

AURO-3D in multi-channel WAV-files

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Introduction

The topic of the correct channel order for AURO-3D content in multi-channel WAV-files regularly comes up when new content is delivered for encoding or playback.

The easy 'workaround' was often to avoid the multichannel WAVs and use multi-mono files instead, where simply mono-files are used, and the channel is identified in the file-name.

This is how many DAWs handle multi-channel audio by default.

With the introduction of the Auro-3D Encoder Service (AES), support for multichannel WAV-files is now also available to encode and export an AURO-3D mix. Furthermore, these multichannel files are used to create FLAC-files, which are offered to consumers for download or via streaming platforms such as Artist Connection. Inside a FLAC-file, the same, correct channel order must be used as in a multichannel WAV-file.

Especially files using a 7.1-based layout must be handled carefully, as otherwise they will result in incorrect playback on the HDMI output of several devices.

In this white paper the different expected channel orders for AURO-3D and non-AURO-3D channel layouts are explained.

AURO-3D Channel Maps

The following Audio Channel Configurations are defined as they are supported by the AURO-3D Encoder Service software.

Note: The channel mask shown in the list below will be explained further.

(AURO-3D) Format	Channel Order	Mask
MONO	M	0x00004
2.0	L R	0x00003
QUAD	L R Ls Rs	0x00603
5.1	L R C LFE Ls Rs	0x0060F
7.1	L R C LFE Lb Rb Ls Rs	0x0063F
Auro 8.0	L R Ls Rs HL HR HLs HRs	0x2D603
Auro 9.1	L R C LFE Ls Rs HL HR HLs HRs	0x2D60F
Auro 10.1	L R C LFE Ls Rs T HL HR HLs HRs	0x2DE0F
Auro 11.1 (7.1+4H)	L R C LFE Lb Rb Ls Rs HL HR HLs HRs	0x2D63F
Auro 11.1	L R C LFE Ls Rs T HL HC HR HLs HRs	0x2FE0F
12.1.	L R C LFE Lb Rb Ls Rs HL HC HR HLs HRs	0x2F63F
Auro 13.1	L R C LFE Lb Rb Ls Rs T HL HC HR HLs HRs	0x2FE3F
22.2 - L R C LFE Lb Rb LC RC Cs Ls Rs T HL HC HR HLb HCs HRb LFE2 HLs HRs BtL BtC BtR		0xFFFFF

Some important remarks:

- Some of the channel orders may seem counter-intuitive, or are seemingly different from channel orders used by SMPTE or various DAWs, such as
 - o Back Surround channels are placed before the (Side) Surround channels for layouts using a 7.1-based surround layer. (Back on 5/6; Surround on 7/8)
 - o The Top channel, when present, comes before the Height Channels
 - o The Height Center channel, when present, is in between the Height Left and Height Right channels
- The channel layout for 22.2 deviates even further from the other layouts.

To better understand the origin of these channel orders, we will investigate the related file formats and standards in more detail in the following chapters.

MS WAVEX Channel Mask

The Microsoft WAVEX Channel Mask is used to identify the different channel roles used inside the WAV-files.

The following table shows the currently known channel labels, as provided by Microsoft on their website.

<https://learn.microsoft.com/en-gb/windows-hardware/drivers/ddi/ksmedia/ns-ksmedia-waveformatextensible?redirectedfrom=MSDN>.

Speaker Position	Flag Bit	AURO Label
SPEAKER_FRONT_LEFT	0x1	L
SPEAKER_FRONT_RIGHT	0x2	R
SPEAKER_FRONT_CENTER	0x4	C
SPEAKER_LOW_FREQUENCY	0x8	LFE
SPEAKER_BACK_LEFT	0x10	Lb
SPEAKER_BACK_RIGHT	0x20	Rb
SPEAKER_FRONT_LEFT_OF_CENTER	0x40	LC
SPEAKER_FRONT_RIGHT_OF_CENTER	0x80	RC
SPEAKER_BACK_CENTER	0x100	Cs
SPEAKER_SIDE_LEFT	0x200	LS
SPEAKER_SIDE_RIGHT	0x400	RS
SPEAKER_TOP_CENTER	0x800	T
SPEAKER_TOP_FRONT_LEFT	0x1000	HL
SPEAKER_TOP_FRONT_CENTER	0x2000	HC
SPEAKER_TOP_FRONT_RIGHT	0x4000	HR
SPEAKER_TOP_BACK_LEFT	0x8000	HLs / HLb (22.2)
SPEAKER_TOP_BACK_CENTER	0x10000	HCs
SPEAKER_TOP_BACK_RIGHT	0x20000	HRs / HRb (22.2)

Some observations and deviations from what is generally assumed:

- Only 18 channels are defined. Not all channels of a 22.2 configuration are defined, but all of the AURO-3D channels (up to Auro 13.1) are, by using the TOP_BACK channel IDs for the Height Surround channels.
- The Back channels are always before the Surround signals.
- The Top channel comes first, before the Height channels.
- The Height Surround channels are labeled TOP_BACK, while in the AURO-3D configurations these are rather considered as TOP_SIDE. Nevertheless, these channels can be used for the Height Surround channels in all AURO-3D configurations. This will lead to a possible conflict when introducing the actual Height Back channels in 22.2 when analyzing the WAVEX channel mask. However, for the actual channel order, this does not make a difference.
- The Height channels follow an L-C-R order for both Front and Back.

The only format that does not fit in this scheme is 22.2, since not all channels are defined, and the channel order will need to be different from the standard 22.2 layout. To maintain the highest compatibility with the definitions above, the following channel IDs are used (as also supported by FFmpeg, see further).

Speaker Position	Flag Bit (non-WAVEX)	AURO Label
SPEAKER_LOW_FREQUENCY_2	0x40000	LFE2
SPEAKER_TOP_SIDE_LEFT	0x80000	HLs (22.2)
SPEAKER_TOP_SIDE_RIGHT	0x100000	HRs (22.2)
SPEAKER_BOTTOM_FRONT_LEFT	0x200000	BtL
SPEAKER_BOTTOM_FRONT_CENTER	0x400000	BtC
SPEAKER_BOTTOM_FRONT_RIGHT	0x800000	BtR

By combining the different channel IDs, the actual format inside the WAV-file can be reconstructed, using the channel masks shown in the table above (as explained here: https://learn.microsoft.com/en-gb/windows-hardware/drivers/ddi/ksmedia/ns-ksmedia-ksaudio_channel_config).

Another explanation on the Microsoft WAVEX channel order can be found here: <https://learn.microsoft.com/en-us/windows-hardware/drivers/audio/mapping-stream-formats-to-speaker-configurations>

However, it is also possible to not use this channel mask and create WAV-files with completely random channel configurations, leading to potentially wrong, or at least

ambiguous, channel layouts as a result. This can result in wrong encodes and incorrect playback in several devices downstream, such as media players using the Android TV OS.

FLAC Channel Order

According to the FLAC specification, the channel order is directly and uniquely defined by the number of channels (up to 8). (<https://www.xiph.org/flac/format.html>)

Where defined, the channel order follows SMPTE/ITU-R recommendations. The assignments are as follows:

Number of channels	Channel Order
1	M
2	L R
3	L R LFE
4	L R Ls Rs
5	L R C LFE Cs
6	L R C LFE Ls Rs
7	L R C LFE Cs Ls Rs
8	L R C LFE Lb Rb Ls Rs

Clearly, the FLAC channel order is the same as used in the WAVEX specification. Again, it is important to notice the fact that the Back Surround channels are placed before the (Side) Surround channels for a 7.1 configuration.

FFMPEG

FFmpeg also shows various pre-configured channel layouts (`ffprobe -layouts`). Here are some of the interesting layouts to investigate, including 22.2.

Format	Channel Order
Mono	M
stereo	L R
quad(side)	L R Ls Rs
5.1(side)	L R C LFE Ls Rs
7.1	L R C LFE Lb Rb Ls Rs
22.2	L R C LFE Lb Rb LC RC Cs Ls Rs T HL HC HR HLb HCs HRb LFE2 HLs HRs BtC BtL BtR

This confirms the channel order used in the WAVEX and FLAC formats for all formats, with the exception of 22.2, where the additional Height Back channels now are used instead of the Height Surround channels, pushing the Height Surround channels further in the channel order.

SMPTE

To make matters very confusing, one of the main standards for channel orders used in production systems, the SMPTE standard, follows a different scheme for 7.1-based layouts: (Side) Surround on 5/6 and Back (or Rear Surround) on 7/8. This is typically the channel order supported by various DAWs or rendering tools.

Note, however, that this routing is not directly related to a file-standard, such as WAVEX, or codec (FLAC, ITU-R). Some systems simply use this routing as a matter of convenience, not taking compatibility with consumer playback systems into account.

ADM-BWF

With the advent of the ADM-BWF format, which also supports configurations of object-based audio, the channel-order of the channel-based beds is defined using metadata, which reduces the risk for mismatches to a minimum. Several profiles are defined to provide a more controlled usage of the vast capabilities of this standard.

Currently, the most-used profile, as supported by several DAWs, rather uses the SMPTE-defined channel-order for 7.1-based formats, instead of the WAVEX channel order: *LeftSideSurround* / *RightSideSurround* / *LeftRearSurround* / *RightRearSurround*.

ADM-BWF support in the AURO-3D Encoder Service therefore also uses this channel order for maximum compatibility with existing ADM profiles.

Film?

And, yes, there are even more variations on this theme. One of the most-used DAWs uses the so-called “Film” channel order, which uses the L-C-R approach, and places the LFE-channel last. This order is currently NOT supported for AURO-3D WAV-files.

Based on these observations, and to maintain with industry practice, multichannel files for AURO-3D will follow the channel orders as indicated at the beginning of this document. The advice is therefore to always carefully check channel orders in multichannel files before exporting or importing them.

For more information or remarks, please contact the AURO-3D support team (support@auro-3d.com).