

Introduction

An audio power amplifier is designed to drive loudspeakers. To do this it needs to deliver lots of volts and lots of current, usually simultaneously, to a low impedance load across a wide range of frequencies, from below 20Hz up to perhaps 40-50kHz, with no audible distortion. For a nominal 100W rms amplifier delivering a sine wave, the peak output voltage needs to exceed $\pm 40V$ for an 8 ohm resistive load and the peak current ± 5 Amps. In practice much more current may be needed to drive real loudspeakers whose impedance dips well below 8 ohms at some frequencies; in the above example ± 8 amps would be a typical requirement. To drive today's 4-8 ohm loads at 100W this should be increased to ± 12 amps or more. In real life the power supply rails will need to be closer to $\pm 50V$ rather than the theoretical minimum of $\pm 40V$ in order to account for in-circuit losses.

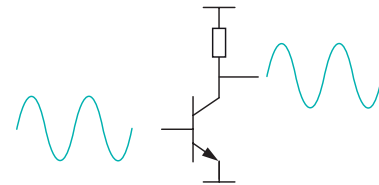
Such high powers mean that a great deal of heat is typically dissipated in the amplifier itself, especially in the output stage. This is expensive, requiring physically large arrays of output transistors, massive heatsinks and a suitably rated power transformer. So efficiency matters, because more efficient amplifiers generate less waste heat and save both money and energy consumption. As we shall see, the various classes of amplifiers shown below vary widely in terms of their efficiency, complexity, cost and fidelity. An amplifier designer will seek to arrive at the best compromise of these for the market requirements.

Class A

The simplest audio amplifiers are single-ended and Class A; that is they make use of just one output transistor which is always conducting, irrespective of the output signal waveform. Class A has good to excellent linearity (and thus high fidelity / low distortion) but very low efficiency. It is almost never used in a power amplifier's output stages but is ideal for the input and high level driver stages of a power amplifier.

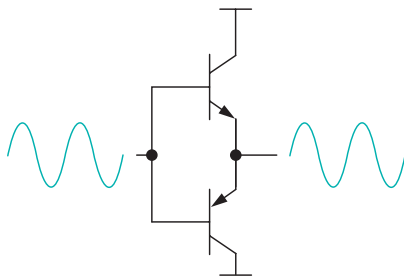
There are some examples of push-pull Class A in the consumer market (Krell, Sugden etc). These use pairs of complementary (opposite polarity) output transistors which at low signal levels pass all the current necessary to drive an attached loudspeaker at full rated power. For the 100W/8ohm example above this would mean the output stage transistors would be biased at 2.5A. With supply voltages of at least $\pm 40V$ the output stages dissipate 200 Watts when delivering no output to the loudspeaker – and that is for just one channel!

It is easy to see why such designs are limited to relatively low maximum power (20 – 50 Watts rms per channel), run hot and are extremely expensive.



Class B

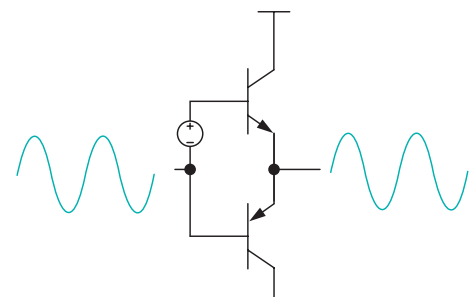
In a push-pull Class B amplifier each output transistor only conducts for one half (180 degrees) of the signal waveform. When there is no signal neither transistor is conducting – the exact opposite of the Class A amplifier above. The top NPN transistor passes only the positive parts of the signal, leaving the bottom PNP transistor turned off. Conversely the bottom transistor only conducts for the negative parts of the signal, leaving the top transistor turned off. Class B amplifiers are much more efficient than Class A amplifiers but they have high distortion due to gross non-linearities at the crossover point, which is where the two transistors transition from on to off. This form of distortion - called crossover distortion - is extremely unpleasant to the ear and thus no commercial amplifier designs use pure Class B.

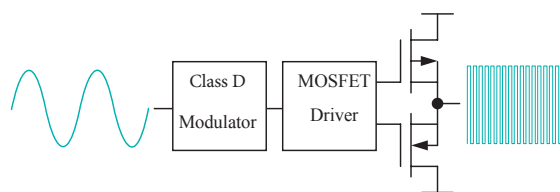


Class AB

A combination of Class A and Class B, the Class AB amplifier has a much higher efficiency than Class A but much less distortion than Class B. This is done by biasing both transistors to conduct a little at and near to zero signal output – the point where Class B amplifiers introduce gross non-linearities. They then transition to Class B for larger signal currents. For any given amplifier design there will be an optimum bias current which minimises (but does not fully eliminate) crossover distortion. A typical bias current is 50mA; thus the quiescent dissipation in our 100W output stage is $80V \times 50mA = 4$ Watts, just 2% of the Class A example above. Most commercial power amplifiers are Class AB designs.

In practice the bias current can drift away from the optimum with time, temperature and signal level and this increases the remaining crossover distortion. Much ingenuity has been devoted to trying to improve this, with varying degrees of success. One good approach is to turn off the non-conducting transistor much more slowly than in normal designs using a mix of positive and negative feedback in the output stage so that it can operate in near Class A up to about 10W output. This is used to good effect in the Arcam AVR600 and AVR750 AV amplifiers as well as the new A49, P49 & A39 stereo amplifiers.





Class D

Class D amplifiers use a different technique in which the output transistors (usually MOSFETs) are rapidly switched on and off at a far higher frequency than the highest audio signal that needs to be reproduced. The audio signal is used to modulate or vary the time ratio of the on and off signals – hence the alternative name for Class D, Pulse Width Modulation or PWM. The lowpass-filtered average of this output waveform corresponds to the actual required audio waveform. Note this is still ultimately an analogue amplifier – the term digital amplifier is often used for Class D but is simply incorrect.

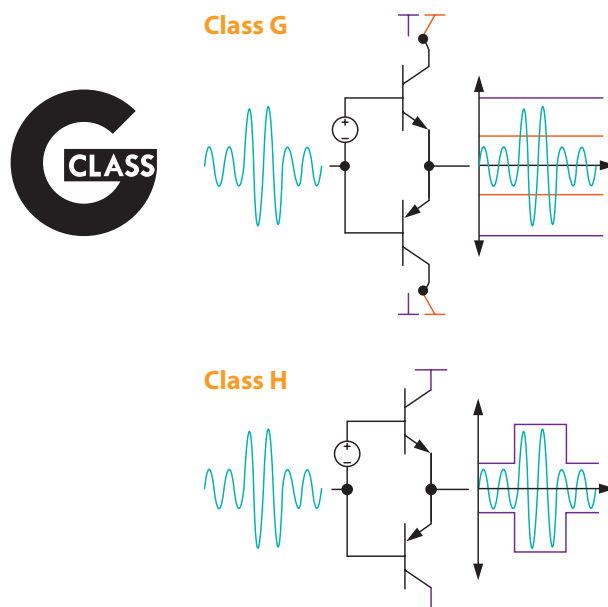
The advantage of Class D is its high efficiency (80-90%) because the output transistors are either turned fully on or fully off during operation. Its quiescent power consumption is comparable with a Class AB amplifier. Disadvantages include the need for expensive output filters plus some degree of electromagnetic radiation/interference from the amplifier and speaker cables, due to the high switching frequencies. In general its sound quality is not as good as a decent class AB amplifier, although the gap is narrowing for the best Class D designer.

Class G & H

These terms refer to amplifier classes where, in the interests of higher efficiency than Class AB, the output stage's supply voltages are varied according to the signal level. This is because music's peak to mean amplitude ratio is quite high – typically 3 to 1 – so the full power supply voltage is only rarely needed. If the 100W output stage above is usually only run at say $\pm 20V$ rather than $\pm 40V$ (the theoretical minimum value) then it will on average run much cooler when playing music. Of course extra power supplies are now needed but this cost can be largely offset by the lower heat dissipation (and smaller size) of the whole system.

The terms G and H are often confused – here we use the term Class G to refer to amplifiers that have two (or more) pairs of supply rails available to the output transistors. These can be either switched hard at a given signal level or softly, whereby the higher rails as presented to the output stage are modulated according to the output signal level. This follows the output waveform up and down to keep a small constant voltage of about 5V across the output transistors at high signal levels. The latter technique is used in Arcam's Class G designs (AVR600/750, A39/A49/P49) because it significantly increases the maximum current delivery available to drive the loudspeakers when compared with other methods.

Class H amplifiers use just one power supply to the output stages which can be changed either in discrete levels or continuously. It requires more complex circuitry to predict and control the supply voltage and comes into its own for the compact very high power amplifiers used in professional touring PA rigs.



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