

BLUE THUNDER

by *Christian Rintelen and R. Luigi Andreoli*

It all started with commercially available 94dB/W/m speakers and a custom-built triode amplifier. The virtues of this combination were evident — but so were its flaws. As always, different component swaps confirmed that the speakers were the weak link in the chain.

We looked and listened around for a speaker that would enhance the strengths and tone down the weaknesses of that configuration. But no commercially available speaker met all our requirements: they were either too big or too ugly or colored too much or did not match the amp or . . .

In short, we decided to start from scratch and build a speaker exactly to our taste.

Building a speaker always means dealing with compromises. The no-compromise speaker does not exist, despite all claims by manufacturers. Satisfaction has a lot to do with defining goals and being fully aware of compromises. There will still be a lot of surprises to handle during the process, but it's better to start with fixed goals. Otherwise, it's a never-ending story.

We defined our ideal speaker as follows:

- It should be a true full-range speaker with drivers that handle as much bandwidth as possible, preferably two-way.
- It should be of high efficiency (SPL over 100 dB @1W/1m).
- It should be easy to drive for triode amplifiers (loads, resonances).
- Its sound should be powerful and dynamic — yet natural, detailed and as uncolored as possible.
- It should not only please the ears, but also the eyes.
- It should work well in medium-sized (i.e. 30 m²) rooms.
- It should not require a listening distance of more than 4 meters.

We couldn't use the room corners for various reasons, so we had to forget about corner horns like certain Klipsch or Lowther designs.

Which way to go? Our goals were lofty and the restrictions clear. We thus decided from the very start that we were willing to invest in the best available components.

The demand for high efficiency and pleasing esthetics narrowed the choice down to reflex port bass and horn-loaded upper bass systems or Onken-like cabinets. Going two-way all the way, on the other hand, required a driver that could manage all frequencies above 500 Hz. Furthermore, such a driver should be horn-loaded to assure homogeneity with the presumably horn-loaded bass.

There are not many high-efficiency drivers that fulfill these requirements. But an evaluation of the different possibilities showed that one driver was perfectly up to the task—the TAD 4001 compression driver. This 2 inch unit with a beryllium diaphragm has a flat frequency response from 600 Hz to well above 20 kHz and a 12 ohm impedance at the crossover frequency range.

Efficiency is around 110 dB/W/m, due to the 2 kilograms of Alnico magnets. The compression driver weighs a hefty 13 kilograms.

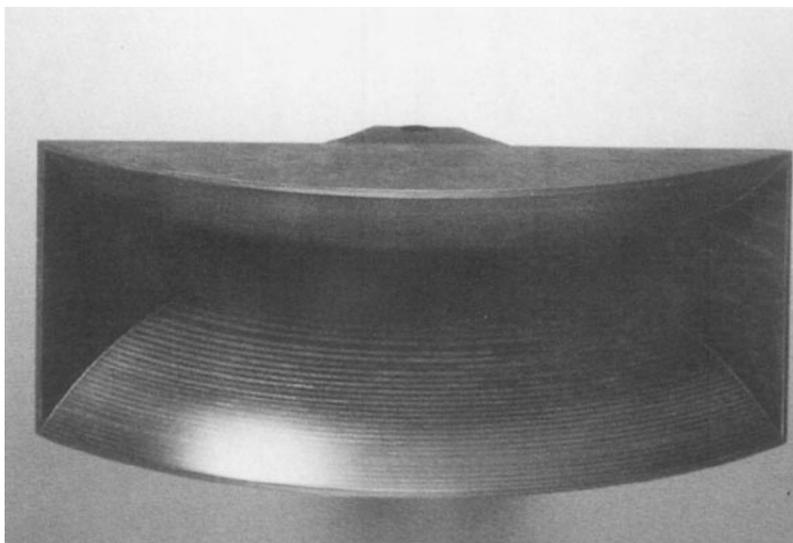
Designing a horn that covers such a wide frequency range with uniform sound dispersion and without high frequency rolloff is a tricky job. We thought about building our own horn using a Hypex or Tractrix expansion. Doing so would require a lot of work and money without guaranteed satisfaction. TAD, on the other hand, offers a horn especially designed for the 4001 compression driver. We decided to go for that option, assuming that the guys at TAD surely know how to tweak the best out of their drivers. After all, their driver/horn combination is considered hot stuff in recording studios all over the world. *[and well received in global audiophile circles, except in the US market where a decades-old divide between pro and high-end gear has prevailed. Of course, the price of the top professional compnents like TAD is somewhat restrictive but Class A high-end speaks ain't cheap either —ed.]*

The TAD horn width is 61 centimeters — a measurement of some significance since we didn't want the speaker to look like a haphazard stack of boxes. The original Onken design is some 80 centimeters wide. Putting the TAD horn on top of it would have been an eyesore. In short, the cabinet of the bass speaker should also be 61 centimeters wide.

This ruled out any Onken-style cabinets with 15 inch woofers, since the area of the reflex openings on that design is equivalent to the driver surface. The Onken bass enclosure was originally designed to be used with transistor amps (even the models with the reduced vents are reported to have a slightly lumpy bass with tube amps compared to transistor designs). It would also have needed a large lower midrange horn to offset the decreasing sound pressure of the direct radiating woofer, so we decided against it.

Comparing the different driver options for the woofer, we went for the Focal Audiom 15 VX II instead of the Altec 416, since the latter needs a 30% larger enclosure volume for the same bottom end. Horn loading all the way down was out of question, since the opening required for 25 Hz would be 4m²!

So we settled for a vented cabinet with horn loading down to approximately 120 Hz, similar to the Voice of the Theatre. Tractrix or exponential? The Tractrix curve horns sound good in the 150 to 500 Hz



TD-4001 High-Frequency Driver

The TD-4001 successfully achieves all the design objectives we set forth — very high efficiency, wide and perfectly flat response from 600Hz to 20kHz, and low distortion.

DIAPHRAGM. The TD-4001 employs a pure beryllium diaphragm 3-15/16 inches (100mm) across. Beryllium is a light but very rigid material that features very high-speed sound propagation. The weight of the dome section has been reduced to a mere 1g, contributing to the very high efficiency (110dB/W) of this driver.

VOICE COIL. The TD-4001 employs an aluminum ribbon voice coil, insulated by alumite film and wound edgewise on the bobbin. The voice coil has a small mass yet offers a high conversion efficiency. The bobbin is formed of polyimide film, displaying excellent heat resistance to temperatures as high as 752°F (400°C).

MAGNETIC CIRCUIT. Total magnetic flux is 228,000Mx, with flux density of 20,000G, thanks to the use of a very heavy (6 lbs. 10 oz./3kg) alnico 5DG magnet. An oxygen-free copper shorting ring prevents impedance rise, resulting in low distortion.

DESIGN. The TD-4001 is of the rear compression design, which eliminates the resonance and phase distortion produced by a surround. It also eliminates cavity resonance interference, achieving very flat frequency response, extremely natural sound and superb definition. A phasing plug helps smooth the response of extra high frequencies.

CROSSOVER. We recommend the use of a crossover frequency of 600Hz or higher, and a cutoff slope of 12dB/oct. or sharper.

TD-4001 SPECIFICATIONS

Voice coil impedance: 16 ohms **Voice coil diameter:** 4 inches/101mm **Equalizing system:** 5-slit type **Frequency range:** 600 — 20,000Hz **Maximum input power:** 60 watts (600Hz, — 12dB/oct.) **Sound pressure level:** 110dB/W (1m) **Crossover frequency:** over 600Hz (— 12dB/oct.) **Total magnetic flux:** 228,000 maxwells **Magnetic flux density:** 20,000 gauss **Hole size for throat connection:** 1-15/16 inches/49.4mm **Mounting dimensions:** 4 inches/101.6mm (4 holes) **Weight:** 29 lbs. 12 oz./13.5kg **Outer dimensions (diameter × depth):** 7 × 6-1/8 inches/178 × 155.5mm

TH-4001 Stabilized Dispersion Horn

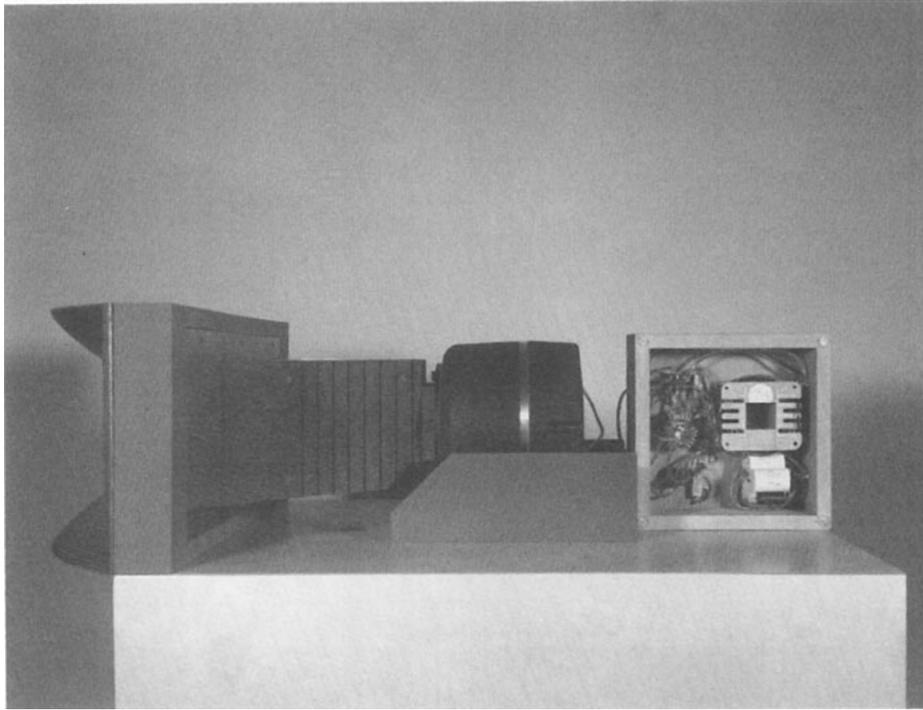
The TAD TH-4001 is a stabilized dispersion horn designed specifically for use with the TD-4001 high-frequency driver. It allows you to exploit the wide frequency response of this unit, providing excellent dispersion of all frequencies, including high frequencies above 10kHz, a feat rarely achieved by large horns. The dispersion pattern is optimized, based on our measurements of actual room acoustics. As a result, the entire output of the TD-4001 is uniformly distributed over a large area. High resolution is another result of our acoustic engineering. The horn is made of genuine maple, for clean, rich, natural sound.

TH-4001 SPECIFICATIONS

Type: Stabilized dispersion horn **Cut-off frequency:** 320Hz **Flare type:** Hyperbolic curve **Radiation angle:** 90° (horizontal)/40° (vertical) **Throat diameter:** 1-31/32 inches/50mm (suitable driver throat diameter: 1-15/16 inches/49.2mm — 2 inches/50.8mm) **Driver mounting system:** P.C.D. 4 inches/101.6mm L90° 4 bolt mounting **Weight:** 24 lbs. 11 oz./11.2kg **Outer dimensions (W × H × D):** 24-1/8 × 9-7/16 × 16-1/8 inches/612 × 239 × 410mm **Accessories:** Horn mounting hardware pieces × 6, Washers × 6, Bolts with hexagonal heads × 6

US office for TAD Professional Components: Pioneer Electronics Service, Inc.,
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Catalog Descriptions of Technical Audio Devices Horn and Driver



Highpass filter with 0.2 dB per step attenuator, 1.2 mH/0.13 Ohm DCR coil, and five PP caps bypassed with a tinfoil cap shown mounted behind the TAD horn

Interior view of bass cabinet.



The interior of the cabinet is lined with black acoustic foam. No further stuffing was used.

Birch plywood "sounds" very nice and is ideally suited for this kind of speaker, but it is a real pain to work with.

Note the two hefty (10 kg each!) 0.27 mH 0.17 Ohm DCR coils made of 5 mm² wire used in the symmetrical low pass filter.



range. In addition to this, a Tractrix curve would allow a nice visual effect because the 45 degree angle of the cabinet walls blends perfectly with the miter joints we intended to use for the cabinets. According to Dinsdale's and Lambert's work, the true cutoff in a Tractrix horn occurs at the 70% to 80% point of the mouth area — the cabinet walls precisely made up for this percentage.

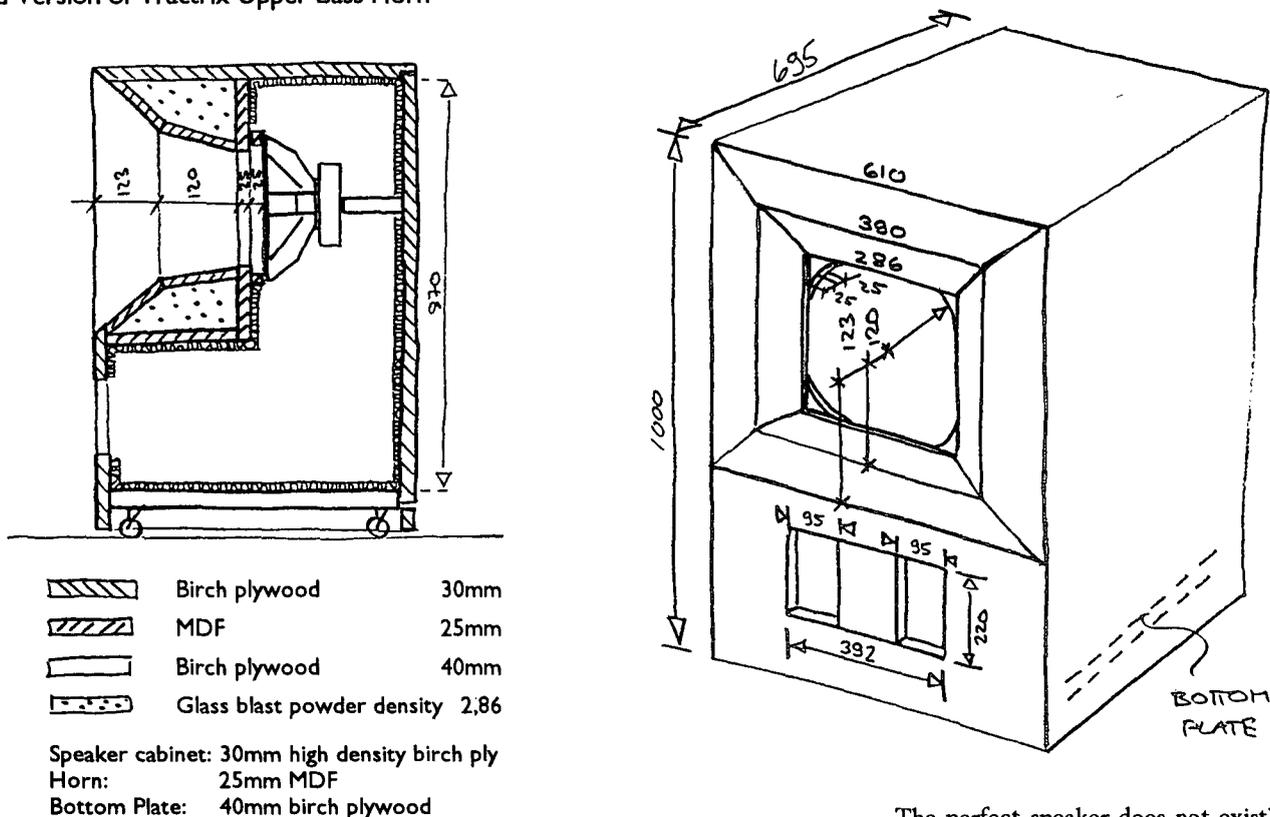
The Audiom driver needs a volume of about 220 liters (0.22 m³) in a vented cabinet to produce bass down to 40 Hz. Add that to the volume of the horn plus the massive plywood, and you get a fairly big cabinet. With the front being relatively narrow, the speaker looks impressive but neither intimidating nor overly conspicuous. The finished speaker is 61 cm wide, 125 cm high, and 70 cm deep (including midrange horn). It weighs approximately 150 kilograms. The finish is clear lacquer for the enclosure and dove-blue Nextel for the Tractrix horn and the crossover box.

The speaker was intended to be used in bi-amp setup using two stereo amps with 6336 dual triodes in the output stage. The amp allows one to drive the twin power triodes either P-P or SE, since phase-splitting is done in the pre-amp and the four channels of the power amps are each connected with two coaxial leads carrying the 0 and 180 phase signal. For push-pull, both input signals are connected and both sections of the 6336 are driven. Conversion to SE can be done in two seconds by disconnecting the phase inverted input signal, so only one section of the twin power triode is driven. We use P-P for the bass and SE for the midrange.

The crossover frequency is 560Hz with a 12dB design using two huge coils in the bass to minimize DC resistance. We chose a symmetrical configuration since the output transformer of the amp is not grounded. This allows the woofer to be driven equally on both leads. The crossover for the TAD can either be used in a conventional configuration for single amp operation with a stepped attenuator providing 0.2 dB steps or with the attenuator bypassed for bi-amping. The choice of excellent drivers allows simpler crossover designs since you don't need extensive filtering to fix any inherent glitches and flaws.

The Audiom woofers were "burned in" for three days with different frequencies before mounting. Despite our best efforts at initial break in, the bass reproduction continued to improve significantly for half a year!

Simplified Version of Tractrix Upper Bass Horn



We selected 30 millimeter birch plywood for the cabinet in order to raise cabinet resonance to a point well above the radiated frequencies. The Tractrix horn was made of 25mm MDF — a wise choice considering the many odd angles of the Tractrix horn. The cavity between Tractrix horn and cabinet was filled with sandblast-grade glass beads.

Like everybody, we wanted a speaker capable of credibly reproducing all kinds of recorded music. To us, this "credibility" includes (among other criteria):

- Convincing micro- and macro-dynamics
- Timbral correctness
- No disturbing coloration in any frequency range
- Credible reproduction of sound stage depth and width
- Authority (i.e. the necessary body and air real music has).

Just a brief description of what we ended up with — as unbiased as possible: the speaker produces a big, emotionally involving, but nevertheless precise and thus credible reproduction of the recorded event. It does not turn a lousy recording into gold, but even mediocre recordings and pressings really shine.

The bottom end has tremendous energy and authority. It is fast, colorful, tight and controlled without audible cabinet resonances. It really moves air when kick-drums are kicked. The far left of a piano has the necessary attack and speed to be considered "almost real." Plucked bass is reproduced sonorously with plenty of snap and color.

The midrange is seamless and very homogeneous, despite the crossover in the critical 500 Hz range. Harmonics of bass instruments really "sing." Forget any prejudice about horn speakers not being suited for voices — the TAD sure is. The highs are neutral, extended and sweet. Hot or bright recordings can be tamed by the very fine increments of the attenuator. What is especially pleasing with this two-horn speaker: you don't have to move 6 meters away to get homogeneity and a seamless blend of the two horns — 3 meters is enough.

We are happy with the result. Of course, the speaker is big. But it integrates well into rooms that measure 30 m² or more. The money spent on excellent component quality was well invested. Our recommendation to all DIYers: Don't build a big speaker with little money — build a small one with the best components you can afford. It certainly pays off!

The perfect speaker does not exist! A fully horn-loaded bass, for instance, would speed up the bass even more. A super-tweeter above 15 kHz would probably add some extra air and reduce the directionality of high frequencies. And who knows how much more magic a SE 2A3 amp with built in passive crossover would add to the TAD drivers? But that's another story.

The authors:

Christian Rintelen is a free-lance writer and spends his spare time editing *HiFi Scene*, a Swiss nonprofit underground magazine. Luigi "Blue" Andreoli studied architecture and design. After completing his first houses, he decided that hi-fi is more fun. He hand crafts everything from MC cartridges and amps to speakers of any size. Christian and Blue live in Zürich, Switzerland.

ed.- *Hi-Fi Scene* is one of those mags like *MJ* from Japan and *Costruire Hi-Fi* from Italy that makes a poor monoglot like me wish that Esperanto was the world language. Every progressive audiomaniac would enjoy the vision this "von Kennern für Kenner" German-language magazine offers. Write Christian for more info on this *inspirierte Zeitschrift*.

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