Home Theatre and Audio System Evolution

We live in a surround sound world.

From dawn to dusk we are surrounded by sounds so consistently and casually, that we even fail to notice it – the perception is automatic. Even when we go to a concert, we see the orchestra in front of us, but the sound still surrounds us. The best-loved auditorium acoustical experience comes from some of the best architectural designs in the world imprinted on the sound. This has nothing to do with the quality of instruments, but a lot do with the relationship between the direct sound and the sound surrounding the listener. This is what I take home from such events – the whole immersive experience.

Yet, when is comes to recreating such an event in the living room, we happily cut the surround sound experience out, and cram every sound into the flat, front plane, represented by two front speakers (stereo). What happened to the concert hall experience?. Origins of stereo sound date back to 1881 http://en.wikipedia.org/wiki/Stereophonic_sound but the first mass produced stereo disc was introduced in 1957. So, it's been here for a while, and with a good market penetration. But, this cost-efficient way of reproducing music, is only one step better than the key-hole experience of monophonic sound reproduction. Stereo reproduction is just that – two front loudspeakers, that are unable to accurately reproduce the sounds originated from around you – the immersive experience. Can't we do any better than this?.

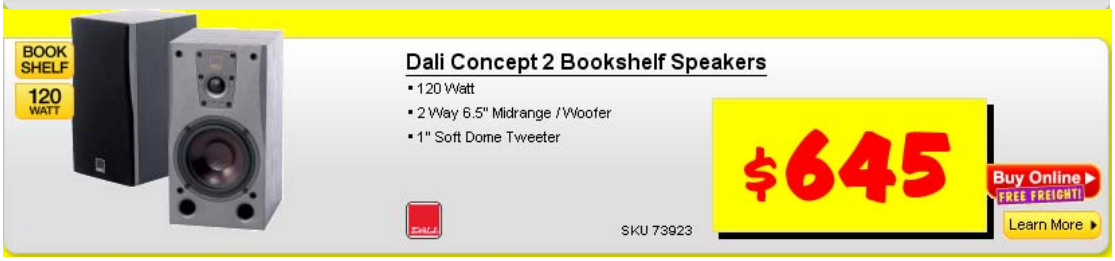
5.1 Audio system dates back to 1976, when Dolby Labs started investing in it, and International Telecommunication Union (ITU) proposed standard 5.1 configuration in ITU-R BS 775 http://en.wikipedia.org/wiki/5.1_surround_sound. Most of us are possibly more familiar with cinema surround sound (THX), which is now present in all contemporary movie theatres. From there, the 5.1 surround sound found its way into the homes and living rooms of many of us.

So we came to the point, where we finally experience the surround sound in the AV room at home. I believe, it's here to stay and progress. The 5.1 (or 7.1) HT systems are necessary to accompany any contemporary 3D Blue-ray movie or even standard DVD movie or concert experience at home. Technology kept progressing fast and now, the audio reproduction systems include 24bit/96kHz DVD-Audio http://en.wikipedia.org/wiki/DVD-Audio . This is a surround sound audio of exceptional quality. Another (competing) audio format has emerged as SACD http://en.wikipedia.org/wiki/Super_Audio_CD and is also capable of discrete surround channel reproduction.

When you pause for a moment, and consider where the capabilities of current audio technology are, and compare it with CD stereo sound, played through two loudspeakers with passive crossovers, you would be forgiven concluding, that there seems to be about 30-year gap between those two pictures.

With this project, I am trying to document my own paradigm change. I started like just about everybody else – with CDs and a stereo Hi-Fi system. I ended up with a more holistic view on sound reproduction system.

The set of speakers below would be considered a good quality 5.2 HT system.

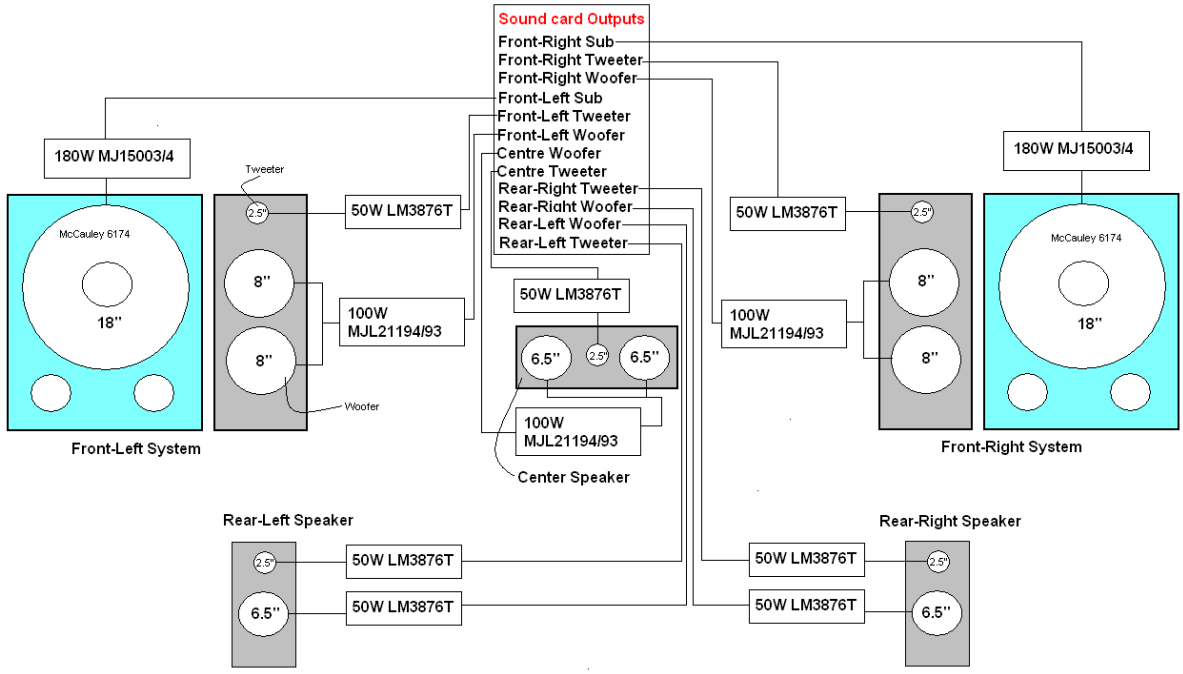


With a $350 DVD player and $450 HT Receiver, the total cost of this 5.2 system would be around $5240.

These commercial speakers are beautifully crafted, and demo of this system conducted in the Hi-Fi showroom was indeed quite impressive. I take my hat off to Dali engineers and designers.

UE3 System

The challenge for me was to use somewhat comparable loudspeaker drivers, and attempt to decisively outperform the above commercial system – can this be done at all, by a guy like me?. I started here:



Very Basic Comparison

Commercial System	UE3 System
Front – 41Hz-25kHz, 100W/110dB SPL	35Hz-22kHz, 100W/111dB SPL
Rear – 43Hz-25kHz, 50W/104dB SPL	38Hz-22kHz, 50W/105dB SPL
Centre – 72Hz-22.5kHz, 100W/109dB SPL	35Hz-22kHz, 100W/111dB SPL
Sub – 29-170Hz, 110dB SPL	16-200Hz, 112dB SPL
SPL/Phase equalization – NO	YES (Inverse HBT)
Linear Phase – NO	YES
Driver AC Alignment – NO	YES
Extensive Voicing – NO (only tone controls)	YES
Room Correction – NO	YES

Here are some of the advantages discussed on the internet within DIY audio community, commonly attributed to **active systems**:

1. Effectively (up to) twice the 'real' power of the amplifiers themselves
2. Reduced inter-modulation distortion
3. Elimination of the low frequency passive crossover, its inherent losses, potentially poor linearity and crossover point inaccuracy

4 Reduction of the difficulty of the load presented to the power amplifier
5 No padding is required to align the driver sensitivities, so we are not simply wasting power
6 The damping factor is greatly improved for both the low and midrange loudspeakers
7 Complete freedom from any interaction between the loudspeaker driver (and its environment) and the crossover network
8 The flexibility to choose amplifiers which are at their best within a defined frequency range
9 Ability to match amplifier power to the exact requirements of the drivers for maximum overall efficiency

However, the new system based on UE3 technology would be characterized as having:

1. Much more **time-accurate and better sounding set of loudspeakers** in comparison to the comparable commercial set-up. This is particularly evident in the centre loudspeaker and subwoofer performance.
2. Completely **active, 12-way, powerful amplification system**.
3. **6in / 16out, precise DSP 24bit/48kHz crossover**. This offers a possibility of expanding the front loudspeaker system to 3-way towers.
4. **HBT equalization for SPL and phase of each individual driver**, resulting in a flat and extended frequency/phase response.
5. Precise **time alignment** for all drivers.
6. **Linear-phase mode**. All transient perfect loudspeakers – you can start with subwoofer chapter for more details.
7. **RoomEQ. Sensible equalization/reduction of most offending room modes**.
8. Practically **unlimited loudspeaker voicing** capabilities (all in linear-phase). Now, all my CDs sound “almost” equally good.
9. Enhanced (surround) playback with rear speakers for ordinary, stereo CDs. The system is also ready for **Audio-DVDs and SACDs**.
10. Complete system settings (profiles) saved to HD. You can have **individual system profiles for different type of music or different vintage CD**s.
11. Windows Media Player – **creation of play-lists, libraries**. This is fantastic feature. I can now play selected music uninterrupted for hours.
12. **Purchasing, downloading and playback of individual songs - this is very significant cost savings on music for me**. This feature alone, paid for the increased cost of the new system within 12 months.
13. Windows Media Player – possibility of eliminating the external DVD player altogether.
14. **Internet connection to download and play Full HD, 5.1 movies**.

From the user’s perspective, my commercial HT receiver had very limited loudspeaker voicing capabilities (only standard tone controls), so I could not really set the sound to my liking. Adding to the problem, I have a collection of CDs with songs from mid-60’ and 70’. Their sound quality/balance could be much enhanced, if I had better voicing capabilities built into my system. Currently recorded CDs are much better balanced sonically. Finally I preferred a genuine 5.2 system rather than 5.1 with 2 subwoofers.

One of the biggest, non-technical drawbacks of the commercial system approach was the need to keep purchasing CDs. My old system could only play CDs, so even if I liked only one or two songs from a particular CD, I had to buy the whole thing. This is how I ended-up with over $3500 worth of mostly unwanted music.

Without any doubts, the list of improvements covers not only the technical quality of the audio playback system, but also functional improvements to it. The system is also much **cheaper** to run and to add new music/movies, and is much **easier** to run, by using play-lists. I now have a dedicated left-channel subwoofer and right-channel subwoofer. Voicing of individual loudspeakers is just as I wanted it to be. I also use different system profiles for different play-lists and some older, vintage CDs.

The new system changes the way you acquire, organize and play your music and movies. It's future oriented, and being software driven, allows for easy expansion in terms of sound quality and functionality. For instance, the UE will be expanded to 8in/16out mode and further to 16in/16out matrix. In addition, 24bit/96kHz studio level performance (current is 24bits/48kHz) is planned too, as is an extension to 7.2HT systems. To expand on the above comments, I would recommend for anybody to read the first 5 pages from this paper: http://www.linkwitzlab.com/dCS_Guide_to_Computer_Audio%282%29.pdf
It seems, that comments found in there, are quite applicable to most of us.

Some Loudspeaker Design Implications From Using UE3

Due to the unique features of UE3, the traditional approach to loudspeaker development, with it's heavy emphasis on crossover design and optimization, went pretty much out the window. In fact, the whole complicated process of crossover design was reduced to selecting the crossover type and frequency. Optimization was reduced to selecting HBT frequency range – that's all. Complete changes to the sonic characteristics of the whole system are made instantly. A good way to do this, is to pre-store project files and treat them as "acoustic profiles" of the whole system.

Shortcomings of passive crossovers are widely acknowledged by experts. Some interesting comments on passive crossovers from Wikipedia:
http://en.wikipedia.org/wiki/Audio_crossover#cite_note-1

"…Passive networks may be bulky and cause power loss. They are not only frequency specific, but also impedance specific. This prevents inter-changeability with speaker systems of different impedances. Ideal crossover filters, including impedance compensation and equalization networks, can be very difficult to design, as the components interact in complex ways…."

Crossover design expert Siegfried Linkwitz said of them that "…..the only excuse for passive crossovers is their low cost. Their behaviour changes with the signal level dependent dynamics of the drivers. They block the power amplifier from taking maximum control over the voice coil motion. They are a waste of time, if accuracy of reproduction is the goal….." from http://www.linkwitzlab.com/crossovers.htm

These views seem to echo Neville Thiele's comments on the future of loudspeaker design (see "An Interview with Neville Thiele" - By Steve Mowry, Voice Coil 2006).

Passive crossovers are loaded by real loudspeaker drivers, therefore load impedance of the crossover will vary with drive level and temperature. Changes in loudspeaker impedance propagate into frequency response irregularities, and any change in one, affects the other. Active design completely removes this whole problem of measuring, incorporating and compensating driver's impedance into the design.

Next, the traditional approach to enclosure type selection and design also seem to become somewhat less relevant. For instance, sealed box offers less bass extension, but better impulse response, contrary to vented design, which offers more bass extension, but poorer impulse response. These characteristics become irrelevant when running UE3 in linear-phase mode. Here, the impulse response and time domain performance is always perfect, regardless of the enclosure type. HBT equalization takes care of any irregularities in the frequency/phase response – as long, as the cone excursion is not exceeded. And linear-phase mode takes care of the rest.

Obviously, with the active configuration, more emphasis is placed on multi-channel amplification system. There are options as well: (1) use commercial multi-channel units: Dayton Audio MA1240a Multi-Zone 12 Channel Amplifier
http://www.parts-express.com/pe/showdetl.cfm?Partnumber=300-815&FTR=ma1240%20multi-zone%2012%20channel%20amplifier
or (2), use amplifier kits to assemble the amplifiers and power supply yourself. There are a number of options on the market for 50W and 100W modules. The 50W modules take 45min each to assemble.

UE3 certainly offers significant design simplicity. For many experienced loudspeaker designers this situation may be somewhat unnerving. Years of valuable engineering experience in the intricate art of passive crossover design, are being replaced by casual knowledge and a couple of simple selections in the computer program?. Detailed enclosure selection and design does not need to be that detailed anymore. Scary stuff indeed. Well, wait a minute, UE3 does not change the laws of physics, it uses them to correct imperfections and maximize existing performance. So being an experienced designer can only help you in understanding imperfections in more details, and to use UE3 technology more efficiently, knowing where the trade-off are. That would be my view.

Transducer accuracy

We have come to expect that audio amplifiers, pre-amplifiers, DACs, CD-players, DVD-players all exhibit absolutely flat amplitude and phase responses. In fact, it would be difficult to design an audio amplifier, that has amplitude and phase response as bad as the loudspeaker.

Yet, when comes to loudspeakers, all of the sudden we call upon limitations of human auditory system, that allows most of us to accept gross transducer inaccuracy under normal listening conditions, manifesting itself clearly under time and frequency domain testing as applicable to general audio equipment.

Perhaps we were slowly conditioned by the audio industry towards this passive acceptance of status-quo, as for many years, there was no real alternative, but to use what was commercially available for sound reproduction. We took our eyes off the ball and accepted a degraded compromise.

Fortunately, we are now in a different position. The UE Technology is a cost-effective answer to this long standing problem. Here, the transducer undergoes two stages of correction: (1) amplitude response is corrected to a flat line, and at the same time, phase response is corrected to a smooth, minimum-phase response, and (2) overall phase response of the transducer is corrected to a flat line. The above equalization results in the linear-phase loudspeaker, capable of perfect reproduction of musical transients (including a square wave).

Each driver in my new UE3 system is now a vastly more accurate transducer.

Time Corrected Loudspeakers

Boston Audio Society has an interesting view on time-corrected loudspeakers.

"….If the stereo loudspeakers differ in their time-shift behaviour by more than about thirty millionths of a second (or a finer tolerance, perhaps, for critical listeners), the stereo image will be perceptibly smeared. The two speakers must "speak" together at all frequencies if the subtlest details in the stereo field are to be preserved.

This, quite simply, may be the principal advantage to be gained from "linear-phase" or "time-corrected" loudspeakers. The manufacturers who are striving to reduce the time dispersion of loudspeakers to zero may also be ensuring that there will be no significant differences in signal propagation timing between the two speakers in a stereo pair. The delicate timing information in a stereo recording is thus accurately retained and is transmitted to the listener unaltered…"

They also point to some of the advantages of such loudspeakers:

"….1.Depth.
This may surprise some listeners when they first hear it, since many speakers(and records) elicit only a general left-to-right spread. But "stereo", as originally conceived, implied a three-dimensional sound in which voices or instruments could be localized at different apparent distances from the listener as well as at various lateral positions. Listeners to time-aligned speakers consistently report hearing a stereo image with unusual depth.

2.Resolution.
The stereo image is reproduced precisely, each voice or instrument having its proper place and width. In complex sound sources such as symphony orchestra, individual instruments can be resolved with unexpected clarity. In the old cliche, "I hear details I never knew were in the recording. " Some listeners have incorrectly attributed the improved resolution of detail to more accurate transient response, but the better definition of details is simply the result of the reduction of blending in the stereo image.

3.Separation of ambience.
With loudspeakers whose stereo image is slightly blended because of time-smear, any hall ambience or reverberation in the recording tends to become slightly mixed with the instrumental sounds, causing coloration of those sounds. Consequently, with such speakers closely-microphoned recordings tend to sound better because of their distinctly defined sound. But with time-corrected loudspeakers, the ambience is resolved as a separate sound, and larger amounts of hall ambience in recordings can be enjoyed……."

The goal is to enjoy all these improvements in my system.

The research on audibility of phase distortion continues. Some newer remarks come from final pages http://rsta.royalsocietypublishing.org/content/360/1794/833.full.pdf
"….Interference effects in the inner ear (cochlea) are more complex as they are influenced by the active mechanism, which introduces strong nonlinearities. Interference effects in the cochlea play a role in many aspects of auditory perception, including the perception of consonance and dissonance, the perception of pitch, the **perception of changes in phase**, and the perception of timbre. Interference effects in the cochlea may also play a role in producing the spectral regularity observed in otoacoustic emissions…"

The UE3 Technology offers a unique capability of switching phase from non-linear to linear, so you can audition your favourite music/movies in both modes. If linear-phase is your preference, than you have possibly the best equipment to achieve this. If your preference stays with non-linear phase, you still have all the benefits of HBT equalization, AC time alignment, RoomEQ, all functional, operational and cost improvements of your audio playback system due to PC integration, and unlimited voicing in UE3 system.

My conclusion at this point is that linear phase is worth using. Not because published scientific papers already point to the conclusion, that phase distortion is subtly audible to some people on some sound material, even though is not on the other. It is because linear-phase loudspeakers measure perfectly. This is enough for me to drive the stake in the ground, and set the UE3 to linear phase and simply forget about the phase issue all together. Now, the phase disappears from the equation, and you never have to worry about it, just like you do not worry about your amplifier's phase response. There are two benefits from this approach: (1) you know for sure, that all loudspeakers in your system are transient-accurate, and (2) you will never procrastinate about a possibility: "should I try linear phase first, to see if it would sound any different on this piece?".

If you take this approach, then you simply by-pass the whole phase audibility dilemma. Now, it does not matter what signals you play through your audio system, how long scientific community will take to perform the all-conclusive research, when it will happen (if ever), and what the overwhelming verdict will be. It simply does not matter anymore. Just like your amplifier, your loudspeakers will measure perfectly with time domain signals, and you will be one step ahead of the rest – at no extra cost.

So this is my take on linear-phase option: it will make your loudspeakers measure and play perfectly, so set-it-and-forget-it.