

Specifying objective audio amplifier performance.

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In a world dominated by fast paced technological advances, it is both surprising and puzzling audio reproduction hosts endless debate among proponents of widely diverse solutions. Militants non only camp on opposing reference topologies like high gain high global feedback against slight or no global feedback at all. Rising from its ashes, vacuum tube technology stands forward as endowed with special attributes lacking in solid state, pushed not only by fashionable allures like hints to old wines or Stradivarius instruments. True believers claim on sound technical basis for their preference, though conclusive evidence is mostly lacking.

Compounding the scenario complexity, the listening experience is at large an emotional one, while at the same time our detailed knowledge of the psychoacoustics phenomena - while advanced - is still a work in progress regularly bringing new and sometimes surprising facts.

Like other endeavors such as practicing sports or painting, listening is a skill benefiting both from innate gifts and from an educational process, only the difference among unskilled beginners and pros does not have the degree of self evidence easily distinguishable for the aforementioned examples.

It is hardly surprising that self appointed referents claiming exceptional listening skills, exploit this blurred gap to point to this or that technology or product as the good or the ugly. An unwary prospect lacking real skills may in turn be led to believe himself capable anyway of perceiving differences and heed on advice. Of course this is fertile ground for commercial ventures of all types.

I may dare advance the situation is not bound to settle one way or another. Diversity is the name of the game in nature and in the human condition, and probably no technology will fit every taste. Yet an attempt to wave a path through the maze has merits, if for no other reason but for an enjoyable exchange among smart and well meant enthusiasts.

We may first acknowledge reproduction accuracy is not – declared or not – the holy grail for everyone. Far too many people love grossly distorted reproduction be it the result of nonlinear even harmonic production or simply frequency response deviations suiting personal tastes. There is nothing wrong with that, but being this type of enjoyment the result of particular esthetics, there is no hope for the time being of achieving a taxonomy capable to translate in objective performance specifications, at least until we know a bit more about the auditory system in connection with cortical sensory reward mechanisms.

Less slippery is the search for means to attain reproduction accuracy, knowing in advance both absolute accomplishment is not practical, and even if attained does not guarantee widespread acceptance for the reasons mentioned earlier. Yet it is from an engineering viewpoint, comfortably closer to the kind of measurable stuff, suitable for peer review and repeatability.

Amplifier specifications for accurate reproduction.

I will propose two unoriginal and orthogonal specifications which may look at first sight deceptively basic and insufficient for many, yet I am convinced are adequate if properly understood and applied. Before the flak starts rising, I encourage would be gunners to take a deep breath, think twice and read carefully.

1. Flat frequency response and null or linear phase response at all amplitude and load conditions from 20 to 20 KHz.
2. Harmonic distortion below 0.01% at all amplitude and load conditions from 20 to 20 KHz.

Both requirements can be fairly well met by selected good commercially available gear, or by design with moderate effort and regular components not necessarily resorting to exotic or ridiculously expensive means.

No particular technology is implied either, or design topology. Whatever the means, the end result will be indistinguishable except the amount of effort and expense will be different depending on the chosen path.

1. Frequency response.

Probably nobody will challenge the requirement for flat frequency response and null or linear phase response within the audio range, but eventually to deem it insufficient. Surprisingly this innocent looking specification is almost never met, while proposed extensions are in fact completely included in the basic statement.

Null phase response implies non-delaying active networks. Linear phase response implies no frequency dependent transfer functions at least in a linear approximation. Propagation delays can safely be considered null for the range of phenomena of interest in audio reproduction, and it is not difficult to build amplifiers exhibiting essentially null phase response within the audio range (cutoff frequencies in the MHz range). Unfortunately there is no such thing as a flat full range driver capable of matching what the amplifier can provide, forcing in mainstream topologies to resort to two or more way speaker systems.

Crossover networks, be passive or reactive component based active ones, do not provide linear phase response, worst of all, the deviations from linearity fall directly within the reproduction range. Two way systems are typically crossed anywhere from less than 2 KHz to 5 KHz, squarely in the region where the auditory system is more finely tuned as a result of evolutionary pressures related with survival and social communications. Systems with more numerous reproduction ranges are equally affected, though may benefit from shifting the offending crossover regions to less sensitive areas. This can in theory be mitigated with FIR based active crossover networks featuring precisely tailored roll off slopes and linear phase response, but then it must be reckoned the drivers themselves impose reactive network originated nonlinear phase responses of their own, partially negating what DSP technology provides. May be future designs can incorporate phase error correcting means by the way of digital signal processing, thus at last fully achieving the desired specification.

It has been argued for years that phase accuracy is not relevant for high performance audio reproduction, on the ground the ear is insensitive to absolute phase relationships. While this is true in an absolute sense for steady state sinusoidal stimuli, it must be reckoned the cochlea is an active non linear device where wave shape distortion arising from flat frequency response in amplitude but nonlinear phase response may indeed elicit different perceptual responses. Nowadays we acknowledge faithful waveform reproduction is important mainly for the sake of the soundstage and spatial accuracy purposes.

Supporters of non global feedback topologies will consider the first specification as insufficient in the sense systems designed on opposite configuration extremes may measure equally yet perform very differently under transient conditions. Alternate complementary specifications have been proposed under different labels such as TIM (transient Intermodulation distortion), "first cycle distortion" etc. The heuristic reasoning goes frequently along the lines that in a system heavily dependent of feedback to achieve linear amplitude response, fast changing signals momentarily disrupt the gain chain perturbing simultaneous low level signals until feedback finally completes the round trip to correct.

While reasonable in principle, this has been conclusively proved wrong, the main argument being embodied in the strict adherence to the first specification. Program source material is of necessity bandlimited, a fact that implies the system cannot expect to be exposed to actual transient spans where the feedback delay cannot cope. Flat frequency response and null or linear phase response under all amplitude and load conditions within the audio band, guarantees that no possible stimuli can elicit an unwanted perturbation also falling within the audio band and thus configuring and accuracy violation. This is not a subject of debate, this is the same objective rational stuff of which science is made of.

That solid state amplifiers based on the canonical Operational Amplifier topology have exhibited questionable performance in some cases, can simply be traced to different reasons, ranging from outright lousy designs to insufficient gain bandwidth product, to frequency and load dependent

weaknesses and so forth. A good global feedback design meeting the frequency response specification as stated, will pass any possible audio signal unscathed as attested by well understood signal processing theory, the same grounds on what TV, cellular phones or deep space probes rely to exist.

2. Linearity

It may be argued – admittedly with good reason – that any proposed number like 0.01% THD is somewhat arbitrary, being an order of magnitude lower or higher more or less equally justifiable depending on the starting assumptions. This I will not discuss either, being the 0.01% figure a representative compromise of what is a threshold for the vast majority of listeners, and at the same time fairly attainable by good design practices and regular components.

THD is an umbrella figure easy to measure and to understand, though the actual composition of distortion products adding up to the bundled result may be very different. But first and foremost, THD is a measure of system linearity, implying that a system featuring a very low figure – at all amplitude levels and load conditions within the audio band – is inherently linear and consequently free from other distortion modes like intermodulation, and where the actual spectral composition of the residual products is largely irrelevant.

This proposition may also raise eyebrows if not outright rage, but let me again stress I am placing a fairly low threshold for acceptance. Were THD specified for example at 0.1% - a quite common performance level – then I should be casting a wary eye on IM and spectral composition, for at this performance level small things begin to matter. The beauty of the 0.01% figure lies on the fact that there is no excuse for not being achieved, while at the same time it guarantees a level of linearity that safely breezes over other performance tests. Again, for this to be true the specification must be met under all possible combinations of level, frequency and load, something that almost never is demonstrated in mainstream products.

Interestingly, chip amplifiers are specified to a level of detail not found in end products but a few exceptions, and have captured the attention of high end discriminating listeners by virtue of their performance. Again, they are almost invariably OpAmp topologies, implying heavy negative global feedback wideband designs. This should not be surprising, they are the result of massive multimillion dollar development efforts, and feature a level of complexity seldom reproduced by discrete designs of whichever topology. Yet, for all their impressive achievements, some key weaknesses stand as insurmountable barriers for perfection, among them the inherent instantaneous thermal feedback from power output stages into low level front end devices, and the lack of massive current drive capability for particularly nasty combinations of frequency and load.

Probably the best of both worlds at least from my point of view is a combination of high performance integrated low level processing, with discrete high power thermally remote output devices. Wideband extremely low distortion audio OpAmps are widely available, as well as wideband powerful output discrete transistors. Marrying both successfully with different topologies has been proven possible and is in my humble opinion something to be strongly recommended.

Exploiting digital processing embedded means to address frequency – phase issues including the speakers themselves, is probably a paradigm to consider seriously.

And then there is the switch mode or class D technology, at this time cautiously wearing long trousers, but there is a long way to go for sure.

Let me finally stress all this discussion makes sense on the assumption reproduction accuracy is a target to be addressed, not implying with this a definite objective suitable of widespread acceptance, but only the kind of ground on which rational, reproducible and peer reviewed knowledge can be elaborated.

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