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INTERNATIONAL STANDARD

Digital audio – Interface for non-linear pcm encoded audio bitstreams applying IEC 60958 –
Part 14: Non-linear PCM bit streams according to the AC-4 format

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DIGITAL AUDIO – INTERFACE FOR NON-LINEAR PCM ENCODED AUDIO BITSTREAMS APPLYING IEC 60958 –

Part 14: Non-linear PCM bit streams according to the AC-4 format

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International Standard IEC 61937-14 has been prepared by technical area 4: Digital system interfaces and protocols, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

The text of this International Standard is based on the following documents:

CDV	Report on voting
100/2723/CDV	100/2932/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 61937, under the general title *Digital audio – Interface for non-linear PCM encoded audio bitstreams applying IEC 60958* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

DIGITAL AUDIO – INTERFACE FOR NON-LINEAR PCM ENCODED AUDIO BITSTREAMS APPLYING IEC 60958 –

Part 14: Non-linear PCM bit streams according to the AC-4 format

1 Scope

This part of IEC 61937 describes the method to convey non-linear PCM bit streams encoded according to the AC-4 format.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60958 (all parts), *Digital audio interface*

IEC 61937-1:2007, *Digital audio interface for non-linear PCM encoded audio bitstreams applying IEC 60958 – Part 1: General*

IEC 61937-1:2007/AMD1:2011, *Digital audio interface for non-linear PCM encoded audio bitstreams applying IEC 60958 – Part 1: General*

IEC 61937-2, *Digital audio interface for non-linear PCM encoded audio bitstreams applying IEC 60958 – Part 2: Burst Information*

ETSI TS 103 190 v.1.1.1, 2014, *Digital Audio Compression (AC-4) Standard*

3 Terms, definitions and abbreviated terms

For the purpose of this standard, the following definitions and abbreviations apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
AC-4 frame
AC-4 sync frame, as specified in Annex A

3.2
audio frame rate
number of AC-4 audio frames per second, indicated by the value of the *frame_rate_index* AC-4 bit stream parameter as specified in ETSI TS 103 190

3.3
base sampling frequency
sampling frequency of the AC-4 bit stream, indicated by the value of the *fs_index* AC-4 bit stream parameter as specified in ETSI TS 103 190

Note 1 to entry: AC-4 supports base sampling frequencies of 44.1 and 48 kHz only.

3.4
latency
delay time of an external audio decoder to decode an AC-4 data burst defined as the sum of two values: the receiving delay time and the decoding delay time

3.5
fractional frame rates
fractional audio frame rates supported by AC-4

Note 1 to entry: These frame rates are written in shorthand notation, as specified in Table 1.

Table 1 – Shorthand notation for fractional frame rates

Fractional AC-4 audio frame rate (fps)	Shorthand version
$24 \times {}^{1\,000}/_{1\,001}$	23,976
$30 \times {}^{1\,000}/_{1\,001}$	29,97
$48 \times {}^{1\,000}/_{1\,001}$	47,952
$60 \times {}^{1\,000}/_{1\,001}$	59,94
$120 \times {}^{1\,000}/_{1\,001}$	119,88
${}^{12\,000}/_{512}$	23,438
${}^{11\,025}/_{512}$	21,533

3.6 Abbreviated terms

ETSI	European Telecommunication Standards Institute
fps	frames per second
HBR	high bit rate
IEC	International Electrotechnical Commission
LD	low delay
UIMSBF	unsigned integer, most significant bit first

4 Mapping of the audio bit stream on to IEC 61937-1

4.1 General

The coding of the bit stream and data-burst is in accordance with IEC 61937-1, IEC 61937-1:2007/AMD1 and IEC 61937-2, including field names such as "Pc", "Pa" and "R".

4.2 AC-4 burst-info

The 16-bit burst-info contains information about the data which will be found in the data-burst (see Table 2).

Table 2 – Fields of burst-info

Bits of Pc	Data-type value (bits 0 – 4)	Data-type value (bits 5 – 6)	Contents	Reference point R	Repetition period of data-burst in IEC 60958 frames
0 – 6	1 – 23	According to IEC 61937-2			
	24	0	AC-4	bit 0 of Pa	See Table 4
		1	AC-4 HBR4	bit 0 of Pa	See Table 10
		2	AC-4 HBR16	bit 0 of Pa	See Table 16
		3	AC-4 LD	bit 0 of Pa	See Table 22
	25 – 31	According to IEC 61937-2			
7 – 15	According to IEC 61937-1				

5 Format of AC-4 data-bursts

5.1 General

This clause specifies the AC-4 audio data-burst. Specific properties such as reference points, repetition period, the method of filling stream gaps, and decoding latency are specified.

The decoding latency (or delay), indicated for the data-type, should be used by the transmitter to schedule data-bursts as necessary to establish synchronization between picture and decoded audio.

5.2 Pause data-burst

The pause data-burst for AC-4 is given in Table 3.

Table 3 – Repetition period of the Pause data-bursts

Data-type of audio data-burst	Repetition period of pause data-burst	
	Mandatory	Recommended
AC-4	-	3
AC-4 HBR4	-	4
AC-4 HBR16	-	4
AC-4 LD	-	3

5.3 Audio data-burst

5.3.1 The AC-4 data

An AC-4 bit stream consists of a sequence of AC-4 frames. The AC-4 data-burst is headed with a burst-preamble, followed by the burst-payload. The structure of the AC-4 data-burst is shown in Figure 1. The data-type bits 0-4 of an AC-4 data-burst is 24, and the data-type bits 5-6 is 0. When AC-4 data is being transmitted, the transmission device shall ensure that both the data-type bits 0-4 and data-type bits 5-6 values are set correctly. Additionally, the receiving device shall utilize both the data-type bits 0-4 and data-type bits 5-6 values to ensure that the content of the data-burst is correctly identified as AC-4.

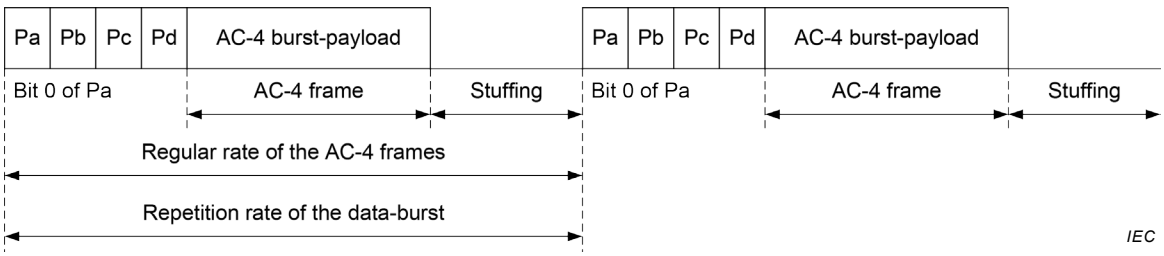

Figure 1 – AC-4 data-burst

The data-type bits 0-4 dependent information for AC-4 is specified in Table 4.

Table 4 – Data-type-dependent information for AC-4

Bits of Pc LSB..MSB	Value	Meaning
8 – 11	See Table 7 and Table 8	Repetition period of the data-burst in IEC 60958 frames
12	Reserved	

The AC-4 burst-payload shall always contain a single AC-4 frame. The transmission device shall ensure that the AC-4 burst-payload is constructed only from a single complete AC-4 frame. It is prohibited to transmit a single AC-4 frame using multiple data-bursts. The length of the AC-4 data-burst will depend on the encoded bit rate (which determines the AC-4 frame length). The AC-4 bit stream is specified in ETSI TS 103 190.

The reference point of an AC-4 data-burst is bit 0 of Pa. The repetition period of the AC-4 data-burst shall be defined by the base sampling frequency (indicated by the value of the *fs_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) and frame rate (indicated by the value of the *frame_rate_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) of the AC-4 audio bit stream. The IEC 60958 frame rate shall be equal to the base sampling frequency of the AC-4 bit stream. As AC-4 supports multiple audio frame rates that match commonly used video frame rates, the transmission device shall ensure that the selected AC-4 data-burst repetition rate is equal to the duration of the AC-4 frame, as specified in Table 5.

Table 5 – AC-4 base sampling frequency, AC-4 audio framerate and corresponding AC-4 data-burst repetition period

AC-4 base sampling frequency	AC-4 audio frame rate (fps)	AC-4 data-burst repetition period in IEC 60958 frames
48 kHz	23,976	2 002
	24	2 000
	25	1 920
	29,97	1 601 / 1 602 (see Table 6)
	30	1 600
	47,952	1 001
	48	1 000
	50	960
	59,94	800 / 801 (see Table 6)
	60	800
	100	480
	119,88	400 / 401 (see Table 6)
	120	400
	23,438	2 048
44,1 kHz	21,533	2 048

For AC-4 audio frame rates of 29,97, 59,94 and 119,88 fps, the duration of an AC-4 audio frame does not correspond to an integer number of IEC 60958 frames. To ensure that precise time alignment is maintained between the AC-4 data-burst and the AC-4 audio frames at these frame rates, the repetition period of data-bursts varies so that over a sequence of 5 data bursts, five AC-4 data-bursts$_{0...4}$ are time-aligned with the corresponding 5 audio frames, as specified in Table 6.

Table 6 – AC-4 data-burst sequence and repetition period variance at 29,97, 59,94 and 119,88 fps

AC-4 audio frame rate	Repetition periods for AC-4 data-burst sequence in IEC 60958 frames				
	Data-burst$_0$	Data-burst$_1$	Data-burst$_2$	Data-burst$_3$	Data-burst$_4$
29,97 fps	1 602	1 601	1 602	1 601	1 602
59,94 fps	801	801	800	801	801
119,88 fps	400	401	400	401	400

The value of bits 8 to 11 Pc shall indicate the repetition period of the AC-4 data-burst. The interpretation of these bits is dependent on the base sampling frequency of the AC-4 bit stream and the IEC 60958 frame rate, as specified in Table 7 and Table 8.

Table 7 – AC-4 data-burst: meaning of Pc bits 8 to 11 at an IEC 60958 frame rate of 48 kHz

Value	Meaning	
0	Repetition period of the AC-4 data-burst in IEC 60958 frames	2 002
1		2 000
2		1 920
3		1 601 / 1 602 (see Table 6)
4		1 600
5		1 001
6		1 000
7		960
8		800 / 801 (see Table 6)
9		800
10		480
11		400 / 401 (see Table 6)
12		400
13		2 048
14, 15	Reserved	

Table 8 – AC-4 data-burst: meaning of Pc bits 8 to 11 at an IEC 60958 frame rate of 44,1 kHz

Value	Meaning	
0 – 12	Reserved	
13	Repetition period of the AC-4 data-burst in IEC 60958 frames	2 048
14, 15	Reserved	

The units of burst-length shall be in bits. The maximum size of an AC-4 burst-payload is dependent on the repetition rate of the data-burst, and is specified in Table 9. The maximum burst-length values shown in Table 9 assume a provision for two IEC 60958 frames for padding between bursts.

Table 9 – Maximum burst-length values per AC-4 data-burst repetition period

Encoded AC-4 base sampling frequency / IEC 60958 frame rate	Repetition period of the AC-4 data-burst in IEC 60958 frames	Maximum burst-length of the AC-4 data-burst in bits
48 kHz	2 002	63 936
	2 000	63 872
	1 920	61 312
	1 601 / 1 602	51 104 / 51 136
	1 600	51 072
	1 001	31 904
	1 000	31 872
	960	30 592
	800 / 801	25 472 / 25 504
	800	25 472
	480	15 232
	400 / 401	12 672 / 12 704
	400	12 672
	2 048	65 408
44,1 kHz	2 048	65 408

5.3.2 Latency of the AC-4 decoder

The latency of an AC-4 decoder is defined as the sum of the receiving delay time and decoding delay time.

The receiving delay time is the time taken to receive the complete AC-4 burst-payload, and is dependent on the encoded bitrate and audio frame rate of the AC-4 bit stream. For the purposes of maintaining synchronization with video, it is recommended that a constant value of receiving delay time for each audio frame rate and corresponding repetition period is assumed. This value is calculated based on the maximum possible size of an AC-4 burst-payload, and is equal to the time occupied by the duration of the AC-4 data-burst in IEC 60958 frames at the IEC 60958 frame rate.

The decoding delay time is equal to the time occupied by 3 195 PCM samples at the AC-4 base sampling frequency (see Figure 2).

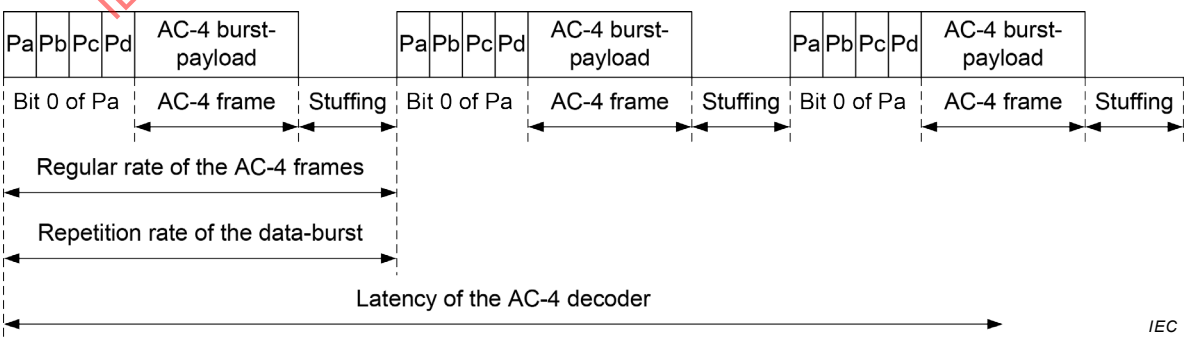

Figure 2 – Latency of AC-4 decoding

It is recommended that pause data-bursts are used to fill stream gaps in the AC-4 bit stream as described in IEC 61937-1, and that pause data-bursts be transmitted with a repetition

period of 3 IEC 60958 frames, except when other repetition periods are necessary to fill the precise stream gap length (which may not be a multiple of 3 IEC 60958 frames), or to meet the requirement on burst spacing (refer to IEC 61937-1:2007, 6.3.3).

When a stream gap in an AC-4 stream is filled by a sequence of pause data-bursts, the Pa of the first pause data-burst shall be located one data-burst repetition period following the Pa of the previous AC-4 frame. It is recommended that the sequence(s) of pause data-bursts that fill the stream gap should continue from this point up to (as close as possible considering the 3 IEC 60958 frame length of the pause data-burst) the Pa of the first AC-4 data-burst which follows the stream gap.

The gap-length parameter contained in the pause data-burst is intended to be interpreted by the AC-4 decoder as an indication of the number of decoded PCM samples that are missing (due to the resulting audio gap).

Some AC-4 decoders may be capable of "concealing" audio gaps. The indication of the audio gap length (gap-length), which may be included in the payload of the pause data-burst, allows the decoder to know how long an audio gap will need to be concealed, and thus allow the decoder to optimize the concealment process for the actual audio gap length. AC-4 decoders will most easily conceal audio gaps that have a length equal to an audio frame. Thus, audio gap-length values that match the duration of the AC-4 audio frame rate (2 002, 2 000, 1 920, etc. IEC 60958 frames) are strongly preferred, and transmitters should provide stream gaps that represent audio gaps with this granularity.

5.3.3 The AC-4 HBR4 data

When the required transmission rate for AC-4 data exceeds the maximum data rate supported by the AC-4 data burst, the AC-4 HBR4 data-type is used instead. An AC-4 HBR4 bit stream consists of a sequence of AC-4 frames. The AC-4 HBR4 data-burst is headed with a burst-preamble, followed by the burst-payload. The structure of the AC-4 HBR4 data-burst is shown in Figure 3. The data-type bits 0-4 of an AC-4 HBR4 data-burst is 24, and the data-type is 1. When AC-4 HBR4 data is being transmitted, the transmission device shall ensure that both the data-type bits 0-4 and data-type bits 5-6 values are set correctly. Additionally, the receiving device shall utilize both the data-type bits 0-4 and data-type bits 5-6 values to ensure that the content of the data-burst is correctly identified as AC-4 HBR4.

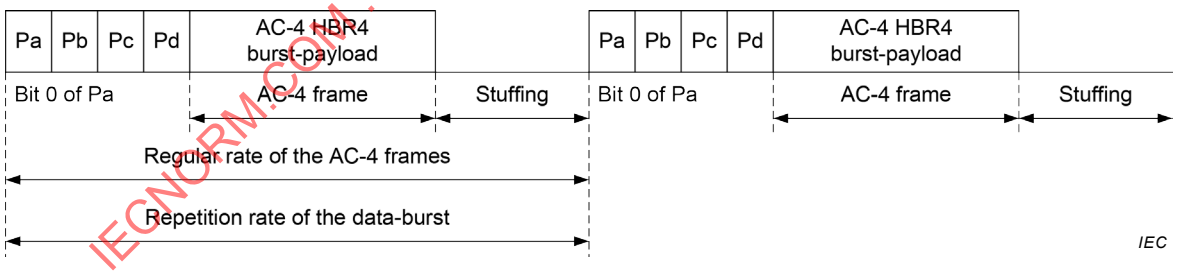

Figure 3 – AC-4 HBR4 data-burst

The data-type-dependent information of bits 8-12 for AC-4 HBR4 is specified in Table 10.

Table 10 – Data-type-dependent information for AC-4 HBR4

Bits of Pc LSB..MSB	Value	Meaning
8 – 11	See Table 13 and Table 14	Repetition period of the data-burst in IEC 60958 frames
12	Reserved	

The AC-4 HBR4 burst-payload shall always contain a single AC-4 frame. The transmission device shall ensure that the AC-4 HBR4 burst-payload is constructed only from a single complete AC-4 frame. It is prohibited to transmit a single AC-4 frame using multiple data-bursts. The length of the AC-4 HBR4 data-burst will depend on the encoded bit rate (which determines the AC-4 frame length). The AC-4 bit stream is specified in ETSI TS 103 190.

The reference point of an AC-4 HBR4 data-burst is bit 0 of Pa. The repetition period of the AC-4 HBR4 data-burst shall be defined by the base sampling frequency (indicated by the value of the *fs_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) and frame rate (indicated by the value of the *frame_rate_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) of the AC-4 audio bit stream. The IEC 60958 frame rate shall be four times the base sampling frequency of the AC-4 bit stream. As AC-4 supports multiple audio frame rates that match commonly used video frame rates, the transmission device shall ensure that the selected AC-4 HBR4 data-burst repetition rate is equal to the duration of the AC-4 frame, as specified in Table 11.

Table 11 – AC-4 base sampling frequency, AC-4 audio frame rate and corresponding AC-4 HBR4 data-burst repetition period

AC-4 base sampling frequency	IEC 60958 frame rate	AC-4 audio frame rate (fps)	AC-4 HBR4 data-burst repetition period in IEC 60958 frames
48 kHz	192 kHz	23,976	8 008
		24	8 000
		25	7 680
		29,97	6 404 / 6 408
		30	6 400
		47,952	4 004
		48	4 000
		50	3 840
		59,94	3 200 / 3 204
		60	3 200
		100	1 920
		119,88	1 600 / 1 604
		120	1 600
		23,438	8 192
44,1 kHz	176,4 kHz	21,533	8 192

For AC-4 audio frame rates of 29,97, 59,94 and 119,88 fps, the duration of an AC-4 audio frame does not correspond to an integer number of IEC 60958 frames. To ensure that precise time alignment is maintained between the AC-4 HBR4 data-burst and the AC-4 audio frames at these frame rates, the repetition period of data-bursts varies so that over a sequence of 5 data bursts, five AC-4 HBR4 data-bursts$_{0...4}$ are time-aligned with the corresponding 5 audio frames, as specified in Table 12.

Table 12 – AC-4 HBR4 data-burst sequence and repetition period variance at 29,97, 59,94 and 119,88 fps

AC-4 audio frame rate (fps)	Repetition periods for AC-4 HBR4 data-burst sequence in IEC 60958 frames				
	Data-burst$_0$	Data-burst$_1$	Data-burst$_2$	Data-burst$_3$	Data-burst$_4$
29,97	6 408	6 404	6 408	6 404	6 408
59,94	3 204	3 204	3 200	3 204	3 204
119,88	1 600	1 604	1 600	1 604	1 600

The value of bits 8 to 11 Pc shall indicate the repetition period of the AC-4 HBR4 data-burst. The interpretation of these bits is dependent on the base sampling frequency of the AC-4 bit stream and the IEC 60958 frame rate, as specified in Table 13 and Table 14.

Table 13 – AC-4 HBR4 data-burst: meaning of Pc bits 8 to 11 at an IEC 60958 frame rate of 192 kHz

Value	Meaning	
0	Repetition period of the AC-4 data-burst in IEC 60958 frames	8 008
1		8 000
2		7 680
3		6 404 / 6 408 (see Table 12)
4		6 400
5		4 004
6		4 000
7		3 840
8		3 200 / 3 204 (see Table 12)
9		3 200
10		1 920
11		1 600 / 1 604 (see Table 12)
12		1 600
13		8 192
14, 15	Reserved	

Table 14 – AC-4 HBR4 data-burst: meaning of Pc bits 8 to 11 at an IEC 60958 frame rate of 176,4 kHz

Value	Meaning	
0 – 12	Reserved	
13	Repetition period of the AC-4 data-burst in IEC 60958 frames	8 192
14, 15	Reserved	

The units of burst-length shall be in bytes. The maximum size of an AC-4 HBR4 burst-payload is dependent on the repetition rate of the data-burst, and is specified in Table 15. The maximum burst-length values shown in Table 15 assume a provision for two IEC 60958 frames for padding between bursts.

Table 15 – Maximum burst-length values per AC-4 HBR4 data-burst repetition period

AC-4 base sampling frequency	IEC 60958 frame rate	Repetition period of the AC-4 HBR4 data-burst in IEC 60958 frames	Maximum burst-length of the AC-4 HBR4 data-burst in bytes
48 kHz	192 kHz	8 008	32 016
		8 000	31 984
		7 680	30 704
		6 404 / 6 408	25 600 / 25616
		6 400	25 584
		4 004	16 000
		4 000	15 984
		3 840	15 344
		3 200 / 3 204	12 784 / 12800
		3 200	12 784
		1 920	7 664
		1 600 / 1 604	6 384 / 6400
		1 600	6 384
		8 192	32 752
44,1 kHz	176,4 kHz	8 192	32 752

5.3.4 Latency of the AC-4 HBR4 decoder

The latency of an AC-4 HBR4 decoder is defined as the sum of the receiving delay time and decoding delay time.

The receiving delay time is the time taken to receive the complete AC-4 HBR4 burst-payload, and is dependent on the encoded bitrate and audio frame rate of the AC-4 bit stream. For the purposes of maintaining synchronization with video, it is recommended that a constant value of receiving delay time for each repetition period be assumed. This value is calculated based on the maximum possible size of an AC-4 HBR4 burst-payload, and is equal to the time occupied by the duration of the AC-4 HBR4 data-burst in IEC 60958 frames at the IEC 60958 frame rate.

The decoding delay time is equal to the time occupied by 3 195 PCM samples at the AC-4 base sampling frequency, which corresponds to 12 780 IEC 60958 frames at the IEC 60958 frame rate (see Figure 4).

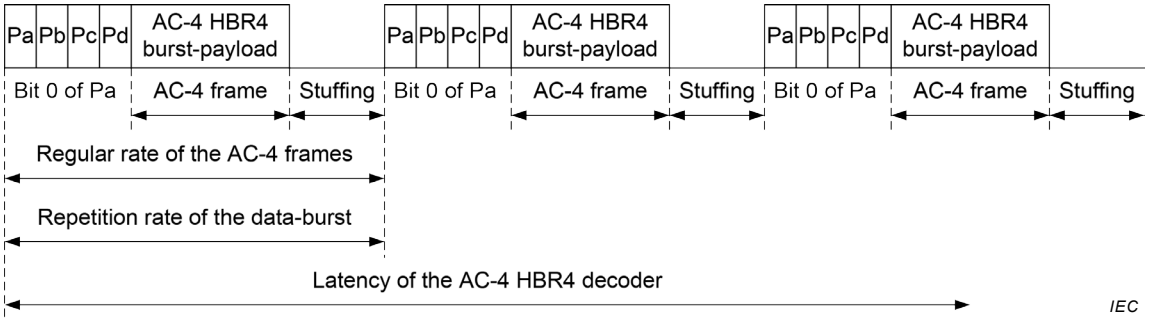

Figure 4 – Latency of AC-4 HBR4 decoding

It is recommended that pause data-bursts are used to fill stream gaps in the AC-4 HBR4 bit stream as described in IEC 61937-1, and that pause data-bursts be transmitted with a repetition period of 4 IEC 60958 frames, except when other repetition periods are necessary to fill the precise stream gap length (which may not be a multiple of 4 IEC 60958 frames), or to meet the requirement on burst spacing (refer to IEC 61937-1:2007, 6.3.3).

When a stream gap in an AC-4 HBR4 bit stream is filled by a sequence of pause data-bursts, the Pa of the first pause data-burst shall be located one data-burst repetition period following the Pa of the previous AC-4 frame. It is recommended that the sequence(s) of pause data-bursts which fill the stream gap should continue from this point up to (as close as possible considering the 4 IEC 60958 frame length of the pause data-burst) the Pa of the first AC-4 HBR4 data-burst which follows the stream gap.

The gap length parameter contained in the pause data-burst is intended to be interpreted by the AC-4 decoder as an indication of the number of decoded PCM samples which are missing (due to the resulting audio gap). The gap-length parameter is intended to indicate the number of decoded PCM audio samples that are missing (due to the resulting audio gap).

Some AC-4 decoders may be capable of "concealing" audio gaps. The indication of the audio gap length (gap-length), which may be included in the payload of the pause data-burst, allows the decoder to know how long an audio gap will need to be concealed, and thus allow the decoder to optimize the concealment process for the actual audio gap length. AC-4 decoders will most easily conceal audio gaps that have a length equal to an audio frame. Thus, audio gap-length values that match the duration of the AC-4 audio frame rate (8 008, 8 000, etc. IEC 60958 frames) are strongly preferred, and transmitters should provide stream gaps that represent audio gaps with this granularity.

5.3.5 The AC-4 HBR16 data

When the required transmission rate for AC-4 data exceeds the maximum data rate supported by the AC-4 HBR4 data burst, the AC-4 HBR16 data-type is used instead. An AC-4 HBR16 bit stream consists of a sequence of AC-4 frames. The AC-4 HBR16 data-burst is headed with a burst-preamble, followed by the burst-payload. The structure of the AC-4 HBR16 data-burst is shown in Figure 5. The data-type bits 0-4 of an AC-4 HBR16 data-burst is 24, and the data-type bits 5-6 is 2. When AC-4 HBR16 data is being transmitted, the transmission device shall ensure that both the data-type bits 0-4 and data-type bits 5-6 values are set correctly. Additionally, the receiving device shall utilize both the data-type bits 0-4 and data-type bits 5-6 values to ensure that the content of the data-burst is correctly identified as AC-4 HBR16.

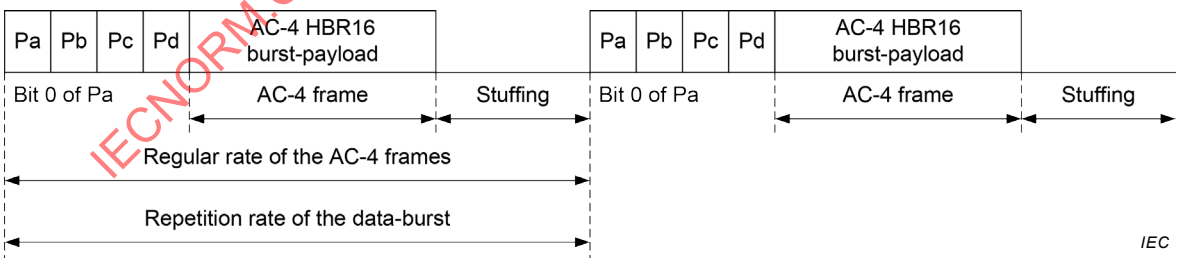

Figure 5 – AC-4 HBR16 data-burst

The data-type-dependent information of bits 8-12 for AC-4 HBR16 is specified in Table 16.

Table 16 – Data-type-dependent information for AC-4 HBR16

Bits of Pc LSB..MSB	Value	Meaning
8 – 11	See Table 19 and Table 20	Repetition period of the data-burst in IEC 60958 frames
12	Reserved	

The AC-4 HBR16 burst-payload shall always contain a single AC-4 frame. The transmission device shall ensure that the AC-4 HBR16 burst-payload is constructed only from a single complete AC-4 frame. It is prohibited to transmit a single AC-4 frame using multiple data-bursts. The length of the AC-4 HBR16 data-burst will depend on the encoded bit rate (which determines the AC-4 frame length). The AC-4 bit stream is specified in ETSI TS 103 190.

The reference point of an AC-4 HBR16 data-burst is bit 0 of Pa. The repetition period of the AC-4 HBR16 data-burst shall be defined by the base sampling frequency (indicated by the value of the *fs_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) and frame rate (indicated by the value of the *frame_rate_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) of the AC-4 audio bit stream. The IEC 60958 frame rate shall be sixteen times the base sampling frequency of the AC-4 bit stream. As AC-4 supports multiple audio frame rates that match commonly used video frame rates, the transmission device shall ensure that the selected AC-4 HBR16 data-burst repetition rate is equal to the duration of the AC-4 frame, as specified in Table 17.

Table 17 – AC-4 base sampling frequency, AC-4 audio frame rate and corresponding AC-4 HBR16 data-burst repetition period

AC-4 base sampling frequency	IEC 60958 frame rate	AC-4 audio frame rate (fps)	AC-4 HBR16 data-burst repetition period in IEC 60958 frames
48 kHz	768 kHz	23,976	32 032
		24	32 000
		25	30 720
		29,97	25 616 / 25 632
		30	25 600
		47,952	16 016
		48	16 000
		50	15 360
		59,94	12 800 / 12 816
		60	12 800
		100	7 680
		119,88	6 400 / 6 416
		120	6 400
		23,438	32 768
44,1 kHz	705,6 kHz	21,533	32 768

For AC-4 audio frame rates of 29,97, 59,94 and 119,88 fps, the duration of an AC-4 audio frame does not correspond to an integer number of IEC 60958 frames. To ensure that precise time alignment is maintained between the AC-4 HBR16 data-burst and the AC-4 audio frames at these frame rates, the repetition period of data-bursts varies so that over a sequence of 5 data bursts, five AC-4 HBR16 data-bursts$_{0...4}$ are time-aligned with the corresponding 5 audio frames, as specified in Table 18.

Table 18 – AC-4 HBR16 data-burst sequence and repetition period variance at 29,97, 59,94 and 119,88 fps

AC-4 audio frame rate (fps)	Repetition periods for AC-4 HBR16 data-burst sequence in IEC 60958 frames				
	Data-burst$_0$	Data-burst$_1$	Data-burst$_2$	Data-burst$_3$	Data-burst$_4$
29,97	25 632	25 616	25 632	25 616	25 632
59,94	12 816	12 816	12 800	12 816	12 816
119,88	6 400	6 416	6 400	6 416	6 400

The value of bits 8 to 11 Pc shall indicate the repetition period of the AC-4 HBR16 data-burst. The interpretation of these bits is dependent on the base sampling frequency of the AC-4 bit stream and the IEC 60958 frame rate, as specified in Table 19 and Table 20.

Table 19 – AC-4 HBR16 data-burst: meaning of Pc bits 8 – 11 at an IEC 60958 frame rate of 768 kHz

Value	Meaning	
0	Repetition period of the AC-4 data-burst in IEC 60958 frames	32 032
1		32 000
2		30 720
3		25 616 / 25 632 (see Table 18)
4		25 600
5		16 016
6		16 000
7		15 360
8		12 800 / 12 816 (see Table 18)
9		12 800
10		7 680
11		6 400 / 6 416 (see Table 18)
12		6 400
13		32 768
14, 15	Reserved	

Table 20 – AC-4 HBR16 data-burst: meaning of Pc bits 8 to 11 at an IEC 60958 frame rate of 705,6 kHz

Value	Meaning	
0 – 12	Reserved	
13	Repetition period of the AC-4 data-burst in IEC 60958 frames	32 768
14, 15	Reserved	

The units of burst-length shall be in 8-byte units. If the AC-4 frame is not equal to an integer number of 8-byte units, the remaining bytes of the AC-4 HBR16 burst-payload shall be set to zero. The maximum size of an AC-4 HBR16 burst-payload is dependent on the repetition rate of the data-burst, and is specified in Table 21. The maximum burst-length values shown in Table 21 assume a provision for two IEC 60958 frames for padding between bursts.

NOTE AC-4 frame sizes are defined in units of bytes, but the size of an AC-4 HBR16 burst-payload (the value of Pd) is defined in 8-byte units. Consequently, it is possible that the length of an AC-4 frame that makes up the AC-4 HBR16 burst-payload may not equal an integer number of 8-byte units. The transmitter is expected to pad the additional bytes that follow the end of the AC-4 frame up to the end of the burst-payload length with zeros, and a receiver might receive a data-burst where the AC-4 frame itself ends before the indicated end of the burst-payload.

Table 21 – Maximum burst-length values per AC-4 HBR16 data-burst repetition period

AC-4 base sampling frequency	IEC 60958 frame rate	Repetition period of the AC-4 HBR16 data-burst in IEC 60958 frames	Maximum burst-length of the AC-4 HBR16 data-burst in 8-byte units
48 kHz	768 kHz	32 032	16 014
		32 000	15 998
		30 720	15 358
		25 616 / 25 632	12 806 / 12 814
		25 600	12 798
		16 016	8 006
		16 000	7 998
		15 360	7 678
		12 800 / 12 816	6 398 / 6 406
		12 800	6 398
		7 680	3 838
		6 400 / 6 416	3 198 / 3 206
		6 400	3 198
		32 768	16 382
44,1 kHz	705,6 kHz	32 768	16 382

5.3.6 Latency of the AC-4 HBR16 decoder

The latency of an AC-4 HBR16 decoder is defined as the sum of the receiving delay time and decoding delay time.

The receiving delay time is the time taken to receive the complete AC-4 HBR16 burst-payload, and is dependent on the encoded bitrate and audio frame rate of the AC-4 bit stream. For the purposes of maintaining synchronization with video, it is recommended that a constant value of receiving delay time for each repetition period be assumed. This value is calculated based on the maximum possible size of an AC-4 HBR16 burst-payload, and is equal to the time occupied by the duration of the AC-4 HBR16 data-burst in IEC 60958 frames at the IEC 60958 frame rate.

The decoding delay time is equal to the time occupied by 3 195 PCM samples at the AC-4 base sampling frequency, which corresponds to 51 120 IEC 60958 frames at the IEC 60958 frame rate (see Figure 6).

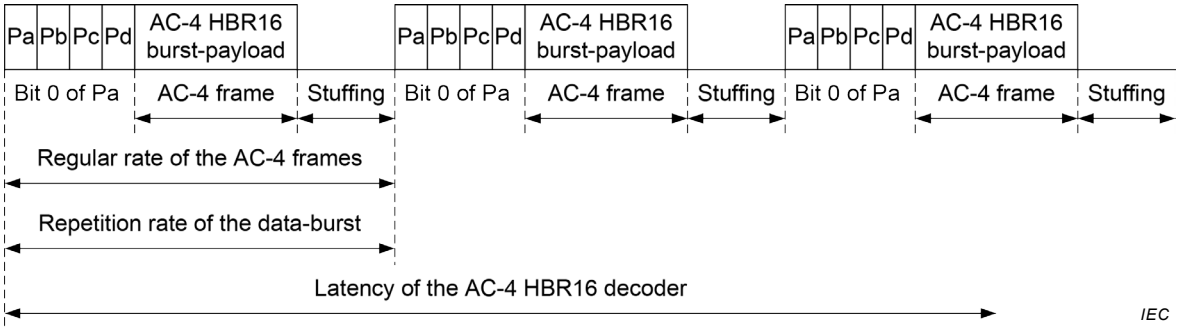

Figure 6 – Latency of AC-4 HBR16 decoding

It is recommended that pause data-bursts are used to fill stream gaps in the AC-4 HBR16 bit stream as described in IEC 61937-1, and that pause data-bursts be transmitted with a repetition period of 4 IEC 60958 frames, except when other repetition periods are necessary to fill the precise stream gap length (which may not be a multiple of 4 IEC 60958 frames), or to meet the requirement on burst spacing (refer to IEC 61937-1:2007, 6.3.3).

When a stream gap in an AC-4 HBR16 bit stream is filled by a sequence of pause data-bursts, the Pa of the first pause data-burst shall be located one data-burst repetition period following the Pa of the previous AC-4 frame. It is recommended that the sequence(s) of pause data-bursts, which fill the stream gap, should continue from this point up to (as close as possible considering the 4 IEC 60958 frame length of the pause data-burst) the Pa of the first AC-4 HBR16 data-burst which follows the stream gap.

The gap length parameter contained in the pause data-burst is intended to be interpreted by the AC-4 decoder as an indication of the number of decoded PCM samples which are missing (due to the resulting audio gap). The gap-length parameter is intended to indicate the number of decoded PCM audio samples that are missing (due to the resulting audio gap).

Some AC-4 decoders may be capable of "concealing" audio gaps. The indication of the audio gap length (gap-length), which may be included in the payload of the pause data-burst, allows the decoder to know how long an audio gap will need to be concealed, and thus allow the decoder to optimize the concealment process for the actual audio gap length. AC-4 decoders will most easily conceal audio gaps that have a length equal to an audio frame. Thus, audio gap-length values that match the duration of the AC-4 audio frame rate (32 032, 32 000 etc. IEC 60958 frames) are strongly preferred, and transmitters should provide stream gaps that represent audio gaps with this granularity.

5.3.7 The AC-4 LD data

An AC-4 LD bit stream consists of a sequence of AC-4 frames. The AC-4 LD data-burst is headed with a burst-preamble, followed by the burst-payload. The structure of the AC-4 LD data-burst is shown in Figure 7. The data-type bits 0-4 of an AC-4 LD data-burst is 24, and the data-type bits 5-6 is 3. When AC-4 LD data is being transmitted, the transmission device shall ensure that both the data-type bits 0-4 and data-type bits 5-6 values are set correctly. Additionally, the receiving device shall utilize both the data-type bits 0-4 and data-type bits 5-6 values to ensure that the content of the data-burst is correctly identified as AC-4 LD.

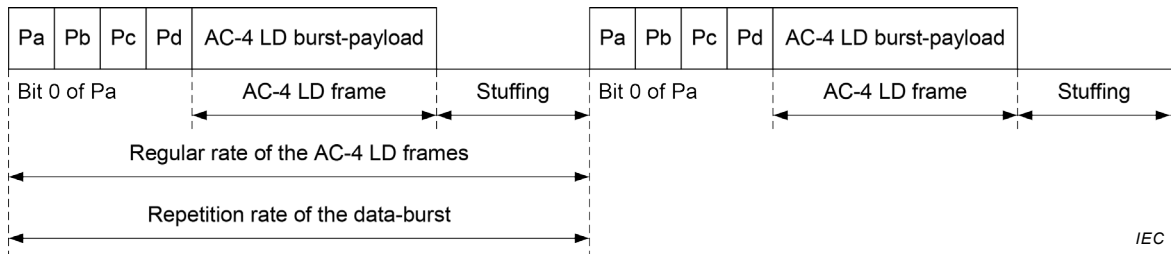

Figure 7 – AC-4 LD data-burst

The data-type bits 0-4 dependent information for AC-4 LD is specified in Table 22.

Table 22 – Data-type-dependent information for AC-4 LD

Bits of Pc LSB..MSB	Value	Meaning
8 – 11	See Table 25	Repetition period of the data-burst in IEC 60958 frames
12	Reserved	

The AC-4 LD burst-payload shall always contain a single AC-4 frame. The transmission device shall ensure that the AC-4 LD burst-payload is constructed only from a single complete AC-4 frame. It is prohibited to transmit a single AC-4 frame using multiple data-bursts. The length of the AC-4 LD data-burst will depend on the encoded bit rate (which determines the AC-4 frame length). The AC-4 bit stream is specified in ETSI TS 103 190.

The reference point of an AC-4 LD data-burst is bit 0 of Pa. The repetition period of the AC-4 LD data-burst shall be defined by the base sampling frequency (indicated by the value of the *fs_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) and frame rate (indicated by the value of the *frame_rate_index* AC-4 bit stream parameter as specified in ETSI TS 103 190) of the AC-4 audio bit stream. The IEC 60958 frame rate shall be equal to the base sampling frequency of the AC-4 bit stream, which for the AC-4 LD data-burst is limited to 48 kHz only. As AC-4 supports multiple audio frame rates that match commonly used video frame rates, the transmission device shall ensure that the selected AC-4 LD data-burst repetition rate is equal to the duration of the AC-4 frame, as specified in Table 23.

Table 23 – AC-4 base sampling frequency, AC-4 audio frame rate and corresponding AC-4 LD data-burst repetition period

AC-4 base sampling frequency	AC-4 audio frame rate (fps)	AC-4 LD data-burst repetition period in IEC 60958 frames
48 kHz	100	480
	119,88	400 / 401 (see Table 24)
	120	400
	187,5	256

For AC-4 LD audio frame rates of 119,88 fps, the duration of an AC-4 audio frame does not correspond to an integer number of IEC 60958 frames. To ensure that precise time alignment is maintained between the AC-4 data-burst and the AC-4 audio frames at these frame rates, the repetition period of data-bursts varies so that over a sequence of 5 data bursts, five AC-4 data-bursts$_{0...4}$ are time-aligned with the corresponding 5 audio frames, as specified in Table 24.