Tone burst response of amplifiers to determine some properties of their dynamic behaviour

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A major issue with amplifiers is their difference in perceived quality, which often does not relate to the specifications. The question is why? One major aspect, in our view, is the *dynamic response* of an amplifier. When measurements are made to obtain the specifications, it is common to use signals with a constant amplitude (e.g. to measure the frequency response or the distortion figures) or with a gradual change of the amplitude (e.g. to determine the distortion as a function of the output power). However, music is highly dynamic, meaning that the signal strength can vary rapidly. How an amplifier reacts to such rapid changes is hardly, if ever, subject of analysis, but it could be of prime importance for the perceived quality. Note that there is no generally accepted specification for this aspect, even though it is trivial that the behaviour under dynamic conditions is of crucial importance for the perceived sound, and thus the quality, of the amplifier.

The above mentioned neglect is probably caused by the common misunderstanding that the response of an amplifier is fully determined by its frequency response and its distortion figure. This, however, is incorrect, as has been shown in ref. 1. This would only be the case when the amplifier is a linear and time-independent system. It is neither. So it is necessary to study the behaviour of amplifiers under more realistic conditions. An option for this is to use tone-burst signals as these include a rapid change at the beginning and at the end of the tone-burst. Although it is, of course, still quite far from the complexity of music, it can reveal undesirable properties of amplifiers.

To that end, two high-quality amplifiers with clear differences in their perceived sound, have been tested with tone-bursts. In this report, only the results at 30 Hz will be reported and discussed, as at these low frequencies the issues show more clearly. The first amplifier will be referred to as Amplifier “X”, the second one is the amplifier of “Temporal Coherence”. To avoid discussions on the influences of the properties of the load, 5.6 Ω resistors have been used as all amplifiers are designed to operate on such loads, which have no phase angle between voltage and current.

It would be logical that an amplifier has the same temporal response at any amplitude within its “linear” range. However, in reality this does not always happen. A major cause of the changes with amplitude is the power supply: when the amplifier has to deliver power, the (average) voltage of an unregulated power supply will diminish *) and this will cause shifts in the operating points of the different amplification stages and thus of their properties. A regulated power supply does not have this problem, so it is expected that amplifiers with an unregulated power supply may show changes in the dynamic response with amplitude. But there might also be other causes (e.g. non-linearities in the amplification stages, which tend to increase with signal strength, see ref. 1), so it cannot be guaranteed that there is a clear distinction between amplifiers with or without regulated power supplies. However, a regulated power supply will be required, albeit insufficient, to create an amplitude-independent response.

*) Another common misunderstanding is that this is not the case for class “A” amplifiers, as the power, taken from the transformer, is constant. However, this is true for its *average* value, but when low frequencies have to be processed, low meaning below the repetition frequency of the rectifier = 100 Hz in Europe, the power supply voltage depends on the output power delivered.

When the temporal response is not independent of the amplitude of the tone-burst, there is an (albeit unknown) mechanism acting and thus it will be hard to predict how this will turn out with music. The amplifiers were tested with a “large” and a “small” signal. The “large” signal was still far within the “linear” range of the amplifiers, but sufficiently large to load the power supply notably. The temporal responses are influenced by the AC coupling in the amplification chain, but this can be calculated with common techniques, so the effect can be predicted and thus compared with the measured response. Note that the influence of AC coupling is not regarded as an artefact, whereas the dependence on amplitude is (because of its non-linear properties).

The results for Amplifier “X” are presented in figs. 1 – 3. It clearly shows an amplitude-dependent effect. The results for the “Temporal Coherence” amplifier are shown in figs. 4 – 6, in fig. 4, also the theoretical influence of the AC coupling is shown (lower trace). Note that in fig. 5, two graphs are shown simultaneously, clearly illustrating that the response of the “Temporal Coherence” amplifiers is independent of the signal strength. In fig. 6, the theoretical response, due to the AC coupling is also shown. So it can be concluded that the deviations between the input and reproduced tone-bursts are solely caused by the AC coupling, the temporal responses are thus close to ideal and independent of signal strength.

The causes of the amplitude-dependence of Amplifier “X” are unknown to the author. The power supply could be an important factor, but this could not be identified (no access to the interior of the amplifier). But the perceived quality of Amplifier “X” is unambiguously determined to be lower than that of the “Temporal Coherence” amplifier, although brand “X” is well-known and well-respected in the high-end community. The design of the “Temporal Coherence” amplifier does include regulated power supplies and the reduction of the non-linearities of the individual amplification stages as much as possible (ref. 1). These measures pay off in the properties of the tone-burst responses and the perceived quality of the amplifier.

Tone-bursts can be helpful to get a better understanding of the dynamic response of an amplifier and although a tone-burst is still very different from music, it still can reveal undesirable properties of amplifiers, which are difficult, if not impossible, to determine from the common measurements. Tone-burst responses should therefore become a part of the standard specifications of amplifiers. As a side remark, it can be noticed that tone-burst responses of loudspeakers could also be very helpful to determine their temporal properties and such results should be published with the documentation and by reviewers. The presentation of ref. 2 clearly illustrates this.

References

1. Dr. Hans R.E. van Maanen, “ Is feedback the miracle cure for high-end audio?, www.temporalcoherence.nl

2. Mike Turner, “Perception of temporal response and resolution in the time domain”, Workshop & Panel Discussion, 142nd AES Convention, Berlin, Germany 20th May 2017, www.temporalcoherence.nl

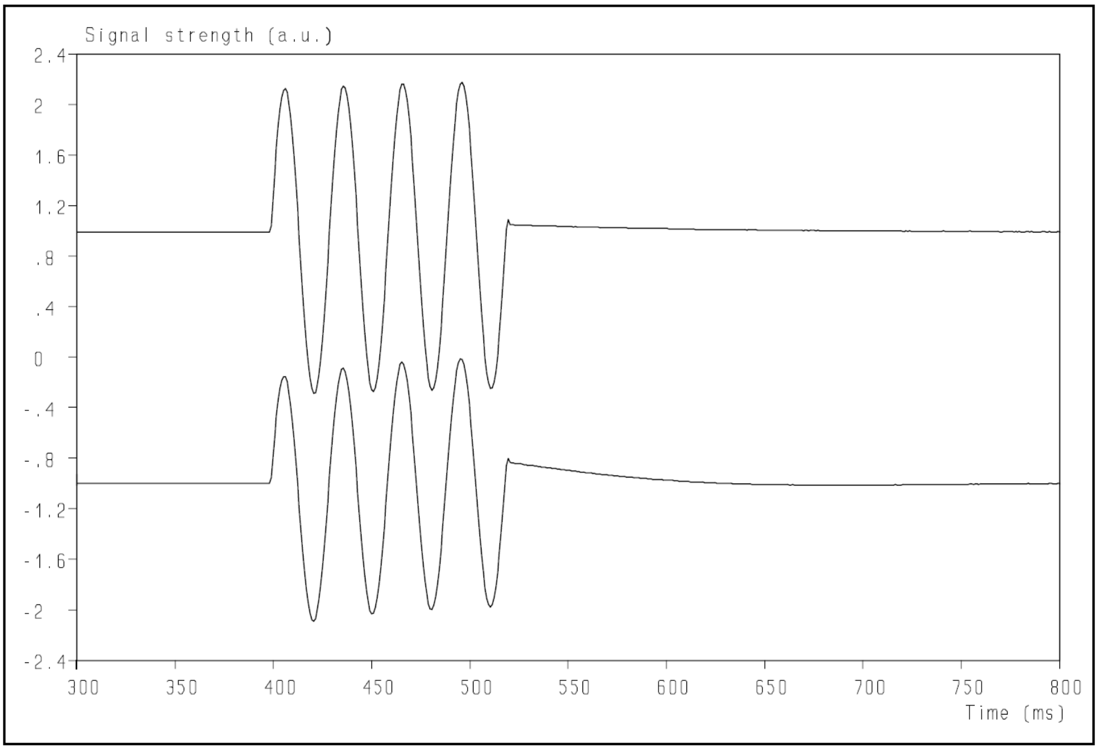

Figure 1: *Response of Amplifier "X" to a tone-burst of 30 Hz with a relatively "large" amplitude, but still far within its power range.*

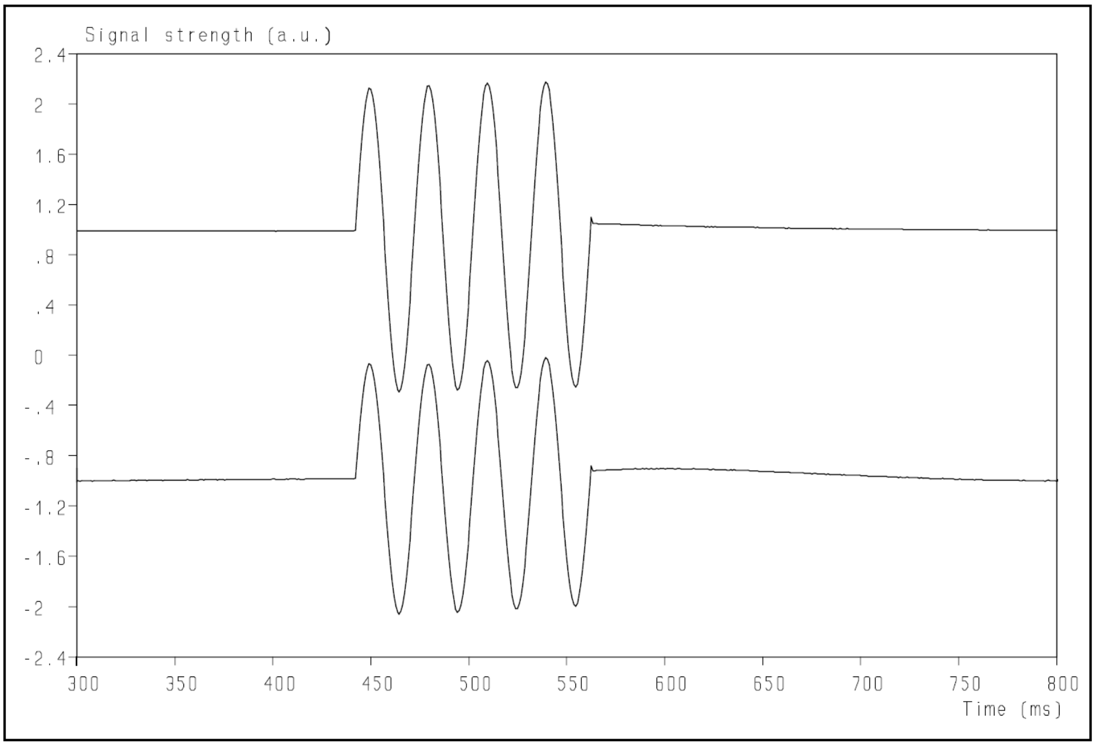

Figure 2: *Response of Amplifier "X" to a tone-burst of 30 Hz with a relatively "small" amplitude, compare with fig. 1.*

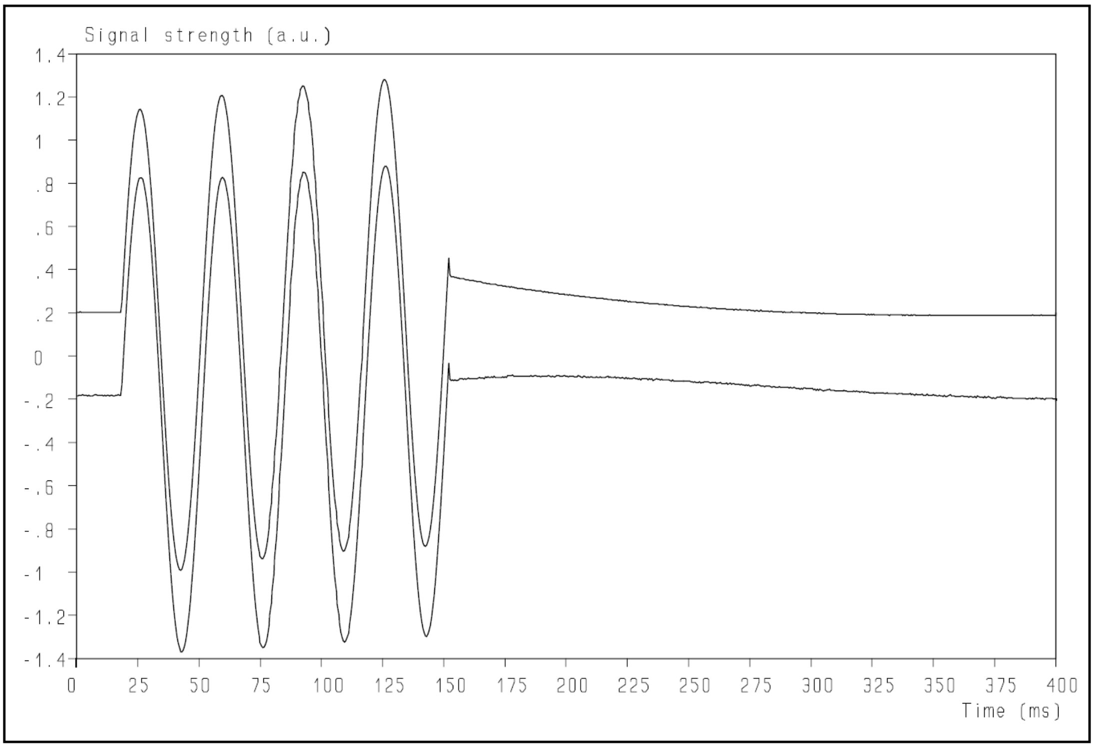

Figure 3: *Response of Amplifier "X" to a tone-burst of 30 Hz with a relatively "large" amplitude (upper trace) and with a relatively "small" amplitude (lower trace). Combination of figs. 1 and 2, amplitudes of tone-burst parts scaled for ease of comparison.*

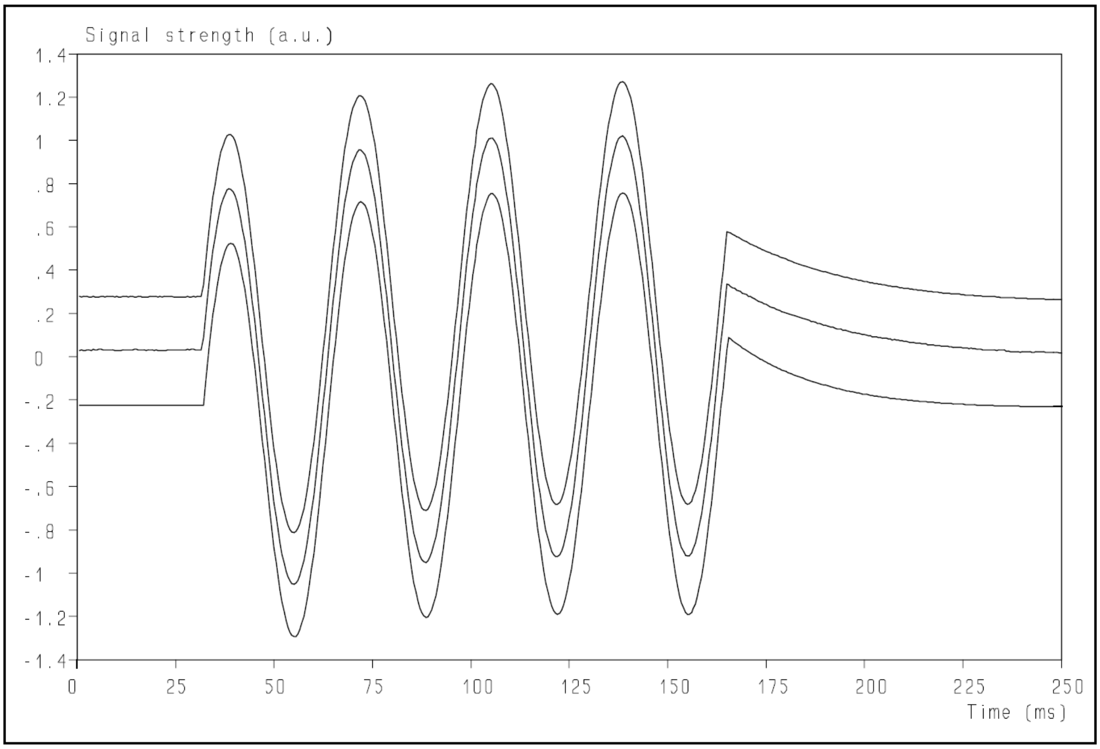

Figure 4: *Response of Amplifier from "Temporal Coherence" to a tone-burst of 30 Hz with a relatively "large" amplitude (upper trace) and with a relatively "small" amplitude (middle trace). Lower trace is calculated response when the AC coupling is approximated by two first-order high pass sections of 5 and 4.8 Hz respectively. Tone-burst sections are scaled for ease of comparison.*

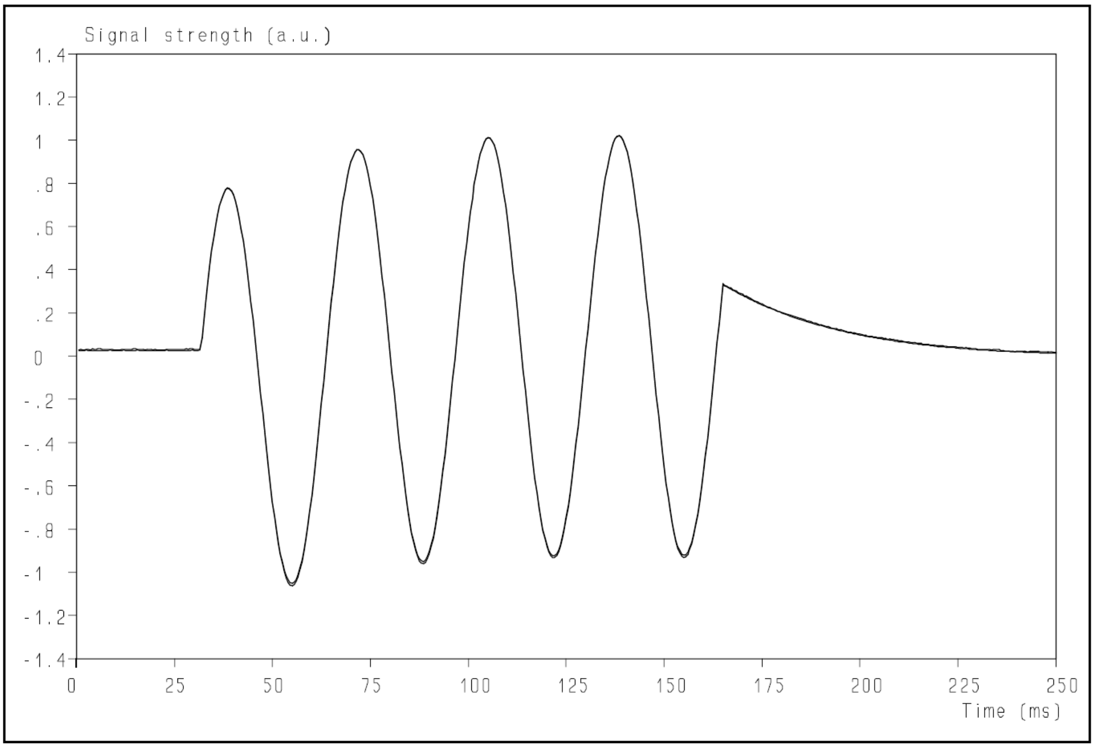

Figure 5: *Responses of Amplifier from "Temporal Coherence" to a tone-burst of 30 Hz with a relatively "large" amplitude and with a relatively "small" amplitude (upper and middle traces of fig. 4). Responses are scaled for ease of comparison and are virtually indistinguishable.*

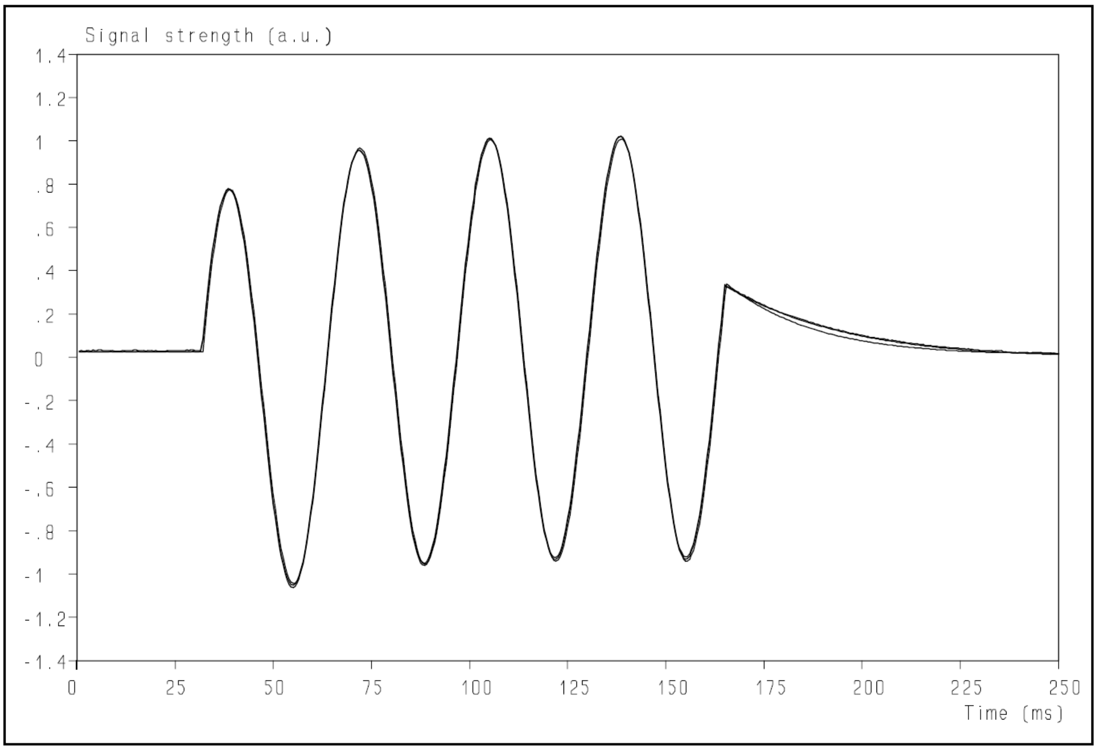

Figure 6: *Responses of Amplifier from "Temporal Coherence" to a tone-burst of 30 Hz with a relatively "large" amplitude, with a relatively "small" amplitude and the calculated response with AC coupling. Responses are scaled for ease of comparison and are virtually indistinguishable. Compare with figs. 4 and 5.*