What is DEQX?

DEQX Technology Whitepaper

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1 OVERVIEW

DEQX® digital audio processing is an advanced process for audio products that corrects for playback system errors. The process places particular emphasis on the speakers, with the DEQX unit changing the time, phase, amplitude and frequency information in the signal being sent to amplifiers and loudspeakers to compensate for measured errors. DEQX room correction and Preference EQ adds further compensation for room acoustics and specific CDs, DVDs etc.

Using DEQX Calibrated™ correction, measured errors caused by loudspeaker drivers, loudspeaker cabinets, signal electronics and even DEQX's own analogue electronics as well as room acoustic problems are significantly removed. DEQX correction results in a more natural and 'realistic' performance because the sound arriving at the listening position more accurately represents the originally recorded audio than has previously been possible, even in expensive audiophile systems.

A DEQX-corrected system typically demonstrates improved three-dimensional resolution, wider listening area, and an accurate harmonic balance when the full suite of DEQX processes are implemented with suitable loudspeakers. DEQX can provide the elusive audiophile 'being there' experience for a fraction of the cost of high-end systems. Even so, DEQX provides further performance gains when using audiophile grade source media and electronics.

DEQX Calibrated™ correction can be implemented in part or in whole using a suite of processes that DEQX's hardware and software processors provide. DEQX can be added to existing playback systems using DEQX off-the-shelf processors combined with DEQX's PC software to measure and set up the system. DEQX processors are used to provide reference monitoring accuracy by leading music and film soundtrack production facilities. Loudspeaker manufacturers can incorporate DEQX correction into loudspeaker designs using DEQX's turnkey OEM Processor Modules with optional digital amplifiers and universal power supplies.

1.1 Speaker correction

DEQX™ speaker correction uses pseudo anechoic (near-field) measurements to correct phase, group delay and frequency response of individual drivers. When implemented, DEQX digital crossovers provide true linear-phase, high order filters that can essentially eliminate crossover distortion including comb-filtering and lobing while providing improved mid to high frequency dispersion and dynamics. Frequency response of a DEQX Calibrated™ loudspeaker is typically in the region of plus/minus 0.5 dB on axis, subject to measurement accuracy. DEQX crossovers provide superior off-axis frequency response.

What DEQX Calibrated™ does for loudspeakers

• Frequency response correction to within 0.5dB using calibrated mic

• Phase and time response correction

• Group delay correction

• Precise time alignment with zero phase error

• Linear-phase zero-distortion digital crossovers

• High-order crossovers to 300dB/octave eliminate driver interaction

• Extremely high digital resolution; 32-bit floating point, 96KHz

1.2 Room correction

While DEQX *speaker* correction is used to correct the 'instrument' itself in its native form, taking care to avoid any room acoustic information in the measurement, DEQX™ *room* correction is aimed primarily at the room acoustic effects that are most difficult to correct using simple room treatment, such as moderate wall and floor damping using carpet, rugs bookshelves etc, which we recommend. Physical room treatment is easy and desirable to moderate sound reverberation for the mid to high band where DEQX speaker correction ensures accurate 'native' speaker behaviour. The lower two or three octaves are difficult or impractical to deal with using physical room treatment, so DEQX *room* correction provides multiple bands of *minimum-phase* parametric equalisation that can be set manually or automatically, based on measurements from the main listening position.

What DEQX Calibrated™ does for listening rooms

• DEQX minimum-phase multiband parametric EQ

• Automated measurement and correction using calibrated mic

• Graphic view of room acoustic behaviour on PC during set-up

• Manual override of parametric bands in graphic environment

• Listen to music and view individual band correction in real time

• Optional DEQX time domain room correction (off line service at this time)

1.3 MEDIA CORRECTION (PREFERENCE EQ)

The DEQX processors also provide DEQX media correction, or Preference EQ. This takes the form of precision 'tone' controls where CDs or film soundtracks can be improved with simple bass, mid or treble correction. Correction should not be needed for quality recordings, but many popular productions will deliberately emphasize or cut certain frequency bands to compensate for poor quality car and compact audio players. The DEQX processor provides 100 presets of variable three-band, minimum-phase equalisation using the remote control. The bass and treble are variable frequency shelf Eqs. The mid band is parametric, with frequency centre from 20Hz to 20K and bandwidth variable from one semitone to four octaves.

What DEQX Calibrated™ does for media

• 100 presets allow ideal settings for specific music discs or film soundtracks

• Three-band DEQX minimum-phase parametric and shelving equalisation

• Real-time correction using remote control

• Low shelf and High shelf filters with variable or default frequency

• Mid-band parametric: Bandwidth 1/12 to 4 octaves; Frequency 20Hz-20KHz

1.4 THE BENEFITS OF DEQX CALIBRATED™ TECHNOLOGY

• Improved imaging and sound-staging

• Improved frequency response and realism

• Improved integration with sub-woofers

• Improved dispersion and wider sweet spot if DEQX crossover implemented

• Improved dynamics if DEQX crossover implemented

• Reduced crossover distortion if DEQX crossovers implemented

• Manages bass in room, improved bass resolution

• Benefits compressed audio formats including MP3, Dolby Digital, DTS

• Benefits high resolution audio sources: DVD-Audio, SACD, CD, LP Vinyl

• Media correction compensates for widely varying mastering standards

2 THE PROBLEM WITH AUDIO PLAYBACK

Today's digital recording, production and distribution technology is capable of providing almost perfect signal integrity from original recording through to the home audio playback system. Why then is it still so difficult to achieve the 'being there' experience in all but the most expensive systems? Even where money is no object and the 'perfect loudspeaker' were possible, this goal remains elusive because the listening room itself can corrupt the sound dramatically.

From a technical standpoint, and apart from acoustic problems relating to the listening room, the loudspeaker is the weakest link in the audio chain. It has errors in the form of distortion, phase accuracy and frequency response that are roughly ten times worse than any other equipment or media in a 'new generation' audio chain from recording through distribution to the playback electronics.

2.1 CROSSOVERS

A typical bookshelf two-way loudspeaker contains a woofer (eg. six inch diameter) to reproduce bass frequencies, and a smaller tweeter (eg. one inch diameter) for treble. The reason for this separation is that it is impractical to manufacture a single driver capable of performing well at all frequencies. When a speaker driver is operated outside or near the limits of its frequency range, non-ideal behaviour is introduced. This can take different forms, but the most common inaccuracies are a non-flat frequency response, frequency dependant directionality (or 'beaming'), and distortion, especially intermodulation distortion.

To minimise these problems, drivers are designed to work best across a limited frequency range, usually of three to four octaves. The drivers are then integrated together into a single loudspeaker cabinet. In consumer speakers, an electrical device known as a passive crossover is normally located inside each speaker cabinet, to divide the full ten-octave spectrum into limited frequency bands sent to the appropriate driver. This is a 'passive' speaker design.

An improved approach used in many professional and high-end consumer speakers is an 'active' speaker design. Here, each driver in the loudspeaker cabinet has its own power amplifier, which can be designed to work ideally for the particular frequency range of the driver. In this case, the 'crossover' electronics is placed before the amplifiers, and so they operate at preamp signal levels, rather than at high power, as required of passive crossovers.

Although this 'active' arrangement requires more amplifiers, it has many overriding advantages. It allows more detailed and effective crossover designs, it reduces intermodulation distortion both in the amplifiers and speakers, it simplifies the load on the amplifiers, which in turn can be far less expensive to design and build. Amplifier power requirements and behaviour can also be targeted to what is actually required in the particular frequency ranges. For example, the treble three-octaves from 2,500 Hertz to 20,000 Hertz requires less than 20% of the power required for the seven octaves below. A tweeter covering this range might afford a low power valve amplifier or Class-A solid state amplifier, while more powerful and affordable amps could be used for bass and midrange. A significant cost of an amplifier is its power supply, and some active speaker amplifiers share the same power supply, which need be no larger driving

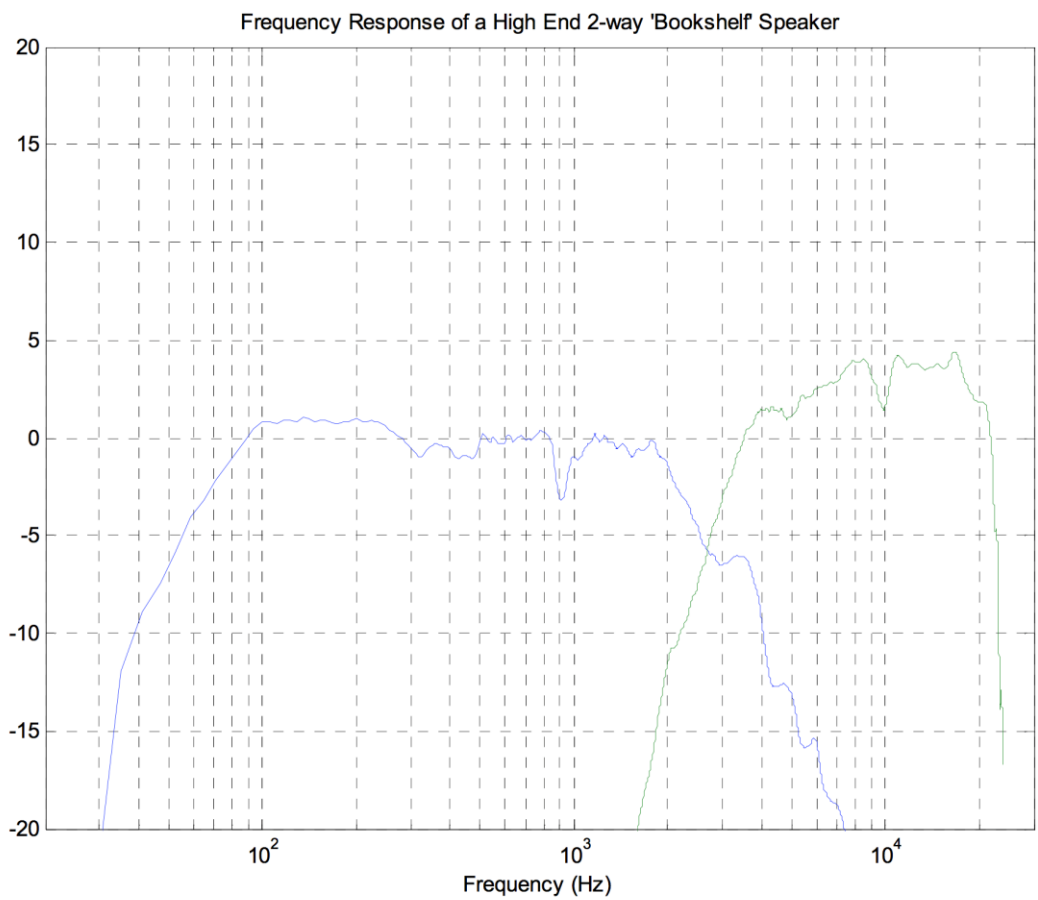

Figure 1. A typical frequency response of a two-way speaker system, showing both woofer and tweeter after passive crossovers. The sum of the woofer and tweeter across the crossover range (typically over two octaves) target a flat frequency-response on-axis.

multiple amplifiers, than required for a single amplifier channel driving a passive speaker.

Even though the audio signal is split up between two specialized drivers, other problems have now been introduced. The simple crossover that is used is not capable of a perfect transition between each driver. In fact, 'passive' crossovers add their own distortion and artefacts to what we hear. Furthermore, typical crossovers only attenuate signals at a rate of 6 or 12 decibels per octave. The effect of this is to allow significant amounts of sound to come from inappropriate speaker drivers, i.e. too much high-frequency from the woofer – which sounds increasingly 'muddy' and 'beams' as frequency increases - and too much low frequency from the tweeter, which will tend to distort at higher volumes, and whose dispersion behaviour is at odds with the woofer's at similar frequencies.

In consumer speakers where crossover slopes of typically 12dB/octave are used, the same sound is coming from both drivers, typically for an octave above and below the crossover frequency. Unless these sources are perfectly timed to meet in phase with each other (time aligned), the resulting mix of sound will produce 'comb filtering', which can sound 'nasal' or 'flanged'.

Another problem has also been introduced by using multiple drivers to reproduce sound – a single instrument may now sound like it is coming from different places. This results in poor off-axis performance because varying degrees of summation and cancellation occur depending on the relative distance between each driver - a phenomenon known as 'lobing'. Because the woofer is often physically placed further back than the tweeter, this lobing is also non-symmetrical in the vertical plane. The loudspeaker's off-axis performance is important because although this is not necessarily what is heard directly, it is ultimately heard because of its coupling into the room.

2.2 THE DEQX SOLUTION

The active DEQX crossover and correction processors provide help to resolve the problems mentioned above at a number of levels. Although impractical even in 'active' analogue crossovers, DEQX provides true linear phase very high-order crossovers that provide absolutely precise time alignment and phase coherence between drivers, while limiting the 'bleed' of similar frequencies over the crossover region so that lobbing effects occur only at the imperceptibly narrow crossover region, and dispersion patterns remain similar between drivers. This is achieved because the dispersion characteristics of the tweeter are typically almost omnidirectional at the crossover frequency from the woofer or mid driver. On the other hand, the woofer or mid driver will increasingly be more directional (beam) as its frequency moves into the tweeter's territory. By rolling off the woofer's output above the crossover frequency typically ten times faster than a passive crossover allows (for practical purposes at least), its off-axis behaviour is more similar to the wide off-axis dispersion from the tweeter around the crossover frequency.

Improved dynamics is another benefit deriving from DEQX crossovers because drivers are operating within a more limited frequency range. In this case, non-ideal behaviour that tended to occur above and below that range before when using low-order crossovers, are no longer an issue. This benefit may also apply to speaker cabinet behaviour, where cabinet resonances may be excited outside a particular driver enclosures intended range. Another advantage is that each driver has its amplifier coupled directly to it without losses and distortion caused by capacitors, resistors or reactive chokes.

Unique to DEQX however, is its ability to correct phase, group delay and amplitude errors at all frequencies, and independently for each driver and amplifier combination. Correction of these fundamental problems for loudspeakers has never been practical or affordable using analogue techniques, nor easy to do using digital techniques. Not surprisingly correction of such fundamental issues is largely a prerequisite in achieving the elusive 'being there' experience that is the goal of DEQX correction.

The problems described in this section are inherent in all multiple driver loudspeaker systems. It is these problems that remove the 'being there' experience when listening to music through loudspeaker systems. Even very expensive loudspeakers can have an inaccurate frequency, and phase response, and so add their own signature to what is heard in counterproductive ways.

2.3 THE PROBLEM WITH LISTENING ROOMS

Even the best audio system will not provide a life-like listening experience if it is set up in a room that interacts poorly with the speakers. Unwanted artefacts such as room reflections can cause unnaturally high or low frequency response at certain frequencies, causing the music to sound "boomy" or thin, or sometimes both. Since DEQX speaker correction already ensures that the 'native' speaker behaviour is accurate (flat anechoic, on-axis response at say 3ft (90cm), the effects of a good listening room should absorb some of the mid to high frequency energy by the time it reaches the listening position, and so in this regard, a 'flat' frequency response is not desirable at the listening position, and in fact would sound too live or harsh.

DEQX recommends that the listening room is both physically and electrically corrected. Specifically, mid to high frequencies should be absorbed to a moderate degree by floor and wall covering. This can be done using carpet or rugs on the floor and walls, and/or limited absorptive furniture such as bookshelves on the walls or behind the speakers, alternatively, professional acoustic treatment products can be used. The bass, and especially low bass is extremely difficult to control using thin furnishings, and this is where electronic correction provides most benefit.

3 THE DEQX CALIBRATED™ SOLUTION

3.1 THE PROCESS

Step 1. Active configuration (Optional but recommended)

A new loudspeaker is built omitting the normal passive crossover components, or the passive crossover is removed from existing loudspeakers. Amplifiers must be obtained for each driver, the tweeter and mid-drivers requiring in the order of 20 to 50 watts, and the bass driver in the order of 100 to 300 watts. The DEQX processor outputs its stereo high, mid and low analogue outputs that drive each amplifier (digital out optional). If DC may be present on any output, a high quality capacitor may be used to protect the tweeter from accidental damage. This 'active' configuration in combination with DEQX's linear-phase, very high order crossovers, virtually eliminates the problems described in the previous section which are related to the non-ideal crossover.

Step 2

A test signal is run through each loudspeaker driver in turn, and the behaviour measured using a DEQX Calibrated™ microphone. If a passive speaker is used, all drivers are measured simultaneously. When setting up to perform this 'pseudo-anechoic' measurement, care is taken to maximise the distance of the first reflected sound wave (from the floor or a piece of furniture for example) to the microphone, compared to the direct sound from the loudspeaker, which is measured on-axis to the speaker baffle, at up to one metre. Ideally, the microphone height should be at least one metre from the floor and preferably mid-height of the room (so that the floor and ceiling reflection are maximised), this is usually easy to arrange for a compact speaker. If a large, floor-standing speaker cabinet makes raising it high from the floor impractical, then very thick absorptive material such as a foam mattress, duvet and blankets can reduce the floor reflection. Tilting the speaker backwards up to say 45 degrees can also help reduce floor reflection intensity. In such cases, DEQX's software allows more 'smoothing' to be applied to the frequency response and consequent correction.

If inside space is limited, measurements can also be performed outdoors if background noise is reasonably low. DEQX uses multiple swept sine waves for measurements to provide the best possible signal to noise measurement. Depending on the measurement circumstances, this process will typically provide accurate results for roughly the top seven octaves (above say the note A-220Hz through 20,000+Hz). In the three or four lower octaves below say 300Hz, the effects of the room acoustics can so overwhelm the speaker's native bass accuracy that room correction is usually more appropriate than speaker correction in this region, although speaker manufacturers may wish to utilise DEQX's true anechoic chamber measurement facilities which is one of the largest anechoic chambers in the world (Guinness book of records – quietest place on earth!) in Sydney Australia.

Step 3

The measurement results are analysed to produce an optimum calibration filter to fix the loudspeaker's non-ideal frequency response, including phase errors and driver misalignment problems. The DEQX CalibrationTM software is used to isolate the loudspeaker's measured behaviour from that of the room and the microphone.

Step 4

The DEQX processor is configured with the new crossover and calibration filter. Verification measurements are taken to confirm operation.

Step 5

With the speakers now corrected, another test signal is run through the loudspeakers with the microphone placed at the listening position to measure the behaviour of the room.

Step 6

The room response is displayed and is either corrected automatically or manually, using multiple minimum-phase parametric equalization bands. The advantages of parametric equalization over conventional graphic equalizers are that the centre frequency of a parametric EQ band can be moved to coincide precisely with the frequency of the unwanted peak or trough, and the width of the band can be adjusted to match that of the peak or trough. Typically, only three or four parametric bands will be required to correct bass frequencies, usually below about 200Hz. Seven bands are available however, and correction can be at any frequency from 20Hz to 22KHz.

Step 7 (Optional)

Additional parametric equalisation, level, delay and other tweaks are carried out to tune the system's behaviour to particular tastes, or to solve any user-specific problems not already covered. The DEQX processor also allows up to 100 preset

3-band parametric EQs, the centre channel allowing variable Q. These EQs are set, stored and recalled from the remote control and do not require that the PC is connected.

Step 8

The PC is removed and the DEQX processor left in place. The system is now DEQX Calibrated™.

3.2 THE RESULTS

Once calibrated, a number of improvements in the sound become apparent. With the individual speaker drivers operating strictly within their optimum frequency ranges, gain and phase errors corrected, and the drivers perfectly time-aligned, the loudspeaker is largely 'removed' from the listening environment, the quality of the inherent

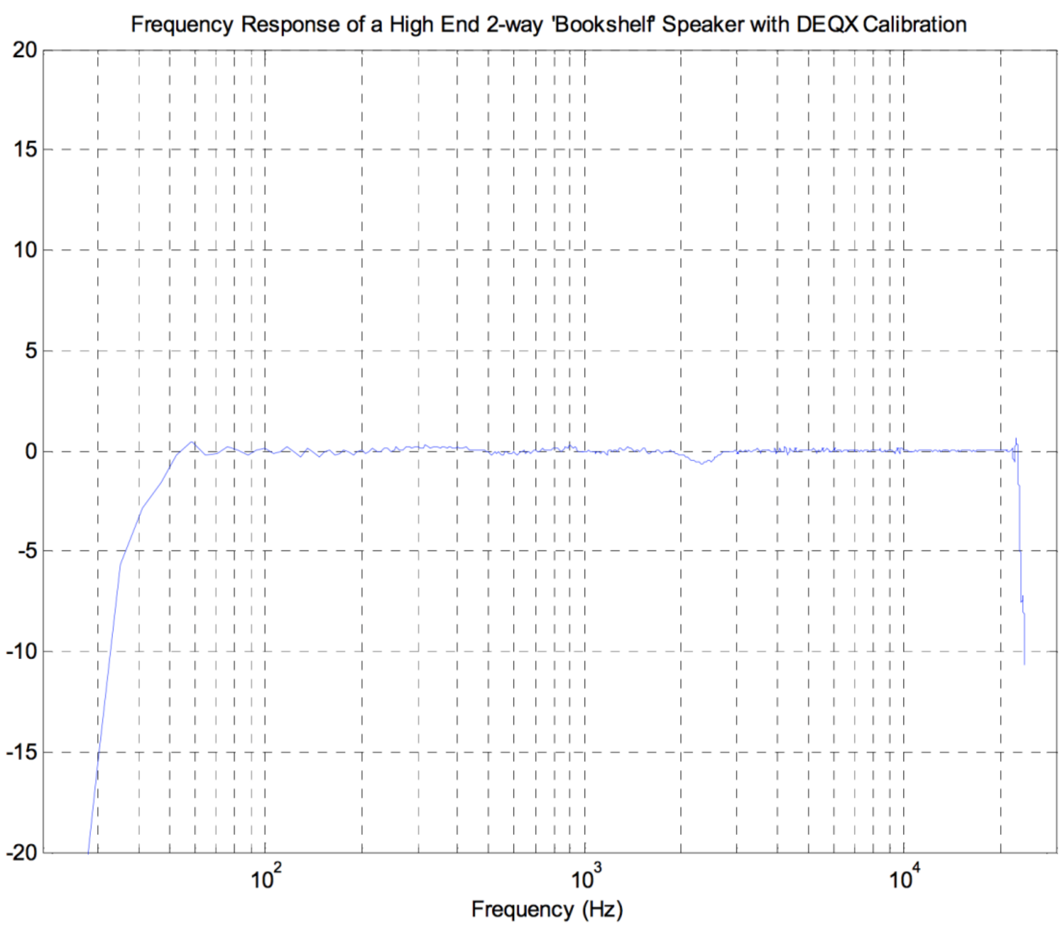

Figure 2. A typical frequency response of a 2-way speaker system after DEQX Calibrated™ 'speaker' correction showing woofer and tweeter combined.

loudspeaker design and its components determining the degree to which this is successful. Stereo imaging and realism improves due to phase and frequency response correction, more ideal dispersion, greater dynamics and lower distortion. The so-called ‘sweet-spot’ in a listening room is also widened as the behaviour of each driver around the crossover frequency is quarantined to its ideal operating range.

A further effect of ‘active’ DEQX Calibration™ is that the loudspeaker has better power handling and is less prone to distortion. This is because the demand on the power amplifier driving each speaker is limited to a smaller frequency band, so the amplifier has less work to do except in the range it can more easily specialise in. Should the amplifier distort, perhaps due to an extremely loud passage of music, the resulting harmonics are restricted to one driver only. ‘Passive’ crossover speakers cannot isolate amplifier distortion in this manner.

4 DEQX TECHNOLOGY

The DEQX Calibrated™ process has been refined over seven years of research and development by DEQX Pty Limited. DEQX is an Australian company whose founder is an AES (Audio Engineering Society) award-winning pioneer of digital audio for the professional audio industry over thirty years. DEQX's team of engineers have developed proprietary Digital Signal Processing (DSP) techniques to allow user friendly measurement, calibration and processing on affordable and scalable hardware, in the form of DEQX's own end-user products, and cost effective OEM modules and licensing for manufacturers.

4.1 MEASUREMENT CONSIDERATIONS

High-resolution loudspeaker measurements can be taken in a typical room. However, the loudspeaker's behaviour is isolated from the room's acoustic behaviour, so that the speaker can be corrected in its 'native' form, as if it were an independent instrument. The advantage of this separation from the room's acoustic allows correction of critical phase and group delay issues through the mid-range and high frequencies. This is not possible when considering the room/speaker measurement as a whole, due to location-specific in- room behaviour. This is why DEQX uses firstly, near-field pseudo-anechoic measurements for speaker correction, and then listening position (far-field) measurements for room correction.

4.2 CALIBRATION

The DEQX Calibrated™ filter is very flexible. Calibration can be limited to certain frequency areas and the amount of gain or cut can be limited as desired. Most importantly, DEQX Calibration™ will correct both magnitude and phase errors based on the measured response. Traditional EQ systems deal only with magnitude correction, which can result in a flat frequency response but leave the phase response in a state which still sounds unnatural.

4.3 Filtering

Once configured, DEQX Calibrated provides extremely low latency (no delay) filtering. This means that in a home theatre situation, the sound will remain synchronised with the images, as a complete suite of DEQX processing is completed in less than one half of a video frame.

4.4 Fine Tuning

The DEQX Calibrated filter can be fine tuned to account for personal tastes in frequency response. The fine tuning includes multiple bands of parametric EQ, further per-speaker time alignment (delay), and individual driver level tuning.

4.5 Calibration Software

Each DEQX processor includes the DEQX Basic Calibration Kit. The DEQXCal software, included with the Kit, guides the user through the installation process via a series of wizards and menus. Some prior understanding of equalisation, audio concepts and terminology is required for users wishing to do their own installation.

4.6 Limitations

Of course, DEQX Calibrated will not solve everyone's problems. Whilst steep crossovers will reduce distortion, a loudspeaker that is only capable of low output levels at certain frequencies will still distort at high levels at those frequencies even after DEQX Calibration. Nor will DEQX Calibration instantly turn a poor audio listening environment into a good one, if the problems are in the high frequencies.

It is a requirement that loudspeaker measurements are carried out in a specific way when running the DEQX software. The best results are achieved when measured in a large area, so that the room behaviour can be more easily removed. That said, the DEQX software is flexible, and can pre-process non-ideal measurements so that a useful calibration is still extracted.