Naim's DR Technology

DOES THE NAIM STATEMENT RESEARCH PROGRAMME CONSTITUTE A REVOLUTION IN AMPLIFIER DESIGN AND TECHNOLOGY? MARTIN COLLOMS INVESTIGATES

The exceptionally detailed and painstaking R&D carried out for Naim's *Statement* amplification has shown just how hard it can be to improve on established technologies, but that once that step has been made, the resultant discoveries may then update the rules for amplifier design in general.

Some elements of this story were introduced in 2015's two issue review of the Naim *Statement* (*HIFICRITIC Vol9 Nos2&3*). Once the reference *Statement* amplifiers had been finalised, Naim's research team (particularly Electronics Design Director, Steve Sells) had time to re-examine some well respected but long established Naim power amplifiers (*NAP200*, *250*, *300* and *500*). Some of these go back 15 years, yet remain in solid demand, and Sells was anxious to see whether some *Statement* technology could be retrospectively applied to the older models.

Furthermore, the upgrade brief involved not only improving current production (consonant with the planned *DR* designations), but also included a requirement to offer these performance upgrades at moderate cost to existing compatible units already out in the field.

Experiences with this new generation amplifier technology have made me reconsider several important performance issues, both measured and subjective, and to think again about the manifest failure of accepted test methodology to define sound quality. We primarily measure audio with steady state sine wave signals, to quite exceptional accuracy and resolution, but of course music is all about complex transients.

When matters go badly wrong, established measurements can sometimes tell us something useful, such as poor load matching, high distortion, gross errors in frequency response, and poor overload thresholds. However, almost all of the better amplifiers measure really well, yet they all sound subtly different when playing music. To add to the confusion, some examples which sound fine musically, may in fact suffer from some readily measurable steady state errors, perhaps of frequency response or distortion.

Feedback

Inside an amplifier are many 'layers' of electronic behaviour that cannot be readily analysed from the outside (by inside, I mean inside the feedback loop). These are hidden and suppressed by feedback when using conventional input/output comparisons. Ultra flat frequency responses with ultra high current, ultra low sine wave distortions, are readily available from modern products, yet they continue to sound different from each other: different in timbre and tonal qualities; in image perspective and focus; in bass definition; in maximum tolerable loudness; and in treble distortion (such as 'edginess', 'fizz' and 'grain'). They also differ in subjective frequency response and bandwidth, in dynamics, transparency, and in their exposition of rhythm and timing.

Nearly 20 years ago, having already reviewed amplifiers for some 25 years, my extensive experience with the many pre- and power amplifiers of the time led me to write *A Future Without Feedback* (1998) for *Stereophile* magazine (1), which discussed some observed correlations between aspects of sound quality and the use of negative feedback. The article generated much controversy, but also some useful debate. Whatever the absolute merits of my low and zero feedback propositions, many designers have thought more deeply about the traditional use of heavy negative feedback, and its role as a panacea for amplifier ills. I would like to think that sound quality has improved since this discussion piece was published. Certainly a fair number of successful and widely advertised low and zero feedback designs have emerged both as pre- and power amplifiers.

While the marketplace now has many such low and zero feedback amplifiers, a number of more traditional designs are also available, and now apply advanced modelling to assess the inside of the feedback loop as it is operating. While the totally new *Statement* power amplifiers do not use loop feedback, the earlier *NAP*-series models do, and continue to do so in their *DR* versions. (The *NAP*-series models do exhibit mild tonal balance variations, departing somewhat from perfection, while the new *Statements* are considered pretty neutral by comparison.)

Despite a perfectly flat frequency response, a given negative feedback amplifier may show a correlation

Footnote (1): *Stereophile* article is available at: http://www.hificritic.com/uploads/2/8/8/0/28808909/classic-sc3-future_without_feedback.pdf)

between the open loop corner frequency and a mild degree of tonal colour (the *pitch* or timbre of the coloration), usually located in the upper midband or lower treble. It is as if an echo of that open loop bandwidth 'filter', present in the upper midrange, is still present after feedback is applied, even though the effective closed loop frequency response is now perfectly flat to well beyond audibility (in some cases greater than 200kHz).

From my own experience of the existing *NAP300*, I consider that a degree of subjective 'darkness' is added to the timbre, leading to a mildly dulled tonal balance. Other amplifier designs might sound thinner or brighter, and such residual tonal balance characterisations often leading to painstaking experiments with source, cable and speaker combinations to optimise a system. Now, although the normal (external) measurements have barely changed, and the in/out frequency response is essentially the same for both, by all accounts the new *NAP300DR* sounds significantly different from the old.

Discrete Regulation

Much of what was learned about feedback (among other issues) in the *Statement* design is now being applied to the revised *DR* series power amplifiers. The *DR* amplifier development story has several strands: although *DR* is a familiar acronym for 'discrete regulation', this is far from the whole story. It is almost trivial to note that Naim's regulators were for many years based on a selected version of the classic *LM317* integrated circuit (the low noise examples): it was not broken, and was therefore not fixed. But more recent research on discrete circuit regulators, seeking lower noise and wider control bandwidth, indicated that a substantial improvement could be made: in source impedance and regulation; in regulator recovery speed; and in vastly lowered noise through using sub-surface zeners. Even though the power amplifier circuits are generally designed to reject noise from power supplies, some still gets through to contaminate the audio path. Other factors may also affect sound quality, such as regulator bandwidth, and the ability to maintain low source impedance over a wider frequency range. We have already experienced the *DR* versions of several Naim external pre-amplifier power supplies, and these have effected significant improvements for many products they partner, including a *SuperLine* phono stage, a *NAC552* pre-amp, an *NDS* streamer, and a *CDS3* CD player, and several *HIFICRITIC* reviews confirm the sound quality improvements.

At a mid-November 2015 technical presentation at Naim headquarters, design chief Steve Sells demonstrated some of the new *DR* amplifier technology issues. Here he explained many of the subtleties of power regulator design, concerning noise, output impedance and rise time (effective bandwidth). He also cooked up a cunning and revealing demonstration for several of the improvements achieved in this area. Using a well crafted, music driven test rig, he took three test power amplifiers through their paces: one unregulated, one standard regulated and one DR regulated. With the amplifiers feeding real audio power but to a silent dummy load, the noise and distortion which was inevitably present on the amplifier supply rails was then specifically amplified and fed to a loudspeaker.

With the unregulated amplifier, the supply line noise was a substantial and frankly very noisy racket, comprising mains hum and very distorted programme, primarily composed of half-wave-rectified music and 50Hz ripple; all of it sounded really unpleasant. (As is the case with most unregulated amplifiers, a small portion of this noise will inevitably be present in the output signal to the loudspeaker.) The earlier pre-*DR* (but still regulated) power amplifier then showed the expected (and much reduced) level of hum and music distortion on its power rail. Finally, when the power supply line of the new *DR* regulated amplifier was put under this aural microscope, it was revealed as essentially silent, free from noise, hum, and from that dreaded music modulation distortion. Technically speaking, the *DR* supplies in the new *NAP*-series amplifiers are of similarly wider bandwidth, lower impedance, and lower noise than before, and should therefore contribute to better overall sound quality, deeper silences, and more transparency with greater low level detail.

As the amplifier power rails 'kick', due to the power draw supplied to the speaker load, they also act as an input to the amplifier, as the power supply noise rejection in the amplifier is necessarily finite. The signal on the power rails is a heavily distorted and time delayed signal; so it's not a great noise to be leaking into a carefully designed amplifier. So when the old power supply is swapped for the *DR*-based type, the power rails now present lower source impedance to the amplifier over a wider frequency range. The new *DR* regulator has substantially lower output impedance and also about 30x (30dB less) noise than before. This effectively constitutes closing down the amplifier's power supply rail as a possible unwanted signal input port, and means that a delayed, noisy and distorted music signal will leak into the amplifier circuit for much less of the time.

Now, when an amplifier is measured as a 'black box' (*ie* from input to output), and audio band

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sine waves are tested for response, distortion and noise, still no difference in performance is seen. But more complex test waveforms do at last show some beneficially improved higher order modulation behaviour at the amplifier output.

Designer Steve Sells has explained that while the *DR*-series amplifier circuits themselves have remained pretty much unchanged, the negative feedback components at higher frequencies have also been recalibrated, in order to optimise the necessary issues of feedback stabilisation (the lead and lag compensation of the amplifier). This was done to take advantage of the improved characteristics of the *DR*-based power supplies. The development also worked hand in hand with the much better high frequency characteristics of the new *Statement*-derived power transistors now fitted. Sells considers that the opportunity to re-optimise the high frequency feedback behaviour, subsequent to fitting the *DR* technology and the better transistors, was crucial for achieving the significant improvement in sound quality.

There has long been a temptation to design amplifiers by looking essentially at the current output and linearity in the audio band, and treat the higher frequency 'radio band' upper limit as just an engineering task: *ie* to fix the stability margin, to make sure the amplifier does not oscillate, and to ensure that it remains stable under working conditions with a range of possible loudspeaker loads. Naim now uses a high class network analyser that can inject 'probe' signals inside the working circuit and then analyse how the amplifier really behaves *inside* the feedback loop. This can be done up to and beyond the amplifier's intrinsic upper frequency response limit, which can be in the Megahertz region (10^6 Hz). (Denis Moorcroft pioneered a related approach at DNM some 20 years ago, examining nonlinear behaviour at very high frequencies using an advanced RF analyser, but here viewing behaviour from the outside rather than the inside of the device.)

Aspects that may affect subjective transparency, such as any minor aspect of misbehaviour which can get into the feedback loop, can end up multiplied by the high internal gain, and potentially become audible. The *Statement* research has opened up a previously untapped seam for amplifier improvements, removing or suppressing poor behaviour which could remain hidden when viewed from outside the feedback loop, but which consequently could still be fed back into the amplifier as modulated noise and distortion. These internal behaviours cannot be measured using standard tests.

For example, if you measure the signal-to-noise ratio by measuring the noise of the amplifier at the speaker terminal, the instrument cannot see injected music-related noise from active power supplies, and will also miss microphony which would also be present if the amplifier was delivering audio power to a system. Distortion readings will also look fine, even in the presence of unwanted 'internal' signals, because when you add a small time-lagged sine wave (maybe from microphony) to a sine wave, the result will still be a sine wave, and will measure without increased distortion. Multi-tone FFT analysis may see some improvement in measurement practice, but the noises we are searching for (which subtly affect sound quality) would still look insignificant. This issue presents a continuing challenge for designers. However by employing non-standard techniques on the test bench, looking inside working amplifier feedback loops, aspects can be explored and adjusted in the research lab to reach out for improved sound quality.

Microphony is the means by which acoustically derived vibration effects can enter an amplifier loop, can arise from quite subtle behaviours. Power transistors, bolted to the heat sink, tend not to be as inert as one would like. In general power transistors can produce noise because they are made of piezo electric silicon which is capable of producing sound (detectable, for example, by using a stethoscope on the heatsinks of an operating power amplifier). They are therefore reciprocally susceptible to vibration, for example from the loudspeaker driven soundfield 'singing along' with the music output. They also react to audio-related vibrations that reach the amplifier from supports.

The *DR* amplifier sound has changed due to other mechanical effects. The new *NA009* power transistor is 'quieter', thanks to removing the ferrous materials used in previous devices. The previous *NA007* power transistor had copper-clad steel-core legs, to match the expansion coefficients of the *TO3* metal transistor case with its glass insulator beads. (If it had pure copper legs the glass could crack and allow contamination of the silicon chip.) By changing the case material, the conductor material is now made non-ferrous and non-magnetic.

It is interesting to compare the mechanical noise emitted on the bench by the *007* and *009* transistors, when high currents are pulsed through them. Using a 5kHz signal into a dummy load, the noise from the earlier transistors can be observed, and the resulting vibration travels down the legs and along the PCB 'sound board', conducted to sensitive microphonic components such as capacitors. These pick up

the time-lagged and distorted vibrations and feed them back into the amplifier. Such subtle effects are invisible when employing sinewave distortion measurements.

As a transistor changes temperature, its characteristics alter dynamically, which is essentially like adding a noise signal, albeit a time-lagged one. The *009* power transistor has an aluminium nitride (AlN) insulator with ten times the thermal conductivity of traditional alumina, and almost one-tenth the capacitance of conventional pads. A superior nano-diamond-based gap-filling thermal paste helps keep the transistor die as cool as possible under dynamic conditions. The result is a transistor that operates with the maximum possible temperature stability and the lowest stray electronic coupling. Furthermore, the chassis and heatsink is necessarily connected to mains earth and is therefore a potential source of electronic noise. The minimal capacitance of the new output transistor arrangement reduces radio frequency noise injection back into the amplifier (as well as reducing the noise contribution from the amplifier back into the mains earth).

The new cleaner, lower impedance supply rails help reduce the already low crossover distortion. At the crossover point, small spikes of current are drawn which appear on the amplifier rails and are partly coupled into the gain path, which the revised lower impedance rails now helps to reduce.

These numerous improvements all help to suppress those inharmonic noises in an amplifier that are entirely invisible when measured normally with sine waves. The design objective is a cleaner sound with lower internal noise and higher clarity. Sells has noted that related improvements in quality might alternatively be found by improving the power supply rejection of the amplifier and by choosing lower microphony audio components. But he also pointed out that it would be significantly harder to maintain a musically exciting and involving sound quality if such a solution involves extra gain stages and more feedback to try to improve power supply rejection.

NAP300DR Sound Quality

FOLLOWING CHRIS BINNS' NAP300DR REVIEW IN VOL 9 NO4, MARTIN COLLOMS PROVIDES A SECOND SOUND QUALITY OPINION

Just before Naim's amazing *NAC S-1* and *NAP S-1 Statement* amplifiers left my premises, a revised version of the *NAP300* turned up, now with a *DR* suffix. Long term *NAP300* owner/reviewer Chris Binns reviewed the new *DR* version in our last issue, but as I've had recent experience of the musical capabilities of the Naim *Statements*, and also recently tried some impressive Constellation monoblocks, I'm in a good position to offer some timely supplementary observations on using a *300DR* in my reference system. In particular, even though it was at an early stage of running in, I was able to drive the *NAP300DR* from the *Statement* pre-amp, and also compare it directly with the *Statement* mono power amplifiers at twelve times the price. (Such opportunities are not to be missed.)

The *NAP300* is already very familiar to me, having reviewed it twice for *HIFICRITIC* over the years (*Vol1 No4; Vol7 No3*) and also recently adopted it as a medium power amplifier reference for longer term review comparisons. Brand new amplifiers can sound a little raw and may appear brighter, coarser, grainier and more two dimensional than when nearer to the end point of their running in. Despite a week of pre-delivery use, first impressions of the *300DR* were of a fast, upbeat quality, but one which was also somewhat disconcerting, as it sounded rather bright, forward and excitable.

I certainly liked the sense of speed but was rather concerned about the lightened timbre. By comparison, a well run in *NAP300* is perceptibly dark, mildly two dimensional but well focused. It is somehow old fashioned in tonal colour, yet continues to satisfy with very good detail and focus, plus excellent dynamics, bass definition and rhythm. If well driven and supported, it remains musically infectious and involving, punching well beyond its weight. While I considered that the *DR* version was more open, brighter, faster and clearer at this early stage, the obvious differences were also disconcerting. Surprisingly perhaps (given the large