Sounds good!

A new approach to audio amplifiers promises much longer battery life. By **Chris Travis**.

Much has been written about the efficiency of Class D amplifiers, with figures of 90% or greater being routinely quoted. Such numbers might suggest the efficiency problem of audio amplifiers has been solved by Class D, but a closer look shows this is far from the truth; these amplifiers frequently see only single digit percentage efficiencies in real usage conditions. To address this problem, a new generation of audio amplifier solutions has emerged, promising a massive reduction in average power consumption.

Figure 1 shows a plot of efficiency versus power output for a typical Class D amplifier, but plotted with a logarithmic power axis. The top right of the graph, corresponding to maximum power output, shows efficiency reaching almost 90%. However, in typical consumer usage, an audio amplifier hits its rated maximum power comparatively rarely – only when the volume is turned right up to the onset of clipping. Even then, maximum power is reached only on the loudest audio peaks, which comprise a relatively small proportion of typical content.

Across the operating life of an amplifier, average power output typically sits at around 20 to 50dB below full scale – 100 to 100,000 times in linear power terms. At this comparatively tiny output level, corresponding to the lower left region of figure 1, the efficiency of the conventional Class D solution is disappointingly low. Clearly, a different approach is needed.

Amplified audio signals have some extreme characteristics, and it is the exploitation of these that underlies the success of the new methods. For example, music content typically has a peak to average power ratio (PAPR) in the range of 10 to 20dB, or 10 to 100 in linear power terms. TV or movie audio is more extreme, typically having a PAPR exceeding 20dB. This is termed the content PAPR (CPAPR, see table 1 for a few examples).

However, an audio amplifier has to cope with a significantly greater dynamic range than just the CPAPR, since the user volume control adds another significant element of power variation. This is characterised as the gain PAPR (GPAPR) – the ratio between the volume gain, when the amplifier is playing at its lifetime average power output, and the volume gain corresponding to the onset of clipping of the amplifier, or 'full blast'. GPAPR typically varies between 10 and 30dB in consumer systems.

To illustrate this, consider two examples.

- ***Example 1***. Consider an audio system that can deliver up to 10W (or 10dBW) peak into a speaker system with an efficiency of 90dB@1W@1m. Assume that CPAPR is 15dB and the average sound pressure level (SPL) is 73dB at 1m (a level commonly used by consumer audio manufacturers for battery lifetime testing). GPAPR can be calculated as

Fig 1: The efficiency of a conventional Class D amplifier

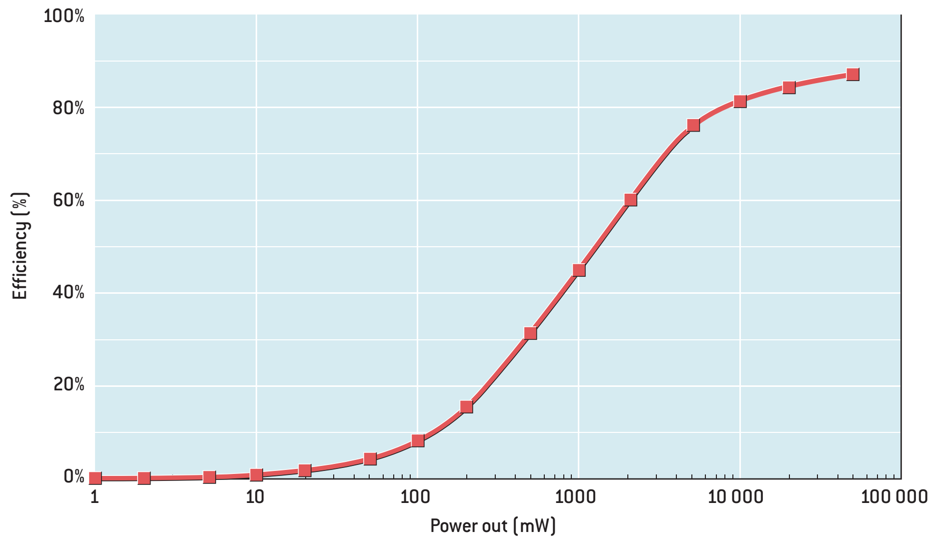
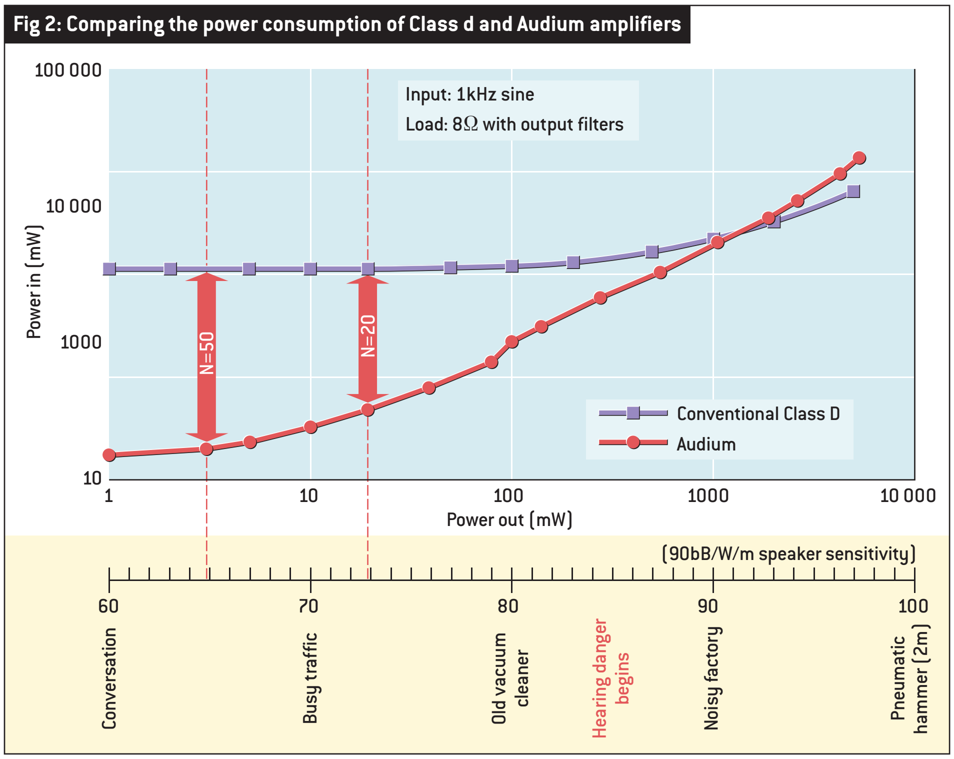


Fig 2: Comparing the power consumption of Class d and Audium amplifiers



follows. At maximum volume, the system delivers 90+10 = 100dB peak SPL at 1m. Accounting for CPAPR, this equates to 100-15 = 85dB average SPL at 1m. In this case, GPAPR = 85-73 = 12dB.

- ***Example 2***. Consider a 100W (or 20dBW) peak system, with the same speaker efficiency, but with a CPAPR of 10dB, and delivering 65dB average SPL at 1m. At maximum volume, this system delivers 90+20-10 = 100dB average SPL at 1m, with GPAPR = 100-65 = 35dB.

Finally, CPAPR and GPAPR are brought together in a measure termed the lifetime PAPR (LPAPR) – the multiple of CPAPR and GPAPR or their sum in dBs. From the figures discussed, since CPAPR lies between 10 and 20dB, and GPAPR lies between 10 and 30dB, LPAPR lies between 20 and 50dB. Maximising amplifier efficiency over this wide range is a challenge that must be solved by any truly energy efficient solution.

In any switching amplifier, energy is lost each time the amplifier switches its output between states. This is true not only for the main output transistors, but also throughout the preceding driver circuitry and logic. Most Class D amplifiers employ PWM, typically at hundreds of kilohertz, to achieve the required system performance. However, low rate modulation (LRM) schemes are emerging that deliver substantially lower average switching rates, with a commensurate reduction in switching power losses.

Conventional amplifiers tend to take a relatively high voltage as the basic supply. The output stage, whether switching or linear, then effectively 'scales down' this supply voltage to the required output signal level. These amplifiers are classed as high supply architectures (HSAs).

The problem is that HSAs are inefficient at handling the large LPAPR of amplified audio. Nearly all power loss mechanisms in amplifiers scale with the square of the rail voltage and, since HSAs use a high voltage just to support very occasional maximum voltage requirements at the output, large losses occur.

However, amplifiers employing low supply architectures (LSAs) are becoming available. These amplifiers start 'low' by taking a low supply voltage and stay 'low' by using this low voltage throughout most of the amplifier's circuitry, including the power stage, for most of the operating time. When the amplifier needs to output a higher voltage, this is provided by a boost converter. Note that, since the converter is only used for a small proportion of the time, any power conversion losses have little effect on the amplifier's average efficiency.

Rail tracking can also be used to counter the voltage dependent losses of amplifiers, by varying the output stage rail voltage either with the audio envelope, or simply tracking the user volume level. One issue for rail tracking can be the speed with which the rail voltage can be varied, especially since it is usual to have relatively large decoupling capacitances on the output rails, implying that considerable currents need to flow to change the rail voltage rapidly. Rail switching uses two rails – a lower voltage rail, used most of the time, and a higher voltage rail used when the output signal exceeds the voltage available on the lower rail.

Both rail tracking and switching have been known for some time in linear amplifier design, as Class G and Class H, but transferring these approaches to a switching amplifier presents new challenges. For example, the switching algorithm must be designed to avoid objectionable clicks or other artefacts, as the amplifier transitions from one rail to another.

The most efficient solutions combine all these techniques and, consequently, bring a multiplicative reduction in power wastage. For example, Audium's audio amplifier ics employ all of the methods discussed here, resulting in an average power consumption that is a fraction of traditional Class D for a range of consumer applications (see figure 2).

By understanding the characteristics of an audio signal, together with normal consumer listening levels, new amplifier solutions have been developed that reduce average amplifier power consumption by at least a factor of 10. This means nattery powered products can enjoy greatly increased battery lifetimes, input power constrained systems (such as USB powered devices) can deliver higher audio power, and mains powered audio systems can be realised in smaller, cooler and lower cost form factors.

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