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

Allowing Mathematics and Physics to Guide Form and Function

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

HOW COULD I CREATE a flagship speaker for the smaller room? To retain all of the clarity and most of the bass of our Continuum 3, then that speaker's mathematics would need to be applied to the design of the Calypso. I knew the math formulas would produce a different shape and I was excited to discover the resulting form.

Challenges

For the highest clarity, the midrange and tweeter in the Continuum 3 are mounted in open air, away from each other and from the woofer cabinet. The Calypso would benefit from that same mounting technique since it eliminates many reflections, but how could those drivers' spacings be reduced for the more compact Calypso? I hoped my mathematical formulas would identify a way to reduce the inter-driver spacings while retaining clarity and maintaining their reflection-free performance. Bass reproduction was another area of concern. For the very best bass from its smaller enclosure, the Calypso could use a 10″ woofer. It could also use an 8″ woofer. Five years ago, the larger one would have been the only choice. As I designed the Calypso, the marketplace included some exceptional 8″ woofers that deserved evaluation.

Beginning with the room

Although any of these challenges seemed like a natural beginning point in the design process, the starting point was much more fundamental. Professional loudspeaker design is guided by first knowing the size of the room, location of listeners, range of music and sounds to be reproduced, and the required loudness. To simply choose to 'make a speaker using a particular woofer, midrange, and tweeter' is to ignore physics and abuse the listener. The room's size determines how low a speaker can perform in the bass. A smaller room will not accept bass below

35Hz (which is still very low). A smaller room puts listeners closer to their speakers, and its walls are closer to both the speakers and listeners.

Together, these facts require that the sound waves from woofer, midrange, and tweeter blend into one wave very close to the cabinet and that the tone balance and clarity must be uniform in all directions — except directly to the sides and behind the speaker. In those directions, the high-voice and treble ranges must be restricted for less reflection from the walls. In a smaller room, less sound pressure leaves the front of the speaker, which results in both the loudest and softest sounds. It is a great challenge to reproduce soft sounds even more softly.

There were many assumptions for the Calypso Project. I assumed the room could be 10-24′ wide, 12-30′ deep, and 7-10′ high. It would be carpeted, at least between the listener and speakers, with no bothersome echoes from walls and windows. Listeners could be seated from 6-20′ away from the speakers, with an ear-height of 36-42″. Casual listeners would be standing 10-20′ away. Any listener could be as far as 60 degrees to either side of center. All types of music and sound effects should be accommodated, including bass fundamentals below 40Hz (into a pipe organ's lowest octave). Undistorted peaks in the voice range needed to exceed 100dB at 12′ away, to be nearly "front row" loud. Finally, I needed to consider that the Calypso would be 18″ from the wall in some rooms.

Bass is fundamental

The first decision, as with the Continuum 3, had to be the size of the woofer. It would set the dimensions of the enclosure. Many speakers use two or more small woofers placed in a vertical line, since together they 'grab' and move perhaps as much or more air as one larger woofer. It is argued they can sound better than one larger woofer, because those small woofers can have more rigid cones than the one larger woofer, which is good for clarity, since flexible cones lead to all sorts of distortions, from 'mushy' to 'harsh.'

However, if that one larger woofer is properly constructed, this argument is moot. Although multiple small woofers allow for a slender cabinet and for less reflected sound, it is only part of the answer to achieving better sound. One larger woofer, though, can always be engineered to reach much lower than any collection of small woofers, because it can have a much softer suspension for its heavier cone. Most importantly, one large woofer produces a more uniform bass response throughout a room because the sound comes from only one point.

So, if the house is to shake, how large must that one woofer be? In smaller rooms, no less than 8″ in diameter — and then only if that woofer is truly exceptional. Although a 10″ woofer would work, using an 8″ woofer led to several benefits which are explained later. There is a limit to how high up the musical scale any woofer can be allowed to reach. Too high, and its cone will buckle and distort, or those high-range sounds will beam straight ahead and thus create a 'hollow' tone balance off to the sides. Also, the higher the tone from the woofer, the more easily we perceive its reflection from the floor as a 'doubling' of the sound source which makes a speaker sound more like a 'speaker.'

Midrange and treble

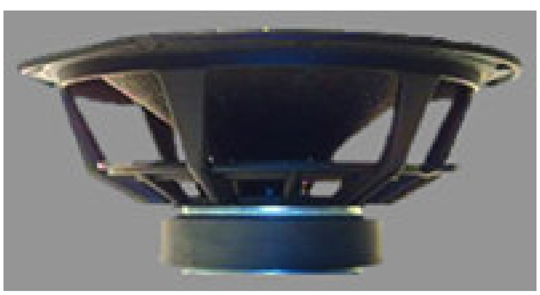
A midrange driver's cone must be large enough to reach down into the woofer's tone range if a smooth transition is to be made between the two. Yet that cone has to be small and light and stiff enough to reach far into the tweeter's range for a smooth transition with that driver, too. The tweeter can go only so low because it must be small to uniformly disperse the highs about the room. When a midrange driver is too large, it cannot meet a small tweeter without its cone breaking up, or without beaming its high-range sounds straight ahead -- which creates a dull tone balance off to the sides.

Could one use two smaller midrange drivers so that together, they 'grab' enough air to meet even a very large woofer? Yes, and they would still be small enough to easily meet the tweeter. But they would interfere with each other as the listener moves around the room. The best clarity and dynamics would be restricted to one seat at that point, and that 'best seat' would become even more narrow the closer one sat to the speakers.

So, the Calypso should use just one midrange driver. It should use just one tweeter, too, for the same reason. There is another benefit to using a single driver in each tone range. The softest sounds are more easily reproduced, because to make soft sounds, that one woofer, midrange, and tweeter stroke farther than multiple woofers, midranges, and tweeters. Any driver's suspension eventually seizes up on very small motions which prevents the cone or dome from moving on the tiniest of signals. 'Rows' of drivers each stroke less for the same loudness, so their 'lower limit' for reproducing soft sounds is higher. Complete freedom of motion for small signals is so important to musicality that a highly-compliant suspension for each driver is very desirable.

Calypso driver selection

From there, the search was on for the lowest-distortion woofer, midrange, and tweeter. Each had to produce the smoothest, flattest frequency response across a very wide tone range -- one far wider than its actual operating range. Each had to be able to deliver the highest dynamic range with the least distortion. Some of these qualities could be deduced from their manufacturers' measurements. Others could be determined by close inspection or by listening and employing proprietary tests using tone bursts.



Woofer choice

If I could find the appropriate 8" instead of 10" woofer, then the cabinet could be smaller in every dimension. An 8" woofer disperses its sound more widely because the cone is smaller and the enclosure around it is smaller. This wider dispersion allows its sound to meld more coherently with the midrange driver's sound at a smaller room's closer listening distances and also creates a more coherent, balanced sound to the sides for the walls to reflect, which makes the reflections more natural-sounding and less 'boxy.' The mathematics also indicated that the smaller cabinet size would result in a speaker which acoustically 'disappeared' better in the smaller room.

The 8" woofer selected for the Calypso has the lowest-distortion I have ever encountered. Manufactured in Denmark, it has a very light and rigid cone made of a triple lamination of different polymers. This allows it to go very high into the voice range without distortion, which is necessary for a seamless blend to the midrange driver. It has a very supple suspension which creates a very low resonance frequency. This means it can go low in the bass and also play very softly. The suspension allows a long stroke that easily accommodates loud bass notes. This woofer's highly focused magnetic field delivers a very clear bass regardless of how far its cone strokes. A cast alloy, non-magnetic frame supports the magnet without unwanted vibrations. The suspension behind the cone is unusually well-ventilated for cooling and releasing air pressures that would otherwise limit the cone's stroke.

Midrange choice

The mathematics determined the best midrange driver's size to be four to 4.5" in diameter, so that its cone 'grabbed' enough air to more than meet the 8" woofer. It would need a very low resonance frequency to make the best blend with the woofer, and its cone would be very light and stiff for the best integration with the tweeter. However, if a very lightweight cone is to have a low resonance frequency, then its suspension has to be very compliant (very soft), which also means better reproduction of soft sounds. Its magnetic structure has to be highly focused for low distortion when that cone is required to stroke, as the math showed it would do. The voice coil driving the cone would be vented for cooling and releasing air pressures behind it which would otherwise inhibit motion.

The only midrange driver that met all of these requirements is the latest version of one I began installing in 1990 with the Imago and again with the Diamante and Continuum 1.5. Handmade in Germany, this driver has a unique cone made of thin Kevlar skins impregnated with a hard resin and bonded to both sides of a honeycomb of Nomex plastic. The result is a very light, stiff, and non-resonant, 2mm thick cone. Unlike any other driver, it has a uniform response well into the treble range without any of the ringing found in metal cones. It has a very low resonance frequency with its thin and very supple, treated-foam suspension. Its chassis is molded of ABS plastic reinforced with aligned carbon fibers that help make it rigid, non-resonant, and non-magnetic (important to keeping the magnetic field well-focused).

Tweeter choice

For the clearest sound, the tweeter for the Calypso needed to have a very supple, long-throw suspension with a large rear chamber behind the dome. Together, those yield a very low resonance frequency for the tweeter to better blend with the midrange driver. The magnetic structure of the tweeter must create a tightly-focused field for low distortion as it strokes, which the mathematics proved. Its dome must be rigid, light, and well-damped so it could not ring at ultrasonic frequencies. Finally, if the Calypso's tweeter was to be mounted in free air, as in the Continuum 3, then it had to be designed to deliver a uniform frequency response without depending upon cabinet reflections to fill in its 'bass' (the low treble/high-voice range).

That 'splash' off the cabinet from conventional tweeters is very much a part of why a speaker sounds less than real. Made in the USA, the same tweeter used in the Continuum 3 was the logical choice, as it is one of the very few to meet every one of these requirements. When any tweeter sends out a pulse of sound in its lower tone range (the high-voice range), those waves are so long compared to the small dome that is doing the pushing and pulling that the waves prefer to spread out in all directions, i.e., form a bubble. If the cabinet's face gets in the way of that bubble, a continuous reflection comes straight off the cabinet's front. Because that reflection process

begins right next to the dome and continues all the way to the edge of the cabinet, the sound heard is a 'hashy' noise, like a mis-tuned radio station. That 'hashy' noise is especially audible on complicated music and soundtracks. It makes a listener believe they are listening to poor recordings.

As the bubble expansion continues around the side of the cabinet, the reflection then bounces off that side to send the treble straight off to the sides, which is mistaken for 'good dispersion to the sides.' The diagrams that show sound reflections behaving like arrows or 'rays' coming off that surface at billiard-ball angles ('optical' angles) are quite misleading. Once around the side of the cabinet, that bubble also tries to expand into the space occupied by the cabinet side. The cabinet side says, "No, thank you," and sends new reflections back out in all directions from each point on that surface. Now, there are as many points on that surface as there are molecules of air striking it, and in only one direction do the majority of all those individual reflections add together to make the loudest reflection -- which is not at a glancing angle off of it, but straight off of that side. I mention this by way of explaining what happens when the sides of the cabinet around the tweeter are small and also curved in the right way. One hears that the treble right behind the plane of the tweeter is very, very soft, because there is nothing there to reflect it back towards the listener. The 'bubble' is actually continuing to expand away from said listener, over to the other side of the speaker. Thus, there is less treble moving towards the listener. This goes a long way towards reducing the treble loudness behind and next to the speaker, so that speaker can be used successfully in tight spaces.

Cabinet-volume determinations

Before applying the mathematics that would determine the final shape of the Calypso, the cubic-inch requirements for the woofer and midrange enclosures had to be known. Although they are getting better, computer programs are notoriously inaccurate for this, so many test boxes were built for the woofer and midrange to determine the correct volumes for each. Test crossover circuits for the drivers also had to be designed to closely match the final circuits, as their resistances alter the required cubic volumes.

Woofer cabinet's volume

I knew that the chosen 8" woofer would deliver a stronger low bass if it were ported. The sound from a port is most acceptable when it is properly 'tuned' to the woofer and cabinet volume, strongly controlled by the woofer, and its tuning frequency lies below the range of most music. With the particular tuning for this woofer and cabinet volume, the Calypso's port would be activated only on large drums, the lowest string bass/electric-bass fundamentals, and synthesizers.

A port and cabinet volume work together with the woofer's natural resonance to make the lowest bass louder. A port's air motion keeps the woofer from stroking too far on loud low-bass notes, which would distort the vocals. Inside a port's tube, a mass of air moves like an invisible piston, literally bouncing off the air inside the enclosure. It is reacting to the woofer's motion, which is also bouncing off that air volume. Good sound depends upon stopping these bounces as rapidly as possible.

The woofer compresses the air in the cabinet. That pressure pushes air down the port's tube, which pressurizes one's room. The woofer, air in the cabinet, and air in the port's tube form a resonating system. Thus, not much 'push' from the woofer is needed to incite the port's air into motion, nor is much push from the port needed to affect the woofer. To tightly control this resonant situation, the woofer must 'communicate' to the port as quickly as possible, and the port must also communicate as quickly as possible back to the woofer. Any time lag results in sluggish or boomy bass. Thus, the air pressure in the cabinet must change all at once, as quickly as possible.

Four important parameters are involved in changing that air pressure as quickly as possible. Each is a give-and-take process. First, the port's intake and woofer must both be located so that they create pressure changes everywhere in the cabinet in the shortest amount of time, so that changes in the pressure arrive at either one of them from everywhere in the cabinet in the shortest time. Secondly, a cabinet's longest dimension can be too long. Air-pressure changes occurring in the remote parts of that cabinet develop late and are released late, which creates extra resonance and sluggish bass.

Thirdly, the port's exhaust and intake must be aerodynamically shaped because the air inside the port's tube is oscillating at just 40 miles per hour, while the air at each end is free to move at 770 miles per hour, the speed of sound. At the ends of the port, air molecules dramatically speed up or slow down and any turbulence in that acceleration means that the pressure is neither changing nor being communicated. Harmonic distortion is the result, which is 'fuzzy bass.' Lastly, the acoustic-absorption materials inside the cabinet must absorb every sound above the port's resonance frequency, and yet absorb nothing at that frequency so that the port and woofer are free to communicate.

For the Calypso, I looked forward to the challenges involved in applying the results of on-going experiments begun 25 years ago. Together with the Calypso design process, I had a collection of validated decisions with which to proceed. I expected that one 3" diameter bass port would be used in the Calypso, with fully-aerodynamic intake and exhaust flares. A 3" port is also much larger than what is normally used for an 8" woofer. It reduces the air velocity inside the port tube, creating "more solid ends" of the invisible air-piston inside it so the bass literally "hits harder." The larger port would also more efficiently pressurize the room's air for a louder output.

The Calypso's bass port should not point to any particular surface in the room, for a bass response that changes little when the speakers are repositioned. If possible, the location for this port should be mirror-imaged, so that the speakers can be placed with both ports either outboard or inboard for the most uniform bass response in any room. This port should reach deep into the cabinet, picking up air-pressure changes equally from all of its portions.

After determining how large the cabinet for the Calypso's 8" woofer needed to be, I saw that our Golden-Ratio Baffle™ would be required. It was first incorporated into the Continuum 1 in 1996 and subsequently modified to suit several other models. The baffle divides the cabinet into two slightly unequal chambers connected by a spiral-shaped opening similar to the "f-hole" in the body of a violin, cello, or string bass.

Golden-ratio mathematics determined the size and shape of this opening. It was surprising to see the simple f-hole shape emerge from the complicated calculations. The f-hole in a violin helps create resonances more evenly across a wide tone range. In the Calypso, this opening works back and forth with the two chambers to allow certain tones through while suppressing others. At very low frequencies, the upper and lower chambers respond as one large chamber to the woofer and port. In the middle and high bass, the two chambers do not 'talk' to each other, which helps make the enclosure very quiet inside.

For the slender enclosure that the Calypso required, further calculations showed that a very precise tuning would be needed for its operation. A particular layering of ultra-low density fiberglass would also help make the woofer cabinet very quiet from the middle-bass tones all the way up through the voice range. Yet the layering would not interfere with the lowest bass, maximum bass output from the port, or for maximum responsiveness of the air inside the cabinet to both the port and woofer.

Midrange's enclosure volume

The air space required behind any midrange driver is always smaller than ideal for enough sound-absorbing material. Also, this sealed air space creates a low-frequency resonance that disrupts the crossover circuit's blending of the midrange to the woofer. Extra parts in the crossover circuit can 'suppress' that low-frequency resonance, at a cost of clarity and dynamics. The real solution is an acoustic/mechanical one, acting at the very point where that resonance tries to develop. A 'resistive vent' in the back wall of the Calypso's midrange enclosure would be required. It 'leaks' low-frequency air pressure in a calculated way before that resonance even begins. It's an 'air brake' supplying the correct amount of 'drag.'

This was not the first time a resistive vent would be applied to a midrange driver. That honor belonged to our Continuum 2 in 1999. It was subsequently used in the Continuum 2 Center Channel, Continuum 3, and most recently in the Vortex Center Channel speaker. In the Calypso, space behind the midrange driver was more limited than in the Continuum 3. There would be just enough room for a 12" labyrinth of wool felt and low-density fiberglass between the midrange and resistive vent on the rear — a shorter labyrinth than the one used in the Continuum 3. This labyrinth absorbs much more sound than any acoustic filling, yet allows the lowest frequencies to be acted upon by the resistive vent.

Also, a felt lining on the sides of the midrange's enclosure would help absorb lateral and tangential soundwaves, which are the ones usually ignored. The labyrinth, sidewall felt, and vent act together to absorb sound at all frequencies for much clearer reproduction. Yet, the shorter 12" length of the Calypso's labyrinth would need a little more help in attenuating the middle-range tones headed to that vent. I designed a cast-marble panel lined with felt that is placed over the vent, on the outside of the midrange enclosure. It traps middle-range tones

passing through the vent. Think of it as a second-stage muffler, for that is exactly what it is. It does not restrict the air flow through that vent.

Tweeter's enclosure volume

The tweeter has its own large rear chamber for sound absorption behind its dome. Using the technique developed for the Continuum 3, compression-damping is applied to the rear of this chamber by dense wool felt so that chamber cannot mechanically vibrate on any note. The cast marble enclosure for the tweeter only needed the extra depth for that felt. It would then be free to shape on the outside for the least reflections.

I now knew the drivers, the volume required behind each one, how the woofer port needed to behave, and basic crossover circuit values. Before I could determine the shape of the Calypso, it was important to know the front-to-rear offset of each driver, so that the sounds from each would arrive at the same instant to the ear of "a listener 10' away on a comfortable sofa." There would be a range of adjustment available to then accommodate a range of seating positions. I call this adjustability Soundfield Convergence™, and introduced it in 1996 with the Continuum 1. It has been incorporated into almost every model since then.

Concepts behind shaping the cabinet

We hear many of the 20,000 wavelengths in sound. They vary in size from just a 1/2" long to more than several hundred inches long. Each reflects off of different-sized surfaces. The longer the wavelength, the larger the surface must be to reflect it. With a speaker cabinet, what radiates the energy is the dome of the tweeter, the cones of the midrange and woofer, the cabinet faces and sides, the floor, and the wall behind the speakers.

How much from each 'portion' depends on the wavelength and from which driver the wavelength originates. The shortest wavelengths emerge from the tweeter and, in general, travel straight ahead. Certain wavelengths from the tweeter and midrange spread out to then bounce off the face of the cabinet and other drivers. Other wavelengths from the tweeter, midrange, and woofer wrap around and reflect straight off the cabinet sides. The longest wavelengths, from the woofer, ricochet off the floor and from the wall behind.

How we respond to each reflection depends upon its wavelength, direction, intensity, and the timing of its arrival. The psycho-acoustic result is that some of those reflections are highly audible and irritating and others are less offensive (until one hears the music with them removed). Still others are inaudible as 'reflections,' yet are necessary to producing 'good tone balance' in the home — such as the presence of the floor and walls 'helping the bass.' Therefore, part of the art of designing speakers means knowing which reflections are necessary and which ones should never be allowed.

Knowing how to create the best transitions between those two extremes is even harder. Outside of my own research, it is not well known how sensitive we are to transitions in the 'reflection spectrum' between these tone ranges. The actual audible effects in each tone range are difficult to imagine. It does not help that reflections off the cabinet, other drivers, the floor and walls are impossible to measure in the way we hear them. To the microphone, most reflections are impossible to measure apart from the music, because the microphone does not hear them separately from the room's echoes the way we hear them in our mind. Yet, when it is known how late a particular reflection arrived, the direction from which it came, and its loudness — compared to the direct sound — it is possible to predict what that reflection should sound like on selected music and how it should measure. I used the results in the mathematics I developed to determine the best shape for any surface affecting that reflection.

But are there not 20,000 reflections of different wavelengths to consider? After many years of work, it turned out that only a few dozen psychoacoustic responses to reflections across 'ranges of tones' needed to be determined to fit into my mathematical concepts. This was fortunate, considering that evaluating 20,000 reflection effects would have taken a few more years. The math behind the shape of the Continuum 3 indicated that the Calypso's sculpture would also be a gradually-changing shape. The purpose of the math was to discover how that shape must change, how fast it needed to change, and in which direction. When the psychoacoustic effects of smaller rooms were incorporated, I saw that Calypso's shape would be unlike the Continuum 3 in many ways.

Determining the tweeter enclosure's shape

As with the Continuum 3, it would be best to elevate the Calypso's tweeter several inches above the midrange to reduce its reflection off the midrange's cone to the point of inaudibility. The cast marble to the sides of the tweeter would be shaped to direct and spread reflections up and down, which would make the treble off to the sides and to the rear very quiet, for less-audible reflections from the walls near the speaker. Here is where a smaller room first affects the Calypso's design. Because that room's walls are closer to the speaker, the Calypso tweeter's dispersion to the sides had to be limited even more. The solution was to enlarge the face of the tweeter's marble housing, making room for dense wool felt to be embedded in recesses next to that driver. This would reduce the tweeter's output to the sides even more, and also to the top and bottom.

Experiments showed that for the listener in a smaller room, the spacing between the tweeter and midrange enclosures should be slightly reduced, compared to the spacing of those enclosures on the Continuum 3. Because the listener is closer, this slight reduction in spacing makes for less difference in the sound between standing and sitting -- but it would generate more reflections. The solution was to have a sharply-changing, concave shape in the transition area immediately under the tweeter and to complement that shape by a broad convex curve to the midrange driver's faceplate, directly below the tweeter. The tweeter's height above the midrange driver wouldn't be audible, thanks to psychoacoustics. Our brains take the image-position cues from middle-range sounds' location, and treble sounds always have supporting, middle-range fundamentals. If the tweeter's sounds arrive coherently in time with the midrange's, then, to our ears, the treble sounds must originate from the midrange cone's height, not from the tweeter's.

Determining the midrange enclosure's shape

The external shape of the midrange's enclosure must fulfill several important requirements. One is that it reflect no sound from the tweeter. For the Calypso's midrange enclosure to 'get out of the way' of the treble, the math I developed and solved led to constantly-changing hyperbolic curves around all its edges, front and rear, and to the parabolic curves up the side.

Another requirement is that the shape not create the single-note resonances of 'diffraction-induced waves.' Those are secondary waves and are created when certain wavelengths 'refract' off of too-sharp cabinet edges. Refraction makes a 'false' wave return to the front when the main wave suddenly expands to the rear upon reaching the edge of the enclosure. Other air molecules from the front naturally rush in to fill the void, and that 'negative' low-pressure rush proceeds away from the cabinet edge right back to the listener, like a smoke ring. Exponential shaping of the corners eases the waves' transition around the edges to minimize any refracted wave. Golden-ratio proportions for the enclosure also prevent any one frequency from 'talking' to all edges at the same instant.

Middle-range sounds also travel down the front of a cabinet, only to reflect towards the listener from the woofer structure. Therefore, another requirement is that the midrange's enclosure be shaped to release much of that pressure to the sides and rear before it reached the woofer's region. The math showed the shape that would permit the Calypso's midrange driver to be placed a few inches closer to its smaller woofer, compared to the Continuum 3. This was a main benefit of using only an 8" woofer for the Calypso because the speaker would acoustically 'disappear' better for a closer listener. The midrange's height above the woofer would not make the woofer's location audible, again thanks to psychoacoustics. Bass sounds always have middle-range harmonics, too. Our ears take the image-position cues from the midrange's location. If the woofer's sounds arrive coherently in time with the midrange's sounds, as they do in the Calypso, then our ears perceive that the bass notes must originate from the midrange cone's height, not the woofer's.

The final requirement in determining the shape of the midrange cabinet is that its face could be neither too large nor too small. It had to be just large enough to prevent the air molecules from escaping while the midrange cone finished any lower-frequency stroke-cycle from plus to minus. If the face was too small, this energy would escape around the back before the cone's stroke was complete and a noticeable 'thinning' of the medium-low voice range would be heard. Too large, and the reflections off of it in the middle-voice range would be heard along with ones from the tweeter and woofer. If the edges were too-gently rounded, it would be similar to making the entire face too large for some wavelengths and wouldn't prevent tweeter reflections from those edges.

Woofer cabinet size and shape

In the low bass, if a reflected wave arrives at one's ear with a round-trip path-length difference less than 25 percent of that wave's length, then it is not audible as a reflection. It is heard to simply make the original wave louder. If it arrives between one-third and one-half of the wavelength 'late,' it is heard to reduce the loudness of the original wave. Keeping that 25 percent in mind, consider low-bass notes, whose wavelengths range from 20 to over 30′ long. With speakers placed up to 3′ off the wall behind, then low-bass reflections from that wall audibly boost all low-bass tones.

This is why speakers have bass inside the house and it goes away when speakers are pulled too far off the wall behind, or when placed outdoors. It is also why a designer must specify the room size in which a speaker will best perform. A woofer enclosure needs to be narrow left-to-right so that it 'gets out of the way' of those lowest bass sound-waves. Otherwise, one would hear the acoustic shadow cast by the large cabinet as one moved around the room. A woofer cabinet can be too narrow, since higher up in the middle-bass the waves are not quite long enough to reach to the wall behind and return within that 25 percent period of those waves' lengths.

However, they are still long enough to slip around the sides of a too-slim cabinet and escape before the woofer can finish its 'push' on the molecules. This is why 'creating a narrow cabinet for several smaller woofers' is not an ideal solution. The ideal solution is to use a cabinet size and shape around the woofer that is neither too large nor too small, and that somehow does not cause reflections for the midrange-driver in the voice range. The presence of the floor also helps hold this energy near the woofer, depending on how far the woofer is from the floor.

If these variables are addressed, one hears that the woofer, floor, and the wall behind are able to apply maximum thrust across the woofer's entire tone range for the most uniform tone balance and dynamic response. The math showed that the Calypso's woofer enclosure could only be a certain width, depth and height.

And late one night, I decided to put in the variable for 'twisting' that enclosure as it dropped away from the woofer to the floor. The result was a column turned 45 degrees to the plane of the woofer, midrange, and tweeter. The few reflections off its flat surfaces would be softer, since the surfaces are farther away from the drivers and because much of the surface area would lay behind the plane of them, where the sound was already less loud.

Finally, the surfaces would be directed away from the front listening area. Now I had the column upon which to build the Calypso's cast-marble superstructure to hold its woofer, midrange, and tweeter. Oh, and the woofer's port could be placed looking at 45 degrees to the wall behind and to any sidewall. The other port could then be mirror-imaged, so that an owner could decide which sounded better -- inboard or outboard.

Fine-tuning the crossovers

Fine-tuning the tweeter crossover

The tweeter in the Calypso operates from 3,000Hz to beyond 20,000Hz, which means it takes over from the midrange driver right in the critical 'ess' and 'tee' part of the voice range. Below 3,000Hz, the crossover circuit rolls off the tweeter's lower-range response very gradually, at a rate of 6dB per octave, which is termed a 'first-order circuit.' It is the only circuit that sends signals to a tweeter and the midrange driver simultaneously, so they move together as one unit. The result is the clearer sound. This 'time-coherent' behavior between drivers is very rare and can only come from such a simple crossover circuit. However, that gradual 6dB/octave rate of rolloff does not protect the tweeter from voices and bass as much as more-complicated circuits, which, unfortunately introduce time delays that distort the music.

So, for time-coherent operation with the midrange driver, this tweeter is required to handle more power, which the Calypso's does graciously. This is also why this tweeter needed an extended stroke, so it could move freely without distortion. That in turn, required a very flexible suspension around the dome and a very focused magnetic field controlling the extended motion.

In the Continuum 3, this tweeter was crossed over a little lower, at 2,870Hz, to better meet that speaker's larger midrange cone. However, the higher crossover point allowed by the smaller Calypso midrange driver results in less difference in the sound between standing and sitting and also lets the two drivers blend together nearer the cabinet. Both of those directly benefit the closer listener in a smaller room. We are fortunate that this tweeter is so linear in its operation — so well-behaved — that the entire crossover circuit feeding it consists of one super-premium capacitor. There is no printed-circuit board to add resonances and its impure conductors. One end of this capacitor is crimped firmly to the positive-gold binding post, and the other end is twisted and soldered to the wire that runs to the tweeter's positive terminal. The return wire is identical but runs to the negative binding post. The solder we use is a new formula from our supplier that sounds cleaner and clearer than any other. With such few parts, no cabinet reflections, and a low-distortion tweeter, it is easy to hear the differences made by wires, capacitors, binding posts, and solder. Can we explain the differences? Not entirely, but they're definitely audible.

Fine-tuning the midrange crossover

The midrange in the Calypso operates from 380 to 3,000Hz, which means it takes over from the woofer right in the middle part of the voice and piano range and runs all the way past the high-voice range. The rate of roll-off at both 380Hz and 3,000Hz is 6dB per octave, for the same reasons as given for the tweeter — so we can use the only circuit that allows the woofer, midrange, and tweeter to move together as if they were one unit. The result is, again, clearer sound. This slower rate of roll-off requires an undistorted response from the midrange far above its high-frequency crossover point. This is why the Calypso's midrange cone is light, rigid, and not prone to ringing. It must handle more bass than an ordinary midrange, hence its very flexible suspension, a highly focused magnetic field, and well-ventilated voice coil. As with the tweeter, we are fortunate that the midrange is so linear in its operation and so well-behaved. The entire crossover circuit on the way to it consists of one super-premium capacitor and three premium capacitors in parallel (making one large capacitor) that keep out the bass. Two small Litz-wire OFC inductors in series (better than one large inductor) keep out the highs.

Fine-tuning the woofer crossover

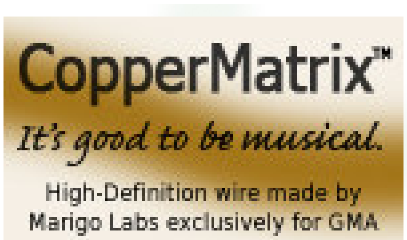
The woofer operates from 45Hz to 380Hz, which means it runs from nearly house-shaking low bass right up to the middle part of the voice and piano range. The rate of roll-off above 380Hz is again 6dB per octave, so that the woofer, midrange, and tweeter move together as if they were one unit. The result is, again, clearer sound. This slower rate of roll-off requires from the woofer an undistorted response far above that crossover point, which is why the Calypso woofer's cone was light, rigid, and non-resonant. As with the midrange and tweeter, this woofer is so linear in its operation and so well-behaved that the circuit on the way to it consists of just one premium, very-low resistance inductor to keep out the voice-range and highs.

Our exclusive CopperMatrix™ High-Definition wire from Marigo Labs

In the Calypso 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. They do so sideways and also along their lengths. These CopperMatrix™ 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, which again, provide mechanical damping much more so than any known plastic insulation, and with far less dielectric effect than even Teflon. This finished wire is then doubly-cryogenically treated, tested and marked for signal directionality.

As you might imagine, this wire takes an extreme amount of patience to terminate and strain relieve, because 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. Then for any connection it makes, whether to the crossover parts or to the drivers, it must first be aligned in its direction. Its solder-covered end is then 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 the minimum solder between each strand. Each connection is then de-oxidized and strain-relieved with heat shrink so that it lasts for life.



When we first obtained this wire, it made such a shocking difference over the excellent-sounding wires we were already using, that one could hear that in another room. It was livelier on dynamics, but in a subtle way, because each peak was clearly defined and yet naturally rounded, with an edge and coarseness to it removed, ones we had never noticed. The decays of any sound, very small or very large, 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 it allowed us to further refine 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 between any two signals, small or large. The increased definition is quite stunning, hence our High-Definition (HD) identifier.

One final point about our Balanced-Phase™ 'first-order' crossover circuits. Any crossover circuit can be thought of as a fork in the road for the electrical energy from the amplifier. Since the energy of the higher-tone ranges cannot easily get through the woofer's inductor, it is deflected down the path of less impedance, through the midrange's capacitor. At that crossover point, if the crossover circuit can be made with only one part each for the woofer and midrange, a very nice thing happens.

The woofer's inductor and midrange's capacitor can be chosen so that each is the conjugate impedance, the 'upside-down mirror image,' if you will, of the other. This creates the ideal 'fork in the road' for the signal, because the amplifier does not know the capacitor and inductor exist. To it, only one 'path' is apparent. The measure of this is a 'flat impedance curve' for the entire speaker. The Calypso appears to an amplifier much like a 6 to 7 Ohm resistor at most every frequency, allowing any amplifier deliver maximum power with the least distortion.

Bringing it all home

All of this work in developing the (now retired) Calypso's cabinet, selecting its drivers, and developing a simple, time-coherent crossover circuit would be wasted if we could not get the separate sounds of the woofer, midrange, and tweeter to re-combine into the original sound-wave at your ear.

Only then will you hear all of the musicality hidden in that complex waveform, follow along with any artist or voice, or hear a sound effect to its maximum effect.

Since we do not know where you will sit or stand, the Calypso HD, with its CopperMatrix™ wire from Marigo Labs, will allow you to adjust the positions of the midrange and tweeter relative to the woofer so that all their sounds arrive to your ear at the same instant.

For you to hear if we extracted every ounce of performance out of our compact flagship speaker, challenge it with any music, at any loudness, in most any room, and from any amplifier.