Letters to the editor

Dear Editor,

Bruno Putzeys (Linear Audio volume 1 pages 112...132) is not in a camp of his own; I read his article about negative feedback with great interest and agree with almost everything he wrote. The only thing I don't agree with is his claim that TIM is a measurement method rather than a special kind of distortion. Otala used the term transient intermodulation distortion to describe how one signal affects another when an amplifier gets close to slewing. That is, TIM relates to slewing-induced distortion as normal intermodulation relates to harmonic distortion. He further proposed tests for measuring this effect which he called DIM30 and DIM100, where DIM stands for dynamic intermodulation.

One storyline that appears to be missing from Mr. Putzeys' article is the story of the error signal as a function of time. In the early 1990's I've searched the literature to find out where the story that feedback amplifiers with small open-loop bandwidths necessarily suffer from TIM comes from and whether there is any truth in it. The earliest related article I could find is the 1966 article by Daugherty and Greiner, "Some design objectives for audio power amplifiers", IEEE Transactions on Audio and Electroacoustics, vol. AU-14, nr. 1, March 1966, pages 43...48. Their conclusions on error signal overshoot were later repeated in a series of articles of the research group of Otala, with some refinements to the amplifier model.

In the appendix of their article, Daugherty and Greiner prove for a single-pole feedback amplifier driven by a first-order low-pass filtered step function that the error signal exhibits no overshoot when the open-loop bandwidth is greater than or equal to the bandwidth of the low-pass filter that precedes the amplifier. Error signal means the difference between the input and feedback signals of the amplifier, which is the signal that drives the input stage.

That is, they have proven that a sufficient condition to prevent slewing is to make the open-loop bandwidth greater than the bandwidth of the filter in front of the amplifier. Given the fact that the achievable gain-bandwidth product in a practical amplifier is limited by non-dominant poles, a large open-loop bandwidth implies a relatively small low-frequency loop gain.

Unfortunately, in the article they present their sufficient condition as if it were a necessary and sufficient condition. It is by no means necessary. The fact that the error signal overshoots in an amplifier with a small open-loop bandwidth is no problem as long as the amplifier's input stage is designed to handle the overshoot.

When you increase the open-loop bandwidth and reduce the low-frequency loop gain of an amplifier by connecting a resistor in parallel with the capacitor that sets the dominant pole, all that happens is that the final value of the error signal gets larger. The overshoot, which is by definition the ratio of the initial peak to the final value, gets smaller but the required linear range of the input stage is not reduced at all.
When you also take square wave input signals into account, the required linear range is reduced, but only by a factor of two.

Peter Garde pointed out these facts in his articles "Transient distortion in feedback amplifiers", Journal of the Audio Engineering Society, vol. 26, nr. 5, May 1978, pages 314...321 (reprinted from the Proceedings of the IREE Australia, October 1977) and "Slope distortion and amplifier design", Journal of the Audio Engineering Society, vol. 26, nr. 9, September 1978, pages 602...608 (reprinted from the Proceedings of the IREE Australia, December 1977). He also explained how the linear range of an input stage can be increased by local feedback.

Apparently the damage was already done by then, because more than thirty years later the idea that a feedback amplifier with a small open-loop bandwidth necessarily suffers from transient problems still exists in high-end audio circles. In fact, it has only become more extreme over the years, changing from 'use as much feedback as you can without making the open-loop bandwidth smaller than 20 kHz' to 'feedback is evil, avoid it at all costs'.

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Bruno Putzeys replies:

Dear Marcel, thank you for your comments. Slew induced distortion shows up in harmonic distortion as well. As soon as SID becomes the dominant source, you can see it as a 60dB/decade rise in THD in a frequency sweep. There is no fundamental difference in mechanism between error products arising from (combinations of) sine waves or from more complex wave forms. DIM-30 will not lay bare distortion mechanisms that sine wave based IMD tests limited to 30kHz would miss.

Daugherty and Greiner certainly show a strange twist of mind. Reducing open loop gain until open loop bandwidth equals signal bandwidth simply means that the input nonlinearity is no longer related to dV/dt but to V itself. It is hard to see how that could be an improvement. I must admit I hadn't heard of this work before you mentioned it. I suppose that means that it didn't exactly make it into our collective consciousness.