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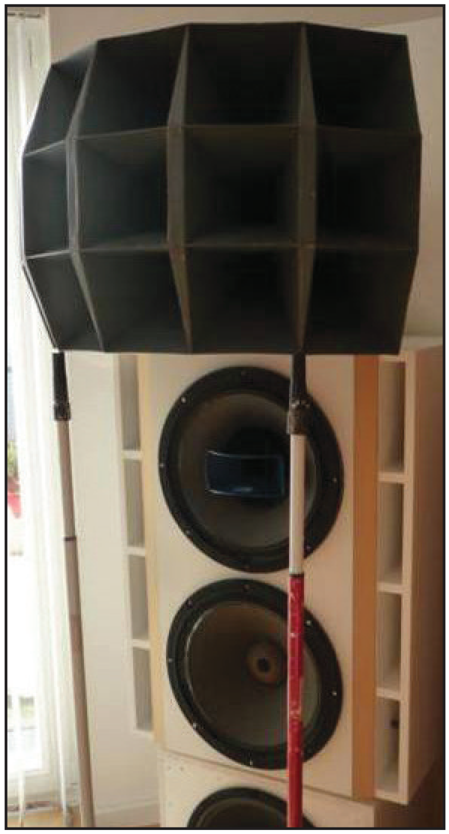

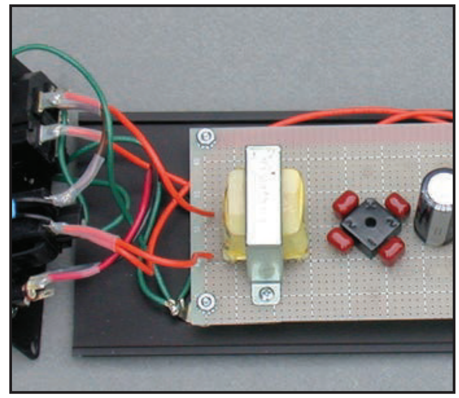

Features

Tips to Resurrect a Classic Speaker or Design a New System (Part 1)

Use a Heil Transformer and an Updated Woofer

By
Thomas Perazella
(United States)

This article is the first of a three-part series that will describe the history, construction, testing, problem solving, and voicing of an old speaker brought back to life by new technology. Although the original goal was to breathe new life into a classic, many of the issues addressed here are also critical when designing a new speaker or even getting the best performance from commercial speakers and associated equipment.

Photo 1: The Eton 7″ drive has a light rigid cone made of a Nomex honeycomb sandwiched between two Kevlar layers for true pistonic behavior.

When it comes to musical taste, you could probably classify me as an omnivore. Depending on my mood, I may lean toward classical, jazz, rock, pop, country, or other genres. Like most of us, there is one special piece that goes directly into my heart, bypassing all logic to create an intense emotional involvement. For me, it is Gustav Mahler's Symphony No. 2, "The Resurrection." It is also a fitting title for my latest completed project.

What is an AMT?

Several years ago, I became interested in the Heil Air Motion Transformer technology. Created by Dr. Oskar Heil, this device uses an unorthodox mechanism to quickly accelerate air, resulting in a very interesting tweeter. There is a lot written about the actual mechanism, including several patents leading up to the AMT version (see Resources). But there is also a lot of misinformation on how it really works. It has been said that the diaphragm, which is a vertically aligned array of pleated material behaves like an accordion squeezing the air in and out. Actually, the whole diaphragm does not move in and out like an accordion, rather alternate folds move either in or out so the air is squeezed out one side and sucked in the other. The folds stop the diaphragm from moving back and forth so the result is a dipole pressure wave. For a better understanding of this device, please refer to the Resources section.

Heil AMT History

The AMT was originally produced by the California company ESS, but the final complete speaker received mixed reviews. It was a two-way design that suffered from running the AMT at too low a frequency and the 12″ woofer at too high a frequency. The two drivers' radiation patterns were different because of their physical shapes and the wavelengths reproduced vs. the size of each throughout their crossover frequency ranges. Also, one was used in open air as a dipole and the other in a box as a monopole. The AMT's crossover point and slopes caused it to operate at the low end in a range that did not work with the given slopes. The resulting speaker did not live up to the AMT's true performance capabilities. In spite of this, people loved the speaker so much it almost became a cult classic because of the AMT's crystalline response.

I do not remember exactly when I decided to use the AMT as the basis of a DIY project, but it was probably in the late 1980s or early 1990s. I obtained a used pair of the tweeters and immediately knew I would have to use a three-way configuration if I was going to be able to get a wide enough dynamic range without exposing the tweeter to undue stress. I would also have a chance to better control the integration of the drivers' radiation patterns.

Although a three-driver three-way is a common configuration, some severe compromises in a one-driver-per-frequency-range configuration must be addressed. Primarily, they have to do with sensitivity, linear displacement capability, and power requirements, which I recalled during the implementation. It also reminded me why I moved on to other solutions. However, the concept has validity because of its smaller size and lower cost.

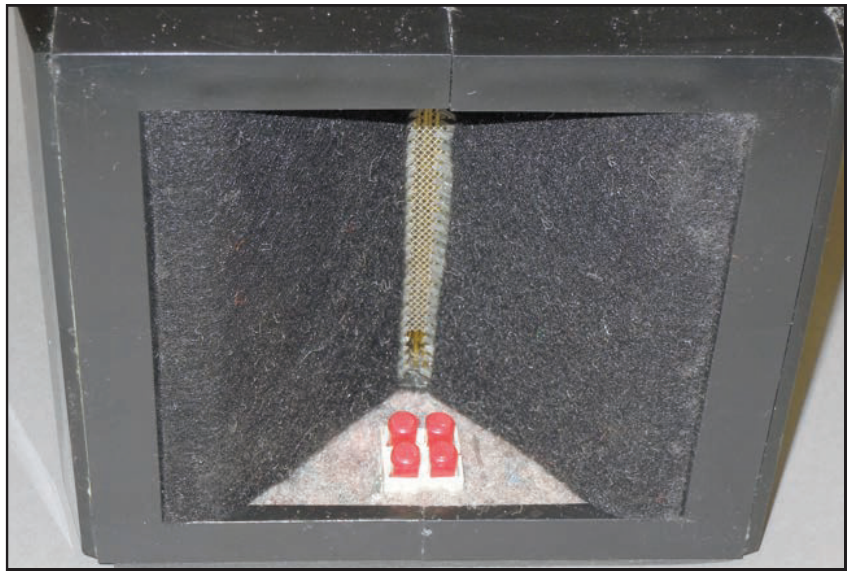

Photo 2: The cavities in the Heil AMT housing were filled with deadening material in an attempt to reduce cavity resonances.

Photo 3: The baffle housing the midrange and tweeter is isolated from the bass cabinet by a rubber sheet and rubber tubing in the holes that receive the indexing pins.

My Original Project

The speaker concept used a sealed box holding a dynamic driver for the bass, a dipole mounted dynamic driver for the midrange, and the AMT as a dipole for the high frequencies. I located a woofer box and grille used in an exceptionally well-performing speaker, the Acarian Alon IV. It was designed for a sealed-box woofer and a dipole-mounted midrange and tweeter (see Resources for more information). I then had to choose the bass and midrange drivers.

When I designed the original speaker, the German company Eton had developed a woofer/midrange driver that used what it called "Hexacone" technology. The cone was made from a Nomex honeycomb sandwiched between two Kevlar layers (see **Photo 1**). The result was a cone that was very light but extremely rigid. Within a certain range, it acted like the ideal piston.

In addition to the sandwich cone, the Eton woofer/driver had an inverted soft rubber surround. The result was a relatively smooth, low-distortion output, even when driven hard. There were some ripples in the passband and if you went up in frequency, an anomaly in the frequency response would appear. I have been told that the ragged response at higher frequencies was due to a difference in impedance between the rigid cone and the compliant surround that resulted in reflections of energy back into the cone at the higher frequencies. I cannot verify the actual mechanism myself, but response problems do appear.

The solution to using a driver that has great performance in most of its range but problems at frequency extremes is simple. Don't use the driver in the problem areas. That may be problematic when using passive crossovers, but with the flexible electronic crossovers now available, it has become a non-issue. At the time, I decided to use the Eton woofer/driver with a home-built 12-dB/octave electronic crossover. I mounted it in a quasi-dipole configuration with an open back but heavy damping. As it turns out, that was okay, but not the best solution.

The original AMT driver was mounted in a plastic housing that had a ridge around the front and back that created triangular-shaped cavities at the top and bottom in the front and rear of the radiating element. Although I had no way to measure those cavities' effects, I altered them by filling the cavities with wool carpet underlayment

Photo 4: The original speaker used an HSU 12″ bass driver, which is shown without the grille.

material. In addition, I fastened some thin black felt material over the faces of the pole pieces to improve the tweeter's looks and possibly reduce some reflected energy (see **Photo 2**). It is interesting to note that the AMT's current version has the cavities removed from the housing and has added what appears to be a black surface-finish treatment on the pole pieces.

Both the AMT and the Eton drivers were mounted on a flat baffle that sat on top of the woofer box in positions to time align the three drivers. I added mass to the baffle base in the form of a box containing cement. I used sand-filled steel tubes to brace the baffle's upright section to the base. The baffle was located on the woofer housing with steel pins fastened to the housing and slip fitted into holes in the baffle's base. I used surgical rubber tubing inserts to isolate the base from any vibration that may have come up the pins. The baffle's base also had a rubber sheet on the bottom for isolation. **Photo 3** shows the layout of the baffle's base.

For the bass range, I originally used 12″ drivers that I already had. However, they did not have much linear excursion, so I switched to 10″ Peerless drivers. They were better, but the additional excursion hardly made up for the loss in cone area. Ultimately I used 12″ drivers from HSU Research that had a higher X_{MAX} and a larger cone area. **Photo 4** shows the completed speaker.

I used those speakers for many years with good results. However, as time went on, I realized they had limitations, including limited bass excursion and a radiation pattern that resulted in more floor and ceiling reflections than I preferred. Ultimately, I replaced them with my current main system that uses Bohlender-Graebener RD75 drivers for the high frequencies, Peerless 831727 10″ drivers for the upper bass/lower midrange, and sealed box subwoofers. (More information about these drivers and midranges is available in my article series, " On Angels Wings," Part 1 and 2, *audioXpress*, January–February, 2001 and "A Dipole Midbass," Part 1 and 2, *audioXpress*, June–July 2004.) The Heil-based speakers were put into storage. With the AMT tweeters available to the public once again, I decided to see if I could improve on the original design, especially since a range of powerful reasonably priced digital signal processing (DSP) equipment is available.

Updating the Design

Although the AMT and Eton drivers have undergone revisions over the years, both versions I had are still adequate for the job so I did not replace them. Woofer designs, however, have progressed dramatically in the intervening time. The search was on to find a suitable substitute.

A major advantage of current speaker control devices is that trying to achieve the woofer's critical tuning in an enclosure is not as much a necessity as in the past. For example, if you use a passive crossover with an incorrect speaker parameters and box volume combination, you may wind up with a Qb that is too high. The result would be a bump in the frequency response at resonance. In the past, that could result in an overly bass-heavy voicing. Most DSP-based electronic crossovers enable you to create a bandpass filter with any center frequency, Q, and any amplitude you desire to flatten out the response bump. Because of this, if you already have an enclosure as I did or are restricted by severe space limitations, your driver choices are greatly expanded. You do not have to worry about achieving critical damping by choosing from a limited range of drivers with the correct parameters for the given box size.

The Woofer

When it comes to speakers with drivers covering separate frequency ranges, the woofer is the group's heavy lifter. For each octave the reproduced frequency decreases, four times the volume displacement of air is necessary to maintain the same sound pressure level (SPL). If you need "X" amount of volume displacement to achieve your desired SPL at 20 kHz, at 20 Hz you need more than 4 million times "X" to achieve the same SPL. Fortunately, music does not produce the same SPLs at the highest frequencies as in the bass, but it quickly becomes apparent why so few speakers can reproduce high-amplitude organ pedal notes at realistic listening levels without excessive distortion, if even at all.

Photo 5: The Dayton Ultimax UM12-22 woofer has several great features, including 19-mm X_{MAX}.

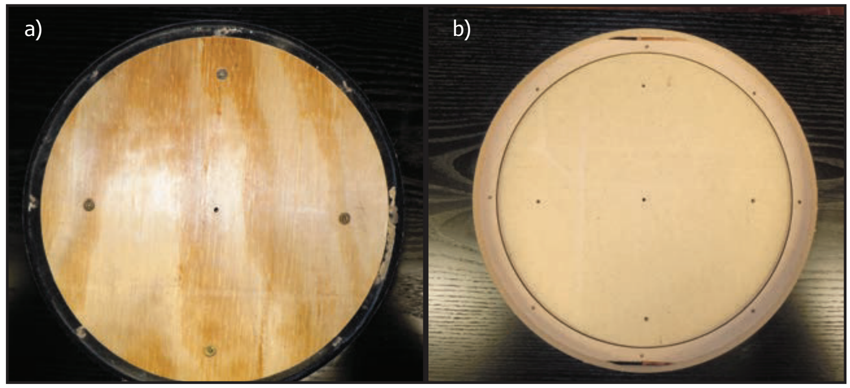

Photo 6: A pivot plate was constructed and inserted into the original woofer mounting hole to provide the alignment point necessary for the Jasper jig and router to properly enlarge the hole (a). The enlarged hole in the bass cabinet is shown with the backer plate and pivot hole before routing of the lower basket clearance hole (b).

To achieve the high linear volume displacements necessary for clean bass, you need a lot of radiating surface combined with a lot of linear excursion. It is similar to an internal combustion engine where displacement is a product of the cylinder bore times the piston stroke times the number of cylinders. If the engine needs more displacement, you must have some combination of more pistons, bigger pistons, or a longer stroke for the pistons.

In this speaker's case, the "bore" was limited to a 12" driver and the number of "cylinders" or woofers in each speaker was one. To get the volume up to a reasonable level, a high linear "stroke" or excursion was needed.

The specification for a dynamic driver's maximum linear one-way excursion is X_{MAX}. It is the excursion where either the motor force factor (Bl) falls to 50% of its peak value or the suspension stiffness (K_{MS}) increases to double the initial value. X_{MAX} is defined as the direction of travel either in or out that has the worst of either of the limiting values.

For example, if a driver is limited to 5-mm travel in one direction by force factor reduction and is limited in the other direction by increased stiffness at 4 mm, the driver's X_{MAX} will be 4 mm. Unfortunately, some manufacturers quote maximum total excursion in both directions regardless of either parameter's nonlinearity as the excursion instead of true X_{MAX}. *Caveat emptor*!

In previous woofer designs, I used drivers from various companies that had different linear excursion vs. price combinations. Some have incredibly high linear volume displacements in small drivers but at a high price. Over the years, my best results for drivers with high linear displacement at reasonable prices have come from Dayton Audio, the house brand of Parts Express. My current reference system uses two Dayton 15" DVC woofers that provide yeoman service for a two-driver arrangement.

Looking at the Parts Express website, the subwoofer section brought me to a relatively new series of drivers called "Ultimax." This series consists of three drivers in 10", 12", and 15" diameters. They all have similar features, which can be viewed on the website. One with a 19-mm X_{MAX} (which is huge for a driver in this price range) was really impressive. I decided to use the Dayton Audio UM12-22 12" driver. It was not so many years ago that drivers with these specifications would have been unheard of, let alone affordably priced. Anyone who refers to "the good old days" obviously didn't build speakers. I purchased two units (see **Photo 5**).

Mounting the Woofers

After receiving the new woofers, I removed the old ones from the enclosures to see what modifications were needed to fit the new drivers. The new drivers turned out to be 0.25" larger in outside diameter than the old ones, so I had to enlarge the original mounting holes to accept the baskets. In addition, the mounting flanges and surrounds were a bit thicker. To provide clearance for the grilles and give it a more finished look, I recessed the drivers further into the housing.

This combination presented two challenges. The first was that I no longer had a center hole to use with my Jasper jig and router to enlarge the hole. The second was that, even though the enclosure's front panel was 1" thick, the amount of recess I desired would leave too little material after routing to securely fasten the drivers.

To solve these problems, I decided to use a backing plate mounted to the inside of the enclosures. First, I cut out two pieces of 0.75" MDF to mount inside the enclosures. The pieces covered the existing holes and extended far enough to provide the necessary strength to mount the drivers. They also acted as a support for the router I used to enlarge the hole's diameter. Two pieces were cut to fit inside the enclosure at the front.

A small problem cropped up when I tried to insert the backers. The enclosure's walls had additional 0.5" thick MDF plates with deadening material fastened to the inside to reduce vibrations. Because of the backers' size, the edges of the plates attached to the sides interfered with the backers. I removed, trimmed, and set them aside to be refastened inside the housing after all the work on the backers was completed. Then, I temporarily screwed the backers into place against the front plate.

Next, I fabricated a temporary pivot plate to fill the existing hole flush with the enclosure front.

About the Author

Thomas Perazella is a retired IT director. He received a BS from the University of California, Berkeley campus. He is a member of the Audio Engineering Society, the Boston Audio Society, and the DC Audio DIY group. He has written for *Speaker Builder* and *audioXpress* magazines. He has authored several articles in professional audio journals and taught commercial lighting at the Winona School of Photography.

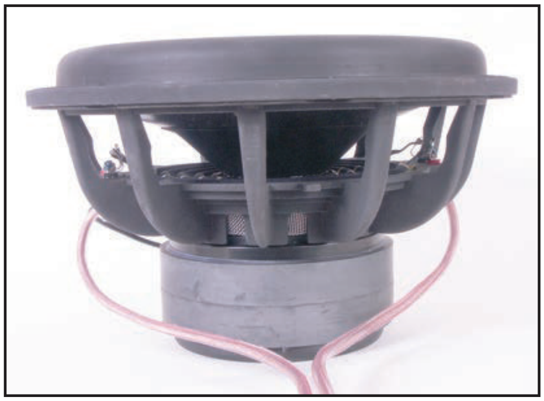

Photo 7: The woofer terminals were connected to the terminal plate using 12-gauge zip cord. A 12-gauge jumper was used to tie the two voice coils together in series.

This plate enabled the router to smoothly slide over the enclosure and provide the necessary pivot hole for the Jasper jig. I used a scrap piece of plywood for the plate that was not quite thick enough to present a totally flush surface by itself. I used several temporary shims of the proper thickness on top of the backer to solve the problem. I screwed the plate to the backer with four flat head wood screws and I drilled not only through the plate but on through the backer to make a pilot hole for the jig. This assured me that the enclosure's newly routed outside clearance hole would be exactly in line with the inside driver frame clearance hole that I later routed (see **Photo 6a**).

Then, I set the proper spacing on the Jasper jig and routed the new mounting hole in the enclosure. Once the hole was finished, I removed the pivot plate and checked its fit with the driver. Note that the backer plate has the four holes that were used to fasten the pivot plate and also the pivot hole that was then used to route the clearance hole in the backer. Because the new driver needed extra depth, the additional routing opened two small holes into the original enclosure's inside (see **Photo 6b**). Although they would be covered by the driver frame and gasket, I decided to use the wood filler to ensure the enclosure was sealed.

Next, I removed the backers and routed the clearance holes through which the rear of the driver baskets would fit. When that was done, I glued the backers and screwed them to the enclosure's inside using the same holes to ensure alignment. I replaced the damping plates. Then I masked, primed, and painted the front of the enclosure.

To maximize the enclosure's apparent inside volume, I stuffed it with the fiber material that had been used in the original speaker. Next I wired the drivers using 12-gauge zip cord and a single piece of 12-gauge wire as a jumper between the two voice coils. To achieve 4-Ω impedance, the two 2-Ω coils on each driver were wired in series with one coil's negative terminal wired to the other's positive terminal. I wired the remaining positive and negative terminals from each of the two coils to the input terminals on the enclosure (see **Photo 7**). I used McFeely's #8 black-oxide square drive wood screws to fasten the two woofers. I have been using square drive screws in critical applications for years as they eliminate the "camming" that often happens with Phillips screws. McFeely's has a good selection. The results provided a secure mounting for the woofers and, with the additional depth to the recess, a clean look. Next I moved on to the midrange and treble sections.

I will cover the remainder of the construction phase plus some problem solving in Part 2 of this article series. I will continue with problem solving plus voicing and music correction curves in the final article in this series.

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