Class “D” Power amplifiers using Hypex modules.

By Fabrizio Montanucci

Class D hasn’t been taken seriously by audiophiles so far, although a few manufacturers of indisputable pedigree (Jeff Rowland, of all) have started introducing them in rather ambitiously targeted products. However, truly innovative switching amplifiers with impeccable performance have been few and far between until recently (or still are).

Thanks to Audio Video Astigiano, these devices are now also available to the DIY market at a price that, given the result, is “competitive” to put it mildly.

The object of this review is a switching power amplifier, assembled by Audio Video Astigiano using modules by the dutch company Hypex, of which it is the exclusive distributor in Italy. The modules are constructed along lines similar to Icepower’s which we’ve seen a few times in the past. The modules are “mono blocks” largely constructed using surface-mounted parts and consist of a separate amplifier and power supply assemblies, the latter here being a traditional supply, not a switch-mode power supply. Such a design choice has been seen before, for instance in PA amplifiers by Crown, and is amply justified on the basis of reliability, efficiency and lack of radio interference.

There are three amplifier modules. The UcD180, good for 180W into 4 ohms, the UcD400 for 400W into 4 ohms and the UcD700 for… well you get the point.

Here combined with two power supply modules and respective toroidal transformers (conservatively rated to get the most out of the UcD modules) the system allows various combinations, according to one’s needs. This is precisely what AVA does, making available pre-assembled amplifiers from one to six channels of 90 to 350 watts in 8 ohms each. The model that we have tested is the largest of the two-channel models, a double mono amplifier of 2x350W using a pair of UcD700’s.

Description

The unit puts a fair amount of weight on the scale, largely due to the power toroids, but the volume and weight is comparable to a linear amplifier capable of a good 70 watts per channel. This should not surprise anyone. Switching technology has been doing such things ever since the late 60’s. Nevertheless one can’t help being amazed because the “dissipating components” really don’t dissipate and manage to get rid of all their heat via the chassis through the tiny “T” onto which they’re mounted. Even after driving the unit up to a total of 2 kilowatts, we didn’t notice any overheating. This demonstrates the low on-resistance of the switching devices. After all, when efficiency figures surpass 90%, a few percentage points really make the difference between one amp and another.

The component complement is of high quality, but it wouldn’t be fair to expect power resistors and ultrahigh-precision resistors like on Krell amps, or gold printed face plates, but what matters is that everything is properly dimensioned.

The assembly is clean and rational, worthy of an industrial product.

On the back panel we find a pair of the german WBT terminals, considered a “must” on any self-respecting product, as well as two balanced inputs mounted in precisely drilled holes.
The circuit structure is such that it can also be driven from an unbalanced source using an unbalanced-to-balanced adapter like the one that came with our unit.

Technology
The technical content constitutes the real added value, as reflected in performance that we’ve never before seen in any switching amplifier, certainly not at this power level.
The circuit structure is that shown in fig. 1, which will arguably leave some perplexed: a “normal” amplifier with a feedback loop closing after a second order filter. At first sight one would reason “So how does it work? The asymptotic phase shift is 180 degrees: if the loop gain is high enough and the feedback path has some phase shift of its own, a circuit like this must oscillate”. Precisely that is the goal. That is, not a runaway condition in which an amplifier would oscillate at a few tens of MHz and self-destruct in a fraction of a second, but a well calculated and controlled self-oscillation. The explanation is shown in the graph of figure 2: the amplifier self-oscillates at the frequency where the global phase shift becomes 180 degrees. This is largely determined by the output filter but also (in a strategic way) by the propagation delay (a few tens of nanoseconds) and the phase lead of the feedback network. The whole is calculated such as to reach 180 degrees around 400kHz i.e. ten times the intended bandwidth. This frequency is fairly high but quite practical to achieve using today’s MOSFETs that can switch in a hundredth of this period.
The self-oscillation is highly independent of the load impedance. Variations of the load impedance change the output filter’s phase shift by only a few degrees in the frequency range where its phase shift is 180 degrees. This minimises drastically the first form of load-dependence of a class D amplifier’s performance. In fact, all that happens when the load is changed from 16 to 2 ohms is that the switching frequency rises from 410 to 434kHz, with a negligible change in total performance. Clearly the self-oscillation also produces the maximum possible modulation of the switching signal. When the input signal is zero, the output signal is zero on average, and the switching signal is reduced by about 40dB by the output filter, and is visible as a small quasi-sinewave. When this signal is returned to the input, we can view it as substitute for the triangular carrier that in archetypical class D amplifiers is generated externally and summed with the audio. Here it is generated internally, which is a good thing because system linearity is now no longer linked to the intrinsic linearity of the triangle wave. Instead, negative feedback is used to improve linearity in the same way as happens in conventional linear power amplifiers.
Like in other class D amplifiers, the audio signal is modulated on the timing of the transitions of the 400kHz signal, creating an offset that is integrated by the output filter and appears as an audio-band signal. Apart from that, note that the feedback loop is closed after the output filter. This renders the latter’s influence on frequency response nearly nonexistent, since frequency response is determined only by the feedback loop. It is designed to produce a two-pole function right in the middle between the time-perfect Bessel (that starts rolling off early) and the amplitude-linear Butterworth (but that has a much less damped impulse response), that has a published corner frequency response of 30kHz but that we found was noticeably higher.

This technique is called UcD (Universal class D amplifier) and the genius who had the idea is Bruno Putzeys, at the time chief engineer class D audio at Philips Applied Technologies that holds the patent (having used it only marginally in its own products) and has licensed the dutch company Hypex to manufacture amplifiers using this technology. Putzeys is now working for the very same Hypex as chief engineer R&D. The author, hoping to have correctly interpreted the available documentation (generous on various collateral engineering questions, more reticent in other respects), with the laboratory tests made on directly accessible test points, has no problems to qualify the solution described above as among the 4-5 most interesting and effective ones in the history of all amplification in the last quarter century.

Conclusion

The probability of an audiophile skeptic changing their opinion towards the "cold classes" must be huge after hearing amplifiers based on the UcD technology. To date, we've never found any behave more similarly like an optimal linear power amp.

Box

*Load limit characteristic
*Power/distortion behaviour (8 ohms/1kHz)
*Frequency/distortion behaviour (8 ohms)
*Frequency reponse (2.83V in 2/4/8/16 ohms)
*Damping Factor in 8 ohms: 501 at 100Hz, 501 at 1kHz, 660 at 10kHz.
*Input: Impedance: 100kOhms/170pF. Sensitivity: 2.23V for 250W into 8 ohms. Input-referred "A" weighted noise level: 2.5uV (unbalanced input terminated with 600 ohms). "A" weighted SNR: 119.0dB (600 ohms input termination, referred to nominal output).
*Tritim in continuous regime: Inductive load, 8ohms, +60º. Capacitive load, 8ohms, -60º. *Tritim in burst regime: Capacitive load 8ohms, -60º

The very first impression on the test bench was hardly positive: half a volt of residual fixed at 400kHz, and apparently perfectly sinusoidal at that. Then one remembers that the handful of "digital" amplifiers tested over the last 10 years nearly all had this characteristic. After all, it's not problematic in itself (this kind of signal will not generate more than a few milliwatts of dissipation in any tweeter) and has little to do with the concept of the "ideal" amplifier, be they linear or switching.
Then I went on to measure frequency response, and that's where the real surprise lay. Although in the past few years we've already seen at least two car amplifiers with similar behaviour, these modules are almost totally free from the problem of load-dependence. In fact, the dependence of the frequency response to the load is much lower than in the majority of conventional power amps. As promised by the theory (in fact, slightly better than what is published in the documentation) the response is flat from the extreme LF up to 29dB with only 1dB of loss, reaches -3dB at 45kHz and continues asymptotically at 12dB/octave beyond that. Given that the output impedance is lower than 15mOhms at all frequencies, the curves measured at 2 to 16 ohms are nearly superimposible, something that's never before happened in an amplifier of this kind in the hi-fi sector. Another weak point in class D power amps, although some do better than others, is current capability, specifically in highly reactive loads and by interaction with the reactance of the output filter. None of the sort happens with the AVA prototype based on Hypex modules. It delivers very high

power levels to any load without breaking a sweat and without appreciable distortion. The load limit curves are nothing short of impressive, because even though at 2.5/3 ohms the supply will current-limit, the total amount of power is really very high. In 2.3 ohms this prototype is capable of putting out 850+850 watts at clip, without the box walls (onto which the modules are bolted) becoming too hot to touch and without the electromechanic “squeal” that linear power amps invariably give off. Highly interesting too are parameters such as distortion versus output power (note that saturation is a bit less abrupt than in high-feedback linear amplifiers) and distortion in function of frequency where we see an increase also found in other class D amps, but much less than average and without becoming excessive.

Captions

The Hypex UcD700, nominally 700W in 4 ohms. In the AVA power amplifiers the supplies are slightly oversized to improve further the reliability.

The insides are well-engineered and is at once robust and high-quality in component terms. Especially surprising is thermal efficiency. A linear power amp with a similar power dissipation capability would already run into problems at 40 to 50 watts per channel.

Figure 2: Phase shift of the output signal and of the feedback signal and how this comes about. The amplifier switches at the frequency where the phase of the feedback signal reaches 180 degrees, which happens just over 400kHz.

Figure 3: Simplified electrical diagram of the UcD power amplifier. Note the double execution of the feedback loop, of which the noninverting side, to quote the designer, “is set up to sense the ground at the speaker terminal”.

The output connectors are the classic and highly desirable WBT’s. The inputs are balanced but are entirely compatible with unbalanced signals.