High current amplifiers

Do we need them?

How important is the current-sourcing ability of amplifiers? Does it need to be specified separately, in addition to power ratings or is it a new marketing ploy dreamed up by the amplifier manufacturers?

by LEO SIMPSON

One of the parameters we read more of in amplifier advertisements these days is current capability. According to some audiophiles and designers, current capability is one of the most important characteristics of an amplifier. Hence, typical amplifiers today, as well as having power ratings into 8-ohm and 4-ohm loads, also have a figure quoted for instantaneous current capability.

For example, a current model (sorry about that) from the USA has a rated power of 70 watts per channel into 8 ohms and an instantaneous current capability of 50 amps. This is said to make it suitable for use with low impedance speakers.

Well, just how important is current sourcing ability? And just how much current should an amplifier be able to deliver, for a given power rating. A few moments' work with a calculator will quickly show the answers to these questions.

For example, let us consider the recent Playmaster Sixty/Sixty amplifier which had a nominal rating of sixty watts per channel. As the spec panel published in the May 1986 issue of EA showed, the amplifier was able to deliver about 74 watts into an 8-ohm load with one channel driven and about 88 watts into a 4-ohm load, again with one channel driven. This means, that on a steady-state basis, the amplifier could deliver about 3 amps into an 8-ohm load and about 4.7 amps into a 4-ohm load.

That does not sound like very much when compared to the figure of 50 amps quoted above, does it? But the figure was quoted as an instantaneous capability, so perhaps we should use the dynamic power figures as a guide. For the Playmaster Sixty/Sixty, these figures were 105 watts into 8 ohms and 153 watts into 4 ohms, both for a single channel being driven.

These figures are obtained using the IHF procedure which involves using a pulsed sinewave signal with a pulse duration of 20 milliseconds and a pulse repetition rate of 2Hz; ie, two pulses per second.

Again, you can calculate the equivalent current figures at about 3.6 amps for the 8-ohm load condition and about 6.2 amps for the 4-ohm load condition. These are RMS figures (root mean square) which are the effective or DC equivalent values for an AC sinewave signal. To get the instantaneous figure, we have to multiply the RMS value by 1.414. This gives instantaneous values of just over 5 amps for the 8-ohm condition and 8.75 amps for the 4-ohm condition.

And while we did not quote the performance of the Playmaster amplifier into 2-ohm loads, it will deliver a peak current of about 11.5 amps. This corresponds to an IHF power output of about 130 watts. Even if we take the highest possible figure of 11.5 amps, it is still paltry compared with the 50 amps figure for the American designed amplifier. So why did they need it?

The note about suitability for low impedance speakers gives the clue. These high current requirements are based on the fact that loudspeakers do not present a simple resistive load to the amplifier terminals. Instead, they are a complex impedance. On some speaker systems, the actual impedance value at a particular frequency may plummet to below two ohms.

This can happen if the loudspeaker system is transformer-coupled, as in the case of an electrostatic system, or has a badly designed crossover network. With these sorts of loudspeakers, the amplifier must be able to deliver very high currents if it is to avoid distorting the signal waveform, for a given volume setting. This will not be a problem for the amplifier at low volume settings but at high settings, where the amplifier is close to clipping, it can cause a serious reduction in power output.

So would it be possible to produce an amplifier with a nominal rating of 70 watts per channel into 8-ohm loads, able to deliver an instantaneous current of 50 amps? Quite simply, yes. But there are a number of big ifs.

Rugged output stage required

First, the output stage must have sufficiently highly rated power transistors to be able to deliver 50 amps peak. To do it safely, the transistors would probably have to be capable of delivering up to 100 amps on a pulsed basis. Surprising though it may seem, such a requirement is not too difficult these days. The designer could even obtain such an output stage capacity with single transistors (or Darlingtons) without the need to parallel transistors.

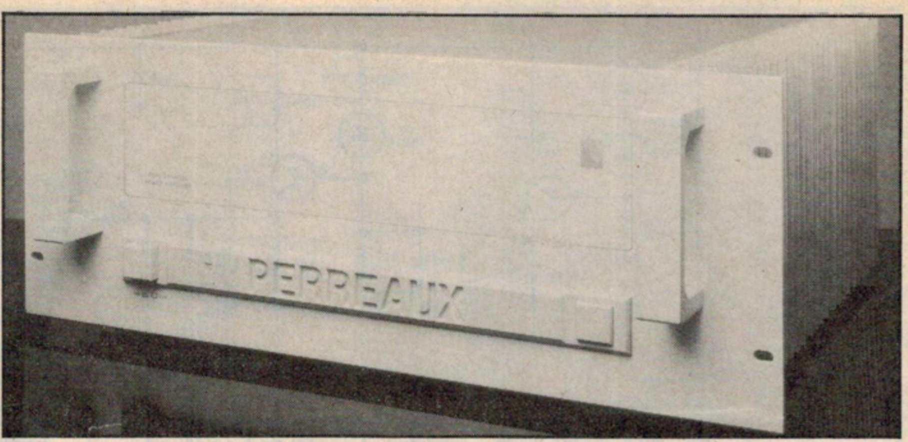
It is a lot more difficult to obtain such a high capacity with power Mosfets though, since they are transconductance devices, ie, they require so many volts into the gate to obtain so many amps of drain current. (Typically, at least three Mosfets would have to be paralleled to obtain a 50 amp capacity, giving an output stage of six transistors.)

Of course, as well as having high current capacity, the output transistors would require adequate voltage and power ratings. A typical device might have a collector rating 120 volts and a power rating of 300 watts. At the same time, it would need very good "second breakdown" characteristics if it was to be able to safely handle reactive loads. Be under no illusions, all loudspeakers are highly reactive somewhere within the audible spectrum.

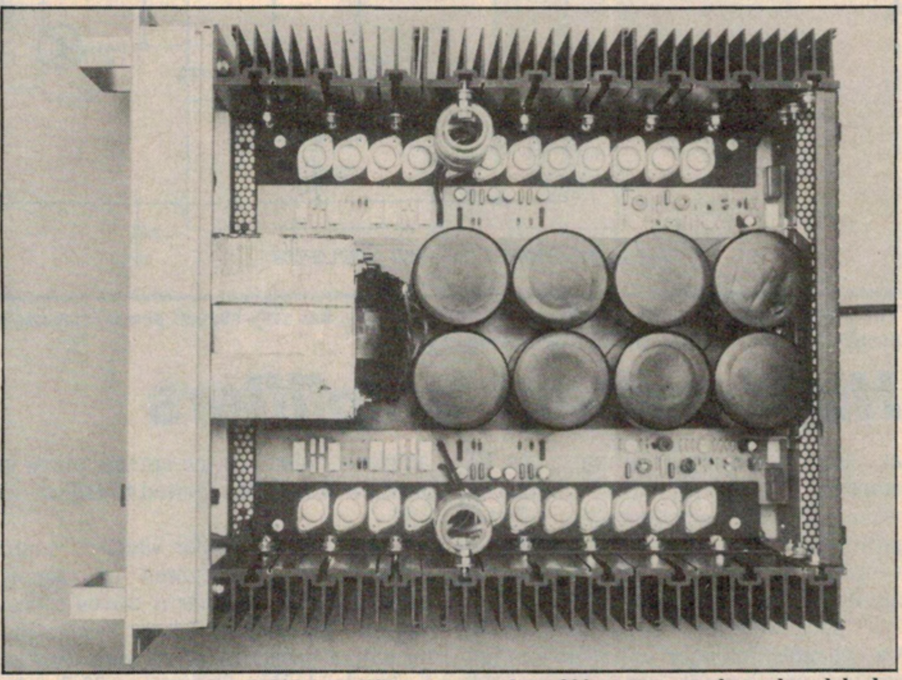
And it is the reactive load condition which rejects most high current transistors as being unsuitable for high power amplifier design. "Second breakdown" is the bugbear. This is the process by which bipolar transistors develop hot spots at the higher voltage and high current conditions. The higher voltages cause current crowding which then causes the hot spots. It is the hot spots on the chip surface which can cause failure of the device.

Because of the second breakdown effect, all bipolar transistors have to be derated to some extent at the higher voltages. And paradoxically, the tendency is for the very high current devices to be derated the most.

So even if you could obtain sufficient current capacity (ie, 50A) with a pair of complementary output transistors, the chances are that a viable output stage would require at least four output transistors if it was to be a reliable design. To be a really conservative design, capable of handling the most difficult, low value, reactive loads, you might need as many as six output devices in each channel.



A rugged amplifier if ever there was one, this Perreaux PM3150 is capable of delivering 10 amps on a short term continuous basis.



This massive Perreaux 5150B amplifier was rated at 800 watts per channel and had a total power supply capacitance of 80,000uF.

As well as making sure that the output transistors have sufficient current sourcing ability, the designer must make sure that the driver stages can also deliver enough current to the output transistors, without any danger of damage to the devices if the loads are short circuit.

Power supply

Having taken care of the amplifier output stage, the next requirement is for sufficient current capacity from the power supply. Since the current only has to be delivered for a very short time, less than 50 milliseconds, say, it is possible to build in this order of current capacity merely by specifying very large filter capacitors in the power supply. So, while the Playmaster Sixty-Sixty used a value of 5000μF for the total filter capacitance for both the positive and negative supply rails, the value probably may have to be increased to around 15,000μF or more, depending on the quality of the capacitors.

At the same time, all the conductors within the amplifier would have to be of sufficient cross-section to ensure that resistive losses did not become excessive

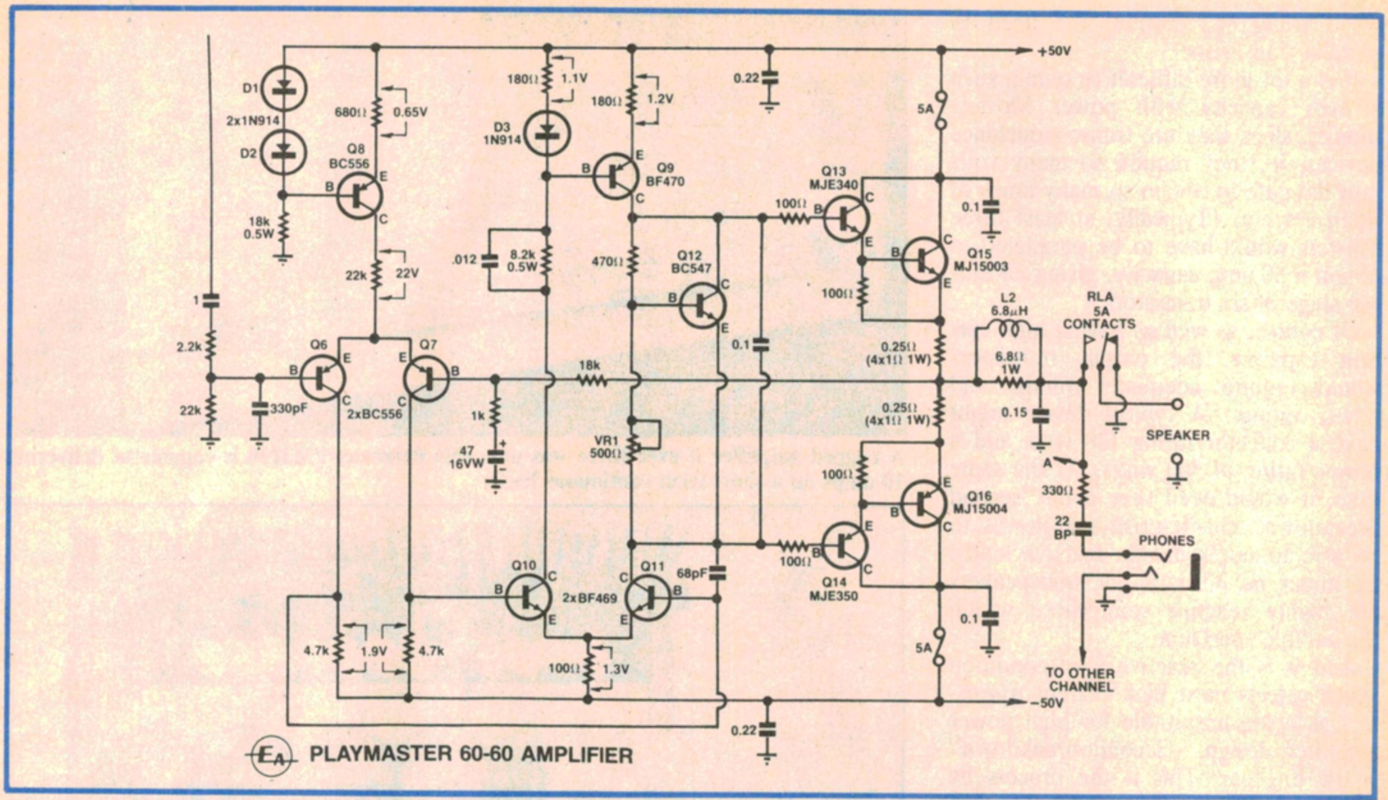
How to calculate maximum amplifier output current

To calculate the maximum instantaneous output current of an amplifier, you need to know how much power it can deliver from one channel into the specified minimum load. For example, if it will deliver 100 watts on a short term basis into a 4Ω load, we calculate the RMS voltage across the load as:

$$V_L = \sqrt{P \times R_L} = \sqrt{100 \times 4} = 20 \text{ volts}$$

We then calculate the peak voltage by multiplying V_L by 1.414 to obtain 28.28 volts. We then calculate the peak current:

$$Ip = \frac{Vp}{R} = \frac{28.28}{4} = 7.07 \text{ amps}$$



The power amplifier of the Playmaster Sixty-Sixty. This has very rugged power transistors in the output stage but these would need to be paralleled up to increase the output current capability.

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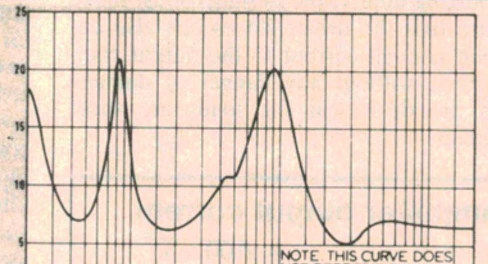
at these high output currents. At 50 amps, a resistance of only 0.1 ohms between the commoned-emitters of the power transistors and the loudspeaker would mean a loss of 5V. That would not be easily achieved.

It goes without saying that a 70 watt/channel amplifier with a 50 amp instantaneous current capability would cost a lot more than an equivalently rated amplifier such as the Playmaster Sixty-Sixty. And having paid for such an amplifier, what are the circumstances in which it would be required to deliver its all?

The conditions under which 50 amps peak would be required are simply these: (a) the amplifier is driven to deliver its full output voltage swing. For an output capability of 70 watts into an 8-ohm load, this amounts to 23.7 volts RMS or 33.5 volts peak; and (b) the loudspeaker impedance for the signal being delivered by the amplifier must be 0.67Ω or less.



This is the B&W DM110 which has an impedence characteristic typical of many well-designed loudspeakers. Notice that it does not dip below 5 ohms at any point in the audible frequency range.

The first condition could occur quite often, particularly if the volume setting is high. The second condition would be very rare, if it is ever likely to happen at all.

Having come this far though, let us look at a more-likely worst case condition. Consider for example, if we have two sets of loudspeakers connected, both of which have a nominal impedance of 4Ω. For a typical loudspeaker system, you can expect that the minimum impedance will be at least two-thirds of the nominal impedance, or 2.68Ω. With two such loudspeakers in parallel, the load impedance is therefore 1.34Ω which is getting pretty low. For the same maximum output condition as listed above, the amplifier will now have to deliver 25 amps.

Frankly, the likelihood of having two sets of loudspeakers which have a minimum impedance of 1.34Ω (to obtain a parallel combination of 0.67Ω) is stretching credibility. And the likelihood of having any loudspeaker with a nominal impedance of 8Ω with such a minimum impedance is zero. Such a loudspeaker would cause so many problems with ordinary amplifiers that it would quickly be withdrawn from sale. No self-respecting loudspeaker designer would produce such a system.

So what conclusion are we left with?

We have to consider that it is possible to have a situation where a user may have two sets of loudspeakers which, when connected in parallel, will have a minimum impedance of 1.34Ω. And therefore, if the amplifier is not to clip prematurely when driven to full output, it needs to be able to deliver 25 amps peak.

More realistically, a typical user may have two pairs of 8-ohm loudspeakers (or one pair of 4-ohm loudspeakers) which can be expected to have a minimum impedance, when connected in parallel, of no less than 2.5Ω. The amplifier now has to deliver 13.4 amps peak.

Or if we use the example cited at the start of this article, where the minimum loudspeaker impedance is 2Ω, the maximum peak output current, for a peak output voltage of 33.5V, is 16.75 amps. Note that this current capability is only required when the amplifier is being driven flat out. The consequence of using a less well endowed amplifier (as far as current capability is concerned) is that difficult loudspeakers would not be able to be driven quite as hard before severe distortion became apparent.

So you could argue that a 70 watt per channel amplifier with an output current of say, 20 amps, is desirable, for the best quality sound, and you would be right, as far as technical considerations are concerned. But to argue that a 70 watt per channel amplifier needs a 50 amp instantaneous current capability is ridiculous.

So where does that leave the Playmaster Sixty-Sixty which we have used as the basis for comparison in this article? Plainly, it is not intended to drive very low impedance loads although it will safely drive a 2-ohm load for short periods. If driven hard into such a low value load, it will blow the fuses. In other words, it is designed to survive being connected to low impedance loads and short circuits, not to drive them.

With typical 8-ohm loudspeakers though, whose impedance values fall into the expected range, it would be extremely hard to better the performance of the Playmaster Sixty-Sixty, at any price.

It would be possible to beef up the output stages of the Playmaster amplifier, but that would require the addition of more output transistors, larger heatsinks and bigger filter capacitors in the power supply. It would add up to a considerably more costly amplifier with no audible improvement to the performance, except on "difficult" loudspeakers. EA