causes the diaphragm to move and energize the air around it. The essential feature of Infinity's EMI tweeter (EMIT™) and EMI midrange (EMIM™) was that a flat radiating diaphragm is uniformly driven across its surface. This causes all points on the diaphragm surface to vibrate in phase, thus reducing the propensity of the diaphragm to exhibit resonances or breakup modes.

EMI devices are able to meet the "thin" goal but fall short when held to the "no compromise in sonic performance" goal. Although innovative at one time, EMI transducers have some performance limitations. They are inherently inefficient devices and are incapable of making the mechanical excursions necessary to reproduce lower frequencies with adequate acoustic output and low distortion. EMI devices also suffer from having coils with low thermal mass, making them prone to thermal-induced compression and failure.

MERGING CONVENTIONAL-CONE AND EMI TECHNOLOGIES

Since EMI devices meet our "thin" goal and conventional-cone transducers meet our "performance" goal, the natural question was how we could combine the two technologies in order to achieve both goals.

The most logical approach was to combine the flat diaphragm aspect of the EMI transducers with a variation on conventional loudspeaker motor technology. Replacing the more familiar cone-shaped diaphragm with a flat diaphragm reduces the depth of the device. However, using conventional motor technology has allowed us to overcome the mechanical excursion and thermal limitations inherent in the EMI device.

The result is the patent-pending Maximum Radiating Surface™ (MRS™) flat-panel transducer, which offers the strengths of both technologies with the weakness of neither. Our engineers were able to combine the two technologies and add a few more to truly optimize the performance of the new device.

About the MRS™ Flat-Panel Driver

There is no question that there were many factors that influenced the decision to pursue a flat radiating diaphragm for our new transducer. But, again, the primary advantage of the flat diaphragm is that it allows us to reduce the overall depth and mounting requirements of the transducer relative to a comparably performing conventional-cone driver, with respect to radiating surface area.

BETTER-SOUNDING AND MORE ATTRACTIVE, TOO

A further advantage to using a flat-panel diaphragm is that its rectangular shape allows us to maximize the useful sound-radiating area on the front of the speaker enclosure. While most loudspeaker baffles are basically rectangular, the radiators mounted on them are circular. This leaves a lot of "wasted," or dormant, space on the baffle which, while contributing to how big and boxy the speaker looks in your room, actually does very little to contribute useful sound. Maximizing the ratio of radiating surface area to baffle area allows higher levels of sonic performance from enclosures that do not dominate your room.

Once again, Infinity is changing the shape of sound by applying innovative **technology** in loudspeakers that deliver superb **performance** from attractive, slender and striking **designs**.

Infinity®

Technology • Performance • Design

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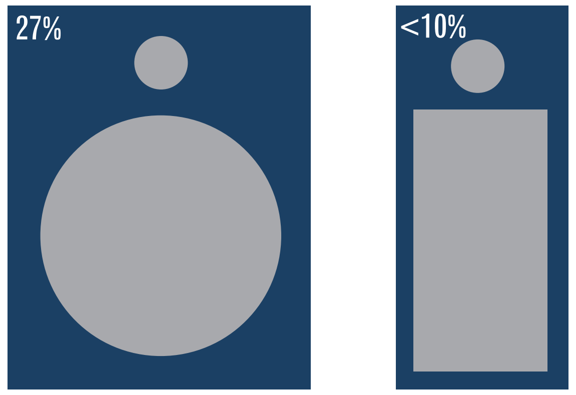


Wasted Baffle Area
Useful Sound-Radiating Surface

CONTROLLED DIRECTIVITY

As with nearly all decisions related to loudspeaker design, each design choice made for one parameter may influence other parameters. While choosing a diaphragm shape that makes the speaker system's appearance more aesthetically pleasing is a good thing, it will often have consequences related to how the speaker sounds. The shape of a loudspeaker cone or diaphragm is a major factor in defining the directional characteristics of a transducer. Putting a physics lecture aside, it can be simply stated that in most cases, at a given operating frequency, a smaller diaphragm will have a wider radiating pattern than a larger diaphragm. This is one of the reasons why high-quality loudspeakers use multiple drivers (woofers, midranges and tweeters). A large-diameter woofer would not be suitable for mid- or high-frequency use, due to its propensity to become too directional at these frequencies.

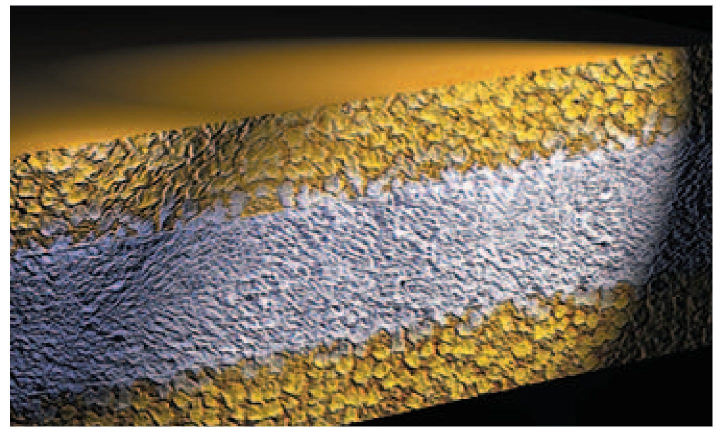
The aspect ratio of the Infinity MRS™ flat-panel diaphragm makes the diaphragm small with respect to width and larger with respect to height. While having the same radiating surface area of a round 6-1/2" woofer, the MRS driver has a horizontal radiating pattern, similar to a 3-1/2" midrange. This contributes a very wide and smooth radiating pattern in the horizontal plane, providing exceptional imaging and soundstage presentation to listeners throughout the room. The height of the flat-panel transducer tends to project a narrow vertical radiating pattern into the listening room, which reduces the detrimental effects of floor and ceiling reflections. The result is exceptional imaging and soundstage presentation across a large listening area, from a compact loudspeaker.

THE DIAPHRAGM MATERIAL

Optimizing the parameters of a flat-panel diaphragm in a loudspeaker presents quite an engineering challenge. Conventional-cone-shaped loudspeaker diaphragms are typically energized by the force generated by a cylindrical voice coil interacting with a static magnetic field. The voice coil is constrained around its perimeter by a corrugated diaphragm (spider) which limits its axial movement at the extremes, and also ensures that the coil stays well centered in the magnetic gap. Mechanical force generated by the coil is applied to the apex of the cone.

The force from the voice coil alternately pushes and pulls one end of the cone, while the other end interacts with the restoring force provided by the surround. Interaction with the surround can cause reflected waves to travel back down the cone toward the voice coil. The net effect of the "outgoing" and "incoming" waves will be some mechanical standing waves or interference pattern distributed along the walls of the cone. These in turn produce unwanted acoustical anomalies from the speaker. This effect is called "cone breakup" and causes frequency response anomalies which act to color the sound of a loudspeaker.

Selection of an appropriate diaphragm material and optimizing the diaphragm/surround interface is the first step to controlling the unwanted "breakup" problem. The theoretically ideal choice for a diaphragm would be a material that possesses zero mass and infinite stiffness. Zero mass would allow the highest electro-acoustic efficiency (the most sound out of your speaker for each watt of amplifier power) and infinite stiffness would prohibit cone breakup. These considerations made Infinity's patented Ceramic Metal Matrix Diaphragm (CMMD®) material a natural choice for our flat-panel diaphragm.



CMMD cones consist of a stiff aluminum core, deep-anodized on both sides (alumina) for increased strength and rigidity. Naturally, no "real world" material has zero mass or infinite stiffness, but by optimizing the tradeoff between diaphragm thickness (mass) and strength through strategic use of ribbing and gussets along the diaphragm surface, our engineers were able to achieve the best balance of electro-acoustic efficiency and reliability. The stiffness in this arrangement is so high that it pushes the lowest frequency breakup mode outside of the flat-panel transducer's region of operation, thereby making it inaudible.

SHAPE MATTERS

Aside from providing directivity and baffle size advantages, the shape and size of the diaphragm used in the flat-panel transducers help to reduce cone breakup or flexing. Reduced cone breakup results in a driver with significantly lower distortion.

The shape of the venerable "cone" transducer results in a certain amount of stiffness. The shallower a cone-shaped diaphragm is, the more likely its walls will flex and bend when force is applied to its apex. This is readily demonstrated by using the tip of your finger to push the center of a sheet of paper. Compare this to pushing at the apex of the same sheet of paper rolled like a cone. This would indicate that the use of a flat diaphragm could be problematic. The solution was to increase the area of contact between the edge of the voice coil and the radiating diaphragm. This was done by adopting a variation on conventional loudspeaker motor design to energize our new flat diaphragm. Our engineers utilized two large, elliptically shaped voice coils to uniformly couple and distribute motor force to the surface of the new flat diaphragm. Distributing the mechanical driving force over a larger area over the diaphragm produces a more uniform application of motor force across the surface of the diaphragm and greatly aids in overcoming the inertial effects of the distributed mass of the diaphragm.

To further decrease the likelihood of diaphragm breakup, gussets and raised ribs were added to the diaphragm. The ribs increase stiffness along the length from which they are drawn. They further help to distribute and decouple energy from the voice coils on the rear of the diaphragm. The gussets reinforce the edge along the outer perimeter of the cone to the point at which the surround is attached. Both the ribs and the gussets are placed along the height of the diaphragm at non-harmonically related distances, in order to distribute the effects of any flexural tendencies to different frequencies, rather than one.

The net result is that the diaphragm moves very nearly like an ideal pistonic radiator, with all points moving together and in phase.

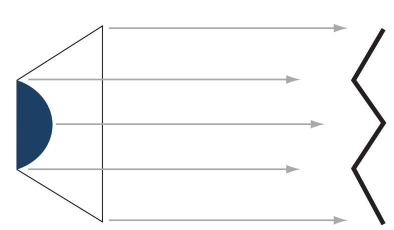
CORRECT TIME ALIGNMENT

Another method used to combat cone breakup is to engineer the driver so that it is "uniformly driven," meaning the panel receives the electrical signal across its entire radiating surface.

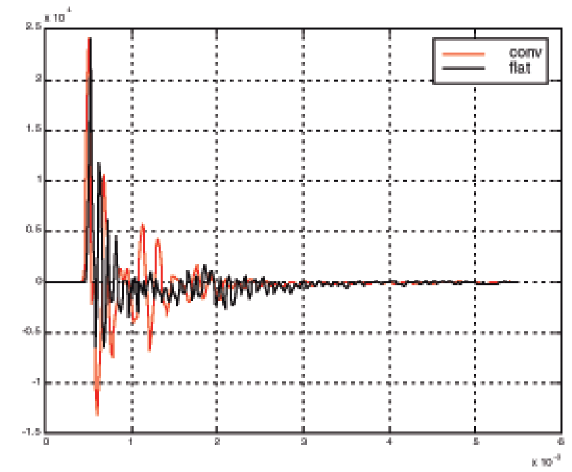
A transducer diaphragm where all points move together and in phase results in less "time domain smear" when compared to conventional-cone transducers.

INFINITY MRS
FLAT-PANEL TRANSDUCER

CONVENTIONAL CONE



Differences in path length related to cone geometry (between signals arriving from the center and outer edges of the cone) cause a "smearing" of the arrivals in the time domain (see plot).



This can be seen by noting the width of the impulse response. Note that the flat-panel diaphragm results in a more concentrated pocket of arrivals compared to that of a cone diaphragm. This helps the Infinity MRS transducer deliver exceptional resolution and detail when compared to conventional transducer systems.

SUSPENDING THE DIAPHRAGM

While developing our low-profile transducer, our transducer engineers needed to think beyond the traditional geometries that have existed between the cone, spider and surround.

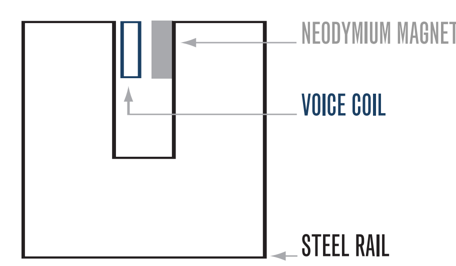
An examination of a force diagram for conventional-cone/spider/surround geometry shows that the location of the interface between the outer edge of the cone and the surround, in relation to the point of application of force from the voice coil, acts as a 'fulcrum' to amplify differential force distributions resulting from small differences in mass distribution. This instability can cause the cone to rock back and forth when it moves. This phenomenon resembles a cork riding on a series of waves in a pond. Ultimately, this can cause the voice coil to scrape the top plate and buzz. Given that typical production tolerances in materials, as well as the manufacturing process, contribute to small differences in the distribution of mass around the moving assembly, this can present audible problems.

Infinity engineers recognized and designed a means (patent pending) to minimize this. By moving the interface between the cone and surround into the same plane as the driving force from the voice coil, the mechanical instability – as well as the cone's tendency to rock – is minimized.

This new innovation is so effective that Infinity's MRS flat-panel transducer does not need the conventional spider to keep the voice coil centered in the gap. The same-plane surround limits excursion at the extremes, as well as keeping the cone and coils well centered at all times.

The Motor Assembly

Our primary design goals placed two primary constraints on the choice of motor for the MRS flat-panel transducer. First, the motor structure could not be a significant contributor to the depth of the transducer. Second, the motor needed to be capable of producing relatively high mechanical excursion with minimal distortion and thermal compression.



Neodymium was a natural choice for the magnet structure. A neodymium-based motor structure offers high magnetic energy in a compact, lightweight package. Neodymium is also inherently magnetically shielded and does not require additional bucking magnets or shielding cans in order to be safely used near a video monitor.

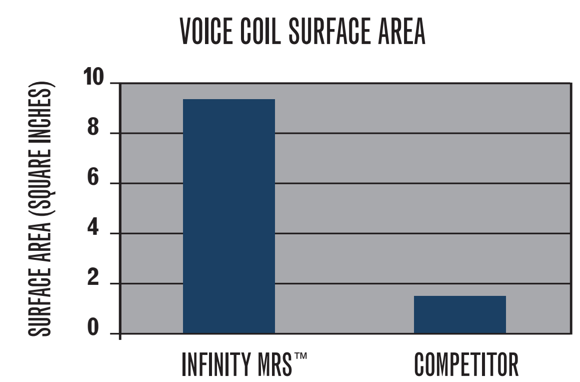
The rectangular neodymium slugs are located along the inside of the top edge of low-carbon steel "U-channel" rails mounted vertically within the transducer's frame. The combination of this motor geometry, neodymium magnets and low-carbon steel rails results in very high magnetic circuit efficiency. Furthermore, the overall height of the magnetic circuit is minimized and is engineered to fit within the structure of the transducer frame.

THE ELLIPTICAL VOICE COIL

The use of elliptically shaped voice coils allows for maximum contact area between the coils and the diaphragm, as well as placing more wire in the static magnetic field.

As a point of comparison, a typical system using a 6-1/2" woofer might have a 1-1/2"-diameter cylindrical voice coil with 4-11/16 linear inches of voice coil edge contacting the cone. The unique, elliptically shaped voice coils used in each Infinity flat-panel transducer have a voice coil edge-to-diaphragm contact length of nearly 30 linear inches – more than 6x that of a typical cone transducer. The combination of greatly improved diaphragm-to-motor coupling and use of our patented CMMD diaphragm ensures that the Infinity MRS driver functions more like a true flat piston. This results in crystal-clear sound and resonance-free operation throughout the operational range.

The advantages offered by our dual elliptical voice coils go beyond the diaphragm to include motor coupling. The dual elliptical design provides a greatly increased coil surface area over conventional designs. It is important to note that the surface area of a transducer's voice coil is directly related to how much electrical power can be dissipated. When power is applied to a transducer voice coil, heat is generated. Most consumer loudspeakers operate with electrical-to-acoustic efficiencies of less than 5%. This means that for every 100 watts of electrical power your amplifier produces, your speakers will dissipate 95 watts as heat. As a voice coil's temperature increases, thermal compression sets in. As a result, the dynamic range capability of a speaker system is dramatically reduced.

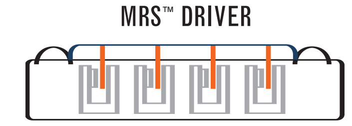


The MRS design yields 9 square inches of voice coil surface area, as opposed to 1-1/2 square inches in a conventional driver, allowing a large power-dissipating surface area and helping to keep the coil cooler at a given operational level. The result is improved transient response and dramatically less thermal compression than what is found in traditional designs. In short, the MRS driver reproduces music and movie soundtracks with more clarity and dynamics, as well as less distortion.

RESULTS

A comparison of cross sections of an MRS flat-panel transducer and a conventional-cone transducer, with similar radiating area, is shown below. The reduced depth of the Infinity MRS transducer relative to a conventional device is clearly shown. Goal number one ("thin") has been achieved. This allows the use of the MRS driver in visually striking loudspeaker designs. Most important, measurements and listening evaluations confirm that all the sonic goals have been met, resulting in unsurpassed sonic performance.

MRS™ DRIVER



CONVENTIONAL-CONE DRIVER