International
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APPLICATION NOTE

Application Note AN-1071

Class D Audio Amplifier Basics

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A Class D audio amplifier is basically a switching amplifier or PWM amplifier. There are a number of different classes of amplifiers. This application note takes a look at the definitions for the main classifications.

What is a Class D Audio Amplifier - Theory of Operation

A Class D audio amplifier is basically a switching amplifier or PWM amplifier. There are a number of different classes of amplifiers. We will take a look at the definitions for the main classifications as an introduction:

Class A – In a Class A amplifier, the output devices are continuously conducting for the entire cycle, or in other words there is always bias current flowing in the output devices. This topology has the least distortion and is the most linear, but at the same time is the least efficient at about 20%. The design is typically not complementary with a high and low side output devices.

Class B – This type of amplifier operates in the opposite way to Class A amplifiers. The output devices only conduct for half the sinusoidal cycle (one conducts in the positive region, and one conducts in the negative region), or in other words, if there is no input signal then there is no current flow in the output devices. This class of amplifier is obviously more efficient than Class A, at about 50%, but has some issue with linearity at the crossover point, due to the time it takes to turn one device off and turn the other device on.

Class AB – This type of amplifier is a combination of the above two types, and is currently one of the most common types of power amplifier in existence. Here both devices are allowed to conduct at the same time, but just a small amount near the crossover point. Hence each device is conducting for more than half a cycle but less than the whole cycle, so the inherent non-linearity of Class B designs is overcome, without the inefficiencies of a Class A design. Efficiencies for Class AB amplifiers is about 50%.

Class D – This class of amplifier is a switching or PWM amplifier as mentioned above. This class of amplifier is the main focus of this application note. In this type of amplifier, the switches are either fully on or fully off, significantly reducing the power losses in the output devices. Efficiencies of 90-95% are possible. The audio signal is used to modulate a PWM carrier signal which drives the output devices, with the last stage being a low pass filter to remove the high frequency PWM carrier frequency.

From the above amplifier classifications, classes A, B and AB are all what is termed linear amplifiers. We will discuss the differences between Linear and Class D amplifiers in the next section. The block diagram of a linear amplifier is shown below in fig 1. In a linear amplifier the signals always remain in the analog domain, and the output transistors act as linear regulators to modulate the output voltage. This results in a voltage drop across the output devices, which reduces efficiency.

Class D amplifiers take on many different forms, some can have digital inputs and some can have analog inputs. Here we will focus on the type which have analog inputs.

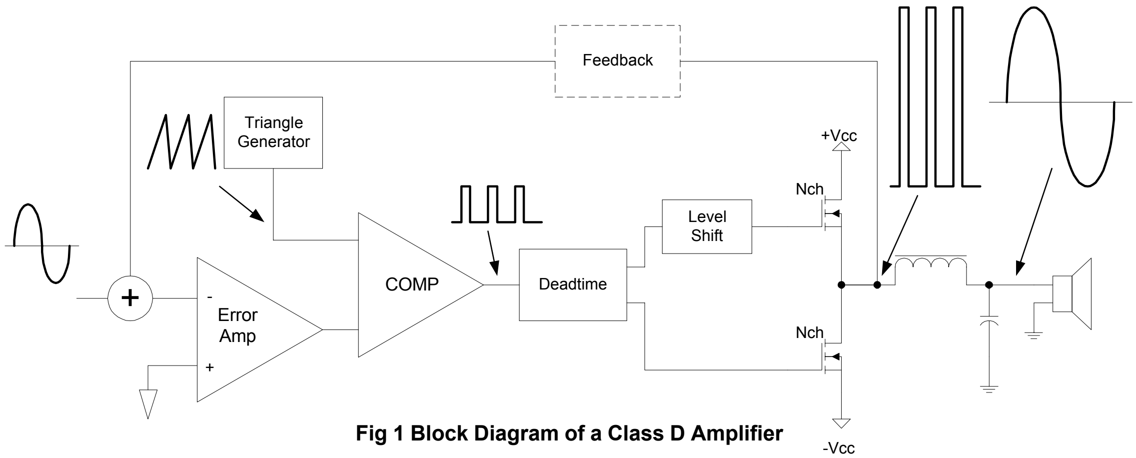


Fig 1 Block Diagram of a Class D Amplifier

Fig 1 above shows the basic block diagram for a Half Bridge Class D amplifier, with the waveforms at each stage. This circuit uses feedback from the output of the half-bridge to help compensate for variations in the bus voltages.

So how does a Class D amplifier work? A Class D amplifier works in very much the same way as a PWM power supply (we will show the analogy later). Let's start with an assumption that the input signal is a standard audio line level signal. This audio line level signal is sinusoidal with a frequency ranging from 20Hz to 20kHz typically. This signal is compared with a high frequency triangle or sawtooth waveform to create the PWM signal as seen in fig 2a below. This PWM signal is then used to drive the power stage, creating the amplified digital signal, and finally a low pass filter is applied to the signal to filter out the PWM carrier frequency and retrieve the sinusoidal audio signal (also seen in fig 2b).

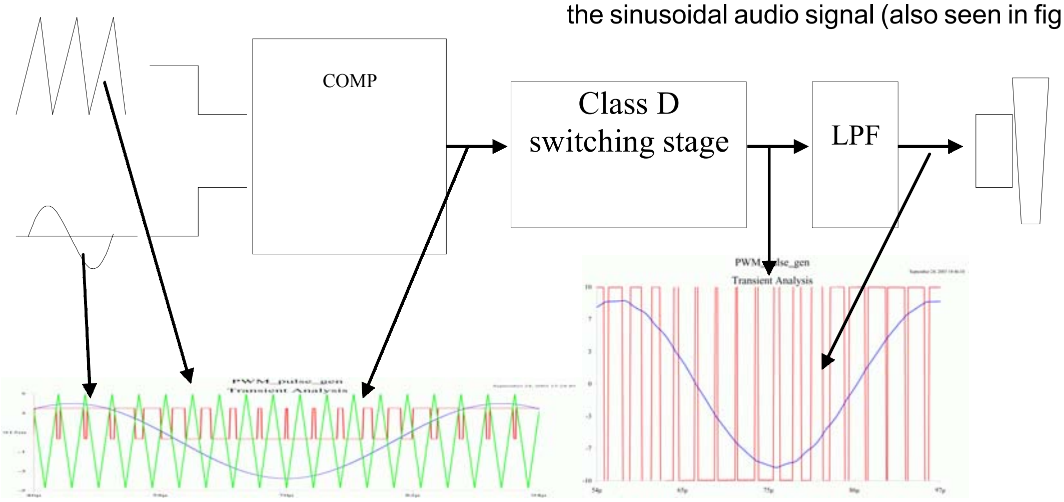


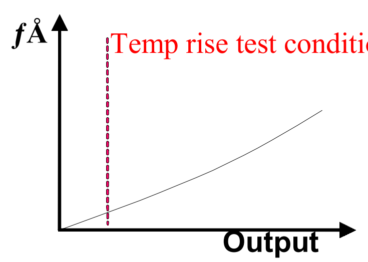
Fig 2a PWM Signal Generation

Fig 2b Output Filtering

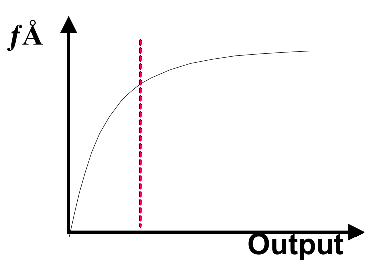
Fig 2) Class D Amplifier Waveforms

Topology Comparison – Linear vs. Class D

In this section we will discuss the differences between linear (Class A and Class AB) amplifiers, and Class D digital power amplifiers. The primary and main difference between linear and Class D amplifiers is the efficiency. This is the whole reason for the invention of Class D amplifiers. The Linear amplifiers is inherently very linear in terms of its performance, but it is also very inefficient at about 50% typically for a Class AB amplifier, whereas a Class D amplifier is much more efficient, with values in the order of 90% in practical designs. Fig 3 below shows typical efficiency curves for linear and Class D amplifiers.



Linear Amplifier



Class D Amplifier

Fig 3 Linear and Class D Amplifier Efficiencies

Gain – With Linear amplifiers the gain is constant irrespective of bus voltage variations, however with Class D amplifiers the gain is proportional to the bus voltage. This means that the power supply rejection ratio (PSRR) of a Class D amplifier is 0dB, whereas the PSRR of a linear amplifier is very good. It is common in Class D amplifiers to use feedback to compensate for the bus voltage variations.

Energy Flow – In linear amplifiers the energy flow is always from supply to the load, and in Full bridge Class D amplifiers this is also true. A half-bridge Class D amplifier however is different, as the energy flow can be bi-directional, which leads to the “Bus pumping” phenomena, which causes the bus capacitors to be charged up by the energy flow from the load back to the supply. This occurs mainly at the low audio frequencies i.e. below 100Hz.

Analogy to a Synchronous Buck Converter

A simple analogy can be made between a Class D amplifier and a synchronous buck converter. The topologies are essentially the same as can be seen below in fig 4.

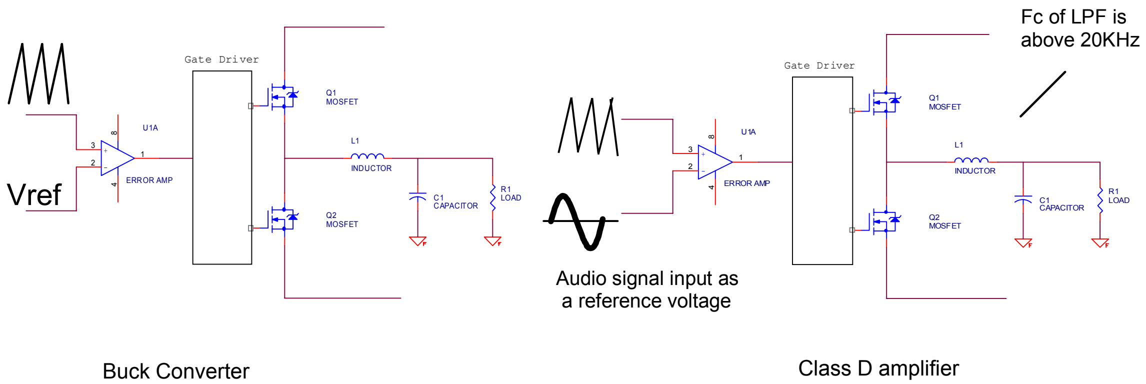


Fig 4 Topologies for Synchronous Buck Converter and a Class D amplifier

The main difference between the two circuits is that the reference signal for the synchronous buck converter is a slow changing signal from the feedback circuit(➔a fixed voltage), in the case of the Class D amplifier the reference signal is an audio signal which is continuously changing. This means that the duty cycle is relatively fixed in the synch buck converter, whereas the duty is continuously changing in the Class D amplifier with an average duty of 50%.

In the synch buck converter the load current direction is always towards the load, but in Class D the current flows in both directions.

The final difference is in the way the MOSFETs are optimized. The Synch buck converter is optimized differently for the high and low side MOSFETs, with lower $R_{DS(on)}$ for longer duty and low Qg for short duty. The Class D amplifier has the same optimization for both of the MOSFETs, with the same $R_{DS(on)}$ for high and low side.

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