Class acts

Designing with Class D Amplifier ics. By **Eric Haber**.

Class D audio amplification is becoming the solution of choice in consumer audio, enabling longer battery life and smaller devices. However, designers must take care to avoid complexity elsewhere in the system, including the power supply, output filtering and input signal conditioning.

The switching – or class D – amplifier has risen quickly to prominence in a range of consumer audio applications, based on is its superior efficiency, which can be as high as 90%. A linear class AB implementation will normally achieve around 25% efficiency at typical listening levels.

In handheld applications, the low power dissipation of class D allows designers to combine high audio performance with longer time between battery recharges – key for all personal communication and audio devices. For mains powered equipment, class D's high power efficiency brings reduced heat dissipation, which means smaller heatsinks, lower profiles, lower bills of materials and lower assembly costs.

Amplifier chips

A class D amplifier comprises a pulse width modulator, a power bridge output circuit and a low pass filter. Class D amplifier ics take away much of the design effort, such as managing the emi produced by the amplifier's switching operation, and selecting the optimal switching frequency. Increased switching frequency reduces output filtering requirements, but results in greater losses due to mosfet gate capacitance. Hence, switching frequency selection requires a balance between external components and power efficiency.

Power bridge design depends upon the amplifier's desired output power. For instance, class D ics are available with headphone or loudspeaker drivers and output stage design is a key difference between these configurations.

Amplifiers designed for use with loudspeakers can produce several Watts of output power from less than 1W without a heatsink. These ics enable a single chip solution in many consumer applications, from portable media players to some lcd tvs. In most of these – particularly handheld products – a single chip solution is essential.

However, for very high output power, a class D amplifier ic can be combined with an external output stage built using audio power mosfets. The ic must provide a suitable pre driver and the chosen discrete mosfets must be optimised for digital audio operation.

Filtering

The output from the class D mosfet H bridge is a square wave representation of the audio signal. Switching frequency components must be attenuated to prevent interference and to ensure the end product will pass emc certification. Low pass filtering, with a cut off frequency just above the audible band, is required. Hence attenuation of these components is greater with higher switching frequencies. This allows smaller external filters.

On the other hand, mosfet losses tend to increase with switching frequency, driving down efficiency and leading to increased power dissipation and associated thermal management issues.

Switching losses in the mosfet gate capacitance increase linearly with operating frequency. So the design of a class D amplifier ic output stage is predicated on fabricating low loss mosfets and setting the switching frequency low enough to meet the specified target for emi.

Filterless connection to a loudspeaker, such as a mobile phone speaker, is a distinct advantage in size and cost sensitive applications. When the class D output is physically close to the speaker, the speaker coil's parasitic resistance and inductance may be used as a suitable RL low pass fil-

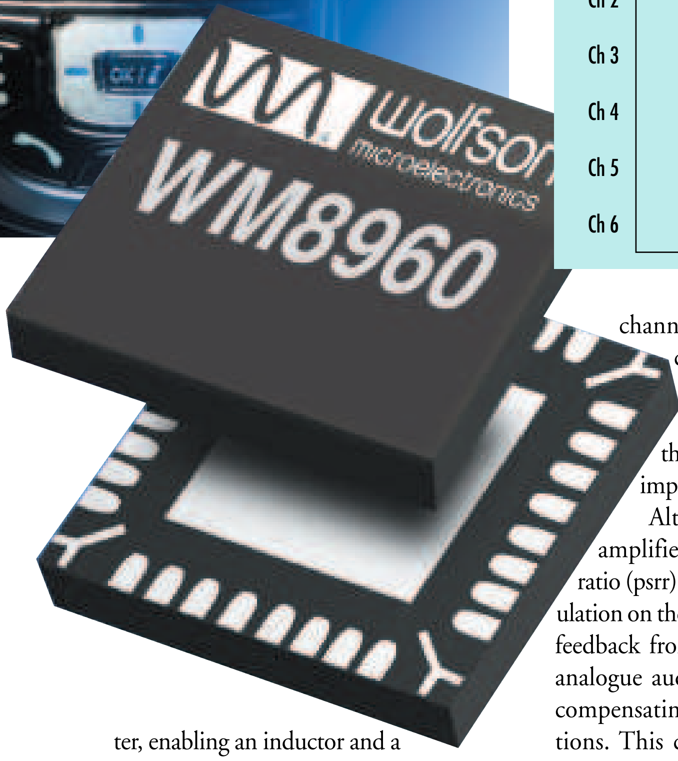
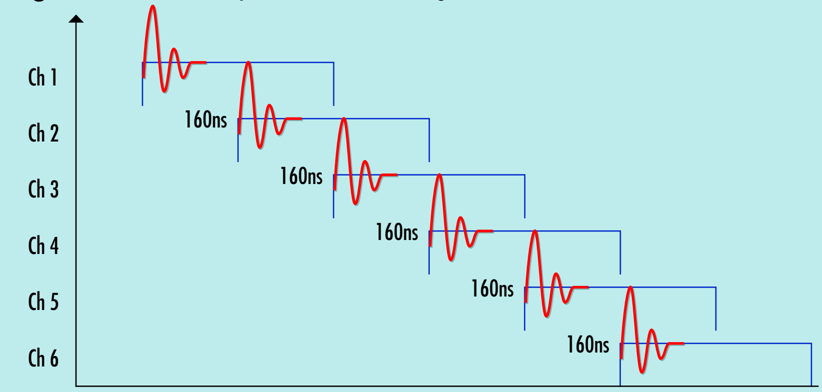


Figure 1: Inaudible dispersal of PWM switching



ter, enabling an inductor and a capacitor to be eliminated from each output connection. Wolfson's WM8960 class D amplifier may be used in a filterless configuration.

If the distance from amplifier output to speaker is longer, additional inductance, in the form of a ferrite bead, will be required to improve emc performance.

Designers specifying class D amplifier ics must pay closer attention to the effect of power supply behaviour on audio output quality. Because the class D output is a switching stage, effectively connecting the supply rail directly to the audio output, audio band fluctuations in the supply will modulate the output signal directly. Designers, therefore, must ensure high load regulation in the audio band or take steps to eliminate the effects of mains or audio band ripple.

Some manufacturers provide floating regulators that can be added to existing supplies to improve load regulation. Using a separate regulator for each amplifier output will reduce crosstalk between audio channels, but adds to the overall cost. Power dissipation in the voltage regulator will offset the efficiency gains that are the justification for a class D implementation.

Alternatively, increasing the amplifier's power supply rejection ratio (psrr) reduces the effect of load regulation on the audio output signal. Adding feedback from the PWM output to the analogue audio input raises the psrr by compensating for supply voltage variations. This can achieve a psrr of up to around 80dB – close to the psrr of a differential Class AB amplifier for portable applications. However, if the class D input signal is pure digital audio, this technique cannot be applied as the psrr of an all digital class D amplifier is 0dB. Designers must ensure close regulation of the supply.

The power supply's transient performance should also be considered. To reproduce the PWM waveform accurately, the power supply must be capable of reacting quickly to sudden changes in current draw. A linear amplifier is less demanding in this respect, since the bandwidth of the output stage is limited to the audio range. In a power supply for a class D amplifier, voltage fluctuations outside the audio band, resulting from poor transient response, will modulate the PWM signal, introducing harmonic distortion that can be heard in the audio output.

High value capacitors can deal with these fluctuations, but physically large capacitors are not desirable in handheld products and high value capacitors in small outline packages are expensive.

A helpful technique is to arrange for the mosfets in the different output stages to switch at different times, thus reducing the peak supply current. For example, Wolfson's WM8608 introduces a 160ns delay between the PWM signals for each output channel. This spreads the switching transients around the PWM cycle (see figure 1) and the 160ns delay is too short to make an audible difference. In a six channel system, this technique diminishes the maximum instantaneous load current significantly and reduces crosstalk.

Switching supplies

One potential concern with switched supplies is emi caused by the rapid switching of large currents. This problem is exacerbated when a switching supply and switching amplifier are operated in the same system at different frequencies.

Intermodulation produces tones that may be audible in the output, so synchronising power supply switching with that of the class D PWM modulator can eliminate this.

A class D amplifier may be powered from a regulated linear supply and this may be attractive where design is dominated by extremely low cost targets. However, switching power supplies are usually preferred, for the same efficiency and size advantages that have drawn class D amplifiers into consumer audio products.

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