Eos HD *featuring our new CopperMatrix™ wire from Marigo Labs*

New Technologies Plus Refinements Equals Eos HD

My Design Concept, by Roy Johnson, designer, Green Mountain Audio, Inc.

I KNEW THE MATHEMATICS behind our award-winning, two-way Callisto were unassailable, and that its audible performance confirmed the calculations on all music and soundtracks. However, portions of that math continued to speak to me about deeper and more refined relationships between the drivers, cabinet, crossover circuit, and the room -- relationships that were even more interdependent.

Those portions showed that certain, highly-curved cabinet shapes would allow the speaker to further dissociate itself from what we hear. The first challenge was that some shapes could not be produced. Other shapes would interfere with mounting the tweeter out in the open, away from the large cabinet face. Another issue was that for the tweeter to blend even better with the woofer, technology needed to significantly reduce its moving mass and provide a far softer suspension. No such tweeter existed. Three years later, the simplicity of the Eos HD belies how those challenges were met.

Selecting the drivers

In general, a two-way speaker's woofer and tweeter must perform to the highest standards over the widest possible frequency range, to better blend into one source of sound for the ear. Small speakers in small rooms also need to have full musicality and produce front-row performances at the softest volumes. The speaker's compact enclosure requires any rear-wave absorption to be efficient and quick. The bass output must be satisfying without a subwoofer. The crossover circuit inside should be as simple as possible, with parts chosen for the

greatest clarity, efficiency, and musicality as well as for time-coherent signal delivery to the drivers. The cabinet must be rigid and well damped with an external body shaped to cause the least reflections -- so its presence is not heard.

The woofer I selected for the Eos is the fourth generation of the same unique one I used in the Callisto, Europa Max, Europa, Aperture, and Continuum 0.5. While improvements in its performance have been subtle over the last 10 years, today it is even more unsurpassed in its wide, smooth frequency response and ability to play both loudly and softly. At all times, its patented neodymium magnetic structure creates a powerful and uniform magnetic field around the underhung voice coil, which allows it maintain complete control of the coil no matter how hard the small cone strokes. Its highly flexible suspension allows both very small and very large cone motions.

The featherlight yet rigid carbon-fiber and wood-pulp cone produces the naturally extended, high-voice and low-treble range necessary for the smoothest blending to the tweeter. Although it does not look like some of the other high-tech toys in the market, this woofer is just as much of a high-tech engine as the sassy but hidden parts in a high-performance race car. Make no mistake -- it is so efficient with its light cone and powerful magnetic field -- you will wonder where the subwoofer is located.

The tweeter is the other powerful engine I selected. It does not depend upon nearby cabinet-face reflections to deliver a uniform output across its frequency range. Most do, however, and their reflections smear the sound, especially when music and soundtracks become complicated.

We prevent reflections off the front surface of this tweeter with 100 percent wool felt of the correct softness and fuzziness necessary for absorption. The non-symmetric arrangement of felt around the dome ensures all wavelengths are equally absorbed and that an acoustic shadow is cast downwards onto the woofer cabinet to prevent even more reflections. To better reproduce the highest treble, the Eos HD tweeter's treated-fabric dome has 30 percent less moving mass than what was installed in the Callisto. Its response now extends smoothly beyond 30kHz -- quite rare for a fabric-dome tweeter.

Metal-dome tweeters continue to have ultrasonic resonances which affect the music, and most of those domes do not have suspensions that permit the extremely small motions required of any tweeter. To permit those motions, a proprietary, unusually soft polymer suspension was developed for the Eos HD dome. Also, the ferrofluid surrounding its voice coil is the latest generation with its viscous and thermal properties selected for the best balance between heat dissipation, transient response, and damping.

A large chamber behind the Eos HD dome is cast from a low-resonance, non-magnetic zinc alloy and filled with absorption materials that more quickly dissipate the sound pressures behind the dome. As the tweeter is mounted into its Q-Stone™ cast marble enclosure, dense wool felt is compressed against the tweeter's chassis to further damp any remaining high-frequency vibrations. The front plate is precision-molded of a plastic reinforced with glass fiber for strength, its lack of magnetic interaction with the voice coil, and minimal resonance.

Determining the shape

The cubic inches required behind the woofer were previously known from Callisto. For Eos HD to improve upon that model, more complex exterior shapes were evaluated -- ones the mathematics indicated as even more favorable to reducing voice-range reflections but which were more complicated to produce as masters for our Q-Stone™ molds. Some shapes compromised the enclosure's interior acoustics. Others could not be molded. The final shape emerged from also knowing an enclosure's external size can be either too small or too large. The ideal shape varies from bass to treble, because we respond to reflections off of it differently in each tone range.

For the lowest bass tones, a cabinet needs to 'get out of the way' as fast as possible because each cycle of a low-bass tone lasts long enough to wrap around the cabinet and reflect off the wall and floor before the woofer finishes its first stroke. What we hear is always 'more low bass,' not 'reflections.' When an enclosure is 'too small' on its front, then tones from the high bass up to the low-voice range also wrap around it to then reflect strongly from the wall behind. When those high-bass and low-voice tones come back from that wall, they cancel the main sound and we hear a 'thin-sounding' speaker, also overly sensitive to placement. On the other hand, when an enclosure is 'too large' on the front, the tones of the main voice range and low treble reflect strongly from it, causing audible smearing and a narrowing of the listening window.

Up in the highest treble, any tweeter sends out sound only into a portion of its front hemisphere, so those tones never reflect off of a cabinet surface or even a tweeter's faceplate. The tones between the lowest bass and highest treble are the ones that reflect in ways that make a speaker sound like a speaker instead of the real thing. For the Eos HD, more complex curves to the exterior would reduce voice-range and low-treble reflections compared to Callisto's more gently curved shape. The size of Eos HD's enclosure is just small enough to allow the lowest bass tones to escape around it, to be smoothly reinforced by the room's nearby surfaces. It is just large enough to block the high-bass and low-voice tones from escaping to the rear by reflecting them off the front face so soon that we do not hear them as reflections but as 'proper tone balance,' no matter where the speaker is placed.

The front panel's broad curvatures diffuse upper-voice reflections down and away from listeners. The strong curvatures of the sides reduce reflections of the rest of the voice range and on into the low treble, including all the sounds coming back to these sides from the room itself. Eos HD thus 'disappears' even more than Callisto at any listening position. The sound is even more 'wide open' and room filling, especially when one is off in the kitchen. As in

Callisto, this external shape allowed an asymmetric, six-sided profile to be created for Eos' interior, reducing interior reverberations and providing the variable wall-thicknesses that reduce what is called 'shear-wave' transmission of sound into the Q-Stone™ marble.

The bass range...

Callisto's twin ports were on the bottom of its enclosure but the Eos HD ports are located on the front. While this did not appreciably change the low-bass loudness coming from the ports, it did improve the impact of the bass because this positioning allowed room for a new aerodynamic design of the ports' intakes.

First, it was important that any front-panel location of these two ports could not reduce the surface area necessary for proper reproduction of the high-bass and low-voice ranges, as described above. The best location on the front was low and apart, but that would place their intake ends at positions unfavorable to picking up bass pressures in the enclosure all at once. While angling them upwards and inwards would solve that issue, it remained that two port openings inside always create more turbulence than one. The solution was to angle them upwards and inwards to the right pressure zone inside and merge their openings into one large, aerodynamic intake. We call this our Bi-Port™ design. It collects bass pressures with greater efficiency while minimizing turbulence. Also, the shape and position of the port assembly interrupt the formation of top-to-bottom standing waves, for the best possible clarity in the upper-bass and lower-voice ranges. The Callisto's tubes helped scatter the middle-range tones behind the woofer for better absorption into the acoustic linings. However, the Eos HD is deeper to allow more absorption materials to be placed behind the woofer.

...the middle range...

It is easy to hear when a speaker has flaws in the voice range because we are so familiar with the sound of a human voice. Several factors are responsible for making the clearest possible voice range and a smooth transition from woofer to tweeter. The woofer must produce a uniform response throughout the voice range and into the low treble. The woofer has the very rigid and light cone required for this uniform, low-distortion response. The voice coil behind this cone is also extremely light. The shape was sculpted to reduce voice-range reflections from its surface in all directions. The shape of the Eos HD interior, the size and location of the Bi-Port™ assembly, and the placement and amount of absorptive materials act together to very quickly absorb all sounds behind the woofer down into the low bass, allowing no resonances at any frequency.

...and the treble

The Eos HD tweeter sits in its own sealed, Q-Stone™ chamber mounted above the woofer enclosure to isolate it from the woofer's sounds, and more importantly, allow the tweeter's sound to expand more freely into the room. The sound heard is more 'wide-open' and the treble more easily travels throughout the home. As with Callisto, dense felt is compressed against the rear of the chassis to damp any remaining vibrations.

Engineering the crossover circuits

When we look at how to blend the woofer and tweeter together, each must first deliver its frequency range smoothly and widely, so that all the sounds spread evenly throughout the room. If one could ask a perfect woofer cone to also be a tweeter, then all the treble from it would project straight ahead like a very narrow flashlight beam. A listener would hear treble only from one best seat; the rest of the room would receive no treble at all. Sitting in that best seat, the sounds coming back from the room would be very 'dark,' or muffled. No recordings would sound 'right' by anyone's standards. That is why a tweeter has to be small -- to project the treble widely. It is also why a woofer has to be larger -- for bass output -- but not too large in a two-way speaker or the upper

voice-range will be projected too narrowly. The crossover circuit divides up the musical spectrum to provide that wide coverage. Our circuits also allow the sounds from the woofer and tweeter to recombine at the listener's ear into the one original wave. This results in 'time-coherent' delivery of their sounds.

Tweeter crossover

The Eos HD tweeter operates from 2,900Hz to beyond 30,000Hz, which means it takes over from the woofer right in the critical 'ess' and 'tee' part of the voice range. Below 2,900Hz, our simple crossover circuit gently rolls off its lower-range response at a rate of 6dB per octave. This gradual rolloff is a by-product of the only circuit which will simultaneously send its signals to the tweeter and woofer, making them move as one unit. The result is 'time-coherent' delivery of their sounds -- a behavior that is very rare in speakers because it is difficult to engineer and can only come from this type of simple crossover circuit. A tweeter used with this simple circuit must then have an extended stroke so it can move freely without distortion. This requires it to have a very flexible suspension around the dome and a very focused magnetic field encompassing its voice coil to control that extended motion. We are fortunate that the Eos HD tweeter is so linear in its operation and so well-behaved that the entire crossover circuit feeding it consists of one, super-premium capacitor coupled with a small bypass capacitor. There is no printed-circuit board to add resonances and impure conductors. One end of that main capacitor is crimped firmly to the positive binding post. Its other end is twisted and soldered to the wire running directly to the tweeter's positive terminal. The return wire is identical but connected directly to the negative binding post. A finely-tuned Zobel network in parallel with the Eos HD tweeter makes the tweeter appear as a simple resistor to the capacitors. Without it, a tweeter presents a different resistance (impedance) at each frequency, which affects how any crossover circuit operates and also changes the load on the amplifier at each frequency, increasing its distortion. All connections are soldered with a formulation that sounds cleaner and clearer than any other we have used. With these few circuit parts, no cabinet reflections, and such a low-distortion tweeter, it is easy to hear the differences made by the type of wires, capacitors, binding posts, and solder. Can we explain the differences? Not entirely, but they are definitely audible.

Woofer crossover

The woofer operates from the low bass to well past 5,000Hz, facilitating a smooth transition to the tweeter at 2,900Hz. The rate of rolloff at 2,900Hz is 6dB per octave from a very simple crossover circuit -- the only circuit which allows the woofer and tweeter to move together. This woofer is so linear in its operation and so well-behaved that the entire crossover circuit on the way to it consists of one small, Litz-wire, oxygen-free-copper inductor to keep out the highs. A properly-tuned Zobel circuit makes the woofer appear to be a simple resistor for that single inductor.

Our Balanced-Phase™ circuit design

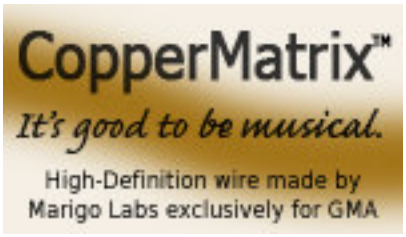
One final point about our simple, 'first-order' crossover circuit. Any crossover circuit can be thought of, quite accurately, as a fork in the road for the electrical signals from the amplifier. Since the signals of the high-voice range and treble cannot easily get through the woofer's inductor, they are deflected down the path of less impedance -- through the tweeter's capacitor. If a crossover circuit can be made with only one electrical component feeding each driver, then a very nice thing happens -- the woofer's inductor and the tweeter's capacitor can be

chosen to have opposite impedance curves, or 'mirror images,' exactly as if they formed a 'Y' adapter for the incoming signals. The ideal 'fork in the road' for the signal is a good thing for the amplifier, because it cannot then know that a capacitor or inductor exists. To the amplifier, only one 'path' is apparent, and it sees no stored energy returned to it. The measure of this is a 'flat impedance curve' for the entire speaker. The Eos HD appears to the amplifier much like a 4- to 5-Ohm resistor at most every frequency, which allows any amplifier to deliver its power with the least distortion. Long speaker wires may be used, since they will have less effect on the sound.

Our exclusive CopperMatrix™ wire from Marigo Labs

In the Eos HD, we are fortunate to be the first and the exclusive user of a new style of Litz wire developed by the physicist responsible for Marigo Labs products. Each positive and negative wire going to each driver from the crossover circuit is a conductor of 500+ ultra-fine strands of ultra-pure, oxygen-free copper. Each strand is individually coated with a proprietary damping and insulating polymer just millionths of an inch thick. These strands are then wound in multiple layers of differing tensions in a proprietary geometric pattern, with the effect of reduced magnetic-field interaction between layers and proper mechanical damping in both the transverse and axial directions. (Pure metals love to ring sideways and along their lengths -- these wires do not and can not.) The exterior of the entire 18-gauge conductor is protected by multiple threads of a cellulose-derived fiber wound in different directions to provide mechanical damping more so than any known plastic insulation and with far less dielectric effect than Teflon. The finished wire is doubly-cryogenically treated, tested, and marked for signal directionality.

Each of its 500+ copper strands is only about 25 microns in diameter (0.001"). Each wire must first be stripped of its organic-thread insulation and then prepared for soldering by applying a unique organic-salt flux, then immersed in a bath of liquid solder. For any connection it makes, it must first be aligned in its direction. Its solder-covered end is either wrapped tightly with the other wire from say, the capacitor in the crossover, or it is heated and bent around the terminal on the driver. Either way, it is then heated again, crushed into the other wire or terminal, and finally soldered again. This produces maximum contact to all the strands and minimum solder between each strand. Each connection is de-oxidized and strain relieved with heat shrink to last for life.



This wire made such a difference over the excellent-sounding wires we were already using that one could hear it in another room. Livelier on dynamics, but in a subtle way. Each peak was clearly defined and yet naturally rounded, with an edge and coarseness to it removed. The decays of any sound were far more defined than before, with much less 'noise' between each note, yet it was obvious no details were being lost. The timbres of each instrument and voice were more accurate and produced new textures. The power in the music or its subtle grace were much more evident. The improvement this wire made, in what we can most simply call clarity, was so great that we further refined the values and choices of any by-pass capacitors used in the crossover circuits, very small ones placed in parallel with any larger capacitors to (usually) make them more transparent to the signals. The result was even better blending between the drivers and increased dynamic contrasts btween any two signals. The total increase in definition is quite stunning -- hence the High-Definition (HD) identifier.

Achieving the goal

All of my loudspeaker design efforts have one goal in mind -- to provide the correct environments in which the separate sounds may be re-combined at our ears in the same, real-life sequence as they were recorded.