MoFi Electronics SourcePoint 10 White Paper

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My aim for SourcePoint 10 was straightforward: Create a loudspeaker inspired by the needs of the mastering studio and able to reproduce as best as possible the sound I've envisioned over my 40-year career, all the while providing deep bass impact and delivering the highest-possible value to listeners. That left a lot of leniency for what the design should be — from the technical aspects of the drive units and cabinet to the visual design.

Coincidentally, my primary technical consideration for SourcePoint 10 was the incorporation of a concentric driver. Departing from my previous designs, I used a large-diameter woofer to meet the needs of excellent bass capability while maintaining all the benefits of a concentric design. This approach required something new — and presented a challenge I enjoyed working on for nearly two years.

First, the Basics of Sound Reproduction

To understand the benefits of concentric drivers, let's go back to basics and what is involved to reproduce the full audio spectrum from the mid-20Hz range all the way up to 20-30kHz.

The physics of sound generation shows us that, for any sound pressure level, to produce low frequencies we must move a large volume of air — but do so relatively slowly. Conversely, to reproduce high frequencies, we only need to move a small volume of air — but have to move it very fast. These two requirements are very different and require distinct designs for the drivers that create the sound. It is almost impossible to achieve that in a single drive unit. The near-universal solution is to split the spectrum into a minimum of two ranges (low and high) and employ a dedicated bass driver and a dedicated tweeter optimized for their particular frequency range.

In order to move enough air at low frequencies, the bass driver needs to have a large diameter or long throw, or a combination of both. This results in a high moving mass that restricts high-frequency response but that is acceptable since it is only required to reproduce low frequencies. In contrast, the tweeter needs to be small in diameter and very light in order to respond all the way up to 20kHz. By splitting the signal to two individual drivers, however, we introduce new problems into the design.

These issues fall into three categories:

- The drivers are now spatially separated. The tweeter is mounted onto the surface of the front baffle of the loudspeaker, and typically, directly above the woofer. Because we can audibly discriminate the height of a sound source, we are aware that the sound of certain instruments is now spatially split — and it sounds unnatural.
- The separation causes changes in how the two drivers integrate when we change our listening position, particularly our listening height, in the region of the crossover frequency. Depending on

where we listen, and because our relative distance — and hence, timing — to each driver has changed, we will experience response nulls or peaks.

- Sound sources uniformly radiate all around at low frequencies. As the frequency increases, the source becomes more directional and focuses the sound forward at the expense of the side. Driver size governs the frequency of the transition of directionality. A typical six-inch driver will start around 800-1,000Hz but a tweeter, being much smaller in diameter, will only start around 5,000-8,000Hz. This results in an off-axis response that is non-uniform across the frequency range, with power dips at the crossover frequency —as well as non-uniform directivity and room response.

The Fix? The Concentric Solution

If we centrally locate the tweeter within the bass driver — the essence of what we mean by a concentric driver — we eliminate all the aforementioned issues.

The tweeter is mounted on the center axis of the woofer and is positioned at the apex of the cone. The common axis removes the spatial disparity and eliminates the distance and timing differences since the listener location is changed.

Locating the tweeter at the apex of the cone also allows the cone to act as a waveguide for the tweeter. The purpose of a waveguide is controlling the directivity of the sound source. In this configuration, it matches the directivity of the tweeter through the crossover frequency range to that of the woofer. The off-axis responses now become much better matched, resulting in improved directivity and room response. Waveguides also improve the low-frequency efficiency of the tweeter by up to 10dB.

This is all good. But what can we do to make it better?

Improving the Concentric

As the sound spreads away from the tweeter and up the cone, it encounters the woofer surround – typically, a half-roll shape that disrupts the wave propagation. It causes re-radiation that interferes with the direct sound from the tweeter to produce dips and peaks in the response, typically in the 10-20kHz region. The greater the required woofer excursion, the larger the surround needs to be — and, hence, the more the disruption.

A second problem happens when the woofer cone is moving. Its location with respect to the tweeter changes from the extreme of being in front of the tweeter location to being behind it. This positional shift causes changes in the tweeter response, resulting in intermodulation distortion, decreased clarity, and added sonic harshness — particularly with vocals.

Both issues can be fixed by limiting the motion of the woofer. We can now use a low-profile surround to minimize disruption of the wavefront. The reduced displacement greatly lessens the frequency-response variations of the tweeter due to cone position. By minimizing cone motion, however, we potentially reduce how much bass we can produce.

Minimizing Movement, Not Bass

For every octave of restricted bass response, the required cone movement reduces four-fold — a significant amount. If we use the concentric driver just as a midrange driver and add a dedicated bass driver via suitable choice of crossover frequency, we drastically minimize cone movement. This arrangement makes for a very complex solution, however. Not only do we now have three drivers, but we need extra crossover components that tend to be bulky and expensive.

The other approach is to simply increase the cone area. As previously explained, bass level is a combination of cone area multiplied by excursion. We can trade one for the other by using a large driver that allows us to stay with the simplicity of a two-way system. This approach is adopted in SourcePoint 10, where a 10-inch-diameter woofer is combined with a low-profile multi-roll surround. By its nature, it meets the goals of our original design brief.

Big Cones Are Better — Right?

The decision to use a large-diameter woofer presents its own complications. The ideal woofer cone would have no resonances within or close to its operating range. Resonances are problematic; they color the sound of the driver and obscure detail. When designing cones, minimizing resonances is critical, but doing so becomes more difficult as we increase cone diameter and operate it over a wider frequency range.

Every material we consider for woofer cones will eventually go into breakup, causing resonances. It's just a matter of how high in frequency — and how well-damped — those resonances are. Exotic materials, like beryllium, attempt to push resonances to much higher frequencies. While such materials may work for smaller woofers, they are either of limited benefit for larger drivers, unaffordable, or cannot be made at a larger size.

Surprisingly, paper has the ideal combination of material properties and is the best solution to create the cone we need. After experimenting with a variety of paper pulp mixes and cone shapes, we developed a custom-tooled solution that both optimizes the resonance behavior and meets the shape requirement for the waveguide.

Low to High

Our next task was to choose a crossover frequency below the breakup mode of the cone. We determined the optimum frequency to be 1.6kHz.

This required a tweeter capable of working down that low, necessitating the use of a large-diameter voice coil of 28mm (approximately 1.1-inch) diameter and a soft dome with a wide-roll surround. The wide surround profile extends both the low- and high-frequency response of the tweeter, while the loading effect of the waveguide significantly increases low-end efficiency. The robust power handling, minimal thermal compression, and greatly lower excursion requirement allows the use of a low 1.6kHz crossover while keeping the distortion very low.

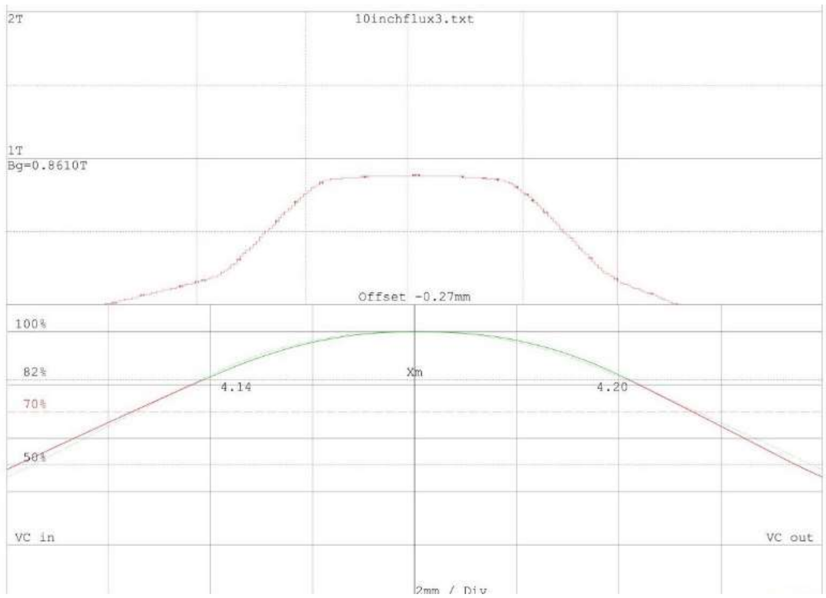
Drive Straight

Optimizing the frequency response of the woofer and tweeter is not enough; we also need to minimize distortion in the motor structure of the drive unit. Though the cone is designed to push the resonances beyond the crossover frequency, that is not sufficient in a nonlinear system. The crossover filters the signal going into the cone, not the signals coming out of it.

If the motor has distortion, it will generate new frequencies outside of the crossover band limit. These signals directly enter the cone and excite the resonances. In SourcePoint 10, we have been very diligent with the design of the motor to reduce these distortions, which are typically caused by three primary mechanisms.

The first is non-symmetrical flux distribution in and beyond the magnet gap, which causes non-constant and non-symmetrical force to be applied to the coil as it moves in and out of the gap. The second factor is the interaction between the fixed field created by the permanent magnets, with the varying field created by the current in the voice coil. This varying field can modulate the fixed field and cause distortion. The third factor is non-constant voice coil inductance, which can vary with the position of the coil and the current level through it.

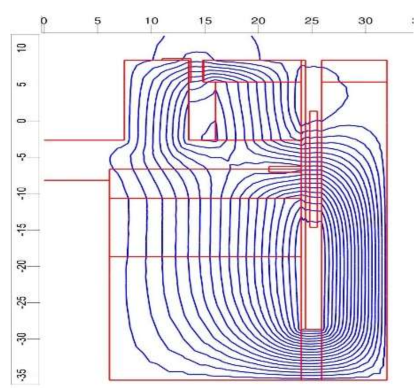
In SourcePoint 10, careful design of the magnet structure has made the flux field fully symmetrical. The result is shown in the accompanying chart displaying the flux profile and force profile.



To minimize the flux modulation, our motor design uses copper through and beyond the magnet gap. Opposing magnet structures cancel the flux modulation. This symmetry, along with the copper in the gap and a structure that keeps constant the amount of metal and magnet (no matter the coil position), minimizes inductance variation. The tweeter motor structure also uses copper in the gap to minimize inductance variation. By utilizing a high-flux density in the gap, along with partial saturation of the pole, flux field modulation gets minimized.

Twin Drive

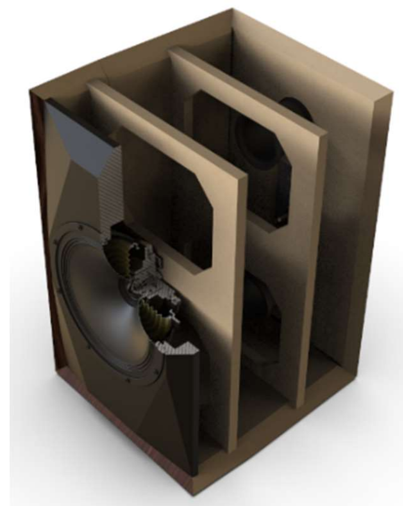
Abiding by the requirement that the tweeter motor structure fit within the voice-coil diameter of the woofer, typical concentric driver designs feature tweeters with relatively low sensitivity. SourcePoint 10 uses a compound motor structure named Twin Drive to solve this issue. The magnets of the woofer and tweeter motor deliberately couple together so that each aids the other in driving flux across both the woofer and tweeter gaps. The result: Greater flux density than either motor can achieve alone, resulting in a tweeter gap flux density of 1.35T.



Boxed In

A large woofer requires a large cabinet. SourcePoint 10 has an internal cabinet volume of 50 liters, or almost two cubic feet. Because of the relationship between box size, low-frequency extension, and efficiency, this volume can be traded to gain both bass extension and efficiency. SourcePoint 10 has a sensitivity of 91dB, low-frequency point of 42Hz, and true eight-ohm impedance with a minimum of 6.4 ohms at 150Hz. This makes SourcePoint 10 very easy to drive and well-suited to a wide range of amplification.

To minimize cabinet resonance, large cabinets require thick side panels and extensive bracing. SourcePoint 10 utilizes one-inch-thick MDF panels for the sides, top, bottom, and back of the cabinet — as well as a two-inch-thick front baffle. Two additional vertical braces connect the top, sides, and bottom to further strengthen the cabinet.



The shape of the front baffle also matters. When mounting any driver in a cabinet, the cabinet edges will refract and reflect the sound that travels across the baffle to the cabinet edge. This radiation interferes with the direct radiation from the driver and causes high-frequency response irregularities that vary with listener location. This can be particularly troublesome with a concentric driver configuration.

In SourcePoint 10, such diffraction is greatly reduced by sculpting the baffle to produce multiple facets. The varying distance from the driver to the edge smooths out the diffraction ripples; the sloping surfaces further minimize them. As the listener, you benefit by hearing only the smooth, even response of the driver — not the sound of the cabinet.

Hear Through to the Recording

All the measures employed in SourcePoint 10 combine to allow you to hear further into the recording and get closer to the original source. You'll be able to hear a great amount of detail even at low listening levels, which lets you connect with the music more closely and feel the emotion in the performance. Relatedly, the speaker's low-distortion characteristics mean you can play music at high volume levels without apparent distress.

In closing, I hope you get the same joy listening to SourcePoint 10 that I did designing it.