design FAQs

FREQUENTLY ASKED QUESTIONS

Class D Amplifiers For Portable Applications

Don Tuite
Analog/Power Editor

What is class D amplification?

Class D amplifiers are a more efficient alternative to class AB (push-pull) power amplifiers for audio signals. Class D is particularly attractive in portable applications because it helps extend battery life. Complete 3-W class D amplifiers are now available in packages as small as 1.5 by 1.5 mm.

Class D uses the audio input to modulate a high-frequency pulse train. Where the output transistors in traditional class AB amplifiers operate in the linear portion of their transfer characteristic (during whichever part of the analog input waveform they are not biased to cutoff), the transistors in a class D amp are always either off or driven to saturation.

Class D can use either pulse-width modulation (PWM) or pulse-density modulation (PDM). With PWM or PDM, the high frequencies in the output are filtered at the output, either by a two-pole LC filter or by the inductance and frequency response of the speaker itself.

What's the difference between PWM and PDM?

PWM compares the analog-audio input signal to a triangular or ramping waveform that runs at a fixed carrier frequency, creating a stream of pulses at the carrier frequency. Within each period of the carrier, the duty cycle of the PWM pulse is proportional to the amplitude of the input signal.

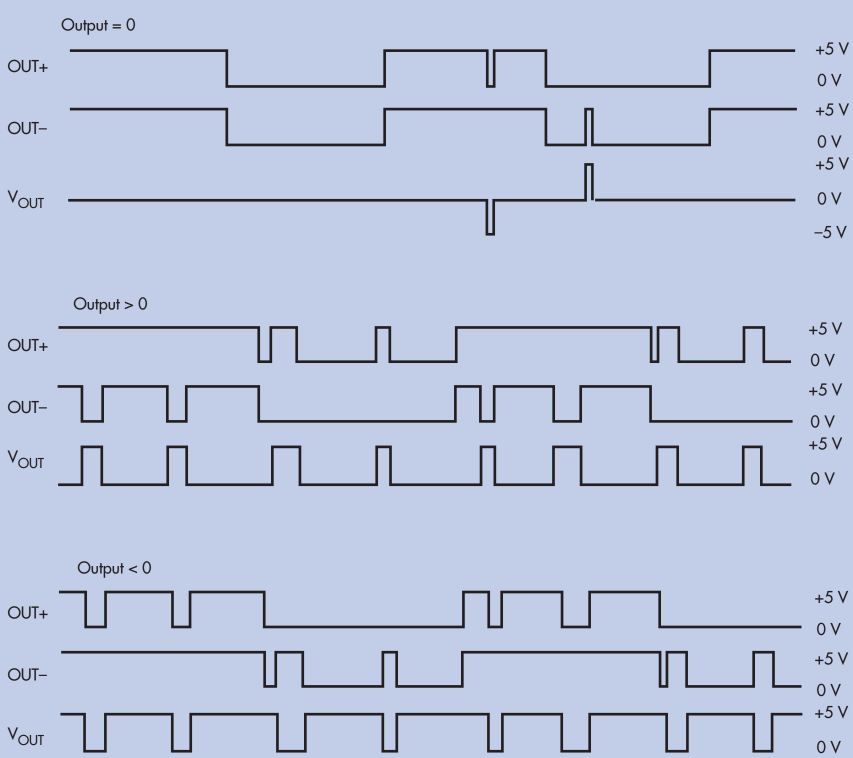
PDM is generally accomplished with a sigma-delta modulator. The number of pulses in a given time window is proportional to the average value of the input signal. Individual pulse widths are "quantized" to multiples of the modulator clock period.

What are the comparative advantages and disadvantages of PWM and PDM?

PWM allows 100-dB or better audio-band signal-to-noise ratio (SNR) at fairly low carrier frequencies. (Lower frequencies limit switching losses.) Theoretically, PWM modulators are stable up to nearly 100% modulation, permitting high output power. Yet in practice, PWM pulse widths become very short near full modulation, challenging real-world drivers.

Much of the appeal of PDM is that a sigma-delta architecture distributes much of the high-frequency signal energy, rather than concentrating it at carrier-frequency harmonics, as in PWM. Further, although energy still exists at images of the PDM sampling clock frequency, the PDM clock frequency is typically much higher than a PWM carrier—on the order of 3 to 6 MHz. That places the sampling clock images outside the audio-frequency band.

Also, in portable devices that have multiple audio channels (main speaker/headset, ringtone, etc.), the inherent randomization of the output modulation in PDM eliminates beating between multiple amplifiers. Finally, PDM can achieve high modulation levels because



In ternary class D modulation, when the signal on the input is absent, the output levels are either OUT+ and OUT–, both high or both low. When both outputs are at the same level, no differential voltage appears across the load, reducing power consumption at idle input. The catch is that the modulator must apply common-mode shaping to try to balance out the "HI/HI" and "LO/LO" states.

pulse widths can never be narrower than one sampling-clock period.

What has worked against the wider use of PDM to date is that conventional 1-bit modulators are only stable to 50% modulation. Additionally, at least 64-times oversampling is needed to achieve sufficient audio-band SNR, so data rates of at least 1 MHz are required, which translates to higher switching losses than PWM.

That's all about modulation. How does one drive the speakers?

Half-bridge and full-bridge configurations are both possible. The half-bridge approach reduces parts count, footprint, and materials cost at the expense of power and efficiency. A recent development in full-bridge configurations is the use of ternary, or "three-state," modulation to reduce differential electromagnetic interference *(see the figure)*.

With conventional (binary) differential operation, the output polarity of one side of the full bridge must be opposite to that of the other side. Only two differential operating states exist: OUT+ high with OUT– low, and OUT+ low with OUT– high. Three-state "ternary" modulation allows both half-bridge outputs to have the same polarity. The zero state is used to represent low input-signal levels.

Ternary modulation extends battery life by inducing a smaller differential voltage across the load than binary modulation. In practice, the extra quiescent current resulting from the differential voltage is on the order of several milliamps for binary, but only 100 to 200 µA for ternary modulation. The tradeoff is in challenges to the chip designer. The modulator must incorporate "common-mode shaping." That is, it must generate the same number of "HI/HI" states as "LO/LO" states.

What kind of performance can class D amplifiers provide portable apps?

When operating from a 5.5-V rail, the latest class D chips for portables operate at 93% efficiency and can drive 3 W into a 3-Ω load, or 1.4 W into an 8-Ω load, with less than 10% total harmonic distortion (THD) and less than 103-dB SNR. It's possible to operate the ICs down to 2.5 V, with some performance loss. In standby, current can be as low as 20 nA. Features such as click and pop suppression and programmable audio compression/limiting are also available.

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