Did You Know?

In 1903, Gustave-Auguste Ferrie directed the installation of a transmitter and antennas on the Eiffel Tower for long-range radiotelegraphy. Within 5 years, he had improved its range from 400 to 6,000 km.

Conferences and Forums

Design Features

Energy Efficiency with Class D Amplifier Modules

Energy Efficiency with Class D Amplifier Modules

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Class-D switching amplifiers are helping audio designers create personal multimedia devices and home audio/visual systems that demonstrate how compact and stylish equipment can also deliver high sound quality and high audio output power. The key to this breakthrough, providing freedom from the large and bulky boxes housing traditional audio products, lies in the class-D amplifier's high energy efficiency, which is typically around 90%. This allows designers to reduce or eliminate heatsinks as well as using smaller-sized PCBs and smaller components such as transformers, connectors and power supplies.

However, switching amplifiers also introduce engineering challenges that may be unfamiliar to specialist audio designers, demanding power electronic skills such as the design of high-voltage switching circuitry. The availability of modules that integrate key elements of class-D amplifier circuitry into a single device helps engineers overcome such challenges, while also reducing component count and time to market.

Operating Principles and Design Challenges

In a class-D amplifier, the input audio signal is compared with a high-frequency sawtooth waveform to produce a pulse-width-modulated square-wave representation of the input. The sawtooth frequency is set well outside the audio signal frequency range, in the region of 400kHz.

The pulse-width-modulated equivalent of the audio signal drives the amplifier output stage, which may be a half-bridge or full-bridge topology. A half-bridge requires positive and negative power supply rails, whereas a full bridge is able to operate from a single power supply and also produces a higher output for a given supply voltage.

The amplified audio signal is contained within the square wave present at the output of the MOSFET bridge. A low pass filter removes the out-of-audio frequencies and restores the pure audio signal to drive the speaker.

Before the audio input signal reaches the PWM comparator, an error amplifier compares the input with the output audio signal to correct for imperfections due to factors such as the finite switching time of the output MOSFETs, over/under-shoots associated with switching transitions, and power supply fluctuations. Since the error amplifier must operate within a very noisy environment, selecting a suitable op-amp for the task can be difficult and costly.

Another important task for the designer is to isolate the noise-sensitive analogue circuitry at the input from the potentially disruptive switching noise generated at the output stage.

In addition, when tackling the switching stage, the designer must optimise deadtime insertion. Deadtime compensates for the finite switching time of the output MOSFETs thereby preventing potentially damaging shoot-through currents, which may arise if the on phases of high-side and low-side MOSFETs are allowed to overlap. Precise gate control, with low pulse-width distortion and good matching between the high- and low-side driving signals, is essential so that deadtime can be minimised in order to achieve the lowest possible audio distortion.

Also, since the power transistors are either switched hard on or fully off, the PWM switching stage must be well protected. If the design of the switching stage and protection circuitry are not handled correctly, prototypes may fail to operate or may fail catastrophically when tested.

Simplifying Class-D Design

Audio systems designers can avoid many of these design challenges and potential risks by using a class-D amplifier module that implements key functions such as the error amplifier and protected PWM switching in a single package.

IR's first-generation integrated class-D module, the IRS2092 audio driver integrates the error amplifier, PWM comparator, switching stage with deadtime insertion, and protection circuitry. It is designed to be connected to discrete output transistors from IR's range of MOSFETs for digital audio applications from 50W to 500W, allowing a chipset approach to building class-D audio solutions. The audio MOSFETs have low on-resistance as well as optimised gate charge and body-diode reverse recovery characteristics, which serve to maximise energy efficiency and ensure low EMI and Total Harmonic Distortion plus Noise (THD+N).

Other important amplifier features that are closely linked with the design of the power switching stage include measures to eliminate EMI caused by the pulse-width modulator, as well as circuitry to implement click/pop noise reduction during start-up and shut-down. By implementing these features internally, the IRS2092 further reduces design overheads and component count. This approach solves the power electronic design challenges associated with class-D amplifiers and provides a foundation from which engineers can apply specialist audio skills to further improve performance.

IR's reference design, IRAUDAMP5, uses the IRS2092 driving two IRF6645 DirectFET® audio MOSFETs to create a 120W two-channel amplifier with half-bridge output, using 60% less board space and around 20% fewer parts than a comparable design built with discrete components. The reference design guides important aspects such as designing the output low-pass filter and feedback loop, programming deadtime, selecting external current and temperature sensing components, and optimising board layout.

Benefiting from the high functionality of the IRS2092 and the high audio performance of the optimised output MOSFETs, the reference design achieves very low THD+N of 0.005% at the output when driving 2x60W into 4Ω speaker loads.

Figure 1 shows a simplified block diagram of this reference design, illustrating the key functional elements of a class-D amplifier and highlighting how a module such as the IRS2092 greatly simplifies circuit design.

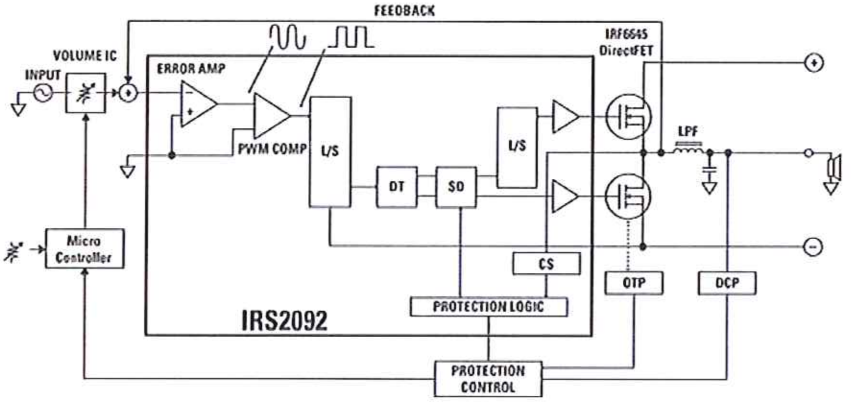

Figure 1: Block diagram of IRAUDAMP5 Class-D amplifier reference design.

Complete Class-D in a Module

Taking this modular concept a step further by building-in optimised power MOSFETs alongside the error amplifier, PWM controller gate driver and protection circuitry within the same package, IR's latest PowIRaudio™ IR43xx integrated power modules enable a further reduction in component count allowing board-space savings of up to 70%.
The PowIRaudio family comprises four devices supporting full-bridge and half-bridge topologies from 35W/4? to 130W/4?. Using these devices, designers can configure 2.1-channel, 5-channel, 6-channel or 7.1-channel applications. The devices have a wide operating voltage range, up to 62V/±31V for the IR4301/4302 or 32V/±16V for the IR4311/4312. Other key features common to the family include over-current protection, thermal shutdown, internal/external shutdown and floating differential input. The IR4302 and IR4312 also offer clip detection.

Using these devices designers can build amplifiers for typical music playback applications that do not require a mechanical heatsink and are capable of achieving outstanding audio performance figures such as THD+N as low as 0.02%. High noise immunity in the controller IC ensures reliable operation in a variety of environmental conditions. The devices are housed in thermally efficient PQFN packages measuring 5mm x 6mm for the IR4301/4311 and 7mm x 7mm for the IR4302/4312, thereby maximising the benefits of IR's advanced class-D co-packaged solution.

To provide a head-start for customers using these devices, IR has compiled six reference designs that include single-ended and split power supply configurations and provide audio output power ranging from 35W to 130W per channel with little or no heat-sinking required. Among these, the IRAUDAMP17 reference design for a 100W 2-channel heatsink-free amplifier using the IR4302, shown in figure 2, illustrates how the high efficiency of the class-D switching amplifier enables an extremely compact, yet high performing result.

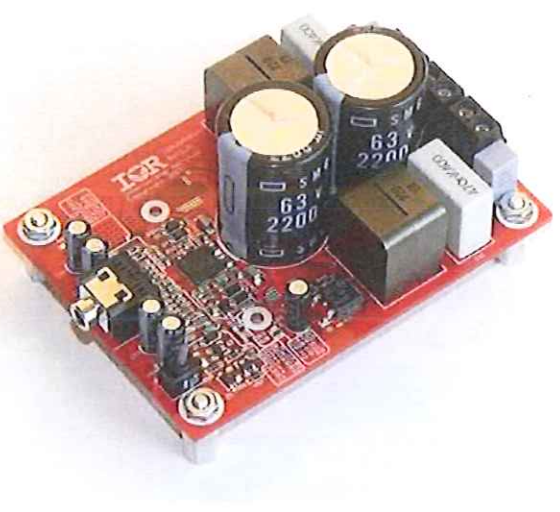

Figure 2: Reference design for100W 2-channel class-D amplifier, using IR4302 featuring integrated output MOSFETs.

Conclusion

As the class-D amplifier becomes widely used in high-performing, miniaturised audio products, semiconductor vendors are taking responsibility for key aspects of the power electronics design by delivering purpose-built gate-driver modules incorporating key functional elements of a class-D amplifier. These modules have enabled a chipset approach to class-D design, using discrete output transistors. The latest generation of modules that also incorporate the audio output MOSFETs in the same package now enable even smaller new products to be delivered to the market at competitive prices.