

TECHNICAL INFORMATION - AN1

CLASS-T DIGITAL AUDIO AMPLIFIER TECHNOLOGY OVERVIEW

A Technical White Paper

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Class-A and Class-AB amplifiers have long dominated the amplifier marketplace. These purely analog devices have low power efficiency, and most integrated circuit Class-AB amplifiers fall short of true high-fidelity audio quality. Another class of amplifier, Class-D, solves the efficiency problem by using switching pulse-width modulation (PWM) technology. However, this produces audio output quality that is inferior to Class-A or -AB, so efficiency is gained at the expense of signal fidelity. As a result, these amplifiers are generally used only in low-frequency subwoofer applications where the audio fidelity performance level of PWM amplifiers is acceptable. The "Holy Grail" of amplification: high audio quality and high power efficiency in a single technology has long eluded the market.

A Watershed in Digital Amplification

Tripath Technology has developed a category of digital audio power amplifiers using a unique technology. Tripath amplifiers use a completely new proprietary method of Digital Power Processing™ that provides superior performance to conventional methods of amplification. For the first time, both high signal fidelity AND high power efficiency can be achieved with the same technology. Tripath refers to this DPP™ based amplifier as a Class-T design. The underlying technology of Class-T does not use PWM and is not a pure analog approach (Classes -A and -AB). It combines the benefits of both with a completely new approach.

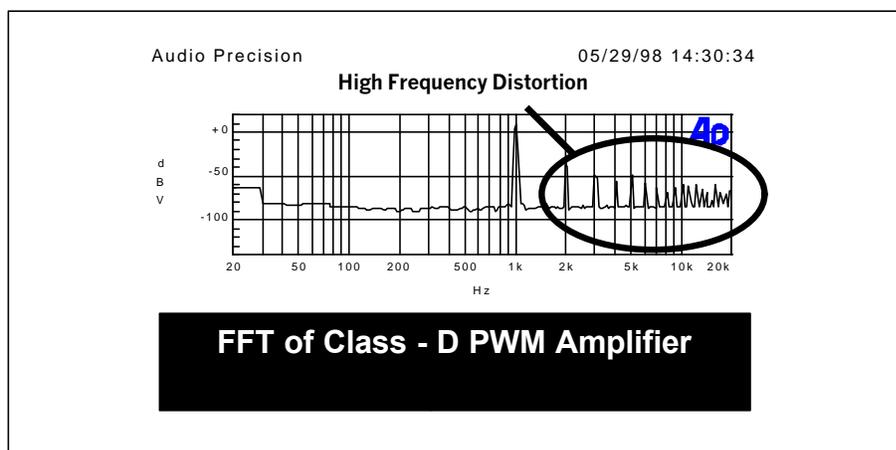
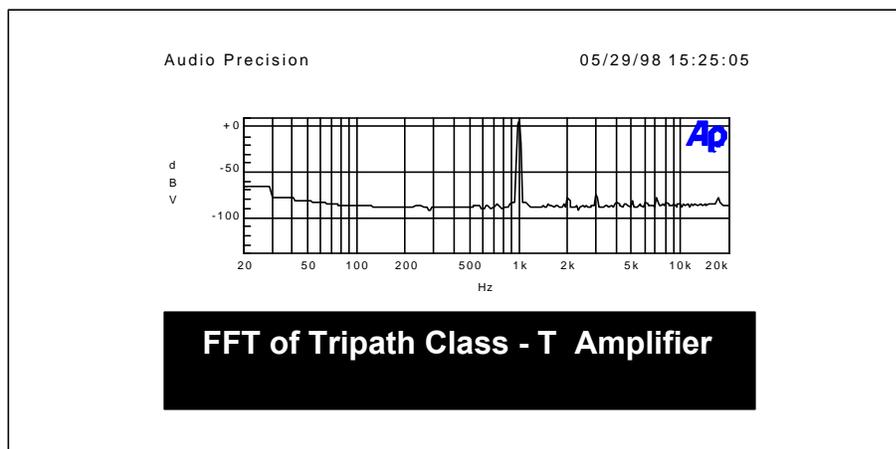
Tripath's Class-T amplifiers are the first application of this breakthrough approach. Class-T amplifiers provide the signal fidelity of sophisticated discrete-component linear Class-A and -AB designs, while offering high power efficiencies and the potential to need less exotic engineering to achieve high-end audiophile performance. These amplifiers also reduce cost for amplifier overhead at high power levels (such as power supply, filtering, and heat venting). Class-T provides power conversion efficiencies of 80 percent to more than 90 percent, which is equal to or better than Class-D amplifiers.

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Customers no longer have to choose between optimizing signal fidelity or efficiency. Both can now be achieved with Class-T technology.

“Audiophile” Sound Fidelity with High Power Efficiency

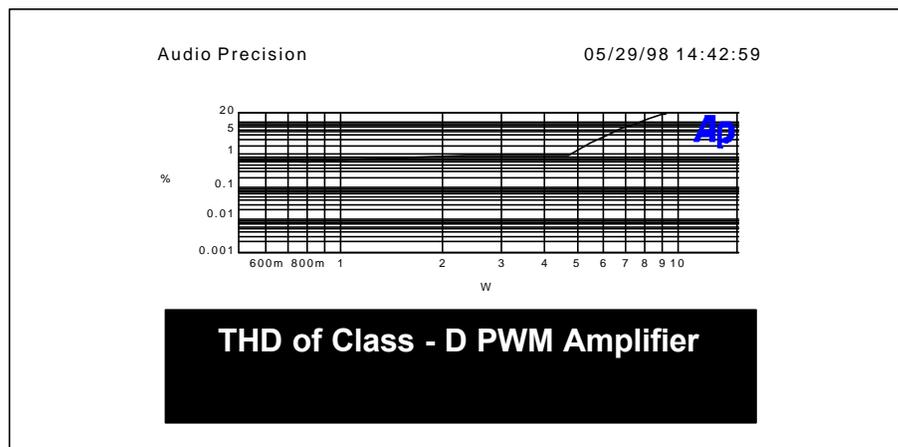
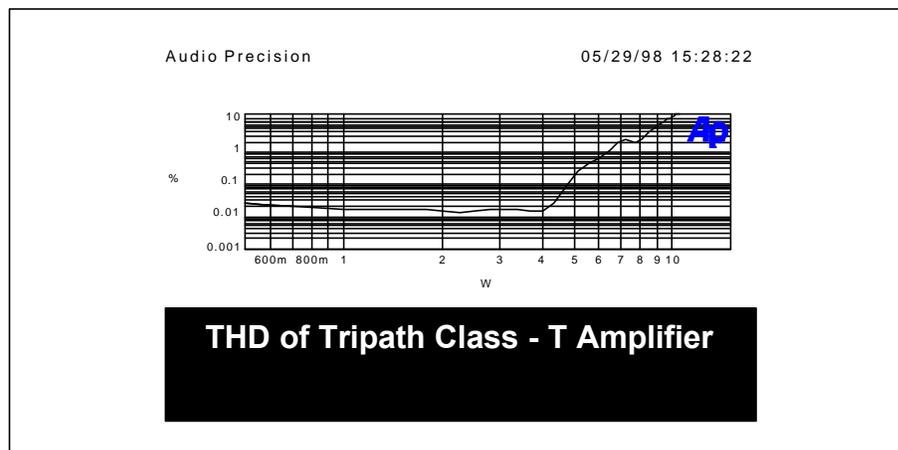
Total Harmonic Distortion plus Noise (THD+N) is often thought to be the definitive figure of merit for audio quality in power amplifiers. Many amplifiers only specify their THD+N performance, frequently at only 1 kHz. However, an amplifier with high THD+N can sound “good” and an amplifier with a low THD+N can sound “bad.” Audiophiles know that the important criteria to consider are which harmonics comprise the THD+N and what interaction there is between signals of different frequencies, particularly the higher frequencies. They generally consider “low distortion” to be both THD+N of less than 0.1% over the full 20Hz to 20kHz audio bandwidth and IHF-IM (high-frequency intermodulation distortion) of less than 0.1%.



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Tripath Class-T amplifiers have THD+N of significantly less than typically 0.08% *over the full audio bandwidth* and IHF-IM less than typically 0.04% and therefore deliver what's often defined as "audiophile performance." Traditional Class-D amplifiers are unable to achieve this level of performance. Their fundamental underlying technology is self-limiting and, as a result, Class-D amplifiers will never be able to approach the sound fidelity of a Class-T amplifier. As the Class-T amplifier becomes ubiquitous, consumers will adjust their method of choosing products to examine intermodulation distortion as a better measure than THD. They will also understand that a lower power amplifier with better intermodulation distortion characteristics will sound better than one which has higher power and low total harmonic distortion.

High signal fidelity is just one of the key benefits of the Class-T technology. High power efficiency in the same package is a benefit not possible before the Tripath breakthrough. The consumer benefits of high efficiency are more output power in a smaller package, all with less input power. Systems can be constructed that are smaller in size, lighter in weight, consume less energy, AND AT THE SAME TIME offer amplification fidelity that rivals systems that are only possible with large heat sinks, massive power supplies, and high input power levels. No other technology offers in one package the signal fidelity and power efficiency of the Tripath Class-T technology.

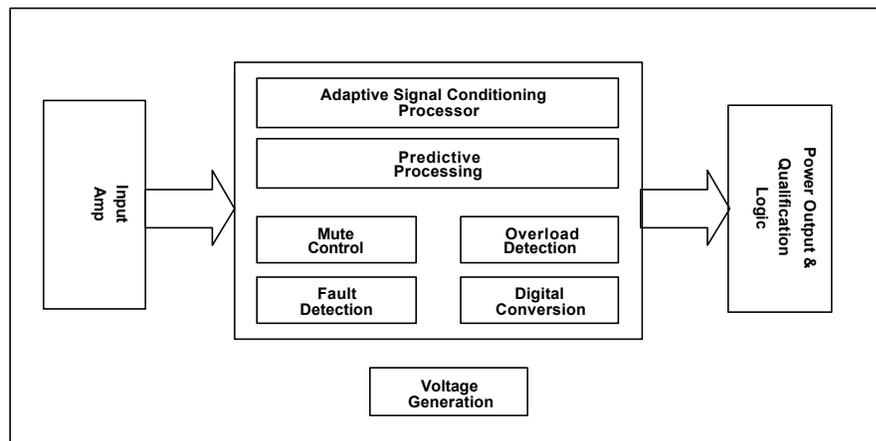


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Class-T Architecture

Tripath Class-T technology uses both analog circuitry and Tripath's Digital Power Processing algorithms that modulate the input signal with a high-frequency switching pattern. Tripath's proprietary algorithms are derivatives of adaptive and predictive algorithms used in telecommunications processors. The modulated signal is sent to output transistors then through a low-pass filter (external to the Tripath amplifier) that demodulates it to recover an amplified version of the audio input.

In a Tripath amplifier there is an input stage that provides analog input signal buffering. The output of this stage drives the Digital Power Processing™ block. This block contains an adaptive signal conditioning processor, a digital conversion function, mute control, overload handling, fault detection, predictive processing and qualification logic functions. The output of the DPP™ block controls a power output stage that drives a speaker through an output filter.



Block Diagram of Class-T Amplifier

In a traditional Class-D PWM amplifier the audio input signal is compared to a higher-than-audio frequency (generally 100-200 kHz) triangle wave. The resultant signal drives switching transistors in a push-pull fashion. Amplification is achieved with the higher voltage and current that the output transistors switch to the speakers. A low-pass filter (inductor and capacitor) positioned before the speaker removes the triangle wave base frequency, leaving amplified audio.

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The audio quality of Class-D PWM amplifiers is inferior because of fundamental problems with the PWM approach. The output transistors are not perfect switches and are not perfectly matched, and this causes distortion. The switching of the transistors causes “ground bounce,” which adds noise. There is crossover distortion caused by the dead time between when one of the output transistors turns off and the other turns on (like a Class-AB amplifier). Finally, all the energy of the triangle waveform cannot be removed from the audio band with a simple low-pass filter, and what remains is distortion.

Instead of using PWM, Tripath Class-T amplifier processors use proprietary algorithms and techniques to create the modulation that drives the switching transistors. A Class-T amplifier’s processors learn the characteristics of the output transistors. Then, based on the analog input signal, they switch the output transistors with exactly the right timing to eliminate Class-D PWM problems: transistors not being perfect switches, ground bounce, output transistor mismatches, dead-time distortion and residual energy from the oscillator in the audio band. The result is a high power efficiency, audiophile-quality audio amplifier – a Class-T amplifier.

If one were to compare the waveform before the output filter of a Class-D PWM amplifier to a Tripath Class-T amplifier, some significant differences would be evident. The waveform for a Class-D PWM amplifier would be a pulse-width varying digital signal at the fixed, 100-200kHz, frequency of the triangle wave generator. The waveform for a Tripath Class-T amplifier would be a complex digital waveform of varying frequency. A Class-T amplifier switches the output transistors in a fashion similar to spread spectrum technology, at a varying rate up to 1.5 MHz and averages 600kHz to 700kHz.

What this difference means, in addition to significantly better audio quality, is that a Tripath Class-T amplifier can use lower-cost inductors and capacitors for its output filter while obtaining the same amount of filtering as a Class-D PWM amplifier. A Class-T amplifier also has lower electromagnetic emissions than a Class-D PWM amplifier broadening its potential application.

But the true test of any amplifier is ultimately how it sounds. Class-T amplifiers have been designed with the latest advances in adaptive signal processing technology, while remaining true to the “warm” sounds that listeners have come to expect from their traditional analog products. With Tripath Technology, listeners can have the best of both worlds: high fidelity sound AND high power efficiency.

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A New Technology Demands a New Brand

The company has embarked on an aggressive program to brand the benefits of Tripath Class-T technology in consumers' minds. It has created a brand name, "Combinant Digital™," which will appear on products using Tripath's technology.

Combinant digital means to combine the best of both worlds: high fidelity and high efficiency; analog and digital processing. It will become the recognized audio brand for products that use Tripath's underlying digital energy processor technology. While the Class-T designation is a technical term that fits within the audio industry model for amplifier classification, Combinant Digital™ is Tripath's proprietary brand for its unique technology.

Combinant Digital is a trademark of Tripath Technology Inc.

Digital Power Processing is a trademark of Tripath Technology Inc.