SCTE | STANDARDS

Digital Video Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 277 2022

Linear Contribution Encoding Specification

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Document Type: Specification

Document Tags:

☐ Test or Measurement	☐ Checklist	☐ Facility
☐ Architecture or Framework	☐ Metric	☒ Access Network
☐ Procedure, Process or Method	☒ Cloud	☐ Customer Premises

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Executive Summary

This document specifies the contents and format of contribution linear source media being provided from origination to a recipient for processing into a distribution format. This document defines a standardized ingest specification for linear content to be distributed across either IP/CDN or QAM delivery platforms. The goal in all included scenarios is to deliver the highest quality video available based on the originally produced content type, bit rate, and codec.

1.2. Scope

This specification has the goal of providing a consolidated set of requirements for content essence and related information from a content provider to a processing facility for subsequent delivery to a Content Delivery Network (CDN) or a QAM distribution plant. The formats are defined to obtain the best resultant quality across a number of distribution methods. This specification will initially only define the contribution linear feed.

This document specifies contribution formats. This document covers linear content and related components preparation for ingest. From the ingest point, content in this format can be used in multiple ways which are covered in other specifications. This document does not specify operational processes such as notifications and content delivery. Where notifications are expected in this document, it is expected other process-oriented documents will address this.

1.3. Document Lifecycle

This document is expected to evolve as audio, video, metadata, and associated technologies evolve. Figure 1 shows the potential roadmap for this document based on upcoming technologies.

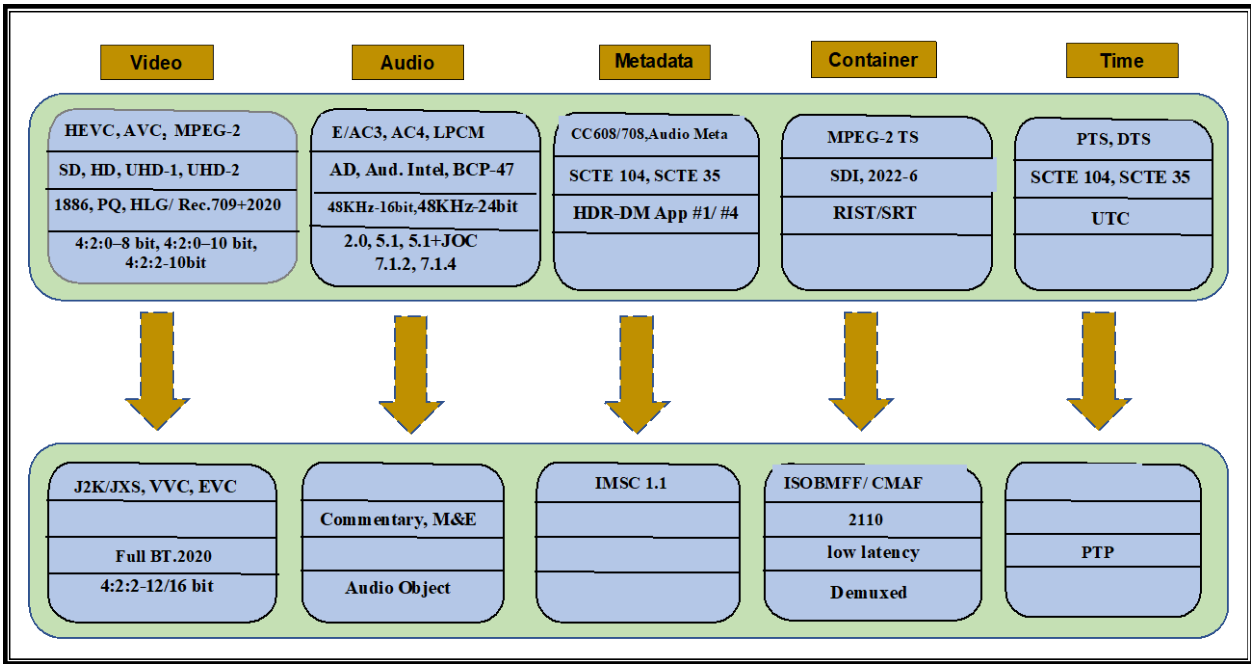

Figure 1 - Document Scope Lifecycle & Future Roadmap

Note: Captioning may also be embedded in the video.

1.4. Linear Contribution Reference Architecture

Linear sources should be self-contained, or otherwise logically or physically 'bundled' including all video, audio, text, and associated metadata to ensure that all necessary components are available for processing. An example of physical bundling is video, audio, secondary audio, content replacement signaling, and captions. External references *may* permit, for example, third-party metadata to be used with video and audio sources for enrichment and enhancement. These elements will be carried through the content transformation process and provided appropriately for the consuming device.

The diagram in Figure 2 represents the high-level Mezzanine file creation and flow. This specification will address the desired and acceptable Mezzanine file content and format. Content encoding, packaging, and delivery are out of scope of this specification.

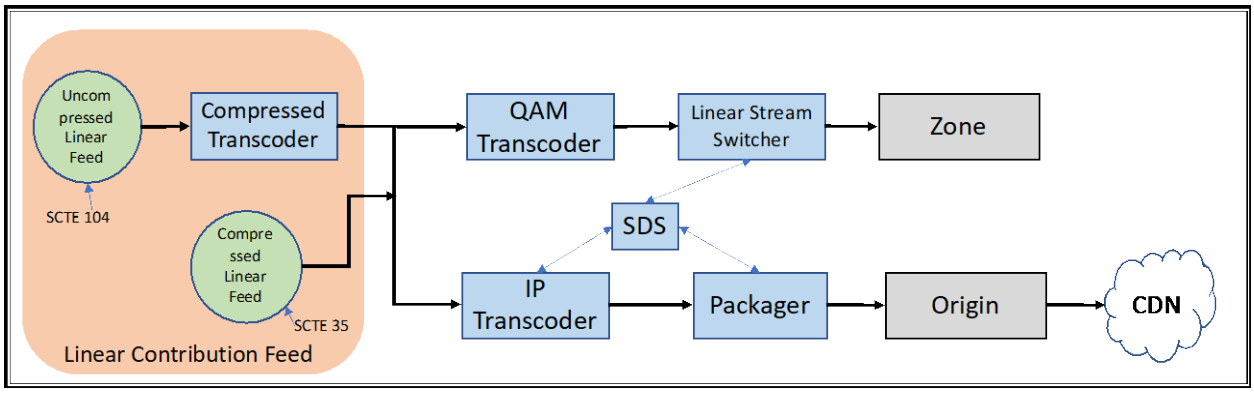

Figure 2 - High Level Architecture

1.5. Benefits

With the use of this document, content providers can reduce the number of mezzanine linear source media versions of their content which can be ingested by multiple recipients while adjusting to each individual recipients' network infrastructure. Without this document, content providers may need to provide many more versions of the contribution linear source media to reach a similar number of recipients.

1.6. Intended Audience

Content providers providing contribution linear media feeds to MVPD recipients intended for processing into a distribution format.

1.7. Areas for Further Investigation or to be Added in Future Versions

This specification will initially only define the contribution linear feed.

This specification will need to accommodate newer technologies that deliver improved media fidelity or experiences or optimize network delivery capacity and robustness.

Additionally, broadcaster feeds will be accommodated in future revisions. A broadcaster's feed differs from a linear contribution feed by being a non-dedicated off-air source at bit rates/ quality suitable for distribution feeds. The feed may also contain separately bundled media components received from different source points and would require time synchronization between these components.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

[SCTE 20] ANSI/SCTE 20 2017, Method for Carriage of Closed Captions and Non-Real Time Sampled Video.

[SCTE 35] ANSI/SCTE 35 2020, Digital Program Insertion Cueing Message for Cable.

[SCTE 54] ANSI/SCTE 54 2020, Digital Video Service Multiplex and Transport System for Cable Television.

[SCTE 104] ANSI/SCTE 104 2019a, Automation System to Compression System Communications Applications Program Interface (API).

[SCTE 128-1] ANSI/SCTE 128-1 2020, AVC Video Constraints for Cable Television Part 1: Coding.

[SCTE 128-2] ANSI/SCTE 128-2 2018, AVC Video Constraints for Cable Television Part 2: Transport.

[SCTE 172] ANSI/SCTE 172 2017, Constraints on AVC and HEVC Structured Video Coding for Digital Program Insertion.

[SCTE 187-1] ANSI/SCTE 187-1 2019, Stereoscopic 3D Formatting and Coding for Cable.

[SCTE 215-1] ANSI/SCTE 215-1 2020, HEVC Video Constraints for Cable Television Part 1-Coding.

[SCTE 215-1-1] ANSI/SCTE 215-1-1 2020b, HEVC Video Constraints for Cable Television Part 1-1 HDR.

[SCTE 215-2] ANSI/SCTE 215-2 2018, HEVC Video Constraints for Cable Television Part 2-Transport.

[SCTE 242-1] ANSI/SCTE 242-1 2017, Next Generation Audio Coding Constraints for Cable Systems: Part 1 – Introduction and Common Constraints.

[SCTE 242-2] ANSI/SCTE 242-2 2017, Next Generation Audio Coding Constraints for Cable Systems: Part 2 – AC-4 Audio Coding Constraints.

[SCTE 242-3] ANSI/SCTE 242-3 2017, Next Generation Audio Coding Constraints for Cable Systems: Part 3 – MPEG-H Audio Coding Constraints.

2.2. Standards from Other Organizations

[13818-1] ISO/IEC 13818-1:2020, Information technology - Generic coding of moving pictures and associated audio information: Systems.

[14496-10] ISO/IEC 14496-10:2020, Information technology - Coding of Audio-visual Objects. Part 10: Advanced Video Coding.

[23008-2] ITU-T Rec. H.265| ISO/IEC 23008-2:2021 – MPEG-H Part 2: High Efficiency Video Coding.

[23008-3] ISO/IEC 23008-3:2019: Information technology -- High efficiency coding and media delivery in heterogeneous environments – Part 3: 3D audio, ISO/IEC 23008-3:2019/Amendment 1:2019, ISO/IEC 23008-3:2019/Amendment 2:2020.

[23091-3] ISO/IEC 23091-3:2018, *Information technology — Coding-independent code-points — Part 3: Audio.*

[A/52] ATSC A/52:2018: Digital Audio Compression (AC-3) (E-AC-3) Standard, December 17, 2012.

[A/53, Part3] ATSC A/53, Part 3:2013: Digital Television Standard Part 3 – Service Multiplex and Transport Subsystem Characteristics.

[A/53, Part4] ATSC A/53, Part 4:2009: Digital Television Standard Part 4 – MPEG-2 Video System Characteristics.

[A/85] ATSC A/85:2021: Recommended Practice: Techniques for Establishing and Maintaining Audio Loudness for Digital Television.

[A/342-1] ATSC A/342 Part 1: 2021 “ Audio Common Elements”.

[A/342-2] ATSC A/342 Part 2:2021 “AC-4 System”.

[A/342-3] ATSC A/342 Part 3:2021, "MPEG-H System".

[CALM] FCC 11-84: Implementation of the Commercial Advertisement Loudness Mitigation (CALM) Act, May 27, 2011.

[CEP 3.0] ANSI/SCTE 254 2019 Content Encoding Profiles 3.0 Specification (Closed).

[CONTENT 3.0] MD-SP-CONTENTv3.0-I02-121210, CableLabs Content 3.0 Specification, December 10, 2012, Cable Television Laboratories, Inc.

[CTA 608] ANSI/CTA-608-E S-2019: Line 21 Data Services.

[CTA 708] ANSI/CTA-708-E R-2018: Digital Television (DTV) Closed Captioning.

[CTA 861] ANSI/CTA-861-H: A DTV Profile for Uncompressed High Speed Digital Interfaces, January, 2021.

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[ETV-AM] OC-SP-ETV-AM1.0.1-120614, Enhanced TV Application Messaging Protocol 1.0.1, June 14, 2012, Cable Television Laboratories, Inc.

[ETV-BIF] OC-SP-ETV-BIF1.0.1-120614, Enhanced TV Binary Interchange Format 1.0.1, June 14, 2012, Cable Television Laboratories, Inc.

[ETSI TS 103 190-2 v1.2.1] ETSI TS 103 190-2 v1.2.1 (2018-02), Digital Audio Compression (AC-4) Standard; Part 2: Immersive and personalized audio.

[ID3] ID3 Tagging System, February 3, 1999, http://www.id3.org/id3v2.3.0.

[ISO 639-2] ISO 639-2:1998, Codes for the Representation of Names of Languages - Part 2: Alpha-3 Code.

[ITU-R BS.1548-7] ITU-R BS.1548-7 (10/2019), User Requirements for Audio Coding Systems for Digital Broadcasting.

[ITU-R BS.2051-2] ITU-R BS.2051-2 (07/2018), Advanced sound system for programme production.

[LPCM] AES3-2009: AES Standard for Digital Audio Engineering – Serial Transmission Format for two-channel linearly represented digital audio data.

[ProResRDD36] RDD 36:2015 SMPTE Registered Disclosure Doc- Apple ProRes Bitstream Syntax and Decoding Process.

[QTFF] Apple Quick Time File Format: https://developer.apple.com/library/mac/#documentation/QuickTime/QTFF/qtff.pdf, August 14, 2012.

[SMPTE-302] SMPTE ST 302:2007, For Television – Mapping of AES3 Data into an MPEG-2 Transport Stream.

[SMPTE-TT] SMPTE ST 2052-1:2013, Timed Text Format (SMPTE-TT).

[BT 2020] Rec. ITU-R BT.2020, *Parameter values for ultra-high definition television systems for production and international programme exchange.*

[SMPTE-2113] SMPTE ST 2113:2018, *Colorimetry of P3 Color Spaces.*

2.3. Published Materials

No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

No informative references are applicable.

3.2. Standards from Other Organizations

[CodePoints] ITU-T H-Series Supplement 19| ISO/IEC TR23091-4 Usage of Video Signal Type Code Points.

[BT 709] Rec. ITU-R BT.709, *Parameter values for the HDTV standards for production and international programme exchange.*

[BT 2407] *Colour gamut conversion from Recommendation ITU-R BT.2020 to Recommendation ITU-R BT.709.*

[BT 1886] Rec. ITU-R BT.1886, *Reference electro-optical transfer function for flat panel displays used in HDTV studio production.*

[BT 2020] Rec. ITU-R BT.2020, *Parameter values for ultra-high definition television systems for production and international programme exchange.*

[BT 2100] Rec. ITU-R BT.2100, *Image parameter values for high dynamic range television for use in production and international programme exchange.*

[H Supp 15/ 23008-14] ITU-T H Suppl. 15 | ISO/IEC TR 23008-14, *Conversion and coding practices for HDR/WCG Y′CbCr 4:2:0 video with PQ transfer characteristics.*

[H Supp 18/ 23008-15] ITU-T H Suppl. 18 | ISO/IEC TR 23008-15, *Signalling, backward compatibility and display adaptation for HDR/WCG video coding.*

[BT 2390] ITU-R BT.2390-9 High dynamic range television for production and international programme exchange.

[BT 2408] ITU-R BT.2408-4 Guidance for operational practices in HDR television practices.

[BT 2446] ITU-R 2446-0 Methods for conversion of high dynamic range content to standard dynamic range content and vice-versa.

[NBCU LUTS] NBCU single stream specification and LUTs, www.movielabs.com, https://www.dropbox.com/sh/kij6u62f3rr1wzf/AADBCBwv58pXmqes4kxuOSXBa?dl=1

[BT 601] Rec. ITU-R BT.601, *Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios.*

[BT 656] Rec. ITU-R BT.656, I*nterface for digital component video signals in 525-line and 625-line television systems operating at the 4:2:2 level of Recommendation ITU-R BT.601.*

[BT 1120] Rec. ITU-R BT.1120. *Digital interfaces for studio signals with 1920x1080 image formats.*

[BT 2077] Rec. ITU-R BT.2077, *Real-time serial digital interfaces for UHDT.*

[UHDF Guide] Ultra HD Forum Guidelines, V 2.4.: 2020.

[ST 2022-5] ST 2022-5:2013, SMPTE Standard- Forward Error Correction for Transport of High Bit rate Media Signals over IP Networks (HBRMT)

[ST 2022-6] ST 2022-6:2012, SMPTE Standard- Transport of High Bit Rate Media Signals over IP Networks (HBRMT)

[ST 2022-7] ST 2022-7:2019, SMPTE Standard- Seamless protection Switching of RTP Datagrams

[NorDig] NorDig Unified Requirements for Integrated Receiver Decoders for use in cable, satellite, terrestrial and managed IPTV based networks, NorDig.

3.3. Published Materials

[47CFR79.1] Code of Federal Regulations 47CFR79.1, Closed Captioning of Video Programming.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

3D-LUT	three dimensional look up table
AAC	advanced audio coding
AD	audio description (also known as description video service)
AFD	active format description
API	Application Programming Interface
ATSC	Advanced Television System Committee
AVC	advanced video coding

CABAC	Context-Adaptive Binary Arithmetic Coding
CALM	Commercial Advertisement Loudness Mitigation
CBR	constant bit rate
CC	closed captioning
CDN	content delivery network
CEP	content encoding profiles
CLL	content light level
D	dialogue
DASH	dynamic adaptive streaming over HTTP
DM	dynamic metadata
DPI	Digital Program Insertion
DTS	decoding time stamp
DVS	descriptive video service
EBP	encoder boundary point
EIDR	Entertainment Identifier Registry Association
ESAM	Event Signaling and Management
ESNI	Event Scheduling and Notification Interface
ETV	enhanced television
FCC	Federal Communications Commission
FPS	frames per second
GBPS	Gigabits per a second
GOP	Group of Pictures
HD	high definition
HDR	high dynamic range
HDTV	high definition television
HEVC	High Efficiency Video Coding
HLG	hybrid log gamma
HLS	HTTP live streaming
HP	high profile
HT	high throughput
HTTP	Hypertext Transfer Protocol
IDR	Instantaneous Decoding Refresh
IEC	International Electrotechnical Commission
IP	Internet Protocol
IRE	Institute of Radio Engineers
ISO	International Organization for Standards
ITU-R	International Telecommunications Union – Radiocommunication
JOC	joint object coding
JPEG	Joint Photographic Experts Group
LFE	low frequency effects
LPCM	linear pulse-code modulation
LUT	look up table
MBAFF	Macroblock-Level Adaptive Frame/Field
MBPS	Megabits per a second
MDCV	master display color volume
MP	main profile
MPD	manifest presentation description
MPEG	Moving Pictures Experts Group
MVPD	Multichannel Video Programming Distributor

M&E	music and effects
NCG	narrow color gamut
NGA	Next Generation Audio
NPT	normal playback time
OOB	out of band
PAFF	Picture Adaptive Frame Field
PAT	Program Association Table
PCM	Pulse-Code Modulation
PCR	program clock reference
PES	Packetized Elementary Stream
PID	Program Identifier or Packet Identifier per [13818-1]
PMT	Program Map Table
PQ	perceptual quantizer
PSI	Program System Information
PTS	presentation time stamp
RIST	Reliable Internet Stream Transport
RTP	Real Time Protocol
SAP	stream access point
SCC	scenarist closed caption
SCTE	Society of Cable Telecommunication Engineers
SD	standard definition
SDI	Serial Digital Interface
SDR	standard dynamic range
SDS	Signal Decision Systems
SDTV	Standard Definition Television
SEI	Supplemental Enhancement Information
SMPTE	Society of Motion Picture and Television Engineers
SPTS	Single Program Transport Stream
SRT	Secure Reliable Transport
TBD	to be determined
TS	transport stream
T-STD	Transport Stream System Target Decoder
UHD	ultra high definition
UHDTV	ultra high definition television
UTC	Universal Time Code
VANC	vertical Ancillary data space
VBI	vertical blanking interval
VBR	variable bit rate
VoD	video on demand
XDS	extended data service
XML	eXtensible Markup Language

5.2. Definitions

AC-3	Dolby Digital Audio Codec.
Adaptive Content	Adaptive Content is an alternative approach for information delivery with the purpose of providing access of content to many types of devices and network conditions.
Advanced Audio Coding	Advanced Audio Coding (AAC) is a lossy compression and encoding scheme for digital audio.

Advanced Video Coding	Advanced Video Coding (AVC) is a standard for video compression (H.264/MPEG-4 Part 10).
Audio Channel	An Audio Signal that is intended to be played back at one specific nominal loudspeaker position.
Dialnorm	The metadata parameter that controls playback gain within the Dolby Laboratories Dolby Digital (AC-3) audio compression system.
Digital Rights Management	A coding system applied to digital content that manages the usage rights of that content.
Field Dominance	The method by which video fields are recorded into a file.
H.264	A standard for High Definition video compression. Can also be called AVC.
HTTP Live Streaming	A protocol for transferring unbounded streams of multimedia data. It specifies the data format of the files and the actions to be taken by the server (sender) and the clients (receivers) of the streams.
I-Picture	A picture type contained within a GOP. It is a reference picture, which represents a fixed image and which is independent of other picture types.
In Point	A point in the stream, suitable for entry, that lies on an elementary presentation unit boundary. An In Point is actually between two presentation units rather than being a presentation unit itself.
LPCM	Linear pulse-code modulation is a method of encoding audio content digitally.
Master	The original source of content prior to any copying or editing which could degrade quality.
Mezzanine	File-based content to be used across IP and QAM delivery platforms.
MPEG-2	A standard as defined by ISO/IEC 13818 for the generic coding of moving pictures and associated audio information.
NPT	Normal play time (NPT) indicates the stream absolute position relative to the beginning of the presentation. The timestamp consists of a decimal fraction. The part left of the decimal may be expressed in seconds or hours, minutes, and seconds. The part right of the decimal point measures fractions of a second.
Out Point	A point in the stream, suitable for exit, that lies on an elementary presentation unit boundary. An Out Point is actually between two presentation units rather than being a presentation unit itself.
Padding	Artificial bits added to a video in order to meet the minimum bit rate requirements defined within this specification.
ProRes	A high quality video compression format developed by Apple, Inc.
Shadow Detail	Darker areas in pictures (shadows) benefit from additional bits dedicated to those perceptual areas when quantized in order to show improved detail (for example dark edges of objects in a scene)
SCC	Scenarist Closed Caption, a file type developed by Sonic. SCC files (.scc) have become a popular format for many different applications of closed captions, and many editing programs have adopted the SCC file format.
Telecine	A process for transferring motion picture content into video format.

6. Media Encoding

This section includes the requirements for the actual audio, video and directly related content, which is expected to be encoded for further distribution. As a reminder, the goal of this specification is to deliver the highest quality video available based on the content type, bit rate and codec, and provide a complete input format which should work well with encoders / transcoders.

Content in a linear contribution feed maybe in an uncompressed or compressed format as determined by the video media component but would need to be transcoded to lower bit rates to be suitable for distribution. The audio component in an uncompressed format has the option to be uncompressed, compressed, or compressed and suitable for pass thru as audio for distribution feeds.

6.1. Video

All compressed contribution linear feed video encodings ***shall*** be of one of the following codecs:

- AVC (H.264) as specified in [14496-10]
- HEVC (H.265) as specified in [23008-2]
- MPEG-2 as specified in [13818-1] (*deprecated*)

All uncompressed contribution linear feed video ***shall*** be in the Y′CbCr in a baseband interface capable of carriage in the MVPD system.

Note: If MVPD desires to do compositing (i.e. server-side graphics, watermarks, or bugs), a linear contribution feed signal would need to be supplied in an uncompressed format before distribution transcoding of the signal.

All contribution linear feed video encodings ***shall*** support either high dynamic range or standard dynamic feeds as defined by the following video properties:

Table 1 - Video Properties Table

	Video Properties
Colour properties	Colour primaries
	Transfer characteristics
	Colour representation
Other	Full/narrow range
	4:2:0 chroma sample location alignment

Note: These video properties are useful to retain video quality for distribution purposes distribution feeds are created from the linear sources. Conversions are typically done through a real-time 3D-LUT processes in the uncompressed domain.

Note: Codec names are also used as profile names within this document. Each profile will have further details specified based on unique characteristics of the profile.

6.1.1. Candidate resolutions and framerates for linear contribution feed profiles

The following tables indicates the supported combinations of resolution/framerates and other video presentation properties for each linear contribution feed profile.

Table 2 - Candidate Linear Contribution Video Resolutions

Vertical Size (lines)	Horizontal Size (pixels)	aspect_ ratio_idc	Display Aspect Ratio	Supported Frame Rates (P-progressive i-interlaced)	Production Format
4320	7680	1	16:9	**P-1,2,6,9,11,12,13**	UHDTV2
2160	3840	1	16:9	**P-1,2,6,9,11,12,13**	UHDTV1
1080	1920	1	16:9	**P-1,2,6,9,11,12,13** **I- 7,8**	HDTV
1080	1440	14	16:9	**P-1,2,3,6,7,8,9** **I- 7,8**	HDTV

Vertical Size (lines)	Horizontal Size (pixels)	aspect_ ratio_idc	Display Aspect Ratio	Supported Frame Rates (P-progressive i-interlaced)	Production Format
720	1280	1	16:9	**P- 1,2,6,9,11,12,13**	HDTV
576	720	2	4:3	**P- 3,10** **I- 4, 5**	SDTV
576	720	4	16:9	**P-3,10** **I- 4, 5**	SDTV
480	854	1	16:9	**P-1,2,6,9** **I- 7,8**	SDTV
480	720	3	4:3	**P-1,2,6,9** **I- 7,8**	SDTV
480	720	5	16:9	**P-1,2,6,9** **I- 7,8**	SDTV

Table 3 - Candidate Framerates for Linear Contribution Frame Rates

Frame Rate Number	Interlaced or Progressive	Frame Rate	vui_time_scale	vui_num_units_in_tick	Allowed pic_struct
1	P	24000/1001 Hz	24,000	1001	0,7,8
2	P	24 Hz	24	1	0,7,8
3	P	25 Hz	25	1	0,7,8
4	I (encoded as frames)	25 Hz	50	1	3,4,5,6
5	I (encoded as fields)	25 Hz	50	1	9.10.11.12
6	P	30000/1001 Hz	30,000	1001	0,7,8

Frame Rate Number	Interlaced or Progressive	Frame Rate	vui_time_scale	vui_num_units_in_tick	Allowed pic_struct
7	I (encoded as frames)	30000/1001 Hz	60,000	1001	3,4,5,6
8	I (encoded as fields)	30000/1001 Hz	60,000	1001	9,10,11,12
9	P	30 Hz	30	1	0,7,8
10	P	50 Hz	50	1	0,7,8
11	P	60000/1001 Hz	60,000	1001	0,7,8
12	P	60 Hz	60	1	0,7,8
13	P	120 Hz	120	1	0,7,8
14	P	120/1.001 Hz	120,000	1001	0,7,8

6.1.2. Conversions of sources for linear contribution feeds

Conversions of ingest signals at the MVPD to Linear Contribution Feed formats *should* be automated, reproducible, and real-time type of operations. Conversions are done in the uncompressed domain as pixel operations using 3D-LUTs or specific purely mathematical conversions. For 3D-LUTs, the use of tetrahedral interpolation is vital for accurate conversions. For purely mathematical conversions higher precision calculations are necessary.

Video conversions can include color (e.g., BT.2020 to BT.709), brightness (e.g. HLG to PQ), size (e.g. 4K to HD, SD to HD), and framerate (e.g. 120 FPS to 60 FPS) and bit depth. Audio conversions can include bit depth, file format, channel order, and/or loudness.

Conversions in framerate, brightness, and color from a linear contribution that feed into SCTE distribution formats *should* be done cautiously. HDR content *may* include the passthrough, recalculation , or supplementation of dynamic and static metadata. It is preferable that a linear contribution feed natively supports the highest intended quality and framerate SCTE distribution format.

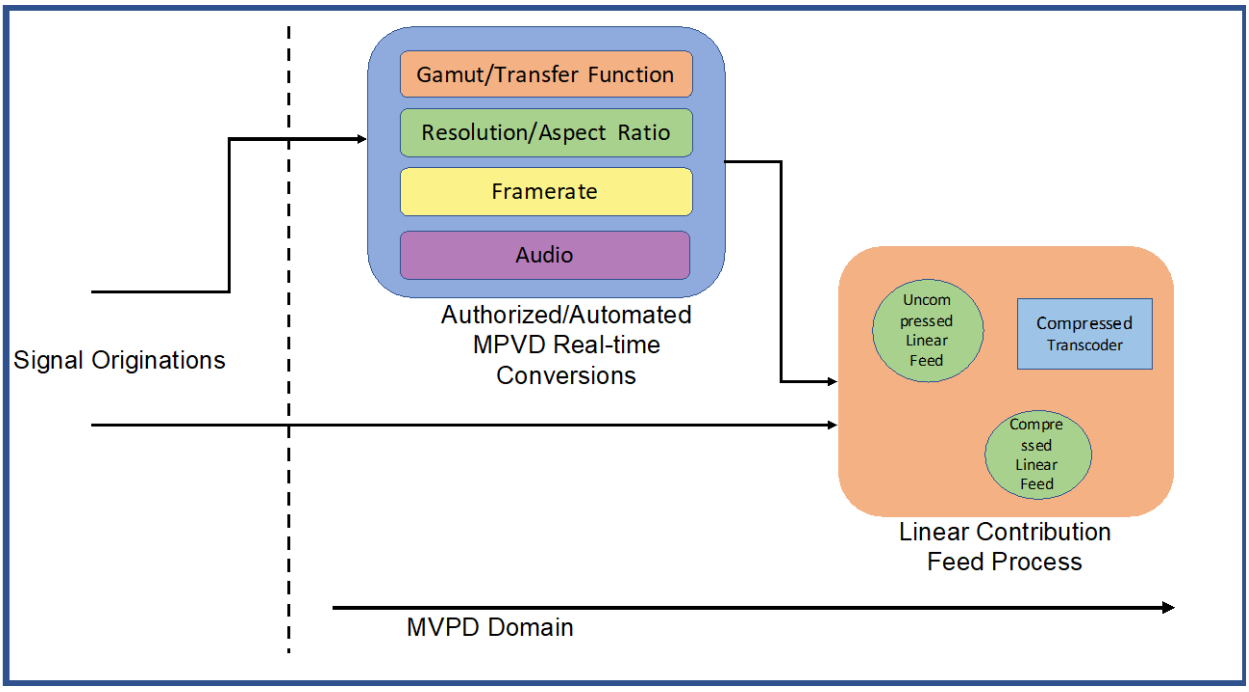

Figure 3 - MVPD Linear Contribution Feed Conversions

The following table from the [CodePoints] document captures a summary of commonly used colour coding characteristics and their tag values. Types of Contribution Linear Feed Signals used from this chart can be for HDR - BT2100_PQ_YCC, BT2100_HLG_YCC; for SDR - BT709_YCC.

Table 4 - SD, HD, and UHD video colour coding characteristics properties

	Tag	Colour		Light		Container space properties		
		Gamut	**Primaries**	**Dynamic Range**	**Transfer function**	**Colour Representation**	**Integer code level scaling**	**4:2:0 chroma sample location alignment (ChromaLocType)**
HD or SD	BT709_YCC	NCG	BT.709	SDR	BT.709	Y′CbCr	Narrow	Vertically interstitial (ChromaLocType = 0)
UHD	BT709_YCC	NCG	BT.2100	SDR	BT.709	Y′CbCr	Narrow	Vertically interstitial (ChromaLocType = 0)
	BT2100_PQ_YCC	WCG	BT.2100	HDR	PQ			Co-sited (ChromaLocType = 2)
	BT2100_HLG_YCC				HLG			

6.1.2.1. Transfer and Gamut Conversions

HDR conversions to other HDR or SDR formats *may* make use of 3D-LUTs or pure mathematical transforms to convert the signal. 3D-LUTs have different interpolation modes which result in different quality levels. A tetrahedral interpolation with at least 33 points is recommended for broadcast quality signals. The signal transformation is a non-linear operation designed to work with signals of a specific type and range (narrow or full) with remapping of the whitepoint.

Both the video essence and the signaling of transfer function, color primaries, matrix coefficients, and signal range characteristics for the input to the transform need to be correct in order for the output to be correct. To assist in verifying that the signal matches the transforms design, signaling is used in SDI, IP, or file (see table from 23091-4/ ITU-T Supp 19)).

Variances in the input signal which can include full/narrow range difference and chromaLocType differences can affect the transforms quality which cause unintended changes in color or light level accuracy which can include hue shifts and/or clipping artifacts which alter the original artistic intent. For information on how to handle the signals refers to BT.2390, BT.2408, BT.2124 (HDR color volume metric), 23091-4, etc.

6.1.2.1.1. Gamut Conversion

Gamut transforms *may* be needed for HDR ⇔ SDR signal conversions if the provider does not offer the signal in one of the defined signal formats. This *may* be necessary to accommodate graphic, logos, or bugs inserted into the signal content. It could also be needed to accommodate SD SDR content in BT.601 format that *may* need to be converted to BT.709 or BT. 2020 format to reduce the variations of ingest content signals. This *may* be done as part of a combined real-time LUT process.

Some useful references for gamut conversions are provided below:

[BT 709] Rec. ITU-R BT.709, *Parameter values for the HDTV standards for production and international programme exchange*

[BT 2407] *Colour gamut conversion from Recommendation ITU-R BT.2020 to Recommendation ITU-R BT.709*

6.1.2.1.2. Transfer Function Conversion

Transfer function conversions also play a critical part of HDR ⇔SDR conversions since the adjustment of the transfer curve is a non-linear process. This is also relevant for conversions of the signal between different HDR formats where the HDR production format *may* be of one format and the HDR distribution format *may* be of another type. The conversion can cause changes to calculated white point, can affect mid-tones in the display picture, bring about unwanted clipping of information of the picture when down-mapping.

Some references for HDR conversions are provided below:

[BT 1886] Rec. ITU-R BT.1886, *Reference electro-optical transfer function for flat panel displays used in HDTV studio production*

[BT 2020] Rec. ITU-R BT.2020, *Parameter values for ultra-high definition television systems for production and international programme exchange*

[BT 2100] Rec. ITU-R BT.2100, *Image parameter values for high dynamic range television for use in production and international programme exchange*

[H Supp 15] ITU-T H Suppl. 15 | ISO/IEC TR 23008-14, *Conversion and coding practices for HDR/WCG Y'CbCr 4:2:0 video with PQ transfer characteristics*

[H Supp 18] ITU-T H Suppl. 18 | ISO/IEC TR 23008-15, *Signalling, backward compatibility and display adaptation for HDR/WCG video coding*

[BT 2390] ITU-R BT.2390-9 High dynamic range television for production and international programme exchange

[BT 2408] ITU-R BT.2408-4 Guidance for operational practices in HDR television practices

[BT 2446] ITU-R 2446-0 Methods for conversion of high dynamic range content to standard dynamic range content and vice-versa

[NBCU LUTS] NBCU single stream specification and LUTs, www.movielabs.com, https://www.dropbox.com/sh/kij6u62f3rr1wzf/AADBCBwv58pXmqes4kxuOSXBa?dl=1

6.1.2.2. Resolution Conversion or Scaling

Resolution conversions *may* be necessary when dealing with international signals or SD picture formats and involve adding more/less information between pixels or adjust the aspect ratio if not in the ingest 16:9 format.

Note: Slight adjustments in aspect ratios are often harder adjustments and may be easier to crop the picture at the sacrifice of active video in the picture.

Some useful references for resolution conversions are provided below:

[BT 601] Rec. ITU-R BT.601, *Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios*

[BT 656] Rec. ITU-R BT.656, I*nterface for digital component video signals in 525-line and 625-line television systems operating at the 4:2:2 level of Recommendation ITU-R BT.601*

[BT 1120] Rec. ITU-R BT.1120. *Digital interfaces for studio signals with 1920x1080 image formats*

[BT 2077] Rec. ITU-R BT.2077, *Real-time serial digital interfaces for UHDT*

6.1.2.2.1. DeInterlacing Operations

A lot of newer distribution for IPTV are progressive transmissions, but some broadcasting signals for SD and HD SDR *may* still be provided in an interlace format which involve successively displaying two fields (two half frames) of content that samples each field at a slightly different point in time. It *may* be beneficial to convert from interlaced format to progressive format upon ingestion of the content provider signal as opposed to performing these same functions multiple times at the distribution encoders.

6.1.2.3. Framerate Conversion

Framerate reductions *should* avoid juddering type artifacts through intelligent approaches of frame synthesis (interpolation) and/or frame dropping algorithms. Additionally, appropriate signaling information offered in the contribution feed such as temporal layering structures *should* also be considered.[UHDF Guide- section 13.3]

6.1.2.4. Audio Conversions

Audio conversion is a common requirement and *may* be accomplished by using commercially available transcoding systems. For example, if a program is delivered with 5.1 channels, it is possible and practical to downmix that audio to stereo or even mono for further distribution. Metadata is used to control how the downmix occurs and also to guide the generation of new metadata for encoding of the resulting stereo or mono signal. This is also true for immersive audio programs which can be downmixed to 5.1 channels, stereo and mono, and metadata plays the same role. In order to properly accommodate metadata, it is imperative to employ a transcoder specifically designed for the purpose (i.e., a rather than patching decoders and encoders together and using static metadata values that *may* not always be correct). See Table 9.

During transcoding and other audio processing operations, it is recommended to leave appropriate margin for watermarks that *may* be present in the audio. As a general rule, it is advisable for the encoder to match the original data rate unless the transcode also downmixes to a lower channel count.

6.1.3. Candidate baseband interface formats for uncompressed linear contribution feed profiles

Linear contribution feeds *may* be received through an uncompressed baseband interface. The following tables indication the maximum resolution and color coding characteristics signaling for commonly used broadband interface specifications. Linear contribution feed profiles *may* choose from a subset of these candidate broadband interface specifications.

The following tables from the [CodePoints] document indicate baseband interfaces capabilities for carriage of media based on resolution and colour coding characteristics.

Table 5 - Baseband Interfaces for signal carriage based on resolution

Standard	Source format data (resolution)[a]					
	SD		HD		UHD	
	720 × 480	720 × 576	1280 × 720	1920 × 1080	3840 × 2160	7680 × 4320
ST 259M (SD-SDI)	√	√				
BT.656M (SD-SDI)	√	√				
ST 292-1 (HD-SDI)			√	√		
BT.1120-9 (HD-SDI)				√		
ST 372-1 (Dual link HD-SDI)				√		
ST 425-1 (3G-SDI)				√		
BT.1120-9 (Dual link HD-SDI/3G-SDI)				√		
ST 425-5 (Quad link 3G-SDI)					√	
ST 2081-10 (6G-SDI)				√	√	
ST 2082-10 (12G-SDI)					√	
ST 2082-12 (Quad link 12G-SDI)					√	√
ST 2036-3 (Single/multi-link 10G-SDI)					√	√
BT.2077-2 (U-SDI)					√	√
[a] Cells with check marks (√) indicate "used combinations". Cells without check marks indicate "not used combinations".						

Note: Checkmarks indicate the maximum resolution carriage for the baseband interface specification. Lower resolutions can also be carried but the bps of the baseband connection will not change.

Table 6 - Baseband Interfaces for signal carriage based on colour coding characteristics

Colour coding characteristics description		**SDR NCG**	**HDR NCG**	
System identifier		**BT709_YCC**	**BT2100_PQ_YCC**	**BT2100_HLG_YCC**
Rec. ITU-R	**SMPTE**			
BT.1120-9 (12/2017)	ST 292-1 1.5 Gb/s	√	√	√
	ST 372-1 Dual 1.5 Gb/s	√	√	√
	ST 425-1 3G	√	√	√
N/A	ST 425-5 Quad 3G	√	√	√
BT 2077-2 (12/2017)	ST 2081-10 6G	√	√	√
	ST 2082-10 12G	√	√	√
	ST 2082-12 Quad 12G	√	√	√
	ST 2036-3 (Single/ Multi-link 10G SDI)	√	√	√
N/A	ST 2036-4 (U-SDI)	√ [1]	√	√
N/A	ST 2022-6	√	√	√
N/A	ST 2110-20 Uncompressed Video/IP	√	√	√
CTA 861.4/HDMI Uncompressed HSDI		√	√	√

[1] In ST.2036-4 only 3840×2160 up to 60Hz is permitted. For Rec. ITU-R BT.2077-2, no combinations are permitted.

6.1.3.1. Automation System to Compression System API (SCTE 104) constraints

The automation system as indicated by [SCTE 104] provides in-stream commands in the uncompressed streams which are responded to by the compression system API in the encoder. This information is contained in the VANC of the encapsulated SDI frame [ST 2022-6]. For timing, SCTE 104 can make use of the time_type parameter, or can make use of the VITC time_code carried by the SDI Frame, or no carriage of timing and allow the distribution encoders to associate the IP encapsulated SDI frame and information within it with their own clock mechanisms (e.g., EBP Timing and/or PTS). This alignment of SCTE 104 information to the uncompressed linear contribution feed is important to stream conditioning of the resulting distribution outputs.

As an alternative approach to in-stream commands, content providers *may* provide SCTE 104 information of the content stream to an OOB interface into an ESNI/ESAM system or by TCP/IP interface although splice point conditioning information still needs to be carried though an in-stream command. The OOB approach *should* have a mechanism to associate timing (e.g., carriage of UTC) with frame alignment in the linear contribution feed.

6.1.4. Compressed Linear Contribution Feed Transport & Media Constraints

This section provides constraints and guidance for the encoding, carriage, and transport of compressed linear contribution feeds entering an MVPD system.

6.1.4.1. Network Carriage of MPEG-2 TS Packets

MPEG2-TS packets can be carried over satellite using QAM/QPSK modulation and over IP networks using SRT, RIST, RTP or HLS/DASH. Preserving the MPEG2-TS stream through these network carriage systems are done through a combination of minimizing bit error rates with error resiliency techniques such as forward error correction [ST 2022-5][ST 2022-6] or through redundancy techniques [ST 2022-7], but *may* affect the latency budget of the MPEG2-TS channel.

Note: If multiplexing of a set of MPEG2-TS channels occurs this can also affect the latency budget of the MPEG2-TS channel.

Redundancy implementations that work across different network carriage systems *should* consider differences in latency between the different network carriages of the MPEG2-TS channel.

6.1.4.2. Transport Constraints

- The transport stream ***shall*** comply with the definition of a transport stream as specified in [13818-1].
- The video elementary stream ***shall*** contain an integral number of access units.
- 3D content ***shall*** be formatted as specified in [SCTE 187-1].
- The transport stream *should* contain only a single program (SPTS) in most cases, but a multiple program (MPTS) can be carried from the content provider.when needed
- The program in the transport stream ***shall*** contain only a single video elementary stream.
- The program in the transport stream ***shall*** contain at least one audio elementary stream.

- Default audio PID ***shall*** contain data. For content that has no audio whatsoever, silent audio is acceptable, but at least one PID shall have audio data on it at all times.

- Secondary audio PIDs *should* contain data to avoid PMT changes at content program boundaries in the linear channel. For content that has no audio whatsoever, silent or default audio is acceptable.

- The audio T-STD ***shall*** comply with section 3.6 of Annex A of [A/52]

- The transport stream *may* carry up to 14 audio elementary streams.

- The transport stream ***shall*** consist of 188-byte transport packets.

- The first byte of the transport stream ***shall*** be the first byte of a transport packet.

- The transport stream ***shall*** contain an integral number of transport packets.

- The transport stream ***shall not*** contain continuity counter discontinuities.

- The transport stream ***shall*** contain exactly one system time-base discontinuity (PCR).

- System time-base discontinuity ***shall*** be signaled in the first PCR packet of the stream.

- PCR continuity ***shall*** be maintained in the case where one or more Out Points and/or In Points exist between two presentation units in the encoded content.

- PCRs ***shall*** have an accuracy of 5 ppm.

- The first PCR packet of the stream ***shall*** have the transport discontinuity indicator flag set to '1'.

- A PCR *should* be present in any transport packet containing the first byte of a video PES payload.

- The audio T-STD ***shall*** comply with section 3.6 of Annex A of [A/52].

- The random_access_indicator ***shall*** be set to '1' in any transport packet containing the first byte of a video PES payload that carries an I-Picture.

- For Video In Point and Out Points, the transitions ***shall*** maintain full compliance with the T-STD model.

- When present, ETV content ***shall*** be delivered as part of the transport stream as described in [ETV-AM] and [ETV-BIF].

- A PID with ETV content ***shall not*** exceed 200 kbps.

6.1.4.3. PSI Constraints

- A complete Program Association Table (PAT) ***shall*** occur in the transport stream before the first byte of a Program Map Table (PMT).
- A PMT that contains a complete program definition ***shall*** occur in the transport stream before the first transport packet with an elementary stream PID.
- The time interval in the transport stream between successive occurrences of the PAT ***shall*** be less than or equal to 250 milliseconds.
- The time interval between successive occurrences of the PAT *should* be 125 milliseconds.
- The stream_type value assigned in the PMT to the video elementary stream ***shall*** be 0x02 or 0x80 for MPEG-2 video, 0x1B for AVC video, and 0x24 for HEVC video.
- The stream_type value assigned in the PMT to AC-3 and E-AC-3 audio elementary streams ***shall*** be 0x81 [A/53, Part3].
- The stream_type value assigned in the PMT to AC-3 audio elementary streams ***shall*** be 0x81 [A/53, Part3].
- The stream_type value assigned in the PMT to E-AC-3 audio elementary streams ***shall*** be 0x87 [A/53, Part3].
- The value of stream_type for an AC-4 elementary stream ***shall*** be set to 0x06 (indicating PES packets containing private data) [ETSI TS 103 190-2 v1.2.1]
- PMT change *should* be avoided.
- PMT *should* contain caption and ISO_639_language descriptors [13818-1]

6.1.4.4. Language Descriptor & Media Component Identification Constraints

The compressed contribution linear feed using MPEG-2 transport *should* use the ISO_639_language descriptor to convey accessibility or role characteristics of the audio stream and is beneficial for IPTV distributions. This information can be described as indicated in Table 7 and Table 8 with how to map with role and accessibility elements in IPTV distributions. This also benefits the contribution stream, by making the compressed stream less reliant on the PID ordering convention for audio.

Table 7 - Audio Services

Type	Role@value	Accessibility@value
Audio default **(audio_type = 0x00 | service_type [bsmod or equivalent] = 000)**	**main**[2]	**N/A**
Clean effects **(audio_type = 0x01 | service_type [bsmod or equivalent] = 001)**	**SCTE: Music & Effects**	**N/A**
Primary Audio **(audio_type = 0x80)**	**main**[3]	**N/A**
Native Audio **(audio_type = 0x81)**	**absence of dub**[4]	**N/A**
Emergency **(audio_type = 0x82 | service_type [bsmod or equivalent] = 110)**	**emergency**	**N/A**
Primary Commentary **(audio_type = 0x83 | service_type [bsmod or equivalent] = 101)**	**main**[5], **commentary**	**N/A**
Alternate Commentary **(audio_type = 0x84)**	**alternate,** **commentary**	**N/A**
service_type [bsmod or equivalent] = 100 or 111	**TBD**	**N/A**

[2] The role of "main" can occur across multiple adaptationSets of the period. This can apply across several dimensions of the media such as audio channel order, or audio codec format. Selection between multiple adaptation sets with the same language and role should be done according to the value of @selectionPriority.

[3] The supplemental property for media language default for audio *should* be set at the **MPD** or **Period** Level

[4] In DASH, native audio is not signaled explicitly but can be determined be the absence of "role = dub" to describe the track. In cases where program language may shift from program to program but all programs are in its native language, the channel language of "qaa" can be used to indicate the channel language is native but can vary in the channel. See [NorDig] see Table 12.6.

[5] The supplemental property for media language default for commentary *should* be set at the **MPD** or **Period** Level

Table 8 - Accessibility Associated Services

Type	Role@value	Accessibility@value
Audio description **(audio_type = 0x03 | service_type [bsmod or equivalent] = 010)**	**alternate**	**description**
Clean audio **(audio_type = 0x02 | service_type [bsmod or equivalent] = 011)**	**alternate**	**enhanced-audio-intelligibility**
Closed Captions[6]	**main**	**captions**
Sign language[7]	**supplementary**	**sign**

- In a muxed transport, audio component streams *should* signal language and audio service values following or similar to the iso_639_ language_descriptor in MPEG-2 Transport. The entry is in the form of ISO_639 – audio language pair. Main channels of an audio language can use the audio_type of "und" (0x00). The primary language of a linear feed will also have an additional language pair with the audio_type of "primary" (0x80). Multiple entries are allowed and can indicate Hearing impaired (0x02- audio enhanced intelligibility) or Visual impaired commentary (0x03- Audio or Video Description).

- For any two or more audio adaptation sets of the period with the role of main, the values of `@lang` ***shall*** be identical.

- The PCR_PID of the program ***shall*** have the same value of the elementary_PID assigned to the main video elementary stream of the program.

Note: Some audio services and associated audio services are prepared for distribution as a standalone playable service or combined with other distribution audio channels to create the playout experience.

6.1.4.5. Digital Program Insertion Constraints

In compressed source streams, SCTE 35 messages can exist and the distribution transcoder is responsible for determining, filtering, and transcoding SCTE 35 messages onto the Distribution transcoded stream output. The distribution transcoder may have ESNI/ESAM interfaces to also adjust the content and SCTE 35 messages on the resulting output transcoded stream.

[6] Closed captioning is an accessibility component for a video or text track indicated by the caption service descriptor in the PSI. The equivalent audio_type value would be 0x00

[7] Sign language is identified through the `@lang` attribute (e.g. "ase" or "bfi"). The equivalent audio_type value would be 0x00.

The constraints in this section are related to creation SCTE 35 messages carried in the compressed linear contribution feed sources.

- For Digital Program Insertion enabled content, transport stream content ***shall*** include In and Out Points embedded within the content.

  Note: This is also referred to as signaling "in-band".

- For MPEG-2, AVC, and HEVC encoding, In and Out Points ***shall*** comply with [SCTE 172].

- For AVC and HEVC encoding, the last byte of the payload of the transport packet transmitted prior to an Out Point ***shall*** be the last byte of a video access unit and the last byte of a PES packet.

- For AVC and HEVC encoding where an exit at an Out Point is optional, the first picture in presentation order following an Out Point ***shall*** have a PTS such that the presentation of this picture follows the presentation of the last picture presented prior to an Out Point at the proper time as determined by the video access unit duration.

  Note: Requirements in this area are to handle certain business rules (e.g., Nielsen C3), where advertising content will be carried in the delivered asset for a period of time before being refreshed with other advertisements.

- For AVC encoding where an exit at an Out Point is optional, the first picture in decode order following an Out Point ***shall*** have a DTS such that the decoding of this picture follows the decoding of the last picture decoded prior to the Out Point at the proper time as determined by the access unit duration.

- Segmentation Descriptor ***shall*** be in proper close/open order with end descriptors appearing before any start descriptors. All close and open descriptors *should* be paired. Pairs also *should* not be mixed.

- All ad events *should* provide for paired starts and ends or a duration. Coincident points for starts and ends *should* have ends preceding in order from starts.

- Events ID *should* not be reused until events using the same EventID are closed.

- Splice information *should* be carried in 1 transport packet.

  Note: Best efforts should be used to constrain splice information to 1 transport packet but occasional splice information may span across 2 or more transport packets.

  Note: Close proximity of splicing events are to be represented as a single coincident splice point whenever possible.

- `SAPType` *should* be indicated in the SCTE 35 message to indicate that the compressed stream has been conditioned at the splice point.

- Wall Clock time *should* be carried in the SCTE 35 message through use of segmentation time descriptor in the linear contribution feed stream. This wall clock time can be sourced and interpolated to generate the wall clock time on the output stream. If output distribution stream is fragmented, this same source can be used to source the EBP wall clock time in the output distribution stream.

- Repetition of segmentation_upid_type (e.g., content_id) does not require a splice point unless it coincide with an event or program boundary. First occurrence of the segmentation_upid_type *should* be tied with segmentation descriptors.

6.1.4.6. Video Constraints

- All HD content ***shall*** be provided with square pixels.

- All content ***shall*** have a black level of 0 IRE.

- All content *should* have a 16:9 aspect ratio except for SD content that can also support a 4:3 aspect ratio

- AVC (H.264) content *should* use CABAC Entropy Encoding.

- All visible VBI ***shall*** be omitted from source content. If omitted, CC and XDS ***shall*** be provided in another format as defined in [CEA 608].

*Note: CC and XDS **shall** be regenerated and re-inserted for FCC compliance on some outputs.*

Note: Visible VBI provided as part of the source content may result in video artifacts.

- Any closed captioning (non-embedded) or time-sensitive metadata ***shall*** take into account the actual program to accommodate the start and end of video indicators based on the appended video. (See Section 7.2.1 for concerns about maintenance of synchrony between program timeline and CC timing).

- Video content *should* use an Active Format Descriptor (AFD) per [A/53, Part4] for MPEG-2 and [SCTE 128-1] for AVC and HEVC, where the width and height *may* not meet that of the active frame. When used, an AFD mode / setting *should* be valid for the entire asset and its value ***shall not*** change during the asset.

- HD content that will be subsequently distributed in SD format ***shall*** include AFD to define the cropping window or instructions on how to process the content when converting to SD.

6.1.4.7. SEI Constraints [AVC or HEVC]

- SEI messages in an input video stream which are not decoded and utilized by a transcoding/transrating process *should* be preserved in the output SEI carriage capable video bitstream of conversion processes (i.e., by distribution conversion devices) unless specifically not allowed by MVPD agreements. Examples of SEI messages which need to be preserved if not decoded and utilized include film grain and HDR static and dynamic metadata. Examples of SEI messages which may be decoded and used by a conversion process include picture timing.

6.1.4.8. GOP Constraints

- Support a Closed Long GOP format (I, B, P) of at the most 90 Frames @ Video< =60fps and 180 Frames @ Video>60 fps
- Support restart of GOP upon scene change detection

6.1.4.9. HDR Constraints [HEVC 10 bit Only]

Y′CbCr HDR signals have a combination of a luminance component and color difference components. The luminance component can peak at up to 10,000 Nits but current peak working range for cinema goes up to 4000 nits. The color components of for HDR signals typically use BT.2100 which has a wider color gamut compared to SDR's BT.709 color gamut. By combining luminance and color components, the entire color volume is defined.

- All HDR video content ***shall*** be progressive.

- MDCV, CLL and DM information *should* be passed through when present if it exists on specific programs on the linear channel. The status of this information *may* change at program boundaries in linear changes.

    - Linear HDR Video *may* be provided with unspecified metadata values.
    - VoD assets played as a program in a linear Contribution Feed *may* contain dynamic metadata of the VoD asset.

- Linear HDR reference / graphics white *should* be provided at 58% in narrow range PQ-BT.2100 per [BT 2390].

  Note: Reference white often serves as an anchor point for secondary conversions.

- Linear HDR Video ***shall*** be delivered in a [BT 2020] container filtered to the P3D65 gamut [ST 2113].

  Note: Content should have a percentage of raster for MaxFALL less than 400 nits to not provide offensive / bright colors. HDR should look like SDR with some bright highlights and speculars and additional shadow detail.

- *HLG feeds shall be normalized to 1,000 nits before conversion to HDR10 (PQ transfer function with additional static metadata) as described in [BT 2390].*

6.1.4.10. Interlace Constraints [SDR: SD or HD]

- Frame-rate converted (e.g., film content with 3:2 Telecine applied) content *should not* be provided unless it is the only format available.

- Field dominance ***shall*** be properly tagged (top field first, bottom field first, or progressive) per [13818-1].

- Broken cadence *should* be avoided when using 3:2 pulldown. When broken cadence has been known to occur, metadata flags *may* be used to indicate that content *should* be kept at a 59.94 frame rate (for example) and de-telecine *should not* be attempted.

- All interlaced content compressed using the AVC codec ***shall*** utilize interlaced compression tools (PAFF and/or MBAFF) if available.

6.2. Audio

Table 9 lists codecs commonly used for contribution and distribution. Codecs suitable for contribution can be decoded and re-encoded. Codecs for distribution are typically passed-through (i.e., no decode/re-encode), but in some applications re-encoding is necessary and most codecs listed will support this.

All Contribution audio encoding ***shall*** be of one of the codecs in Table 9:

Table 9 - Contribution Audio Codecs

Audio Format	Channels	Min. Bit Rate	Max Bit Rate	Contribution/ Distribution	Suitable for Re-encode and/or Passthrough
E-AC-3 [A/52]	Stereo	192 kbps	192 kbps	Distribution	Both
E- AC-3 [A/52]	5.1	384 kbps	448 kbps	Distribution	Both
AC-3 [A/52]	Stereo	192 kbps	192 kbps	Distribution	Both
AC-3 [A/52]	5.1	384 kbps	640 kbps	Distribution	Both
E- AC-3 [A/52] Atmos	5.1.4	448 kbps	768 kbps	Distribution	Passthrough Only
AC-4 [A/342-2]	5.1	192 kbps	512 kbps	Distribution	Both
AC-4 [A/342-2]	5.1.4	288 kbps	512 kbps	Distribution	Both
AC-4 [A/342-2]	5.1.4 M&E + 2D + AD	432 kbps (288+48+48+48)	512 kbps	Distribution	Both
MPEG-H Audio [A/342-3]	5.1	192 kbps	512 kbps	Distribution	Both
MPEG-H Audio [A/342-3]	5.1+4H	256 kbps	512 kbps	Distribution	Both
MPEG-H Audio [A/342-3]	Up to 16 core channels[8] (e.g., 5.1+4H M&E + 4D + AD + MD)	32 kbps per core channel	64 kbps per core channel	Distribution	Both
AC-4 Primary Distribution Mode	5.1.4	512/768 kbps	1024 kbps	Contribution	Re-encode Only

[8] The encoded core channels can be audio channels and audio objects. All configurations are fully described by the audio metadata according to ISO/IEC 23008-3 and ATSC A/342-3.

MPEG-H Audio [23008-3, Clause 4.7]	Up to 16 core channels	96 kbps per core channel	192 kbps per core channel	Contribution	Re-encode Only
Dolby E	8	1,920 kbps	1,920 kbps	Contribution	Re-encode Only
ED2	16	3,840 kbps	3,840 kbps	Contribution	Re-encode Only
Linear PCM (LPCM)	2	1,536 kbps	2,304 kbps	Contribution	Re-encode Only

6.2.1. Phase Alignment

All audio channels comprising a program ***shall*** be sample aligned to maintain consistent phase between all channels. This is imperative for proper performance of encoding and any subsequent downmixing.

Note: Phase alignment between the two channels of a stereo channel pair does not necessarily guarantee phase alignment between pairs. This is true with Linear PCM particularly if the stereo pairs are delivered via separate PIDs, and also applies to stereo codecs such as MPEG 1, LII. Phase alignment across PCM channel pairs then must be deliberately configured and tested.

6.2.2. Audio Channels

Audio most often follows the channel ordering listed in Table 10 which is derived from ITU-R BS.2051-2. In the case of immersive audio, the channels are labeled to match speaker outputs and may differ slightly from the input labels on the encoder, but the order is identical.

Compressed audio has pre-defined channel assignments required by the encoders and consistency is thus straightforward to maintain.

Next Gen Audio (NGA), also called personalized audio is an extension of immersive audio. It supports so-called compositional audio which separates M&E (Music and Effects) and (D) dialog. While there are no specific standards for channel ordering, the order shown in Table 10 matches the latest AC-4 and MPEG-H Audio NGA codecs which can support up to 5.1.4 M&E + 4 dialog channels + Audio Description (describer audio only). Channels match the naming convention of the inputs to AC-4 encoders. Decoders will produce outputs for loudspeaker channels specified in ETSI TS 103 190-2 v1.2.1 Digital Audio Compression (AC-4) Standard and ITU-R BS.2051-2 System J. Channel Configuration indices match the ISO/IEC 23091-3 Coding-independent code-points and the precise channel order used for MPEG-H Audio is provided in [23008-3], Section 24.3.4.7.

Table 10 NGA Audio Channel Order and Resolution/Sample rate

Audio Format	Channel Configuration as defined in ISO/IEC 23091-3[9]	Channel Order[10]	Min/Max Resolution and Samplerate (LPCM)
2.0 Stereo	CICP index 2	Left, Right	16-bit/24-bit, 48kHz
5.1 Surround	CICP index 6	Left, Right, Center, Low Frequency Effects (LFE), Left Surround, Right Surround	16-bit/24-bit, 48kHz
5.1.4 (Immersive)	CICP index 16	Left Front, Right Front, Center, LFE, Left Surround, Right Surround, Left Top Front, Right Top Front, Left Top Rear, Right Top Rear	16-bit/24-bit, 48kHz
5.1.4 + 4D + AD (NGA)	CICP index 16 + 5 Objects	Left Front, Right Front, Center, LFE, Left Surround, Right Surround, Left Top Front, Right Top Front, Left Top Rear, Right Top Rear, Dialog 1-4, AD	16-bit/24-bit, 48kHz

6.2.3. Linear PCM (LPCM) Uncompressed Audio Examples

Below are examples of commonly used LPCM audio configurations for AD carriage:

Example 1:

- Channel 1-6, 5.1, spoken language English, language descriptor “eng”
- Channel 7-8, dual mono (two identical mono channels), spoken language English AD, language descriptor “eng” , title = ‘AD’

Example 2:

- Channel 1, stereo mix, spoken language English, language descriptor “eng”

[9] Channel Configuration indices match the ISO/IEC 23091-3 Coding-independent code-points and the precise channel order used for MPEG-H Audio is provided in ISO/IEC 23008-3, Section 24.3.4.7.

[10] Channels match the naming convention of the inputs to AC-4 encoders. Decoders will produce outputs for loudspeaker channels specified in ETSI TS 103 190-2 v1.2.1 Digital Audio Compression (AC-4) Standard and ITU-R BS.2051-2 System J.

- Channel 2, stereo mix, spoken language English AD, language descriptor “eng” , title = ‘AD’

Example 3

- Channel 1-6, 5.1, spoken language: English, language descriptor: “eng”
- Channel 7:
    - Mono channel, Spanish, language descriptor: “las”, “spanish”, “spa"

      -OR-

    - Left channel of a stereo mix, M&E, language descriptor: “eng”, “english” or null
- Channel 8:
    - Mono channel, spoken language English AD, language descriptor “eng” , title = ‘AD’ -OR-
    - Right channel of a stereo mix, M&E, language descriptor: “eng”, “english” or null

Example 4:

- Channel 1-2 = dual mono (two identical mono channels), spoken language English, language descriptor “eng”
- Channel 3-4:
    - dual mono (two identical mono channels), spoken language Spanish, language descriptor “las”, “spanish”, “spa"

      -OR-

    - Stereo, M&E, language descriptor “eng”, “english” or null
- Channel 5-6, dual mono (two identical mono channels), spoken language English AD, language descriptor “eng” , title = ‘AD’

Sample LPCM Audio Channel detail

Audio #x

Format : PCM

Bit rate mode : Constant

Bit rate : 2 304 Kbps

Channel(s) : 2 channels

Channel positions : Front: L R (Matrix)

Sampling rate : 48.0 KHz

Title : AD

Language : English

6.2.4. Compressed Audio

Compressed or encoded audio (i.e., not Linear PCM) is a common method to contribute multichannel audio for surround, immersive, and next generation audio applications. It is also a common method for stereo and mono audio. The formats listed in Table 11 contain both audio and metadata (data that describes the content of the encoded bitstream).

A single bitstream can carry multiple audio channels, where channel layout and phase alignment are maintained. Each bitstream typically carries complete programs, or elements necessary to create a complete program. See Table 11.

For example, a 5.1 channel mix plus a stereo mix would require separate bitstreams in the cases of AC-3 and E-AC-3, but both programs can be carried as a single AC-4 or MPEG-H Audio bitstream. In the case of Next Generation Audio (NGA), a single AC-4 bitstream may contain Music and Effects (M&E) and multiple Dialog (D) elements to enable decoders to reproduce multiple versions of the program by combining those M&E and D elements.

6.2.5. Audio Continuity

It has become increasingly important for audio services to have signals present even if the audio content has stopped. For example, if a secondary audio program like AD is not present, then a downmix of the main program *should* be substituted, or at a minimum, audio silence. This is particularly important at the DASH level where continuity *should* remain constant for at least the segment period as any changes might not be recognized downstream.

Table 11 - Audio Codecs vs. PIDs and Channels

Audio Configuration	Audio Codec	Encoded Audio Streams (PIDs)	Discrete Audio Channels
Stereo Mix only	AC-3, E-AC-3, AC-4, MPEG-H Audio	1	2
5.1 Surround Mix only	AC-3, E-AC-3, AC-4, MPEG-H Audio	1	6
5.1 Surround Mix + Stereo Mix	AC-3, E-AC-3 AC-4, MPEG-H Audio	2 1	8 8
Immersive 5.1.4	E-AC-3 + JOC, AC-4, MPEG-H Audio	1	10
NGA 5.1.4 M&E + xD + AD	AC-4, MPEG-H Audio	1	12-15

7. Linear Contribution Feed Profiles

Linear contribution feed profiles are needed to reduce the variants of contribution feeds that are ingested by the MVPDs. This simplifies equipment and software needed for conversions to distribution feeds from the linear contribution feed. More than one type of linear contribution feed *may* be needed at each profile to simplify the conversion process due to changes in resolution, framerate, brightness, colorimetry, or bitrate from contribution feed to distribution streams.

Note: HDR Linear contribution feeds can source SDR distribution channels, but considerations should be made to simplify the conversion process while preserving video quality in the contribution to distribution workflow.

7.1. UHD linear contribution feed profile

The UHD profile can handle progressive resolutions from 1080 to 8K.

Table 12 - UHD Linear Contribution Feed Profile

Property	Uncompressed	Transport Stream	Comment
Resolution/ Framerates	7680x4320 P- 1,2,6,9,11,12,13 3840x2160 P-1,2,6,9,11,12,13 1920x1080 P-13 Progressive only (native framerates preferred)	7680x4320 P-1,2,6,9,11,12,13 3840x2160 P-1,2,6,9,11,12,13 1920x1080 P-13 Progressive only (native framerates preferred)	
System Colorimetry	Rec.709 for SDR, Rec. 2100* for HDR *limited to P3 values (ST2113)	Rec.709 for SDR, Rec. 2100* for HDR *limited to P3 Values (ST2113)	For HDR follows: BT2100_PQ_YCC or converted from 1000 nit BT2100_HLG_YCC For SDR follows: BT709_YCC
Transfer Function	BT.1886 for SDR, PQ, or HLG for HDR	BT.1886 for SDR, PQ or HLG for HDR	
Encoding	SDI or 2022-6	HEVC 4:2:0– Main10/HT 4:2:2- Main 4:2:2 10/HT L5.1<= 4KP60 L5.2>4KP120	
Chroma Subsampling	4:2:0, 4:2:2	4:2:0, 4:2:2	
Bitdepth	10	10	
Bitrates (Peak/Avg +/-Rate) or (Constant)	60 Gbps for 8K 12 Gbps for 4K and below Physical interfaces see Table 4 & 5	85(Peak)/70 (Avg)+/- 20% Mbps (10 bit)	*Note: Video elementary streams are not intended to be delivered as Variable Bitrate (VBR). Streams should be delivered as Constant Bitrate (CBR) with rate variation tolerances that do not exceed the peak bitrate.*
Audio	LPCM, AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	
Closed Captioning	Embedded 608/708	Embedded 608/708	
Audio Metadata	Embedded	Embedded	
Inband Metadata	SCTE-104	SCTE-35	

7.1.1. Additional Video Constraints

- All video content ***shall*** be progressive.
- Ultra High Definition (HD) video content with an original picture resolution at or above 7680x4320 ***shall*** be delivered at 7680x4320.
- Ultra High Definition (UHD) video content with an original picture resolution between 7680x4320 and 3840x2160 ***shall*** be delivered at 3840x2160.
- Ultra High Definition (HD) video content with an original picture resolution between 3840x2160 and 1920x1080 ***shall*** be delivered at 1920x1080.

7.2. HD linear contribution feed profile

The HD Profile can handle and process both progressive and interlaced linear contribution feeds.

Table 13 - HD Linear Contribution Feed Profile

Property	Uncompressed	Transport Stream	Comment
Resolutions/ Framerates	1920x1080 **P-1,2,6,9,11,12 I- 7,8** 1280x720 **P-1,2,6,9,11,12** (native framerates preferred)	1920x1080 **P-1,2,6,9,11,12 I- 7,8** 1280x720 **P-1,2,6,9,11,12** (native framerates preferred)	
System Colorimetry	Rec.709 for SDR, Rec. 2020* for HDR *limited to P3 values	Rec.709 for SDR, Rec. 2020* for HDR *limited to P3 values	For HDR follows: BT2100_PQ_YCC or BT2100_HLG_YCC For SDR follows: BT709_YCC
Transfer Function	BT.1886 for SDR, PQ, or HLG for HDR	BT.1886 for SDR, PQ, or HLG for HDR	
Encoding	SDI or 2022-6	MPEG-2(*Deprecated) 4:2:0 - 8 bit* High@HighLevel, 4:2:2- 10 bit 4:2:2@ML AVC 4:2:0 High-8 bit 4:2:0 High 10 – 10 bit 4:2:2 High 4:2:2	

Property	Uncompressed	Transport Stream	Comment
		HEVC 4:2:0– Main10/HT 4:2:2- Main 4:2:2 10/HT	
Chroma Subsampling	4:2:0, 4:2:2	4:2:0, 4:2:2	
Bitdepth	8,10	8, 10	
Bitrates (Peak/Avg +/- Rate) or (Constant)	2.90 Gbps or above Physical interfaces see Table 4 & 5	MPEG 2 80(Peak)/40 (Avg) +/-25% Mbps SDR 8-Bit Only AVC 45(Peak)/40(Avg)+/- 25% Mbps SDR 8 or 10 bit HDR 10 bit only HEVC 45(Peak)/30(Avg) +/- 25% Mbps SDR 8 or 10 bit HDR 10 bit only	*Note: Video elementary streams are not intended to be delivered as Variable Bitrate (VBR). Streams should be delivered as Constant Bitrate (CBR) with rate variation tolerances that do not exceed the peak bitrate.*
Audio	LPCM, AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	
Closed Captioning	Embedded 608/708	Embedded 608/708	
Audio Metadata	Embedded	Embedded	
Inband Metadata	SCTE-104	SCTE-35	

7.2.1. Additional Video Constraints

- High Definition (HD) video content with an original picture resolution between 3840x2160 and 1920x1080 ***shall*** be delivered at 1920x1080.

- High Definition (HD) video content with an original picture resolution between 1280x720 and 1920x1080 ***shall*** be delivered at 1280x720

- SDR content can be progressive or interlaced content.

7.2.1.1. Additional HDR Constraints [HEVC Only]

- All HDR video content ***shall*** be progressive.

7.3. SD linear contribution feed profiles

The SD Profile can handle and process both progressive and interlaced linear contribution feeds. Originating signals with resolutions that are different than 720x480 needs to be cropped or modified to one of these resolutions.

Table 14 - SD Linear Contribution Feed Profile

Property	Uncompressed	Transport Stream	Comment
Resolutions	480x720 [16:9/4:3] 480x854 [16:9] P-1,2,6,9 I- 7,8	480x720 [16:9/4:3] 480x854 [16:9] P-1,2,6,9 I-7,8	
System Colorimetry	Rec.709 for SDR	Rec.709 for SDR	Follows : BT709_YCC
Transfer Function	BT.1886	BT.1886	
Encoding	SDI or 2022-6 Physical interfaces see Table 4 & 5	MPEG-2 (*Deprecated) 4:2:0 - 8 bit* High@HighLevel, 4:2:2- 10 bit 4:2:2@ML AVC 4:2:0 High-8 bit 4:2:2 High 4:2:2 HEVC 4:2:0– Main10/HT 4:2:2- Main 4:2:2 10/HT	
Chroma Subsampling	4:2:0, 4:2:2	4:2:0, 4:2:2	
Bitdepth	8	8	
Bitrates (Peak/Avg +/-Rate) or (Constant)	1.45 Gbps or above Physical interfaces see Table 4 & 5	MPEG2 35(Peak)/25(Avg) +/-25% Mbps AVC 35(Peak)/25(Avg) +/-25% Mbps HEVC 20(Peak)/15(Avg) +/-25% Mbps	*Note: Video elementary streams are not intended to be delivered as Variable Bitrate (VBR). Streams should be delivered as Constant Bitrate (CBR) with rate variation tolerances that do not exceed the peak bitrate.*
Audio	LPCM, AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	AC-3 / E-AC-3, E-AC-3+JOC, AC-4, MPEG-H Audio	
Closed Captioning	Embedded 608/708	Embedded 608/708	
Audio Metadata	Embedded	Embedded	
Inband Metadata	SCTE-104	SCTE-35	

7.3.1. Additional Video Constraints

- Any Content with an original picture resolution less than 1280x720 ***shall*** be delivered as SD content with one of the following resolutions:
    - 720 x 480 for 4:3 content
    - 720 x 480 or 854 x 480 for 16:9 content

- All Content ***shall*** be SDR.

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