OpenCable™ Specifications

Content Encoding Profiles 3.0 Specification

OC-SP-CEP3.0-I03-120123

ISSUED

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Key to Document Status Codes:

Work in Progress	An incomplete document, designed to guide discussion and generate feedback, that may include several alternative requirements for consideration.
Draft	A document in specification format considered largely complete, but lacking review by Members and vendors. Drafts are susceptible to substantial change during the review process.
Issued	A stable document, which has undergone rigorous member and vendor review and is suitable for product design and development, cross-vendor interoperability, and for certification testing.
Closed	A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs.

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1 INTRODUCTION

This specification defines the video, audio, and related encoding parameters for both Standard and High-Definition content for distribution to cable television systems. Encoding parameters defined by this specification can be applied to different content types, including broadcast programming, which may be switched digital video (SDV), VOD content, and advertising content to be inserted into broadcast or VOD content. Broadcast programming is encoded in streams with no finite length and is not formatted as files. Individual VOD programs or ads of finite length are encoded and formatted as files or byte streams for storage on video servers or other headend equipment.

The encoding parameters described in this document are not constraints on the streams delivered by cable systems to a home or business. The streams delivered to a home or business are generally more complex: they may not be finite in length, they are often multiplexes of multiple feeds, and they may include dynamic transitions from program to program.

In general, this specification is used in conjunction with other related specifications from CableLabs to create a full "package" of content. Other standards (e.g., VC-1) are currently beyond the scope of this document.

1.1 Purpose of Document

This document defines the content specifications for use with encoding systems, asset management, and distribution. It does not define a distribution method nor define all aspects of the cable system infrastructure that content may encounter during distribution and playback.

1.2 Organization of Document

This document contains three major sections. Section 6 covers general encoding, Section 7 gives additional constraints specific to Standard Definition encoding, and Section 8 covers High Definition encoding.

2 REFERENCES

2.1 Normative References

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

[ATSC A/52B] ATSC A/52B: Digital Audio Compression (AC-3, E-AC-3), Revision B, 2005.

[ATSC A/53, Part 3] ATSC A/53, Part 3: Service Multiplex and Transport Subsystem Characteristics, 2009.

[ATSC A/53, Part 4] ATSC A/53, Part 4: MPEG-2 Video System Characteristics, 2009.

[ATSC A/53, Part 5] ATSC A/53, Part 5: AC-3 Audio System Characteristics, 2007.

[CEA 608-E] EIA/CEA-608-E: Line 21 Data Services, 2008.

[CEA 708-D] EIA/CEA-708-D: Digital Television (DTV) Closed Captioning, 2008.

[CONTENTv3.0] MD-SP-CONTENTv3.0-I01-100812, CableLabs Content 3.0 Specification, August 12, 2010, Cable Television Laboratories, Inc.

[ETV-AM1.0] OC-SP-ETV-AM1.0-I06-110128, Enhanced TV Application Messaging Protocol 1.0, January 28, 2011, Cable Television Laboratories, Inc.

[ETV-BIF1.0] OC-SP-ETV-BIF1.0-I06-110128, Enhanced TV Binary Interchange Format 1.0, January 28, 2011, Cable Television Laboratories, Inc.

[IEC 11172-3] ISO/IEC 11172-3:1998 (E), International Standard, Information Technology - Coding of Moving Pictures and Associated Audio for Digital Storage Media at up to about 1.5 Mbits/s – Part 3: Audio.

[IEC 13818-1] ISO/IEC 13818-1:2007, International Standard, Information Technology - Generic Coding of Moving Pictures and Associated Audio Information: Systems.

[IEC 13818-2] ISO/IEC 13818-2:2000 (E), International Standard, Information Technology - Generic Coding of Moving Pictures and Associated Audio Information: Video.

[IEC 13818-3] ISO/IEC 13818-3:1998 (E), International Standard, Information Technology - Generic Coding of Moving Pictures and Associated Audio Information: Audio.

[IEC 13818-4] ISO/IEC 13818-4:1998/Cor-2:1998, International Standard, Information Technology - Generic Coding of Moving Pictures and Associated Audio Information: Conformance Testing, Technical Corrigendum 2.

[IEC 13818-7] ISO/IEC 13818-7:2006, Information technology -- Generic coding of moving pictures and associated audio information -- Part 7: Advanced Audio Coding (AAC)

[IEC 14496-3] ISO/IEC 14496-3, 2005: Information technology - Coding of audio-visual objects – Part 3 Audio including amendment 1: "Bandwidth Extension" and amendment 2 "Parametric coding for High Quality Audio".

[IEC 14496-10] ISO/IEC 14496-10, 2010: Information technology -- Coding of audio-visual objects -- Part 10: Advanced Video Coding.

[IEC 61672-1] IEC 61672-1, Electroacoustics – Sound level meters – Part 1: Specifications.

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

[ITU H.264] ITU-T. Recommendation H.264 (03/2010), Advanced video coding for generic audio visual services.

[ITU-R BS.1770] ITU-R BS.1770 (07/2006), Algorithms to measure audio programme loudness and true peak audio level.

[OCAP] OC-SP-OCAP1.2.1-120112, OpenCable Application Platform Specification, January 12, 2012, Cable Television Laboratories, Inc.

[SCTE 128] ANSI/SCTE 128 2010-a, AVC Video Systems and Transport Constraints for Cable Television.

[SCTE 172] ANSI/SCTE 172 2011, Constraints on AVC Video Coding for Digital Program Insertion.

[SCTE 20] ANSI/SCTE 20 2004, Methods for Carriage of Closed Captions and Non-Real Time Sampled Video.

[SCTE 27] ANSI/SCTE 27 2003, Subtitling Methods for Broadcast Cable.

[SCTE 35] ANSI/SCTE 35 2007, Digital Program Insertion Cueing Message for Cable.

[SCTE 43] ANSI/SCTE 43 2005, Digital Video Systems Characteristics Standard for Cable Television.

[SCTE 54] ANSI/SCTE 54 2009, Digital Video Service Multiplex and Transport System Standard for Cable Television.

2.2 Informative References

This specification uses the following informative references.

[CEA-CEB10-A] CEA-CEB10-A: EIA-708-B Implementation Guidance, 2002.

[FCC 47 CFR 79.1] FCC Rules 47 CFR 79.1: Closed Captioning of Video Programming

[FCC 00-259] FCC 00-259: Closed Captioning Requirements for Digital Television Receivers

[SCTE 30] ANSI/SCTE 30 2009, Digital Program Insertion Splicing API.

[SCTE 104] ANSI/SCTE 104 2004, Automation System to Compression System Communications Applications Program Interface (API).

[VOD 1.1] MD-SP-VOD-CONTENT1.1-I06-091229, CableLabs Video-On-Demand Content 1.1 Specification, December 29, 2009, Cable Television Laboratories, Inc.

2.3 Reference Acquisition

- ATSC Specifications

  http://atsc.org/cms/
- CableLabs Specifications:

  http://www.cablelabs.com/
- CEA Specifications

  http://www.ce.org/
- FCC Specifications:

  http://wireless.fcc.gov/rules.html
- ISO Specifications:

  http://www.iso.ch/
- ITU Specifications

  http://www.itu.int/
- SCTE Specifications

  http://www.scte.org/

3 NOTATION, DEFINITIONS, AND TERMINOLOGY

3.1 Compliance Notation

Throughout this document, words are used that define the significance of particular requirements. These words are:

"MUST"	This word means that the item is an absolute requirement of this specification.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word 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 weighed 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 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.

4 TERMS AND DEFINITIONS

The syntax and semantics of this specification conform to [IEC 13818-1].

The following terms warrant a definition as used in the context of this specification:

Access unit In the case of audio, an access unit is the coded representation of an audio frame. In the case of MPEG-2 video, an access unit includes all the coded data for a picture and any stuffing that follows it. If the picture is preceded by a Sequence Header, the access unit begins with the first byte of the sequence_header_code. If the picture is preceded by a Group of Pictures Header and no Sequence Header, the access unit begins with the first byte of the group_start_code. If the picture is not preceded by a Sequence Header or Group of Pictures, the access unit begins with the first byte of the picture_start_code. In the case of AVC video, an access unit is as defined in [IEC 13818-1] section 2.14.1.

Group of Pictures A Group of Pictures is a sequence of coded pictures, beginning with an I-Picture and ending just before the subsequent I-Picture. Also referred to as a GOP.

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.

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.

Video content Video content is a single file composed of an MPEG-2 transport stream that is an encoding of a feature and optionally trailers and advertising. The video content can contain one or more audio tracks and one or more sets of subtitles. It may also contain private or additional data PID streams.

5 ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this specification:

ANSI	American National Standards Institute
ATSC	Advanced Television System Committee
AVC	Advanced Video Coding
CBR	Constant Bit Rate
CEA	Consumer Electronics Association
DPB	Decoded Picture Buffer
DTS	Decoding Time Stamp
DTV	Digital Television
DVB	Digital Video Broadcasting Group
DVS	Digital Video Specification
EIA	Electronic Industries Alliance
fps	Frames per second
GOP	Group of Pictures
HD	High Definition
IDR	Instantaneous Decoder Refresh
IEC	International Electrotechnical Commission
IRE	Institute of Radio Engineers
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JVT	Joint Video Team
Mbps	Megabits Per Second
MPEG	Moving Picture Experts Group
NPT	Normal Play Time
NTSC	National Television System Committee

PAT	Program Association Table
PCR	Program Clock Reference
PID	Packet Identifier
PES	Packetized Elementary Stream
PMT	Program Map Table
PSI	Program-Specific Information
PTS	Presentation Time Stamp
QAM	Quadrature Amplitude Modulation
S3D	Stereoscopic, three-Dimensional
SAR	Sample Aspect Ratio
SbS	Side-by-Side
SCTE	Society of Cable Telecommunication Engineers
SD	Standard Definition
SEI	Supplemental Enhancement Information
SPS	Sequence Parameter Set
SPTS	Single Program Transport Stream
T-STD	Transport Stream System Target Decoder
TaB	Top-and-Bottom
UI	User Interface
VBR	Variable Bit Rate
VOD	Video on Demand
VUI	Video Usability Information

6 BASIC ENCODING

This section describes general coding constraints that are applicable to both SD and HD content.

6.1 Metadata Specification

This section describes the normative specification of Metadata associated with encoded video content.

Metadata MUST be created in accordance with [CONTENTv3.0].

6.2 Video Encoding Specification

This section describes the normative specification of the encoded video content.

1. For MPEG-2 encoding, the first byte of the video elementary stream MUST be the first byte of a sequence_start_code.
2. The video elementary stream MUST contain an integral number of access units.
3. For MPEG-2 encoding, a Sequence Header and a Sequence Extension MUST precede each I-Picture.
4. All B-Pictures in the video bit stream MUST use prediction based on pictures present in the bit stream. Specifically, the first GOP in the video elementary stream MUST NOT begin with a B-Picture predicted from a reference picture that does not exist in the stream. That is, the first GOP MUST be closed.
5. For MPEG-2 encoding, the length of each GOP SHOULD be 15 frames long for 30 fps video-source material, and 12 frames long for 24 fps film-source material. Conformance to this GOP constraint MUST apply where an Out Point is specified using an NPT value per Section 6.11.
6. For MPEG-2 encoding, there MUST be an I-Picture at the In Point.
7. For AVC encoding, In and Out Points MUST comply with [SCTE 172].
8. For MPEG-2 encoding, the number of consecutive B-Pictures between anchor pictures (I-Picture or P-Picture) MUST be two or less.
9. For MPEG-2 encoding, the 2-bit picture_structure field in the picture_coding_extension() of each picture MUST have the value of '11' in binary, indicating that the picture is encoded as a frame picture.
10. The video elementary stream MUST NOT use any MPEG-2 scalable extensions, which include the Sequence Scalable Extension, the Picture Temporal Scalable Extension, and the Picture Spatial Scalable Extension.
11. Black level of content MUST be at 0 IRE.
12. For MPEG-2 encoding, no audio PES packets MUST exist with a PTS in the content prior to the I-Picture designated as NPT 0 as defined in Section 6.11.
13. For AVC encoding, no audio PES packets MUST exist with a PTS in the content prior to the IDR (AVC) designated as NPT 0 as defined in Section 6.11.
14. For AVC encoding, the constraints specified in [SCTE 128] MUST be observed.
15. AVC encoding MUST support the Encoding Guidelines to Enable Trick Play Support of AVC Streams as defined in [SCTE 128], Appendix B.2.4 "Smooth Trick Play and Compression Efficiency". Other compatible techniques to support trick play smoothness at different rates of play MAY also be supported.
16. For MPEG-2 and AVC encoding, the last byte of the payload of the transport packet transmitted prior to an Out Point MUST be the last byte of a video access unit and the last byte of a PES packet.

17. For MPEG-2 encoding, the last picture in presentation order prior to an Out Point MUST be either a P or I picture.

18. For MPEG-2 encoding, to accommodate horizontal resolution changes after the Out Point, the last access unit prior to an Out Point MUST end with a sequence end code.

19. For MPEG-2 encoding, following an In Point or Out Point, the first transport packet carrying a video payload MUST contain a PES header and meet the Video PES constraints specified in Section 6.6.1. The payload of that PES packet MUST contain an I-Picture and meet the encoding requirements for MPEG-2 I-Pictures specified in Section 6.2.

20. For MPEG-2 encoding, the sequence header fields vertical_size_value, aspect_ratio_information, frame_rate and constrained_parameters_flag MUST contain values identical to those fields within the last sequence header transmitted prior to the In Point or Out Point. The field horizontal_size_value is permitted to change within the format constraints specified in [SCTE 43]. The sequence extension MUST be identical to the last sequence extension transmitted prior to the In Point or Out Point. Field parity MUST be maintained across the In Point or Out Point.

    Note: For applications (ex. Ad insertion into on demand content using playlists) that switch between encoded content files, these constraints should be observed in selecting content files to play out in sequence.

21. For MPEG-2 encoding, the access unit following an In Point MUST contain a GOP header, and the closed_gop bit in the GOP header MUST be set to '1', indicating that this first GOP is closed.

22. For MPEG-2 and AVC encoding, the first picture in presentation order following an Out Point MUST 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: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.

23. For MPEG-2 and AVC encoding, the first picture in decode order following an Out Point MUST 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.

    Note: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.

24. For AVC encoding, when the last access unit prior to the Out Point is decoded, all of the pictures in the DPB which are not yet output (displayed/presented) MUST be, starting immediately, contiguously displayable (no discontinuity in their PTS values).

25. For AVC encoding, the first transport packet following an In Point carrying a video payload MUST contain a PES header and meet the PES constraints specified in section 6.5 of [SCTE 128]. The payload of that PES packet MUST be an SRAP access unit containing an IDR constrained by [SCTE 172] and [SCTE 128]. The SPS and VUI parameters of this IDR access unit MUST be the same as the SPS and VUI parameters of coded video sequence transmitted prior to the transition point except for the field 'PicWidthInMBs' as constrained by [SCTE 128]. The no_output_of_prior_pics_flag in this IDR access unit MUST be set to '0'.

26. For AVC encoding, field parity MUST be maintained at a transition point from one piece of encoded content to another. At the transition point, content MUST NOT switch between progressive and non-progressive video content.

27. For MPEG-2 and AVC encoding, the encoded content following an In Point MUST comply with the In Point constraints in this specification. The beginning of an encoded file MUST be a valid In Point. A valid In Point MUST exist where an In Point can occur between two positions within the same file or between two different files.

28. For MPEG-2 and AVC encoding, the encoded content prior to the Out Point MUST comply with the Out Point constraints in this specification. The end of an encoded file MUST be a valid Out Point. A valid Out Point

MUST exist where an Out Point can occur between two positions within the same file or between two different files.

6.3 Usage of ANSI/SCTE 35

6.3.1 ANSI/SCTE 35 Registration Descriptor Specification

This section describes the normative specification of requirements for inclusion of the ANSI/SCTE 35 descriptor.

The ANSI/SCTE 35 Registration Descriptor, as specified in section 6.1 of [SCTE 35], MUST be present in the PMT.

6.3.2 Usage of the ANSI/SCTE 35 segmentation_descriptor()

This descriptor provides a standardized mechanism for placing declarations into the bitstream for content identification as well as providing a standardized mechanism for segmenting the content into chapters. While additional uses are possible, these two uses will be documented here.

The segmentation_descriptor() MUST be used only with the time_signal() and the splice_null() constructs of [SCTE 35]. The descriptor syntax and semantics are defined in section 8.3.3 of [SCTE 35].

6.3.2.1 Content Identification Declaration

This usage of the segmentation_descriptor() MUST place the descriptor within a splice_null() as defined in section 7.3.1 of [SCTE 35]. The use of this declaration covers content including all content types, both live feeds as well as pre-encoded content of both long and short forms (includes programming and advertising).

The semantics of the fields within the segmentation_descriptor() for this purpose follow:

segmentation_event_id - A 32-bit segmentation event identifier, unique within the content duration.

segmentation_event_cancel_indicator - MUST be set to '0'.

program_segmentation_flag - MUST be set to '1'.

segmentation_duration_flag - MUST be set to '0'.

segmentation_upid_type - MUST be set to the relevant value found in table 8-6 of [SCTE 35] identifying the type of UPID.

segmentation_upid_length - MUST be set to the relevant value found in table 8-6 of [SCTE 35].

segmentation_upid( ) - MUST be set to the value assigned to the UPID and be consistent with table 8-6 in [SCTE 35] and the associated **segmentation_upid_type** and **segmentation_upid_length** fields.

segmentation_type_id - MUST be set to 0x00 indicating "not indicated".

segment_num and **segments_expected** - MUST be set to zero, indicating "not used".

Duplicate occurrences of a Content Identification Declaration message are permitted. To avoid unnecessary use of bandwidth, the minimum time spacing of duplicates MUST be no less than one per minute. The minimum occurrence of a Content Identification Declaration message is once per program. Actual spacing of these messages is likely to be determined by the content provider's Legal and Content Protection staffs.

6.3.2.2 Segmenting Content

This usage of the segmentation_descriptor() MUST place the descriptor within a time_signal() as defined in section 7.3.4 of [SCTE 35]. Segments MUST have a logical hierarchy consisting of programs (highest level), chapters, and

advertisements (refer to table 8-7 of [SCTE 35]). Provider and Distributor advertisements share the lowest logical level and should not overlap.

Descriptors should normally be paired, the first for a given segment start and the second for segment end. Each segment end usage MAY be followed by another segment start. Overlapping segment definitions MAY be used. Segmentation_descriptor() pairs are uniquely identified by segmentation_upid(), segmentation_event_id, and segment_num. The segmentation_upid() MAY be omitted, but if present, MUST be the same between identifier pairs.

For the purposes of defining the segmentation_descriptor() semantics, the following definition applies:

Segment - MUST be either a **Program**, a **Chapter**, a **Provider Advertisement**, a **Distributor Advertisement**, or an **Unscheduled Event** as listed in table 8-7 of [SCTE 35]. The valid pairings are:

Program start/end - Program end can be overridden by program early termination

Program breakaway/resumption

Chapter start/end

Provider advertisement start/end

Distributor advertisement start/end

Unscheduled_event_start/end

The semantics of the fields within the segmentation_descriptor() for segmenting content follow:

segmentation_event_id - A 32-bit segmentation event identifier, unique within the content duration. If a segment end is signaled, the Segment end time_signal() **segmentation_event_id** value MUST match the Segment start **segmentation_event_id** value.

segmentation_event_cancel_indicator - MUST be set to '0'.

program_segmentation_flag - MUST be set to '1'.

segmentation_duration_flag - MAY be set to '0' or '1'. If set to '1', a valid **segmentation_duration()** MUST be included in the descriptor.

segmentation_upid_type - MUST be set to the relevant value found in table 8-6 of [SCTE 35] identifying the type of UPID. A value of 0x00 may be used if desired.

segmentation_upid_length - MUST be set to the relevant value found in table 8-6 of [SCTE 35].

segmentation_upid( ) - MUST be set to the value assigned to the UPID and be consistent with table 8-6 in [SCTE 35] and the associated **segmentation_upid_type** and **segmentation_upid_length** fields. A null value may be provided if **segmentation_upid_type** is set to 0x00.

segmentation_type_id - MUST be set to a valid value from table 8-8 of [SCTE 35].

segment_num - MUST be set to non-zero values ranging from one to the value of **segments_expected**. For Program segments, this value MUST be set to one. This field may be used for Chapters and Advertisements as desired.

segments_expected - MUST be set to a non-zero value, providing the number of segments in the program. For Program segments, this value MUST be set to one.

6.4 Audio Encoding Specification

This section describes the normative specification of the encoded audio content.

1. For AC-3 audio elementary streams, the audio compression format MUST conform to the bit stream syntax for the Digital Audio Compression (AC-3) Standard in accordance with [ATSC A/52B]. The Enhanced AC-3 audio elementary stream MUST conform to [ATSC A/52B] as constrained per [ATSC A/53, Part 5] with additional data rates up to 448 kbps.
2. When available, the source audio SHOULD be encoded as 5.1 channel AC-3 or Enhanced AC-3, i.e., the audio coding mode SHOULD be 3/2 and the low frequency effects channel SHOULD be on. If the source audio cannot be encoded as AC-3 5.1, then the audio coding mode MUST be 2/0, i.e., 2-channel stereo (Left & Right).
3. If the audio is encoded as 5.1 channel, then the encoded bit rate MUST be under 448 kbps.
4. If the audio is encoded as 2-channel stereo (2/0), then the encoded bit rate MUST be 192 kbps.
5. The audio sample rate MUST be 48 kHz.
6. The first byte of the audio elementary stream MUST be the first byte of an audio access unit.
7. The audio elementary stream MUST contain an integral number of access units.
8. The dialogue normalization value (dialnorm) in each AC-3 elementary stream MUST be set to agree with (i.e., indicate) the level of average spoken dialogue within the encoded audio program. The dialogue level can be measured by means of an A-weighted integrated measurement (Leq(A) [IEC 61672-1] or [ITU-R BS.1770]). **Informative note**: Receivers (i.e., Set-top Boxes, Home Theaters, etc.) use the dialnorm value to adjust the reproduced audio level upon decoding to normalize the dialogue level.[1]
9. For MPEG audio elementary streams, the audio compression MUST conform to the bit stream syntax for one of the following:
   - MPEG-1 audio Layer I, II & III [IEC 11172-3]
   - MPEG-4 AAC, [IEC 14496-3]
   - MPEG-4 HE-AAC [IEC 14496-3]
   - MPEG-4 HE-AAC-v2 [IEC 14496-3].
   - MPEG-2 AAC-LC [IEC 13818-7].

   Note: MPEG-2 AAC-LC may not be supported by all receivers.
10. The last byte of the payload of the transport packet transmitted prior to an Out Point MUST be the last byte of an audio access unit and the last byte of a PES packet.
11. The first audio payload following an In Point MUST start with a PES header and the start of an audio access unit.
12. The values of PTS of the first audio access unit after an Out Point MUST be such that the presentation of this access unit follows the presentation of the last access unit transmitted prior to the Out Point at the proper time as determined by the audio access unit duration.
13. The bit stream syntax MUST remain the same for the encoded content.

    Note: For applications (ex. Ad insertion into on demand content using playlists) that switch between encoded content files, the bit stream syntax should remain the same.

6.5 Subtitling Data Specification

This section describes the normative specification of the encoding and transport of subtitling data.

Subtitling data MUST be encoded and carried in the transport stream in accordance with [SCTE 27].

[1] For further information see http://www.dolby.com/about/contact_us/contactus.cfm?goto=31

6.6 MPEG-2 Systems Constraints

This section describes the coding constraints that apply to the use of the MPEG-2 Systems specification in creation of a single transport stream. Because this document is for stored content, there should not be any discontinuities or PSI version changes. Other applications, such as broadcast, may have PSI version changes and time base discontinuities. These uses are outside the scope of this document.

6.6.1 Video PES Constraints

This section describes the coding constraints that apply to the video Packetized Elementary Stream (PES).

1. Each video access unit MUST be completely contained within one PES packet, and the first byte of the PES packet payload MUST be the first byte of the video access unit.
2. Decoding and presentation time stamps (DTS and PTS), DTS present only if DTS differs from the PTS, MUST be contained in the PES packet header of each PES packet that carries an I-Picture.

6.6.2 Transport Stream Constraints

1. The transport stream MUST comply with the definition of a transport stream as specified in [IEC 13818-1].
2. The transport stream MUST carry only a single program (SPTS).
3. The program in the transport stream MUST contain only a single video elementary stream.
4. The program in the transport stream MUST contain at least one audio elementary stream.
5. The transport stream MUST consist of 188-byte transport packets.
6. The first byte of the transport stream MUST be the first byte of a transport packet.
7. The transport stream MUST contain an integral number of transport packets.
8. The transport stream MUST NOT contain continuity_counter discontinuities.
9. The transport stream MUST contain exactly one system time-base discontinuity (PCR), which MUST be signaled in the first PCR packet of the stream. PCR continuity MUST be maintained in the case where one or more Out Points and/or In Points exist between two presentation units in the encoded content.

   Note: Output devices (ex. a video streamer) MAY maintain PCR continuity when transitioning from one piece of encoded content to another. Alternatively, an output device may choose to signal time-base discontinuity at such transitions between encoded content. If signaled by the output device, the time-base discontinuity MUST be signaled in the first PCR packet follow the transition to the new content.
10. PCRs MUST have an accuracy of 5 ppm.
11. The first PCR packet of the stream MUST have the transport discontinuity_indicator flag set to '1'.
12. A PCR SHOULD be present in any transport packet containing the first byte of a video PES payload.
13. The audio T-STD MUST comply with section 3.6 of Annex A of [ATSC A/52B].
14. The random_access_indicator MUST be set to '1' in any transport packet containing the first byte of a video PES payload that carries an I-Picture.
15. For Video In Point and Out Points, the transitions MUST maintain full compliance with the T-STD model.

6.6.3 Transport Bit Rate Constraints

The transport stream MUST be constant bit rate within the tolerances provided by [IEC 13818-1] section 2.4.2.2.

6.6.4 PSI Constraints

1. A complete Program Association Table (PAT) MUST occur in the transport stream before the first byte of a Program Map Table (PMT).
2. A PMT that contains a complete program definition MUST occur in the transport stream before the first transport packet with an elementary stream PID.
3. The time interval in the transport stream between successive occurrences of the PAT MUST be less than or equal to 250 milliseconds. It is recommended that the time interval between successive occurrences of the PAT be 125 milliseconds.
4. The time interval in the transport stream between successive occurrences of the PMT MUST be less than or equal to 250 milliseconds. It is recommended that the time interval between successive occurrences of the PMT be 125 milliseconds.
5. The stream_type value assigned in the PMT to the video elementary stream MUST be 0x02 or 0x80 for MPEG-2 video and 0x1B for AVC video.
6. The stream_type value assigned in the PMT to AC-3 and E-AC-3 audio elementary streams MUST be 0x81 [ATSC A/53, Part 3]. The stream_type values for MPEG-1 audio (Layer I, II, & III); MPEG-4 (MPEG-4 HE-AAC and MPEG-4 HE-AAC-v2) audio MUST conform to the specified values in table 2-34 of [IEC 13818-1].
7. Descriptors MUST be included in the PMT to comply with SCTE and ATSC standards. The descriptors in Table 1 SHOULD be considered.

Table 1 - Descriptors

Descriptor	Defining Specification	Notes
Registration	ISO/IEC 13818-1	Optional per ANSI/SCTE 54 2009
ISO-639 language	ISO/IEC 13818-1	Not required after 1 March 2008 per [ATSC A/53, Part 3]
AC-3 Audio Stream	ATSC A/52B	After 1 March 2008 will include ISO 639 language descriptor per [ATSC A/53, Part 3]

8. Other private data PIDs are allowed in the PMT. These entries in the PMT SHOULD have registration_descriptors identifying their structure.
9. There MAY be PIDs in the transport stream that are not referenced in the PSI. The use and handling of these PIDs are beyond the scope of this document.
10. PMT sections SHOULD be no longer than 183 bytes in length and SHOULD be placed into a single transport stream packet. It is anticipated that future PMT sections may exceed this length due to PID demands for audio, ETV/OCAP, and other applications.
11. All PATs in the file SHOULD be identical and should have a constant version_number.
12. All PMTs in the file SHOULD be identical and should have a constant version_number.

6.6.5 PID Value Constraints

This specification uses a fixed PID allocation for PSI, video, audio, and data streams. In future versions of this specification, these PIDs may be unconstrained. In anticipation of this change, users and implementers should not assume these fixed values will always be used, and instead should determine the PIDs based on the contents of the PSI.

1. The program_map_PID for the program MUST have the value 0x1E0 (decimal 480).
2. The elementary_PID assigned to the video elementary stream MUST have the value 0x1E1 (decimal 481).
3. The PCR_PID of the program MUST have the value 0x1E1 (decimal 481).

4. The elementary_PID assigned to the first, or primary, audio elementary stream listed in the PMT MUST have the value 0x1E2 (decimal 482).
5. If one or more audio elementary streams are present in addition to the primary audio elementary stream, the elementary_PID assigned to the Nth additional audio elementary stream listed in the PMT MUST have the value 0x1E0 + N + 1.
6. If one or more data elementary streams are present in addition to one or more audio elementary streams, the elementary PID assigned to the data elementary streams listed in the PMT MUST have values higher than the last audio elementary stream.

6.7 Recommended Video Compression Practices (Informative)

This section is for informative purposes only.

1. Film-source material SHOULD be encoded using "reverse" or "inverse" telecine, resulting in a coded frame rate of 23.97 Hz.
2. Each stream within the program SHOULD start without any significant leader (such as black video frames) and end without any significant trailer to facilitate the seamless back-to-back splicing of separate programs.
3. Quality Control cleanup MAY be performed, if necessary, using noise reduction and bandwidth limiting.

6.8 Bit Rate (Informative)

This section describes bit rate calculations and concerns for video content. The examples here use SD values, but the calculations, with appropriate values, are applicable to HD as well.

6.8.1 Transport Bit Rate

There are many concerns, constraints, and issues that determine the optimal bit rate for a given situation. For example, success has been widely achieved using the 3.75 Mbps transport bit rate for SD; other rates are possible. However, users and implementers should be aware that installed and legacy systems have constraints on bandwidth and system resource management that do not currently support widely-varied bit rates–especially within a single QAM multiplex as may be encountered in actual use. Thus, 3.75 Mbps is a "safe harbor" for SD until planned system improvements occur.

Depending on MPEG-2 encoder quality, desire to maintain high consumer picture quality, etc., it has been suggested that low-motion, low-complexity content can be successfully encoded at 3.37 Mbps, while sports content may require a rate exceeding that permitted by this specification (e.g., 4.125 Mbps). However, optimal picture quality can be obtained by changes to raw bit rate and/or changes in encoder resolution and/or filtering. Considering the "safe harbor" noted above, it is desired to change filtering first and bit rate as required on a secondary basis.

6.8.2 Video Bit Rate

The maximum bit rate that is available for video is dependent on the number of audio services and their bit rates. For example, in the SD case where the transport stream is limited to 3.75 Mbps, the video rate must be lower when 5.1 audio is included at 384 kbps than when stereo audio at 192 kbps is used. If multiple audio streams are included, the video must leave room for the highest bit rate audio. For example, if both stereo and 5.1 audio are included, then the video and the 384 kbps audio must fit into 3.75 Mbps.

It is important to take overhead into account when determining the video rate. The video rate is just that - the rate of the video elementary stream. This does not include the PES and transport overhead. The transport overhead will add about 2.2%, and the PES and PCR will add 4.4 kbps. These numbers are estimates.

For example, assuming a 5.1 audio at 384 kbps, what is the max video rate for SD? The audio rate is increased by the PES and transport overhead to 396 kbps. The PSI (PAT and PMT) at 10 times per second add another 30 kbps. This leaves 3.324 Mbps for the video. Reducing by the transport overhead (2%), and subtracting the PES and PCR overhead, leaves 3.25 Mbps. This calculation is meant to show how the maximum video rate is affected by the audio and how the transport and other overhead comes into play. The actual maximum video rate will depend on the encoding and multiplexing system in use.

Complex SD sequences, such as sports or action scenes, will require rates over 3 Mbps. It may be possible to use a much lower rate in some circumstances, such as for slide-show type sequences of pictures. Because of the wide variety of source material, no limits are placed on the video elementary stream rate by this specification.

For AVC encoding, the recommended transport stream bit rate[2] SHOULD be the minimum rate for any given content according to business requirements that fit into one of the defined bit rates in the table below[3]:

Table 2 - Recommended AVC Transport Stream Bit Rates

Rate	Content type	Peak Transport Stream bit rate
1	MPEG 4, SD Transport Rate:	1.875 Mbps
2	MPEG 4, SD Transport Rate:	3.750 Mbps
3	MPEG 4, HD Transport Rate:	5.625 Mbps
4	MPEG 4, HD Transport Rate:	7.500 Mbps
5	MPEG 4, HD Transport Rate:	9.375 Mbps
6	MPEG 4, HD Transport Rate:	11.250 Mbps
7	MPEG 4, HD Transport Rate:	15.000 Mbps
8	MPEG 4, HD Transport Rate:	18.750 Mbps

6.9 Handling Multiple Audio Streams (Informative)

This section is for informative purposes only.

Content encoded with additional or alternative audio elementary streams will have PID assignments pursuant to Section 6.6.5, and will not exceed the nominal transport bit rate specified in Section 6.6.3. It is expected that the provisioning of the content conceptually occurs as in the following narrative (in this example, Spanish audio is the "first alternate" language and, thus, is encoded on PID 0x1E3):

1. Consumer is presented with a selection of content that has alternative (Spanish) audio available. (Note: it is beyond the scope of this narrative to discuss the language of Metadata and/or UI).
2. Consumer selects the alternative language via the UI.
3. The server source / consumer sink session streams with Video PID=0x1E1 and Audio PID=0x1E3 (alternate audio). Primary audio PID=0x1E2 is dropped by the server and does not consume any QAM bandwidth. In the

[2] The bit rates shown are for the distribution over the cable system between the VOD server and the VOD client; actual bit rate for delivery to the cable system may be higher. The bit rates shown represent the peak transport stream bit rates, including the sum of the video elementary stream, one audio language or service with the highest bit rate, and any ETV (EBIF) or OCAP bound-application data that may accompany the content. If more than one audio service is provided with the content, the highest bit rate of any single service or language will be used for the calculation of the peak transport stream bit rate.

[3] The recommended bit rates are designed to allow optimal use of the bandwidth provided by a QAM 256 channel. Other delivery mechanisms, outside the scope of this document, may use different bit rates.

example that primary audio was Dolby 5.1 (384 kb/s) and the secondary audio was Dolby 2/0 (192 kb/s), the transport stream is 192 kb/s lower than the nominal bit rate in Section 6.6.3.

4. For clarity: It is important to note that the server did **not** re-map the alternative audio from 0x1E3 to 0x1E2.

6.10 Data Specification

This section describes the normative specification of optional data content.

1. ETV content MUST be delivered as part of the transport stream as described in [ETV-AM1.0] and [ETV-BIF1.0].
2. OCAP content MUST be delivered as part of the transport stream as described in [OCAP].
3. While multiple profiles MAY be included in the content encoded per this specification, the data PIDs matching the profile of the requesting device SHOULD be used in choosing the actual data content delivered. Profiles are discussed in more detail in the referenced ETV and OCAP specifications.

6.11 NPT Usage Specification

NPT generation and interpretation is constrained by the following.

1. For MPEG-2, the first I-Picture following the PMT following the PAT MUST be considered NPT 0. See PSI constraints in Section 6.6.4.
2. For AVC, the first IDR following the PMT following the PAT MUST be considered NPT 0. See PSI constraints in Section 6.6.4.
3. An NPT MUST be based on the difference between the PTS at the referenced point and the PTS at NPT 0.
4. An NPT reference MUST be resolved by adding the NPT as an offset to the PTS at NPT 0. The NPT MUST be no more than 1 ms before the referenced picture.
5. For an out point, presentation MUST be up to but not including the referenced picture.
6. For an in point, presentation MUST start with the referenced picture.

7a. In the case of a timebase discontinuity that is indicated by the discontinuity_indicator in the transport packet adaptation field, the discontinuity is the result of some stream manipulation upstream of the VOD system. The VOD system MUST assume that the upstream device has created a compliant stream and the relative timing across the discontinuity has been maintained. The stream is expected to conform to ISO 13818-1 and 13818-4 requirements for signaled discontinuities. When the server detects the discontinuity indicator, it MUST recalculate the offset described in (4) above by the following mechanism:

   1. the server MUST calculate the effective PCR in the original timebase of the first packet containing a PCR in the new timebase. If the content is not CBR, the server MUST use the bitrate calculated for the last PCR interval.
   2. the difference between the calculated PCR and the new PCR carried after the discontinuity_indicator MUST be applied to the active offset to create the new offset value.
   3. the new offset value MUST be used to convert all PTS values following the signaled discontinuity to NPT values.

   Note: If the stream commences with a discontinuity indicator, it is not subject to this processing.

7b. In the case where the discontinuity is not signaled, it is assumed to be the result of an error upstream of the VOD system. Since an unknown number of packets may be missing, the VOD system MUST continue to use the same offset value that was in effect prior to the discontinuity.

8. In the case of a rollover in any time-based value (PCR or PTS), NPT calculations MUST be performed as if there were an infinite number of bits in the field, e.g. by virtually adding extra bits to the existing value and carrying out the lost rollover bit before performing any calculation of NPT.

7 STANDARD DEFINITION (SD) ENCODING - MPEG-2

This section is applicable to "Standard Definition" (SD) MPEG-2 encoding of video content. SD video compression is constrained to the so-called "NTSC 480i" format. Although based on the same core SCTE parameters, this SD encoding specification contains parameters that were (and may continue to be) applicable to certain "legacy" implementations, and are not relevant to HD-compatible set-top devices and/or 2-way compatible host devices.

Further, there are some "fixed" or "set" values within this section that are applicable to the "state of the industry" as of this writing. For example, although MPEG video encoding continues to improve, some of the bit rate parameters specified herein are necessary due to limitations in QAM and system bandwidth resource management systems.

7.1 Metadata Specification

This section describes the normative specification of Metadata associated with SD-encoded video content.

The Metadata MUST comply with [CONTENTv3.0].

7.2 Video Encoding Specification

This section describes the normative specification of the SD-encoded video content.

1. The video compression format MUST conform to the requirements of [IEC 13818-2]. The allowable parameters MUST be bounded by the upper limits specified for the Main Profile at Main Level.
2. The video bit stream MUST meet the constraints and extensions described in [SCTE 43] for a coded vertical size of 480, aspect ratio of 4:3, and interlaced scan, i.e., it MUST be constrained to the entries in table 3 of [SCTE 43] with the vertical_size_value equal to 480, the aspect_ratio_information equal to 2 (4:3 display aspect ratio), the frame_rate_code equal to 4 (29.97 Hz), and the progressive_sequence equal to 0 (interlaced scan).

   Note: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.
3. The video elementary stream MUST be encoded at a constant bit rate (CBR). In the future, variable bit rate (VBR) encoding may be allowed.

7.3 MPEG-2 Systems Constraints

This section describes the coding constraints that apply to the use of the MPEG-2 Systems specification in creation of a single transport stream containing SD-encoded video content.

1. Every transport packet MUST NOT have an adaptation_field_length equal to zero, i.e., the adaptation field, when present, in any transport packet MUST have a length greater than one byte.
   Informative Note: This constraint exists to support legacy set-top boxes.
2. The number of bytes between the last byte of the start code preceding each Picture Start Code to the first byte of the Picture Start Code MUST be a multiple of four (commonly referred to as "quad-byte alignment").
   Informative Note: This constraint exists to support legacy set-top boxes.

7.3.1 Transport Bit Rate Constraints

The aggregate transport bit rate for PID 0, the PMT PID, the video PID, any one audio PID, and any data PIDs MUST NOT exceed 3.75 Mbps.

7.4 Closed Caption / V-Chip Requirements for MPEG-2 SD

This section describes the normative specification of the encoding and transport of closed caption data in video picture user data.

1. [SCTE 20] formatted CEA-608 user data are required.
2. ATSC [ATSC A/53, Part 4] formatted CEA-708D user data are required. The ATSC [ATSC A/53, Part 4] data MUST include cc_type '00' and '01' CEA-608 data pairs containing CC1 captions, and cc_type '10' and '11' data pairs containing DTVCC Service 1 captions.
3. User data sections MUST observe the interleave requirements of [SCTE 43] section 5.2.2. Additional closed caption services embedded in the ATSC [ATSC A/53, Part 4] and [SCTE 20] user data constructs are optional.
4. V-Chip data, encoded in accordance with [CEA 608-E], MUST conform to the ratings and/or content advisory data values set in Metadata.

Notes:

1. Refer to informative reference [FCC 47 CFR 79.1] for rules governing carriage of closed captioning and exemptions.
2. Refer to informative reference [FCC 00-259] for rules governing carriage of CEA-708 full syntax data.

8 HIGH DEFINITION (HD) ENCODING - MPEG-2

This section is applicable to "High Definition" (HD) MPEG-2 encoding.

8.1 Metadata Specification

This section describes the normative specification of Metadata associated with HD-encoded video content.

The Metadata MUST comply with [CONTENTv3.0].

8.2 Video Encoding Specification

This section describes the normative specification of the HD-encoded video content.

1. The video compression format MUST conform to the syntax of [IEC 13818-2], and MUST be subject to the constraints specified in Annex A of [ATSC A/53, Part 4]. The allowable parameters MUST be bounded by the upper limits specified for the Main Profile at High Level.
2. For video produced using the 1080i production format, the video bit stream MUST meet the constraints and extensions described in table 3 of [SCTE 43] for a coded vertical size of 1080, coded horizontal size of 1920, aspect ratio of 16:9, the frame_rate_code equal to 4 (29.97 Hz), and the progressive_sequence equal to 0 (interlaced scan).

   Note: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.
3. For video produced using the 720p production format, the video bit stream MUST meet the constraints and extensions described in table 3 of [SCTE 43] for a coded vertical size of 720, coded horizontal size of 1280, aspect ratio of 16:9, the frame_rate_code equal to 7 (59.94 Hz), and progressive scan (progressive_sequence equal to 1).

   Note: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.
4. For video produced using the 1080p production format or film-source material, the video bit stream MUST meet the constraints and extensions described in table 3 of [SCTE 43] for a coded vertical size of 1080, coded horizontal size of 1920, aspect ratio of 16:9, the frame_rate_code equal to 1 (23.976 Hz) or 2 (24 Hz), and the progressive_sequence equal to 1 (progressive scan).

   Note: Output devices (ex. a video streamer) SHOULD also comply with this constraint when transitioning from one piece of encoded content to another.

8.3 Audio Encoding Specification

This section describes the normative specification of the audio associated with the HD-encoded video content.

Alternatively, for applications of this standard outside of North America, the audio compression format MAY conform to either [IEC 11172-3], [IEC 13818-3], or [IEC 14496-3] subject to constraints and restrictions that are to be determined.

Informative Note: This feature exists to support DVB systems.

8.4 MPEG-2 Systems Constraints

This section describes the coding constraints that apply to the use of the MPEG-2 Systems specification, in creation of a single transport stream containing HD-encoded video content.

8.4.1 Transport Bit Rate Constraints

The aggregate transport bit rate for PID 0, the PMT PID, the video PID, any one audio PID, and one or more data PIDs MUST NOT exceed 19 Mbps.

8.5 Recommended Video Compression Practices (Informative)

This section applies to HD encoding of video content and is for informative purposes only.

The video elementary stream MAY be encoded at a variable bit rate (VBR).

8.6 Transport Bit Rate (Informative)

This section applies to HD encoding of video content and is for informative purposes only.

There are many concerns, constraints, and issues that determine the optimal bit rate for a given situation. Success has been widely achieved using the 15 Mbps transport bit rate, which is a multiple integer of the Standard Definition transport bit rate, using a variety of encoding systems and a variety of content types; other rates are possible.

However, users and implementers should be aware that installed and legacy systems have constraints on bandwidth and system resource management that do not currently support widely varied bit rates–especially within a single QAM multiplex as may be encountered in actual use. Thus, 15 Mbps is a "safe harbor" until planned system improvements occur. Improvements in both system resource management as well as MPEG encoding will result in successful accommodation of varied (and lower) bit rates; however, it does not appear that deployed systems can benefit from those improvements at this time.

8.7 Closed Caption / V-Chip Requirements for MPEG-2 HD

This section describes the normative specification of the encoding and transport of closed caption data in video picture user data.

1. ATSC [ATSC A/53, Part 4] formatted CEA-708 user data are required. ATSC [ATSC A/53, Part 4] data MUST include type '00' and '01' CEA-608 data pairs containing CC1 captions, and type '10' and '11' data pairs containing DTVCC Service 1 captions.
2. V-Chip data, encoded in accordance with [CEA 608-E], MUST conform to the ratings and/or content advisory data values set in Metadata.

Notes:

1. Refer to informative reference [FCC 47 CFR 79.1] for rules governing carriage of closed captioning and exemptions.
2. Refer to informative reference [FCC 00-259] for rules governing carriage of CEA-708 full syntax data.
3. [SCTE 20] is not used for MPEG-2 HD video.

9 ADVANCED VIDEO ENCODING

This section applies to both SD and HD video encoding based upon [ITU H.264] and [SCTE 128].

9.1 Metadata Specification

This section describes the normative specification of Metadata associated with AVC-encoded video content.

The Metadata MUST comply with [CONTENTv3.0].

9.2 Video Encoding Specification

This section describes the normative specification of the AVC-encoded video content.

1. The video compression format MUST conform to the syntax of [ITU H.264], and MUST be subject to the constraints specified in [SCTE 128]. The allowable parameters MUST be bounded by the upper limits specified for the High Profile at Level 4.0.
2. For SD video produced using the 480i production format, the video bit stream MUST meet the constraints and extensions described in table 9 of [SCTE 128] for a coded vertical size of 480, the aspect_ratio_idc equal to 3 (10:11 and 4:3 display aspect ratio), the frame_rate_code equal to 4 (29.97 Hz), and the progressive_sequence equal to “I” (interlaced scan).
3. For HD video produced using the 1080i production format, the video bit stream MUST meet the constraints and extensions described in table 9 of [SCTE 128] for a coded vertical size of 1080, coded horizontal size of 1920, aspect ratio of 16:9, the frame_rate_code equal to 4 (29.97 Hz), and the progressive_sequence equal to “I” (interlaced scan).
4. For HD video produced using the 720p production format, the video bit stream MUST meet the constraints and extensions described in table 9 of [SCTE 128] for a coded vertical size of 720, coded horizontal size of 1280, aspect ratio of 16:9, the frame_rate_code equal to 7 (59.94 Hz), and progressive scan (progressive_sequence equal to “P”).
5. For HD video produced using the 1080p production format or film-source material, the video bit stream MUST meet the constraints and extensions described in table 9 of [SCTE 128] for a coded vertical size of 1080, coded horizontal size of 1920, aspect ratio of 16:9, the frame_rate_code equal to 1 (23.976 Hz) or 2 (24 Hz), and the progressive_sequence equal to “P” (progressive scan).

9.3 Audio Encoding Specification

This section describes the normative specification of the audio associated with the AVC-encoded video content.

Alternatively, for applications of this standard outside of North America, the audio compression format MAY conform to either [IEC 11172-3] or [IEC 13818-3], subject to constraints and restrictions that are to be determined.

Informative Note: This feature exists to support DVB systems.

9.4 MPEG-2 Systems Constraints

This section describes the coding constraints that apply to the use of the MPEG-2 Systems specification as constrained in [SCTE 54], in creation of a single transport stream containing AVC-encoded video content.

9.4.1 Transport Bit Rate Constraints

The aggregate transport bit rate for PID 0, the PMT PID, the video PID, any one audio PID, and any data PIDs MUST NOT exceed 20 Mbps.

9.5 Recommended Video Compression Practices (Informative)

This section applies to HD encoding of video content and is for informative purposes only.

The video elementary stream MAY be encoded at a variable bit rate (VBR), provided the peak bit rate does not exceed the designated peak bit rate of one of the valid rates shown in Section 6.8.2, Table 2.

9.6 Closed Caption / V-Chip Requirements for AVC

This section describes the normative specification of the encoding and transport of closed-caption data in AVC.

1. Closed Caption MUST be transported in the AVC bitstream using registered user data SEI as specified in Section 8.0 of [SCTE 128].
2. Closed Caption MUST be encoded in the AVC bitstream as specified in CEA-708 and MUST include both CEA-608 (cc_type values of '00', '01') and DTVCC (cc_type values of '10' and '11').
3. Closed caption MUST be implemented with all video formats specified in table 9 of [SCTE 128].
4. V-Chip data, encoded in accordance with [CEA 608-E], MUST conform to the ratings and/or content advisory data values set in Metadata.

Notes:

1. Refer to informative reference [FCC 47 CFR 79.1] for rules governing carriage of closed captioning and exemptions.
2. Refer to informative reference [FCC 00-259] for rules governing carriage of CEA-708 full syntax data.
3. [SCTE 20] is not used for AVC-coded video.

10 STEREOSCOPIC 3D FORMATTING SPECIFICATION

This section describes the normative specifications for stereoscopic 3D-encoded video. Stereoscopic 3D-encoded content MUST meet all other sections of this specification with additional requirements noted below.

10.1 Synchronization

1. TaB formatting MUST be coded with time-synchronous Left-eye and Right-eye images within a single frame.
2. SbS formatting MUST be coded with time-synchronous Left-eye and Right-eye images within a single frame.

10.2 Top-and-Bottom (TaB) frame-compatible format

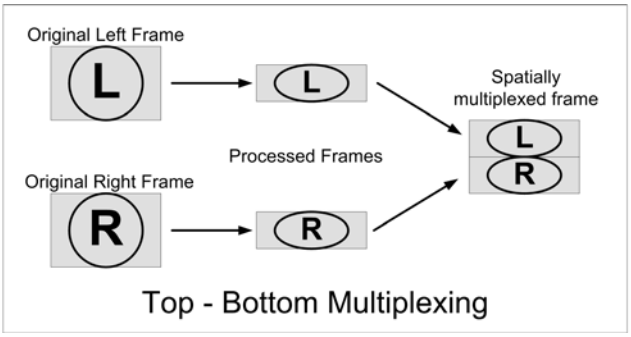

Figure 1 - TaB Multiplexing

1. TaB formatting MUST be used with progressive (720p and 1080p) HD video formats exclusively.
2. TaB formatting MAY be used with MPEG-2 or with AVC/H.264 Video coding.
3. TaB formatting MUST be oriented with the Left-eye image on the top half of the frame and Right-eye image on the bottom half of the frame, without any inversion or mirroring.
4. For 720p formats, the Left-eye image MUST occupy lines 26 to 385, and the Right-eye image MUST occupy lines 386 to 745.
5. For 1080p formats, the Left-eye image MUST occupy lines 42 to 581, and the Right-eye image MUST occupy lines 582 to 1121.
6. TaB formatting MUST be coded using any anti-aliased resizing algorithm that reduces resolution and alias components only in the vertical direction without specific line structure orientation between left and right views. This means that a simple 2-dimensional image processed in this way will produce exactly the same reduced image for the left and right views. Note: Figure 2 below illustrates the rearrangement and upconversion processing of the TaB 3D format used for cable systems:

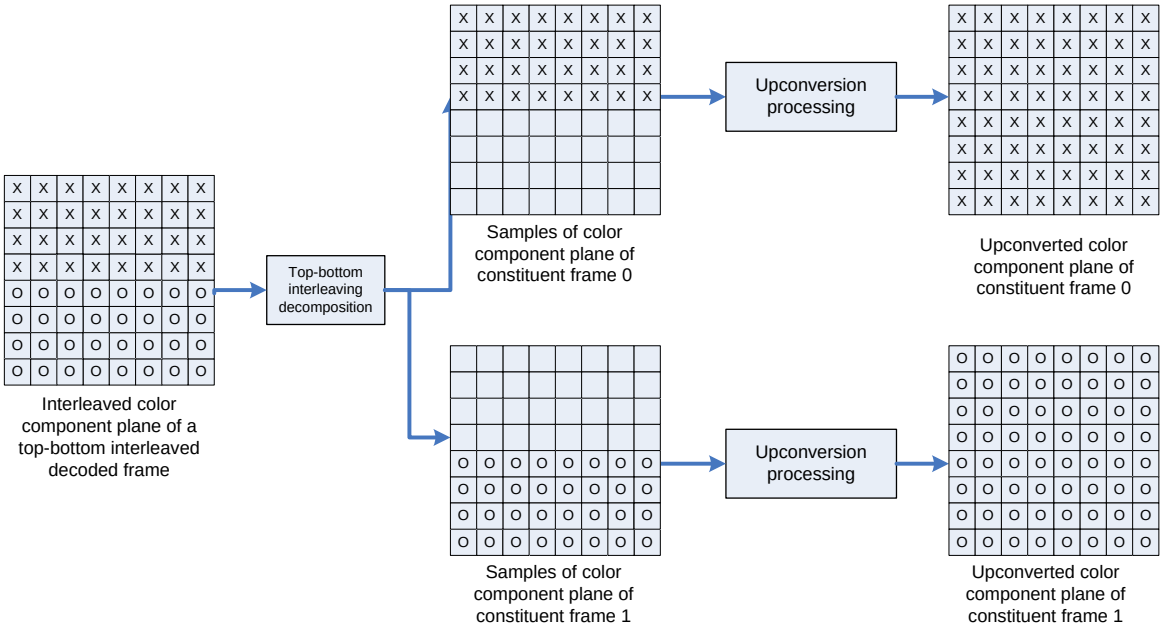

Figure 2 - Rearrangement and upconversion of TaB format

7. TaB formatting MUST comply with the details described in Figure 3 and Figure 4 below:

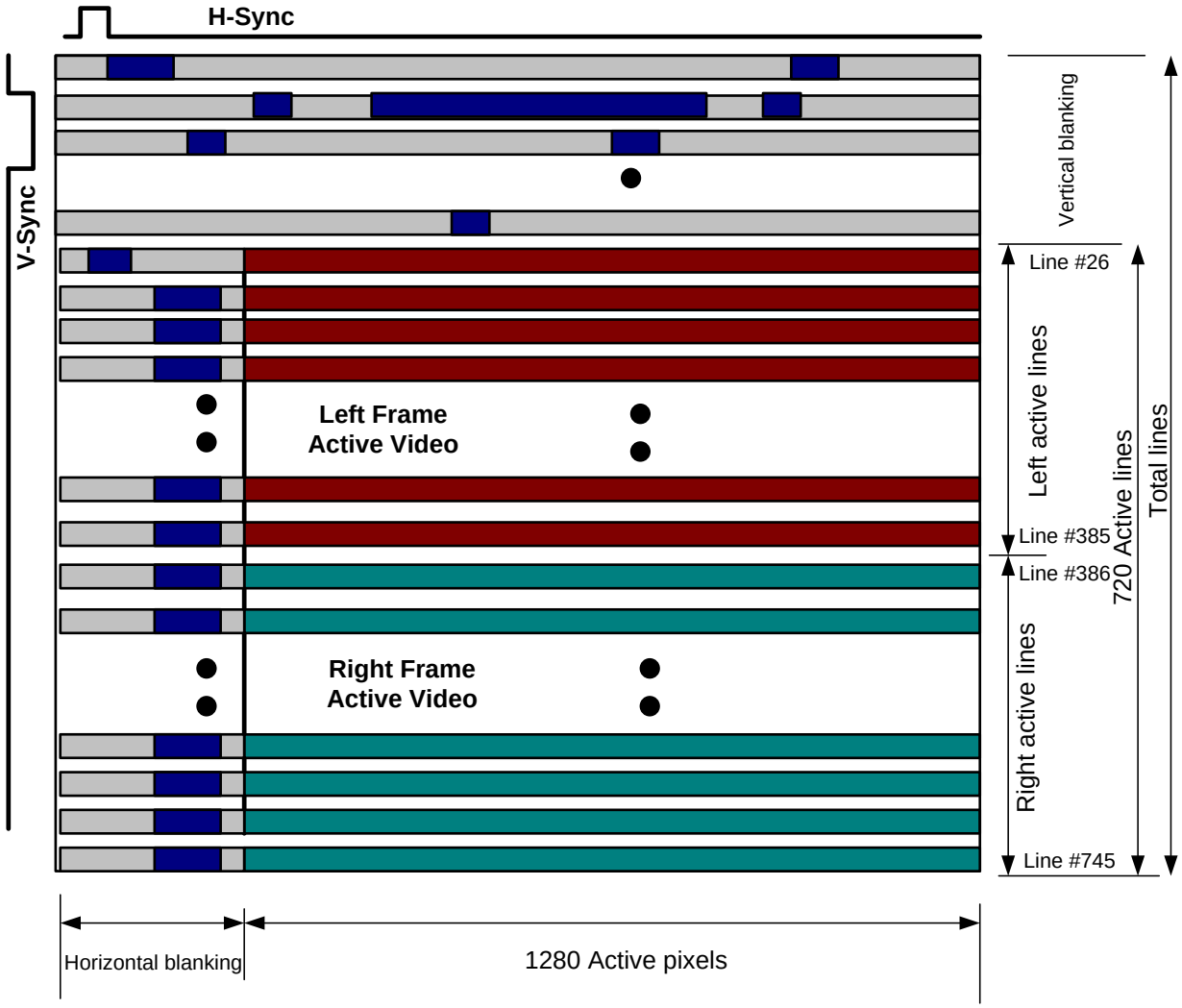

Figure 3 - TaB formatting for 720p video format

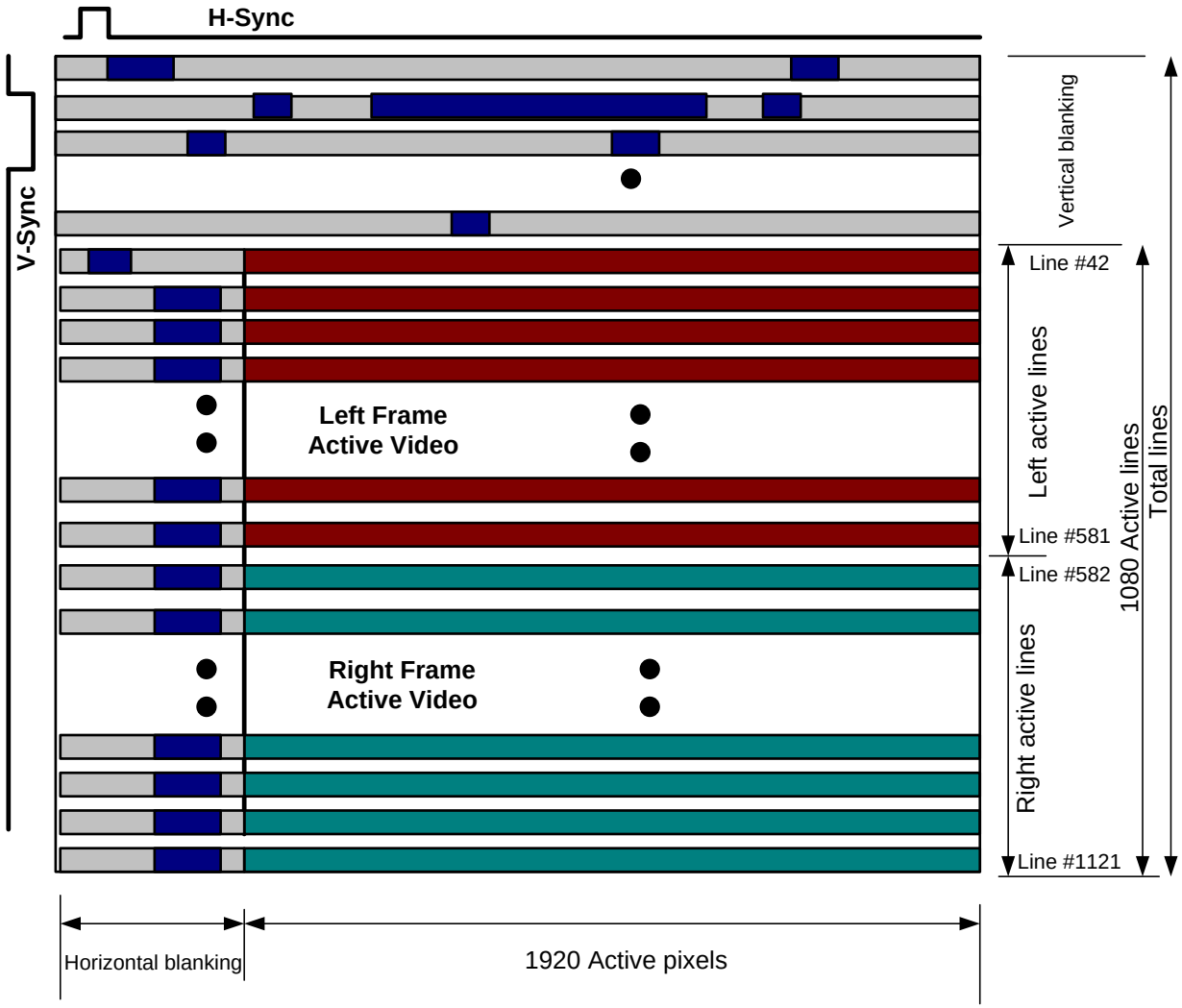

Figure 4 - TaB formatting for 1080p video format

10.3 Side-by-Side (SbS) frame compatible format

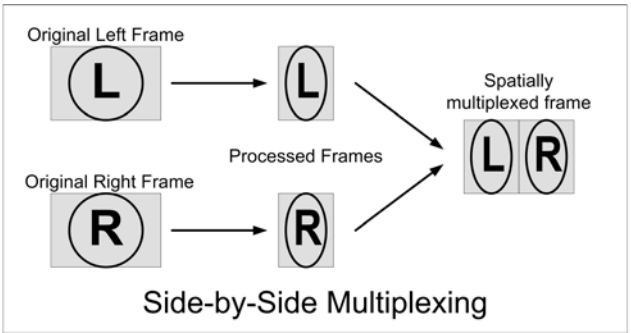

Figure 5 - SbS Multiplexing

1. SbS formatting MUST be used with interlaced (1080i) HD video formats exclusively.

2. SbS formatting MAY be used with MPEG-2 or with AVC/H.264 Video coding.
3. SbS formatting MUST be oriented with the Left-eye image on the left half of the frame and Right-eye image on the right half of the frame, without any inversion or mirroring.
4. SbS formatting MUST be coded using any anti-aliased resizing algorithm that reduces resolution and alias components only in the horizontal direction without specific column structure orientation between left and right views. This means that a simple 2-dimensional image processed in this way will produce exactly the same reduced image for the left and right views. Figure 6 below illustrates the rearrangement and upconversion processing of the SbS 3D format used for cable systems:

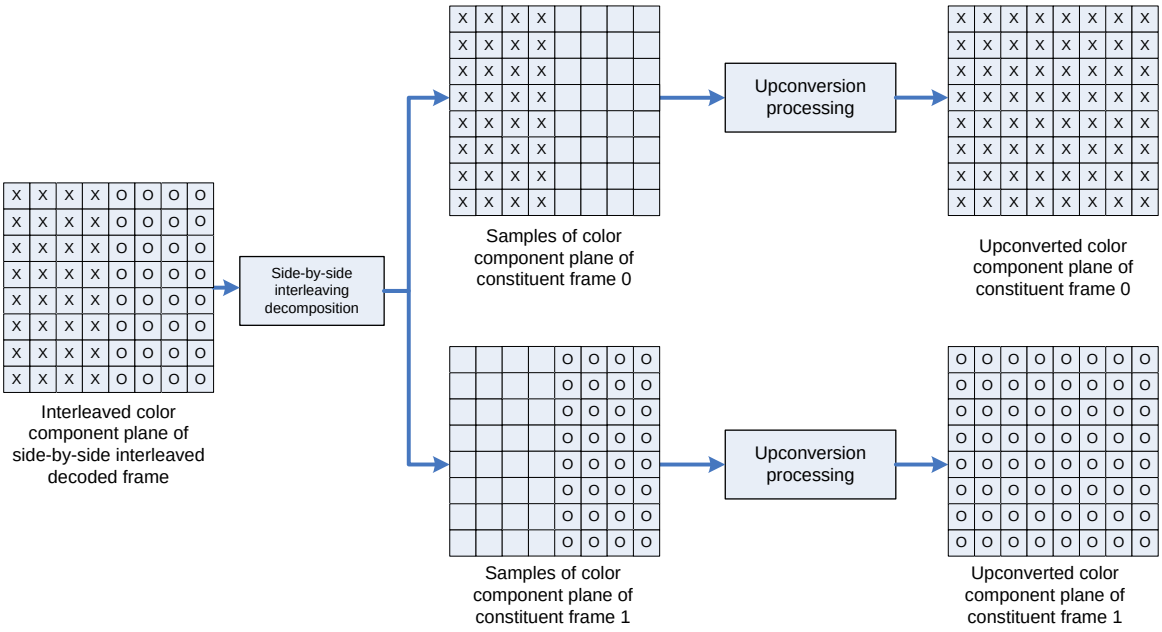

Figure 6 - Rearrangement and upconversion of SbS format

5. SbS formatting MUST comply with the details described in Figure 7 below:

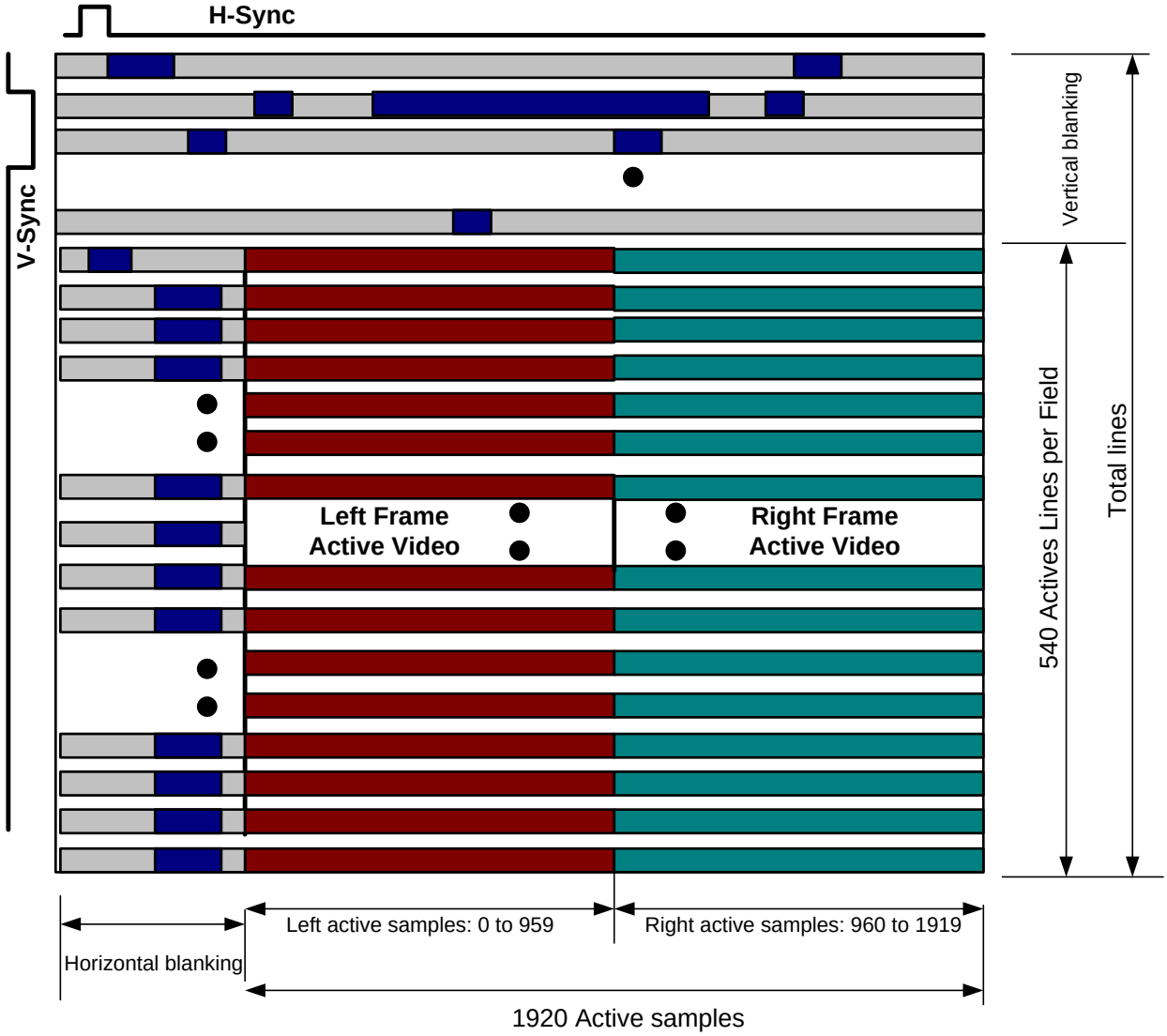

Figure 7 - SbS formatting for 1080i video format (same for both fields)

10.4 Letterboxing and Side-panels with 3D content

1. Any 1080 line S3D content formatted as TaB where the source material is letter-boxed MUST be formatted such that corresponding picture elements of the left image are always separated by exactly 540 lines from those corresponding picture elements of the right image. For example, elements of line 62 are aligned with corresponding elements of line 602 and so on down the picture structure so that elements of line 519 are also aligned with line 1059 as shown in Figure 8 below.
2. Any 720 line S3D content formatted as TaB where the source material is letter-boxed MUST be formatted such that corresponding picture elements of the left image are always separated by 360 lines from those corresponding picture elements of the right image. For example, elements of line 26 are aligned with corresponding picture elements of line 385 and so on down the picture structure so that elements of line 386 are also aligned with line 745.

3. Any blank scan lines at the top of the picture SHOULD also align with blank scan lines at the bottom of the picture as shown in Figure 8 below. [Variations in the blank lines will be discussed in a future annex to this specification.]

Figure 8 - TaB formatting with preferred letterboxing

4. Any S3D content formatted as TaB where the source material is letter-boxed, MUST NOT be misaligned such that corresponding elements of the Left-eye image and the Right-eye image are not on the corresponding scan lines. For example, when the letterboxed images are connected by adjacent scan lines as shown in Figure 9 below:

Figure 9 - TaB formatting with incorrect letterbox alignment

5. Any S3D content formatted as SbS where the source material is side-paneled (pillarboxed) SHOULD be formatted with exactly the same number of blank samples on the left side of the picture as the right side of the picture as shown in Figure 10 below. [Consideration for horizontal image translation adjustment and floating windows will be discussed further in a future annex to this specification.]
6. Any S3D content formatted as SbS where the source material is side-paneled (pillarboxed) MUST be formatted such that corresponding picture elements of the left image are always separated by exactly 960 pixels (columns) from corresponding picture elements of the of the right image, when placed at the screen plane or zero parallax setting (ZPS). For example, elements of column 20 are aligned with corresponding elements of column 980 and so on across the image so that elements of column 939 are also aligned with elements in column 1899. Differences in this horizontal alignment will naturally occur on portions of the picture not at ZPS.
7. Any blank columns on the left side of the picture SHOULD also align with corresponding blank columns on the right sides of the picture as shown in Figure 10 below. [Variations in these column widths and symmetry will be discussed in a future annex to this specification.]

Figure 10 - SbS formatting with preferred Side-Panels

10.5 PSI Requirements for S3D Video

10.5.1 MPEG-2 video based S3D

In addition to the signaling in the video, the following descriptor MUST be carried in the PMT of an S3D video service to signal whether the service in MPEG-2 Transport Stream carries the signaling metadata described below in Section 10.7 (for MPEG-2 video based S3D). This descriptor is reproduced from MPEG as part of amendment-7 to [IEC 13818-1]. This descriptor MUST be included in the PMT for 3DTV coded services as well as 3DTV services that include a mix of 2D content. This descriptor should only be used with stream_type value of 0x02 or 0x80 (MPEG-2 video).

Table 3 - MPEG2_stereoscopic_video_format_descriptor syntax

Syntax	No. of bits	Format
MPEG2_stereoscopic_video_format_descriptor{		
descriptor_tag	8	uimsbf
descriptor_length	8	uimsbf
stereo_video_arrangement_type_present	1	bslbf
If (stereo_video_arrangement_type_present)		
arrangement_type	7	bslbf
else {		
reserved }	7	bslbf
}		

Use and application:

1. The MPEG2_stereoscopic_video_format_descriptor MUST be associated in the PMT for MPEG-2 S3D video components (and 2D video components within a 3DTV service) with stream_type values equal to 0x02 or 0x80.
2. When present, the MPEG2_stereoscopic_video_format_descriptor MUST be located in the loop following ES_info_length field in PMT.
3. If the MPEG2_stereoscopic_video_format_descriptor is included in the PMT, then the associated MPEG-2 video elementary stream MUST contain stereoscopic video format information in the user_data extension as specified in ITU-T Rec. H.262 | [IEC 13818-2]/Amd.4.
4. For any service or stream that includes concatenated elements of 2D and 3D content, the PMT MUST contain the MPEG2_stereoscopic_video_format_descriptor for both 2D and 3D segments.

Syntax:

descriptor_tag - The descriptor_tag value MUST be 0x34.

descriptor_length - An 8-bit unsigned integer, in the range of 1 to 255, that indicates the number of byte to follow. The value of descriptor_length MUST be set to 0x01 for the present version of the descriptor. If extensions to the descriptor are defined in the future, the descriptor_length may change accordingly.

stereo_video_arrangement_type_present - When this bit is set to '1', then the following 7 bits indicate the type of stereo_video_format included in the user_data of associated MPEG-2 video elementary stream. This bit MUST NOT be set to '0'.

arrangement_type - This field MUST be set to the same value as arrangement_type defined in table L-1 of ITU-T Rec. H.262 | [IEC 13818-2]/Amd.4 and included in the user_data extension of associated MPEG-2 video elementary stream.

10.5.2 AVC Video Based S3D

In addition to the signaling in the video, the following descriptor MUST be carried in the PMT of an S3D video service to signal whether the service in MPEG-2 Transport Stream carries the signaling metadata described below in Section 10.6 (for AVC video based S3D). This descriptor is reproduced from [IEC 13818-1] / FDAM 6 (2011) and MUST be included in the PMT for stream_type value = 0x1B (AVC video) when the component is 3DTV coded.

Table 4 - AVC video descriptor

Syntax	No. of bits	Mnemonic
AVC_video_descriptor() {		
descriptor_tag	8	uimsbf
descriptor_length	8	uimsbf
profile_idc	8	uimsbf
constraint_set0_flag	1	bslbf
constraint_set1_flag	1	bslbf
constraint_set2_flag	1	bslbf
constraint_set3_flag	1	bslbf
constraint_set4_flag	1	bslbf
constraint_set5_flag	1	bslbf
AVC_compatible_flags	2	bslbf
level_idc	8	uimsbf
AVC_still_present	1	bslbf
AVC_24_hour_picture_flag	1	bslbf
Frame_Packing_SEI_not_present_flag	1	bslbf
reserved	5	bslbf
}		

Use and application:

1. The AVC_video_descriptor MUST be associated in the PMT for AVC S3D video components with stream_type values equal to 0x1B.
2. When present, the AVC_video_descriptor MUST be located in the loop following ES_info_length field in PMT.
3. If the AVC_video_descriptor is included in the PMT and the syntax element Frame_packing_SEI_not_present_flag is set to '0', then the associated AVC video elementary stream MUST contain stereoscopic video format information in the AVC SEI message as specified in [ITU H.264] | [IEC 14496-10].
4. For any service or stream that includes concatenated elements of 2D and 3D content, the PMT MUST contain the AVC_video_descriptor for both 2D and 3D segments, and the syntax element Frame_Packing_SEI_not_present_flag MUST be set accordingly.
5. If the descriptor is not present, then the video component in the service does not carry the frame_packing_arrangement_type SEI message described below in Section 10.6. Thus, the video component is not 3DTV encoded.

Syntax:

descriptor_tag - The descriptor_tag value MUST be 0x28.

10.5.3 Optional S3D descriptor for MPEG-2

The following descriptor MAY also be included optionally in the PMT of a S3D video service to signal whether the service in MPEG-2 transport stream carries signaling metadata as described below in Sections 10.6 or 10.7:

Table 5 - 3d_video_descriptor syntax

Syntax	No. of bits	Format
3d_MPEG2_descriptor{		uimsbf
descriptor_tag	8	
descriptor_length	8	
3d_frame_packing_data_present	1	
reserved	7	
}		

Use and application:

1. The 3d_video_descriptor MAY be associated in the PMT for MPEG-2 video components with stream_type value equal to 0x02 and 0x80 and AVC/H.264 video components with stream_type 0x1B.
2. When present, the 3d_video_descriptor MUST be located in the loop following ES_info_length field in PMT.
3. If the 3d_video_descriptor is included with stream_type 0x02 or 0x80 in the PMT and the syntax element 3d_frame_packing_data_present is set to '1', then the associated MPEG-2 video elementary stream MUST contain stereoscopic video format information in the user_data extension as specified in ITU-T Rec. H.262 | [IEC 13818-2]/Amd.4.
4. If the 3d_video_descriptor is included with stream_type 0x1B in the PMT and the syntax element 3d_frame_packing_data_present is set to '1', then the associated AVC/H.264 video elementary stream MUST contain the frame_packing_arrangement_type SEI message.
5. For any service or stream that includes concatenated elements of 2D and 3D content with this descriptor, the PMT MUST contain the 3d_video_descriptor for both 2D and 3D segments with the appropriate value of syntax element 3d_frame_packing_data_present.

Syntax:

descriptor_tag - The descriptor_tag value MUST be 0xE8.

descriptor_length - An 8-bit unsigned integer, in the range of 1 to 255, that indicates the number of bytes to follow. The value of descriptor_length MUST be set to 0x01 for the present version of the descriptor. If extensions to the descriptor are defined in the future, the descriptor_length may change accordingly.

3d_frame_packing_data_present - This flag MUST be set to '1' when either the video component in the service carries the S3D_video_format_signaling() in the user_data described below in Section 10.7, or the frame_packing_arrangement_type SEI message described below in Section 10.6. A value of '0' MUST indicate that the video service is 2D encoded.

Note: When this descriptor is used, transitions between 2D and 3D content are indicated by a change in the value from "0" to "1" within the 3d_frame_packing_data_present field of the descriptor.

reserved - These bits are reserved for future use and MUST be set to value '1'. The values may change in future revisions.

10.6 SEI Settings for S3D With AVC/H.264 Encoding

Listed below are the details on SEI Metadata for signaling 3DTV MPEG-4 AVC content. SEI messages have been defined in [ITU H.264] for transmission of supplemental information (such as picture timing SEI that carries film mode information and user data registered by ITU-T SEI for carriage of registered metadata). [SCTE 128] has used

the user_data SEI messages in [ITU H.264] to carry information like Closed-Captions and AFD/Bar data. The primary message that is transmitted in a 3D video service is the frame packing arrangement SEI message.

The payloadType for this message is 0x2D (decimal 45). **frame_packing_arrangement_type** indicates the type of packing arrangement of the frames as specified.

1. The frame packing arrangement SEI MUST be present in every access unit of the coded video sequence.
   - The content of the SEI syntax elements (specified above) SHOULD NOT change over the video sequence or event.
   - If other SEI payload types are present in any access unit (such as pic_timing or user_data_registered_itu_t_t35), the frame packing arrangement SEI (payload type = 45) MUST be included in a separate NAL unit (nal unit type = 6) instead of being concatenated with other SEI payload types in the same NAL unit (note that this is allowed by AVC/H.264 specification).
2. S3D programs with SEI messages MUST fully match the bold values below for interoperability with set-tops to trigger the automatic graphics "panelization" and HDMI 3DTV signaling:
   - frame_packing_arrangement_id: **0** (Golomb code of '1', which is 1 bit)
   - frame_packing_arrangement_cancel_flag: **0** (informs STB that new SEI message follows)

     Note: Since the content of the SEI syntax elements is not supposed to be changed over the video sequence or event, **1** is not used.
   - frame_packing_arrangement_type: **0000011** (=Side-by-side) –OR- **0000100** (=Top/bottom)
   - quincunx_sampling_flag: **0** (default is that the luma/chroma planes in each L/R frame is not quincunx sampled)
   - content_interpretation_type: **000001** (frame 0: L, frame 1: R)
   - spatial_flipped_flag: **0** (no flipping of either frame)
   - frame0_flipped_flag: **0** (must be zero if spatial_flipped_flag=0)
   - field_views_flag: **0** (must be zero for top/bottom and side-by-side)
   - current_frame_is_frame0_flag: **0** (must be zero for top/bottom and side-by-side)
   - frame0_self_contained_flag: **0**
   - frame1_self_contained_flag: **0**

	Side-by-side (option 1)	**Side-by-side (option 2)**	**Top/Bottom (option 1)**	**Top/Bottom (option 2)**
• frame0_grid_position_x:	**0000** (0 decimal)	**0100** (4 decimal)	**0000** (0 decimal)	**1000** (8 decimal)
• frame0_grid_position_y:	**0000** (0 decimal)	**1000** (8 decimal)	**0000** (0 decimal)	**0100** (4 decimal)
• frame1_grid_position_x:	**0000** (0 decimal)	**0100** (4 decimal)	**0000** (0 decimal)	**1000** (8 decimal)
• frame1_grid_position_y:	**0000** (0 decimal)	**1000** (8 decimal)	**0000** (0 decimal)	**0100** (4 decimal)

   - frame_packing_arrangement_reserved_byte: **00000000** (required by standard)
   - frame_packing_arrangement_repetition_period: **0** (Golomb code of '1', which is 1 bit)
   - frame_packing_arrangement_extension_flag: **0** (required by standard)

3. S3D programs formatted as SbS (frame_packing_arrangement_type = **3**) MUST be arranged for display upconversion as described above in Figure 6.
4. S3D programs formatted as SbS MUST also set the following VUI syntax elements as follows:
   - aspect_ratio_info_present_flag = 1; aspect_ratio_idc =1 (8 bits); sar_width = 1 (16 bits); sar_height = 1 (16 bits) for SAR of **1:1**
5. S3D programs formatted as TaB (frame_packing_arrangement_type = **4**) MUST be arranged for display upconversion as described above in Figure 2.
6. S3D programs formatted as TaB MUST also set the following VUI syntax elements as follows:
   - aspect_ratio_info_present_flag = 1; aspect_ratio_idc =1 (8 bits); sar_width = 1 (16 bits); sar_height = 1 (16 bits) for SAR of **1:1**

10.7 User Data Settings for S3D With MPEG-2 Encoding

Listed below are the details on user data settings for signaling 3DTV MPEG-2 content. User data settings have already been applied to carry information like Closed-Captions and AFD/Bar user_data. The primary message that is transmitted in a 3D MPEG-2 video service is the S3D_video_format_signaling() data.

The frame packing arrangement signaling information MUST be inserted in the picture layer user data of Rec. ITU-T H.262 | ISO/IEC 13818-2 video bitstreams. The signaling supports switching between 2D and S3D video at frame boundaries, as well as between different frame packing arrangements for S3D video at frame boundaries. Switching between 2D and S3D video, and between different frame-packing arrangements for S3D video, MUST meet the following:

- The last access unit in video sequence before the switch MUST include the sequence_end_code indicating an end to the current video sequence.
- Video sequence after the switch MUST start with an I picture and closed GOP (see also Section 6.2).

For compatibility with existing video decoders, the method uses an indicator to be provided in extensions_and_user_data(2), which follows the picture_header() and picture_coding_extension().

Table 6 specifies the syntax and semantics that indicate a frame packing arrangement in the user_data() of extensions_and_user_data(2).

Table 6 - S3D Video Format Signaling in User Data

Syntax	No. of bits	Mnemonic
user_data() {		
user_data_start_code	32	bslbf
S3D_video_format_signaling_identifier	32	bslbf
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
S3D_video_format_signaling()	8	uimsbf
}		
next_start_code()		
}		

user_data_start_code - MUST be set to the bit string 0x000001B2.

S3D_video_format_signaling_identifier - MUST be set to the bit string 0x4A503344 (“JP3D” in ASCII).

Note: This S3D format signaling identifier is a 4-byte code value that has been selected to avoid conflict with other applications of user_data mechanism.

Table 7 - S3D_video_format_signaling() syntax

Syntax	No. of bits	Mnemonic
S3D_video_format_signaling() {		
S3D_video_format_length	8	uimsbf
reserved_bit	1	uimsbf
S3D_video_format_type	7	bslbf
reserved_data	16	bslbf
}		

S3D_video_format_length - MUST be set to the bit string 0x03.

reserved_bit - This bit MUST be set to the value '1'. Decoders are recommended to ignore this value.

S3D_video_format_type - See Table 8.

Table 8 - Semantics of S3D_video_format_type

S3D_video_format_type	Meaning
0000011	S3D side by side
0000100	S3D top and bottom
0001000	2D video
Other value	Reserved

reserved_data - This is a 16-bit integer set to the bit string 0x04FF. Decoders are recommended to ignore this value.

It is recommended that for the entire duration of a program containing 3D video content or a mix of 3D and 2D content, the video stream should contain user data with S3D_video_format_signaling() for every picture.

In the case of the "S3D side by side" arrangement, the picture is divided into two halves that each have half resolution horizontally. The left view is on the left side, and the right view is on the right side. The border position between the two halves is at the center of the active sampling pixels on a scan line. The indicated sampling position is the same across all scan lines. The sampling positions for the "S3D side by side" arrangement are shown in Figure 11.

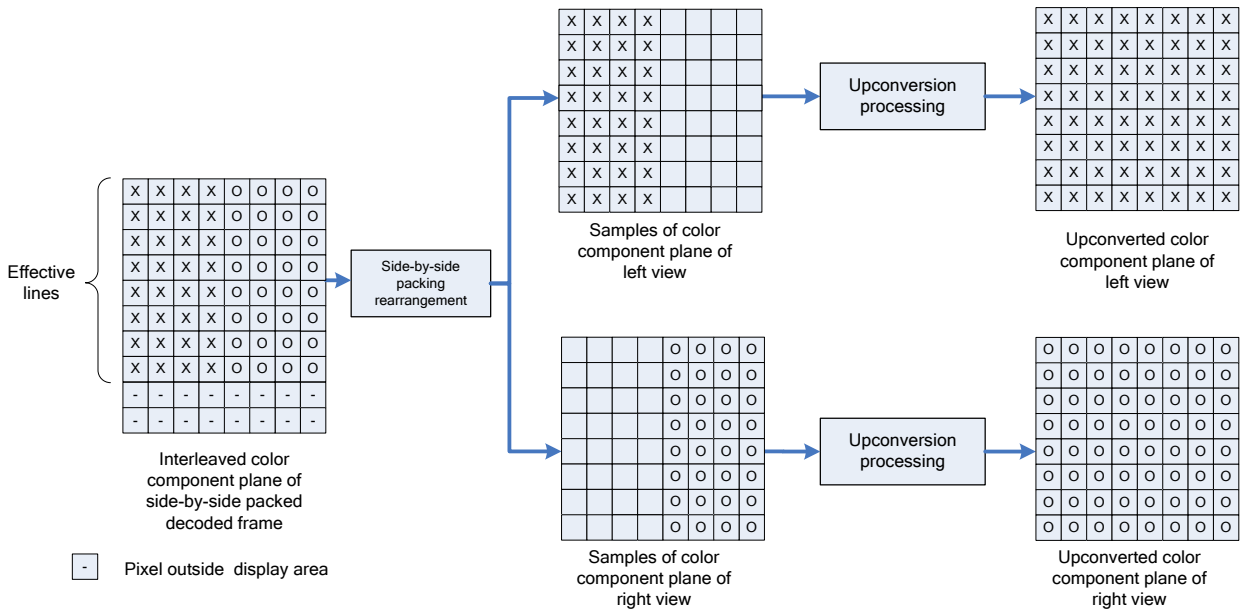

Figure 11 - Rearrangement and upsampling of "S3D side by side"

Note: The pixels marked as "-" in Figure 11 correspond to the last eight lines of a 1088-line coded picture and are outside the display area. These pixels are discarded after decoding of picture and are not displayed.

In case of "S3D top and bottom", one picture is divided by two halves sub sampled vertically. The left view is in the upper part of the picture, and the right view is in the lower part of the picture. The border position between the two halves is at the center of the effective lines. The indicated sampling position is the same across all scan lines. The sampling positions for the "S3D top and bottom" arrangement are shown in Figure 12.

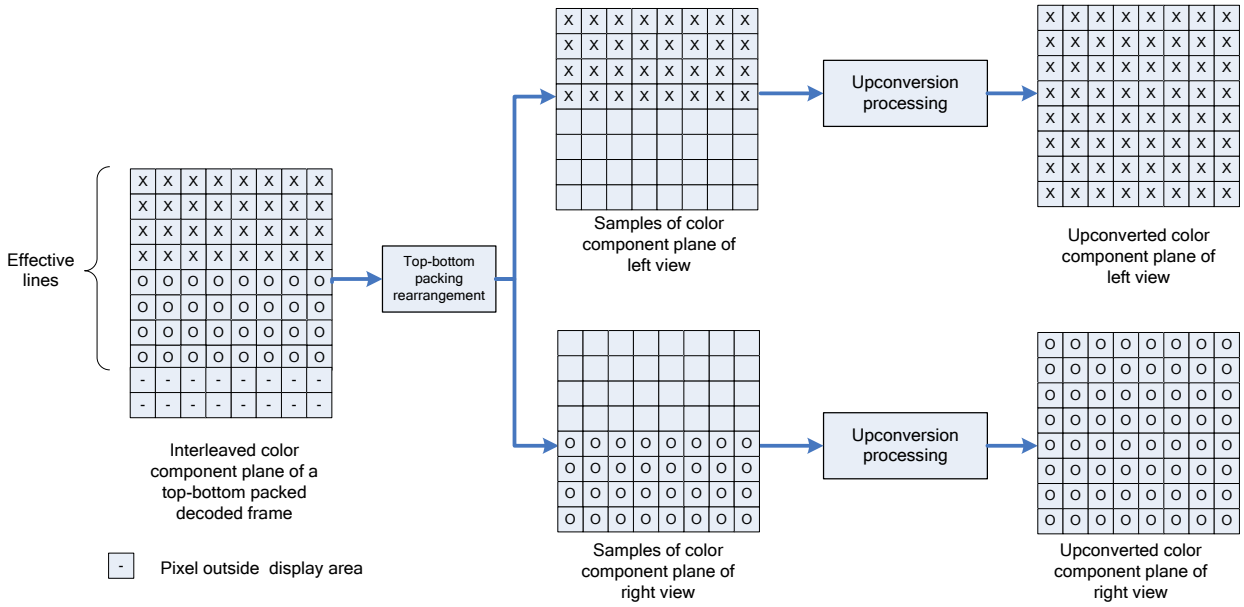

Figure 12 - Rearrangement and upsampling of "S3D top and bottom"

Note: The pixels marked as "-" in Figure 12 correspond to the last eight lines of a 1088-line coded picture and are outside the display area. These pixels are discarded after decoding of picture and are not displayed.

When switching from 3D to 2D, or 2D to 3D, the picture in which the signaling information changes should be temporally aligned with the change of the content.

Appendix I Revision History

The following ECNs were incorporated into version I02 of this specification:

ECN	Title of EC	Date Accepted
CEP3.0-N-10.1587-1	Editorial changes to section 10.6 clarifying VUI elements	11/19/2010
CEP3.0-N-10.1596-1	Minor changes to support transmission of SEI with each picture	11/5/2010
CEP3.0-N-10.1603-1	MPEG-4 Trick Mode Requirements	11/19/2010
CEP3.0-N-10.1617-3	Signaling for MPEG-2	1/14/2011
CEP3.0-N-10.1627-1	Correct SEI signaling of SAR	1/14/2011
CEP3.0-N-10.1628-1	SEI Settings for S3D With AVC/H.264 Encoding	1/31/2011
CEP3.0-N-10.1635-2	Modifications to Section 10.4	1/31/2011

The following ECNs were incorporated into version I03 of this specification:

ECN	Title of EC	Date Accepted
CEP3.0-N-11.1649-1	NPT Specification	4/8/2011
CEP3.0-N-11.1650-3	Changes to sections 10.5 and 10.7	11/18/2011
CEP3.0-N-11.1677-1	Labeling corrections to MPEG-2 signaling of Section 10.5	8/26/2011
CEP3.0-N-11.1705-1	Content Conditioning at out and in points	11/4/2011