



New Infineon's MERUS™ multilevel class D amplifiers

Clear, exceptional sound are the benefit of all who love audio

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Voices, noises, music – they are part of our lives. Sound has always been all around us. It connects us to our surroundings either we produce or just listen to them. Being an integral part of our everyday, conception and design of audio products and their environments have become more and more essential. In the recent decades, audio applications developed rapidly due to innovative solutions in designs and semiconductor technologies. The technological advancement from class AB amplifiers to class D has been significant, enabling increasingly improved performance of audio products over time. And now the next big step has been taken to elevate the user experience to the next level with multilevel class D audio amplifiers. This innovative class D technology enables higher music listening levels with higher efficiency in smaller size. Bulky, demanding and inefficient audio components are things of the past.

Infineon's groundbreaking MERUS™ multilevel class D technology excels in contemporary applications that require small

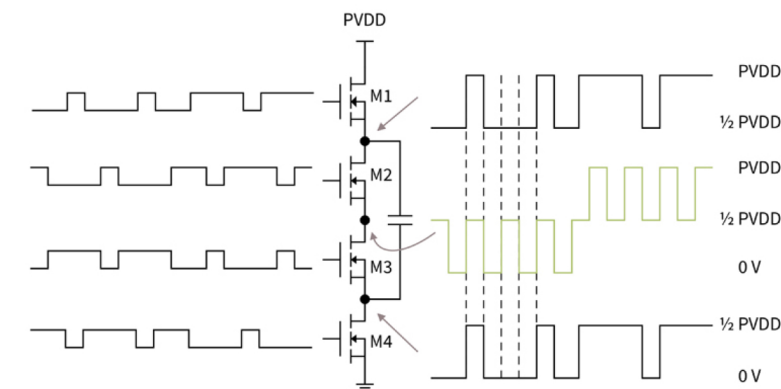


Figure 1: MERUS™ amplifiers have a special power stage topology. In this design each half-bridge uses four MOSFETs (M1-M4) and the capacitor is “flying” between those to serve as an extra supply rail, resulting in a three-level output signal at the output switching node.

size, low heat or low power consumption, such as battery powered and wireless speakers, soundbars, multi-room audio and home theater systems.

The benefits and the operation principles of multilevel technology

However, traditional class D audio amplifiers can achieve an efficiency of 90 percent or above, they have a relatively high power consumption, their typical music volume listening level is only around 50 percent, and they are space demanding due to need for an LC filter and a heatsink (making them also more costly).

The MERUS™ multilevel class D amplifiers overcome the above limitations. The benefits of this innovative technology include:

- smaller solution size and lower cost without output LC filters
- improved efficiency at typical listening levels
- lower heat generation through greatly reduced power loss
- enhanced audio quality through finer granularity of multilevel switching

These revolutionary amplifier products use a multilevel half-bridge power stage to achieve low power consumption at idle as well as



Figure 2: Full bridge-tied load five-level output signal with MERUS™ multilevel class D amplifiers. These ICs generate output with up to five levels that eliminates external output stage filtering and minimizes the overall power loss, while the output audio signal much closer approximated to the input waveform than a conventional class D amplifiers.

near-idle operations. Instead of the traditional class D's two, they have four transistors/MOSFETs for each of the half-bridge power stages. These half-bridges establish multiple PWM output levels (each MOSFET is driven by an individual PWM signal) from a single supply. This offers great flexibility and allows for configuring the amplifier for optimal power performance in any audio application. The capacitor (Cfly), which is “flying” between the top and bottom MOSFETs, is constantly charged by separate circuitry, thereby maintaining a fixed voltage potential. The “flying capacitor” therefore functions essentially as an extra supply rail. In this way, each half-bridge power stage establishes a three-level output signal at the output-switching node: 0 V, $\frac{1}{2}$ PVDD and PVDD.

In a full bridge-tied load (BTL) configuration - which is achieved by combining two three-level half-bridges with a switching pattern in

which each half-bridge switching pattern is modulated with a 90° phase shift relative to the other - the resulting power stage can provide also up to five levels of multilevel modulation patterns to a differentially connected speaker load.

With multilevel modulation, the resulting output frequency is higher and the individual voltage steps are smaller, thus the output audio signal much closer approximated to the input waveform than a conventional class D amplifiers.

A five-level system inherently quadruples the switching frequency at the output nodes the differentially connected speaker load also has much less out-of-band switching residuals. With high efficiency and better EMI and EMC management, the amplifier can thereby effectively be configured for filterless operation. In this case, the speaker load switching frequency is four times

the switching frequency of the MOSFETs at the half-bridge output nodes. Also note that the switching pattern gives rise to three states (as opposed to just one in a conventional class D amplifier) where complete cancellation of the out-of-band switching residue takes place, namely at $-\frac{1}{2}$ PVDD, 0 V and $+\frac{1}{2}$ PVDD. In these states the output of the two half-bridge outputs are either both 0V or they both produce a perfectly ‘mirrored’ 50 percent duty-cycle output. For the application this translates directly to a reduction of the ripple current in the audio system output section. With no need to suppress out-of-band switching noise or artefacts, many applications do not require a common-mode applied LC filter. The effect of the reduced ripple current is shown in Figure 3. When normalized to the ripple current of a traditional class D amplifier (purple line), the three-level or half bridge (green line) and the five-level or BTL (grey line) modulated output signals exhibit strongly reduced ripple currents. In addition to the inherently more efficient switching principle, overall dissipation and power losses are also significantly reduced due to the reduced ripple current in the external components.

Design benefits with multilevel class D amplifiers

Multilevel class D amplifiers enable highly efficient operation due to their significantly reduced power consumption. With low power consumption both for idle operation and for average audio volume lev-

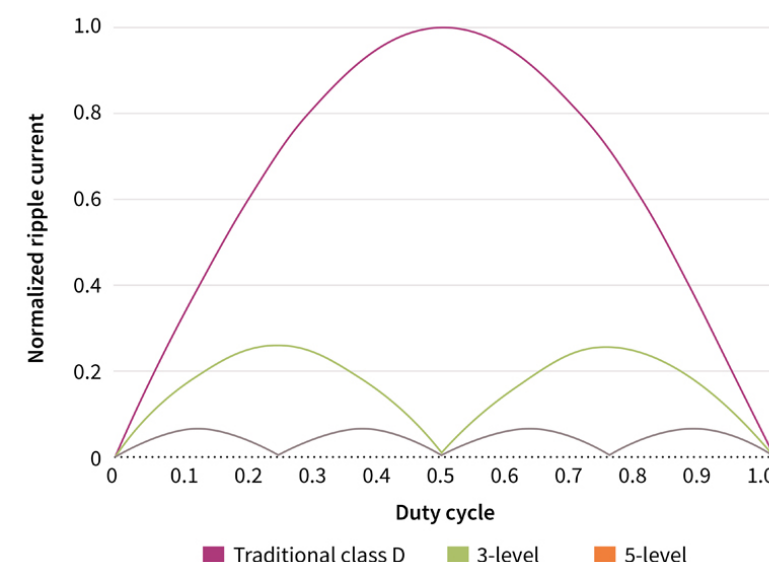


Figure 3: Significantly reduced ripple current in the external components leads to lower total dissipation and power loss in the audio application. For three- and five-level signals at zero states there is no ripple current.

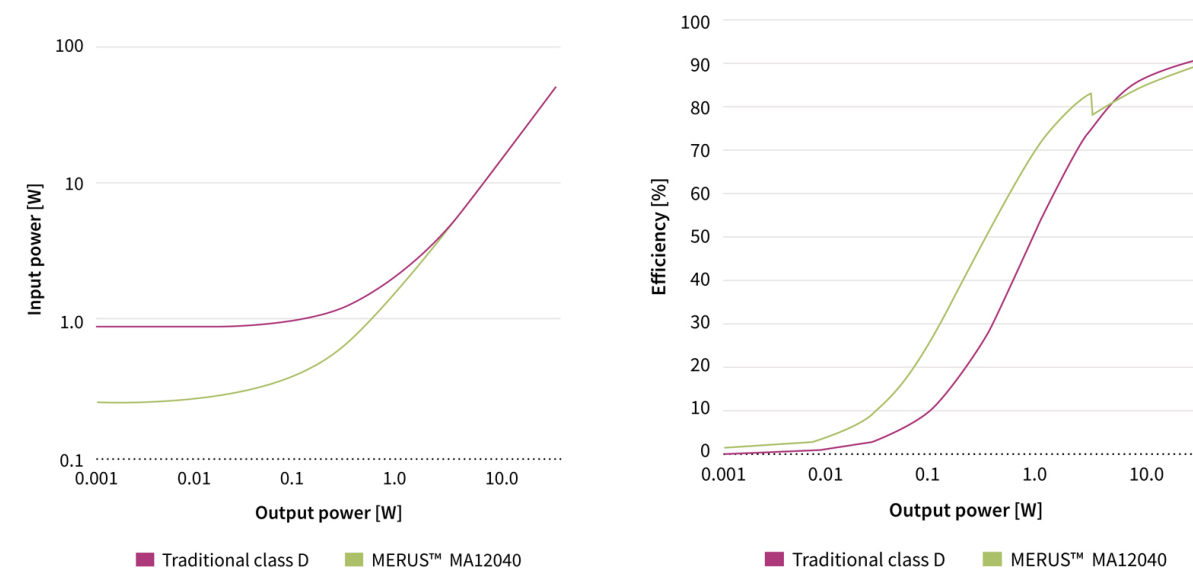


Figure 4a (left) and 4b (right): The MERUS™ MA12040 multilevel class D amplifier consumes only 250 mW in idle. The near-idle power consumption is relatively flat and significantly lower than for a conventional class D amplifier all the way up to 2 W output power per channel. The importance of improved power consumption is further emphasized when efficiency is considered in the figure on the right side. (The MERUS™ MA12040 amplifier has a maximum output power of 40 W into a 4Ω load; running on an 18V power rail in both cases.)

els, portable audio systems can be designed for remarkably extended battery life or smaller batteries.

Since the overall power consumption is determined by the average power loss and as this is greatly

dominated by idle loss when reproducing common audio signals, compared to most conventional class D amplifiers the multilevel amplifiers demonstrate an overall power efficiency improvement factor of four or higher. Using a digital control interface, various power modes can be accessed by selecting the modulation method and the switching frequency. During amplifier operation, the integrated power management algorithm automatically selects the optimal power mode for a given power level. The seamless transition between power modes allows to minimize the power losses across the entire output power

range while still ensuring high audio performance and low EMI. With no need for significant filter-

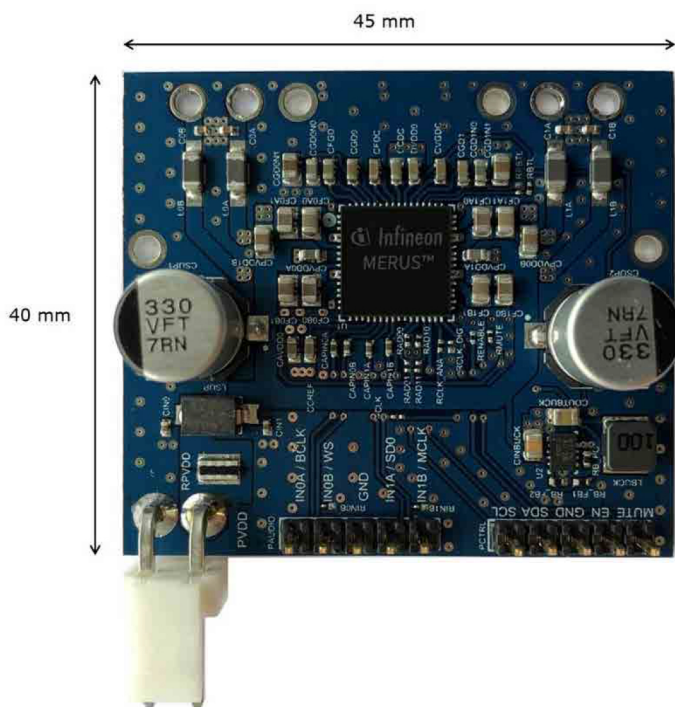


Figure 5: Infineon's reference design as a small-sized circuit board is used to demonstrate MERUS™ multilevel amplifier devices for ultra-compact and low-power consumer applications. The solution measures 40 mm x 45 mm and yet still achieves output power up to 80 W per channel. Only a small EMI filter is used with an SMD-sized (1210) ferrite bead and an SMD-sized (0402) 1.0 nF capacitor placed at each half-bridge output of the amplifier.

ing to combat unwanted interference, multilevel amplifiers can drive speakers directly often without the use of LC and RC filters even in higher-powered applications, which reduces application costs. If the audio product designer still wishes to use LC filters they can be smaller than those used for traditional class D amplifiers.

Lower power loss directly translates to less heat generation and cooler operating conditions. In most cases, the amplifier circuit board itself will offer sufficient heatsinking capability, even in relatively high-powered applications that would traditionally require a dedicated

heatsink. With generally cooler operation inside the audio application, there is much larger headroom for periods of higher output power, for example during music playback at high volume levels. Cooler operation reduces thermally accelerated aging, which also improves audio application reliability.

The next generation of audio products is enabled with no compromise on audio quality

Now designers are enabled to achieve loop stability and satisfactory performance while minimizing the design-in effort, avoiding a time-consuming selection and optimization procedure for the ex-

ternal loop filter component. Both analog and digital input versions of the MERUS™ amplifiers integrate a fourth-order feedback loop on-chip. This suppresses more effectively error sources that might cause audio quality degradation. A multilevel amplifier uses the audio signal to modulate the duty cycle of the PWM signal inside the fourth-order feedback control loop. A fourth-order loop gives much better gain, and thus suppression of error sources compared to the more traditional second-order loop. This guarantees very low signal distortion, excellent audio performance and robustness against real-world system imperfections such as a non-ideal power supply rail voltage which produces noise/ripple.

The combination of a multilevel switching topology and a dynamic power management scheme pushes the boundaries of efficiency and the compactness of audio amplifier solutions with exceptional audio quality. MERUS™ amplifiers inspire and allow product designers to develop some of the world's most efficient portable audio devices, appealing to a vast market of environmentally-conscious consumers who want innovative products.

For more information about MERUS™ audio solutions, please watch the video by scanning the QR code or visit www.infineon.com/merus.

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