

# Class distinction and amplifiers

"From each according to its bias — each draws power according to its needs."

MOST PEOPLE interested in hi-fi have heard of 'class A' and 'class B' amplifiers. The latter are commonly used in hi-fi components these days whereas class A amplifiers were common during the valve era. A 'class D' amplifier has also been produced — Sinclair marketed such an amplifier in kit form in the 60's. More recently, Hitachi's 'class G' amplifier has gained some publicity.

## Roger Harrison

These alphabetical classifications describe the electrical operating conditions of the amplifier and how the signal waveform is handled from beginning to end of a full cycle.

Unlike the Aristocratic classes, the Bourgeoisie and the Proletariat, the various classes of audio power amplifier produce from each according to its bias — and each draws power according to its needs! Technical concepts sometimes have their social parallels . . . which I should perhaps explain.

### Class A

Class A power amplifiers belong to the aristocracy. These days they're very thin on the ground! They have excellent linearity — what goes in comes out with nothing added, just stronger. But, as some people believe about the aristocracy, they tend to be inefficient.

The transistor performing the amplification is biased so that current flows through it during the complete signal cycle. This is illustrated in Figure 1. The current drawn at full signal output varies

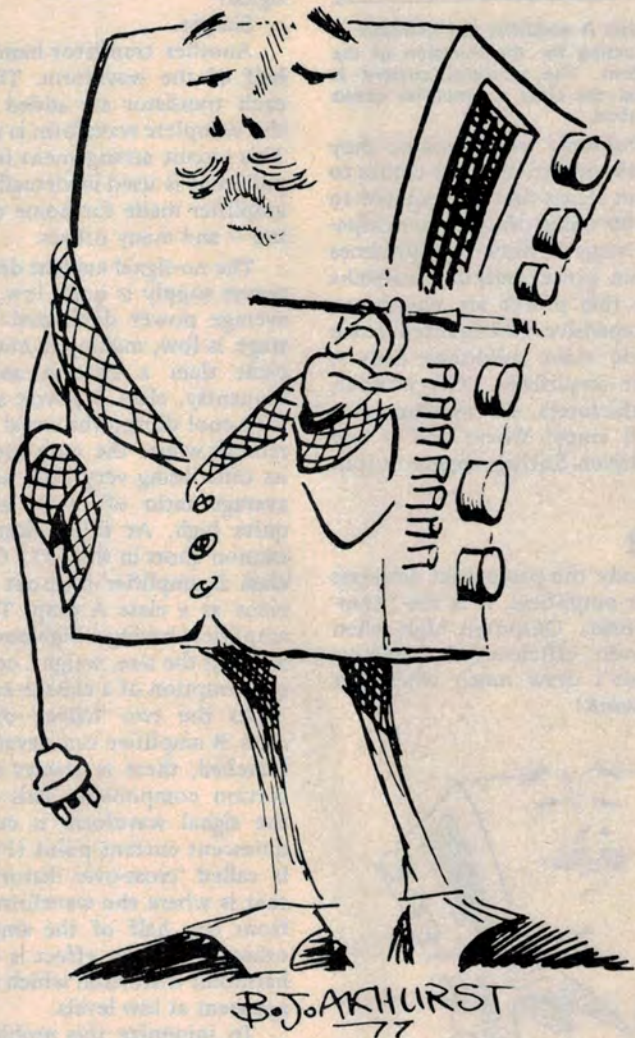
between about twice no-signal (or 'quiescent') current and almost zero over the signal cycle. The average current passing through the transistor is constant whether there is a signal present or not as the signal waveform is symmetrical about the no-signal line (Io).

As most hi-fi amplifiers operate at low signal levels much of the time (unless you're a hard rock fanatic) the overall efficiency of a class A amplifier is very low. Near zero in fact. This means that it is constantly drawing current from the power supply but delivering little

output. The class A power amp spends most of its time bludging off the state.

Even at full power output, most class A amplifiers are only about 30 percent efficient. Maximum theoretical efficiency is only 50 percent. Whilst they add 'dignity' to occasions, they laze on the job whilst doing so! Their saving grace is low distortion — they have superb linearity. And we all know how essential that is in hi-fi.

The low efficiency is not a problem in preamp or other low-level stages of a system where class A voltage ampli-▶



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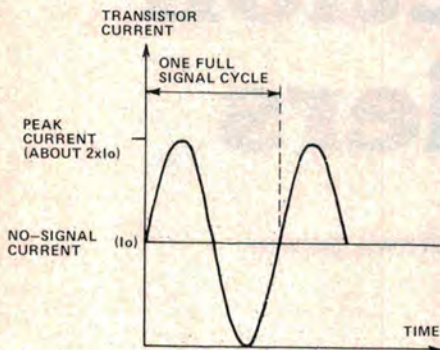


Fig 1. In a Class A amplifier the transistor is on and conducting for the duration of the signal waveform. The no-signal current is quite high and the class A amplifier draws power all the time.

fiers are commonly used, because they consume little power. When it comes to power output stages that are required to deliver 20-100 watts, the power dissipation of the stage is three or four times the maximum power output. Heatsinks to dissipate this power are enormous, heavy and expensive. Not daunted, some companies do make solid-state class A audio power amplifiers. Even weirder, some manufacturers are making *valve* class A hi-fi amps! Where will it end (... steam-driven Stirling engine output stages...)?

## Class B

Class B is truly the proletariat amongst audio power amplifiers. It is the "common workhorse.. Output is high when properly driven, efficiency is attractive and they don't draw much when not required to work!



Class A: aristocratic with excellent linearity - tendency to be inefficient.

In class B operation, the transistor stage conducts for close to half the signal cycle (See Figure 2.) The no-signal or quiescent current in a class B stage is quite small compared with the peak current drawn at the top of the signal waveform. When the signal waveform goes below the quiescent current the output waveform is 'clipped' at this point. Surely that produces lots of distortion; and what about the rest of the signal?

Simple.

Another transistor handles the other half of the waveform. The outputs of each transistor are added together and the complete waveform is reconstituted. This circuit arrangement is called 'push-pull' and is used in virtually every audio amplifier made for home entertainment use - and many others.

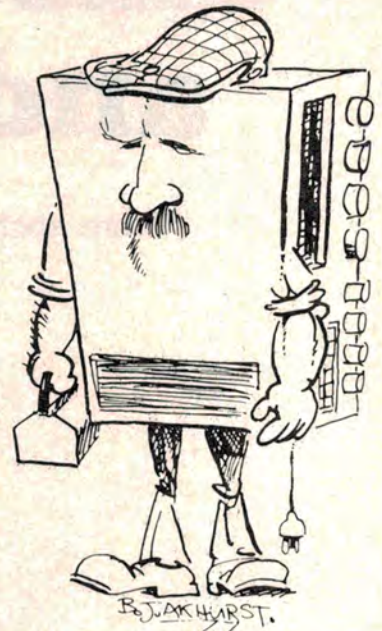
The no-signal current drawn from the power supply is quite low, and thus the average power dissipated by a class B stage is low, making it much more efficient than a class A amplifier. Consequently, class B power amplifiers run very cool during the usual sort of programme where the amp spends much of its time doing very little as the peak-to-average ratio of music and speech is quite high. At full power output (the cannon shots in the 1812 Overture!) the class B amplifier is about twice as efficient as a class A amp. This results in amplifiers having a high power capability without the size, weight, cost and power consumption of a class A amp.

As the two 'halves' of a push-pull class B amplifier can never be perfectly matched, there is always a residual distortion component. This occurs where the signal waveform is cut off at the quiescent current point (Figure 2). This is called 'cross-over distortion' because that is where the waveform crosses over from one half of the amplifier to the other. The main effect is objectionable harmonic distortion which is particularly apparent at low levels.

To minimize this problem, the stage can be biased more towards class A operation. This reduces output and efficiency, but linearity is improved. Called 'class AB' operation, one might think of it as the 'bourgeoisie' of the audio power amplifiers.

## Class C

This class of amplifier is widely used in radio frequency transmitters. A class C stage conducts for much less than half the period of the signal cycle. This produces enormous distortion but efficiency



Class B: the common workhorse - output is high if properly driven.

is very high (theoretical maximum 100 per cent) as the stage is biased so that it is 'cut off' or not conducting for most of the period of the signal cycle. Simple tuned circuits filter out most of the distortion components. They are quite useless in audio amplifier applications so we won't concern ourselves with them further.

## Class D

Even though class B power amplifiers are quite efficient, their heat dissipation requirements are still substantial. If only the amplifier could be made even more efficient - was the question considered by designers for many years.

The heat dissipation in a transistor is lowest when it is either conducting 'fully on', or not conducting at all. In a normal amplifier situation, the transistor

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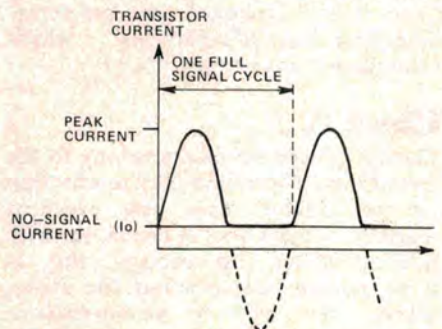


Fig. 2. Class B power amplifiers are arranged in a 'push-pull' circuit configuration. Each half is biased so that each transistor conducts for about half the duration of the signal cycle. Transistors conduct during alternate cycles.

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varies between these two states with the signal waveform. A transistor driven by a series of pulses spends its time either fully on or off. Class D amplification makes use of this.

The pulses can be used as a 'carrier' of the audio signal. Class D amplification employs a pulse-width modulation scheme. A series of ultrasonic pulses, at around 200-300 kHz, far above the audible range, is passed through the amplifier. The audio waveform is used to vary the width of these pulses. Switching transistors are used rather than the conventional types found in audio amplifiers as their efficiency is much higher.

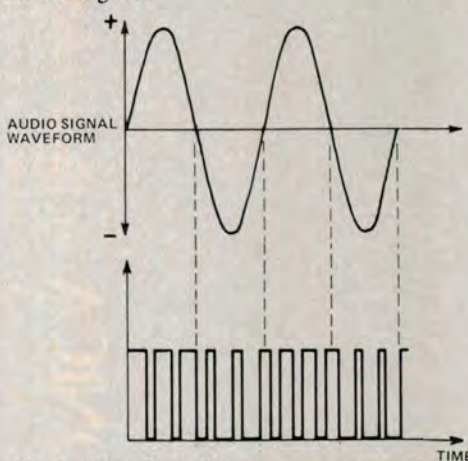


Fig. 3. Class D amplification uses pulse-width modulation. Pulse amplifiers are very efficient and the pulse-width modulation process can be made very linear.

As illustrated in Figure 3, the width of the pulses varies in sympathy with the signal waveform. During the positive portions of the signal the pulses increase in width. The pulse width decreases during the negative portion.

A low pass filter, similar to the crossover network used for a mid-range speaker in a multi-speaker enclosure, is all that is required to restore the original waveform. This filter passes the 'slow' audio signal variations while excluding the ultrasonic pulses.

As the modulation can be made very linear the distortion figures of such an amplifier are extraordinarily low.

The advantages of the class D system make it quite attractive. For a given power output a class D amp will be much smaller, require very much less heatsink and will be cooler than conventional designs.

However, the powerful high frequency pulses produce harmonics which will be radiated by the amplifier circuitry. These harmonics can interfere with broadcast and television reception!



Class AB: the bourgeoisie — a compromise but quite effective in practice.

Apart from that, other technical difficulties have prevented the widespread adoption of class D amplifiers.

A good worker with no place in the bureaucracy — as yet. Sort of Democratic party.

## Class G

This was originally called class E by Hitachi who later changed the nomenclature.

In the class G amplifier a low power and a high power stage work together in an arrangement that permits each to operate with relatively high efficiency and low distortion.

At low signal levels the low power stage drives the speakers; the higher power stage takes over at a point where it is advantageous to do so. The low power stage operates from a separate higher voltage supply. These supply voltages are selected so that the 'transition' between stages occurs smoothly so that the waveform remains largely undisturbed and the efficiency of each stage is optimum.

Efficiency of this arrangement is much higher than for a conventional class B amplifier. This has the obvious advantages of reduced weight, size and power consumption. The heatsink requirement is much less than for a class B amplifier of similar power rating.

The operating area where one stage takes over from the other, the transition point mentioned previously, is a potential source of distortion. It is similar to cross-over distortion in push-pull class B amplifiers. Hitachi claim to

have reduced this source of distortion to negligible proportions with an inexpensive circuit addition. The result, so Hitachi tells us, is an amplifier with distortion at least comparable with similar conventional amplifiers.

The Quad 'current dumping' amplifier seems to be based on a similar concept. It is however, somewhat different in realisation. It employs a class A amplifier to drive the speakers at low levels — voltage drive operation — and a class B power amplifier to provide the necessary high current drive at high power levels. Thus, at low levels, where distortion is critically evident, is where the highly-linear class A amplifier operates. The class B power amplifier operates in its most efficient and linear region at the high power level. This arrangement massively reduces cross-over distortion in a high-power amplifier.

Now. The aristocracy work hand-in-hand with the bourgeoisie and become the new proletariat!

## New classes

A relatively new approach, but using an old idea, is to vary the class of the output stage according to the signal demands.

Special circuits in the amplifier monitor the signal level and adjust automatically the output stage bias as the signal level demands. This arrangement was once known as the 'sliding bias' technique but is a little more sophisticated here. The amplifier operates, from moment to moment, nearest the class that produces the desired results with respect to distortion, power output and efficiency. At low signal levels for example, the output stage will operate in class A. As the signal level increases, the output stage will shift from class AB to class B, at peak power. Two-way social climbing — up the ladder and down the ladder.

## Which is best?

Well, that really remains unanswered. Some amplifiers may have audible advantages over others. It is difficult, in practice, to choose an amplifier with superior characteristics that are clearly linked to its class of operation.

Companies, their designers or their marketing staff, advocate a certain approach for many good reasons. Results achieved, according to the depth of your pocket, is inevitably the best way to judge rather than on the technique used to achieve such results. ●