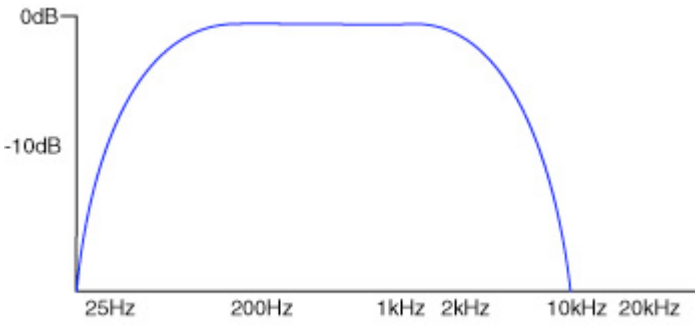
SURROUND SOUND REFERENCE LEVEL, EQUALISATION AND ALL THAT

Ideally, a sound system should have as flat a frequency response as possible for the listener.

Early cinema of the 1930s was anything but. There existed an overabundance of movie theatres with loudspeakers having poor high frequency response and an almost non-existent low frequency content. In addition, the film sound track itself suffered from a curtailed high frequency response and an inherent hiss. This was unacceptable to the movie production houses of the day as it impacted on the quality and popularity of their product. In 1938 the American Motion Picture Academy specified the response to the "worst case" acceptable response of the day, and the Academy Curve was born.



Academy Curve (not to scale)

Mixing stages and better theatres applied equalisation to dull down to the poor response of lesser exhibition facilities, ensuring that they were evaluating and crafting the soundtrack such as it would be heard by the public. Thus was laid the foundation for standardisation of sound-track presentation. The *Academy Curve,* also known as the *Normal Curve* was defined as flat 100 Hz - 1.6 kHz, down 7 dB at 40 Hz, down 10 dB at 5 kHz, and down 18 dB at 8 kHz. This was low-fi by any standard but it helped bring uniformity and also limit the distraction of high frequency hiss from the amplifier chains.

Naturally, speakers and other audio hardware improved as the decades marched on, but the optical soundtrack did not. Eliminating the Academy Curve would simply have exposed the inherent hiss which it masked, so it was retained.

When Dolby got involved with cinema sound in the 70s, the first thing they did was apply their noise reduction technology which was already well entrenched in the music industry. The 1971 film "A Clockwork Orange" demonstrated to the world an improved bandwidth and high frequency extension thanks to Dolby's A-Type noise reduction. As a result, the world was finally in a position to give up the Academy Curve . . . but not for a flat response.

Research done a decade earlier by C.P. and C.R. Boner defined a need for a "room EQ curve". They based this on the fact that a flat electro-acoustic frequency response in a large room sounds too bright on well-balanced program material. In simple terms we *perceive* sound in a large room to have more overall high frequencies and so need to back off the level.

Here was an opportunity to put into place an EQ curve which could go beyond simply dictating a flat response, but also address the psycho-acoustic differences of sound in large, medium, and small theatres and mixing facilities. The “X Curve” was born.

Unlike the Academy Curve before it, the X curve had nothing to do with high frequency capability in the playback chain. The X curve considered human perception issues.

The draw-backs of the draw-back curve

Cinema sound reproduction needs to deliver relatively consistent sound levels throughout the cinema from the front-most seats to the rear stalls. This is at odds with the inverse square law for sound propagation that would imply 20 – 30 db differences between the nearest and furthest customers. To achieve better uniformity, professional cinema sound systems use directional array loudspeakers that fire “over the top” of the listeners, using the seat tiering to bring the furthest customers more on-line with the array centre axis and so minimise the variations in Sound Pressure Level (SPL) for the customers in any seat. By this means, variations in SPL can be held to quite low levels, particularly in the mid and high frequency bands. He measured variation in SPL from front to back in the cinema is referred to as the “draw-back curve”.

The net result of this is that the overall mid to high frequency energy entering the (large) auditorium is lower than would be the case for true omni-directional loudspeakers. The X curve further attenuates this because of perceived boost from reverberation times for the mid to high frequencies.

For home cinema, the room is smaller and so the distances to the loudspeakers is less. The listener is further into the non-reverberant sound field and so reverberation is less of an influence but the response of the loudspeakers is no longer directionally tailored. More mid to high frequency energy enters the room.

The net result is that a home cinema system sounds brighter and needs high frequency response attenuation but not as severe as the X curve. Typically -20 dB at 20 kHz relative to a flat response is needed to make an omni-directional home cinema sound system sound un-bright (i.e. natural). Where the loudspeakers beam or concentrate sound towards the listener at high frequencies, the net result is a lower general sound level at mid to high frequencies throughout the room and so there is some need for additional level - but not much as the listener is well into the directional near-field of the speakers. The target of -20 dB at 20 kHz is still reasonably appropriate.

For almost 30 years, the X-Curve has provided the motion picture industry with a simple, valuable standard that ensures plausible (or at least justifiable) interchangeability of program material from one studio to the next, from studio to theatre, and from film to film, which takes into account the different *perceived* spectral response that different room sizes will have. It has also been adopted as a general guide for home cinema but should not be applied too rigorously.

How loud?

The concept of a calibrated playback level for mixing facilities and movie theatres was also pioneered at this time. A reference-level pink noise was fed through the audio chain and calibrated to 85 dBc (the "c" means the curve is "C Weighted" vs. "A Weighted" or “Linear”, referring to the way humans hear different frequencies). This corresponds to a maximum system SPL capability of 103 dB – representing the loudest (undistorted) sound the cinema could reproduce. With mixing facilities and theatres setting their master volume level by the same rule, the levels chosen by the film makers would be assured in the cinema.

In 1977, "Star Wars" brought us not only a new genre of science fiction film, but a new sound format that would impact motion pictures like no other. Dolby created a way to deliver four channel soundtracks optically on the film, addressing both cost and wear issues. When 'decoded' in the theatre, the system yielded three screen

channels and one surround. The thrill of multiple screen channels and surround sound was now within reach of the masses.

By the mid 80s, virtually every commercial release featured four-channel Dolby Stereo sound. Most of today's digital soundtrack releases keep the Dolby Stereo soundtrack as a backup to the digital track and to maintain compatibility with older cinemas.

Despite extreme rarity, the six-track magnetic sound on 70mm release prints of the 50's such as Oklahoma and South Pacific was not yet dead in the 70s. Dolby's involvement with cinema sound would lead to their refinement of the decades-old magnetic sound system.

It was observed that soundtrack artists had all but abandoned the middle two screen channels (left-centre and right-centre). Initially, in 1975, Dolby used those tracks to create a discrete subwoofer track, affectionately known in its day as the 'boom' track. By providing a separate segregated channel for a subwoofer system, the bass headroom of the system was greatly extended without taxing existing speakers and without any extraneous crossovers in the signal path. Then in 1979 they used the upper bandwidth of those same two tracks for stereo surrounds (left-surround and right-surround). The first feature film released with a *Dolby Stereo 70mm* soundtrack was the 1979 "Apocalypse Now".

Dolby continued to improve optical analogue sound with Dolby Stereo SR (Spectral Recording). Introduced in 1987 with "Robocop", it brought the improved fidelity of Dolby's SR noise reduction to cinema sound, extending the dynamic range by 3 dB. Because the process for calibrating playback level remained the same, the extra headroom was exactly that**:** more head room, meaning better dynamics during explosive scenes.

By 1990, digital audio was a household word. As has been a tradition since its inception, the cinema kept pace. In 1992, Dolby unveiled the next generation of motion picture sound with the release of "Batman Returns"**:** Dolby Digital (a.k.a. Dolby Stereo SR-D). Modelled on the Dolby Stereo 70 mm format, Dolby Digital featured three front screen channels, two rear surrounds, and one LFE (Low Frequency Effect) track. The sound was digital and all channels were discrete, meaning that each channel was a discrete or separate track in the recording, rather than the rear channel and front centre channel having to be extracted from two stereo channels like it was with Dolby Pro Logic.

What does all this mean for the home user?

Although rare, there are old, classic films with their mono soundtrack intact on home video. These could benefit from the use of the high frequency attenuation of the Academy Curve.

The soundtrack of virtually every movie today (be it Analogue or Digital) is crafted for playback over a system equalised to the X-Curve and set at the reference playback level.

Unfortunately there is no entry in the X-Curve table for rooms as small as most home theatres, and even if there were, like theatres and studios, you would need 1/3 octave equalisation on each channel to conform.

If you could get your hands on the X-Curve table, one corollary would become evident: As the rooms get smaller, less and less of a roll-off is defined, because as we said, smaller rooms have less of the reverb which the X-Curve addresses.

By the time we shrank a room down to typical home theatre size, we could argue that no X-Curve compensation was needed, contrary to popular opinion. There is not an

inherent overabundance of treble in motion picture soundtracks, *at least not due to the X-Curve*.

The factors which make home theatres sound subjectively "too bright" are varied and numerous, and no two home theatres are going to be the same in this regard. Home theatres are usually more reverberant than studios, cinemas, and dubbing stages, sustaining high frequency energy much longer, despite their small size. The speakers are often much brighter than properly set up theatre arrays. As we push the playback level up towards reference level, the problem gets worse. If a system is genuinely capable of high output with low distortion, then it is possible to recreate the "movie theatre experience" and enjoy it. Unfortunately, there are far, far fewer systems capable of this than we are lead to believe. Many so called high-end speakers and many receivers exhibit harmonic build-up at high output and tilt the spectrum in favour of the treble, further exacerbating the brightness problem. Just because you paid a lot for it does not necessarily mean it is suitable for reference level movie playback!

THX chose an X-Curve type filter since their listening tests show that it's more likely to produce an accurate correction more of the time. Of course, playback systems and film transfers are sufficiently variable that a single curve is never going to be "correct" all of the time. It is not intended as an absolutely correct interpretation. As with everything THX does, they look at the consumer's reality, the realities of the Consumer Electronics industry and the available technical tools, and then create a solution that makes rational sense for most consumers most of the time.

When Dolby Digital AC-3 was chosen as the audio format for HDTV, among other things a 2-bit flag called "Room Type" was included which was intended to define the type of mixing room used. The flag can be set as follows:

00 not indicated
01 large room, X-curve monitor
10 small room, flat room monitor
11 reserved

Contrary to some opinions, this flag is not meant to be a "Re-Eq on/off" signal. If the correct X-Curve were properly implemented in the studio, it should make no difference, at least in terms of EQ in a "good" home theatre (one which does not sound too bright).

Doing acoustic treatments in a home theatre is the equivalent of applying an X-Curve in a commercial or professional facility. While we don't have 1/3 octave EQ and a curve to guide us, once we have the loudspeakers we can still fine tune the room to sound "right". A little absorption here and some diffusion there can make a monumental difference in a room. After all, a modest system in a "good" room can easily out-perform expensive equipment in a bad one.

A word of caution to the home user. The overall result of the equalisation saga is that most home systems need a gradually falling high frequency response generally targeting a 20 dB drop in level at 20 kHz. This is not a license for manufacturers to avoid high frequency reproduction responsibilities by eliminating tweeters or performing other cost cutting actions, then using low grade amplifiers because the distortion cannot be heard. Some popular systems on the market have measured as low as 60 dB under their mid-band level at 20 kHz. This is unacceptable in modern equipment.

What about the low frequencies?

Reference level requires 103 dB at the listener for each surround channel. For a five channel surround system, this equates to an average SPL at the listener of approximately 111 dB for all channels working, assuming that the channels are each independent and do not reproduce correlated sound (this would be monophonic). There is usually only one sub-woofer. This needs to match the sound level at the listener but additionally must deliver the +10 dB of the LFE channel on movies. This equates to a maximum SPL of 121 dB at the listener for the low frequencies if the woofer handles all the low frequency content for the surround channels and the movie LFE channel. This should be achieved with inaudible distortion (less than 2% into the air). Very few home cinema systems can even approach this level of performance.

HuonLabs licenses the manufacture of reference level loudspeakers of this capability. These are the only sub-woofers in the world approved to TMH specification for use in post production Hollywood studios.

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