TMH QUALIFIED

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RDMI White Paper #27:

Bass Management

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Bass management is a critical function of monitoring multichannel audio programs. Several functions required of any multichannel audio monitoring system or product as well as the specific performance of the TMH MAPS Bass Manager are presented.

Topics covered include:

1. ***What is Bass Management?***
2. ***Why do I need bass management; I've got good monitor speakers?***
   Typical "full range" studio monitors roll off starts at 40 - 50 Hz.
   Acoustical summation is different than electrical summation.
3. ***What is the crossover frequency for bass management?***
   Best no more than 80 Hz in studios; possibly higher at home.
4. ***What are the right slopes for the crossover filters?***
5. ***What about LFE?***
   The .1 channel is not a "subwoofer channel".
6. ***What are the features of the TMH Bass Manager?***
   Only unit on the market that adjusts to individual loudspeakers.
   133 dB dynamic range main channel 123dB on sub - take that digital!
   Compact and designed by the person who gave 5.1 its name.
   LFE filter included
   TMH Qualified

1. What is Bass Management?

Bass management is a MONITOR system method of signal handling that ensures all the bass, recorded on all the tracks of a multichannel master, is heard reproduced in the control/mix room, in the correct proportion. In a bass managed system, bass below the cutoff frequency of the main monitors is combined and sent to one or more subwoofers. The purpose of this is to extend the bass response of the main channels downwards from the lower frequency limit of the main speakers to the lower frequency limit of the subwoofer—in many professional cases this will be by about one octave.

The fact is that it is increasingly difficult to localize sound as the frequency becomes lowest. Although we can "localize bass instruments" humans can not localize lower frequencies. Rather than localizing the actual fundamental frequencies of bass instruments, humans localize the higher frequency transients or harmonics. In a properly bass managed system these transients and harmonics localize where they are supposed to at or between the main channels. (see section 3 to learn the threshold frequency of localization)

If you localize the subwoofer in your system, it may be because the crossover frequency is too high or the slope of the crossover is not steep enough, or the subwoofer is producing distortion or "chuffing" noises at frequencies high enough by which you localize it.

The term bass management is sometimes erroneously applied to what is done to the bass before recording it on the medium. More about that later.

2. Why do I need bass management; I've got good monitor speakers?

a) because even very good "full range" monitors typically roll off below 40 to 50 Hz.

It is the very rarest of monitor that goes down to 20 Hz. A roll off at 40 Hz puts the sound from the loudspeaker down quite significantly at 25 Hz. The significance of this rolloff is made even greater because the equal loudness contours of hearing converge as frequency decreases below 400 Hz. This means that a 2 dB change at 40 Hz is like making a 4 dB change above 400 Hz, for instance. So bass management is done to ensure you are hearing the lowest octave of bass in its correct balance, in all of the channels.

If you do not use bass management, your monitor system will be bass shy, and you will tend to record too much bass. Someone playing your tracks back at home, where bass management is the overwhelming norm, will hear low frequencies go lower and play louder than you do in the studio, possibly to the point of overloading their system.

Among other problems that occur if you don't bass manage are not just frequency response balance effects, but your not hearing the lowest frequencies could mean that you miss faults in the recording, such as moving stage scenery (happened to a very famous producer in an awards show mix), hearing the conductor tap time on the podium (happened during the multichannel remix of a valuable classical music performance from the vault), and so forth.

b) because electrical summation and acoustic summation produce different results.

Bass management *electrically* combines the bass from all of the channels together. Even if you had full range monitors, with say a subwoofer spliced to each of the five or more main channels, you would then be hearing an *acoustical* summation of the multichannel bass in your room. The two levels, acoustically summed or electrically summed, could be very different. Let's say front and surround channels are out-of-phase with each other. Then electrically they will cancel, but acoustically, depending on where you are standing, you may hear them sum (the room standing wave adds its own phase shifts!). Thus you might hear bass in your studio that would be completely canceled out at home (happened to a famous DVD-V production that had to be recalled).

3. What is the crossover frequency for bass management?

It could be anywhere in the range from 25 Hz to over 100 Hz, depending on the loudspeakers. As the frequency gets higher, there is more likelihood of separately localizing the subwoofer. Eighty Hz is two standard deviations below the mean frequency for the most sensitive listener to the most sensitive program material for hearing the subwoofer separately, so is widely used in home systems. Those that use a higher frequency, such as some "home-theater-in-a-box" systems should be considered a compromise on localization.

For Pros, the *crossover* frequency should be no higher than 80 Hz, and most importantly, it should match that of the main speakers in use, so that the smoothest response is obtained. In general it is a requirement of bass management systems either to be devoted to one or a small range of known loudspeakers, or to be adjustable in frequency. (The TMH Bass Manager is adjustable from 25 Hz to 80 Hz, and, so far as we know, is the only one available that is adjustable.)

Note that the crossover frequency is different from the bandwidth of the LFE channel, explained below.

4. What are the right slopes for the crossover filters?

Interestingly, the high-pass filter (low cut) removing the out-of-band bass (from the point of view of the main speakers) should be 12 dB/octave, and the low-pass filter (high cut) removing the higher frequency components from the subwoofer output should be 24 dB/octave. What? Not the same? How can this be?

Well, the main speakers have a rolloff too, and when the 12 dB/octave filter is set to the same frequency as their low-frequency 3-dB corner we get an overall 24 dB/octave response, down 6 dB at the crossover frequency. The electrical low-pass 24 dB/octave filter dominates the response of the subwoofer (without it most subs would go happily up to 1 kHz or more) so much that it is the response to be considered. Thus we have two 24 dB/octave filters with their 6 dB corner (note not 3 dB) at the crossover frequency: a classic Linkwitz-Riley acoustical alignment proved in practice in very critical loudspeaker designs. (Note this is not the arbitrary LR4 you find in electronics, but instead acoustical LR4 as intended by Linkwitz. The thing most often called an LR4 is not! Again, this is according to Linkwitz.)

5. What about LFE?

LFE is a distinct, low-frequency only track (the 0.1 channel) destined to be played back over the available facilities of the end user system. Usually this means over a subwoofer. LFE by definition has a 10 dB level stagger—turned down 10 dB on the medium, and turned up 10 dB in playback—all to provide 10 dB more headroom than that of one main channel. This was the rationale for LFE in the first place: to add low-frequency headroom to help follow the equal loudness contours. This means that it takes more energy in the low bass to sound equally as loud as the midrange, and if a medium distorted with a flat overload characteristic vs. frequency, it would seem (to humans) to overload first in the bass. By following the equal loudness contours, a more uniform overload vs. frequency characteristic is obtained for human listeners.

The bandwidth of LFE is 120 Hz. This frequency does not depend on the frequency of the crossover between the main loudspeakers and the subwoofer, which may be 40 Hz in the same system, for instance.

The 0.1 LFE channel is the same thing as the "subwoofer channel" in movie theater systems, but for other professional environments things are more complicated. LFE is a distinct channel, and sent to the subwoofer. But in a bass managed system the lowest octave of the main channels is also sent to the subwoofer, to extend the bass downwards by, say, an octave. So the subwoofer does the duties for all 5.1 or more channels at the lowest frequencies, and LFE up to 120 Hz.

On the production side, what to send to LFE is always a question. It was developed for the headroom purposes described above. The footfall of a dinosaur belongs there, as does a cannon shot in the *1812 Overture.* It may in fact not be needed for a lot of music, but moving content from the main channels to LFE does help low-frequency headroom. So the fundamental of bass guitar could belong there, but the harmonics belong in the main channels, or else the bass guitar will lose its bite upon being mastered to a X.1 channel medium.

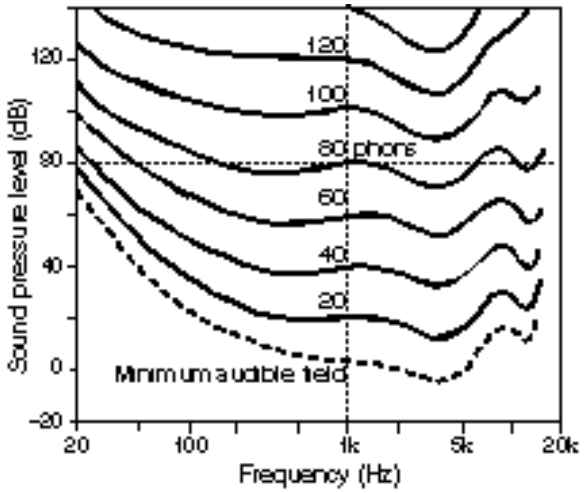
6. What are the features of the TMH Bass Manager?

• Adjustable 12 db/octave high pass filters on the five main channels. Continuously variable from 25 Hz to 80 Hz, with a detent at 50 Hz, the most common 3 dB corner frequency for monitors. The detent is coincident with a tap on the control that electrically defines the center of the range for greater accuracy. There is very little circuitry involved, and the resulting dynamic range exceeds 130 dB! This makes it better than the best a/d and d/a converters.

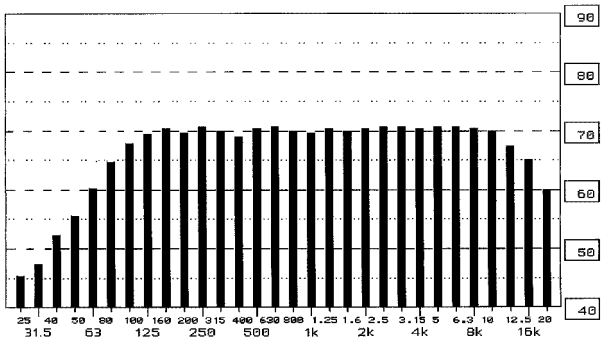
• Adjustable 24 dB/octave low pass filter on the summed subwoofer output of the main channels. Stepped in 1/3 octave steps from 25 Hz to 80 Hz (25, 31.5, 40, 50, 63, 80 Hz). The stepped control here offers greater conformity to the desired response curve for the higher-order (4th) filter topology than could be obtained from a continuously variable control.

• LFE filter is a 7th order low pass, simulating the digital filter that will be applied in mastering. It is switchable in and out so that you can see the effect that the mastering will have on the LFE content. The topology is an FDNR ladder filter for low sensitivity to component variations.

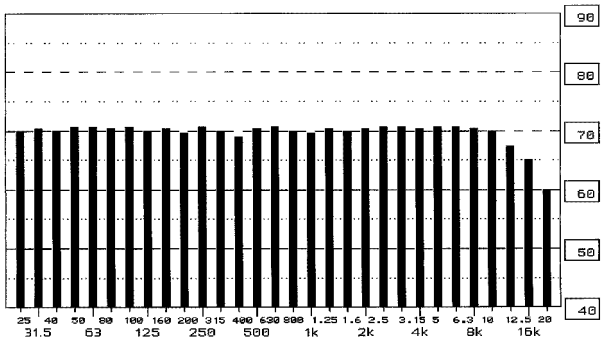
• The inputs and outputs are unbalanced. A balanced box is available to provide superior balancing when needed. Rather than saddle all units in the MAPS series with the cost of correctly balanced circuitry, we decided to make the balanced box another member of the group of MAPS products, so that a number of MAPS units can be cascaded, then wrapped within the balanced structure. While it would have been possible to equip the Bass Manager with the typical cheap one op amp balanced input, and inverter output circuit and call it balanced, this would not do for us due to problems in their real world use. Among these is poor rejection of hum under real world conditions where the source impedance in the two legs of the balanced line are unequal, and producing 6 dB different output level when confronted with balanced or unbalanced inputs following the box.



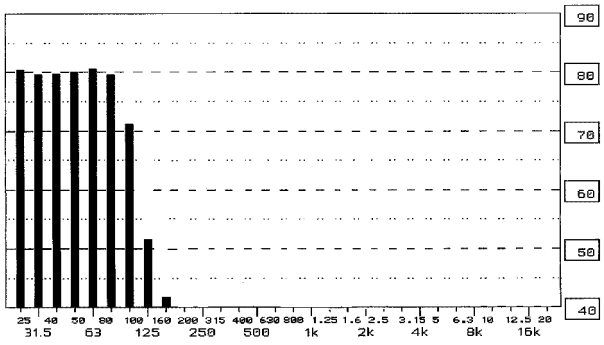
1. Equal loudness contours of hearing, sound pressure level in dB re 20 $\mu N / m^2$ (0 dB SPL is about the threshold of hearing) vs. frequency in Hz, from ISO 226. These curves show that at no level is the sensation of loudness flat with frequency; more energy is required in the bass to sound equally as loud as the mid-range.



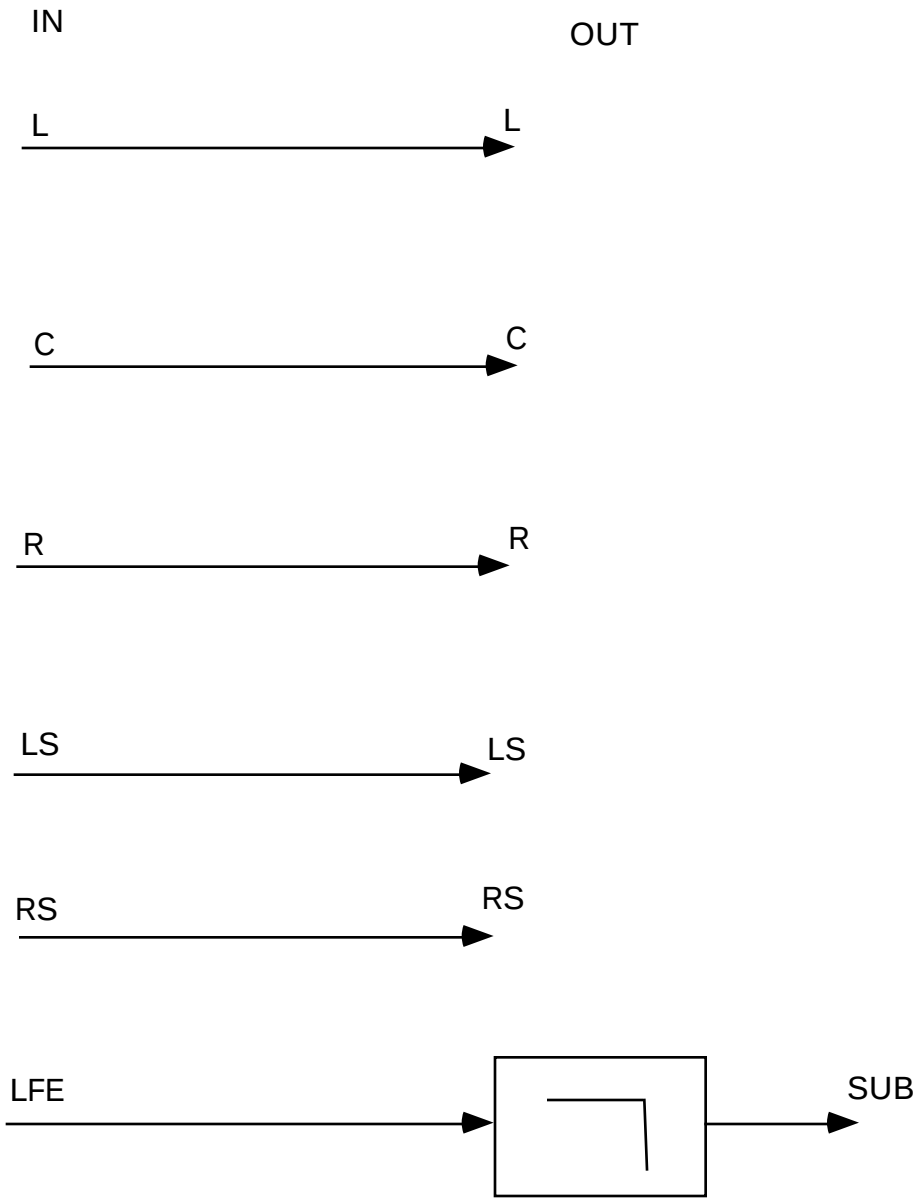
2. 1/3-octave band spectrum analyzer display showing one main channel level vs. frequency. The low-frequency rolloff is typical of a home system; a professional system might rolloff starting about an octave lower. The high-frequency rolloff will be explained in a future article. Note the average mid-band 1/3-octave level is about 70 dB SPL. All of these bands added together make up a level of about 83 dB SPL.



3. 1/3-octave band spectrum analyzer display showing level vs. frequency of a main channel spliced to a subwoofer. This is one of the jobs of bass management—to extend the low frequency limit on each of the main channels by applying the correct signal to one or more subwoofers.



4 . 1/3-octave band spectrum analyzer display showing level vs. frequency of a properly aligned LFE channel playing over the same subwoofer as used in Fig. 3. The level of pink noise on the medium is the same as for Fig. 3, but the reproduction level is +10 dB of “in band gain.”



5. Block schematic diagram of 5.1 channel systems without bass management. This is typical of most film dubbing stages and television mixing rooms. Although the main channels are “wide range,” they typically roll off below 40 Hz, so the very lowest frequencies are attenuated in the main channels. This can lead to not hearing certain problems, covered in the text. The anti-aliasing low-pass filter in the LFE channel is included in media encoders, such as those by Dolby and DTS. If your studio does not have an encoder, then this function must be performed by a filter that simulates the encoder one.

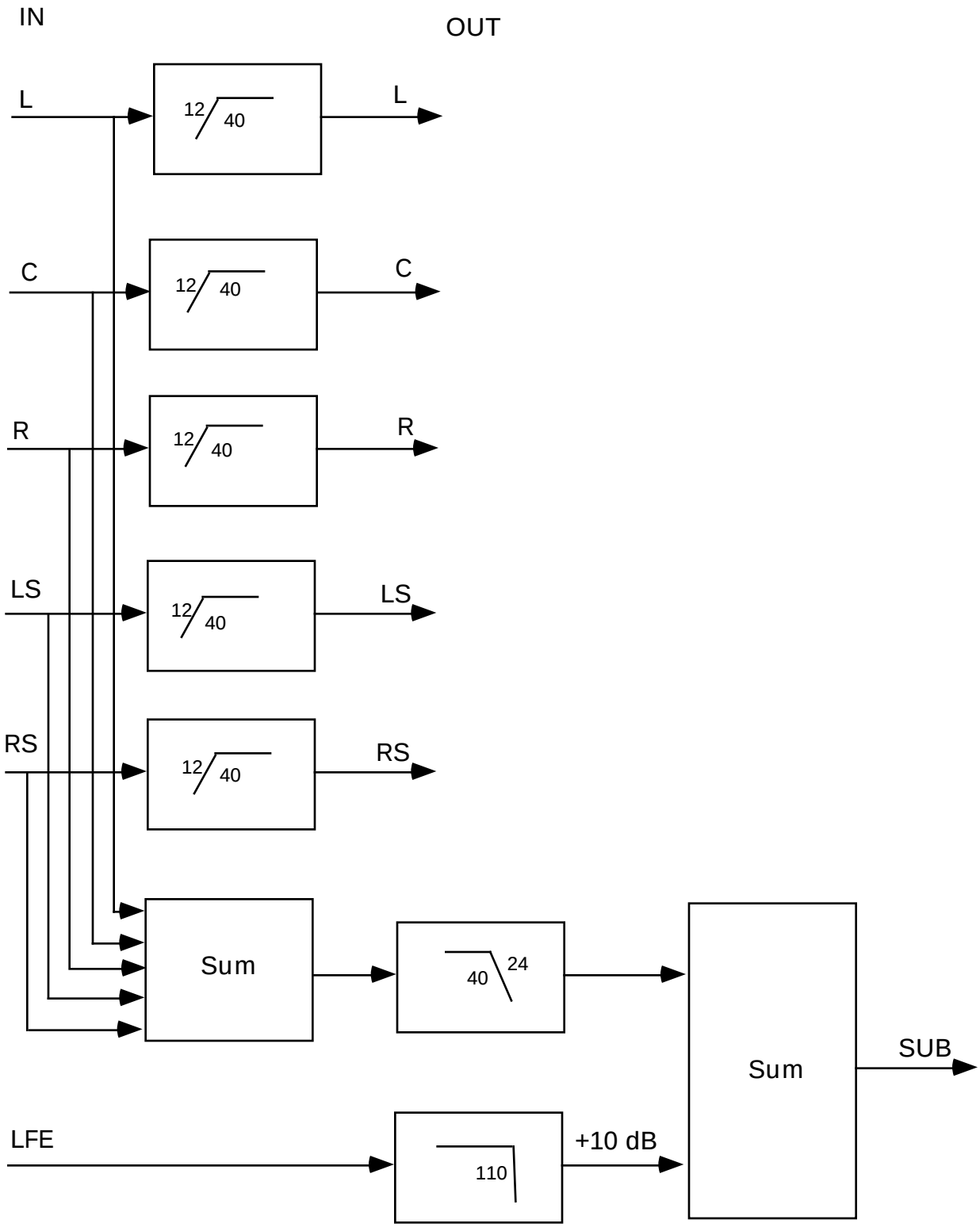


Figure 6. Block diagram of a bass management system, with typical characteristics for pro audio shown. High-pass filters in each of the main channels are complemented by a low-pass filter in the subwoofer feed, considering the effects of the loudspeaker responses, so that each of the channels is extended downwards in frequency with a

flat acoustical response. Note that this requires five matched bandwidth loudspeakers. The LFE channel is low-pass filtered with an anti-aliasing filter, which may be part of the encoding process or be simulated in monitoring, with its level summed into the bass extension of the main channels at +10 dB relative to one main channel.