CHAPTER 31

Class D Measurement, Performance, and Efficiency

This chapter concludes the class D amplifier discussion by considering the amplifier as a whole, ignoring the highly technical implementation details. It is written more from a user perspective, with emphasis on applications that demand high sound quality. For those who demand the highest sound quality and who can compromise on efficiency, there is a middle ground available at the expense of greater complexity. This approach can be referred to as *hybrid class D*. In such a design a class D amplifier provides the lion's share of the power while the actual signal delivered to the loudspeaker comes from a low-power analog class AB amplifier.

Measurement of class D amplifiers requires a different approach in many cases. This is due in part to the fact that class D amplifiers usually have smaller bandwidth than traditional linear amplifiers. Distortion harmonics that lie above the audio band may be seriously attenuated. As a result, the measurement of high-frequency THD (like THD-20) is virtually useless and can be downright misleading. The presence of out-of-band noise at the output of most class D amplifiers further complicates many measurements. Measurement techniques for class D amplifiers are covered in Section 31.2.

31.1 Hybrid Class D

In some cases higher sonic performance can be achieved by combining class D amplifiers with analog power amplification. A simple example of this is to amplify the signal with both class D and class AB amplifiers to the same level. The class AB amplifier is a low-power, high-current amplifier that actually drives the load. Its output stage power supply is floating on the output signal of the class D amplifier. This is somewhat analogous to a linear power amplifier wherein a floating class A amplifier is driven by a class AB amplifier.

Figure 31.1 is a conceptual illustration of a hybrid class D amplifier. The most straightforward approach is to have the class D amplifier drive the entire power supply of the class AB amplifier. That power supply can be either a linear supply or a switcher.

The hybrid class D amplifier has several advantages. It isolates the class D output from the load, taking the output filter out of the signal path and greatly reducing EMI. It also preserves the damping factor that would be attained by a linear amplifier. Finally, it allows the negative feedback to be closed from the output terminals of the amplifier without suffering the consequences of phase shift introduced by the output filter.

Note also that only the output stage of the class AB amplifier needs to be run from the flying rails provided by the class D amplifier. All of the earlier stages can be run

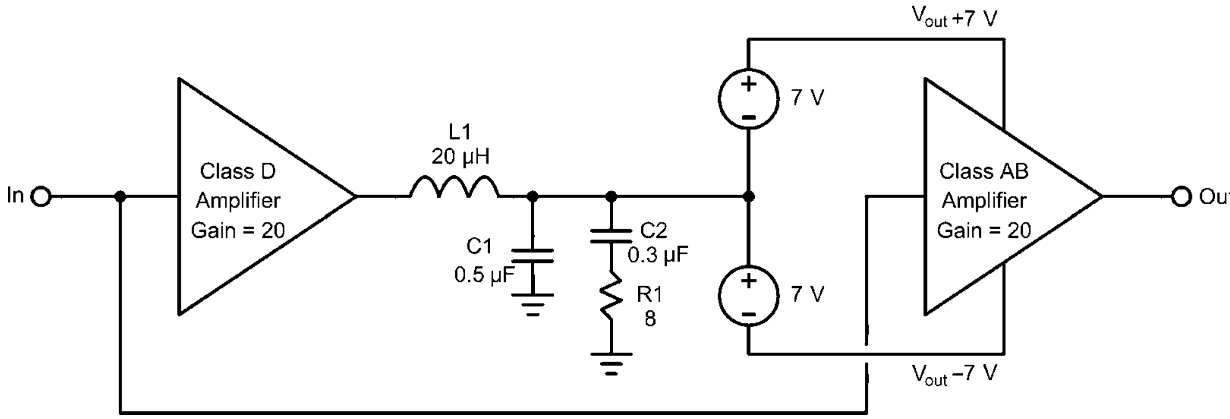

FIGURE 31.1 Conceptual diagram of a hybrid class D amplifier.

from a very clean linear supply because they require very little power. Then, decent PSRR of the linear output stage is all that is needed.

The hybrid class D amplifier is an intelligent trade-off, providing improved sound quality in exchange for a reduction in efficiency. The class AB amplifier can be run at low voltage, but it must still be designed to be able to deliver the full current produced by the amplifier. The use of small local rail voltages in the class AB amplifier section greatly eases safe area requirements for the output transistors.

Figure 31.2 shows estimated power dissipation as a function of output power for a conventional class AB amplifier, a hybrid class D amplifier, and a standard class D

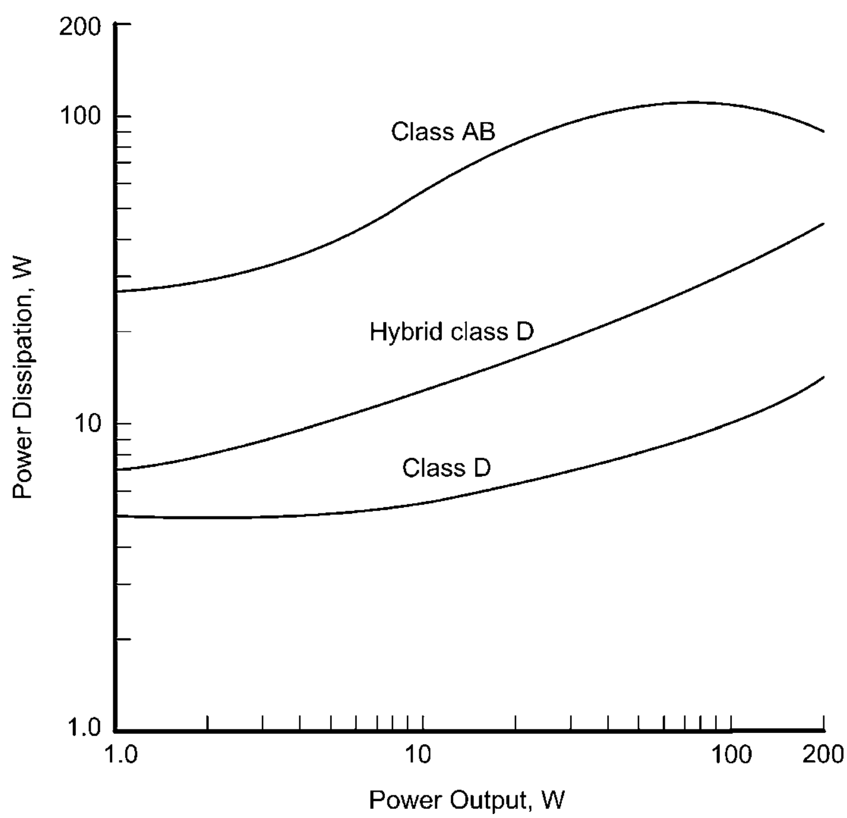

FIGURE 31.2 Estimated power dissipation of class AB, hybrid class D, and standard class D amplifiers.

amplifier, all rated at 200 W/8 Ω. The class AB amplifier within the hybrid class D amplifier is assumed to have ±7-V floating rails. Even with low-voltage rails, the floating class AB amplifier dominates the total power dissipation of the hybrid design. All of its input power is dissipated as heat because it really delivers no added power to the load. Unfortunately, given the need to deliver high current into low-impedance loads and the reality of implementation tolerances, it is very challenging to design a floating class AB amplifier with rail voltages less than about 7 V.

It is interesting to note that the hybrid class D amplifier does not exhibit increased power dissipation at less than full power, even though it includes a class AB amplifier as part of its implementation. The hybrid class D amplifier enjoys its greatest advantage over the class AB amplifier at power output levels between 5 and 50 W. In this region its power dissipation is smaller by a factor of about 4.

Audiophiles usually care most about maximum dissipation as opposed to overall efficiency. These are two very different things. Audiophiles don't care as much about power drawn from the outlet. They care about how big they must make their heat sinks in order to achieve a given output power and sound quality. This is why hybrid class D may be attractive for some audiophiles.

31.2 Measuring Class D Amplifiers

Class D amplifiers do not usually have as much bandwidth as analog amplifiers and so they present some measurement challenges. More importantly, the inevitable high-frequency noise and carrier leak-through at the output corrupts distortion and SNR readings. At times, high-frequency EMI at the output of a class D amplifier can actually disturb the functionality of sensitive test equipment connected to the amplifier.

The AES17 Filter

To deal with the spurious EMI that may be present at the output of class D amplifiers, the Audio Engineering Society published a filtering recommendation called AES17 [1]. The low-pass filter is placed between the amplifier output and measurement instruments like distortion analyzers. The filter is very sharp, flat to 20 kHz and then down by 60 dB at 24 kHz. This usually requires a seventh-order elliptic filter, most or all of which should be implemented with passive components so that sensitive active circuitry in test instruments is not disturbed by the EMI. Without the filter, measurements at low signal levels will be especially affected in an adverse way.

Total Harmonic Distortion

THD measurement of class D amplifiers is practical and relevant when conducted at low frequencies like 1 kHz. However, THD measurements are of very limited use when conducted at high frequencies like 20 kHz. This is because the class D amplifier's output filter will block many of the upper harmonics, rendering an optimistic result and low sensitivity to those higher harmonics considered most offensive. If the AES17 filter is in place, all harmonics of a 20-kHz test signal will be blocked. Indeed, only the second harmonic of a 10-kHz test signal will barely manage to get through. THD-1 is a satisfactory basic test, but it provides virtually no information about high-frequency nonlinearities.