HDMI audio and De-embedding/Decoding/Down-mixing

There is a lot of misinformation about this topic, even more so now that HDMI carrying 4K/UHD with HD Audio and 3D surround sound is becoming common. So let's try to remove the confusion by first considering how audio is sent as part of an HDMI connection.

HDMI Audio: Bitstream or PCM?

Many source devices, such as Blu-ray Players and STB (Set Top Boxes), have an audio output setting for their HDMI port that allows a choice of Bitstream or PCM (Pulse Code Modulation) format to suit the equipment it is connected to.

Bitstream is a serial digital signal that contains two or more channels of audio. It is very similar to the signal used by S/PDIF optical or co-axial ports (Sony/Philips Digital Interface Format) but because it is transported by HDMI it can far exceed the S/PDIF bandwidth of just 640kbps.

While S/PDIF bandwidth is sufficient for uncompressed 2-channel stereo or compressed 5.1 surround sound (Dolby Digital or DTS encoding) any higher quality surround sound formats (HD Audio or 3D Audio) that need more bandwidth must always use an HDMI connection.

PCM (Pulse Code Modulation) is the general term for a lossless digital audio format. Because it is not compressed it needs more bandwidth than lossy encoded formats, but has the advantage that the receiving device does not need to decode the audio for playback. HDMI 1.4 can send up to 8 channels of PCM audio (sufficient for 7.1 surround sound) , while HDMI 2.0 can send up to 32.

What happens when you choose either setting?

The Bitstream Option

If you select Bitstream as the HDMI audio output setting of your Blu-ray Disc player, the player will bypass its own internal Dolby and DTS audio decoders and send the un-decoded signal to your HDMI-connected AV Receiver. With this setting, the AV Receiver must do all the audio decoding of the incoming signal.

As a result the AV Receiver can display Dolby, Dolby TrueHD, DTS, DTS-HD Master Audio, Dolby Atmos, DTS:X, etc. as appropriate on its front panel display depending on which type of bitstream signal is being decoded.

The PCM Option

If you set the Blu-ray Disc player to output audio as PCM, the player will perform the audio decoding internally of all Dolby/Dolby TrueHD and DTS/DTS-HD Master Audio contained on the disc and send the decoded audio signal in uncompressed multi-channel PCM format to your AV Receiver. As a result, your AV Receiver will not have to perform any additional audio decoding before the audio is sent through the amplifier section and the speakers. With this option, the AV Receiver will display the term "PCM", "Multi-channel", or something similar, on its front panel display.

Why a Choice?

With either Bitstream or PCM the audio quality should be the same, so why do you need a choice?

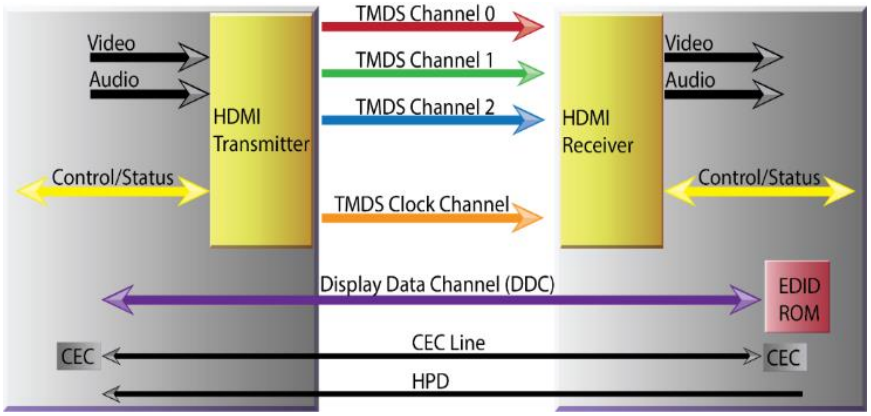
One reason involves access to secondary soundtracks, such as audio commentaries, descriptive audio, or other supplementary audio tracks stored on the disc. If access to these audio features is important to you, then the PCM audio output option must be used as then the secondary audio is

mixed with the main soundtrack in the player so you can hear it. (If you select bitstream output, then you won't hear this secondary audio).

Another reason involves system designs that process the audio and video parts of the HDMI signal separately. For example a Blu-ray Disc player that must output surround sound and video to a home cinema room and stereo audio only to a multi-room audio system. In such cases the audio portion of the HDMI signal must be extracted and converted from digital surround sound to analogue stereo. A process that will differ depending on the choice of bitstream or PCM audio format.

De-embedder

An HDMI audio de-embedder is a device that has an HDMI input and usually an HDMI output to act as a pass through. Internally the electronics reads the digital audio information, performs digital to analogue conversion and outputs stereo audio, usually as Left & Right phono sockets. If the HDMI audio is in 2-channel PCM format, then this process is straight forward. However. If the HDMI audio is in multi-channel PCM format, then such a simple de-embedder will still work but only for the Left & Right PCM channels, with the remaining Centre, Surround & LFE channels omitted and hence unheard. The solution is to add an additional process to the de-embedder called downmixing.



HDMI sends audio and video data as a single stream

Downmixing

Reproducing 5.1 channels of audio through a lesser number of speakers requires a process called downmixing. Simply put, downmixing combines the Left, Right, Centre, Left surround, and Right surround channels in a logical manner to drive stereo, or mono, speakers.

The first rule of downmixing is to discard the LFE (Low Frequency Effects) channel. This channel (the .1 part of 5.1) only carries low frequency information, usually below 120Hz, that is of little use to stereo or mono speakers.

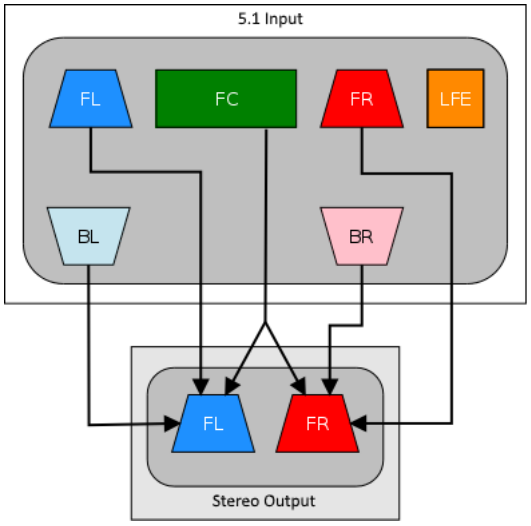
Creating a stereo downmix (LoRo), is very straightforward. The Left stereo output is created by adding Left, plus Centre (at -3dB), plus Left Surround (at -3dB), and the Right stereo output is created similarly by adding Right, plus Centre (at -3dB), plus Right Surround (at -3dB). This downmix equation is fully stereo and mono compatible with very few side effects.

However, creating a two-channel downmix of a 5.1 channel program that is matrix surround (LtRt) e.g. Dolby Pro Logic, etc. compatible is more difficult. The process is similar to downmixing to stereo except that the Left Surround and Right Surround channels are added together to create a single "S" Surround signal, which is then added out of phase (180 degrees) to the Left and Centre signal to create Lt, and added in phase (zero degrees) to Right and Centre signal to create Rt. These complex

phasing issues can cause problems with content that has similar signals in surround and front channels that can result in unwanted audio cancellations.

In practice most de-embedders, standalone or built-in to other distribution components (e.g. matrix switches etc.) that have a downmixing ability produce stereo only outputs, as matrix surround is rarely needed these days.

From the above we can see that de-embedding and downmixing to stereo is simplest when the HDMI audio is multi-channel PCM. But if the HDMI audio is in Bitstream format then an additional decoding process is needed.



LFE channel not included in downmix

Decoder

So far we have looked at HDMI audio de-embedding when the audio is sent as either 2-channel or multi-channel PCM but what if the audio is sent as a bitstream (e.g. Dolby Digital Plus, Dolby TrueHD or Atmos, etc.)? In this case the de-embedder must include an internal decoder that converts the extracted audio bitstream into 2, 6 or 8 PCM channels that can then be downmixed as before to an analogue stereo output. Note that older decoders are not able to decode the newest 3D audio formats i.e. Dolby Atmos and DTS:X.

There are also standalone Decoders that accept an HDMI input and decode the audio into 6 o8 analogue outputs. These can be useful if no AV Receiver is used and 6 active speakers are connected to the decoder.

HDMI version matters

Because HDMI is a multi-media signal, it is important to realise that even audio only components, like de-embedders, must be capable of handling the video part without loss or blocking. This means that the HDMI pass through bandwidth must be sufficient for the version of HDMI in use. For HDMI 1.4 or older then 10.2Gbps will be enough, but for HDMI 2.0 or newer then 18Gbps will be needed. Plus if the video content is HDCP copy protected, then the de-embedder must comply with the correct version of HDCP also. For HDMI 1.4 this usually means HDCP 1.4 but if the content is 4K/UHD Lite then it will need to be HDCP 2.2. For HDMI 2.0 it must be HDCP 2.2 capable.

Conclusion

The process of extracting audio from an HDMI signal is dependent on many things; the format sent by the source device, the format of the audio output needed, the bandwidth of the HDMI signal and its copy protection. Only when all of this information known can a product with the correct combination of de-embedding, decoding, dowmixing and HDMI pass-through be selected.