Perfecting "Punch" In Your Loudspeakers

Short Literature Study By Bohdan Raczynski, November 2015

We all seem to know when to describe music as 'punchy' when we hear it. This term is quite common, and often used by audio professionals when describing a particular perceptual sensation found in produced music or sound tracks, which we call 'punch'. The term is entirely subjective, in terms of both its meaning and subsequent auditory effect on the listener. Different music may have different level of punch attribute.

'Punch' and Science

A "technical" description of music in general can be found in several sources. For instance. Fenton at el. [6], describe music as:

"…a collection of complex tones, with complex tone consisting of a number of differing harmonic components with varying magnitudes and phases. Each tone component consists of both steady state and transient parts. Previous work has identified that the transient portion of a complex tone contains a great deal of information with respect to perceptual attributes of the source. The transient part of the signal can be loosely defined as the initial time interval in which the signal is evolving into its steady state….."

And further "….Modification of the transient portion of a sound source has been shown to modify the perception of the source by the listener…"

Audio workers involved in researching the "punch", apply methodology that allows them to separate complex musical signal into its components: (1) transient, (2) steady state and (3) residual components. In the next step, the transient portion of the investigated signal is analyzed independently of other components. By doing the research this way, low level parameters can be extracted and perceptual modeling can be solely applied to the transient component of the investigated signal.

So, transient analysis is the fundamental tool of evaluating an analyzing the "punch".

The "punch" is very much a parameter related to dynamics of the reproduced sound. Punch is often looked at as a short period of significant change in power in the analyzed sound. **Essentially, a music piece, that does not possess any transient information cannot possess punch**. Therefore, it follows, that punch is related to transient change and energy density at a particular moment in time. Since the analysis of the sound sample takes place in several frequency bands simultaneously, one can also add, that dynamic change in the frequency bands contribute to the overall perception of punch.

In addition, given the transient information is inherently related to defined moments of change in a piece of music, this information is paramount in determining a punch measure.

Fenton et al. [7] comment "…Almost all genres of music have significant transient content throughout as a result of differing tone onsets. Onsets can be considered to have differing onset rates, e.g. drums would result in fast onset times whilst a bowed instrument such as a violin may have slower onset times. Despite having a slow onset, it can still be considered as having a transient characteristic initially. Modification of the transient portion of a sound source has been shown to modify the perception of the source by the listener…."

Fenton et al. [6] comment "…If a mix engineer needs to achieve a level of punch required by an artist or client, can this be done easily without a known reference? A mastering engineer may want to achieve an equal level of perceived punch between two songs without affecting any other perceptual attributes and creating additional nuisance artefacts or annoyance…."

The above is indeed quite commonly seen in action movies. The director requires certain immersive audio impact to be synchronized with the fast, catastrophic events happening on the screen, consequently, the level of punch may go up.

Interestingly, the punch can be "manipulated". Several researchers proposed methods of extracting transient information and enhancing it or reducing it, thus affecting the perception of punch intensity and modifying the perception of the source by the listener.

Goodwin et al. [2] describe "punch" as a legitimate perceptual attribute. They state that "…a punch attribute might be established in terms of a range of sensitivity parameters for a transient detector and a range of intensity parameters for the intensity modifier…." So, the level of punch can be designed by the sound engineer. In their paper, they describe a processing approach which enables perceptually compelling modification of audio signals via accentuation or suppression of transients.

Zaunschirm et al. [1] introduces 'punchiness' as a perceptual attribute of a sound mix, and their work goes to show results that imply the perception of punch is altered by the modification of the transient.

Peter Dowset [9] Chapter 6.2.5, offers beautifully simple approach to punch:

"…If your tracks fail to have punch, it is usually down to two issues:

1. Not enough percussive sounds. To create punch, you need sharp transients, particularly those with low-frequency content: kick drum, snares, handclaps, cowbell or wood block add punch. To a certain extent, even other sounds with sharp transients can create a level of drive or momentum that some would say constitutes punch.

2. Too heavily compressed/limited. The nemesis of punch is compression. If compression is reducing the initial transient peak of percussive sounds too much, then you will suck the life out of those types of sounds. Like I have mentioned above, compression can also be used to create more punch if the settings on the compressor leave the initial transient alone and compress the sustain of the signal…."

As stated earlier, **loss of transient information leads to loss of punch**. Since the importance of preserving transient information is so paramount, we must understand what can we do to prevent such loss from happening.

This leads us to the next step in punch analysis.

Transients

Xavier Rodet and Florent Jaillet in their "Detection and modeling of fast attack transients" [3], paper offer an excellent and concise definition of transients.

"…Attack transients or simply attacks, are zones of short duration and fast variation of the sound signal short-time spectrum such as at the attack of percussion instruments…Their detection is based on the detection of energy peaks appearing simultaneously in several frequency bands of a time-frequency representation…."

Let's repeat the important part of the statement above: **energy peaks appearing simultaneously in several frequency bands.** This can only happen, if there is no relative delay between signal energy propagating in all frequency bands. And this in turn, can only happen if the phase response of the device propagating the signal is constant in frequency (flat line), or even better – equal to zero.

Is there a simple way to test this in an audio device?.

One of the most useful test signals in electronics is a humble square wave. The "ideal" square wave is a superposition of an infinite number of sine waves, each contributing it's required amplitude and phase. It is due to this very feature, that when passed through an audio system, the square wave can reveal time domain performance issues of the system. This is because all of it's sine wave components must be passed by the system without time distortion, or different delays, in order to recombine as a square wave at the output of the system under test. Practically generated square waves have limited number of contributing sine waves, but the number is still sufficiently large, that for audio frequency range testing, we can fully utilize the "almost perfect" square waves.

It is important to realize, that the system time delay does not need to be zero. But is must be the same for all frequencies within the audio system pass band. Such condition will be easily met if the system under test has a zero-degree phase response.

So, simple solution is to test your speakers with square waves.

Implications For Loudspeaker Design

We have now defined the basic, poor-man, requirement of transient perfect loudspeaker system – this is a ruler-flat phase response (ruler-flat amplitude response would be also desirable)

Personally, I was introduced to transient perfect loudspeaker concept and inspired by John Kreskovsky of Music and Design in early 2000'. John has been championing this concept in DIY circles for many years. However, it was difficult (to say the least) to popularize this concept using passive or even active technologies alone.

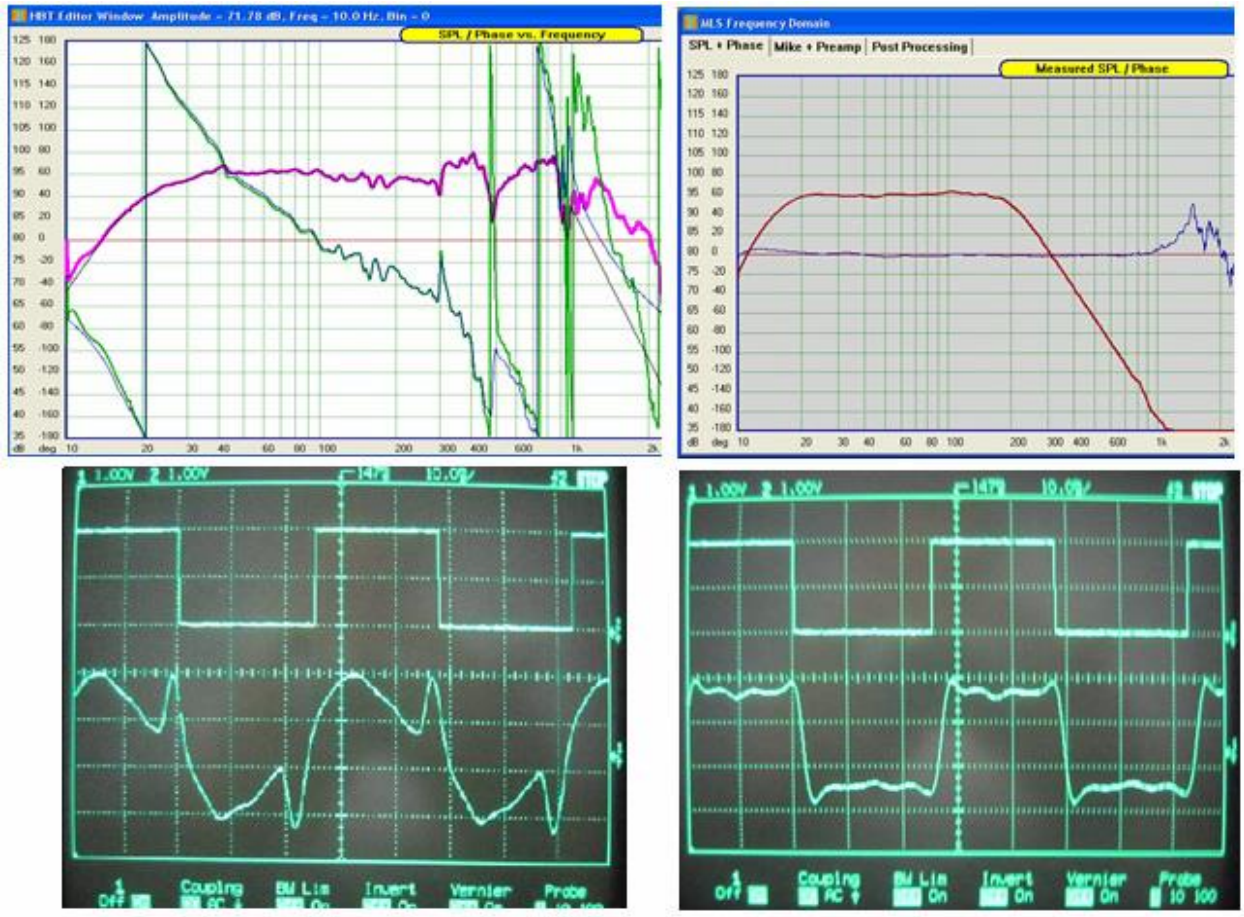
Introduction of DSPs into the DIY audio has changed this completely, and we are now able to design and built linear-phase loudspeakers. The simplest way I can put it is:

Linear Phase = Transient Perfect Loudspeaker = Perfectly Preserved Punch

Perhaps this is why linear-phase bass is so well regarded [10]:

1. **1. Michael Gerzon** " The subjective effect of phase compensation of the bass from loudspeakers is very marked, giving a much tighter and more 'punchy' quality, with greater transparency, and interestingly a subjective extension of bass response of at least half an octave. The improvement is audible even on loudspeakers with a very high cut-off frequency, such as Quad electrostatic designs. . . . The benefits of bass phase equalisation are considered, **by those who have heard it**, to be a substantial improvement over what was hitherto possible with analog technology, and digital equalisation provides a way of improving bass performance without going to ridiculously large giant space-consuming power-hungry monster speakers, and is certainly a much cheaper route ".

2. **Keith Howard** "As I pressed Play, I didn't know what to expect: a mild improvement or a revelation. To use a curry-house analogy, I was half-prepared for korma rather than phal. But when I compared the unprocessed and phase-corrected tracks, it took only a few seconds of the latter to persuade me that here was a significant improvement. Just as Michael Gerzon described, the phase-corrected sound was both weightier and punchier, and distinctly more coherent. It simply sounded more like a bass guitar, to the extent that I almost hummed along—not something that I would normally expect to do when listening to a bass-guitar accompaniment shorn of all else (sorry, John), and certainly not an urge I felt with the unprocessed track. Still, time-consuming as it was, this experiment involved only a single music excerpt and was conducted in mono, and so hardly offers a comprehensive insight into the full benefit of bass phase correction. But what I heard convinces me that this is an area in which the application of DSP can make a significant contribution to fidelity."
   Source: http://www.stereophile.com/reference/706deep/index.html



Traditional, Minimum-Phase Bass in frequency/time -------Linear-Phase Bass + HBT (same subwoofer)

Conclusions

Ideal audio playback system must deliver music or movie sound track to our ears just as the recording engineer intended. This is a large subject, and I have only concentrated on one specific aspect of it – perceptible 'punch' attribute.

Yes, it is quite perceptible, we can all hear it, so my interest revolved around trying to understand what approach has the science taken to explain and quantify the 'punch' attribute. The available literature has offered the following main summary points:

1. Punch is determined by transient information.
2. Transient information is determined by phase linearity.
3. Manipulating transient content will result in changed punch perception.
4. Manipulating punch is possible, and some methods have been proposed, including software "Transient Shaping to add punch" [11],[12],[13].

From the loudspeaker designer point of view - punch can not be estimated or evaluated from frequency response curve.

Since punch is so much time-related phenomenon, the importance of phase response has been elevated to the same level as the frequency response in assessing the punch attribute. It is clear, that designing loudspeakers using frequency-domain characteristics as the main (or only) criteria leads to stagnated, oversimplified, and ultimately inaccurate system. It is therefore essential, that the loudspeaker provides undistorted transient waveforms to the auditory system to enable correct processing of punch attribute.

And this brings us to linear-phase loudspeakers.

It is somewhat unfortunate, that for many loudspeaker designers the linear-phase loudspeakers are still a “novelty”. Past attempts in creating them resulted in offerings that were simply too expensive for wide-spread acceptance and use. The most accurate implementation of linear-phase loudspeaker requires a full set of individual driver measurements, coupled with a DSP approach, in addition to an active amplification system. This really makes the linear-phase system highly customized device – a world of difference in comparison to the current approach of mainstream loudspeaker industry.

However, this particular feature makes the linear-phase system an ideal DIY device. In our world, everything is custom-built, with an aim to typically outperform comparable commercial designs. Linear-phase loudspeakers offer everything that minimum-phase loudspeakers can offer, and then reward you with often vastly superior performance in time domain, as explained in the pages above.

Contemporary loudspeakers need to be accurate in both: frequency domain and in time domain.

Thank you for reading.

Bohdan

Complete list of papers and internet sources

1. M.Zaunschirm, J.Reiss and A.Klapuri, A High Quality Sub-Band Approach to Musical Transient Modification, Computer Music Journal, Volume 36, Number 2, Summer 2012, pp. 23-36

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4. S.Fenton., B.Fazenda, and J.Wakefield, 'Objective quality measurement of audio using multiband dynamic range analysis'. Institute of Acoustics (IOA) Conference- November 2009,

5. S.Fenton and J.Wakefield, Objective profiling of perceived punch and clarity in produced music.132nd Audio Engineering Society Convention, April 2012,

6. Steven Fenton, Hyunkook Lee, and Jonathan Wakefield in "Elicitation and Objective Grading of 'Punch'Within Produced Music" Convention Paper 9043, Presented at the 136th Convention 2014 April 26–29 Berlin, Germany,

7. Hybrid Multiresolution Analysis Of 'Punch' In Musical Signals. Steven Fenton, Hyunkook Lee, and Jonathan Wakefield, Convention Paper 9229 Presented at the 138th Convention 2015 May 7–10 Warsaw, Poland

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9. Peter Dowset "Audio Production Tips: Getting the Sound Right at the Source", CRC Press, 538 pages.

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