SCTE | STANDARDS

Digital Video Subcommittee

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ANSI/SCTE 281-1 2023

VVC Video Constraints for Cable Television
Part 1- Coding

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Note: Standards that are released multiple times in the same year use: a, b, c, etc. to indicate normative balloted updates and/or r1, r2, r3, etc. to indicate editorial changes to a released document after the year.

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1. Introduction

1.1. Executive Summary

This document specifies the creation of a VVC coded video elementary stream for SDR and HDR formats (specifically HDR10) and is intended for cable video services applications such as broadcast, time-shifting (e.g., PVR/DVR service), Video-on-Demand services, and splicing (e.g., Ad-insertion) that could employ the specifications in this document. However, constraints specific to those applications are outside of the scope of this document.

A single type of HDR transfer function is mandated for delivery in a cable network. Dynamic metadata applications backwards compatible to the specified HDR format can be used to adapt HDR imagery to a multiplicity of displays that have different characteristics than the underlying content.

The means to carry SCTE dynamic metadata Application #1 (DM App #1) and Application #4 (DM App #4) in an VVC bitstream is described in section 7 and in Appendix B and C. SCTE DM Apps describe parametric data sets to be used to adapt the imagery for viewers' displays and environment.

1.2. Scope

This document defines the coding constraints on ITU-T Rec. H.266 | ISO/IEC 23090-3 [MPEG-VVC] video compression (hereafter called "VVC") for Cable Television. In particular, this document describes the coding of a single VVC coded video elementary stream in an SDR or HDR format carried in MPEG-2 transport (ISO/IEC 13818-1) [MPEG-2 TS] for linear delivery systems supporting ad insertion services [SCTE 35] or for adaptive bitrate streaming delivery technologies [SCTE 214-1]. Beyond linear delivery with DPI, signaling is provided for segmentation of content for xDVR applications.

1.3. Background (Informative)

This document specifies the creation of a VVC coded video elementary stream and is intended for cable video services applications such as broadcast, time-shifting (e.g., PVR/DVR service), Video-on-Demand services, and splicing (e.g., Ad-insertion) that could employ the specifications in this document. However, constraints specific to those applications are outside of the scope of this document at this time.

2. Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this document. The editions indicated were valid at the time of subcommittee approval. 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 54]	ANSI/SCTE 54 2020, Digital Video Service Multiplex and Transport System Standard for Cable Television.
[SCTE 128-1]	ANSI/SCTE 128-1 2020, AVC Video Constraints for Cable Television: Part 1 – Coding.
[SCTE 35]	ANSI/SCTE 35 2022, Digital Program Insertion Cueing Message for Cable.
[SCTE 214-1]	ANSI/SCTE 214-1 2022, MPEG DASH for IP-Based Cable Services Part 1: MPD Constraints and Extensions.

[SCTE 281-2] SCTE 281-2 2023 VVC Video Constraints for Cable Television Part 2- Transport.

2.2. Standards from other Organizations

[MPEG-2 TS] ISO/IEC 13818-1:2022, Information Technology – Generic coding of moving pictures and associated audio – Part 1: Systems.

[MPEG-VVC] ITU-T Rec. H.266 | ISO/IEC 23090-3:2020 – MPEG-I Part 3: Versatile Video Coding.

[MPEG-VSEI] ITU-T Rec. H.274 | ISO/IEC 23002-7:2020 – Versatile supplemental enhancement information messages for coded video bitstreams.

[CTA 608-E] CTA-608-E 2014, Line 21 Data Services.

[CTA-708-E] CTA-708-E 2013, Digital Television (DTV) Closed Captioning.

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

[SMPTE ST 2016-1] SMPTE ST 2016-1-2009: Standard for Television – Format for Active Format Description and Bar Data.

[SMPTE ST 2086] SMPTE ST 2086:2018: SMPTE Standard – Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images

[MPEG-2 AUDIO] ISO/IEC 13818-2:2013, Information Technology – Generic coding of moving pictures and associated audio -Part 2: Video.

[ITU-R BT.709-6] ITU-R BT.709-6, Parameter values for the HDTV standards for production and international programme exchange.

[ITU-R BT.2100-2] ITU-R BT.2100-2:2018 Image parameter values for high dynamic range television for use in production and international programme exchange.

[CTA-861.6] CTA-861.6:2022 “A DTV Profile for Uncompressed High Speed Digital Interfaces”.

[ETSI TS 103 572] ETSI TS 103 572 V1.2.1 (2020-10): HDR Signalling and Carriage of Dynamic Metadata for Colour Volume Transform; Application #1.

[ETSI TS 103 433-1] ETSI TS 103 433-1 V1.4.1 High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 1: Directly Standard Dynamic Range (SDR) Compatible HDR System (SL-HDR1).

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

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

[SCTE 07] ANSI/SCTE 07, Digital Transmission Standard for Cable Television.

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

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

[SCTE 187-2] ANSI/SCTE 187-2, Stereoscopic 3D PSI Signaling.

[SCTE 67] ANSI/SCTE 67, Recommended Practice for SCTE 35 Digital Program Insertion Cueing Message for Cable.

[SCTE 215-1-1] ANSI/SCTE 215-1-1, VVC Video Constraints for Cable Television Part 1-1 HDR10 Coding.

[SCTE 277] ANSI/SCTE 277 2022, Linear Contribution Encoding Specification.

3.2. Standards from other Organizations

[ETSI TS 101 154] ETSI TS 101 154 V2.5.1 Digital Video Broadcasting (DVB): Specification for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream.

[SMPTE ST 170] SMPTE ST 170, Television – Composite Analog Video Signal – NTSC for Studio Applications.

[SMPTE ST 274] SMPTE ST 274, Standard for television, 1920 x 1080 Scanning and Interface.

[SMPTE ST 296] SMPTE ST 296, Standard for television, 1280 x 720 Scanning, Analog and Digital Representation, and Analog Interface.

[ITU-R BT.601-6] ITU-R BT.601-6, Encoding parameters of digital television for studios.

[ITU-R BT.2020-2] ITU-R BT.2020-2, Parameter values for ultra-high definition television systems for production and international programme exchange.

[ITU-T J.83] ITU-T J.83 Digital Video Transmission Standard for Cable Television.

[CEA-CEB16] CEA-CEB16: Active Format Description (AFD) & Bar Data Recommended Practice.

[SMPTE ST 125] SMPTE ST 125, Standard for television, Component Video Signal 4:2:2, Bit Parallel Digital Interface.

[SMPTE ST 293] SMPTE ST 293, Standard for television, 720x483 Active Line at 59.95 Hz Progressive Scan Production, Digital Representation.

[SMPTE ST 267] SMPTE ST 267, Standard for television, Bit Parallel Digital Interface- Component Video Signal 4:2:2 16x9 Aspect Ratios.

[ITU-T T.35] ITU-T Rec. T.35, “Procedure for the allocation of ITU-T defined codes for non-standard facilities.”

[ATSC A/53 -3] ATSC A/53, Part 3, “Service Multiplex and Transport Subsystem Characteristics”.

[SMPTE ST 2036-1] SMPTE ST 2036-1, Ultra High Definition Television- Image Parameter Values for Program Production.

[SMPTE ST 2046-1] SMPTE ST 2046-1, Specifications for Safe Action and Safe Title Areas for Television.

[ITU-R BT.2390] ITU: Report ITU-R BT.2390, “High dynamic range television for production and international programme exchange,” International Telecommunications Union, Geneva.

[CICP 23091-4] ITU-T H. Supplemental 19 | ISO/IEC TR 23091-4 : 2020, Information technology- Coding-independent code points- Part 4: Usage of video signal type code points.

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 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 or the adjective "*optional*" indicate a course of action permissible within the limits of the document.
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.

This document contains symbolic references to syntactic elements used in the video and transport coding subsystems. These references *may* contain the underscore character (e.g., constraint_set0_flag) and *may* consist of character strings that are not English words (e.g., pic_width_in_mbs_minus1).

5. Abbreviations and Definitions

5.1. Abbreviations

AFD	Active Format Description
ATSC	Advanced Television Systems Committee
AU	Access Unit
AVC	Advanced Video Coding
CLL	Content Light Level
CLLI	Content Light Level Information
CPB	Coded Picture Buffer
CRA	Clean Random Access
CVS	Coded Video Sequence
DM	dynamic metadata
DPB	Decoded Picture Buffer
DPI	Digital Program Insertion
DTS	Decoding Time Stamp
DTV	Digital Television
DVB	Digital Video Broadcasting
DVS	Digital Video Subcommittee
ETSI	European Telecommunications Standards Institute
EOTF	Electro-Optical Transfer Function
FPP	Forward Predicted Picture
FPS	Frames Per Second

HDR	High Dynamic Range
HDTV	High Definition Television
HEVC	High Efficiency Video Coding
HRD	Hypothetical Reference Decoder
IDR	Instantaneous Decoding Refresh
IEC	International Electrotechnical Commission
IRAP	Intra Random Access Point [see definitions in 5.2]
ISO	International Organization for Standardization
ITM	Inverse Tone Mapped
MDCV	Mastering Display Color Volume
MPEG	Moving Picture Experts Group
NAL	Network Abstraction Layer
NCG	Narrow Color Gamut
nPVR	Network based Personal Video Recorder
PES	Packetized Elementary Stream
POC	Picture Order Count
PPS	Picture Parameter Set
PQ	Perceptual Quantization
PTS	Presentation Time Stamp
PVR	Personal Video Recorder
SDR	Standard Dynamic Range
SDTV	Standard Definition Television
SEI	Supplemental Enhancement Information
SVRAP	SCTE VVC Random Access Point [see definitions in 5.2]
SPS	Sequence Parameter Set
T-STD	Transport Stream System Target Decoder
VCL	Video Coding Layer
VOD	Video on Demand
VPS	Video Parameter Set
VUI	Video Usability Information
VVC	Versatile Video Coding [MPEG-VVC]
VSEI	Versatile Supplemental Enhancement Information [MPEG-VSEI]
WCG	Wide Color Gamut
xDVR	Generic Digital Video Recorder (see definitions in 5.2)

5.2. Definitions

DM App	Dynamic metadata associated with a specific application used on the HDR video content stream. This type of information is encapsulated within an SEI message used by the application in a post decode process.
FPP	A predicted picture that does not use any later-displayed picture as a reference.
HDR DM	Additional information about an HDR video content stream. Use is optional and intended to enhance video presentation quality. It is dynamic in that it may change at each access unit or group of access units. It may be transmitted either along with the content stream or by other delivery means

HDR10	High Dynamic Range with a PQ EOTF, BT.2100 WCG container, 10 bit pixel values which may include MaxCLL, MaxFALL, and Mastering Display Color Volume information.
SDR Derived	An SDR signal that has been tone and gamut mapped from an HDR signal.
VVC	ITU-T Rec. H. 266 | ISO/IEC 23090-3: MPEG-I Part 3: Versatile Video Coding [MPEG-VVC].
VSEI	ITU-T Rec. H.274 | ISO/IEC 23002-7:2020 – Versatile supplemental enhancement information messages for coded video bitstreams [MPEG-VSEI].
VVC Receiver	The term "VVC Receiver" in this standard for coding means a receiver having at least the attributes (in no particular order) listed below: 1. Able to parse and decode the normative elements from VVC [MPEG-VVC] that are specified with constraints in this standard; 2. Not adversely affected by the presence or absence of optional and informative elements from VVC [MPEG-VVC]; 3. Not adversely affected by the presence or absence of optional and informative elements in this standard; 4. Able to parse and process all elements from VVC [MPEG-VVC] Annex D (SEI messages) and VSEI [MPEG-VSEI] that are normatively specified and/or constrained by this standard and conveyed in-band; *NOTE 1: These are optional elements in the VVC specification .* 5. Supports the processing of end_of_bitstream_rbsp() syntax element (NAL unit type =22, EOB_NUT) required by applications where another bitstream follows the end_of_bitstream NAL unit. The bitstream that follows will start with an IDR picture (NAL unit type = 8, IDR_N_LP or NAL unit type = 7, IDR_W_RADL) and *may* be accompanied by a time base discontinuity. *NOTE 2: Management of DPB frame buffers in accordance with the VVC Specification* [MPEG-VVC] *supports graceful output transitions between fields and frames at an SVRAP containing an IDR picture.* 6. Supports the processing of elementary streams in Low Delay Mode and Still Pictures.

	NOTE 3: The additional information from items 5 and 6 is optionally provided for the benefit of VVC receivers that include support for applications such as PVR, DPI and VOD. *NOTE 4: Transport related attributes for an VVC Receiver definition can be found in [SCTE 281-2].*
IRAP	IRAP as specified in VVC [MPEG-VVC].
SVRAP Picture	An IRAP picture that is part of an SVRAP AU .
xDVR	Generic DVR implementation. This could be Cloud DVR (cDVR), Network DVR (nDVR), local DVR or any other generic DVR.

Numerical formats are defined in Table 1:

Table 1 - Numerical Format Definitions

Example Values	Description
12345	Example of a decimal value format
0x2A	Example of a hexadecimal value format
'10010100'	Example of a string of binary digits

6. Video Production Formats (informative)

The television production standards shown in Table 2 correspond to the video production formats specified for UHDTV1/2, HDTV, and SDTV.

Table 2 - Standardized Video Production Formats

Video Standard	Active Lines	Active Samples/ Line	Name
[SMPTE ST 2036-1]	4320	7680	UHDTV2
[SMPTE ST 2036-1]	2160	3840	UHDTV1
[SMPTE ST 274]	1080	1920	HDTV
[SMPTE ST 296]	720	1280	HDTV
[SMPTE ST 125]	576	720	SDTV
[SMPTE ST 2046-1]	480	720	SDTV

The compression formats *may* be derived from one or more appropriate video input formats.

Production standards supported by this standard may include formats with frame rates of 24/1.001 (23.976), 24, 25, 30/1.001 (29.97), 30, 50, 60/1.001 (59.94), 60, 100, 120 and 120/1.001 Hz and the video properties format [SCTE 277].

7. Video Emission Formats

Video streams can be in the form of standard dynamic range (SDR) which are identified by video streams using a transfer characteristic for BT.709 [ITU-R BT.709-6] assuming a display characteristic corresponding to BT.1886 [ITU-R BT.1886]

Video streams can also be in the form of high dynamic range (HDR) which consists of streams of dynamic range types identified in Table 3. Within a single cable distribution network, distributed HDR streams ***shall*** be backwards compatible to a single specific HDR transfer format (e.g. HDR10). Bitstreams that contain additional dynamic metadata ***shall*** use either HDR10 with SCTE DM App #1 (2094-10), HDR10 with SCTE DM App #4 (2094-40), or SDR Derived (SL-HDR1) types of dynamic metadata formats.

Table 3 - Dynamic Range Types of Video

Delivery Format	Transfer Function	Color Primaries	Bits/Pixel	Additional Info
SDR	BT.709 [ITU-R BT.709-6]	BT.709 [ITU-R BT.709-6]	10	**Mandatory:** MDCV SEI [SMPTE ST 2086]
HDR10	PQ Native [ITU-R BT.2100-2]	BT.2020 [ITU-R BT.2100-2]	10	**Mandatory:** MDCV SEI [SMPTE ST 2086] **Optional:** CLLI SEI
HDR10 with SCTE DM App #1 (2094-10)	PQ Native [ITU-R BT.2100-2]	BT.2020 [ITU-R BT.2100-2]	10	**Mandatory:** MDCV SEI [SMPTE ST 2086] SCTE DM App #1 SEI **Optional:** CLLI SEI
HDR10 with SCTE DM App #4 (2094-40)	PQ Native [ITU-R BT.2100-2]	BT.2020 [ITU-R BT.2100-2]	10	**Mandatory:** MDCV SEI [SMPTE ST 2086] SCTE DM App #4 SEI **Optional:** CLLI SEI

Delivery Format	Transfer Function	Color Primaries	Bits/Pixel	Additional Info
SDR Derived (SL-HDR1)	SDR (Derived) BT.709 [ITU-R BT.709-6]	SDR (Derived) BT.709 [ITU-R BT.709-6]	10	**Mandatory:** MDCV SEI (for SDR) [SMPTE ST 2086] SL_HDR_INFO SEI Requires SL-HDR1 decoding capabilities support for HDR reconstruction Please read notes 9,10,11
	PQ Native (Reconstructed) [ITU-R BT.2100-2]	BT.2020 (Reconstructed) [ITU-R BT.2100-2]	10	

NOTE 5: Resolution of video can be considered orthogonal to the dynamic range properties of video. For example, HDR10 streams may be resolutions other than 2160P.

NOTE 6: Syntax and semantics for SCTE DM App #1 can be found in Appendix B.

NOTE 7: Syntax and semantics for SCTE DM App #4 can be found in Appendix C.

NOTE 8: A single HDR10-based program may have neither, either or both Dynamic Metadata types of App #1 and App #4 present.

NOTE 9: SL-HDR1 uses native HDR video essence as input and outputs SDR-BT.709 video essence with dynamic metadata which become SL-HDR_INFO SEI messages for reconstructing the original HDR input. While SL_HDR_INFO SEI messages optionally encapsulate MDCV SEI syntax elements, these are required for SCTE. The SL-HDR_INFO SEI messages encapsulate MDCV SEI syntax elements such that an HDR10 equivalent output may be generated.

NOTE 10: The signal provider should take special care with native SDR video images that have been inverse-tone-mapped (ITM) to provide input to SL-HDR1 so that a roundtrip may retain the original artistic intent (more testing and research is required to understand best practice). SL-HDR1 ITM requires additional metadata in order to preserve original artistic intent during a roundtrip.

NOTE 11: Special consideration should be given to native HDR video essence input into SL-HDR1 with graphics that generate SDR output that is dynamically tone mapped. More testing and research are required to understand how to preserve the relationship between graphics white and SDR peak white during SL-HDR1 SDR dynamic tone mapping.

8. Constraints on VVC Coding

8.1. Syntactical Constraints on Parameter Sets

VVC bitstreams ***shall*** conform to the VVC Specification [MPEG-VVC] and ***shall*** also satisfy the normative constraints described in this document. Unless specified otherwise in this document, the allowable parameters ***shall*** be bounded by the limits specified in the VVC Specification [MPEG-VVC]. Parameters pertaining to Profile, Level, and Tier ***shall*** be constrained as shown in Table 4 and Table 5 of section 8.1.1.

Profiles and levels for respective production formats ***shall*** be constrained as shown in Table 4.

VVC bitstreams ***shall*** include the SEI and the VUI syntactic elements as normatively specified and/or constrained in this document. SEI and the VUI syntactic elements are defined in VVC [MPEG-VVC] Annexes D and VSEI [MPEG-VSEI]. Some VUI and SEI messages are optional and *may* be ignored by the VVC Receiver as specified herein. Unless otherwise constrained by this standard, VVC Receivers *should* be able parse and decode and not be adversely affected by any legal structure permitted by VVC [MPEG-VVC] including the presence of syntax elements with values specified as reserved or unspecified at the time of publication of this document.

8.1.1. Profiles, Levels, and Tiers constraints

VVC ***shall*** operate with the coding constraints described in Table 4:

Table 4 - General Video Profile Coding Constraints

Allowed video profile coding constraints	**VVC Value**
Profiles	Main 10
Levels	Up to Level 6.2 (see VVC [MPEG-VVC] Appendix A)
Tier	Main

In addition, if the bitstream contains multiple sub-layers, (for which sps_max_sublayers_minus1 is greater than 0), then the value of the following flag ***shall*** be:

ptl_sublayer_level_present_flag [i] = 0.

The tables in the following sections list the allowed values for each of the VVC syntax elements that are restricted beyond the limits imposed for the above specified profiles, levels, and tiers in the VVC specification [MPEG-VVC]. The **profile_tier_level** syntax structure ***shall*** be located in the SPS.

Table 5 - Profile, Tiers, Levels Constraints

profile_tier_level constraints	**Allowed Value**
general_tier_flag	0 (Main Tier)
general_profile_idc	1 (Main 10)
general_level_idc	Up to 102

All VVC receivers are defined to support a specified Level and be capable of processing VVC Bitstreams up to that specified Level.

The time interval between consecutive changes in general_level_idc ***shall*** be greater than or equal to one second.

NOTE 12: Level changes should be avoided as they may result in disruption of the decoder's video output.

8.1.2. Constraints Restrictions with respect to nal_unit_type

This section provides constraints to the values of nal_unit_type in a nal_unit_header.

The parameter nuh_layer_id ***shall*** be equal to 0.

DCI NAL Units (Decoding Capability Information) are allowed in the VVC bitstream but *may* be ignored.

OPI NAL Units (Operating Point Information) are allowed in the VVC bitstream but *may* be ignored.

GDR NAL Units (Gradual Decoder Refresh) ***shall*** be forbidden in the VVC bitstream.

VPS NAL Units (Video Parameter Set) are not recommended in the VVC bitstream. If present, a VPS NAL unit may be ignored. The sps_video_parameter_set_id in SPS *should* be set to "0", indicating that the SPS does not refer to any VPS.

NAL Unit types of 7 to 9 are allowed to be used for RAPs.

8.1.2.1. Constraints for nal_unit_types associated with an SVRAP

A SVRAP access unit is an VVC access unit shown pictorially in Figure 1. A SVRAP access unit ***shall*** include exactly one access unit delimiter (AUD), exactly one Sequence Parameter Set (SPS) (that is active) with VUI, and at least one Picture Parameter Set (PPS) that is required for decoding the associated picture. The SPS and any PPS ***shall*** precede any SEI NAL units that *may* be present in an SVRAP access unit. VPS may exist within the stream but is ignored.

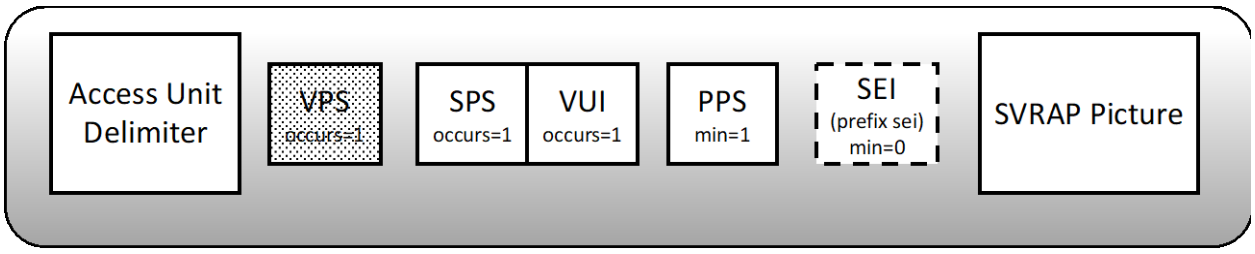

Figure 1 - NAL Unit Order for a Typical SVRAP Access Unit

The value of nuh_temporal_id_plus1 ***shall*** be equal to 1 for all NAL units in an SVRAP AU.

The constraints for Video Usability Information (VUI) parameters are specified in section 7.1.6 of this document. The SVRAP picture ***shall*** have a nal_unit_type value in the range of 7 to 9, inclusive. This range of nal_unit_type values correspond to an IRAP picture in accordance with the VVC specification [MPEG-VVC].

The first access unit after an access unit that contains an end of sequence NAL unit ***shall*** be the access unit of an SVRAP containing an IDR or CRA picture.

The first access unit after an access unit that contains an end of bitstream NAL unit ***shall*** be an IDR access unit corresponding to an SVRAP.

Pictures after the SVRAP picture in the bitstream that have output time prior to the SVRAP picture are leading pictures. The output time of a picture is equal to its PTS. The PTS of a picture *may* be used to identify leading pictures after the SVRAP picture. The PTS is not sufficient to distinguish between decodable and non-decodable leading pictures.

8.1.3. Video Parameter Set (VPS) constraints

VPS NAL Units (Video Parameter Set) are not recommended in the VVC bitstream. If present, a VPS NAL unit may be ignored. The sps_video_parameter_set_id in all SPS *should* be set to "0", indicating that the SPS does not refer to any VPS.

8.1.4. Sequence Parameter Set (SPS) constraints

The Sequence Parameter Set (SPS) ***shall*** comply with Table 6.

Table 6 - Sequence Parameter Set Constraints

Parameter Set Syntactic Element	Allowed Value	
	SDR	**HDR**
sps_video_parameter_set_id	0	0
sps_chroma_format_idc	1 (4:2:0)	1
sps_ptl_dpb_hrd_params_present_flag	1	1
sps_sublayer_dpb_params_flag	0	0
sps_long_term_ref_pics_flag	0	0
sps_vui_parameters_present_flag	1	1
sps_bitdepth_minus8	0 (8 bit) or 2 (10 bit)	2
sps_field_seq_flag	***Shall*** be 1 for a field-coded video sequence. ***Shall*** be 0 otherwise.	0
sps_timing_hrd_params_present_flag	1	1
sps_num_extra_sh_bytes, sps_num_extra_ph_bytes	0	0
sps_gdr_enabled_flag	0	0

Setting the sps_timing_hrd_params_present_flag to true enables the general_timing_hrd_parameters which contain the num_units_in_tick and time_scale parameters referred to in Table 13.

NOTE 13: Some syntactical elements require that the corresponding preceding flag, "xxx_present_flag", if it exists, be equal to 1 (for example, the colour_description_present flag).

All bitstreams ***shall*** contain general and OLS timing parameters (sps_timing_hrd_params_present_flag equal to 1). Additionally, bitstreams may contain additional HRD parameters (general_nal_hrd_params_present_flag and/or general_vcl_hrd_params_present_flag equal to 1) for ols_timing_hrd_parameters information. Timing and HRD parameters ***shall*** be constrained as shown in Table 7 and Table 8.

A fixed frame rate bitstream ***shall*** be constrained with parameter values shown in Table 7.

NOTE 14: ***low_delay_hrd_flag*** *[maxNumSubLayersMinus1] = 0 when* ***fixed_pic_rate_general_flag****[maxNumSubLayersMinus1] = 1.*

Table 7 - HRD Parameter Constraints for fixed frame rate

HRD Syntactic Element	Allowed Value
(OLS timing & HRD parameters)	
fixed_pic_rate_general_flag [i] (ols)	1
elemental_duration_in_tc_minus1[i] (ols)	0

For Low Delay mode, the bitstream ***shall*** contain HRD parameters (general_nal_hrd_params_present_flag and/or general_vcl_hrd_params_present_flag equal to 1). Timing and HRD parameters ***shall*** have the values shown in Table 8 for Low Delay Mode.

Table 8 - HRD Parameter Constraints for Low Delay Mode

HRD Syntactic Element	Allowed Value
(OLS timing & HRD parameters)	
fixed_pic_rate_general_flag [i] (ols)	0
fixed_pic_rate_within_cvs_flag[i](ols)	0
low_delay_hrd_flag[i] (ols)	1

8.1.5. Picture Parameter Constraints and Level Limits

The Picture Parameter Set (PPS) ***shall*** comply with Table 9.

All pictures in VVC Bitstreams ***shall*** be displayable pictures except when a RASL picture of an associated IRAP has unavailable reference pictures.

Between two SVRAPs, the content of a picture parameter set with a particular pps_pic_parameter_set_id ***shall not*** change. That is, if more than one picture parameter set is present in the bitstream and these picture parameter sets are different from each other, then each picture parameter set ***shall*** have a different pps_pic_parameter_set_id.

Table 9 - Picture Parameter Set Constraints

PPS Header Syntactic Element	Allowed Value
pps_output_flag_present_flag	0

8.1.6. Codec Agnostic VUI Constraints

The VUI parameters as specified VSEI [MPEG-VSEI] ***shall*** comply with Table 10.

Table 10 - Video Usability Information Constraints

VUI Header Syntactic Element	Allowed Value
vui_ ratio_idc aspect_	See Appendix A
vui_colour_description_present_flag	1 when general_level_idc >= 80 (Level 5.0)
vui_chroma_loc_info_present_flag	***Shall*** be 1 when sps_field_seq_flag = 1

It is recommended to send colorimetry information in the form of the following parameters in the VUI (colour_primaries, transfer_characteristics, and matrix_coeffs) as the implied values for these parameters results in unspecified values. It is noted that BT.2100 [ITU-R BT.2100-2], BT.709 [ITU-R BT.709-6] and ST 170 [SMPTE ST 170] are the most likely parameters to be used in practice.

Additional VUI constraints sets for colorimetry information are listed in Table 11:

Table 11 - Video Usability Information Constraints

VUI Header Syntactic Element	Allowed Value	
	SDR	**HDR10**
vui_colour_primaries [MPEG-VSEI]	1 9 (for UHDTV1/2)	9
vui_transfer_characteristics [MPEG-VSEI]	1	16
vui_matrix_coeffs [MPEG-VSEI]	1	9
vui_full_range_flag [MPEG-VSEI]	0	0
Chroma420LocType [MPEG-VSEI]	0	2

It is required that the colorimetry information be sent for Level 5 and higher bitstreams and for all HDR type bitstreams. For SDR streams with unspecified values for colorimetry information, a decoder *may* assume that the values are those listed in Table 11.

NOTE 15: vui_matrix_coeffs are orthogonal to the dynamic range type of the stream and in the future could extend to additional values.

ChromaFormatIDC of VSEI [MPEG-VSEI] is set equal to sps_chroma_format_idc. For 4:2:0 content (ChomaFormatIDC is set to 1), Chroma420LocType of VSEI [MPEG-VSEI] *should* be set to '0' for SDR (both SD and HD) Content and '2' for HDR content [CICP 23091-4]

8.1.7. Supplemental Enhancement Information (SEI) Constraints

SEI Messages can either be specified in VSEI [MPEG-VSEI] for codec agnostic type of information or VVC [MPEG-VSEI] for VVC specific type of information. In this document, SEI messages sourced from VSEI [MPEG-VSEI] will be referenced as such with the remaining unreferenced SEI messages being sourced from the VVC [MPEG-VSEI]. Unless specified as a constraint or as indicated through syntax restrictions on the configuration of the bitstream, SEI messages not indicated in the document are permitted in the bitstream.

All prefix SEIs ***shall not*** occur after the first VCL NAL unit of the access unit and ***shall*** be placed after all NAL units of type VPS_NUT, SPS_NUT and PPS_NUT and prior to the first VCL NAL unit. All suffix SEIs ***shall*** not occur before the last VCL NAL unit of the access unit.

NOTE 16: The constraint in the present clause forbids SEI messages from occurring between the first and the last VCL NAL units of an access unit. The VVC specification [MPEG-VVC] allows SEI messages (both prefix and suffix SEI) to occur between the first and the last VCL NAL units of an access unit.

Repeated SEI messages of the same type in the same access unit *should not* occur. The use of SEI messages with identical payload information for the same persistence scope, as defined in Table 142 of VVC [MPEG-VVC] and Table 4 of VSEI [MPEG-VSEI] , provide no additional information at the expense of increased bitrate and require increased decoder processing capabilities. The use of SEI messages with inconsistent payload information for the same persistence scope results in ambiguity about which payload is the proper one to utilize.

Cable MVPD usage constraints on types of SEI messages are listed in Table 12.

Table 12 - Supplementary Enhancement Information Constraints

SEI Header Syntactic Element	Usage Constraints
Frame-field information SEI Message (VSEI [MPEG-VSEI])	Required in each AU for interlaced sequences. Optional for progressive sequences that can signal repeated frames
Frame packing arrangement SEI Message (VSEI [MPEG-VSEI])	Top/Bottom & Side by Side Configurations only permitted as per SCTE 187 Television. [SCTE 187-2]
Mastering Display Colour Volume SEI message	Optionally used at Sequence Level for HDR10 streams
Content Light Level Information SEI message	Optionally used at Sequence Level for HDR10 streams
Decoding Unit Information SEI message	Prohibited
Scalable nesting SEI message	Prohibited
User data registered by ITU-T Rec. T.35 SEI message (VSEI [MPEG-VSEI])	Sent in prefix SEI Only

There *may* be additional SEI messages needed for HDR content as identified in each HDR subpart section.

8.1.7.1. Frame-field SEI Message

For interlaced sequences, a frame-field information SEI message ***shall*** be present for every coded picture in the CLVS and ***shall*** be constrained as follows:

- A field coded video sequence ***shall*** contain only paired fields. **ffi_pairing_indicated_flag** ***shall*** be equal to 1 when **ffi_field_pic_flag** is equal to 1.

NOTE 17: In the context of VVC, paired fields are two fields that are in consecutive access units in decoding order as two coded fields of opposite parity of the same frame, regardless of their display order.

- When **ffi_field_pic_flag** is equal to 0, **ffi_display_fields_from_frame_flag *shall*** be 1**.**

For progressive sequences, a frame-field information SEI message is optional but the message can signal to repeat pictures . The parameters ***shall*** be constrained as follows.

- **ffi_field_pic_flag *shall*** be equal to 0. **ffi_display_fields_from_frame_flag *shall*** be equal to 0**.**

8.1.7.2. T.35 SEI Messages for AFD, Bar Data, and Closed Captioning

When supporting AFD, bar data, and closed captioning (see section 9 for more details), related SEI information ***shall*** comply with what is described in [SCTE 128-1] section 7.2.1.4 (“Supplemental Enhancement Information (SEI) Constraints”).

8.1.7.3. HDR Dynamic Metadata

When supporting Dynamic Metadata through a T.35 SEI payload 4 construct, one or more data structures can be carried in separate SEI messages.

For SCTE DM App #1, the video stream ***shall*** contain metadata messages as specified in Appendix B, which ***shall*** be included in a "user_data_registered_itu_t_t35” SEI T.35 construct as defined in [SCTE 128-1]

For SCTE DM App #4, the video stream ***shall*** contain metadata messages as specified in Appendix C.

8.1.7.3.1. Additional Constraints for SCTE DM App #1

Where a SCTE DM App #1 metadata message is present, the following constraints ***shall*** apply:

- The SCTE DM App #1 metadata message ***shall*** be associated with every access unit of the bitstream.
- The number of extension blocks with ext_block_level equal to 1 ***shall*** be constrained to be equal to 1.
- The number of extension blocks with ext_block_level equal to 2 ***shall*** be constrained to be less than 16.
- The number of extension blocks with ext_block_level equal to 4 ***shall*** be constrained to be equal 0 or 1.
- The number of extension blocks with ext_block_level equal to 5 ***shall*** be constrained to be equal 0 or 1.

Data structure of SCTE DM App #1 is defined in SCTE Appendix B.

8.1.7.3.1.1. Additional Supplemental Enhancement Information (SEI) Constraints

When SCTE DM App #1 is present in the bitstream, the MDCV SEI message ***shall*** also be present.

8.1.7.3.2. Additional Constraints for SCTE DM App #4

SCTE DM App #4 uses a NAL_unit_type set equal to PREFIX_SEI_NUT to convey the metadata message. Where a SCTE DM App #4 metadata message is present, the following constraint ***shall*** apply:

- The SCTE DM App #4 metadata message ***shall*** be associated with every access unit of the bitstream.

Data structure of SCTE DM App #4 is defined in Appendix C.

8.1.7.3.2.1. Additional Supplemental Enhancement Information (SEI) Constraints

When SCTE DM App #4 is present in the bitstream, the MDCV SEI message ***shall*** also be present.

8.2. Compression Format, Conformance Points & Format Constraints

This section supports definition and constraints on compression formats with horizontal sizes and vertical sizes as well as frame rates. The aspect_ratio_idc *should* be equal to 1 (square samples) for most formats. The display aspect ratio is nominally 16:9 (for UHDTV1/2 and HDTV signals) or 4:3 (for SDTV signals).

All compression ***shall*** comply with the constraints and levels of the Main Tier. Therefore general_tier_flag ***shall*** equal 0.

Tables for format resolutions and codec constraints are listed in Appendix A specific to different applications used in cable systems.

Video formats with vertical sizes of 1080 lines can be coded as either 1080 lines or 1088 lines with a conformance cropping window of 1080 lines. If 1088 lines is used to code 1080 line pictures, the conformance cropping window ***shall*** be defined with sps_conf_win_top_offset equal to 0 and sps_conf_win_bottom_offset = 4.

*NOTE 18: The formula to determine the number of lines to crop from the bottom is SubHeightC * sps_conf_win_bottom_offset and SubHeightC has a value of 2 when chroma_format_idc = 1 for 4:2:0 video.*

The values for num_units_in_tick, time_scale, and fixed_pic_rate_general_flag[i] ***shall*** be explicitly indicated in the general_timing_hrd_parameters( ) and ols_timing_hrd_parameters(). Table 13 indicates the entire set of defined frame rates, and the values for num_units_in_tick and time_scale that ***shall*** be used. In the Appendix section describing format constraints for each application, a numbered subset of frame rates will be defined.

Table 13 - Complete Frame Rate Parameter Constraints for VVC

Interlaced or Progressive	Frame Rate	time_scale	num_units_in_tick
P	24/1.001 Hz	24,000	1001
P	24 Hz	24	1
P	25 Hz	25	1
I (encoded as frames)	25 Hz	50	1

Interlaced or Progressive	Frame Rate	time_scale	num_units_in_tick
I (encoded as fields)	25 Hz	50	1
P	30/1.001 Hz	30,000	1001
I (encoded as frames)	30/1.001 Hz	60,000	1001
I (encoded as fields)	30/1.001 Hz	60,000	1001
P	30 Hz	30	1
P	50 Hz	50	1
P	60/1.001 Hz	60,000	1001
P	60 Hz	60	1
P	100 Hz	100	1
P	120 Hz	120	1
P	120/1.001 Hz	120,000	1001

The Maximum Luma Picture Size, Max Video Bit Rate, and Max CPB (Coded Picture Buffer) for a particular Profile, Level, and Tier does not exceed the limitations set forth in Appendix A of the VVC specification [MPEG-VVC].

NOTE 19: Refer to VSEI [MPEG-VSEI] *Table 14 for allowable display modes for progressive and interlaced format modes for designated frame rates beyond constraints as specified in this document.*

8.3. Constraints on Alternative Application Modes

Most common cable applications are in fixed frame rate mode, however, there are alternative applications such as VOD trickplay speeds or music channels that *may* not require fixed frame rate operation and do not have associated audio or require audio/video synchronization. This section describes some of the constraints on these alternative application modes.

8.3.1. Low Delay Mode

In Low Delay Mode, picture coding constraints are as follows:

1. All pictures ***shall*** be intra coded pictures or FPP pictures.
2. The output time of each picture ***shall*** be equal to or inferred equal to its decode time.

   NOTE 20: The decode time of a picture, or DTS in accordance with the VVC Transport constraints[SCTE 281-2], may or may not be present in the PES packet header.

3. The POC value, or PTS, in accordance with the VVC Transport constraints [SCTE 281-2], of each picture in the bitstream ***shall*** be greater than the POC value of the prior picture.
4. Each decoded picture ***shall*** be output repeatedly until the next decoded picture is available.

5. The CPB *may* underflow.

8.3.2. Program Splicing Constraint

System processes (such as digital ad insertion and program splicing) *may* require a resolution change in the VVC stream within the same program that results in a seamless or near-seamless behavior in the VVC receiver. The stream *may* also undergo colorimetry changes. When a user of this standard wishes to facilitate such a change, the VVC elementary stream ***shall*** be encoded in accordance with these additional constraints (also see [SCTE 172]):

If such seamless or near-seamless behavior in the VVC receiver is desired, it is highly recommended that parameters such as general_level_idc, the vertical picture size, and colorimetry information in the VVC elementary stream *should* not change within the same program.

NOTE 21: Profile changes, display aspect ratio changes, frame rate changes, colorimetry changes and interlaced/progressive transitions (in either order) should be avoided as they may result in disruption of the decoder's video output.

NOTE 22: A disruption of the pixel clock rate may cause non-seamless output behavior receivers.

8.3.3. Support of Still Picture Mode in VVC

VVC still pictures *may* be used in transport multiplex and when used ***shall*** comply with the following picture coding constraints. Transport constraints for VVC still pictures are found in part 2 of VVC video constraints for cable television [SCTE 281-2].

- The still picture coding ***shall*** comply with section 2.1.103 of 13818-1 [MPEG-2 TS]. In addition, still picture applications *should* conform to the video coding constraints (except frame rate) specified in Table 14 in Appendix A
- **low_delay_hrd_flag[i]** (as defined in VVC [MPEG-VVC]) *may* be either set to '0' or '1'. Still picture applications *should* follow the coding constraints specified in section 7.3.1 when **low_delay_hrd_flag[i]** is equal to 1.
- The time interval between successive still pictures ***shall*** be less than or equal to 60 seconds.
- The fixed_pic_rate_general_flag and fixed_pic_rate_within_cvs_flag are set to '0' in the HRD parameters.

9. Carriage of Captioning, AFD, and Bar Data

The carriage of closed captions, AFD, and bar data when present ***shall*** be carried as per specified in [SCTE 128-1] in section 8.0.

Appendix A. Examples of Common Broadcast Resolutions, Formats & Frame Rates

Table 14 lists the common resolutions and their format constraints used in broadcast applications. Content originally created for broadcast is native to one of these resolutions supported in the intended 16:9 or 4:3 display aspect ratios which makes the encoding and display of content more automated since native resolutions are followed. Other resolutions beyond this table can be used for encoding and displaying this content but require additional transformations to display in 16:9 or 4:3 display aspect ratios.

Table 14 - Common Resolution/Compression Formats for VVC Bitstreams

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-1,2,3,6,7,8,9	UHDTV2
2160	3840	1	16:9	P-1,2,3,6,7,8,9	UHDTV1
1080	1920	1	16:9	**P-1,2,3,6,7,8,9, 10 I- 4,5**	HDTV
1080	1440	14	16:9	**P-1,2,3,6,7,8,9, 10 I- 4,5**	HDTV
720	1280	1	16:9	**P-1,2,3,6,7,8,9, 10**	HDTV
480	720	3	4:3	**P-1,2,3,6 I- 4,5**	SDTV
480	720	5	16:9	**P-1,2,3,6 I- 4,5**	SDTV

The frame rates associated with the integer values in the "Supported Frame Rates" column of Table 14 are defined in Table 15.

Table 15 - Frame Rate VUI Parameter Constraints for VVC

Frame Rate Number	Interlaced or Progressive	Frame Rate	time_scale	num_units_in_tick
1	P	24000/1001 Hz	24,000	1001
2	P	24 Hz	24	1
3	P	30000/1001 Hz	30,000	1001
4	I (encoded as frames)	30000/1001 Hz	60,000	1001
5	I (encoded as fields)	30000/1001 Hz	60,000	1001
6	P	30 Hz	30	1
7	P	60000/1001 Hz	60,000	1001
8	P	60 Hz	60	1
9	P	120 Hz	120	1
10	P	120/1.001 Hz	120,000	1001

NOTE 22: Refer to VSEI [MPEG-VSEI] *table 14 for allowable display modes for progressive and interlaced format modes for designated frame rates beyond constraints as specified in this document.*

Appendix B. Syntax and Semantics for SCTE DM App #1

Refer to [ETSI TS 103 572].

Appendix C. Syntax and Semantics for SCTE DM App #4

Refer to [CTA-861.6].

Appendix D. Syntax and Semantics for SCTE SDR Derived

Refer to [ETSI TS 103 433-1].