



# Rio

## All Roads Led to Rio

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

PROJECT RIO BEGAN BY CHOOSING THE RIGHT PATHS to follow for its design work. My original investigation was about keeping as much of Eos' sound quality as possible while reducing the cost. However, I had been pushing my soundfield mathematics even farther along, which revealed interesting aspects of how a speaker enclosure's shape and size interact with the nearby surfaces of smaller rooms. So, the guide to making Rio came from answering three questions: 1. How can Eos technology cost less? 2. Can the most important aspects of Eos sound quality be retained? 3. What enclosure size and shape benefits a smaller room the most?



The last question had to come first. To my surprise, the math yielded Rio's cut-crystal look! And I immediately recognized such a compact enclosure left absolutely no margin for error in the casting of its substantial mass in our proprietary Q-Stone™ marble. No one had yet tried to hold tolerances this tight using flexible molds. Darn.

### **Designing Rio's enclosures**

A small speaker is often placed quite near other objects and room walls. Sonic reflections from those surfaces are particularly annoying on some tones, while others only change the tone balance -- which is not annoying, but it is not right, either.

The most irritating reflections happen in the high-voice range and treble. Therefore, Rio's tweeter could not be allowed to radiate fully to its left or right, but instead be made to cut off sharply to the sides. An evolution of the technology used for Eos and Aperture tweeters led to the new pattern of absorptive wool felt placed around Rio's tweeter. It captured all of the highs usually sent to the sides, and up and down as well.

Combined with its 6" woofer's dispersion pattern, Rio 'speaks' far less to nearby surfaces than any other speaker, even Eos, in the voice range and treble. One hears much more of the direct sound, making everything more clear, more musical, and purer of tone.

My soundfield mathematics also revealed the detailed relationship between an enclosure's shape and very-nearby surfaces for tones from the low-voice down into the bass. Across that range, nearby reflections are heard not as a 'splash' as in the highs, but as simply making all those lower tones louder. In this lower tone range, any enclosure's shape and size also act to boost those tones, from having its own surface reflections.

Therefore, a speaker placed in tight quarters will be too 'warm' in tone, because its surface reflections are combining (and driving) the very-nearby room reflections. The solution was a shape of enclosure that 'gets out of the way' even more quickly across that tone range, than does even our Eos.

Much calculation and experiment led to Rio's very narrow enclosure, of particular proportion with sharply beveled edges. Further developments in our casting process allowed us to then mold this simple enclosure in a highly efficient, yet precise manner. This went a long way into reducing the cost for Rio's enclosure, with no compromise to its rigidity or damping. Further research showed how several design factors would allow Rio's tweeter to be mounted in a fixed position. If I was successful, then Rio would cost less and be very compact indeed.

Adjusting the tweeter's position has been necessary for three reasons normally beyond our control: The distance between the speaker and listener, the height of the listener's ears, and the height of the speakers. Adjusting a tweeter back and forth allows its sound to arrive at the listener's ears at the same instant as the sound from the woofer, no matter the position of the listener relative to the speaker. This is called time-coherent delivery and it creates the most perfect blend between the sounds from woofer and tweeter, for the most clarity and musicality -- a hallmark of our designs. However, during the design of Rio it became apparent that its compact size, a certain slope to its front faceplate, and particular inset for its tweeter would accommodate most listener heights and distances. All an owner need do is choose from two speaker stand heights (visit the Specifications webpage for details).

## Selecting Rio's drivers

As with Eos, a two-way speaker's woofer and tweeter must perform to the highest standards over the widest possible frequency ranges, so we can better blend them into just one source of sound for the ear. Rio's drivers produce full musicality and front-row clarity at the softest volumes -- especially important in smaller rooms.

Rio's woofer is the same as used in Eos and Eos HD. We match it into pairs using the same ultra-high tolerances. It is the fifth generation of the woofer we first used in 1997. It remains unsurpassed in its wide and smooth frequency response and ability to play both loudly and softly.



This woofer has a patented neodymium magnetic structure creating a powerful and uniform field around what is called an underhung voice coil. This large field always surrounds the woofer's voice coil, no matter how hard the coil is made to stroke, for complete control at all times. A highly flexible suspension allows proper motion of the cone on both very small signals and very large ones.

The woofer's cone is a featherlight yet rigid blend of carbon-fiber and wood-pulp, producing a naturally extended, high-voice and low treble range necessary for blending smoothly to the tweeter. Although this cone does not resemble the high-tech toys in the market, it helps make this woofer just as much of a high-tech engine as the 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 chassis of this woofer is a rather light-gauge sheet metal, because the woofer's neodymium-magnet structure weighs just 10 percent of a regular magnet. However, we strengthen and deaden this chassis with a fiber-reinforced epoxy putty, as for Eos and Eos HD. The woofer is held in by eight screws, clamping its rim evenly and firmly to more than an inch of our solid Q-Stone™ marble.



The new tweeter for Rio is essentially the little brother to the one used in Eos and Eos HD. It costs less mostly because it uses a regular ceramic magnet instead of an expensive neodymium one. We are quite proud of this new tweeter on all music and at every loudness.

As in Eos, this tweeter does not depend upon nearby cabinet-face reflections to produce a 'proper tone balance.' Most others do, which means you also hear the 'splash' from their cabinet faces -- guaranteed to hurt ears, especially of the female variety.

We prevent reflections off the front surface with 100 percent wool felt of the correct softness and fuzziness for maximum absorption. Its non-symmetric arrangement around the dome gives the correct amount of absorption and dispersion pattern to each wavelength. A second layer of felt applied around the edges of the front face acts to further cut off treble sounds sent directly to the sides, and also cast an 'acoustic shadow'

down over the woofer's face, preventing even more reflections.

To reproduce the highest treble, this tweeter's treated-fabric dome has only 10 percent more mass than the one for Eos, yet still 25 percent less than the one used in Callisto and far less than metal-dome tweeters. Metal-dome tweeters continue to have ultrasonic resonances which affect the music, and most all have suspensions that do not permit extremely small motions. That leads to a 'dry,' uninvolved sound, especially at soft volumes.

To permit the microscopic motions, Rio's dome has a very wide and highly flexible, treated-fabric suspension. The ferrofluid surrounding this dome's voice coil is the latest generation with its viscous and thermal properties providing the best balance between heat dissipation and transient response. The front plate of Rio's tweeter is

precision-molded of resin reinforced with glass fibers for strength; a lack of magnetic interaction with the voice coil, and lack of mechanical resonance when installed in our Q-Stone™ marble.

## Engineering Rio's crossover circuit

Any crossover circuit inside should be made as simple as possible, with parts chosen for the greatest clarity, efficiency, musicality, and for time-coherent signal delivery. When we look at how to blend a woofer and tweeter together, each must first deliver its own frequency range smoothly and widely, so that all their sounds spread evenly across the room. If one could ask the perfect woofer cone to also be a perfect tweeter, unfortunately all the treble would project straight ahead in a very narrow beam, because that cone is too large for short treble wavelengths. One would hear treble only from the best seat while the rest of the room received no treble at all. The music would sound very 'dark,' or muffled.

So a woofer can never be a tweeter, and any tweeter must be small to spread its treble widely. A woofer has to be large for bass output, but not too large in a two-way speaker or it will then project the upper voice-range in a too-narrow pattern. Our friend, the crossover circuit, divides the musical spectrum between woofer and tweeter. For fidelity, it must do its work without slowing down the signal sent to the woofer compared to the tweeter. This is also necessary for time-coherent delivery, something absent in most every speaker on the planet. Our simple, first-order Balanced-Phase™ crossover circuit allows sounds from Rio's woofer and tweeter to recombine into the one original wave.

### Tweeter crossover

Rio's tweeter operates from 3,100Hz to beyond 24,000Hz, which means it takes over from the woofer right in the critical 'ess' and 'tee' part of the voice range. Below 3,100Hz, our simple crossover circuit gently rolls off the tweeter's lower-range at a rate of 6dB per octave. This gradual rolloff is a function of the Balanced-Phase™ circuit, so the tweeter must be robust and have a goodly amount of stroke -- very few such tweeters exist, and they are expensive.

Because we have such a wonderful tweeter in Rio, the entire crossover circuit feeding it consists of just one, super-premium capacitor on the way to it. There is no printed-circuit board to add resonances and impure conductors. Two resistors turn this tweeter down slightly, and a finely-tuned Zobel network placed across (in parallel) with it makes the tweeter appear as just one more simple resistor to that single capacitor. All connections are soldered with a formulation that sounds cleaner and clearer than any other we have used. A 14-gauge wire feeds Rio's woofer -- strands of pure oxygen-free copper (OFC), each heavily plated in silver and encased in Teflon insulation from Audio Magic. The tweeter is connected with an ultra-pure 22-gauge copper of very fine stranding from Jena Labs, cryogenically treated for clarity. Binding posts are located on the rear of the Rio. They are an ultra-high purity machined brass, directly plated with silver then gold, made by Vampire Wire.

With these few circuit parts, no cabinet reflections, and this low-distortion tweeter, it was easy to hear the





differences made by the wires, capacitors, binding posts, and solder. Can we explain the differences? Not entirely, but they are definitely audible.

### Woofer crossover

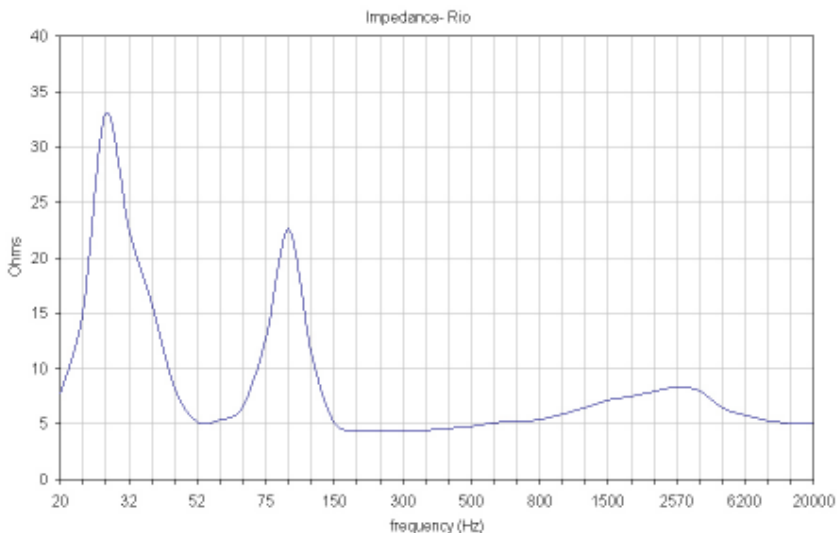
The woofer naturally operates from the low bass to well past 5,000Hz, which allows us to make a very smooth transition to the tweeter beginning nearly an octave lower, down at 3,100Hz.

The rate of rolloff for the woofer above 3,100Hz is again 6dB per octave from its portion of the very simple Balanced-Phase™ crossover circuit. This woofer is so linear in its operation that the entire crossover circuit on the way to it consists of one small Litz-wire inductor of OFC to keep out the highs. A uniquely-tuned Zobel circuit makes this woofer also appear to be only a simple resistor to that single inductor, for the lowest distortion.

One final point about our version of a simple, 'first-order' crossover circuit. Any crossover circuit can be thought of, quite accurately, as a fork in the road for the electrical signals coming from the amplifier. Signals in the high-voice range and treble cannot get through a woofer's inductor, and so follow the path of less impedance -- through the tweeter's capacitor. Signals in the voice range and lower cannot make it through the tweeter's capacitor, and so are channeled into the woofer's inductor. If a crossover circuit can then be made with only those two electrical components, a capacitor and an inductor, then a very nice thing can happen -- the woofer's inductor and the tweeter's capacitor can be chosen to have opposing impedance curves. One is going up in impedance with frequency while the other is going down. This forms 'mirror images' of each other, making the perfect 'Y' adapter for incoming signals.

We call this our Balanced-Phase™ circuit design -- as an ideal 'fork in the road' for the signal. This is good for the amplifier because it cannot then know either a capacitor or inductor exists, and that means it sees no stored-

energy reflected back to it. This allows any amplifier to exert more control over the speaker and deliver more power with less distortion. The measure of this is a 'flat impedance curve' for the entire speaker, a rare thing in speaker design, especially one using a simple crossover circuit. Rio appears to the amplifier as a 4- to 8-Ohm resistor at most every frequency, which allows any amplifier to deliver its power with the least distortion. Longer speaker wires also have much less effect, which is important in a smaller room where the stereo gear cannot fit near the speakers.



### Acoustics of a small enclosure

In a compact enclosure, it is especially important that the rear-wave sound be absorbed immediately at all tones, except in the low bass where no absorption can be permitted so that the woofer and bass port communicate directly. Those two requirements are each a very difficult challenge, and in most speakers are seldom met individually. Extending the research done for Eos, the Rio's non-symmetric interior shape drives the sound velocities (not 'sound pressures') into a special arrangement of very-low density fiberglass. The result

delivers maximum bass output and maximum sound absorption in all other tone ranges. The only drawback is the time it takes to cut and fit 15 layers of fiberglass. Other manufacturers quickly shove in a pre-measured amount of polyfill, widely known to have little absorption.

### **The bass...**

For Rio to be simple to produce, it could have only one bass port, not the two of Eos. Complex 3-D modeling indicated that a particular non-symmetric hexagonal shape to the inside of an enclosure could efficiently drive bass sound pressures into one region where the port's intake should then be positioned. Rio's enclosure shape makes the highest-pressure bass tones appear right at its large port's intake, for maximum bass efficiency. We call this Optimal-Point™ pickup technology, and when coupled with the frequency-dependent absorption of the bass from Rio is very impressive indeed!

One fact about Rio is that its bass tuning has been slightly altered from that of Eos to create a proper tone balance in smaller rooms, in which speakers are also not played loudly. It was a small change but worth the extra time in Rio's design phase.

### **...the middle range...**

It is easy to hear when a speaker has flaws in the middle range because we are so familiar with the sound of voices. Several factors are responsible for making the clearest possible voice range, including having a smooth and time-coherent transition from woofer to tweeter. Another is the shape of Rio, designed to greatly reduce middle-voice range reflections off its exterior, and subtly reduce ones that occur in the low-voice range which the math had shown necessary for smaller rooms.

### **...and the treble**

The Rio tweeter sits in its own pocket of felt-lined Q-Stone™ marble, with no reflections off the enclosure's surfaces nor from nearby room surfaces, for the clearest sound. The tweeter, unlike Eos, is placed in very close proximity to the woofer. This minimizes stand-up/sit-down differences in the sound, which are especially important when one is always close to the speakers, such as in the smaller room. While this does make the treble slightly less 'wide-open' sounding when directly compared to Eos in a large room, it does remove the need to adjust the tweeter, which also reduced the cost for Rio. We are very pleased with the results!

## **Achieving the goal**

All of my loudspeaker design efforts have one goal in mind -- to provide the correct mechanical, electrical, and acoustic environments for woofer and tweeter. Only then can their direct sounds re-combine at your ears in the same, real-life sequence as was recorded. Hearing it all changes your life.

*Hear it all.*  
**It's about . . . time.**