Hunting crossover distortion

THERE'S STILL NO SUCH THING AS A PERFECT AMPLIFIER, SAYS STAN CURTIS, WHO EXPLAINS THAT SOME DESIGNERS LOST THEIR WAY SIMPLY BECAUSE THEY WERE LOOKING FOR THE WRONG KIND OF DISTORTION – AND OTHERS ARE STILL MAKING THE SAME MISTAKE

It is some 60 years since the first 'solid state' or 'transistor' audio amplifiers started to be sold commercially – a period roughly corresponding with my involvement as a designer in the industry. So you'd think that with all the development and research that has taken place in those decades the design of amplifiers would be pretty much settled with improvements limited to the use of new materials and expensively exotic semiconductors. Certainly with some amplifiers costing a hundred thousand pounds or more you could be forgiven for expecting them to be close to perfection with, for example, no sources of distortion remaining no matter how insignificant. Regrettably that just isn't so and there are still some problems that always seem to have been swept under the carpet. From time to time I'll return to this topic but for this issue we'll make a start by looking at crossover distortion.

To understand the origins of crossover distortion we need to start with a history lesson. The first generation of transistor amplifiers were quite low power and had an output stage comprising of a single power transistor; often transformer coupled to the loudspeaker. When customers demanded higher power outputs; perhaps as much as 15 watts per channel, a new type of circuit was needed. This development was the "push-pull" circuit where the output stage comprised two transistors, one conducting the positive half of the waveform and the other conducting the negative half of the waveform. This arrangement worked well and today virtually all analogue audio amplifiers use a variant of this circuit topology. In theory the positive and negative halves of the waveform join together seamlessly and any residual distortion is minimised by feeding a portion of the output signal back to the amplifier's input – the so-called negative feedback. Except that in reality it doesn't work like that because silicon transistors need to have applied an input voltage of about 0.6 volts before they start to conduct. So there is a dead region of 1.2 volts in the output signal heard as horrendous distortion at low signal levels. And the distortion reducing negative feedback can't help because in the dead region there is no output signal so nothing to feedback.

For some reason early designers got fixated on measuring the distortion at the rated power level, in this case 15 watts; and paid less attention to the distortion at low power levels, say 0.2 watts, ignoring the fact that some 30 dB of the 60 dB dynamic range would be in that region of gross distortion. The result was a generation of terrible sounding transistor amplifiers which could have killed off this new technology. In response some designers came up with a fix; apply a DC voltage of over 1.2 volts to the output stage so that the output transistors were always conducting and the dead zone disappears. However another problem quickly appeared. When the output transistors start conducting the current flowing heats up the transistor which in turn reduces the DC bias voltage needed for conduction and so more and more current flows until the transistor destroys itself. I can still recall the pungent smell of burning output stages from my own early designs!

And I wasn't alone; Radford in particular going through some difficult days before they sorted out their designs. And so engineers had to design some sort of thermal feedback arrangement to ensure that the bias current tracked the temperature of the output transistors to ensure that the "no-signal" or quiescent current remained stable. With the output transistors heating up and cooling down with the varying amplitude of the music signal and with each output transistor not being a perfect match to the other, this is far from being an easy task. Even the choice of optimum bias current is open to question with designers having to decide upon the relative audibility of the residual distortion.

Examining the alternatives

There have been a few alternatives to the classic DC bias being proposed over the years. One is Peter Bomley's 1971 design, which has two mirror imaged current mode amplifiers whose output is combined. By working with current amplifiers rather than the more familiar voltage amplifiers the distortion is kept below 0.1% before any feedback is applied and there is no discernible crossover distortion. Although this circuit can be a little difficult to understand by those brought up on conventional amplifiers I remain