Introducing Harman Kardon Digital Loop Amplifier Technology

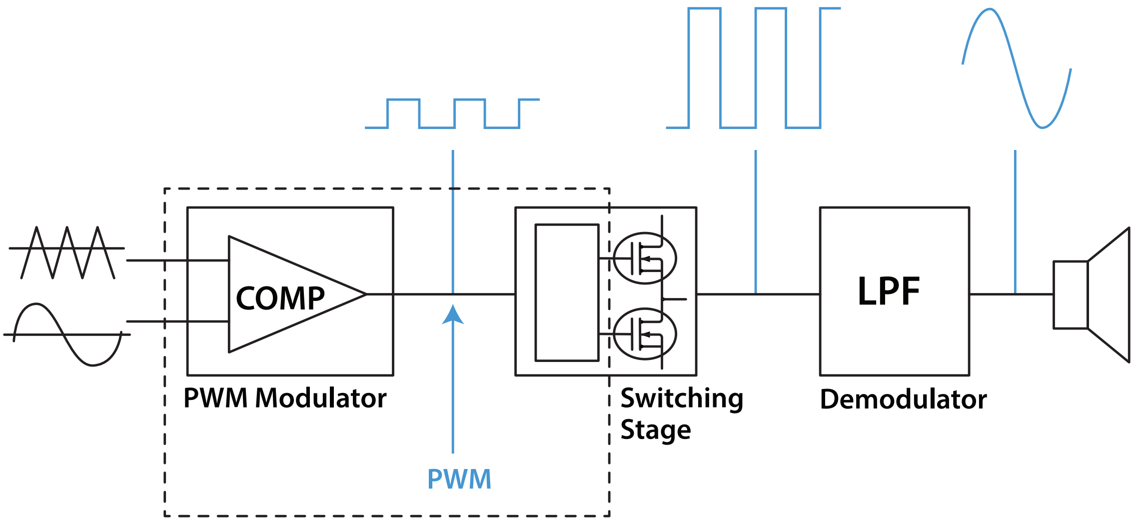
Introduction

Digital amplifiers, known as Class-D amplifiers, have increased in popularity in recent years for mainstream audio products, replacing traditional "Hi-Fi" components. Class D advantages include high efficiency, compact size, and low heat dissipation compared to traditional Class A and A/B amplifier designs. The result is a broad application of Class D amplifiers in modern products such as AVR's, soundbars, and smart speakers.

However, despite technical advances over traditional amplifiers, lingering technical limitations to audio fidelity draw objections from audiophiles who pursue a flawless, high-fidelity sound.

This white paper explores the current state of Class D amplifiers and highlights how Harman Kardon raises the bar with its new Digital Loop Amplifier (DLA) amplifier technology.

How a Class-D Amplifier works

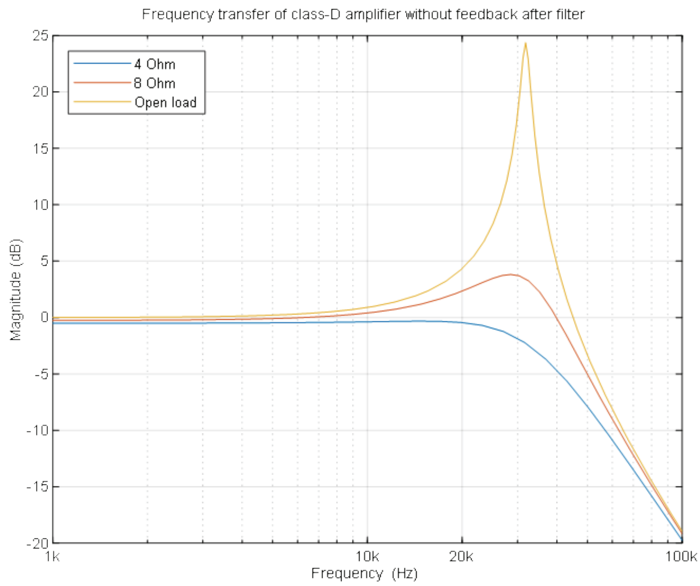


A Class D amplifier works by taking the input audio signal and creating a PWM (pulse width modulation) copy—a chain of pulses which represent the amplitude and frequency of the input signal. Then, the PWM signal is amplified by an output stage in an ultra-high speed "switching" mode with 2 states: high or low. In contrast, a traditional analog amplifier's output stage is active for the full waveform (Class A) or more than half of the waveform (Class A/B). The Class D switching behavior greatly increases the amplifier efficiency and reduces the system heat.

The amplified PWM waveform is then passed through a low-pass filter to remove the high-frequency, ultrasonic switching noise before it is passed out to the loudspeakers.

Challenges to Class D design

Any audio amplifier should reproduce sound with low distortion, however there are at least four common design challenges that cause distortion: output filter load dependency over audio frequency, power stage dead time, supply voltage ripple, and analog feedback loop limitations. In case of a small analog signal path (e.g. when a DAC is used), another source of possible distortions is present.



As mentioned previously, the final stage of a Class D amplifier is the output filter that passes audio to the speaker and suppresses high-speed PWM switching frequencies used to process the audio signals. Although the output filter should be sonically transparent, it actually is significantly affected by the speakers connected to the system. This is because the output impedance of a Class-D amplifier has a "loading effect" in the audio frequency range. When combined with the impedance of a speaker, the frequency response of the output filter will vary, thus negatively changing the overall sound quality of the amplifier. Because the impedance of each speaker will vary, the Class-D amplifier will not accurately reproduce the input signal and the sound will change from speaker-to-speaker.

"Dead Time" is the short interval that occurs during the amplifier switching between the high and low state. It creates an error at the ideal switching moment and introduces audio distortions such as sharp sounds and timing errors. These distortions get worse for the higher audio frequencies as the amplifiers audio volume increases.

Finally, an audio amplifier relies on the quality and stability of the power supply (PSU), and if a PSU experiences a sudden voltage variance, then it could cause a "voltage ripple." For example, if a user watches a movie with a sudden loud explosion, then the audio system will suddenly demand a large amount of current, and therefore the power supply will experience an instantaneous voltage drop. This variation introduces ripple. Since the ripple frequencies (and their harmonics) are in the audio band, there is a direct impact on the amplifier sound. This ripple also reduces the accuracy of the Class-D audio conversion process.

Each of these factors increase amplifier nonlinearity, unnatural sharp-sounding distortion, and noise. This reduces the sound fidelity, stereo imaging, and subtlety of any audio performance.

Class-D amplifiers designs commonly feature analog feedback to suppress these distortions. The amplifier compares the signal at the output of the power stage with the input signal. Most of the disturbances, such as ripple and nonlinearity, are suppressed for the low audio frequencies. However, the feedback signal is typically taken before the final output filter—so, these amps can suppress ripple, dead time-and other nonlinear distortions, but still suffer the same variance from the loudspeaker impedance. Also, the Class-D analog feedback loop gain is typically not high enough to suppress all distortions. Finally, to maintain stability, most analog feedback loops are limited to 2nd order control loops and steadily lose effectiveness inside the audio band, which affects the sound that should be passed to the loudspeaker.

In recent years, new Class D amplifiers designs introduced new direct digital feedback loops that allow higher order suppression within the entire audio band. However, these new designs are still limited to control before the output filter. Therefore, the variance of the loudspeaker impedance on the output filter still remains.

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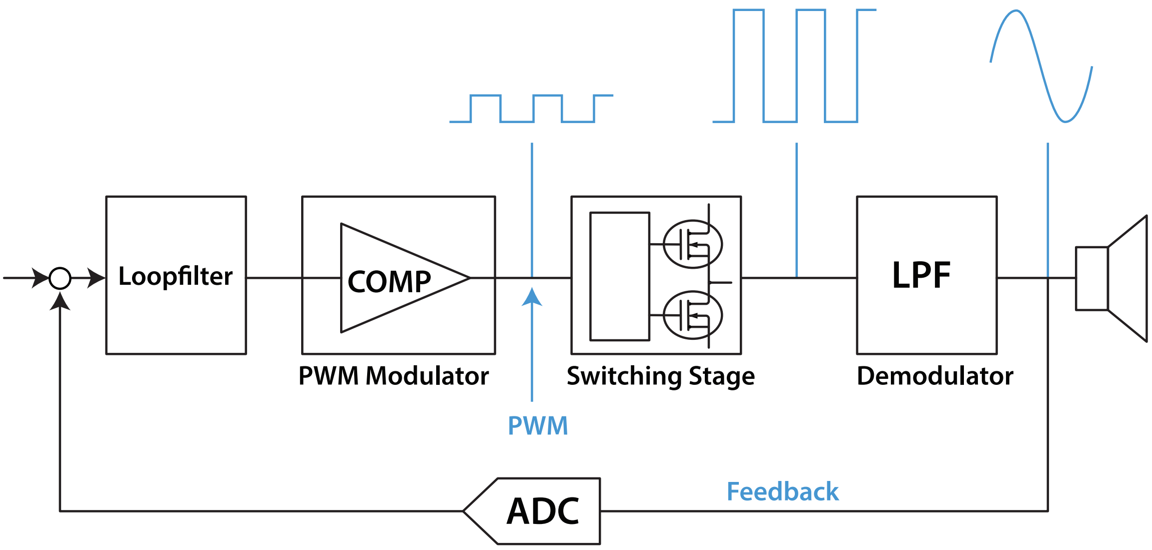
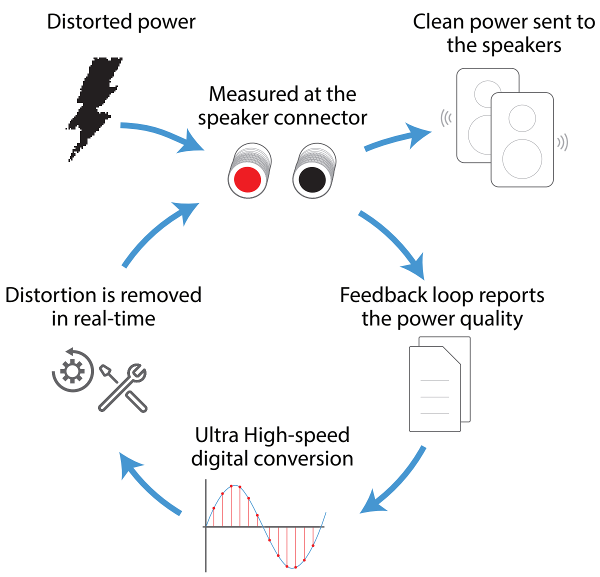


To address these challenges to great sound, Harman Kardon introduces Digital Loop Amplifier technology. With DLA, feedback is taken across the speaker terminals, after the output filter. As a result, the feedback accurately reflects how the wired speakers' impedance is affecting the amplifier's sound—this is then compared with the input signal and corrected in real-time. The result is a digital amplifier that exactly reproduces the desired output signal for any type of wired loudspeaker, no matter the impedance.

Creating this solution for Class D shortcomings requires deep innovation. The key breakthrough is an ultra-fast, low-latency analog-to-digital conversion (ADC) of the analog output signal from the speaker terminals back into the digital control loop. The DLA can achieve speeds of 20 nanoseconds. The result is that the feedback can accurately enter the digital domain and correct any differences from the audio input signal – throughout the entire audio band.

The next innovation is employing high loop gain without compromising amplifier stability. Typical analog amplifier feedback systems can



only obtain a low loop gain before experiencing stability issues. Low loop gain weakens the effectiveness of the feedback loop's distortion and noise-suppression. However, DLA uses a high digital loop gain that is typically 100 times higher than other amplifiers, without a drop inside the audio band. The effect is that the feedback loop is more effective at cleaning the distortions and restoring the sound to its proper form.

Amplifier feature	Standard Class-D Amps		Other direct digital feedback	DLA
	Analog-in	Digital-in	Digital-in	Digital-in
Feedback across the loudspeaker connectors	✗	✗	✗	☑
Ultra high-speed ADC in the feedback loop	✗	✗	✗	☑
4 Ω, 8 Ω, open load independent frequency response	✗	✗	✗	☑
High order Digital Feedback Loop, flat low THD+N over the entire audio bandwidth (related to clear sound quality)	✗	✗	☑	☑
No Inter Modulation Distortion (related to defined sound quality)	✗	✗	☑	☑
No audible Pop Sound	✗	✗	☑	☑
Digital input (no loss of dynamic range at the input)	✗ DAC required	☑	☑	☑
Dynamic Range (related to low noise on set-level	97 dB-A	105 dB-A	111 dB-A	117 dB-A
THD+N @ 10 W / 8 Ω / 6 kHz	0.1%	0.1%	0.005%	0.001%

Conclusion

Although digital feedback loops are not unique in the market, DLA is a first-in-class technology with its full audio bandwidth feedback loop taken from after the output filters and converted at ultra-high speeds. With DLA, Harman Kardon solves all audio performance limitations inherent in traditional class-D amplifiers and brings a product to market that allows passive loudspeakers to sound and perform their best, creating a new benchmark for extremely accurate, high fidelity, and musical signal reproduction in consumer audio amplifiers. The results speak for themselves: When listening to a Harman Kardon audio product with DLA technology, even purist audiophiles will be satisfied with its crystal clear, pure high-fidelity sound performance.