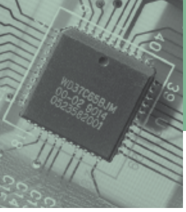

Trends in class D amplifiers

Improving audio quality and system performance with digital amplifiers

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Modern class D solutions have vastly improved over previous generations, as designers of these systems have made great strides to improve system robustness and increase audio quality. In fact, the advantages of using these amplifiers now outweigh any disadvantages associated with them for most applications.

In traditional class D amplifiers, a controller is used to convert analog or digital audio to a PWM signal before being amplified by power MOSFETs, usually integrated into a power backend device. These amplifiers have the benefit of high efficiency, leading to smaller or no heat sinks and reduced power supply output power requirements. However, they also have inherent system issues such as cost, performance, and EMI as compared to traditional class A/B amplifiers. New trends in class D amplifiers work to address these issues.

Reducing EMI

One problem that has plagued system designers since the introduction of class D is the high amounts of radiated EMI, due to the rail-to-rail switching nature of the amplifier. This will cause the equipment to fail required FCC and CISPR certifications.

Within class D modulators, digital audio is converted to PWM by comparing the audio waveform to a high-frequency constant waveform and modulating the result on a fixed-carrier frequency. The resulting signal is a fixed-carrier frequency (usually in the hundreds of kilohertz) of varying pulse width. Higher-voltage power MOSFETs are then used to amplify this PWM signal. The amplified PWM signal goes through a low-pass filter, thereby removing the carrier frequency and recovering the original baseband audio signal.

While this topology is effective, it results in some unwanted artifacts, such as high amounts of radiated EMI. Since the modulator uses a fixed-carrier frequency, harmonics of that carrier will radiate. Also, due to the switching nature of the PWM signal, over/undershoot and ringing will generate fixed-rate high-frequency (10 to 100-MHz region) radiated-EMI components. To counter the radiated EMI, a key trend within the latest generation of PWM modulators is to employ spread-spectrum modulation.

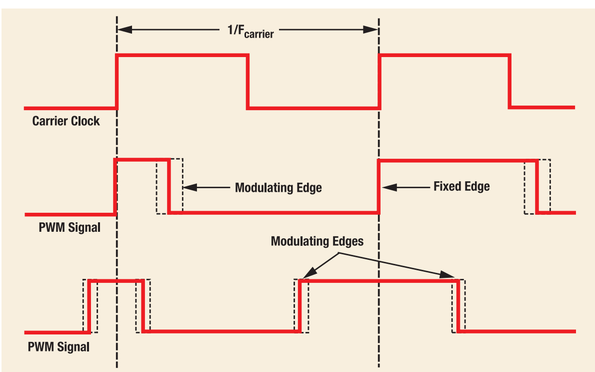

Fig.1. In traditional PWMs, EMI is corrected by varying both edges of the signal.

Spread-spectrum modulation is used in applications to spread the spectral energy of the switching PWM signal over a larger bandwidth, without changing the original audio content. An effective way to correct for the high EMI of traditional PWM modulators is to vary both edges of the switching PWM signal, as shown in *Fig. 1*.

The signal is centered on the carrier frequency, but neither edge is repetitive cycle to cycle. This has the benefit of maintaining a constant-carrier frequency, but because the edges are not switching at a constant rate, the radiated energy at the carrier frequency (and its related harmonics) is greatly reduced.

Improving audio quality

Class D is often associated with lower audio performance (high distortion and lower dynamic range) when compared with good class A/B amplifiers. However, current class D amplifier designers are being pushed to increase this level of performance. With the integration of high-performance sample rate converters (SRCs) and delta-sigma processing, new solutions offer greatly improved distortion (THD + N) and over 100 dB of dynamic range.

One source of noise in today's class D amplifiers is jitter within the audio sampling clocks. These clocks are usually generated by the SOC (MPEG decoder, DSP, etc.). Even small amounts of jitter can quickly degrade the performance of a typical class D amplifier since the modulator's output is clocked from

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the audio clocks.

One solution to this issue is to employ an SRC. Since an SRC reclocks the digital audio using a local stable clock source such as a crystal oscillator, the modulator's output is virtually independent of jitter on any of the audio clocks. An added benefit of an SRC is that the output switch rate is fixed, regardless of the input audio sample rate, unlike a PLL-based modulator. An SRC also improves system robustness by eliminating audible artifacts when audio sources change or input clocks are lost.

By incorporating high-order delta-sigma processing, similar to the technology found in today's high-end D/A converters, audio quality is also improved. Delta-sigma-based modulators incorporate internal feedback that reduces modulator errors. By minimizing sampling errors, the modulator can improve the output distortion, resulting in higher-quality sound reproduction.

Lowering system costs

To address the higher costs associated with class D amplifiers, designers are adopting the half-bridge amplifier topology for power stages in order to take advantage of the decreased complexity and reduced bill of material costs. Since a half-bridge is literally half of a normal full-bridge output, the number of power MOSFETs and external filter components are reduced by a factor of 2. This also increases the number of channels-per-power backend device. However, half-bridge amplifiers require a dc-blocking capacitor at the output and are highly susceptible to noise on the power supply rail.

At startup, the dc-blocking capacitor must be charged to the bias point (one-half of the high-voltage rail). This action will cause a large audible pop in the speaker if the output signal is not ramped from ground to the bias point. New class D solutions are incorporating the ability to precharge the capacitor, resulting in a quiet startup.

One method to quietly charge the dc-blocking capacitor is to use a digital ramp, where the PWM duty cycle is slowly increased from no switching to a nominal 50% duty cycle. While this results in no loud pop, it is not silent, due to the high amount of instantaneous current delivered from the MOSFETs switching.

Another method, which results in near silent charging of the capacitor is an analog ramp. During this type of ramp, a current source charges the capacitor to the bias point. The current source is switched off once the voltage across the capacitor reaches the bias point.

Power supply feedback

Since a half-bridge is a single-ended topology, there is no common-mode rejection as in the differential full-bridge topology. In a full-bridge amplifier, since the differential outputs of the amplifier are powered from the same voltage source, noise on that common voltage source will be cancelled at the output.

In a half-bridge, any ac ripple noise on the amplifier's voltage source will directly couple to the output. The half-bridge's susceptibility to power supply noise requires incorporating power supply rejection feedback (PSR).

While analog class D amplifiers have some inherent PSR, completely digital class D amplifiers do not. In current digital PSR solutions, an external A/D converter is used to monitor the amplifier's voltage source.

The feedback and noise cancellation processing is then completed in the digital domain in the modulator. Some manufacturers are only using this feedback to compensate for the effects of ac noise on the power supply rail that couples on to the PWM output, degrading system performance.

Other manufacturers are also compensating for dc supply level changes (droop) caused by load variations such as quick current surges needed for low frequency audio (subwoofer) or power line fluctuations. The added benefit for PSR feedback covering both ac and dc components also extends to full-bridge amplifiers, improving the interchannel isolation in today's multichannel home-theater amplifiers, effectively rejecting crosstalk and line voltage changes before they reach the output. ■