Power DAC: A new approach for high-precision power amplifiers

Introduction
A steady demand exists for the development of ever more powerful precision amplifiers. The tendency in various application areas, such as MRI and lithography, as shown in Fig. 1, is that the requirements set on power rating, and at the same time the requirements of the relative accuracy of the generated signals, are increasing. A related issue is that the bandwidth of the controlled amplifier needs to increase, which implies that ever higher switching frequencies are demanded. Without a breakthrough in technology, this would lead to ever higher switching losses, which translates into a major cooling effort and large, heavy systems. As such, there exists a dilemma in finding the optimal balance between power, efficiency and accuracy for a specific design of a power converter.

Figure 1: Example of high-precision power amplifier applications: (a) MRI and (b) lithography.

Objectives
A classical converter topology, which is commonly used in the design of a power amplifier, is based on a two-level class-D amplifier topology. The power stage consists of two active switch devices (MOSFET or IGBT) which are operating in on-off mode. Consequently, the output voltage has a square waveform, because the stage switches between the positive and negative rail of the supply voltage. An example of such a PWM signal, compared to the desired reference waveform, is shown in Fig. 2. The actual desired output voltage waveform can be obtained by a demodulation process by placing a filtering part consisting of reactive elements after the power stage. This filter is used to suppress unwanted spectral components and to fulfill the requirements of the relative accuracy of the desired waveform. During the design of this filter there will always be a trade-off between the transient state and steady state requirements of the total converter.

Unfortunately, beside the already mentioned trade-off, filter components can contribute up to 40% of the weight or volume of such amplifier systems. Because of that, in the Power DAC project a new approach in power amplification will be investigated. Extending the power stage in such a way that the output filter can be reduced or even eliminated. As an example, when a converter would be created having eleven levels instead of two and interleaved switching or phase-shifted carrier PWM is used, the waveform of Fig. 3 could be created. From this figure it can already be seen that the desired waveform is better approximated by the PWM wave. In the harmonic spectrum this becomes even more visible.

Figure 2: Example of waveforms of a two-level converter: (a) waveform and (b) spectrum.

Figure 3: Example of waveforms in a multilevel converter: (a) waveform and (b) spectrum.

Approach
A possible approach in this quest for an ultra-level topology would be the combination of different power stages with different switch-device (MOSFET, IGBT) technologies (Si, SiC, GaN) in a single power amplifier structure. An example of such a topology is shown in Fig. 4.

Figure 4: Example of an ultra-level topology.

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