Cone Break Up – Is it Mimum-phase?.

By Bohdan Raczynski

I would like to start this short paper with a quote from Lynn Olson in "Some Of The Collective Wisdom Of Lynn Olson": http://www.lyrita-audio.in/page10.html

"…I'm surprised that you haven't seen drivers depart from minimum phase. This is one of the most direct indicators of cone breakup, and it's gotten much worse with the popularity of very rigid Kevlar, carbon-fiber, composite, ceramic, and metal cones. When a cone no longer moves as unit and enters the breakup region, there are multiple, asynchronous centers of radiation all over the cone. This is a clear indication of a "no-go" zone, and indirectly shows a requirement for an aggressive high-slope crossover to avoid gross coloration…"

This is possibly the most concise approach to the break up phenomenon, and it's side effects visible in the measured SPL/phase response.

Modelling Cone Break Up

There are several papers describing cone break up available from AES website. Typical approach to modelling this phenomenon would involve dividing the cone into a number of small areas (or nodes) and calculating summed response (at one meter distance) from all areas, upon applying excitation to the voice coil.

An elegant way of dealing with such modelling is FEM approach. Here, the cone is modelled as a mesh pattern of interconnected nodes. More elaborate models would include dust cap, outer suspension and the spider. The problem often arising in such situation is the necessity of knowing physical properties of all material involved.

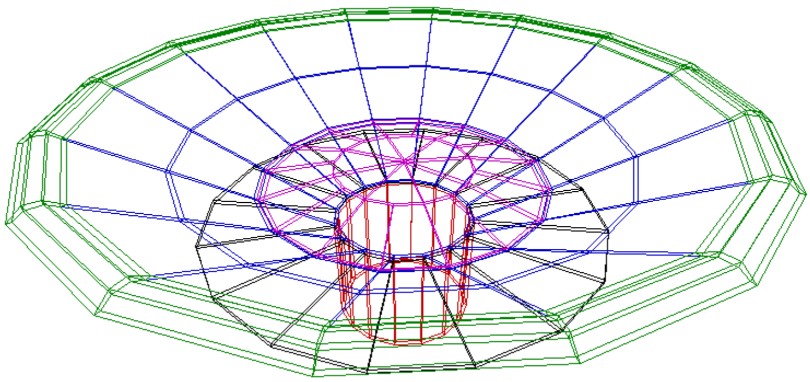

Figure 1. FEM mesh used in cone break up analysis

A simple FEM model, using the mesh shown above, has been described in this paper: http://www.bodziosoftware.com.au/Cone_Break_Up

The paper is at least 6 years old, and quite possibly needs an update, however, the essence of modelling process remains unchanged.

Minimum-phase System

Minimum-phase system - where the phrase comes from is that, for a given magnitude of frequency response, it corresponds to the system, that has the least amount of group delay.

From http://en.wikipedia.org/wiki/Minimum_phase: For all causal and stable systems that have the same magnitude response, the minimum phase system has the minimum group delay.

Personally, I like the "poor-man" definition: A minimum phase system is one which is able to transfer input energy to its output in the least amount of time for a given frequency response. Please note, "in the least amount of time" condition – it's essential here, because typically, there is only one system possible, that satisfies this condition.

It follows, that if the said system is created by summation of several sub-systems, and each subsystem has different group delay (or different time-of-flight), then the combined response is typically non minimum-phase.

As Lynn Olson mentioned before, the above logic is applicable to cone break up phenomenon. At low frequencies a cone moves as a whole. This is the 'pistonic' area of operation. At higher frequencies the cone starts to flex, leading to resonances. This is what is referred to as 'breakup', or "phase loss".

Now, the cone has divided itself into a number of radiating areas, and due to cone geometry, each area is physically located at different distance (different time-of-flight) from the measurement microphone. Taken in isolation, each area can be a minimum-phase sound source. However, the microphone picks up the combined sum of all radiating areas and is unable to distinguish between the contribution from eacharea.

Martin Colloms (High Performance Loudspeakers, page 41) explains: "…a source of "phase loss" caused by the time difference between radiation from the edges and centre of a diaphragm due to propagation velocity. Strictly speaking, this is another way of looking at the break up or loss of rigidity phenomenon….".

And in sixth edition on page 446: "…Over it's primary operating range, a piston exhibits minimum-phase behaviour…".

Loudspeaker Measurements

In order to gain better visibility into the break up phenomenon making it’s mark on the frequency response, I have measured several low-frequency transducers using MLS measurement techniques.

The results arepresented on the figures below. The figures are rather busy, but the issues discussed in this brief paper are quite pronounced.

Pink – measured SPL

Green – measured Phase

Black – HBT supplied SPL curve.

Blue - HBT calculated Phase

Brown – (Measured Phase – HBT Phase) = phase error

In SoundEasy V20 one can plot phase difference between measured and HBT-derived. So this curve (brown) acts as the “min-phase” detector. Flat curve - corresponds to HBT phase the same as measured phase. Deviation – corresponds to a non-minimum phase region.

Example 1

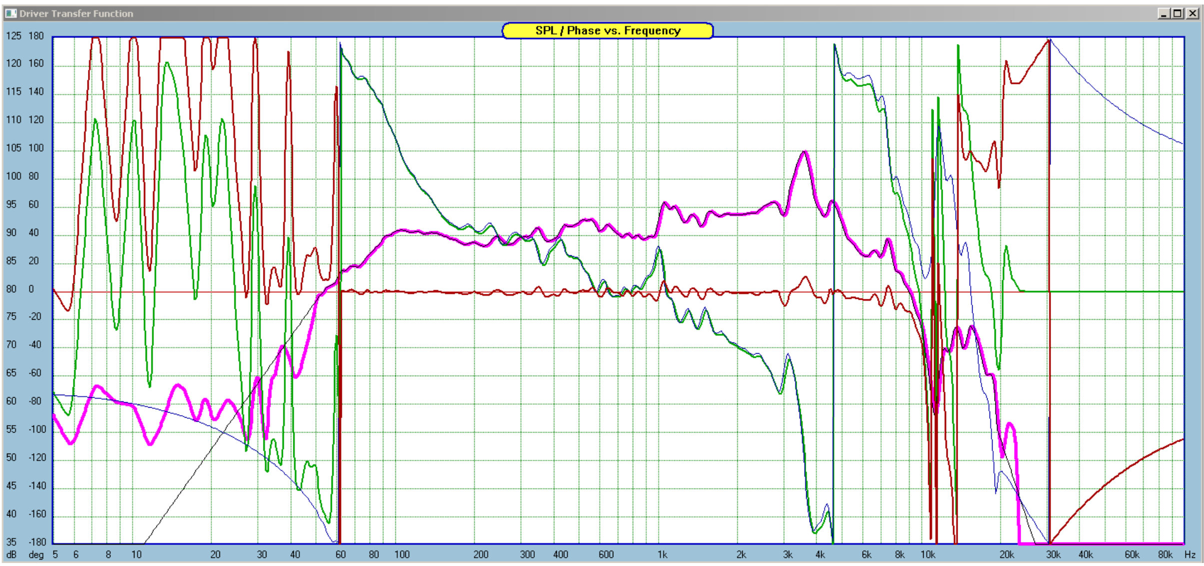

Figure 2. 12” guitar speaker. Same curve legend as before.

HBT parameters:

	High-Pass Tail		Low-Pass Tail	
Stop	52.00	Start	20000.0	Hz
Slope	20.0	Slope	43.0	dB/oct

Example 2

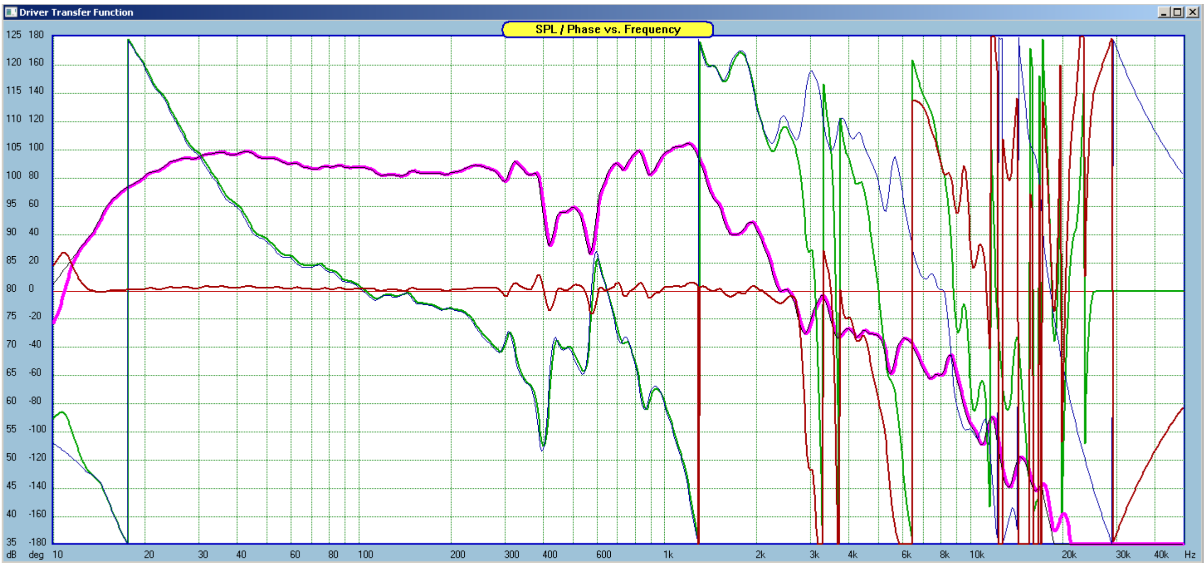

Figure 3. 18" McCauley Subwoofer. Same curve legend as before.

HBT parameters:

	High-Pass Tail		Low-Pass Tail	
Stop	12.0	Start	17500.0	Hz
Slope	22.0	Slope	75.0	dB/oct

Example 3

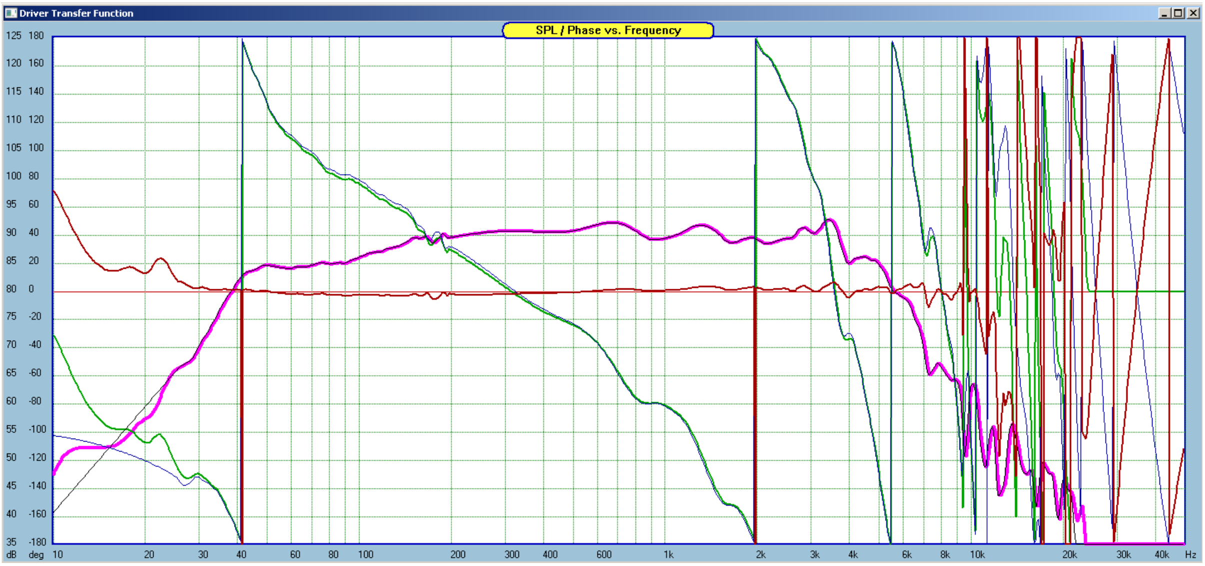

Figure 4. 8" woofer 1. Same curve legend as before.

HBT parameters:

	High-Pass Tail		Low-Pass Tail	
Stop	26.0	Start	22000.0	Hz
Slope	19.0	Slope	221.0	dB/oct

Example 4

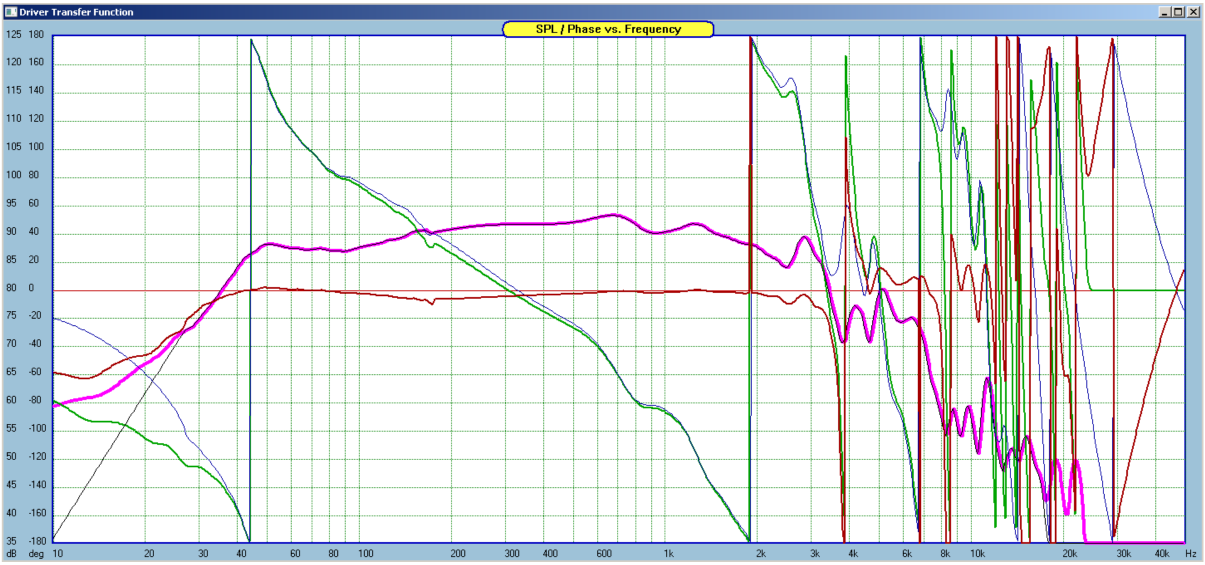

Figure 5. 8" wofer 2. Same curve legend as before.

HBT parameters:

	High-Pass Tail		Low-Pass Tail	
Stop	27.0	Start	17500.0	Hz
Slope	26.0	Slope	138.0	dB/oct

Conclusions

Standard, 1-meter measurements of typical low-frequency transducers appear to confirm statements coming from seasoned loudspeaker designers.

Now, we can observe, that the brown curve is flat (well, with small wiggles) within pistonic range of driver's operation, and even going a bit into the cone break up region – this is the minimum-phase region of operation. But eventually, above 3-10kHz the minimum-phase relationship breaks down.

Example 2 – This is large, 18" subwoofer, so the brown curve shows non minimum-phase behaviour already above 3kHz.

Example 3 – This is the "best behaving" loudspeaker with the most extended minimum-phase area of operation.

Example 4 is interesting in the fact, that the brown curve shows non-minimum phase behaviour from 3kHz, but then returs briefly to minimum-phase in 5-7kHz range.

Thank you for reading

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