Power Factor Correction, Linea's Position

Why have we written this ?

Over the past several years' amplifiers have been introduced fitted with power supplies that include power factor correction (PFC). Unsurprisingly the marketing that accompanies these products creates the impression that PFC is a universal good. Of course as usual with complex subjects things are not as simple as "it has PFC therefore it is good - it does not have PFC therefore it is bad". As Linea has recently introduced a range of very high power amplifiers with power supplies that do not include conventional PFC we feel the need to explain why.

What is PFC ?

The job of PFC is to make a product look like a resistance to the mains supply network. This is because resistive loads require the minimum current to transfer a given amount of power. Some types of product, heaters and old style filament light bulbs for example naturally look resistive. Amplifiers and most other electronic equipment does not unless it is fitted with PFC. As the name implies, the aim of PFC is to make the power factor (PF) 1 or 'unity'. With a unity PF the actual current drawn will be the same as the resistive current. A PF of 0.5 means that for the same power, the actual current is 1/PF = 1/0.5 or twice the resistive current. This is why companies that manufacture amplifiers with a PFC in their power supply all state that PFC is a good thing, primarily because it can reduce the mains current demanded.

It is important to appreciate that irrespective of the PF, the power consumed from the mains supply is the same. Or put another way, a PF of less than unity does not imply that additional power is wasted or that efficiency is compromised.

The issue

When talking about amplifiers, striving for a unity power factor is not the whole story. Modern power factor correctors can achieve a very good PF figure, often better than 0.9 but they can only do this if their load is more or less constant. To think of this another way, the PFC must continually adjust the shape and timing of the current draw to be the same as the mains voltage which is more or less a sine-wave. If the load is constant this is not too much of a problem. However if the load, in this case an amplifier responding to an audio signal suddenly demands more power, the PFC has two choices :

- Ignore the power demand, keep the current waveform pure and maintain the PF close to unity. BUT this means that the amplifier may be starved of the current required and the audio may suffer.
- Increase the current draw to meet the demand. BUT this means that the PF will be compromised until the PFC has adjusted itself, which can take tens of milliseconds.

In practice the design of the PFC will have to be a compromise between these two conflicting requirements which means that it will not perform as effectively when the amplifier is fed with program material as it does when fed from a stable pink noise or sine-wave test signal. Of course it is almost certain that stable test signals were are used to create the PF number for the products' specification sheet.

Linea's position

Currently Linea's products do not include conventional PFC. This is not because we do not understand the technology, it is because we believe that for the techniques currently employed the benefits do not outweigh the disadvantages. One area of particular concern is compromising the dynamics of the audio signal, particularly at very high powers and particularly in the bass region. Adding a PFC to the power supply also reduces a products' overall efficiency which as will be seen, is a significant consideration.

There is another important reason that Linea do not include a PFC, our power supplies have a PF that *increases* with increasing load. On typical mains at low loads the PF is approximately 0.6 but this improves so that during high power audio transients it can be expected to be about 0.75. As we saw, an amplifier fitted with PFC needs to compromise between PF accuracy and audio performance so it is likely that under the same conditions its PF will degrade from the published figure, possibly to something like 0.8 or 0.85 and maybe much lower.

Remember that for all amplifiers it is the current drawn at *high power* that determines the mains distribution requirement.

Some numbers

Using the example of amplifiers delivering 5kW transients, running on 230V mains and for the moment assuming 100% efficiency :

Linea amplifier, PF = 0.75
Current draw = (5000/230) x (1/0.75) = **29A**

PFC amplifier, PF = 0.8
Current draw = (5000/230) x (1/0.80) = **27A**

PFC amplifier, PF = 0.85
Current draw = (5000/230) x (1/0.85) = **25.5A**

This difference is not as large as might be expected from the PF specification of PFC amplifiers.

Efficiency

There is another very important point to make, and that concerns the efficiency of the amplifier. Taking Linea's M series amplifiers as an example, independent testing shows them to be about 8% more efficient (mains power in to audio power out) than their best competition. This does not sound like much but in addition to wasting less power in the form of heat, efficiency has a significant effect of the mains current drawn for the same audio output. Using the above example :

Linea amplifier, PF = 0.75, overall efficiency 84%
Mains power required = 5000 x (100/84) = 5950W
Current draw = (5950/230) x (1/0.75) = **34.5A**

PFC amplifier, PF = 0.8, overall efficiency 76%
Mains power required = 5000 x (100/76) = 6580W
Current draw = (6580/230) x (1/0.8) = **35.8A**

PFC amplifier, PF = 0.85, overall efficiency 76%
Mains power required = 5000 x (100/76) = 6580W
Current draw = (6580/230) x (1/0.85) = **33.7A**

This result is perhaps even more surprising. Doing equivalent work, Linea's amplifier without conventional PFC actually demands nearly the same or slightly less current from the mains than the PFC endowed product.

Conclusion

From the above it is clearly important when comparing amplifiers to consider a product as a whole rather than selecting individual specifications. When viewed in this way it becomes apparent that it is possible to produce an amplifier without conventional PFC that out-performs a product that includes one.

In fact there is a real problem hiding in the calculations because if a user assumed that the PF of their amplifier really was >0.9 under all conditions and did not take overall efficiency in to account, they might conclude that the mains system needs to supply much less current than their system actually requires.

Ben Ver, Linea Research 2016