Testing a Tripath Power Amplifier

By
Ron Tipton
(United States)

A Tripath or Class-T power amplifier is a proprietary version of the Class-D switching amplifier developed by Tripath Technology. Tripath claims its architecture uses "adaptive" processing to improve general switching amplifier design. This article examines two amplifiers that use Tripath ICs: the Tripath TA2024, which is rated at 15 W per channel, and the Lepai TA2020A+, which is rated at 20 W per channel. The amplifiers sound good, but testing them is problematic. This article explains their testing challenges.

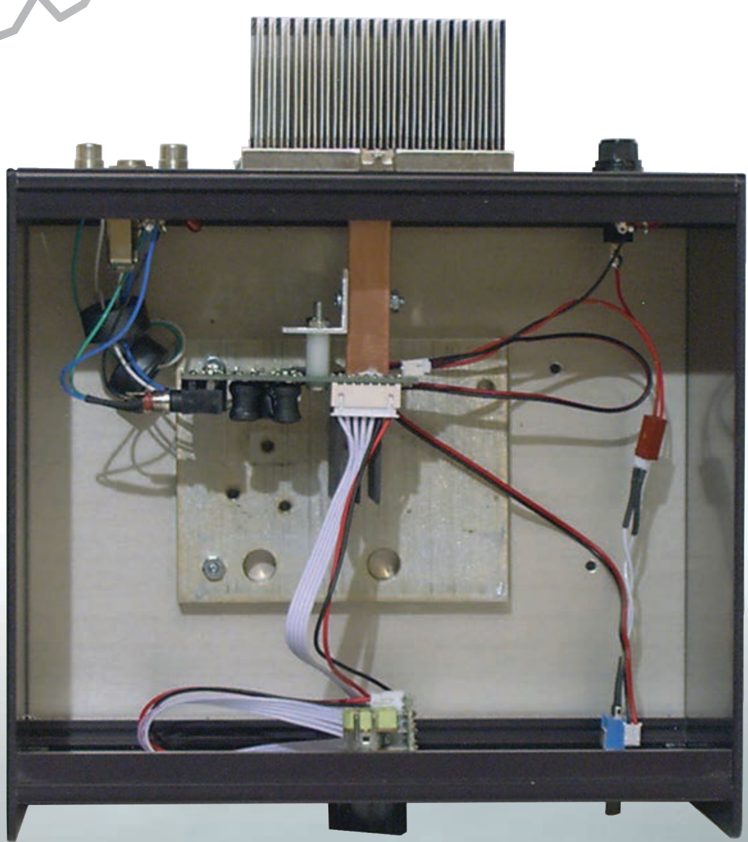

Photo 1: The Tripath TA2024 amplifier module is shown with its heat removal system. The underside of the circuit board rests on one end of the copper bar that is soldered to the finned heatsink. A portion of the finned heatsink expoxied to the top surface of the IC can be seen underneath the light-colored ribbon cable.

As I mentioned, the Tripath works very well reproducing music but distortion testing must be done at a single frequency. So, this architecture does not deliver much output power at a single frequency because the IC heats up and its internal thermal sensor shuts it down.

Getting the Heat Out

I increased the cooling for a Tripath Technology TA2024 module by adding heatsinks (see **Photo 1**). The IC's underside rests on the end of a 0.5" × 0.5" copper bar, which is soldered to the copper bottom of the finned radiator fastened to the back of the enclosure. I used some silver bearing thermal grease between the IC and the copper bar to maximize the heat conduction. I also used conductive epoxy to cement a finned black aluminum heatsink to the top of the IC. The modifications are very effective.

The TA2020 IC in the Lepai TA2020A+ is physically larger and it is spring clipped to a finned aluminum heatsink inside the enclosure. I increased the cooling by adding a 12-VDC fan (see **Photo 2**). I also drilled six 0.3" diameter holes in each side of the enclosure for increased air flow. The Lepai unit is lightweight and the cables drag it around so I added a walnut base and a switch on the left rear corner to turn the fan off for normal listening. Again, the increased cooling is very effective.

Floating Speaker Connectors

Most, if not all, analog power amplifiers do not object if the "low" sides of the speaker outputs are connected to a signal common. But the Tripath architecture does object and the internal fault detection circuit shuts down the amplifier. The speaker connectors are floating so one side of the dummy load can't be connected to circuit common. This calls for an output isolation transformer. I used a pair of 70-V line to 8-Ω units connected "line to line" for 8 Ω in and 8 Ω out. This isolation works well and was used for testing both amplifiers.

Output Filter

Switching amplifiers generate a lot of high-frequency "noise" in their output signals. Loudspeakers ignore the noise so it isn't a listening problem; however, it does interfere with distortion testing. I built an active output filter with an eight-pole Bessel low-pass response and a 30-kHz cutoff frequency. **Photo 3** shows the filter. **Figure 1** shows the circuit diagram. The output isolation transformer attenuates some of the high-frequency noise but there seems to be enough coupling for the output filter to be useful.

Testing

Now that I've taken care of the housekeeping issues, it's time to test the unit. The total harmonic distortion (THD) test is straightforward (see **Figure 2**). My signal source is a 1,000-Hz Wein-bridge oscillator with a 0.0095% measured THD that I built for another project. **Figure 3** shows its output spectrum as measured by TrueRTA.

The TA2020 module's THD measures 0.13% at 2.5 W RMS into 8 Ω. **Figure 4** shows the TrueRTA spectrum. At 5 W RMS into an 8-Ω output the THD increases to 0.19% with the second and third harmonics still predominate. At higher outputs into 8 Ω, the THD increases rapidly. For example, at 10 W RMS the sine wave is severely clipped and the THD is 38%. The 12-VDC power supply is insufficient to deliver 10 W RMS into an 8-Ω load.

The Lepai module measures 0.16% at 2.5 W RMS into 8 Ω and 0.17% at 5 W RMS. The output spectra are very similar to **Figure 4**. These numbers exceed the published THD specifications for power into 8 Ω but not by a significant amount.

Intermodulation Distortion

Rather than making static intermodulation distortion (IMD) measurements, I chose to use a transient intermodulation distortion (TIM) test. This test is not as well known but I fully described a method for it in my article "TIM Revisited" (*Multimedia Manufacturer,* 2008).

Physically, TIM is produced in analog power amplifiers by global negative feedback. This occurs when the open-loop cutoff frequency of the output stages is less than the open-loop cutoff frequency of the input stages. Many modern analog power amplifiers have low TIM, but I was uncertain if this was true with a Tripath amplifier.

My measurement method uses a signal source of a microprocessor-generated 3,100-Hz square wave added to a sine wave at 14,368 Hz that has an amplitude 12 dB lower than the square wave. (This composite signal is band limited 2 to 30 kHz by an eight-pole Butterworth low-pass filter.) With 3,100 Hz

About the Author

Ron Tipton has degrees in electrical engineering from New Mexico State University and is retired from an engineering position at White Sands Missile Range. In 1957 he started Testronic Development Laboratory (now TDL Technology) to develop audio electronics. He is still the TDL president and principal designer.

Photo 2: The Lepai TA2020A+ amplifier is shown with its cooling fan and the walnut base added for increased weight. The rear, left toggle switch turns the fan on or off.

Photo 3: A front view of the active low-pass filter used in the Class-T amplifier testing to remove the output high frequency switching noise is shown. This filter was not used for the transient response test.

being f1 and 14,368 Hz being f2, the measurement circuit looks for a product at 1,132 Hz (i.e., 5f1 – f2). **Figure 5** shows the TIM test waveform. **Figure 6** shows the spectrum. Note that **Figure 6** shows no product at 1,132 Hz above –117 dBu so any 1,132 Hz in the output is due to amplifier TIM. The idea is the sharp rise and fall times of the square wave stress any slew-rate limited portions of the amplifier. This makes the intermodulation products between the square wave harmonics and the sine wave show up as TIM. **Figure 7** shows a block diagram of the test setup. The measurement is straightforward, however, building the equipment wasn't!

In my referenced article, I measured eight different analog amplifiers. One used an integrated circuit (National LM3876), six were all solid-state and one used a vacuum-tube input with a MOSFET output. The IC design and the Leach "Low TIM" design showed no TIM that I could measure at either 1 or 10 W RMS output, while the others did.

Figure 8 shows the TIM test result for the TA2024 module at 2.5 W RMS into 8 Ω. It shows a TIM product of about 10 dB. The Lepai results are similar with 15 dB at 2.5 W RMS and 21 dB at 5 W RMS. These numbers mean the Tripath designs are similar to what I measured on some of the analog designs. Although measurable TIM is present, it is probably not audible. I measured TIM as high as 30 dB on one of the analog amplifiers, yet it sounded fine in listening tests. TIM is audibly similar to crossover distortion so it would be heard if it was present at large enough amplitude.

Transient Response

Transient response is a function of an amplifier's bandwidth. The higher the bandwidth, the better it is at reproducing percussive sounds with fast rise or fall times. Although these transient sounds are often above the range of human hearing, it has been amply demonstrated that they are perceived when they are cleanly reproduced. Music with percussive sounds (e.g., cymbals, harps, harpsichords, etc.) sound more "real" with a wider bandwidth amplifier given the same audio system.

The TIM signal generator's 3,100-Hz square wave is produced by a microprocessor running at a 18 -MHz clock rate so the square wave has rise and fall times of 220 nS (four times the clock period). I used this signal to drive two amplifiers to 2.5 W RMS into 8 Ω.

Figure 9 shows the result for the Lepai amplifier. The top trace is the input and the lower trace is the

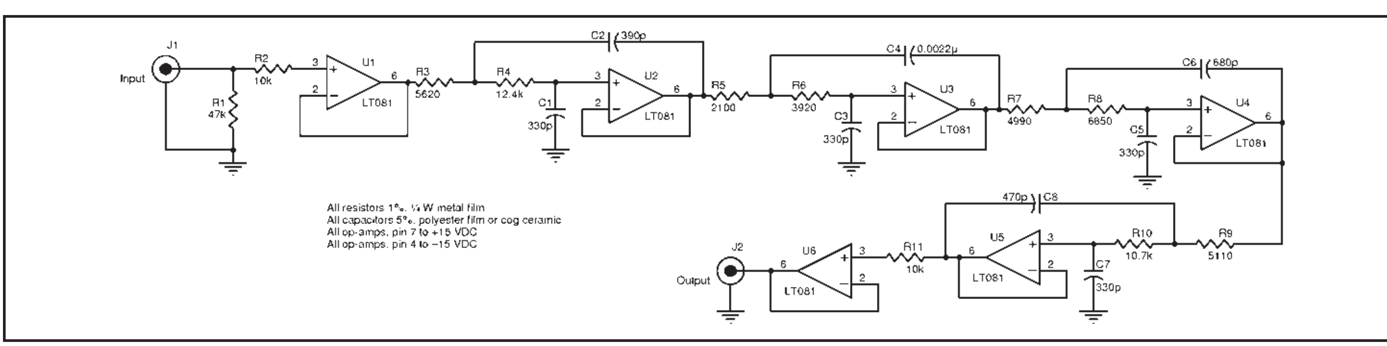

Figure 1: The Tripath amplifier output is tested with a low-pass filter with an eight-pole Bessel response and 30-kHz cutoff frequency. Low noise op-amps are not needed for this application.

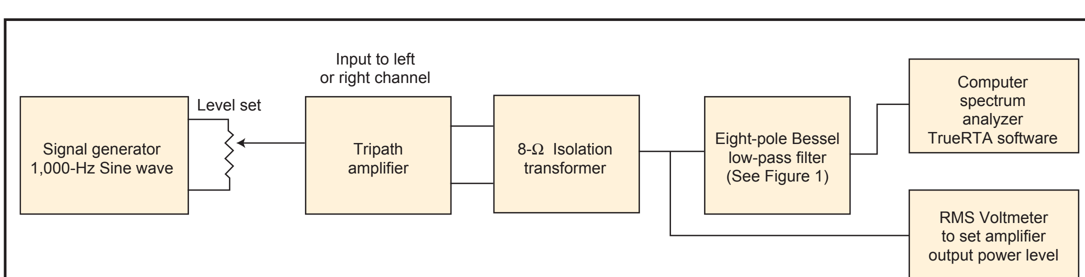

Figure 2: The block diagram of the harmonic distortion test equipment setup is shown. Any low-distortion signal generator could be used.

The Tripath Story

In 1995, Dr. Adya S. Tripathi had some ideas for improving the performance of Class-D audio power amplifiers so he started Tripath, Inc. to pursue these goals. Apparently he found adequate venture capital as evidenced by the headquarters building in Santa Clara, CA, with some 200 employees (see **Photo 1**).

Photo 1: Tripath's headquarters were built in Santa Clara, CA.

Photo 2: A Tripath TA2041 four-channel amplifier was rated at a maximum output of 280 W (70 W per channel).

Class-D designs were enjoying some popularity, especially for woofer power, because of their high efficiency compared to Class-A and Class-AB. However, their total harmonic distortion (THD) was fairly high at higher audio frequencies. This was one area in which Tripath achieved significant improvement. Just how this was accomplished can be surmised from online information.

A starting point is an interview Crutchfield Company, a consumer audio and video distributor, conducted with Shawn Scarlett, Tripath's Senior Product Manager. In answer to the question "how does a Class-T amplifier work?" Scarlett replied, "Class-T (a registered trademark) is the name for our proprietary architecture that improves on general switching amps. It uses a combination of 'predictive' and 'adaptive' processing. On top of that, we use a very high switching frequency."

The switching frequency is variously reported in different sources. A web post by Jon Iverson (*Stereophile* magazine, November 1998) refers to the switching frequency as "up to 1.5 MHz." However, Brian Santos's article, "25 Microchips That Shook the World," (*IEEE Spectrum*, May 2009) refers to a 50-MHz switching frequency. Datasheets (up to 2002) agree with up to 1.5 MHz, but perhaps the frequency was increased as technology permitted.

Scarlett continued, "The basic idea is that we look at the incoming signal to determine the best way to encode it, making sure to minimize interference or mistakes. We then use feedback, or 'adaptive' processing to analyze the output and keep the system stable. The high switching frequency allows it to correct any issues quickly before they become audible. Because of the robustness of the system, we can maintain our fidelity even with mismatches in the output field-effect transistors (FETs), power supply 'ripple,' and other issues."

Scarlett presented us with three basic ideas: a high switching frequency, output-to-input feedback, and "processing" of some kind to overcome any mismatch between the output switching transistors. During its 12-year operating life, Tripath was granted some 100 patents. The most significant one from the point of view of this story seems to be US Patent #5,777,512, a 20-page document with many claims and quite a bit of detail. It reinforces the three basic ideas I mentioned. From the information, I drew **Figure 1.** It is my "best guess" at a commercial Tripath design. **Photo 2** shows the TA2041, a four-channel audio amplifier. This is a four-channel amplifier, with 50-W per channel at 10% THD with an efficiency of 85% at 50 W into 4 Ω. Note the relatively small size of the heatsink to dissipate the other 15% of input power.

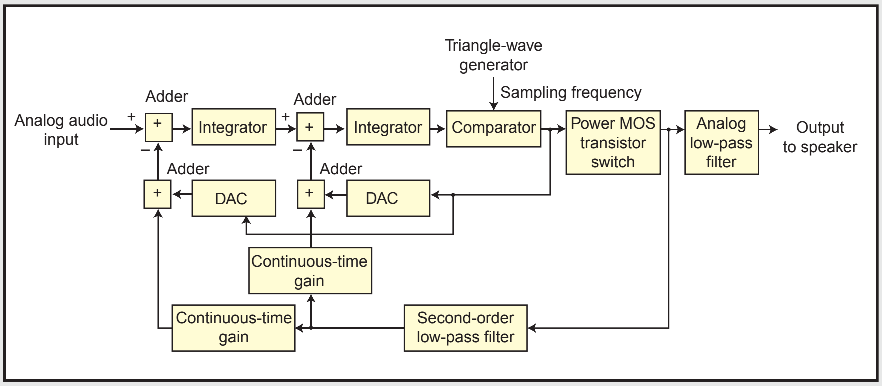

Figure 1: I derived this block diagram of the Tripath power amplifier design based on the available online information.

I have spoken with a trademark-patent attorney and all a patent actually does is enable the holder to sue for possible infringement. When granted, the patent document is public information so anyone can use the ideas as long as the embodiment is not copied. It is apparent from the improvements that appeared in Class-D designs that other manufacturers were vigorously applying these ideas. The competition proved too great a burden so Tripath filed for Chapter 11 (reorganization) bankruptcy in February 2007. The company was purchased by Cirrus Logic latter that year but they soon discontinued the Tripath operation.

A web search will show there is no shortage of either Tripath amplifiers or chips so excellent innovation lives on even though Tripath probably did not profit from it as much as it had anticipated.

output. The output square wave rise time is 10 µs so the bandwidth is 35 kHz (i.e., bandwidth in Hz = 0.35/rise time in seconds). As a sanity check, I also made this test with an input isolation transformer and 8-Ω load instead of the output isolation transformer. The result was the same. A 35-kHz bandwidth would provide a fair transient response. Whether it would be audibly noticeable depends on the type of music, the loudspeaker system, and the room acoustics.

Contrast **Figure 9** with **Figure 10** to get the

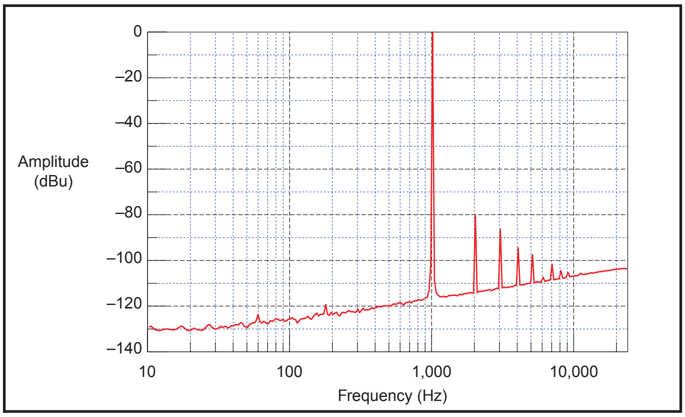

Figure 3: The output frequency spectrum of the 1,000-Hz Wein-bridge test signal generator provides a 0.0095% measured THD.

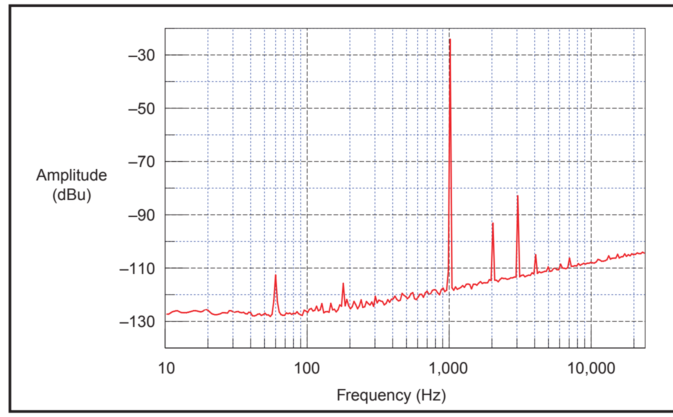

Figure 4: The TA2024 Tripath amplifier's output frequency spectrum is shown at 2.5 W output into 8 Ω. The amplifier volume control set to mid position. An attenuator was placed between the amp output and the sound-card input to prevent over driving. The measured THD is 0.13%.

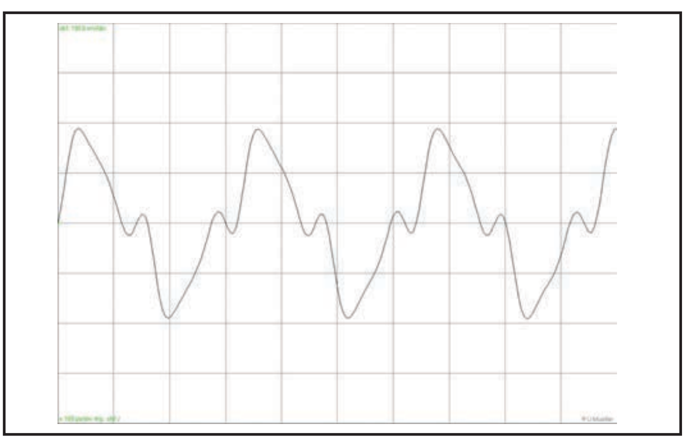

Figure 5: The TIM test signal consists of a 3,100-Hz square wave added to a 14,368-Hz sine wave with an amplitude 12 dB lower than the square wave. The horizontal axis is linear time, 100 µs per division. The vertical axis is amplitude, 100 mV per division.

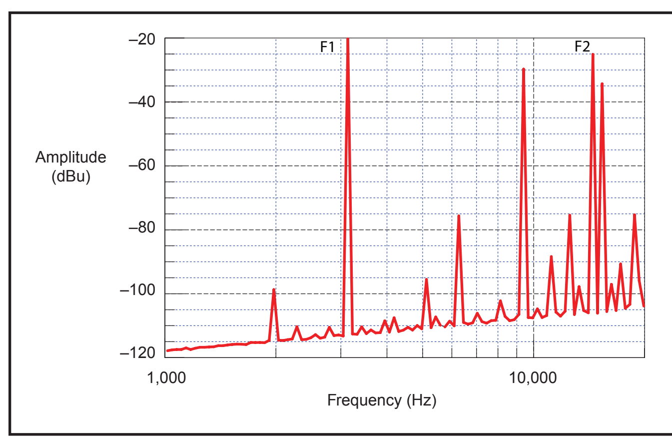

Figure 6: TIM test signal is shown at the output of the TIMFIL-1 eight-pole Butterworth band-pass filter. The lower band edge is 2,000 Hz and the upper band edge is 30 kHz. This is an active filter and it is housed in a cast aluminum enclosure to minimize noise pickup.

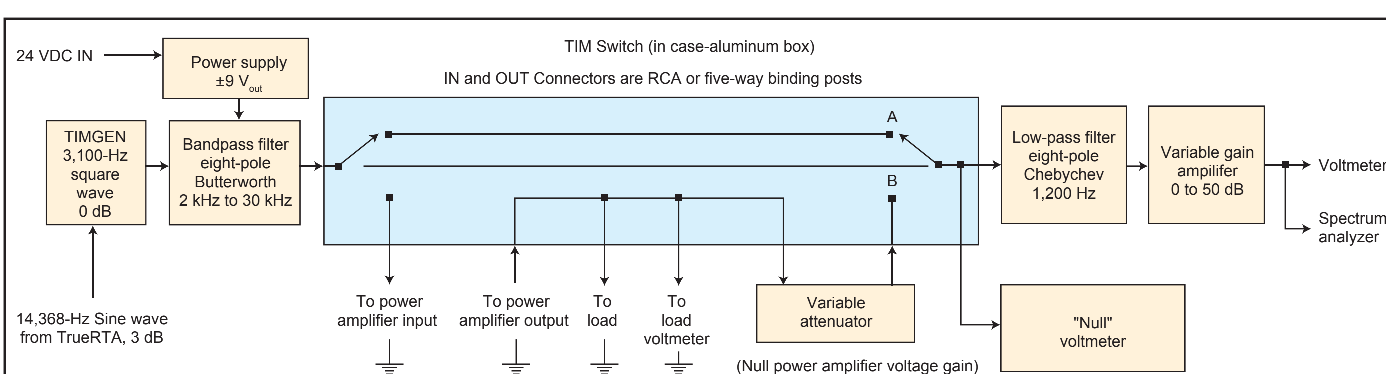

Figure 7: TIM measurement block diagram is shown here.

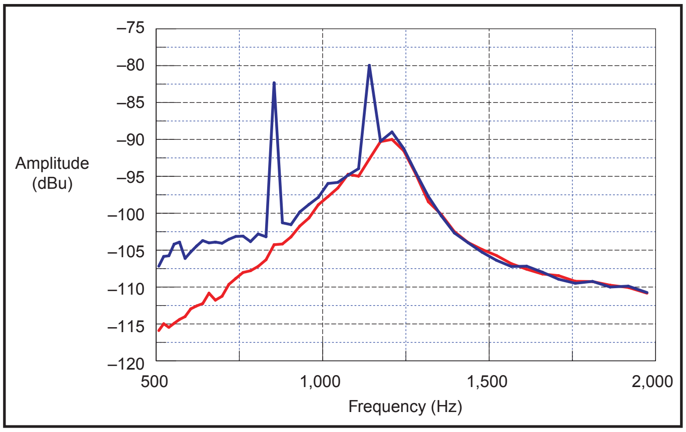

Figure 8: A TIM test result for the Tripath TA2024 is shown at 2.5 W RMS into 8 Ω. The lower graphed line (black) is the calibration baseline. The upper line (blue) is the TIM measurement with a 10 dB peak at 1,132 Hz.

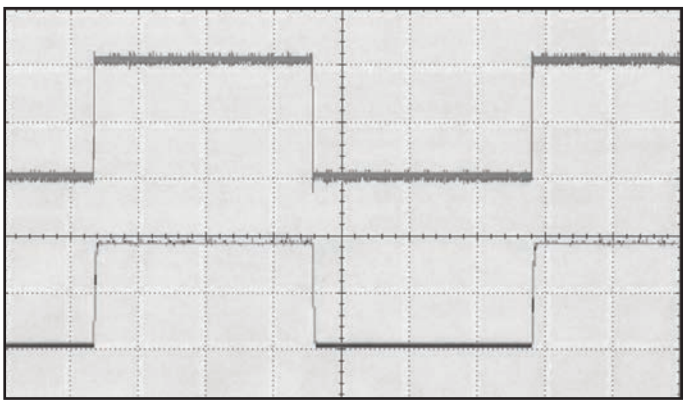

Figure 10: The transient test result for the Leach Low-TIM amplifier (version 4.5) shows 2.5 W RMS into 8 Ω. The upper trace is the input 3,100-Hz square wave. The lower trace is the amplifier output showing rise and fall times of about 1 µs with no overshoot or ringing. The horizontal scale is linear time, 0 to 500 µs.

result for the Leach Low-TIM amplifier. The rise time is less than a microsecond and there is no overshoot or ringing. The Tripath ringing shown in **Figure 9** is probably the result of the Tripath's lower bandwidth and perhaps its overall architecture. The Leach design is an excellent amplifier and you can get all the details, including a copy of Leach's original *Audio* magazine article by downloading the zip file from my website.

Resources

TDL Technology, Inc., www.tdl-tech.com/tim-mmm.zip.

R. Tipton, "TIM Revisited," *Multimedia Manufacturer*, November–December, 2008.

Sources

Tripath TA202A+ Amplifier
Lepai | www.lepai.us

LM3876 Amplifier
Texas Instruments, Inc. | www.ti.com

Tripath TA2024 Module and isolation transformers
Parts Express | www.parts-express.com

TrueRTA audio spectrum analyzer software
TrueAudio | www.trueaudio.com

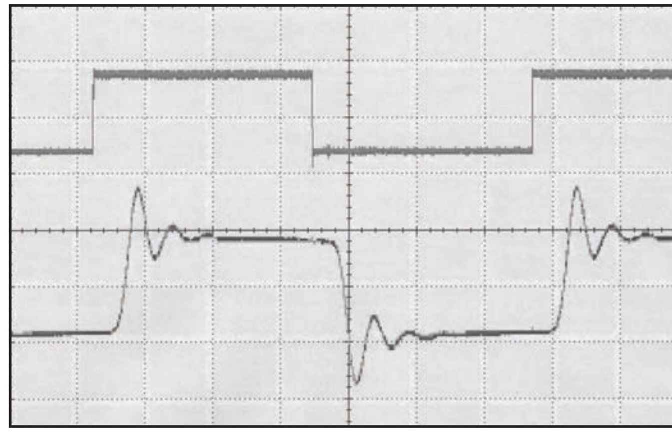

Figure 9: A transient test result for the Lepai amplifier is shown at 2.5 W RMS into 8 Ω. The top trace is the input 3,100-Hz square wave. The lower trace is the amplifier output showing rise and fall times of 10 µs. The horizontal scale is linear time, 0 to 500 µs.

Final Thoughts

The Tripath amplifiers are inexpensive so in a way it's unfair to compare them to amplifiers that cost hundreds of dollars. Nevertheless, the comparison is useful because you do "get what you pay for." Both the Tripath models I tested sounded excellent in listening tests until I compared them using music that stressed the transient response, then I could hear some differences. Still, there are many applications where these small, inexpensive, and power-efficient units will do nicely.