TPA3255 – Some Insights You Will Not Find In AppNotes

Introduction

About 2017 Dr Mord and me evaluated TPA3255 and did some measurements with the TI EVM. Performance was promising and just for fun we decided to go beyond TIs solution and push this chip to its limits, surpassing the excellent technical data of the vendors reference design.

Beginning with distortion it turned out that SE configuration produces one order of magnitude higher THD than BTL. This is no real surprise and documented in the data sheet as well.
Thus SE configuration was no longer considered.

Full bridge in parallel mode (PBTL) offers lowest on resistance hence lowest THD and best efficiency, enabling the smallest heatsink. As there is only one feedback loop operating in PBTL loop, achieving lowest THD requires direct parallelling of the bridge outputs. This is in contrast to the feature selecting between stereo BTL and mone PBTL where paralleling is done behind the output LC filter.

Consequently we have to abandon this feature and the configuration boils down to a PBTL mono-block using an entire TPA3255/channel, driving one pair of output LC-filters. This is the setup with lowest THD and it is not available with the TI-EVM.

Comparision ot THD:

Some remarks on THD measurements: These were carried out with the emu-tracker USB soundcard and ARTA. Compared to professional equipment these are a bit noisy so THD+N measurements deliver poor results. Instead the measured values THD and of the harmonics H1, H2 and H3 deliver a much better base for comparision.

Plot THD/power TI & Plot THD/V steps

Post-Filter Feedback Part 1

Post-filter feedback is accomplished by closing the feedback loop at the LC-filter output. Theoretically distortions introduced by non-linearities of the output inductors as well as the output impedance (damping factor) can be signifanctly reduced.
Practically all these TI class-d-amps use pre-filter feedback. I assume the main reason is simplicity, the internal feedback loop

is fixed and no customization to different filter parameters is necessary. Even without PFFB THD is more than acceptable and output impedance is mainly given by the LC-filter impedance (with Rdson of the power-FETs in series).

Nonetheless there have been efforts to implement some post-filter feedback. To improve linearity you need some extra loop gain that you get by reducing the closed loop gain of your amp. This worked fine for instance with TPA3118 programming its gain to the max value of 36dB and then using 16dB feedback with a resulting gain of 20dB. But with a fixed gain of 21.5dB typical for TPA3255 there is not much headroom for such reduction. Summarizing the appnote SLAA702 reducing the gain to 13.8dB yields a neg feedback of 7.7dB and the measured improvements of THD and noise have been in the ballpark of 6dB. And this requires additional 7.7dB input level to be delivered by the driving op-amps – at a very low distortion of course. So I really doubt that gaining 6dB lower THD and noise voltage this way are worth the effort.

Post-Filter Feedback Part 2

One drawback of pre-filter feedback is the lack of control over the output LC-filter self-resonance. With L=7uH and C=1uF the resonant frequency results in 60kHz, for instance. As a consequence the bridge outputs are loaded with a series resonant tank. Its impedance drops close to zero at 60kHz, acting like an output short circuit while the output voltage increases beyond supply voltage, limited only by the breakdown voltage of the tank capacitors. Simultaneously inductor current may rise to insane levels where the core saturates. In that case current rises sharply and the overcurrent-protection maybe too slow to protect the chip from burning.

Surprisingly you will not find much hints to this resonant phenomen in the data sheets. The output LC-filter is calculated in the appnotes for critical dampening and for any speaker impedance acting as dampening resistor a specific filter is proposed. So everything is fine, as long as the speaker of appropriate impedance is present? No, not all all, because an 8 Ohm speaker is NOT equivalent to an 8 Ohm dampening resistor. To be effective, a pure resistive impedance is required, i.e. 8 Ohms with zero phase shift at 60kHz in this case. Obviously this is far beyond the impedance of real life speakers and it is much more realistic to *consider the output unloaded at frequencies above 20kHz – with the critical implications mentioned above.*

This worst case scenario appears to be desastrous. But does it occur in reality?

The resonant tank needs some excitation to swing, otherwise nothing happens at all. That requires some significant input signal in the resonant frequency region. Most audio sources nowadays originate from digital sources and have passed some sharp lowpass-filters close to 20kHz. If you test your amp with a soundcard sampling at 44.1kHz no harm is to be expected. Obviously in 99.999% of the time nothing will happen at all. But sometimes I do test my amps with sine waves beyond 20 kHz and with quare waves providing risetimes <1us – just because I can!

*A close look at the frequency transfer characteristic of the undamped LC filter reveals a rising level above 20kHz ending in the resonant peak around 60kHz. It can be measured easyly with a sharp square input signal revealing more or less slowly decaying ringing after each transition. This resonant peak is equivalent to a peak of amplifier gain and gave me the idea for a special type of post-filter feedback: A small capacitor tied from the output to the input will be quite effective around the resonant peak, but do very little at distant frequencies – the **diffentiating PFFB** is born. Experimental results of square response ended with a perfect square wave without overshoot.*

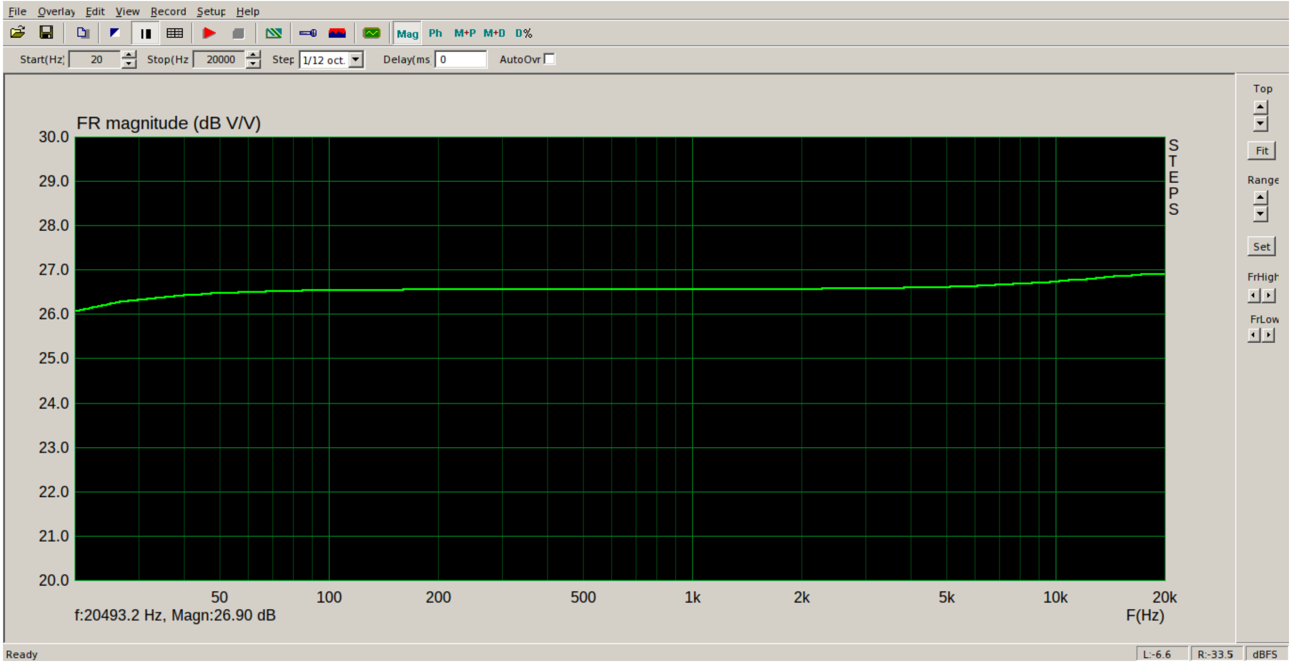
*With the resonant peak vanishing the LC-circuit is obviously perfectly dampened – without the need of **lossy snubbers!***

*As a consequence there is **no peaking of output impedance** as well, and,*

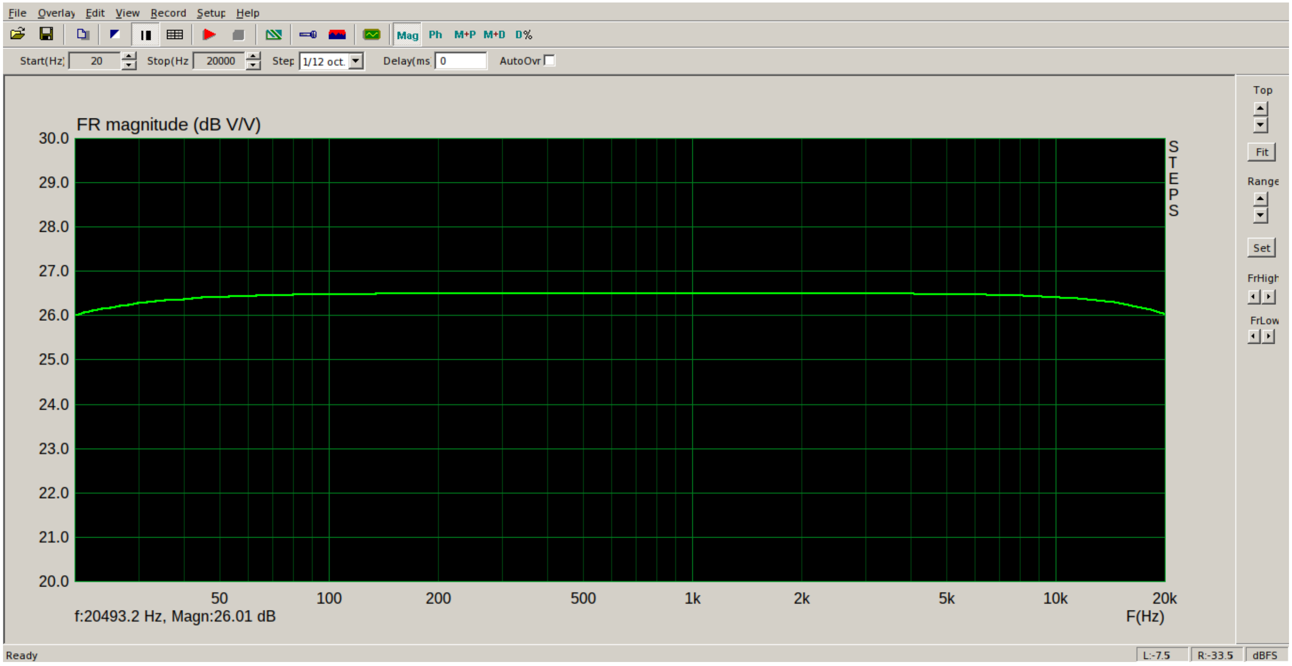
best of all, the difference between loading with a dummy resistor and no load at all is tiny.

Open circuit problem solved!

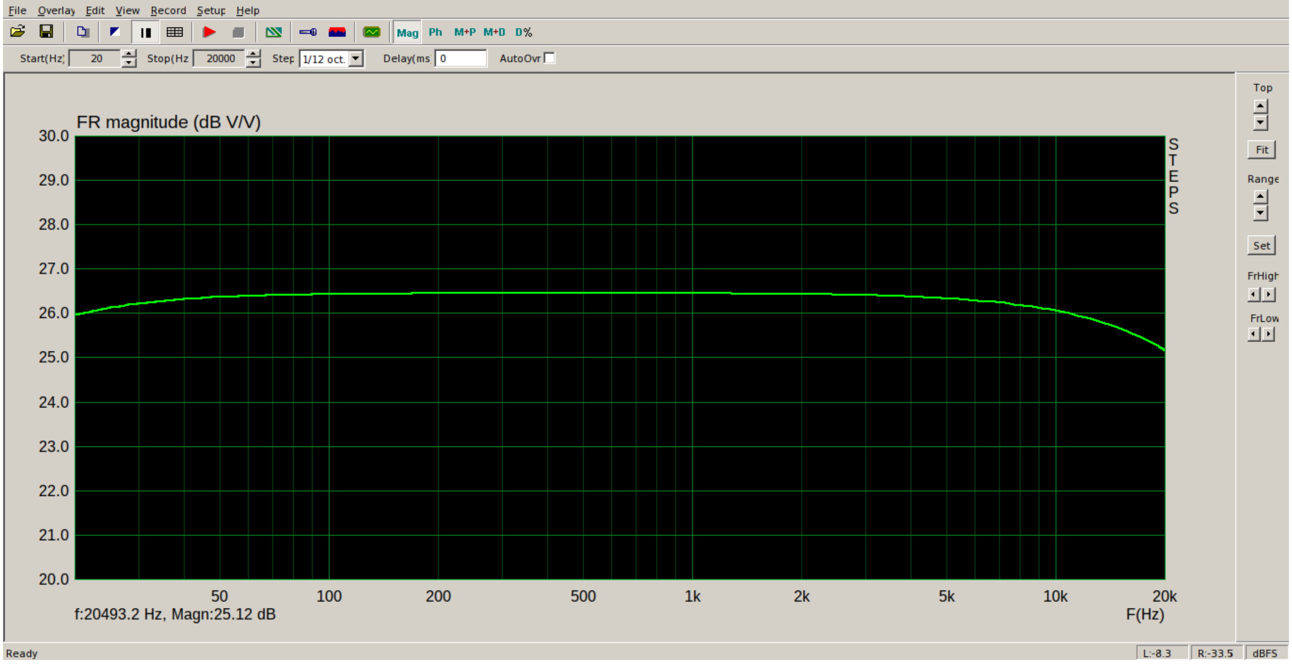
With the differentiating postfilter feedback applied, the frequency response of the PBTL-module has been measured:



Plot1: Frequency response without load



Plot2: Frequency response 10R load



Plot3: Frequency response 5R load

It can be seen that frequency response is nearly independant of speaker impedance. As most real loudspeaker incorporate some significant inductance, thus the no load plot will come closest to reality.